Appendix F2. Biological Assessment: Impacts of the Delta Wetlands Project on Fish Species

Biological Assessment:

Impacts of the Delta Wetlands Project on Fish Species

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Section 1. Introduction

PURPOSE OF THE BIOLOGICAL ASSESSMENT

Section 7 of the federal Endangered Species Act of 1973 (16 USC 1536), as amended, requires federal agencies, in consultation with the U.S. Fish and Wildlife Service (USFWS) and the National Marine Fisheries Service (NMFS), to ensure that their actions do not jeopardize the continued existence of endangered or threatened species, or result in the destruction or adverse modification of the critical habitat of these species. Under the federal Endangered Species Act, winter-run chinook salmon (*Oncorhynchus tshawytscha*) is listed as endangered and delta smelt (*Hypomesus transpacificus*) is listed as threatened. Sacramento splittail (*Pogonichthys macrolepidotus*) is proposed for listing as threatened, longfin smelt (*Spirinchus thaleichthys*) is a candidate species that may be considered for future listing, and steelhead trout (*Oncorhynchus mykiss*) is under petition for listing under the federal Endangered Species Act. Because operation of the proposed Delta Wetlands (DW) project may affect these species or their habitat, the U.S. Army Corps of Engineers (Corps) is required to meet the consultation requirements of the federal Endangered Species Act. This biological assessment (BA) of the DW project has been prepared to satisfy these Corps consultation requirements and USFWS and NMFS regulations (50 CFR Part 402).

This BA will also be submitted to the California Department of Fish and Game (DFG) as part of the California State Water Resources Control Board's (SWRCB's) consultation under the California Endangered Species Act. Winter-run chinook salmon is listed as endangered and delta smelt is listed as threatened under the California Endangered Species Act.

This BA evaluates the effects of DW project operations on species of fish that are listed, proposed for listing, and candidates for future listing to determine whether the DW project is likely to be detrimental to the continued existence of those species. Separate BAs are currently being prepared for analysis of DW project effects on terrestrial species to satisfy requirements of both the federal and state Endangered Species Acts. These terrestrial species BAs will be submitted to USFWS and DFG separately.

BACKGROUND

Previous Biological Assessments for Fish Species

In October 1989, a BA evaluating the effects on winter-run chinook salmon that would result from implementing the DW project, as proposed in applications to the Corps and SWRCB in 1987, was prepared and presented to NMFS for review. The 1989 BA determined that DW project operations could have minor adverse effects on juvenile winter-run chinook salmon. Although the Corps requested initiation of formal consultation, that formal consultation was suspended primarily because the effects of existing conditions and ongoing water project operations in the Sacramento-San Joaquin Delta (Delta) had not been determined. The additional effects of new water project operations could not be determined without consideration of ongoing effects.

A draft supplemental BA evaluating the 1987 DW project effects on winter-run chinook salmon, delta smelt, Sacramento splittail, and longfin smelt was completed in November 1992. The supplemental BA addressed the deteriorating condition of winter-run chinook salmon and the recognized decline in delta smelt, longfin smelt, and Sacramento splittail and incorporated new information and impact evaluation methodologies that were not included in the 1989 BA. The assessment was reviewed and comments were provided by NMFS, USFWS, DFG, the Corps, and SWRCB.

Need for the Current Biological Assessment for Fish Species

After agency review of the 1992 draft supplemental BA, changes in the regulatory environment affecting Delta fisheries delayed revisions and responses to comments. Draft Water Right Decision 1630 (D-1630), which was proposed to establish the terms and conditions for interim protection of public trust uses of the San Francisco Bay/Sacramento-San Joaquin Delta (Bay-Delta) estuary, appeared close to approval by SWRCB (SWRCB 1993). During April 1993, however, California's Governor Pete Wilson requested that SWRCB withdraw D-1630 and stated that federal actions would provide interim protection.

Federal actions providing interim protection include publication of the biological opinion for effects on winter-run chinook salmon from operation of the federal Central Valley Project (CVP) and the State Water Project (SWP) (NMFS 1993) and the listing of delta smelt as a threatened species on March 5, 1993 (58 FR 12854). Additional federal actions affecting the Delta include publication of the biological opinions for effects on delta smelt from CVP operations for 1993, 1994, and 1995 (USFWS 1993a, 1994, 1995), issuance of U.S. Environmental Protection Agency's (EPA's) rule for establishing criteria to protect the designated uses of the estuary (59 FR 810), reclassification of winter-run chinook salmon from threatened to endangered by the National Oceanic and Atmospheric Administration (NOAA) (59 FR 440, January 4, 1994), USFWS designation of critical habitat for delta smelt (59 FR 852, January 6, 1994), and USFWS's proposed listing of Sacramento splittail as threatened under the federal Endangered Species Act (59 FR 862, January 6, 1994).

In July 1993, DW revised the project's water right applications and applied for direct diversion water rights in an attempt to adapt to the changing regulatory constraints of water operations in the Delta. Accordingly, DW revised its project description to incorporate more flexible monthly and yearly water storage operations for two of the project islands and a year-round habitat management plan (HMP) for the other two project islands.

In 1994, the state and federal governments entered into a Framework Agreement to develop a joint state/federal program addressing water quality and quantity problems in the Bay-Delta. Under this agreement, in December 1994 SWRCB proposed a water quality control plan that meets federal and state requirements under the federal and California Endangered Species Acts. In May 1995, the Water Quality Control Plan for the San Francisco Bay/Sacramento-San Joaquin Delta Estuary (1995 WQCP) (SWRCB 1995) was finalized. This new biological assessment was prepared to reflect the substantial changes in the regulatory environment affecting Delta fisheries and assess the revised DW project.

PROJECT PURPOSE AND OBJECTIVES

Project Overview

DW proposes a water storage project on four islands in the Delta. The project would involve the potential year-round diversion and storage of water on two islands (Bacon Island and Webb Tract, or "reservoir islands") and the seasonal diversion and use of water for wetland creation and enhancement and wildlife habitat management on two islands (Bouldin Island and Holland Tract, or "habitat islands"). Bacon Island, Webb Tract, and Bouldin Island are wholly owned by DW; Holland Tract is partially owned by DW.

The purpose of the DW project is to divert surplus Delta inflows, transferred water, or banked water to the two reservoir islands for later sale and/or release for Delta export or to meet Bay-Delta estuary water quality or flow requirements. DW also intends to fully compensate for wetland and wildlife effects of the water storage operations on those islands by implementing the HMP on the two habitat islands. Additionally, small amounts of stored water may be released from the two habitat islands for sale or use for the same purposes as the water released from the reservoir islands; such use of the habitat islands will be incidental to habitat uses and subject to the restrictions of the HMP. To operate its proposed project, DW would improve levees on all islands and install additional siphons and water pumps on the reservoir islands. The proposed project is described in detail in Section 2, "Project Description".

The DW project would divert water onto the reservoir islands during periods of availability through 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. The DW project would divert water onto the habitat islands, for wetland and wildlife habitat creation and management. The wetland diversions would most likely begin in September and water would be circulated throughout winter. Habitat island water discharges would be scheduled to maintain wetland and wildlife values. Portions of the habitat islands and the reservoir islands (when not used for water storage) may be flooded to shallow depths during winter to attract wintering waterfowl and support private hunting clubs. (See Section 2.)

Potential Beneficial Uses of DW Project Discharges

The following discussions describe Delta export demands, Delta water quality needs, and environmental flow requirements that DW project water could be used to satisfy.

Delta Export Demands

DW project operations could help satisfy Delta export demands by augmenting water supply for exports.

Water sent from northern California to central and southern California or the Bay Area by the SWP, operated by the California Department of Water Resources (DWR), and the CVP, operated by the U.S. Bureau of Reclamation (Reclamation), must pass through the Delta. Water is diverted from the Delta by the CVP and the SWP; agricultural users of water from approximately 1,800 local irrigation diversions; and cities such as Antioch and Concord to supply the domestic needs of two-thirds of the state's population and irrigate several million acres of farmlands (DWR 1994). Destinations for DW project water could include the SWP, the CVP, and third-party buyers that use the SWP or CVP facilities for transport of water (a process often referred to as "wheeling").

As described in DWR's California Water Plan Update (Bulletin 160-93), demands for water in California are estimated to exceed dependable supplies. Assuming the levels of Delta water supply availability under SWRCB Water Right Decision 1485 (D-1485), improved water management, and existing SWP facilities, DWR estimated that California would have an annual deficit in dependable supplies of 2.9-4.9 million acre-feet (MAF) of water by 2020. (DWR 1994.) As discussed in Section 2, estimated mean annual DW discharges for export range from 188 thousand acre-feet (TAF) to 202 TAF.

Delta Water Quality Needs

DW project water could be used to increase the Delta supply of high-quality water and freshwater releases for outflow from the Delta.

Water quality considerations have a direct bearing on the quantity of Delta water available for use. Delta waters provide a rich habitat for fish and wildlife and are a major source of supply for uses throughout the state. Drinking water for about 20 million Californians flows through the Delta. Water quality parameters such as temperature; turbidity; and oxygen, mineral, dissolved metal, organic, and nutrient content all affect the usability of water and therefore affect the total quantity available for specific uses and the overall availability of water supplies in California. Urban water supplies diverted from the south Delta, for example, face the threat of increasing water quality degradation resulting from both salinity intrusion and the presence of organic substances and salinity originating in agricultural drainage from Delta islands or tributary streams. The pressures of a steadily growing population, additional requirements for water to meet environmental needs, and potentially more frequent water shortages pose serious water management and risk management problems for California. (DWR 1994.)

SWRCB has established specific water quality objectives to protect the uses of water in the Bay-Delta. Many of these objectives relate to salinity. The SWP and the CVP are required to release sufficient fresh water to meet these Delta salinity standards. However, DWR estimates that increasingly stringent water quality standards for public health protection will affect the continued availability and cost of water supplies (DWR 1994).

Environmental Flow Requirements

DW project water could be used to increase the amount of water available to meet environmental flow needs.

The Bay-Delta estuarine system has long been an important resource to California. Among the many factors affecting the estuarine environment are the rate and timing of freshwater inflow to the estuary; the quantities of fresh water reaching it seasonally, annually, and over a series of years; and diversions from the estuary for both local and export uses.

In the past 50 years, developments near the Bay-Delta estuary, along with numerous local, state, and federal water developments on Central Valley tributary streams, caused changes in the timing and amounts of Delta inflows and outflows during most years.

Water-related factors having the greatest effect on the Bay-Delta estuary are:

- Delta inflow,
- flows from the Sacramento River through the Delta Cross Channel (DCC),

- reverse flows,
- water project and local agricultural diversions,
- agricultural return flows, and
- Delta outflow and salinity.

Environmental flow needs are based on instream fishery flow needs, requirements for wild and scenic river flows, water needs of freshwater wetlands (and Suisun Marsh), and Delta outflow requirements to meet estuarine salinity and flow objectives. DWR calculates that annual environmental demands for water in California are currently at 28.4 MAF and could increase to 28.8 MAF by 2020 (DWR 1994).

Section 2. Project Description

OVERVIEW OF PROJECT OPERATIONS

The project applicant's proposed project consists of storage of water on two reservoir islands and implementation of an HMP on two habitat islands. The operational scenarios presented below as Alternatives 1 and 2 both represent DW's proposed project and differ only with regard to operating criteria for discharges of stored water. An additional operational scenario, Alternative 3, consists of use of all four of the DW project islands as reservoirs and provision of limited compensation habitat on Bouldin Island. All alternatives are designed to operate within the objectives of SWRCB's 1995 WQCP.

General Overview

Alternatives 1 and 2 entail the potential year-round diversion and storage of water on two Delta islands owned by DW (Bacon Island and Webb Tract) and wetland and wildlife habitat creation and management, with the incidental sale of the water used for wetland and wildlife habitat creation, on two Delta islands owned primarily by DW (Bouldin Island and Holland Tract) (Figure 2-1). The reservoir island operations may include shallow-water management during periods of nonstorage at the discretion of DW and incidental to the proposed project. To operate Alternative 1 or 2, DW would improve levees on the perimeters of the DW project 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.

Under Alternative 1 or 2, during periods of availability throughout the year, water would be diverted onto the reservoir islands to be stored for later sale or release; water would be discharged from the islands into Delta channels for beneficial uses during periods of demand, subject to state and federal regulatory standards, endangered species protection measures, and Delta export pumping capacities. Water discharged into the Delta channels under proposed project operations would mix with Delta inflows from the Sacramento and San Joaquin Rivers and other tributary rivers and would be available as either export water or Delta outflow (e.g., outflow necessary to satisfy 1995 WQCP objectives or other state or federal standards).

The DW project islands could also be used for interim storage of water being transferred through the Delta from sellers upstream to buyers served by Delta exports (water transfers) or for interim storage of water owned by parties other than DW for use to meet scheduled outflow requirements (water banking) or for export. Such uses could only occur after the transferrers or bankers of the water applied to SWRCB for rights to new points of diversion or rediversion onto the DW project islands. The frequency and magnitude of these transfer/banking activities is uncertain at this time; each would require separate authorization and may require further environmental documentation beyond that provided for the DW project.

During periods of nonstorage, DW could choose to divert water onto the reservoir islands for wetland habitat management; typically, diversion would begin after September 1, after an appropriate dry period to allow for growth of wetland plants of value to wintering waterfowl as forage and cover. Wetland habitat created on the reservoir islands would be flooded as storage water becomes available. An inner levee system would be constructed on each reservoir island to manage shallow water circulation during nonstorage periods.

Water would be diverted onto the habitat islands to be used for wetland and wildlife habitat creation and management during periods of need. Most likely, the water diversions for wetland management would begin in September and water would be circulated throughout winter. Except for small areas of permanent water, water used on the habitat islands would be discharged on a schedule related to wetland and wildlife values, with drawdown typically by May. As a secondary operation, the water released at this time from the habitat islands may be sold or used for the same purposes as water released from the reservoir islands.

Portions of the habitat islands and the reservoir islands would support recreation activities. Waterfowl hunting would be allowed on all four DW project islands; licensed upland bird hunting would be allowed on the reservoir islands but would be prohibited on the habitat islands. Private recreation facilities would be located along the perimeter levees on all four DW islands. Recreational use and location of the recreation facilities on the habitat islands would be subject to restrictions of the HMP; recreational use on the reservoir islands would depend on water storage operations.

The following sections describe DW's proposed reservoir and habitat island operations and describe the differences between the two operational scenarios for the proposed project presented as Alternatives 1 and 2. Chapter 2 and Appendix 2 of the revised draft environmental impact report/environmental impact statement (EIR/EIS) (JSA [in prep.]) contain more details on the proposed project operations and features.

Reservoir Islands

Bacon Island and Webb Tract would be managed for water storage under Alternatives 1 and 2. Facilities that would be needed for the 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. DW 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 would be installed on Bacon Island, for a total of 72 new pumps. Figures 2-2 and 2-3 show the proposed locations of siphon and pump stations and recreation facilities on Bacon Island and Webb Tract, respectively. DW has proposed locations for these facilities; flexibility exists to choose other locations for the siphon and discharge stations before initial construction if, at the end of the state and federal environmental review process, the lead agencies determine that different locations are desirable because of channel hydraulics or environmental, water quality, or other considerations. Reservoir island operations and features are described below.

Water Storage Operations

Storage Capacity. The reservoir islands would be designed for water storage levels up to a maximum pool elevation of +6 feet relative to mean sea level (based on U.S. Geological Survey [USGS] data) providing a total estimated initial capacity of 238 TAF, allocated between Bacon Island and Webb Tract as 118 TAF and 120 TAF, respectively. Water availability, permit conditions, and requirements of the DWR Division of Safety of Dams (DSOD) 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 (local or regional sinking, mainly resulting in the Delta from the oxidation of peat soil). Subsidence on the reservoir islands is currently estimated to average 2-3 inches per year and is thought to be caused mostly by agricultural operations. With water storage operations replacing agricultural operations, the rate of subsidence on the reservoir islands is expected to be greatly reduced, although some subsidence may still occur. No method currently exists to predict the rate of subsidence on a Delta island used for water storage operations. DW estimates, however, that the reservoir islands could subside at a rate of approximately 0.5 inch per year, even with the cessation of agricultural operations and possible sedimentation during filling and storage. Under this hypothetical scenario for subsidence on the reservoir islands, the storage capacity of the reservoir islands could increase by as much as 9% in 50 years, increasing total storage capacity of the reservoir islands to 260 TAF.

Siphon Station Design. Two new siphon stations for water diversions would be installed along the perimeter of each reservoir island. Each siphon station would consist of 16 siphon pipes 36 inches in diameter. Fish screens to prevent entrainment of fish in DW diversions would be installed around the intake end of each existing and new siphon pipe (see "Fish Screens" below). The individual siphons would be placed as close together as possible but would be spaced at least 40 feet apart to incorporate fish screen requirements (Figure 2-4). DW could use the existing reservoir island siphons for diversions to create shallow-water wetland habitat. In-line booster pumps would be available on the reservoir islands to supplement the siphon capacity during final stages of reservoir filling.

Pump Station Design. One discharge pump station would be located on each reservoir island (Figures 2-2 and 2-3). The pump stations would have 32 new pumps (on Webb Tract) or 40 new pumps (on Bacon Island) with 36-inch-diameter pipes discharging to adjacent Delta channels. Typical spacing for the pumps would be 25 feet on center. An assortment of axial-flow and mixed-flow pumps would be used to accommodate a variety of head conditions throughout drawdown. Actual rates of discharge of each pump would vary with the remaining pool elevations. As water levels decrease on the islands, the discharge rate of each pump also would decrease. Existing pump stations on the islands may be modified and used when appropriate to help with dewatering or for water circulation for water quality purposes.

Diversion and Discharge Operations. The DW project alternatives are designed to operate within the objectives of the 1995 WQCP and with Corps requirements for maximum SWP exports. The following discussions define terms used to describe DW project operations in the context of Delta operations criteria; explain the criteria for diversion operations under Alternatives 1 and 2; describe the assumed operating criteria for discharges under Alternative 1; and describe the assumed criteria for discharges under Alternative 2, contrasting them with the criteria for Alternative 1.

Definition of Terms. Following are definitions of several terms used below to describe the manner in which the project alternatives would operate relative to 1995 WQCP requirements and other conditions:

- **Export limits.** The 1995 WQCP specifies that Delta exports are limited to a percentage of total Delta inflow (generally 35% during February-June and 65% during July-January).

- **Outflow requirements.** The 1995 WQCP specifies Delta outflow requirements 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 the model known as "DWRSIM"), "outflow" represents the difference between inflow and exports; the outflow term therefore includes Delta consumptive use.

- **Available water.** Under the 1995 WQCP, available water is total Delta inflow less Delta outflow requirements.

- **Allowable export.** Water allowable for export under the 1995 WQCP is 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).

- **Physical export pumping capacity.** The SWP export pumps have a maximum physical pumping capacity of 10,300 cubic feet per second (cfs) and the CVP export pumps have a maximum physical pumping capacity of 4,600 cfs, for a combined physical export pumping capacity of 14,900 cfs. At times, the canal capacity for the CVP is reduced to 4,200 cfs, reducing the combined physical export pumping capacity to 14,500 cfs.

- **Permitted export pumping rate.** Corps permit conditions currently limit SWP export pumping to a maximum rate of 6,680 cfs. The maximum combined export pumping rate that complies with Corps permit conditions is therefore 11,280 cfs (6,680 cfs for the SWP pumps and 4,600 cfs for the CVP pumps). The Corps' permit conditions 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 rate of 12,700 cfs in January and February. For assessment of the DW project alternatives, it is assumed that the SWP and CVP pumps will always pump the maximum amount allowable (i.e., the lesser of available water and the amount specified by the export limits) within the limits of the permitted pumping rate.

- **Future permitted export pumping capacity.** In the future, new permit conditions may be established for the SWP, thereby allowing the permitted export pumping rate of the SWP pumps to be increased to the physical export pumping rate of 10,300 cfs. If that occurs, the combined permitted export pumping rate of the SWP and CVP pumps would then equal 14,900 cfs or 14,500 cfs..

- **Actual exports.** Actual exports are the least of the following: the amount specified by the export limits (i.e., as percentage of inflow), available water (i.e., water available after outflow requirements are met), and permitted export pumping rate.

- **DW discharge for export.** DW may sell its stored and discharged water to buyers south or west of the Delta who would arrange to have the purchased water transported to areas of use through either the SWP or CVP aqueducts. The term "wheeling" is often applied to this process of transporting water owned by the purchasing entity through the SWP or CVP aqueducts.

Diversions under Alternatives 1 and 2. Under Alternatives 1 and 2, DW diversions are treated consistently with the 1995 WQCP objectives for Delta exports at the SWP and CVP pumping plants. That is, DW diversions are considered to be the same as SWP and CVP exports in complying with the 1995 WQCP objectives, although DW's new water rights for diversions have a lower priority than the senior SWP and CVP water rights.

DW diversions to storage would occur only when the volume of allowable water for export (i.e., the lesser of the amount specified by the export limits and the amount of available water) is greater than the permitted pumping rate of the export pumps. This would occur when two conditions are met: 1) when all Delta outflow requirements are met and the export limit is exceeded and 2) when water that is allowable for export is not being exported by the SWP and CVP 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. Situations may exist, however, in which the SWP and CVP may not be pumping at capacity because of low demands during winter, but DW would still be able to divert water for storage.

Figure 2-5 shows two examples of months with opportunities for DW diversion to storage. The panel on the left shows a month with 40,000 cfs of total Delta inflow when the export limit is 35% of inflow and when required outflow is 7,000 cfs. The permitted pumping rate of 11,280 cfs limits CVP and SWP exports to less than the export limit of 14,000 cfs (35% of 40,000 cfs), providing an opportunity for DW diversions of 2,720 cfs.

The panel on the right in Figure 2-5 illustrates a month with total inflow of 20,000 cfs when the export limit is 65% of inflow and when required outflow is 4,000 cfs. In this month also, CVP and SWP exports are limited by permitted pumping rate, so that DW has an opportunity to divert 1,720 cfs, the difference between the export limit and the permitted pumping rate.

Current and applied-for water rights for the reservoir islands and their proposed uses are discussed below under "DW's Existing and Pending Water Rights".

Discharges under Alternative 1. Under Alternative 1, it is assumed that discharges of water from the DW islands would be exported in any month when unused capacity within the permitted pumping rate exists at the SWP and CVP pumps and strict interpretation of the export limits (percentage of total Delta inflow, or "percent inflow", specified in the 1995 WQCP) do not prevent use of that capacity. Such unused capacity could exist when the amount of available water (i.e., total inflow less Delta outflow requirements) is less than the amount specified by the export limits.

Figure 2-6 presents an example of DW discharges for export under this alternative. In the example, total Delta inflow is 20,000 cfs in a month with an export limit of 35% of inflow, or 7,000 cfs. The outflow requirement is 14,000 cfs, leaving only 6,000 cfs of available water (20,000 cfs - 14,000 cfs). The difference between the 35% export limit and the available water (7,000 - 6,000 = 1,000 cfs) could present an opportunity for export of DW releases.

Under this alternative, DW releases would be treated as additions to total Delta inflow. Export of DW releases thus would be limited to the lesser of the permitted export pumping capacity and the amount calculated under the export limit, based on the adjusted inflow amount (20,000 cfs + DW additions to inflow). For example, if DW water is released and exported at the DW maximum monthly discharge rate of 4,000 cfs, the adjusted total Delta inflow would be 24,000 cfs and the adjusted export limit would be 8,400 cfs. With this adjusted export limit, the opportunity for DW discharge for export would be 2,400 cfs (8,400 cfs export limit - 6,000 cfs available water). The remainder of the 4,000-cfs DW discharge (1,600 cfs) could be added to Delta outflow or held in storage.

Under Alternative 1, DW has two choices regarding allocation of discharges. If DW chooses to discharge at the maximum DW discharge rate, some of the releases must be used to increase Delta outflow while the balance is exported, as shown in this example. Alternatively, DW could choose to limit discharges so that no allocation to Delta outflow is needed. In this same example, if DW were to release only 1,500 cfs, the adjusted inflow would be 21,500 cfs and the adjusted export limit would be 7,525 cfs (35% of 21,500 cfs), allowing the 1,500-cfs DW discharge to be exported, along with the 6,000 cfs of available water, without an allocation to Delta outflow.

Discharges under Alternative 2. Under Alternative 2, it is assumed that releases of water from the DW islands would be exported by the SWP and CVP pumps when unused capacity within the permitted pumping rate exists at the SWP and CVP pumps. DW discharges would be allowed to be exported in any month when such capacity exists and would not be subject to strict interpretation of the export limits (percentage of total Delta inflow). Under this alternative, it is assumed that export of DW discharges is limited by the 1995 WQCP Delta outflow requirements and the permitted combined pumping rate of the export pumps but is not subject to the 1995 WQCP "percent inflow" export limit.

Figure 2-6 shows an example of an opportunity for wheeling DW discharges under this alternative. For the example month, total Delta inflow is 20,000 cfs when the export limit is 35% of inflow and when required outflow is 14,000 cfs. Total inflow less requirements would leave 6,000 cfs available for export by the CVP and SWP. Maximum DW discharge of 4,000 cfs could be exported under this alternative, for a total Delta export of 10,000 cfs. The export limit of 7,000 cfs (35% of 20,000 cfs) would not limit export of the DW discharge.

Timing of Diversions onto the Reservoir Islands. The timing and volume of diversions onto the reservoir islands would depend on how much water flowing through the Delta is not put to reasonable beneficial use by senior water right holders or required for environmental protection. A procedure to coordinate DW project diversions with SWP and CVP operations on a daily basis would have to be established to ensure that DW diversions capture only available Delta flows, satisfy 1995 WQCP water quality objectives, and maximize efficiency of the DW water storage operations.

Diversion rates of water onto the reservoir islands would vary with pool elevation and water availability. The maximum rate of diversions onto either Webb Tract or Bacon Island would be 4,500 cfs (9 TAF per day) at the time diversions begin (i.e., when head differential [the pressure created by water within a given volume] between channel water elevations and island bottoms is greatest). The diversion rate would be reduced as the reservoirs fill and the head differentials diminish. The combined maximum diversion rate for all the islands (including diversions to habitat islands, described below) would not exceed 9,000 cfs. The maximum average monthly diversion rate would be 4,000 cfs.

Estimated mean monthly diversions under Alternatives 1 and 2 are shown in Table 2-1. This table presents an overview of estimated DW project operations but does not show the pattern of estimated operations, which includes values that vary widely from the average values. (Table entries for the No-Project Alternative and existing conditions are explained under "Alternatives Analyzed in this Biological Assessment" in Section 3, "Alternatives Considered".)

Timing of Discharges from the Reservoir Islands. DW proposes to discharge stored water from the reservoir islands during periods of demand, subject to Delta regulatory limitations and export pumping capacities. Discharges would be pumped at a combined maximum daily average rate of 6,000 cfs per reservoir island. The combined monthly average discharge rate of the reservoir islands, however, would not exceed 4,000 cfs. The pump station pipes would discharge underwater to adjacent Delta channels.

Estimated mean monthly discharges from the reservoir islands under Alternatives 1 and 2 are shown in Table 2-1.

Shallow-Water Management on the Reservoir Islands

Incidental to project operations, Alternatives 1 and 2 could include shallow-water management on Bacon Island and Webb Tract to enhance forage and cover for wintering waterfowl when water would not be stored on the reservoir islands. DW would not be required to create wetland habitat on the reservoir islands to compensate for impacts on wildlife or wetland resources resulting from water storage operations; creation of wetland habitat would be implemented at DW's discretion.

From September through May, when water is not being stored on the islands, they could be flooded to shallow depths (approximately 1 acre-foot [af] of water per acre of wetland) for creation of wetland 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 reach maturity. Once shallow flooding for wetland management occurred, water would be circulated through the system of inner levees until deep flooding occurred or through April or May. If the reservoir islands were not deeply flooded by April or May, water in seasonal wetlands would be drawn down in May, and if no water were available for storage, the island bottoms would remain dry until September when the cycle would potentially repeat. If DW were to use its new appropriative rights for shallow flooding, it could potentially sell that water when it was drawn down in April or May.

Recreation Facilities

Water storage operations on Bacon Island and Webb Tract would not preclude recreation on those islands. DW proposes to construct a maximum of 11 recreation facilities on each island along the perimeter levees, as shown in Figures 2-2 and 2-3. Each recreation facility would be constructed on approximately 5 acres and would include vehicle and boat access.

Operations and Maintenance

Operation and maintenance activities for the reservoir islands under Alternatives 1 and 2 would include:

- onsite siphon and pump operation during water diversions and discharges;
- perimeter levee inspections and maintenance, including placement of fill and rock revetment as needed;
- inner levee maintenance for shallow-water management;
- maintenance and monitoring of siphon units and fish screens;
- pump and siphon station inspections and maintenance; and
- recreation facility maintenance and operations performed by seasonal employees.

Habitat Islands

Bouldin Island and Holland Tract would be managed for wetlands and wildlife habitat under Alternatives 1 and 2 (Figures 2-7 and 2-8). An incidental operation of the habitat islands would involve the sale or use of water required to be drained from the islands. The sale or use of this water would be for the same purposes as for the water discharged from the reservoir islands.

Wetland management on the habitat islands would require grading areas, revegetating, and diverting water. As part of Alternatives 1 and 2, improvements would 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 would be constructed on habitat islands. Recreation facilities would be constructed on the habitat island perimeter levees.

Summary of the Habitat Management Plan

DW proposes to dedicate Bouldin Island and Holland Tract as wetland and wildlife habitat areas to offset water storage operation effects on wetlands and wildlife habitat. The HMP was developed to describe how the habitat islands will be managed to provide for wetlands and wildlife habitat to offset acreage affected by operation of the project. Also incorporated into the HMP were provisions for best land management practices to benefit wildlife species other than those special-status target species specifically addressed by the HMP. The HMP specifically describes wildlife habitat management goals and objectives, habitat design and function, habitat and recreation management guidelines, and procedures for ensuring short- and long-term success of project compensation.

Habitat Island Diversions and Discharges

Bouldin Island and Holland Tract would be managed for improvement and maintenance of wetland and wildlife values. The timing and volumes of diversions onto the habitat islands would depend on the needs of wetlands and wildlife habitat. Wetland diversions would typically begin in September and water would be circulated through winter. Existing siphons would be used for diversions to the habitat islands. Fish screens would be installed on all siphons used for diversions.

The maximum rate of proposed diversions onto Holland Tract and Bouldin Island would be 200 cfs per island. Diversions onto the habitat islands would not cause the combined daily average maximum diversion rate of 9,000 cfs for all four DW project islands to be exceeded. Water would be applied to the habitat islands for management in each month of the year of acreages of open water and perennial wetlands, flooded seasonal wetlands, and irrigated croplands specified in the HMP. On an annual basis approximately 19 TAF would be diverted onto the habitat islands.

Water would be discharged from the habitat islands based on wetland and wildlife management needs. Typically, water would be drawn down by May and the habitat islands would remain dry until September, except for permanent water areas and other areas kept wet because of vegetation needs. Existing pumps would be used for discharges and for water circulation on the habitat islands. If new appropriative rights were approved for the water diverted onto the islands for wetland and wildlife management needs, DW could potentially sell that water when it is discharged as long as such discharge does not conflict with the HMP.

Recreation Facilities

Recreation facilities on the habitat islands would be similar to those described above for the reservoir islands. Consistent with the HMP, DW would construct up to 10 new recreation facilities on Bouldin Island and six new recreation facilities on Holland Tract. The Bouldin Island airstrip will be available for use by hunters and other recreationists to fly to the island.

Operation and Maintenance

Operation and maintenance activities for the habitat islands under Alternatives 1 and 2 would include:

- siphon and pump unit operations and routine maintenance;
- management of habitat areas, including but not limited to the control of undesirable plant species and the maintenance or modification of inner levees, circulation ditches, canals, open water, and shallow flooded habitats to facilitate flooding and drainage;
- fish screen maintenance and monitoring during water diversions for habitat maintenance;
- wildlife and habitat monitoring for the HMP;
- perimeter levee inspections and maintenance;
- aircraft operations for seeding, fertilizing, etc.;
- operation of recreation facilities using seasonal workers; and
- monitoring and enforcement of hunting restrictions.

FISH SCREENS

Fish screens would be installed around the intake end of each existing and new siphon pipe (Figures 2-4 and 2-9). The purpose of screen design and operation would be to prevent entrainment and impingement of most adult and juvenile fish that are present in the Delta. DW has proposed fish screen design criteria, which are part of the project to be evaluated. Final fish screen design characteristics, such as approach velocity, mesh size, flow uniformity, and cleaning frequency, may be modified through negotiations with USFWS, NMFS, and DFG to ensure effective operation under all Delta conditions.

The proposed 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 (Figure 2-10). Each siphon opening would be enclosed by stainless steel woven wire mesh screen (7 by 0.035 = seven openings per inch in 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, would be spaced approximately 40 feet apart on center.

DW proposes to design the screens for a maximum initial average approach velocity of 0.33 feet per second (fps). The average approach velocity would decrease rapidly as the islands are filled because the head differential of the siphons would decrease with island filling. The fish screens would be sufficiently strong to withstand handling and cleaning and would withstand at least a 24-inch head differential in water levels.

The screens would be monitored daily to determine the need for cleaning and assess damage from floating logs, boats, or other causes. Spare screen modules would be available to replace damaged screens and thus ensure the reliable performance of the screens. Algae and other clogging debris would be removed from the screens as required by agreement with DFG, USFWS, and NMFS. Removal methods may include regularly raising the screen modules out of the water and brushing or spraying the screens.

A monitoring program may be implemented to estimate fish entrainment losses if the information is needed to evaluate direct diversion effects. Sampling protocol would be subject to fishery agency requirements for the Delta. The monitoring efforts could be coordinated with other regional monitoring efforts.

EXTERIOR SLOPES OF EXTERIOR LEVEES

DW proposes to continue the current levee maintenance and vegetation management programs conducted by the reclamation districts on the four DW project islands. The programs include mechanical and chemical maintenance methods.

COORDINATION OF DIVERSION AND DISCHARGE OPERATIONS WITH EXISTING WATER PROJECTS, STANDARDS, AND FISH TAKE LIMITS

The project's permits, if granted by SWRCB, would contain terms and conditions to protect prior water right holders and the public interest and public trust. All existing and any future Delta water quality, flow, and diversion standards would be applicable to the DW project alternatives as appropriate. The project permits would require that project diversions not interfere with the diversion and use of water by any other user with riparian or prior appropriative rights.

Coordination regarding Senior Water Rights

Most holders of riparian and senior appropriative water rights are located upstream of the Delta in the Sacramento or San Joaquin River basins. Many holders of riparian rights are located in the Delta and senior appropriative water rights are also held by the SWP and CVP, as well as Contra Costa Water District (CCWD) and several smaller diverters. The proposed project would not interfere with diversions by these prior water right holders.

The DWR Delta Operations and Maintenance Section and Reclamation's Central Valley Operations Coordinating Office (CVOCO) maintain the official daily water budget estimates for the Delta and designates the Delta condition each day as being "in balance" or "in surplus". The term "in balance" indicates that all Delta inflow is required to meet Delta standards and satisfy diversions by CCWD, the CVP, the SWP, and Delta riparian and senior appropriative water users. Under nearly all circumstances, when Delta conditions are designated to be in balance, no additional water would be available for diversion by the proposed DW project under new water rights.

When Delta conditions are determined to be in surplus and other terms and conditions are met, the proposed project would be allowed to divert available surplus water for storage on the designated reservoir islands under new appropriative water rights. DW diversions under existing riparian and senior appropriative rights would be permitted, subject to applicable water right laws, even when the Delta is not determined to be in surplus. The daily quantity of available surplus water would be estimated according to DWR's normal accounting procedures. In addition to the 1995 WQCP, SWRCB could establish requirements for various buffers or other measures to protect Delta standards, existing water right holders, and public trust values. Nevertheless, during major runoff events, surplus Delta inflow will likely be available for diversion by the proposed DW project.

Coordination regarding Water Quality Standards

All existing and any future Delta water quality standards adopted by SWRCB or other regulatory agencies would be applicable to the proposed diversions. Project operations for water storage would not be allowed to violate applicable Delta water quality standards and public trust values or interfere with their being upheld.

The DW project permits would contain terms and conditions that specify the allowable project operations for a variety of possible Delta conditions related to water quality or fish and wildlife requirements. SWRCB terms and conditions for the requested DW water rights would specify DW operational rules and guidelines related to meeting applicable Delta standards.

Coordination regarding Endangered Species

Under the federal Endangered Species Act, biological opinions are expected to identify DW project operational criteria, take limits, and facility design (i.e., fish screen criteria) for winter-run chinook salmon, delta smelt, and possibly Sacramento splittail. The project permits would require that project operations fully comply with any applicable Endangered Species Act conditions and allowable take limits as specified in the biological opinions. The SWP's and CVP's own biological opinion requirements will apply at the SWP and CVP export facilities regardless of the source of the exported water.

Table 2-1. Estimated Mean Monthly Diversions and Discharges under DW Project Alternatives 1 and 2 (TAF)

	October	November	December	January	February	March	April	May	June	July	August	September	Annual
Diversions													
Alt. 1	39	41	31	42	24	13	1	2	1	3	1	22	222
Alt. 2	39	41	31	40	24	14	5	2	1	3	1	22	225
No-Project Alternative	2	0	3	3	3	0	0	3	13	16	12	6	60
Existing conditions	1	0	1.5	1.5	1.5	0	0	1.5	6.5	8	6	3	30
Discharges													
Alt. 1	0	1	13	2	10	5	12	16	8	56	49	18	188
Alt. 2	0	1	11	3	37	27	5	17	46	30	18	5	202

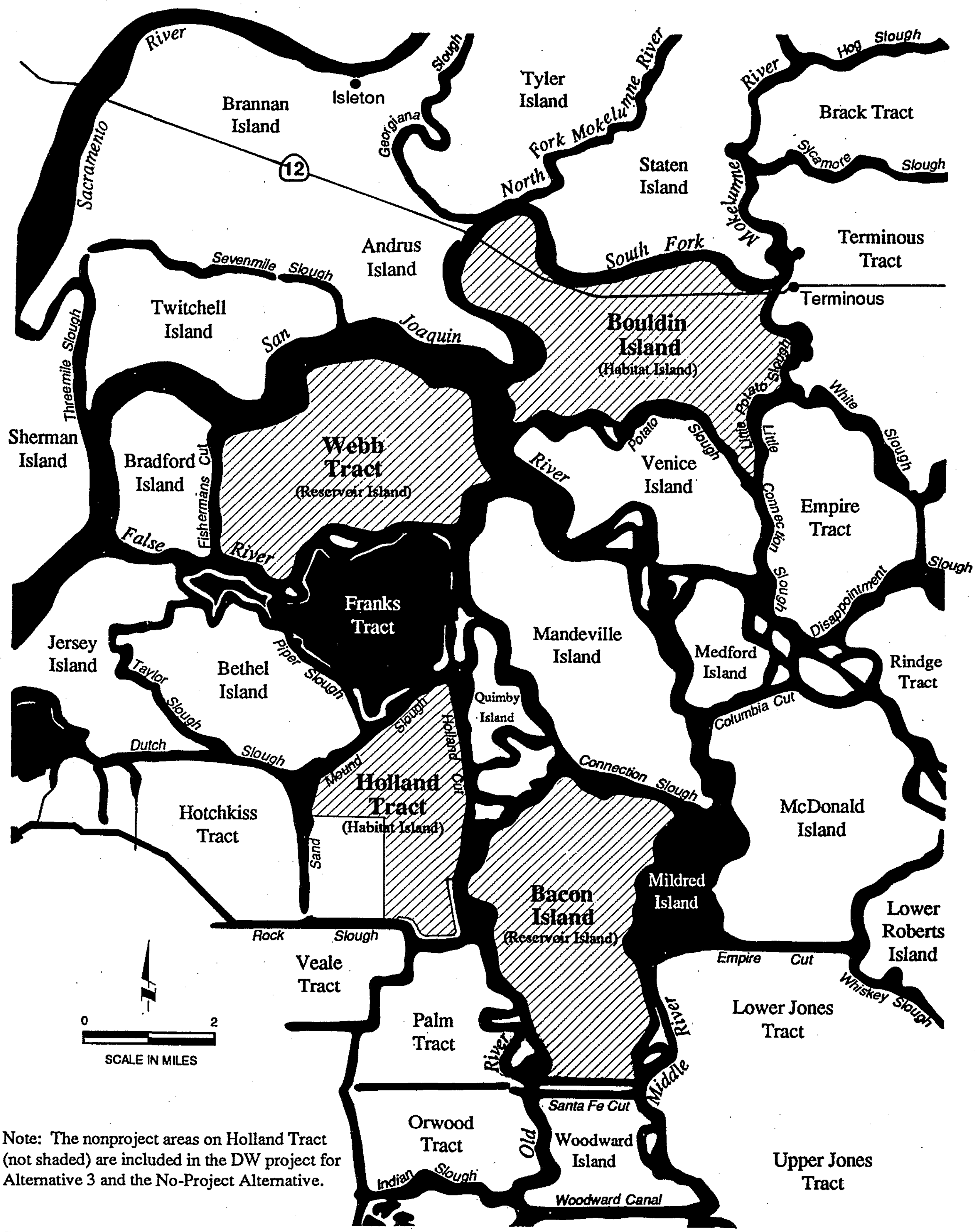
Notes: Values for Alternatives 1 and 2 are derived from simulations of DW project diversions to reservoir storage based on the historical hydrologic record for 1922-1991 and assuming current Delta standards.

Values for the No-Project Alternative represent average combined diversions for irrigation and salt leaching estimated for intensified agricultural use of the DW project islands.

The annual simulated patterns of DW project operations vary widely from these average values.

Annual values may not total correctly because of rounding.

C—061953



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 1993a.

Figure 2-1.
DW Project Islands

DELTA WETLANDS PROJECT
Prepared by: Jones & Stokes Associates

C-061954

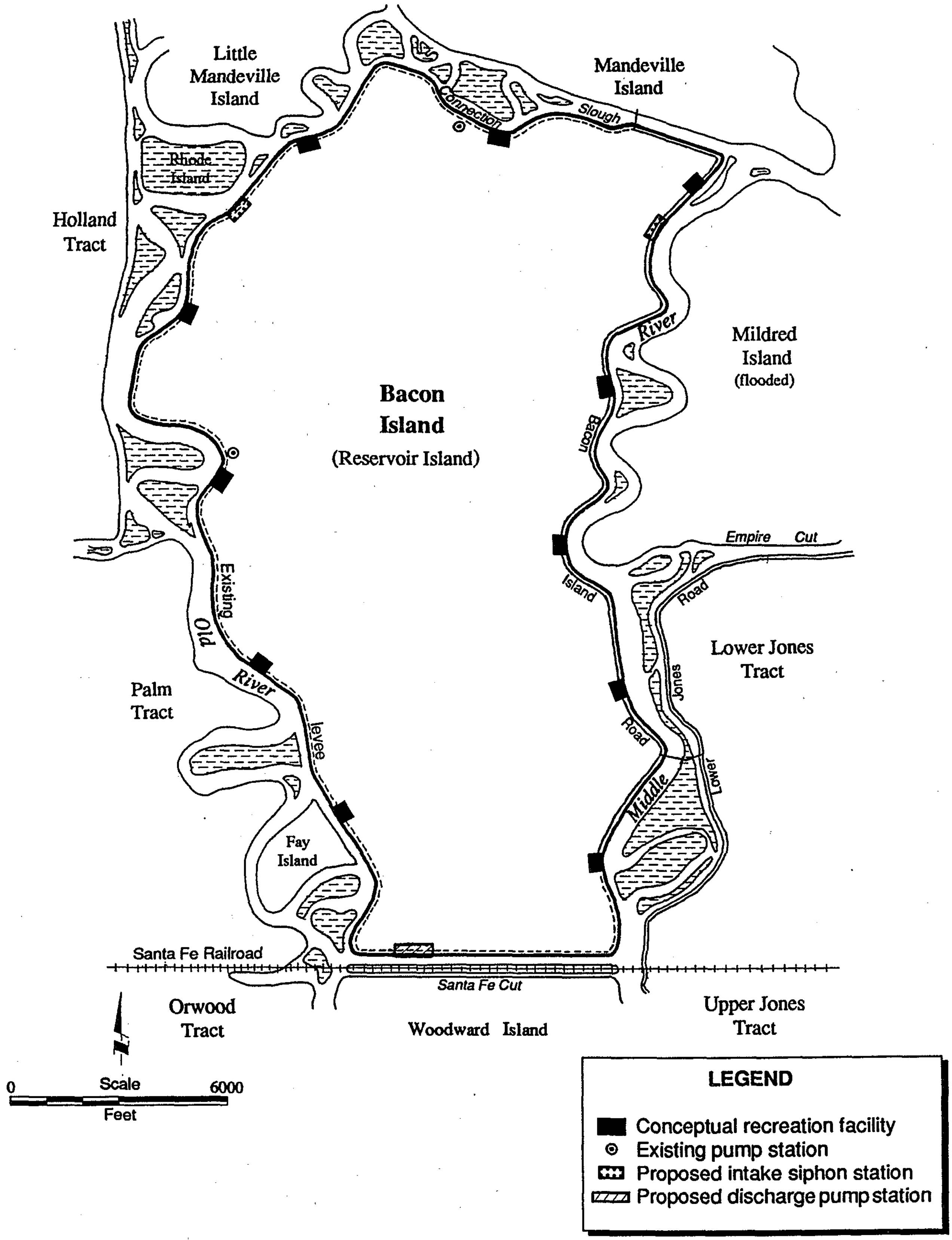


Figure 2-2.
DW Project Facilities for Bacon Island under Alternatives 1 and 2

DELTA WETLANDS PROJECT
Prepared by: Jones & Stokes Associates

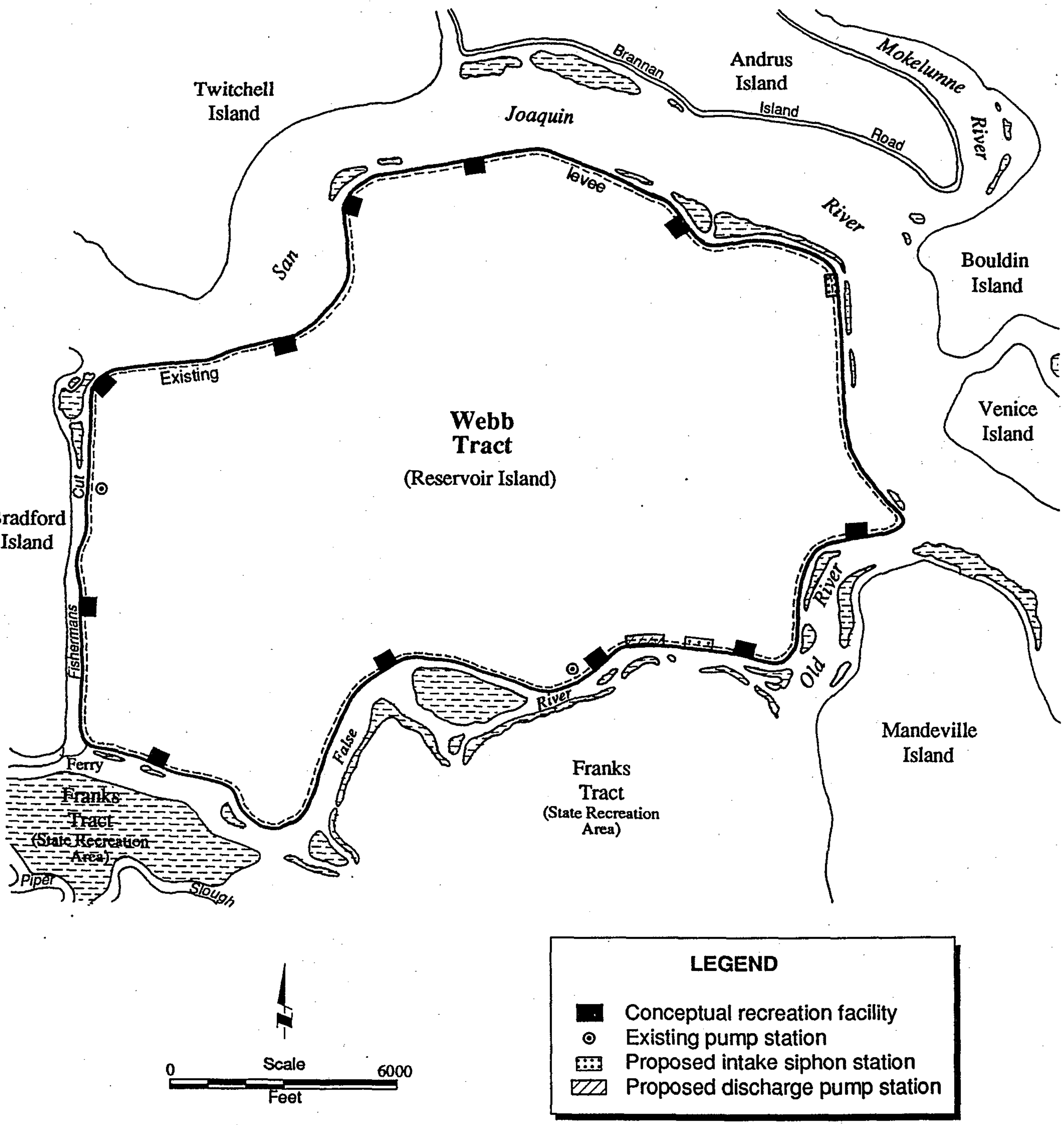
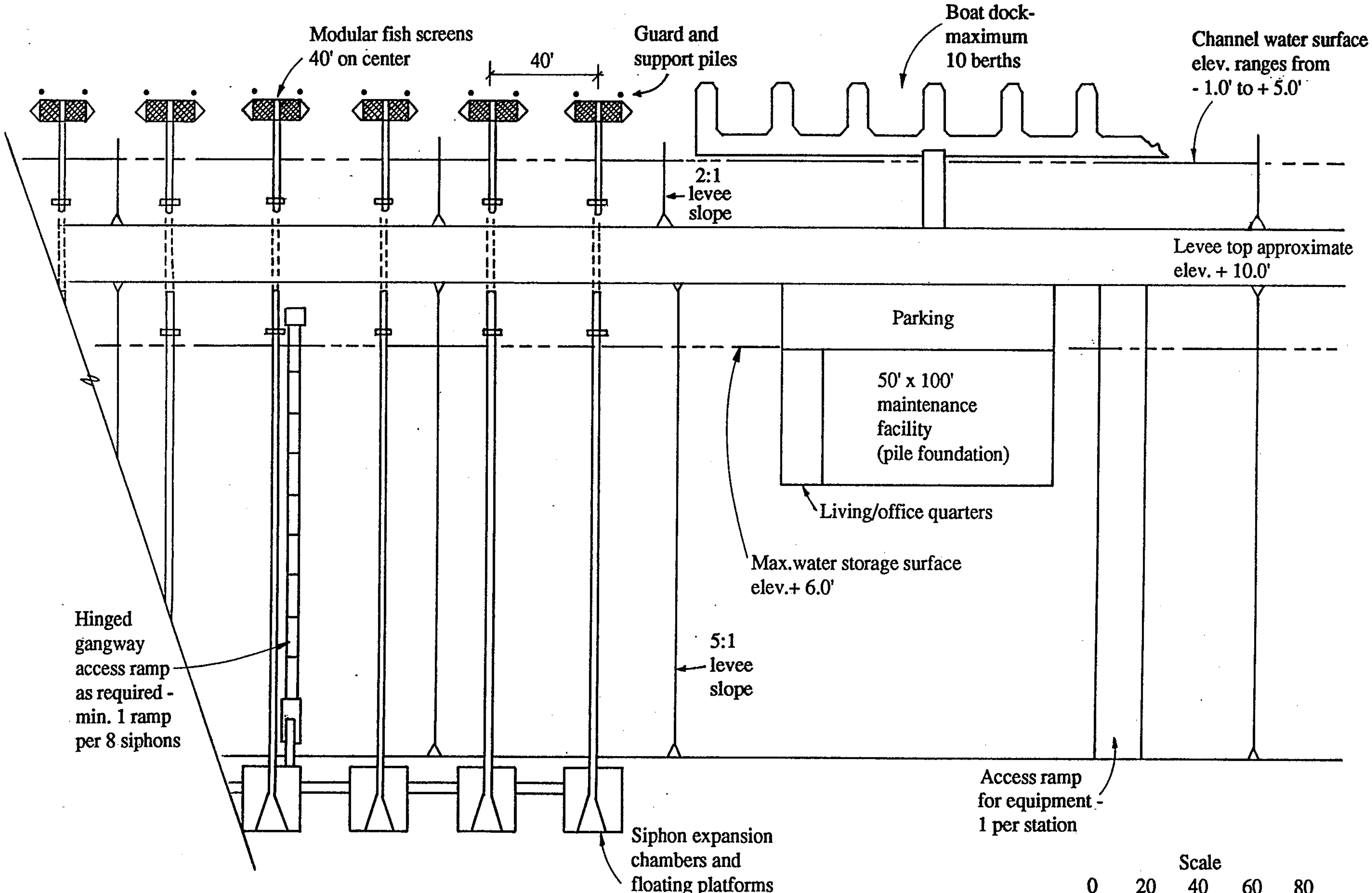


Figure 2-3.
DW Project Facilities for Webb Tract
under Alternatives 1 and 2

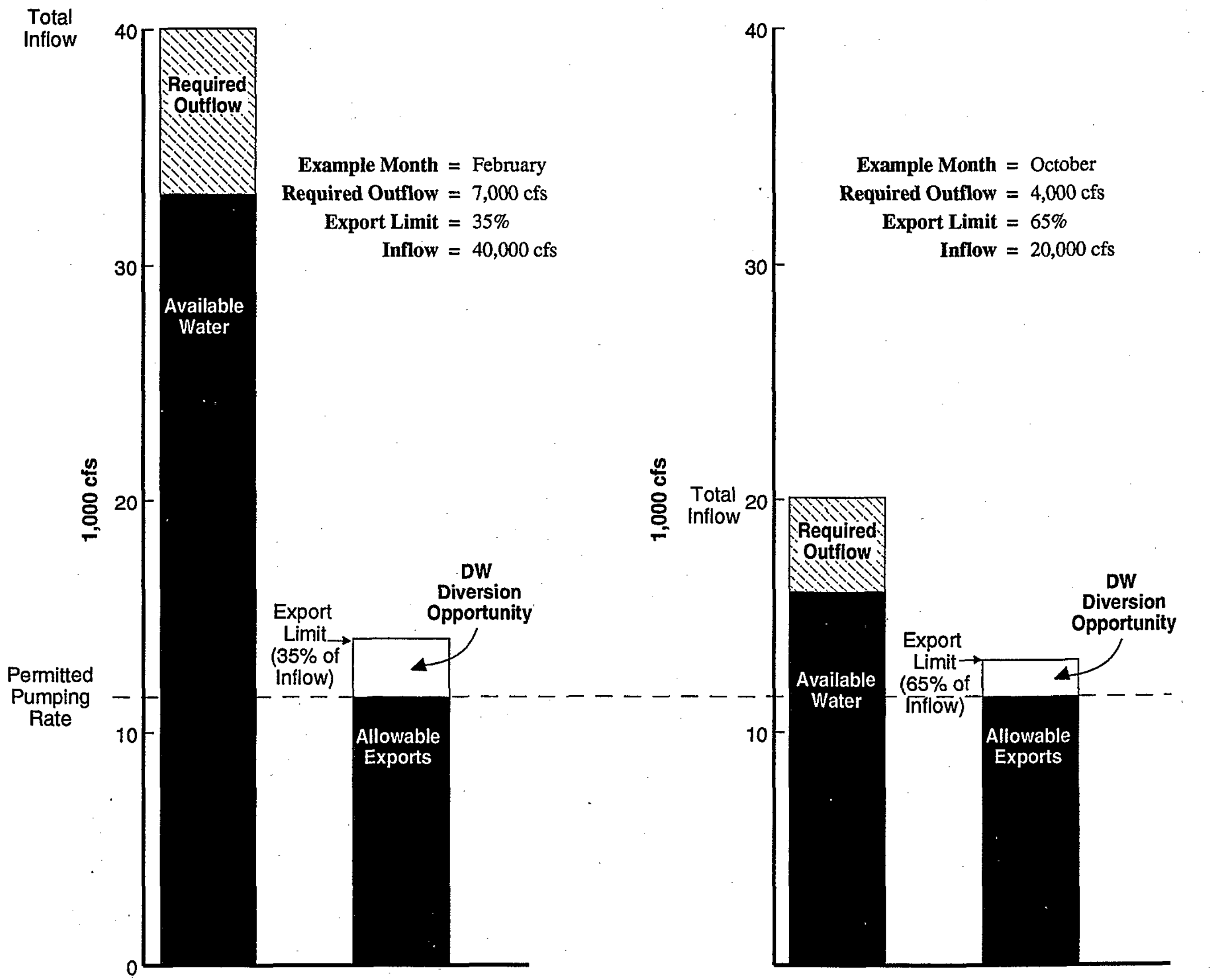
DELTA WETLANDS
PROJECT
Prepared by: Jones & Stokes Associates



Note: The interior levee slope depicted is modified by a constant-slope buttress. Levees may also be modified by a broken-slope buttress.

Figure 2-4.
Siphon Station Plan View

DELTA WETLANDS PROJECT
Prepared by: Jones & Stokes Associates



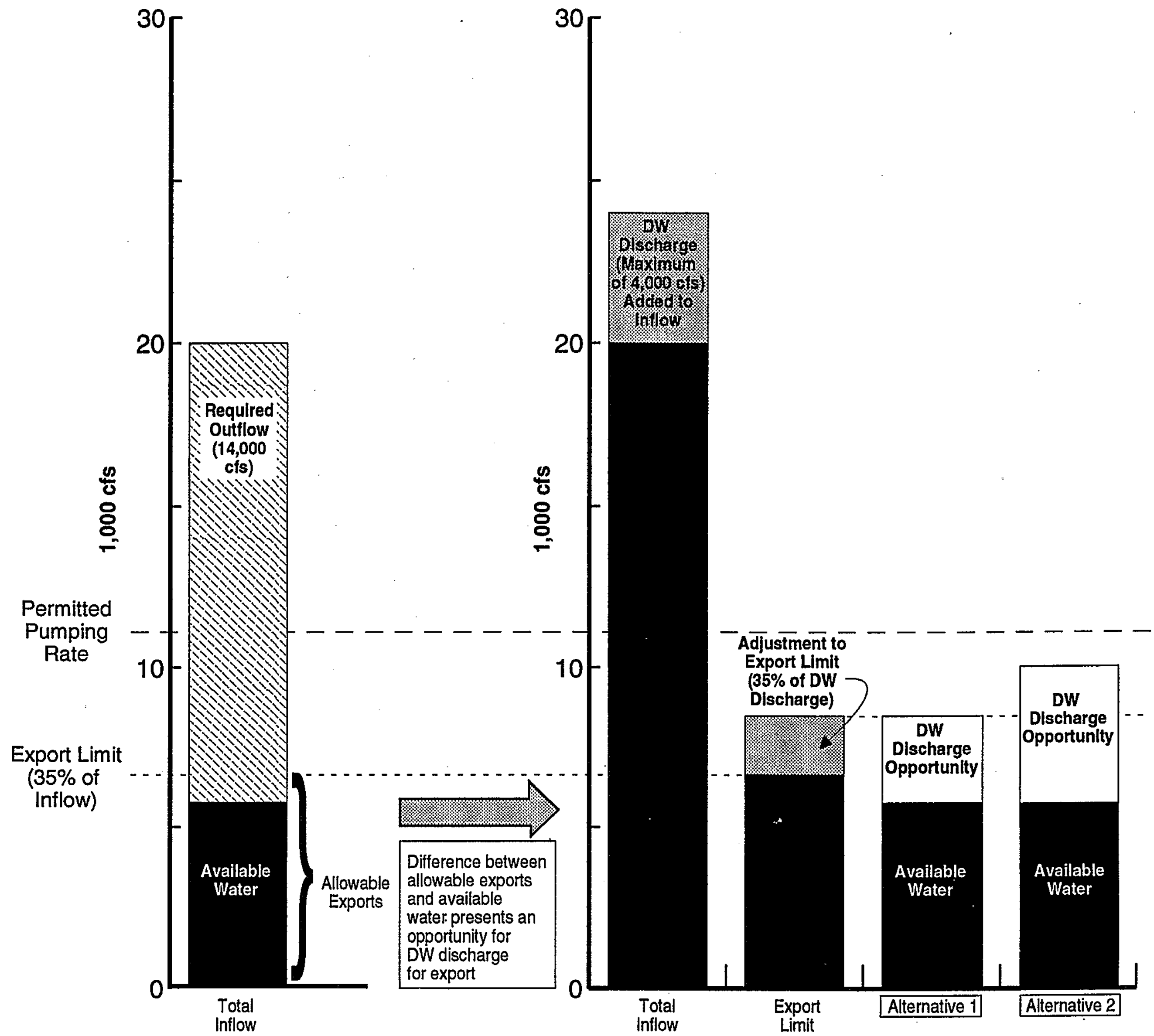
DW diversion opportunity = export limit - allowable exports (allowable exports = permitted pumping rate)

Figure 2-5.
Examples of DW Diversion Opportunities

DELTA WETLANDS PROJECT
Prepared by: Jones & Stokes Associates

C-061958

Required Outflow = 14,000 cfs
Export Limit = 35%
Inflow = 20,000 cfs



Alternative 1: DW discharge subject to the (adjusted) export limit

Alternative 2: DW discharge not subject to the export limit. The amount of DW discharge added to inflow and to the export limit are not relevant to this alternative. DW discharges for export would be allowed up to the permitted pumping rate as long as outflow requirements are met.

Figure 2-6.
Examples of DW Discharge Export Opportunities

DELTA WETLANDS PROJECT
Prepared by: Jones & Stokes Associates

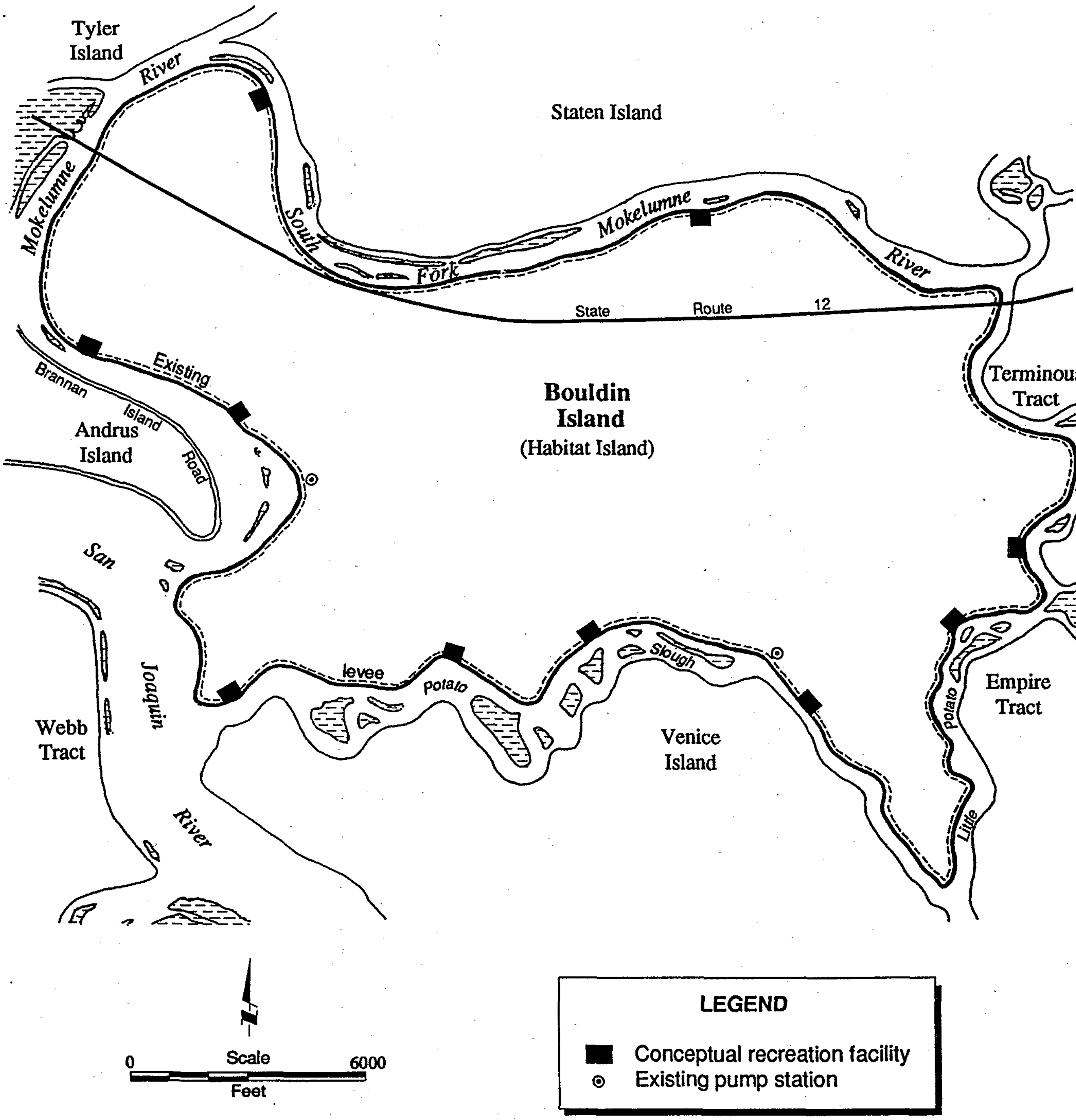


Figure 2-7.
DW Project Facilities for Bouldin Island under Alternatives 1 and 2

DELTA WETLANDS PROJECT
Prepared by: Jones & Stokes Associates

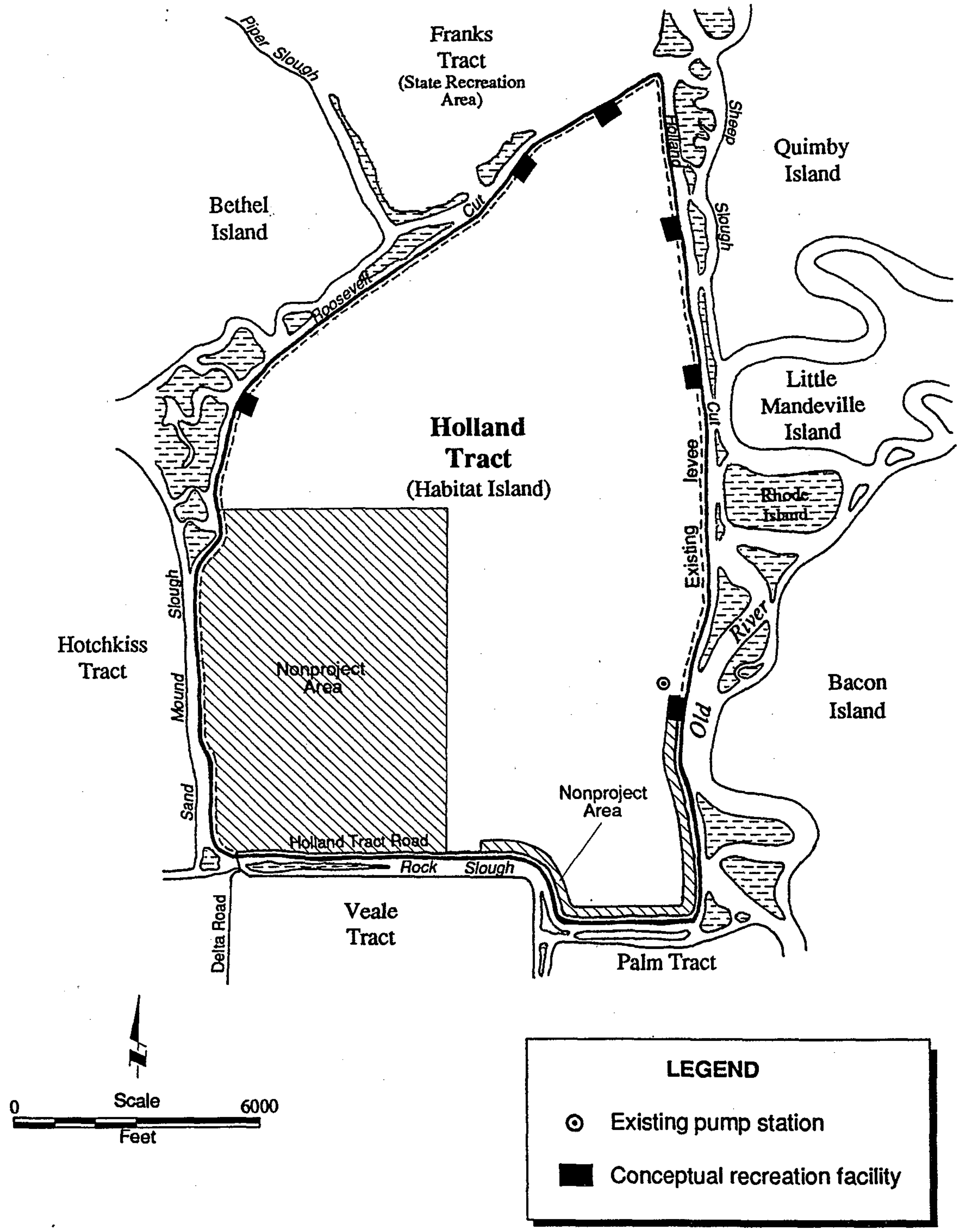
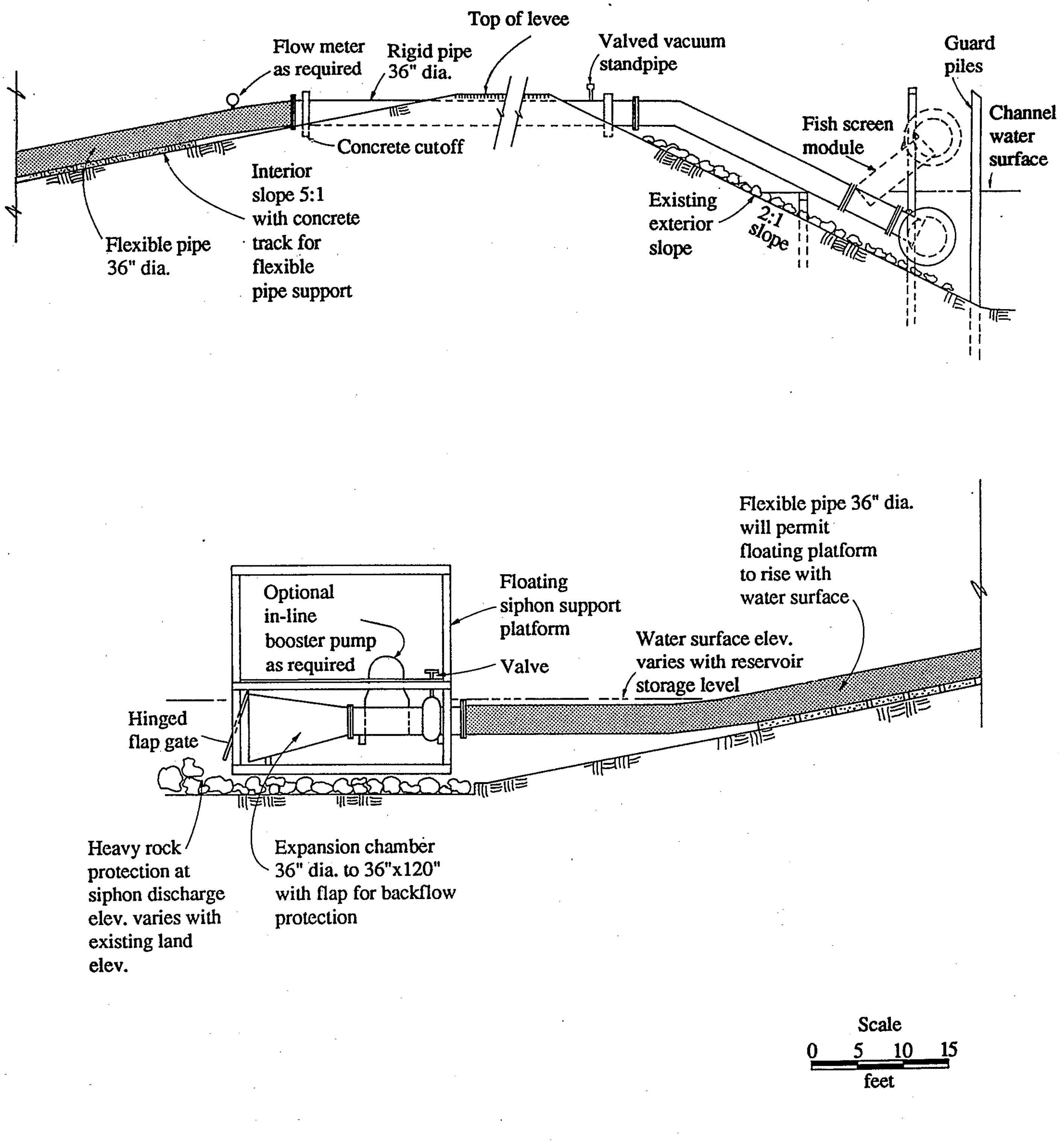


Figure 2-8.
DW Project Facilities for Holland Tract under Alternatives 1 and 2

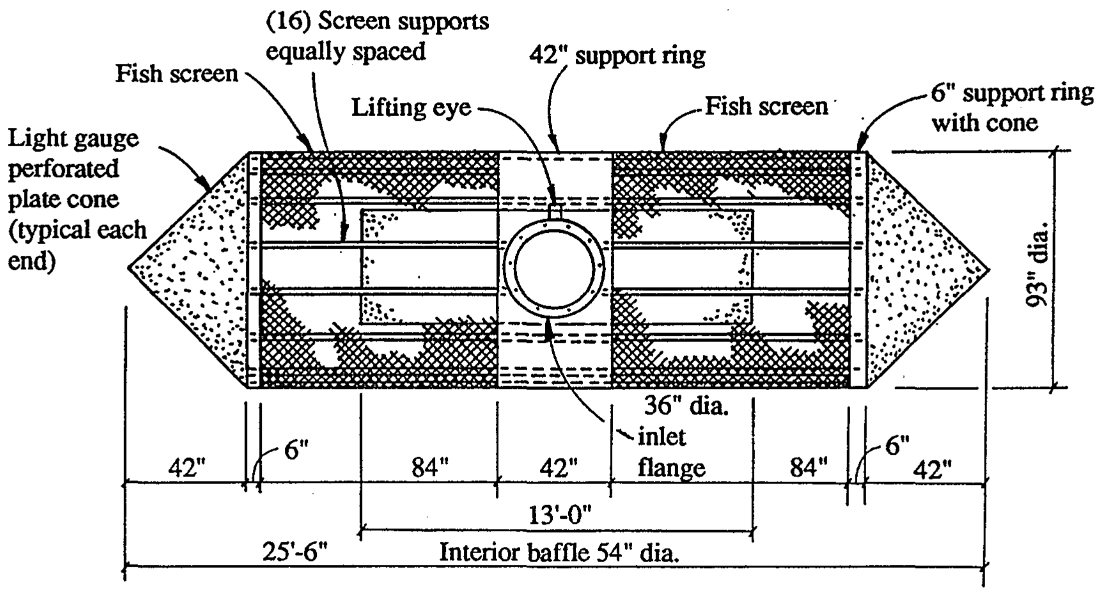
DELTA WETLANDS PROJECT
Prepared by: Jones & Stokes Associates



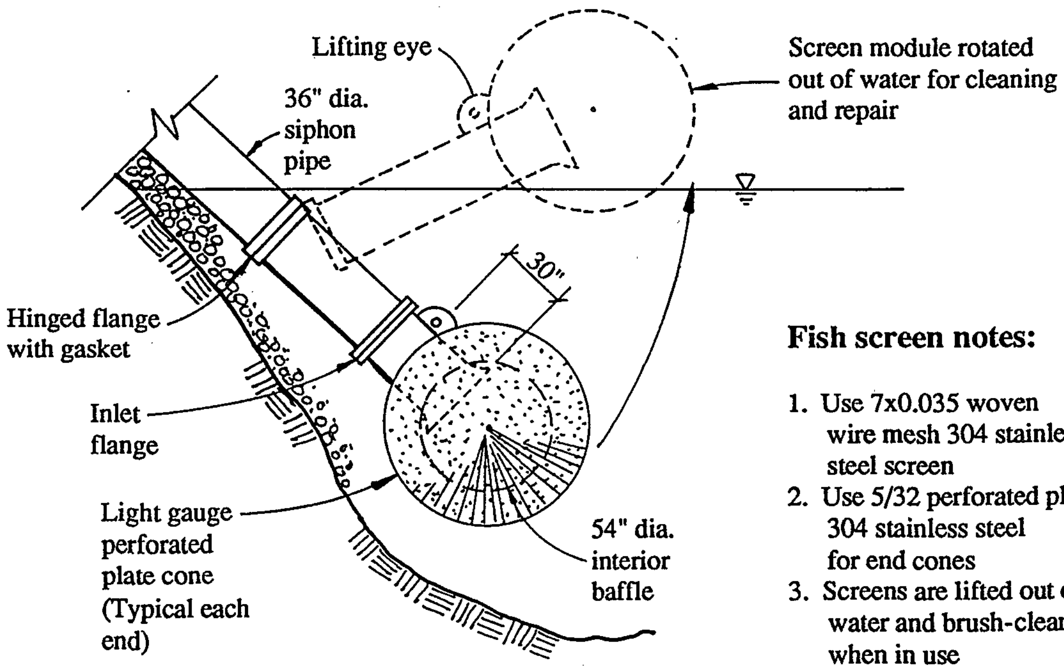
Note: The interior levee slope depicted is modified by a constant-slope buttress. Levees may also be modified by a broken-slope buttress.

Figure 2-9.
Conceptual Siphon Unit

DELTA WETLANDS PROJECT
Prepared by: Jones & Stokes Associates



Front view



Side view

Fish screen notes:

1. Use 7x0.035 woven wire mesh 304 stainless steel screen
2. Use 5/32 perforated plate 304 stainless steel for end cones
3. Screens are lifted out of water and brush-cleaned when in use
4. Screens are removed from water when not in use
5. Interior baffle, 16 gauge stainless steel with 1" dia. perforations, 25% open

Figure 2-10.
Fish Screen Design

DELTA WETLANDS PROJECT
Prepared by: Jones & Stokes Associates

Section 3. Alternatives Considered

This section discusses the DW project alternatives considered by the lead agencies reviewing the project for compliance with the California Environmental Quality Act (CEQA), the National Environmental Policy Act (NEPA), and EPA's Section 404(b)(1) guidelines. A complete analysis of these alternatives and discussion of reasons for carrying them forward or eliminating them from detailed analysis are presented in the EIR/EIS and Section 404(b)(1) Alternatives Analysis for the DW project (JSA [in prep.]).

The alternatives that were considered were not limited to typical water storage facilities in the Delta and included nonstructural and structural projects. Nonstructural alternatives are those that do not require construction of new major facilities. Nonstructural alternatives considered for this analysis were a no-project alternative, an alternative for reoperation of the SWP and the CVP, a water conservation alternative, and a water transfers alternative.

Structural alternatives are those that require construction of new facilities offsite or onsite. Offsite structural alternatives considered for this analysis were a non-Delta (upstream and offstream) water storage alternative and an alternative for water storage on other Delta islands. Onsite structural alternatives considered for this analysis were:

- Alternative 1, consisting of operation of two reservoir islands and two habitat islands and with discharges subject to the "percent inflow" export limits specified in the 1995 WQCP;
- Alternative 2, consisting of operation of two reservoir islands and two habitat islands and with discharges not subject to the "percent inflow" limits; and
- Alternative 3, consisting of maximum water storage on four islands and with the same diversion and discharge operating criteria as Alternative 2.

Alternatives 1, 2, and 3 are described below under "Onsite Structural Alternatives". Alternatives 1 and 2 represent alternative operations of the proposed project and are described in detail in Section 2, "Project Description".

NONSTRUCTURAL ALTERNATIVES

No-Project Alternative

The No-Project Alternative represents the activities that would be continued or implemented if Corps permit applications under Section 404 of the Clean Water Act and Section 10 of the Rivers and Harbors Act or SWRCB water right applications for the DW project are denied. No form of the proposed DW project would be feasible without inundation of island bottoms by stored water and without deposit of dredged or fill material for levee improvements. If the Corps denies the DW permit applications, DW could not implement a project that meets the project purpose. Instead, DW would implement intensive agricultural operations on the four project islands or sell the property to another entity that would probably implement intensive agricultural operations.

The No-Project Alternative would be limited to farming activities that could be implemented without a Section 404 permit or water right approval. Under Section 404(f)(1) of the Clean Water Act, normal farming activities, such as plowing, seeding, cultivating, and maintaining ditches, are exempt from Section 404 permit requirements if part of an existing operation. Additional farming activities that are not part of an existing operation will not be under Section 404 regulation as long as they do not involve the discharge of dredged or fill material, including surface materials redistributed by blading or grading to fill wetland areas. The No-Project Alternative would entail the return of efficient drainage and weed management practices to Holland and Webb Tracts and some shifts in crop types on Bacon and Bouldin Islands.

The No-Project Alternative would not satisfy the project purpose. Under this alternative, intensified agricultural operations would be conducted on the four project islands. This activity would decrease the supply of high-quality water in the Delta. This alternative would not contribute to meeting the existing and future needs for high-quality water in the Delta for export and outflow.

The No-Project Alternative was eliminated from further evaluation as a practicable alternative to the proposed project because it would decrease the availability of high-quality water in the Delta for sale for export south or west of the Delta or as outflow to San Francisco Bay. However, for purposes of satisfying the requirements of NEPA and CEQA and for comparing alternatives, the No-Project Alternative is analyzed in the EIR/EIS, as discussed below under "Alternatives Analyzed in this Biological Assessment".

Reoperation of the CVP and the SWP

Under this alternative, DWR and Reclamation would further integrate and consolidate operations of the CVP and the SWP. Currently, the federal and state water projects operate their systems under different sets of rules. Integrating the CVP and the SWP would facilitate greater operational flexibility of the two systems and could facilitate improved water management throughout California's water system. A more efficient water system could result from better coordination of groundwater and surface water supplies and deliveries and easier implementation of water conservation techniques, market-based water transfers, and groundwater management.

Reoperation of the CVP and the SWP, as described above, would require combined management of the CVP and the SWP to increase the operational flexibility of the two projects and therefore result in a more efficient water storage and delivery system.

CVP and SWP facilities are operated for several distinct, and at times conflicting, purposes, including water supply for agricultural and urban uses, hydroelectric power generation, water quality maintenance, flood control, navigation, recreation, and fish and wildlife benefits. Many institutional, legal, and economic considerations are associated with the transfer of the CVP.

This alternative could increase the supply of high-quality water in the Delta for sale for export south of the Delta or as Delta outflow to San Francisco Bay. However, this alternative has not been sufficiently defined to determine whether it could achieve the project purpose of increasing the supply of high-quality water in the Delta. It is presently impossible to estimate how much the combined management of the CVP and SWP would contribute to increasing the quantity of high-quality water in the Delta.

Reoperation of the CVP and the SWP is not an available alternative to the project proponent. No role exists for a private participant in the management of an integrated CVP and SWP system. Financial implications of the reoperation of the CVP and the SWP are uncertain. The alternative could require substantial financial investments to evaluate, negotiate, plan, and implement CVP transfer and coordinated management of the two systems.

For the reasons stated above, reoperation of the CVP and the SWP was eliminated from further evaluation as a practicable alternative.

Water Conservation Alternative

Under this alternative, an entity (presumably governmental) would implement a water conservation program that would result in increased supplies of water in the Delta. Conservation measures for residential developments include retrofitting existing residences and constructing new developments with low-flow fixtures and appliances, relandscaping existing developments and landscaping new developments with drought-tolerant plants, and installing drip irrigation systems. Conservation measures for commercial and industrial uses include landscaping with xerophytic plants to reduce irrigation to a minimum, retrofitting existing structures, constructing new developments with low-flow fixtures, recycling water, and repairing leaks. Conservation measures for agriculture include furrow irrigation techniques, irrigation management, and irrigation system assessment.

DWR (1994) estimated that urban and agricultural water conservation programs might achieve 3 MAF of demand reduction statewide by 2020. This demand reduction was accounted for in the DWR (1994) projections for long-term California water demand. It is not possible to estimate the extent to which a reduction in California water demand would reduce demand in the Delta watershed, or how a reduction in demand in the Delta might contribute to increased Delta water supply. Therefore, the water conservation alternative cannot be defined sufficiently to support the conclusion that it would be able to satisfy the project purpose.

Water conservation, on a very small scale, is available to the project applicant. DW could implement water conservation efforts for intensified agricultural uses on its four Delta islands, but these efforts would not generate a measurable supply of water for sale for export or outflow. Conservation on a scale broad enough to have the potential to supply a minimum amount of water would require public, institutional, local agency, private industry, and agricultural community participation and would therefore be unavailable as a project alternative to DW.

For the reasons stated above, the water conservation alternative was eliminated from further evaluation as a practicable alternative.

Water Transfers Alternative

The water transfers alternative would consist of voluntary, market-based temporary and long-term water transfers directly using the Delta. The voluntary transfer of water has the potential to be an important means of achieving better water management in California. The California Legislature has declared that the established policy of the state is to facilitate voluntary water transfers and has directed DWR, SWRCB, and all other state agencies to encourage voluntary water transfers (California Water Code Sections 109 and 475).

Voluntary, market-based temporary and long-term water transfers directly using the Delta could increase the supply of high-quality water in the Delta for sale for export and/or outflow. Although DW could act as a type of broker for potential suppliers and buyers of market water, the feasibility of this role is highly speculative. The role DW would play in this alternative is not defined clearly enough to allow proper evaluation of the financial feasibility of DW being a broker in the water transfer market. A broker may not have a financially feasibly role in the water transfer market if suppliers and buyers contract directly with each other without the aid of a broker.

Water transfers can be short term (1 year or less) or long term. Many short-term water transfers were implemented through the State Drought Water Bank in 1991 and 1992 (DWR 1994). Short-term transfers are typically based on fallowing of irrigable agricultural land for short periods or on temporary shifts of supplies not needed by the seller on an interim basis. Long-term transfers that could increase water supply to the Delta are not sufficiently definable to be considered a practicable alternative to meet the project purpose. Because of the temporary or interim nature of these transfers, they cannot achieve the basic project purpose of long-term increase in Delta water supply.

As stated above, the water transfers alternative was eliminated from further evaluation as a practicable alternative because:

- it would not realistically be available to the project proponent,
- it is not definable as a program of long-term transfers to increase Delta water supply,
- temporary transfers cannot meet the long-term project purpose, and
- the alternative may have limited financial feasibility for DW as a participant.

OFFSITE STRUCTURAL ALTERNATIVES

Non-Delta Water Storage or Conjunctive Use

Non-Delta water storage entails the construction of storage facilities with the capacity to store high-quality water for later use for Delta export or outflow. Such storage facilities could include surface water storage reservoirs or groundwater storage basins. Such facilities also could be operated conjunctively to improve overall supply reliability.

Agencies that are responsible for municipal, regional, state, and federal water systems are presently considering non-Delta options for offstream storage between the Delta and places of use (e.g., Los Banos Grandes Reservoir; Kern Water Bank; and Domenigoni Reservoir and the Los Vaqueros Project, which are under construction) (DWR 1994). These entities are also pursuing several options for conjunctive use of groundwater basins to produce drought-year water supplies (DWR 1994).

Under this alternative, a water storage facility could be constructed and operated to increase the long-term supply of high-quality water in the Delta. Similarly, a conjunctive use program could be developed to increase Delta water supplies in drought years.

Conjunctive use programs require sponsorship and direction by regional water districts that coordinate management of large areas of irrigated farmland and defined groundwater basins in combination with centralized points for surface water diversions. Therefore, a conjunctive use water management program does not appear to be available to the project proponent. Furthermore, a conjunctive use program would not increase Delta water supplies over the long term but could increase Delta inflows in dry years.

As stated above, this alternative was eliminated from further evaluation as a practicable alternative for the following reasons:

- definable options that might be implemented under this alternative by 2020 are not available to the project proponent;
- other options require extensive investigation to determine their financial feasibility or their compatibility with a long-term Delta solution and thus are not currently definable; and
- conjunctive use programs might increase Delta water supplies only in drought years and are not available to the project proponent.

Water Storage on Other Delta Islands

This alternative could include using any number of the islands in the Delta other than DW's Bacon and Bouldin Islands and Holland and Webb Tracts to provide water storage for later sale for export or outflow. The facilities and operations used for this alternative would be similar to those described for Alternatives 1 and 2. However, because operation of the islands is, to some extent, a function of their geographic location, operations and facilities on other Delta islands may be very different from those proposed under Alternative 1, 2, or 3.

Although this alternative was generally available to the project proponent at the time of initial project planning, specific islands were unavailable and certain factors particular to each Delta island affect the financial feasibility of using an island as a potential site for water storage. Therefore, this alternative was eliminated from evaluation as a practicable alternative.

ONSITE STRUCTURAL ALTERNATIVES

The onsite DW project alternatives represent a range of project operations that would meet the basic project purpose. Any of the configurations could provide high-quality water in the Delta for export or outflow over the long term. The onsite alternatives would be implemented on the four islands presently owned wholly or in part by DW and therefore are available to the project proponent. All onsite alternatives would operate in full compliance with the objectives of the 1995 WQCP and all other applicable Delta water quality criteria, endangered species protection measures, and water system operational constraints.

The onsite alternatives are practicable operational scenarios that would meet the basic project purpose and were carried forward for analysis in the EIR/EIS.

Alternatives 1 and 2

As described in Section 2, DW's proposed project is represented by two operational scenarios, Alternatives 1 and 2, which differ only with regard to operating criteria for discharge of stored water. The proposed project consists of operation of Bacon Island and Webb Tract (reservoir islands) for their maximum water storage capabilities and Bouldin Island and Holland Tract (habitat islands) for their wetland and wildlife habitat values. During nonstorage periods, incidental shallow-water wetlands and waterfowl habitat could be available on the reservoir islands.

Alternative 3

Under this alternative, all four DW islands (Bacon and Bouldin Islands and Holland and Webb Tracts) would be operated for their maximum water storage capabilities. Under Alternative 3, a habitat reserve would be created north of State Route 12 on Bouldin Island to compensate for some of the impacts associated with water storage operations.

Levees on the islands would be constructed for maximum pool elevations of +6 feet. DW diversion and discharge operations would be the same as under Alternative 2 (except for diversion and discharge rates).

ALTERNATIVES ANALYZED IN THIS BIOLOGICAL ASSESSMENT

This BA assesses the impacts of the proposed project on the fish species listed as threatened or endangered under the federal Endangered Species Act. As stated above, the proposed project is represented by two operational scenarios that differ only with regard to operating criteria for discharge of stored water. These operational scenarios, Alternatives 1 and 2, are presented in the EIR/EIS to bracket the range of operational interpretations of the proposed project within the 1995 WQCP. It is anticipated that DW project operations receiving final approval will likely fall somewhere between operations of the two alternatives, depending on the conclusions of the lead agencies within the CEQA/NEPA process and the conclusions of USFWS and NMFS within the Endangered Species Act process. Therefore, for purposes of assessing the effects of the proposed project on the listed fish species and their habitat, the analysis for this BA used the operational scenarios associated with Alternative 2 and the No-Project Alternative (described below) to model the widest range of potential operations available under the proposed project (see also Section 5, "Impact Assessment"). It is assumed that Alternative 2 would operate in the context of current Delta facilities, demand for export, and operating constraints, as described in Section 5.

Estimated Delta conditions under operations of the proposed DW project (Alternative 2) cannot be directly compared with the historical record of Delta operations for purposes of impact assessment because historical Delta operations did not include current operating criteria; facilities; and conditions, such as demand for exports. To provide a point of reference for assessment of impacts associated with operations of the DW project, it was also necessary to estimate conditions that would occur with existing Delta facilities and operating criteria but without operations of the DW project. This point of reference is represented by the No-Project Alternative. As described above, the No-Project Alternative represents the intensified agricultural operations that would be implemented on the DW project islands if the DW project were not approved. The DW island water budget terms for the No-Project Alternative are assumed to be approximately 50% higher than water budget terms under existing conditions, reflecting more intensive agricultural use of the islands. Average monthly diversions for combined irrigation and salt leaching on the DW project islands are shown in Table 2-1 in Section 2, "Project Description", for the No-Project Alternative and existing conditions, for comparison with estimates of diversions under the proposed project. Currently existing siphon facilities on the islands, which are unscreened, would not be modified under the No-Project Alternative.

Results of assessment of all potential impacts of the DW project, reported in Section 5, represent changes that would result from operations of Alternative 2 in relation to the baseline represented by the No-Project Alternative.

Section 4. Endangered, Threatened, and Candidate Fish Species

INTRODUCTION

This section provides information needed to assess impacts of DW project operations and facilities on winter-run chinook salmon, delta smelt, Sacramento splittail, longfin smelt, and steelhead trout.

The fishery resources on the DW project reservoir islands (Bacon Island and Webb Tract) and habitat islands (Bouldin Island and Holland Tract) are limited to perennial ponds and drainage ditches. The ponds primarily support introduced sunfish, catfish, and minnows. No fish species that are listed as threatened or endangered or that are candidates for future listing under the federal Endangered Species Act are known to be present on the project islands.

DW project reservoir and habitat island operations and facilities may affect fish species using the Delta, including winter-run chinook salmon, delta smelt, Sacramento splittail, longfin smelt, and steelhead trout. Localized modification of habitat could result from construction and installation of intakes and fish screens and from levee stabilization, but the major DW project effects would be the effects of diversions on Delta fish (i.e., entrainment and impingement) and fish habitat (i.e., reduced Delta outflow and change in Delta flow patterns). Entrainment losses associated with DW project diversions could vary, depending on the timing and location of diversions, the temporal and spatial distribution of fish, and the efficiency of DW project fish screens.

WINTER-RUN CHINOOK SALMON

Winter-run chinook salmon (*Oncorhyncus tshawytscha*) have the same physical appearance as other runs of chinook salmon. Winter-run salmon also have habitat requirements similar to those of other runs and currently spawn and rear in the same habitats used by other runs. Timing of adult migration and spawning distinguishes the winter run from other chinook salmon runs that spawn in the Sacramento River. Winter-run salmon adults ascend the Sacramento River during winter and spawn primarily during spring and early summer.

Status

The winter-run chinook salmon was listed as a threatened species under the federal Endangered Species Act of 1973 (16 USC 1536) by an emergency interim rule on August 4, 1989. NOAA reclassified the listing status of winter-run chinook salmon from threatened to endangered effective on February 3, 1994 (59 FR 440, January 4, 1994).

The portion of the Sacramento River from Keswick Dam to Chipps Island, all waters westward from Chipps Island to the Carquinez Strait Bridge, all waters of San Pablo Bay, and all waters of San Francisco Bay north of the San Francisco-Oakland Bay Bridge have been designated as critical habitat for winter-run chinook salmon (58 FR 33212, June 16, 1993). Critical habitat includes the river water, river bottom, and adjacent riparian zone (i.e., those adjacent terrestrial areas that directly affect a freshwater aquatic ecosystem).

The California Fish and Game Commission was petitioned in November 1987 to list the winter-run chinook salmon as endangered under the California Endangered Species Act. The commission rejected the original petition to list the winter-run chinook salmon in March 1989 primarily because existing programs appeared to have a high probability of resulting in a significant recovery of the species and because a serious threat of extinction was not substantiated by the available information. In May 1989, however, the commission reversed the previous action and listed the winter-run chinook salmon as endangered. Listing was warranted because the spawning population in 1989 was estimated to be smaller than populations of previous years, indicating a substantial and continuing decline.

The winter-run chinook salmon and its habitat, primarily the Delta portion, could be affected by changes in flow volume, direction, and origin attributable to the proposed project. The following discussion summarizes available information on the winter run and its habitat. Potential effects of the proposed project on the winter-run chinook salmon are evaluated in Section 5, "Impact Assessment".

Background

Construction of Shasta Dam in the 1940s excluded the winter-run chinook salmon from its historical spawning grounds on the McCloud River and in other upstream areas. Coldwater releases from Shasta and Keswick Dams, however, created more spawning and rearing habitat in the mainstem Sacramento River than previously existed in the McCloud River headwaters (Slater 1963).

The abundance of winter-run chinook salmon prior to the construction of Shasta Reservoir is unknown. Some biologists believe the run was relatively small, possibly consisting of a few thousand fish (Slater 1963). Others, relying on anecdotal accounts, believe the run could have numbered over 200,000 fish (NMFS 1993). The population during the mid-1960s, more than 20 years after the construction of Shasta Dam, consisted of more than 80,000 fish (Reclamation 1986).

In 1966, Red Bluff Diversion Dam (RBDD) was constructed approximately 60 miles below Keswick Dam. The winter-run salmon escapement (i.e., the number of adult fish returning to spawn) declined drastically after the dam was completed (Figure 4-1) (Reclamation 1986). By 1979, the estimated number of winter-run salmon migrating past RBDD had declined from a 3-year average (1967-1969) of 83,916 fish to 20,000-30,000 fish. The continued decline in the winter-run salmon population since 1979 is attributable to adverse natural conditions, such as elevated water temperatures during the 1976-1977 drought; degradation of habitat conditions attributable to water diversions; water pollution; and other factors (e.g., ocean fishing and predation).

In 1989, the winter-run escapement was estimated at less than 550 fish (DFG 1989). The sharp decline in the 1989 run prompted listing of the winter-run chinook salmon as endangered under the California Endangered Species Act and as threatened under the federal Endangered Species Act (as indicated above, the species was reclassified as endangered in 1993). Escapement continued to decrease, diminishing to an estimated 450 fish in 1990 and 191 fish in 1991. Escapement in 1992 was estimated to be 1,180 fish, indicating good survival of the 1989 class. NOAA data indicate that the population continues to be depressed and only about 340 fish returned to spawn in 1993 (59 FR 440, January 4, 1994).

Distribution and Life History

Adult winter-run chinook salmon leave the ocean and migrate through the Delta into the Sacramento River from November through July (Figure 4-2). Salmon migrate upstream past RBDD on the Sacramento River from mid-December through July, and most of the spawning population has passed RBDD by late June (Figure 4-2).

Winter-run chinook salmon spawn from mid-April through August, and incubation continues through October (Figure 4-2). The primary spawning grounds in the Sacramento River are above RBDD. Some fish may spawn below RBDD, but deleterious temperatures below RBDD kill the eggs during most summers (Fisher pers. comm.).

Juvenile winter-run chinook salmon rear in the Sacramento River from July through March (Figure 4-2). Juveniles migrate downstream past RBDD from July through March (Hallock and Fisher 1985, Smith pers. comm.). Juveniles descending the Sacramento River above RBDD from August through October and possibly November are mostly presmolts (smolts are juveniles that are physiologically ready to enter seawater) and probably rear in the Sacramento River below RBDD. Juveniles have been observed in the Delta during October through December, especially during high Sacramento River discharge caused by fall and early winter storms.

Juvenile chinook salmon move out of upstream spawning areas into downstream habitats in response to many factors, including inherited behavior, habitat availability, flow, competition for space and food, and water temperature. The number of juveniles that move and the timing of movement are highly variable. Storm events and the resulting high flows cause movement of substantial numbers of juvenile chinook salmon to downstream habitats. In general, juvenile abundance in the Delta increases as flow increases (Figure 4-3) (USFWS 1993b).

Winter-run salmon smolts may migrate through the Delta and Bay to the ocean from December through as late as May (Figure 4-2) (Stevens 1989).

The Sacramento River channel is the main migration route through the Delta. Water drawn through the DCC and Georgiana Slough transports an unknown number of migrants into the Delta south and east of the Sacramento River. The number of juveniles entering the DCC and Georgiana Slough is assumed to be proportional to the volume of flow diverted out of the Sacramento River (USFWS and DFG 1987). Juvenile chinook salmon may also leave the lower Sacramento River in the west Delta by moving through Threemile Slough or up the lower San Joaquin River. During downstream migration, smolts are most likely to be drawn off the Sacramento River through the DCC and Georgiana Slough and would not be affected by net flow through Threemile Slough.

Adult winter-run chinook salmon spend 1-3 years in the ocean. About 67% of the adult escapement that leaves the ocean to spawn in the Sacramento River consists of 3-year-olds, 25% consists of 2-year-olds, and 8% consists of 4-year-olds (Hallock and Fisher 1985). The 2-year-olds in the escapement (primarily immature males) are not believed to contribute to spawning success and production of the year class (Fisher pers. comm.).

Factors Affecting Winter-Run Salmon Abundance

The primary human-caused factors influencing winter-run chinook salmon abundance are activities that have occurred upstream of the Delta. Delta diversions, however, have contributed to increased mortality of winter-run chinook salmon.

For winter-run chinook salmon, ongoing factors affecting mortality include deleterious water temperatures in spawning and rearing habitat, delay of adult and juvenile migration, increased predation during juvenile migration (e.g., at RBDD), and entrainment of juveniles in diversions. All these problems have resulted from construction and operation of facilities for water diversion, water storage, agricultural drainage, and flood control on the Sacramento River and in the Delta.

Red Bluff Diversion Dam

Operation of RBDD is considered one of the primary causes of the reduction in winter-run chinook salmon abundance. RBDD is a barrier to upstream-migrating adults, preventing upstream passage of up to 40% of the winter-run salmon and delaying the remaining fish for several days (USFWS 1988, Hallock et al. 1982). Winter-run chinook salmon that do not migrate upstream past RBDD do not spawn successfully during most years because of deleterious temperatures (Fisher pers. comm.). Salmon that are delayed may suffer reduced fecundity.

Since 1986, the RBDD gates have been raised during winter and early spring as part of a protection program for winter-run chinook salmon, thereby reducing the incidence of delay and blockage of winter-run adults. Improved passage through RBDD after 1986 has not reversed the decline in abundance, possibly because drought conditions during 1987-1992 adversely affected spawning and rearing success.

Annual loss of juvenile chinook salmon to diversion at RBDD is estimated at 1% of the total migrating population (USFWS 1988). New fish screens were installed at RBDD in 1990, however, and ongoing evaluations may show reduced losses.

Losses of juvenile chinook salmon to predation have been estimated to range from 29% to 77% of the migrating population (Hallock 1983). Predation by squawfish, the primary predator of juvenile chinook salmon at RBDD, is particularly evident during the spring upstream squawfish migration (USFWS 1988). Squawfish are not concentrated below RBDD during the expected peak winter-run salmon migration, but predation losses have been identified as a potential factor in the decline of winter-run salmon (USFWS 1988, Hallock 1983). Although squawfish may consume large numbers of juvenile salmon (especially where dams and diversions provide unusually favorable environments for predation), evidence does not conclusively show that squawfish predation measurably reduces productivity (Brown and Moyle 1981). As discussed for adult migration above, raising of RBDD gates during juvenile migration could reduce predation (NMFS 1993).

Temperature

Deleterious temperatures during spawning, incubation, and early rearing periods reduce survival of winter-run salmon in the Sacramento River above

RBDD. The expected monthly survival of eggs and alevins (larval salmon that have not yet emerged from the gravel) begins to decline substantially at water temperatures above 57°F (Figure 4-4). In addition, temperature is a primary factor influencing the survival of juvenile chinook salmon in the Delta, especially during May and June (Kjelson et al. 1989a). Survival of juveniles begins to decline substantially at temperatures above 66°F (Figure 4-4). Survival of juvenile fall-run chinook salmon during migration though the Delta appears to decline when water temperature exceeds 60°F (Kjelson et al. 1989b, USFWS 1992) (Figure 4-5). During juvenile winter-run migration through the Delta, however, water temperature is generally below 60°F, and winter-run juveniles may not experience the magnitude of loss that fall-run juveniles have experienced (USFWS 1993b).

Juvenile growth rate can decline at temperatures exceeding 60°F, with the rate of decline depending on food availability and other factors (Figure 4-4). Smaller juveniles are more vulnerable to predation and entrainment in diversions during freshwater residence and are less likely to survive in the ocean.

Escapement of winter-run chinook salmon declined following high water temperatures in summer during the 1976-1977 drought and the population size has remained low. During the 1976 and 1977 spawning and incubation period, water temperatures exceeded 62°F in the Sacramento River over most of the winter-run chinook salmon's spawning area (USGS 1988). Eggs are not expected to survive water temperatures exceeding 61°F (Healey 1979).

Elevated water temperatures during 1976-1977 resulted from low Shasta Reservoir storage and high ambient temperatures. Drought conditions and release of stored water to supply downstream demands caused the reservoir storage to be low. Future downstream demands may cause additional reductions in storage and increase the frequency and intensity of elevated water temperatures in the section of the Sacramento River between Keswick Dam and RBDD (Reynolds et al. 1990).

Releases of cool water from Shasta and Clair Engle Reservoirs into the Sacramento River during warm periods can reduce temperature-related egg mortality (USFWS and DFG 1987). Within winter-run salmon spawning habitat (Keswick Dam to RBDD), ambient air temperature (the main factor) and flow volume determine the distance to which cool water released from Shasta and Clair Engle Reservoirs affects downstream river temperature.

Water management efforts during the 1987-1992 drought conditions, including bypass of power-generating capacity, have resulted in temperature control being maintained in the upper river as provided for in the consultation regarding 1992 CVP operations (NMFS 1992). The biological opinion for long-term operations of the CVP and SWP specifies temperature criteria and reservoir operations necessary to protect spawning and rearing habitat in the Sacramento River (NMFS 1993).

Reclamation is now operating the CVP to meet temperature criteria established in the February 12, 1993 biological opinion for winter-run chinook salmon. In addition, other actions to improve temperature control have been implemented (e.g., Whiskeytown temperature curtains). The frequency and intensity of adverse temperatures has diminished. Also, installation of the Shasta Temperature Control Device under the Central Valley Project Improvement Act (CVPIA) may further improve water temperature conditions.

Iron Mountain Mine

Metals from Iron Mountain Mine may have contributed to the winter-run chinook salmon decline. In June 1986, an accidental spill of mine waste may have reduced survival of the 1986 year class, contributing to the unexpected low escapement in 1989 (NOAA 1989). However, there is no direct evidence that Iron Mountain Mine metal pollution has contributed to the decline of winter-run chinook salmon. Although existing facilities may not prevent catastrophic losses during a spill event, future remedial actions may virtually eliminate existing threats to Sacramento River fishes.

River Diversions

Water diversions, in addition to the diversion at RBDD described previously, may also reduce survival of winter-run salmon. These diversions are primarily agricultural withdrawals, with about 60% of Sacramento River diversions occurring upstream of Ord Ferry (south of Hamilton City) (Reclamation 1986). Winter-run chinook salmon juveniles rear in this section of river and are subject to entrainment in diversions from July through October (diversions after October usually constitute a negligible proportion of Sacramento River flow). Fish screens may be installed as part of the Anadromous Fish Restoration Program (CVPIA) and could reduce entrainment effects.

River Sport Fishing

In 1987, new sport-fishing regulations were implemented to protect winter-run chinook salmon in the Sacramento River above RBDD (DFG 1989). Less than 4% of the spawning population was harvested each year by sport anglers in 1987, 1988, and 1989. More restrictive regulations were enacted when the winter run was listed by the state as endangered in 1989. Fishing for chinook salmon is now prohibited from January through July 15, when adult winter-run salmon are in the Sacramento River (DFG 1989).

Delay of Adult Migration through the Delta

The most direct route upstream through the Delta during adult migration to spawning areas is the Sacramento River channel (Figure 4-6). If the water mass in the lower San Joaquin River consists primarily of Sacramento River water, winter-run salmon adults may be attracted into the San Joaquin River part of the Delta and migration may be delayed or blocked until they find their way back to the Sacramento River (Hallock et al. 1970). Sacramento River water enters the lower San Joaquin River via the DCC, Georgiana Slough, and Threemile Slough and at the confluence of the Sacramento and San Joaquin Rivers. Factors affecting the proportion of Sacramento River water drawn into the lower San Joaquin River are diversions from and inflow to the Delta east of the Sacramento River, position of the DCC gates, tidal exchange patterns, and Sacramento River discharge.

The effect of delay on spawning condition depends on duration of delay and condition of females during the spawning migration. Winter-run chinook salmon females usually pass through the Delta in green condition (i.e., before eggs mature) and the eggs ripen months after the salmon arrive in their natal spawning area (Richardson and Harrison 1990). Delays of ripe females during migration through the Delta, however, may adversely affect spawning success.

Effects of the DCC and Georgiana Slough on Juvenile Migration

Winter-run salmon juveniles enter the Delta via the Sacramento River during migration to the ocean. As stated above, the most direct route through the Delta is the Sacramento River channel; some winter-run juveniles are drawn along an alternate route through the DCC and Georgiana Slough (Figure 4-6), where migration is delayed and losses to diversions and predation are increased.

Juvenile chinook salmon appear to enter Georgiana Slough and the DCC in numbers proportional to the amount of Sacramento River flow transferred into the channels, but the proportion varies with flood and ebb tide (Schaffter 1980, USFWS and DFG 1987, Hood 1990). Fish behavior and other factors probably also influence the relationship. The proportion of Sacramento River volume drawn into the DCC depends on DCC gate position, tidal exchange patterns, and Sacramento River discharge. The proportion of Sacramento River flow at Walnut Grove that is drawn into Georgiana Slough and the DCC has ranged from 5% to 76% (DWR 1990) (Figure 4-7).

With the DCC gates open, survival of hatchery-reared fall-run chinook salmon released in the Sacramento River upstream of the DCC and Georgiana Slough is lower than the survival of fish released in the Sacramento River downstream of Georgiana Slough (USFWS and DFG 1987). Some of the fish released upstream of the DCC are drawn into the DCC and Georgiana Slough and move into the lower San Joaquin River. Migration of fall-run salmon through the DCC and Georgiana Slough exposes juveniles to increased predation, higher temperatures, more agricultural diversions, and complex channel configurations (potentially delaying or preventing seaward migration). Juvenile winter-run salmon may be similarly affected.

USFWS and DFG (1987) concluded that when the proportion of Sacramento River flow drawn into the DCC and Georgiana Slough was high (greater than 60%) and the DCC gates were open, survival of juvenile fall-run chinook salmon released above the DCC was about 50% lower than that of juveniles released below Georgiana Slough. When the DCC gates were closed, only Georgiana Slough drew water out of the Sacramento River and survival was similar for the two release locations.

During spring 1989, juvenile fall-run survival was estimated during relatively constant riverflow (about 10,000 cfs in May and 13,000-14,000 cfs in June) at variable temperatures (60°-62°F in May and 67°-73°F in June) and fish release locations (Kjelson et al. 1990). Survival of juveniles released above the DCC (gates open) was lower than survival of juveniles released below Georgiana Slough; survival of juveniles released below Georgiana Slough was lower than survival of juveniles released in Steamboat and Sutter Sloughs. Juvenile chinook salmon released below Georgiana Slough may be carried upstream by tidal currents and drawn into the DCC or Georgiana Slough, accounting for reduced survival rates relative to survival rates for juveniles released in Steamboat and Sutter Sloughs. These study results indicate that survival is highest for fall-run juvenile salmon migrating through Steamboat and Sutter Sloughs, thus avoiding effects of the DCC and Georgiana Slough. Winter-run juveniles may also benefit from bypassing the DCC and Georgiana Slough.

Agricultural diversions may contribute to the difference in survival between chinook salmon migrating through the Delta via the Sacramento River and those migrating via the DCC and Georgiana Slough (USFWS and DFG 1987). Juvenile chinook salmon drawn into the DCC and Georgiana Slough are exposed to more agricultural diversions for a longer time than juveniles continuing down the Sacramento River. Peak winter-run migration occurs before agricultural diversion levels become high during late spring and summer (DWR 1990), but agricultural diversions occur during winter and can be substantial during April.

Increased predation has not been documented for juvenile chinook salmon migrating via the DCC and Georgiana Slough, but the longer and more complex migration route may increase exposure to predators. Although abundance of Sacramento squawfish and striped bass is highest in the Delta during late winter and early spring (Pickard et al. 1982) and coincides with the peak winter-run migration (Figure 4-2), predation has not been shown to be a significant factor in winter-run salmon survival.

The longer and more complex migration route for smolts migrating through the DCC and Georgiana Slough may also delay migration and lead to physiological stress, which in turn may increase susceptibility to disease, predation, and entrainment in unscreened diversions. Under the 1995 WQCP, operation of the DCC during November-January, coordinated with real-time fish monitoring, could reduce the proportion of winter-run chinook salmon entering the central Delta and increase survival.

Effects of Lower San Joaquin River Flow on Juvenile Migration

Juvenile winter-run chinook salmon migrating via the DCC and Georgiana Slough eventually enter the lower San Joaquin River (Figure 4-6). USFWS and DFG (1987) found that hatchery-reared juvenile fall-run salmon released at several Delta locations experienced the lowest survival rate when released south of the San Joaquin River in Old River near Holland Tract. The lower survival rate probably resulted from migration into the south Delta. Predation in Clifton Court Forebay (assumed to average 75%), losses at the SWP and CVP fish protection facilities (about 15%), and entrainment in diversions substantially reduces survival of juvenile chinook salmon in the south Delta.

Reverse flow in the lower San Joaquin River may reduce the survival of juvenile winter-run chinook salmon migrating through the Delta (USFWS 1993b). Diversion levels that are high relative to inflow cause reverse flow conditions. For juvenile chinook salmon released at Ryde on the Sacramento River, temperature-corrected survival was lower when net flows between the central and western Delta (a calculated flow known as QWEST [DWR 1990]) were low or reversed (Figure 4-8).

When San Joaquin River inflow to the Delta is less than export levels at the SWP and CVP Delta pumping facilities, or when Old River near Mossdale is closed with a barrier, flows in Old and Middle Rivers north of the SWP and CVP pumping facilities are reversed (i.e., toward the south). Reverse flows in Old and Middle Rivers occur most of the time and may have an adverse effect on juvenile salmon migrating through the Delta, including Sacramento River salmon that have entered the central Delta (USFWS 1992). Information is currently unavailable to determine the effect of reverse flow on survival of juvenile chinook salmon from the Sacramento River and whether survival changes with the magnitude of reverse flow.

Entrainment Losses

During migration of most juvenile winter-run chinook salmon through the Delta (i.e., January through April), agricultural diversion levels are low, except during April (Figure 4-2); diversion levels are highest during late spring and summer (DWR 1990). Diversion levels at the CVP and SWP pumps, however, are high during March and April, and entrainment losses of winter-run juveniles may be substantial (DWR 1990). As discussed above under "Distribution and Life History", storm events and increased Sacramento River discharge may move proportionally more juvenile winter-run chinook salmon to the Delta during October-January. Exports during October-January under the 1995 WQCP may increase relative to historical exports (SWRCB 1995). Increased export of water that coincides with relatively high abundance of winter-run juveniles in the Delta could increase direct and indirect entrainment losses.

Annual estimated salvage of apparent winter-run juveniles at SWP and CVP fish protection facilities exceeded 25,000 during 1981 and 1988 (DFG 1989). Total entrainment loss may have exceeded 100,000 juveniles, including substantial losses to predation (assuming about 75% loss at the SWP and 15% at the CVP) and 20%-40% loss attributable to the salvage procedure (about 70% screening efficiency and additional losses during handling and trucking). Fish size criteria are used to separate winter-run salmon from other races; therefore, the estimated losses may include juvenile spring-run salmon and hatchery-reared fall-run salmon.

Most winter-run juveniles entrained at the CVP and SWP pumps probably migrated via the DCC and Georgiana Slough. Juveniles that continue down the Sacramento River to the west Delta are less likely to be entrained in SWP and CVP diversions. Tidal currents dominate Sacramento River hydrodynamics at the junction of Threemile Slough and the lower San Joaquin River except during periods of very high river discharge. Most juvenile salmon that avoid the DCC and Georgiana Slough (especially smolts) continue migrating toward the ocean, possibly following the salinity gradient.

Movement of juveniles up the lower San Joaquin River from the west Delta and into the south Delta may occur when net reverse flow creates conditions that disorient the migrants; however, net flow volume is usually less than 1% of tidal volume in the lower San Joaquin River. Some of the tagged juvenile chinook salmon released in the San Joaquin River at Jersey Point (Figure 4-6) in 1989 were recovered at the Banks Pumping Plant (Kjelson et al. 1990). The juvenile salmon, possibly disoriented by transport, were released on flood tide that may have moved them farther upstream, where the influence of cross-Delta flow increases.

Ocean Fishing

Although less than 1% of total ocean landings of Central Valley chinook salmon consist of winter-run salmon, commercial and sport fishing may reduce adult winter-run salmon escapement to the rivers by 35%-45% (Pacific Fishery Management Council 1989, DFG 1989). The harvest rate of winter-run salmon (less than 35%) is lower than the harvest rate calculated for other runs (as high as 80%) primarily because winter-run adults migrate from the ocean during December through May before the main fishing season. Also, adults migrate when 2-3 years old. Fish that are 2 years old do not reach legal commercial size in the ocean and most 3-year-old fish reach legal size during the later months of the commercial season. Legal size limits for sport fishing allow the take of 2-year-old fish, and about 70% of the ocean catch of winter-run salmon may be attributable to sport fishing.

Ocean fishing regulations have been implemented that further restrict the sport season and close some areas to fishing, but the changes do not conclusively reduce the catch of winter-run chinook salmon. DFG and NMFS do not consider fishing mortality to be a major factor in the decline of the winter-run chinook salmon population (DFG 1989, Fullerton pers. comm.). Fishing mortality, however, reduces population resiliency and could slow recovery of the run if other limiting factors are ameliorated.

Other Factors

Other factors that may affect survival of winter-run chinook salmon include the following, which are discussed in greater detail for other species (e.g., delta smelt). Although winter-run salmon spend a relatively small proportion of their life in the estuary, they may reside in the estuary for several months, especially during wetter years. During Delta residence, the availability of shaded riverine aquatic habitat and shallow habitat in general may be important to survival. Toxic substances discharged to the estuary and tributaries, entrainment (direct and indirect effects) in Pacific Gas and Electric Company's (PG&E's) Pittsburg and Contra Costa power plants, competition with introduced species, and changes in estuarine food availability could affect winter-run survival.

Summary

Habitat degradation has reduced the population of winter-run chinook salmon. Major factors are blockage of adult passage to suitable spawning and rearing areas and lethal water temperatures during egg incubation and early rearing. Other factors that may impede recovery to former levels of abundance and continue to adversely affect winter-run salmon include entrainment loss to diversions, increased predation, the presence of toxic mine waste, diversion from the primary juvenile migration path through the Delta, and ocean fishing.

DELTA SMELT

The delta smelt (*Hypomesus transpacificus*) is a small (2- to 3-inch-long), translucent, slender-bodied fish with a steely-blue sheen. The delta smelt is found only in the Bay-Delta estuary (including Suisun Bay and sometimes San Pablo Bay). USFWS data indicate that most adults (1 year old) die after spawning, although a few survive to a second year (56 FR 50075, October 3, 1991).

Status

USFWS designated the delta smelt as a threatened species under the federal Endangered Species Act of 1973 on March 5, 1993 (58 FR 12854). USFWS's earlier proposal to list the delta smelt (56 FR 50075, October 3, 1991) indicated that federal listing of the delta smelt was justified by the apparent decline in its abundance and continued threats to its existence (e.g., upstream shift of the delta smelt's aquatic estuarine habitat, reduced habitat availability, poor water quality, and changes in food availability) and because existing regulatory mechanisms were inadequate to ensure the long-term existence of delta smelt or its habitat. USFWS's proposed critical habitat for delta smelt includes the Delta and Suisun Bay (59 FR 65256, December 19, 1994).

DFG recommended that the state list the delta smelt as a threatened species in August 1990. DFG's recommendation was based on the following factors, which it stated could inhibit recovery to former population levels:

- decline in the abundance of the copepod *Eurytemora affinis* (unless other food resources become major components of the smelt's diet or this copepod recovers to its former abundance);
- low stock levels, which may inhibit major increases in abundance because smelt produce relatively few eggs per individual and larval and juvenile mortality is probably high;
- water diversions from the Delta;
- presence of toxic substances; and
- adverse effects of exotic fish and invertebrate species.

On August 30, 1990, the California Fish and Game Commission ruled that the petition to list the species under the California Endangered Species Act was unwarranted because it could not be determined that the population was in imminent danger of extinction. The commission directed DFG, in coordination with DWR and other agencies, to implement studies to obtain information needed to address management and recovery objectives. The management and recovery objectives included the following:

- improve species identification and fish handling procedures at the CVP and SWP diversion locations,
- modify pumping schedules at the SWP and CVP diversion locations to reduce entrainment losses when delta smelt are most abundant,
- increase spring and summer Delta outflows to maintain the entrapment zone in Suisun Bay,
- support regulations to restrict ship ballast water discharge and potential introduction of harmful exotic species,
- evaluate losses to agricultural diversions in the Delta, and
- assess pond culture as a means of creating refuge populations.

A comprehensive investigation, divided into 10 different projects, has been designed and implemented by DFG and other agencies to provide information needed to address the management and recovery objectives set forth by the commission.

The California Fish and Game Commission ruled to list the delta smelt as threatened on August 21, 1993. State listing of the species implements protective regulatory mechanisms, such as memoranda of understanding on water project operations to prevent jeopardizing the continued existence of the species.

The delta smelt and its habitat could be affected primarily by changes in flow volume, direction, and origin attributable to the proposed project. The following discussion summarizes available information on the delta smelt and its habitat. Potential effects of the proposed project on the delta smelt and its habitat are evaluated in Section 5, "Impact Assessment".

Background

Biologists disagree on whether available data indicate a dramatic decline in the delta smelt population (DFG 1991) or a low, stable abundance that has been increasing since 1985 (State Water Contractors 1991). Delta smelt abundance is characterized by high variability between years and rapid recovery from low to high abundance (Figure 4-9). Reproductive failure can occur in some years and large numbers of smelt in one year may be followed by low numbers the following year (Stevens et al. 1990).

Six independent studies indicate that the abundance of delta smelt has been low since 1983 (Stevens et al. 1990). Although annual smelt abundance in single years had been as low, or nearly as low, before 1983 as it has been since 1983, 1983-1992 was the only multiple-year period of low abundance since sampling began in 1959.

Beginning in 1967, midwater trawl surveys have measured fall abundance of young-of-the-year striped bass and other species, including delta smelt, in the Delta and Suisun Bay. The fall midwater trawl survey provides a measure of the smelt population, although smelt may be less susceptible to capture by the trawls than are young striped bass (Sweetnam pers. comm.). The trawl survey may provide a measure of the relative abundance of each year class, assuming that the distribution of smelt is the same each year. A general downward trend in fall abundance appears to extend back to the peak population in 1970 (except for a high 1980 index). Although the fall index was lower during 1983-1988 than in any previous year, the indices for 1989, 1990, 1991, and 1993 increased (Figure 4-9). The trawl index for 1993 was one of the highest ever recorded and was followed by the lowest index ever recorded (101.2) in 1994 (USFWS 1995).

Summer tow-net surveys have been conducted from June to August each year since 1959 (except 1966). The survey objective is to index the abundance of young striped bass; catches of delta smelt are incidental. The summer tow-net survey samples of Suisun Bay and the Delta provide an index of delta smelt abundance during early summer, except during high-flow years, when larvae may be carried into San Pablo Bay. Delta smelt abundance has been very low every year since 1983, except 1986, 1993, and 1994, when the indices indicated moderate abundance (Figure 4-9).

As part of the San Francisco Bay Outflow Study, midwater trawls have captured smelt primarily during August through March (Stevens et al. 1990). Although sampling occurs year round, catches decline substantially after March because adults spawn upstream of the sampling area, adults die, and juveniles do not become vulnerable to the sampling gear until August. The survey indicates a striking decline in delta smelt abundance after 1981. Smelt abundance is not sampled in the Delta as part of the San Francisco Bay Outflow Study, however, and the smelt population may have been outside the study sampling area, especially during dry years.

Delta smelt have been an incidental catch during the salmon trawl and seine surveys since 1976. The salmon trawl survey samples are collected only near Chipps Island, and indices of smelt abundance are somewhat inconsistent with indices from other surveys because changes in smelt distribution vary with hydrologic conditions.

Salmon seine surveys are conducted during January to April, May, or June in the Delta and the Sacramento River. Catches may reflect the number of delta smelt undertaking their spawning migration. Smelt abundance indices for the salmon seine surveys are generally consistent with the summer tow-net and fall midwater trawl surveys.

Estimated salvage of delta smelt at the SWP and CVP fish screens is affected by annual variations in geographical distribution, variation in export rate, and data quality control problems. The salvage records, however, are consistent with other data sets, indicating that smelt abundance is currently low relative to abundance in the 1970s.

Also, scientists from the University of California, Davis (UC Davis), have used otter trawls to sample fish populations in Suisun Marsh since 1979 (Stevens et al. 1990). Smelt catch has declined substantially since 1981, consistent with results of other surveys. The midwater trawl and summer tow-net surveys, however, may better depict the overall trend in smelt abundance because the UC Davis survey is limited to Suisun Marsh and cannot account for annual changes in geographic distribution.

The summer tow-net and fall midwater trawl surveys provide the best geographical coverage and probably the best basis for evaluating delta smelt population trends. The other data sources confirm the general downward trend in smelt abundance and provide additional information on distribution patterns (Stevens et al. 1990). Although the long-term trends in abundance are the same for the summer tow-net and fall midwater trawl indices, the indices may not indicate the same level of abundance for a given year (i.e., one index cannot be used to accurately predict the other). Schooling behavior, decreases in uniformity of distribution as the smelt grow larger, and changes in sampling efficiency may increase the variability of the surveys in a given year. Differences in trends shown by the fall midwater trawl indices and the summer tow-net indices may also be attributable to variations in survival and smelt distribution between summer and fall.

Distribution and Life History

USFWS data indicate that delta smelt are found in the Bay-Delta estuary where salinity is generally less than 2 parts per thousand (ppt) (56 FR 50075, October 3, 1991). Smelt are rarely found in estuarine waters with salinity of more than 10-12 ppt; for example, delta smelt are virtually absent from San Francisco Bay. Except when spawning in fresh water, delta smelt are most frequently caught in or slightly upstream of the entrapment zone, where salinity is between 0.5 ppt and 5.2 ppt (Moyle et al. 1992). Since the start of the 1986-1992 drought, most delta smelt have been almost entirely absent from Suisun Bay and Marsh.

Delta smelt disperse widely into fresh water in late fall and winter as the spawning period approaches, moving as far upstream as Mossdale on the San Joaquin River and the confluence with the American River on the Sacramento River. In 1989 and 1990, spawning locations ranged from Roe Island in Suisun Bay to Garcia Bend on the Sacramento River and to Medford Island on the San Joaquin River (Wang 1991). During 1989, spawning in the Delta was more intensive in the San Joaquin River than in the Sacramento River and was centered around Bradford Island (Wang and Brown 1993). Some spawning has been recorded in Montezuma Slough. The distribution of spawning may depend on the distribution of fresh water downstream of the Delta and the location of the salinity gradient. During high freshwater inflow to the Delta in 1993, spawning appeared to be relatively dispersed.

Delta smelt spawning occurs in fresh water from February through June and may peak during late April and early May (Wang 1991, Sweetnam and Stevens 1991, Stevens et al. 1990). Individual females probably spawn over a short period, but it is unclear whether individual smelt spawn more than once or whether individuals mature at different times and then spawn only once over a 4- to 5-month period (Wang 1991, Moyle et al. 1992).

The most probable spawning locations for delta smelt are dead-end sloughs and shallow edge waters of the channels of the Delta and the Sacramento River. Ideal spawning areas are those with moderate to fast flows (including tidal action) and thriving aquatic vegetation (Wang 1991). Females deposit 1,200-2,600 demersal and adhesive eggs on substrates such as rock, gravel, tree roots, and submerged vegetation (Sweetnam and Stevens 1991, Wang 1986).

After the eggs hatch (in about 12-14 days), larvae float to the surface and are carried by the currents (Stevens et al. 1990). Under natural outflow conditions, the larvae are carried downstream to near the entrapment zone (Figure 4-10), where they typically remain and grow to adult size. When the entrapment zone is in Suisun Bay, where both shallow and deep water exist, smelt are caught most frequently in shallow water.

The proportion of the delta smelt population found in Suisun Bay during summer and fall is correlated with Delta outflow volume (Stevens et al. 1990). During summer and fall 1991, most of the smelt population was located where the concentration of total dissolved solids (TDS) was 1,300 milligrams per liter (mg/l), (i.e., at a salinity of about 1.3 ppt). Delta outflow determines the location of the salinity gradient and may strongly influence delta smelt distribution during spring, summer, and fall.

Delta smelt feed almost exclusively on zooplankton, primarily copepods (*Eurytemora affinis, Pseudodiaptomus forbesi*, and others). Sufficient data have not been collected to determine food preference. Mysids (*Neomysis mercedis*), rotifers, cladocerans, and amphipods may be important food items, depending on availability or size relative to the size of delta smelt.

Juvenile smelt grow rapidly and young smelt are 40-50 millimeters (mm) long by early August (Stevens et al. 1990). Within 6-9 months, the young smelt reach adult lengths (59-70 mm) and grow only a few millimeters during the months preceding spawning.

Factors Affecting Delta Smelt Abundance

Year-class abundance of delta smelt is assumed to depend on the environmental conditions experienced by the eggs and young fish. This assumption is supported by high variability in annual delta smelt abundance, historical recovery from low to high abundance in short periods, poor agreement between fall and summer abundance indices, and a relatively weak spawner-recruit relationship.

Spawning Stock Abundance

Although the spawner-recruit relationship is weak, the low fecundity of delta smelt and the likely low survival of the planktonic larval stage indicate that reproduction probably depends on the presence of relatively large spawning populations. Low stock levels may inhibit potential increases in abundance and are likely to increase vulnerability to extinction. Relatively low adult abundance in 1992, however, resulted in relatively high juvenile abundance in fall 1993. Rapid recovery may indicate the potential resilience of the species but may also reflect inaccuracy of existing monitoring programs.

Food Availability

Although some information is available on prey items in the diet of delta smelt, little is known about their food preference and dietary requirements. Changes in the abundance of major prey items (e.g., the copepod *Eurytemora affinis*) could affect survival and growth of delta smelt. Populations of *E. affinis* have recently declined, possibly reflecting changes in the Delta environment attributable to introduction of competitive and predatory species, reduced Delta inflow, increased diversions, and other unknown factors. Before its decline, *E. affinis* was abundant during the smelt larval period (Obrebski et al. 1992).

The introduced copepod species *Sinocalanus doerii* and *Pseudodiaptomus forbesi* have become abundant in the estuary (Stevens et al. 1990). *S. doerii* appears to be rarely eaten by Delta smelt; however, *P. forbesi* has been a primary component in stomach samples of smelt. *P. forbesi* may not be available to larval and early juvenile stages of the delta smelt because abundance of this copepod peaks during summer.

Essentially nothing is known about the feeding requirements of larval delta smelt, but fish larvae generally require high densities of small food particles, such as copepod nauplii or rotifers (Hunter 1981). Densities of these potential prey may have decreased greatly in recent years (Obrebski et al. 1992).

Diversions

Delta smelt are vulnerable to diversions throughout their life cycle, particularly in dry years, when they are concentrated in the Delta, where most fresh water is diverted (DWR 1993b). Smelt distribution may be a function of salinity (see "Delta Outflow" below). Smelt are most frequently caught in the upstream end of the entrapment zone, where salinity is between 0.5 ppt and 5.2 ppt (Sweetnam and Stevens 1991). The location of the entrapment zone (which includes the null zone, where salinity near the bottom is about 2 ppt) depends on the volume and duration of Delta outflow (Williams and Hollibaugh 1987). Increasing outflow moves the entrapment zone toward Suisun and San Pablo Bays and out of the Delta. Low Delta outflow results from reduced inflow caused by drought conditions, diversions within and upstream of the Delta, and reservoir storage upstream of the Delta.

Diversions from the Delta include those at PG&E's Pittsburg and Contra Costa power plants, over 1,800 agricultural diversions, exports by the CVP and SWP, and miscellaneous municipal and industrial diversions. Millions of smelt larvae and thousands of juveniles have been entrained in the diversions at PG&E's Pittsburg and Contra Costa power plants (Stevens et al. 1990). The number of smelt entrained in agricultural diversions is unknown, but losses are probably high. Stevens et al. (1990) reported that smelt were the most numerous among the species entrained at the Roaring River Slough diversion from Montezuma Slough in Suisun Marsh.

The number of smelt salvaged at the SWP and CVP fish facilities has exceeded 1 million during some years. Peak salvage occurs from May through July and consists primarily of juvenile smelt, the progeny of the current year's spawn (Figure 4-11). Large numbers of adults have been salvaged from December through April, when Delta conditions distributed smelt to areas where they were vulnerable to entrainment (i.e., as occurred during January 1978). The number of fish surviving salvage is probably exceeded by pre-entrainment losses, losses through the fish screens, and losses attributable to stress during handling and trucking from the fish facilities. Major entrainment losses of larvae probably occur during late March, April, and May but have not been recorded because smelt are small and pass through the fish screens during the first month or two of life.

Entrainment losses have not been shown to reduce delta smelt abundance; however, the losses cannot be discounted. Losses resulting from entrainment can be a major factor contributing to the total annual mortality of smelt.

Toxic Substances

Agricultural chemicals (including pesticides and herbicides), heavy metals, petroleum-based products, and other waste materials toxic to aquatic organisms enter the estuary through nonpoint runoff, agricultural drainage, and municipal and industrial discharges. The effects of toxic substances have not been tested on delta smelt, but some of the substances are present in Delta fishes at levels that exceed safe human consumption criteria and may affect fish reproduction. Also, recent bioassays by the Central Valley Regional Water Quality Control Board indicate that water in the Sacramento River is periodically toxic to larvae of the fathead minnow, a standard EPA test organism (Stevens et al. 1990). Although effects on abundance have not been shown, toxic substances may kill delta smelt and reduce their capacity to adapt to variable conditions in the estuary.

Delta Outflow

Delta outflow is highly variable across years; seasonally; and, at times, daily. In general, month-to-month outflows in any given year are highly autocorrelated (i.e., flow during one month is related to flow the previous month), whereas year-to-year outflows are not (i.e., flows during one year are not related to flows the previous year). This generally means that in wet years, high outflows occur across several months (Herbold et al. 1992). Historical total annual outflow has ranged from less than 10 MAF to more than 50 MAF.

Although dependent on the natural hydrology of the Sacramento-San Joaquin River system, the timing and volume of Delta outflow have been substantially modified by changes in system characteristics (i.e., channelization and flood control projects) and by operations of water project facilities (i.e., reservoirs and diversions) (Herbold et al. 1992). Channelization and flood control projects (not including reservoir storage) enable water to move more quickly through the Delta. Storage results in reduction of peak flows and changes in the timing of water movement down the rivers. Consumptive diversions remove water from the system.

In general, water projects have increased summer and fall outflow and reduced winter and spring outflow (Herbold et al. 1992). Total annual Delta outflow may be reduced by 50%-60% of the outflow expected in the absence of storage and diversions, with less proportional change in wet years and more in dry years.

Delta outflow, including the interrelated effects of Delta diversions, may be the primary factor controlling delta smelt abundance and distribution. High outflow may transport smelt larvae and early juveniles downstream of the Delta, provide improved habitat conditions in Suisun Bay, and locate salinity preferred by larval and juvenile smelt downstream of the Delta and away from the effects of Delta diversions (USFWS 1994). High outflow may also dilute toxic materials and increase turbidity that may reduce predation on eggs, larvae, and adults.

Relationship between Outflow and Delta Smelt Distribution. Delta smelt distribution is a function of outflow. Stevens et al. (1990) showed that more than 50% of the variation in the proportion of the smelt population found in Suisun Bay is explained by variation in Delta outflow. The mechanism of distribution (i.e., whether outflow transports the larvae downstream or larvae actively maintain their location relative to the entrapment zone) is not known.

Data suggest that the buoyancy of early larvae may enhance downstream transport. Delta smelt larvae are buoyant for 4-5 days after hatching because of the buoyancy of an oil globule in the yolk sac. After this period, the larvae sink toward the bottom. Reduced buoyancy with age may enable larvae to actively maintain their location relative to the entrapment zone.

The parameter X2 (2-ppt salinity or about 3,000 microsiemens electrical conductivity [EC]) is generally considered the upstream boundary of the entrapment zone (San Francisco Estuary Project 1993). The location of X2 in the estuary is a function of Delta outflow volume; as outflow increases, X2 moves farther downstream.

When X2 is in Suisun Bay, the proportion of the delta smelt population in the Delta (upstream of Chipps Island) is lower than when X2 is in the Delta (DFG 1992a). A similar relationship exists for striped bass (DFG 1992b). Comparison of the relationships between X2 and the proportion of larvae and early juveniles in the Delta for striped bass and delta smelt indicates that delta smelt may be located farther upstream. The relationship between distribution and salinity, however, is dependent on life stage, with younger life stages found in fresher water. Detailed data on distribution of delta smelt larvae by size are not available.

During years with high flows, the entrapment zone and the majority of delta smelt larvae and juveniles are located in Suisun Bay throughout summer and into fall (DFG 1992a). During low-flow years, the entrapment zone and the majority of delta smelt are located in the Delta.

Relationship between Outflow and Delta Smelt Abundance. A shift in geographic location of the entrapment zone (X2) during winter may have contributed to the decline in delta smelt abundance since 1984 (Moyle et al. 1992). Before 1984, the entrapment zone was located in Suisun Bay (characterized by shallow, productive shoal areas) during winter of most years. From 1984 to 1992, the entrapment zone was generally confined to narrow, relatively deep river channels in the Delta.

Variability in the abundance of delta smelt (as indicated by the fall midwater trawl index) may be partially explained by the number of days that X2 is located in Suisun Bay ($r^2 = 0.25$) (USFWS 1994, Herbold 1994). Delta smelt abundance is greatest when X2 is located in Suisun Bay during February-June. Abundance is lowest when X2 is upstream or downstream of Suisun Bay.

As in the case of juvenile striped bass, location of delta smelt in the estuary may determine the effect of other factors (i.e., entrainment). Since 1970, survival of striped bass in the Delta habitat appears to have declined (DFG 1992b). Survival of delta smelt in the Delta, especially considering their more upstream distribution relative to the distribution of striped bass, may also have declined. The reduction in striped bass survival after 1970 may be attributed to increased diversion (i.e., the SWP Delta pumping facilities began substantial diversion during and after 1970).

Lower San Joaquin River

Rates of diversion in the southern Delta that exceed San Joaquin River and eastside tributary stream inflow often cause net reverse flow in the lower San Joaquin River and other Delta channels. Net reverse flow may transport delta smelt larvae toward the SWP and CVP export facilities and may alter natural adult, larval, and early juvenile migration patterns. Moyle and Herbold (1989) found that delta smelt abundance in Suisun Bay was low in years with many days of reverse flow during spring, when delta smelt spawn. However, delta smelt abundance was also low in some years with relatively few days of reverse flows. As discussed previously, the location of delta smelt in the estuary may determine the effects of other factors, including the effect of lower San Joaquin River flow.

Other Factors

Introduction of exotic species may also affect delta smelt abundance. Competition and predation cannot be ruled out as potential factors affecting the abundance of delta smelt; however, there has been no consistent increase in the abundance of potential predators or competitors that could account for the reduced abundance of delta smelt after 1983. Striped bass have been the most abundant predator and competitor occupying the delta smelt environment. Delta smelt are occasionally consumed by striped bass, but they are not a significant prey item; smelt appear to occur in the striped bass diet less often than would be expected based on the proportional abundance of smelt relative to other prey species (Stevens et al. 1990). Also, a substantial decline in abundance of striped bass preceded the reduced abundance of smelt after 1983, suggesting that striped bass predation was not previously limiting smelt abundance.

Summary

With the exception of 1993, delta smelt abundance has been consistently lower after 1983 than in previous years. Abundance is highly variable from year to year and the population has historically rebounded (e.g., the increase in abundance from 1992 to 1993) (Figure 4-9). Introductions of exotic organisms have potentially altered the delta smelt food supply. Upstream water storage, upstream diversions, and diversions from the Delta have modified delta smelt habitat and distribution and possibly reduced abundance. The single most important factor affecting smelt abundance may be the location of X2 in the estuary (i.e., abundance is highest when X2 is located in Suisun Bay during February-June). Environmental changes may have adverse effects on smelt survival and result in a relatively rapid reduction in abundance because delta smelt have essentially a 1-year life cycle, low fecundity, and planktonic larvae and are confined to the Bay-Delta estuary.

SACRAMENTO SPLITTAIL

Sacramento splittail (*Pogonichthys macrolepidotus*) are large (more than 30 centimeters [cm] in length) cyprinids (minnow family) endemic to the lakes and rivers of the Central Valley (Moyle et al. 1989). Splittail are most abundant in Suisun Bay and Marsh and in the Delta.

Status

USFWS has estimated that splittail abundance has declined by 62% over the last 15 years and has proposed the splittail for listing as threatened under the federal

Endangered Species Act (59 FR 862, January 5, 1994). The decline in abundance prompted DFG to designate splittail as a species of special concern.

Background

Fall midwater trawl surveys provide the longest, most accurate index of splittail abundance. Results of the fall midwater trawl surveys indicate that juvenile splittail abundance has been highly variable from year to year, with peaks and declines coinciding with wet and dry periods (Figure 4-12). Splittail abundance declined after 1983.

Distribution and Life History

DFG sampling surveys from September 1963 to August 1964 determined that splittail were the most evenly distributed cyprinid in the Delta (Turner 1966). Splittail are largely confined to the Delta, Suisun Bay, Suisun Marsh, and Napa Marsh and are rarely found more than 5-10 miles above the upstream boundaries of the Delta (Moyle et al. 1989, Natural Heritage Institute 1992). Historically, they ranged much farther upstream in the Sacramento and San Joaquin Rivers and their tributaries.

USFWS has found that splittail are abundant in Suisun and Grizzly Bays (59 FR 862, January 6, 1994). Since 1985, splittail have been rare in San Pablo Bay, indicating that their range may be declining further. Splittail are also abundant in the western and northern part of the Delta (Moyle et al. 1989). In recent years, splittail distribution appears to have shifted to the lower Sacramento River and south Delta (59 FR 862).

Incidental catches of large splittail in fyke traps set by DFG to catch migrating striped bass in the lower Sacramento River during spring indicate that splittail may migrate from lower river reaches to upstream spawning habitats.

Sacramento splittail are freshwater fish capable of tolerating moderate levels of salinity (10-18 ppt) (59 FR 862). They grow to be 40 cm long and live as long as 5 years. The diet of adults and juveniles includes decayed organic material; earthworms, clams, insect larvae, and other invertebrates; and fish. The mysid *Neomysis mercedis* is a primary prey species, although decayed organic material constitutes a larger percentage of the stomach contents of Sacramento splittail (Daniels and Moyle 1983).

Both male and female splittail become sexually mature by their second winter, when they are about 10 cm in length. Female splittail are capable of producing over 100,000 eggs per year (Daniels and Moyle 1983, Moyle et al. 1989).

Splittail deposit adhesive eggs over flooded streambanks or aquatic vegetation when water temperatures are between 9°C and 20°C (Moyle 1976, Wang 1986). Splittail spawn in late April and May in Suisun Marsh and between early March and May in the upper Delta and lower reaches of the Sacramento and San Joaquin Rivers (Moyle et al. 1989). Spawning has been observed to occur as early as January and to continue through July (Wang 1986).

Larval splittail are commonly found in the shallow, weedy areas where spawning occurs. Larvae eventually move into deeper, open water habitats as they grow and become juveniles. During late winter and spring, young-of-year juvenile splittail (i.e., less than 1 year old) are found in sloughs, rivers, and Delta channels near spawning habitat. Juvenile splittail gradually move from shallow, nearshore habitats to the deeper, open water habitats of Suisun and San Pablo Bays (Wang 1986). In areas upstream of the Delta, juvenile splittail can be expected to be present in the flood basins (i.e., Sutter and Yolo Bypasses and the Sacramento River) (JSA 1993).

Factors Affecting Sacramento Splittail Abundance

Reduced Delta outflow, entrainment in diversions, dams and reservoirs, introduced aquatic species, loss of wetlands and shallow-water habitats, and the recent drought may have contributed to the apparent decline in Sacramento splittail distribution and abundance (USFWS 1993a).

Habitat

Habitat modification is probably the largest factor contributing to the decline of Sacramento splittail (DFG 1992c). Water diversions, land reclamation, flood control, and agricultural developments have eliminated and drastically altered much of the splittail habitat in the lowland areas, and dams have restricted access to spawning areas and upstream habitats. USFWS estimates that diking and dredging have eliminated approximately 96% of the wetland habitats that splittail apparently require (59 FR 862, January 6, 1994). Most diking and filling of wetlands preceded the recent decline in splittail abundance. In the past 20 years, only relatively small habitat areas have been lost to levee riprapping and wetland filling.

Flow

The fall midwater trawl index for Sacramento splittail is positively correlated with Delta outflow during March-May (Figure 4-13), indicating that variability in abundance is at least partially explained by flow. Because spawning and early rearing of larval splittail are associated with shallow vegetated areas, inundation of riparian and seasonally flooded habitats may be an important factor determining year-class success. River flow determines the availability of shallow-water habitats with submerged vegetation during late winter and spring (Daniels and Moyle 1983).

Upstream water storage facilities and water diversions have reduced the magnitude and duration of flows to upstream habitats and the Delta. Reduced habitat availability and reduced duration of flooding may degrade conditions necessary for spawning and larval development and habitat may be desiccated before larvae have moved to channels providing permanent rearing conditions.

Delta diversions reduce Delta outflow and may affect Sacramento splittail habitat in Suisun Marsh and slow transport of juveniles to areas downstream of the Delta. USFWS notes that longer residence in the Delta may increase entrainment loss of juvenile splittail in Delta diversions (59 FR 862, January 6, 1994).

Entrainment

The magnitude of losses resulting from diversions depend on the timing, size, and location (geographic location and position in the channel) of individual diversions relative to the seasonal distribution and abundance of splittail. Thousands of splittail larvae, juveniles, and adults are entrained annually in exports by CVP and SWP pumping facilities. An unknown percentage is salvaged and returned to the Delta alive.

Salvage data from the CVP and SWP pumping facilities indicate that adult splittail are entrained at the pumping facilities year round, primarily during January-April (Figure 4-14). The highest entrainment of adults coincides with the migration and spawning season.

Juvenile splittail are salvaged primarily during May-July (Figure 4-14). Juveniles from the current year's spawn first appear in salvages during April. Substantial numbers of small juveniles (i.e., less than 30 mm long) and larvae may be entrained and lost before and during April and May. The tendency of larvae to remain near spawning habitat, however, may restrict entrainment of larvae and small juveniles to nearby diversions.

Splittail larvae, juveniles, and adults probably are entrained in the approximately 1,800 Delta agricultural diversions, PG&E's Contra Costa and Pittsburg power plant diversions, and numerous other diversions from the Delta and Suisun Bay and Marsh. Entrainment losses, however, cannot be estimated with the available data.

Other Factors

Sacramento splittail survival may be reduced by entry of toxic materials into the Sacramento-San Joaquin River system from agricultural runoff, discharge of industrial and municipal waste, and runoff from nonpoint sources (e.g., urban stormwater runoff). In the Delta, pollutants of particular concern are trace elements (selenium, copper, cadmium, and chromium) and agricultural chemicals and their derivatives, which are used extensively in the Central Valley. No specific information exists on the effect of toxic materials on Sacramento splittail; however, toxic concentrations in the Bay-Delta estuary have been shown to adversely affect other species (see "Delta Smelt" above).

The effects of competition and predation are difficult to evaluate in wild populations. Splittail are subjected to predation by Sacramento squawfish and striped bass (Wang 1986). Numerous introduced species (such as sunfish and catfish) may compete with and prey on splittail larvae and juveniles. The effect of competition and predation on splittail abundance is unknown, but abundance may be affected substantially more by habitat and outflow than by recent changes in competition and predation.

Summary

Dams, diversions, pollution, and agricultural development have eliminated or altered Sacramento splittail habitat (Moyle et al. 1989). Year-class survival is affected by Delta outflow, possibly because spawning success depends on spawning habitat availability (Moyle et al. 1989) (Figure 4-13); upstream storage reservoirs and diversions may reduce the frequency and magnitude of floodflows, thereby affecting the availability of flooded vegetation during the spawning season.

Diversions entrain adult and juvenile fish. Peak salvage at the CVP and SWP fish protection facilities occurs during May-July (Figure 4-14). Adult fish are salvaged primarily during January-April. Annual progeny generally first appear in salvage operation facilities during April, when they are about 40 mm long. Although larvae are entrained, vulnerability of larvae to entrainment is unknown. Most larvae may rear near the spawning area and avoid exposure to more distant diversions. Diversions appear to entrain primarily young-of-the-year juveniles and sexually mature fish; few yearling splittail are salvaged.

Pollution (from sources including agricultural runoff, sewage discharge, industrial discharge, and nonpoint runoff) has altered water quality in the Bay-Delta estuary, possibly reducing survival. Channelization of rivers and Delta waterways has reduced habitat availability.

LONGFIN SMELT

Longfin smelt (*Spirinchus thaleichthys*) is a 3- to 6-inch-long silvery fish (Moyle 1976). Longfin smelt were the most abundant smelt species in the Bay-Delta estuary prior to 1984 and have been commercially harvested (Wang 1986).

Status

In 1993, USFWS was petitioned to list the longfin smelt under the federal Endangered Species Act. In January 1994, however, USFWS determined that the longfin smelt does not warrant listing because other longfin smelt populations exist along the Pacific Coast, the Bay-Delta estuary population does not appear to be biologically significant to the species as a whole, and the Bay-Delta estuary population may not be sufficiently reproductively isolated (59 FR 869, January 6, 1994). Longfin smelt was included in this biological assessment because of the decline in abundance after 1982 and the relatively small increase in abundance following 1993 (a wet year) and because the species may be considered for listing under the California Endangered Species Act.

Background

None of the existing fishery surveys encompasses the entire geographic range of longfin smelt in the estuary. DFG's fall midwater trawl survey, which began in 1967 and was conducted during September-December, sampled about 90 stations extending from around Stockton and Walnut Grove in the Delta to the middle of San Pablo Bay. The fall midwater trawl survey captures primarily young-of-year juveniles (DFG 1987).

Fall midwater trawl surveys provide the longest, most accurate index of longfin smelt abundance. Results of the fall midwater trawl surveys indicate that, like Sacramento splittail abundance, longfin smelt abundance has been highly variable from year to year, with peaks and declines coinciding with wet and dry periods (Figure 4-15). Longfin smelt abundance has steadily declined since 1982. Longfin abundance was very low from 1987 to 1992, with 1992 having the lowest index on record. Abundance increased somewhat in 1993.

Distribution and Life History

Longfin smelt are widely distributed in estuaries on the Pacific Coast. They have been collected from numerous river estuaries from San Francisco to Prince William Sound in Alaska (Moyle 1976).

Longfin smelt are euryhaline (i.e., adapted to a wide salinity range) and anadromous. Spawning adults are found seasonally as far upstream in the Delta as Rio Vista, Medford Island, and the CVP and SWP pumps. Before construction of Shasta Dam in 1944, saline water intruded in dry months as far upstream in the Delta as Sacramento, so it is likely that longfin smelt periodically ranged much farther upstream at that time than they do now (Herbold et al. 1992).

Except when spawning, longfin smelt are most abundant in Suisun and San Pablo Bays, where salinity generally ranges between 2 ppt and 20 ppt (Natural Heritage Institute 1992). Adults are found seasonally as far downstream as the south Bay and are occasionally collected in the open ocean.

Prespawning adults and yearling juveniles are generally most abundant in San Pablo Bay and downstream areas, whereas the young-of-year (survivors of current year's spawn) are found primarily in San Pablo and Suisun Bays. The ultimate distribution of longfin smelt larvae in the estuary is determined by Delta outflow during the period of larval development (February-May), with larvae being dispersed farther downstream in years of high outflow than in years of low outflow (DFG 1992c).

Maturation of longfin smelt begins late in their second summer (August and September) of life. As they mature, the smelt begin migrating upstream from San Francisco and San Pablo Bays toward Suisun Bay and the Delta. Most longfin smelt spawn and die at 2 years of age (DFG 1992c, Natural Heritage Institute 1992).

Longfin smelt spawn primarily from January through April, although some spawning may occur at any time from November through June. A female deposits about 5,000-24,000 eggs at one time. (Natural Heritage Institute 1992.) The eggs are adhesive and are probably deposited on rocks or aquatic plants.

Longfin smelt spawn in fresh water, primarily in the upper end of Suisun Bay and in the lower and middle Delta. In the Delta, they spawn mostly in the Sacramento River channel and adjacent sloughs (Wang 1991). During the recent drought, when saline water intruded into the Delta, larval longfin smelt were found near the CVP and SWP pumps, well upstream of the usual spawning habitat (Wang 1991).

Longfin smelt eggs hatch in 37-47 days at 45°F. Larval abundance in the Bay-Delta estuary peaks during February-April. (DFG 1992c.)

Shortly after hatching, a longfin smelt larva develops a gas bladder that allows it to remain near the water surface (Wang 1991). The larvae do not vertically migrate, but instead remain near the surface on both the flood and ebb tides (DFG 1992c). Larvae in near-surface waters are swept downstream into nursery areas in the western Delta and Suisun and San Pablo Bays (DFG 1987, Baxter pers. comm.). Early development of gas bladders by longfin smelt causes the larvae to remain near the surface much longer than delta smelt larvae and may explain why the longfin smelt larvae are dispersed much farther downstream in the estuary than are delta smelt larvae (Baxter pers. comm.).

Metamorphosis of longfin smelt from the larval to the juvenile form begins 30-60 days after hatching, depending on temperature. Most longfin smelt growth in length occurs during the first summer, when length typically reaches 6-7 cm. During their second summer, smelt reach 9-11 cm in length. (Natural Heritage Institute 1992.)

The main prey of adult longfin smelt is the opossum shrimp, *Neomysis mercedis* (Natural Heritage Institute 1992). There is little information on food habits of longfin smelt larvae, but fish larvae of most species, including delta smelt, are known to feed on phytoplankton and small zooplankton such as rotifers and copepod nauplii (Hunter 1981, Reclamation 1993).

Juvenile longfin smelt feed on copepods, cladocerans, and mysids. The mysid *Neomysis mercedis* is the most important prey of larger juveniles.

Factors Affecting Longfin Smelt Abundance

Year-class abundance of longfin smelt appears to depend on the environmental conditions experienced by the eggs and young fish. Generally, year-class abundance is positively related to Delta outflow (i.e., high abundance follows high outflow during winter and spring). Factors possibly contributing to the recent decline in longfin smelt abundance are reduced Delta outflow, entrainment in diversions, introductions of exotic species, loss of habitat, and the recent drought.

Delta Outflow

Relationship between Delta Outflow and Longfin Smelt Distribution. Outflow may influence the timing and location of longfin smelt spawning, which may begin as early as November (Natural Heritage Institute 1992). In years of high outflow, upper Suisun Bay has relatively fresh water that may support spawning. In years of low outflow, the smelt migrate into the Delta to reach fresh water.

The distribution of longfin smelt larvae is strongly related to Delta outflow. Higher outflows lead to greater downstream dispersion of larvae. In years of low outflow (1981, 1985, 1987, and 1988), longfin smelt larvae were found primarily in the western Delta and Suisun Bay, and in years of high outflow (1980, 1982-1984, and 1986), larvae were equally or more abundant in San Pablo and San Francisco Bays.

The distribution of young-of-year juveniles is determined primarily by the dispersion of larvae in winter and spring (DFG 1992c). Juveniles older than 1 year may be dispersed farther downstream by winter and spring outflow. Yearling juveniles and adults are generally distributed farther downstream in the estuary than are young-of-year juveniles (Baxter pers. comm.).

Relationships between Delta Outflow and Longfin Smelt Abundance. Higher outflows result in higher longfin smelt survival. DFG's (1987) index of survival computed as the ratio of the index of abundance from fall midwater trawl surveys to an index of larval abundance in previous springs was strongly correlated (r = 0.95) with December-August Delta outflow. Delta outflow or factors associated with outflow affect survival of larvae and early juveniles.

Young-of-year juvenile abundance (according to the fall midwater trawl survey index) is positively related to Delta outflow (Figure 4-16) (Stevens and Miller 1983; DFG 1987, 1992c). Regression analysis indicated that 79% of variability in the midwater trawl survey index is explained by changes in January and February Delta outflow. The significant relationship between the index of abundance from the fall midwater trawl surveys and Delta outflow may reflect the effect of outflow on survival of larvae and early juveniles. Year-class strength may be largely determined by survival of the early life stages.

High Delta outflow may increase the amount of suitable brackish water rearing habitat; reduce salinity in the estuary, reducing competition and predation by marine organisms; reduce predation because young smelt are more dispersed and turbidity is higher; increase phytoplankton and zooplankton production; and increase transport of larvae out of the Delta and away from diversions (DFG 1992c, Stevens and Miller 1983, Baxter pers. comm.). Any of these mechanisms may be responsible for the observed relationship between Delta outflow and longfin smelt abundance.

The position of the entrapment zone, location of X2, and volume of critical nursery habitat are determined by Delta outflow. In addition to the relationship with outflow, the fall midwater trawl survey index has a positive relationship with the location of X2 and the volume of critical nursery habitat (Jassby 1993, Herrgesell 1993).

Delta smelt abundance tends to be highest when X2 has an intermediate value (i.e., X2 is located in upper Suisun Bay). The location of X2 is also a good predictor of longfin smelt abundance, but longfin smelt abundance is highest when X2 has minimal values (i.e., X2 is located in lower Suisun Bay) (Jassby 1993). The location of X2 and the volume of critical nursery habitat are largely determined by Delta outflow, so the relationship between longfin smelt abundance and the location of X2 or volume of critical habitat may simply reflect effects of outflow or other correlates of outflow on longfin smelt abundance.

Lower San Joaquin River

Reverse flow in the lower San Joaquin River usually transports relatively fresh water drawn from the Sacramento River and may increase upstream migration of adults to the south Delta. Reverse flow may also transport larvae to the south Delta. In the south Delta, adults, larvae, and juveniles are vulnerable to entrainment, predation, and other sources of mortality.

Entrainment

Entrainment of longfin smelt by Delta diversions affects spawning adults, larvae, and early juveniles. Older juveniles and prespawning adults generally inhabit areas downstream of the Delta.

Salvage at both the CVP and SWP fish protection facilities has varied greatly between years. Salvage represents entrainment but the number of fish salvaged is often much lower than total number entrained because fish smaller than about 20-30 mm pass through the fish screens at the salvage facilities and therefore are not salvaged.

With the exception of 1986, a wet year, the annual salvage of longfin smelt at the CVP and SWP pumps was much higher during 1984-1990 than during 1979-1983. Figure 4-15 shows that longfin smelt abundance declined substantially after 1984. The decline in abundance may be attributable to increased entrainment by the CVP and SWP pumps and other diversions, but reduced Delta outflow, discussed previously, may be a more important factor affecting abundance.

Entrainment of adult longfin smelt has a potentially greater adverse effect on the population than entrainment of larvae and young juveniles because unless the adults have already spawned, their reproductive value is much greater than that of younger fish. Adult smelt are entrained at the SWP and CVP pumping facilities primarily during November-February (Figure 4-17). The number of adults entrained is low relative to the number of juveniles entrained.

Longfin smelt larvae have been captured in the south Delta near the CVP and SWP pumps (Spaar 1990, 1993; Wang 1991). Larvae smelt are too small to be salvaged at the SWP and CVP fish protection facilities. Based on the high salvage rates of young-of-year juveniles in some years (Figure 4-17), it can be assumed that many thousands of longfin smelt larvae were also entrained, especially during February, March, and April.

During years of high flows, longfin smelt larvae are transported out of the Delta and therefore are unlikely to be entrained in diversions. During the 1987-1992 drought, however, outflows were low and exports were high. Larvae and juveniles remained in the Delta, as indicated by salvage at the CVP and SWP fish protection facilities. Most juveniles were entrained during April-June and averaged 30-45 mm long, with length correlated with the month of entrainment (Figure 4-17).

Adult, juvenile, and larvae longfin smelt are vulnerable to entrainment in diversions other than exports at the CVP and SWP pumps, including diversions to PG&E's power generating plants, industrial diversions, agricultural diversions, and others. However, entrainment of longfin smelt in these diversions has not been studied.

Other Factors

Other factors that may affect survival of longfin smelt include food limitation and presence of toxic materials and introduced species.

Abundance of *Neomysis* and other zooplankton prey (e.g., rotifers) of longfin smelt have declined in recent years (Obrebski et al. 1992). It is not known what effect the decline in prey abundance has had on longfin smelt; however, food limitation may be important because year-class strength of many fish populations, particularly species with planktonic larvae, may be strongly influenced by feeding conditions during the larval life stage (Lasker 1981).

Agricultural chemicals (including pesticides and herbicides), heavy metals, petroleum-based products, and other waste materials toxic to aquatic organisms enter the estuary through nonpoint runoff, agricultural drainage, and municipal and industrial discharges. The effects of toxic substances have not been tested on longfin smelt, but recent bioassays indicate that water in the Sacramento River is periodically toxic to larvae of the fathead minnow, a standard EPA test organism (Stevens et al. 1990). The short life span of longfin smelt and relatively low position in the food chain probably reduce the accumulation of toxic materials in their tissues and make them less susceptible to injury than species that live longer (Natural Heritage Institute 1992).

Many exotic species have invaded the estuary in recent years. These species may compete with or prey on longfin smelt. No single invasion of exotic species parallels the decline in longfin smelt closely enough to suggest that competition from or predation by the species was a primary cause of the longfin smelt's recent decline. The effects of multiple-species invasions, which have occurred in the estuary, are extremely difficult to assess.

Summary

Delta outflow may be the single most important factor controlling longfin smelt abundance. High outflows increase dispersion downstream; available habitat; and, possibly, food availability. High outflow may also reduce predation and the effects of other adverse factors (i.e., toxin concentrations). Low outflow conditions reduce downstream dispersion and increase vulnerability to entrainment in Delta diversions.

STEELHEAD TROUT

Steelhead trout (*Oncorhyncus mykiss*) have habitat requirements similar to those of chinook salmon, and in the Sacramento-San Joaquin River system, steelhead spawn and rear in the same habitats used by chinook salmon. Reproducing runs of steelhead in the Central Valley are currently restricted to the Sacramento River and its tributaries (Reynolds et al. 1993).

Status

On February 14, 1994, NMFS was petitioned to list steelhead trout of the Sacramento River Basin under the federal Endangered Species Act (Oregon Natural Resources Council 1994). NMFS has not made a decision to propose the Sacramento River Basin steelhead for listing as endangered or threatened.

Steelhead trout was included in this BA because of the species' historical decline in abundance, the relatively low abundance of existing Sacramento River system populations, and the possibility that steelhead will be listed under the federal Endangered Species Act in the future. The steelhead trout and its habitat, primarily the Delta portion, could be affected by changes in flow volume, direction, and origin attributable to DW project operations. The following discussion summarizes available information on the steelhead and its habitat.

Potential effects of the DW project on the steelhead trout are presented in Section 5, "Impact Assessment".

Background

Historically, steelhead trout spawned and reared in the most upstream portions of the Sacramento River and its perennial tributaries. There are few specific data regarding the historical steelhead trout abundance; however, data indicate that dams have resulted in a 95% reduction of river habitat available to anadromous fish (Reynolds et al. 1993). Steelhead population abundance has undoubtedly been reduced from historical levels.

The average annual total steelhead run in the Sacramento River system was estimated by DFG in 1990 at about 35,000 fish. More than 90% of the annual steelhead run consists of hatchery-raised fish stocked as smolts or fingerlings (Reynolds et al. 1993).

Completion of RBDD in 1967 made it possible to count returning adult spawners. The steelhead population abundance in the upper Sacramento River has exhibited a decline similar to that of the winter-run chinook salmon population. During 1967-1991, the highest adult steelhead abundance (19,615) occurred in 1968 and the lowest abundance (470) occurred in 1989 (Mills and Fisher 1993). Average abundance of steelhead trout during 1967-1991 was about 7,000, with an average of 15,055 in the first 5 years (1967-1971) and a decline to an average of 1,714 in the last 5 years (1987-1991).

Distribution and Life History

Adult steelhead return to spawn in the Sacramento River and its tributaries after 1-3 years of ocean residence. Upstream migration occurs from August through March. Upstream migration of smaller adults peaks in November. Peak upstream migration of larger adults occurs during mid-December through February. Spawning occurs primarily during December through April. Spawning areas overlap with those of chinook salmon, although steelhead generally spawn farther upstream and utilize smaller gravel sizes (with fewer fines) than are used by chinook salmon (Reynolds et al. 1990). Adult steelhead that survive spawning return to the ocean between April and June (Mills and Fisher 1993).

Steelhead fry emerge from the gravel nests 2-8 weeks after hatching, usually during April and May (Barnhart and Parsons 1986, McEwan and Nelson 1991, Reynolds et al. 1993). Fry generally remain in their natal river or stream. Juveniles rear in the rivers through summer and migrate downstream to the ocean during November-May (Schaffter 1980).

Steelhead have been collected in nearly every month at the SWP and CVP Delta pumping facilities. Peak salvage at the SWP and CVP facilities occurs primarily during March and April. Migration timing is similar to the timing of seaward migration of winter-run chinook salmon, although water temperature and river flow affect the timing of juvenile steelhead migration through the Delta.

Factors Affecting Steelhead Trout Abundance

As with winter-run chinook salmon abundance, the primary human-caused factors influencing steelhead trout abundance are activities that have occurred upstream of the Delta (e.g., dam closure, elevated water temperature, and diversions). Delta diversions have contributed to increased mortality of juvenile steelhead trout during their migration through the Delta.

Ongoing factors affecting mortality of steelhead trout include deleterious water temperatures in spawning and rearing habitat, delay of juvenile migration, increased predation during juvenile migration, and entrainment of juveniles in diversions. All these problems have resulted from construction and operation of facilities for water diversions, water storage, agricultural drainage, and flood control on the Sacramento River and its tributaries and in the Delta.

Temperature

Deleterious temperatures during spawning, incubation, rearing, and migration periods reduce survival of steelhead trout in the Sacramento River system. Steelhead do not survive extended elevations in water temperatures that occur during the summers of many years below reservoirs on the American River and other Sacramento Valley streams (McEwan and Nelson 1991, Reynolds et al. 1993, California Resources Agency 1989).

Water temperature may also be a primary factor influencing survival of juvenile steelhead trout during their migration through the Delta. Water temperatures in excess of 60°F are believed to be stressful to juvenile steelhead and, as with chinook salmon, may increase mortality (Leidy and Li 1987).

River Diversions

The freshwater residence time is longer for steelhead than for salmon; consequently, juvenile steelhead are generally larger than juvenile salmon during out-migration down the rivers and through the Delta. Their larger size and greater swimming ability enables steelhead to better avoid entrainment in diversions. Steelhead, however, are subject to the same sources of entrainment mortality discussed for winter-run chinook salmon.

River Sport Fishing

The estimated annual catch of adult steelhead in the upper Sacramento River was 11,000 fish in the 1950s and 7,000 fish in the 1960s, and the estimated current catch is less than 1,100 fish (Reynolds et al. 1990). Sport harvest of adult steelhead in the Sacramento River system totals several thousand fish annually.

In addition to adults being harvested, many juvenile steelhead are caught by sport anglers fishing for resident rainbow trout. The fishing pressure on juvenile steelhead may exceed that for adult steelhead (Barnhart and Parsons 1986).

Delta Flow Conditions Affecting Adult and Juvenile Steelhead Migration

The effects of Delta flow conditions (i.e., DCC and Georgiana Slough diversion from the Sacramento River, lower San Joaquin River flow, and Delta diversions) on mortality of migrating juvenile steelhead are likely similar to the effects described previously for winter-run chinook salmon. Steelhead trout drawn off the Sacramento River into the Delta channels of the Mokelumne River and the lower San Joaquin River may experience delayed migration and increased losses to diversions and predation.

Adult steelhead may enter the central Delta in response to the presence of Sacramento River water. Sacramento River water enters the central Delta through the DCC, Georgiana Slough, Threemile Slough, and reverse flows in the lower San Joaquin River. In the central Delta, migration may be delayed until the adult steelhead find their way back to the Sacramento River.

Delta Entrainment Losses

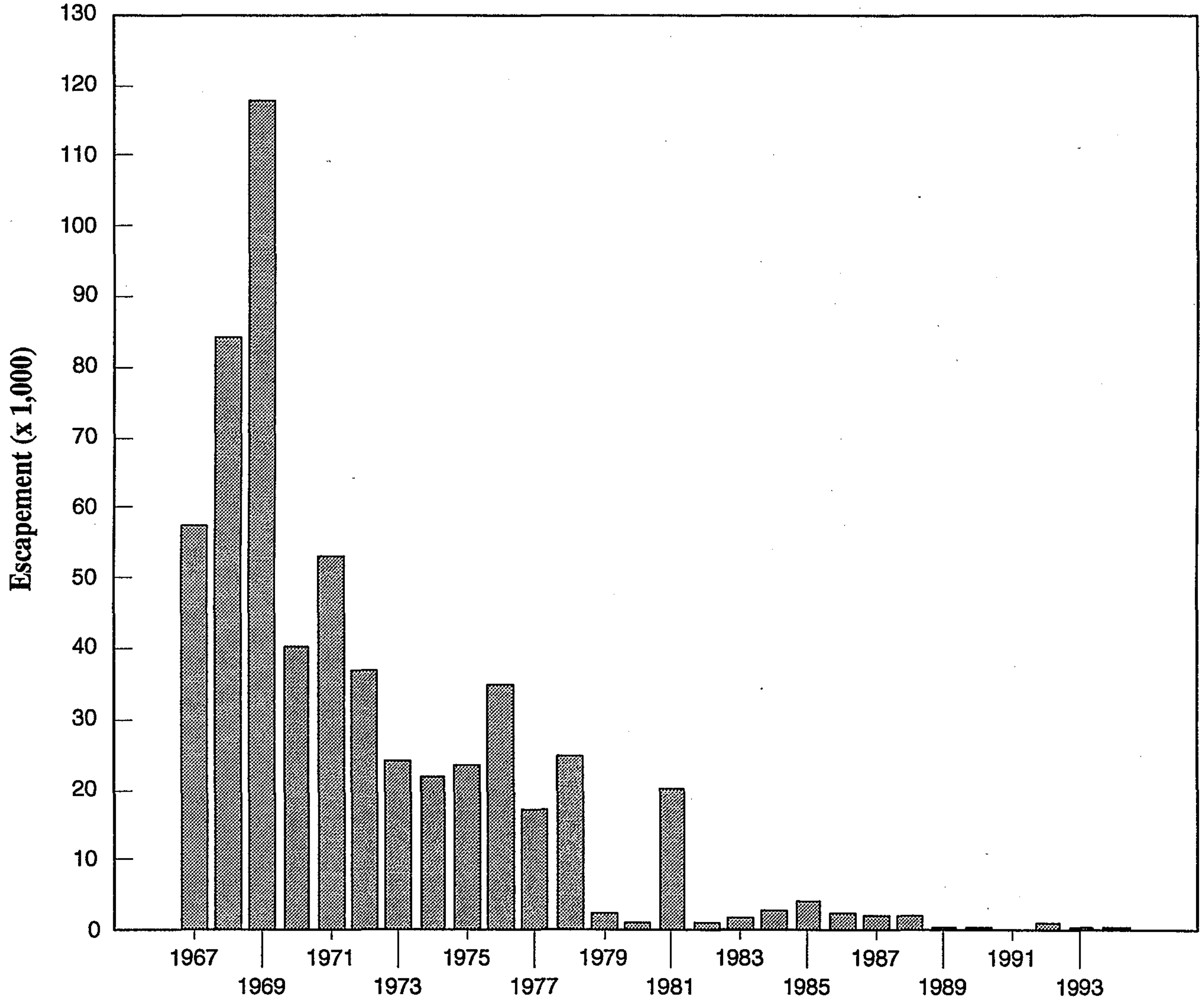
During migration of most juvenile steelhead trout through the Delta (February-April), agricultural diversion levels are low; diversion levels are highest during late spring and summer (DWR 1990). Diversion levels at the CVP and SWP Delta facilities, however, are high during February-April and entrainment losses of steelhead juveniles may be substantial (Figure 4-18).

Other Factors

Other factors that may affect survival of steelhead trout include the following, which are discussed in greater detail for other species (e.g., winter-run chinook salmon). Although steelhead are rarely caught in commercial and sport fisheries along the California coast, incidental losses to national and international fisheries may increase mortality of steelhead trout. Toxic substances (e.g., pesticides and mine waste) discharged to the rivers and the estuary, entrainment in PG&E's Pittsburg and Contra Costa power plants, competition with introduced species, and changes in estuarine habitat and food availability could affect steelhead trout survival.

Summary

Habitat degradation has reduced the population of steelhead trout. Major factors are blockage of adult passage to suitable spawning and rearing areas and lethal water temperatures during egg incubation and early rearing. Other factors that may impede recovery to former levels of abundance and continue to adversely affect steelhead trout include entrainment loss to diversions, in-river sport fishing, increased predation, the presence of toxic mine waste, and diversion off the primary juvenile migration path through the Delta.



Source: National Oceanic and Atmospheric Administration (58 FR 33212, June 16, 1993).

Figure 4-1.
Winter-Run Chinook Salmon Spawning Escapement, 1967–1994

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Prepared by: Jones & Stokes Associates

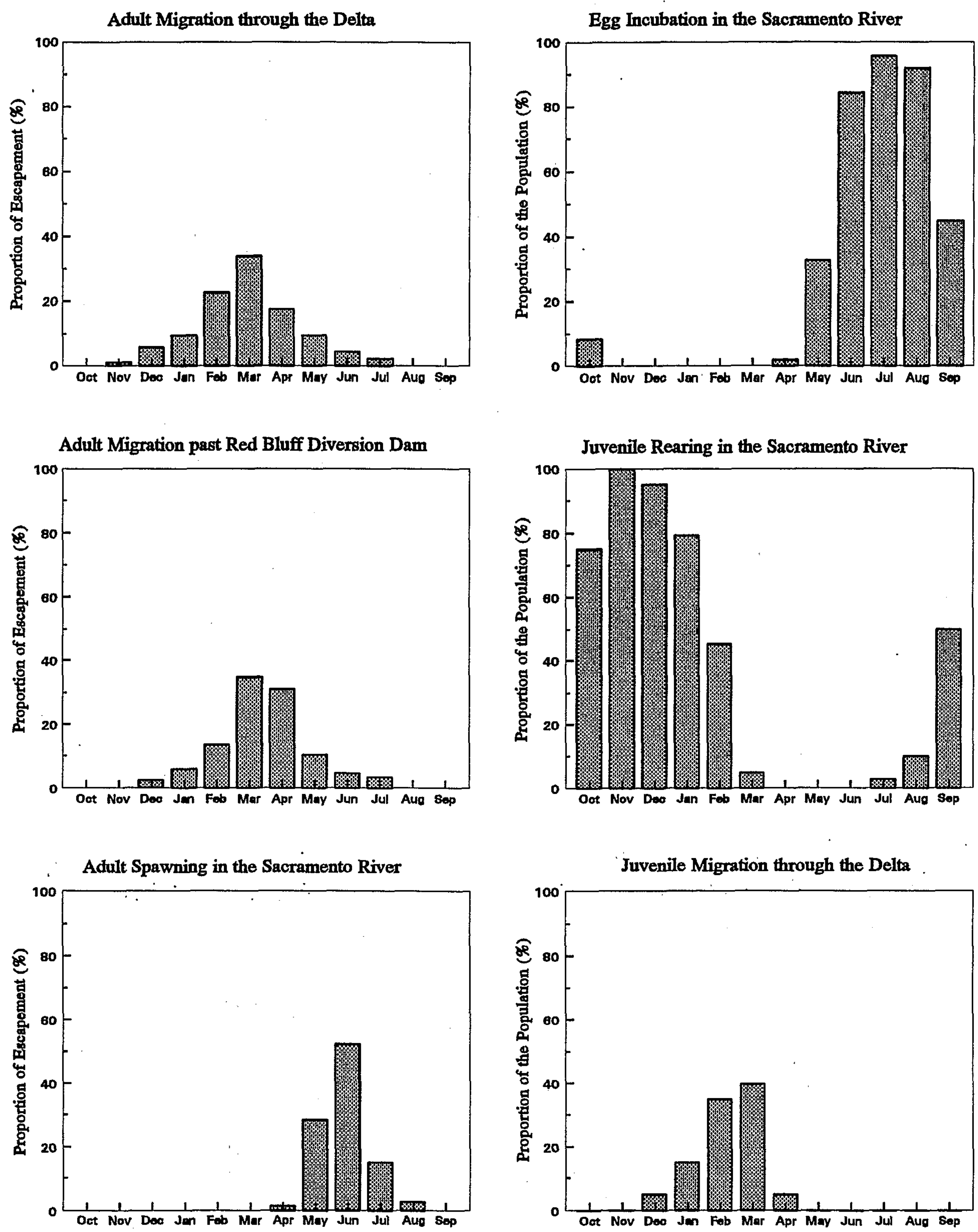

Figure 4-2.
Monthly Abundance of Winter-Run Chinook Salmon by Life Stage and Location

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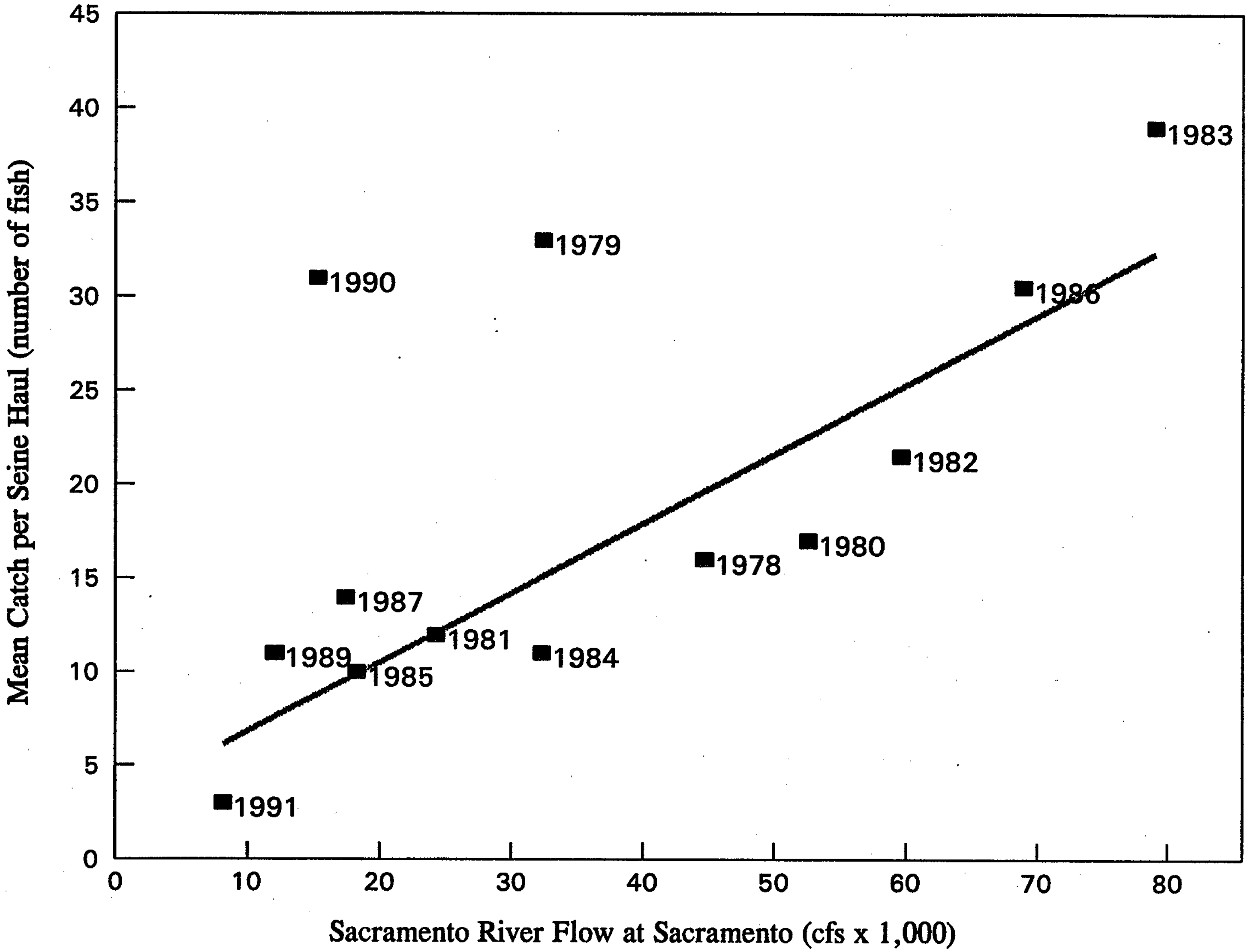
Prepared by: Jones & Stokes Associates



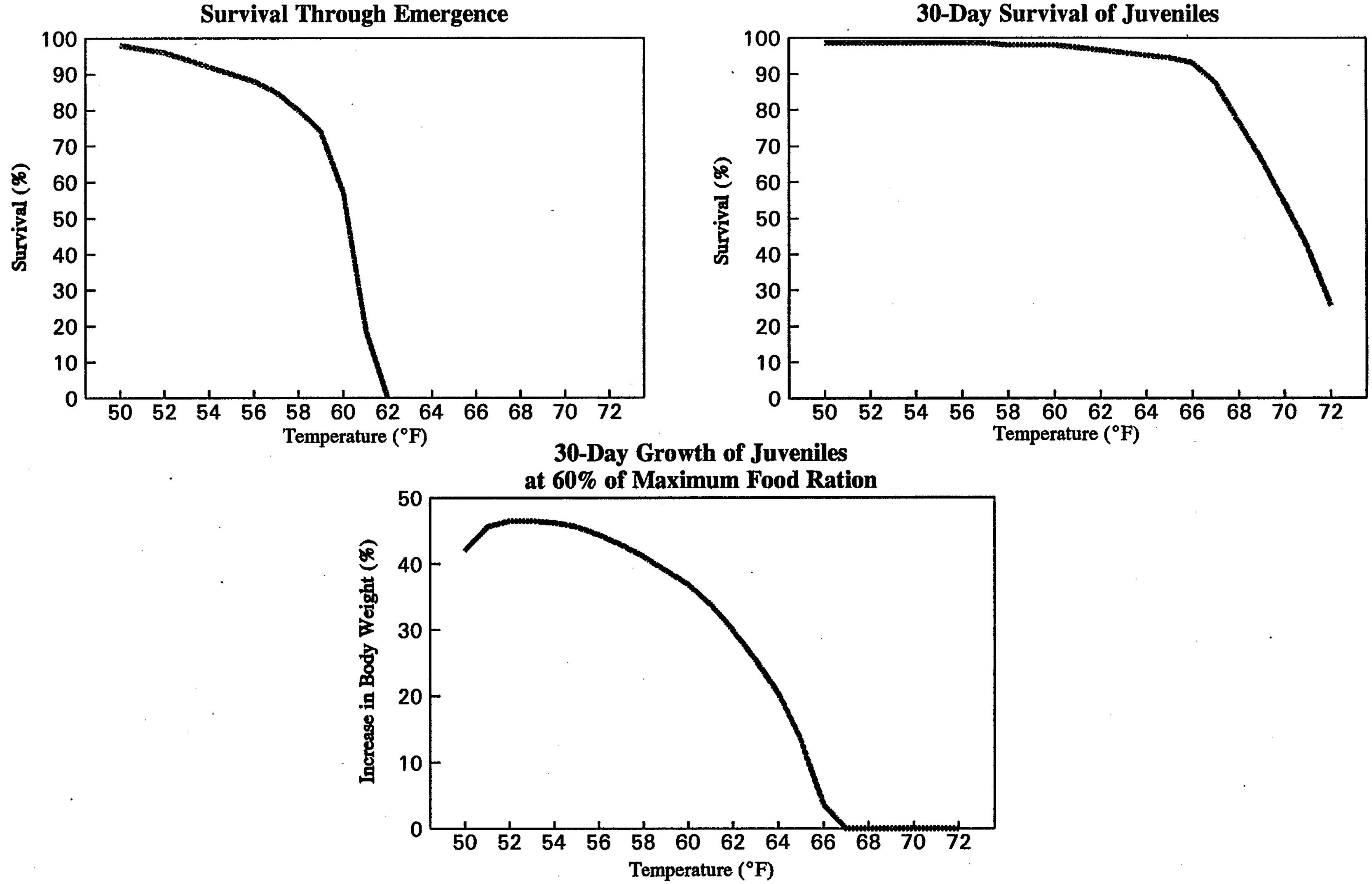
Note: The diagonal line represents the regression of catch on flow, excluding data for 1990 and 1979.
Source: U.S. Fish and Wildlife Service 1993b.

Figure 4-3.
Relationship between Juvenile Chinook Salmon Abundance (i.e., Catch per Seine Haul) in the Delta and Sacramento River Flow in February 1978–1991

DELTA WETLANDS PROJECT
Prepared by: Jones & Stokes Associates

C-061992

C-061992



Sources: Brett et al. 1982, Raleigh et al. 1986, and Jones & Stokes Associates 1989.

Figure 4-4.
Temperature-Survival and Temperature-Growth Relationships for Chinook Salmon

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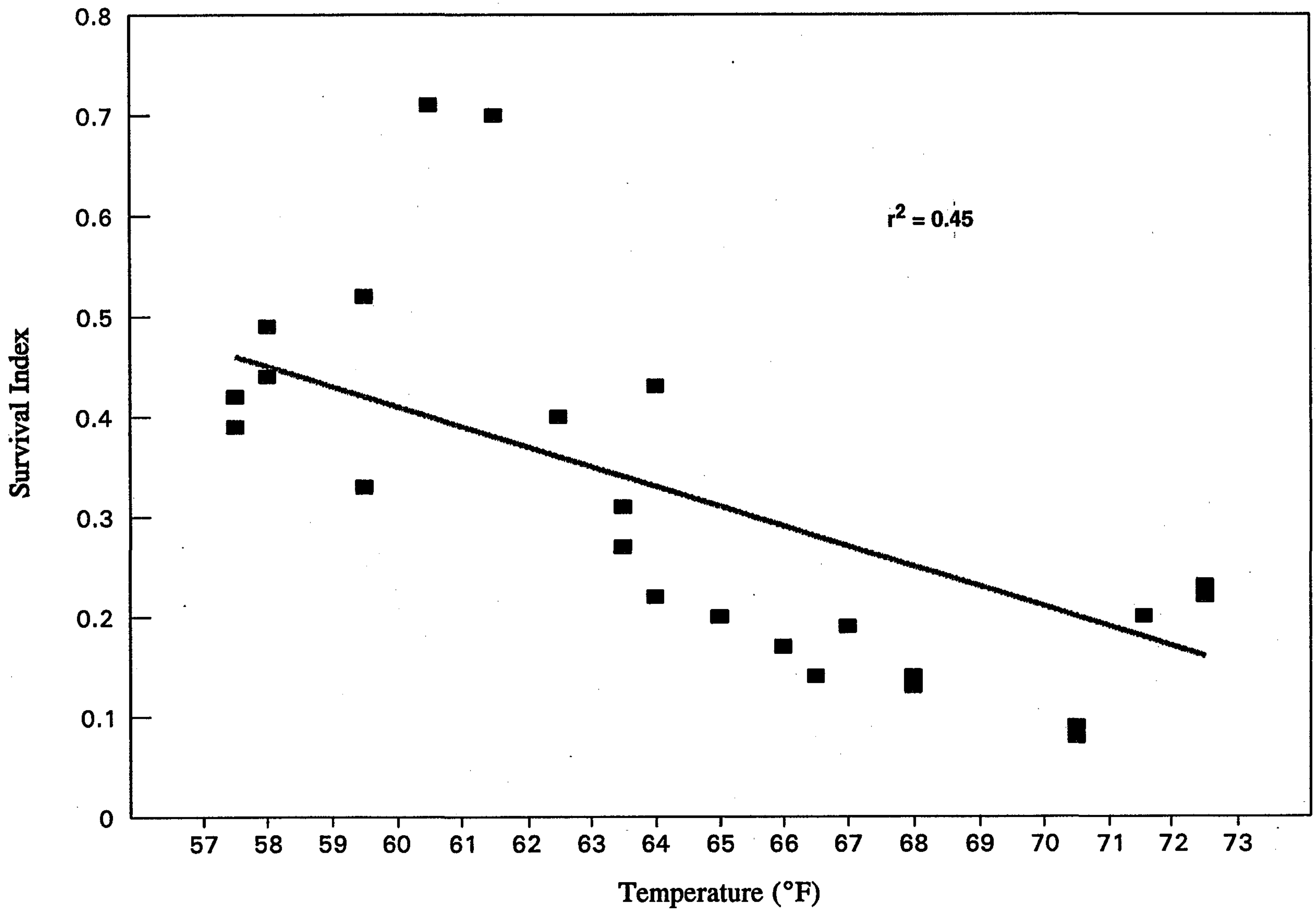

Note: The diagonal line represents the regression of the survival index on temperature, including all data points.
Source: U. S. Fish and Wildlife Service 1992.

Figure 4-5.
Relationship between Temperature and Natural Fall-Run Smolt Survival through the Delta in April, May, and June 1988

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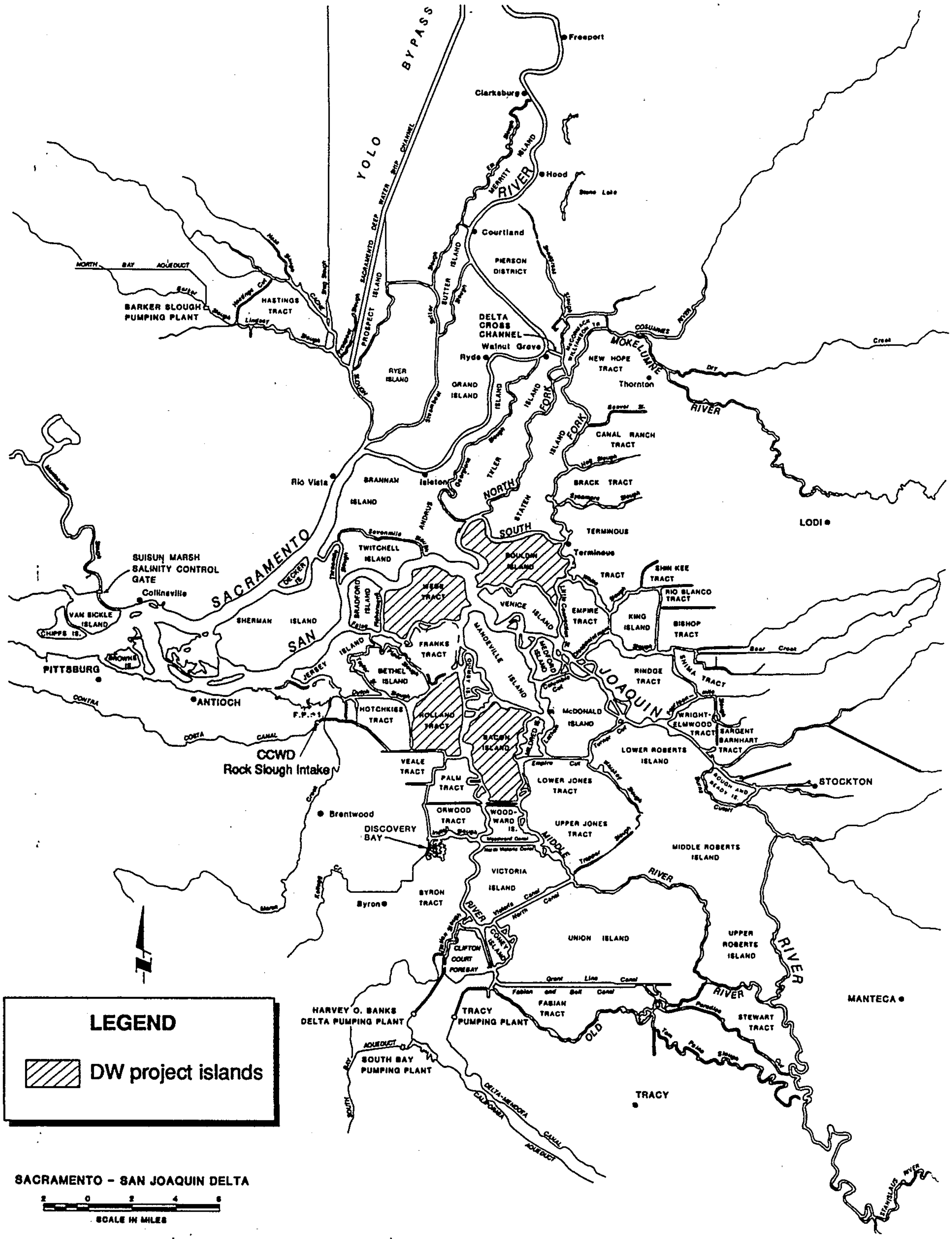
Prepared by: Jones & Stokes Associates



Source: Adapted from California Department of Water Resources 1993a.

Figure 4-6.
Sacramento-San Joaquin Delta

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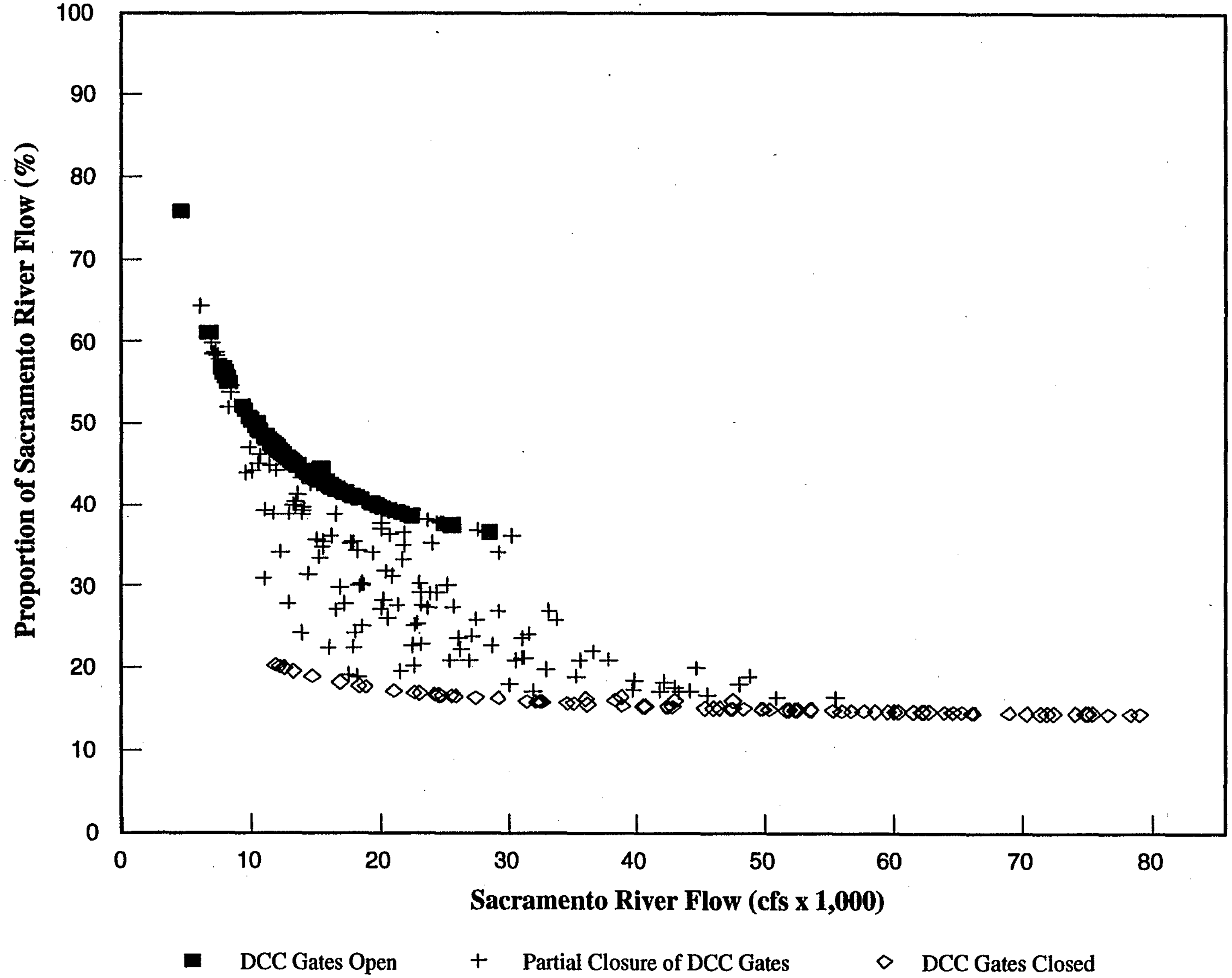

Source: California Department of Water Resources 1990.

Figure 4-7.
Percentage of Sacramento River Flow Diverted into the DCC and Georgiana Slough

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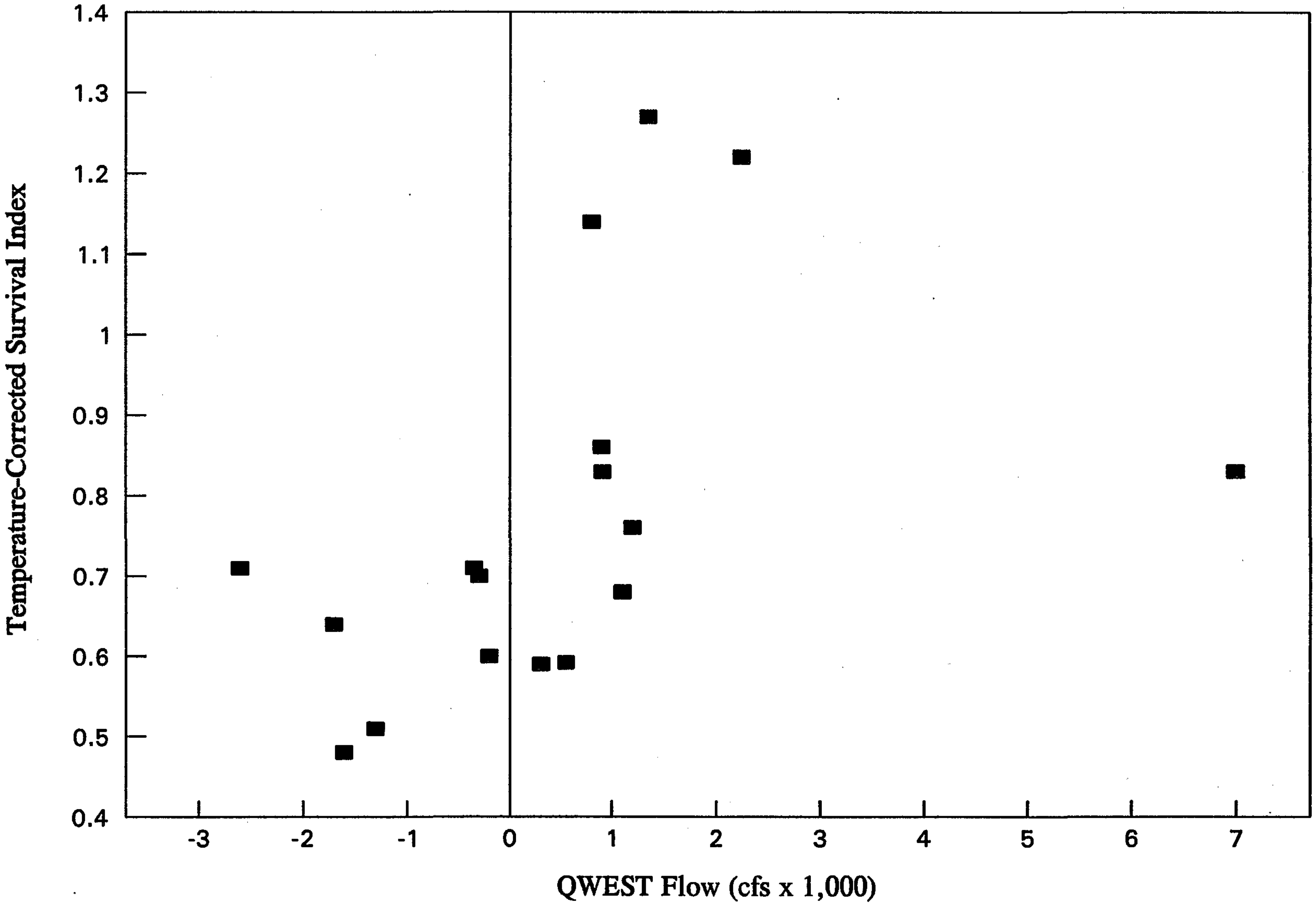
C-061996



Source: U. S. Fish and Wildlife Service 1993b.

Figure 4-8.
Temperature-Corrected Survival for Fish Released at Ryde Versus QWEST Flow, Studies Performed during 1984–1992

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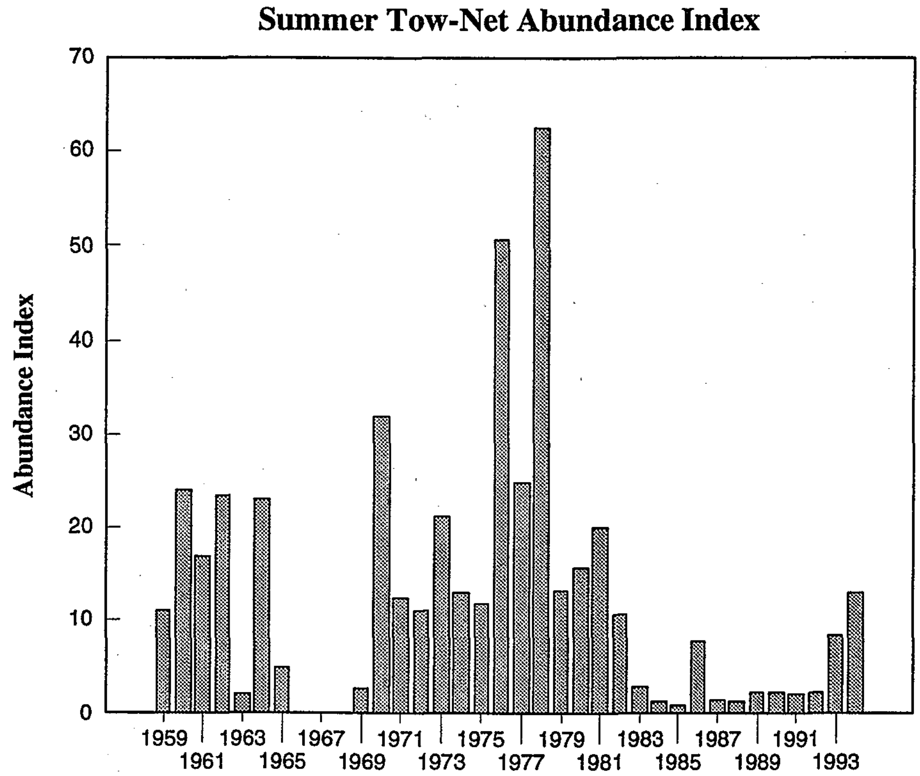

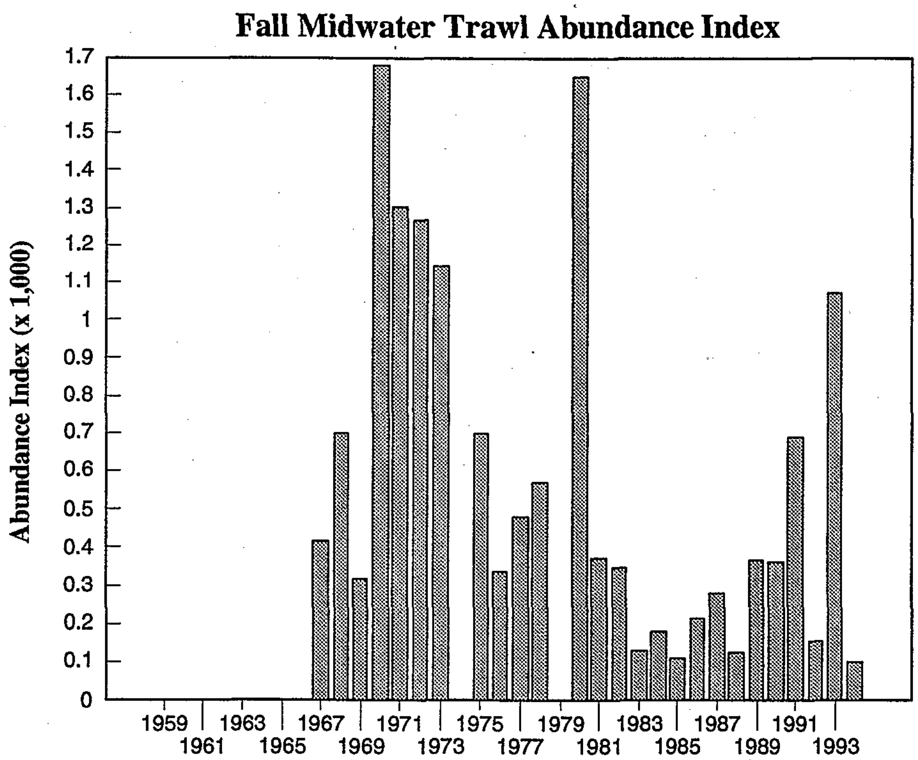

Figure 4-9.
Delta Smelt Summer Tow-Net and Fall Midwater Trawl Abundance Indices, 1967–1994

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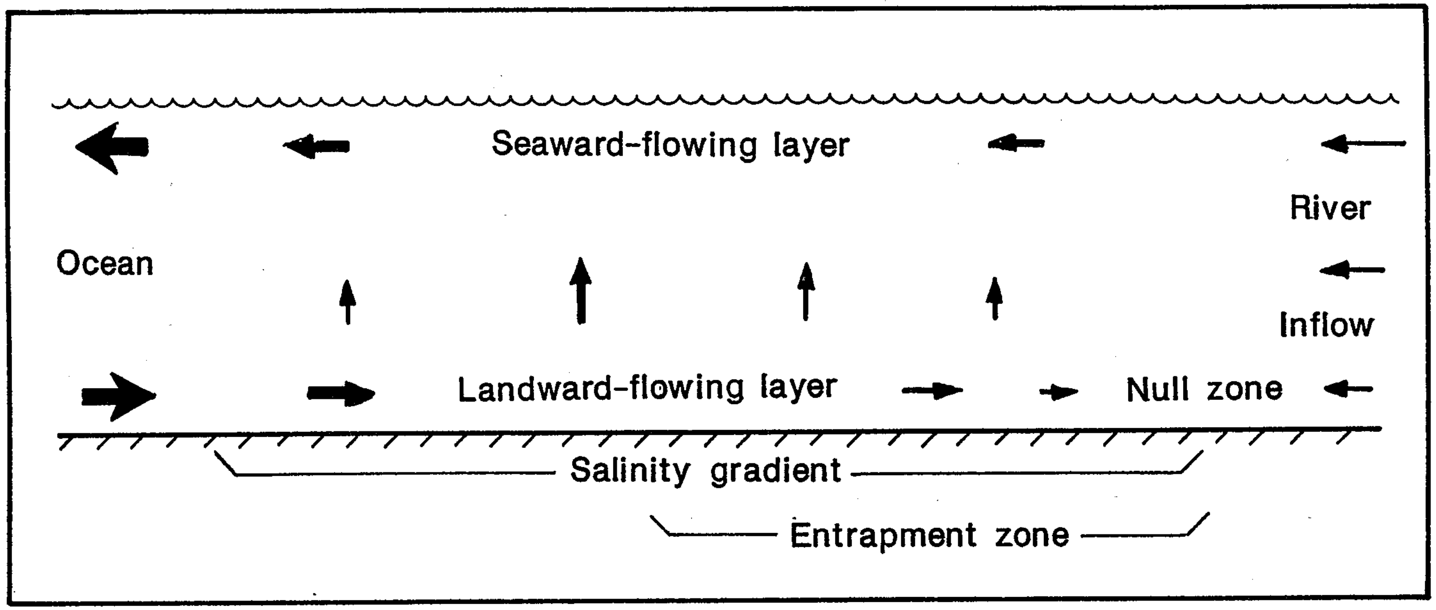
Prepared by: Jones & Stokes Associates



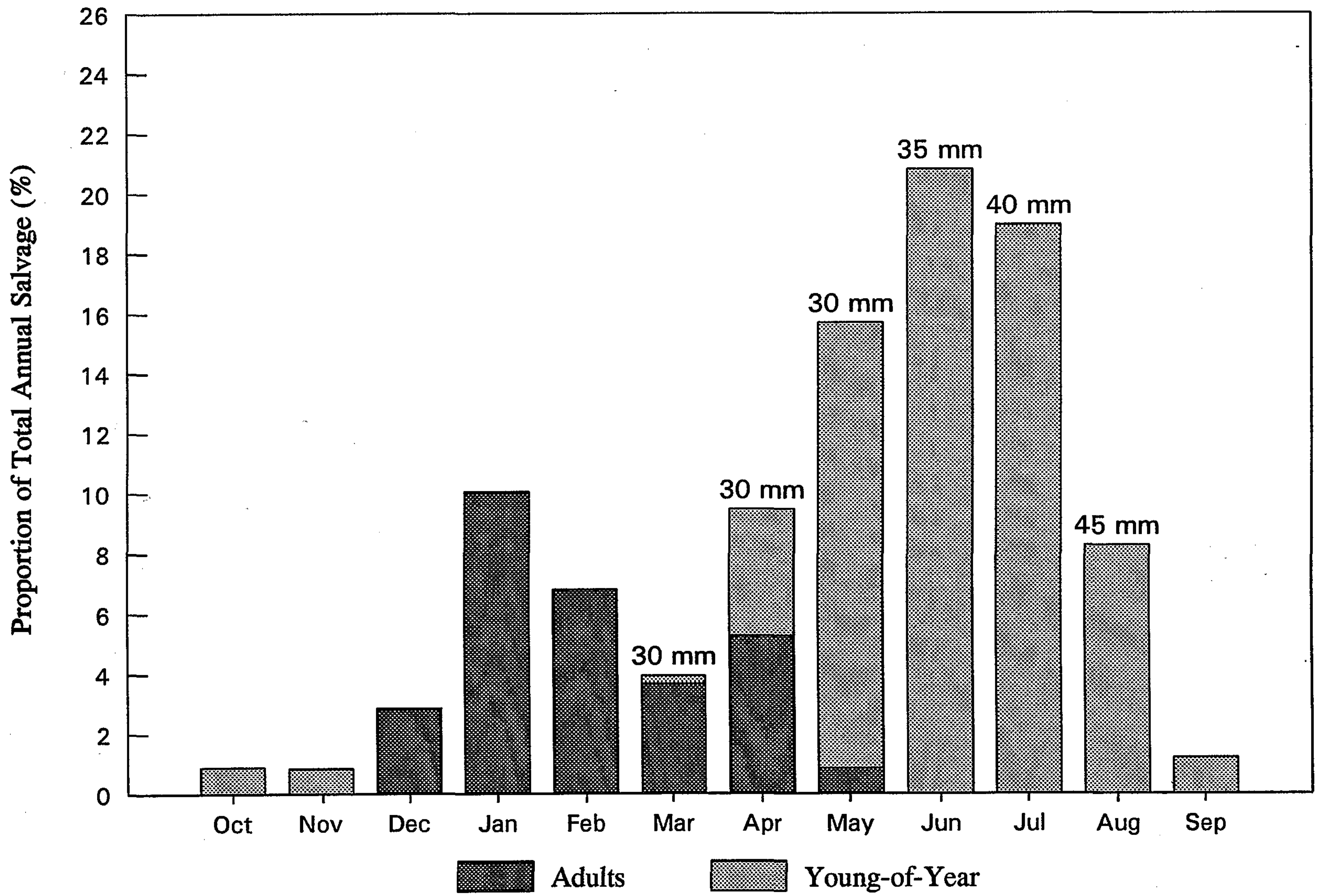
Notes: Width of arrow indicates intensity of flow.

Null zone is where vertical velocity and net horizontal velocity near bottom are zero.

Entrapment zone lies between null zone and area of maximum vertical velocity in water column.

Salinity gradient is area of increasing surface salinity seaward of null zone.

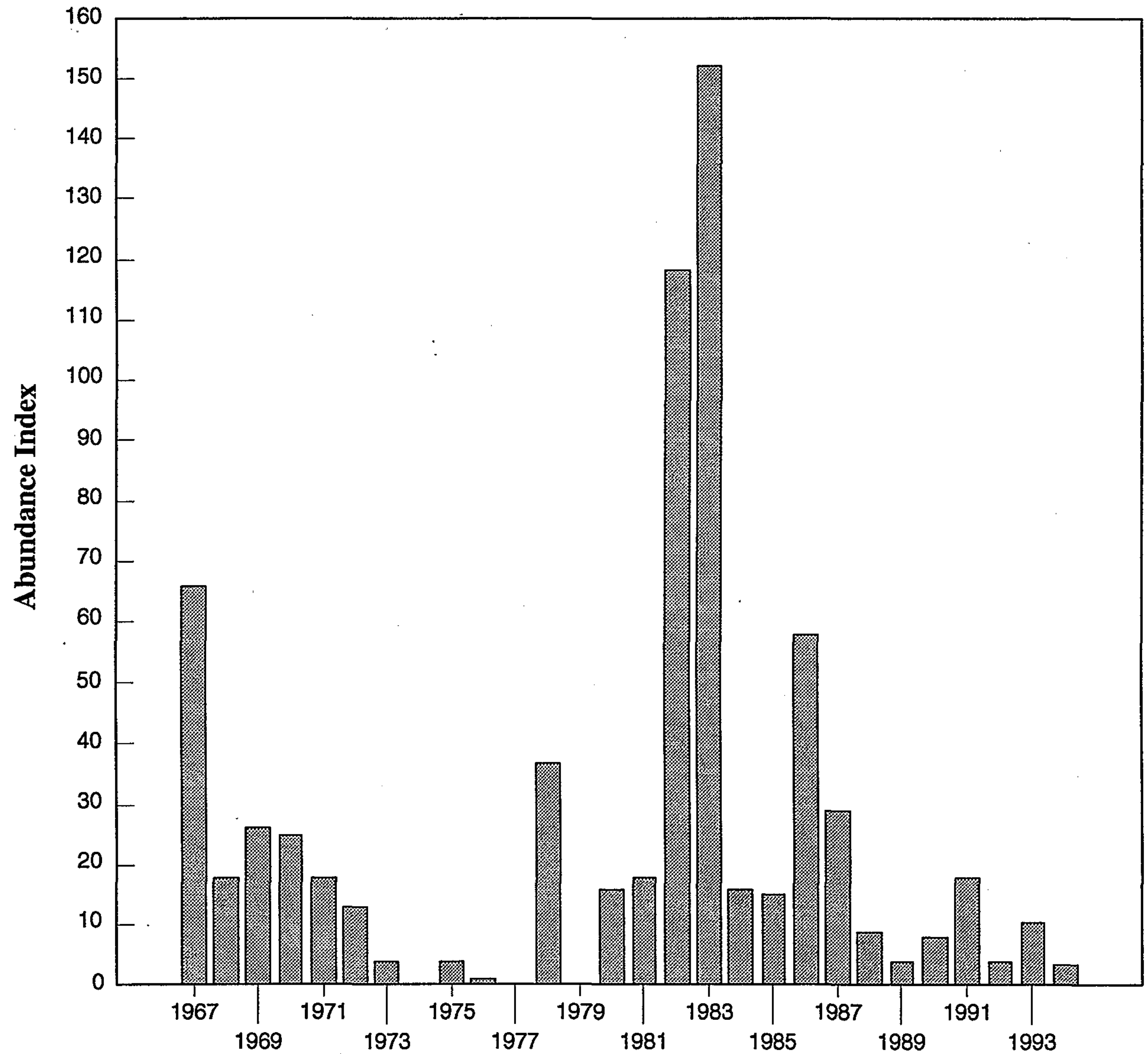
Figure 4-10.
Location of the Null Zone, Entrapment Zone, and Salinity Gradient in a Stylized Representation of a Two-Layered Estuary



Note: Numbers on top of the bars indicate the average length of salvaged young-of-year juveniles.
Source: Barrows pers. comm.

Figure 4-11.
Average Monthly Proportion of Annual Delta Smelt Salvage at the SWP and CVP Fish Protection Facilites, 1979–1990

DELTA WETLANDS PROJECT
Prepared by: Jones & Stokes Associates

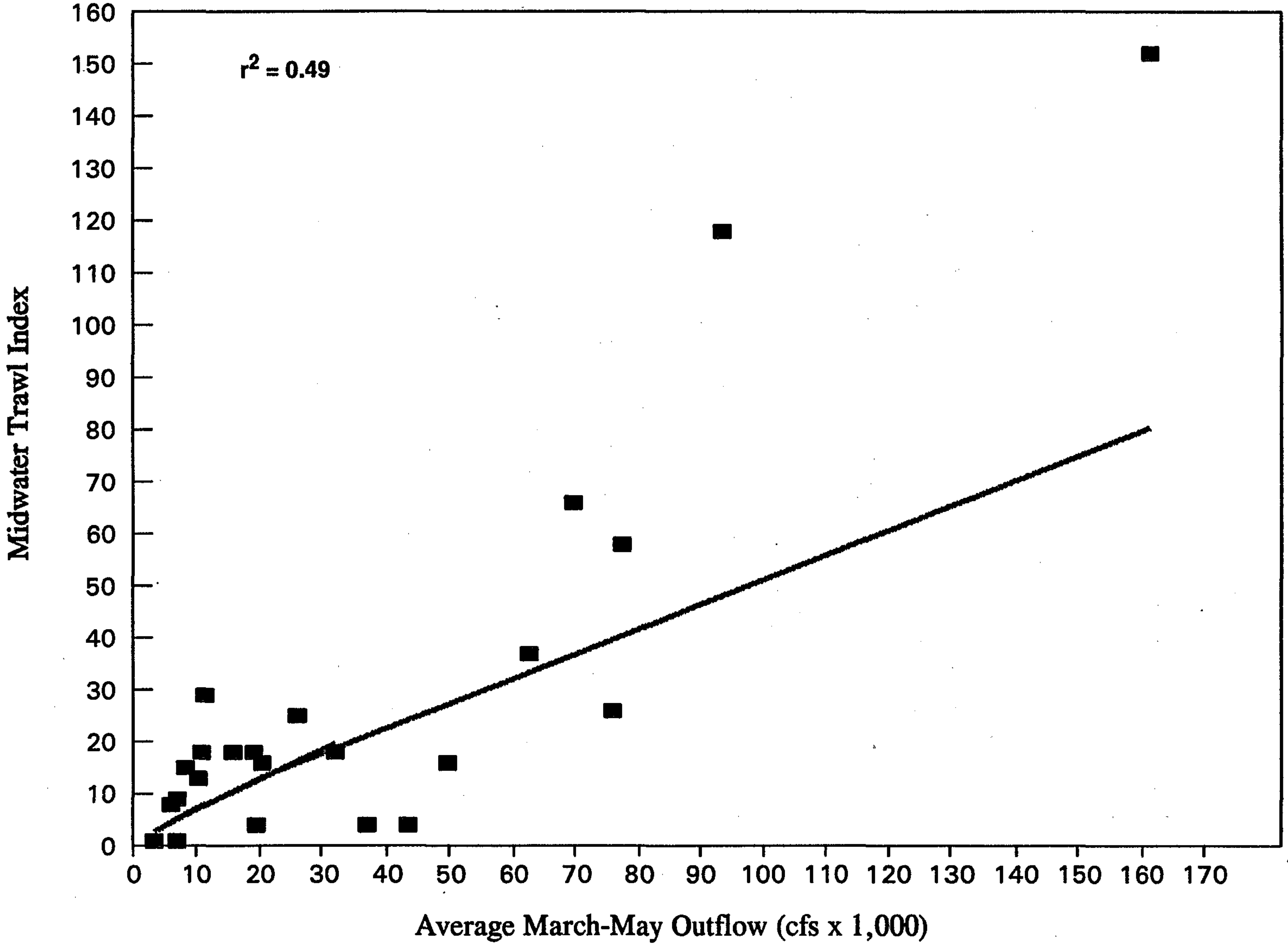


Source: Baxter pers. comm.

Figure 4-12.
Sacramento Splittail Fall Midwater Trawl Abundance Index, 1967–1994

DELTA WETLANDS PROJECT

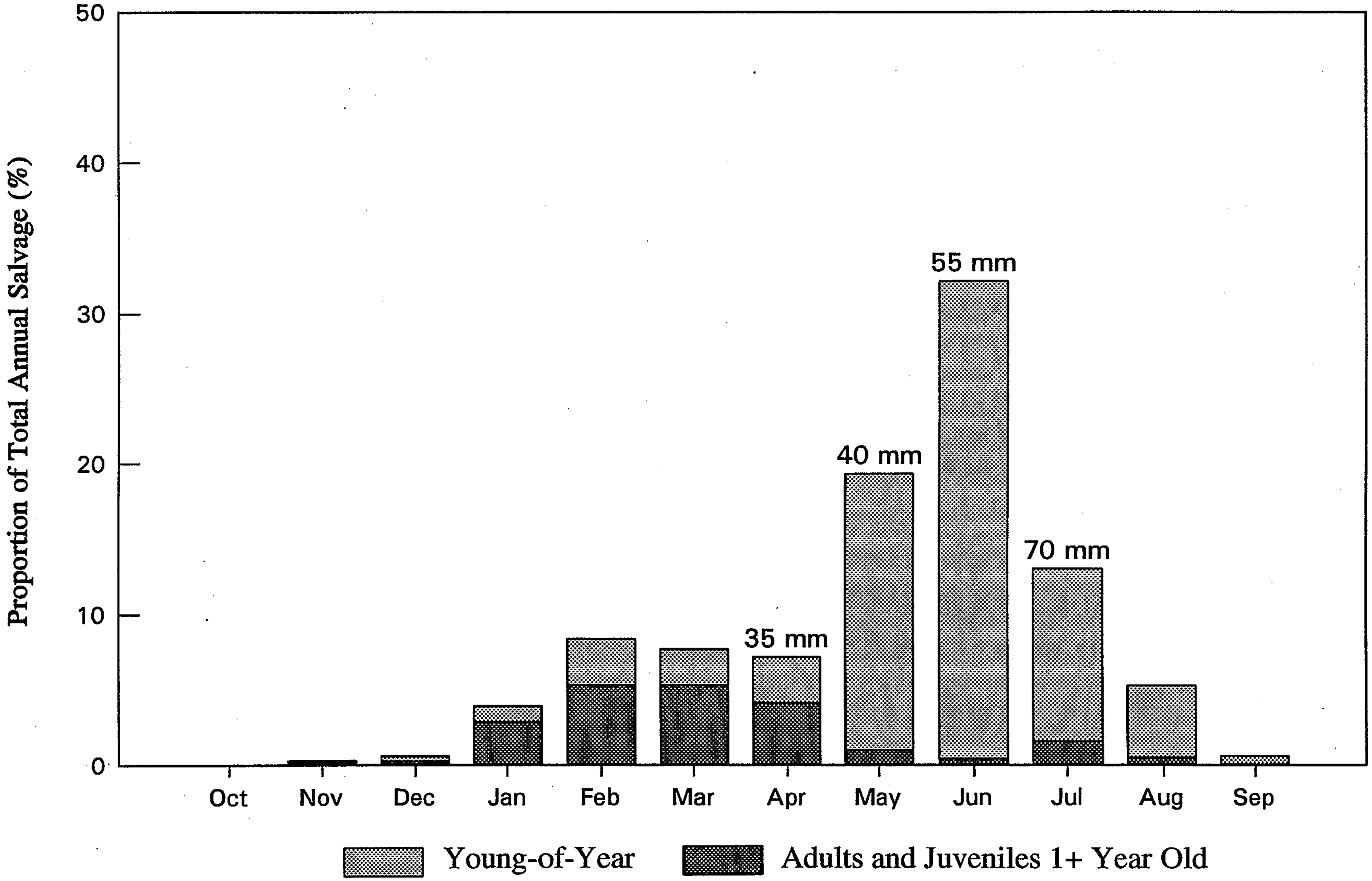
Prepared by: Jones & Stokes Associates



Note: The diagonal line represents the regression of the log of the midwater trawl index on the log of outflow.

Figure 4-13.
Relationship between Delta Outflow (March–May) and the Fall Midwater Trawl Index for Sacramento Splittail, 1967–1991

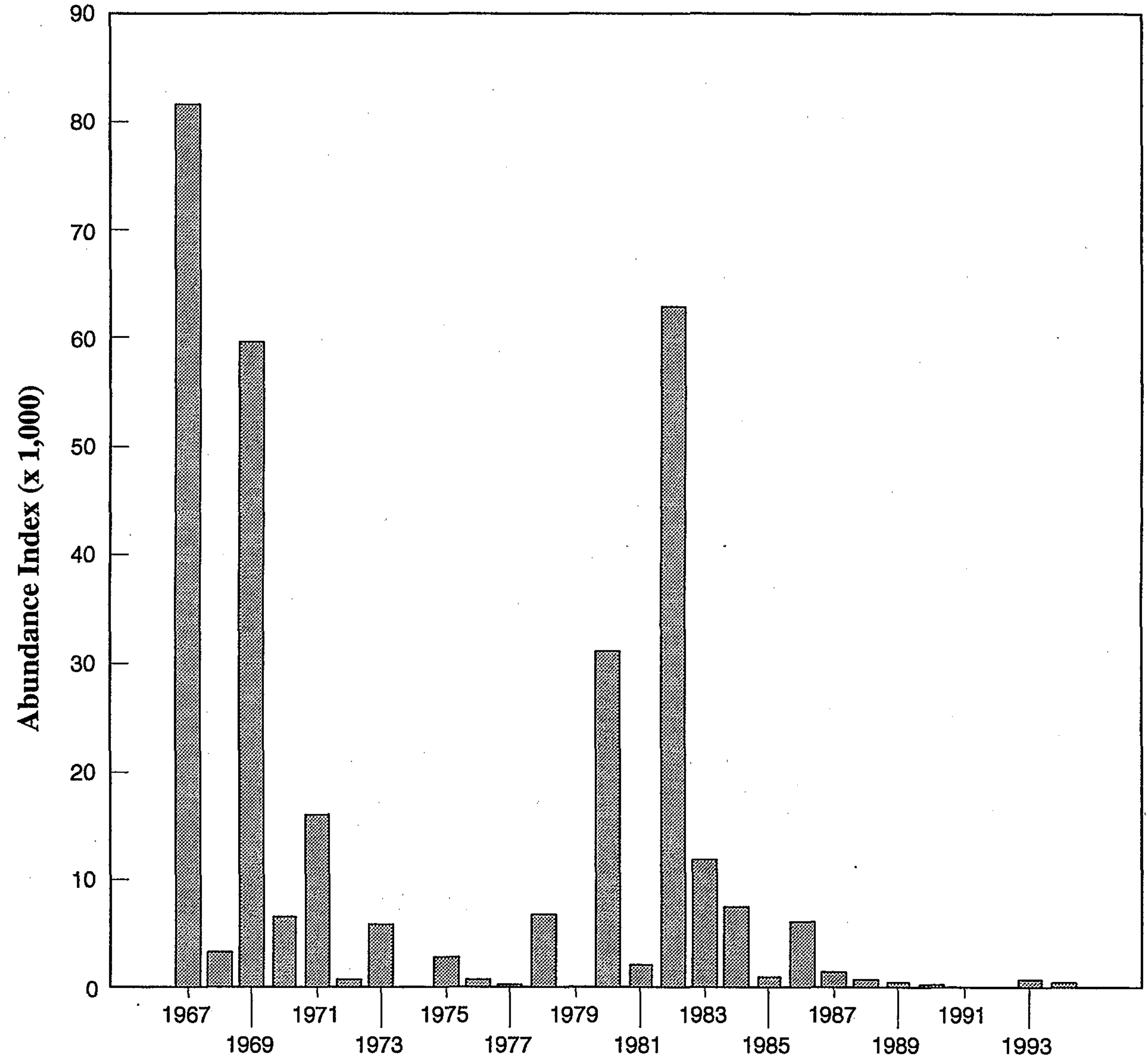
DELTA WETLANDS PROJECT
Prepared by: Jones & Stokes Associates



Note: Numbers on top of the bars indicate the average length of salvaged young-of-year juveniles. Juveniles from the current year's spawn first appear in April salvage.
Source: Barrow pers. comm.

Figure 4-14.
Average Monthly Proportion of Annual Sacramento Splittail Salvage at the SWP and CVP Fish Protection Facilities, 1979–1990

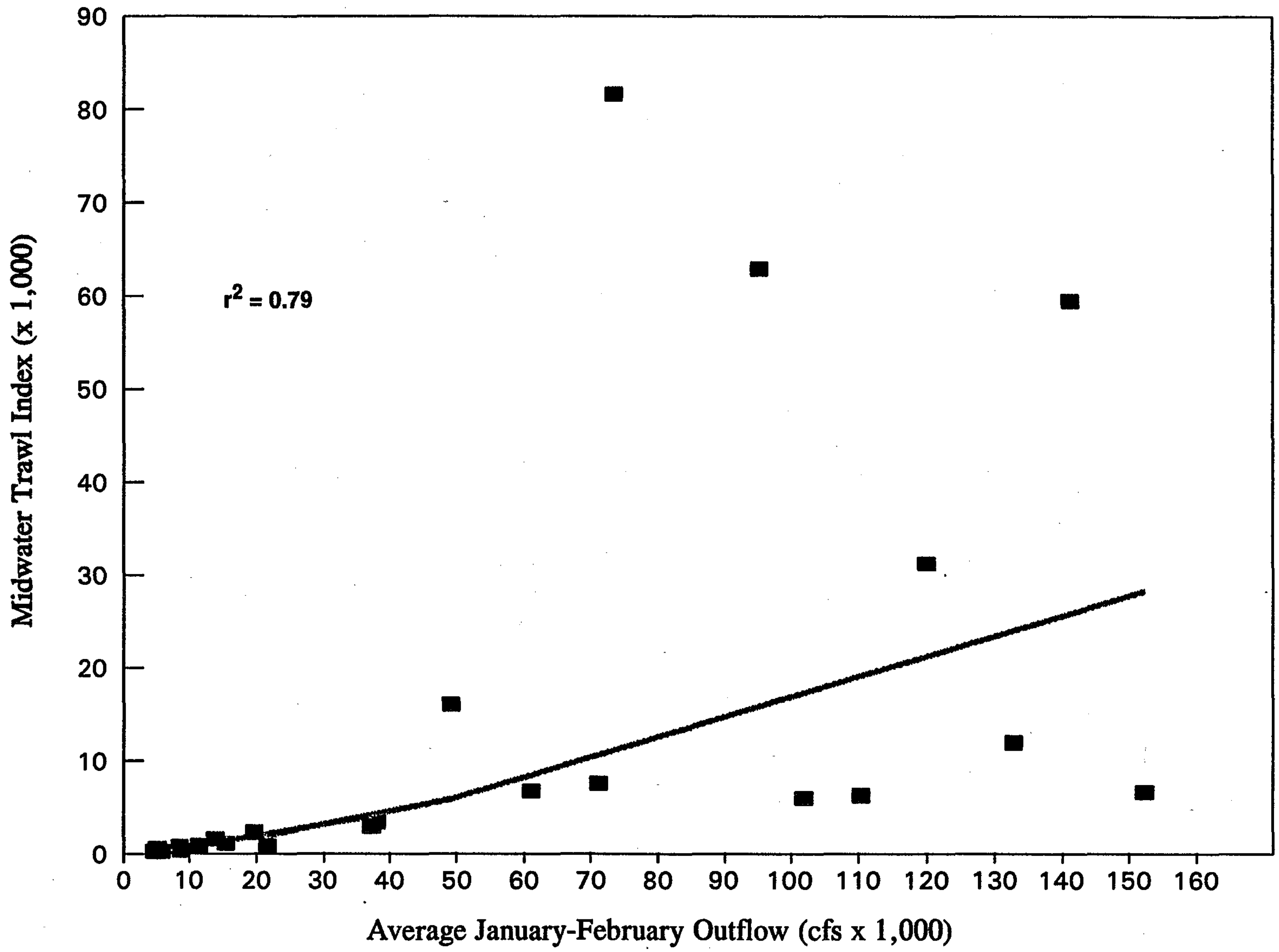
DELTA WETLANDS PROJECT
Prepared by: Jones & Stokes Associates



Sources: Herrgesell 1993, Baxter pers. comm.

Figure 4-15.
Longfin Smelt Fall Midwater Trawl Abundance Index, 1967–1994

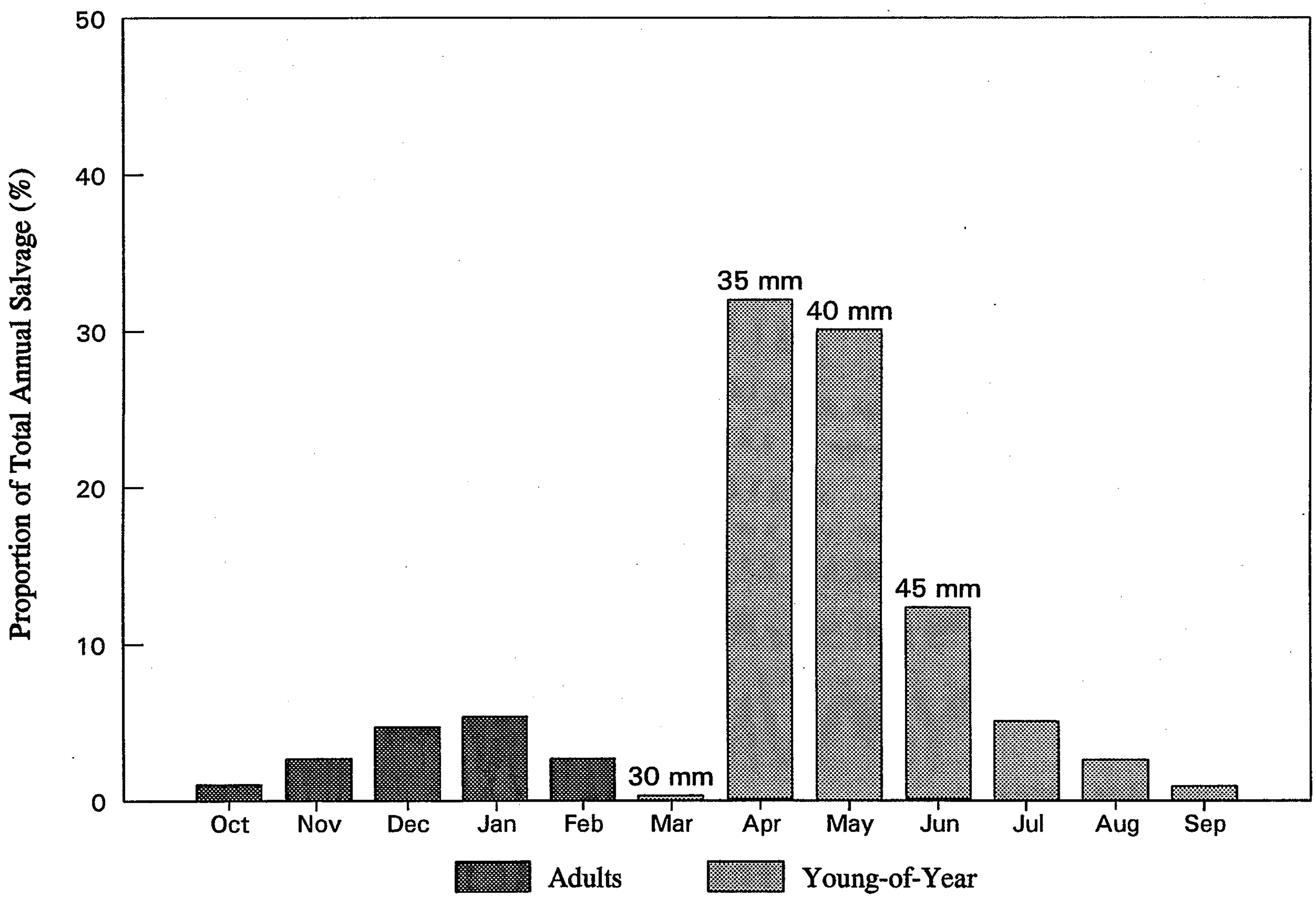
DELTA WETLANDS PROJECT
Prepared by: Jones & Stokes Associates



Note: The diagonal line represents the regression of the log of the midwater trawl index on the log of outflow, including all data points.

Figure 4-16.
Relationship between Delta Outflow (January–February) and the Fall Midwater Trawl Index for Longfin Smelt, 1967–1991

DELTA WETLANDS PROJECT
Prepared by: Jones & Stokes Associates



Note: Numbers on top of the bars indicate the average length of salvaged young-of-year juveniles.
Source: Barrow pers. comm.

Figure 4-17.
Average Monthly Proportion of Annual Longfin Smelt Salvage at the SWP and CVP Fish Protection Facilities, 1979–1990

DELTA WETLANDS PROJECT
Prepared by: Jones & Stokes Associates

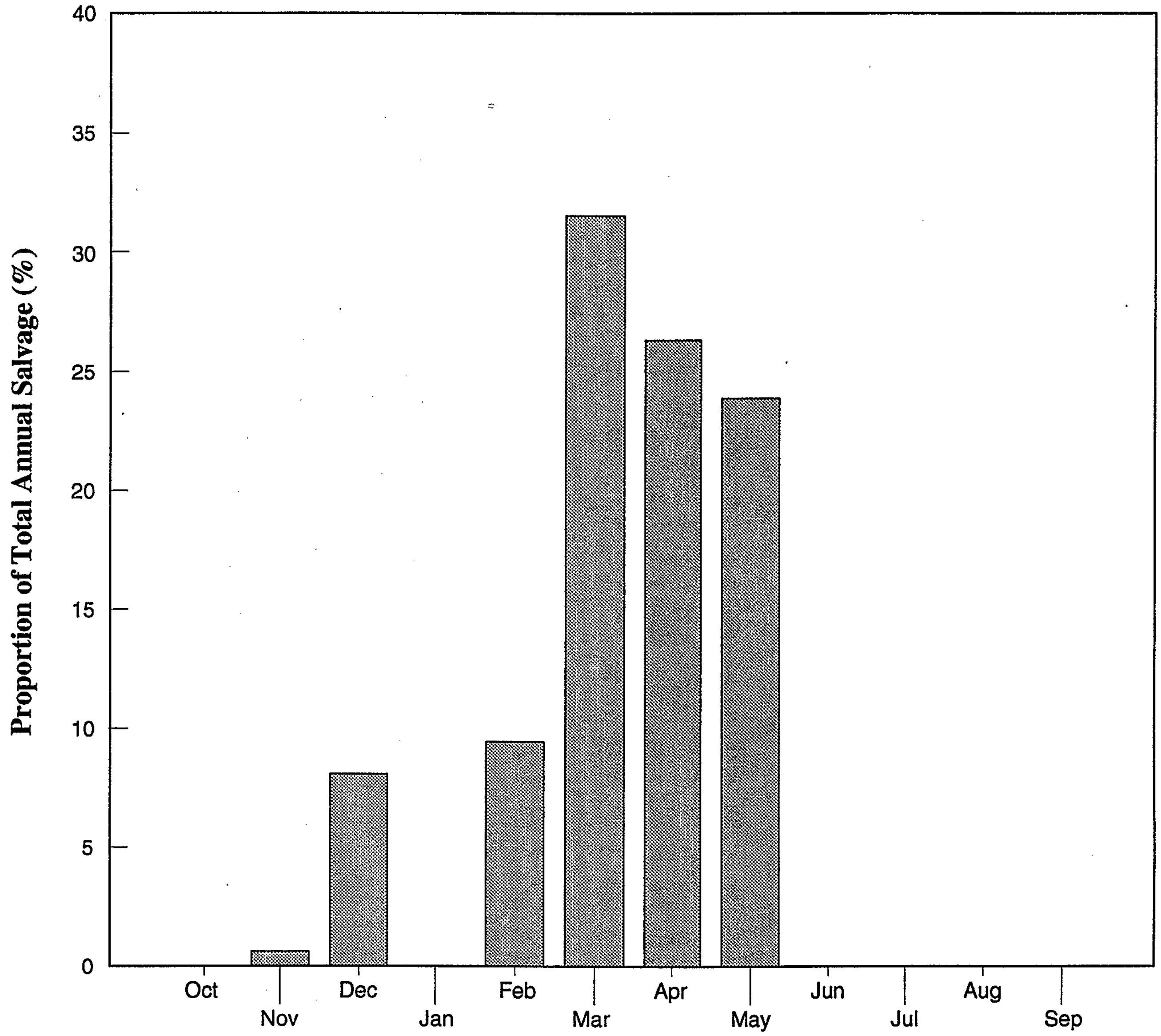


Figure 4-18.
Average Monthly Proportion of Annual Salvage of Juvenile Steelhead Trout at the SWP and CVP Fish Protection Facilities, 1980–1990

DELTA WETLANDS PROJECT
Prepared by: Jones & Stokes Associates

Section 5. Impact Assessment

INTRODUCTION

This assessment addresses potential effects of the proposed DW project operations and facilities on winter-run chinook salmon, delta smelt, Sacramento splittail, longfin smelt, and steelhead trout.

Historically, efforts under the federal Endangered Species Act to prevent extinction of species have focused on prohibiting the destruction of individual species without considering the complexity of the ecosystem in which a particular species exists. Recently, resource management policies have begun to focus on the importance of the ecosystem in the recovery of individual species and in preventing the decline of associated species within a common ecosystem. The 1995 biological opinion for delta smelt (USFWS 1995) incorporated water project effects on other species, including winter-run chinook salmon and Sacramento splittail.

This assessment evaluates the effects of DW project operations and facilities on habitat conditions common to multiple species and life stages throughout the Bay-Delta estuary, as well as factors affecting population abundance and distribution of individual species. The assessment integrates available information on Delta fish species and their habitat requirements with results of simulations of operations under the DW project and the No-Project Alternative and with information on construction and design of proposed fish screens and project facilities.

This impact assessment consists of the following sections:

- "Simulations of DW Project Operations and Changes in Delta Flows" explains the modeling assumptions and approach used for simulating DW project diversions and discharges and estimating effects of DW project operations on Delta flows through comparison with simulated conditions under the No-Project Alternative.
- "Impact Assessment Methods" describes methods used to determine potential impacts (changes in habitat quality and availability, fish transport, and fish entrainment) that could be associated with DW diversions and discharges and Delta channel flow effects of DW project operations. Methods described are use of a chinook salmon mortality model and the fish transport model DeltaMOVE, computations of area and location of optimal salinity habitat, and use of CVP and SWP pumping facility salvage records to estimate entrainment effects of DW project operations.
- "Potential Flow and General Habitat Effects of the DW Project" describes potential general flow and habitat effects of project-related construction activities, activities at proposed boat docks, and DW diversion and discharge operations, based on DeltaSOS simulations and information on construction and design of proposed project facilities.
- "Potential Species-Specific Effects of the DW Project" describes potential impacts of DW project operations on specific life stages and habitat needs of the five species assessed in this BA, based on the impact assessment methods described for fishery effects, combined with the potential flow and general habitat effects identified.
- "Potential Effects on Other Species" summarizes potential effects of DW project operations on other Delta fish species. Effects of the DW project on other species are addressed in detail in the DW project EIR/EIS.
- "Cumulative Impacts" discusses potential effects of DW project operations under anticipated future conditions, such as increased upstream demands, an increase in the permitted pumping rate for SWP's Banks Pumping Plant, and addition of storage facilities south of the Delta.
- "Summary of Potential Fishery Effects of the DW Project" summarizes potential beneficial and adverse effects of DW project implementation on winter-run chinook salmon, delta smelt, Sacramento splittail, longfin smelt, and steelhead trout that could result from DW project implementation.

SIMULATIONS OF DW PROJECT OPERATIONS AND CHANGES IN DELTA FLOWS

Assessment of DW project effects on Delta fish species and their habitat involves predicting fish and habitat responses to changes in Delta conditions that could result from DW project operations. This section provides an overview of the modeling performed for the DW project EIR/EIS. The modeling was used to simulate DW diversions, storage, and discharges and estimate changes in channel flows, outflow, and exports that would be associated with DW project operations under a range of hydrologic conditions. The results of these DW project simulations, in combination with information on fish behavior and habitat needs, provided the basis of the fishery impact analysis described below under "Impact Assessment Methods", which estimated potential effects of DW project operations on habitat conditions, fish transport, and fish entrainment in Delta facilities.

Models Used and General Modeling Assumptions

The simulations used to estimate DW project effects were performed with the Delta Standards and Operations Simulation (DeltaSOS) model. DeltaSOS is the monthly Delta operations model developed by JSA to evaluate compliance of specified Delta water management operations, such as DW's proposed project, with Delta standards and to predict effects of project operations on Delta hydrology. DeltaSOS simulates operations of a project according to a specified set of assumptions regarding facilities, demand for exports, and Delta standards.

The historical record of Delta diversions, flows, and water quality provides basic data for evaluating effects of water project operations and facilities on fish habitat. Although this hydrologic record serves as the best estimate of likely future hydrologic conditions, it does not provide an accurate estimate of future Delta operating conditions. Historical data do not represent conditions that would occur with existing reservoirs and diversion facilities, under the current operations criteria, with applicable Bay-Delta standards, and for the existing levels of demand (including municipal, agricultural, industrial, and fish and wildlife needs) for surface water from the Sacramento-San Joaquin River system. Appropriate modeling of future Delta project operations must be based on anticipated regulatory standards, facilities, and demand for exports, rather than those conditions that existed during the years of the hydrologic record.

These anticipated conditions are represented in the initial Delta water budget used for the DeltaSOS simulations, which consists of results of DWR's SWP operations planning model DWRSIM. DWR uses DWRSIM to simulate monthly water project operations (e.g., channel flows, exports, and outflow) that would occur under existing and anticipated conditions and standards, based on the range of hydrologic conditions represented by the hydrologic record for the Delta for 1922-1991. The results of DWRSIM 1995-C6B-SWRCB-409, performed in January 1995, were provided to SWRCB for use by JSA as the initial Delta water budget in these DeltaSOS simulations to evaluate proposed DW project impacts. These DWRSIM results were used by SWRCB to describe likely Delta conditions under the objectives of the 1994 draft WQCP (issued in March 1995). DWR is continually refining its DWRSIM runs and used a slight modification of this January run when finalizing the 1995 WQCP. The results of these two runs have no differences that affect the DW project simulations.

In the DWRSIM simulation, Delta operations were controlled by criteria specified by SWRCB in the 1995 WQCP. CVP and SWP operations criteria included in the biological opinions for winter-run chinook salmon and delta smelt are encompassed by and consistent with the operations criteria in the 1995 WQCP (USFWS 1995, Stern pers. comm.).

In the DeltaSOS simulations of the DW project alternatives, the CVP and SWP Delta pumping facilities were assumed to export all water that was available under existing operations criteria and existing facility capacities. That is, the DeltaSOS simulations were based on the assumptions that available water would be exported, irrespective of an actual export demand, and that south-of-Delta storage facilities (e.g., MWD's Domenigoni Reservoir) were available for any required storage of the exported water. This simulated level of export is likely representative of future conditions and the potential availability of water to diversion, storage, and discharge for export by DW.

Details regarding DWRSIM and DeltaSOS simulations are provided in Appendix A1, "Delta Monthly Water Budgets for Operations Modeling of the Delta Wetlands Project", and Appendix A2, "DeltaSOS: Delta Standards and Operations Simulation Model", of the DW project EIR/EIS (JSA [in prep.]).

Modeling Assumptions regarding DW Project Operations

The proposed DW project consists of two islands managed as reservoirs and two islands managed under an

HMP. As described in Section 2, "Project Description", Alternatives 1 and 2 both represent operations of the proposed project, differing only with regard to discharge operations. Because it is anticipated that the DW project operational scenario receiving final approval will likely fall somewhere between the two alternatives, the analysis for this BA used the operational scenarios associated with Alternative 2 and the No-Project Alternative to model the widest range of potential operations available to the proposed project for purposes of assessing the proposed project's effects on the listed fish species and their habitat.

DW Reservoir Islands

The DW reservoir islands (Webb Tract and Bacon Island) would have a combined storage capacity of 238 TAF. The reservoirs would be filled in any month when water is available and drawn down during periods of demand. Under appropriate conditions, the DW reservoir islands may be filled and drawn down more than once each year. The cumulative annual capacity (i.e., actual diversion) could therefore be greater than the maximum storage capacity of the reservoirs.

Under the DW project, the average daily maximum rate of diversion onto each reservoir island would be 4,500 cfs, and the total average daily maximum diversion rate would be 9,000 cfs (including diversions onto the habitat islands, discussed below). The maximum monthly average diversion rate would be 4,000 cfs. The maximum diversion rate could be realized only during initial filling. As the islands filled, the head differential of the siphons would diminish and the diversion rate would decline (Figure 5-1). Diversion capacity provides the capability of filling the reservoir islands in one month or less. Siphon diversions would be supplemented by booster pump diversions as the head differential declines to complete filling of the islands within one month or less.

In simulations of the DW project, diversions to storage on the DW reservoir islands could occur anytime a surplus Delta inflow is available, DW reservoir storage is below capacity, and there are no 1995 WQCP constraints.

Surplus Delta inflows available for DW diversion, under the 1995 WQCP objectives, are the amount of allowable export (i.e., the amount within the specified percentage of Delta inflow that may be exported) that is not required for estimated Delta channel depletion and specified outflow requirements. Because DeltaSOS simulations of Delta inflows available for DW diversion always assumed full SWP and CVP export pumping, DW diversions were only simulated for months of maximum allowable SWP and CVP pumping.

The maximum average daily discharge rate would be 6,000 cfs for Bacon Island and 4,000 cfs for Webb Tract; however, the total combined average daily maximum discharge rate would not exceed 6,000 cfs. The maximum discharge rate would be realized only during full reservoir conditions. As the reservoir empties, discharge rates would decline. The combined maximum monthly average discharge rate for the reservoir islands would be 4,000 cfs. Discharge capacity would be sufficient to empty each island in one month or less.

In simulations of Alternative 2, discharge from the DW reservoir islands could occur during any month when stored water remains in the DW reservoirs and there is available CVP and SWP pumping capacity. Available CVP and SWP pumping capacity would exist when export pumping is limited by Delta outflow requirements or by the 1995 WQCP restrictions regarding "percentage of Delta inflow diverted" (or percent inflow) (see Section 2, "Project Description").

The simulation of DW operations assumes that DW diversions adhere to outflow and percent inflow criteria included in the 1995 WQCP. DW discharge, however, is not counted as inflow, and export of DW discharge is assumed not to be constrained by the percent inflow criteria in the 1995 WQCP.

DW Habitat Islands

The proposed DW project habitat islands (Holland Tract and Bouldin Island) would be designed and operated for enhanced wetland and wildlife values. Water would be used to fulfill wetland requirements. Wetland diversions would typically begin in September and continue through winter; irrigation diversions would occur in the summer.

The maximum diversion rate for each habitat island is 200 cfs, for a maximum combined diversion of 400 cfs onto Holland Tract and Bouldin Island. After the initial diversion, water would be diverted periodically to maintain habitat island water levels and to maintain circulation to meet wetland requirements (see Section 2). The general average monthly pattern of water diversion onto the habitat islands is shown in Table 5-1.

No-Project Alternative

Simulated effects of DW project operations on the Delta cannot be directly compared with the historical record of Delta operations for purposes of impact assessment because historical Delta operations did not include current operating criteria; facilities; and conditions, such as demand for exports. To provide a point of reference for assessment of impacts associated with simulated operations of the DW project, it was also necessary to simulate a baseline condition consisting of existing Delta facilities and operating criteria but without operations of the DW project. This point of reference is represented by the simulated No-Project Alternative. As described in Section 3, "Alternatives Considered", the No-Project Alternative represents the intensified agricultural operations that would be implemented on the DW project islands if the DW project were not approved. Results of assessment of all potential impacts of the DW project represent changes that would result from DW project operations in relation to the baseline represented by the No-Project Alternative.

IMPACT ASSESSMENT METHODS

The assessment of potential effects of DW project operations on the habitat and populations of fish species in the Bay-Delta estuary is based on literature review, contacts with appropriate agency experts, analysis of the effects of simulated DW project operations on simulated Delta fish transport patterns, and analysis of other available data.

DW project facilities and operations would primarily affect Delta flows. DW project operations and facilities could also affect water quality, local habitat conditions, and entrainment of fish in diversions..

As described in the preceding section, DeltaSOS simulations (based on DWRSIM simulations of 1922-1991 inflows under the 1995 WQCP objectives) provided the data for the evaluation of flow changes resulting from DW operations. Simulation results for total Delta diversions, DW project diversions, DW discharges for export, DCC and Georgiana Slough flows, lower San Joaquin River flow, and Delta outflow were used to determine the effects of DW project operations on fish habitat conditions and individual species entrainment or mortality. Information on the distribution and timing of fish life stages was incorporated into the evaluation of flow effects. A model developed by JSA for assessing fish transport and entrainment impacts (DeltaMOVE) was used to simulate effects of DW project operations on some species; the model is discussed below under "Methods for Assessing Effects on Fish Transport" and in Appendix A, "Detailed Methodology for Using Transport, Chinook Salmon Mortality, and Estuarine Habitat Models". Additionally, the impact assessment identified area and type of fish habitat that could be affected by construction activities, including additional levee improvements (i.e., riprapping) and construction of intake and discharge structures, fish screens, and boat docks.

The following discussions describe the methods used to assess effects on winter-run chinook salmon, fish transport, estuarine habitat area, and direct entrainment loss. These methods are explained in detail in Appendix A.

Methods for Assessing Effects on Winter-Run Chinook Salmon

Except for migration timing data, specific information on winter-run chinook salmon survival in the Delta is not available for reasonably assessing impacts of Delta water projects on this species. The analysis for winter run therefore relies in part on information available for fall-run chinook salmon.

Mortality of juvenile winter-run chinook salmon could be affected by discontinuation of unscreened agricultural diversions onto the DW reservoir and habitat islands, addition of diversions to fill the reservoir islands (including the resulting reduction in outflow), export of DW discharges (i.e., changes in central Delta flows), and changes in the magnitude and timing of diversions onto the habitat islands.

A mortality index for winter-run chinook salmon migrating through the Delta was calculated using a chinook salmon mortality model that accounts for some of the effects of Delta diversions and flow (Kjelson et al. 1989b). The mortality index for Delta conditions with the DW project indicates the direction and magnitude of potential change in mortality relative to conditions simulated for the No-Project Alternative. The mortality index should not be construed as the actual level of mortality that would occur because simulated monthly conditions cannot accurately characterize the complex conditions and variable time periods that affect survival during migration through the Delta.

The mortality model was developed for migration of hatchery-reared juvenile fall-run chinook salmon through the Delta during April-June. Use of the model to estimate winter-run mortality assumes applicability to in-river juvenile migration during September-May.

The mortality model has two major components: mortality attributable to temperature and mortality attributable to Delta export. In this impact assessment, a cross-Delta flow parameter (CDFP) was substituted for export (Appendix A). It is assumed that the effect of export on salmon migrants from the Sacramento River depends on the volume of Sacramento River water diverted. Exports composed primarily of San Joaquin River flow would presumably have less effect on salmon migrants from the Sacramento River than would exports composed primarily of Sacramento River flow. CDFP is an index of the movement of water from the Mokelumne River side of the Delta to the south Delta and the export facilities (i.e., the proportion of Sacramento River water entering the central Delta that is exported).

CDFP is calculated with the DeltaMOVE fish transport model discussed below under "Methods for Assessing Effects on Fish Transport" and in Appendix A. 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 at the end of the month is the monthly CDFP. The CDFP, the salmon mortality model, and DeltaMOVE are described in detail in Appendix A.

Methods for Assessing Effects on Fish Transport

The distribution of many fish species, including delta and longfin smelt, is affected by changes in Delta flow patterns and diversions during the larval and early juvenile life stages. Many other factors affect the distribution of larvae and juveniles in the estuary, including the distribution and timing of spawning, larval growth, the response of fish to various environmental conditions (i.e., salinity, temperature, and prey distribution), Delta inflow and outflow, and tidal flow patterns.

The fish transport model DeltaMOVE was used to simulate an entrainment index for evaluating the effects of water project operations on fish distribution and entrainment loss in the Delta (Appendix A). Although relationships between physical and biological factors controlling larval and early juvenile distribution are complex and difficult to ascertain, the fish transport model simulations are based on the assumption that movement of water is representative of the movement of young fish. The fish transport model uses net channel flows, tidal mixing flows, channel volume, and salinity to estimate effects of Delta inflows and water project operations on distribution and entrainment loss of larval and early juvenile life stages. The effects of the DW project on the distribution and potential entrainment loss of larvae and early juvenile life stages were evaluated by comparing entrainment indices for the No-Project Alternative conditions with entrainment indices for conditions under DW project operations.

The entrainment index for Delta conditions with the DW 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 in the Delta.

Delta and longfin smelt larvae are assumed to be transported primarily by net channel flow and tidal mixing flows. Whether fish are lost as a result of Delta diversions depends on the volume of diversions, the volume of net flow moving fish toward the diversion points, and the length of time that larvae reside in the Delta channels. Increased rate of movement out of the Delta and toward Suisun Bay results in lower losses to Delta diversions. Delta residence time is determined by the magnitude of Delta outflow; higher outflows reduce the period of residence in the Delta spawning areas and increase the proportion of the simulated population transported to Suisun Bay during a given period.

Methods for Assessing Changes in Estuarine Habitat Area

Salinity is an important habitat factor and is strongly affected by Delta outflow; therefore, estuarine habitat often is defined in terms of a salinity range (Hieb and Baxter 1993). All estuarine species are assumed to have optimal salinity ranges, and different life stages within a species often vary in their salinity preferences. Species survival may be determined partly by the amount of habitat available within the optimal salinity range. Because survival during an early life stage often determines the size of the year class, which in turn affects the size of the adult population, the optimal salinity habitat of the limiting life stage may be particularly important.

Habitat area, based on the estimated optimal salinity range, was calculated for delta and longfin smelt. The optimal salinity range for delta smelt is 0.3-1.8 ppt; the optimal salinity range for longfin smelt is 1.1-18.5 ppt (Obrebski et al. 1992, Hieb and Baxter pers. comm.).

The geographical location of the upstream and downstream limits of the optimal salinity habitat are computed from monthly average Delta outflow and the optimal salinity range of the species. The Bay-Delta estuary has a complex shape and the area of optimal salinity habitat varies greatly with its location. The surface area at different locations was estimated from nautical charts. Total area of optimal salinity habitat was computed for each month through addition of all areas contained between the upstream and downstream limits of the optimal salinity range that was calculated from monthly average Delta outflow.

The annual optimal salinity habitat area was the weighted average of all months. The habitat area for a month was weighted according to the proportion of the limiting life stage present each month. For delta smelt, limiting life stages are assumed to be larvae and early juveniles, which are present during February-August. The proportion present peaks during May at 30%. Limiting life stages for longfin smelt are assumed to be larvae and early juveniles, which are present during January-May, peaking during February and March at about 40%. Appendix A includes details of these calculations of location and area of optimal salinity habitat.

Methods for Assessing Direct Entrainment Loss

Direct entrainment loss is the total mortality of fish contained in water diverted onto the DW project islands, impinged on DW project fish screens, and eaten by predators exploiting habitats created by the intake facilities.

The intakes on all DW island siphons would have fish screens. Fish screen operations and design are being developed in consultation with DFG and NMFS; DW will apply the best available technology at the time of construction to obtain the highest efficiency under variable Delta conditions. For juvenile and adult fish greater than 38 mm in length (including all juvenile chinook salmon), the fish screens are assumed to nearly eliminate direct entrainment losses. Losses of fish eggs and larvae and juvenile fish that cannot be effectively screened are discussed in greater detail under the respective species in the impact assessment. The presence of fish screens, fish screen supports, boat docks, pilings, and other structures associated with the intakes could provide habitat for predatory fish that could cause prescreening losses.

The historical (1979-1990) CVP and SWP salvage records (see Section 4, "Endangered, Threatened, and Candidate Fish Species") were used to estimate the timing and magnitude of vulnerability to entrainment for screenable-sized fish of all target species. The information was used in conjunction with simulated estimates of the volume and timing of diversions to determine potential entrainment loss.

POTENTIAL FLOW AND GENERAL HABITAT EFFECTS OF THE DW PROJECT

This section discusses potential general DW project effects on fish habitat, transport, and entrainment. The discussion covers the following:

- effects of DW project facility construction on localized habitat availability and quality;
- effects of DW project operations (discharges of stored water and boat dock activities) on water constituents and habitat suitability;
- effects of project diversions on outflow and salinity and, therefore, on habitat availability;
- effects of DW project diversions and discharges on Delta channel flow patterns, which affect fish transport to suitable habitat and to pumping facilities where they may be vulnerable to entrainment; and
- effects of DW project diversions and discharges on percentage of Delta inflow diverted, which is associated with fish entrainment at the CVP and SWP export pumping facilities.

Effects of DW project operations were determined through comparison of flow and habitat conditions for operations and facilities simulated by DeltaSOS with and without the DW project (i.e., under the DW project and under the No-Project Alternative). The flow and salinity conditions simulated for the No-Project Alternative are listed in Appendix B, "Flow and Salinity Conditions under the No-Project Alternative". The DeltaSOS simulations of Delta inflows and water project operations provided the basis for most of the species-specific evaluations discussed below under "Potential Species-Specific Effects of the DW Project".

Tables 5-2 and 5-3 show the results of DeltaSOS simulations of DW reservoir island diversions and discharges, respectively, based on hydrologic conditions for 1922-1991. Timing and volume of diversions depend on DW reservoir storage space and the amount of water available for diversion under 1995 WQCP operations criteria. Timing and volume of discharges depend primarily on stored volume and unused permitted export pumping capacity at the CVP and SWP Delta pumping facilities. Habitat island diversions under the DW project (Table 5-1) would vary little from year to year, although timing of diversions would be flexible and would depend on habitat island water management needs.

Effects of Construction Activities

Construction activities for the DW project include construction of intake facilities and fish screens, discharge facilities, and boat docks. Boat docks would be constructed in conjunction with each of the discharge and diversion facilities. Additionally, boat docks would be constructed at other locations on the DW reservoir and habitat islands. Piles would be driven to hold the floating docks in place. Dredging is not anticipated and exterior levee improvements will be minor. Ongoing maintenance programs for the exterior levees, however, would continue. Additional construction and maintenance activities for DW project facilities that could affect fish habitat in the Delta would be limited primarily to areas around the existing and new intake siphons, discharge pumps, and boat docks.

The intake and discharge facilities and boat docks will be situated on relatively steep, riprapped levee slopes. Dredging of levee slopes and channels is not proposed. The proposed location of the facilities is not in what is believed to be preferred spawning or rearing habitat of delta smelt and Sacramento splittail (i.e., shallow vegetated habitat).

If intake sites or boat docks were located in or near shallow vegetated habitat, however, spawning habitat for delta smelt and Sacramento splittail could be lost or altered. The habitat area lost would be small relative to the total area of similar habitat in the Delta, and such loss would have minimal effects on delta smelt and Sacramento splittail populations. Loss of habitat could adversely affect localized delta smelt and Sacramento splittail reproduction.

Effects of DW Project Operations on Water Quality

This section addresses potential water quality effects of proposed discharges of stored water from the DW reservoir islands (Webb Tract and Bacon Island) and boat-related spills at docks on the DW islands. Effects of DW project operations on seawater intrusion (i.e., the location of X2) are discussed below under "Effects of DW Diversions on Delta Outflow and Salinity".

DW Project Island Discharge

Organic Materials and Toxics. Water discharged from the DW project islands is not expected to contain materials toxic to aquatic organisms. Pesticides, currently a component of Delta agricultural discharge, would be applied at reduced levels on the DW project islands. Soluble toxic materials are not known to be present in the soil or water on the DW reservoir islands (see Chapter 3C, "Water Quality", of the DW project EIR/EIS).

Although water discharged from the DW project islands would contain reduced levels of toxic materials, it may have elevated levels of dissolved organic carbon (DOC). Discharge of such additional DOC is expected to have minimal biological effects in the Delta. Chapter 3C of the DW project EIR/EIS contains a full analysis of the potential effects of the DW project on Delta water quality.

Dissolved Oxygen. When filled, the DW reservoirs would be relatively shallow (i.e., generally less than 20 feet deep) and water would be well mixed. It is assumed that dissolved oxygen levels in the DW reservoirs would be similar to those in the Delta channels. DW discharge would not be allowed to reduce dissolved oxygen levels in the receiving channel by more than 1 mg/l (see Chapter 3C, "Water Quality", of the DW project EIR/EIS).

Water Temperature. Factors controlling the effect of DW discharges on Delta channel water temperature include initial channel water temperature, temperature of the stored water on the DW reservoir islands at the time of discharge, volume of the discharge, volume of the receiving channel, flow and mixing in the receiving channel, and meteorological conditions.

Delta channel water temperature depends primarily on meteorological conditions. During some months, water temperature may depend also on flow; Figure 5-2 shows the relationship between water temperature and average monthly Sacramento River flow at Freeport. Under high flow conditions, river inflow may affect water temperature in the channels adjacent to the DW reservoir islands.

If the temperature on the DW project islands is substantially greater than water temperature in the Delta channels, DW discharges could increase channel water temperature. If the altered channel water temperature exceeds 60°F (Kjelson et al. 1989b), winter-run chinook salmon survival could be adversely affected.

During November-February, major months of winter-run migration through the Delta, water temperatures are in equilibrium with air temperatures (i.e., the regression of water temperature on flow is not significant). During November-February, DW reservoir water temperature would be similar to Delta channel water temperature. During March, the relationship between water temperature and flow is significant;

however, maximum water temperatures are less than 60°F (Figure 5-2).

October and April are the only months of winter-run juvenile migration when the temperature of DW discharge is likely to exceed 60°F and may also exceed water temperature of the receiving channel. The proportion of the juvenile winter-run population migrating during October or April is variable but is probably less than 10% (migration is discussed below under "Winter-Run Chinook Salmon" in the section "Potential Species-Specific Effects of the DW Project").

Boat Docks

The introduction of DW project boat docks is not expected to substantially increase boat-related activities in the Delta (see Chapter 3J, "Recreation and Visual Resources", of the DW project EIR/EIS). The boat docks, however, could concentrate effects of minor fuel and lubricant spills from individual boat engines and other boat-related discharge at the dock locations. Fueling stations are not proposed as part of the boat docks. The relatively strong tidal currents in the channels surrounding the DW habitat and reservoir islands would disperse spills quickly. Boat docks located adjacent to spawning and early rearing areas of Sacramento splittail, delta smelt, and longfin smelt could have localized adverse effects.

Effects of DW Diversions on Delta Outflow and Salinity

Delta outflow is a primary factor associated with Bay-Delta fish abundance, distribution, and habitat conditions. The effects of outflow on transport of fish larvae and juveniles is discussed below under "Potential Species-Specific Effects of the DW Project".

DW project diversions would directly reduce Delta outflow. Although the maximum average monthly DW diversion rate is 4,000 cfs, the average daily maximum DW diversion rate could reach 9,000 cfs for a few days (Figure 5-1). DW diversions reduce outflow by more than 5% in less than 25% of the simulated years for any month. When DW diversions occur, outflow can be reduced by as much as 39% (Table 5-4).

During the primary months of winter-run juvenile migration (December-March) and delta smelt habitat needs (February-June), simulated DW project diversions had the greatest effect on Delta outflow during December and January (Table 5-4). During other months, DW diversions were less likely or diversions coincided with high outflow volumes (i.e., reductions in outflow were relatively small) (see Appendix B, Table 9, for simulated outflows under the No-Project Alternative). The effect of DW diversions on simulated Delta outflow, however, would not cause the Delta outflow objectives of the 1995 WQCP to be violated.

A primary habitat condition affected by Delta outflow is salinity distribution in the estuary. Delta outflow may also affect concentration of toxic and organic materials, but the relationship of outflow to concentration of organics or toxics is currently not quantified.

The effect of reduced outflow on salinity is represented by the change in X2 (distance in kilometers of the 2-ppt isohaline from the Golden Gate Bridge). The simulations of DW project operations show that X2 would shift upstream when outflow is reduced by DW diversions.

During February-June (the critical habitat months for many estuarine species), DW project operations would cause upstream shifts in X2 of less than 1.4 kilometers (Table 5-5). During September and October, the simulated upstream shift in X2 would exceed 3 kilometers in some years. The magnitude of the shift in X2 is a function of both the change in Delta outflow (DW diversion) and the outflow. Reductions in outflow caused by DW diversions have less effect on the location of X2 when the outflow is greater. The greatest shift in X2 occurs at relatively low outflows, when X2 is located upstream near the confluence of the Sacramento and San Joaquin Rivers. Table 10 in Appendix B shows X2 simulated for the No-Project Alternative.

Although the objectives of the 1995 WQCP would be met under DW project operations, the upstream shift in X2 attributable to DW diversions could reduce the volume of optimal salinity habitat in Suisun Bay and the Delta. Change in area of optimal salinity habitat in the estuary is discussed in the sections on individual species under "Potential Species-Specific Effects of the DW Project", below. The change in average X2 for February-June attributable to DW diversions would range from 0 to 0.38 kilometers (Figure 5-3). Considering the small change in X2 during February-June and that the objectives of the 1995 WQCP are met, it can be assumed that DW operations would have minimal effects on availability of low-salinity habitat in the estuary during February-June.

Effects of DW Operations on Delta Flow Patterns

Delta flow patterns potentially affect the movement of fish through the Delta and their arrival in downstream habitats or entrainment in diversions. Net flow in the Delta channels is affected by river inflows, channel geometry, location and volume of Delta diversions, and closure or removal of channel barriers.

Channel flows affecting the central Delta (i.e., the San Joaquin River from Stockton to Twitchell Island, including the most northerly parts of Old and Middle Rivers) are discussed in this section. The central Delta is the "switchyard" of the Delta. Channel flows into and out of the central Delta could affect fish movement in the Sacramento, Mokelumne, and San Joaquin Rivers. The channel flows discussed in this section include major inflows to the central Delta from the Sacramento River (i.e., the DCC and Georgiana Slough) and the San Joaquin River (at Stockton), flow between the central and western Delta (QWEST), and flows in Old and Middle Rivers.

DCC and Georgiana Slough

Diversion of Sacramento River flow through the DCC and Georgiana Slough could have detrimental effects on winter-run chinook salmon and could also affect distribution and survival of other species. Flow through the DCC and Georgiana Slough is a function of Sacramento River flow and operation of the DCC gates. DW project operations would not affect Sacramento River flow and DCC gate operation. The volume of the DCC and Georgiana Slough flow would be the same under the No-Project Alternative (Appendix B, Table 4) and the DW project because exports and DW diversions would not change the DCC and Georgiana Slough flows (see discussion of hydrodynamic model simulations in Appendix B1, "Hydrodynamic Modeling Methods and Results for the Delta Wetlands Project", of the DW project EIR/EIS).

San Joaquin River at Stockton

With a barrier in Old River, nearly all San Joaquin River flow moves through the Delta past Stockton. The barrier was assumed to be in place during April-May and October for the 1922-1991 simulations. The barrier was assumed to be removed if San Joaquin River inflow exceeded 10,000 cfs.

When the Old River barrier is not in place, flow past Stockton is a function of San Joaquin River inflow and, to a lesser extent, export at the SWP and CVP Delta pumping facilities. When the San Joaquin River flow at Vernalis exceeds 2,000 cfs, flow toward Stockton is approximately 40% of the total San Joaquin River inflow. As the inflow volume declines, the proportion of flow toward Stockton also declines. When total San Joaquin River inflow is about 500 cfs, flow toward Stockton is negligible but may be slightly reversed.

DW project operations would not affect total San Joaquin River inflow and Old River barrier placement. The volume of San Joaquin River flow past Stockton would be the same under the No-Project Alternative (Appendix B, Table 7) and the DW project.

QWEST Flow

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 Threemile 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).

The effects of DW operations on QWEST are similar to the effects previously described for Delta outflow. DW project diversions would directly reduce QWEST (Table 5-6). DW discharge for export would not affect QWEST.

If QWEST under the No-Project Alternative is positive (i.e., net flow is toward Suisun Bay), DW diversions would reduce the net flow volume or reverse the direction of net flow. If QWEST under the No-Project Alternative is negative (i.e., net flow is toward the central Delta), DW diversions would increase the net flow volume. QWEST under the No-Project Alternative is shown in Appendix B, Table 5.

The effects of change in QWEST on fish species depend on flow conditions throughout the Delta, tidal mixing, and the distribution of fish. More detailed analysis of effects of DW diversions and changes in QWEST are presented under "Potential Species-Specific Effects of the DW Project" below.

Old and Middle Rivers

Net flow in Old and Middle Rivers is toward the south during most months of most years of the 1922-1991 simulations (Appendix B, Table 6). DW project diversions would increase net southerly flow in Old and Middle Rivers between Bacon Island and Webb Tract (Table 5-7). The increase would not exceed 4,500 cfs, the maximum diversion capacity of Bacon Island. Flows to the south of Bacon Island would not be affected by DW diversions.

DW discharge for export would also increase net southerly flow in Old and Middle Rivers (Table 5-7). Net flow would change in Old and Middle Rivers between Webb Tract and Bacon Island only when DW project water is discharged from Webb Tract. Discharge from Bacon Island would affect only flows south of Bacon Island. Discharge for export could increase net southerly flow by a maximum of 6,000 cfs between Bacon Island and the CVP and SWP Delta pumping facilities and a maximum of 4,000 cfs between Webb Tract and Bacon Island.

The effects of the change in net Old and Middle River flow on fish species depend on concurrent flow changes in the rest of the Delta, tidal mixing, and the distribution of fish. More detailed analysis of effects of DW diversions and DW discharges for export are presented under "Potential Species-Specific Effects of the DW Project" below.

Effects of DW Operations on Percentage of Delta Inflow Diverted

Percentage of Delta inflow diverted was introduced in the 1995 WQCP as an export limit to reduce entrainment of various species' life stages by the major export pumps (CVP and SWP) in the south Delta. A major concern is the movement of fish toward the south Delta with water drawn from the Sacramento River. South Delta diversions (SWP, CVP, CCWD, and agricultural diversions) generally exceed the San Joaquin River inflow and draw Sacramento River water across the Delta.

In simulations of DW project operations, DW diversions were treated the same as CVP and SWP exports and were limited by the percent inflow criteria of the 1995 WQCP (i.e., during any month, the sum of DW diversions and export as a percentage of Delta inflow would not exceed the maximum allowed under the 1995 WQCP). The criteria allow export (plus DW diversion) of 35% or less of Delta inflow during February-June and 65% during July-January (between 35% and 45% during February if January runoff is less than 1.5 MAF). According to these criteria, percent of inflow diverted could exceed 35% in February in 40 of the 70 simulated years. In simulations of the No-Project Alternative, there were 15 years when percentage of inflow diverted exceeded 35% in February (Figure 5-4). With DW diversions, percentage of inflow diverted exceeded 35% for 18 of the 70 simulated years during February.

In DeltaSOS modeling, DW discharge for export was allowed to increase total exports above the 1995 WQCP percent inflow criteria. Percent inflow is calculated by dividing export, including export of DW discharge, by Delta inflow. Figure 5-4 presents the resulting export as percentage of Delta inflow related to the 1995 WQCP criteria.

The increase in percent inflow diverted could increase entrainment of estuarine species by Delta diversions. A detailed discussion of entrainment effects of DW project operations is presented below under "Potential Species-Specific Effects of the DW Project".

Daily Operations

Monthly simulations provide general information on the monthly timing and volume of DW project diversions and discharges. Simulations of daily operations would provide a more accurate representation of DW project operations. Daily water project operation models, however, are not available to simulate Delta inflows and operation of upstream facilities. Monthly simulations of operations (using DWRSIM and Reclamation's planning model PROSIM) are currently the best available tool for estimating Delta inflows and upstream operations.

Figure 5-5 compares the daily and monthly average flows and operations for several months of an example water year, 1981 (DWR 1990). Water year 1981 was selected for illustration because under 1981 conditions a wide range of export and outflow conditions occurred. The monthly flows shown in Figure 5-5 are averages of the daily flows and should not be confused with DWRSIM-simulated monthly flows used for the overall assessment.

In general, monthly average Delta outflow does not reflect daily variability that may occur. Peak daily flows may greatly exceed monthly average flows (Figure 5-5). Also, daily diversion rates may exceed monthly average diversion rates; however, the total monthly volume diverted in daily simulations may be greater or less than the volume diverted under a monthly simulation. As discussed above under "Modeling Assumptions regarding DW Project Operations", monthly average DW diversions onto the reservoir islands would not exceed 4,000 cfs. Daily diversions could approach 9,000 cfs at the beginning of the filling period when the reservoir islands are empty (Figure 5-1).

Use of simulated monthly average flows in the impact assessment provides a general indication of how the DW project would operate and how DW operations may affect Delta flows. As the comparison in Figure 5-5 shows, DW operations under daily conditions could be less constrained or more constrained by the operations criteria than DW operations under monthly average conditions. For example, during February the monthly average percentage of inflow diverted indicates that exports would be well below the 35% criterion of the

1995 WQCP. The daily percentage of inflow diverted, however, exceeds the 35% criterion at least once during the month.

The magnitude and occurrence of DW effects on fisheries may be similarly under- or overestimated. A more detailed discussion of monthly versus daily effects on fish is provided below under "Potential Species-Specific Effects of the DW Project".

POTENTIAL SPECIES-SPECIFIC EFFECTS OF THE DW PROJECT

DW project effects on abundance of winter-run chinook salmon, delta smelt, Sacramento splittail, longfin smelt, and steelhead trout were determined using available species-specific models that relate species effects to habitat conditions. Species abundance indices and habitat conditions were compared for operations under the No-Project Alternative and under DW project operations. Results of the assessment of effects are described below for each of the five target species of this BA.

Winter-Run Chinook Salmon

As described above, a mortality index for winter-run chinook salmon during migration through the Delta was simulated with a mortality model that accounts for some of the effects of diversion and flow. The following discussions describe changes in the mortality index of juvenile winter-run chinook salmon that were estimated to result from simulated DW project operations relative to simulated operations of the No-Project Alternative. As discussed below, mortality under DW project operations may be reduced during some years relative to mortality under the No-Project Alternative because agricultural diversions would be eliminated from the DW reservoir islands. Mortality directly attributable to entrainment in diversions onto the DW reservoir and habitat islands would be minimized by operation of effective fish screens. Mortality under DW project operations may increase during some years relative to conditions under the No-Project Alternative because the schedule of diversions onto the habitat islands would be altered, new diversions to fill the reservoir islands would be added to island operations, and DW discharge would be exported.

Figure 5-6 shows the winter-run migration mortality index attributable to all Delta diversions for the 70-year simulation. The total Delta mortality index simulated for the 1922-1991 period ranges from 6% to 16% of the annual production of winter-run chinook salmon juveniles. Simulated DW project operations under the 1995 WQCP would increase mortality relative to mortality under the No-Project Alternative by 0% to 0.45% (Figure 5-6). The increased mortality includes direct DW effects and indirect effects (i.e., mortality attributable to other Delta diversions that results from DW effects on Delta flow conditions). Mortality estimates, however, did not include the benefits of fish screens, and DW project operations with effective fish screens in place would have minimal adverse direct effects on juvenile winter-run chinook salmon mortality.

Variable Migration Timing

The simulations of DW project operations assumed that the first available Delta water would be diverted onto the DW reservoir islands. If fish abundance is a function of flow (i.e., water availability), vulnerability to DW diversion effects may also be a function of flow. Migration timing of winter-run chinook salmon each year is assumed to be a function of flow and inherent run characteristics. In the simulation of mortality during migration, migration timing varies each year according to occurrence of storm events. In general, migration peaks during February and March (Figure 5-7); however, storm events (increased availability of water) can cause greater proportions of the winter-run chinook salmon population to migrate downstream to the Delta. The simulated proportion migrating each month varies by more than 30% from year to year (e.g., during February, migration percentage ranged from 13% to 53% for the 70-year simulation).

Agricultural and Habitat Island Diversions

Existing unscreened agricultural diversions onto the DW islands (60 TAF/yr) constitute about 3% of total Delta agricultural diversions (1,800 TAF/yr) and generally less than 1% of total Delta diversions (8 MAF/yr). The timing of most agricultural diversion does not coincide with the normal migration of winter-run chinook salmon (Table 5-1 and Figure 5-7).

The difference between winter-run mortality attributable to unscreened agricultural diversions on the DW islands under the No-Project Alternative and mortality attributable to DW habitat island diversions under the DW project (i.e., change in mortality attributable to forgone agricultural diversions) ranges from 0% to -0.02% (Figure 5-8). Net juvenile mortality during migration through the Delta would be reduced because agricultural diversions are forgone. Simulated mortality attributable to the habitat island diversions is less than the mortality attributable to agricultural diversions under the No-Project Alternative because the volume of diversions is reduced and the timing of diversions coincides less frequently with winter-run salmon migration. The absence of agricultural diversions on the proposed DW reservoir islands and change in diversion pattern on the habitat islands generally provide a DW project benefit to winter-run chinook salmon survival.

Additionally, winter-run chinook salmon would be efficiently screened from DW reservoir and habitat island diversions. The benefit of fish screens has not been accounted for in the estimate of change in mortality discussed above. Salmon screened from the diversions on Holland Tract and Bacon Island may continue down Old and Middle Rivers with net flow and be entrained in the SWP and CVP Delta pumping facilities or in other Delta island diversions. Some of the winter-run salmon entrained by the SWP and the CVP would be salvaged and returned to their migration route on the Sacramento River. Direct effects of DW project diversions on winter-run chinook salmon entrainment would be minimal.

DW Reservoir Island Diversions

Water would be diverted to fill the DW reservoir islands during the winter-run salmon migration period as well as other times of the year (Table 5-2 and Figure 5-7). Over the 70-year simulation, the contribution of DW reservoir island diversions to the mortality index for migrating winter-run salmon ranges from 0% to 0.42% (Figure 5-8). The estimated contribution to the total mortality index does not take into consideration potential benefits of fish screens, which would reduce DW project effects.

DW Discharge for Export

As explained in Section 2, water discharged from the DW reservoir islands is assumed to be exported by the CVP and SWP Delta pumps. For some years, simulated export of DW project discharge coincides with the presence of winter-run salmon (Table 5-3 and Figure 5-7).

Delta exports affect survival of winter-run chinook salmon that have left the Sacramento River with the flow division at the DCC and Georgiana Slough. Survival may be a function of factors that affect the movement of juvenile chinook salmon out of the central Delta. Export of DW discharge may increase winter-run chinook salmon mortality because export of DW discharge will increase total exports, even though outflow from the central Delta would not be changed by DW discharges for export.

The chinook salmon mortality model was used to evaluate the total mortality of winter-run chinook salmon migrating down the Sacramento River. The estimated annual mortality attributable to increased export of DW discharge ranges from 0% to 0.3% (Figure 5-8). The simulations show that Webb Tract discharge has the greater effect because of its location in the central Delta. Bacon Island is located in the south Delta and the simulated effect on estimated juvenile winter-run mortality during migration is about 75% less than the effect simulated for Webb Tract.

The chinook salmon mortality model likely overestimates the effects of DW discharge for export on mortality of juvenile chinook salmon during migration through the Delta. In the mortality model, export of DW discharge from Webb Tract and Bacon Island increases the movement of water from the central and south Delta toward the export facilities. Movement of water across the Delta (i.e., movement of water from the lower San Joaquin River, Sacramento River, and Mokelumne River) is not affected. Juvenile chinook salmon may not behave like particles and may not be influenced by tidal mixing and the change in flow conditions in the central and south Delta. Therefore, mortality attributable to DW discharge for export may be less than the mortality shown in Figure 5-8.

Delta Smelt

Delta Smelt Transport

DW project operations could affect delta smelt survival and abundance by affecting transport flows. As described in Section 4, delta smelt spawn in freshwater channels in the Delta. After hatching, larvae may 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 (Appendix A). The estimated percentage of the spawned population that is entrained provides an index of losses during transport to downstream optimal low-salinity habitat.

As described below, similar to mortality of chinook salmon, mortality of delta smelt may be reduced during some years relative to conditions under the No-Project Alternative because agricultural diversions would be eliminated from the DW islands. Mortality may increase in some years relative to conditions under the No-Project Alternative because new diversions would be made to fill the reservoir islands and DW project discharge would be exported during months when delta smelt larvae were simulated to occur in the central Delta.

Figure 5-9 shows the total annual entrainment loss of delta smelt attributable to all Delta diversions, including exports, for the 70-year simulation. Total Delta entrainment loss simulated for 1922-1991 ranges from 1% to over 35% of the annual production of delta smelt larvae. The simulations indicate that DW project operations under the 1995 WQCP criteria for the SWP and CVP Delta pumping facilities could increase the annual entrainment loss relative to loss under the No-Project Alternative by 0% to 3.5% (Figure 5-9). The increased entrainment index includes direct entrainment in DW diversions (and export of DW discharge) and indirect entrainment that could result from DW operation effects on Delta flow conditions. DW project operations could have adverse effects on transport of delta smelt larvae.

Variable Spawning Location and Timing. Little is currently known about factors influencing the annual variability in distribution and timing of delta smelt spawning. Hatching is assumed to take place during February-June. For the impact assessment, 50% of the total annual spawn was assumed to occur on the Sacramento River side of the Delta and 50% of the spawn was assumed to be distributed equally between the San Joaquin River, Mokelumne River, and central Delta areas (i.e., 16.66% in each area).

The assumed spawning distribution can have a substantial effect on the simulated entrainment index for total Delta diversions (Figure 5-10). Larvae hatched on the Sacramento side of the Delta are less affected by export than larvae hatched in the central Delta.

Agricultural and Habitat Island Diversions. Under DW project operations, existing unscreened agricultural diversions onto Webb Tract and Bacon Island would be eliminated. The timing of diversions onto Bouldin Island and Holland Tract would be similar to the timing of diversions under the No-Project Alternative, although some additional water would be diverted during fall under the DW project (Table 5-1). The estimated difference between entrainment in agricultural diversions on the DW islands under the No-Project Alternative and entrainment in DW habitat island diversions (i.e., change in entrainment attributable to forgone agricultural diversions) is negligible (Figure 5-11).

DW Reservoir Island Diversions. The contribution of simulated DW reservoir island diversions to annual entrainment loss ranges from about 0% to 2.8% (Figure 5-11). These DW project diversions were estimated to cause entrainment losses of greater than 1% during eight years.

DW Project Discharges for Export. As explained previously, water discharged from the DW islands under the proposed project is assumed to be exported by the CVP and SWP Delta pumping facilities. The entrainment loss of larvae attributable to DW discharges for export is shown in Figure 5-11 and ranges from 0% to about 1.4%. Losses greater than 1% result from DW discharge for export during eight of the simulated years (Figure 5-11).

Because Webb Tract is located in the central Delta and is closer to higher simulated densities of delta smelt, discharge from Webb Tract for export is simulated to have a greater effect on entrainment of delta smelt larvae than discharge from Bacon Island (Figure 5-11). Simulated Bacon Island discharge for export results in only about 25% of the increased entrainment that would occur with discharge of the same volume from Webb Tract. The relationship would be true for larvae hatching anywhere in the Delta north of Bacon Island.

Daily versus Monthly Transport Effects

The monthly simulation provides a general indication of potential impacts of the DW project on delta smelt transport (i.e., entrainment index). Daily entrainment losses will vary from the entrainment losses estimated based on average monthly flows depending on Delta flow conditions, total Delta diversions, and daily abundance and distribution of delta smelt larvae.

Delta flow conditions, described above under "Daily Operations" in the section "Potential Flow and General Habitat Effects of the DW Project", were used as input to the DeltaMOVE model to simulate an entrainment index for daily and monthly average flows during January and February 1981. For each day of the simulation, either the daily hydrology or the average monthly hydrology was used. Entrainment indices were evaluated for independent hatching events each day of the month. The distribution of spawning in the Delta was the same as the distribution assumed in the impact analysis discussed above.

In general, the pattern of entrainment loss is similar for daily and average monthly hydrology (i.e., the entrainment index declines from January to February) (Figure 5-12). The magnitude of the entrainment index for daily flows, however, may be substantially greater or less than the entrainment index for monthly average flows. The difference between the daily and monthly average effects indicates the importance of considering flow conditions over time increments of less than a month in developing project operations criteria. The level of DW project effects during actual operation, and actions necessary to avoid substantial adverse effects on delta smelt and other species, will depend on daily flow conditions in the Delta and on the real-time distribution of vulnerable fish life stages.

Delta Smelt Optimal Salinity Habitat

As discussed above under "Methods for Assessing Changes in Estuarine Habitat Area", delta smelt year-class survival may be related to optimal salinity habitat area. Salinity is assumed to be a major factor defining delta smelt habitat, and salinity between 0.3 ppt and 1.8 ppt is assumed to delineate the optimal habitat.

Under operations of the No-Project Alternative and the DW project, the annual weighted habitat area available for delta smelt during the simulated 1922-1991 period ranges from 41 km^2 to 67 km^2. Change in habitat area under DW project operations relative to the area under the No-Project Alternative ranged from -2.0% to 2.2% (Figure 5-13). In general, DW project operations would increase optimal salinity habitat available to delta smelt during most years. The small increase in area relative to the total area available occurs because of increased outflow attributable to forgone agricultural diversions during the rearing period (February-August).

Direct Entrainment of Delta Smelt

Potential entrainment of larvae is described above under "Delta Smelt Transport". Although the presence of adult and juvenile delta smelt near DW project diversions (Figure 4-11) may coincide with the timing of diversions (Tables 5-1 and 5-2), older juvenile and adult delta smelt would be screened from DW reservoir and habitat island diversions.

Use of fish screens would reduce adverse effects of diversions on adults and larger juveniles. Additionally, information is being developed to facilitate better understanding of diversion-related mortality of smelt (e.g., entrainment, impingement, abrasion, and predation).

The DW project would likely have minimal adverse effects on direct entrainment of adult and older juvenile delta smelt.

Sacramento Splittail

Construction of DW project facilities could affect localized Sacramento splittail habitat, and DW project diversions could increase splittail entrainment. Although DW project operations could have adverse effects on localized populations of splittail, the effect on overall population abundance would be minimal.

Sacramento Splittail Habitat Effects

As discussed under "Effects of Construction Activities" above, splittail spawning and rearing habitat could be affected near proposed DW project intakes, discharge pumps, and boat docks. Sites for the facilities would be relatively steep, riprapped levee slopes. The facilities are unlikely to be located in preferred spawning or rearing habitat of Sacramento splittail.

If intake siphons, discharge pumps, or boat docks were located in or near shallow vegetated habitat, splittail spawning and rearing habitat could be lost or altered. The area of lost habitat would be small relative to the area of similar habitat available in the Delta, and such loss would have minimal effects on splittail populations. Loss of habitat could adversely affect localized splittail reproduction.

Splittail spawn over flooded vegetation. Most of the seasonally flooded spawning habitat, representing most of the available spawning habitat, is upstream of the Delta. Spawning area increases as high flows inundate seasonally available habitats. Splittail abundance is likely not directly dependent on Delta outflow but rather on flooding of habitats upstream of the Delta. Based on available information, it is estimated that reduced outflow attributable to DW project operations would have little effect on splittail spawning habitat.

Direct Entrainment of Sacramento Splittail

Entrainment of splittail larvae and early juveniles could occur if the DW intakes are located in areas that support spawning and rearing, but entrainment would affect local populations. The presence of adult and juvenile splittail near DW project diversions (Figure 4-14) may coincide with the timing of diversions (Tables 5-1 and 5-2). As described for delta smelt, adult and juvenile splittail would be efficiently screened from DW project diversions. The DW project would likely have minimal adverse entrainment effects on adult and older juvenile Sacramento splittail.

Longfin Smelt

As with delta smelt, DW project operations could affect longfin smelt survival and abundance through changes in transport flows and habitat availability. As described in Section 4, "Endangered, Threatened, and Candidate Fish Species", longfin smelt spawn in fresh water. After hatching, larvae may require net flow movement for transport to downstream habitat. The availability of downstream habitat may depend on salinity distribution in the estuary, and variation in salinity distribution is controlled by outflow volume.

Longfin Smelt Transport Effects

Transport effects of total Delta diversions would be substantially less for longfin smelt than the effects described for delta smelt (Figure 5-14). Longfin smelt spawn primarily in the Sacramento River; in the confluence area; and, when salinity conditions are adequate, in Suisun Bay. Because of spawning location, longfin smelt larvae are less likely to be entrained or transported toward south and central Delta diversions.

The increase in the entrainment indices for longfin smelt under DW project operations ranges from 0% to 6% (Figure 5-14). Simulated diversions onto the DW project islands are greater during periods when longfin smelt are present (Table 5-2) than when delta smelt are present; therefore, DW diversions are more likely to affect longfin smelt. Peak occurrence of longfin smelt larvae is during February and March (see Section 4). DW discharge for export, however, occurs after the abundance of longfin smelt in the Delta declines. Therefore, DW discharge for export would have minimal effects on the entrainment index for longfin smelt.

As with delta smelt, the assumed spawning distribution can have a substantial effect on the simulated entrainment index for Delta diversions. For the impact assessment, all longfin smelt were assumed to spawn on the Sacramento River side of the Delta. In wetter periods (i.e., when water is available for DW diversions), spawning may be distributed from Rio Vista downstream to Suisun Bay. DW diversion effects on transport conditions in the confluence and Suisun Bay would be less than the effects shown in Figure 5-14.

DW project operations would likely have minimal effects on longfin smelt transport and entrainment loss because spawning location is outside the primary influence of central and south Delta diversions and peak larval abundance occurs prior to the DW project discharges for export simulated for May and June.

Longfin Smelt Habitat Effects

As discussed above under "Methods for Assessing Changes in Estuarine Habitat Area", longfin smelt year-class survival may be related to optimal salinity habitat area. Salinity is assumed to be a major factor defining longfin smelt habitat, and salinity between 1.1 ppt and 18.5 ppt is assumed to delineate the optimal habitat.

Under simulated operations of the No-Project Alternative and the DW project for 1922-1991, the annual weighted habitat area available for longfin smelt ranges from 122 km^2 to 248 km^2. Change in habitat area under DW project operations relative to the No-Project Alternative conditions ranged from -4.5% to 1.5% (Figure 5-15). The greater estimated percent change in habitat area for longfin smelt compared with that for delta smelt results from the coincidence of larval longfin smelt presence and simulated DW project diversions to fill the reservoir islands (Table 5-2). Reductions in habitat area approaching 4%, however, would be infrequent and substantial habitat area (i.e., greater than 122 km^2) would remain.

Direct Entrainment of Longfin Smelt

Potential entrainment of larvae is described above under "Longfin Smelt Transport Effects". Although the presence of adult and juvenile longfin smelt near DW project intake siphons (Figure 4-17) may coincide with the timing of diversions (Tables 5-1 and 5-2), older juvenile and adult longfin smelt would be screened from DW reservoir and habitat island diversions. Use of fish screens would reduce adverse effects of diversions on adults and larger juveniles.

The DW project would likely have minimal adverse effects on direct entrainment of adult and older juvenile longfin smelt.

Steelhead Trout

The timing of steelhead migration through the Delta is similar to the timing of winter-run chinook salmon migration (Figure 4-18); therefore, the effects of DW project operations on steelhead trout would be similar in pattern to the effects described for winter-run chinook salmon. Juvenile steelhead trout, however, are generally larger than juvenile winter-run chinook salmon, and the magnitude of DW project effects on steelhead would likely be less because screening efficiency of DW siphons and the CVP and SWP pumping facilities would be higher.

OTHER SPECIES

DW project operations and facilities could cause or contribute to adverse effects on distribution and abundance of other fish species. The effects on other species are discussed in detail in the DW EIR/EIS. Following are the adverse effects identified:

- Increased water temperature in Delta channels adjacent to DW reservoir islands during discharge of project water could have an adverse effect on survival of fall-, late fall-, and spring-run chinook salmon.

- Increased Delta outflow during periods of diversion onto the DW islands could have an adverse impact on the habitat area and survival of striped bass and other estuarine species.

- Increased mortality indices may indicate potential adverse effects of DW project operations on survival of chinook salmon (fall, late fall, and spring runs).

- Increased entrainment indices estimated for larval and early juvenile fish during DW project operations could have an adverse impact on survival of striped bass and other species with planktonic life stages.

CUMULATIVE IMPACTS

The cumulative impacts, including impacts of natural factors (drought) and human-caused factors such as water project operations during droughts, continue to reduce fish population abundance. This section discusses the relationship between these ongoing impacts and the effects of proposed DW project operations. This cumulative impact evaluation is based on the following scenario: increased upstream demands; increased demands south and west of the Delta; an increased permitted pumping rate at the Banks Pumping Plant; implementation of the DWR South and North Delta Projects; and additional storage south of the Delta in the Kern Water Bank, Los Banos Grandes Reservoir, Metropolitan Water District's Domenigoni Reservoir and Arvin-Edison projects, and the CCWD Los Vaqueros Reservoir.

DW project operations would not affect upstream conditions. Upstream conditions for fish, however, would continue to deteriorate. Increased demands could further reduce Shasta Reservoir storage, which would adversely affect riverine conditions.

Without criteria to reduce Delta habitat degradation (including entrainment losses), ongoing factors and future projects could reduce the survival and abundance of all the species included in this assessment. DW project operations depend on the availability of surplus flows. Under future conditions, surplus flows are likely to be less available than under existing conditions. Reduced availability would result from operations that reduce the frequency of spill from upstream reservoirs, reduction of Delta surplus flows because of buildout by senior water right holders, and changes in the criteria that define surplus flows relative to beneficial uses of water in the Delta (e.g., the ongoing SWRCB actions relative to the 1995 WQCP). The effect of the DW project operations under cumulative future conditions would be similar to or less than the effects described previously in this assessment.

If DW project water is purchased by the CVP or the SWP and the DW project is integrated into CVP or SWP operations, upstream conditions could be affected. Water discharged from the DW reservoir islands to supplement Delta outflow or for CVP or SWP export may modify upstream releases from Shasta, Oroville, and Folsom Dams. In general, reservoir water could be stored for longer periods rather than being released to meet Delta flow needs.

SUMMARY OF POTENTIAL FISHERY EFFECTS OF THE DW PROJECT

Beneficial Effects

Following are potential beneficial fishery effects of the DW project:

- **Increased survival of winter-run chinook salmon, Sacramento splittail, and steelhead trout during migration through the Delta and in upstream habitats**:

  - **Forgone agricultural diversions.** Existing annual agricultural diversions onto the DW islands total 60 TAF. The DW project could reduce the annual diversion by about 40 TAF. The elimination of these diversions could reduce entrainment of juvenile winter-run chinook salmon, Sacramento splittail, and steelhead trout and increase central Delta outflow during juvenile migration.

  - **Fish screens**. Fish screens on the existing siphons for agricultural diversions on the DW habitat islands and on the siphons for DW reservoir diversions would reduce impingement and entrainment of juvenile winter-run salmon, Sacramento splittail, and steelhead trout.

  - **Improved levees**. Reinforcement of DW project island levees would reduce the probability of levee failure and associated detrimental effects (e.g., increased diversion during uncontrolled island flooding coinciding with migration of juvenile winter-run chinook salmon and steelhead trout).

- **Upstream reservoir management**. DW reservoir island operations could be coordinated with upstream reservoir operations to meet Delta flow needs and improve upstream habitat conditions for winter-run chinook salmon and steelhead trout. DW project water could be exchanged with CVP or SWP water to meet Delta export and outflow needs, allowing retention of CVP water in Shasta Reservoir. Coordination of DW operations depends on development of agreements with federal, state, local, and private agencies.

■ **Reduced entrainment of delta and longfin smelt and improved spawning and rearing habitat conditions**:

- **Forgone agricultural diversions**. The elimination of agricultural diversions could reduce entrainment of all life stages and increase larval transport flow when the DW project islands are not filling.

- **Fish screens**. Fish screens on the existing siphons for agricultural diversions on the DW habitat islands and on the siphons for DW reservoir diversions would prevent entrainment of adult and juvenile delta and longfin smelt (although impingement may occur).

- **Improved levees**. Reinforcement of DW project island levees would reduce the probability of levee failure and associated detrimental effects (e.g., increased diversion during uncontrolled island flooding coinciding with peak transport and habitat needs of delta and longfin smelt). (Levee failure would result in temporary flooding that would not provide long-term habitat availability but could result in entrapment on the island, reduced transport flows, and reduced optimal salinity habitat availability.)

- **Upstream reservoir management**. DW reservoir island operations could be coordinated with upstream reservoir operations to meet Delta flow needs and maintain transport flows and habitat conditions for delta and longfin smelt. DW project water could be exchanged with CVP or SWP water to reduce response time for meeting Delta outflow needs and improve Delta flow patterns. Coordination of DW operations depends on development of agreements with federal, state, local, and private agencies.

- **Production of particulate organic carbon, phytoplankton, and zooplankton**. Depending on the timing and fate of DW discharge (i.e., proportion going to export), water discharged from the reservoir islands could increase food availability for Delta fish species.

- **Reduced discharge of agricultural toxics**. Application of pesticides, herbicides, and fertilizers on the DW project islands would be reduced; therefore, the contribution of DW discharge to total agricultural toxic input to the Delta would be reduced.

Adverse Effects

Following are potential adverse fishery effects of the DW project:

■ **Increased mortality of winter-run chinook salmon and steelhead trout during migration through the Delta**:

- **DW reservoir island diversion**. Central and south Delta diversions would be increased under the DW project. DW diversions would comply with the rules for percentage of Delta inflow diverted in the 1995 WQCP; however, the change in Delta channel flow conditions during DW diversions could increase mortality of juvenile winter-run chinook salmon and steelhead trout attributable to the effects of all Delta diversions.

- **DW discharge for export**. Export of DW discharges may increase the movement of water toward the south Delta. The main effect on flow would occur in the channels between the DW reservoir island discharge points and the SWP and CVP facilities to the south.

- **Increased temperature-related mortality of winter-run chinook salmon and steelhead trout**:

  - **DW discharge for export**. Discharge of reservoir island water could increase water temperature in adjacent Delta channels and could adversely affect survival of winter-run chinook salmon and steelhead trout.

- **Increased entrainment of delta and longfin smelt larvae**:

  - **DW reservoir island diversion**. DW diversions would comply with the rules for percentage of Delta inflow diverted in the 1995 WQCP. The level of entrainment would depend on the Delta flow conditions during the diversion period and distribution of smelt larvae in the Bay-Delta estuary during the diversion period.

  - **DW discharge for export**. Export of DW reservoir island discharge may increase the movement of water toward the south Delta. The level of entrainment would depend on Delta flow conditions during the discharge period and the distribution of smelt larvae in the central and south Delta.

- **Loss of delta smelt, longfin smelt, and Sacramento splittail spawning and rearing habitat**:

  - **DW reservoir island diversion**. Reduced Delta outflow during DW diversion could reduce habitat availability for delta and longfin smelt. Reservoir island diversions would comply with outflow and X2 criteria in the 1995 WQCP. Habitat changes would be small relative to the total habitat area available.

  - **DW construction activities**. Construction and operation of DW diversion and discharge facilities and boat recreation facilities could reduce suitability of localized delta smelt and Sacramento splittail habitat.

Table 5-1. Average Monthly Total Delta Diversion, Existing DW Agricultural Diversion, and Proposed DW Habitat Island Diversion

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	Jul	Aug	Sept	Total
Total Delta diversion													
cfs	985	0	950	950	950	0	0	2,188	6,709	8,059	6,040	2,980	
TAF	61	0	58	58	58	0	0	135	413	496	371	183	1,833
DW agricultural diversion[a]													
cfs	28	0	47	47	47	0	0	45	224	267	196	92	
TAF	2	0	3	3	3	0	0	3	14	16	12	6	61
Habitat island diversion													
cfs	32	28	32	3	18	0	0	7	50	60	43	45	
TAF	2	2	2	0	1	0	0	0	3	4	3	3	20

[a] From Table A1-8 in Appendix A1, "Delta Monthly Water Budgets for Operations Modeling of the Delta Wetlands Project", of theDW project EIR/EIS.

Table 5–2. DW Project Diversions (cfs) (includes only diversions greater than 100 cfs)

Water Year	Year Type [a]	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1922	AN			1,744	2,047	135			172	118			
1923	BN	3,871											
1924	C												
1925	D					4,000							
1926	D				869	3,354							
1927	W		4,000		161								
1928	AN		4,000				657						
1929	C												
1930	D				3,871		179						
1931	C												
1932	D			863	1,593								
1933	C												
1934	C				2,005								
1935	BN				3,871			1,869					
1936	BN				3,871								
1937	BN					4,000	307						
1938	W		4,000							118			2,749
1939	D	1,263											
1940	AN				3,871								
1941	W			3,871									
1942	W	3,871						269					
1943	W	3,871											
1944	D					742							
1945	BN			1,686		2,465							
1946	BN		3,606	394									
1947	D												
1948	BN								297				
1949	D						3,871						
1950	BN				3,326	634							
1951	AN		4,000										
1952	W		1,196	2,726						118			4,000
1953	W												
1954	AN	3,262	654		645								
1955	D		103	3,784	100								
1956	W			3,871					312				204
1957	AN	3,726				3,132	1,091						
1958	W	2,610	1,328							118			3,853
1959	BN	195			2,852								

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Table 5–2. Continued

Water Year	Year Type	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1960	D					2,520							
1961	D					3,684							
1962	BN					4,000							
1963	W	3,871											
1964	D	1,710	2,258		1,059								
1965	W			3,871				3,125					
1966	BN	631	3,373										
1967	W			3,871						118	130		3,879
1968	BN	170											
1969	W			3,871						118			4,000
1970	W												
1971	W		4,000				2,408		223				
1972	BN	2,451		1,627			1,020						
1973	AN		4,000		103								
1974	W		4,000										3,000
1975	W	1,020							172				734
1976	C	3,213											
1977	C												
1978	AN				3,871								
1979	BN	3,019	193		3,871								
1980	AN		2,939	1,040									
1981	D	2,867		1,198			696						
1982	W		4,000		138								4,000
1983	W									118	130	115	
1984	W												
1985	D	3,019	906										
1986	W			384	2,491	1,149							
1987	D						1,106						
1988	C				3,845								
1989	D						3,769						
1990	C				990								
1991	C												
Minimum		0	0	0	0	0	0	0	0	0	0	0	0
Mean		629	684	490	640	420	213	74	17	12	4	2	372
Maximum		3,871	4,000	3,871	3,871	4,000	3,871	3,125	312	118	130	115	4,000

[a] Note: W = wet, AN = above normal, BN = below normal, D = dry, C = critically dry (Sacramento Valley water–year hydrologic classification as specified in the 1995 WQCP).

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Table 5–3. DW Project Discharges for Export (cfs) (includes only discharges greater than 100 cfs)

Water Year	Year Type[a]	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1922	AN										3,741		
1923	BN					4,000	181						
1924	C												
1925	D						3,319						
1926	D						3,822						
1927	W			146						3,780			
1928	AN					621			383	3,308			
1929	C												
1930	D					4,000	181	110					
1931	C												
1932	D					2,263	248						
1933	C												
1934	C					2,189							
1935	BN					4,000	181		734	891			
1936	BN								407	3,283			
1937	BN								2,456	1,166			
1938	W										3,741		
1939	D				800	3,353							
1940	AN								457	3,308			
1941	W									2,832	886		
1942	W						139				3,627		
1943	W								1,502	2,228			
1944	D						646						
1945	BN							555	693		2,105		
1946	BN					4,000	181						
1947	D												
1948	BN									114			
1949	D								945	2,727			
1950	BN						2,636		396				340
1951	AN							167		3,537			
1952	W										2,749	876	
1953	W					1,202	2,568						
1954	AN			617					354	3,414			
1955	D					2,166	1,838						
1956	W							144			2,727	784	
1957	AN		515	3,335				562		3,142			
1958	W										3,741		
1959	BN			2,824			3,822						

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Table 5–3. Continued

Water Year	Year Type	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1960	D						2,309						
1961	D						3,278						
1962	BN						1,089	1,053	386	810			
1963	W									2,114	1,141	324	
1964	D			1,031		4,000							
1965	W						2,902		677	3,080			
1966	BN					911	742		949			592	164
1967	W											3,755	
1968	BN							414	880			2,144	
1969	W										3,741		
1970	W							540	664			2,239	
1971	W					2,581						3,596	
1972	BN		176			1,661		407	312				2,161
1973	AN									3,424			
1974	W									2,416	1,190		
1975	W									841	1,533	1,165	
1976	C			715	2,721	406							
1977	C												
1978	AN									3,711			
1979	BN			3,169						3,112	443		
1980	AN							556	1,548	1,549			
1981	D		162			686		439	880			2,120	
1982	W			123							2,614	933	
1983	W												
1984	W							139	536		697	1,972	
1985	D				183	3,530	408						
1986	W								3,771				
1987	D							563	266				
1988	C					4,000							
1989	D								537				2,861
1990	C					1,065							
1991	C												
Minimum		0	0	0	0	0	0	0	0	0	0	0	0
Mean		0	12	168	52	657	429	80	278	772	488	289	78
Maximum		0	515	3,335	2,721	4,000	3,822	1,053	3,771	3,780	3,741	3,755	2,861

[a] Note: W = wet, AN = above normal, BN = below normal, D = dry, C = critically dry (Sacramento Valley water–year hydrologic classification as specified in the 1995 WQCP).

C—062030

Table 5–4. Percent Change in Delta Outflow Attributable to DW Project Operations

Water Year	Year Type[a]	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1922	AN	(0)	(0)	(21)	(18)	(0)	0	0	(0)	(0)	1	1	1
1923	BN	(34)	(0)	(0)	0	0	1	0	1	1	(0)	(0)	1
1924	C	(0)	(0)	(0)	(1)	0	1	1	1	2	2	2	1
1925	D	(0)	(0)	(0)	0	(9)	1	0	1	1	(0)	1	1
1926	D	(0)	(0)	(0)	(11)	(11)	1	2	1	1	(0)	1	1
1927	W	(0)	(33)	(0)	(1)	(0)	0	(0)	0	1	1	1	1
1928	AN	(0)	(21)	(0)	0	0	(1)	0	0	1	(0)	1	1
1929	C	(0)	(0)	(0)	0	0	1	1	1	1	1	2	1
1930	D	(0)	(0)	(0)	(27)	0	(0)	0	1	1	1	1	1
1931	C	(0)	(0)	(0)	0	0	1	1	1	2	2	2	1
1932	D	(0)	(0)	(10)	(17)	0	1	0	1	1	2	1	1
1933	C	(0)	(0)	(0)	0	0	1	0	1	1	2	2	1
1934	C	(0)	(0)	(0)	(21)	0	1	0	1	1	2	2	1
1935	BN	(0)	(0)	(0)	(18)	0	0	(5)	0	1	(0)	1	1
1936	BN	(0)	(0)	(0)	(16)	(0)	0	0	1	1	(0)	1	1
1937	BN	(0)	(0)	(0)	0	(11)	(1)	0	1	1	1	1	1
1938	W	(0)	(16)	(0)	0	(0)	0	(0)	(0)	(0)	1	1	(33)
1939	D	(8)	(0)	(1)	0	0	1	0	1	1	(0)	1	1
1940	AN	(0)	(0)	(0)	(19)	(0)	0	(0)	0	1	(0)	1	1
1941	W	(0)	(0)	(10)	0	(0)	0	(0)	(0)	1	1	1	0
1942	W	(30)	(0)	(0)	0	(0)	0	(0)	(0)	0	1	1	0
1943	W	(27)	(0)	(0)	0	(0)	0	(0)	0	1	1	1	1
1944	D	(0)	(0)	(0)	0	(3)	0	1	1	1	(0)	1	1
1945	BN	(0)	(0)	(20)	0	(5)	0	0	1	1	1	1	1
1946	BN	(0)	(34)	(1)	0	0	0	0	1	1	(0)	1	1
1947	D	(0)	(0)	(0)	0	0	0	0	1	1	(0)	(0)	1
1948	BN	(0)	(0)	(0)	0	0	1	0	(1)	1	(0)	(0)	0
1949	D	(0)	(0)	(0)	0	0	(9)	1	1	1	1	1	1
1950	BN	(0)	(0)	(0)	(27)	(2)	0	0	1	1	(0)	(0)	1
1951	AN	(0)	(9)	(0)	0	(0)	0	0	0	1	(0)	1	1
1952	W	(0)	(16)	(7)	(0)	(0)	0	(0)	(0)	(0)	1	1	(37)
1953	W	(0)	(0)	(0)	0	0	0	0	0	0	1	1	0
1954	AN	(34)	(4)	(0)	(3)	(0)	0	(0)	0	1	(0)	1	1
1955	D	(0)	(2)	(23)	(1)	0	1	1	1	1	(0)	(0)	1
1956	W	(0)	(0)	(5)	0	(0)	0	0	(1)	0	1	1	(3)
1957	AN	(26)	(0)	(0)	0	(10)	(3)	0	0	1	(0)	(0)	1
1958	W	(29)	(15)	(0)	0	(0)	0	(0)	(0)	(0)	1	1	(39)
1959	BN	(1)	(0)	(0)	(10)	(0)	0	1	1	1	(0)	1	1

C — 0 6 2 0 3 1

Table 5–4. Continued

Water Year	Year Type	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1960	D	(0)	(0)	(1)	0	(12)	1	0	1	1	(0)	1	1
1961	D	(0)	(0)	(0)	0	(17)	1	0	1	1	(0)	1	1
1962	BN	(0)	(0)	(0)	0	(8)	0	1	1	1	(0)	1	1
1963	W	(13)	(0)	(0)	(1)	(0)	0	(0)	(0)	1	1	1	0
1964	D	(22)	(10)	(0)	(5)	0	1	1	1	1	(0)	(0)	1
1965	W	(0)	(0)	(5)	0	(0)	0	(7)	0	1	(0)	1	1
1966	BN	(10)	(18)	(0)	0	0	0	0	1	1	(0)	1	1
1967	W	(0)	(0)	(11)	0	(0)	0	(0)	(0)	(0)	(1)	1	(39)
1968	BN	(1)	(0)	(1)	0	(0)	0	0	1	1	(0)	1	1
1969	W	(0)	(0)	(28)	0	(0)	0	(0)	(0)	(0)	1	1	(30)
1970	W	(0)	(0)	(0)	0	(0)	0	0	1	1	(0)	1	1
1971	W	(0)	(26)	(0)	0	0	(5)	0	(1)	1	(0)	1	0
1972	BN	(30)	(0)	(13)	(1)	0	(4)	1	1	1	(0)	(0)	1
1973	AN	(0)	(26)	(0)	(0)	(0)	0	0	0	1	1	1	1
1974	W	(0)	(7)	(0)	0	(0)	0	(0)	0	1	1	1	(32)
1975	W	(8)	(0)	(0)	0	(0)	0	0	(0)	0	1	1	(10)
1976	C	(24)	(0)	(0)	0	0	1	1	1	1	1	2	1
1977	C	(0)	(0)	(0)	0	0	1	1	1	2	2	2	1
1978	AN	(0)	(0)	(0)	(7)	(0)	0	(0)	0	1	1	1	0
1979	BN	(33)	(3)	(0)	(19)	(0)	0	0	0	1	1	1	1
1980	AN	(0)	(31)	(9)	(0)	(0)	0	0	0	1	1	1	0
1981	D	(32)	(0)	(17)	0	0	(2)	0	1	1	(0)	1	1
1982	W	(0)	(15)	(0)	(0)	(0)	0	(0)	(0)	0	1	1	(25)
1983	W	(0)	(0)	(0)	0	(0)	0	(0)	(0)	(0)	(0)	(1)	(0)
1984	W	(0)	(0)	(0)	0	(0)	0	0	1	1	1	1	0
1985	D	(32)	(3)	(0)	0	0	1	1	1	1	(0)	1	1
1986	W	(0)	(0)	(6)	(22)	(1)	0	(0)	1	1	1	1	1
1987	D	(0)	(0)	(0)	0	0	(4)	0	1	1	(0)	1	1
1988	C	(0)	(0)	(1)	(21)	0	1	1	1	1	1	2	1
1989	D	(0)	(0)	(0)	0	0	(12)	0	1	1	(0)	(0)	1
1990	C	(0)	(0)	(0)	(12)	0	1	0	1	1	1	2	1
1991	C	(0)	(0)	(0)	0	0	0	0	1	1	2	2	1
Minimum		(34)	(34)	(28)	(27)	(17)	(12)	(7)	(1)	(0)	(1)	(1)	(39)
Mean		(6)	(4)	(3)	(4)	(1)	(0)	0	0	1	1	1	(3)
Maximum		(0)	(0)	(0)	0	0	1	2	1	2	2	2	1

[a] Note: W = wet, AN = above normal, BN = below normal, D = dry, C = critically dry (Sacramento Valley water–year hydrologic classification as specified in the 1995 WQCP).
Negative values shown in parentheses.

C–062032

Table 5–5. Upstream Shift in X2 (kilometers) Attributable to DW Project Operations

Water Year	Year Type[a]	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1922	AN			1.8	2.1	0.7	0.2	0.1					
1923	BN	3.2	1.1	0.4	0.1								
1924	C												
1925	D					0.7	0.2						
1926	D				0.9	1.2	0.3						
1927	W		3.1	1.1	0.4	0.1							
1928	AN		1.8	0.6	0.2	0.1	0.1						
1929	C												
1930	D				2.4	0.8	0.3	0.1					
1931	C												
1932	D			0.8	1.6	0.5	0.2	0.1					
1933	C												
1934	C				1.8	0.6	0.2	0.1					
1935	BN				1.6	0.5	0.1	0.4	0.1				
1936	BN				1.4	0.5	0.1						
1937	BN					0.9	0.3	0.1					
1938	W		1.3	0.4	0.1								3.1
1939	D	1.7	0.6	0.2	0.1								
1940	AN				1.6	0.5	0.2	0.1					
1941	W			0.8	0.3	0.1							
1942	W	2.7	0.9	0.3	0.1								
1943	W	2.4	0.8	0.3	0.1								
1944	D					0.2							
1945	BN			1.7	0.5	0.6	0.2						
1946	BN		3.2	1.1	0.4	0.1							
1947	D												
1948	BN								0.1				
1949	D						0.7	0.2	0.1				
1950	BN				2.4	1.0	0.3	0.1					
1951	AN		0.7	0.2	0.1								
1952	W		1.3	1.0	0.3	0.1							3.6
1953	W	1.2	0.4	0.1									
1954	AN	3.2	1.4	0.5	0.4	0.1							
1955	D		0.1	2.0	0.7	0.2							
1956	W			0.4	0.1								0.2
1957	AN	2.4	0.8	0.3	0.1	0.8	0.5	0.2					
1958	W	2.7	2.2	0.7	0.2	0.1							3.8
1959	BN	1.3	0.5	0.2	0.8	0.3	0.1						

C-062033

Table 5–5. Continued

Water Year	Year Type	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1960	D			0.1		1.0	0.3	0.1					
1961	D					1.4	0.4	0.1					
1962	BN					0.6	0.2	0.1					
1963	W	1.1	0.4	0.1	0.1								
1964	D	1.9	1.5	0.5	0.6	0.2							
1965	W			0.4	0.1			0.6	0.2	0.1			
1966	BN	0.8	1.8	0.6	0.2	0.1							
1967	W			0.9	0.3	0.1							3.8
1968	BN	1.3	0.5	0.2	0.1								
1969	W			2.5	0.8	0.3	0.1						2.7
1970	W	0.9	0.3	0.1									
1971	W		2.3	0.8	0.3	0.1	0.4	0.1	0.1				
1972	BN	2.7	0.9	1.4	0.5	0.2	0.4	0.1					
1973	AN		2.4	0.8	0.3	0.1							
1974	W		0.5	0.2	0.1								3.0
1975	W	1.6	0.6	0.2	0.1								0.8
1976	C	2.4	0.8	0.3	0.1								
1977	C												
1978	AN				0.5	0.2	0.1						
1979	BN	3.1	1.3	0.4	1.7	0.6	0.2						
1980	AN		2.8	1.6	0.5	0.2	0.1						
1981	D	3.0	1.0	1.7	0.6	0.2	0.2	0.1					
1982	W		1.3	0.4	0.1								2.2
1983	W	0.7	0.2	0.1								0.1	
1984	W												
1985	D	2.9	1.2	0.4	0.1								
1986	W			0.4	2.1	0.7	0.2	0.1					
1987	D						0.3	0.1					
1988	C			0.1	1.9	0.6	0.1						
1989	D						1.0	0.3	0.1				
1990	C				1.0	0.3							
1991	C												
Minimum		0	0	0	0	0	0	0	0	0	0	0	0
Mean		0.6	0.6	0.4	0.5	0.3	0.1	0.0	0.0	0.0	0.0	0.0	0.3
Maximum		3.2	3.2	2.5	2.4	1.4	1.0	0.6	0.2	0.1	0.0	0.1	3.8

[a] Note: W = wet, AN = above normal, BN = below normal, D = dry, C = critically dry (Sacramento Valley water–year hydrologic classification as specified in the 1995 WQCP). Negative values shown in parentheses.

C-062034

Table 5–6. Change in QWEST Flow (cfs) Attributable to DW Project Operations

Water Year	Year Type[a]	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1922	AN	(10)	(12)	(1,766)	(2,032)	(112)	25	51	(112)	(49)	78	60	25
1923	BN	(3,880)	(37)	(34)	0	23	73	51	60	69	(8)	(7)	25
1924	C	(10)	(12)	(21)	(41)	23	73	51	60	69	78	60	25
1925	D	(10)	(12)	(21)	15	(3,977)	73	51	60	69	(8)	60	25
1926	D	(10)	(12)	(21)	(854)	(3,330)	73	330	60	69	(7)	60	25
1927	W	(10)	(4,011)	(34)	(146)	(7)	25	(25)	60	69	78	60	25
1928	AN	(10)	(4,011)	(34)	0	23	(584)	51	60	69	(8)	60	25
1929	C	(10)	(12)	(21)	15	23	73	51	60	69	78	60	25
1930	D	(10)	(12)	(21)	(3,856)	23	(106)	51	60	69	78	60	25
1931	C	(10)	(12)	(21)	15	23	73	51	60	69	78	60	25
1932	D	(10)	(12)	(884)	(1,579)	23	73	51	60	69	78	60	25
1933	C	(10)	(12)	(21)	15	23	73	51	60	69	78	60	25
1934	C	(10)	(12)	(21)	(1,990)	23	73	51	60	69	78	60	25
1935	BN	(10)	(12)	(21)	(3,856)	47	73	(1,819)	60	69	(8)	60	25
1936	BN	(10)	(12)	(21)	(3,856)	(7)	25	51	60	69	(8)	60	25
1937	BN	(10)	(12)	(21)	15	(3,977)	(233)	51	60	69	78	60	25
1938	W	(10)	(4,011)	(34)	0	(7)	25	(25)	(39)	(49)	78	60	(2,724)
1939	D	(1,273)	(37)	(34)	15	23	73	51	60	69	(8)	60	25
1940	AN	(10)	(12)	(21)	(3,856)	(7)	25	(25)	60	69	(7)	60	25
1941	W	(10)	(12)	(3,892)	0	(7)	25	(25)	(39)	69	78	60	25
1942	W	(3,880)	(37)	(34)	0	(7)	73	(219)	(39)	69	78	60	25
1943	W	(3,880)	(37)	(34)	0	(7)	25	(25)	60	69	78	60	25
1944	D	(10)	(12)	(21)	15	(720)	73	51	60	69	(8)	60	25
1945	BN	(10)	(12)	(1,707)	15	(2,442)	25	51	60	69	78	60	25
1946	BN	(10)	(3,617)	(415)	0	23	73	51	60	69	(8)	60	25
1947	D	(10)	(12)	(21)	15	23	73	51	60	69	(7)	(7)	25
1948	BN	(10)	(12)	(21)	15	23	73	51	(236)	69	(7)	(7)	25
1949	D	(10)	(12)	(21)	15	23	(3,797)	51	60	69	78	60	25
1950	BN	(10)	(12)	(21)	(3,311)	(610)	73	51	60	69	(9)	(8)	25
1951	AN	(10)	(4,011)	(34)	0	(7)	25	51	60	69	(7)	60	25
1952	W	(10)	(1,208)	(2,747)	(34)	(7)	25	(25)	(39)	(49)	78	60	(3,974)
1953	W	(63)	(37)	(34)	0	23	73	51	60	69	78	60	25
1954	AN	(3,272)	(665)	(21)	(630)	(7)	25	(25)	60	69	(9)	60	25
1955	D	(10)	(115)	(3,805)	(86)	23	73	51	60	69	(8)	(6)	25
1956	W	(10)	(12)	(3,892)	0	(7)	25	51	(252)	69	78	60	(179)
1957	AN	(3,736)	(12)	(21)	15	(3,108)	(1,017)	51	60	69	(8)	(7)	25
1958	W	(2,620)	(1,340)	(34)	0	(7)	25	(25)	(39)	(49)	78	60	(3,827)
1959	BN	(205)	(37)	(21)	(2,837)	(7)	73	51	60	69	(7)	60	25

Table 5–6. Continued

Water Year	Year Type	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1960	D	(10)	(12)	(62)	15	(2,498)	73	51	60	69	(8)	60	25
1961	D	(10)	(12)	(21)	15	(3,660)	73	51	60	69	(7)	60	25
1962	BN	(10)	(12)	(21)	15	(3,977)	73	51	60	69	(8)	60	25
1963	W	(3,880)	(37)	(34)	(73)	(7)	25	(25)	(39)	69	78	60	25
1964	D	(1,720)	(2,269)	(21)	(1,044)	23	73	51	60	69	(8)	(8)	25
1965	W	(10)	(12)	(3,892)	0	(7)	73	(3,074)	60	69	(8)	60	25
1966	BN	(641)	(3,384)	(34)	0	23	73	51	60	69	(8)	60	25
1967	W	(10)	(12)	(3,892)	0	(7)	25	(25)	(39)	(49)	(52)	60	(3,853)
1968	BN	(180)	(37)	(34)	0	(7)	25	51	60	69	(7)	60	25
1969	W	(10)	(12)	(3,892)	0	(7)	25	(25)	(39)	(49)	78	60	(3,974)
1970	W	(63)	(37)	(34)	0	(7)	25	51	60	69	(9)	60	25
1971	W	(10)	(4,011)	(34)	0	23	(2,335)	51	(163)	69	(7)	60	25
1972	BN	(2,461)	(12)	(1,648)	(75)	23	(947)	51	60	69	(8)	(6)	25
1973	AN	(10)	(4,011)	(34)	(89)	(7)	25	51	60	69	78	60	25
1974	W	(10)	(4,011)	(34)	0	(7)	25	(25)	60	69	78	60	(2,975)
1975	W	(1,030)	(37)	(34)	0	(7)	25	51	(112)	69	78	60	(709)
1976	C	(3,223)	(37)	(21)	15	23	73	51	60	69	78	60	25
1977	C	(10)	(12)	(21)	15	23	73	51	60	69	78	60	25
1978	AN	(10)	(12)	(21)	(3,856)	(7)	25	(25)	60	69	78	60	25
1979	BN	(3,029)	(205)	(21)	(3,856)	(7)	25	51	60	69	78	60	25
1980	AN	(10)	(2,951)	(1,061)	(5)	(7)	25	51	60	69	78	60	25
1981	D	(2,876)	(12)	(1,219)	0	23	(623)	51	60	69	(8)	60	25
1982	W	(10)	(4,011)	(34)	(123)	(7)	25	(25)	(39)	32	78	60	(3,974)
1983	W	(63)	(37)	(34)	0	(7)	25	(25)	(39)	(49)	(52)	(55)	(62)
1984	W	(63)	(37)	(34)	0	(7)	25	51	60	69	78	60	25
1985	D	(3,028)	(917)	(34)	15	23	73	51	60	69	(8)	60	25
1986	W	(10)	(12)	(405)	(2,477)	(1,126)	25	(25)	60	69	78	60	25
1987	D	(10)	(12)	(21)	15	23	(1,033)	50	60	69	(7)	60	25
1988	C	(10)	(12)	(62)	(3,830)	23	73	51	60	69	78	60	25
1989	D	(10)	(12)	(21)	15	23	(3,696)	51	60	69	(8)	(7)	25
1990	C	(10)	(12)	(21)	(975)	23	73	51	60	69	78	60	25
1991	C	(10)	(12)	(21)	15	23	9	51	60	69	78	60	25
Minimum		(3,880)	(4,011)	(3,892)	(3,856)	(3,977)	(3,797)	(3,074)	(252)	(49)	(52)	(55)	(3,974)
Mean		(650)	(650)	(650)	(650)	(650)	(650)	(650)	(650)	(650)	(650)	(650)	(650)
Maximum		(10)	(12)	(21)	15	47	73	330	60	69	78	60	25

[a] Note: W = wet, AN = above normal, BN = below normal, D = dry, C = critically dry (Sacramento Valley water–year hydrologic classification as specified in the 1995 WQCP).
Negative values shown in parentheses.

C–062036

Table 5–7. Change in Old and Middle River Flow (cfs) Attributable to DW Project Operations

Water Year	Year Type [a]	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1922	AN	0	0	0	0	0	0	0	0	0	(3,741)	0	0
1923	BN	0	0	0	0	(4,000)	(181)	0	0	0	0	0	0
1924	C	0	0	0	0	(30)	0	0	0	0	0	0	0
1925	D	0	0	0	0	0	(3,319)	0	0	0	0	0	0
1926	D	0	0	0	0	0	(3,822)	280	0	0	0	0	0
1927	W	0	0	(146)	0	0	0	0	0	(3,780)	0	0	0
1928	AN	0	0	0	0	(621)	0	0	(383)	(3,308)	0	0	0
1929	C	0	0	0	0	0	0	0	0	0	0	0	0
1930	D	0	0	0	0	(4,000)	(181)	(110)	0	0	0	0	0
1931	C	0	0	0	0	0	0	0	0	0	0	0	0
1932	D	0	0	0	0	(2,263)	(248)	0	0	0	0	0	0
1933	C	0	0	0	0	0	0	0	0	0	0	(0)	0
1934	C	0	0	0	0	(2,189)	0	0	0	0	0	0	0
1935	BN	0	0	0	0	(4,486)	(181)	0	(734)	(891)	0	0	0
1936	BN	0	0	0	0	0	0	0	(407)	(3,283)	0	0	0
1937	BN	0	0	0	0	0	0	0	(2,456)	(1,166)	0	0	0
1938	W	0	0	0	0	0	0	0	0	0	(3,741)	0	0
1939	D	0	0	0	(800)	(3,353)	0	0	0	0	0	0	0
1940	AN	0	0	0	0	0	0	0	(457)	(3,308)	0	0	0
1941	W	0	0	0	0	0	0	0	0	(2,832)	(886)	0	0
1942	W	0	0	0	0	0	(139)	0	0	0	(3,627)	0	0
1943	W	0	0	0	0	0	0	0	(1,502)	(2,228)	0	0	0
1944	D	0	0	0	0	0	(646)	0	0	0	0	0	0
1945	BN	0	0	0	0	0	0	(555)	(693)	0	(2,105)	(4)	0
1946	BN	0	0	0	0	(4,000)	(181)	0	0	0	0	0	0
1947	D	0	0	0	0	0	0	0	0	0	0	0	0
1948	BN	0	0	0	0	0	0	0	0	(114)	0	0	0
1949	D	0	0	0	0	0	0	0	(945)	(2,727)	0	0	0
1950	BN	0	0	0	0	0	(2,636)	0	(396)	0	0	0	(340)
1951	AN	0	0	0	0	0	0	(167)	0	(3,537)	0	0	0
1952	W	0	0	(34)	0	0	0	0	0	0	(2,749)	(876)	0
1953	W	0	0	0	0	(1,202)	(2,568)	0	0	0	0	0	0
1954	AN	0	0	(617)	0	0	0	0	(354)	(3,414)	0	0	0
1955	D	0	0	(86)	0	(2,166)	(1,838)	(0)	0	0	0	0	0
1956	W	0	0	0	0	0	0	(144)	0	0	(2,727)	(784)	0
1957	AN	0	(515)	(3,335)	0	0	0	(562)	0	(3,142)	0	0	0
1958	W	0	0	0	0	0	0	0	0	0	(3,741)	0	0
1959	BN	0	0	(2,824)	0	0	(3,822)	0	0	0	0	(0)	0

C-062037

Table 5–7. Continued

Water Year	Year Type	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1960	D	0	0	0	(26)	0	(2,309)	0	0	0	0	0	0
1961	D	0	0	0	0	0	(3,278)	0	0	0	0	0	0
1962	BN	0	0	0	0	0	(1,089)	(1,053)	(386)	(810)	0	0	0
1963	W	0	0	(73)	0	0	0	0	0	(2,114)	(1,141)	(324)	0
1964	D	0	0	(1,031)	0	(4,000)	(52)	0	0	0	0	0	0
1965	W	0	0	0	0	0	(2,902)	0	(677)	(3,080)	0	0	0
1966	BN	0	0	0	0	(911)	(742)	0	(949)	0	0	(592)	(164)
1967	W	0	0	0	0	0	0	0	0	0	0	(3,755)	0
1968	BN	0	0	0	0	0	0	(414)	(880)	0	0	(2,144)	0
1969	W	0	0	0	0	0	0	0	0	0	(3,741)	0	0
1970	W	0	0	0	0	0	0	(540)	(664)	0	0	(2,239)	0
1971	W	0	0	0	0	(2,581)	0	(52)	0	0	0	(3,596)	0
1972	BN	0	(176)	(75)	0	(1,661)	0	(407)	(312)	0	0	0	(2,161)
1973	AN	0	0	(89)	0	0	0	0	0	(3,424)	(92)	0	0
1974	W	0	0	0	0	0	0	0	0	(2,416)	(1,190)	0	0
1975	W	0	0	0	0	0	0	0	0	(841)	(1,533)	(1,165)	0
1976	C	0	0	(715)	(2,721)	(406)	0	0	0	0	0	0	0
1977	C	0	0	0	0	0	0	0	0	0	0	0	0
1978	AN	0	0	0	0	0	0	0	(67)	(3,711)	0	0	0
1979	BN	0	0	(3,169)	0	0	0	0	0	(3,112)	(443)	0	0
1980	AN	(0)	0	(5)	0	0	0	(556)	(1,548)	(1,549)	0	0	0
1981	D	0	(162)	0	0	(686)	0	(439)	(880)	0	0	(2,120)	0
1982	W	0	0	(123)	0	0	0	0	0	0	(2,614)	(933)	0
1983	W	0	0	0	0	0	0	0	0	0	0	0	0
1984	W	0	0	0	0	0	0	(139)	(536)	0	(697)	(1,972)	0
1985	D	0	0	0	(183)	(3,530)	(408)	0	0	0	0	0	0
1986	W	0	0	0	0	0	0	0	(3,771)	0	0	0	0
1987	D	0	0	0	0	0	0	(563)	(266)	0	0	0	0
1988	C	0	0	0	(26)	(4,000)	(26)	0	0	0	0	0	0
1989	D	0	0	0	0	0	0	0	(537)	0	0	0	(2,861)
1990	C	0	0	0	0	(1,065)	0	0	0	0	0	0	0
1991	C	0	0	0	0	0	0	0	0	0	0	0	0
Minimum		(0)	(515)	(3,335)	(2,721)	(4,486)	(3,822)	(1,053)	(3,771)	(3,780)	(3,741)	(3,755)	(2,861)
Mean		(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)
Maximum		0	0	0	0	0	0	280	0	0	0	0	0

[a] Note: W = wet, AN = above normal, BN = below normal, D = dry, C = critically dry (Sacramento Valley water–year hydrologic classification as specified in the 1995 WQCP).
Negative values shown in parentheses.

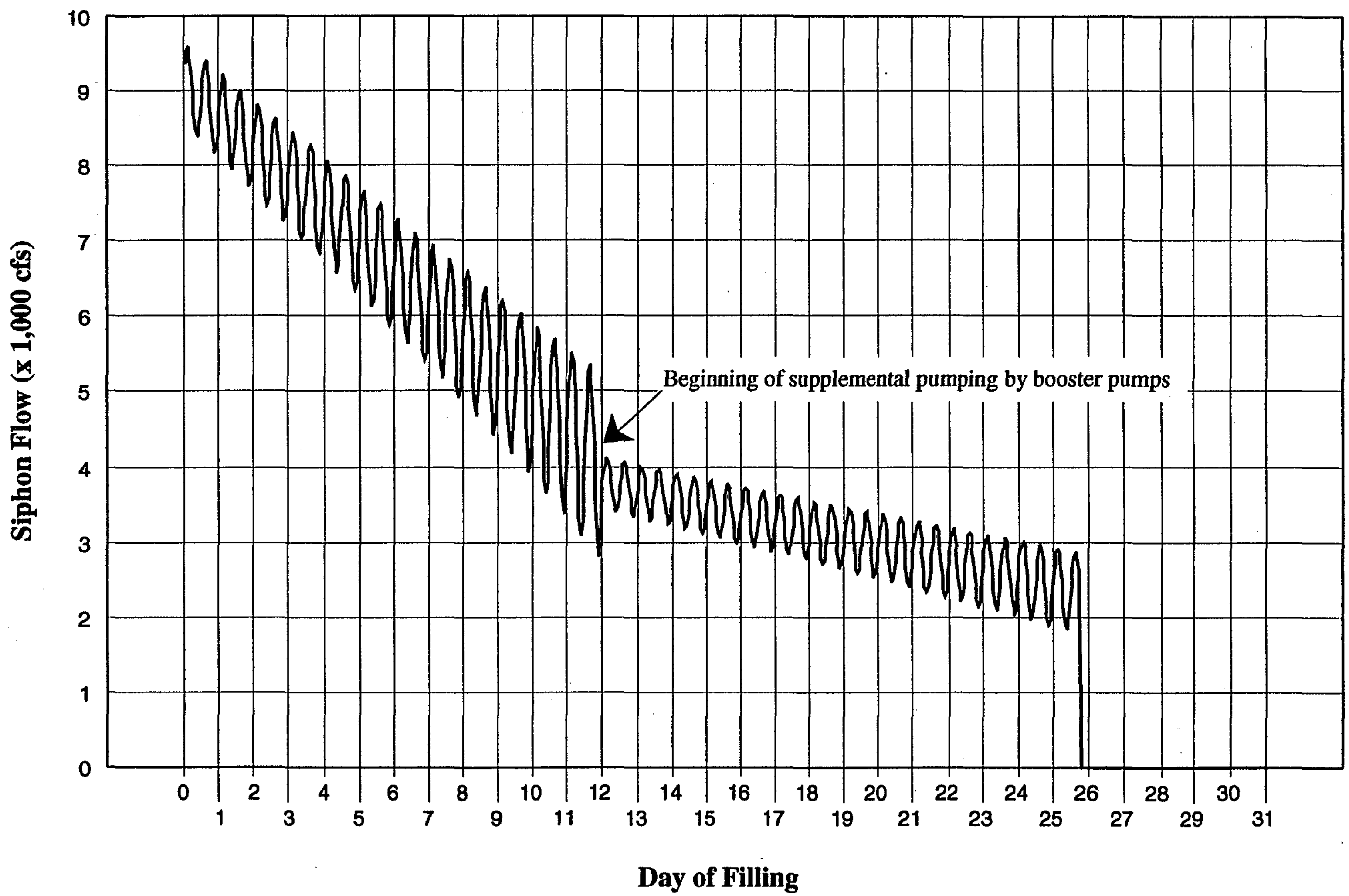
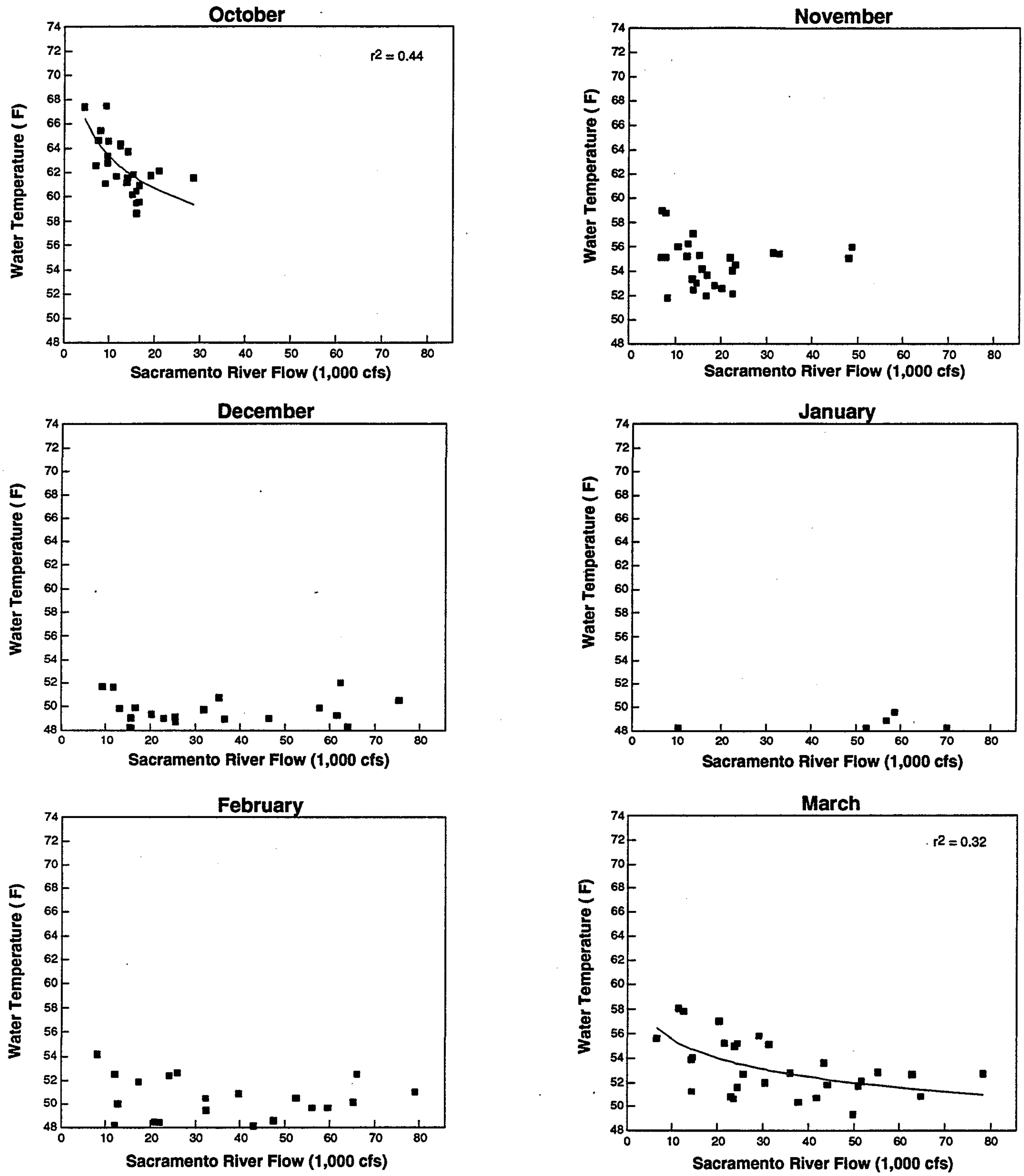


Figure 5-1.
Estimated Filling Rate of the DW Reservoir Islands

DELTA WETLANDS PROJECT
Prepared by: Jones & Stokes Associates

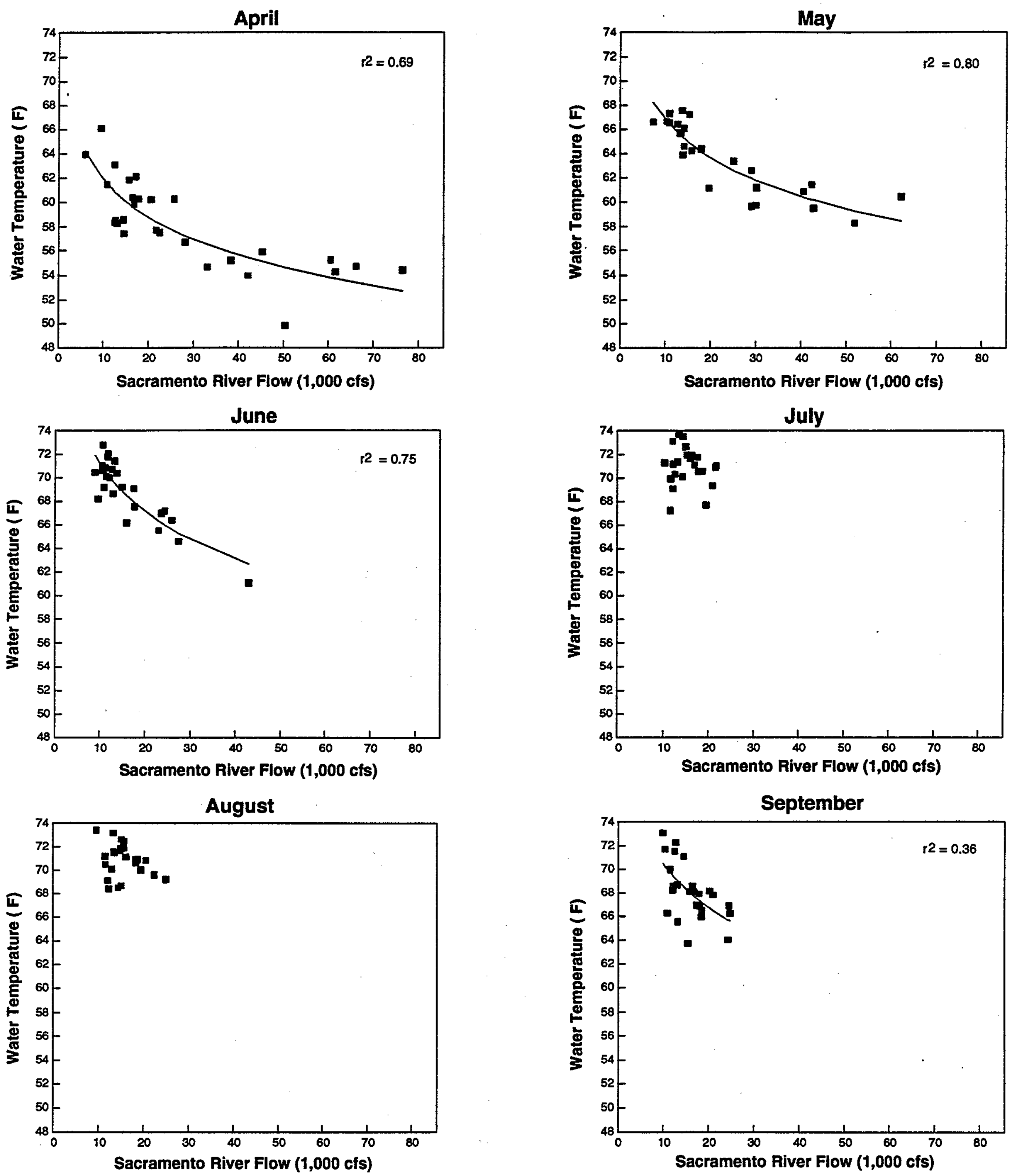


Note: The line indicates the relationship between flow and water temperature (i.e., linear regression of temperature on the logarithm of flow).

Figure 5-2a.
Relationship between Average Monthly Flow and Water Temperature in the Sacramento River at Freeport for Selected Months, 1962–1992

DELTA WETLANDS PROJECT

Prepared by: Jones & Stokes Associates



Note: The line indicates the relationship between flow and water temperature (i.e., linear regression of temperature on the logarithm of flow).

Figure 5-2b.
Relationship between Average Monthly Flow and Water Temperature in the Sacramento River at Freeport for Selected Months, 1962–1992

DELTA WETLANDS PROJECT
Prepared by: Jones & Stokes Associates

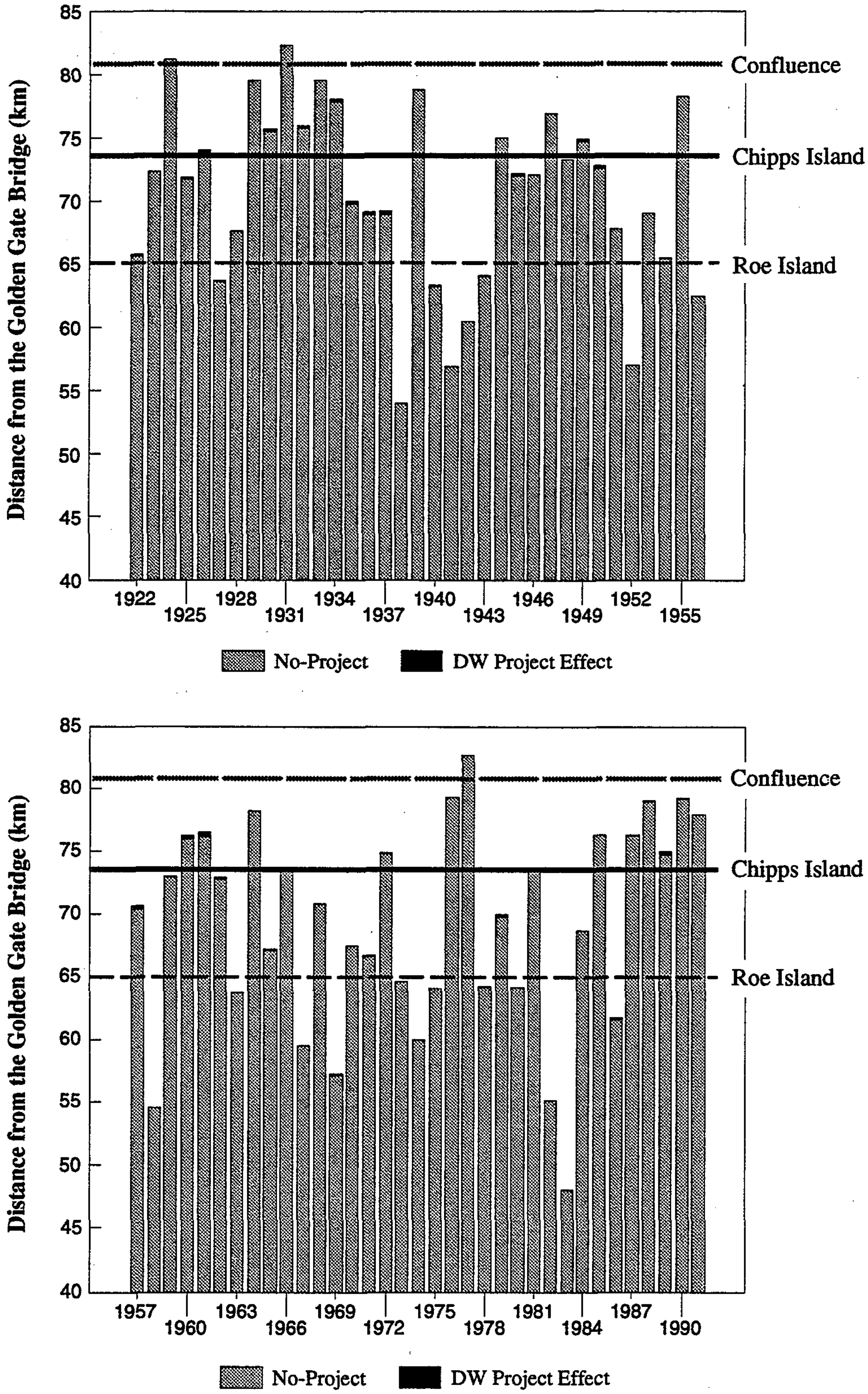
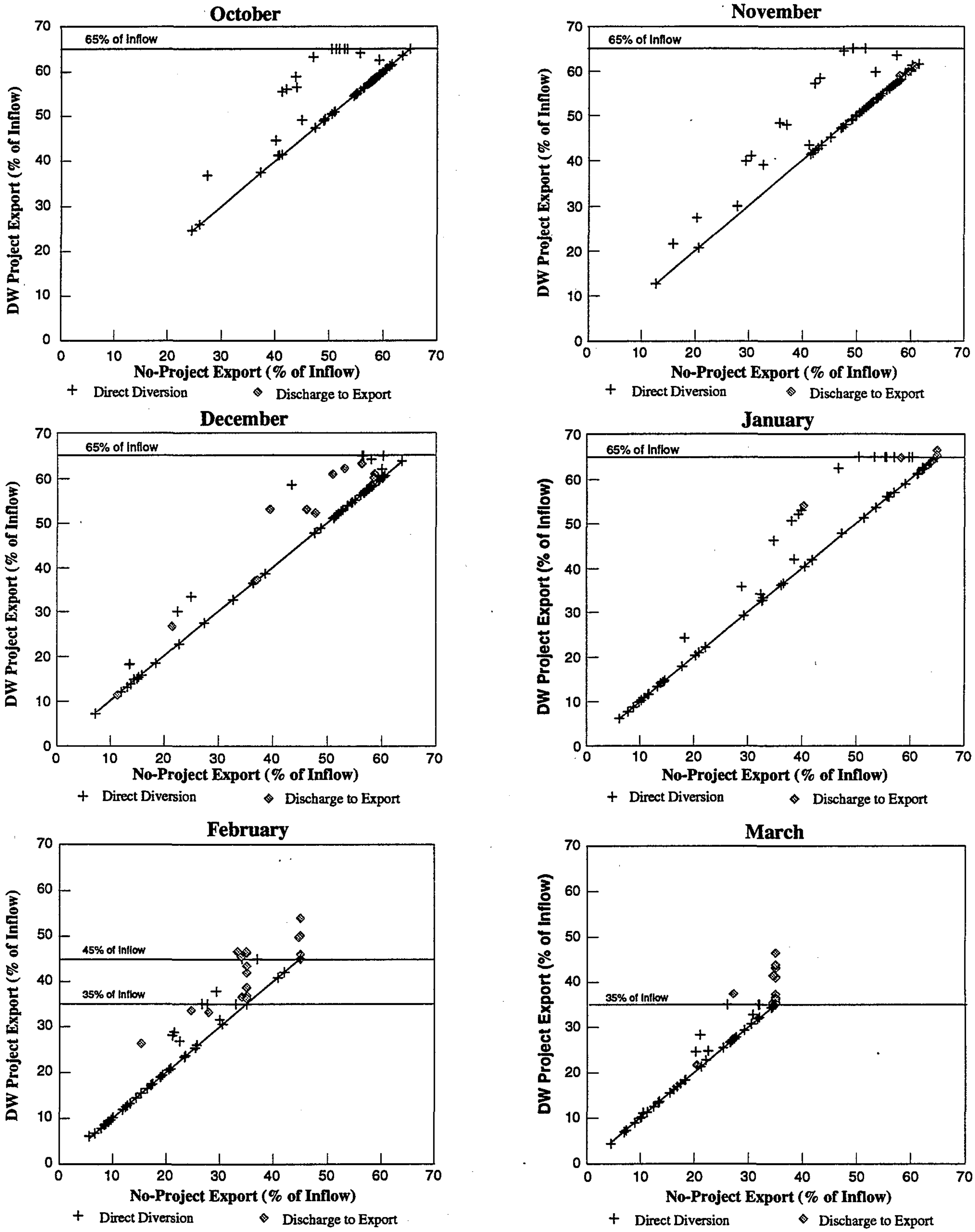


Figure 5-3.
Change in X2 (Average of Monthly X2 Estimates for February–June) under DW Project Operations

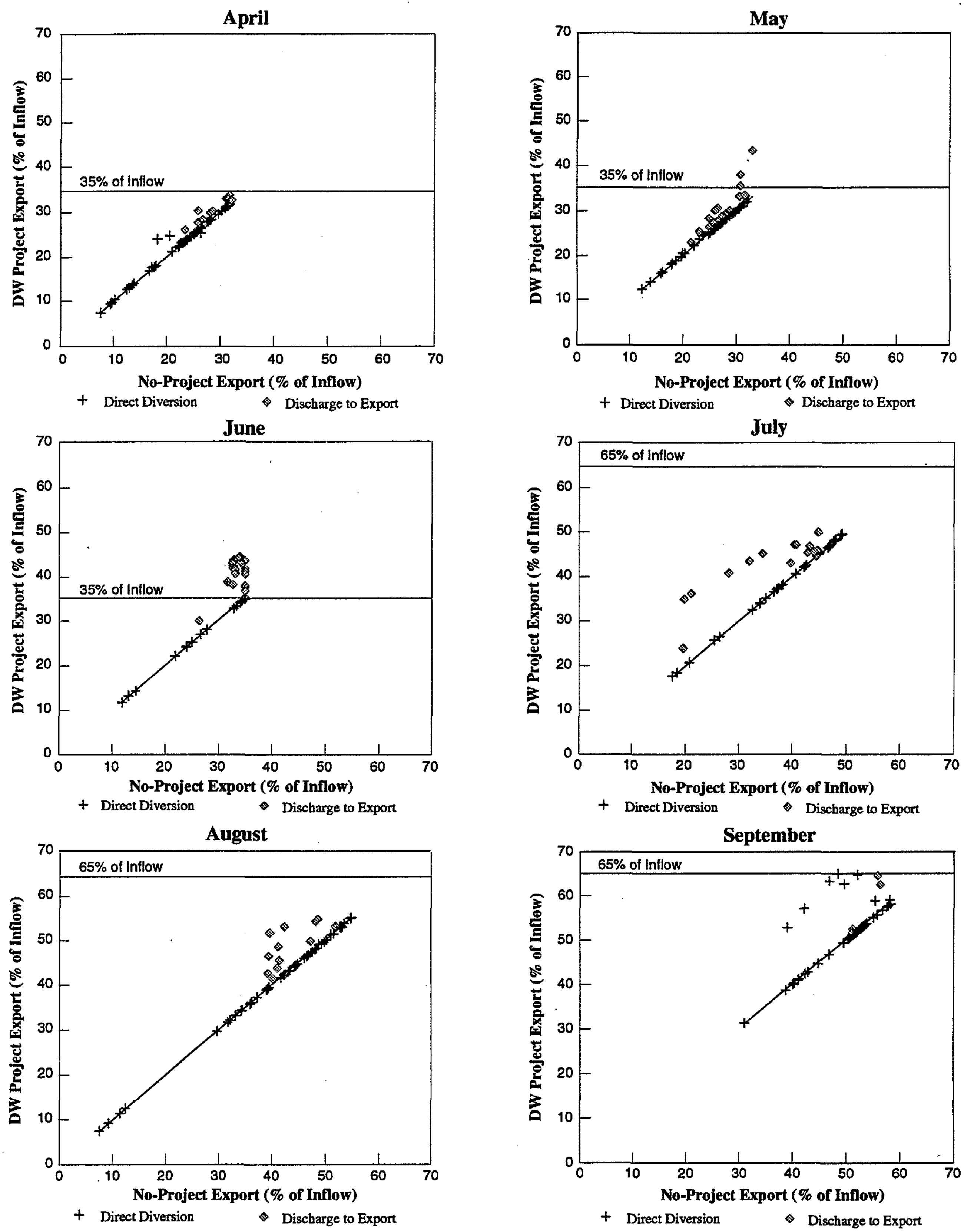
DELTA WETLANDS PROJECT
Prepared by: Jones & Stokes Associates



Notes: The diagonal line represents no change between conditions under the No-Project Alternative and DW project conditions. The symbols indicate change relative to the diagonal line attributable to DW project operations.

Figure 5-4.
Change in DW Project Diversion for Export as Percentage of Delta Inflow Diverted (% of Inflow) under DW Project Operations, 1922–1991 Simulation

DELTA WETLANDS PROJECT
Prepared by: Jones & Stokes Associates



Notes: The diagonal line represents no change between conditions under the No-Project Alternative and DW project conditions. The symbols indicate change relative to the diagonal line attributable to DW project operations.

Figure 5-4., continued
Change in DW Project Diversion for Export as Percentage of Delta Inflow Diverted (% of Inflow) under DW Project Operations, 1922–1991 Simulation

DELTA WETLANDS PROJECT
Prepared by: Jones & Stokes Associates

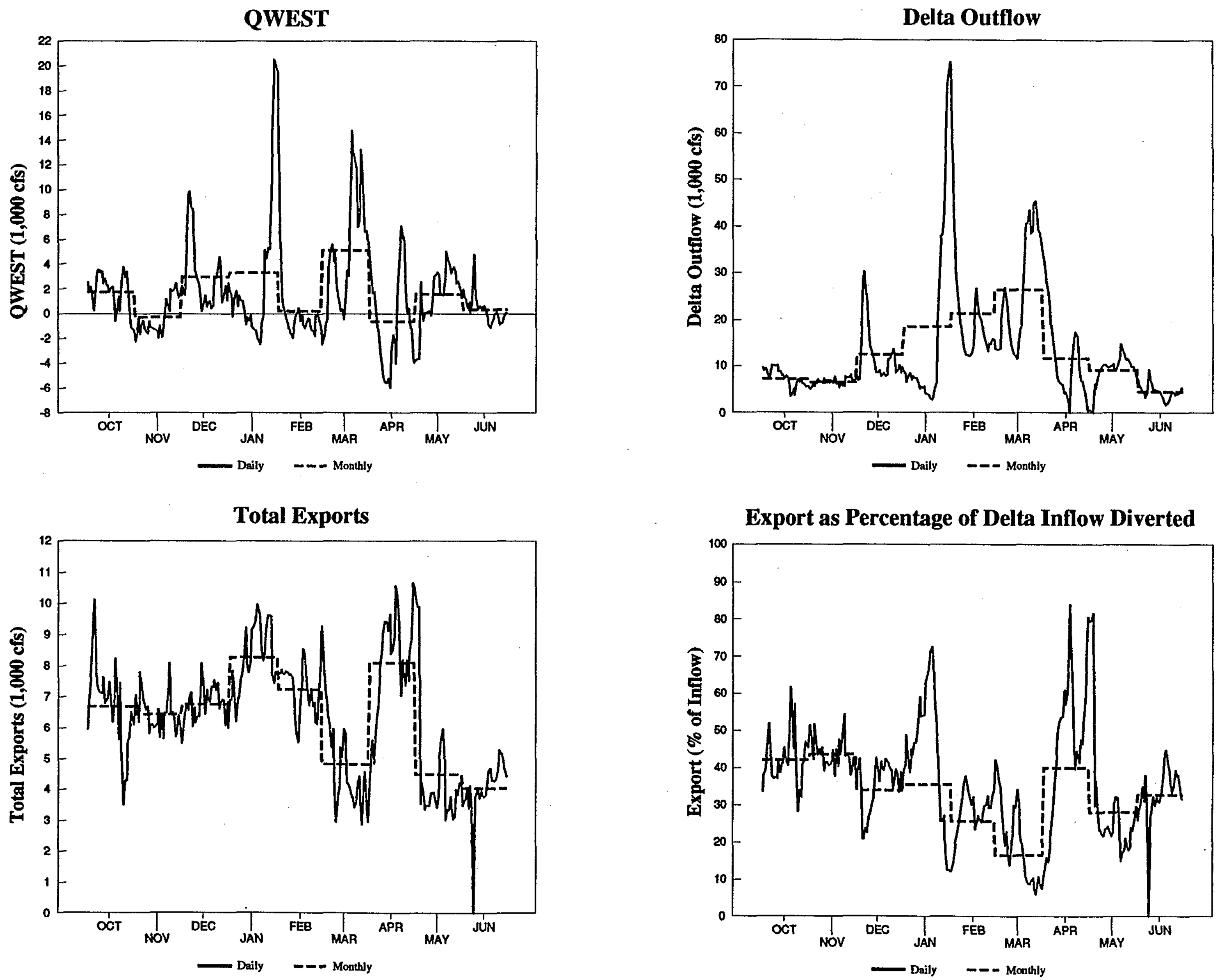


Figure 5-5.
Comparison of Average Daily and Monthly Simulations of QWEST, Delta Outflow, and Delta Exports, October through June, 1981

DELTA WETLANDS PROJECT
Prepared by: Jones & Stokes Associates

C-062045

C — 0 6 2 0 4 5

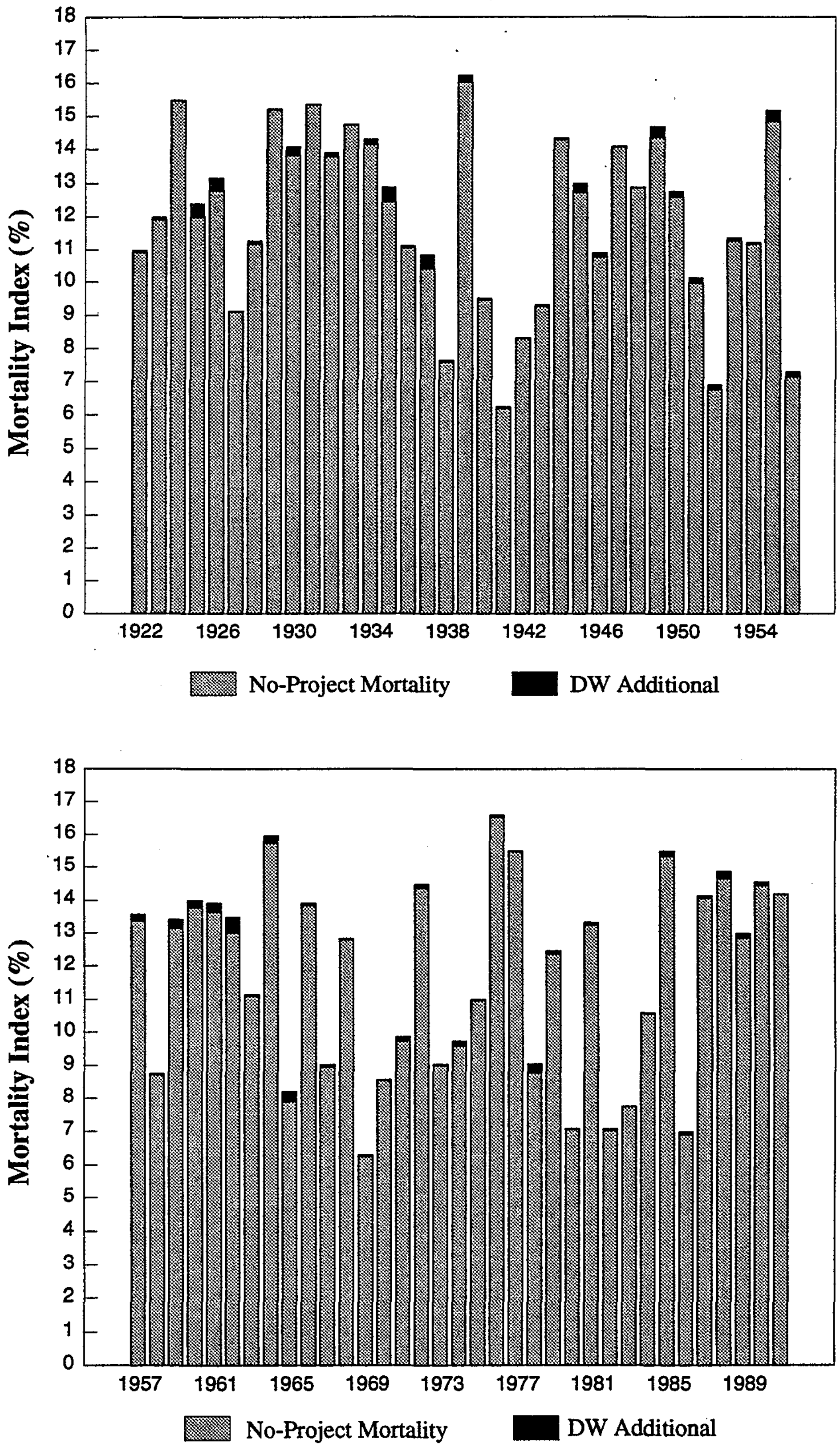


Figure 5-6.
Total Mortality Index for Winter-Run Chinook Salmon during Migration through the Delta, 1922–1991 Simulation

DELTA WETLANDS PROJECT
Prepared by: Jones & Stokes Associates

C-062046

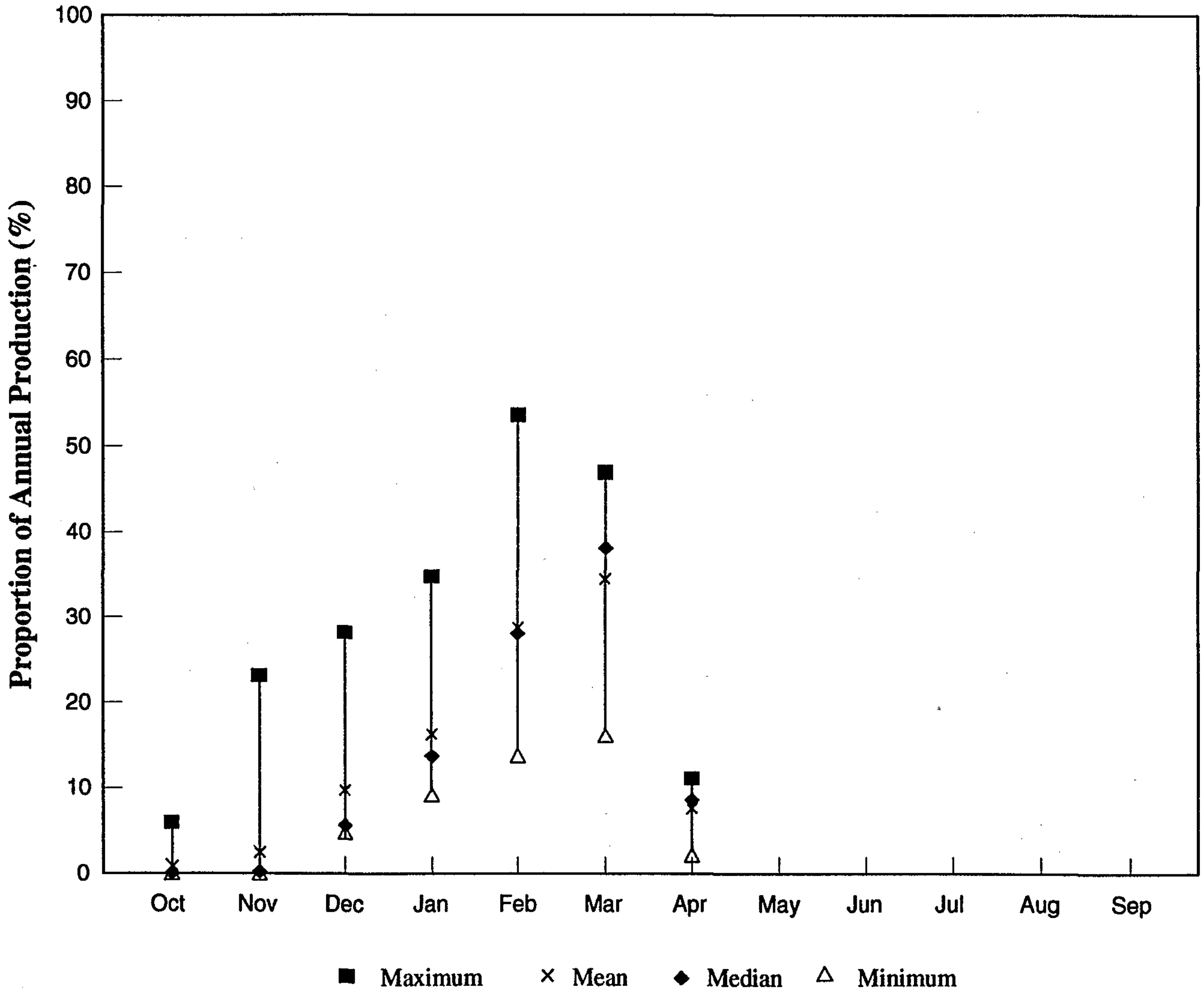
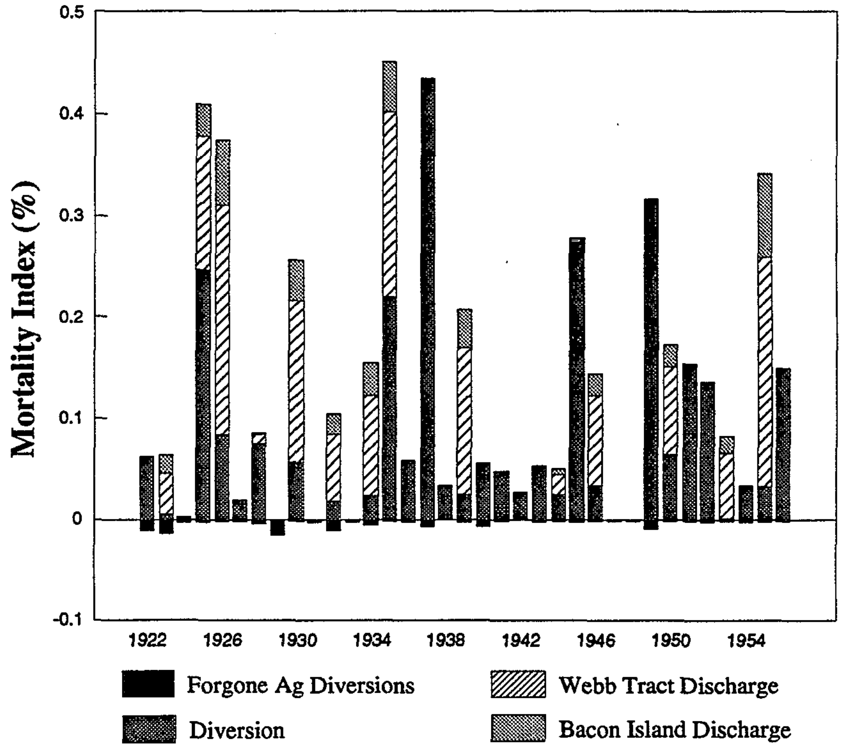
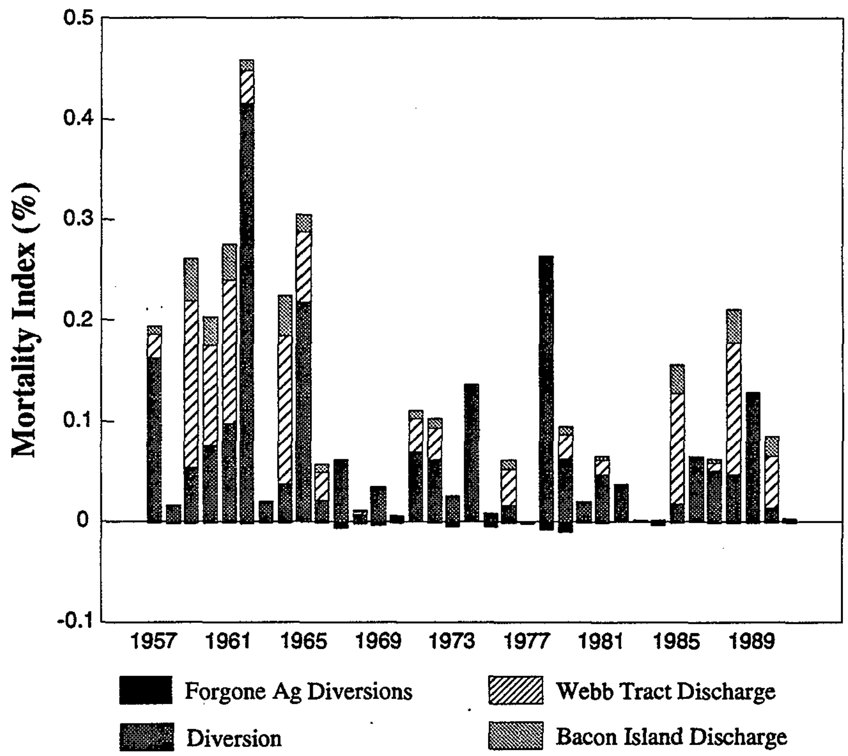


Figure 5-7.
Timing of Winter-Run Chinook Salmon Migration
through the Delta, 1922–1991 Mortality Model Simulation

DELTA WETLANDS PROJECT
Prepared by: Jones & Stokes Associates



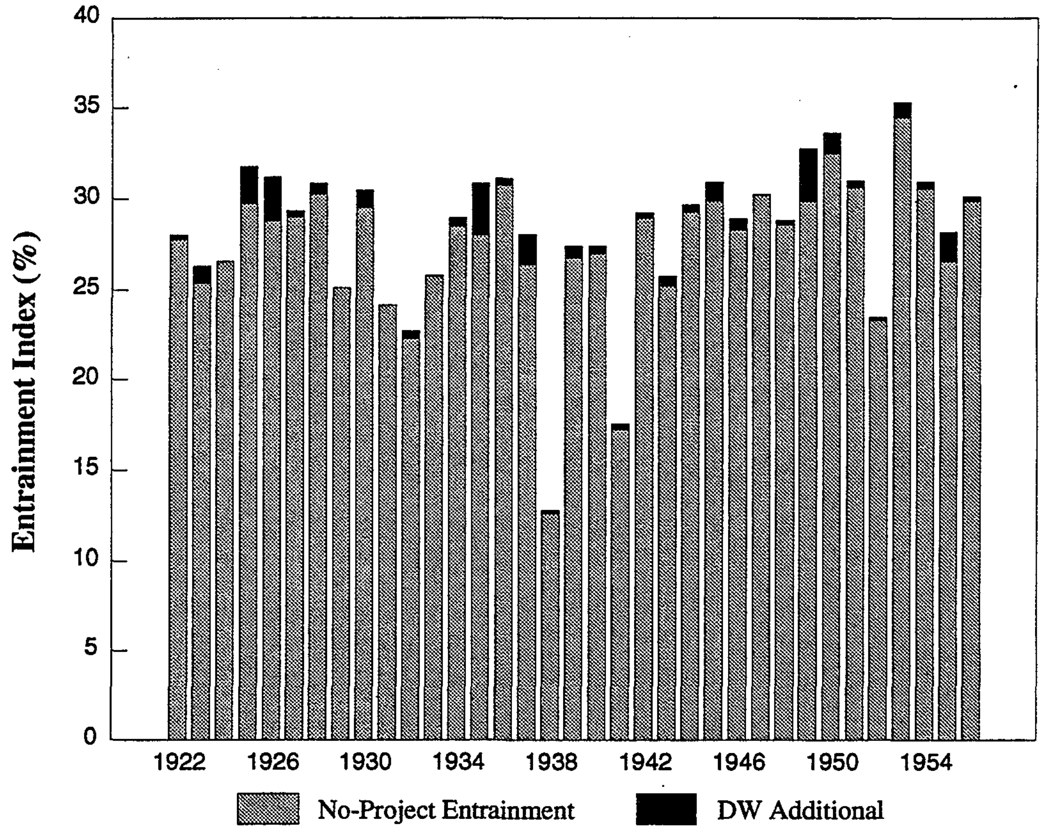


Note: Forgone Agricultural Diversions is the difference between mortality attributable to agricultural diversions on the DW islands under the No-Project Alternative and mortality attributable to DW habitat island diversions.

Figure 5-8.
Mortality Index for Winter-Run Chinook Salmon during Migration through the Delta Attributable to Forgone Agricultural Diversions, DW Reservoir Island Diversions, and Bacon Island and Webb Tract Discharge to Export, 1922–1991 Simulation

DELTA WETLANDS PROJECT

Prepared by: Jones & Stokes Associates



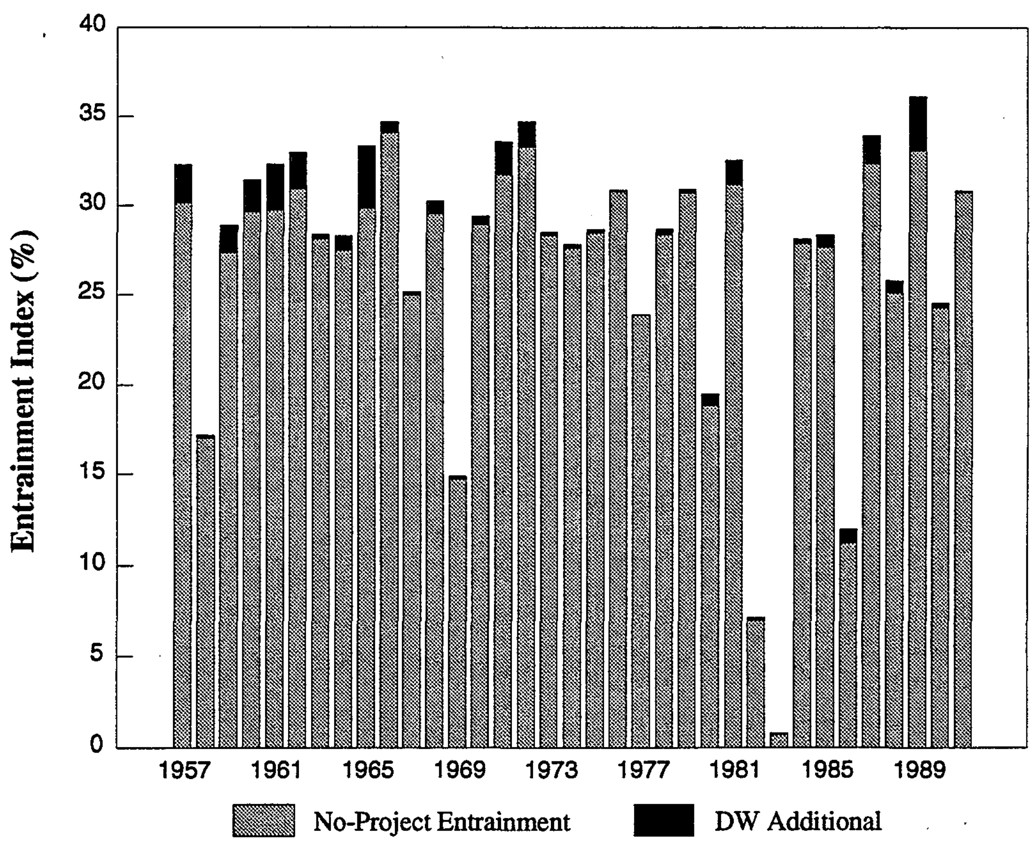


Figure 5-9.
Total Entrainment Index for Delta Smelt Larvae Entrained in All Delta Diversions, 1922–1991 Simulation

DELTA WETLANDS PROJECT

Prepared by: Jones & Stokes Associates

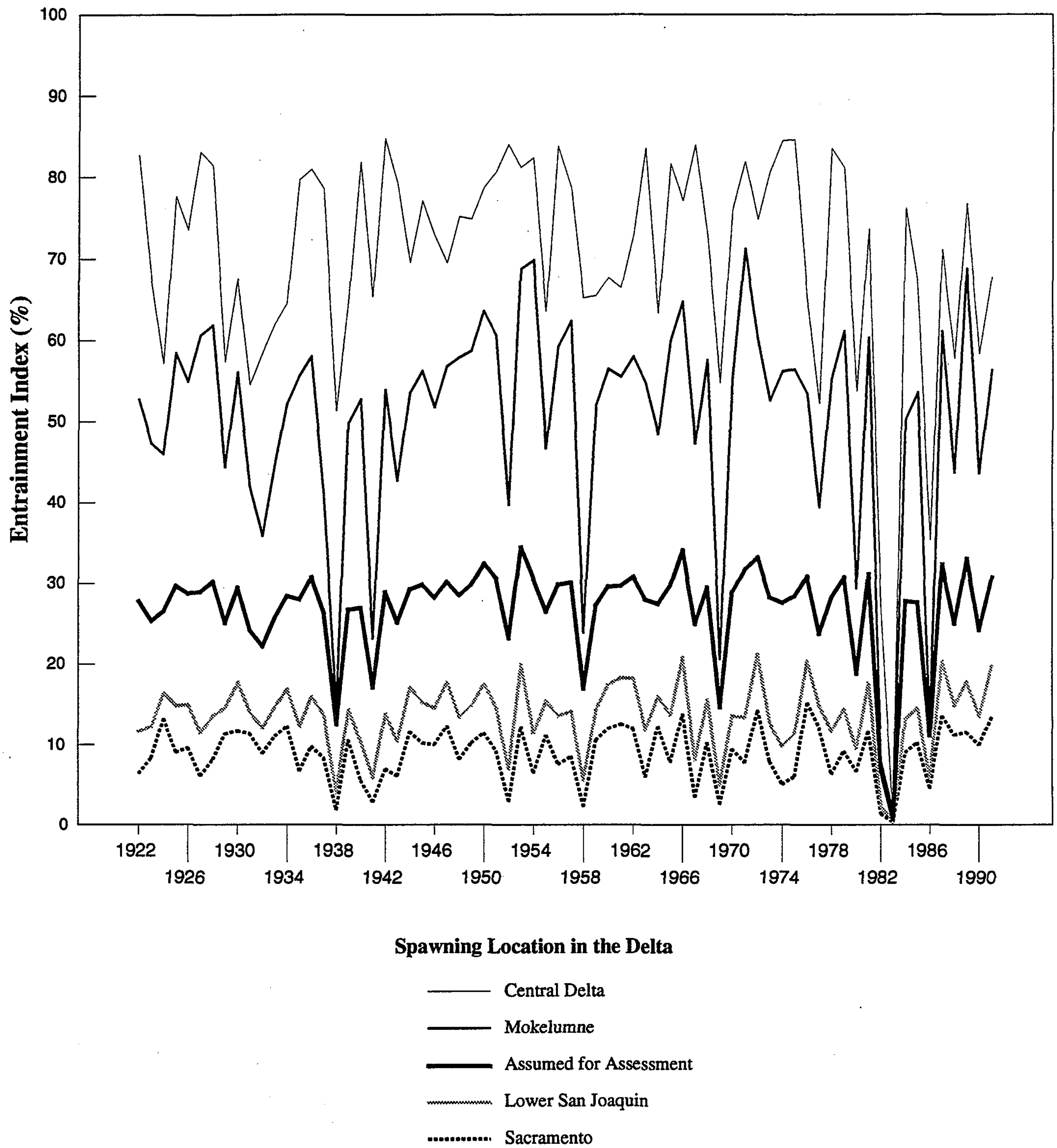
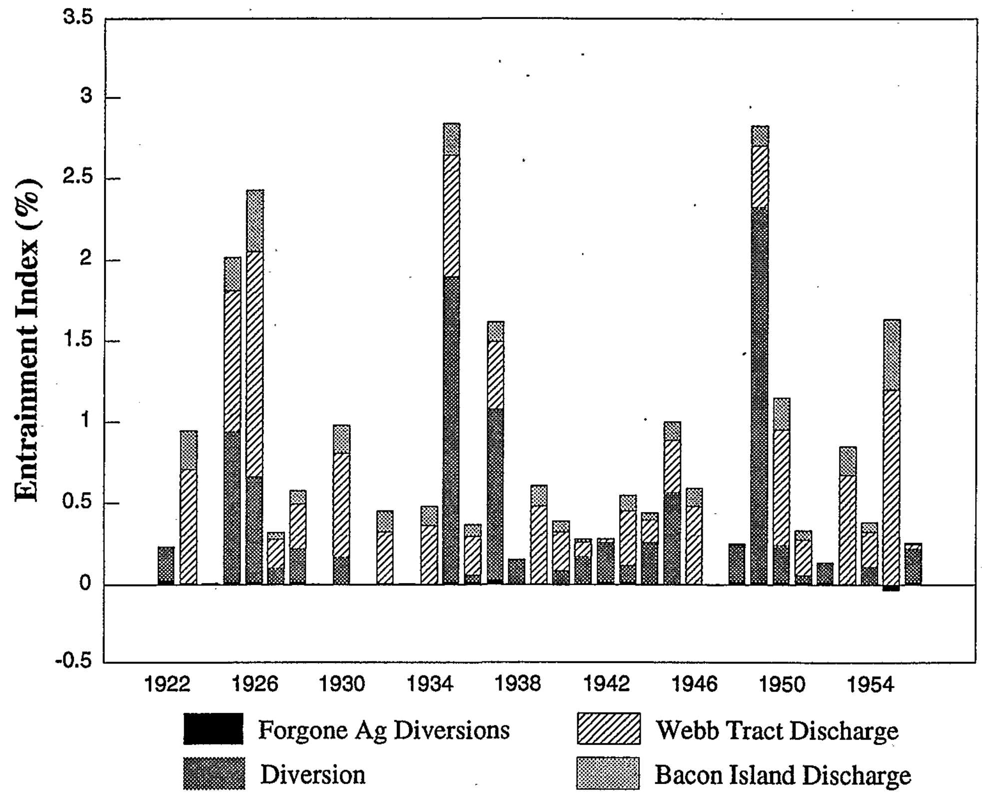
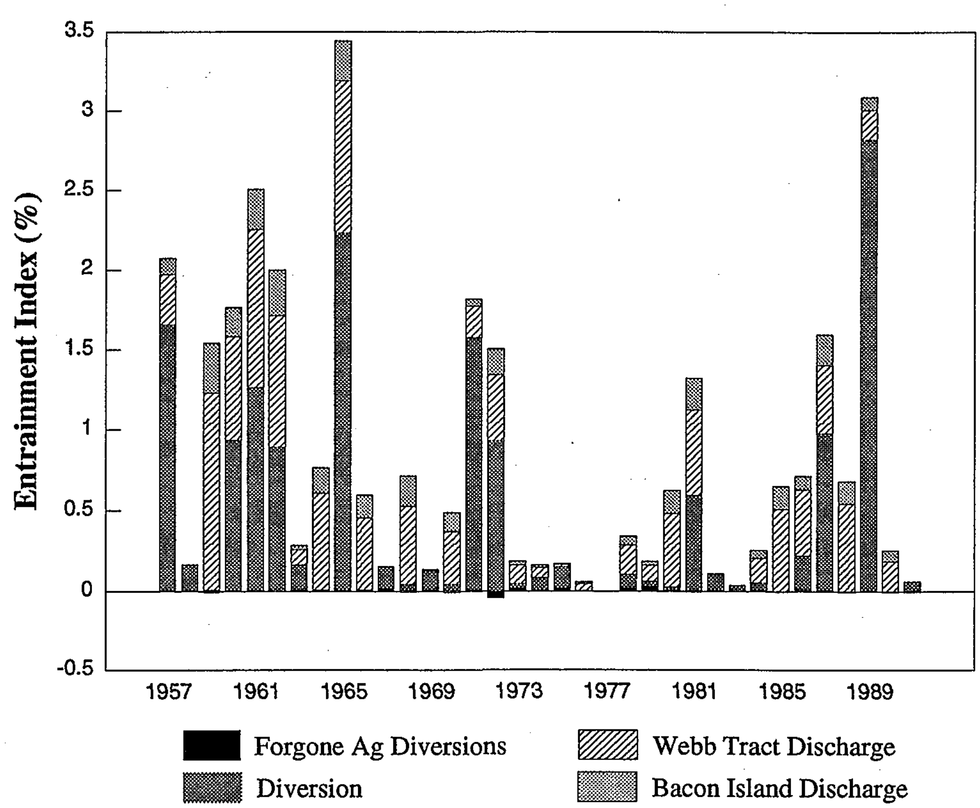


Figure 5-10.
The Effect of Spawning Location on the Entrainment Index for Delta Smelt under the No-Project Alternative, 1922–1991 Simulation

DELTA WETLANDS PROJECT
Prepared by: Jones & Stokes Associates





Note: Forgone Agricultural Diversions is the difference between entrainment in agricultural diversions on the DW islands under the No-Project Alternative and entrainment in DW habitat island diversions.

Figure 5-11.
Entrainment Index for Delta Smelt Larvae Attributable to Forgone Agricultural Diversions, DW Reservoir Island Diversions, and Bacon Island and Webb Tract Discharge to Export, 1922–1991 Simulation

DELTA WETLANDS PROJECT
Prepared by: Jones & Stokes Associates

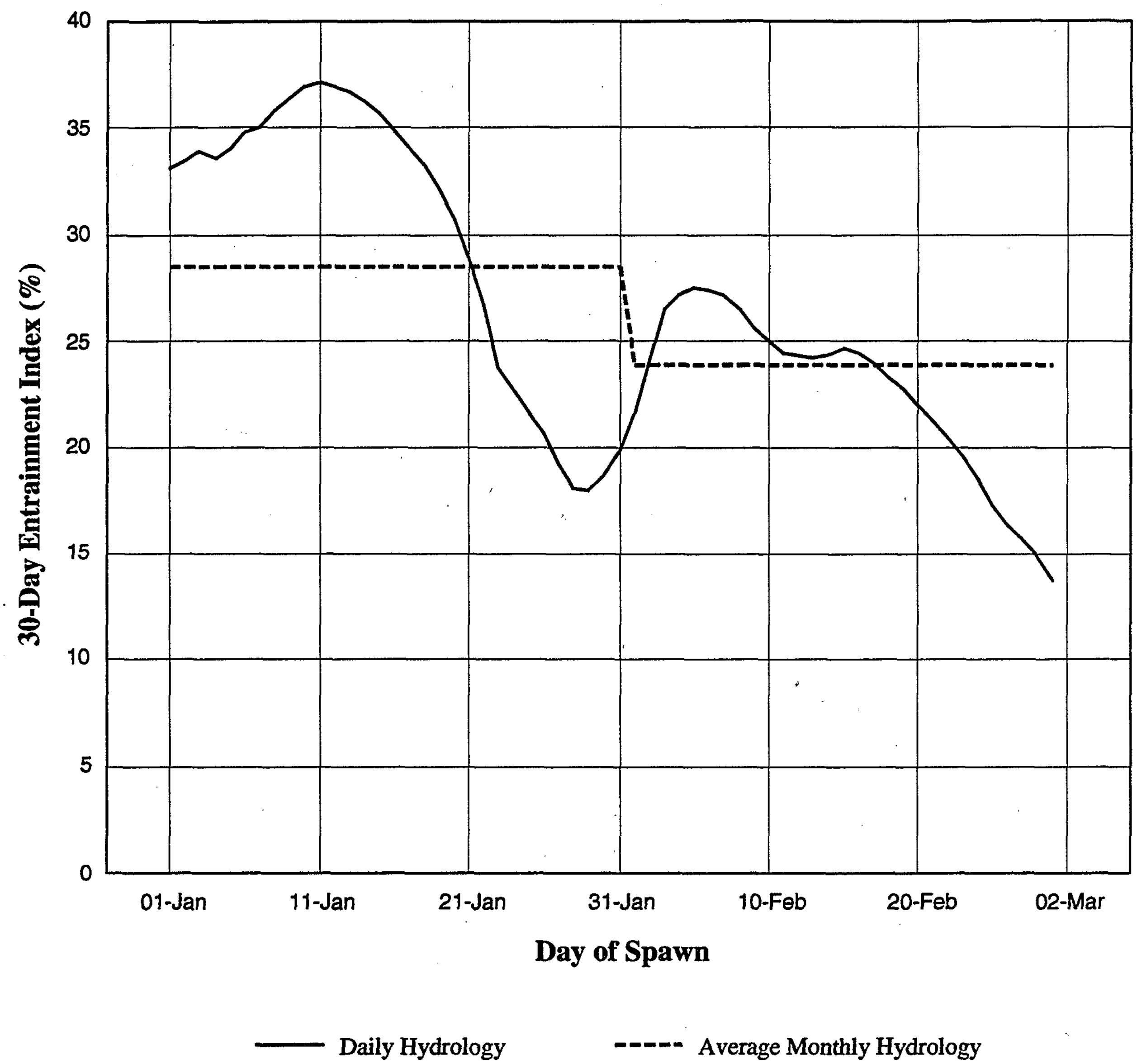


Figure 5-12.
Comparison of 30-Day Entrainment Indices for Daily and Average Monthly Hydrology, January–March, 1981

DELTA WETLANDS PROJECT
Prepared by: Jones & Stokes Associates

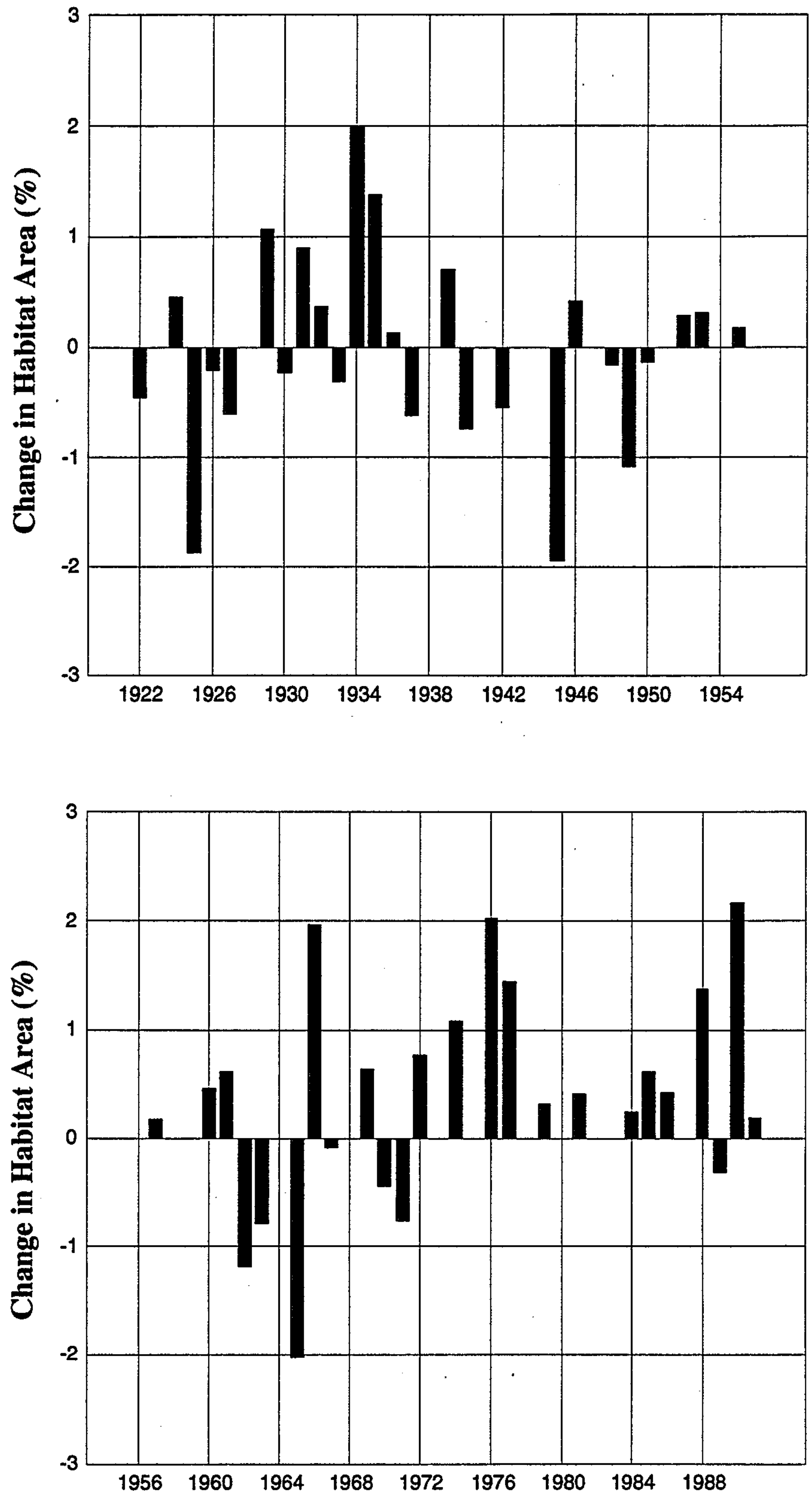


Figure 5-13.
Change in Estuarine Habitat Area for Delta Smelt under DW Project Operations, 1922–1991 Simulation

DELTA WETLANDS PROJECT

Prepared by: Jones & Stokes Associates

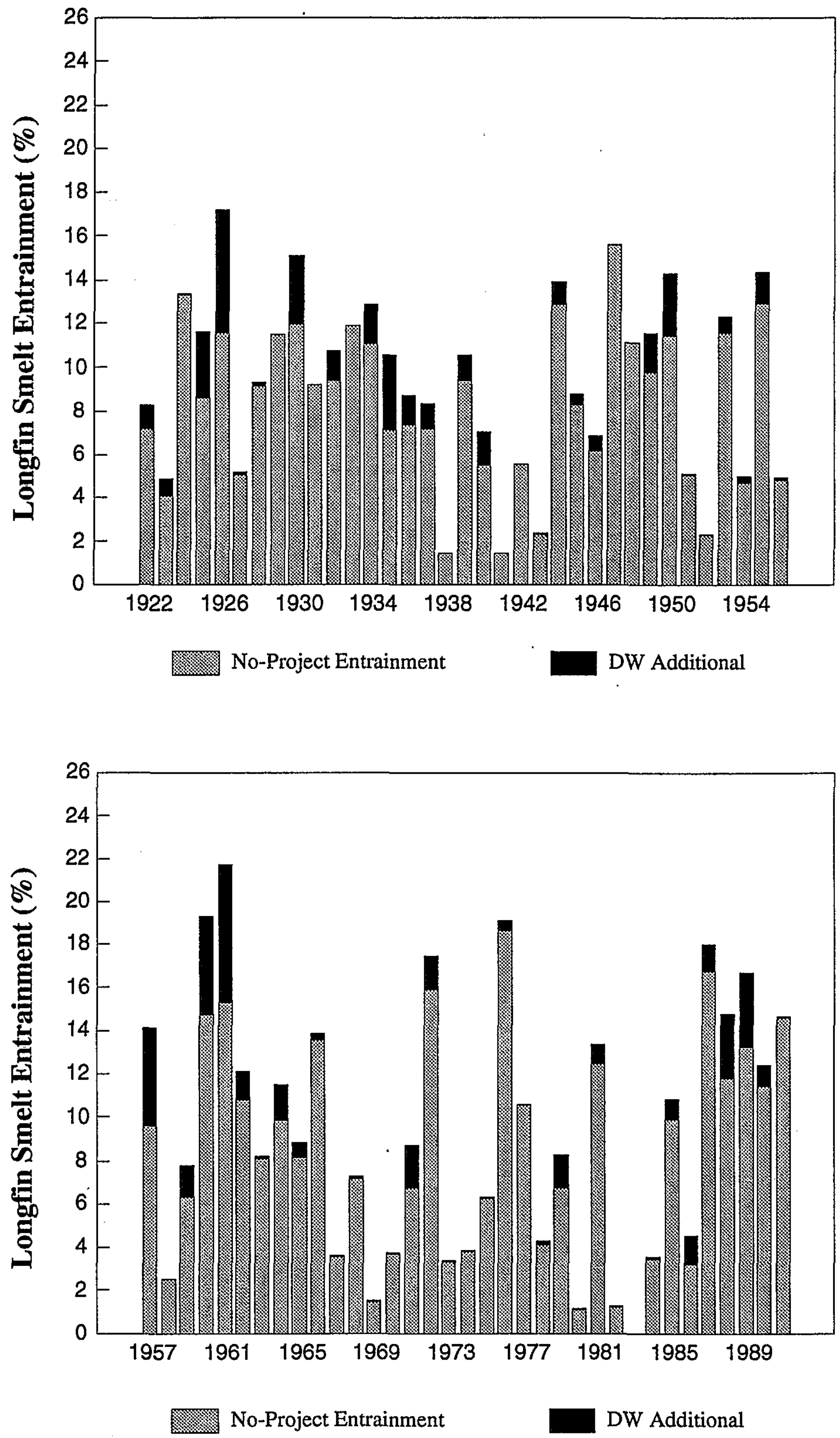
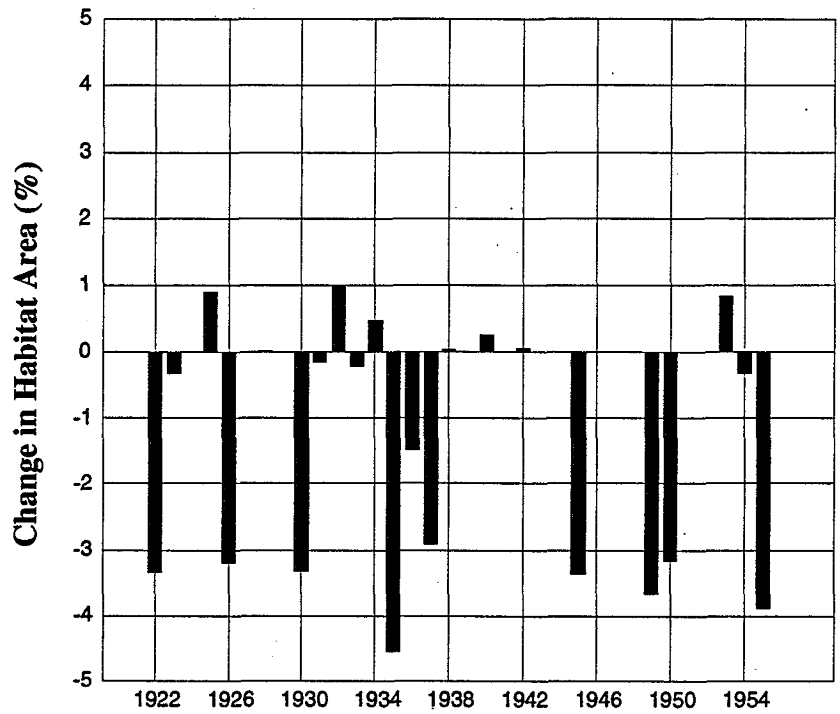


Figure 5-14.
Total Entrainment Index for Longfin Smelt Larvae Entrained in All Delta Diversions, 1922–1991 Simulation

DELTA WETLANDS PROJECT
Prepared by: Jones & Stokes Associates



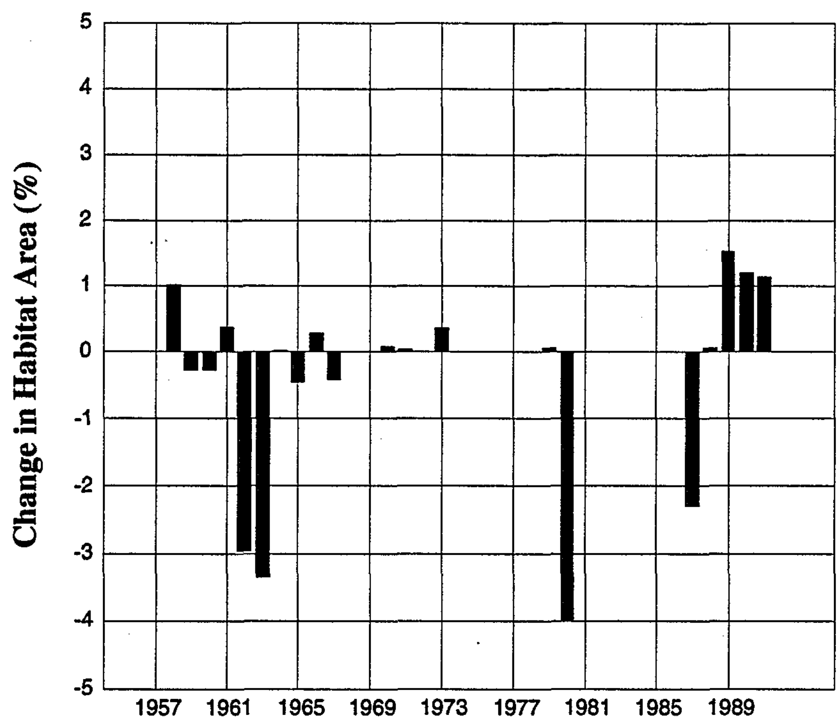


Figure 5-15.
Change in Estuarine Habitat Area for Longfin Smelt under DW Project Operations, 1922–1991 Simulation

DELTA WETLANDS PROJECT
Prepared by: Jones & Stokes Associates

Section 6. Citations

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