Appendix B

Simulation of Environmental Water Account Actions to Reduce Fish Entrainment Losses: Interactive Daily Environmental Water Account Gaming Evaluations

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Acronyms and Abbreviations

Bay-Delta	San Francisco Bay/Sacramento–San Joaquin River Delta
CALFED	CALFED Bay-Delta Program
CALFED ROD	CALFED Programmatic Record of Decision
CBDA	California Bay-Delta Authority
CCF	Clifton Court Forebay
CCWD	Contra Costa Water District
cfs	cubic foot per second
CVP	Central Valley Project
CVPIA	Central Valley Project Improvement Act
CWT	code-wire tag
D-1641	State Water Resource Control Board Decision 1641
DailyOPS	Daily Operations and Protections Simulation
DCC	Delta Cross Channel
DEFT	Diversion Effects on Fisheries Team
Delta	Sacramento–San Joaquin River Delta
DFG	California Department of Fish and Game
DNCT	DEFT-No-Name coordination team
DWR	Department of Water Resources
E/I	export/inflow
EDF	Environmental Defense Fund
EPA	U.S. Environmental Protection Agency
ESA	federal Endangered Species Act
EWA	Environmental Water Account
EWAT	EWA Team
km	1 kilometer
maf	million acre-feet
Metropolitan	The Metropolitan Water District of Southern California
NHI	Natural Heritage Institute
NOAA Fisheries	National Marine Fisheries Service
Reclamation	U.S. Department of Interior, Bureau of Reclamation
SLDMWA	San Luis & Delta-Mendota Water Authority
SWP	State Water Project
taf	thousand acre-feet
taf/yr	thousand acre-feet per year
USFWS	U.S. Fish and Wildlife Service
VAMP	Vernalis Adaptive Management Plan
WMCT	Water Management Coordinating Team
WQCP	Water Quality Control Plan

Appendix B
Simulation of Environmental Water Account Actions to Reduce Fish Entrainment Losses: Interactive Daily Environmental Water Account Gaming Evaluations

Introduction

This appendix describes the daily simulation model that was used to evaluate the potential fish entrainment reductions that could be achieved with the Environmental Water Account (EWA) that was proposed by the CALFED Bay-Delta Program (CALFED) as a fish protection action to reduce federal Endangered Species Act (ESA) concerns at the Central Valley Project (CVP) and State Water Project (SWP) facilities. The appendix introduces the challenges to providing both improved fish protection and increased water supply reliability using the existing Sacramento–San Joaquin River Delta (Delta) facilities. The historical pumping and fish salvage patterns are reviewed for a number of recent years. The procedures for the interactive EWA "gaming" sessions, where project operations staff and fisheries agency staff jointly simulated the operations of the proposed EWA to reduce CVP and SWP pumping during periods of increased fish density, are described. Results from these interactive EWA gaming sessions are presented and reviewed. A comparison of the EWA gaming actions with the actual 2001–2003 EWA operations is presented. These simulations of the CVP and SWP pumping patterns are accomplished with a daily model that retains many of the variations in hydrologic conditions and fish density patterns that are actually encountered by the operators and the ESA agencies (i.e., National Marine Fisheries Service [NOAA Fisheries], U.S. Fish and Wildlife Service [USFWS], California Department of Fish and Game [DFG]) staff. This provides a more accurate understanding of how the proposed 8,500–cubic foot per second (cfs) Clifton Court Forebay (CCF) diversion limits would actually be used within the Delta regulatory framework of State Water Resource Control Board Decision 1641 (D-1641), Central Valley Project Improvement Act (CVPIA) b(2) and recent EWA operations.

The annual combined CVP and SWP Delta water supply target of 5–6 million acre-feet (maf) requires that the Delta export pumping plants be operated for the majority of the time. However, efforts to reduce fish entrainment losses would restrict the number of days with high export pumping. The current method for accomplishing this balance is the EWA, which provides an annual budget to purchase water from either upstream of the Delta (from water districts) or downstream of the Delta (from contractors) to allow periods of reduced export pumping during periods of high fish density to be accomplished without water supply reductions (unless sold to EWA).

Entrainment losses occur when a vulnerable life stage of a fish species of interest is directly entrained at the pumping facilities or indirectly drawn toward the vicinity of the pumping facilities where increased predation losses are likely. The daily entrainment loss is assumed proportional to the density of fish in the south Delta water and the volume of water diverted. The existing fish salvage facilities were designed to effectively screen some of the larger fish life stages (e.g., Chinook salmon and striped bass). These fish salvage facilities may not be as effective for smaller fish (e.g., delta smelt). The density of fish in the south Delta is governed by natural spawning and migration events, but may also be influenced by the tidal hydraulic transport and mixing conditions that are partially controlled by the Delta inflow and south Delta pumping patterns. Changes in Delta inflow or south Delta pumping patterns may change the distribution of vulnerable fish within the Delta channels. However, because these possible effects cannot be simulated with the existing knowledge of fish movement in the Delta, it is assumed that the historical fish density patterns would remain unchanged by export pumping reductions or increases that result from higher pumping (i.e., 8,500-cfs limit) or from EWA actions.

Management Tools to Reduce Entrainment Losses

Many of the existing San Francisco Bay/Sacramento–San Joaquin River Delta (Bay-Delta) Water Quality Control Plan (WQCP) objectives (incorporated into D-1641) such as the export/inflow ratio and X2 requirements attempt to govern basic Delta hydrodynamic conditions that are thought to influence entrainment losses. The distribution and abundance of each fish population are influenced by the hydrodynamic conditions within the Delta, but are also a function of other habitat conditions in the Delta. Therefore, in addition to operating the existing fish salvage facilities and complying with Delta flow and salinity objectives, entrainment losses may be reduced with the following basic entrainment management “tools”:

1. Sacramento River inflow can be increased to control conditions along the migratory pathway for fish entering the Delta from the Sacramento River corridor, and to regulate Delta outflow and other hydrodynamic conditions.
2. The Delta Cross Channel (DCC) gates can be closed to reduce the diversion of fish into the central Delta where habitat conditions are less suitable. Fish are more likely to be drawn toward the pumps once they enter the central Delta channels.
3. San Joaquin River inflow can be increased to control conditions along the migratory pathway for fish entering the Delta from the San Joaquin River

corridor and to regulate central Delta hydrodynamic conditions. Higher San Joaquin River flows will reduce the net flow from the central Delta toward the pumps and increase the fraction of San Joaquin River fish making it downstream to Antioch.

4. The temporary head of Old River barrier can be closed to reduce the diversion of fish from the San Joaquin River into the south Delta channels. The head of Old River barrier directly influences hydrodynamic conditions in the south Delta and may increase the net flow from the central Delta toward the pumps. This may increase the number of vulnerable fish from the central Delta that are drawn toward the pumping plants.
5. Delta export pumping can be reduced to protect vulnerable life stages of fish species of interest during periods when high densities of these fish are observed in the south Delta salvage facilities or in central Delta tow-net samples. This is the major purpose of the CALFED EWA.

These entrainment management tools are being implemented in combination because they are the only actions currently available for reducing fish entrainment losses during initial years of the CALFED strategy (Stage 1). Additional entrainment management tools may be implemented in the future but will require the construction of new facilities or habitat restoration areas. The additional tools include:

1. The temporary rock barrier at the head of Old River can be replaced with an operable tidal gate (planned as part of SDIP). This would provide direct control of the fraction of San Joaquin River water that is diverted into Old River. Opening the gate during some portion of the tidal cycle (i.e., flood-tide) might allow fish that may be migrating or trapped in south Delta channels to escape into the San Joaquin River.
2. The fish salvage facilities can be upgraded or replaced with new facilities that would allow fish to remain in south Delta channels or be more successfully salvaged and moved to another Delta location that is more isolated from the pumping effects. The handling (i.e., size separation) and release (i.e., nighttime barge) procedures might be improved for delta smelt and other smaller fish.
3. A channel from the CCF tidal gate to the Skinner Fish Facility channel might be constructed with a permeable rock levee to transport fish more rapidly from the gate to the salvage facilities and thereby reduce predation losses. The water storage features of CCF would be preserved with water moving through the rock levee, but the majority of fish are expected to remain in the "salvage channel."
4. Screens can be installed on more agricultural diversions within the Delta, and improved screens can be installed on the cooling water intakes for the Delta power plants at Antioch and Pittsburg.
5. A new screened diversion channel at Hood (or screen/louver facilities at DCC and Georgiana Slough) would allow diversion of the water from the Sacramento River into the central Delta without also diverting vulnerable fish life stages. The DCC gates could be automated to allow more flexible

tidal operations for fish protection, water quality control, and recreation (boat passage) uses.

6. New and restored Delta habitat may increase fish populations and shift the distributions of vulnerable life stages. This should reduce the effects of entrainment losses on fish populations, although the higher fish populations within the Delta may numerically increase the salvage losses.

Environmental Water Account

The EWA is a combination of water contracts, available storage and/or conveyance capacity, and necessary funding and agreements to allow increased pumping during periods of low fish entrainment risk and reduced pumping during periods of high fish entrainment risk. The EWA is formulated as a method for providing additional fish protection by allowing exports to be shifted to periods that have lower entrainment losses, without reducing the net exported water supply. Water purchases from willing sellers south of the Delta will reduce the demand for exported water. Water purchases from upstream of the Delta are generally moved across the Delta and exported during the summer when fish densities are relatively low.

The EWA provides an accounting method to allow the shifting of exports from one period to another. The EWA puts definitive boundaries on the amount of water that can be used for entrainment loss reduction, and provides assurances for the payback of any water supply shortages that these reductions may cause. The EWA has the following advantages compared with the No Action Alternative (i.e., no further entrainment reduction measures) or compared with the likely alternative of imposing additional export restrictions using prescriptive (fixed rule) standards or ESA "take" limits:

1. The EWA provides the ability to increase and decrease exports consistent with fish protection goals (i.e., flexibility) and without the constraints of fixed monthly rules.
2. The EWA allows more efficient use of water for environmental protection because only the water necessary for protection will be used, and the EWA managers look for periods when increased exports (export/inflow [E/I] relaxation) can be allowed to replenish the EWA. The existing monthly Delta objectives (D-1641) provide a good starting point for EWA adjustments to increase fish protection.
3. The EWA requires accounting of the water supply impacts caused by reduced exports for fisheries protection. The value of California water is properly considered because the water supply impacts must be balanced with replacement water (from E/I relaxation), purchased water transfers, or purchased south-of-Delta water supply.

Two difficult tasks for operating a successful EWA are the development of a biological decision-making framework for EWA actions and quantitative performance measures for evaluating EWA fish protection actions. Interactive group simulations of the EWA operations and fish salvage reductions have been accomplished with a "gaming" model tool. The results from the initial gaming that was used to formulate the original EWA for the CALFED Programmatic Record of Decision (CALFED ROD), and recent gaming simulations of the changes in EWA that might be necessary if the SWP Harvey O. Banks Pumping Plant (SWP Banks) pumping (CCF diversion) capacity is allowed to be increased to 8,500 cfs, are described in this appendix.

Benefits from the Environmental Water Account

Potential benefits of EWA actions that change net Delta flow conditions (i.e., Delta inflows, outflow, DCC diversions, head of Old River diversions, and export pumping) are difficult to evaluate because there are always multiple factors affecting fish populations, and the effects of any single factor on fish survival cannot be experimentally determined.

Measurements of fish distribution and abundance (density) are the fundamental biological data that must be evaluated to estimate the potential benefits of EWA changes in net Delta flows and export pumping patterns. The timing of a species within the Delta (migration, spawning, or rearing) is important because this controls the fraction of the population that is exposed to Delta conditions during a specific time period. The location of the population within the Delta is important because it controls the fraction of the population that is exposed to direct and indirect effects of net flows and export pumping. Because the available biological data are generally incomplete (compared with the daily hydrologic and water quality conditions), a wide range of possible assumptions (hypotheses) about the relationships between habitat conditions and the resulting fish distribution and abundance patterns in the Delta must be considered. The interactive EWA gaming model used the historical CVP and SWP daily salvage densities as the basic biological measure of EWA success, assuming that the density patterns would not change with pumping or Delta flow modifications.

Implementation of the EWA

The EWA was implemented as a major fish protection program as part of CALFED Stage 1, beginning in water year 2001. The water project agencies (California Department of Water Resources [DWR] and U.S. Department of Interior, Bureau of Reclamation [Reclamation], referred to as the PAs) and the fish management agencies (DFG, USFWS, and NOAA Fisheries, referred to as the MAs) coordinate and cooperate through weekly meetings of a management level group (Water Operations Management Team) and a technical operations and scheduling group, called the EWA Team (EWAT). The technical team and EWA staff coordinate extensively with the CVPIA b(2) interagency team that directs the use of CVPIA b(2) water at CVP facilities. Annual reports document the implementation success in purchasing water from both north-of-Delta and south-of-Delta contractors, using the EWA water to provide fish protection at the exports during periods of high fish density, and evaluating the likely success of these fish protection actions. An annual peer review and workshop evaluate the EWA.

The EWA has been implemented and is guided by several California Bay-Delta Authority (CBDA) and DWR staff. The CALFED review workshops and peer-review reports for the actual EWA operations in 2001, 2002, and 2003 are available. The Bay Institute also has published reviews of the EWA operations and performance. Additional documentation on the CALFED EWA program can be found at the CALFED/CBDA Web site:

<http://Calwater.ca.gov/programs/EnvironmentalWaterAccount/>.

The guidance documents and major decisions of the EWA technical team are documented in meeting notes and handout materials from the CALFED Operations Group and are available at their Web site:

<http://wwwoco.water.ca.gov/calfedops/>.

The negotiations and financial arrangements for the annual and long-term water contracts with willing sellers, and the coordination with the CVP and SWP operations staff to schedule fish protection actions based on daily fish salvage numbers and other fish sampling information, are sizable undertakings that require dedicated staff. The EWA gaming model results that were used to initially formulate the EWA and evaluate the potential changes necessary with the proposed 8,500-cfs SWP pumping limit are described in this appendix.

Daily EWA Simulation Model Features

A combination of CALSIM monthly planning model results and a daily simulation model of the Delta flows and exports was used for the interactive EWA gaming simulations to explore and recommend the EWA program. The CALSIM results were used to approximate the baseline conditions for upstream reservoirs and water supply demands and export patterns. The daily model DailyOPS (Daily Operations and Protections Simulation) was then used to show the daily patterns of Delta flows and allowable export pumping corresponding to these Delta inflows. The daily model includes the daily historical CVP and SWP salvage density data, which were used to guide the EWA adjustments in a month-by-month gaming exercise, with pumping restrictions specified on a weekly basis. The major features of the daily simulation model are briefly described below.

The DailyOPS model uses the historical daily Delta inflows (i.e., DAYFLOW records) for any selected recent year of record (1981–2003). The daily historical data can be adjusted to match the monthly average CALSIM results for each month, if desired, by adding the monthly difference between the CALSIM value and the historical average value. Inflows, channel depletions, Contra Costa

Water District (CCWD) diversions, and south-of-Delta CVP and SWP demands can be adjusted to match CALSIM. If CALSIM results are not available (e.g., 1995–2003), the historical inflows can be manually adjusted to reflect any modifications from the historical conditions that CVP or SWP water management staff may suggest.

The allowable CVP and SWP exports that would satisfy each of the specified Delta objectives (D-1641) are calculated for each day. The daily model calculates daily X2 requirements and export/inflow ratio limits, for example, and determines adjustments in historical export that would be required to satisfy these specified objectives, assuming adjusted historical inflows. CVP and SWP San Luis reservoir storage volumes are simulated as the combination of allowable exports and monthly water supply deliveries, beginning at the historical or adjusted initial storages.

The daily model simulates EWA fish protection actions by allowing the CVP and SWP pumping to be reduced to less than allowable pumping during periods with relatively high historical fish salvage densities. The daily model allows the pumping limits and the maximum E/I ratio (relaxation) to be specified on a weekly basis. The daily model tracks the EWA adjustments to the baseline (adjusted historical) conditions. Periods of relaxation in the E/I ratio or increased exports from upstream water transfers will produce an EWA credit, with increased San Luis storage. Periods of reduced pumping for fish protection will reduce the EWA account and create an EWA debt in San Luis Reservoir. South-of-Delta water purchases are used to reduce the EWA debt with a specified monthly purchase pattern.

The upstream reservoirs that control Delta inflow can be included in the EWA daily modeling. This allows the effects of EWA reductions in Delta exports to be balanced by reducing reservoir releases to minimum required release flows and holding EWA water in upstream storage, unless the reservoir storage is already at flood control levels. These upstream reservoir management opportunities have not been fully explored in the EWA gaming simulations, and more efforts at coordination between Delta actions and upstream actions should be included in future gaming sessions.

During the gaming sessions, graphs of the baseline allowable exports and the historical salvage density patterns at CVP and SWP are displayed. The EWA fish protection representatives then adjust the exports on a weekly basis during periods of high fish salvage density. The amount of EWA water required for these fish protections is accounted for in a monthly spreadsheet that summarizes the various EWA transactions (water options, upstream or south-of-Delta water purchases, source shifting). The number of fish salvaged with the baseline and with the EWA protections is calculated in the daily model and summarized as monthly values. The monthly salvage of particular fish that might have been reduced by the EWA pumping reductions is the basic performance measure used to evaluate the effectiveness of the EWA actions.

The goal of the interactive EWA gaming simulations is to combine the most accurate representation of reservoir storage, river flows, and Delta water management constraints with the best available biological data about fish abundance and distribution, so that EWA adjustments will provide the greatest possible benefits to important fish populations.

Historical Central Valley Project and State Water Project Salvage Data

The interactive EWA gaming simulations have used the historical salvage density (fish per thousand acre-feet [taf]) from the CVP and SWP facilities to estimate and compare the baseline and EWA–modified daily fish salvage. The CVP and SWP daily salvage data are considered to be more reliable since 1981; earlier salvage data are available but are more uncertain in some of the species identification (e.g., delta smelt). The EWA gaming sessions therefore have started with water year 1981.

Converting the historical salvage records to density provides a standardized measure of relative fish abundance near the pumps that is assumed to be independent of the pumping rate. However, this assumption implies that changes in allowable pumping will not change the basic fish occurrence (i.e., timing) and abundance (i.e., density) patterns. Under this assumption, the calculated daily salvage will vary directly with the daily pumping rate. Reducing the exports during periods with the greatest historical salvage density can therefore protect the greatest number of fish.

The changed pumping pattern may have a secondary effect on historical salvage density if the fish population density was not uniform throughout the Delta, and pumping draws water with high fish density from the central Delta or the San Joaquin River inflow toward the exports. This might occur, for example, if the majority of the Chinook salmon salvage originates from the San Joaquin River. Higher pumping may draw a greater fraction of the San Joaquin River Chinook salmon toward the pumps. The head of Old River barrier may reduce the Chinook salmon salvage density at the CVP and SWP. However, assumptions about how to adjust historical Chinook salmon and splittail salvage density for various changes in Delta inflows and net channel flows have not been specified by the EWA modeling team and are not included in the daily EWA calculations.

This effect of pumping on salvage density might also occur for delta smelt or striped bass that have spawned in the central or northeast Delta and are drifting passively in the water column. Greater-than-historical pumping might increase the salvage density, and less than historical pumping might delay and reduce the historical salvage density. These possible changes in historical salvage density have not yet been incorporated into the interactive EWA gaming calculations because the historical distribution patterns are generally unknown. The fish biologists did consult the 20-mm delta smelt survey distributions as part of their selection and timing of EWA actions in some of the EWA gaming sessions for recent years (i.e., 1995–2003).

One of the fish biologists involved with the EWA gaming (Bruce Herbold, U.S. Environmental Protection Agency [EPA]) suggested that a shift from the historical X2 position would likely change the historical delta smelt and striped bass salvage density. The EWA gaming has assumed that a downstream shift in the X2 position of 1 kilometer (km) (which would require approximately 10% more outflow) would reduce the historical delta smelt density by 10%. An upstream movement of 1 km is assumed to increase the delta smelt historical density by 10%.

In addition to the historical CVP and SWP salvage records, there are some available daily records of fish density from the Chipps Island trawling station. In more recent years, trawling at Sacramento and at Mossdale on the San Joaquin River have also provided daily records during months with greatest likelihood of Chinook salmon presence (the target fish species for these sampling efforts). However, these data have not been included in the daily EWA gaming simulation model to provide comparisons with the south Delta salvage density for Chinook salmon, delta smelt, or other fish species.

Review of Interactive EWA Gaming Sessions

The first series of interactive EWA gaming sessions was conducted in the fall of 1998 as part of the CALFED process to evaluate alternative actions proposed for the initial years of the CALFED strategy (Stage 1). These EWA evaluation sessions emerged from the combination of the Diversion Effects on Fisheries Team (DEFT) and the CALFED Operations Group real-time data evaluation group (called the No-Name group) to form DEFT-No-Name coordination team (DNCT). This work was conducted under the Water Management Coordinating Team (WMCT). Peter Louie from The Metropolitan Water District of Southern California (Metropolitan) had proposed the use of the SWP and CVP salvage numbers to develop “fish triggers” to schedule export reductions to reduce entrainment losses of endangered fish to avoid ESA take limits.

An EWA modeling team was organized that included Peter Louie (Metropolitan), Bruce Herbold (EPA), Jim Snow (DWR), Paul Fujitani and Chet Bowling (Reclamation), Art Hinojosa (SWP), George Barnes (DWR), Dave Briggs (CCWD), Dave Fullerton (Natural Heritage Institute [NHI]), Spreck Rosekrans (Environmental Defense Fund [EDF]) as well as B.J. Miller and Tom Boardman (San Luis & Delta-Mendota Water Authority [SLDMWA]). A series of initial gaming sessions using water years 1991–1995 were conducted in spring (April–June) 1999 to explore the possibilities for an EWA.

A biology team was also formed to develop general guidelines or rules for fish protection measures that became known as the biological “templates” for the periods and level-of-pumping protection. The biology team included Karl

Halupka and Gary Stern (NOAA Fisheries), Bruce Herbold (EPA), Sheila Greene (DWR), Pete Rhoads (Metropolitan), Chuck Hanson, Pete Chadwick (DFG retired), Jim White (DFG), and Mike Fris (USFWS).

A workshop was held on November 30, 1999, to demonstrate the EWA gaming approach and seek stakeholder review and comment. Based on favorable review, the interactive EWA gaming model was expanded to include the ability to adjust historical inflows to match results from the CALSIM monthly model for water years 1981–1994. A full series of EWA gaming sessions were conducted in spring 2000, and final recommendations based on these gaming results were incorporated into the CALFED ROD in August 2000.

Gaming sessions generally required several days to complete the series of water years 1981–1994. Depending on the water year and interactive discussion of operations changes and fish protection decisions, between 2 and 4 years could be simulated during a day of gaming. The EWA gaming sessions involved extensive planning and coordination to prepare the participants. The first stage in the planning for the EWA gaming sessions was to clearly determine the CVP and SWP operating assumptions that should be used in the baseline simulation. This generally included the existing Delta objectives (D-1641) and facilities. Next the available assets for the EWA were identified. A series of biological templates were developed, based on a review of the historical operations and salvage records, to identify likely periods of high fish density and to determine acceptable pumping levels during these protection periods. These biological templates were used to guide the EWA actions during the gaming. A monthly water accounting procedure was used in the gaming sessions to track the use and repayment of water from the assumed EWA assets.

Dave Fullerton, who was with the NHI and is now with Metropolitan, was the key player in visualizing and organizing these gaming sessions. He drafted an initial proposal for export reductions by a proposed "environmental water district" with an assumed water allocation in May 1998. Ron Ott, CALFED CH2MHill consultant, facilitated the early EWA gaming in 1999 and 2000 that was used to formulate the EWA for the CALFED ROD in 2000. Many exceptional members of the fisheries agencies and the CVP and SWP operations staff participated in the EWA gaming sessions. Some of these staff are still active in helping to guide the EWA implementation. The process of gaming the EWA, with both project operators and fish protection staff participating in these interactive sessions, provided a level of confidence that this type of adaptive management of the exports could be implemented as a more efficient and cooperative approach to fish entrainment protection.

Another series of interactive EWA gaming sessions was conducted in July and August 2002 to evaluate changes in the size of the EWA that might be required if the SWP pumping limit was increased to 8,500 cfs. It was generally understood that the same level of EWA protection achieved from a specified pumping level would be more costly if measured from an increased baseline pumping limit. However, the increased pumping capacity in the winter might allow San Luis Reservoir to be filled earlier and allow reduced pumping in the early spring period, when highest densities of fish were observed. The gaming years were 1981–1994 using adjusted inflows to match the CALSIM results. The more recent years of 1997 and 1999–2001 were added to the gaming sessions without any adjustments from historical operations, to evaluate the incremental effects of the proposed 8,500-cfs SWP Banks pumping limit.

The latest session of interactive EWA modeling was performed in September 2003 to review the historical operations for 1999–2003 and evaluate the necessary changes in EWA to allow the same level of fish protection with the proposed 8,500-cfs SWP pumping limit. Results from these evaluations allowed a direct comparison with the gaming EWA actions and the actual EWA actions implemented in years 2001, 2002, and 2003.

Results from some of these EWA gaming sessions will be shown and discussed in the following sections to provide an understanding of the historical daily Delta CVP and SWP operations, and the actual fish density patterns that govern the EWA actions. The initial EWA gaming sessions assumed the existing (D-1641) Delta objectives and the existing 6,680-cfs SWP Banks pumping capacity. The likely changes in Delta operations that would result from the increased SWP pumping limit of 8,500 cfs were simulated in more recent EWA gaming sessions. DailyOPS results comparing the EWA actions simulated for both 6,680-cfs capacity and the proposed 8,500-cfs capacity are shown in figures for recent years of operations.

Simulated EWA Actions with 6,680-cfs and 8,500-cfs SWP Banks Pumping Capacity

Interactive gaming of EWA actions with the DailyOPS model was used to evaluate the potential changes in the EWA that might be required to provide effective fish salvage protection if the permitted CCF diversion capacity for the SWP Banks facility were increased to 8,500 cfs. Comparisons were made with daily EWA simulations for the existing SWP Banks capacity of 6,680 cfs for the period 1981–2001 (skipping the wet years of 1983, 1995, 1996, and 1998) during July and August 2002. The gaming was based on earlier sessions that simulated the size of the EWA necessary to provide protections that were similar to the biological template used in the initial formulation of the EWA for the CALFED ROD. Slightly different CVP and SWP monthly operations results (from CALSIM rather than DWRSIM) were used in the 2002 gaming sessions. Existing CVP and SWP facilities and operations (D-1641) were used for the EWA baseline.

Table B-1 gives the annual summary values for CVP and SWP exports, along with the CVPIA b(2) and EWA fish protection actions that were simulated in the EWA gaming sessions to reduce exports for both the existing 6,680-cfs SWP pumping limit and the proposed 8,500-cfs pumping limit. The EWA export reductions were assumed to be fully compensated for with upstream or south-of-Delta water purchases. CVP export reductions were assumed to be accomplished with CVPIA b(2) water. The SWP export reductions were assumed to be made with EWA water. The resulting annual fish salvage values for Chinook salmon, delta smelt, splittail, and steelhead for the baseline and EWA actions using both the existing 6,680-cfs SWP limit and the proposed 8,500-cfs SWP pumping limit are given in Tables B-2 to B-7.

Table B-1 compares the historical CVP and SWP pumping to the simulated pumping under D-1641 with CALSIM-adjusted inflows. For the 17 years simulated, the average historical pumping was 4,810 thousand acre-feet per year (taf/yr), and the baseline simulated pumping was 5,042 taf/yr for the 6,680 cfs SWP Banks limit. Fish protection cuts are separated into the CVPIA b(2) and assumed EWA reductions. The CVPIA b(2) cuts averaged 200 taf/yr and the EWA cuts averaged 243 taf/yr. The average percentage of the baseline pumping that was reduced by these fish protection actions was 8%. The additional baseline pumping possible with the 8,500 cfs SWP Banks limit was 115 taf/yr, and the additional fish protection actions to provide the same EWA protections averaged 26 taf/yr.

Tables B-2 to B-7 show the annul salvage corresponding to these five pumping conditions for each year. Very large reductions in Chinook salmon salvage are shown in Table B-2 (average reduction of more than 30%) because of the large CVP and SWP reductions during VAMP, which corresponds to the peak fall-run Chinook salmon densities. Table B-3 indicates the protection of October–March Chinook salmon (i.e., winter-run and spring-run) was moderate (18%). Table B-4 indicates that the average reduction in delta smelt salvage was nearly 50%, because the highest densities are usually in April and May when the majority of EWA and CVPIA b(2) actions were simulated. Table B-5 indicates the protection of adult delta smelt (October–March salvage) was about 20%. Table B-6 shows the good protection of splittail, averaging more than 25%. Table B-7 indicates that the simulated reduction of steelhead salvage averaged about 20%. These are quite good reductions for reductions in pumping that averaged less than 10% of the baseline pumping.

CALSIM monthly results for D-1485 and D-1641 (1995 Bay-Delta WQCP objectives) were available from DWR from a simulation completed in May 2002 that included water years 1981–1994. The changes from D-1485 to D-1641 are used in the CVPIA b(2) accounting for the CVP facilities. The daily historical inflows were adjusted to match the monthly average values estimated by CALSIM for D-1641 conditions for each of these years. The monthly CVP and SWP deliveries were used to simulate daily San Luis Reservoir storage changes, with San Luis storage starting with the CALSIM values from the previous water year. The CALSIM model does not include water years 1995–2001, so the historical inflows and deliveries were used as the baseline conditions, without any EWA actions. The gaming session specified the weekly EWA protections that would be required to provide sufficient fish salvage reductions to satisfy the fisheries template. Although this was a subjective level of fish protection, it used results from previous gaming sessions within a framework of assumed EWA assets that were similar to the CALFED ROD description.

The DailyOPS model was used to estimate daily allowable exports, once the historical inflows were adjusted to match the monthly CALSIM values. This baseline simulation of CVP and SWP daily pumping was then adjusted in the interactive EWA gaming sessions by a team of fish agency representatives (DFG, NOAA Fisheries, USFWS) and water project operators (Reclamation, DWR) and water contractor representatives. The EWA gaming adjustments are made on a week-by-week basis during periods with relatively high historical salvage density. The comparison to the proposed 8,500-cfs SWP capacity was then made by adjusting the baseline to the assumed 8,500-cfs capacity and applying the same EWA protections (i.e., SWP and CVP pumping levels during weeks with protections) as used in the 6,680-cfs game. Several figures will be shown to illustrate the EWA gaming procedures. Water years 1987 and 1988 will be used as examples.

Figure B-1 shows the DailyOPS model adjustments to the historical Sacramento and San Joaquin River inflows to match the CALSIM monthly inflows for water year 1987 with the existing SWP pumping limit of 6,680 cfs. The monthly adjustments in Sacramento River flows were greater than 2,000 cfs in several months. The largest reductions in the San Joaquin River flows of about 1,000 cfs were made in November, December, and March.

Figure B-2 shows the DailyOPS model calculations of export limits and Delta outflow conditions for water year 1987 with the existing SWP pumping limit of 6,680 cfs. There are four different export limits that are calculated in the model. The E/I limits are based on the 14-day moving average of inflow. The outflow limits are based on the required Delta outflow. The capacity limits are based on the CVP capacity and the 6,680-cfs SWP limit. The San Luis Reservoir limits are equal to the CVP and SWP deliveries once San Luis Reservoir is filled. The minimum of these four export limits controls the allowable daily total exports that are shown in as the green area on the graph.

The top graph reflects the E/I limits that shift from 65% in the months of October–January, to 45% in February (because the 8-river runoff index in January 1987 was low), to 35% in March–June, and back to 65% in July–September. The E/I limit is equal to the San Joaquin River inflow during the Vernalis Adaptive Management Plan (VAMP) period of April 15–May 15. The bottom graph shows the required Delta outflow, which is controlled by the X2 objectives in the February–June period. The CVP exports are shown with the yellow line and are generally equal to the CVP capacity except during the VAMP period. The CVP portion of San Luis Reservoir was filled in March and the CVP exports were equal to the CVP demands.

The historical CVP and total exports are shown for comparison. However, the historical 1987 Delta operations were controlled by D-1485, while the EWA simulations were made with D-1641 operating objectives. The simulated exports are also affected by the adjustments in the Sacramento River and San Joaquin River inflows that were made to match the CALSIM monthly values. For this example year of 1987, the existing 6,680-cfs SWP Banks capacity was a limiting factor controlling SWP exports only in the first half of October and in July and

August. These are, therefore, the only periods when SWP export pumping likely would have been increased with the proposed 8,500-cfs SWP Banks limit.

Figure B-3 shows the EWA gaming results for water year 1987 with the existing SWP Banks pumping capacity of 6,680 cfs. The historical pumping (red line), baseline D-1641 pumping (yellow area), and the EWA–adjusted pumping (brown line) are shown along with the historical SWP and CVP salvage densities (logarithmic scale) for Chinook salmon, delta smelt, splittail, and steelhead. This comparison of the SWP and CVP export pumping patterns with the historical fish density pattern illustrates the dilemma of Delta water operations and fish protection. The EWA was proposed and implemented as a method of making these two conflicting goals more compatible with each other.

For the 1987 gaming simulations, the major EWA actions to reduce export pumping were specified in March. Baseline D-1641 pumping was already low during the VAMP period, but the EWA protections reduced the exports slightly. EWA was simulated to purchase water from upstream and transfer it in late June and September. Table B-1 indicates that the reduced pumping for fish protection actions in 1987 was 68 taf at Tracy (assumed to be CVPIA b(2) water) and 130 taf at SWP Banks (assumed to be EWA water).

The CVP and SWP salvage densities are similar but not always identical. The gaming of EWA actions was usually based on the SWP salvage densities, and the calculations of the baseline salvage and the EWA protections were made with the SWP densities. Assuming that the daily pattern of fish density remained the same, the calculated Chinook salmon baseline D-1641 salvage was much less than the historical salvage. The October–March period is assumed to be spring- and winter-run Chinook salmon. The baseline salvage during this period was greater than historically. The combination of CVPIA b(2) and EWA actions reduced the 1987 annual salvage of Chinook salmon by 32% and reduced the 1987 October–March salvage by 27%. This is quite a high protection for Chinook salmon considering that only 4% of the total baseline exports were reduced by the CVPIA b(2) and EWA actions in 1987. This high level of protection was achieved because the March reductions in exports corresponded with relatively high Chinook salmon densities and the slight reduction in exports during the VAMP period corresponded with very high Chinook salmon densities.

These periods of CVPIA b(2) and EWA protections during 1987 also provided some protection for steelhead (25%). However, the simulated salvage of delta smelt was increased by 36% because the additional exports that were allowed in June and September (to transfer EWA purchased water from upstream) corresponded with high densities of delta smelt. The salvage of adult delta smelt in the October–March period was also increased by 7% because of the periods of increased pumping (E/I relaxation) that was allowed in January.

Splittail salvage was increased by 59% because of the historical salvage in June and September. Figure B-4 shows the same graphs for 1987 with the SWP Banks pumping capacity increased to 8,500 cfs. Although the baseline exports were slightly higher during a couple of periods of increased SWP Banks pumping

(October and March), the fish protection achieved was almost identical to that achieved with the EWA gaming with the existing 6,680-cfs capacity. The major EWA protections were specified in March and during VAMP. Table B-1 indicates that the total salvage numbers were within a few percent of the 6,680-cfs EWA game values.

Figure B-5 provides another example of the simulated EWA actions for 1988 with a SWP Banks capacity of 6,680 cfs. The EWA and CVPIA b(2) actions were taken in December and January to protect winter/spring-run Chinook salmon and delta smelt adults. Protections for steelhead and splittail were also provided in these periods. Water year 1988 was a very dry year, and allowable export pumping was very limited during the spring and summer. Total simulated fish protections cut CVP exports by 152 taf and SWP exports by 173 taf, which was about 10% of the total baseline exports for 1988 with SWP Banks capacity of 6,680 cfs.

The 1988 annual Chinook salmon salvage reduction was only 4% from the baseline, although the baseline (D-1641 objectives) reduced Chinook salmon salvage to only 37% of historical salvage in 1988. A somewhat larger reduction (11%) in the October–March Chinook salmon salvage was achieved with the 1988 EWA simulation. A 19% reduction in delta smelt was achieved, and a 53% reduction in adult delta smelt was achieved by the simulated EWA actions in December and January. A 12% reduction in splittail salvage during 1988 was achieved primarily by the January cuts.

Figure B-6 shows the simulated EWA actions for the assumed increased 8,500-cfs SWP Banks capacity in 1988. The baseline D-1641 pumping was increased only slightly in December and in January because the inflows were generally low in 1988. The simulated CVP reductions with CVPIA b(2) water remained the same, and the same fish protections at the SWP facility required 287 taf of EWA water (114 taf more than the 6,680-cfs game). Table B-1 indicates that the EWA annual salvage numbers with the 8,500-cfs capacity were very close to the 6,680-cfs EWA annual salvage values.

Summary of EWA Annual Fish Salvage Protection

Figure B-7 shows the annual SWP exports for the baseline D-1641 and EWA gaming simulation compared with the historical exports for these 17 simulated years with the existing SWP capacity of 6,680 cfs. The purpose of these EWA simulations was to determine the general size of the EWA account that would likely provide the level of fish protections considered adequate by the fish protection agencies. The CVPIA b(2) and EWA reductions are shown with the blue bars. Figure B-8 shows the annual CVP exports for the baseline D-1641 and the CVPIA b(2) gaming results.

Figures B-7 and B-8, as well as Table B-1, indicate that the annual EWA cuts in SWP exports averaged about 240 taf, and the annual CVP cuts (assumed to be provided with CVPIA b(2) water) averaged about 200 taf. Some years required much larger cuts. As a percentage of the total CVP and SWP exports, these simulated EWA and CVPIA b(2) reductions ranged from 3% to 17%, with an average of 8%. The simulated credits represent pumping that was shifted to periods of reduced fish density, relaxations, and assumed north-of-Delta purchases that were simulated as increased inflows. South-of-Delta EWA purchases were tracked in the gaming as reduced SWP demands to maintain the simulated baseline D-1641 SWP San Luis Reservoir storage pattern, but are not included in the credits. The simulated CVP cuts using CVPIA b(2) water were assumed to reduce the CVP deliveries. The simulated SWP and CVP exports simulated for the D-1641 Delta objectives are compared with the historical exports to indicate the changes in allowable pumping under D-1641.

Annual graphs for the fish salvage protection achieved in the EWA gaming with 6,680-cfs SWP Banks pumping capacity indicate the most recent estimates of the EWA and CVPIA b(2) actions for the 17 years that have been gamed (1981–2001, without wet years of 1983, 1995, 1996 and 1998). These salvage values are calculated in the daily EWA model using the daily historical SWP salvage densities and the simulated daily exports. The historical CVP salvage densities are used for a second estimate of salvage in the gaming, but are not shown here. Historical salvage calculations are shown to indicate the fish salvage protection achieved with the D-1641 objectives, but may also reflect increased salvage when the simulated baseline exports were greater than historical exports.

Figure B-9 shows the annual total Chinook salmon salvage values for the baseline D-1641 and with EWA and CVPIA b(2) actions assuming 6,680-cfs SWP Banks capacity. The percent reductions in salvage are indicated by the bars. An overall reduction of 32% was achieved, with the baseline annual average salvage of 200,000 Chinook salmon reduced to an annual average of 135,000 Chinook salmon with the CVPIA b(2) and EWA export reductions (Table B-2).

Figure B-10 shows the assumed spring/winter-run Chinook salmon salvage (October–March) comparisons indicating the percentage reductions assuming 6,680-cfs SWP Banks capacity. An overall reduction of 17% was achieved for these spring/winter-run Chinook salmon. The annual average baseline salvage of 47,000 was reduced to an annual average of 39,000 with the CVPIA b(2) and EWA actions (Table B-3).

Figure B-11 shows the annual delta smelt salvage values for the baseline and the EWA gaming results, assuming 6,680-cfs SWP Banks capacity with the percent reductions shown as bars. The historical values are shown for comparison. An average reduction of 48% was achieved with the EWA and CVPIA b(2) actions (Table B-4). Figure B-12 shows the comparison for the October–March adult delta smelt salvage calculations assuming 6,680-cfs SWP Banks capacity (Table B-5). An average reduction of 19% was simulated for these adult delta smelt. The annual average baseline salvage of 10,600 fish was reduced to an annual salvage of 8,600 fish.

Figure B-13 shows the annual salvage values for splittail, assuming 6,680-cfs SWP Banks capacity. An average reduction of 28% was simulated, although this average reduction was dominated by the huge salvage in 1986 (Table B-6). The annual average baseline salvage of 242,000 was reduced to an annual average of 176,000 with the CVPIA b(2) and EWA actions.

Figure B-14 shows the annual salvage values for steelhead assuming 6,680-cfs SWP Banks capacity. The annual average baseline salvage of 11,000 was reduced to an annual average of 9,000 with the CVPIA b(2) and EWA actions (Table B-7) for an average reduction of 18%.

Simulated Changes in EWA with 8,500-cfs SWP Capacity

Table B-1 also gives the annual simulated CVP and SWP exports and EWA and CVPIA b(2) export reductions for the same set of fish protection actions, but using the proposed 8,500-cfs SWP Banks pumping limit. The CVP and SWP deliveries were taken from the CALSIM D-1641 simulations. The total change in SWP and CVP exports for baseline D-1641 Delta operations with the 8,500-cfs SWP Banks limit was 115 taf. This indicates the magnitude of the potential yield increase from the higher pumping limit. The simulated increase in the EWA cuts needed to provide the same pumping levels during the weeks of EWA and CVPIA b(2) protections averaged about 25 taf. This suggested that the increase in the size of the EWA account (i.e., assets) to compensate for the higher baseline pumping that might be allowed with the 8,500-cfs limit was only about 25 taf. As already shown for 1987 and 1988, the periods when the pumping could actually be raised with the higher SWP Banks pumping capacity are relatively limited in most years. A moderate increase in the EWA assets would allow the same level of fish protection with the increased 8,500-cfs pumping capacity.

Tables B-2–B-7 show the annual fish salvage calculations for the simulations of the same EWA and CVPIA b(2) actions, but with the proposed 8,500-cfs SWP Banks pumping limit. The simulated reductions in annual or seasonal fish salvage numbers were very similar for all fish that were tracked in the EWA gaming simulations.

Comparison of Recent Years of Simulated EWA Operations

Interactive EWA gaming sessions were used to simulate EWA actions under the existing D-1641 Delta objectives and evaluate the changes between the 6,680-cfs capacity and the 8,500-cfs capacity for the recent years of 1997 and 1999–2003. The CVP and SWP Delta operations in these years were controlled by D-1641 and provide an opportunity to compare the DailyOPS gaming model results with historical operations under D-1641. The actual EWA operations in 2001, 2002 and 2003 also can be compared with the gaming session results. These simulations of recent years did not use CALSIM monthly deliveries and Delta inflows because the CALSIM planning model only simulates the period of 1922–1994. The historical deliveries and Delta inflows were used in these gaming sessions, although some adjustments were made by the CVP and SWP staff participants to adjust reservoir operations to be consistent with the assumed 8,500-cfs capacity.

Figure B-15 shows the baseline exports and EWA protections patterns as simulated for the 6,680-cfs capacity for 1997. The bottom graph shows the resulting Delta outflow for the baseline and EWA protections. The baseline pumping generally was limited by outflow requirements in the fall and summer, but was limited by deliveries during the winter period because the SWP portion of San Luis Reservoir was filled at the end of November, and the CVP portion filled by mid-January. No EWA actions were taken in December–February because the pumping was already limited. The high X2 outflow requirements limited exports during the second week of March. The EWA protections were simulated during VAMP and extended into the first week of June. Exports were at the maximum permitted pumping capacity (included 500-cfs increment for EWA) in July–September.

Figure B-16 shows the results of the EWA actions on the SWP and CVP San Luis Reservoir storage patterns. The cumulative reductions in CVP and SWP exports by the second week of June were about 380 taf. The EWA needed 300 taf south-of-Delta purchases and delayed delivery, along with the 500-cfs export allowance for north-of-Delta purchases in July–September to return the San Luis Reservoir storage to its baseline values by the end of the water year. The bottom graph compares the DailyOPS model exports to the historical exports for 1997. There was reasonable agreement through the VAMP period. Historical pumping was higher in June (because there were no EWA protections in historical 1999 conditions), and SWP pumping was lower in portions of July and August. The historical SWP San Luis Reservoir storage was about 500 taf lower than the EWA gaming simulations as a result.

Figure B-17 shows the SWP and CVP pumping and salvage density patterns for 1997. The peak Chinook salmon density of 100 fish/taf at SWP and CVP facilities occurred in the last week of March and first week of April, ahead of the VAMP period. The peak in delta smelt density of almost 1,000 fish/taf occurred in mid-May. Both Chinook salmon and delta smelt were special-status species with the May and early June export reductions. The highest densities are often observed within the mid-March to mid-June period, but anticipating the week(s) with the highest density within a year is a very difficult task for the staff guiding the EWA actions.

Figure B-18 shows the baseline exports and EWA protections patterns as simulated for the 6,680-cfs capacity for 2000. The bottom graph shows the resulting Delta outflow for the baseline and EWA protections. The baseline pumping was generally limited by a combination of the outflow requirements and the E/I ratio and the permitted pumping capacity in the fall months. Pumping was not limited by deliveries until February when the SWP portion of San Luis Reservoir was filled. CVPIA b(2) water was used to reduce both CVP and SWP exports in mid-December for a Chinook salmon code-wire tag (CWT) experiment and spring-run entrainment protection. An additional CVPIA b(2) action in late January for spring-run Chinook salmon reduced the CVP exports. These fish protection actions were "removed" in the baseline EWA gaming simulation. EWA actions were simulated in the gaming session in February 2000. EWA protections were also simulated during VAMP and extended into the third week of June. Exports were at the maximum permitted pumping capacity (included 500-cfs increment for EWA) in July–September.

Figure B-19 shows the results of the EWA actions on the SWP and CVP San Luis Reservoir storage patterns. The gaming did not include the December and January CVPIA b(2) actions, so San Luis Reservoir filled by the beginning of March. The cumulative reductions in CVP and SWP exports by the third week of June were about 550 taf. The EWA needed 250 taf south-of-Delta purchases and delayed delivery, along with the 500-cfs export allowance for north-of-Delta purchases in July–September to return the San Luis Reservoir storage to its baseline values by the end of the water year. A CVPIA b(2) use of 200 taf (reduced CVP deliveries) was assumed. The gaming CVP San Luis Reservoir storage was higher than historically, but the ending San Luis storage with EWA and CVPIA b(2) actions was close to historical values.

The bottom graph compares the DailyOPS model exports to the historical exports for 2000. The historical CVPIA b(2) actions in December and January were the major differences. Historical pumping was higher in February because there was no EWA protection.

Figure B-20 shows the SWP and CVP pumping and salvage density patterns for 2000. The peak Chinook salmon density of 500 fish/taf at SWP and CVP facilities occurred in April and May, during the VAMP period. The peak in delta smelt density of almost 1,000 fish/taf occurred in late May. The highest densities are often observed within the mid-March to mid-June period, but anticipating the week(s) with the highest density within a year is a very difficult task for the staff guiding the EWA actions.

Comparison of Actual 2001–2003 Environmental Water Account Actions

The first three years of actual EWA actions and accounting of EWA assets have been used to simulate the historical operations during these three years with the DailyOPS model. These results show that a good simulation of the EWA actions can be obtained using specified weekly "actions" that mimic the actual EWA decisions to reduce pumping to protect fish. The allowable exports and the EWA costs are reasonably well simulated with the DailyOPS model. The allowable pumping with the same EWA actions, but with the 8,500 cfs SWP Banks pumping limit, are shown and described in the following section.

2001 Environmental Water Account Actions

Figure B-21 shows the allowable D-1641 export limits for water year 2001. The DailyOPS model results for the baseline conditions with historical inflows are shown as the red line for total pumping and the black line for CVP pumping. The exports were limited by the required outflow and the E/I ratio for most of the year. The EWA was implemented for the first time in 2001. Fish protection actions were taken in the winter (January–March) and during the VAMP period that was extended through May. The reported EWA actions totaled 290 taf from January to June of 2001. The simulated SWP export reductions for EWA amounted to 300 taf, with a shifted pumping of 125 taf in the second half of March, for a net EWA use of 175 taf. The simulated CVP reductions during VAMP were about 125 taf, using CVPIA b(2) water. The total reduction in exports was therefore about 300 taf, which was about 5.5% of the 5,390 taf that was the simulated D-1641 baseline pumping. The historical pumping of 4,936 taf was just a little less (156 taf) than the simulated exports of 5,092 taf with the EWA and VAMP actions. This is a very close match between the historical pumping and the DailyOPS simulated pumping with CVPIA b(2) and EWA actions.

Figure B-22 shows the simulated and historical San Luis Reservoir storage patterns. The CVP portion of San Luis Reservoir was filled by mid-December, and the SWP portion was filled in mid-March. The simulated storage pattern with the EWA actions was quite close to the historical storage patterns. The bottom graph shows that the simulated exports were similar to the historical exports. It can be seen from this graph that the opportunity to use a higher SWP pumping capacity was limited in 2001. The only period with enough Delta inflows to allow 8,500 cfs of SWP pumping would have been in the January–March period. However, EWA fish protections were scheduled for several of these weeks, including the first two weeks of March. Higher pumping limits would have allowed higher pumping in some of the other weeks to reduce the EWA debt and fill San Luis Reservoir earlier in March. Higher SWP pumping limits in the summer would not have increased exports because they were limited by required Delta outflows in 2001.

Figure B-23 shows the SWP and CVP fish salvage densities, along with the historical pumping and simulated D-1641 and EWA pumping patterns for 2001. Steelhead were relatively abundant (more than 20 fish/taf) in February and March. Chinook salmon densities were high in April and May, with maximum densities of 500–1,000 fish/taf. Delta smelt densities were greater than 100 fish/taf in May. The simulated SWP and CVP export reductions were similar to the historical accounting for the EWA and the CVPIA b(2) actions. The simulated reductions in fish salvage from the D-1641 baseline pumping to the EWA and CVPIA b(2) conditions (with VAMP) were about 32% for Chinook salmon, 8% for steelhead, 6% for splittail, and 61% for delta smelt.

2002 Environmental Water Account Actions

Figure B-24 shows the simulated D-1641 baseline and with CVPIA b(2) and EWA actions for water year 2002, which was the second year of actual EWA implementation. The DailyOPS model results for the baseline conditions with historical inflows are shown as the red line for total pumping and the black line for CVP pumping. The exports were limited by the required outflow and the E/I ratio for most of the year. Fish protection actions were taken in the first week of December, the first week of January, and during the VAMP period that was extended through May. The reported EWA actions totaled 290 taf (including 70 taf for CVP pumping during the extended VAMP) for water year 2002.

The simulated SWP export reductions for EWA amounted to 190 taf, with a shifted pumping of 100 taf in the second half of February and the first half of March, for a net EWA use of 90 taf. The simulated CVP reductions during the extended VAMP were about 85 taf, using CVPIA b(2) water and some EWA water. The total simulated reduction in exports was therefore about 275 taf, which was about 5% of the 5,568 taf that was the simulated D-1641 baseline pumping for 2002. The historical pumping of 5,379 taf was just a little less (65 taf) than the simulated exports of 5,444 taf with the EWA and VAMP actions. This is a very close match between the historical pumping and the DailyOPS simulated pumping with CVPIA b(2) and EWA actions. The DailyOPS model provides a very close simulation of allowable exports for the historical inflows and using the historical monthly SWP and CVP deliveries.

Figure B-25 shows the simulated and historical San Luis Reservoir storage patterns for 2002. The CVP portion of San Luis Reservoir was filled by late January, and the SWP portion was filled by mid-March. The simulated storage pattern with the EWA actions was quite close to the historical storage patterns. The bottom graph shows that the simulated exports were very similar to the historical exports. It can be seen from this graph that there would have been some opportunity to use a higher SWP pumping capacity in December and January of water year 2002. Although fish protection actions were taken in both months, higher pumping outside these protections would have allowed San Luis to fill earlier, reducing the pumping earlier in March. Higher pumping might also have been helpful in July and August, although Delta outflow requirements limited pumping in September.

Figure B-26 shows the SWP and CVP fish salvage densities, along with the historical pumping and simulated D-1641 and EWA pumping patterns for 2002. Delta smelt were relatively abundant (more than 20 fish/taf) in early January (EWA action taken). Chinook salmon densities were high in April and May, but with maximum densities of only 100–200 fish/taf. Delta smelt densities at the CVP salvage facilities were greater than 100 fish/taf in May. The delta smelt densities at the SWP salvage facility were greater than 1,000 fish/taf in late May (EWA extended VAMP). The simulated SWP and CVP export reductions were similar to the historical accounting for the EWA and the CVPIA b(2) actions. The simulated reductions in fish salvage from the D-1641 baseline pumping to the EWA and CVPIA b(2) conditions (with VAMP) were about 23% for Chinook salmon, -9% (loss) for steelhead, 5% for splittail, and 54% for delta smelt for 2002. The fact that these percentage salvage reductions were much higher than the percentage export reductions (5%) is the result of scheduling the protections to correspond to period with the highest salvage densities for Chinook salmon and delta smelt. The potential effects on the surviving populations of these fish species are unknown.

2003 Environmental Water Account Actions

Figure B-27 shows the simulated D-1641 baseline with CVPIA b(2) and EWA actions for water year 2003, which was the third year of actual EWA implementation. Fish protection actions were taken in the last week of December, the third and fourth weeks of January, during VAMP, and the second half of May to extend VAMP. The reported EWA actions totaled 325 taf for water year 2003. Relaxation of E/I and "State Gain" credits in March yielded 50 taf, and about 50 taf of EWA water was transferred to Oroville during the summer.

The simulated SWP export reductions for EWA amounted to 325 taf, with about 75 taf of summer exports of EWA water under the 7,180-cfs limit. The total simulated reduction in exports was about 5% of the 6,208 taf that was the simulated D-1641 baseline pumping for 2003. The historical pumping of 6,143 taf was higher (300 taf) than the simulated exports of 5,850 taf with the EWA and VAMP actions. This difference was caused by two periods of simulated outflows for X2 at Roe Island in early February and early March that did not occur in the historical operations. Except for this difference in allowable pumping associated with the X2 requirement, the DailyOPS model provides a very close simulation of allowable exports for the historical inflows and historical monthly SWP and CVP deliveries.

Figure B-28 shows the simulated and historical San Luis Reservoir storage patterns for 2003. The CVP portion of San Luis Reservoir was filled by late January, but the SWP portion was not quite filled by the beginning of VAMP. The bottom graph shows that the simulated exports were very similar to the historical exports. It can be seen from this graph that there would have been some opportunity to use a higher SWP pumping capacity in the winter and early spring of water year 2003. Although fish protection actions were taken in December and January, higher pumping outside these protections may have allowed San Luis Reservoir to fill earlier. Higher pumping might also have been helpful in July and August, although Delta outflow requirements limited pumping in September.

Figure B-29 shows the SWP and CVP fish salvage densities, along with the historical pumping and simulated D-1641 and EWA pumping patterns for 2003. Delta smelt were relatively abundant (more than 20 fish/taf) in late December and through January (EWA action taken). Chinook salmon densities were high in mid-January (EWA action taken), and in April and May, but with maximum densities of only 100 fish/taf. Delta smelt densities at the CVP salvage facilities were greater than 100 fish/taf in May. The delta smelt densities at the SWP salvage facility were approaching 1,000 fish/taf in late May (EWA extended VAMP). The simulated SWP and CVP export reductions were similar to the historical accounting of EWA and the CVPIA b(2) actions. The simulated reductions in fish salvage from the D-1641 baseline pumping to the EWA and CVPIA b(2) conditions (with VAMP) were about 18% for Chinook salmon, 12% for steelhead, 6% for splittail, and 56% for delta smelt for 2003. The fact that these percentage salvage reductions were much higher than the percentage export reductions (5%) is the result of scheduling the protections to correspond to the period with the highest salvage densities for Chinook salmon and delta smelt. The potential effects on the surviving populations of these fish species, however, are unknown.

Historical Environmental Water Account Actions with 8,500-cfs Pumping Limit

The possible additional pumping that would have occurred with historical inflows and historical EWA actions for these first three years of actual EWA implementation were simulated with the DailyOPS model. Figure B-30 shows that in 2001, the opportunity for increased pumping in December, January, and March would have allowed San Luis to fill earlier, and reduced pumping in late March would have been beneficial for the increasing salvage densities of Chinook salmon and moderate salvage densities of delta smelt. Although the baseline pumping was often above 6,680 cfs during the December 15–March 15 period of 2001, an increment to the historical EWA in 2001 would have been required to provide the same EWA pumping protections for 4 weeks of EWA cuts in December, January, and early March.

Figure B-31 shows that in 2002, the opportunity for increased pumping in December and January would have allowed San Luis to fill earlier and reduced pumping in all of March. Although the Chinook salmon and delta smelt densities were relatively low, reduced pumping in March may have been beneficial for allowing more delta smelt spawning in the central Delta to escape the influence of pumping. EWA protection during 2002 was provided for a week in December and a week in January, with the majority of entrainment protection during VAMP and the post-VAMP period of late May. Only the EWA actions in December and January would have required more assets. Some additional pumping with the 8,500-cfs limit would have been allowed in July and August. There was considerable remaining export capacity in August and September for water transfers.

Figure B-32 shows that in 2003, the opportunity for increased pumping in January, February, and March still would not have allowed SWP San Luis to fill (CVP San Luis filled in February). EWA actions in December and January would have required more assets with the increased pumping limit. The majority of EWA actions were taken in VAMP and late May to protect delta smelt and Chinook salmon. The late-May actions also would have required additional

EWA assets with the 8,500-cfs pumping limits. Some additional pumping with the 8,500-cfs limit was allowed in July, August, and September. There was considerable remaining export capacity in August and September for water transfers.

The additional EWA assets that may be needed to provide the same EWA protections under the proposed SWP Banks limit of 8,500 cfs will depend on the actual sequence of Delta inflows and the periods of EWA protections. For these first three years of actual EWA actions, the additional EWA assets that would have been required are estimated to be between 50 taf and 75 taf.

Conclusions from Interactive Environmental Water Account Gaming Simulations

The interactive EWA gaming model sessions provided a realistic simulation of baseline D-1641 CVP and SWP Delta operations and allowed potential EWA actions for fish entrainment protection to be explored and evaluated. The daily EWA model used information from the latest CALSIM monthly planning model as well as the historical daily Delta inflows to calculate daily allowable export pumping subject to the D-1641 (1995 Bay-Delta WQCP) objectives and operating constraints. The historical CVP and SWP salvage data were used to illustrate periods of high abundance (salvage density) for Chinook salmon, delta smelt, splittail, and steelhead. A monthly accounting of EWA actions to protect fish (e.g., export reductions) and to purchase water to replace the water supply reductions caused by pumping restrictions followed the assumed EWA budget and strategy. The results from the EWA gaming were used to formulate the original EWA program, as described in the 2000 CALFED ROD.

Using the historical SWP Skinner salvage records, the EWA gaming sessions demonstrated substantial reductions in the calculated salvage of these four fish species. The annual salvage results from the EWA gaming with both the current SWP pumping limits (6,680 cfs) and the proposed increase to 8,500-cfs capacity are given in Tables B-1–B-7. There are large differences from year to year in the Delta hydrology and the salvage density pattern for each fish. Nevertheless, the simulated EWA actions were able to reduce the annual salvage of these species substantially. The amount of water used for EWA actions was generally about 5% to 10% of the annual exports. Some of these reductions were assumed to be CVPIA b(2) water, and some would be made up with shifted exports in the weeks following the export reductions. The required water purchase amounts have not been identified in this summary of the EWA gaming, because the focus of this appendix was on the likely export changes with EWA actions.

The reductions in calculated fish salvage that would likely be achieved for special-status species with these carefully timed weeks of simulated CVPIA b(2) and EWA export restrictions were often more than 20% of the D-1641 baseline salvage numbers. The simulated baseline salvage values were often less than the historical salvage numbers, because the D-1641 (1995 WQCP) objectives for X2, E/I ratio, and the VAMP period (exports equal to San Joaquin River inflow) have provided substantial fish entrainment protection compared to the D-1485 objectives. It is not possible, however, to accurately translate these export entrainment reductions into estimates of the likely effects on the populations of these fish species. This should be an important next step in the evaluation of EWA effectiveness.

One of the benefits of the interactive EWA gaming sessions was to provide an opportunity for the CVP and SWP operations staff and DFG, NOAA Fisheries, and USFWS technical staff to sit in the same room and view the same projected graphics showing the upstream and San Luis Reservoir operations, Delta flows, export pumping, and fish salvage numbers. Viewing daily water conditions and fish salvage numbers in the same place at the same time was a very realistic setting for the adaptive management decisions that are the trademark of the EWA. The water project and fisheries staff became more familiar with the seasonal as well as the unpredictable nature of the runoff conditions and the fish abundance patterns in the Delta. The wide range of natural conditions and the general principles for water management and fish entrainment protection actions were better understood after the gaming sessions.

The potential effects of the proposed 8,500-cfs SWP pumping limit were evaluated in EWA gaming sessions that took place during 2001 and 2003. In comparison with the CALSIM monthly model results, the daily modeling of allowable exports with adjusted historical inflows and D-1641 objectives and operating constraints provided a very accurate and realistic picture of the daily variations in runoff and allowable pumping. The simultaneous display of historical CVP and SWP fish salvage patterns provided the ability to simulate weekly EWA actions, with subsequent higher pumping in weeks following the EWA actions. The net monthly effects of these short-term actions on exports were reported in the DailyOPS model. This is simply not possible with the CALSIM monthly model.

The gaming sessions allowed the monthly CALSIM exports to be compared to more accurate daily pumping values. The CALSIM CVP exports are generally accurate because the CVP pumping is very steady at capacity in almost all months. It was generally found that CALSIM monthly SWP pumping was about 10% higher than the daily values during the winter and spring when runoff events produce considerable inflow (and allowable export) variations. The monthly SWP averages were more accurate during summer and fall periods when the daily variations in Delta inflows are relatively small. The CALSIM SWP export values may be 5% to 10% higher than actual daily values, although the variations between different years (which is the primary goal of the CALSIM modeling) are more likely to be reliable.

The daily simulations, using adjusted historical inflows and D-1641 baseline, demonstrated that opportunities to use the proposed 8,500-cfs SWP pumping capacity would not likely require the EWA assets to be increased dramatically to provide the same level of pumping during weeks of EWA protections. The higher pumping limits would require a larger use of EWA water, but would also allow pumping to recover following periods of EWA protection and would allow San Luis Reservoir to fill earlier in many years (eliminating some of the EWA debt). The higher pumping during the July–September window would allow more upstream EWA water, as well as other potential transfers, to be exported during these peak water supply demand months, without increased fish entrainment losses.

Table B-1. Summary of Annual Exports and CVPIA b(2) and EWA Actions with 6,680 cubic feet per second (cfs) and 8,500 cfs

Water Year	Historical Exports (taf)	6,680 cfs Baseline Exports (taf)	6,680 cfs B2 Cuts (taf)	6,680 cfs EWA Cuts (taf)	6,680 cfs Total Cuts (%)	8,500 cfs Baseline Exports (taf)	8,500 cfs B2 Cuts (taf)	8,500 cfs EWA Cuts (taf)	8,500 cfs Total Cuts (%)	8,500 cfs minus 6,680 cfs Exports	8,500 cfs minus 6,680 cfs EWA Cuts
1981	4,720	6,066	202	247	7	6,229	202	327	8	162	80
1982	4,619	7,175	398	298	10	7,423	398	263	9	248	-35
1983											
1984	3,827	5,660	210	300	9	5,781	210	294	9	121	-6
1985	5,469	5,998	268	197	8	6,186	268	244	8	188	47
1986	5,284	5,931	318	334	11	5,955	317	363	11	25	29
1987	5,041	4,845	68	130	4	5,056	68	194	5	211	63
1988	5,588	3,308	152	173	10	3,390	152	287	13	82	113
1989	5,965	4,507	58	252	7	4,729	58	244	6	222	-8
1990	5,806	3,110	97	88	6	3,142	97	125	7	32	37
1991	3,184	2,760	0	197	7	2,795	0	233	8	36	36
1992	2,907	2,893	0	152	5	2,919	0	175	6	27	22
1993	4,669	6,000	338	401	12	6,148	338	451	13	149	49
1994	3,996	4,856	38	102	3	4,909	38	108	3	53	7
1995											
1996											
1997	4,962	5,442	202	224	8	5,663	296	191	9	221	-33
1998											
1999	4,664	5,252	525	351	17	5,453	525	359	16	201	8
2000	6,137	6,523	332	361	11	6,355	317	365	11	-168	4
2001	4,938	5,392	198	317	10	5,530	198	352	10	138	35
Average	4,810	5,042	200	243	8	5,157	205	269	9	115	26

Table B-2. Summary of Annual Chinook Salmon Salvage for EWA with 6,680 cubic feet per second (cfs) and 8,500 cfs

Water Year	Historical Salvage (Fish)	6,680 cfs Baseline Salvage (Fish)	6,680 cfs EWA Salvage (Fish)	6,680 cfs EWA Reduced (Fish)	6,680 cfs EWA Reduced (%)	8,500 cfs Baseline Salvage (Fish)	8,500 cfs EWA Salvage (Fish)	8,500 cfs EWA Reduced (Fish)	8,500 cfs EWA Reduced (%)	8,500 cfs Base minus 6,680 cfs Base	8,500 cfs EWA minus 6,680 cfs EWA
1981	175,909	118,793	87,358	31,435	26	123,638	90,677	32,961	27	4,845	1,526
1982	450,293	674,511	487,924	186,587	28	683,281	503,329	179,952	26	8,770	-6,636
1983											
1984	226,281	235,495	161,920	73,575	31	235,126	161,972	73,154	31	-369	-420
1985	344,365	259,044	184,037	75,006	29	264,115	187,149	76,965	29	5,071	1,959
1986	969,224	1,153,811	734,589	419,222	36	1,153,446	738,494	414,952	36	-365	-4,270
1987	397,370	160,762	109,231	51,531	32	163,039	109,386	53,653	33	2,277	2,121
1988	335,266	123,232	117,881	5,351	4	126,897	120,296	6,600	5	3,665	1,249
1989	182,822	101,759	91,079	10,681	10	105,257	95,454	9,802	9	3,497	-878
1990	106,064	32,105	31,275	830	3	32,201	31,207	994	3	96	165
1991	65,586	40,862	37,822	3,039	7	41,608	37,822	3,785	9	746	746
1992	42,767	42,583	36,507	6,076	14	43,612	36,678	6,934	16	1,029	858
1993	14,299	27,373	16,769	10,605	39	28,586	17,115	11,471	40	1,213	866
1994	7,189	7,329	6,560	769	10	7,397	6,600	796	11	67	27
1995											
1996											
1997	29,959	38,637	23,857	14,781	38	38,667	23,745	14,922	39	30	141
1998											
1999	94,348	181,426	51,610	129,816	72	181,457	51,413	130,045	72	31	229
2000	70,451	110,126	56,155	53,970	49	110,251	56,665	53,586	49	126	-384
2001	55,235	98,062	51,886	46,176	47	98,411	52,358	46,054	47	349	-123
Average	209,849	200,348	134,498	65,850	33	202,176	136,492	65,684	32	1,828	-166

Table B-3. Summary of October–March Chinook Salmon Salvage for EWA with 6,680 cubic feet per second (cfs) and 8,500 cfs

Water Year	Historical Salvage (Fish)	6,680 cfs Baseline Salvage (Fish)	6,680 cfs EWA Salvage (Fish)	6,680 cfs EWA Reduced (Fish)	6,680 cfs EWA Reduced (%)	8,500 cfs Baseline Salvage (Fish)	8,500 cfs EWA Salvage (Fish)	8,500 cfs EWA Reduced (Fish)	8,500 cfs EWA Reduced (%)	8,500 cfs Base minus 6,680 cfs Base	8,500 cfs EWA minus 6,680 cfs EWA
1981	28,713	42,471	38,966	3,505	8	44,445	39,400	5,045	11	1,975	434
1982	116,784	147,412	128,208	19,204	13	149,183	131,848	17,335	12	1,771	3,640
1983											
1984	4,444	5,632	4,703	929	16	5,234	4,580	654	12	(398)	(123)
1985	65,227	83,967	77,060	6,907	8	89,038	80,036	9,002	10	5,071	2,976
1986	127,380	329,342	249,342	80,000	24	330,064	249,669	80,395	24	722	327
1987	9,908	15,097	11,059	4,037	27	17,255	11,097	6,158	36	2,159	38
1988	64,436	56,013	49,970	6,043	11	59,678	52,386	7,293	12	3,665	2,416
1989	22,161	20,258	14,550	5,708	28	22,191	17,059	5,132	23	1,933	2,509
1990	17,265	10,150	8,635	1,515	15	10,247	8,567	1,680	16	96	(68)
1991	8,237	7,686	4,647	3,039	40	8,097	4,647	3,450	43	411	0
1992	35,687	36,775	30,697	6,077	17	37,804	30,869	6,935	18	1,029	172
1993	4,752	5,404	4,243	1,162	21	5,485	4,177	1,308	24	81	(65)
1994	3,164	3,489	3,428	60	2	3,556	3,469	87	2	67	41
1995											
1996											
1997	4,292	3,610	3,610	0	0	3,630	3,630	0	0	20	20
1998											
1999	8,064	7,287	7,287	0	0	7,294	7,294	0	0	7	7
2000	16,456	12,767	11,183	1,584	12	11,108	10,042	1,066	10	(1,660)	(1,141)
2001	12,031	13,032	12,190	842	6	13,382	12,764	618	5	349	573
Average	32,294	47,082	38,811	8,271	18	48,099	39,502	8,598	18	1,018	691

Table B-4. Summary of Annual Delta Smelt Salvage for EWA with 6,680 cubic feet per second (cfs) and 8,500 cfs

Water Year	Historical Salvage (Fish)	6,680 cfs Baseline Salvage (Fish)	6,680 cfs EWA Salvage (Fish)	6,680 cfs EWA Reduced (Fish)	6,680 cfs EWA Reduced (%)	8,500 cfs Baseline Salvage (Fish)	8,500 cfs EWA Salvage (Fish)	8,500 cfs EWA Reduced (Fish)	8,500 cfs EWA Reduced (%)	8,500 cfs Base minus 6,680 cfs Base	8,500 cfs EWA minus 6,680 cfs EWA
1981	163,241	194,775	165,214	29,560	15	198,933	163,890	35,043	18	4,158	(1,325)
1982	22,178	46,630	43,742	2,888	6	48,062	47,348	713	1	1,431	3,606
1983											
1984	12,032	10,521	8,459	2,062	20	10,631	8,562	2,069	19	110	103
1985	25,383	18,613	15,065	3,549	19	19,123	15,341	3,782	20	509	276
1986	7,786	11,115	8,525	2,590	23	11,404	8,944	2,460	22	289	419
1987	49,954	15,547	21,090	(5,543)	(36)	17,035	22,454	(5,419)	(32)	1,488	1,363
1988	148,124	40,539	32,833	7,706	19	41,788	32,243	9,545	23	1,249	(590)
1989	25,256	15,996	14,918	1,078	7	16,935	15,737	1,198	7	939	819
1990	93,897	17,703	22,584	(4,881)	(28)	17,733	22,581	(4,848)	(27)	30	(3)
1991	37,477	28,687	33,134	(4,447)	(16)	28,841	33,139	(4,298)	(15)	154	5
1992	9,384	4,189	3,978	212	5	4,334	3,982	352	8	145	4
1993	51,412	113,328	66,298	47,030	41	120,749	69,359	51,390	43	7,421	3,060
1994	46,914	82,548	78,127	4,421	5	82,544	78,127	4,417	5	(4)	0
1995											
1996											
1997	55,051	73,578	22,124	51,454	70	73,623	21,561	52,062	71	46	(562)
1998											
1999	338,627	693,528	200,793	492,735	71	699,025	132,846	566,179	81	5,496	(67,947)
2000	123,555	76,455	27,209	49,245	64	179,459	63,458	116,001	65	103,004	36,249
2001	37,424	63,203	16,952	46,251	73	149,885	40,889	108,997	73	86,682	23,937
Average	73,394	88,644	45,944	42,701	48	101,183	45,909	55,273	55	12,538	(34)

Table B-5. Summary of October–March Delta Smelt Salvage for EWA with 6,680 cubic feet per second (cfs) and 8,500 cfs

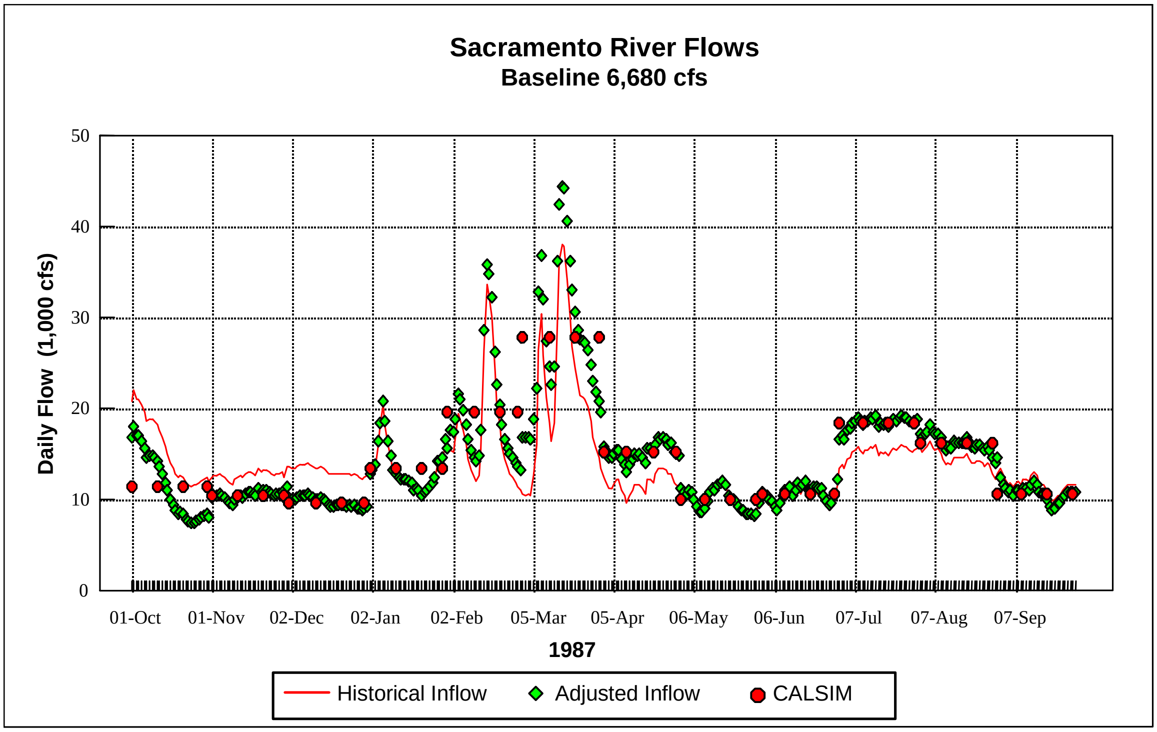
Water Year	Historical Salvage (Fish)	6,680 cfs Baseline Salvage (Fish)	6,680 cfs EWA Salvage (Fish)	6,680 cfs EWA Reduced (Fish)	6,680 cfs EWA Reduced (%)	8,500 cfs Baseline Salvage (Fish)	8,500 cfs EWA Salvage (Fish)	8,500 cfs EWA Reduced (Fish)	8,500 cfs EWA Reduced (%)	8,500 cfs Base minus 6,680 cfs Base	8,500 cfs EWA minus 6,680 cfs EWA
1981	52,830	89,376	74,856	14,520	16	92,741	72,114	20,627	22	3,366	(2,742)
1982	15,711	32,826	29,863	2,963	9	31,180	30,658	522	2	(1,645)	795
1983											
1984	102	147	148	(0)	(0)	150	150	(0)	-0	2	2
1985	2,650	4,051	3,618	433	11	4,514	3,845	669	15	463	227
1986	5,935	9,477	7,326	2,151	23	9,852	7,629	2,223	23	375	303
1987	2,068	4,259	4,539	(280)	(7)	4,371	4,559	(187)	-4	113	20
1988	19,271	16,058	7,561	8,497	53	17,305	6,971	10,334	60	1,247	(590)
1989	3,696	3,031	2,487	544	18	3,092	2,498	594	19	60	11
1990	2,794	724	658	66	9	754	655	99	13	29	(3)
1991	3,417	2,136	1,601	535	25	2,196	1,601	595	27	60	0
1992	2,659	2,104	1,395	709	34	2,249	1,400	849	38	145	4
1993	6,847	7,001	4,513	2,488	36	7,034	4,475	2,559	36	33	(37)
1994	466	855	868	(13)	(2)	911	920	(10)	-1	56	53
1995											
1996											
1997	500	468	468	0	0	471	471	0	0	2	2
1998											
1999	691	630	630	0	0	629	629	0	0	(0)	(0)
2000	11,740	4,061	3,698	364	9	7,412	7,373	39	1	3,351	3,675
2001	6,854	3,542	2,790	752	21	9,010	7,254	1,757	19	5,469	4,464
Average	8,131	10,632	8,648	1,984	19	11,404	9,012	2,392	21	772	364

Table B-6. Summary of Annual Splittail Salvage for EWA with 6,680 cubic feet per second (cfs) and 8,500 cfs

Water Year	Historical Salvage (Fish)	6,680 cfs Baseline Salvage (Fish)	6,680 cfs EWA Salvage (Fish)	6,680 cfs EWA Reduced (Fish)	6,680 cfs EWA Reduced (%)	8,500 cfs Baseline Salvage (Fish)	8,500 cfs EWA Salvage (Fish)	8,500 cfs EWA Reduced (Fish)	8,500 cfs EWA Reduced (%)	8,500 cfs Base minus 6,680 cfs Base	8,500 cfs EWA minus 6,680 cfs EWA
1981	25,074	29,086	22,216	6,870	24	29,607	20,723	8,884	30	521	(1,493)
1982	347,524	569,183	501,390	67,792	12	593,296	538,569	54,727	9	24,114	37,179
1983											
1984	126,352	146,257	136,525	9,732	7	149,640	139,958	9,682	6	3,383	3,433
1985	78,241	81,177	67,436	13,742	17	81,616	68,564	13,051	16	438	1,129
1986	2,375,154	2,664,364	1,716,738	947,626	36	2,664,592	1,717,629	946,963	36	228	891
1987	275,947	79,392	125,935	(46,543)	(59)	80,252	126,470	(46,218)	-58	860	536
1988	118,825	65,888	58,031	7,857	12	69,613	56,860	12,754	18	3,725	(1,171)
1989	82,133	62,819	60,515	2,305	4	65,069	65,042	27	0	2,250	4,528
1990	27,386	9,741	8,881	861	9	9,760	8,894	866	9	19	14
1991	44,101	27,438	27,345	93	0	27,826	27,345	481	2	388	0
1992	8,448	7,633	5,842	1,791	23	7,961	5,876	2,085	26	327	34
1993	100,990	177,895	112,363	65,531	37	174,062	113,552	60,509	35	(3,833)	1,189
1994	932	1,124	1,146	(23)	(2)	1,140	1,165	(25)	-2	16	18
1995											
1996											
1997	29,182	33,210	30,462	2,749	8	33,548	30,083	3,465	10	338	(379)
1998											
1999	27,746	31,040	28,664	2,376	8	33,200	30,449	2,751	8	2,161	1,786
2000	104,554	110,628	65,535	45,093	41	110,962	66,088	44,874	40	334	553
2001	17,837	15,729	14,921	808	5	15,731	15,309	422	3	2	389
Average	222,966	241,918	175,526	66,392	27	243,993	178,387	65,606	27	2,075	2,861

Table B-7. Summary of Annual Steelhead Salvage for EWA with 6,680 cubic feet per second (cfs) and 8,500 cfs

Water Year	Historical Salvage (Fish)	6,680 cfs Baseline Salvage (Fish)	6,680 cfs EWA Salvage (Fish)	6,680 cfs EWA Reduced (Fish)	6,680 cfs EWA Reduced (%)	8,500 cfs Baseline Salvage (Fish)	8,500 cfs EWA Salvage (Fish)	8,500 cfs EWA Reduced (Fish)	8,500 cfs EWA Reduced (%)	8,500 cfs Base minus 6,680 cfs Base	8,500 cfs EWA minus 6,680 cfs EWA
1981	16,682	23,655	20,668	2,987	13	25,569	21,811	3,758	15	1,914	1,143
1982	30,885	39,428	35,638	3,790	10	39,761	34,732	5,029	13	334	(906)
1983											
1984	883	713	345	368	52	720	352	368	51	7	7
1985	6,632	3,687	2,793	894	24	3,691	2,797	894	24	4	4
1986	4,060	3,053	1,775	1,278	42	3,053	1,775	1,278	42	0	0
1987	13,187	15,128	11,358	3,770	25	17,125	11,369	5,757	34	1,997	10
1988	11,723	3,878	3,834	44	1	3,898	3,827	71	2	20	(7)
1989	13,104	11,582	8,817	2,766	24	12,811	10,949	1,861	15	1,228	2,133
1990	7,881	2,824	2,194	630	22	2,824	2,194	630	22	0	0
1991	14,395	13,348	9,434	3,914	29	13,978	9,434	4,544	33	630	0
1992	17,209	16,540	12,007	4,533	27	17,429	12,119	5,309	30	889	112
1993	20,213	25,443	22,477	2,966	12	25,948	21,825	4,122	16	504	(652)
1994	966	1,573	1,491	82	5	1,618	1,538	79	5	45	47
1995											
1996											
1997	612	729	587	141	19	724	583	141	20	(5)	(5)
1998											
1999	2,170	3,385	1,569	1,816	54	3,398	1,582	1,816	53	12	13
2000	9,765	8,328	7,180	1,147	14	7,450	6,648	802	11	(878)	(533)
2001	12,572	14,331	11,802	2,529	18	15,258	12,234	3,024	20	927	432
Average	10,761	11,037	9,057	1,980	18	11,486	9,163	2,323	20	449	106



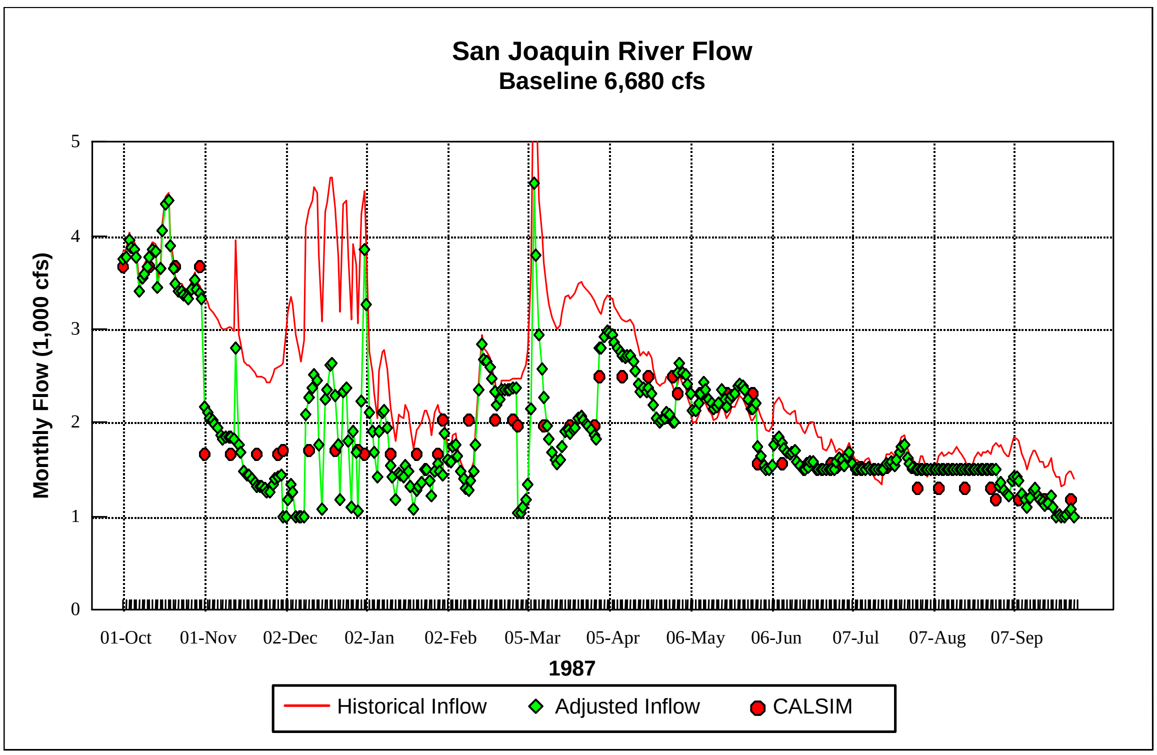


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Figure B-1

DailyOPS Model Adjustments to Sacramento and San Joaquin River Daily Inflows to Match CALSIM Monthly Inflows for Water Year 1987 with 6,680–cubic foot per second (cfs) SWP Pumping Limit

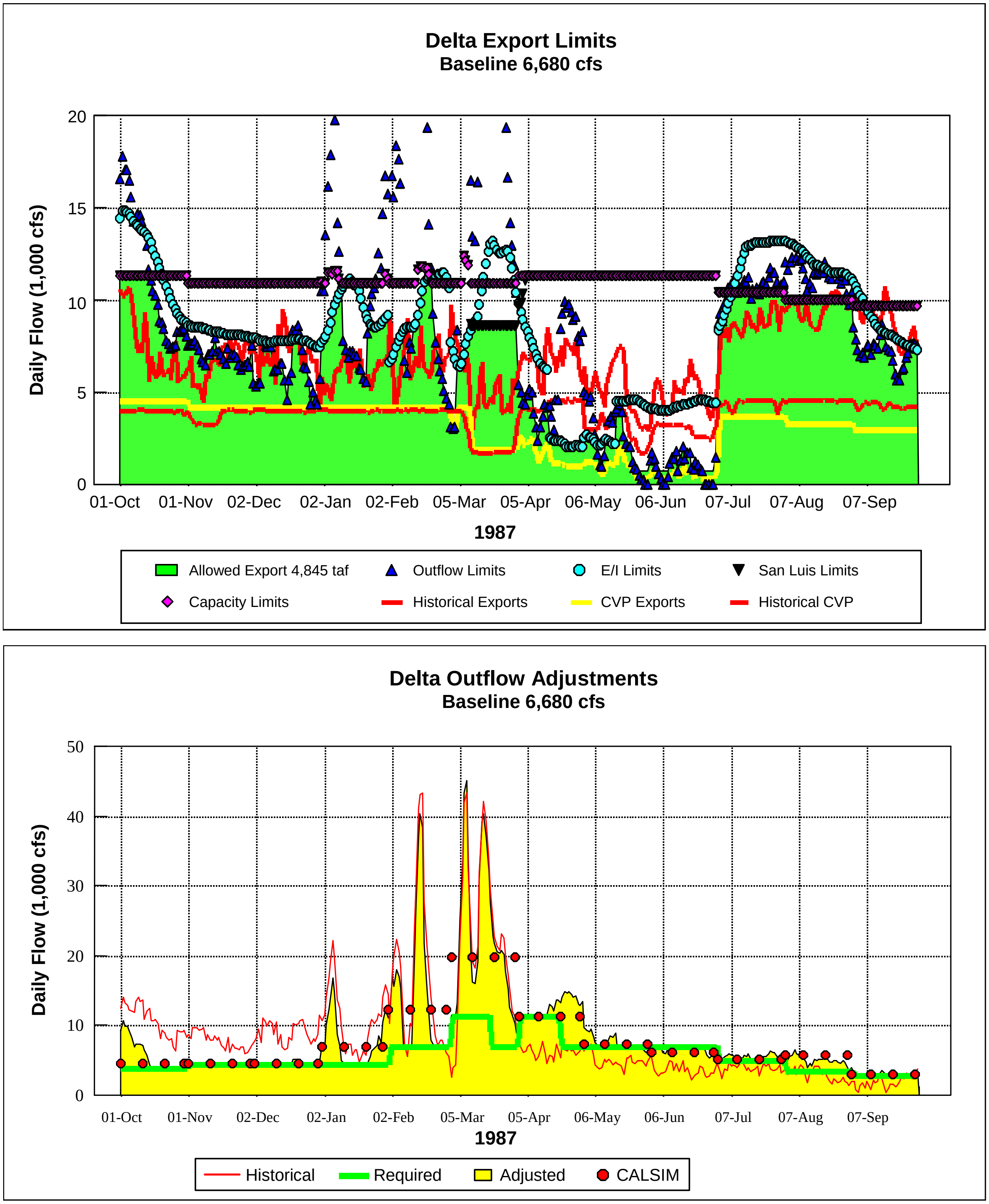

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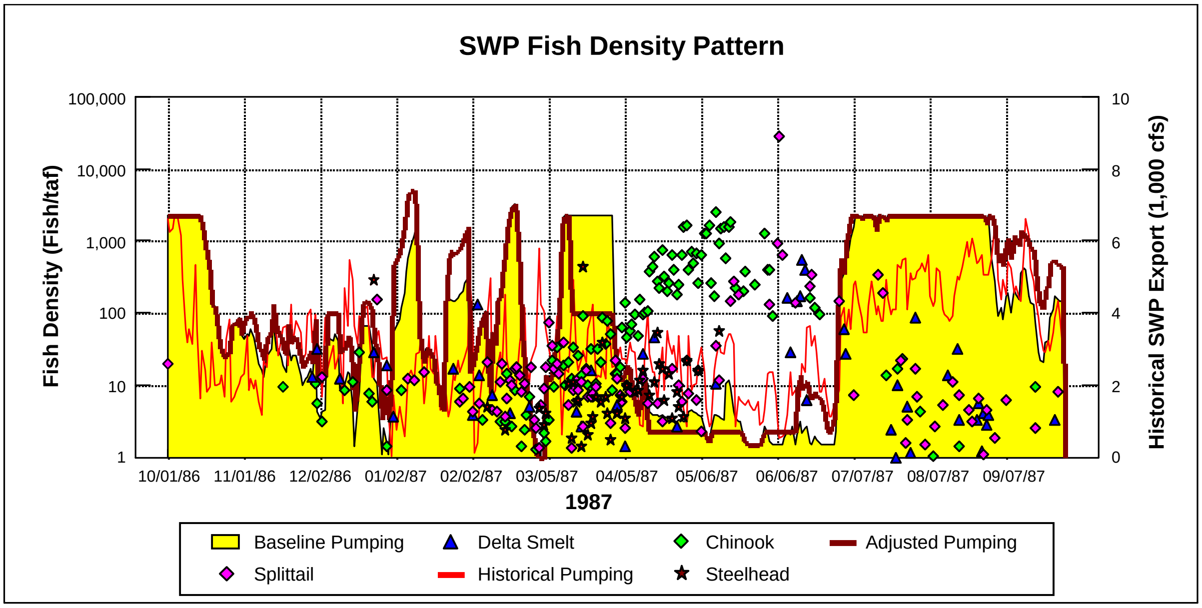
Figure B-2

DailyOPS Model Calculated Export Limits (Export/Inflows [E/I], Required Outflow, Capacity, San Luis) and Delta Outflow Conditions for Water Year 1987 with 6,680–cubic foot per second (cfs) SWP Pumping Limit



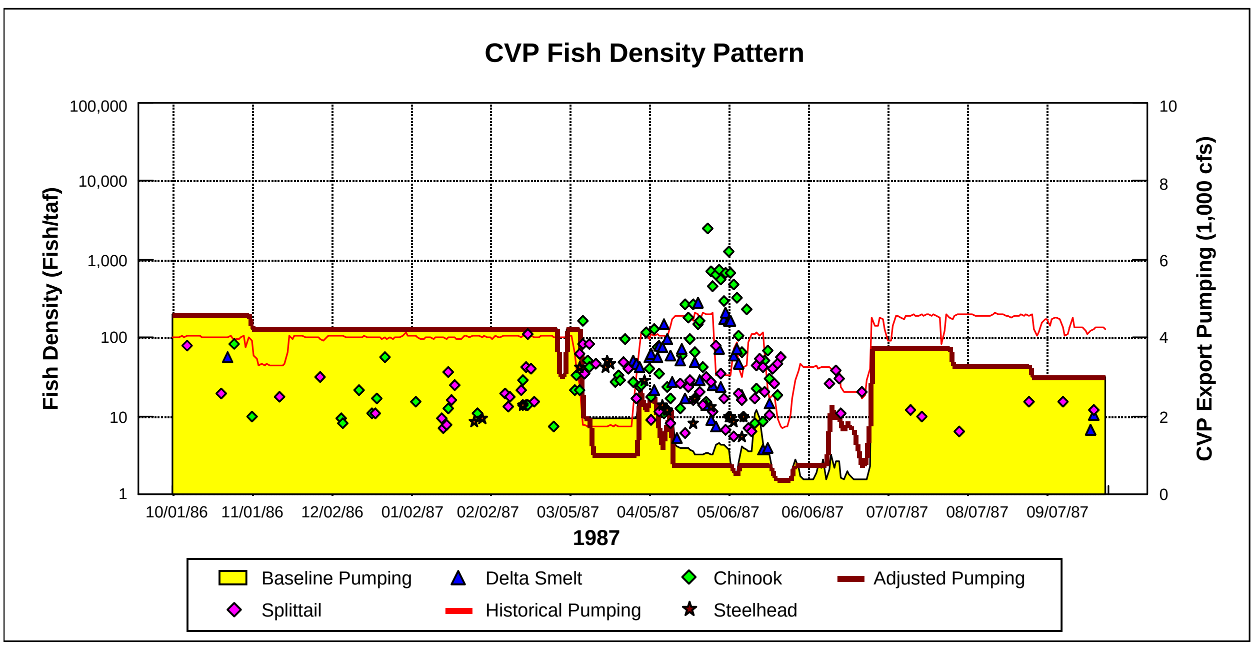


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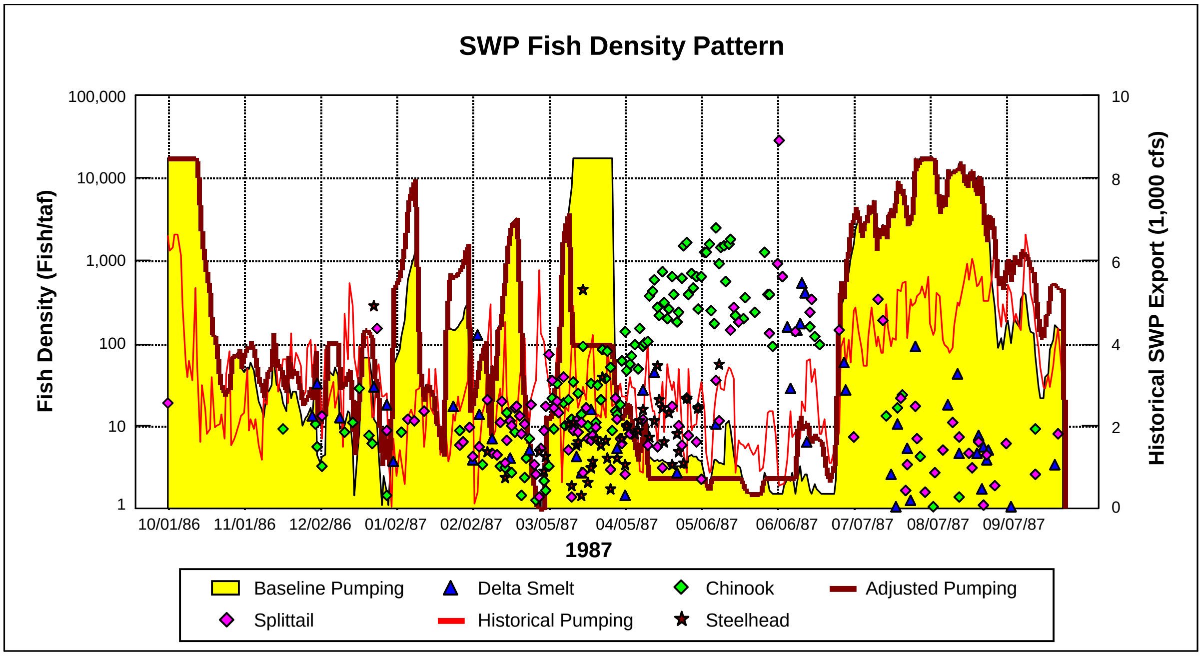
Figure B-3

EWA Gaming Results for 1987 with SWP Banks Pumping Capacity of 6,680 cubic feet per second (cfs)



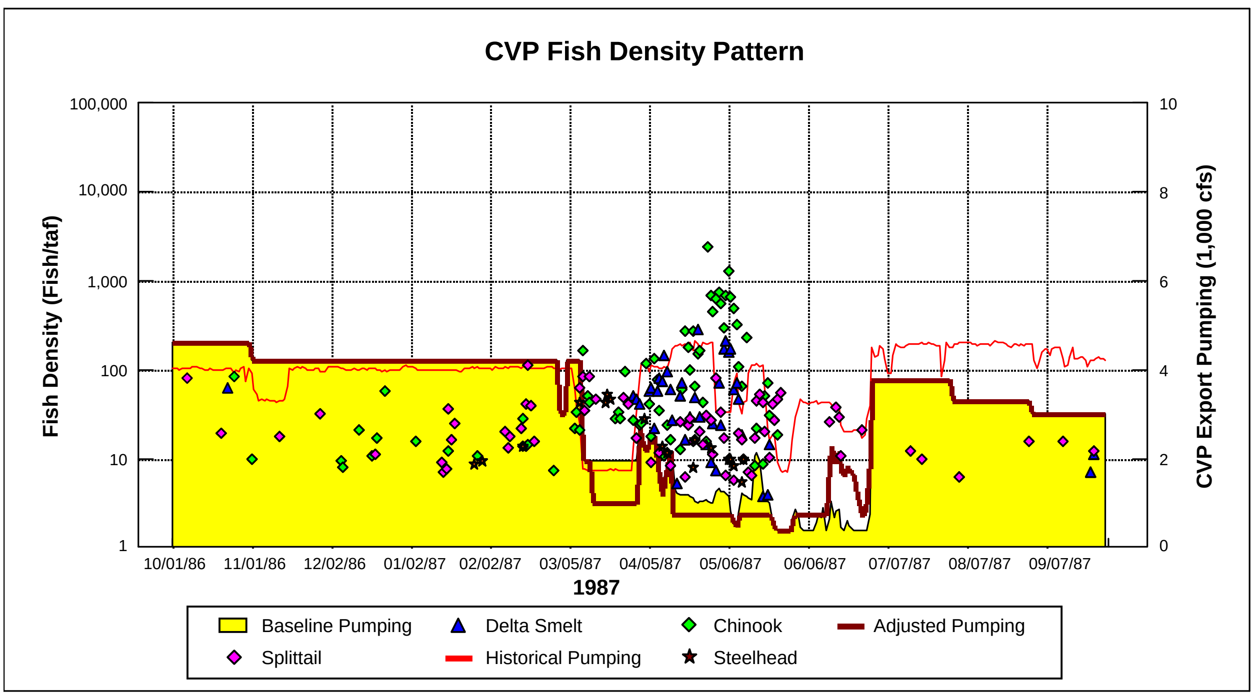


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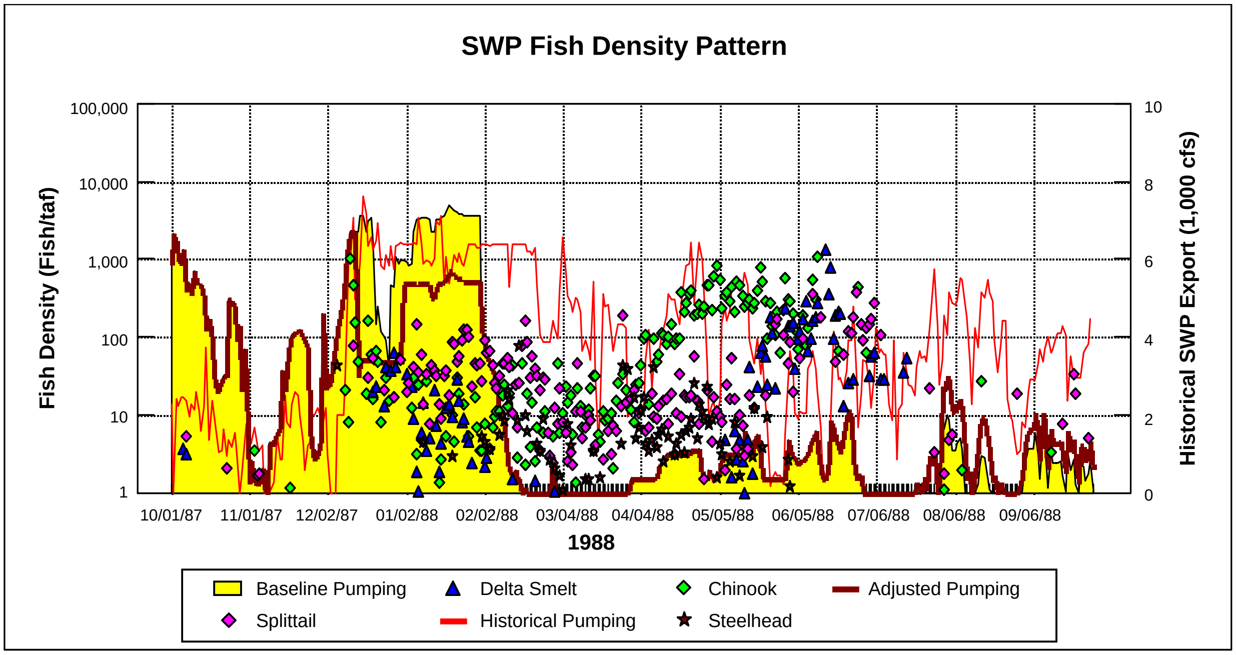
Figure B-4

EWA Gaming Results for 1987 with SWP Banks Pumping Capacity of 8,500 cubic feet per second (cfs)



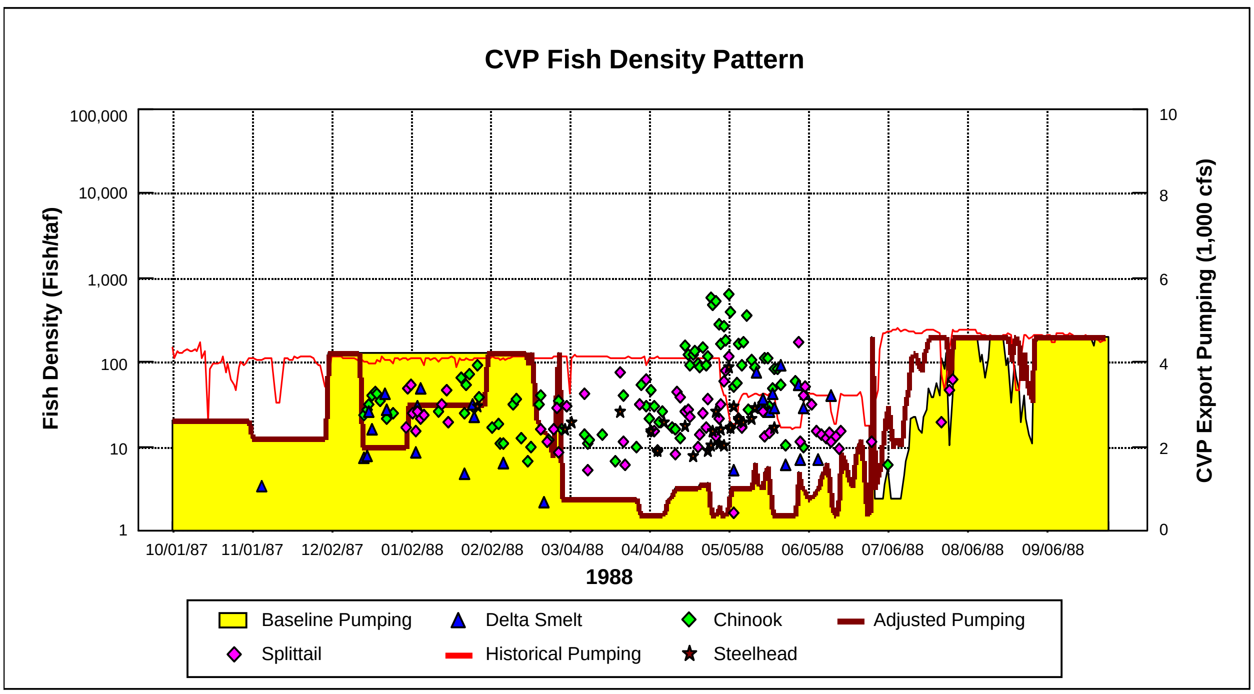


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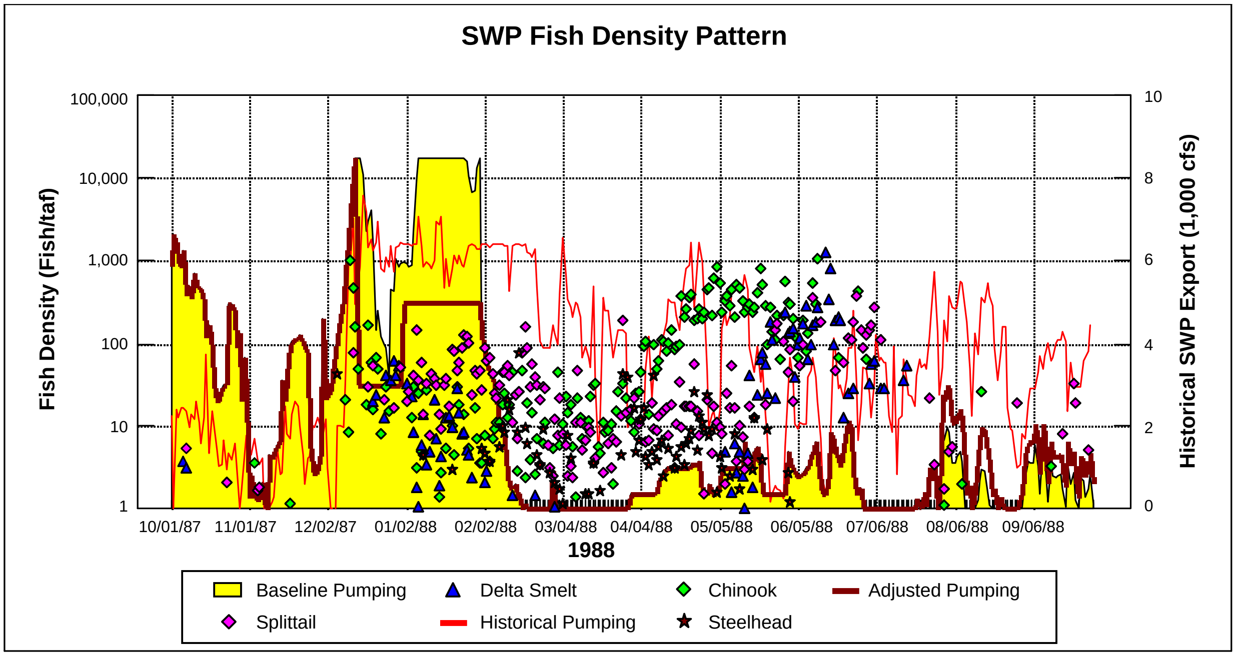
Figure B-5

EWA Gaming Results for 1988 with SWP Banks Pumping Capacity of 6,680 cubic feet per second (cfs)



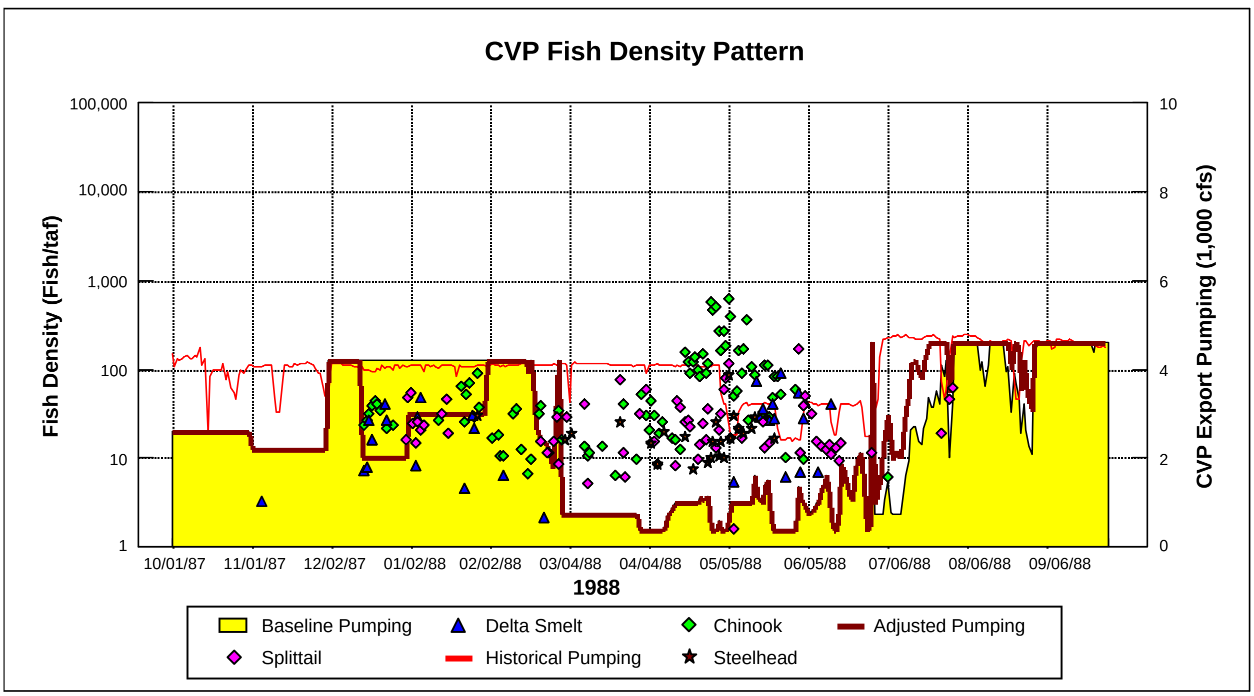


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Figure B-6

EWA Gaming Results for 1988 with SWP Banks Pumping Capacity of 8,500 cubic feet per second (cfs)

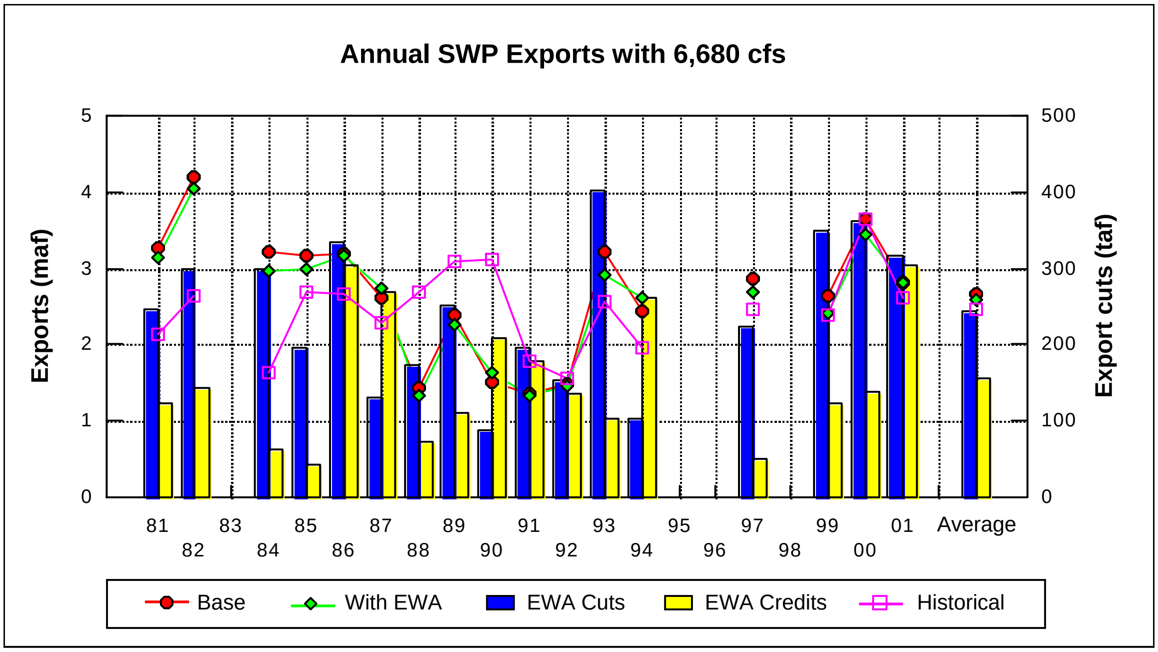

Figure B-7. Annual SWP Exports for Simulated Baseline with 6,680–cubic feet per second (cfs) SWP Banks Capacity and with EWA Fish Protection Actions

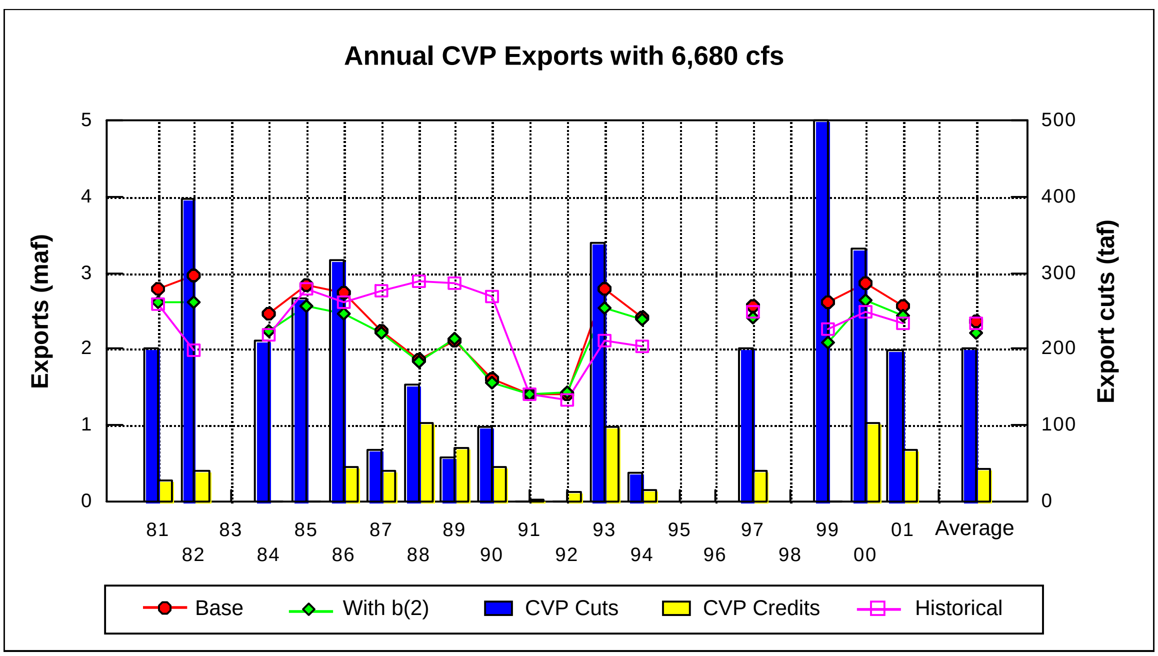

Figure B-8. Annual CVP Exports for Simulated Baseline with 6,680–cubic feet per second (cfs) SWP Banks Capacity and with CVPIA b(2) Fish Protection Actions

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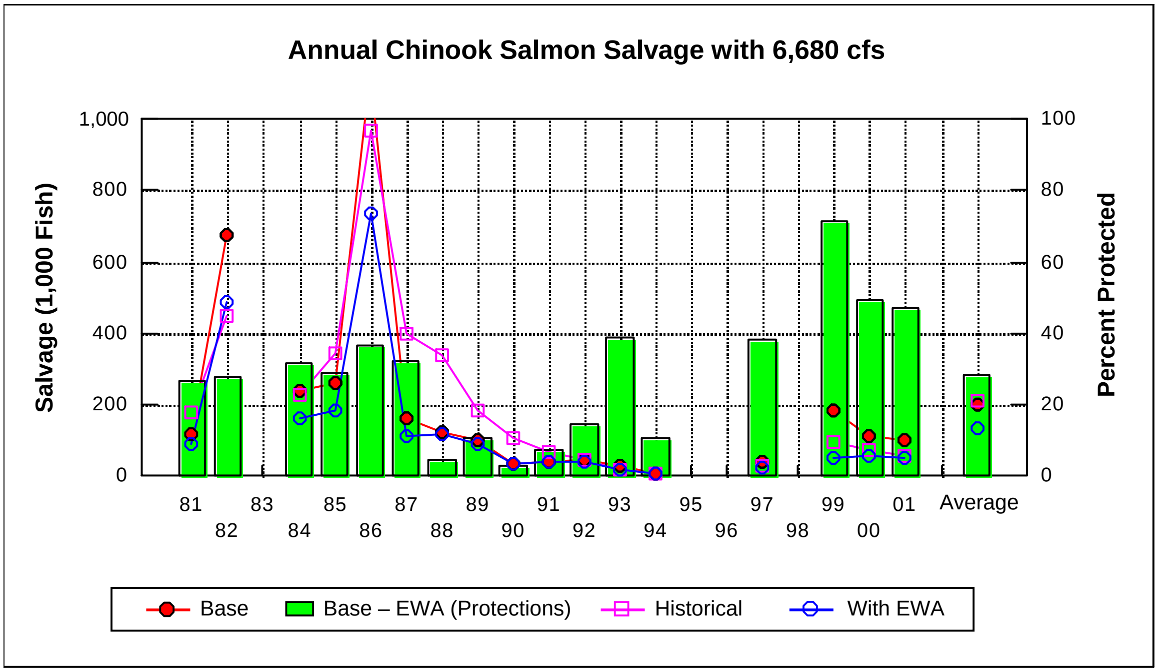

Figure B-9. Annual Chinook Salmon Salvage with Baseline Pumping Compared with EWA Gaming for 6,680-cubic feet per second (cfs) SWP Banks Pumping Capacity

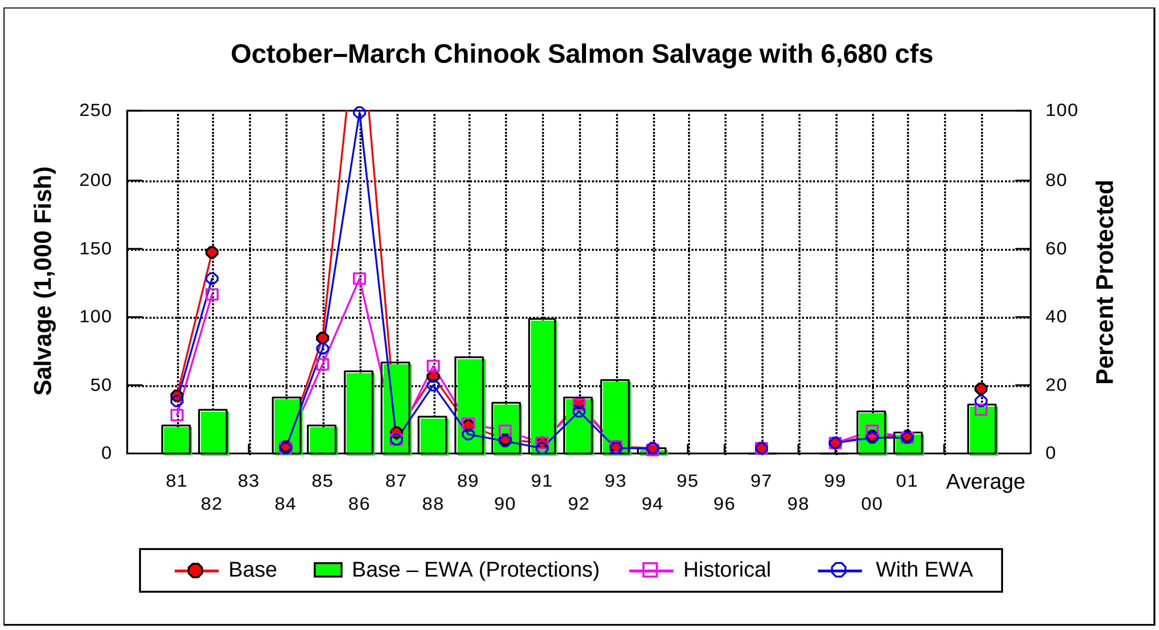

Figure B-10. Salvage of October–March Chinook Salmon Salvage for Baseline Pumping Compared with EWA Results for 6,680–cubic feet per second (cfs) SWP Banks Pumping Capacity

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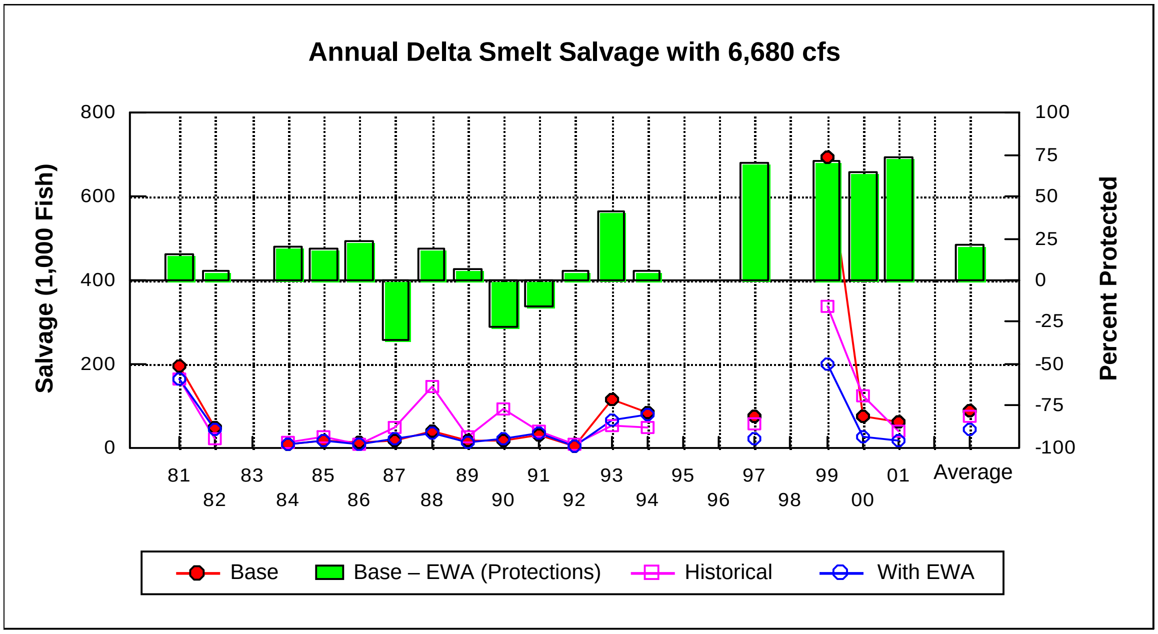

Figure B-11. Annual Salvage of Delta Smelt for Baseline Pumping Compared with EWA Results for 6,680–cubic feet per second (cfs) SWP Banks Pumping Capacity

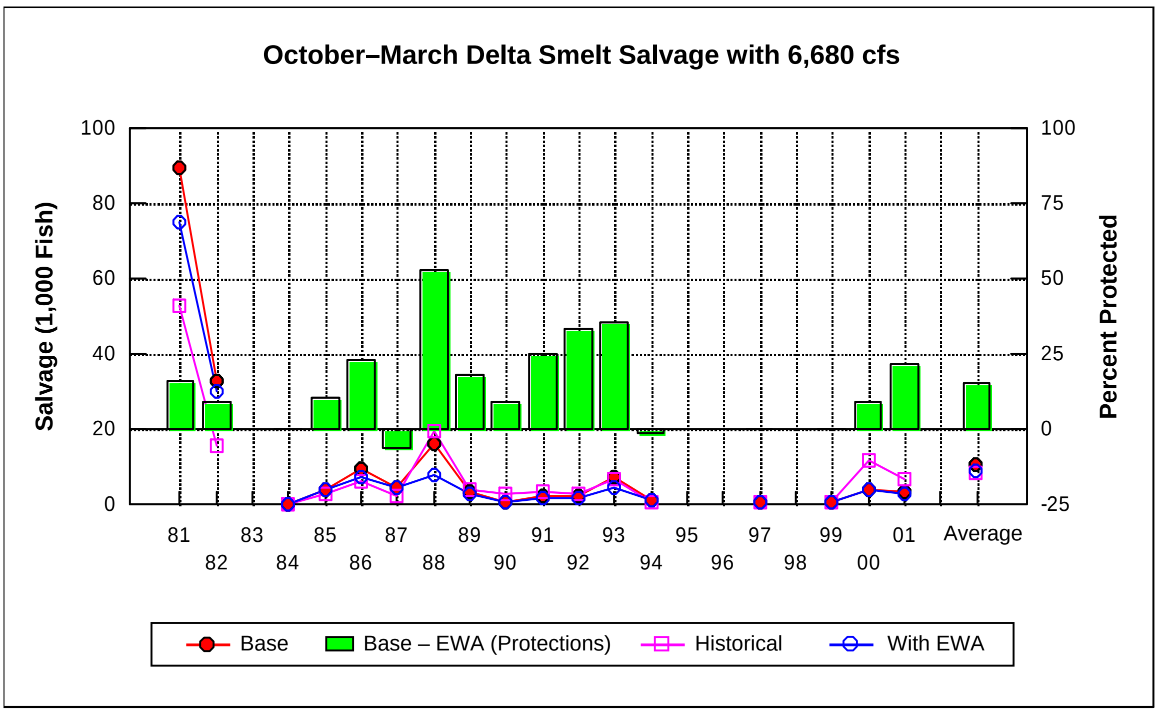

Figure B-12. Salvage of October–March Delta Smelt Salvage for Baseline Pumping Compared with EWA Results for 6,680–cubic feet per second (cfs) SWP Banks Pumping Capacity

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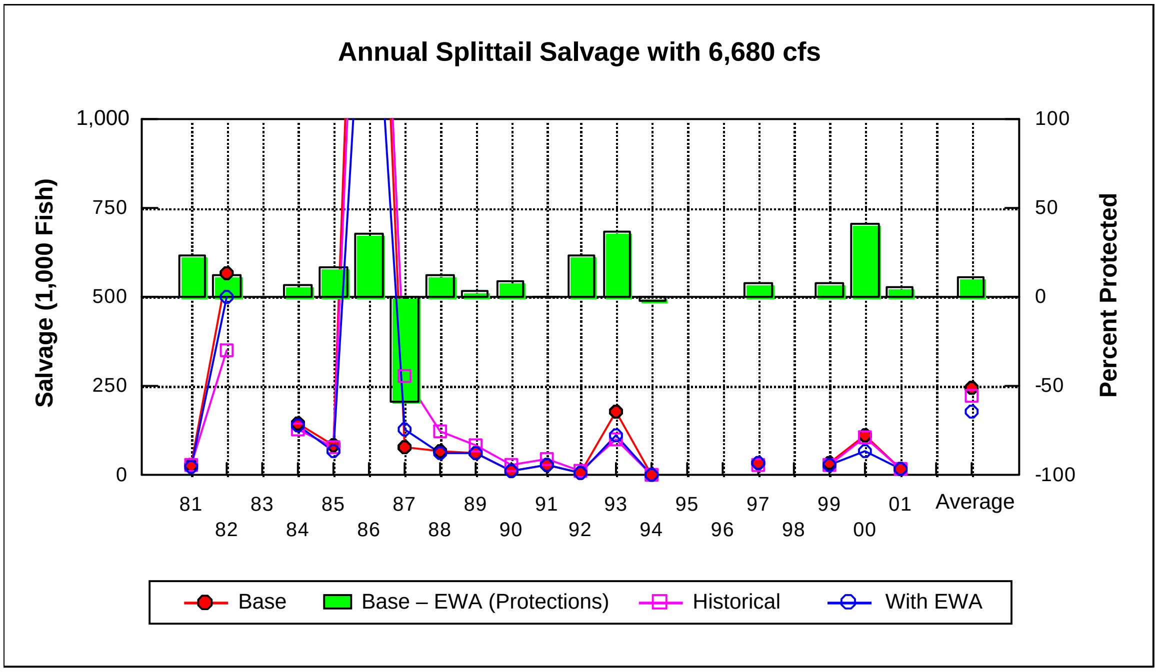

Figure B-13. Comparison of Annual Splittail Salvage for SWP Banks Capacity of 6,680 cubic feet per second (cfs)

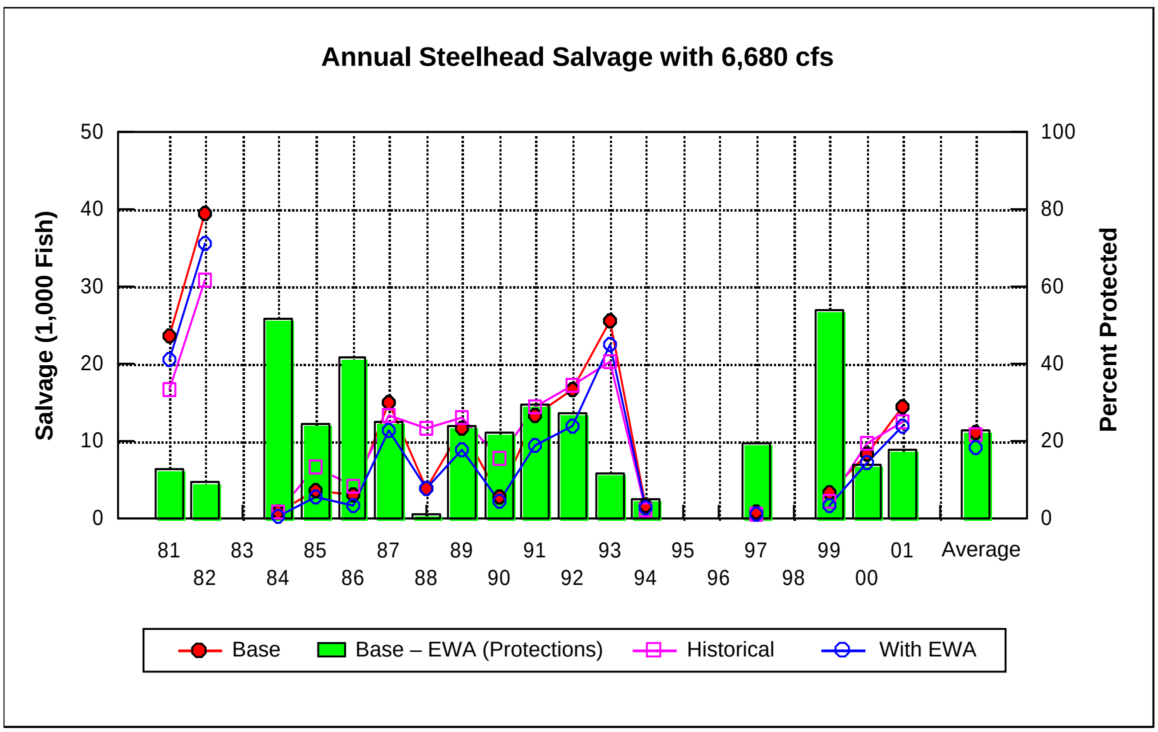

Figure B-14. Comparison of Steelhead Salvage for SWP Banks Capacity of 6,680 cubic feet per second (cfs)

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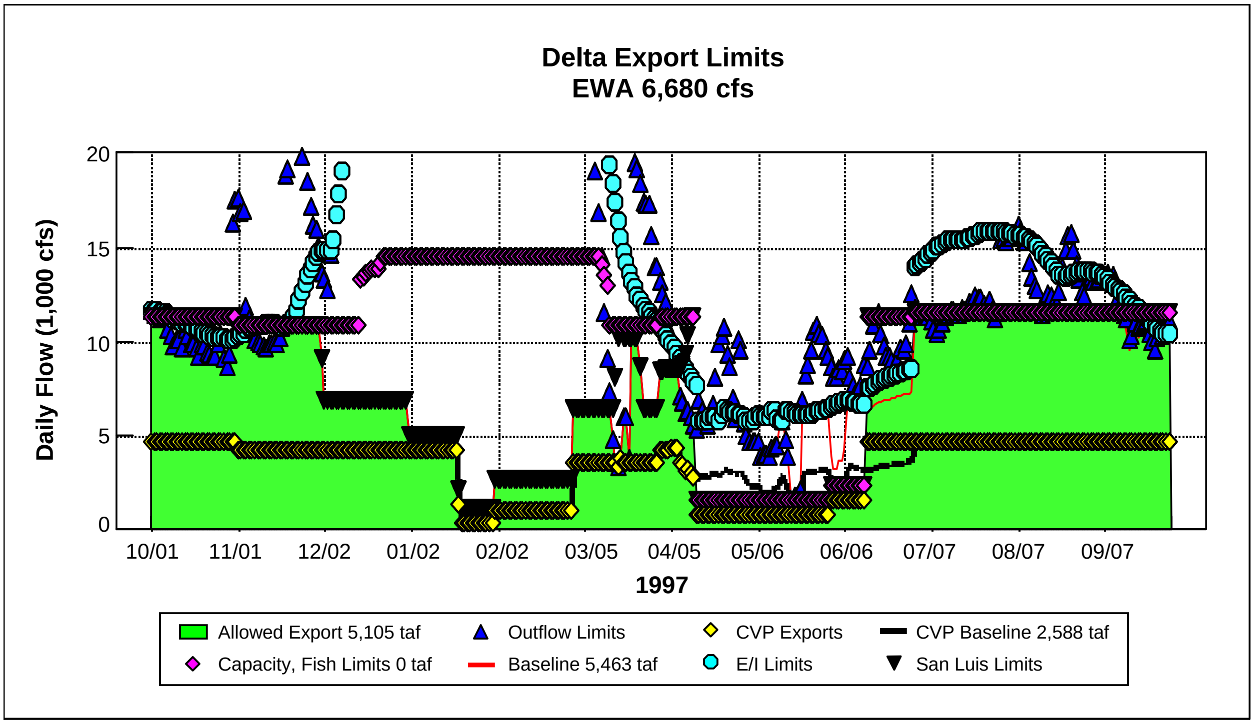

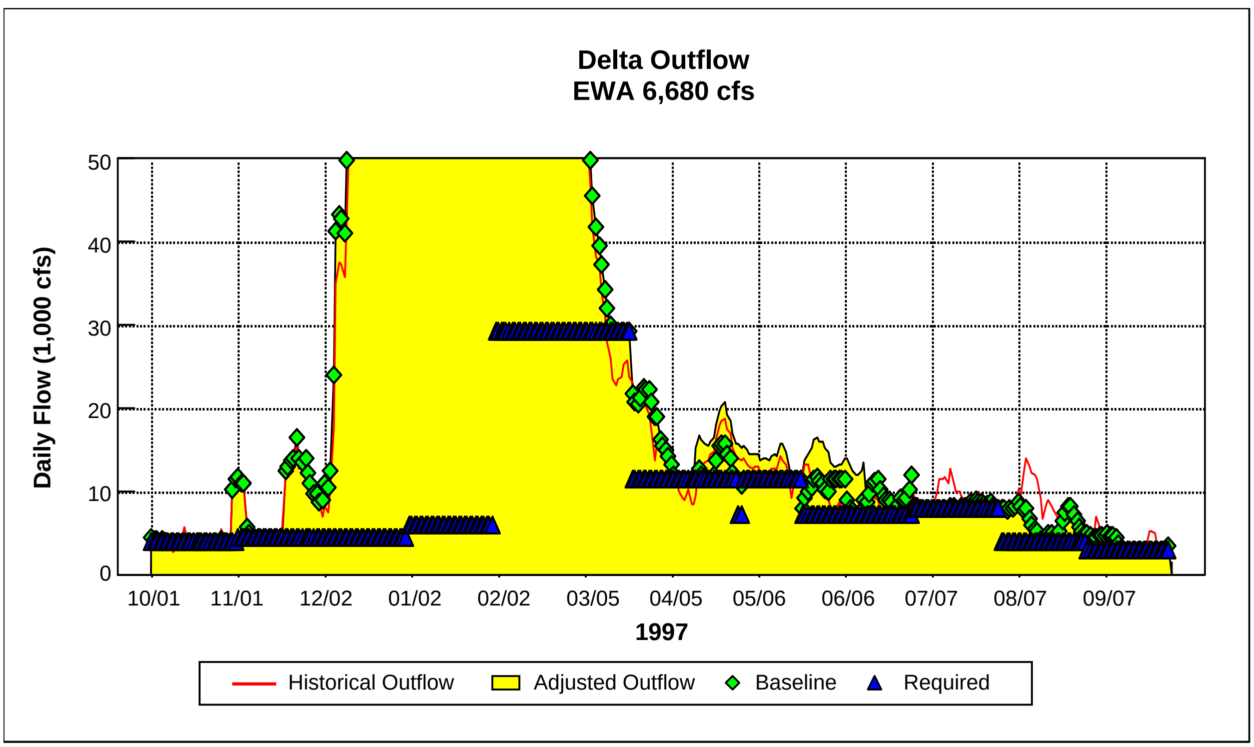

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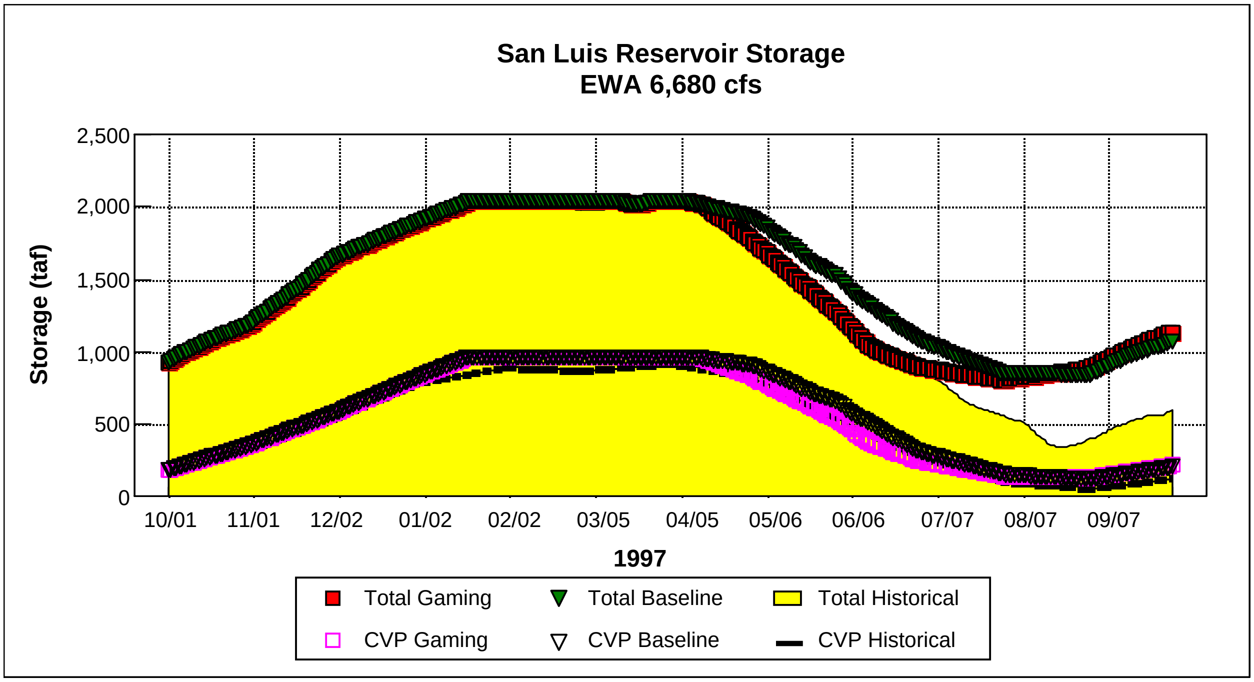
Figure B-15

Simulated Delta Exports and Outflow for EWA Gaming of 1997 with SWP Capacity of 6,680 cubic feet per second (cfs)



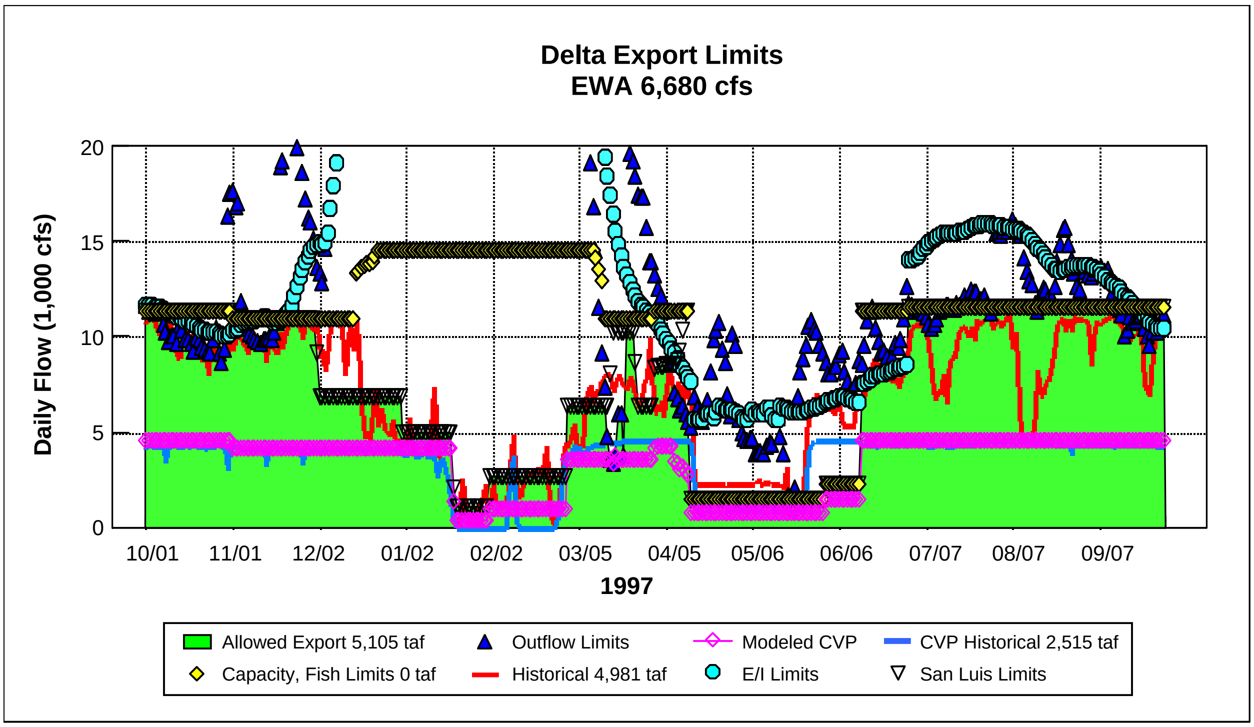


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Figure B-16

Comparison of Simulated and Historical San Luis Reservoir and Delta Exports for 1997 with 6,680–cubic feet per second (cfs) SWP Pumping Capacity

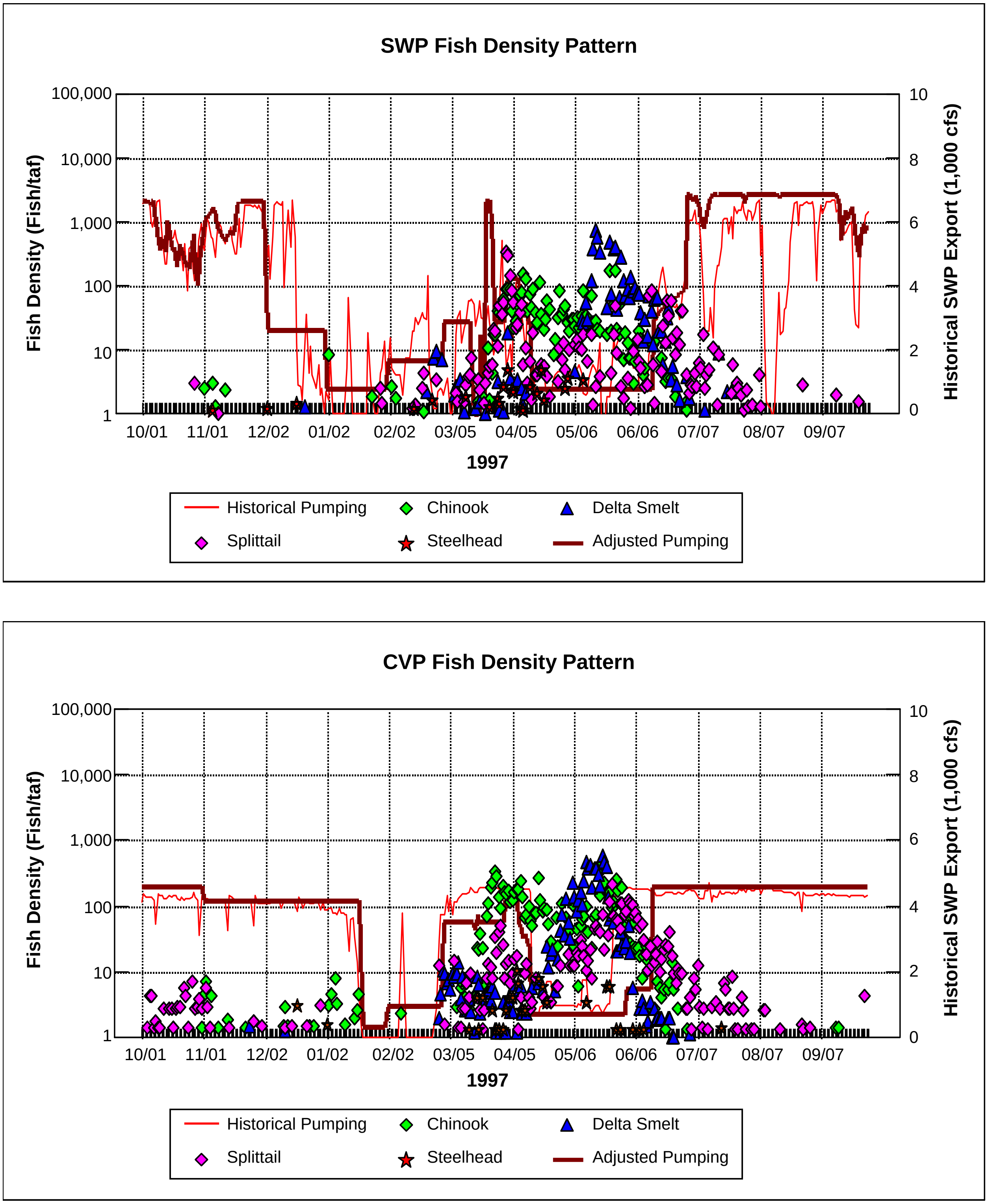

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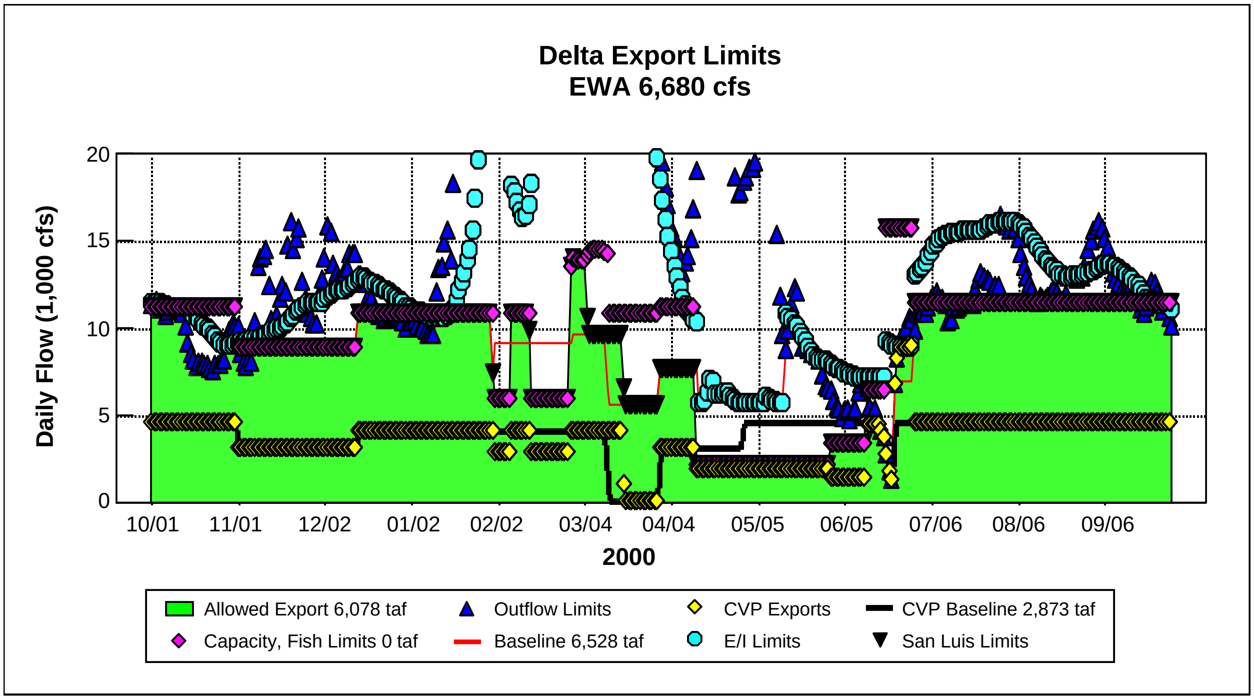
Figure B-17

Simulated SWP and CVP Exports Compared with Salvage Density for 1997 with 6,680–cubic foot per second (cfs) SWP Capacity



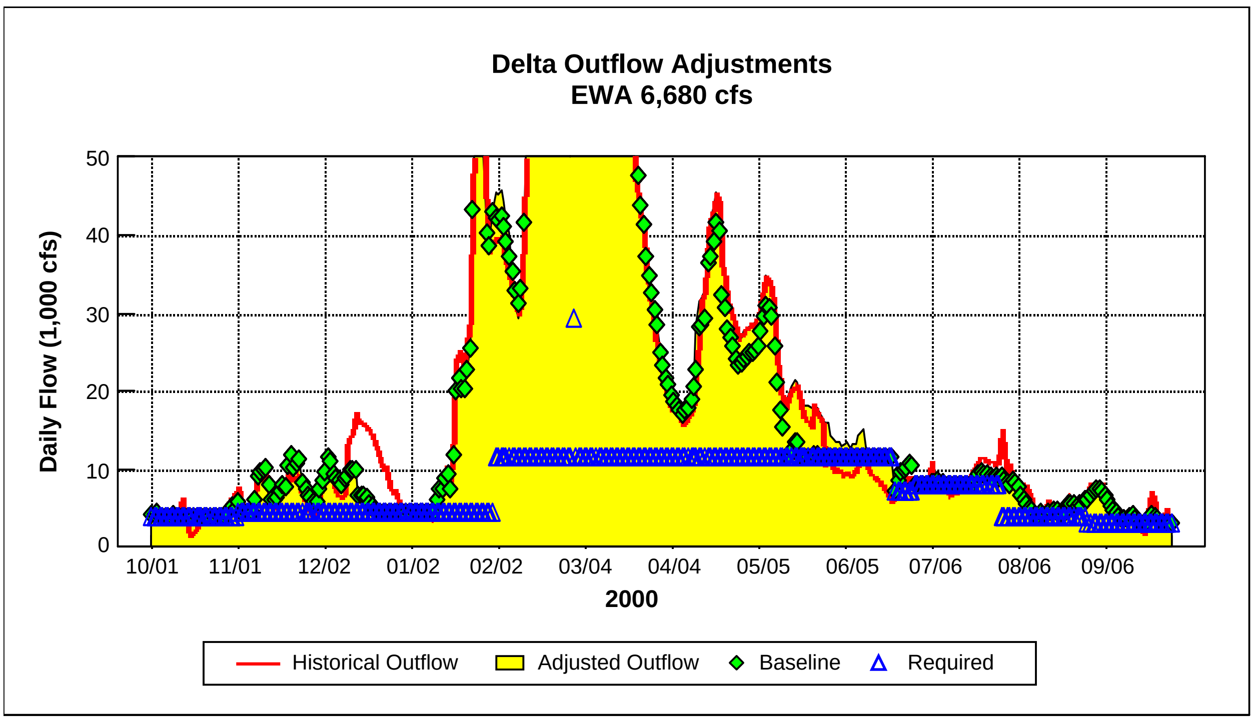


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Figure B-18

Simulated Delta Exports and Outflow for EWA Gaming of 2000 with SWP Capacity of 6,680 cubic feet per second (cfs)

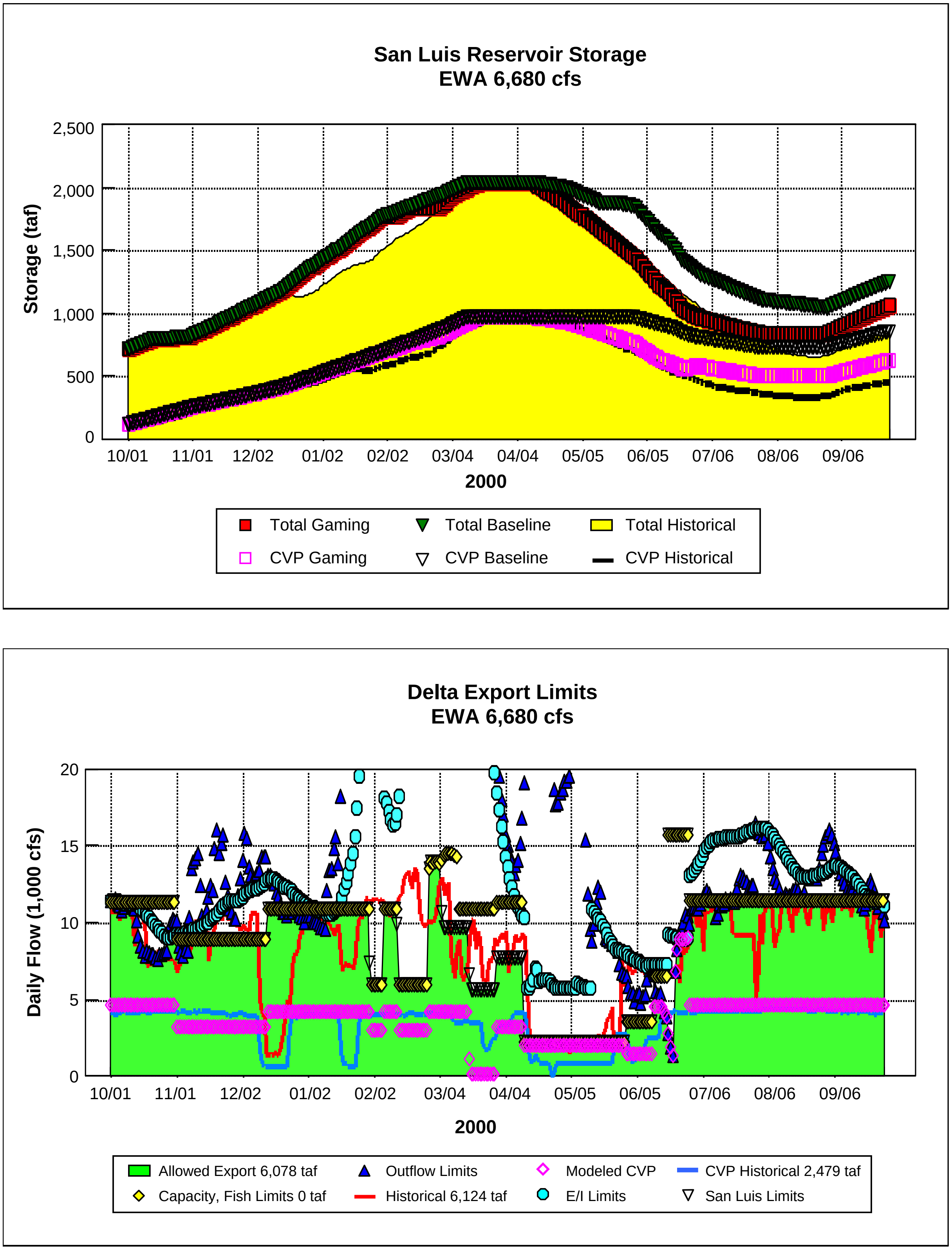

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Figure B-19

Comparison of Simulated and Historical San Luis Reservoir and Delta Exports for 2000 with 6,680–cubic feet per second (cfs) SWP Pumping Capacity

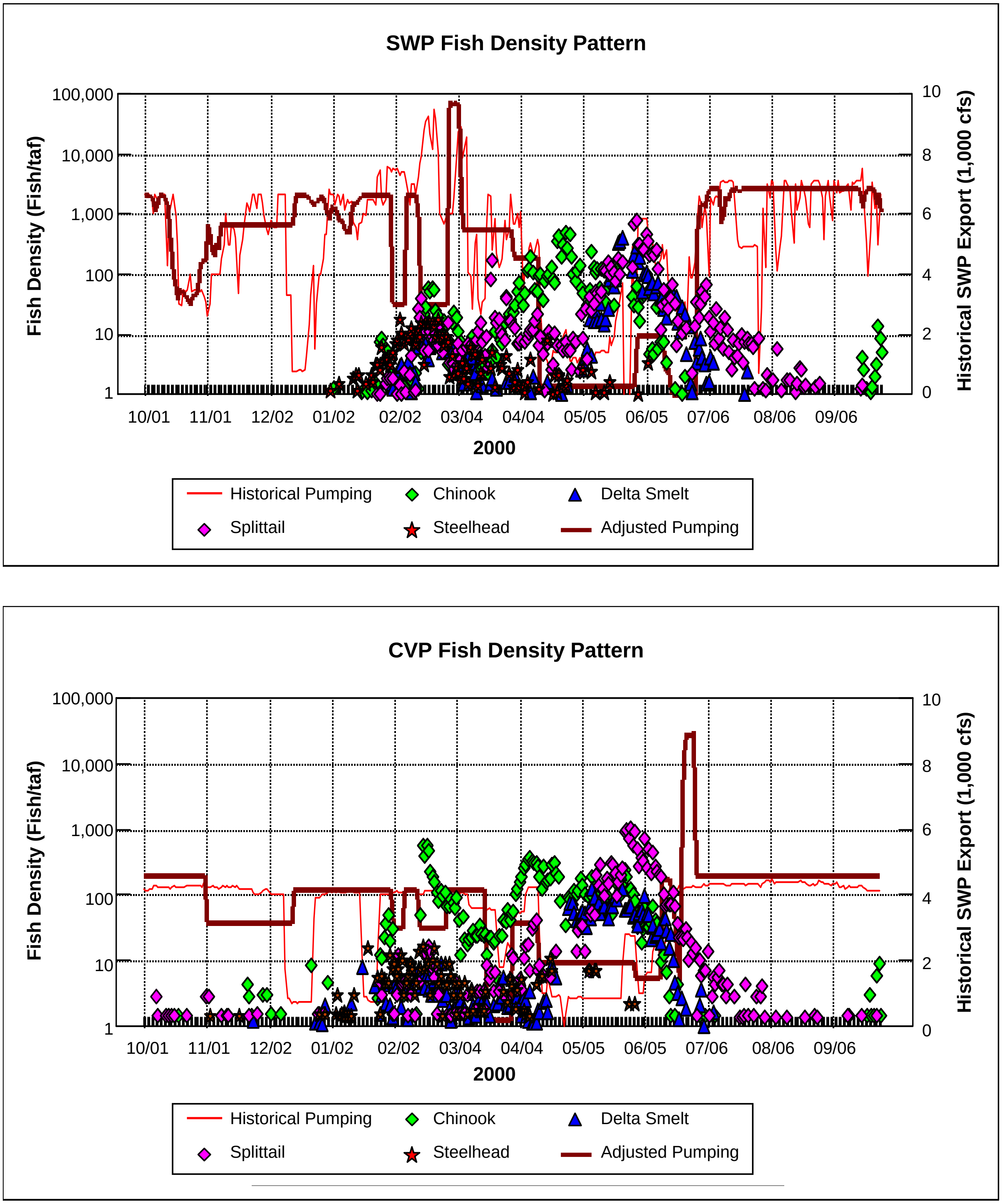

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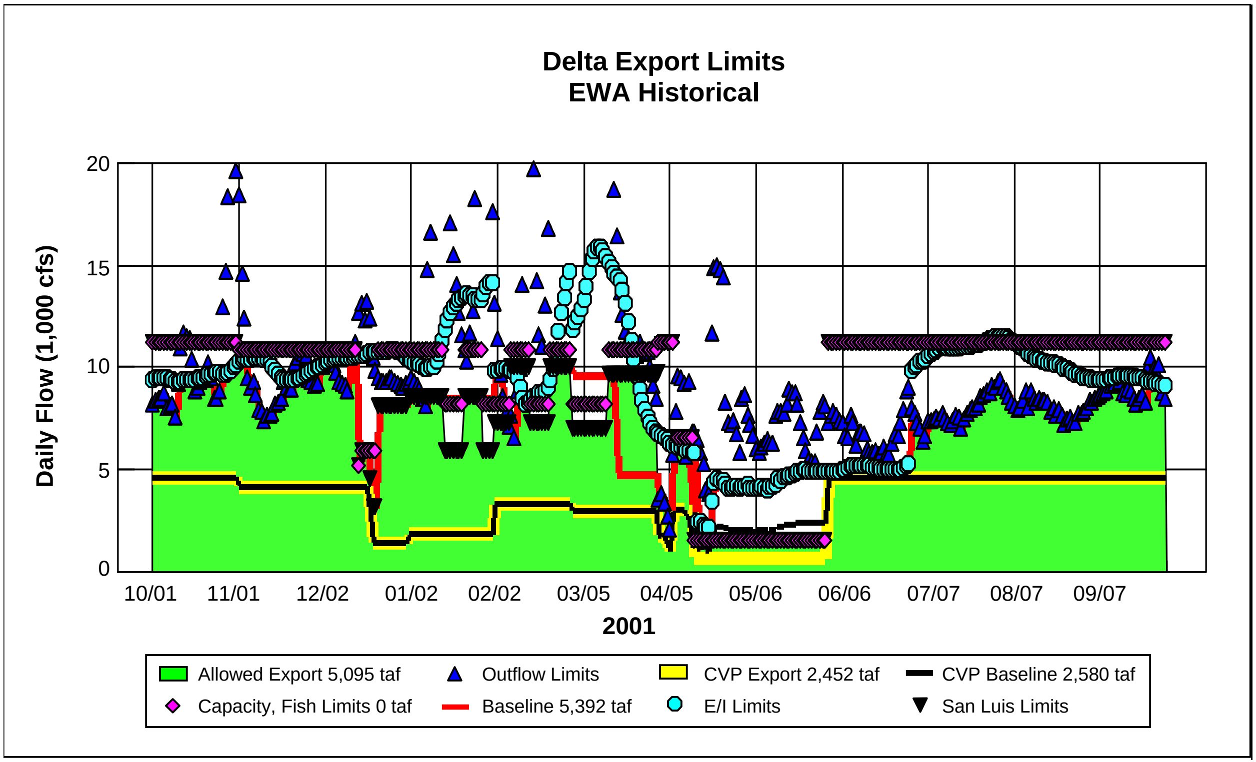
Figure B-20

Simulated SWP and CVP Exports Compared with Salvage Density for 2000 with 6,680–cubic feet per second (cfs) SWP Capacity



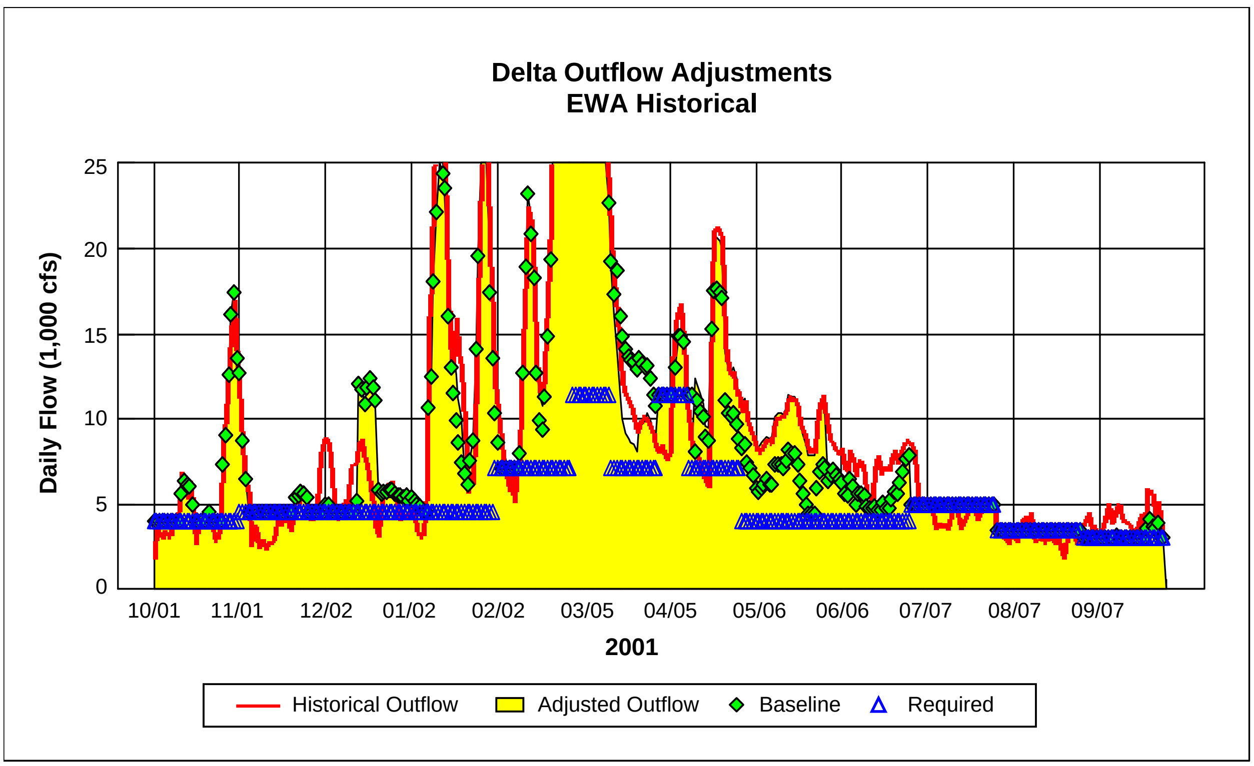


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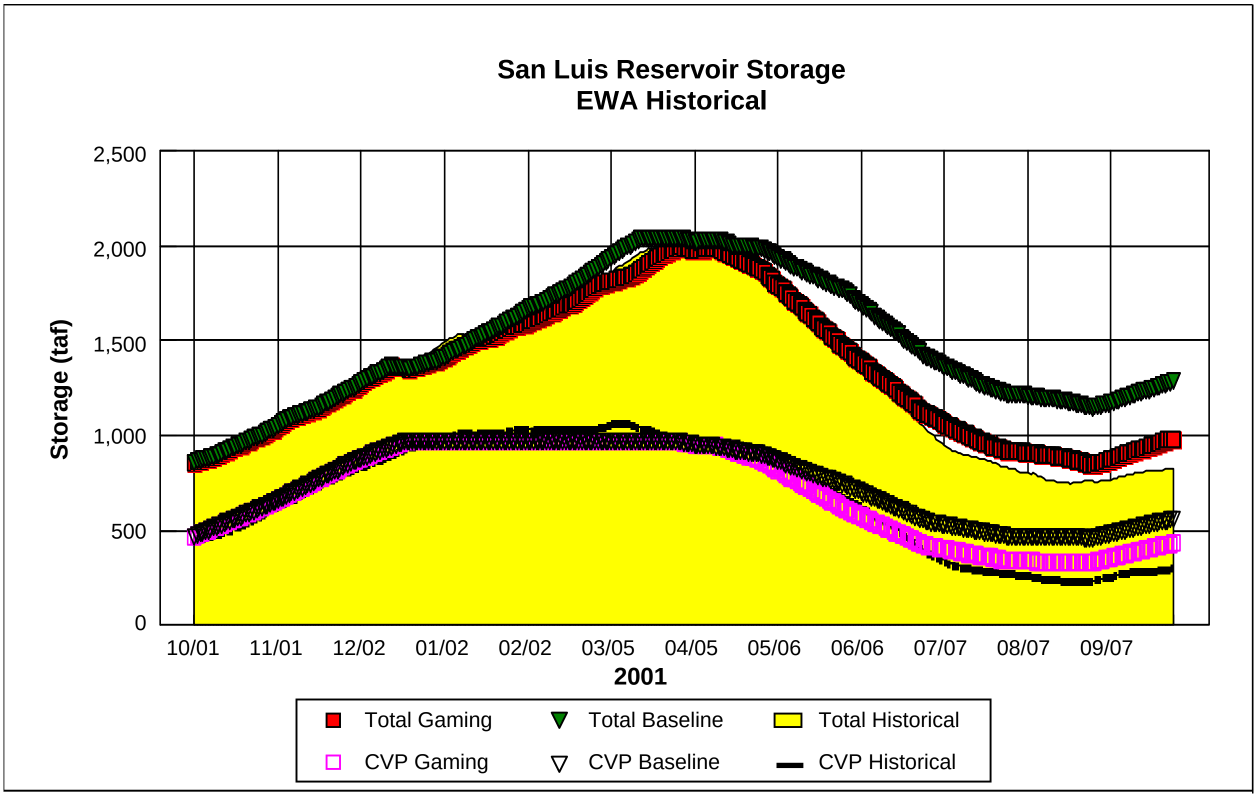
Figure B-21

Simulated Delta Exports and Outflow for D-1641 Baseline and with Actual EWA Actions in Water Year 2001



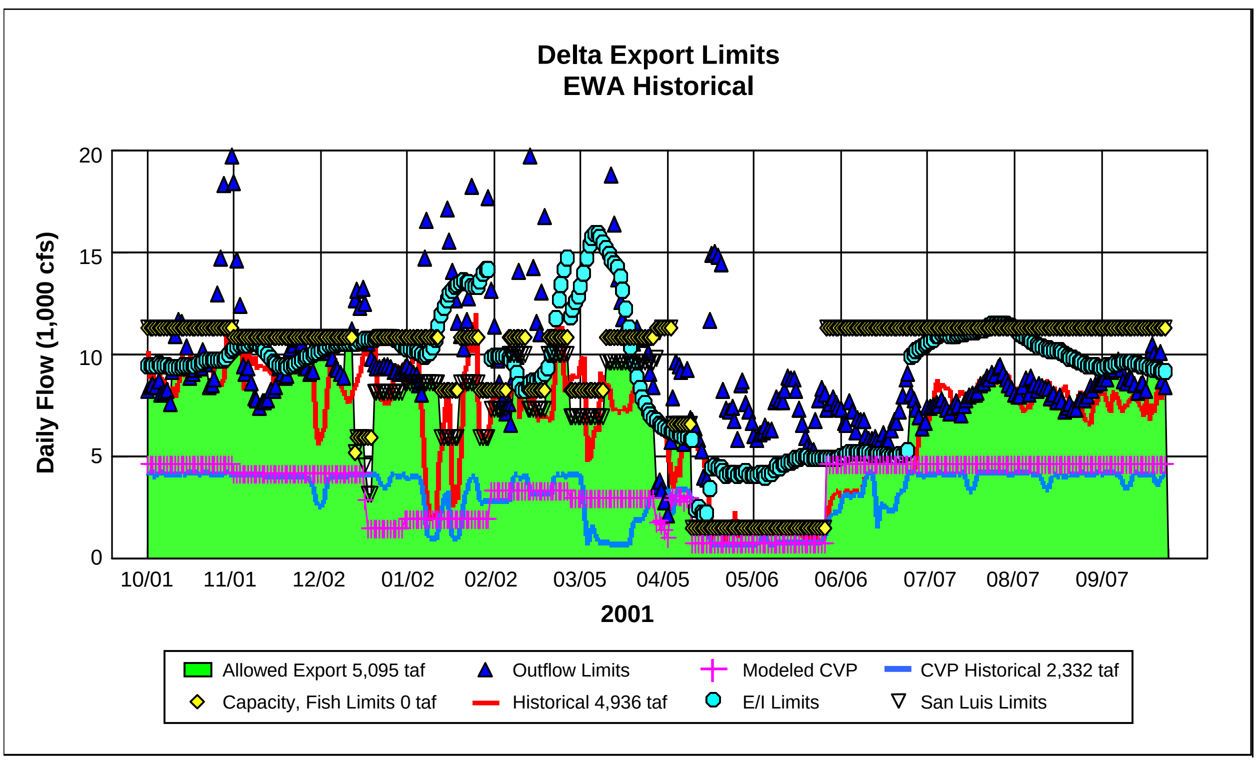


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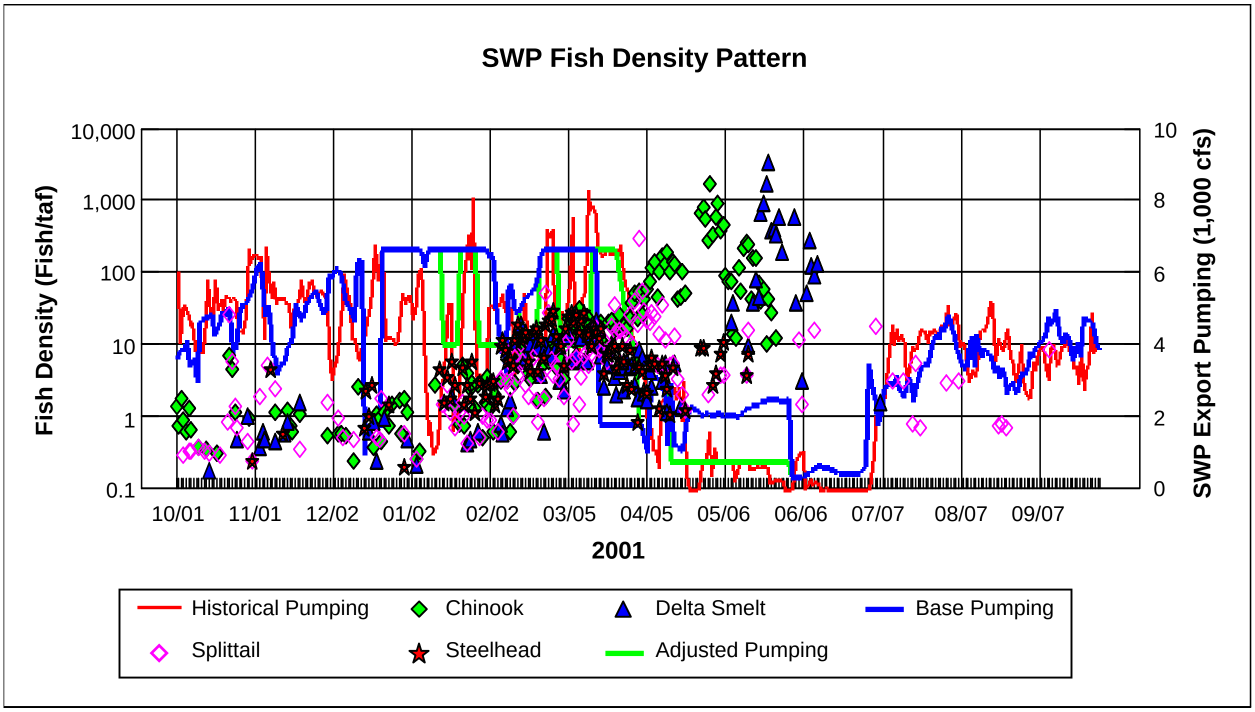
Figure B-22

Simulated San Luis Reservoir Storage with Comparison of Simulated and Historical Exports for D-1641 Baseline and Actual EWA Actions in Water Year 2000



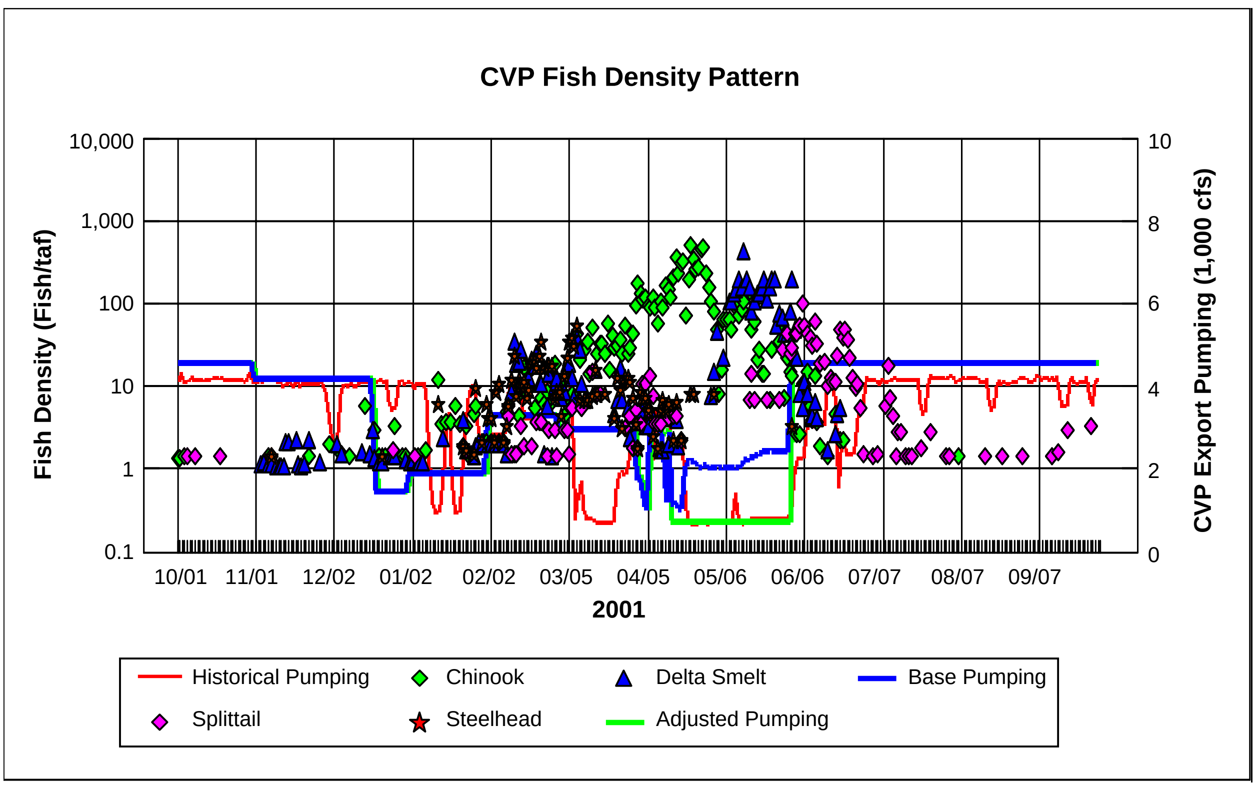


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Figure B-23

Measured SWP and CVP Fish Salvage Density with Historical and Simulated D-1641 and EWA Exports for Water Year 2001

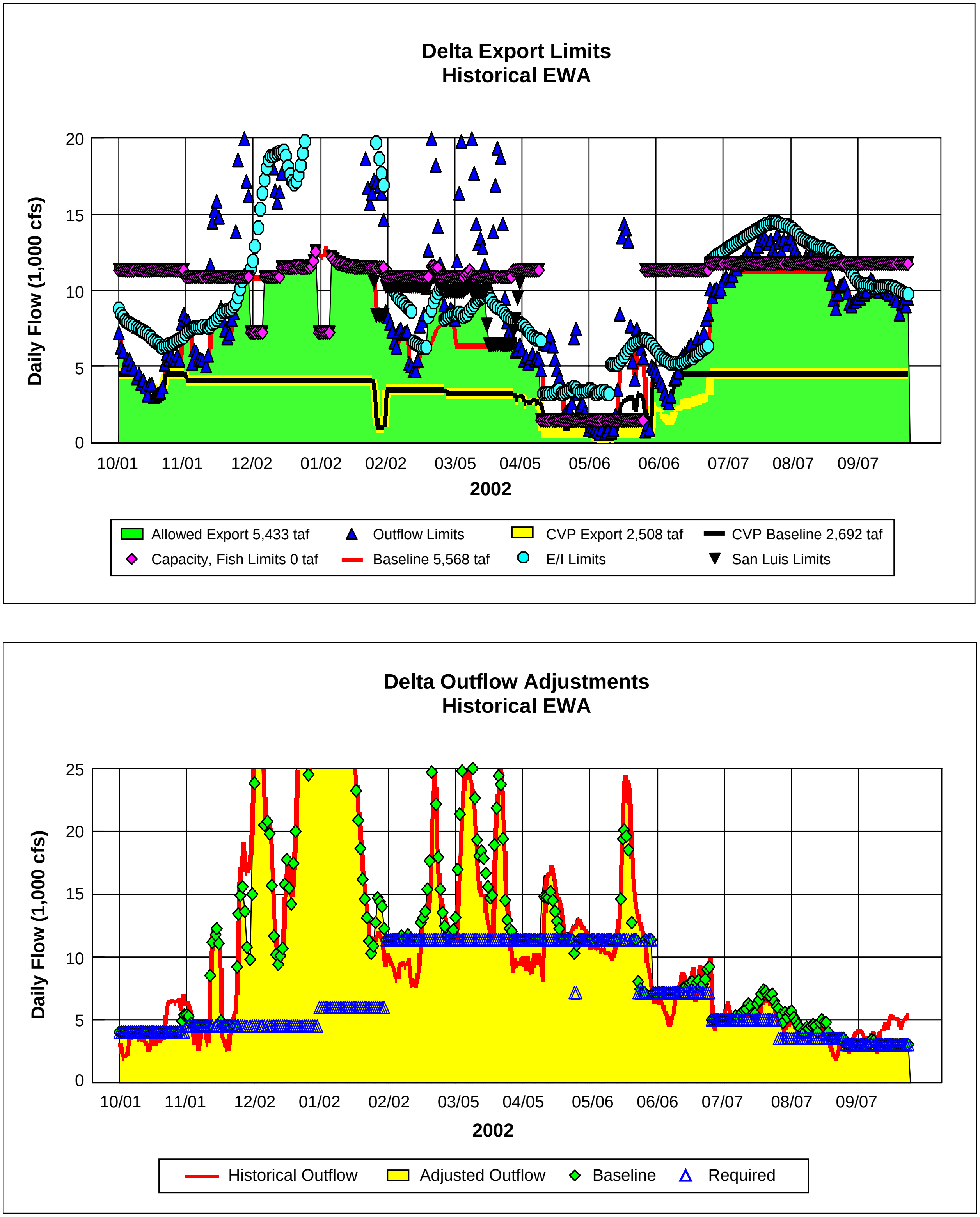

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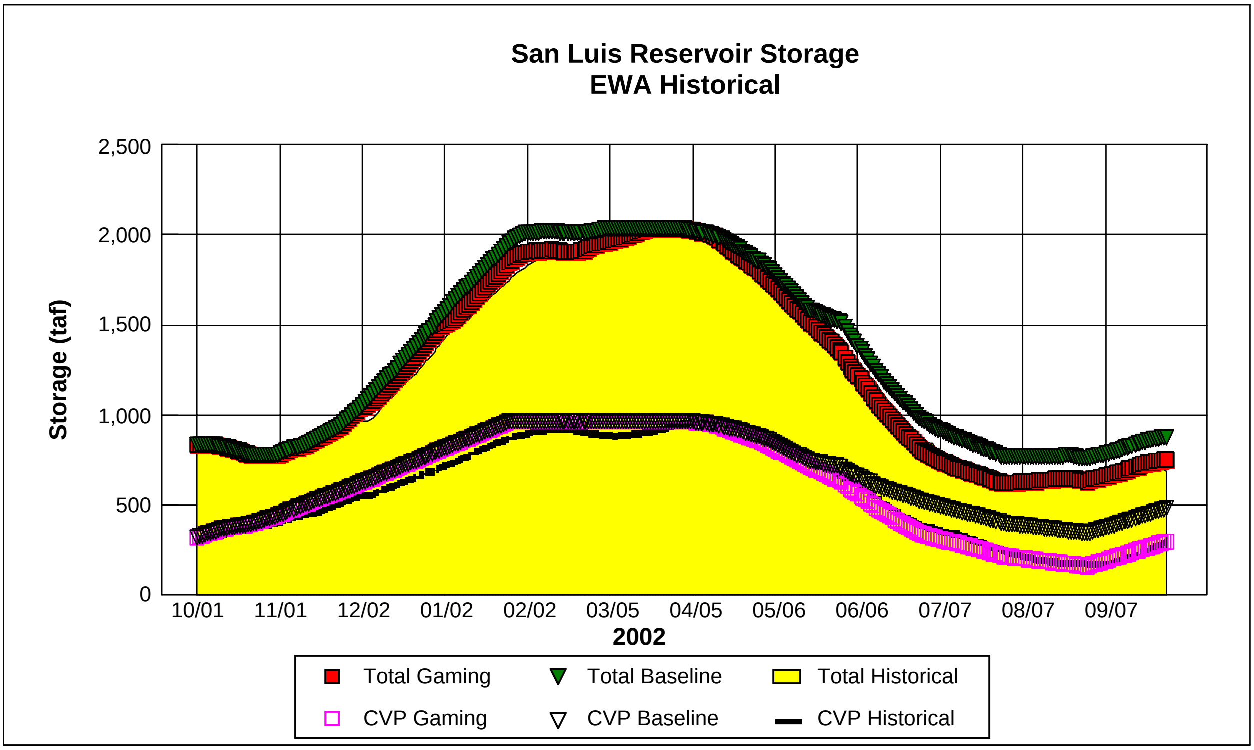
Figure B-24

Simulated Delta Exports and Outflow for D-1641 Baseline and with Actual EWA Actions in Water Year 2002



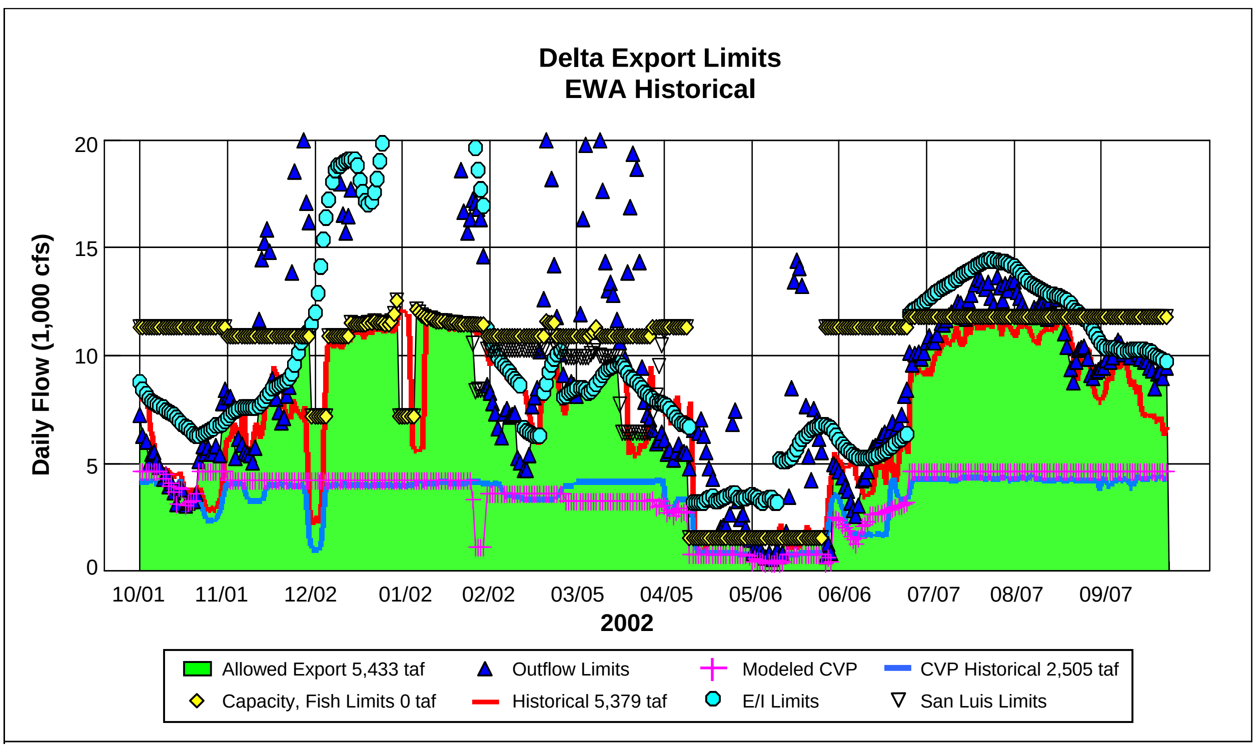


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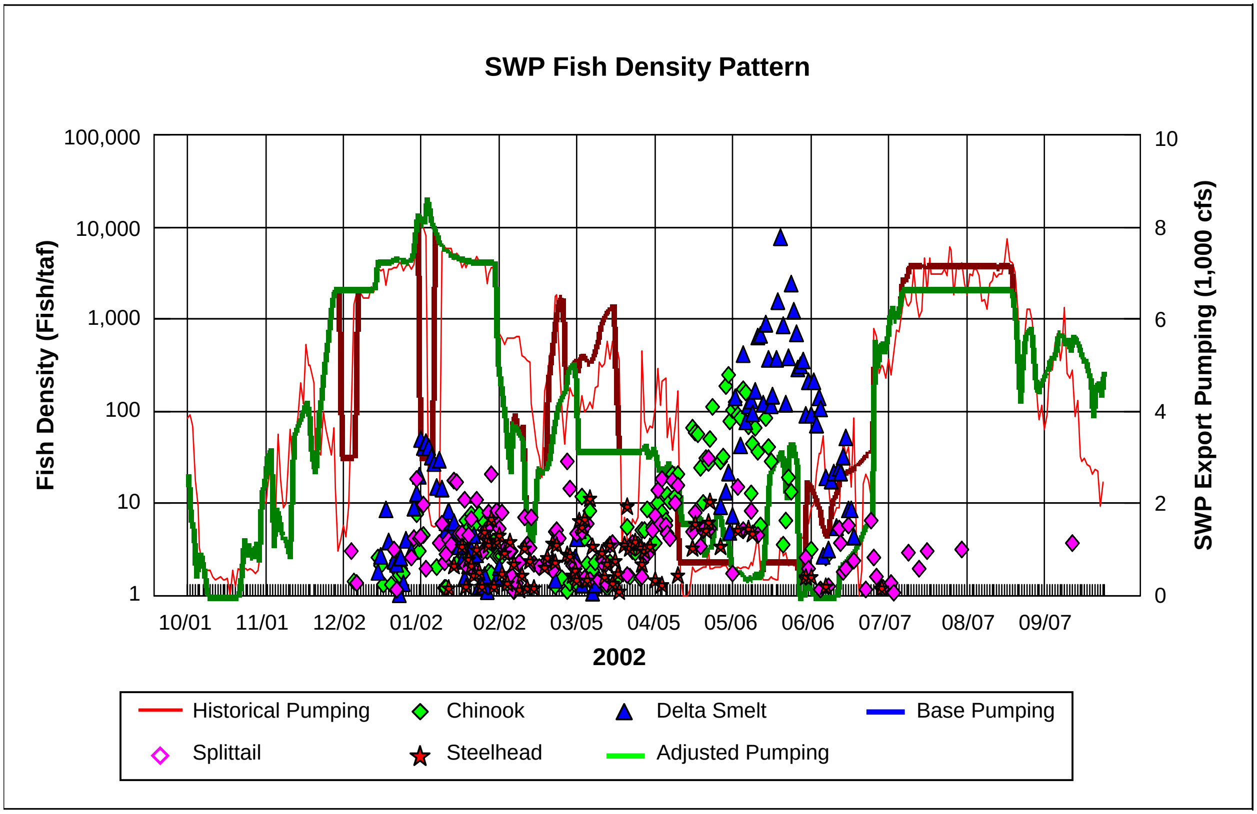
Figure B-25

Comparison of Simulated and Historical San Luis Reservoir Storage and Delta Exports with D-1641 Baseline and Actual EWA Actions for 2002



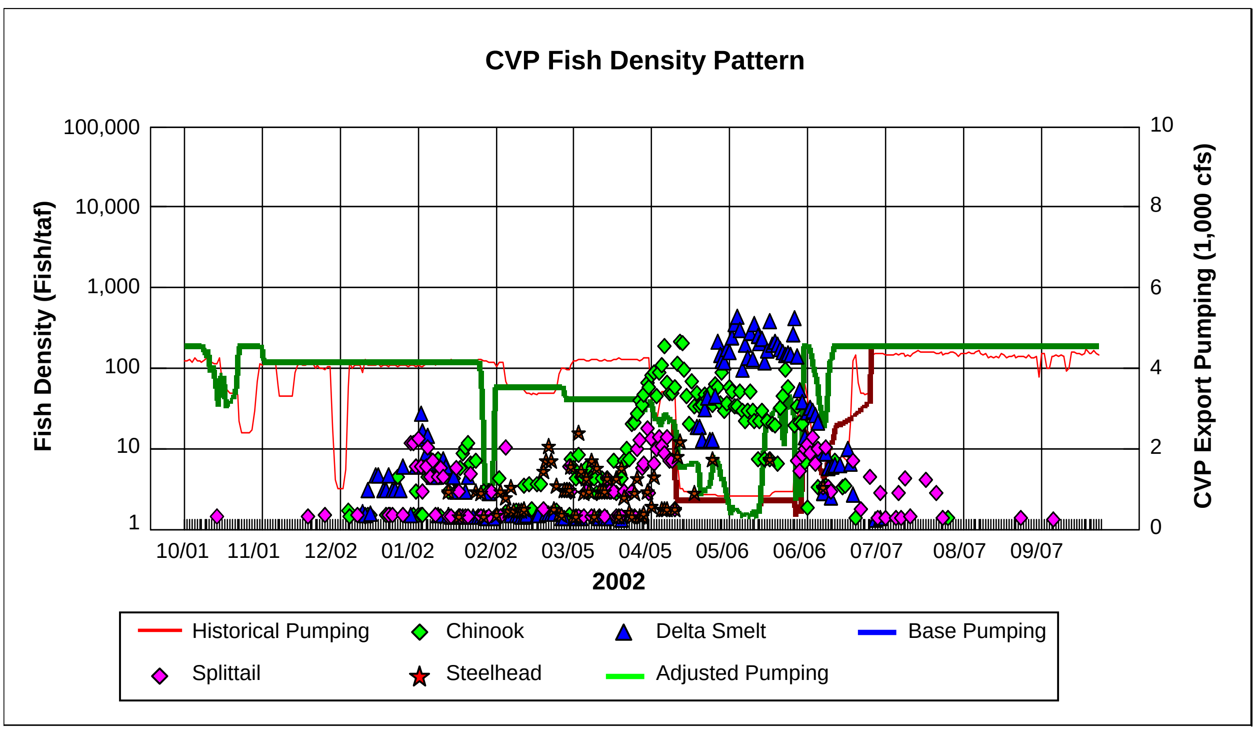


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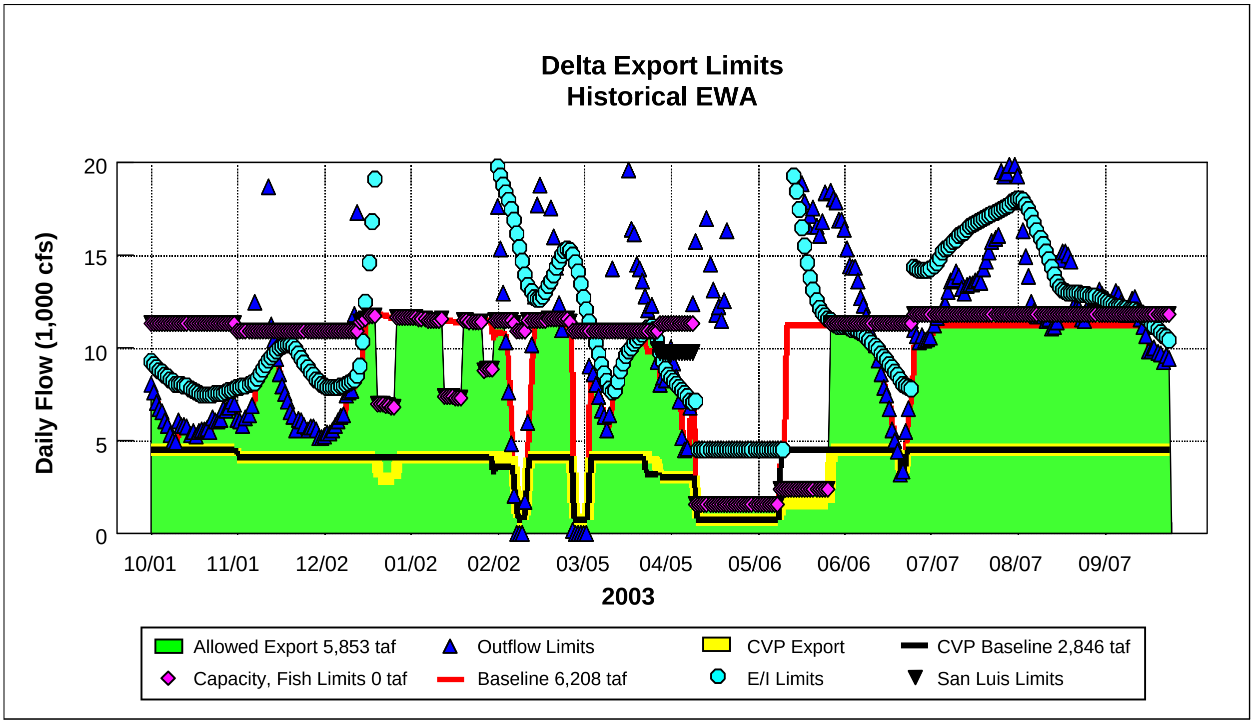
Figure B-26

Measured SWP and CVP Fish Salvage Density with Historical and Simulated D-1641 and EWA Exports for Water Year 2002



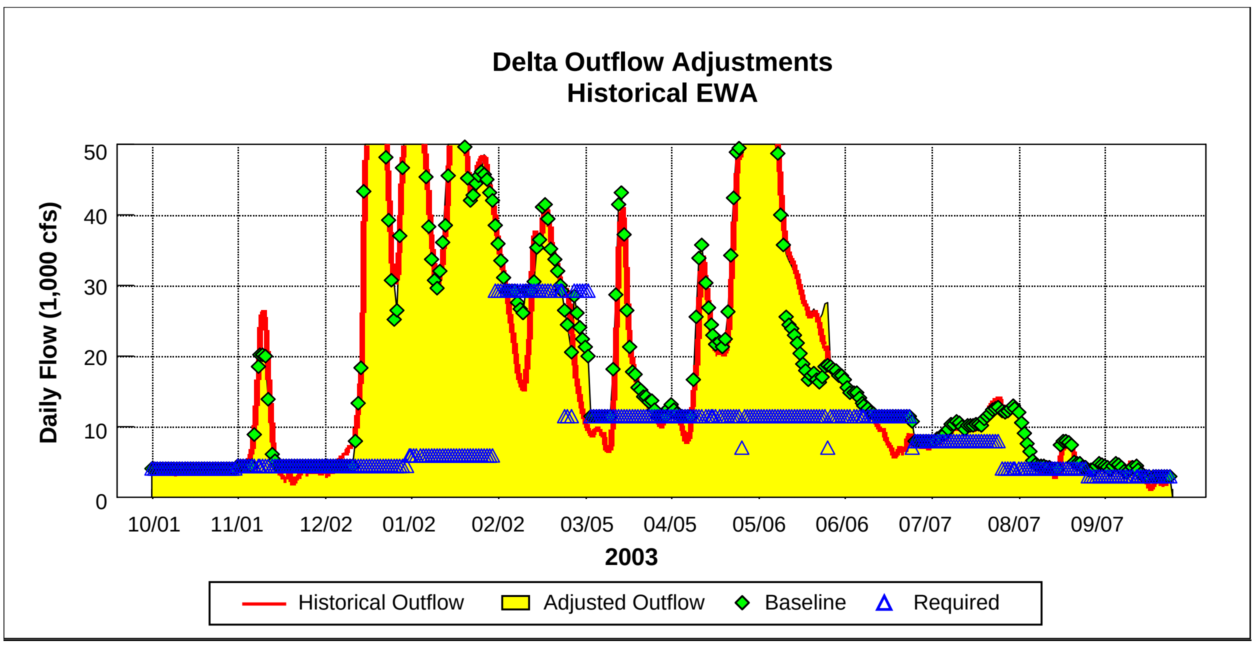


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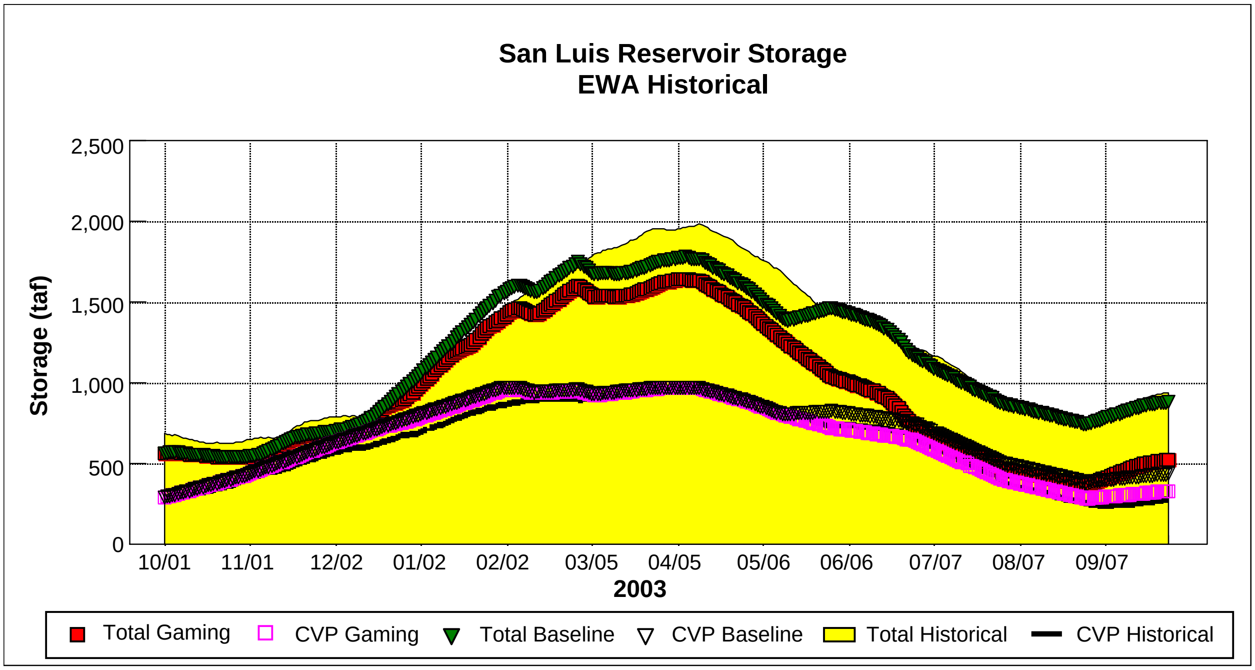
Figure B-27

Simulated Delta Exports and Outflow for D-1641 Baseline and with Actual EWA Actions in Water Year 2003



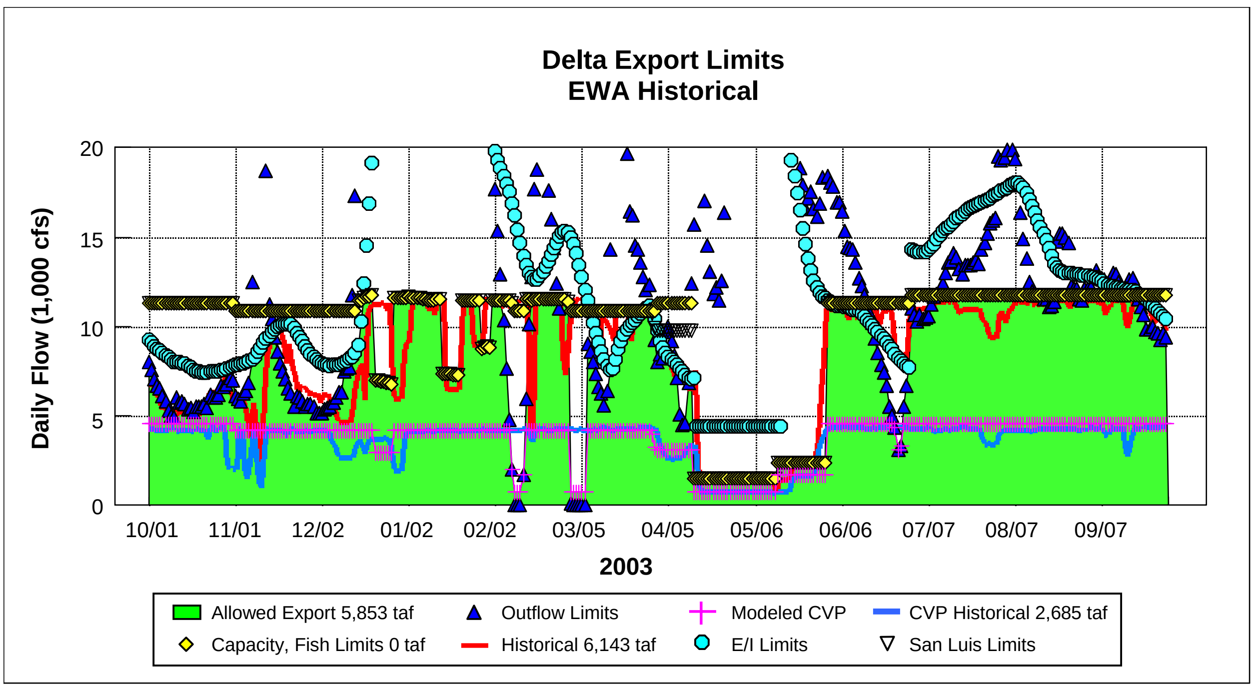


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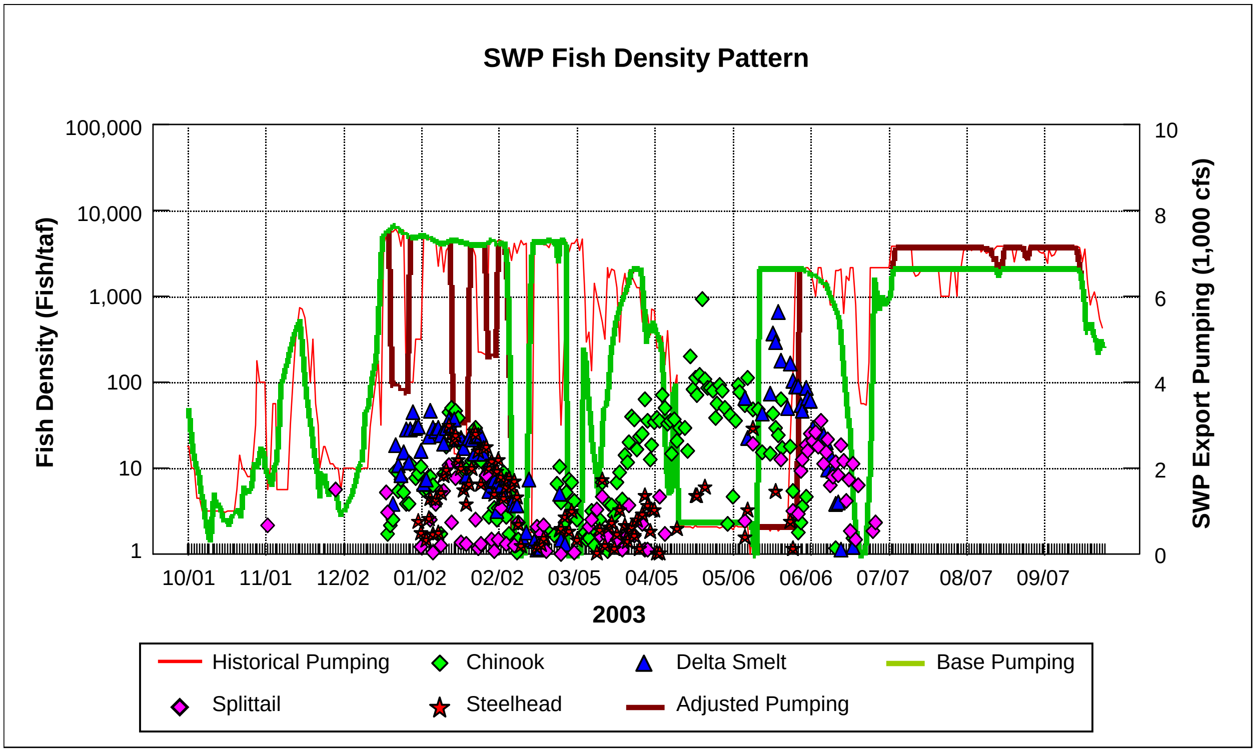
Figure B-28

Comparison of Simulated and Historical San Luis Reservoir Storage and Delta Exports with D-1641 Baseline and Actual EWA Actions for Water Year 2003



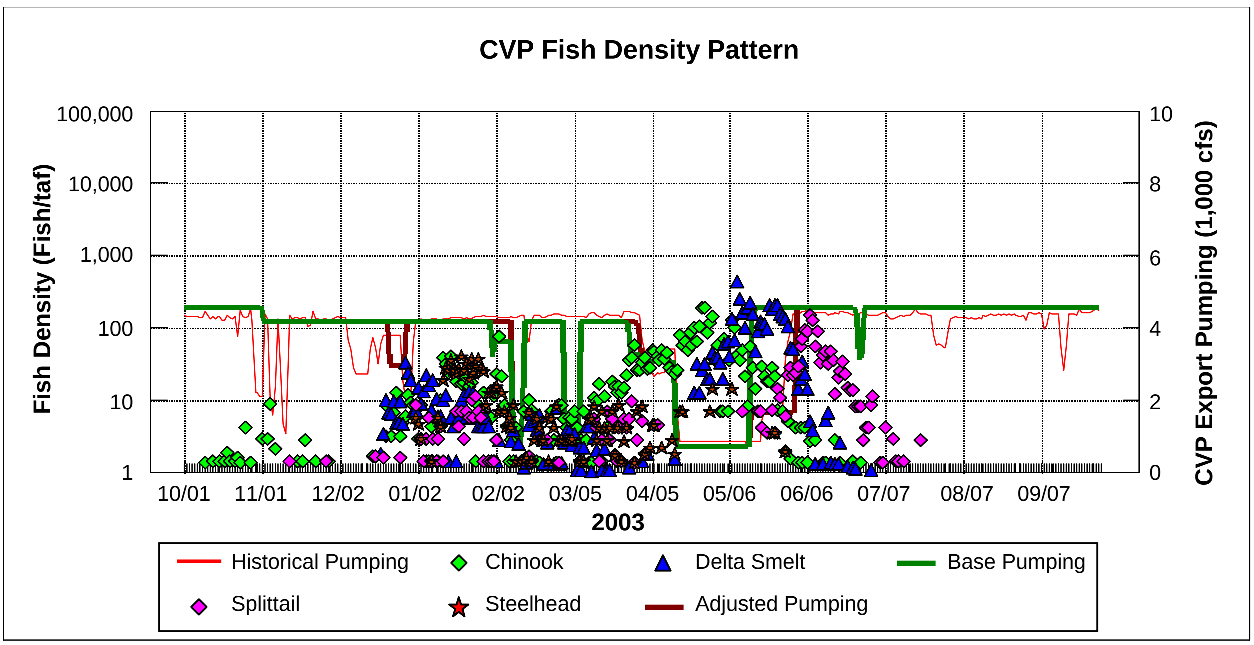


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Figure B-29

Measured SWP and CVP Fish Salvage Density with Historical and Simulated D-1641 and EWA Exports for Water Year 2003

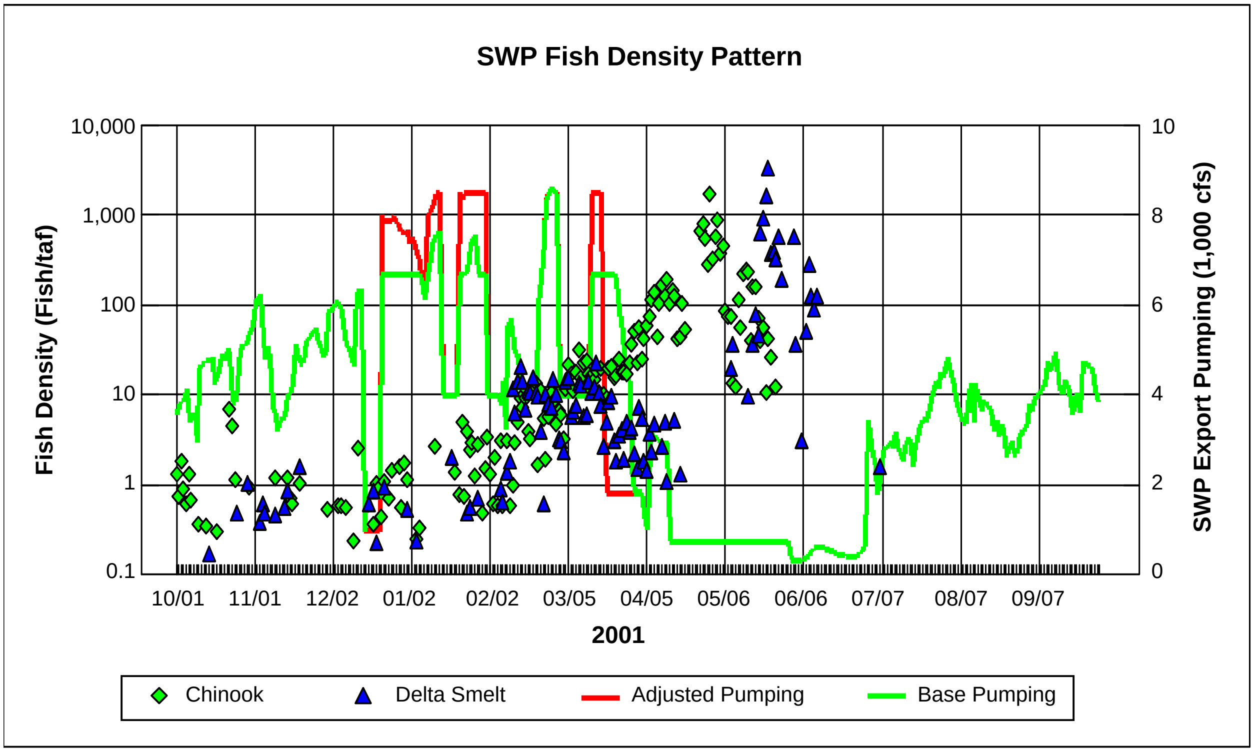

Figure B-30. Measured SWP Fish Density and Simulated Pumping with Historical EWA Actions for Water Year 2001 Compared with Simulated 8,500–cubic feet per second (cfs) SWP Banks Pumping

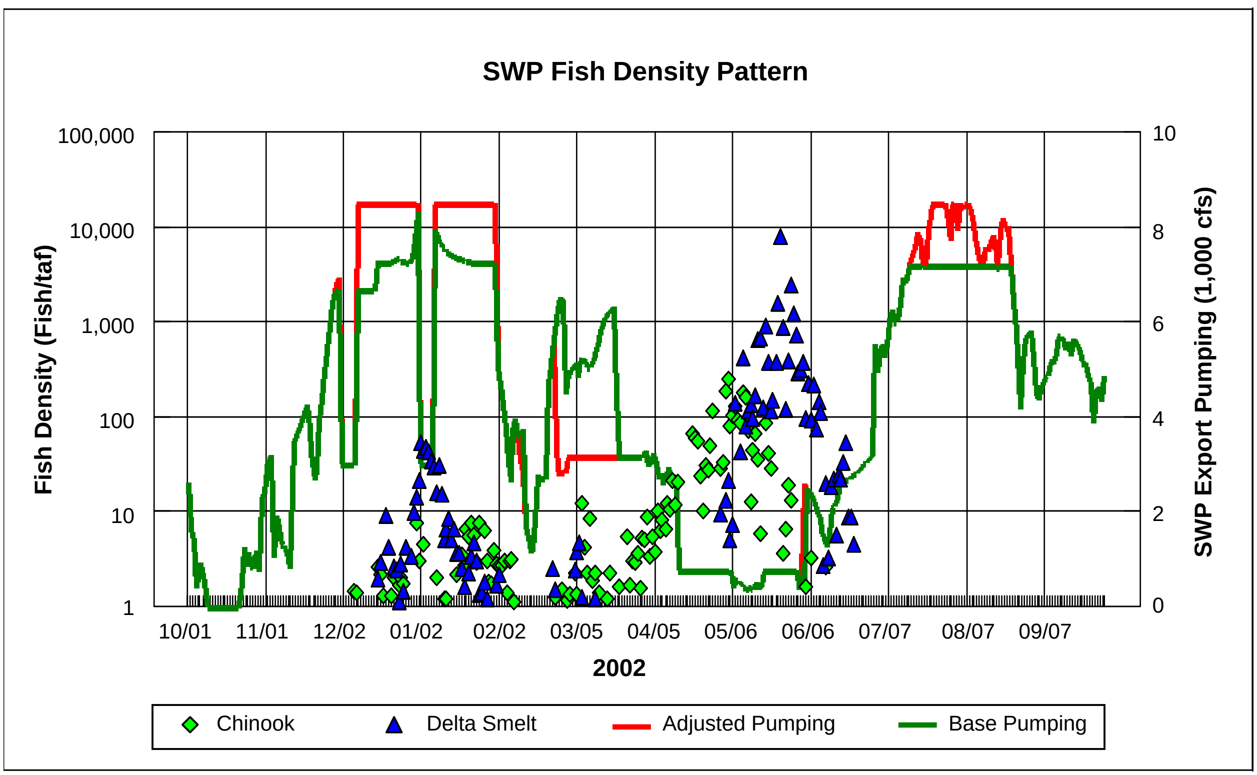

Figure B-31. Measured SWP Fish Density and Simulated Pumping with Historical EWA Actions for Water Year 2002 Compared with Simulated 8,500–cubic feet per second (cfs) SWP Banks Pumping

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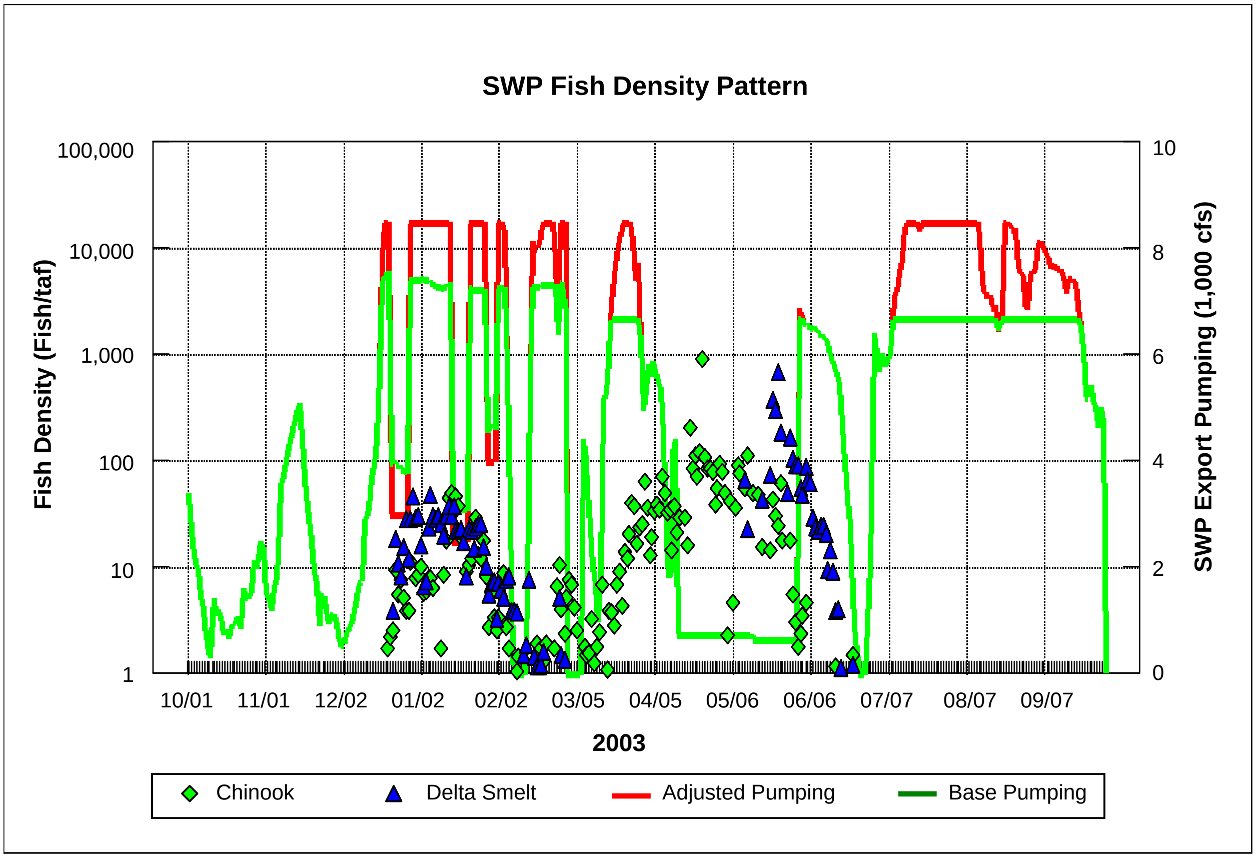

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Figure B-32

Measured SWP Fish Density and Simulated Pumping with Historical EWA Actions for Water Year 2003 Compared with Simulated 8,500–cubic feet per second (cfs) SWP Banks Pumping