2009

ANNUAL TECHNICAL REPORT

San Joaquin River Agreement

VERNALIS ADAPTIVE MANAGEMENT PLAN

SAN JOAQUIN RIVER GROUP AUTHORITY

Figure 1-1

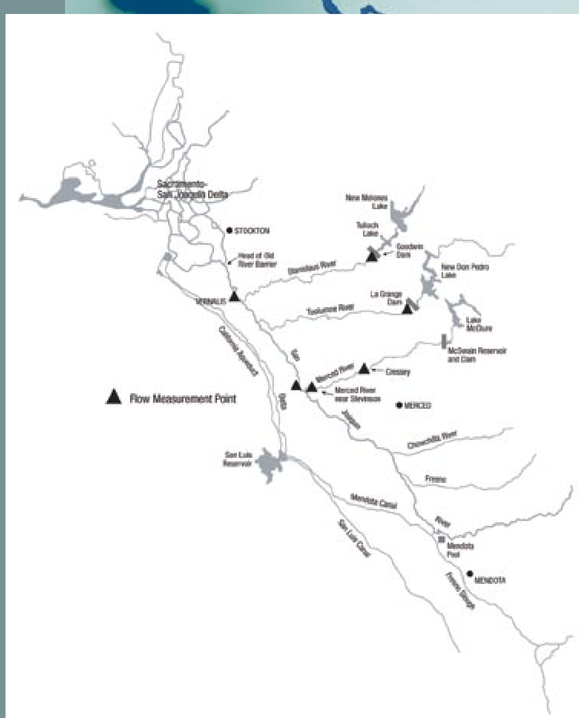

Figure 2-1

2009 ANNUAL TECHNICAL REPORT

On Implementation and Monitoring of the San Joaquin River Agreement and the Vernalis Adaptive Management Plan (VAMP)

Prepared by
San Joaquin River Group Authority

Prepared for the
California Water Resources Control Board
in compliance with D-1641

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TABLE OF CONTENTS

EXECUTIVE SUMMARY

The San Joaquin River Agreement (SJRA) is the cornerstone of a history-making commitment to implement the State Water Resources Control Board (SWRCB) 1995 Water Quality Control Plan (WQCP) for the lower San Joaquin River and the San Francisco Bay-Delta Estuary (Bay-Delta). The Vernalis Adaptive Management Plan (VAMP), officially initiated in 2000 as part of SWRCB Decision 1641, is a large-scale, long-term (12-year), experimental-management program designed to protect juvenile Chinook salmon migrating from the San Joaquin River through the Sacramento-San Joaquin Delta. The VAMP is also a scientific experiment to determine how salmon survival rates change in response to alterations in San Joaquin River flows and State Water Project (SWP)/Central Valley Project (CVP) exports with the installation of the Head of Old River Barrier (HORB), however the HORB was not installed in 2009.

The VAMP design provides for a 31-day pulse flow (target flow) in the San Joaquin River at the Vernalis gage along with a corresponding reduction in SWP/CVP exports. The magnitude of the pulse flow is based on an estimated flow that would occur during the pulse period absent the VAMP. As part of the implementation planning, the VAMP hydrology and biology groups meet regularly to review current and projected information on hydrologic conditions occurring within the San Joaquin River watershed. This facilitates communication and coordination for both the VAMP Chinook salmon smolt survival experiments and for scheduling stream flow releases on the Tuolumne, Merced, and Stanislaus rivers to facilitate the experimental investigations and protection for juvenile salmon.

The 2009 Technical Report consolidates the annual SJRA Operations and the VAMP Hydrology and Fish Monitoring Reports. The 2009 VAMP program represents the tenth year of formal compliance with SWRCB Decision 1641 (D-1641). D-1641 requires the preparation of an annual report documenting the implementation and results of the SJRA program. Specifically, this 2009 report includes the following information on the implementation of the SJRA: the hydrologic chronicle; management of any additional SJRA water; the acoustic telemetry experimental design; flow and fisheries monitoring in the lower San Joaquin River, Old River, and Delta; results of the juvenile salmon acoustic tag study; discussion of complementary investigations; conclusions and recommendations and a summary of the 2008 acoustic tagging survival study which was not available for inclusion in the 2008 Annual Technical Report due to delays in data processing.

Head of Old River Fish Barrier Installation

In previous years, a physical barrier had been installed at the head of Old River to block the movement of salmon smolts into Old River while allowing them to continue down the main stem of the San Joaquin River. With concerns for the protection of endangered delta smelt, a physical barrier was not installed in 2009 at the head of Old River, similar to 2008. In 2009 however, the Department of Water Resources (DWR), in cooperation with the Bureau of Reclamation (USBR), began the initial testing of a non-physical behavior barrier at the head of Old River. In addition, DWR was conducting a complimentary study on the effects of south Delta temporary barriers on juvenile salmon. Many of the receivers used in both these studies were established to complement the VAMP study thus providing a better picture of the salmon smolt route selection and survival through key channels within the interior South Delta. Receiver locations for the VAMP study were coordinated with these two studies to ensure that the maximum amount of data is available to all three studies and that no duplication of effort takes place. In addition, the

VAMP fish releases were coordinated to compliment these studies. A discussion of these two barrier studies is included in Chapter 4 of the 2009 Annual Report.

Hydrology

The seasonal precipitation in the San Joaquin Hydrologic Region (Cosumnes, Mokelumne, Stanislaus, Tuolumne, Merced and San Joaquin Rivers) measured only 90% of average on April 1, 2009. The forecasted April-July runoff as of April 1st in the four basins above Vernalis (Stanislaus, Tuolumne, Merced and San Joaquin) ranged from 77% to 89% of average. Water Year 2009 was classified as "dry" based on the April 1st- 90% probability of exceedence forecast of the San Joaquin Valley Water Year Type Index (60-20-20 Index). The dry classification for Water Year 2009 along with the "critical" water-year type classification for both of the previous two water years, 2007 and 2008, triggered the "Sequential Dry-Year Relaxation" condition in Section 5.3 of the SJRA, which states:

"During years when the sum of the current year's 60-20-20 indicator and the previous two years' 60-20-20 indicator is four or less, the SJRGA's members will not be required to provide water above Existing Flow."

The planning process for the VAMP operation remained nearly unchanged from those of prior VAMP years as outlined in the SJRA until the April 1st forecast data was available and it was known with certainty that the sequential dry-year relaxation condition was triggered. The implementation process was different from previous years since there was no VAMP target flow or VAMP supplemental water. Because the VAMP fish release and acoustic tracking experiment was occurring and the Sequential Dry-Year Relaxation condition was in affect, the tributary agencies agreed to coordinate their operations to the degree possible to minimize the variation in flow in the San Joaquin River near Vernalis. Since the Merced River was being operated to a minimum flow requirement, the tributary operational flexibility was limited to the volume of pulse water on the Tuolumne River required by FERC and a volume of Central Valley Project Improvement Act (CVPIA) Section 3406 (b)(2) and 3406 (b)(3) water being provided on the Stanislaus.

The mean daily flow at Vernalis varied between 1,830 cubic feet per second (cfs) and 2,650 cfs during the target flow period. Since the Sequential Dry-Year Relaxation condition was in affect the combined CVP and SWP Delta export rate target during the VAMP period was specified by the CALFED Water Operations Management Team (WOMT) as follows: "The Projects will operate to a combined export pumping rate of 1,500 cfs or a combined rate equivalent to flow on the San Joaquin River at Vernalis (1:1), whichever is greater, starting April 17th and continuing through May 17th." The observed exports during this period averaged 1,990 cfs and ranged from 1,350 cfs to 2,590 cfs.

Fish Monitoring Experimental Design

VAMP is intended to employ an adaptive management strategy using current knowledge to protect Chinook salmon as they migrate through the Delta, while gathering information to allow more efficient protection in the future. The 2009 VAMP represented the fourth year of using the acoustic telemetry technology. The first year was a pilot trial, followed in the second year by a slightly extended receiver network and 2008 was to have been the first full-scale year with a full receiver network. As reported in the 2008 VAMP Technical Report, the VAMP team experienced considerable equipment malfunctions, including tag failure that made survival estimates potentially biased. For 2009, the VAMP team was intent on overcoming these shortcomings while following the same structural setup as the 2008 VAMP study used.

The VAMP Technical Committee began formulating a plan using a network of acoustic receivers to estimate fish survival similar to 2008. The key to this network is the highly technical dual-array four-port receivers at Mallard Island (Chipps Island) and Jersey Point. Unfortunately VAMP did not have the assistance of the United States Geologic Survey in 2009 to install the key monitoring stations at Jersey Point and Chipps Island. Without acoustic receivers at those locations, overall fish survival to Mallard Island could not be estimated or compared with data obtained in previous years using coded wire tag (CWT) procedures. As a result the program for 2009 was redefined to look more closely at salmon smolt survival in key reaches of the South Delta and fish route "selection" probabilities at critical flow splits (i.e., head of Old River and Turner Cut).

The VAMP team in 2009 focused on demonstrating that the acoustic telemetry technology could be utilized to determine fish survival and route selection in the South Delta, by continuing to test the acoustic receiver network and equipment, and refining logistical approaches to a larger-scale field study should a study of this nature be continued in future years.

Specific experimental objectives of VAMP 2009 included:

- Quantification of Chinook salmon smolt survival along individual San Joaquin River segments between Durham Ferry, Mossdale, Head of Old River, Lathrop, Stockton, and Turner Cut by detection of acoustic signals from transmitters implanted in the test fish.

- Quantification of Chinook salmon smolt survival along Old and Middle rivers by detecting of acoustic signals from transmitters implanted in the test fish.

- Evaluation of migration path selection at the San Joaquin River – Old River flow split at the Head of Old River and at the San Joaquin River – Turner Cut split under the 2009 low flow conditions and the use of the non-physical barrier.

- Monitoring predation activities near the Head of Old River, the CVP export facility, and the San Joaquin River main stem from Durham Ferry to Stockton.

- Evaluation of fish mortality to Clifton Court Forebay.

- Evaluation of the acoustic receiver network performance under the unique temperature, flow and environmental conditions found in the South Delta.

- Evaluation of acoustic tag reliability and tag battery life under South Delta conditions.

- Health and physiology testing of dummy tagged VAMP fish at Durham Ferry to evaluate the incidence of disease, in addition to weekly bioassays conducted on dummy tagged and unmarked fish at Stockton and Durham Ferry to assess differential health of test fish between the two locations.

- Determine the condition and mortality of "dummy tagged" salmon held for 48 hours in net pens near the holding and release sites.

Study Implementation

During the 2009 study, Chinook salmon smolts were acoustically tagged with Hydroacoustic Technology Incorporated (HTI) tags and seven releases were made in the San Joaquin River at Durham Ferry over a three and a half week period between April 22nd and May 13th with three releases made during the day (1700 hours) and four releases made at night (2100 hours). This design was intended to obtain an "average" survival rate for juvenile salmon migrating through the Delta. Each tagged fish was detected and uniquely identified as it passed acoustic receivers placed on key migration routes. Principal objectives of the hydrophone layout were to: (1) obtain fish survival estimates in some key reaches of the Delta, and (2) obtain fish route "selection" probabilities at critical flow splits (i.e., head of Old River and Turner Cut). Detection data from receiver sites were analyzed within a release-recapture model to simultaneously estimate survival, route distribution, and detection probabilities throughout the Delta. Detection data from mobile tracking and predator tracking were also obtained to help interpret the survival estimates.

To determine the "behavior" of dead fish, a total of five tagged smolts were intentionally sacrificed immediately before release and released with the live study fish. The intent of this effort was to evaluate how far downstream a dead fish may travel since detection of dead fish at a receiver would be perceived in the model as survival of that fish to that point.

In order to evaluate the effects of tagging, transportation and release several groups of fish were implanted with inactive, or dummy, transmitters. Dummy tags were interspersed randomly into the tagging order for each release group. For each Durham Ferry release, 10 fish implanted with dummy transmitters were included in the tagging process. Procedures for tagging these fish, transporting them to the release site, and holding them at the release site were the same as for fish with active transmitters. These tests showed little affect from tagging or handling.

As in prior years computerized temperature recorders were employed at the fish handling facilities, in the transport trucks, at the release sites and throughout the lower San Joaquin River and Delta for a continuous record of temperatures encountered by the migrating test fish. Overall the average temperature at all sites remained below 20º C, which is considered suitable for salmon smolts.

A tag life study was conducted to determine any bias in the survival estimates caused by premature failure of the acoustic tags. A random sample of 50 tags was used to determine tag life. Each tag was programmed and the first tags did not begin to die until 21 days after initialization. Thus tag life was not an issue in 2009 as it was in 2008. A study was also conducted to determine if there was any difference between taggers and none was found thus making the survival modeling stronger.

Acoustically tagged salmon smolts were tracked through a series of receivers located on key migration routes. Principal objectives of the hydrophone layout were to: (1) obtain fish survival estimates in some key reaches of the Delta, and (2) obtain fish route "selection" probabilities at critical flow splits (i.e., head of Old River and Turner Cut).

Survival Study Results

USGS utilized both auto-marking (to improve efficiency) and manual validation (to ensure accuracy) for processing VAMP data in 2008. In 2009, data were processed manually to try to differentiate between acoustic signals coming from live salmon and acoustic signals coming from predators that had eaten tagged salmon, in an effort to evaluate the potential bias associated with predation within the study. This information was then used in the survival modeling to determine the importance of this factor.

A total of 468 tags were detected downstream of Durham Ferry with a "smolt-type" detection and used in the survival analysis, out of the 933 tagged salmon smolts that were released in 2009. Very few tagged salmon smolts were detected at the exit points of the study area in either the San Joaquin River route or the Old River route. No tagged salmon were detected at exit point receivers at Turner Cut, Middle River at Highway 4 or the interior receivers at Clifton Court Forebay. When all detections were used, including those with a "predator-type" signal, a higher number of tags were detected overall (650 vs. 468). However, even including the predator-type detections, there was only a single tag detected at Turner Cut, and no tags detected at Middle River. This high loss rate is of concern and needs to be studied in any future VAMP or VAMP-like studies.

Mobile telemetry surveys were also conducted this year from the fish release point to Stockton and to Clifton Court. During the VAMP these surveys found a total of 173 acoustic tags believed to be dead tagged salmon or tags defecated by predatory fish. This represents 19% of the fish released at Durham Ferry. Not all the river channels were surveyed and the mobile monitoring was only done periodically and may have missed some transmitters on the river bottom. The high loss rate that was observed, whether from predation, latent mortality from fish tagging/transport or indirect effects of tagging/transport that may have made the salmon smolts more prone to predation, needs to be examined in greater detail to help in planning future studies.

When using only those tags that showed "smolt-like" behavior, total salmon smolt survival through the study area was estimated to be $\hat{S}_{Total}$ = 0.06 (SE=0.01). Estimated survival from Mossdale through the San Joaquin River route was $\hat{S}_A$ = 0.05 (SE=0.02), while estimated survival from Mossdale through the Old River route was $\hat{S}_B$ = 0.08 (SE=0.02). It is important to note that the estimated survival in the Old River route ($\hat{S}_B$) includes survival to the receivers that marked the entries of the water export facilities, but does not include survival into the holding tanks or salvage facilities at these sites. If it included them, survival in the Old River Route would be even lower than 0.08.

When all detections were used in the survival model, including those detections with a "predator-type" signal, total survival through the study area was estimated to be $\hat{S}_{Total}$ = 0.34 (SE=0.03). This estimate of survival was much higher than the estimate from only the smolt-type detections, indicating that ignoring predation may yield strong positive biases in overall salmon survival estimates. Estimated route-specific survival through the San Joaquin River route was very similar whether the predator-type detections were used or not. However, route-specific survival through the Old River route depended heavily on whether or not predator-type detections were included in the analysis, with an estimate of $\hat{S}_B$ = 0.08 without predator-type detections and an estimate of $\hat{S}_B$ = 0.58 with predator-type detections. This is because the majority of the tags detected at either the Clifton Court Forebay or the Central Valley Project were classified as being in predators at the time of detection. Using predator-type detections to estimate survival through these areas is likely to overestimate salmon survival, and should be avoided. In future years, it will be important to attempt to distinguish between acoustic signals from live salmon smolts and those from predators that have eaten study fish in order to minimize bias in the survival estimates that is introduced by predation.

The acoustic telemetry data can also be used to estimate travel time between fixed points. Because no fish arrived at the Turner Cut receiver, it is only possible to estimate travel time from the Durham Ferry release point to Channel Marker 18 in the Deep Water Ship Channel of the San Joaquin River. Estimated travel time was 6.3 days (SE=0.7 d) while from the release point to the pumping facilities was estimated at 2.3 days (SE=0.2 d). These travel times are clearly within the life of the acoustic tags being used.

Twenty-three striped bass predators were tagged during and prior to the 2009 VAMP study to track their movements. Movement was extensive and the low number of tagged fish did not allow any analysis of their movements in relation to salmon smolt movement. Because of the extensive findings of predator-like movements of the tagged smolts, it is strongly recommended to develop and execute a more extensive predator tagging effort in the future.

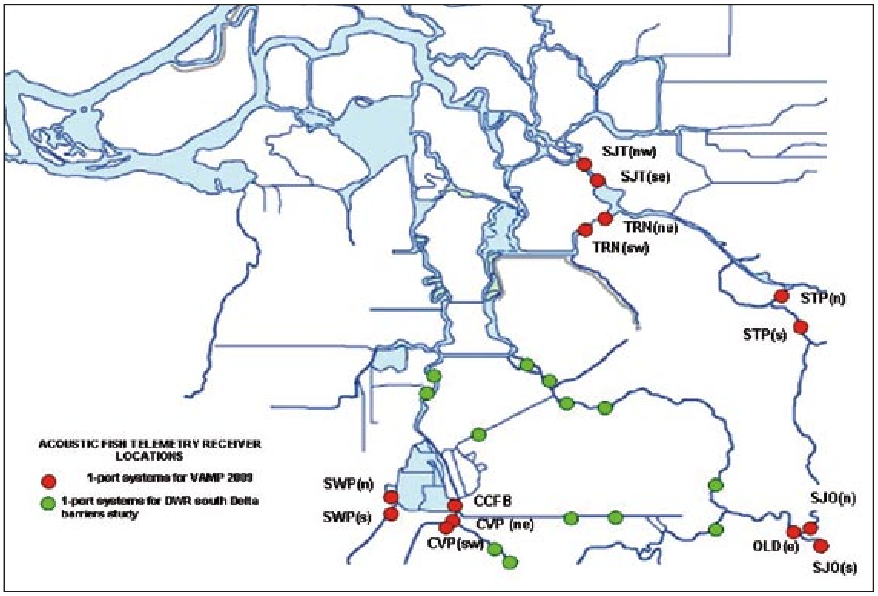
To further refine the relationship between survival and exports with the HORB, the VAMP experiments were designed to estimate survival at a flow of 7,000 cfs at two export levels, 1,500 and 3,000 cfs. We have not yet been able to estimate survival under these experimental conditions. In addition with the new National Marine Fisheries Service requirements for the protection of steelhead, it is unlikely that the export rates will be above 1,500 cfs during the VAMP period. In addition, due to concerns for Delta smelt, it is uncertain that a physical barrier at the Head of Old River will be installed during VAMP in the future.

CHAPTER 1
INTRODUCTION

Actions associated with the Vernalis Adaptive Management Plan (VAMP) were implemented between April 19 and May 19, 2009 to protect juvenile Chinook salmon and evaluate the survival of marked juvenile Chinook salmon migrating through the Sacramento – San Joaquin Delta. Diminished adult salmon returns and low smolt production at the Merced River Fish Hatchery did not allow for the standard VAMP coded wire tag study to be implemented. For the third straight year, the 2009 VAMP relied on the acoustic telemetry and tracking methodology to monitor the migration of salmon smolt through the Delta. The VAMP Fish Monitoring Experiment start date was delayed seven days to April 22nd from the default start date of April 15th to allow for additional growth of the experimental fish. The total 1,000 fish were tagged with 950 released for the experiment and 50 held for continuous monitoring in a closed system to quantify the rate of tag failure throughout the study period. A total of seven releases were made between April 22nd and May 13th. All the releases took place at Durham Ferry (near Vernalis) with three releases made during the day and four releases made at night.

The VAMP Experiment is to look at salmon smolt survival through the Delta in relation to three factors; flow in the San Joaquin River at Vernalis, export rates at the State Water Project and Central Valley Project pumping operations and the effectiveness of the barrier at the Head of Old River. The water districts coordinate their operations in order to maintain stable flow in accordance with the SJRA throughout the VAMP 31-day target flow period. State and federal export pumping was also coordinated to maintain a steady total export rate. A physical barrier has been installed at the head of Old River until recently when a Federal Court decision on delta smelt protection halted the installation of a physical barrier at the HORB for both the 2008 and 2009 VAMP period. In 2009 however, the California Department of Water Resources (DWR), in cooperation with the US Bureau of Reclamation (USBR) began the initial testing of a non-physical behavior barrier at the head of Old River.

Figure 1-2.
Locations of acoustic receivers for the 2009 VAMP study (modified Plan) including locations of acoustic receivers that DWR plans to deploy for the south Delta temporary barriers study.



Experimental Design Elements

As described by the San Joaquin River Agreement (SJRA), VAMP is an experimental/management program designed to protect juvenile Chinook salmon migrating from the San Joaquin River while at the same time conducting a scientific experiment to determine how salmon survival changes in response to alterations in San Joaquin River flows, State and federal water project (SWP/CVP) export rates, and the operation of a physical barrier at the head of Old River (HORB). The original VAMP experimental design measures salmon smolt survival through the Delta under six different combinations of flow and export rates with the presence of a physical barrier at the head of Old River. The original experimental design described in Appendix A and B of the SJRA includes two mark-recapture studies performed each year during the April-May juvenile salmon outmigration period that provide estimates of salmon survival under each set of conditions. The primary technique used was coded wire tags (CWT). Results from the CWT studies conducted as part of the first seven years of the VAMP experiments are available in San Joaquin River Agreement Technical Reports, for each respective year (2000-2006). Similar coded wire tag (CWT) experiments were conducted prior to the official implementation of VAMP with results available in South Delta Temporary Barriers Annual Reports (DWR 2001 and DWR 1998).

During 2007, due to a combination of events, test fish were not available from the Merced River Fish Hatchery (MRH) to permit a fully implemented CWT study. The primary reason was that an adequate number of smolts were not produced at the MRH. In addition, the CWT study was further constrained by recent concerns for delta smelt that seriously limited the traditional recovery (recapture) methods envisioned in the original study plan. To make up for this loss in 2007, a group of study fish from the MRH were surgically implanted with acoustic transmitters capable of emitting an electronic signal for up to 3 weeks. Stationary receivers were used to intercept the transmitted electronic signals and data were collected on salmon smolt behavior and mortality conditions within the South Delta and through the San Joaquin River from Durham Ferry to Chipps Island. Survival was also estimated for intermediate reaches along various migration paths.

Because of a continuing shortage of test fish from the MRH and the apparent success of the acoustic telemetry method, a full study program using acoustic telemetry was initiated in 2008 including an expanded number of acoustic receivers to better understand the movement of salmon smolts once they enter the Delta. This same study design was used in the 2009 VAMP study and is reported on here. This report describes the experimental design used in 2009, the hydrologic planning and implementation during the third year of a drought, the additional water supply arrangements and deliveries, fishery monitoring within the San Joaquin River and Old River using the acoustic tagging procedure along with experimental and complimentary studies related to VAMP, including the use of a non-physical barrier at the head of Old River. Conclusions and recommendations for future VAMP studies are also included.

2009 VAMP Experimental Design Concept

In 2008, due to unforeseen and excessive tag and equipment malfunctions, it was not possible to obtain an unbiased survival estimate. Even though conclusive survival estimates could not be determined from the 2008 experiment, valuable information was collected on smolt behavior (smolt distribution, migration timing and predator problems) and on methods of implementing an acoustic telemetry study under South Delta conditions. For 2009, the VAMP experimental design was to follow the structural setup of the 2008 study Figure 1-1 (inside front cover). After reconsideration of resources and project staff and the projected dry year, the VAMP Technical team implemented a modified plan that emphasized a better understanding of fish survival estimates in several key reaches of the South Delta and fish route selection probabilities at critical flow splits (i.e., head of Old River and Turner Cut). Fourteen acoustic receiver sites located along the lower San Joaquin River, Old River, in south Delta channels and at the export fish facilities were used to track smolt movement throughout the South Delta. This final layout of the fourteen receivers is shown by the red dots in Figure 1-2. This study structure focused the VAMP Team on a more concise effort that emphasized the original objectives for 2009 which were demonstrating that the acoustic telemetry technology can be utilized to determine fish survival and route selection the South Delta, continued testing of the acoustic receiver network and equipment under the extreme conditions of the South Delta, and refining logistical approaches to a larger-scale field study should a study of this nature be continued in future years.

In addition, DWR was conducting a simultaneous study of the effect of the South Delta temporary barriers on juvenile salmon by installing acoustic receivers at the unlabeled, green sites shown in Figure 1-2. There sites, along with the VAMP acoustic receiver sites provided almost complete coverage of the South Delta migration routes that may be used by salmon smolts.

The 2009 VAMP represents the tenth year of the VAMP experiment. This report summarizes the efforts made during the VAMP flow and fish monitoring programs. Chapter 2 of this report describes the hydrologic planning and implementation during what was to be the third year of drought in the San Joaquin River Basin thus requiring different flow regimes than found in previous years. Chapter 3 describes the additional water supply arrangement and deliveries that occurred during the drought year and fall attraction waters following the third year of drought. The efforts to install and monitor the performance of the non-physical (behavior) barrier at the Head of Old River is outlined in Chapter 4 along with the operational changes that were put in place at the State and federal pumping facilities during the third year of drought.

Salmon smolt survival investigations are presented in Chapter 5. These include discussions on fish rearing and transport as well as the transmitter implantation techniques used. The discussion also includes the development and operation of the receiver network and the data processing from the receivers as well as results from mobile tracking conducted simultaneously. A discussion of predator activity during the 2009 VAMP is also included. The study this year also included the development and execution of a survival model and how well the receiver network and data development allowed an estimate of survival. Also included in this year's report as an appendices is the salmon smolt survival analysis for the 2008 VAMP Fish Monitoring Program that was not available for the 2008 VAMP report.

As in previous years, the report also includes a summary of complementary studies that were conducted at the same time as VAMP or were related to VAMP. These included salmon data from the tributaries, the 2009 Mossdale Trawl and health studies done on tagged fish to determine if this impacted the survival results.

CHAPTER 2

HYDROLOGIC PLANNING AND IMPLEMENTATION

Implementation of the Vernalis Adaptive Management Plan (VAMP) is guided by the framework provided in the San Joaquin River Agreement (SJRA) and recognition of the hydrologic conditions within the watershed. The Hydrology Group of the San Joaquin River Technical Committee (SJRTC) was established for the purpose of forecasting hydrologic conditions and for planning, coordinating, scheduling and implementing the flows required to meet the test flow target in the San Joaquin River near Vernalis. The Hydrology Group is also charged with exchanging information relevant to the forecasted flows, and coordinating with others in the SJRTC, in particular the Biology Group, whose responsibility is to plan and implement the salmon smolt survival study.

Participation in the Hydrology Group is open to all interested parties, with the core membership consisting of the designees of the agencies responsible for the water project operations that would be contributing water to meet a target flow. In 2009, the agencies belonging to the Hydrology Group included: Merced Irrigation District (MeID), Turlock Irrigation District (TID), Modesto Irrigation District (MID), Oakdale Irrigation District (OID), South San Joaquin Irrigation District (SSJID), San Joaquin River Exchange Contractors (SJRECWA), and the U.S. Bureau of Reclamation (USBR). Though not a water provider, the California Department of Water Resources (DWR) was closely involved with the coordination of operations relating to the potential installation of the Head of Old River Barrier (HORB) and the planning and coordination with the USBR on Delta exports consistent with the VAMP.

VAMP Background and Description

The VAMP provides for a steady 31-day pulse flow (target flow) at the Vernalis gage on the San Joaquin River (see Figure 2-1 inside front cover) during the months of April and May, along with a corresponding reduction in State Water Project (SWP) and Central Valley Project (CVP) Sacramento-San Joaquin Delta exports. The VAMP target flow and reduced Delta export are determined based on a forecast of the San Joaquin River flow that would occur during the target flow period absent the VAMP (Existing Flow) as shown in Table 2-1. The Existing Flow is defined in the SJRA as "the forecasted flows in the San Joaquin River at Vernalis during the Pulse Flow Period that would exist absent the VAMP or water acquisitions," including such flows as minimum in-stream flows, water quality or scheduled fishery releases from New Melones Reservoir on the Stanislaus River, flood control releases, uncontrolled reservoir spills, and/or local runoff. Achieving the target flow requires the coordinated operation of the three major San Joaquin River tributaries upstream of Vernalis: the Merced River, the Tuolumne River and the Stanislaus River.

As part of the development of the VAMP experimental design, the SJRTC had identified a level of variation in San Joaquin River flow and SWP/CVP export rate thought to be within an acceptable range for specific VAMP test conditions. In developing the criteria, the SJRTC examined both the ability to effectively monitor and manage flows and exports within various ranges (e.g., the ability to accurately manage and regulate export rates is substantially greater than the ability to manage San Joaquin River flows) and the flow and export differences among VAMP targets (Table 2-1). Through these discussions, the SJRTC agreed that SWP/CVP export rates would be managed to a level of plus or minus 2.5% of a given export rate target. Furthermore, the technical

Table 2-1
VAMP Vernalis Flow and Delta Export Targets as Defined in the San Joaquin River Agreement (SJRA)

Forecasted Existing Flow (cfs)	VAMP Target Flow (cfs)	Delta Export Target Rates (cfs)
0 to 1,999	2,000	
2,000 to 3,199	3,200	1,500
3,200 to 4,449	4,450	1,500
4,450 to 5,699	5,700	2,250
5,700 to 7,000	7,000	1,500 or 3,000
Greater than 7,000	Provide stable flow to extent possible	1,500, 2,250 or 3,000*

* Suggested rates at higher flows.

committees agreed that, to the extent possible, it would be desirable that exports be allocated approximately evenly between SWP and CVP diversion facilities.

The ability to manage and regulate the San Joaquin River flow near Vernalis is difficult due to uncertainty and variation in unregulated flows, inaccuracy in real-time flows due to changing channel conditions, lags and delays in transit time, and a variety of other factors. Concern was expressed that variation in San Joaquin River flow on the order of plus or minus 10% would potentially result in overlapping flow conditions between two VAMP targets. To minimize the probability of overlapping flow conditions among VAMP targets, the SJRTC explored an operational guideline of plus or minus 5% flow variation at the Vernalis gage; however, system operators expressed concern about the ability to maintain flows within this range. As a result of these discussions and analysis, the SJRTC agreed to a target range variation of plus or minus 7% of the Vernalis flow target. It was recognized by the SJRTC that these guidelines are not absolute conditions, but are to be used to evaluate the potential effect of flow and export variation on the ability to detect and assess variation in juvenile Chinook salmon survival.

Under the SJRA, the San Joaquin River Group Authority (SJRGA) member agencies MeID, OID, SSJID, SJRECWA, MID and TID have agreed to jointly provide the supplemental water needed to achieve the VAMP target flows, limited to a maximum of 110,000 acre-feet. The MeID supplemental water would be provided on the Merced River from storage in Lake McClure and would be measured at the DWR Merced River at Cressey stream-gage. The OID and SSJID supplemental water would be provided on the Stanislaus River through diversion reductions and would be measured below Goodwin Dam. The SJRECWA supplemental water would be provided via Salt Slough, West Delta Drain, Boundary Drain and/or Orestimba Creek. The MID and TID supplemental water would be provided on the Tuolumne River from storage in Don Pedro Lake and would be measured at the Tuolumne River below LaGrange Dam stream-gage.

The target flow of 2,000 cubic feet per second (cfs) shown in Table 2-1 does not represent a VAMP experiment target flow data point, but, rather, is used to define the SJRGA supplemental water obligation limit when Existing Flow is less than 2,000 cfs. In preparation of the conceptual framework for the VAMP it was recognized that in extremely dry conditions the San Joaquin River flow and associated exports would be determined in accordance with the existing biological opinions under the Endangered Species Act and the 1994 Bay-Delta Accord. In consideration of these factors, when the Existing Flow is less than 2,000 cfs, the target flow will be 2,000 cfs and the USBR, in accordance with the SJRA, shall act to purchase additional water from willing sellers to fulfill the requirements of existing biological opinions.

When the Existing Flow exceeds 7,000 cfs the parties to the SJRA will exert their best efforts to maintain a stable flow during the VAMP target flow period to the extent reasonably permitted. Under such conditions the SJRTC shall attempt to develop a plan to carry out the studies pursuant to the SJRA.

Based upon hydrologic conditions, the target flow in a given year could either be increased to the next higher value (double-step) or the supplemental water requirement could be eliminated entirely (sequential dry-year relaxation). These potential adjustments to the target flow are dependent on the hydrologic year type as defined by the 60-20-20 Index, which is given a numerical indicator as shown in Table 2-2 to make this determination. A double-step flow year occurs when the sum of the numerical indicators for the previous year's year type and current year's forecasted 90 percent exceedence year type is seven (7) or greater, a general recognition of either abundant reservoir storage levels or a high probability of abundant runoff. A sequential dry-year relaxation year occurs when the sum of the numerical indicators for the two previous years' year-types and the current year's forecasted 90 percent exceedence year-type is four (4) or less, an indication of extended drought conditions.

Table 2-2
San Joaquin Valley Water Year Hydrologic Classification Numerical Indicators Used in VAMP as Defined in the San Joaquin River Agreement (SJRA)

Water Year Classification (60-20-20 Index)	VAMP Numerical Indicator
Wet	5
Above Normal	4
Below Normal	3
Dry	2
Critical	1

Under the SJRA, the maximum amount of supplemental water to be provided to meet VAMP target flows in any given year is 110,000 acre-feet. In a double-step year, the quantity of supplemental water required may be as high as 157,000 acre-feet. In any year in which more than 110,000 acre-feet of supplemental water is needed, the USBR will attempt to acquire the needed additional water on a willing seller basis. In accordance with the SJRA, the SJRGA has agreed to extend a "favored purchaser" offer to the USBR through each current year's VAMP period.

2009 VAMP Year

The Water Year 2009[1] winter was dry in the San Joaquin River watershed, with seasonal precipitation in the San Joaquin Hydrologic Region (Cosumnes, Mokelumne, Stanislaus, Tuolumne, Merced and San Joaquin Rivers) measuring 90% of average on April 1, 2009[2]. The forecasted April-July runoff as of April 1st in the four basins above Vernalis (Stanislaus, Tuolumne, Merced and San Joaquin) ranged from 77% to 89% of average[2]. Water Year 2009 was classified as "dry" based on the April 1st 90% probability of exceedence forecast of the San Joaquin Valley Water Year Type Index (60-20-20 Index). The dry classification for Water Year 2009 along with the "critical" water year type classification for both of the previous two water years, 2007 and 2008, triggered the "Sequential Dry-Year Relaxation" condition in Section 5.3 of the SJRA, which states:

> *"During years when the sum of the current year's 60-20-20 indicator and the previous two years' 60-20-20 indicator is four or less, the SJRGA's members will not be required to provide water above Existing Flow."*

The planning process for the VAMP operation remained nearly unchanged from those of prior VAMP years and that outlined in the SJRA until the April 1st forecast data was available and it was known with certainty that the sequential dry-year relaxation condition was triggered. The implementation process was different from previous years since there was no VAMP target flow or VAMP supplemental water. However, since the VAMP fish release and acoustic tracking experiment was occurring, the flow conditions were monitored and tributary operations were coordinated to the degree possible to minimize flow fluctuations in the San Joaquin River near Vernalis during the VAMP study period.

Hydrologic Planning for 2009 VAMP

The SJRTC Hydrology Group held two meetings to discuss and plan the 2009 VAMP operation: February 27th and March 19th. At these meetings, forecasts of hydrologic and operational conditions on the San Joaquin River and its tributaries were discussed and refined.

A significant difference for 2009 was that it was the first year since the VAMP experiment started where there was a possibility of the "Sequential Dry-Year Relaxation" condition occurring. The previous two water years, 2007 and 2008, were both classified as Critical under the 60-20-20 classification. As per Table 2-2, each of these years has a VAMP numerical indicator of one. This meant that a 60-20-20 Index forecast for 2009 of Dry (VAMP numerical indicator of two) or Critical (VAMP numerical indicator of one), using the April 1st 90% probability of exceedence forecast, would trigger the Sequential Dry-Year Relaxation condition.

February - Initial Monthly Operation Forecast

As part of the initial planning efforts in February, a monthly operation forecast was developed by the Hydrology Group to provide an initial estimate of the Existing Flow and VAMP Target Flow. Inflows to the tributary reservoirs used in these forecasts were based on February 1st DWR Bulletin 120 runoff forecasts. The monthly operation forecasts used the 90 percent and 50 percent probability of exceedence runoff forecasts to provide a range of estimates. The initial monthly operation forecast was presented at the February 27th SJRTC Hydrology Group meeting. The 90 percent probability of exceedence forecast indicated an existing flow of about 1,900 cfs with a corresponding VAMP target flow of 2,000 cfs; the 50 percent probability of exceedence forecast indicated an existing flow of about 3,700 cfs with a corresponding VAMP target flow of 4,450 cfs. Since the previous year, Water Year 2008, was a Critical year (VAMP numerical indicator of 1) there was no chance of Water Year 2009 being a double-step year.

As noted above, a Dry or Critical water year classification for 2009 would trigger the Sequential Dry-Year Relaxation condition. Based on the February 26th DWR interim runoff forecast, the 90% and 50% probability of exceedence forecasts of the water year classification were Critical and Dry, respectively. At this point in the planning this meant that an average to below average March would result in the Sequential Dry-Year Relaxation condition, and that above average conditions would be needed to avoid it.

March - Daily Operation Plan Development

Starting in mid-March, the Hydrology Group began development of a daily operation plan, updating it as hydrologic conditions and operational requirements changed. The purpose of the daily operation plan is to provide a forecast of the Existing Flow, which sets the VAMP target flow, and to coordinate the tributary operations needed to meet the target flow. It also provides a forecast of the daily flows expected during the HORB installation period. The daily operation plan calculates an estimated mean daily flow at Vernalis based on forecasts of the daily flow at the major tributary control points, estimates of ungaged flow between those

[1] *Water Year 2009 is October 2008 through September 2009.*

[2] *Water Conditions in California, California Cooperative Snow Surveys Bulletin 120, Report 3, April 1, 2009. California Department of Water Resources.*

control points and Vernalis, and estimates of flow in the San Joaquin River above the Merced River.

The following travel times for flows from the tributary measurement points and upper San Joaquin River to the Vernalis gage are used in the development of the daily operation plan. Whole day increments are used because the daily operation plan is developed using mean daily flows.

Flow Travel Times

a. Merced River at Cressey to Vernalis....................3 days

b. San Joaquin River at Merced River to Vernalis...2 days

c. Tuolumne River below LaGrange Dam to Vernalis...2 days

d. Stanislaus River below Goodwin Dam to Vernalis...2 days

The forecast of the ungaged flow is the factor with the greatest uncertainty in the development of the daily operation plan. By definition, the ungaged flow at Vernalis is the unmeasured flow entering or leaving the system between the Vernalis gage and the upstream measuring points and is calculated as follows:

Ungaged flow at Vernalis = VNS - GDW_{lag} - LGN_{lag} - CRS_{lag} - $USJR_{lag}$

Where:

VNS = San Joaquin River near Vernalis

GDW_{lag} = Stanislaus River below Goodwin Dam lagged 2 days

LGN_{lag} = Tuolumne River below LaGrange Dam lagged 2 days

CRS_{lag} = Merced River at Cressey lagged 3 days

$USJR_{lag}$ = San Joaquin River above Merced River lagged 2 days

(USJR is not a gaged flow but is the calculated difference between the gaged flows immediately downstream of the Merced River confluence with the San Joaquin River at the San Joaquin River at Newman (NEW) gage and the gage on the Merced River near Stevinson (MST) which is immediately upstream of the Merced River inflow to the San Joaquin River).

An extensive review of historical ungaged flows has been made to determine if there are any correlations between the ungaged flow and the current hydrologic conditions that could be used to reduce the uncertainty. Unfortunately, no significant correlations were found. However, the review did indicate that the amount of ungaged flow at the beginning of the VAMP target flow period is a reasonable estimate of the average ungaged flow for target flow period. It is impossible to forecast day-to-day fluctuations of the ungaged flow, so the daily operation plan is developed assuming a constant ungaged flow throughout the target flow period essentially equal to the value entering the target flow period.

The VAMP 31-day target flow period can occur anytime between April 1st and May 31st. Factors that are considered in the determination of the timing of the VAMP target flow period include installation of HORB, availability of salmon smolt at the Merced River Hatchery (MRH), and manpower and equipment availability for salmon releases and tracking. Until a specific start date is defined, a default target flow period of April 15th to May 15th is used for the VAMP operation planning. Prior to the March Hydrology Group meeting the SJRTC had defined a VAMP target flow period of April 19th to May 19th for 2009 to allow the test salmon smolts to mature to the desirable size.

The initial daily operation plan was prepared for the March 19th Hydrology Group meeting. The daily operation plan was modified as hydrologic conditions and operational requirements changed. Table 2-3 provides a summary of the daily operation plans developed during the VAMP planning and implementation. All of the daily operation plans are provided in Appendix A-1, Tables 1 through 4.

Even though it seemed more likely that the Sequential Dry-Year Relaxation condition would occur, the final determination would be based on the April 1st forecast so the Hydrology Group continued planning as if a normal VAMP operation would be needed. A period of wet weather arrived in late February and early March which resulted in the 90% probability of exceedence forecast of the water year classification improving from Critical to Dry. Though an improvement, the potential for the Sequential Dry-Year Relaxation condition was still strong. After a wet first week of March the weather turned dry, and by April 1st, the 90% probability of exceedence forecast of the water year classification was Dry, thereby triggering the Sequential Dry-Year Relaxation condition.

Tributary Flow Coordination

Although the primary goal of the VAMP operation is to provide a stable target flow in the San Joaquin River near Vernalis, an important consideration in the planning and operation is that the flows that are scheduled on

Table 2-3 Summary of Daily Operation Plans for the 2009 VAMP								
Phase	**VAMP Forecast Date**	**DWR Runoff Forecast Date**	**VAMP Target Flow Period**	**Single or Double Step**	**Assumed Ungaged Flow at Vernalis (cfs)**	**Existing Flow (cfs)**	**VAMP Target Flow (cfs)**	**SJRGA Supplemental Water Requirement (acre-feet)**
Planning	3/19/09	3/10/09	April 20 - May 20	Single	500	2,960	3,200	14,630
					0	1,980	3,200	75,300
	4/15/09	4/14/09	April 19 - May 19	na	-100	2,220	na	na
Implementation	5/13/09	—	April 19 - May 19	na	-260	2,080	na	na

Table 2-4 Real-time Mean Daily Flow Data Sources Used in the 2009 VAMP	
Measurement Location	**Data Source**
San Joaquin River near Vernalis	USGS, station 11303500 (http://waterdata.usgs.gov/ca/nwis/dv?cb_00060=on&format=html&begin_date=2008-02-01&site_no=11303500&referred_module=sw)
Stanislaus River below Goodwin Dam	USBR, Goodwin Dam Daily Operation Report (http://www.usbr.gov/mp/cvo/vungvari/gdwdop.pdf)
Tuolumne River below LaGrange Dam	USGS, station 11289650 (http://waterdata.usgs.gov/ca/nwis/dv?cb_00060=on&format=html&begin_date=2008-02-01&site_no=11289650&referred_module=sw)
Merced River at Cressey	CDEC, station CRS (http://cdec.water.ca.gov/cgi-progs/queryDgroups?s=fw2)
Merced River near Stevinson	CDEC, station MST (http://cdec.water.ca.gov/cgi-progs/queryDgroups?s=fw2)
San Joaquin River at Newman	USGS, station 11274000 (http://waterdata.usgs.gov/ca/nwis/dv?cb_00060=on&format=html&begin_date=2008-02-01&site_no=11274000&referred_module=sw)

the Merced, Tuolumne and Stanislaus Rivers to achieve this goal are beneficial and do not conflict with studies or flow requirements on those rivers. During the development of the daily operation plan, the Hydrology Group consults with DFG and the tributary biological teams to determine periods when pulse flows and stable flows are desirable on the tributaries, what flow rates are desired, what rates of change are acceptable, and what minimum and maximum flows are acceptable.

Even though the Sequential Dry-Year Relaxation condition was triggered, meaning that no VAMP target flow would be defined or supplemental water provided, the fish release and tracking experiment was still taking place. Because of this, the tributary agencies agreed to coordinate their operations to the degree possible to minimize the variation in flow in the San Joaquin River near Vernalis. Since the Merced River would be operating to a minimum flow requirement, the tributary operational flexibility was limited to the volume of pulse water on the Tuolumne River required by FERC and a volume of Central Valley Project Improvement Act (CVPIA) Section 3406 (b)(2) and 3406 (b)(3) water being provided on the Stanislaus. As initially scheduled in mid-April and shown in the April 19th daily operation plan in Appendix A, the expectation was for a relatively stable flow of around 2,200 cfs. However, relatively wet and cool weather around May 1st resulted in an increase in the ungaged flow which resulted in a 300 to 400 cfs flow increase at Vernalis (see Figure 2-1 inside front cover), and an emergency water transfer on the Merced River for the San Luis-Delta Mendota Water Authority (SLDMWA) from May 6th to May 12th resulted in an additional increase in flow at Vernalis of about 200 to 300 cfs.

Implementation

Since the Sequential Dry-Year Relaxation condition was in affect, and no VAMP supplemental water was being provided, the implementation phase of the VAMP hydrologic operation consisted mainly of monitoring the flow conditions during the VAMP period and making modifications to the daily operation plan to the degree possible.

Operation Monitoring

The planning and implementation of the VAMP spring pulse flow operation was accomplished using the best available real-time data from the sources listed in Table 2-4. The real-time flow data used during the implementation of the VAMP flow have varying degrees of quality. The CDEC real-time data has not been reviewed for accuracy or adjusted for rating shifts, whereas the USGS real-time data has had some preliminary review and adjustment. During the VAMP flow period, the real-time flows at Vernalis and in the San Joaquin River tributaries are continuously monitored. Similarly, the computed ungaged flow at Vernalis and the flow in the San Joaquin River upstream of the Merced River are continuously updated. The monitoring is done to assure that the supplemental water deliveries are adhering to the tributary allocations contained in the SJRA Division Agreement to the extent possible, as well as to determine if adjustments need to be made to the operation plan.

Normally, the USGS makes monthly measurements of the flow at Vernalis to check the current rating shift. The real-time flows reported by the USGS and CDEC are dependent on the most current rating shift, therefore a new measurement and shift can result in a sudden and significant change in the reported real-time flow. In the past, arrangements were made with the USGS to measure the flow at Vernalis on a weekly basis during the VAMP target flow period in order to minimize the potential for these sudden and significant changes in the reported real-time flow. Since the Sequential Dry-Year Relaxation condition was in affect, the Hydrology Group decided that the weekly measurements which were made primarily for operational purposes were unnecessary, but since the flow record would be important for this period one additional measurement in April was arranged.

Table 2-5
Summary of USGS Flow Measurements at the San Joaquin River near Vernalis Gage During the 2009 VAMP

Date	Time	Gage Height (ft)	Measured Flow (cfs)	Rating Curve Shift (ft.)
1/21/09	9:56	8.39	1,070	+0.08
3/19/09	11:51	8.92	1,310	+0.08
4/15/09	11:15	8.96	1,260	+0.08
4/30/09	10:09	9.90	2,030	+0.39
5/13/09	11:30	10.64	2,730	+0.39
7/8/09	11:15	7.60	606	0.00

The results of these measurements are summarized in Table 2-5. There were no significant rating curve shifts experienced during the 2009 VAMP target flow period.

Results of Operations

The final record of flows during the VAMP period are based on the provisional mean daily flow data available from USGS and DWR as of October 1, 2009. Provisional data is data that has been reviewed and adjusted for rating shifts but is still considered preliminary and subject to change. Plots of the real-time and provisional flows at the primary measuring points are provided in Appendix A-2, Figures 1 through 7, to illustrate the differences between the real-time and the provisional data.

The mean daily flow in the San Joaquin River at the Vernalis gage averaged 2,280 cfs during the VAMP target flow period (April 19th – May 19th). Figure 2-2 shows the observed flows at Vernalis and at each of the tributary measurement points. The mean daily flow at Vernalis varied between 1,830 cfs and 2,650 cfs during the target flow period. A tabulation of the observed mean daily flows during and around the VAMP target flow period is provided in Table 2-6.

The mean daily ungaged flow at Vernalis averaged -71 cfs during the VAMP period, ranging from a minimum of -448 cfs to a maximum of 268 cfs. A plot of the ungaged flow is provided in Figure 2-3.

Since the Sequential Dry-year Relaxation condition was in affect the combined CVP and SWP Delta export rate target during the VAMP period was specified by the CALFED Water Operations Management Team (WOMT) as follows: "The Projects will operate to a combined export pumping rate of 1,500 cfs or a combined rate equivalent to flow on the San Joaquin River at Vernalis (1:1), whichever is greater, starting April 17th and continuing through May 17th." The observed exports during this period, shown in Figure 2-4, averaged 1,990 cfs and ranged from 1,350 cfs to 2,590 cfs.

Hydrologic Impacts

The Merced VAMP supplemental water is provided from storage in Lake McClure on the Merced River and the MID/TID VAMP supplemental water is provided from storage in Don Pedro Lake, thereby resulting in potential impacts on reservoir storage as a result of the VAMP operation. Any storage impacts, though, would be offset by any water conservation measures that have been instituted as a result of the SJRA and that result in a reduced reliance on river diversions. The OID/SSJID VAMP supplemental water is made available from their diversion entitlements and therefore there are no storage

impacts in New Melones Reservoir on the Stanislaus River due to the SJRA. Due to the extended nature of the VAMP, a 12-year plan, the storage impacts can potentially carry over from year to year, especially in below normal or dry years. Reservoir storage impacts are reduced or eliminated when the reservoirs make flood control releases.

Since the Sequential Dry-year Relaxation condition was in affect in 2009 no VAMP supplemental water was provided and therefore there were no corresponding storage impacts. However, Merced still provides the Fall pulse flow of 12,500 acre-feet as specified in Paragraph 8.4 of the SJRA (see Chapter 3). If it is assumed that Merced ID diversions from the Merced River are the same as they would have been without the SJRA, then the storage impact on Lake McClure following the 2009 VAMP operation and Fall SJRA transfer would be -104,610 acre-feet, as shown in Figure 2-5. However, as a result of the SJRA, Merced ID has undertaken a number of conservation measures that have resulted in a reduced reliance on Merced River diversions. Any reductions in Merced River diversions would offset the storage deficit shown in Figure 2-5. The impact of the Merced ID SJRA related conservation measures on Merced River diversions have not yet been quantified. It should be noted that even under the assumption that the storage deficit is equal to the supplemental water contribution, the SJRA has resulted in no reductions in Merced River flow during the ten years of VAMP operation as shown in Appendix B, Figure 3.

The cumulative storage impact to Don Pedro Reservoir is unchanged from that following the 2008 VAMP operation, -19,650 acre-feet (see Figure 2-6) since the Sequential Dry-year Relaxation condition was in affect during the 2009 VAMP and no target flow were released.

Summary of Historical VAMP Operations

2009 marks the tenth year of VAMP operation in compliance with D-1641. A summary of the VAMP target flows for these first ten years is provided in Table 2-7. A summary of the SJRGA supplemental water contributions is provided in Table 2-8. The SJRTC Hydrology Group monitors the cumulative impact of the SJRA on reservoir storage and stream flows. Plots of storage and flow impacts throughout the ten years of VAMP operation are provided in Appendix B, Figures 1 through 4.

Over the ten years of the program considerable variation has occurred in both the flow entering the system upstream of the Merced River and the ungaged flow within the system. With each update of the daily operation plan throughout the planning and implementation phases the upstream and ungaged flows would vary causing the SJRGA to reduce or increase the contribution of supplemental water in order to support the VAMP target flow. Analysis of the variability in the ungaged flow at Vernalis and the San Joaquin River above Merced River flow and how these affect the forecasting of the existing and supplemental flows is ongoing.

Table 2-6
2009 Vernalis Adaptive Management Plan (VAMP)
Final Flows and Accounting of Supplemental Water Contributions
VAMP Target Flow Period: April 19 – May 19 · Target Flow: N/A

Date	Merced R. at Cressey (3 day Travel Time to Vernalis)				Tuolumne R. blw LaGrange Dam (2 day Travel Time to Vernalis)			Stanislaus R. blw Goodwin Dam (2 day Travel Time to Vernalis)			San Joaquin R. above Merced R. Flow [2]	Ungaged Flow at Vernalis	San Joaquin River at Vernalis		
	Existing Flow [1]	Observed Flow	Merced ID Supplemental Flow	Exchange Contractors Supplemental Flow	Existing Flow [1]	Observed Flow	MID/TID Supplemental Flow	Existing Flow [1]	Observed Flow	OID/SSJID Supplemental Flow			Existing Flow [1]	Observed Flow	VAMP Supplemental Water
	(cfs)	(cfs)	(cfs)	(cfs)	(cfs)	(cfs)	(cfs)	(cfs)	(cfs)	(cfs)	(cfs)	(cfs)	(cfs)	(cfs)	(cfs)
04/01/09	209	209			167	167		451	451		360	(219)	1,060	1,060	
04/02/09	213	213			166	166		455	455		335	(196)	1,050	1,050	
04/03/09	217	217			167	167		455	455		344	(119)	1,070	1,070	
04/04/09	203	203			167	167		453	453		325	(105)	1,060	1,060	
04/05/09	222	222			167	167		525	525		321	(99)	1,080	1,080	
04/06/09	220	220			167	167		553	553		301	(92)	1,070	1,070	
04/07/09	228	228			168	168		656	656		331	(156)	1,060	1,060	
04/08/09	244	244			168	168		707	707		313	(143)	1,100	1,100	
04/09/09	241	241			168	168		704	704		294	(195)	1,180	1,180	
04/10/09	238	238			167	167		703	703		302	(166)	1,250	1,250	
04/11/09	236	236			167	167		706	706		304	(130)	1,280	1,280	
04/12/09	241	241			167	167		708	708		310	(43)	1,370	1,370	
04/13/09	243	243			167	167		702	702		339	(45)	1,370	1,370	
04/14/09	232	232			168	168		704	704		364	(101)	1,320	1,320	
04/15/09	224	224			188	188		702	702		364	(149)	1,300	1,300	
04/16/09	229	229			236	236		703	703		364	(179)	1,300	1,300	
04/17/09	225	225	0	0	342	342		1,000	1,000		364	(176)	1,310	1,310	
04/18/09	223	223	0	0	524	524	0	1,200	1,200	0	329	(207)	1,320	1,320	
04/19/09	232	232	0	0	674	674	0	1,208	1,208	0	297	(365)	1,570	1,570	
04/20/09	235	235	0	0	681	681	0	1,140	1,140	0	300	(448)	1,830	1,830	0
04/21/09	225	225	0	0	680	680	0	1,104	1,104	0	284	(442)	1,960	1,960	0
04/22/09	221	221	0	0	680	680	0	1,108	1,108	0	271	(373)	1,980	1,980	0
04/23/09	222	222	0	0	679	679	0	1,100	1,100	0	263	(393)	1,910	1,910	0
04/24/09	219	219	0	0	675	675	0	1,102	1,102	0	260	(304)	1,980	1,980	0
04/25/09	208	208	0	0	670	670	0	1,106	1,106	0	254	(253)	2,010	2,010	0
04/26/09	214	214	0	0	671	671	0	1,099	1,099	0	243	(149)	2,110	2,110	0
04/27/09	186	186	0	0	630	630	0	1,111	1,111	0	242	(79)	2,170	2,170	0
04/28/09	160	160	0	0	510	510	0	1,239	1,239	0	242	(61)	2,160	2,160	0
04/29/09	152	152	0	0	482	482	0	1,302	1,302	0	247	(57)	2,140	2,140	0
04/30/09	162	162	0	0	483	483	0	1,303	1,303	0	260	(67)	2,110	2,110	0
05/01/09	170	170	0	0	484	484	0	1,308	1,308	0	268	(11)	2,180	2,180	0
05/02/09	275	275	0	0	483	483	0	1,310	1,310	0	260	152	2,350	2,350	0
05/03/09	248	248	0	0	482	482	0	1,305	1,305	0	243	268	2,490	2,490	0
05/04/09	244	244	0	0	526	526	0	1,312	1,312	0	306	267	2,490	2,490	0
05/05/09	244	244	0	0	679	679	0	1,243	1,243	0	336	135	2,440	2,440	0
05/06/09	412	412	0	0	838	838	0	1,073	1,073	0	340	28	2,420	2,420	0
05/07/09	494	494	0	0	900	900	0	944	944	0	243	(102)	2,400	2,400	0
05/08/09	693	693	0	0	918	918	0	904	904	0	214	(105)	2,390	2,390	0
05/09/09	784	784	0	0	955	955	0	909	909	0	139	(29)	2,470	2,470	0
05/10/09	805	805	0	0	951	951	0	905	905	0	122	10	2,540	2,540	0
05/11/09	809	809	0	0	951	951	0	902	902	0	122	(76)	2,620	2,620	0
05/12/09	382	382	0	0	950	950	0	900	900	0	165	(122)	2,640	2,640	0
05/13/09	235	235	0	0	950	950	0	901	901	0	217	(130)	2,650	2,650	0
05/14/09	213	213	0	0	951	951	0	913	913	0	177	(294)	2,530	2,530	0
05/15/09	204	204	0	0	951	951	0	907	907	0	146	(50)	2,400	2,400	0
05/16/09	195	195	0	0	951	951	0	908	908	0	138	64	2,340	2,340	0
05/17/09	220	220	0	0	938	938	0	769	769	0	126	123	2,340	2,340	0
05/18/09	216	216			902	902	0	705	705	0	121	99	2,300	2,300	0
05/19/09	194	194			886	886		703	703		147	102	2,130	2,130	0
05/20/09	178	178			839	839		705	705		159	82	2,030	2,030	0
05/21/09	176	176			716	716		703	703		175	18	1,970	1,970	
05/22/09	187	187			602	602		706	706		173	(17)	1,880	1,880	
05/23/09	177	177			531	531		708	708		152	48	1,820	1,820	
05/24/09	172	172			491	491		697	697		163	123	1,780	1,780	
05/25/09	182	182			432	432		700	700		181	112	1,690	1,690	
05/26/09	161	161			390	390		707	707		170	122	1,650	1,650	
05/27/09	162	162			385	385		705	705		161	55	1,540	1,540	
05/28/09	156	156			348	348		708	708		157	1	1,450	1,450	
05/29/09	168	168			325	325		702	702		139	(22)	1,390	1,390	
05/30/09	171	171			300	300		702	702		143	(5)	1,370	1,370	
05/31/09	177	177			281	281		703	703		144	8	1,330	1,330	
							VAMP Period								
Average (cfs):	307	307	0	0	735	735	0	1,072	1,072	0	231	(71)	2,275	2,275	0
Supplemental Water (ac-ft):			0	0			0			0					0

■ VAMP Period

[1] Existing Flow: Flow that would have occured without VAMP operation.

[2] Upper SJR = Flow in San Joaquin River above Merced River = San Joaquin River at Newman minus Merced River at Stevinson.

Observed Flow Sources:

Merced River at Cressey (CA DWR B05155): California DWR, USDAY V64 Output 8/17/09

Merced River near Stevinson (CA DWR B05125): California DWR, USDAY V64 Output 8/17/09

Tuolumne River below LaGrange Dam near LaGrange (USGS 11289650): USGS, provisional data as of 9/29/09

Stanislaus River below Goodwin Dam: USBR, Goodwin Reservoir Daily Operations Report - OID/SSJID/Tri-Dams, 5/1/09 (April report) and 6/1/09 (May report)

San Joaquin River near Vernalis (USGS 11303500): USGS, provisional data as of 9/29/09

San Joaquin River at Newman (USGS 11274000): USGS, provisional data as of 9/29/09

Table 2-7
Summary of VAMP Flows, 2000-2009

Year	60-20-20 Water Year Hydrologic Classification	VAMP Numerical Indicator	VAMP Target Flow Period	VAMP Target Flow (cfs)	Observed VAMP Period Mean Flow (cfs)	Existing Flow (cfs)	VAMP Supplemental Water (acre-feet)	Delta Export Target (cfs)	Observed Delta Exports (cfs)
2000	Above Normal	4	4/15 - 5/15	5,700	5,869	4,800	77,680	2,250	2,155
2001	Dry	2	4/20 - 5/20	4,450	4,224	2,909	78,650	1,500	1,420
2002	Dry	2	4/15 - 5/15	3,200	3,301	2,757	33,430	1,500	1,430
2003	Below Normal	3	4/15 - 5/15	3,200	3,235	2,290	58,065	1,500	1,446
2004	Dry	2	4/15 - 5/15	3,200	3,155	2,088	65,591	1,500	1,331
2005	Wet	5	5/1 - 5/31	>7,000	10,390	10,390	0	2,250	2,986 [a]
2006	Wet	5	5/1 - 5/31	>7,000	26,220/24,262 [b]	26,020	0	1,500/6,000	1,559/5,748 [b]
2007	Critical	1	4/22 - 5/22	3,200	3,263	2,721	33,330	1,500	1,486
2008	Critical	1	4/22 - 5/22	3,200	3,163	1,939	75,250	1,500	1,520
2009	Dry	2	4/19 - 5/19	na	2,260	2,260	0	na	1,990

[a] May 1 through 25 average was 2,260 cfs; exports were increased starting May 26 inconjunction with increasing existing flow; May 26 through 31 average was 6,012 cfs.
[b] "First fish release-recapture period"/"Second fish release-recapture period"

Table 2-8
Summary of VAMP Supplemental Water Contributions, 2000 - 2009

Year	VAMP Supplemental Water (acre-feet)		Supplemental Water (acre-feet) Merced ID	Oakdale ID	South San Joaquin ID	SJRECWA	Modesto ID	Turlock ID
2000	77,680	Observed:	42,770	7,300 [a]	7,300 [b]	8,280	5,580	6,450
		Division Agreement:	41,180	7,300	7,300	7,300	7,300	7,300
		Deviation:	+ 1590			+ 980	- 1,720	- 850
2001	78,650	Observed:	42,120	7,365	7,365	7,740	7,030	7,030
		Division Agreement:	42,150	7,300	7,300	7,300	7,300	7,300
		Deviation:	- 30	+ 65	+ 65	+ 440	- 270	- 270
2002	33,430	Observed:	25,840	3,795	3,795	0	0	0
		Division Agreement:	25,000	4,215	4,215	0	0	0
		Deviation:	+ 840	- 420	- 420	0	0	0
2003	58,065	Observed:	33,257	5,039	5,039	5,000 [c]	4,865	4,865
		Division Agreement:	33,065	5,000	5,000	5,000	5,000	5,000
		Deviation:	+ 192	+ 39	+ 39		- 135	- 135
2004	65,591	Observed:	37,680	5,880	5,880	5,000 [c]	5,576	5,576
		Division Agreement:	36,500	7,045.5	7,045.5	5,000	5,000	5,000
		Deviation:	+ 1,180	- 1165.5	- 1165.5		+ 576	+ 576
2005	0 [e]	Observed:	0	0	0	0	0	0
		Division Agreement:	0	0	0	0	0	0
		Deviation:	0	0	0	0	0	0
2006	0 [e]	Observed:	0	0	0	0	0	0
		Division Agreement:	0	0	0	0	0	0
		Deviation:	0	0	0	0	0	0
2007	33,330	Observed:	28,960	2,185 [d]	2,185 [d]	0	0	0
		Division Agreement:	25,000	4,165	4,165	0	0	0
		Deviation:	+ 3,960	- 1,980	- 1,980	0	0	0
2008	75,250	Observed:	38,150	7,260	7,260	7,300 [c]	7,640	7,640
		Division Agreement:	38,750	7,300	7,300	7,300	7,300	7,300
		Deviation:	- 600	- 40	- 40	0	+ 340	+ 340
2009	0 [f]	Observed:	0	0	0	0	0	0
		Division Agreement:	0	0	0	0	0	0
		Deviation:	0	0	0	0	0	0

[a] Provided by Modesto ID
[b] Provided by Merced ID (54.55%), Oakdale ID (15.91%), Modesto ID (15.91%) and Turlock ID (13.64%)
[c] Provided by Merced ID
[d] Provided by Modesto ID/Turlock ID on the Tuolumne River due to flow constraints on the Stanislaus River
[e] Existing Flow greater than 7,000 cfs.
[f] Sequential dry-year relaxation.

Figure 2-2

Recorded Flows during the 2009 VAMP on the San Joaquin River at Vernalis (VNS) and the Three Tributaries (Stanislaus, Tuolumne and Merced Rivers) Inflowing into the San Joaquin River above Vernalis

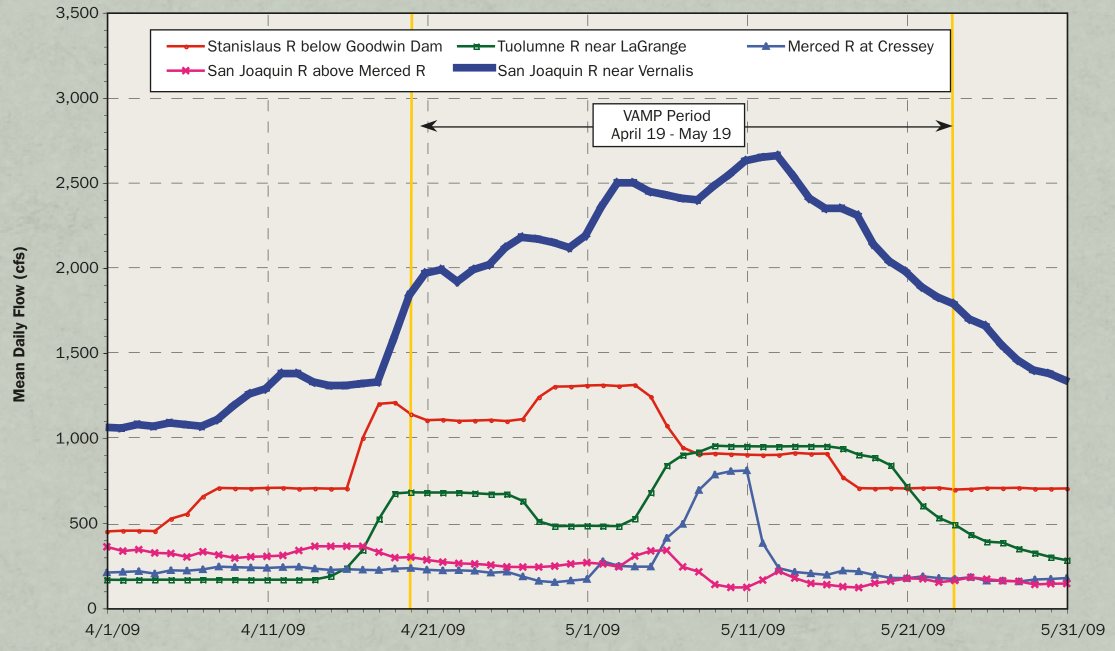


Figure 2-3

Ungaged Flow in the San Joaquin River at Vernalis (VNS) during the 2009 VAMP

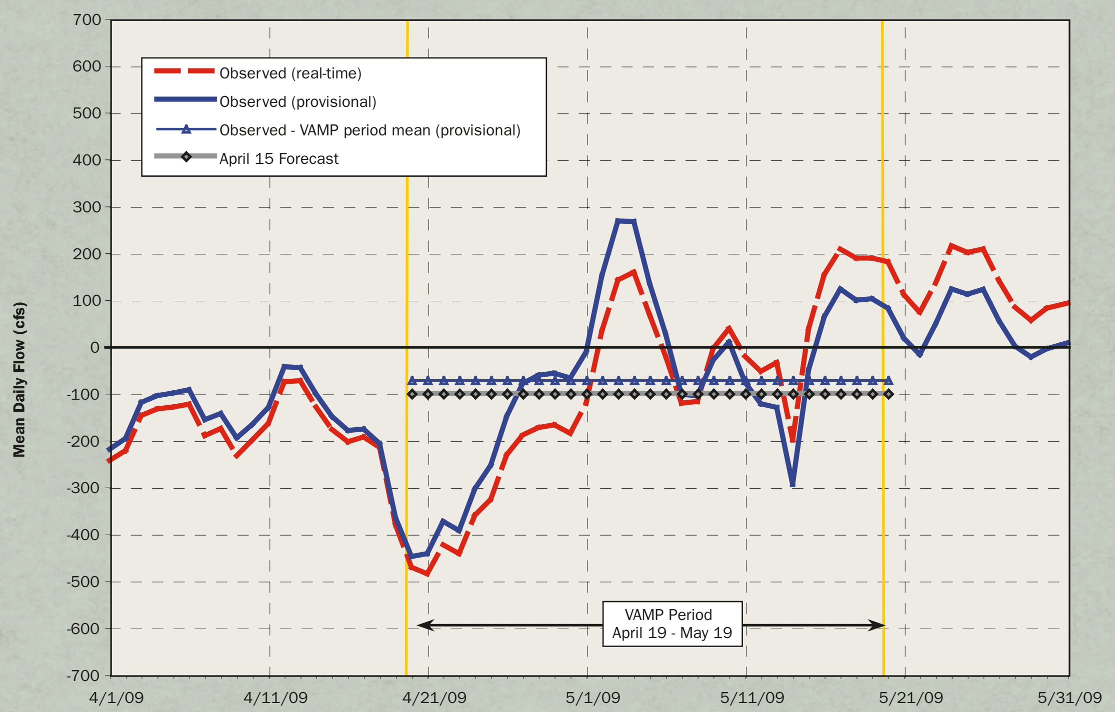


Figure 2-4
Federal and State Delta Exports during the 2009 VAMP

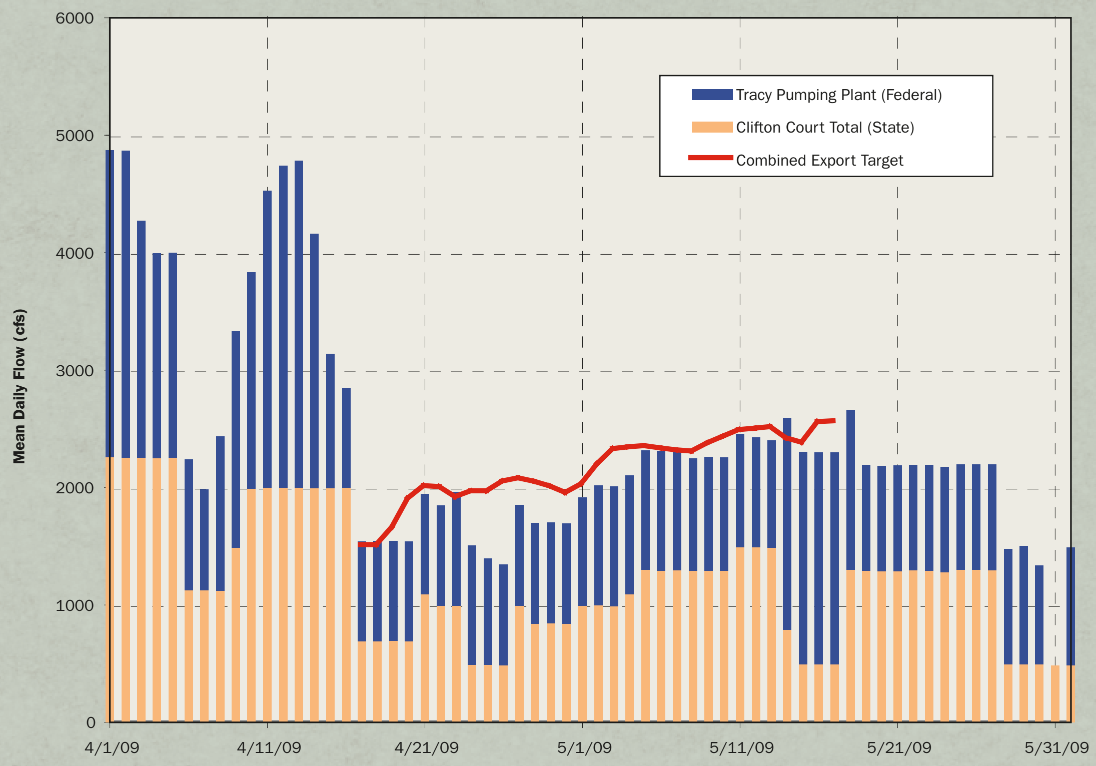


Figure 2-5
San Joaquin River Agreement (SJRA) Storage and Flow Impacts
Merced River – Lake McClure Storage and Release - 2009

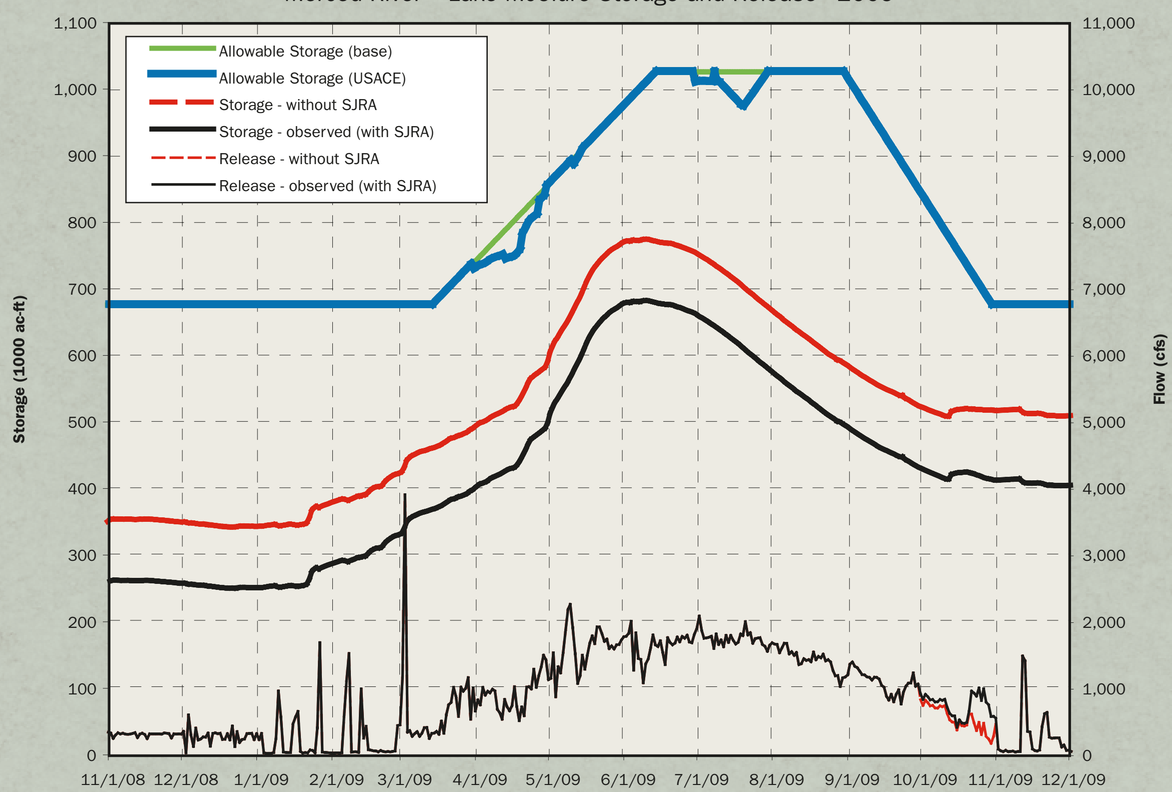
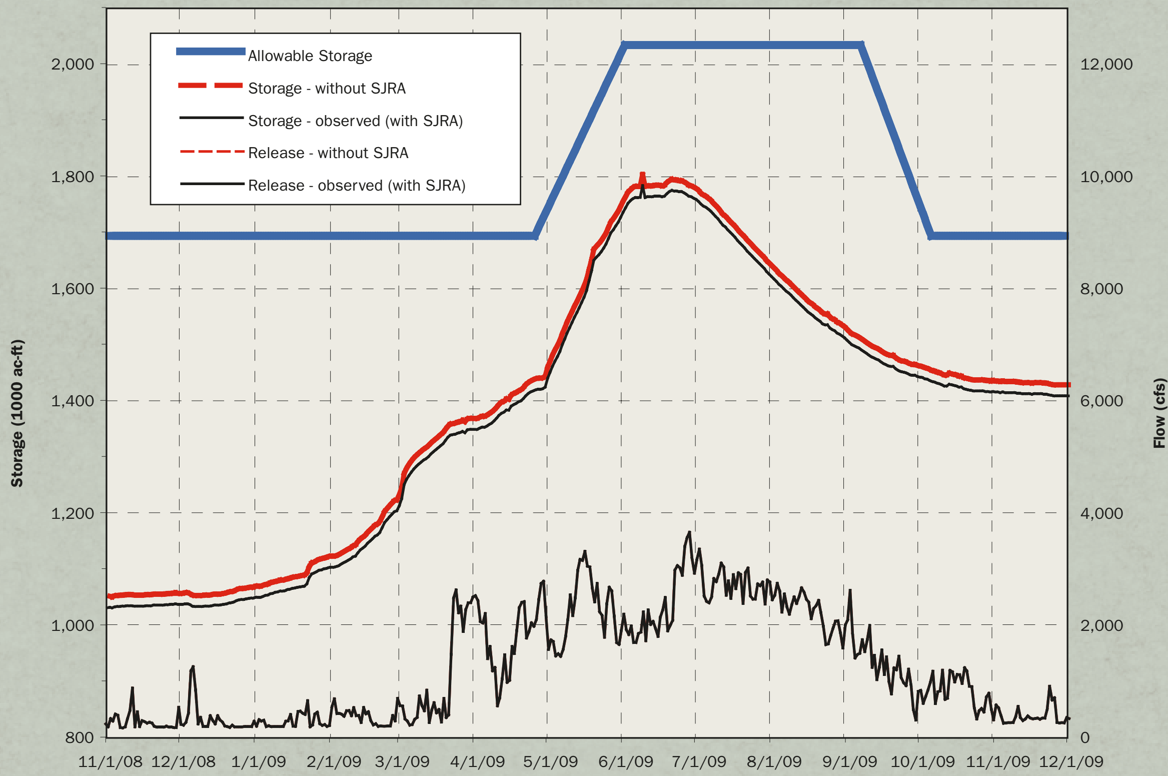


Figure 2-6
San Joaquin River Agreement (SJRA) Storage and Flow Impacts on the Tuolumne River
New Don Pedro Reservoir Storage and Release - 2009



CHAPTER 3

ADDITIONAL WATER SUPPLY ARRANGEMENTS AND DELIVERIES

Paragraph 8.4 of the San Joaquin River Agreement (SJRA) states that "Merced Irrigation District shall provide, and the USBR shall purchase 12,500 acre-feet of water…during October of all years." The SJRA also states in Paragraph 8.4.4 that "Water purchased pursuant to Paragraph 8.4 may be scheduled for months other than October provided Merced, DFG and USFWS all agree." The purpose of additional water supply deliveries in the fall months is to provide instream flows to attract and assist adult salmon during spawning.

Paragraph 8.5 of the SJRA states that "Oakdale Irrigation District shall sell 15,000 acre-feet of water to the USBR in every year of this Agreement." Paragraph 8.5 also states that "in addition to the 15,000 acre-feet, Oakdale will sell the difference between the water made available to VAMP under the SJRGA division agreement and 11,000 acre-feet," which is referred to as the Difference Water. The Oakdale Irrigation District (OID) additional water is to be used by the USBR for any authorized purpose of the New Melones project.

Merced Irrigation District (MeID)

The Paragraph 8.4 water is referred to as the Fall SJRA Transfer Water. The daily schedule for the Fall SJRA Transfer Water is developed by the California Department of Fish and Game (DFG), United States Fish and Wildlife Services (USFWS) and MeID.

The schedule for the Fall SJRA Water Transfer was finalized on September 29, 2009, with the water to be provided from October 1st through November 1st as shown in Table 3-1 and Figure 3-1. Table 3-1 also includes an accounting of the observed Fall SJRA Water Transfer with provisional flow data available at the time of the writing of this report.

Oakdale Irrigation District (OID)

The combined Paragraph 8.5 water is referred to as the OID Additional Water. As the provisions of Paragraph 5.3 of the SJRA (sequential dry-year relaxation) were in effect for the 2009 VAMP, OID provided no supplemental

Table 3-1 2009 Merced Irrigation District SJRA Fall Water Transfer Daily Summary							
		SCHEDULED			OBSERVED		
		SJRA Transfer Water				SJRA Transfer Water	
Date	Base Flow at Shaffer Br/Cressey (cfs)	SJRA Transfer Water Flow (cfs)	Cumulative SJRA Transfer Water Volume (acre-ft)	Target Flow at Shaffer Br/Cressey (cfs)	Shaffer Br/ Cressey Flow (cfs)	SJRA Transfer Water Flow (cfs)	Cumulative SJRA Transfer Water Volume (acre-ft)
1-Oct	30	90	179	120	151	121	240
2-Oct	30	90	357	120	145	115	468
3-Oct	30	90	536	120	151	121	708
4-Oct	30	90	714	120	140	110	926
5-Oct	30	90	893	120	160	130	1,184
6-Oct	30	90	1,071	120	180	150	1,482
7-Oct	30	90	1,250	120	177	147	1,773
8-Oct	30	95	1,438	125	180	150	2,071
9-Oct	30	95	1,626	125	160	130	2,329
10-Oct	30	95	1,815	125	160	130	2,586
11-Oct	30	95	2,003	125	164	134	2,852
12-Oct	30	95	2,192	125	177	147	3,144
13-Oct	30	95	2,380	125	248	218	3,576
14-Oct	30	95	2,569	125	194	164	3,901
15-Oct	30	95	2,757	125	180	150	4,199
16-Oct	85	40	2,836	125	173	88	4,374
17-Oct	85	40	2,916	125	173	88	4,548
18-Oct	85	40	2,995	125	167	82	4,711
19-Oct	85	40	3,074	125	167	82	4,873
20-Oct	85	40	3,154	125	154	69	5,010
21-Oct	85	40	3,233	125	133	48	5,105
22-Oct	85	345	3,917	430	366	281	5,663
23-Oct	85	445	4,800	530	449	364	6,385
24-Oct	85	515	5,821	600	499	414	7,206
25-Oct	85	515	6,843	600	522	437	8,073
26-Oct	85	515	7,864	600	533	448	8,961
27-Oct	85	515	8,886	600	530	445	9,844
28-Oct	85	515	9,907	600	541	456	10,748
29-Oct	85	515	10,929	600	536	451	11,643
30-Oct	85	400	11,722	485	461	376	12,389
31-Oct	85	300	12,317	385	388	56	12,500
1-Nov	220	90	12,496	310	294		
2-Nov	220			220	278		
3-Nov	220			220	243		
4-Nov	220			220	225		
5-Nov	220			220	221		
6-Nov	220			220	239		
7-Nov	220			220	239		
8-Nov	220			220	234		
9-Nov	220			220	234		
10-Nov	220			220	221		
11-Nov	220			220	217		
12-Nov	220			220	225		
13-Nov	220			220	217		
14-Nov	220			220	213		
15-Nov	220			220	221		
16-Nov	220			220	217		
17-Nov	220			220	221		

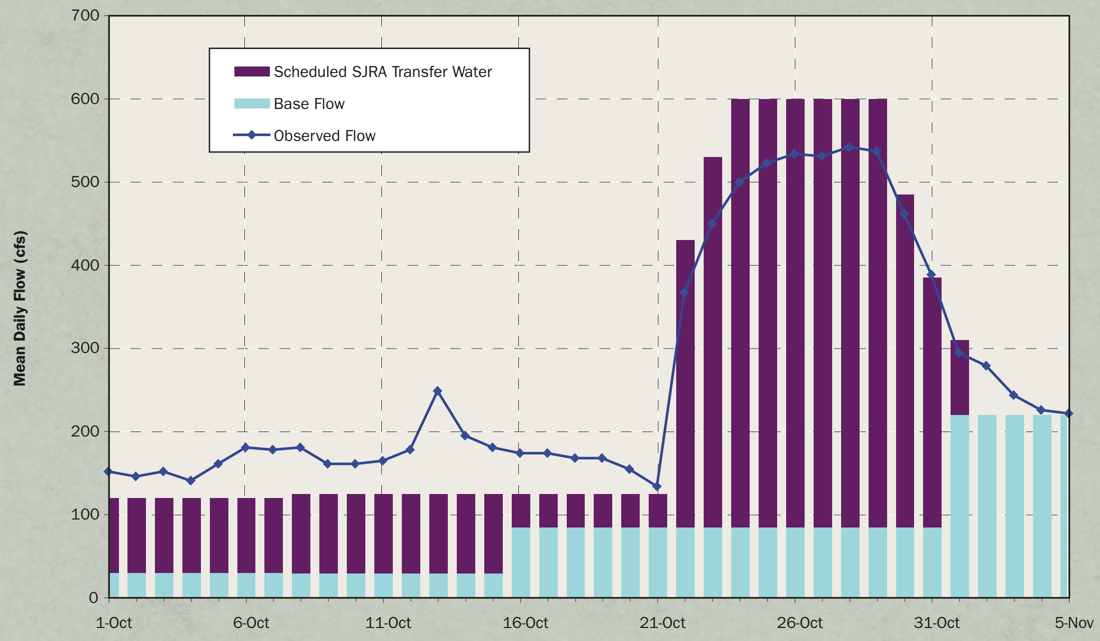
water for the 2009 VAMP operation. Under the terms of the SJRA, OID will sell to the USBR the difference between the water made available to VAMP under the SJRGA division agreement and 11,000 acre-feet (Difference Water). As a result, OID made available the full 11,000 acre-feet of Difference Water for purchase by the USBR. The SJRA also states that OID is to sell 15,000 acre-feet to the USBR in every year. Thus the total OID additional water purchased by the USBR under Paragraph 8.5 of the SJRA was 26,000 acre-feet (15,000 acre-feet plus 11,000 acre-feet of Difference Water). The OID additional water is made available in New Melones Reservoir for use by the USBR for any authorized purpose of the New Melones project.

The 11,000 ac-ft of Difference Water was released from April 17th through April 27th of 2009 to provide supplemental flow to the Stanislaus River for fishery purposes as shown in Table 3-2. The 15,000 ac-ft of additional water was used to supplement river flows during October through December of 2009.

Table 3-2
2009 Oakdale Irrigation District SJRA Difference Water Daily Release Summary

Date of Release	Estimated Flow in cubic feet per second (cfs)
4/17/09	300
4/18/09	550
4/19/09	558
4/20/09	490
4/21/09	454
4/22/09	458
4/23/09	450
4/24/09	452
4/25/09	456
4/26/09	874
4/27/09	504

Figure 3-1
Merced Irrigation District Fall 2009 Water Transfer as Shown by Merced River Flow at Shaffer Bridge/Cressey

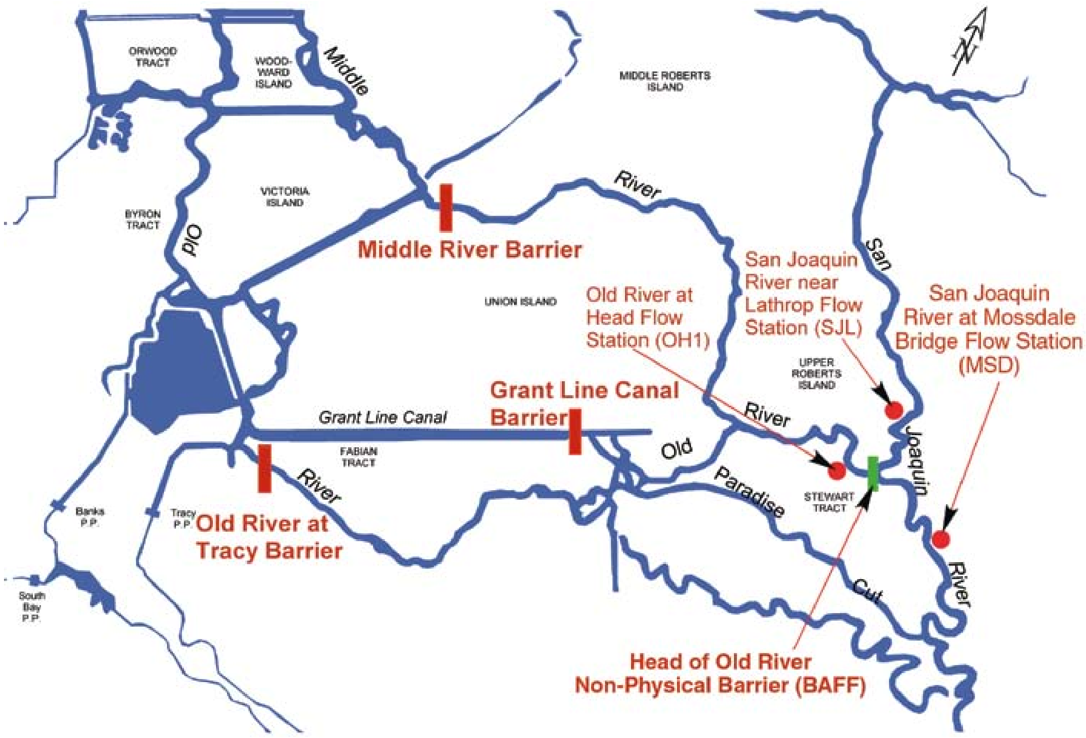


CHAPTER 4

HEAD OF OLD RIVER BARRIER INSTALLATION AND FLOWS

The South Delta Temporary Barriers Project began in 1991 and included three temporary rock-fill agricultural barriers on interior channels in the south Delta and a physical rock-fill barrier at the head of Old River. Installation of a physical temporary spring Head of Old River Barrier (HORB) in 2009 was prohibited in a Federal Court decision by United States District Court Judge Wanger for increased protection for delta smelt. To provide equivalent protection in 2009, several agencies and groups designed, implemented and monitored a non-physical barrier call the Bio-Acoustic Fish Fence (BAFF).

Figure 4-1
Location Map - South Delta Barriers Program



Flow Measurements at and Around the Head of Old River

The California Department of Water Resources (DWR) operates three Acoustic Doppler Current Meters (ADCM) in the vicinity of the head of Old River as shown in Figure 4-1. One in the San Joaquin River 1,500 feet downstream of Old River (San Joaquin River below Old River near Lathrop, SJL) and another located in Old River 840 feet downstream of the head of Old River (Old River at Head, OH1). The third acoustic Doppler was installed in 2006 in the mainstem of the San Joaquin River at the abutment of the railroad bridge near Mossdale (San Joaquin River at Mossdale Bridge, MSD), about 10,000 feet upstream from the head of Old River.

The ADCMs record velocity measurements at a 15-minute interval from which flow values can be determined. Table 4-1 lists the daily minimum and maximum flow and mean daily flow for the April 1, 2009 through June 30, 2009 period for the three ADCMs. These values are depicted graphically in Figures 4-2, 4-3, and 4-4. Figure 4-5 presents in graphical format a comparison of the mean daily flow for the San Joaquin

River gage at Mossdale Bridge (MSD) and the San Joaquin River near Vernalis gage (VNS) for the same April 1st through June 30th period.

As 2009 was a sequential dry-year relaxation (see Chapter 2 and 3) because of the continued drought, the impact of reduced flows in the San Joaquin River and not having a physical flow barrier at the head of Old River needed to be evaluated. As shown in Table 4-1, during the VAMP fish release and tracking period (4/22/- 6/13), on average 75% of the flow recorded in the San Joaquin River at Mossdale Bridge (MSD) was moving into Old River (OH1) and 25% was continuing downstream in the mainstem San Joaquin River toward the gage near Lathrop (SJL). During the entire period of record shown in Table 4-1, the average flow split was 80%:20%.

It was agreed by the CALFED Water Management Operations Team (WOMT) that during VAMP, exports from the State and federal project pumping would be held to a level as close as possible to a 1:1 ratio with the San Joaquin River flow recorded at Vernalis (VNS). During the VAMP fish release and tracking period (4/22/- 6/13), as shown in Table 4-2, export flows averaged 100% (1 : 1) of the flow recorded at the San Joaquin River at Vernalis (VNS) gage and averaged 110% (1.1 : 1) of the flow recorded at the San Joaquin River at Mossdale Bridge (MSD) gage. During the entire time period shown in Table 4-2 (4/1 – 6/30), export flows averaged 160% of the flow recorded at the San Joaquin River at Vernalis (VNS) gage. This ratio increased to 190% when the flow recorded at the San Joaquin River at Mossdale Bridge (MSD) gage was considered.

Development of a Barrier at the Head of Old River

(The following section is a summary of work conducted by DWR and the U. S. Bureau of Reclamation (USBR) in cooperation with VAMP and will be presented in full in Technical Memorandum 86-68290-09-05 by the USBR. Contact person for further information is Mark Bowen, Reclamation Technical Service Center, Denver, Colorado)

A physical rock barrier at the head of Old River has been used in the past to prevent juvenile Chinook salmon from entering Old River because survival appears to be lower in Old River than it is in the mainstem San Joaquin River (Newman, 2008). Each spring installation of a physical temporary Head of Old River Barrier (HORB) had been used until 2007 when it was prohibited in a Federal Court decision by United States District Court Judge Wanger for increased protection for delta smelt. This prohibition continued during the 2009 VAMP. The U. S. Bureau of Reclamation (USBR) and DWR working in coordination with Fish Guidance Systems (Southampton, England), Jacobs Engineering (Southampton, England), EIMCO Water Technologies (Salt Lake City, UT), Hydroacoustic Technology Inc. (Seattle, WA), and the VAMP Technical Committee designed, implemented, and monitored a non-physical barrier called the Bio-Acoustic Fish Fence (BAFF). The BAFF was deployed upstream of the divergence of the San Joaquin River and Old River. The BAFF was 112 m long and was placed at a 24 degree angle incident to the San Joaquin River west shore as shown in Figure 4-6. This layout was to allow the BAFF to maximize fish guidance down the mainstem of the San Joaquin River and away from Old River as depicted in Figure 4-7. The goal of the BAFF was to deter anadromous salmonid juveniles from entering Old River.

Photo 4-1
Bubble Barrier Being Tested at the Divergence of the San Joaquin River and Old River During the 2009 VAMP. Photo taken from the North Bank.

The BAFF was made up of three components: sound, bubble curtain, and hi-intensity light-emitting diode (LED) strobe lights as depicted in Figure 4-8. The BAFF components, air, sound and light are attached to a truss style frame mounted 0.45 m off the river bottom. This height allowed passage of sturgeon, both green and white, under the BAFF. The physical structure of the BAFF is shown in Figure 4-9.

An important function of the BAFF is to emit sound in a frequency range of 5 to 600 Hz which acts as the main deterrent to salmon smolts. The primary function of the bubble curtain is to contain the sound generated by the sound projectors by encapsulating the sound within the bubble curtain, allowing a precise linear wall of sound to be developed (Photo 4-1). The trapping of the sound signal within the air curtain prevented saturation of the area surrounding the BAFF with sound. Sound levels are designed to fall to ambient levels within a distance

Table 4-1
Measured Flows in San Joaquin River near Mossdale, Old River at Head and San Joaquin River near Lathrop (below Old River)

Date	Old River at Head (OH1)			San Joaquin River below Old River (SJL)			San Joaquin River at Mossdale (MSD)			Flow Split (% of Total Flow)	
	Minimum Flow (cfs)	Maximum Flow (cfs)	Mean Daily Flow (cfs)	Minimum Flow (cfs)	Maximum Flow (cfs)	Mean Daily Flow (cfs)	Minimum Flow (cfs)	Maximum Flow (cfs)	Mean Daily Flow (cfs)	OH1	SJL
4/1/2009	-757	1368	679	-1656	1891	58	-1078	2226	892	92.1%	7.9%
4/2/2009	-441	1307	697	-1587	1737	27	-715	1984	828	96.3%	3.7%
4/3/2009	-541	1708	815	-1464	1691	114	-636	1983	873	87.7%	12.3%
4/4/2009	-295	1630	950	-1261	1431	81	-602	1769	856	92.2%	7.8%
4/5/2009	-342	1723	954	-1207	1262	38	-424	1719	810	96.2%	3.8%
4/6/2009	-472	1687	851	-1284	1415	65	-488	1651	751	92.9%	7.1%
4/7/2009	-482	1765	804	-1474	1549	44	-727	1737	686	94.8%	5.2%
4/8/2009	-165	1739	853	-1445	1435	74	-642	1769	799	92.1%	7.9%
4/9/2009	-262	1980	1020	-1458	1562	107	-657	2005	961	90.5%	9.5%
4/10/2009	-395	1992	1112	-1537	1669	82	-554	2135	1039	93.1%	6.9%
4/11/2009	-90	1980	1195	-1555	1732	130	-558	2199	1130	90.2%	9.8%
4/12/2009	144	1883	1297	-1496	1564	144	-228	2171	1265	90.0%	10.0%
4/13/2009	17	1979	1270	-1403	1513	132	-262	2327	1302	90.6%	9.4%
4/14/2009	-293	1803	1141	-1406	1760	165	-307	2162	1181	87.3%	12.7%
4/15/2009	-224	1634	1067	-1127	1435	268	-249	2161	1248	79.9%	20.1%
4/16/2009	-57	1468	1023	-959	1376	245	-58	2090	1205	80.7%	19.3%
4/17/2009	53	1612	969	-842	1272	260	225	2028	1216	78.9%	21.1%
4/18/2009	3	1626	953	-955	1256	234	169	2051	1179	80.3%	19.7%
4/19/2009	170	1917	1070	-991	1239	325	179	2296	1417	76.7%	23.3%
4/20/2009	238	1997	1251	-969	1316	404	611	2412	1673	75.6%	24.4%
4/21/2009	416	2186	1421	-980	1472	432	663	2574	1818	76.7%	23.3%
4/22/2009	595	2264	1433	-1069	1555	404	682	2559	1784	78.0%	22.0%
4/23/2009	165	2472	1452	-1274	1766	390	372	2766	1751	78.8%	21.2%
4/24/2009	166	2412	1445	-1299	1880	474	418	2838	1870	75.3%	24.7%
4/25/2009	-93	2445	1464	-1235	2048	532	416	2917	1933	73.4%	26.6%
4/26/2009	270	2545	1578	-1388	1884	490	423	3082	2048	76.3%	23.7%
4/27/2009	199	2500	1576	-1298	2066	502	475	3091	2068	75.8%	24.2%
4/28/2009	14	2509	1551	-1455	2235	542	423	3167	2057	74.1%	25.9%
4/29/2009	58	2400	1475	-1219	2143	631	468	3036	2108	70.0%	30.0%
4/30/2009	244	2298	1452	-1031	1967	633	626	3039	2100	69.6%	30.4%
5/1/2009	438	2319	1483	-888	1781	582	778	2956	2047	71.8%	28.2%
5/2/2009	510	2428	1522	-982	1785	637	907	3051	2159	70.5%	29.5%
5/3/2009	739	2549	1690	-813	1801	714	1303	3063	2370	70.3%	29.7%
5/4/2009	798	2593	1714	-867	1769	732	1380	3004	2382	70.1%	29.9%
5/5/2009	827	2623	1739	-1067	1848	651	1179	3091	2301	72.7%	27.3%
5/6/2009	575	2691	1721	-1017	1833	611	981	3200	2226	73.8%	26.2%
5/7/2009	363	2651	1670	-1224	1899	621	813	3114	2181	72.9%	27.1%
5/8/2009	364	2608	1655	-1137	1962	596	750	3139	2155	73.5%	26.5%
5/9/2009	366	2667	1677	-1222	2015	600	805	3269	2217	73.7%	26.3%
5/10/2009	318	2715	1705	-1199	2121	631	898	3319	2292	73.0%	27.0%
5/11/2009	406	2703	1780	-1169	2147	645	1035	3439	2378	73.4%	26.6%
5/12/2009	407	2752	1779	-1130	2300	758	1143	3434	2482	70.1%	29.9%
5/13/2009	466	2660	1764	-858	2086	748	1443	3385	2509	70.2%	29.8%
5/14/2009	713	2524	1707	-808	2040	727	1379	3360	2464	70.1%	29.9%
5/15/2009	637	2518	1589	-731	1889	725	1184	3115	2328	68.7%	31.3%
5/16/2009	732	2444	1574	-741	1740	706	1254	2979	2288	69.0%	31.0%
5/17/2009	718	2362	1579	-789	1627	653	1168	2868	2196	70.7%	29.3%
5/18/2009	557	2421	1545	-1049	1636	545	1006	2823	2063	73.9%	26.1%
5/19/2009	574	2356	1471	-1263	1768	557	732	2810	1950	72.5%	27.5%
5/20/2009	414	2328	1455	-1172	1705	499	398	2810	1890	74.4%	25.6%
5/21/2009	315	2365	1418	-1266	1762	397	243	2932	1790	78.1%	21.9%
5/22/2009	-133	2379	1339	-1557	2121	351	-72	2942	1646	79.2%	20.8%
5/23/2009	-276	2353	1289	-1746	2202	327	-175	2945	1589	79.8%	20.2%
5/24/2009	-297	2426	1326	-1771	2272	346	-246	2997	1630	79.3%	20.7%
5/25/2009	-514	2531	1340	-1795	2279	305	-343	2998	1568	81.5%	18.5%
5/26/2009	-687	2473	1303	-1772	2337	289	-366	2918	1511	81.8%	18.2%
5/27/2009	-618	2368	1215	-1694	2256	263	-551	2748	1389	82.2%	17.8%
5/28/2009	-702	2287	1101	-1641	2254	272	-507	2653	1307	80.2%	19.8%
5/29/2009	-654	2246	1022	-1472	2015	247	-547	2552	1247	80.5%	19.5%
5/30/2009	-327	2111	1033	-1431	1749	273	-463	2404	1257	79.1%	20.9%
5/31/2009	-457	2023	954	-1374	1743	331	-466	2219	1216	74.2%	25.8%
6/1/2009	-407	2034	1000	-1478	1707	275	-588	2264	1174	78.4%	21.6%
6/2/2009	-342	2164	1060	-1472	1709	231	-505	2363	1203	82.1%	17.9%
6/3/2009				-1415	1741	227	-672	2388	1099		
6/4/2009				-1558	1909	211	-859	2345	992		
6/5/2009				-1542	1940	188	-976	2370	918		
6/6/2009				-1488	1931	140	-947	2278	849		
6/7/2009				-1458	2080	192	-923	2469	986		
6/8/2009				-1506	2177	239	-669	2650	1149		
6/9/2009				-1470	2134	250	-613	2565	1140		
6/10/2009				-1399	1930	225	-720	2364	1039		
6/11/2009	-798	1996	875	-1335	1944	231	-617	2334	987	79.1%	20.9%
6/12/2009	-598	1894	838	-1253	1759	191	-708	2173	901	81.4%	18.6%
6/13/2009	-528	1881	774	-1284	1601	158	-683	1945	775	83.1%	16.9%
6/14/2009	-426	1769	789	-1330	1490	199	-812	1857	811	79.9%	20.1%
6/15/2009	-517	1728	754	-1326	1511	180	-856	1735	785	80.8%	19.2%
6/16/2009	-475	1649	726	-1355	1591	127	-1008	1814	683	85.1%	14.9%
6/17/2009	-768	1785	705	-1412	1745	135	-1162	1870	626	83.9%	16.1%
6/18/2009	-820	1778	671	-1491	1877	105	-1223	2034	619	86.5%	13.5%
6/19/2009	-1011	1706	596	-1580	1815	17	-1316	2040	457	97.2%	2.8%
6/20/2009	-1046	1927	642	-1726	1863	88	-1289	2170	550	87.9%	12.1%
6/21/2009	-1091	2051	714	-1749	1858	158	-1222	2342	726	81.8%	18.2%
6/22/2009	-992	2028	795	-1696	1978	126	-1177	2374	817	86.4%	13.6%
6/23/2009	-1051	1908	820	-1697	2068	111	-1093	2458	855	88.1%	11.9%
6/24/2009	-769	2048	899	-1849	2173	96	-972	2498	963	90.3%	9.7%
6/25/2009	-489	2113	1017	-1701	2080	202	-716	2573	1137	83.4%	16.6%
6/26/2009	-174	1896	1040	-1513	2013	260	-267	2454	1231	80.0%	20.0%
6/27/2009	83	1879	1077	-1297	1665	305	-415	2372	1282	78.0%	22.0%
6/28/2009	25	1732	963	-1397	1512	232	-696	2082	1090	80.6%	19.4%
6/29/2009	-92	1720	973	-1433	1418	77	-781	1937	895	92.7%	7.3%
6/30/2009	-358	2092	919	-1520	1482	83	-908	1985	805	91.7%	8.3%

No Data

Figure 4-2
Daily Flow Range - Old River at Head (OH1)

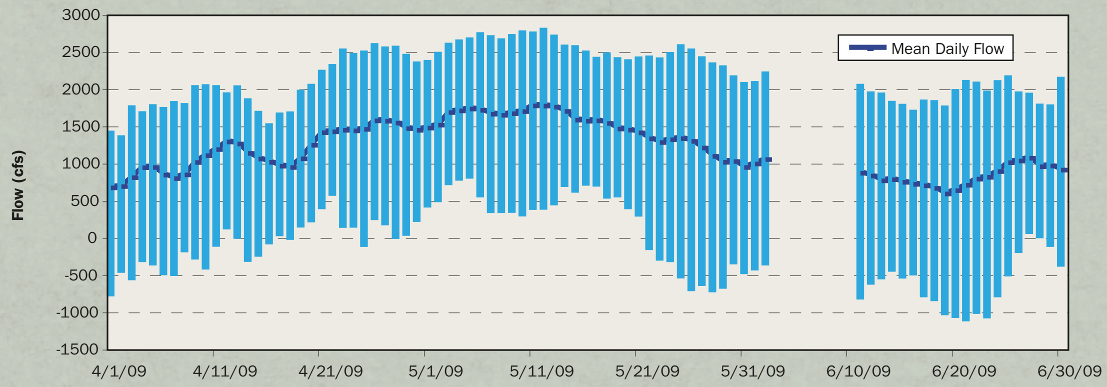


Figure 4-3
Daily Flow Range - San Joaquin River below Old River Near Lathrop (SJL)

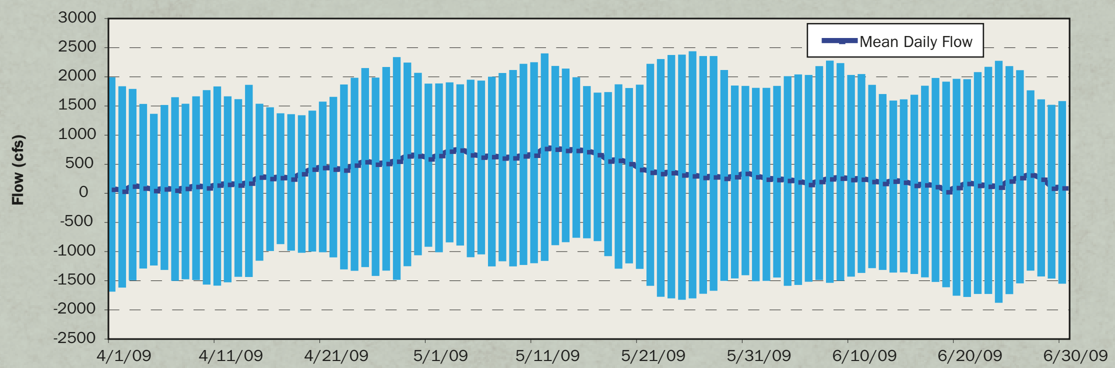


Figure 4-4
Daily Flow Range - San Joaquin River at Mossdale Bridge (MSD)

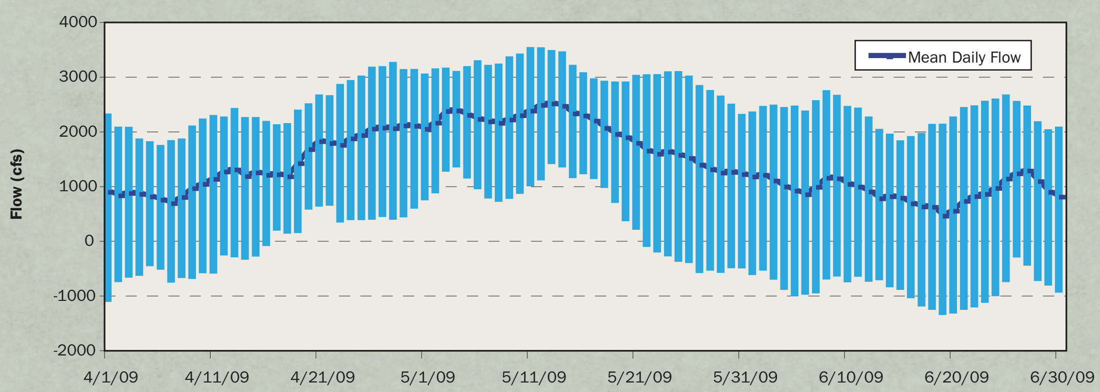


Figure 4-5
San Joaquin River Flow near Vernalis (VNS) and at Mossdale Bridge (MSD)

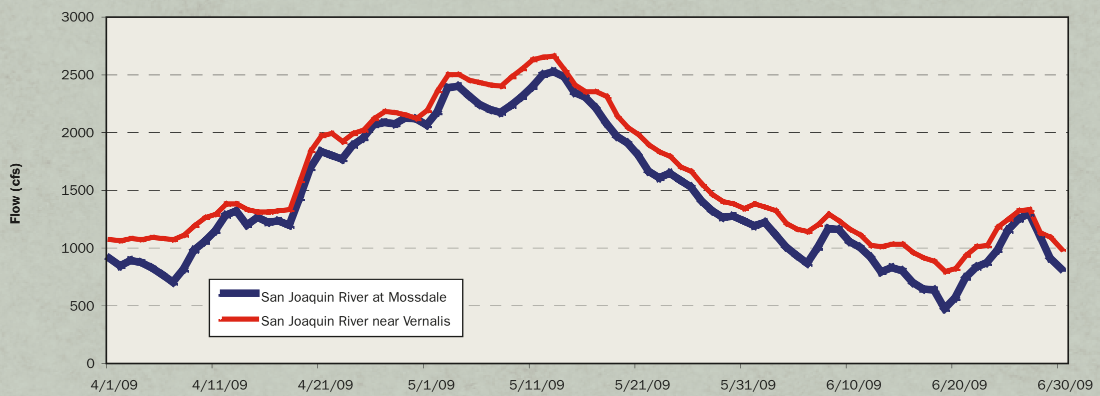


Table 4-2
Measured Flows in San Joaquin River near Vernalis (VNS) as Compared to Export Flows at the State Water Project (SWP-Banks Pumping Plant) and the Central Valley Project (CVP-Tracy Pumping Plant)

Date	San Joaquin River near Vernalis (VNS) [A]	San Joaquin River at Mossdale Bridge (MSD) [B]	State Water Project (SWP) at Harvey O Banks Pumping Plant (HRO)	Central Valley Project (CVP) at Tracy Pumping Plant (TRP)	San Joaquin River Flow at Mossdale Bridge(MSD) as % of Flow Measured near Vernalis(VNS)	Exports as a Ratio of SJR Flow near Vernalis (VNS)	Exports as a Ratio of SJR Flow at the Mossdale Bridge (MSD)
	Mean Daily Flow** (cfs)	Mean Daily Flow** (cfs)	Mean Daily Flow** (cfs)	Mean Daily Flow** (cfs)	(%)	Exports : VNS	Exports : MSD
4/1/2009	1,060	892	2202	2614	84	4.5 : 1	5.4 : 1
4/2/2009	1,050	828	2202	2611	79	4.6 : 1	5.8 : 1
4/3/2009	1,070	873	2202	2017	82	3.9 : 1	4.8 : 1
4/4/2009	1,060	856	2168	1747	81	3.7 : 1	4.6 : 1
4/5/2009	1,080	810	2148	1746	75	3.6 : 1	4.8 : 1
4/6/2009	1,070	751	1099	1114	70	2.1: 1	2.9 : 1
4/7/2009	1,060	686	1095	859	65	1.8 : 1	2.8 : 1
4/8/2009	1,100	799	1094	1314	73	2.2 : 1	3.0 : 1
4/9/2009	1,180	961	1474	1841	81	2.8 : 1	3.4 : 1
4/10/2009	1,250	1039	1099	1841	83	2.4 :1	2.8 : 1
4/11/2009	1,280	1130	1648	2531	88	3.3 : 1	3.7 : 1
4/12/2009	1,370	1265	2192	2743	92	3.6 : 1	3.9 : 1
4/13/2009	1,370	1302	2161	2783	95	3.6 : 1	3.8 : 1
4/14/2009	1,320	1181	1106	2167	89	2.5 : 1	2.8 : 1
4/15/2009	1,300	1248	2182	1144	96	2.6 : 1	2.7 : 1
4/16/2009	1,300	1205	2201	851	93	2.3 : 1	2.5 : 1
4/17/2009	1,310	1216	1086	851	93	1.5 : 1	1.6 : 1
4/18/2009	1,320	1179	1084	853	89	1.5 : 1	1.6 : 1
4/19/2009	1,570	1417	1077	852	90	1.2 : 1	1.4 : 1
4/20/2009	1,830	1673	1077	850	91	1.1 : 1	1.2 : 1
4/21/2009	1,960	1818	1074	853	93	1.0 : 1	1.1 : 1
4/22/2009	1,980	1784	1077	854	90	1.0 : 1	1.1 : 1
4/23/2009	1,910	1751	1077	971	92	1.1 : 1	1.2 : 1
4/24/2009	1,980	1870	1075	1016	94	1.1 : 1	1.1 : 1
4/25/2009	2,010	1933	354	905	96	0.6 : 1	0.7 : 1
4/26/2009	2,110	2048	135	858	97	0.5 : 1	0.5 : 1
4/27/2009	2,170	2068	138	856	95	0.5 : 1	0.5 : 1
4/28/2009	2,160	2057	1085	859	95	0.9 : 1	0.9 : 1
4/29/2009	2,140	2108	670	857	98	0.7 : 1	0.7 : 1
4/30/2009	2,110	2100	447	855	100	0.6 : 1	0.6 : 1
5/1/2009	2,180	2047	1079	923	94	0.9 : 1	1.0 : 1
5/2/2009	2,350	2159	1077	1018	92	0.9 : 1	1.0 : 1
5/3/2009	2,490	2370	1078	1022	95	0.8 : 1	0.9 : 1
5/4/2009	2,490	2382	1077	1012	96	0.8 : 1	0.9 : 1
5/5/2009	2,440	2301	1078	1018	94	0.9 : 1	0.9 : 1
5/6/2009	2,420	2226	675	1021	92	0.7 : 1	0.8 : 1
5/7/2009	2,400	2181	1088	1015	91	0.9 : 1	1.0 : 1
5/8/2009	2,390	2155	1085	957	90	0.9 : 1	0.9 : 1
5/9/2009	2,470	2217	1083	971	90	0.8 : 1	0.9 : 1
5/10/2009	2,540	2292	2182	966	90	1.2 : 1	1.4 : 1
5/11/2009	2,620	2378	2447	966	91	1.3 : 1	1.4 : 1
5/12/2009	2,640	2482	0	935	94	0.4 : 1	0.4 : 1
5/13/2009	2,650	2509	0	912	95	0.3 : 1	0.4 : 1
5/14/2009	2,530	2464	0	1804	97	0.7 : 1	0.7 : 1
5/15/2009	2,400	2328	1260	1807	97	1.3 : 1	1.3 : 1
5/16/2009	2,340	2288	1138	1803	98	1.3 : 1	1.3 : 1
5/17/2009	2,340	2196	1126	1806	94	1.3 : 1	1.3 : 1
5/18/2009	2,300	2063	2193	1360	90	1.5 : 1	1.7 : 1
5/19/2009	2,130	1950	1758	899	92	1.2 : 1	1.4 : 1
5/20/2009	2,030	1890	627	898	93	0.8 : 1	0.8 : 1
5/21/2009	1,970	1790	798	901	91	0.9 : 1	0.9 : 1
5/22/2009	1,880	1646	424	897	88	0.7 : 1	0.8 : 1
5/23/2009	1,820	1589	1391	899	87	1.3 : 1	1.4 : 1
5/24/2009	1,780	1630	1295	896	92	1.2 : 1	1.3 : 1
5/25/2009	1,690	1568	1323	898	93	1.3 : 1	1.4 : 1
5/26/2009	1,650	1511	1290	899	92	1.3 : 1	1.4 : 1
5/27/2009	1,540	1389	1328	901	90	1.4 : 1	1.6 : 1
5/28/2009	1,450	1307	209	981	90	0.8 : 1	0.9 : 1
5/29/2009	1,390	1247	455	1006	90	1.1 : 1	1.2 : 1
5/30/2009	1,370	1257	0	842	92	0.6 : 1	0.7 : 1
5/31/2009	1,330	1216	0	0	91	0.0 : 1	0.0 : 1
6/1/2009	1,370	1174	413	1002	86	1.0 : 1	1.2 : 1
6/2/2009	1,340	1203	418	1007	90	1.1 : 1	1.2 : 1
6/3/2009	1,310	1099	652	1008	84	1.3 : 1	1.5 : 1
6/4/2009	1,200	992	511	1010	83	1.3 : 1	1.5 : 1
6/5/2009	1,150	918	606	1009	80	1.4 : 1	1.8 : 1
6/6/2009	1,130	849	602	1003	75	1.4 : 1	1.9 : 1
6/7/2009	1,190	986	559	1006	83	1.3 : 1	1.6 : 1
6/8/2009	1,280	1149	419	1007	90	1.1 : 1	1.2 : 1
6/9/2009	1,220	1140	467	1007	93	1.2 : 1	1.3 : 1
6/10/2009	1,150	1039	491	1015	90	1.3 : 1	1.4 : 1
6/11/2009	1,100	987	477	1019	90	1.4 : 1	1.5 : 1
6/12/2009	1,010	901	486	1018	89	1.5 : 1	1.7 : 1
6/13/2009	1,000	775	476	1020	77	1.5 : 1	1.9 : 1
6/14/2009	1,020	811	558	1013	80	1.5 : 1	1.9 : 1
6/15/2009	1,020	785	466	1016	77	1.5 : 1	1.9 : 1
6/16/2009	947	683	485	999	72	1.6 : 1	2.2 : 1
6/17/2009	902	626	418	1338	69	1.9 : 1	2.8 : 1
6/18/2009	871	619	489	1662	71	2.5 : 1	3.5 : 1
6/19/2009	785	457	530	1671	58	2.8 : 1	4.8 : 1
6/20/2009	810	550	532	1675	68	2.7 : 1	4.0 : 1
6/21/2009	925	726	550	1678	79	2.4 : 1	3.1 : 1
6/22/2009	1,000	817	548	1673	82	2.2 : 1	2.7 : 1
6/23/2009	1,010	855	352	1674	85	2.0 : 1	2.4 : 1
6/24/2009	1,170	963	222	1678	82	1.6 : 1	2.0 : 1
6/25/2009	1,240	1137	135	1671	92	1.5 : 1	1.6 : 1
6/26/2009	1,310	1231	137	1670	94	1.4 : 1	1.5 : 1
6/27/2009	1,320	1282	329	1662	97	1.5 : 1	1.6 : 1
6/28/2009	1,120	1090	167	1663	97	1.6 : 1	1.7 : 1
6/29/2009	1,080	895	1126	1663	83	2.6 : 1	3.1 : 1
6/30/2009	979	805	1707	1762	82	3.5 : 1	4.3 : 1

** Data taken from CDEC (http://cdec.water.ca.gov/)
Note: column [B] data is provisional subject to revision.

Figure 4-6
Approximate Location of the Bio-Acoustic Fish Fence (BAFF) (shown as a red line) at the Divergence of San Joaquin River (SJR) and Old River (OR). Locations of the Underwater Hydrophones are Shown by the Numbers in the Colored Circles. The Yellow Dotted Line is VAMP Fish Tag 5072 as the Fish Approached and Passed Through the BAFF on 5/14/09 at 12:41 Hours while the barrier was off. (Data From Bowen et al. (in press)).

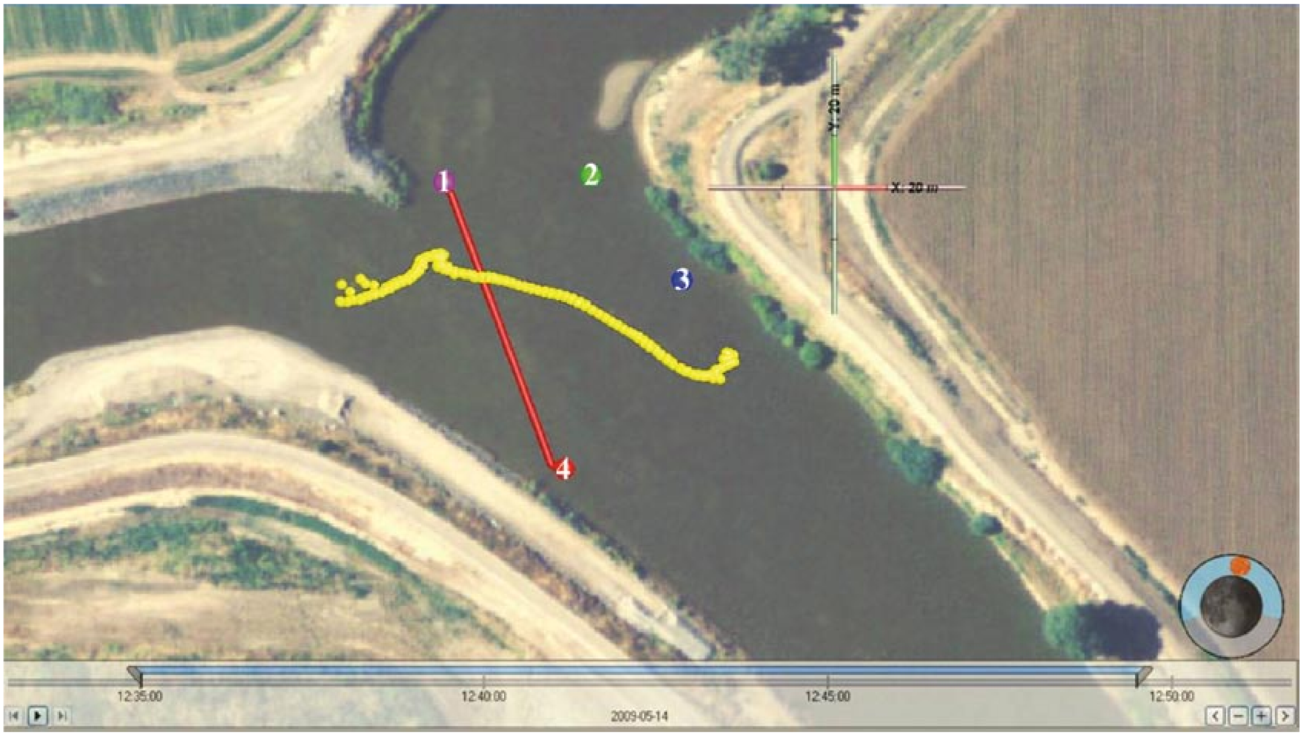


Figure 4-7
Schematic of Probable Operation of the Bio-Acoustic Fish Fence (BAFF) planned and developed for deployment at the Divergence of San Joaquin River (SJR) and Old River (OR). (Figure courtesy of EIMCO Water Technologies)

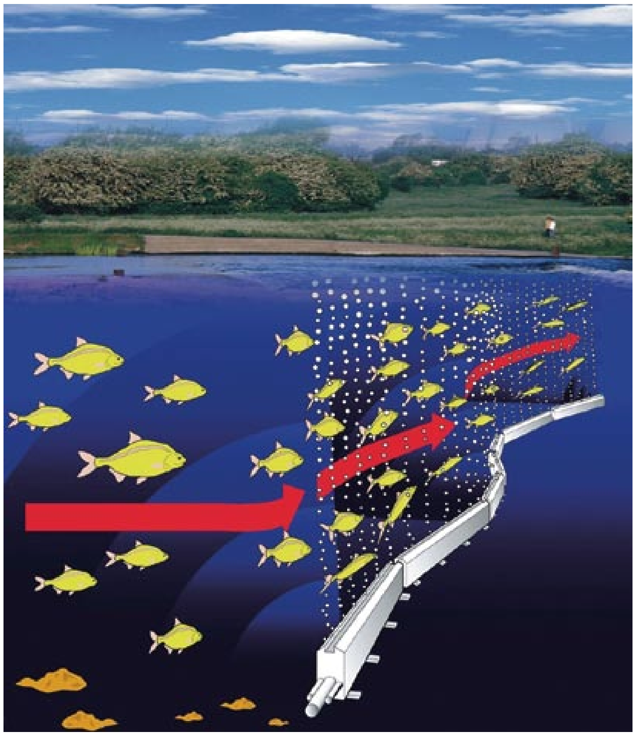


Figure 4-8
Basic Components of the Bio-Acoustic Fish Fence (BAFF) planned and developed for deployment at the Divergence of San Joaquin River (SJR) and Old River (OR). (Figure courtesy of EIMCO Water Technologies)

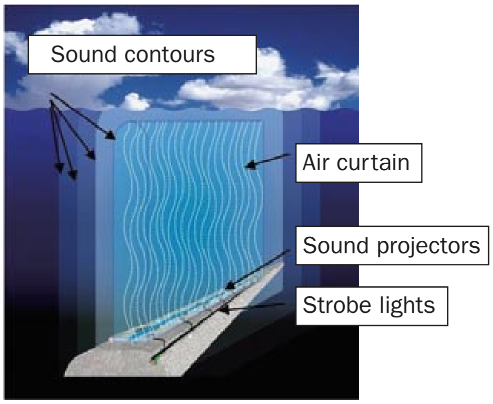
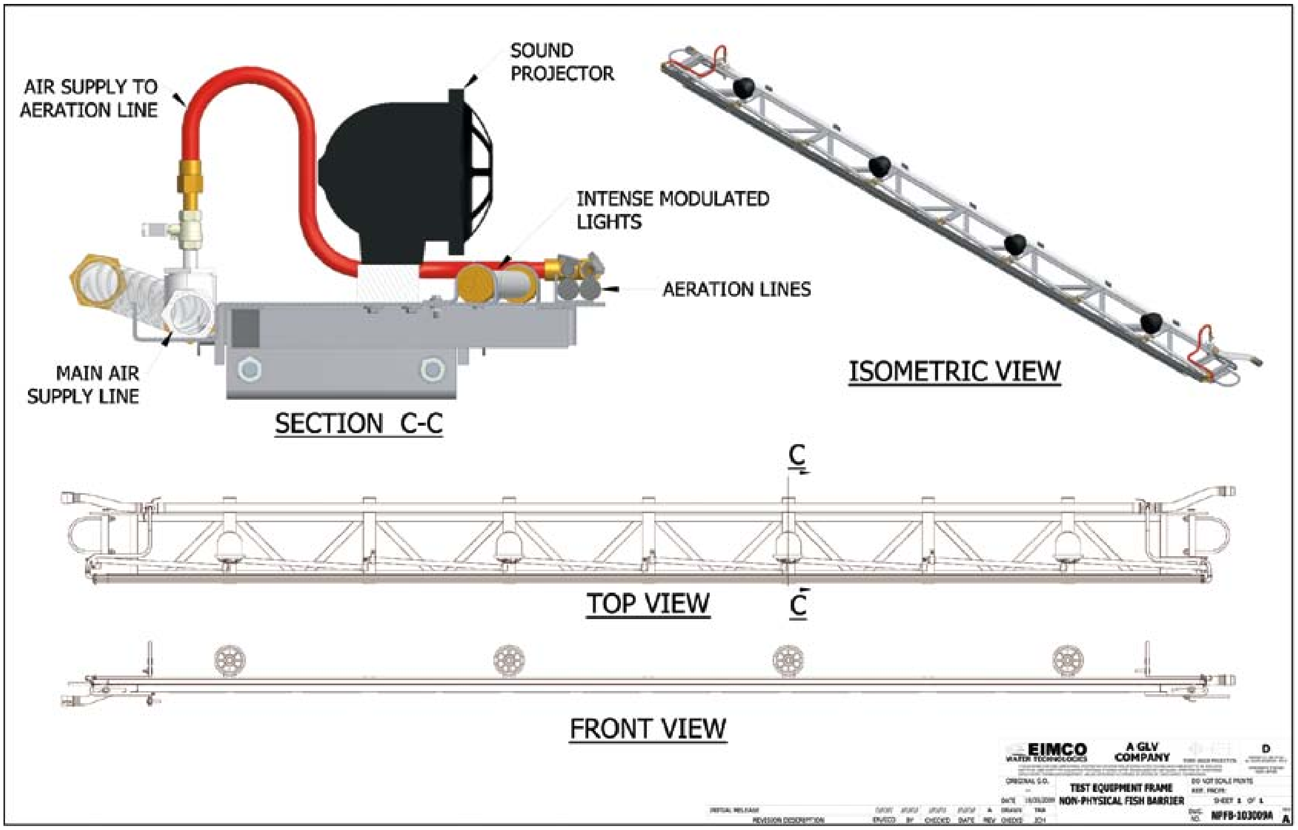


Figure 4-9
Physical Structure of the Bio-Acoustic Fish Fence (BAFF) Similar to that Deployed at the Divergence of the San Joaquin River and Old River During the 2009 VAMP.



of 3 m from the bubble curtain. The light is generated by an array of LED strobe lights that create white light in a vertically orientated beam of 22º beam width. This allows the light beam to be projected onto the rising bubble curtain. The narrow beam angle minimizes light saturation of the area surrounding the BAFF. This served to reflect the beam and improve visibility from the direction of approaching fish.

Installation of the BAFF began on April 7th. After the BAFF was deployed, four (4) underwater hydrophones were deployed (Figure 4-6) to provide for 2D tracking in the vicinity of the BAFF. Each hydrophone was connected to an on-shore receiver capable of tracking the acoustic tags implanted in the juvenile Chinook salmon by the VAMP Fish Monitoring Program. The receiver and hydrophone array was constructed by the same manufacturer as those used in the VAMP receiver network so the acoustic tags could be detected at the HORB and throughout the Delta by VAMP. Each VAMP acoustic tagged fish transmits an underwater signal or acoustic "ping" that sends identification information about the tagged fish to the hydrophones. The hydrophones around the HORB were deployed in an array at known locations that maximize spacing of the hydrophones in two dimensions. For two dimensional tracking, tags pings must be received on at least three hydrophones. Figure 4-6 shows a typical two-dimensional (2D) track of one tagged salmon smolt as it approaches the BAFF. The smolt shown in Figure 4-6 passed through the BAFF while the BAFF was off.

The hydrophone array cannot provide a 2D position behind the BAFF when the BAFF is on because a ping must be received on three hydrophones to provide a 2D position. When the BAFF is in operation, hydrophones 2, 3, and 4 (see Figure 4-6) are unlikely to receive a ping because the bubble curtain portion of the BAFF blocks sound passage.

A full report on the efficiency of the BAFF is in preparation at the time of this report writing. Initial results however show that the BAFF appears to be very efficient (>80%) in deterring acoustically tagged fish from entering Old River. The testing of the BAFF was during a period of time when the flow split was averaging 75% down Old River (Table 4-1). When the BAFF was off, it appears only 25% of the tagged salmon smolts remained in the mainstem San Joaquin River, a value similar to that found by Holbrook et al. (2009) in 2008 when no barrier was present and the flow split was 68% down Old River and 32% down the mainstem San Joaquin River.

One of the things that complicated the analysis of the BAFF efficiency was the very high loss rate of tagged fish from the point of release at Durham Ferry to the Head of Old River. Hydrophones in the vicinity of the BAFF showed a high proportion of the tagged fish never arrived in the vicinity of the BAFF; loss rates ranged from 25 – 61 % for the 7 VAMP release groups. It is unclear what caused the loss but predation is highly likely. This is supported by the findings in the immediate vicinity of the BAFF that showed that predation rates ranged from 12 – 40 % for the seven groups released at Durham Ferry. The combined loss rate from Durham Ferry to the BAFF and the loss rate in the vicinity of the BAFF combined to show a loss rate between 60 -76% of the seven groups released at Durham Ferry. This extremely high loss rate needs to be evaluated and if possible mitigated. A full report on the effectiveness of the 2009 Non-Physical Fish Barrier (BAFF) will be prepared by the USBR in the coming months.

South Delta Temporary Agricultural Barriers Project

(The following section is a summary of work conducted by the California Department of Water Resources (DWR) with guidance from the National Marine Fisheries Service (NMFS). In 2009, this project included evaluating the movement of salmon and steelhead smolts in the interior channels of the South Delta and was done in cooperation with VAMP. Results of this effort will be presented in full in DWR Technical Reports. Contact person for further information is Mark Holderman or Kevin Clark, California Department of Water Resources, Bay-Delta Unit, Sacramento, California)

The South Delta Temporary Barriers Project (TBP) began in 1991 and consists of the construction, operation, and monitoring of four temporary rock-fill barriers (Figure 4-1). Three of the barriers, located in three South Delta channels (Grant Line Canal, Old and Middle rivers), are constructed seasonally and operate during the agricultural season, usually April through November. They are designed to: (1) improve water levels and circulation patterns for agricultural users and (2) collect data for the design of permanent barriers. The fourth barrier, located at the head of Old River, is installed during the spring as a fish barrier. The head of Old River Barrier is normally installed to prevent fall-run San Joaquin River Chinook salmon smolts and Central Valley steelhead smolts from migrating down through Old River towards the Central Valley Project (CVP) and the State Water Project (SWP) export facilities. However, a recent court order and a subsequent United States Fish and Wildlife Service (USFWS) biological opinion (BO) has restricted the spring installation of a physical barrier at the head of Old River Barrier in order to protect Delta Smelt. The head of Old River Barrier is discussed in more detail in the previous section which explains the present effort to try a non-physical barrier to eliminate concerns for the impacts on Delta smelt.

Because of varying hydrological conditions and concerns for endangered fish species, the number of temporary agricultural barriers installed and the installation schedules have been slightly different each year of the program. Installation, operation, and removal of the temporary agricultural barriers have raised concerns as they may harm, harass, or cause mortality to juvenile Chinook salmon, juvenile steelhead, and juvenile green sturgeon. The TBP, therefore, is performed in compliance with the terms and conditions of the National Marine Fisheries Service (NMFS) BO and incidental take permits. A recent NMFS (2008) BO requires that a fishery monitoring program be established to (1) examine the movements and survival of listed fish through the channels of the South Delta and (2) examine predation effects associated with the TBP.

To comply with the requirements of the NMFS (2008) BO, the California Department of Water Resources (DWR) designed and initiated a three year study (2009 – 2011) comprised of a series of acoustic biotelemetry experiments similar to those now being conducted under the Vernalis Adaptive Management Plan (VAMP) to:

- Evaluate juvenile salmon and juvenile steelhead behavior and movement patterns directly adjacent to the temporary barriers;
- Evaluate predatory fish behavior and movement patterns directly adjacent to the temporary barriers;
- Develop quantitative estimates of survival of juvenile salmon and steelhead migrating through the South Delta; and
- Evaluate juvenile green sturgeon behavior and movements patterns within the South Delta.

The first year of the experimental field investigation included a pilot study conducted March – June 2009. In order to track the movement of acoustic tagged salmon and steelhead throughout the South Delta, a broad scale receiver network was used to monitor acoustic tagged predators (striped bass, largemouth bass and white catfish) and acoustic tagged salmon and steelhead in a manner similar to that done in the 2009 VAMP (see Figure 1-2). The network of fixed-point receivers was set up to cover the South Delta including Old River, Middle River, Grant Line Canal, Clifton Court Forebay and the fish facilities. These receivers were placed in conjunction with those of the VAMP to limit duplication of effort and allow maximum use of the data collected by both programs. In addition, an array of hydrophones and receivers capable of tracking fish in two dimensions was installed at the Old River Barrier at Tracy to examine the behavior of tagged fishes as they interacted with the barrier.

The pilot study was designed to (1) test various assumptions inherent in the experimental design for quantifying survival of juvenile salmonids in the South Delta, and (2) provide preliminary information on the behavior of these fishes near the temporary barriers. Results of the studies will be used to assess the potential significance of the temporary barriers to salmon and steelhead migrating through the South Delta. Results of these investigations will also provide useful information on predator-prey interactions that could serve to reduce the potential vulnerability of juvenile Chinook salmon, steelhead, and other fish species to predation mortality near the temporary barriers.

Results of the 2009 pilot study in combination with information from similar survival investigations, such as those performed as part of the VAMP, will be used as part of the technical foundation for the 2010 and 2011 full-scale studies. The specific objectives of the experimental investigations are to provide qualitative and quantitative information about the movement, behavior, and survival of juvenile salmon, steelhead, and green sturgeon within the South Delta. Results of the fishery investigation are intended, in part, to provide information on the design and operation of the future permanent operable gates.

The permanent operable gates are a major component of the South Delta Improvements Program (SDIP) which is currently in the planning, design, and environmental documentation development processes.

The study design will be looking a several important management questions including:

- Does relative abundance of predatory fish change in response to the installation of the temporary barriers?
- Do predatory fish exhibit site fidelity or learned behavior near the temporary barriers?
- What is the response of predatory fish behavior to changes in the near field hydraulics associated with the temporary barriers?
- Does the distribution and behavior of predatory fish vary in response to operation of the temporary barriers (i.e. flap gates open or flap gates closed)?
- What is the behavior of sensitive fish species (salmon, steelhead, and green sturgeon) as they pass the temporary barriers?
- What is the survival of out migrating juvenile salmon and juvenile steelhead within the South Delta during the time when the temporary barriers are installed?

A full study design is available from the technical team at the California Department of Water Resources.

CHAPTER 5

SALMON SMOLT SURVIVAL INVESTIGATIONS

The lack of study fish from the Merced River Hatchery (MRH) in conjunction with the potential for interruptions in trawling at Chipps Island due to incidental catches of delta smelt prompted a transition away from use of coded wire tagged (CWT) salmon and toward acoustic telemetry methodologies starting in 2007. This transition continued with the biological investigations associated with the 2009 VAMP study. Compared to traditional mark-recapture techniques, acoustic telemetry provides greater temporal and spatial coverage of the outmigration process. Further, continuous, simultaneous monitoring at several locations allows estimation of distribution probabilities at junctions and reach-specific survival throughout the study region. Moreover, acoustic telemetry data are amenable to a suite of robust and well developed statistical approaches that allow quantification of the uncertainty associated with estimates of survival, detection, and distribution probabilities.

Introduction

During the 2009 study, Chinook salmon smolts were acoustically tagged with Hydroacoustic Technology Incorporated (HTI) tags and released at Durham Ferry in the San Joaquin River. A total of seven releases were made over a three and a half week period between April 22nd and May 13th, with three releases made during the day (1700 hours) and four releases made at night (2100 hours). This design was intended to obtain an "average" survival rate for juvenile salmon migrating through the Delta while also meeting the study needs of the joint Department of Water Resources (DWR) and the Bureau of Reclamation (Reclamation) evaluation of a non-physical barrier at the head of Old River. Each tagged fish was detected and uniquely identified as it passed acoustic receivers placed at various locations throughout the Delta. Detection data from receiver sites were analyzed within a release-recapture model to simultaneously estimate survival, route distribution, and detection probabilities throughout the Delta. Detection data from mobile tracking and predator tracking were analyzed to help interpret the survival estimates.

Study Design and Methods

Study Fish

All fish used in the VAMP 2009 study originated from Feather River Hatchery (FRH). A group of approximately 3000 juvenile fall/spring-run hybrid Chinook salmon was transferred by California Department of Fish and Game (DFG) from FRH to MRH on March 5. Although efforts were made to accelerate growth through a modified feeding regime, these fish did not grow well at MRH and few were large enough for tag implantation. Those transferred from MRH to the Tracy Fish Facility (TFF) near the end of the study continued to exhibit slow growth and mortality was relatively high for several weeks after transfer.

Fish transferred directly from FRH to TFF for other studies appeared to grow better and exhibit a lower rate of mortality. These fish were larger than those reared at MRH and many were used to meet the needs of this study. Some of the fish used for VAMP had previously been handled for a mark recapture experiment at the TFF.

Transmitter Programming

Transmitters were programmed according to modified guidelines developed during 2008. Programming occurred the day prior to tagging which was two days prior to release. Transmitters were soaked for approximately 24 hours prior to programming. After programming, tags were sniffed in a cup of water using a HTI sniffer and monitored through at least three transmission cycles. At least 5 attempts were made to program each tag. During 2008 we encountered some tags that passed activation and sniffing, but then could not be heard. To address this issue in 2009, we briefly listened to all activated tags immediately after programming and prior to surgical implantation in study fish to confirm tag function and programming. Only six tags failed to initialize and one could not be heard during validation after programming in 2009.

Transmitter Implantation and Validation

During 2009 training and tagging operations were moved to the TFF. In 2007 and 2008 training occurred at the Mokelumne River Hatchery and tagging occurred at Merced River Hatchery. The TFF was selected as a preferred alternative to Merced River Hatchery for tagging due to the proximity and similar water quality conditions to the release site at Durham Ferry. Transit time to the release site and large differences in temperature and other water quality conditions between MRH and Durham Ferry posed significant challenges and introduced potential bias to the study in previous years. Moving the tagging operations to a location in the Delta improved the study design by addressing these issues. The ability to conduct both training and tagging at a single site was an added benefit of moving to TFF.

Tagging operations occurred at TFF between April 21st and May 12th. Study fish were withheld food for 24 hours prior to transmitter implantation. During each tagging session 133 to 136 fish were surgically implanted with HTI acoustic transmitters following procedures defined by Adams et al. 1998 and Martinelli et al. 1998. The HTI Model 795 Lm micro acoustic tag used for this study weighed 0.65 g in air (range: 0.62 g to 0.69 g), was 16.4 mm long, with a diameter of 6.7 mm. Due to challenges with fish size, many fish exceeded the 5.4% maximum tag weight to body weight (TWBW) criteria applied during 2008. During 2009, only 6% of the live study fish had a TWBW ratio of less than 6%, while 22% had a TWBW ratio of 6%, 65% had a ratio of 7-8%, and 7% had a ratio of 9-10% (Figure 5-1).

Tagging procedures were based on a standard operating procedure (SOP) developed by the Columbia River Research Lab (CRRL) of the United States Geological Survey (USGS). The SOP directed all aspects of the tagging operation, and several quality assurance checks were made during each tagging session to ensure compliance with the SOP guidance. Prior to transmitter implantation, fish were anesthetized in 70 mg/L tricane methanesulfonate buffered with an equal concentration of sodium bicarbonate until they lost equilibrium. Fish were removed from anesthesia, and were measured (fork length (FL) to nearest mm) and weighed (to nearest 0.1 g). Following implantation procedures outlined in Adams et al. 1998 and Martinelli et al. 1998, fish were surgically implanted with acoustic transmitters. Typical surgery times were less than 3 min. Fish were then placed into perforated 19 L holding containers with high dissolved oxygen concentrations (110 – 130%) to recover from anesthesia effects. Holding containers were perforated, starting 15 cm from the bottom, to allow water exchange. The non-perforated section of the container held 7 L of water to allow transfer without complete dewatering. Each holding container was stocked with three tagged fish, and was covered with a snap-on lid. Holding containers were held in large round tanks until loaded for transport to the release site. Water levels were adjusted in these tanks to ensure that tagged fish had access to air to be able to adjust their buoyancy to compensate for the weight of the transmitter.

Tagged fish were monitored by hydrophones installed at TFF to confirm the operational status of each transmitter prior to transportation to the release sites. A total of four transmitters were found to be non-functional during this evaluation and these fish were removed from the study.

Transportation to Release Sites

In order to minimize fish transfers and the associated stress to fish, specially designed transport tanks were used to move fish from TFF to the release sites. The tanks were designed to securely hold a series of 19 L buckets filled with fish. Tanks had an internal frame that held 21-30 buckets in individual compartments to minimize contact between containers and to prevent tipping. Insulation was added to the exterior of the metal tanks to reduce water temperature fluctuations. Two transport tanks were positioned on a flatbed truck equipped to deliver oxygen during transport.

Immediately prior to loading, all buckets were visually inspected for fish mortalities or signs of poor recovery (e.g. erratic swimming behavior). Tags were removed from four fish that were dead or exhibiting signs of poor recovery and were implanted into other fish before transporting the group to the release site. Buckets were removed from holding tanks and loaded into the transport tanks.

Temperature and DO in the transport tanks was recorded after loading and before leaving for the release site. Water temperature in the transport tanks at TFF prior to transporting the fish to the release site ranged between 16.6°C and 21.6°C. Upon arrival at the release site and prior to unloading fish from the transport tanks, temperature and DO in the transport tanks and in the river was recorded. Over the course of the 45-60 minute drive from TFF to the release site, water temperatures in the transport tanks generally remained constant with the exception of the first release when ambient temperatures were high and temperatures in the tanks increased 0.8-1.4°C. Water temperature in the river at the time of placement ranged between 16.1°C and 21.1°C.

Buckets were removed from the transport tanks and carried to the river. The first release group was transferred from buckets to a 1 m^3, 3-mm mesh net pen where fish were held until release. After the net pen became snagged during the first release, nine, 32 gallon, perforated trash cans were used instead of the net pen for holding the remaining six release groups. Five buckets were emptied into each trash can. Fish were held in the net pen or in trash cans for a minimum of

Figure 5-1
Frequency Distribution of Tag Weight to Body Weight (TWBW)
Ratio of Live Study Fish Released During the 2009 VAMP.

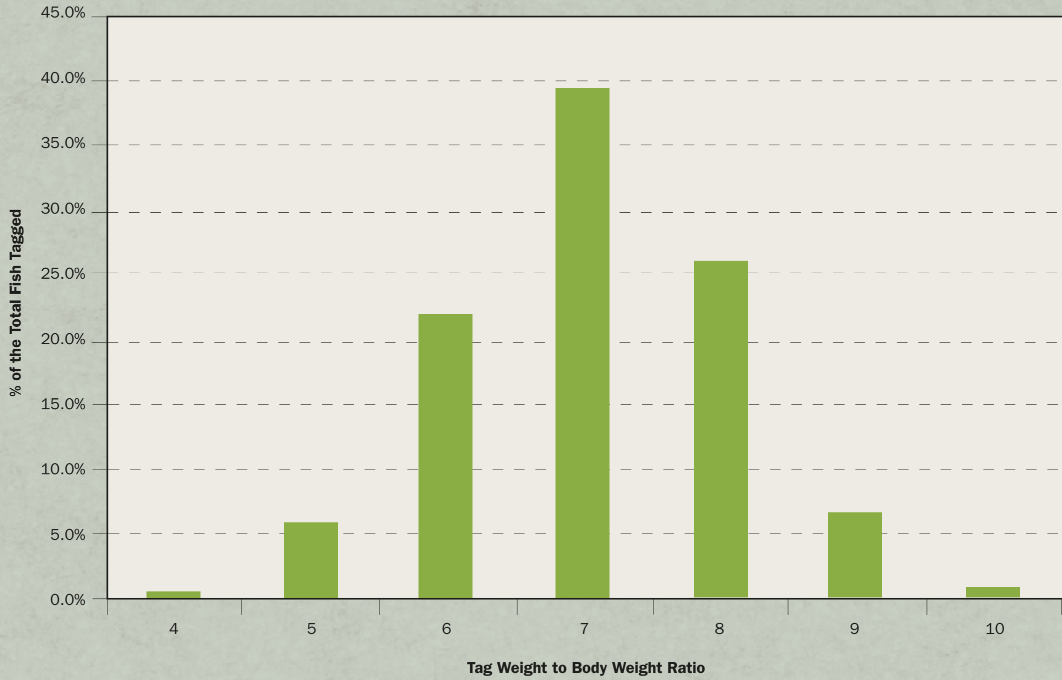
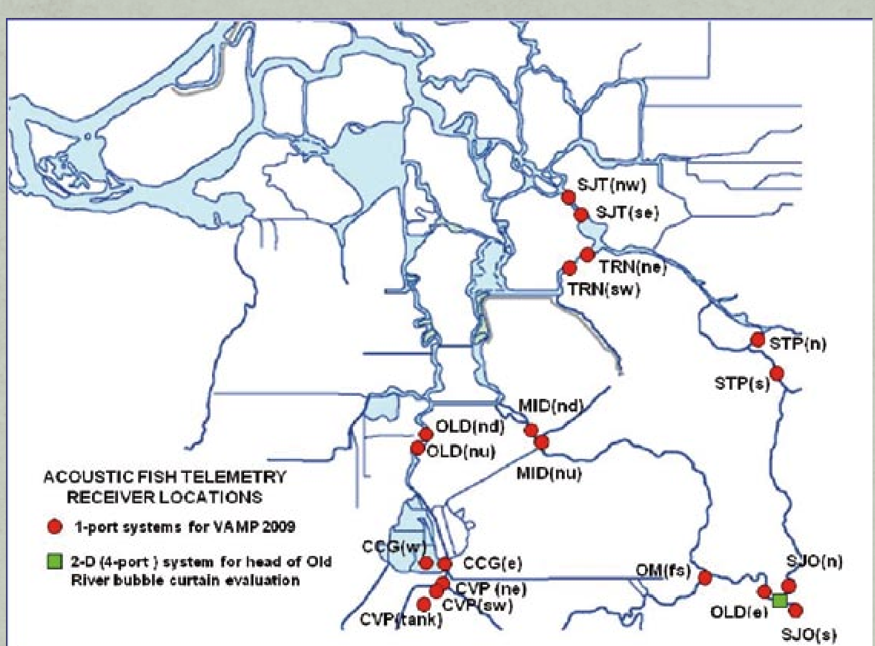


Figure 5-2
Locations of Acoustic Receivers for the 2009 VAMP Study Including Locations of Acoustic
Receivers DWR Planned to Deploy for the South Delta Temporary Barriers Study.



24 hours, prior to release. At least one person remained onsite for the duration of the holding period to ensure that study fish and equipment were not vandalized or otherwise tampered with.

During the holding and recovery period tagged fish were also monitored by a hydrophone installed at the release site. This monitoring period allowed confirmation of the operational status of each transmitter prior to release.

Releases

A total of seven releases were made over a three and a half week period between April 22nd and May 13th, with three releases made during the day (1700 hours) and four releases made at night (2100 hours). Immediately prior to release each trash can was checked for any dead or impaired fish. However, a thorough inspection could not be made of the net pen used for the first release and additional mortalities could have been present but not seen. To assure the fish from our releases did not experience mortality or differential mortality associated with potential operation of an agricultural pump located adjacent to the release site at Durham Ferry, a boat was used to ferry tagged fish in a net pen or perforated trash cans downstream about 300 yards before releasing them at river mile [RM] 69.5.

To determine the "behavior" of dead fish, a total of five tagged smolts were intentionally sacrificed immediately before release and released with the live study fish. The intent of this effort was to evaluate how far downstream a dead fish may travel since detection of dead fish at a receiver would be perceived in the model as survival of that fish to that point. The shorter the distance that a dead fish can travel, the less potential there is for the survival estimates to be biased by detection of dead fish.

Dummy-tagged fish

In order to evaluate the effects of tagging, transportation and release several groups of fish were implanted with inactive, or dummy, transmitters. Dummy tags were interspersed randomly into the tagging order for each release group. For each Durham Ferry release, 10 fish implanted with dummy transmitters were included in the tagging process. Procedures for tagging these fish, transporting them to the release site, and holding them at the release site were the same as for fish with active transmitters. For four of the seven releases, an additional eight untagged fish were also transported to the release sites and held. Both the dummy tagged fish and unmarked fish were evaluated for condition and mortality after being held at the release site for approximately 48 hours.

After dummy tagged fish and eight, untagged fish, were held for 48 hours they were euthanized with MS-222, measured (FL to nearest mm) and examined qualitatively for percent scale loss, body color, fin hemorrhaging, eye quality, gill coloration and vigor (Table 5-1). Mortality and condition of the fish held was also documented. For four of the seven releases at Durham Ferry, the 10 dummy tagged fish, in addition to eight, untagged fish, were sampled for bacteriology, virology and gill ATPase (Chapter 6). In addition, a portion of the VAMP study fish was observed to have short or thin operculum. Eight fish were examined to determine if this was an indication of poor health.

To determine if there were differences in mortality for fish held near the Stockton Wastewater Treatment Plant relative to those held near Durham Ferry, bioassays were performed on additional sets of dummy tagged fish held at Durham Ferry and Stockton once per week as a complementary study (Chapter 6). These fish were placed into live-cars (15.24 cm diameter PCV pipe with small mesh (~1mm) flow through screens) and immersed in 89 L ice chests with small aquarium pumps providing oxygen for transport immediately after tagging. One live-car was used for 10 dummy tagged fish for each location. Following transport, the live-cars were transferred from the coolers to the river. Following an approximately 40 hour holding period blood and histology samples were collected (see Chapter 6).

Table. 5-1
Characteristics Assessed for Chinook Salmon Smolt Condition and Short-Term Survival.

Character	Normal	Abnormal
Percent Scale Loss	Lower relative numbers based on 0-100%	Higher relative numbers based on 0-100%
Body Color	High contrast dark dorsal surfaces and light sides	Low contrast dorsal surfaces and coppery colored sides
Fin Hemorrhaging	No bleeding at base of fins	Blood present at base of fins
Eyes	Normally shaped	Bulging or with hemorrhaging
Gill Color	Dark beet red to cherry red colored gill filaments	Grey to light red colored gill filaments
Vigor	Active swimming (prior to anesthesia)	Lethargic or motionless (prior to anesthesia)

During the last tagging session on May 12th an additional 20 fish were implanted with dummy transmitters to evaluate delayed mortality and tag retention over a 17-day period. These fish were held at TFF along with a control group of 20 untagged fish, and the tank was checked for mortalities daily by TFF staff. Water temperature was 19°C in the holding tank. At the end of the evaluation period (May 29th) fish were examined to document their condition, including dissection of tagged fish. All fish were also weighed and measured to compare growth rates of tagged and untagged fish.

Receiver Deployment

The hydrophone receiver network shown in Figure 5-2 was developed as part of a series of collaborative and collegial VAMP biology group meetings involving SJRA partners along with agency (NOAA, EPA, USGS, etc.) and stakeholder input. Throughout these discussions a hierarchy of study objectives were discussed in relation to the tradeoffs associated with a variety of different hydrophone placement scenarios. Principal objectives of the hydrophone layout were to: (1) obtain fish survival estimates in some key reaches of the Delta, and (2) obtain fish route "selection" probabilities at critical flow splits (i.e., head of Old River and Turner Cut).

Natural Resource Scientists, Inc. (NRS) programmed and installed the electronic equipment at receiver locations (Vogel, 2010). Cross-sectional depth profiles were measured at each site to ensure that riverbed topography did not obscure direct passage of acoustic signals from transmitters to the hydrophones. Continuously pinging "beacon" tags were programmed and anchored underwater near each site throughout the study period in order to verify that each receiver was operating properly. Receivers were turned on, on April 22nd.

Equipment was installed by NRS under a variety of conditions. Equipment was installed at DWR or USGS gaging stations and at the federal or State water export facilities. In the Stockton Deep Water Ship Channel, electronic equipment was placed on top of channel markers. Other sites required that the equipment be housed in tamperproof metal job boxes and anchored to large riprap using concrete anchor bolts.

To alleviate overheating of the external receivers during the VAMP 2009, as was suspected to have occurred in 2008, job boxes housing the receivers were modified by NRS using three techniques: 1) incorporating a water bath inside the job boxes, 2) cutting ventilation holes in the bottom and top for convection cooling, and 3) painting the exterior of the metal boxes with a ceramic paint (Vogel, 2010).

Receiver Monitoring

Personnel from the DFG, USFWS Stockton Office, DWR, USBR, and FISHBIO maintained the receiver sites shown in Figure 5-2. The receivers were monitored daily from April 22nd through May 29th. At each site, the receiver job box was opened and the battery was removed, replacing it with a fully-charged battery three times per week. Used batteries were recharged for use the following day of exchange. Data was downloaded every Monday, Wednesday, and Friday during the study and data was uploaded to a FTP site soon after collection.

Several sites required use of a boat operator and crew to change out the batteries and retrieve the data. Sites that were maintained using a boat were Old River (Old(e)), San Joaquin River at Lathrop(SJO(n)), Navy Bridge (STP(n)), Stockton Waste Water Treatment Facility/ USGS gage (STP (s)), channel marker 16 (SJT(nw)) and 18 (SJT(se)), and Turner Cut (TRN(ne) and TRN(nw)).

Temperature Monitoring

Water temperature was monitored during the VAMP 2009 study using individual computerized temperature recorders (e.g., Onset Stowaway Temperature Monitoring/Data Loggers). Water temperatures were measured at locations along the longitudinal gradient of the San Joaquin River and interior Delta channels between Durham Ferry and Chipps Island – locations along the migratory pathway for the juvenile Chinook salmon released as part of these tests (See Figure C-1 and Table C-1 in Appendix C). As part of the 2009 VAMP monitoring program, additional temperature recorders were deployed in the south and central Delta to provide geographic coverage for characterizing water temperature conditions while juvenile salmon emigrate from the lower San Joaquin River through the Delta. Water temperature was recorded at 24-minute intervals throughout the period of the VAMP 2009 investigations.

Tag life study

An in-tank tag life study was conducted to quantify the rate of tag extinction under the operating parameters used for the study (i.e., encoding, range, and pulse width), following similar methods employed by the CRRL during 2008. A stratified random sample of 50 tags was taken across the 1,000 model 795 Lm tags purchased from HTI which were comprised of seven manufacturing lots. The tag life study began May 12th and tags were programmed according to the same procedures used for the field study. Tags were secured to a PVC stand with hook and loop closure that was placed into the study tank immediately after programming.

Two independent detection systems were used to continuously monitor the tags. Tags were considered dead when they were not detected during any single one hour period. The date and time when the tag initially failed was recorded for each tag and used in conjunction with the time of initialization to determine the active life of each tag. Some tags functioned intermittently following failure and these observations were also recorded.

Water temperatures in the tank were held at approximately 18-21°C. A recording thermograph was placed in the tank prior to tag initialization and temperature readings were logged every 30 minutes for the duration of the study.

Data Processing for Survival Analysis

Acoustic telemetry receivers developed by HTI, Inc. generate hourly raw acoustic tag data files (.rat files). These files are processed using the vendor's proprietary software program (*MarkTags®*) to view and evaluate collected data. Two techniques are commonly used to process the hourly files: auto-marking and manual processing. Auto-marking is advantageous when processing large numbers of files and large numbers of study fish have been released. USGS utilized both auto-marking (to improve efficiency) and manual validation (to ensure accuracy) for processing VAMP data in 2008. In 2009, data was processed manually to try to differentiate types of acoustic signals to evaluate the potential bias associated with tagged salmon being detected after they had been eaten by predators.

The University of Washington received the processed detection data from NRS including date, time, location, period, and subcode of each valid detection of the acoustic tags on the fixed-site receivers. The period and subcode indicated the acoustic tag ID, and were used to identify the tag activation time, tag release time, and release group from the tagging database. For each tag, the processed acoustic detection data were converted to a capture history that indicated the chronological sequence of detections on the fixed site receivers throughout the study area. In cases in which a tag was observed passing a particular receiver or river junction multiple times, the capture history represented the final route of the tagged fish past the receiver or river junction. Detections were pooled from the two receivers located at the Central Valley Project trash racks.

In addition to identifying the location and timing of the detection events for each acoustic tag, the data received from NRS also characterized the shape of the acoustic signal pattern during the hour of detection according to four distinct patterns: 1 = inverted "V" shape, 2 = inverted curve, 3 = wavy pattern, and 4 = flat line (see Vogel, 2010 for further description). Codes 1 and 2 were considered consistent with salmon smolt movement past a receiver, while codes 3 and 4 were considered more consistent with predator movement. Using the four identified acoustic signal patterns, an attempt was made to distinguish between detections of salmon smolts tagged in the study and detections of predators that had eaten the tagged study fish, and then remove the predator detections from the data set. This was necessary because the salmon survival model depended on the assumption that all detections of the acoustic tags represented live salmon smolts, rather than a mix of live smolts and predators. Without removing the detections that came from predators, the survival model would produce positively biased estimates of juvenile salmon survival. Thus, acoustic signal pattern codes 1 and 2 were classified as "smolt-type detections" and codes 3 and 4 as "predator-type detections." Five alternative approaches were considered for handling detections representing predators, and simulated capture histories under a simplified release-recapture model in order to identify the approach that would minimize the bias in the survival estimates caused by predation of the study fish. The five approaches were:

Approach 1: Use all tag detections, regardless of the signal pattern code.

Approach 2: Remove tags that were detected with codes 3 or 4 from the data set.

Approach 3: Remove all detections with codes 3 and 4.

Approach 4: Remove all detections with codes 3 and 4, and all other detections that occurred after the first detection with code 3 or 4.

Approach 5: Remove all detections with codes 3 and 4 and all subsequent detections, and insert a detection at the last site passed before the first detection with code 3 or 4.

Data were simulated under the following assumptions:

Assumption 1: Smolt survival through any given reach was intermediate (0.5).

Assumption 2: The probability of detection of any tagged fish that was near an acoustic receiver was high (0.9).

Assumption 3: The probability of a detected smolt being recorded with a smolt-type detection (code 1, 2) was high (0.8).

Assumption 4: The probability of a predator moving downstream to the next receiver was high (0.9).

Assumption 5: The probability of a detected predator being recorded with a smolt-type detection (code 1, 2) was intermediate (0.5).

Under these assumptions, Approach 4 minimized the bias in the survival estimates, followed closely by Approach 5. Therefore, we estimated the migration and survival parameters using Method 4 to remove the detections caused by predators: we used all smolt-type detections until the first predator-type detection, and then ignored all subsequent detections. This approach was similar to that used by the California Department of Water Resources to remove predator detections from their data set (Kevin Clark, DWR, personal communication, 4 February 2010). In order to assess the sensitivity of the results to the approach used to handle predator detections, we compared the results from approaches 4 and 5. In addition, in order to observe the size of the potential bias caused by including all predator-type detections, we also estimated the migration and survival parameters using Approach 1, which used all tag detections regardless of the signal pattern code.

The detection data were stratified by release group according to the operations of the acoustic receivers throughout the study area. The survival model is based on the assumption that all fish in a release group have a common probability of detection at a given receiver, conditional upon arriving at the receiver. In the event of a malfunctioning receiver or a receiver that has data gaps caused by excessive environmental noise, tagged fish that passed when the receiver was not recording detections would have zero probability of detection, whereas tagged fish passing at other times would have positive probability of detection. Thus, it was necessary to remove detections from receivers with data gaps from analysis for release groups that passed the receivers during the data gap. We identified such cases by comparing the travel time distributions from release to the receivers with data gaps for each release group. Release groups with shortened travel time distributions or with detection gaps that coincided with the known data gaps at particular receivers were analyzed without detections from those receivers. This affected release groups 1 and 2, which passed the Mossdale receiver (SJO(s)) before it was fully operational. In addition, high amounts of environmental noise at the Lathrop receiver (SJO(n)) during the time when release group 7 was passing meant that detections from both the Lathrop receiver and the Old River east receiver (OLD(e)) had to be omitted from analysis for group 7. Thus, the detection data were grouped into three strata:

Stratum 1 = release groups 1 and 2, analyzed without detections from Mossdale (SJO(s));

Stratum 2 = release groups 3 – 6, analyzed using detections from all receivers;

Stratum 3 = release group 7, analyzed without detections from the Lathrop (SJO(n)) or Old River east (OLD(e)) receivers.

Survival Model

A multi-state release-recapture model was developed and used to estimate salmon smolt survival and migration route parameters throughout the study area. The release-recapture model was similar to the model developed by Perry et al. (2010), and represented movement and survival throughout the study area to six exit points (Figure 5-2 and 5-3). Fish migrating solely within the San Joaquin River exited the study area at the dual acoustic array in the San Joaquin River shipping channel just downstream of the junction with Turner Cut (SJT, route A). Fish entering Turner Cut exited at the Turner Cut receivers (TRN, route F). These two exit points and the routes to them collectively comprised the San Joaquin River route (route A). Fish using the Old River route exited at one of four exit points: the dual array in Old River at Highway 4 (OLD(n), route B), the dual array in Middle River at Highway 4 (MID(n), route C), the receiver in the access channel of Clifton Court Forebay (CCG(e), route D), and the receivers at the Central Valley Project trash rack (CVP(ne), CVP(sw), route E). These four exit points and the routes to them collectively comprised the Old River route (route B). The detections from receivers inside the radial gates at Clifton Court Forebay (CCG(w)) were omitted from the survival model because the status of the radial gate (open or closed) was unknown at the time of arrival of tagged fish in the access channel. However, detections of tagged fish on the radial gate receiver were summarized. Similarly, detections on the receiver in the holding tank at the Central Valley Project (CVP(tank)) were omitted from the survival model because of sparse data, but were summarized separately. In summary, routes and exit points are defined as follows:

A = San Joaquin River: survival and exit point

B = Old River: survival and exit point

C = Middle River: exit point from Route B

D = State Water Project: exit point from Route B

E = Central Valley Project: exit point from Route B

F = Turner Cut: exit point from Route A

The release-recapture model used parameters that denoted the probability of detection (P_{hi}), route entrainment (ψ_{hl}), salmon survival (S_{hi}), and transition probabilities equivalent to the joint probability of movement and survival ($\phi_{hi,kj}$) (Figure 5-3; Table D-1, Appendix D). The model also used "last reach" parameters (λ_{hi}), representing the joint probability of survival and detection in the last reach. The full model consisted of 29 parameters for each release group stratum: 11 detection probabilities, 7 survival probabilities, 2 route entrainment probabilities, 4 transition probabilities, and 5 last reach parameters. It was assumed that detection at CCG(e) (in the Clifton Court Forebay access channel) was 100% (i.e., P_{D1a}=1); this assumption was supported by the detections from the receiver inside the radial gates (CCG(w)). The model parameters were:

P_{hi} = detection probability: probability of detection at telemetry station *i* within route *h*, conditional on surviving to station *i*.

S_{hi}= survival probability: probability of survival from telemetry station *i* to *i*+1 within route *h*, conditional on surviving to station *i*.

ψ_{hl} = route entrainment probability: probability of a fish entering route *h* at junction *l* (*l* =1, 2), conditional on fish surviving to junction *l*.

$\phi_{hi,kj}$= transition probability: joint probability of route entrainment and survival, the probability of surviving and moving from station *i* in route *h* to station *j* in route *k*.

λ_{hi}= last reach parameter: joint probability of survival from the next to last receiver at station *i* in route *h* to the last receiver, and detection at the last receiver.

In addition to the basic model parameters, derived performance metrics measuring migration route probabilities and survival were estimated as functions of the model parameters. The probability of taking the San Joaquin River route (Route A) was $\psi_A = \psi_{A1}$. The probability of migrating into the South Delta via Old River was $\psi_B = 1 - \psi_{A1}$. Survival through the San Joaquin River route from Mossdale was $S_A = S_{A2} S_{A3} S_{A4} S_{A5}$. Survival through the Old River route in the South Delta to the four exit locations (OLD(nu), MID(nu), CCG(e), or CVP(sw/ne)) was $S_B = S_{A2} S_{B1} S_{B2}$, where S_{B2} represented the total survival from the head of Middle River (OM(fs)) to the four exit locations. Because survival between OM(fs) and the four exits required both movement toward any of the four exits and survival to the exit chosen, S_{B2} was defined as the sum of the four transition probabilities:

$$S_{B2} = \phi_{B2,B3} + \phi_{B2,C1} + \phi_{B2,D1} + \phi_{B2,E1}.$$

Total survival from Mossdale (SJO(s)) to the six exit locations (SJT(se), TRN(ne), OLD(nu), MID(nu), CCG(e), or CVP(sw/ne)) was

$$S_{Total} = \psi_A S_A + \psi_B S_B.$$

Parameter Estimation

Individual capture histories were constructed for each tag as described above. Each capture history consisted of nine fields representing initial release at Durham Ferry (field 1), detection on the San Joaquin River receivers upstream of Turner Cut (fields 2 – 5; sites SJO(s), SJO(n), STP(s), STP(n)), detection on the Old River receivers upstream of Middle River (fields 6 – 7; sites OLD(e), OM(fs)), and detection on the receivers at the exit points to the study area (fields 8 – 9; sites SJT(se), SJT(nw), OLD(nd), OLD(nu), MID(nd), MID(nu), CCG(e), CVP(ne)/CVP(sw), CVP(tank), TRN(ne), TRN(sw)) (Figure 5-3). Detection was indicated by a capital letter representing the route and location of the detection (A, B, C, D, or F), and non-detection was represented by 0. For example, the detection history R0AA000AA represented a tag that was released at Durham Ferry, passed Mossdale (SJO(s)) without detection, was detected at Lathrop in the San Joaquin River (SJO(n)) and again in the San Joaquin at the USGS gauge (STP(s)), passed the receiver at the Navy Bridge in Stockton (STP(n)) without detection, and was detected at both receivers in the San Joaquin River just downstream of the junction with Turner Cut (STP(se), STP(nw)). The probability of having this detection history was

$$S_{A1}(1-P_{A2})S_{A2}\psi_{A1}P_{A3}S_{A3}P_{A4}S_{A4}(1-P_{A5})S_{A6}\psi_{A2}P_{A6a}\lambda_{A6a}$$

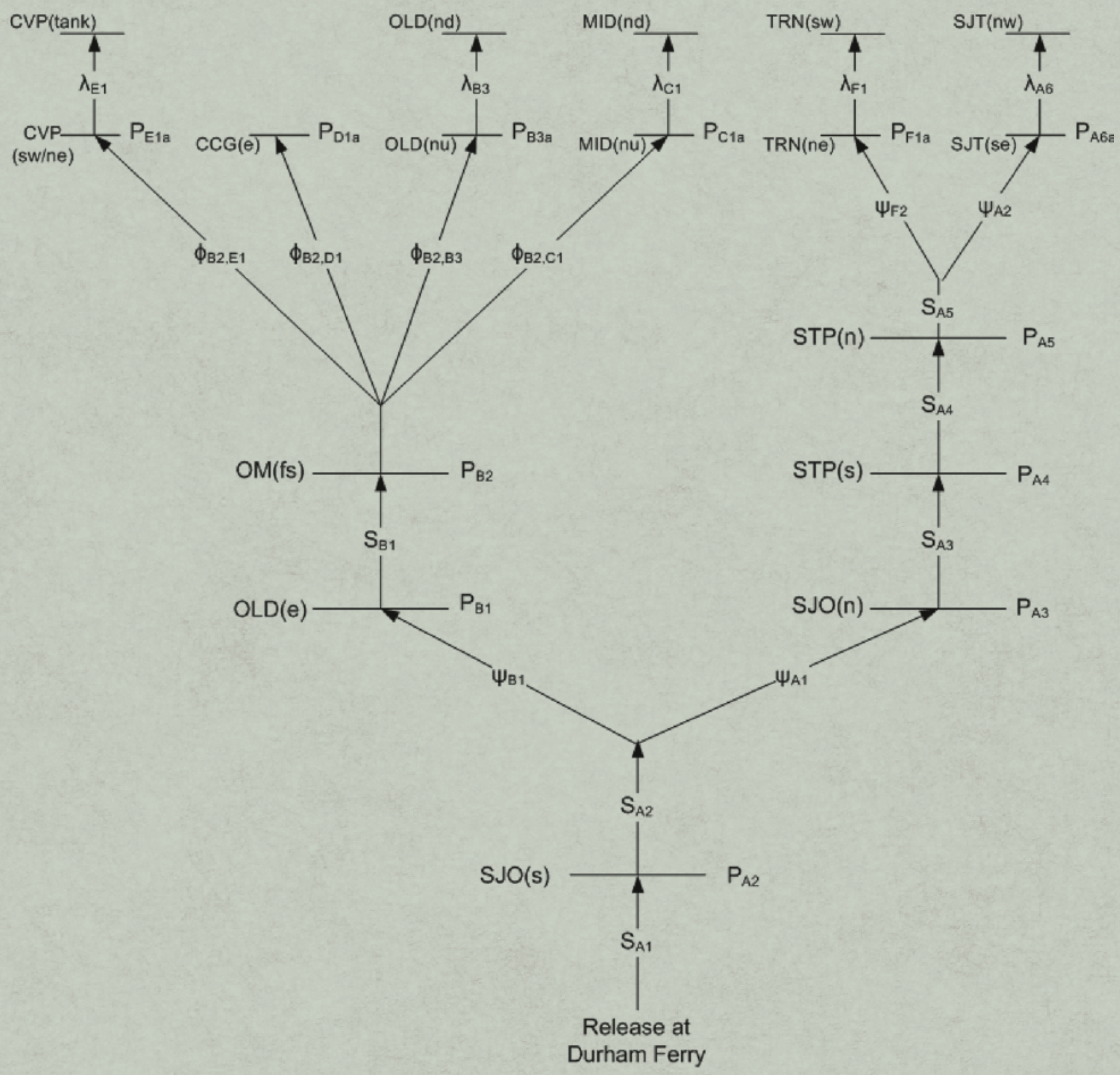
A second example is the detection history RA000BBEE. This detection history represented a tag that was released at Durham Ferry and detected at Mossdale (SJO(s): A), at the Old River detection site just downstream of the head of Old River (OLD(e); B), and at the head of Middle River (OM(fs); B). The next detection was at the trash rack at the entry to the Central Valley Project (CVP(ne/sw); E), followed the final detection in the holding tank (E). This detection history has probability

$$S_{A1}P_{A2}S_{A2}(1-\psi_{A1})P_{B1}S_{B1}P_{B2}\phi_{B2,E1}P_{E1}\lambda_{E1}.$$

Under the assumptions of common model parameters and independent detections among the tagged fish in the release group, the likelihood function for each release group was a multinomial likelihood with 198 cells denoting the possible capture histories. The model was numerically fit to the set of capture histories according to the principle of maximum likelihood using Program USER, developed at the University of Washington (Lady et al. 2009). Point estimates, standard errors, and 95% profile likelihood confidence intervals were computed for each parameter. Standard errors of derived performance measures were estimated using the delta method (Seber 2002: 7-9). Sparse data meant that some parameters could not be estimated for some release strata. Transition, survival, and detection probabilities

Figure 5-3

Schematic of Release-recapture Model Used to Estimate the Probabilities of Survival (S_{hi}), Route Entrainment (ψ_{hl}), Transition ($\phi_{hi,kj}$), and Detection (P_{hi}), and the Joint Probabilities Survival and Detection in the Last Reach of Each Ro ute (λ_{hi}) for Acoustically Tagged Juvenile Chinook Salmon Tagged and Released in the 2009 VAMP. Horizontal Bars Represent Detection Stations. P_{Dla}=1.



were fixed to 1.0 or 0.0 as appropriate, based on the observed detections. Parameters were estimated across the three release strata in three ways:

Model MO: All strata have common parameters, with the exception of the detection probability at SJO(s) (=0 for release groups 1 and 2), and at SJO(n) and OLD(e) (=0 for release group 7).

Model M1: All strata have common survival, route entrainment, and last reach parameters, but unique detection probabilities.

Model M2: All strata have unique parameters.

Model selection was performed using the Akaike Information Criterion (AIC) as described in Burnham and Anderson, 2002. Goodness-of-fit was assessed using Anscombe residuals (McCullagh and Nelder 1989).

Parameters and performance measures were estimated for each release stratum separately. Population-level parameters and performance measures were estimated as weighted averages of the stratum-specific estimates. In particular, if $\hat{\theta}_i$ is the estimate of the measure θ_i for release stratum i (i=1,2,3), then the population-level measure was estimated as

$$\hat{\theta} = w_1\hat{\theta}_1 + w_2\hat{\theta}_2 + w_3\hat{\theta}_3 ,$$

where w_i is the proportion of all fish released that were in release stratum i (i=1,2,3). The weight w_i was set equal to 0 for parameters and performance measures whose estimates were unavailable for stratum i. Standard errors were estimated using the delta method (Seber 2002: 7-9).

Analysis of Tag Failure

The arrival distribution of tags at each detection site was compared to the results of the tag-life study in order to determine whether it was necessary to adjust the estimated survival probabilities for tag failure. No such adjustments were necessary (see Results: Tag Life Adjustment).

Analysis of Tagger Effects

Differential effects of tagger on survival throughout the study area were tested by fitting the survival model to detection data that were stratified by tagger. Estimates of both reach survival and cumulative survival throughout the study area were visually compared to assess any tagger effect on survival.

Analysis of Travel Time

Travel time through each reach was calculated for tags detected at the beginning and end of the reach, and summarized across all tags with observations. Travel time between two sites was defined as the time delay between the first detection at the first site and the first detection at the second site. The arithmetic mean was used to summarize travel times.

Mobile Telemetry Monitoring

Mobile telemetry was performed in channels within the acoustic receiver array after equipment was installed and fish were released. The technique was developed from prior juvenile salmon telemetry studies in the Delta (e.g., Vogel 2007a, 2008). Mobile monitoring is conducted by anchoring a boat (with no motor or depth sounders operating) with a suspended hydrophone and cable. This is done approximately every ¼ mile in a specific reach or site. The receiver is operated for 5 to 10 minutes at a fixed location to obtain a sufficient recording of any transmitters within the hydrophone detection range. GPS coordinates are noted for later data processing to document hydrophone positioning. A further explanation of the mobile monitoring can be found in Vogel, 2010.

Priority was given to two specific river reaches: Durham Ferry to the Deep-Water Ship Channel and Old River from the head to the south Delta water export facilities. NRS periodically surveyed the reach between the head of Old River and the ship channel and FISHBIO surveyed the reach between Durham Ferry to the head of Old River and in Old River and Grant Line Canal (Figure 5-4).

Predatory Fish Tagging

Acoustic-tagging of predatory fish by NRS was anticipated to provide information on striped bass and black bass movements within the VAMP study area and possible affinity of those species to specific locales. During the study, 23 striped bass (*Morone saxatilis*) and one large-mouth bass (*Micropterus salmoides*) were captured and externally tagged with individually identifiable acoustic transmitters and released at the fish capture locations in the lower San Joaquin River and interior Delta. Various sized predatory fish, sufficiently large to eat a salmon smolt, were tagged as shown in Table 5-2 (Vogel, 2010). Capture and release sites included scour holes, near structures, and in front of the trash racks at the federal Tracy Fish Facilities. The acoustic transmitters were similar but larger (13 grams) than the 0.65-gram transmitters implanted in salmon smolts released during the VAMP study and lasted for the duration of the VAMP study. Each transmitter was individually identifiable and did not overlap with the smolt transmitters. Movements of tagged striped bass were monitored and recorded using the VAMP and Temporary Barriers study fixed-station acoustic receiver networks.

Figure 5-4
Areas Surveyed (Shaded Blue) Using Mobile Acoustic Receivers During the 2009 VAMP Study (Vogel, 2010).

Table 5-2
Predatory Fish Tagged with Acoustic Transmitters During the 2009 VAMP Study (Vogel, 2010).

Fish Species	Fork Length (mm)	Date/Time of Release	Location of Release
Striped Bass	690	4/29/09 1400 hrs.	Upstream of Tracy Fish Facilities trash racks
Striped Bass	550	4/29/09 1400 hrs.	Upstream of Tracy Fish Facilities trash racks
Striped Bass	520	4/29/09 1400 hrs.	Upstream of Tracy Fish Facilities trash racks
Striped Bass	665	4/29/09 1400 hrs.	Upstream of Tracy Fish Facilities trash racks
Striped Bass	550	4/29/09 1400 hrs.	Upstream of Tracy Fish Facilities trash racks
Striped Bass	585	4/29/09 1400 hrs.	Upstream of Tracy Fish Facilities trash racks
Striped Bass	570	4/29/09 1400 hrs.	Upstream of Tracy Fish Facilities trash racks
Striped Bass	655	4/29/09 1400 hrs.	Upstream of Tracy Fish Facilities trash racks
Striped Bass	635	4/29/09 1400 hrs.	Upstream of Tracy Fish Facilities trash racks
Striped Bass	680	4/29/09 1400 hrs.	Upstream of Tracy Fish Facilities trash racks
Striped Bass	460	5/4/09 1340 hrs.	San Joaquin River ½ mile downstream of Dos Reis
Largemouth Bass	315	5/6/09 1500 hrs.	San Joaquin River at head of Old River
Striped Bass	370	5/7/09 1500 hrs.	San Joaquin River at Burns Cut
Striped Bass	370	5/12/09 1820 hrs.	San Joaquin River at head of Old River
Striped Bass	450	5/12/09 1900 hrs.	San Joaquin River at Burns Cut
Striped Bass	420	5/13/09 1420 hrs.	San Joaquin River ½ mile downstream of Dos Reis
Striped Bass	425	5/24/09 1510 hrs.	San Joaquin River at Stockton waste water treatment plant
Striped Bass	470	5/24/09 1610 hrs.	San Joaquin River at Stockton waste water treatment plant
Striped Bass	390	5/24/09 1630 hrs.	San Joaquin River at Stockton waste water treatment plant
Striped Bass	490	5/24/09 1730 hrs.	San Joaquin River at Stockton waste water treatment plant
Striped Bass	410	5/24/09 1820 hrs.	San Joaquin River at Stockton waste water treatment plant
Striped Bass	400	5/27/09 1640 hrs.	San Joaquin River at Stockton waste water treatment plant
Striped Bass	360	5/27/09 1720 hrs.	San Joaquin River at Stockton waste water treatment plant
Striped Bass	370	5/27/09 1940 hrs.	San Joaquin River at Stockton waste water treatment plant

Table 5-3
Results of Dummy Tagged Juvenile Chinook Salmon Evaluated After Being Held for 48 Hours at the Release Sites as Part of the 2009 VAMP Study.

Holding Site, Holding container *	Examination Date, Time	Mean (sd) Forklength (mm)	Mortality	Mean (sd) scale loss	Normal Body Color	No Fin Hemorrhaging	Normal Eye Quality	Normal Gill Color
Stockton, LC	4/23/09, 1000	97.3 (5.6)	0/10	5.1 (2.9)	10/10	10/10	10/10	10/10
Durham Ferry, LC	4/23/09, 1205	97.6 (5.0)	2/10	5.3 (0.7)	8/8	8/8	8/8	8/8
Durham Ferry, NP	4/23/09, 1300	93.5 (4.0)	1/18	5.0 (0.0)	17/17	17/17	17/17	17/17
Durham Ferry, LC	4/26/09, 1500	93.1 (4.1)	0/10	5.9 (2.2)	10/10	8/10	10/10	10/10
Stockton LC	4/30/09, 1310	94.0 (3.8)	1/10	4.1 (2.1)	9/9	9/9	9/9	9/9
Durham Ferry, LC	4/30/09, 1510	98.6 (3.4)	0/10	6.4 (1.8)	10/10	9/10	10/10	10/10
Durham Ferry, TC	4/30/09, 1610	95.9 (4.8)	0/18	4.7 (1.8)	18/18	18/18	18/18	18/18
Durham Ferry, LC	5/3/09, 1105	95.8 (4.4)	0/10	4.6 (1.7)	10/10	10/10	10/10	10/10
Stockton, LC	5/7/09, 1215	93.3 (7.4)	1/10	4.9 (1.7)	9/9	9/9	9/9	9/9
Durham Ferry, LC	5/7/09, 1400	89.8 (3.4)	0/10	6.3 (1.5)	10/10	10/10	10/10	10/10
Durham Ferry, TC	5/7/09, 1450	90.5 (6.6)	2/15	6.3 (3.0)	13/13	13/13	13/13	13/13
Durham Ferry, LC	5/10/09, 1220	90.9 (2.4)	0/10	4.3 (2.0)	10/10	10/10	10/10	10/10
Stockton, LC	5/14/09, 1145	93.9 (3.0)	0/10	5.2 (1.9)	10/10	10/10	10/10	10/10
Durham Ferry, LC	5/14/09, 1348	92.9 (1.3)	0/10	5.2 (1.2)	10/10	10/10	10/10	10/10
Durham Ferry, TC	5/14/09, 1430	93.3 (2.5)	0/18	4.8 (1.2)	18/18	18/18	18/18	18/18

* (LC = Live Car, NP = Net Pen, TC = Trash Can)

Study Results and Discussion

Mortality Evaluations

Of the five intentional mortalities released, three were detected with mobile tracking. Tag 6976.13 and tag 6990.21 were both detected less than 1000 ft downstream from the release point on May 18th. Tag 6501.13 was detected twice (April 28th and May 11th) in the same location approximately three miles downstream of the release point. It is unclear if the dead smolt drifted this far downstream or if it was consumed by a predator and the tag defecated in this location.

Dummy Tagged Fish

Four of the one hundred fifty dummy tagged fish (2.7%) evaluated after 48 hours were found dead. Six of the thirty-two un-tagged fish (18.8%) had either escaped (3) or died (3). Two of three un-tagged fish that died were found caught halfway through the container's flow-through holes. All remaining fish were found swimming vigorously, had normal gill coloration, normal eye quality and normal body coloration. Three of one hundred seventy-two fish had slight fin hemorrhaging. Mean scale loss for all fish assessed ranged from 4.1 to 6.4 %. Roughly 10% of the examined fish had loose sutures or slight hemorrhaging around the sutures. Mean fork lengths of fish ranged from 89.8 to 98.6 mm. Some of the fish in this study had been used previously in mark recapture experiments prior to being tagged or used to assess fish health. Short term survival was 97% within the live-car and trashcan containers. These data indicate that the fish used for the VAMP in 2009 were in generally good condition, despite some being used in previous mark recapture studies (Table 5-3).

During the first week of releases, net pens (volume ~1m3; mesh size ~3 mm) were used to contain tagged and un-tagged fish, but later proved to be cumbersome and awkward when towed by boat. Flow-through trashcans were instead used for later releases. The trashcan's initial flow-through holes were too large and were changed from 1.27 cm to 0.95 and 0.64 cm after experiencing fish escapement

No significant health or physiological problems were detected in the 2009 VAMP release groups. Light infections of *Tetracapsuloides bryosalmonae*, the parasite that causes Proliferative Kidney Disease (PKD), were detected, but all infections were at very early stages and would not likely impact survival during the VAMP study period. It is possible that a portion of the population had asymptomatic infections from opportunistic bacteria. Most fish had undergone or were in the process of smoltification (see Chapter 6).

No differences were observed in bioassay groups held adjacent to the Stockton Wastewater Treatment Plant or at the Durham Ferry site. While some low levels of mortality in the bioassay groups was observed, it occurred at both sites and was likely a result of handing and transport (Chapter 6). No indications of significant tissue changes were observed at either site by histology. Minor gill edema was observed in fish from both locations in several weeks. It was not known if these changes were due to water quality at the site or handling of the sample groups. Blood clinical chemistry and white blood cell (WBC) count data did not demonstrate any consistent difference between bioassay groups.

The elevated WBC count observed from the Durham Ferry control group in Week 3 was the only exceptional observation and may have been caused by infections of Tb or an adverse reaction to tagging (see Chapter 6).

A portion of the VAMP study fish observed with gill abnormalities were examined but no signs of tissue lesions or parasites were observed. Variation in operculum length and thickness was noted, but gills remained protected by the operculum in all samples. All fish were alive, and gill condition did not appear to be compromised. No signs of ongoing infections on gills or operculum were observed. No significant inflammation or other pathology was observed in gills.

In the future, fish with "short operculum" can be used for VAMP study so long as operculum covers the entire gill.

Groups of tagged and untagged fish held at TFF to evaluate delayed mortality and tag retention were evaluated after 17 days. During the evaluation period one mortality was observed from each group and one fish did not retain a tag, indicating long-term survival of 95% and tag retention of 95%. Observation of similar long-term survival rates between the tagged and untagged groups suggest that little to no mortality could be attributed directly to tag implantation.

All surviving fish were generally in good condition, but signs of inflammation or infection were observed at the site of the incision in a few tagged fish. Tagged

Table 5-4
Periods of Non-operation of Acoustic Receivers During the 2009 VAMP Study.
(Refer to Figure 5-2 for Receiver Locations) (Vogel, 2010)

Site Name	Receiver Location	Start Down Time	End Down Time
SJO(S)	Mossdale	4/22/09 1000 hrs.	4/28/09 1000 hrs.
SJO(N)	Lathrop gage	5/15/09 0200 hrs.	5/15/09 0600 hrs.
		5/15/09 0800 hrs.	5/15/09 1300 hrs.
		5/15/09 1500 hrs.	5/15/09 1900 hrs.
		5/15/09 2100 hrs.	5/18/09 1200 hrs.
OLD(E)	Head of Old River	5/4/09 1300 hrs.	5/6/09 1200 hrs.
STP(S)	Stockton USGS gage	4/22/09 1000 hrs.	4/28/09 1200 hrs.
		5/1/09 1200 hrs.	5/3/09 1400 hrs.
		5/12/09 0800 hrs.	5/18/09 1200 hrs.
STP(N)	Navy Bridge	5/24/09 2300 hrs.	5/25/09 0900 hrs.
		5/26/09 1300 hrs.	5/27/09 0200 hrs.
SJT(SE)	Shipping Channel red 18	5/1/09 1100 hrs.	5/2/09 0500 hrs.
SJT(NW)	Shipping Channel red 16	5/1/09 1000 hrs.	5/2/09 0800 hrs.
		5/25/09 0800 hrs.	5/26/09 0900 hrs.
CVP(SW)	Tracy FF inside trash racks	5/15/09 1300 hrs.	5/18/09 1000 hrs.
OLD(ND)	Old River upstream of Hwy 4	5/4/09 0900 hrs.	5/11/09 0900 hrs.

fish also appeared to grow more slowly than untagged fish, although untagged fish were not measured at the beginning of the evaluation. Untagged fish were obtained from the same tank as the tagged fish so it could be assumed that fish size was similar between the two groups. At the end of the evaluation, tagged fish averaged 98.9 mm forklength and 11.2 g whereas untagged fish averaged 106.0 mm forklength and 14.1 g. However, since the VAMP study evaluates survival during such a brief period of time, reduced growth rate of tagged fish is not likely to affect the survival estimates. Similar evaluations were not conducted in previous years for comparison, but such evaluations should continue in future years.

Receiver performance

Based on evaluation of the acoustic receivers' performance during the study, one or more of the actions modifying the job box appeared to have fixed the suspected overheating problem that had occurred in previous years (Vogel, 2010). However, other problems associated with receiver function at some locations occurred during the 2009 VAMP study. For several of the receivers there were periods during the study where the acoustic receiver did not function properly. The largest time periods were in the beginning of the study at Mossdale (SJO(s)) and Stockton USGS gage station (STP(s)) due to AC grounding issues (Table 5-4).

Temperature Monitoring

Water temperatures measured at the 20 locations on the San Joaquin River and throughout the Delta during the April-June fall-run Chinook salmon smolt emigration are shown in Appendix C. One of the temperature recorders deployed in 2009 at the Grant Line Canal at Tracy Blvd. Bridge site malfunctioned.

Water temperatures measured within the lower San Joaquin River and Delta were within a range considered to be suitable (typically < 20º C; 68 F) during April and early May in the mainstem San Joaquin River (e.g., Durham Ferry, Old River at HORB, and Dos Reis (Appendix C). Seasonal water temperatures typically exceeded 20º C (68º F) beginning in mid-May both within the lower San Joaquin River and Delta.

Results of the 2009 water temperature monitoring showed a longitudinal gradient of temperatures that generally increased as a function of distance downstream within the mainstem San Joaquin River and Delta. Water temperatures measured in the San Joaquin River during early April through mid-May would not be expected to result in adverse effects or reduced survival of emigrating juvenile Chinook salmon released as part of the VAMP 2009 investigations. Water temperatures measured

downstream within the Delta during April and early May were within the general range considered to be suitable for juvenile fall-run Chinook salmon migration, however temperatures during late May and June were within the range considered to be stressful for juvenile Chinook salmon.

Temperature results for 2009 were also compared to results for 2008 and 2007. Because of past logger malfunctions and losses, 2007, 2008 and 2009 results were compared using four locations: Durham Ferry, Dos Reis, Old River/Indian Slough Confluence, and Werner Cut (Channel above Woodward Isle). The average 2007 temperature of the four locations was 18.9º C. The average 2008 temperature of the four locations was 18.4º C. The average 2009 temperature of the four locations was 19.2º C. Temperatures were warmest in 2009 at all locations except for Werner Cut, which was warmest in 2007. It appears that although the flow in 2009 was significantly lower than in 2007 and 2008, temperatures in 2009 were only slightly, and inconsistently, higher.

Tag life study

Results from the tag life study demonstrated that the tags used for the 2009 VAMP were highly reliable and none of the challenges with tag performance encountered during 2008 were identified in 2009. All tags randomly selected for the tag life study were successfully programmed and tags did not begin to die until 21 days after initialization. As soon as tags began to fail, the rate of attrition was high and all tags were dead by the end of the 29th day following initialization (Figure 5-5).

About one-third of the tags (n=16) used in the tag life study intermittently transmitted signals after the initial failure. For most of these tags (63%; n=10), intermittent signals were detected during only the first four hours after initial failure. The remaining one-

Table 5-5
Number of Juvenile Chinook Salmon Tagged in Each Release Group by Tagger in the 2009 VAMP Study.

Release Group	Tagger				Total Tags
	A	B	C	D	
1	33	33	34	33	133
2	36	34	31	33	134
3	35	37	26	36	134
4	34	33	34	33	134
5	32	33	31	36	132
6	33	28	33	39	133
7	34	33	33	33	133
Total Tags	237	231	222	243	933

Table 5-6
Estimates (and Standard Errors) of Survival Probabilities ($S_{Ai,\ Bi}$) and Transition Probabilities ($\phi_{B2,kj}$) by Tagger for the VAMP 2009 Study.

Parameter	Tagger A	Tagger B	Tagger C	Tagger D
S_{A1}	0.538 (0.041)	0.515 (0.040)	0.583 (0.036)	0.584 (0.042)
S_{A2}	0.778 (0.058)	0.765 (0.056)	0.830 (0.041)	0.781 (0.052)
S_{A3}	0.559 (0.085)	0.595 (0.081)	0.614 (0.067)	0.540 (0.078)
S_{A4}	0.714 (0.099)	0.920 (0.054)	0.706 (0.078)	0.773 (0.089)
S_{A5}	0.133 (0.088)	0.130 (0.070)	0.040 (0.039)	0.100 (0.067)
S_{B1}	0.711 (0.068)	0.644 (0.071)	0.768 (0.056)	0.826 (0.056)
$\phi_{B2,B3}$	0.000 (NA)	0.000 (NA)	0.000 (NA)	0.023 (0.023)
$\phi_{B2,D1}$	0.143 (0.054)	0.061 (0.042)	0.217 (0.061)	0.114 (0.048)
$\phi_{B2,E1}$	0.048 (0.033)	0.061 (0.042)	0.000 (NA)	0.046 (0.031)

third of these tags completely failed after 8-13 hours of intermittent function.

Survival Effect of Tagger

Fish in the release groups were evenly distributed across taggers (Table 5-5). A chi-squared test also found a good distribution of taggers across the seven release groups (P= 0.9998).

Estimated smolt survival through each river reach showed no consistent evidence of a tagger effect on survival (Table 5-6). Cumulative survival to the receivers along the San Joaquin Route (Figure 5-6) and at the exit points of the Old River Route (Figure 5-7) also showed no consistent evidence of a tagger effect on survival. Consequently, detection data were pooled across taggers within each release group.

Tag Life Adjustment

No tags in the tag life study failed before day 21 (Figure 5-8). Comparison of arrival timing of the tagged salmon smolts to the fitted tag survivorship curve shows that no tag failure had occurred before the time of smolt arrival at the downstream reaches (Figure 5-9, Figure 5-10). Thus, no adjustment for tag failure was made to the survival estimates from the release-recapture model.

Detections of Acoustic-Tagged Fish

A total of 468 tags were detected downstream of Durham Ferry with a "smolt-type" detection and used in the survival analysis, out of the 933 tagged salmon smolts that were released in 2009 (Table 5-7). The majority of the detections were at Mossdale (SJO(s)), Lathrop (SJO(n)), and the east Old River site (OLD(e)) (Table 5-7). Very few tagged salmon smolts were detected at the exit points of the study area in either the San Joaquin River route or the Old River route (Table 5-7). No tagged salmon were detected at the Turner Cut receivers (TRN), the Middle River receivers at Highway 4 (MID(n)), or the interior receivers at Clifton Court Forebay (CCG(w)) (Table 5-7). When all detections were used, including those with a "predator-type" signal, a higher number of tags were detected overall (650 vs. 468). However, even with the predator-type detections, there was only a single tag detected at Turner Cut, and no tags detected at the Middle River receivers at Highway 4 (Table 5-7).

Figure 5-5
Acoustic Tag Extinction Rate for Model 795Lm Tag Evaluated During the 2009 VAMP

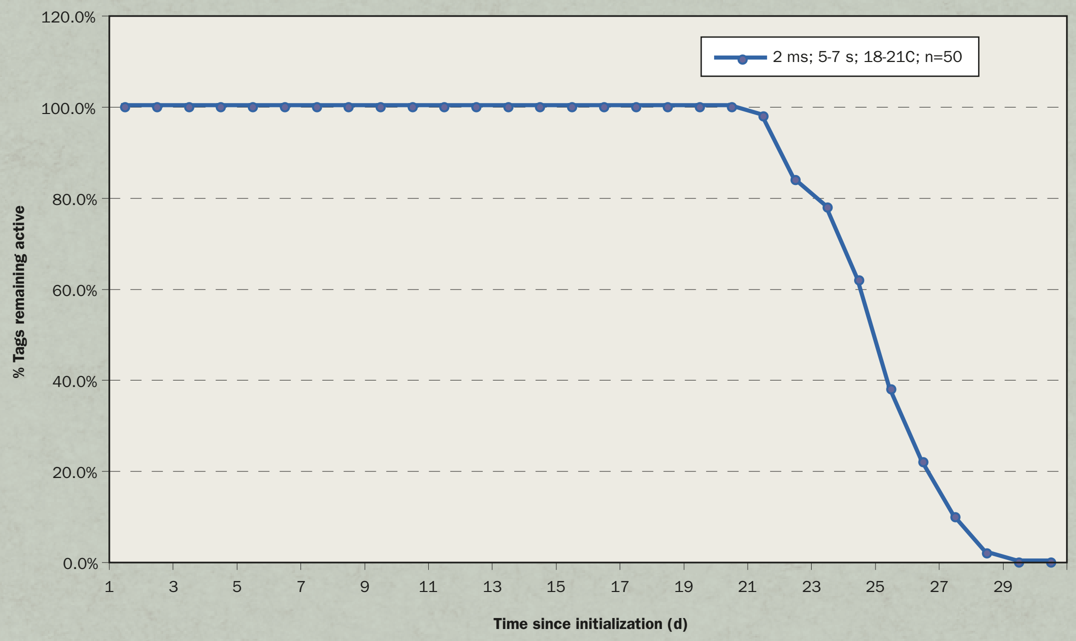


Figure 5-6
Estimated Cumulative Survival from the Release at Durham Ferry
to Receivers Along the San Joaquin River Route by Tagger for the 2009 VAMP Study.

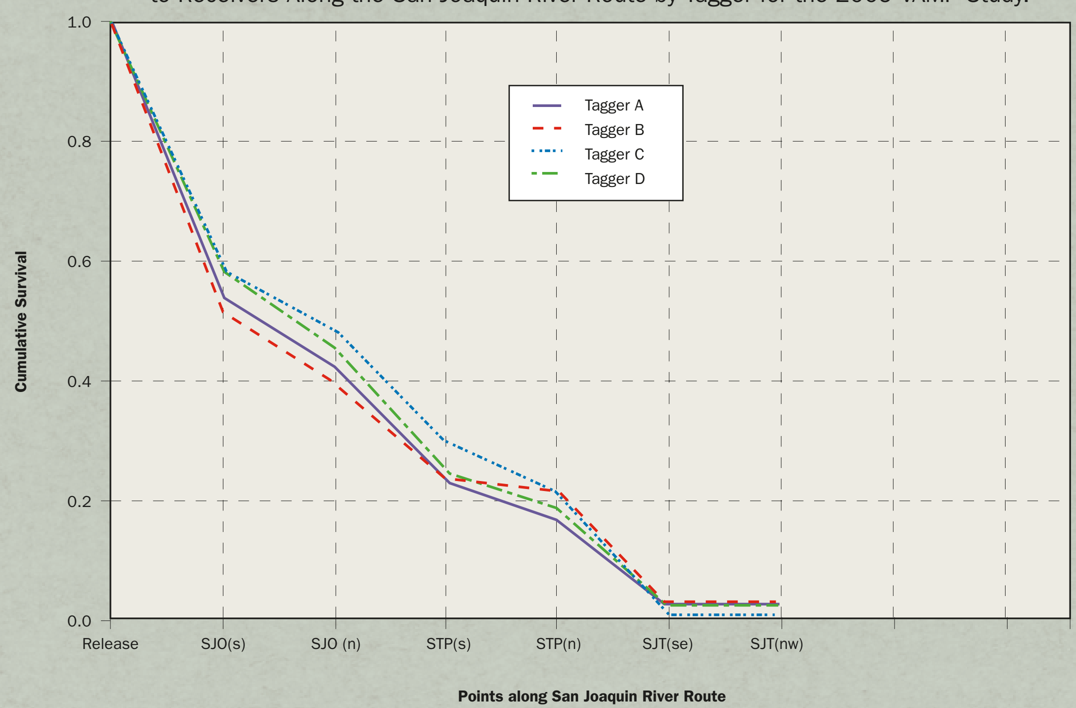


Figure 5-7
Estimated Cumulative Survival from the Release at Durham Ferry to Receivers Along the Old River Route by Tagger for the 2009 VAMP Study.

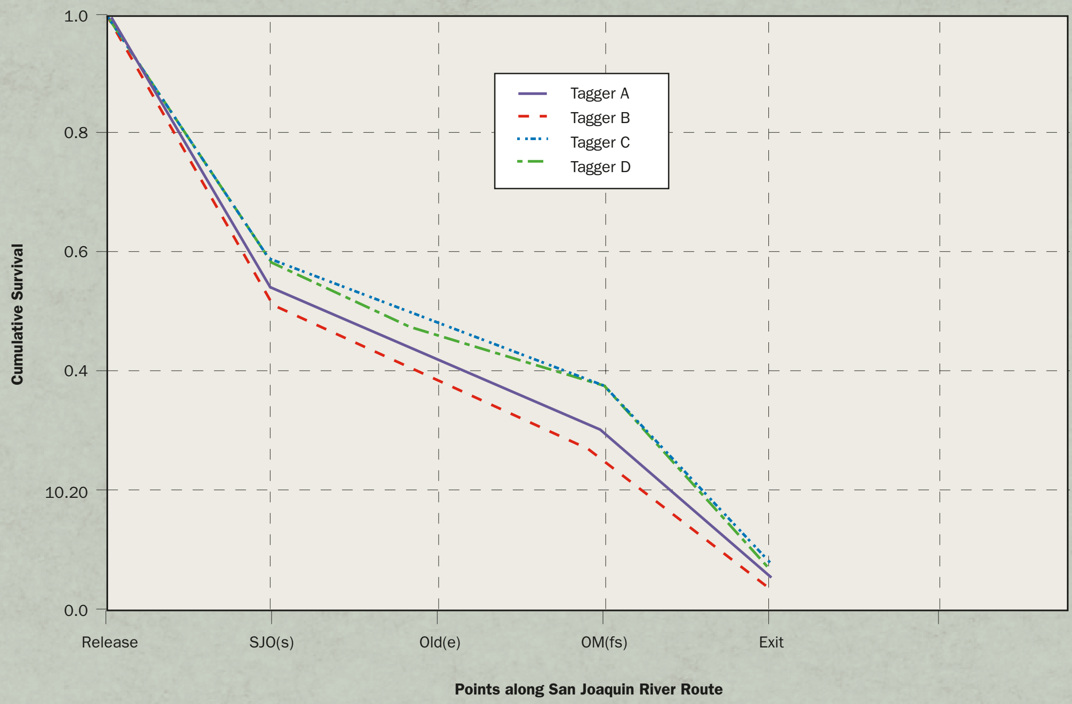


Figure 5-8
Observed Tag Failure Times from the 2009 Tag Life Study, and Fitted Three-Parameter Weibull Curve.

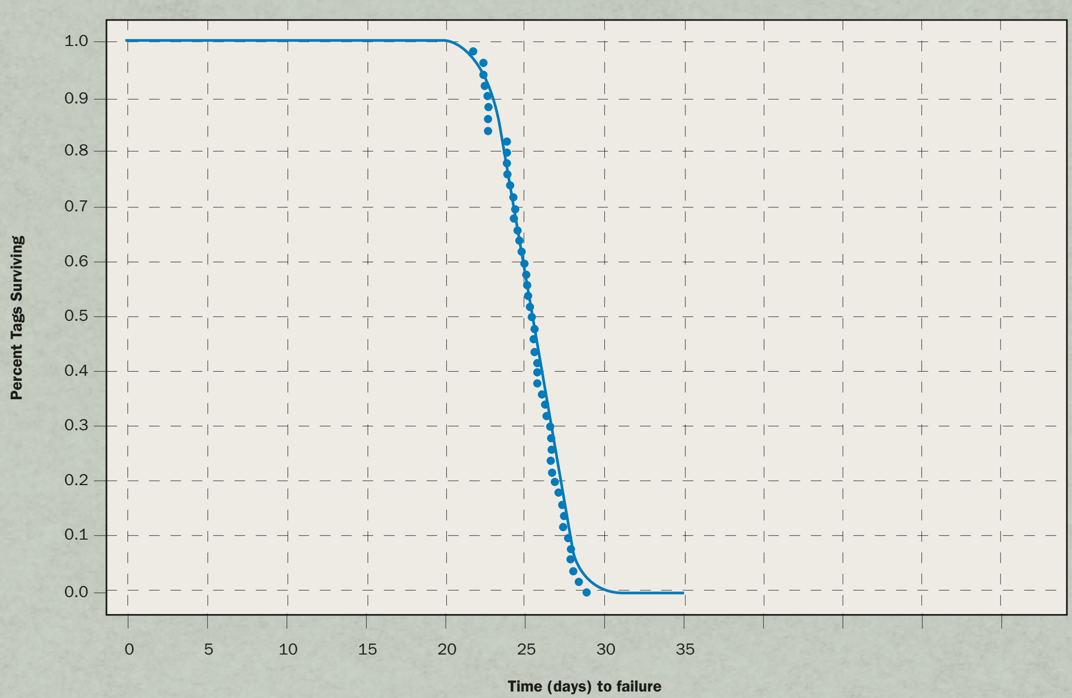


Figure 5-9

Three-parameter Weibull Survivorship Curve for Tag Life and the Timing of Downstream Detections of Acoustic-tagged Chinook Salmon Smolts at Receivers Located in the San Joaquin River Route During the 2009 VAMP Study.

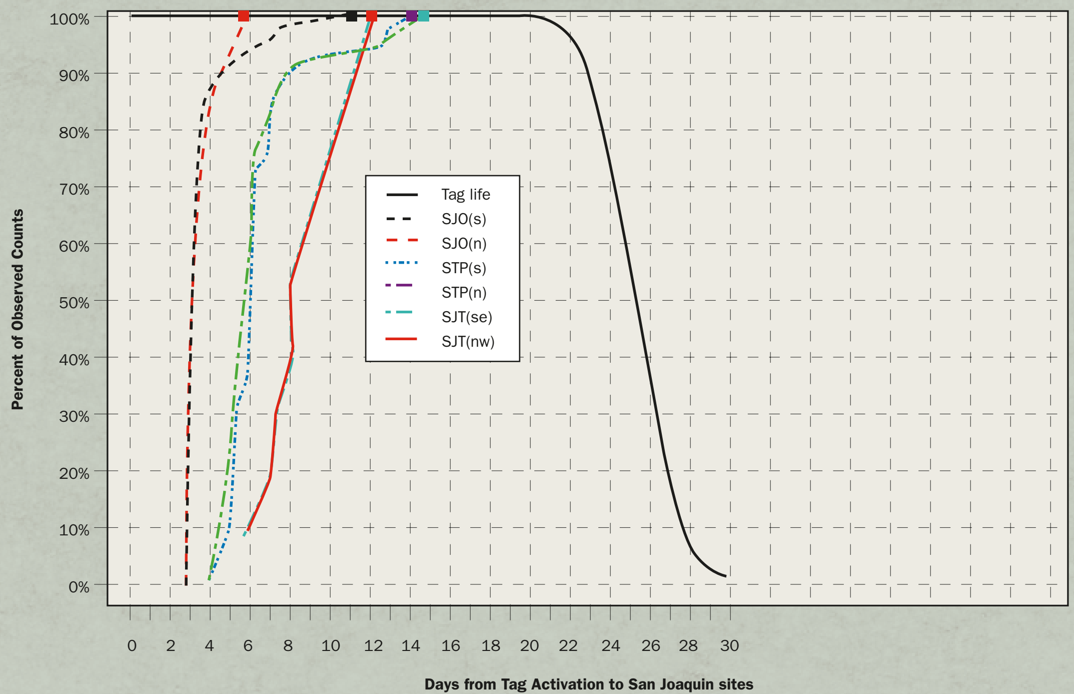


Figure 5-10

Three-parameter Weibull Survivorship Curve for Tag Life and the Timing of Downstream Detections of Acoustic-tagged Chinook Salmon Smolts at Receivers Located at the Exit Points of the Old River Route During the 2009 VAMP Study.

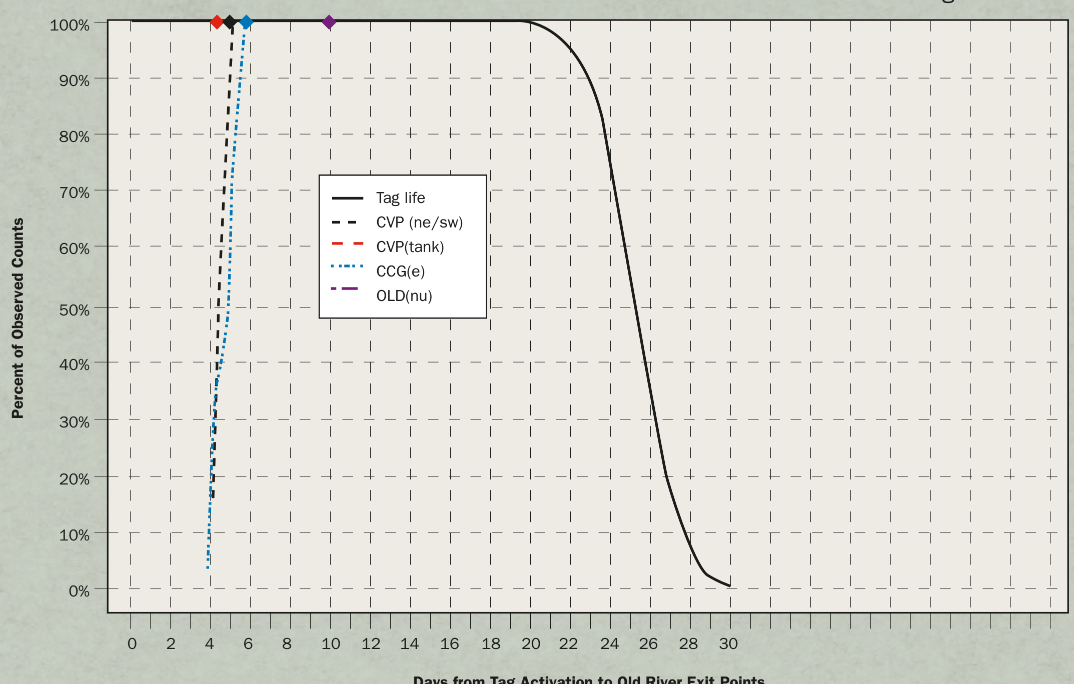


Table 5-7
Number of Tags Observed at Each Detection Site in 2009 and Used in the Survival Analysis, With and Without Predator-type Detections.
(Detections were pooled across release groups 1 and 2, and across groups 3 – 6. Numbers in parentheses represent detections removed from analysis because of data gaps during the bulk of fish passage past the receiver)

		Without Predator-Type Detections				With Predator-Type Detections			
Release Group		1 – 2	3 – 6	7	Total	1 – 2	3 – 6	7	Total
Number Released		267	533	133	933	267	533	133	933
Total Number Detected		158	247	63	468	178	369	103	650
		Without Predator-Type Detections				**With Predator-Type Detections**			
Detection Site	Site Code	1 – 2	3 – 6	7	Total	1 – 2	3 – 6	7	Total
Mossdale	SJO(s)	(3)	245	63	311	(13)	367	103	483
Lathrop	SJO(n)	57	102	(14)	173	50	140	(30)	220
Stockton USGS Gauge	STP(s)	26	66	10	102	26	107	24	157
Stockton Navy Bridge	STP(n)	23	52	8	83	26	101	21	148
Shipping Channel Marker 18	SJT(se)	1	7	0	8	2	14	0	16
Shipping Channel Marker 16	SJT(nw)	1	7	0	8	2	10	0	12
Turner Cut North East	TRN(ne)	0	0	0	0	0	1	0	1
Turner Cut Resort	TRN(sw)	0	0	0	0	0	1	0	1
Old River East	OLD(e)	100	91	(1)	192	117	163	(4)	284
Head of Middle River	OM(fs)	72	76	19	167	104	154	38	296
Central Valley Project Trash Rack	CVP(ne), CVP(sw)	3	0	3	6	34	50	19	103
Central Valley Project Holding Tank	CVP(tank)	0	0	1	1	6	9	4	19
Clifton Court Forebay Access Channel	CCG(e)	15	8	0	27	24	50	5	79
Clifton Court Forebay Radial Gates	CCG(w)	0	0	0	0	16	27	3	46
Old River North upstream	OLD(nu)	70	1	0	71	6	5	1	12
Old River North downstream	OLD(nd)	0	0	0	0	4	2	1	7
Middle River North upstream	MID(nu)	0	0	0	0	0	0	0	0
Middle River North downstream	MID(nd)	0	0	0	0	0	0	0	0

Survival and Route Entrainment Probabilities

Analysis of the Anscombe residuals from the multinomial likelihood model found little evidence of overdispersion in the model with unique survival, route entrainment, and detection parameters across release strata (model M2) for the data set that excluded the predator-type detections. Both models that assumed common survival and route entrainment parameters across release strata (models M0 and M1) showed evidence of overdispersion, indicated by Anscombe residuals that were larger than expected (e.g., greater than 1.96). Models M0, M1, and M2 had AIC values of 287.30, 291.06, and 271.83, respectively. Based on the AIC comparisons and the observed overdispersion among the models M0 and M1, model M2 was selected for parameter estimation. Based on model M2, unique survival, route entrainment, and detection probability estimates for each release stratum are reported, as well as population-level estimates that are weighted averages of the stratum-specific estimates. Estimates are provided for the derived performance metrics including route-specific survival and total survival both with and without predator-type detections (Table 5-8, Table 5-9). Additionally, estimates of the basic model parameters are provided both with and without the predator-type detections (Appendix D: Table D-2, Table D-3). Results without predator-type detections were based on Approach 4 to removing predator detections (i.e., remove all detections from the first predator-type detection onward). Results using Approach 5 were very similar, and are not shown.

Total salmon smolt survival through the study area was estimated to be $\hat{S}_{Total}$ = 0.06 (SE=0.01), based on release groups 3 – 7 (Table 5-8), with a 95% confidence interval of (0.04, 0.09). Estimated survival from Mossdale through the San Joaquin River route was $\hat{S}_A$ = 0.05 (SE=0.02), with a 95% confidence interval of (0.02, 0.10), while estimated survival from Mossdale through the Old River route was $\hat{S}_B$ = 0.08 (*SE* =0.02), with a

95% confidence interval of (0.04, 0.13) (Table 5-8). Both estimates of route-specific survival were available only for release groups 3 – 6 because of missing data for the other release groups.

It is important to note that the estimated survival in the Old River route ($\hat{S}_B$) includes survival to the receivers that marked the entries of the water export facilities, but does not include survival into the holding tanks or salvage facilities at these sites. No fish classified as salmon smolts were detected on the interior receivers at the Clifton Court Forebay (CCG(w)), and only one tag classified as a salmon smolt was detected in the holding tank at the Central Valley Project (CVP(tank); Table 5-7). Thus, survival in the Old River route to the interior Clifton Court Forebay receivers or to the Central Valley Project holding tank is even lower than 0.08. Likewise, the total survival through the study area ($\hat{S}_{Total}$) does not include survival through the Central Valley Project or past the radial gates at the Clifton Court Forebay.

The route entrainment probabilities at the junction of Old River with the San Joaquin River were estimated at $\hat{\psi}_A = 0.47$ (*SE* =0.03) for the San Joaquin River (95% confidence interval = (0.42, 0.52)), and $\hat{\psi}_B = 0.53$ (*SE* =0.03) for Old River (95% confidence interval = (0.48, 0.58); Table 5-8). The route entrainment probabilities were estimated for release groups 1 – 6. The first two release groups showed many more fish entering the Old River than the later groups, with the Old River route entrainment probability estimated at 0.64 (*SE*=0.04) for groups 1 and 2, and at 0.48 (*SE*=0.04) for groups 3 – 6 (Table 5-8). No estimates of the route entrainment probabilities were available for group 7.

In addition to fitting the survival model to the data that represented only salmon smolts, we also fit the model to the full set of detection data, without removing the "predator-type" detections. The resulting estimates are biased for salmon survival, and should not be used for management purposes. However, the model results from the full data set, including detections from both salmon and predators, may be used to determine how much bias is likely in the survival estimates if the effect of predation on the study fish is ignored. These estimates are provided for comparison purposes only, and should not be used for inference to juvenile salmon migrating through the Delta.

When all detections were used in the survival model, including those detections with a "predator-type" signal, total survival through the study area was estimated to be $\hat{S}_{Total} = 0.34$ (*SE*=0.03), with a 95% confidence interval of (0.29, 0.57) (Table 5-9). This estimate of survival was much higher than the estimate from only the smolt-type detections (Table 5-8), indicating that ignoring the predation problem may yield strong positive biases in overall salmon survival estimates. Estimated route-specific survival through the San Joaquin River route was very similar whether the predator-type detections were used or not ($\hat{S}_A = 0.05$ without predator-type detections [Table 5-8], vs. $\hat{S}_A = 0.10$ with predator-type detections [Table 5-9]). However, route-specific survival through the Old River route depended heavily on whether or not predator-type detections were included in the analysis, with an estimate of $\hat{S}_B = 0.08$ without predator-type detections (Table 5-8) and an estimate of $\hat{S}_B = 0.58$ with predator-type detections (Table 5-9). This is because the majority of the tags detected at either the Clifton Court Forebay or the Central Valley Project were classified as being in predators at the time of detection (Table 5-7). On the other hand, the route entrainment probability estimates were very similar both with and without the predator-type detections, with $\hat{\psi}_A = 0.47$ and $\hat{\psi}_B = 0.53$ without the predator-type detections (Table 5-8), and $\hat{\psi}_A = 0.41$ and = $\hat{\psi}_B$ 0.59 with the predator-type detections (Table 5-9). Thus, the primary effect of including the predator-type detections was in the estimates of survival through the Old River route, and consequently through the entire study area. Using predator-type detections to estimate survival through these areas is likely to overestimate salmon survival, and should be avoided.

Travel Time

For tags classified as being in salmon smolts, average travel time through the reaches ranged from 0.23 days (*SE*=0.02) from the east Old River receiver (OLD(e)) to the head of Middle River (OM(fs)), to 2.29 days (*SE*=0.12) from Lathrop (SJO(n)) to Stockton USGS gage (STP(s)) (Table 5-10). Similar patterns were seen when predator-type detections were included. The exception was for travel times between the head of Middle River and the water projects. The average travel time between the head of Middle River and Clifton Court Forebay access channel was 1.02 days (*SE*=0.08) without predator-type detections, and 2.04 days (*SE*=0.28) with predator-type detections. The average travel time from the head of Middle River to the Central Valley Project trash rack was 1.03 days (*SE*=0.20) without the predator-type detections, and 1.75 days (*SE*=0.10) with the predator-type detections (Table 5-10). In general, tagged fish that were classified as predators took longer to reach the water projects than tagged fish assumed to be salmon smolts.

Mobile Telemetry

Mobile telemetry has been described as a useful technique to complement fixed-station telemetry for interpreting fish behavior and confirming fish mortality between fixed stations (Vogel 2008). Additionally,

Table 5-8
Performance Metric Estimates (standard error in parentheses) with 95% Profile Likelihood Confidence Intervals (CI) for Tagged Juvenile Chinook Salmon Released at Durham Ferry in the 2009 VAMP, Omitting the Predator-type Detections. (Population-level estimates are weighted averages of the release group estimates)

Parameter	Release Groups 1 – 2		Release Groups 3 – 6		Release Group 7		Population	
	Estimate (SE)	95% CI	Estimate (SE)	95% CI	Estimate (SE)	95% CI	Estimate (SE)	95% CI
SA			0.05 (0.02)	0.02, 0.10			0.05 (0.02)	0.02, 0.10
SB			0.08 (0.02)	0.04, 0.13			0.08 (0.02)	0.04, 0.13
ψA	0.36 (0.04)	0.29, 0.44	0.52 (0.04)	0.45, 0.59			0.47 (0.03)	0.42, 0.52
ψB	0.64 (0.04)	0.56, 0.71	0.48 (0.04)	0.41, 0.55			0.53 (0.03)	0.48, 0.58
STotal			0.06 (0.02)	0.04, 0.10	0.05 (0.03)	0.01, 0.12	0.06 (0.01)	0.04, 0.09

Table 5-9
Performance Metric Estimates (standard error in parentheses) with 95% Profile Likelihood Confidence Intervals (CI) for Tagged Juvenile Chinook Salmon Released at Durham Ferry in the 2009 VAMP, Including the Predator-type Detections. (Population-level estimates are weighted averages of the release group estimates)

Parameter	Release Groups 1 – 2		Release Groups 3 – 6		Release Group 7		Population	
	Estimate (SE)	95% CI	Estimate (SE)	95% CI	Estimate (SE)	95% CI	Estimate (SE)	95% CI
SA			0.10 (0.02)	0.06, 0.15			0.10 (0.02)	0.06, 0.15
SB			0.58 (0.06)	0.50, 1.13			0.58 (0.06)	0.50, 1.13
ψA	0.30 (0.04)	0.23, 0.37	0.46 (0.03)	0.41, 0.52			0.41 (0.02)	0.36, 0.45
ψB	0.70 (0.04)	0.63, 0.77	0.54 (0.03)	0.48, 0.59			0.59 (0.02)	0.55, 0.64
STotal			0.36 (0.03)	0.30, 0.66	0.24 (0.04)	0.17, 0.33	0.34 (0.03)	0.29, 0.57

Table 5-10
Average Travel Time in Days of Acoustic-tagged Juvenile Chinook Salmon Smolts Through the San Joaquin River Delta During the 2009 VAMP Study. (Average travel time is arithmetic mean)

Reach		Without Predator –Type Detections			With Predator –Type Detections		
Upstream Boundary	Downstream Boundary	N	Travel Time	SE	N	Travel Time	SE
Durham Ferry	Mossdale (SJO(s))	311	0.96	0.05	438	1.07	0.05
Mossdale (SJO(s))	Lathrop (SJO(n))	115	0.25	0.03	169	0.29	0.03
Lathrop (SJO(n))	Stockton USGS Gauge (STP(s))	95	2.29	0.12	145	2.51	0.12
Stockton USGS Gauge (STP(s))	Stockton Navy Bridge (STP(n))	79	0.44	0.13	143	0.42	0.06
Stockton Navy Bridge (STP(n))	Shipping Channel Marker 18 (SJT(se))	8	2.15	0.52	16	2.37	0.30
Mossdale (SJO(s))	Old River East (OLD(e))	93	0.37	0.04	168	0.51	0.06
Old River East (OLD(e))	Head of Middle River (OM(fs))	142	0.23	0.02	253	0.27	0.02
Head of Middle River (OM(fs))	Old River North upstream (OLD(nu))	1	2.26	NA	12	2.35	0.58
	Clifton Court Forebay Access Channel (CCG(e))	23	1.02	0.08	79	2.04	0.28
	Central Valley Project trash rack (CVP(ne), CVP(sw))	6	1.03	0.20	103	1.75	0.10

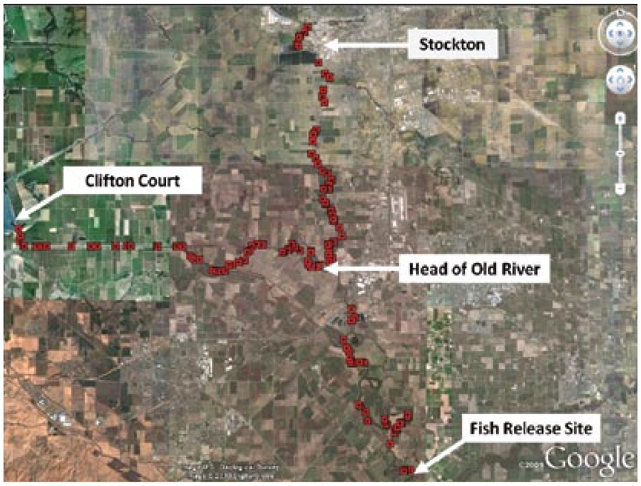
Vogel (2010), discusses the benefits of mobile telemetry because it pinpoints locations where motionless transmitters accumulate and provides an indication of where high mortality of juvenile salmon may have occurred. As a caveat, however, this technique cannot precisely determine where the mortality occurred, only where the motionless transmitter was located. For example, a predator could consume an acoustic-tagged salmon, swim to another location, and then defecate the tag. In addition, motionless tags are only found in areas where mobile telemetry is occurring or if the tag is defecated near a fixed station receiver.

During the VAMP study, mobile telemetry surveys were used to determine where fish may have been lost in reaches between the fixed receiver stations. Mobile surveys found a total of 173 acoustic tags believed to be dead acoustic-tagged salmon or tags defecated by predatory fish in the reaches surveyed (Figure 5-11) (approximately 19% of the fish released at Durham Ferry). The 173 acoustic tags do not represent all of the tags lost during the 2009 VAMP study as the mobile surveys did not provide complete coverage of all of the Delta channels during these surveys nor did they provide complete continuous coverage of the channels surveyed. In addition, Vogel, (2010) notes that if a tag was defecated and the transmitter settled into the riverbed in silt or in a location where the acoustic signals were muffled, the mobile telemetry surveys would not have detected those tag codes. There are three sites where high juvenile salmon mortality is suspected: at the deep scour hole near the head of Old River, near a railroad bridge in Stockton, and in front of the Tracy FF trash racks (Vogel 2007b and Vogel, 2010).

Forty-seven transmitters were found in the reach surveyed between Durham Ferry and Mossdale. The reach between Durham Ferry and Mossdale was not surveyed frequently enough to ascertain if tags were present for extended periods. Relatively high numbers of transmitters were found downstream of the release site long after release suggesting that some fish may have died shortly after release from unknown causes. Possible causes could have been predation, latent mortality from fish tagging/transport, or indirect effects of tagging/transport causing salmon to be more prone to predation (Vogel, 2010).

Vogel (2010) describes the survey of the downstream San Joaquin River as follows: "Fifty-seven transmitters were found in the reach between the head of Old River and the Stockton Deep Water Ship Channel. Some areas where relatively high numbers of transmitters were located tended to be in the vicinity of channel bends/scour holes and near pump stations. There was no occurrence of large numbers of transmitters found near the Stockton Waste Water Treatment Plant as was the case during the 2007 VAMP study (Vogel 2007b). Unlike prior years' surveys, only one tag was located in the scour hole just downstream of the head of Old River, but mobile telemetry coverage in the area was infrequent during the study. Although substantial predatory fish activity and acoustic-tagged salmon (or the transmitters) inside predators was believed to occur in this area, the results suggest that predatory fish did not reside in the scour hole for sufficient periods to defecate tags at the site or that defecated tags escaped detection by settling into the riverbed. Based on presumed predators frequently passing the receivers placed in Old River [Old(e)] and the San Joaquin River at the Lathrop gage [SJO(n)], it is likely predators defecated the tags elsewhere."

Figure 5-11
Location of 173 Acoustic Tags Detected During the 2009 VAMP Study Believed to be Dead Acoustic-tagged Salmon or Tags Defecated by Predatory Fish. Specific Tag Locations are Approximate and Represent the General Vicinity of the Tag (Vogel, 2010).



Vogel, (2010) also describes the survey in Old River "Sixty-nine transmitters were found in the reach between the head of Old River and the south Delta water export facilities. There were occurrences of tags located in the sinuous portion of Old River near channel bends as noted in the reaches surveyed in the San Joaquin River. In the relatively featureless, straight Grant Line Canal, there were no obvious habitat features suggesting why tags were found in most locations. If the Canal served primarily as a migratory route for predatory fish, the tags may have simply been defecated from predators moving from one location to another. However, five transmitters were located near one of the south Delta barriers just east of the South Tracy Boulevard bridge suggesting predation on salmon at that location."

Predatory Fish Tagging

Although sample sizes were limited because low numbers of fish were tagged by NRS (mostly not until well into the study period), some data were obtained

Figure 5-12
Movements of an Acoustic-tagged Striped Bass Released in Front of the Tracy Fish Facilities Trash Rack and Later Detected Behind the Clifton Court Forebay Gates (Vogel, 2010).

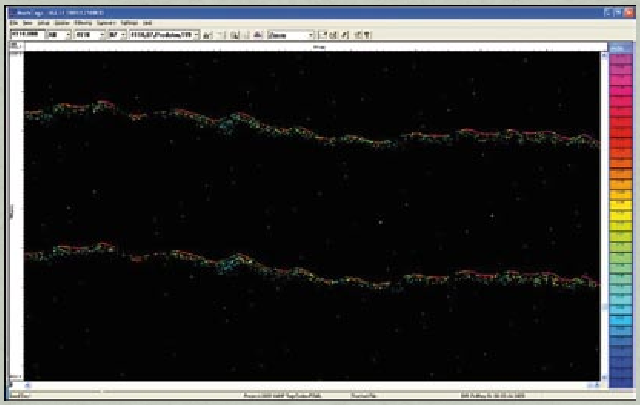


Figure 5-13
Movements of a 460-mm FL Striped Bass Tagged with Transmitter 4138.07 near Dos Reis on the Lower San Joaquin River. Nearly Two Weeks after Release, the Bass Was Detected Passing Two Downstream Receivers Positioned in Stockton Just Upstream of the Deep Water Ship Channel (Vogel, 2010).

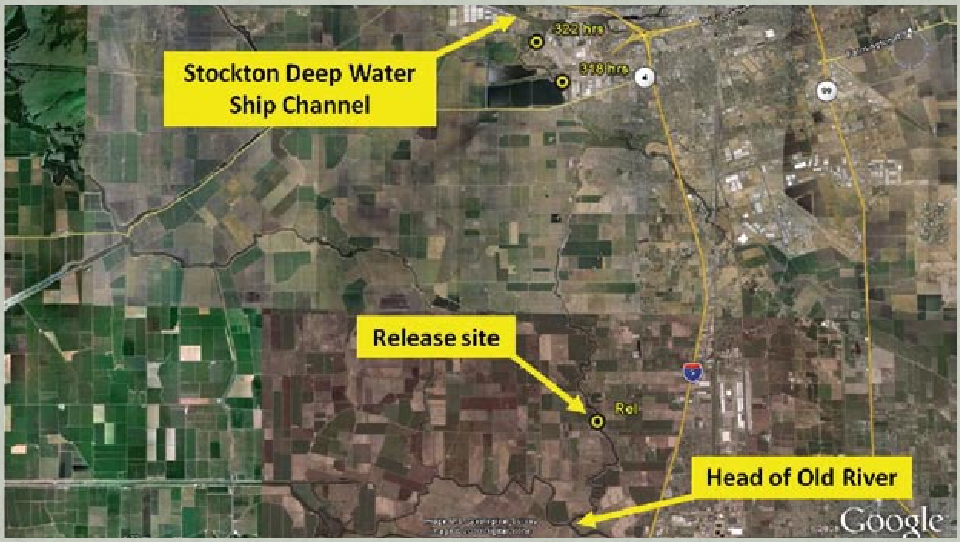


Figure 5-14
Movements of a 370-mm FL Striped Bass Tagged with Transmitter 4054.07 near Burns Cut on the Lower San Joaquin River. The Bass Was Detected in the General Vicinity of Release after More Than Two Weeks Then Subsequently Swam Upstream and Entered Old River; Last Detected Moving West in Old River Passing the Middle River Flow Split (Vogel, 2010).

for those tagged predators within detection range of the VAMP receivers. For example, Figure 5-12 shows the movements of a striped bass tagged and released near the Tracy Fish Facilities, but subsequently detected by the hydrophone positioned behind the gate inside Clifton Court Forebay. These movements depict the code 3 display as described in Vogel 2010. However, Vogel, (2010) also felt that there were instances where the predatory fish movements (based on graphical post-processing displays) looked very similar to movements of salmon smolts.

Vogel (2010) frequently observed acoustic-tagged predators moving against the local flow conditions, but also observed the predators moving with the flow. Because of the small sample size and the late tagging of predators by NRS no definitive conclusions based on comparisons between known predator movements and assumed acoustic-tagged salmon movements could be made. Figures 5-13 and 5-14 show some of the complex range of predator movements during the 2009 VAMP study.

Vogel (2010) reported that there were several examples of striped bass moving long distances through the Delta (both downstream and upstream) during the VAMP study. In contrast, Vogel, (2010) also reported that other tagged striped bass lingered in the general vicinity of their release location. Vogel (2010) also reported that during the VAMP study, striped bass frequently moved back and forth with the flow and migrated throughout the telemetry array, in some instances, similar to that expected for salmon smolts. These complex circumstances significantly affect how juvenile salmon telemetry data can be interpreted.

Comparison with Past Years

San Joaquin River Salmon Protection

One of the objectives of VAMP is to improve conditions to increase the survival of juvenile Chinook salmon smolts produced in the San Joaquin River tributaries during their downstream migration through the lower river and Delta. It is hypothesized that these actions to improve conditions for the juveniles will translate into greater adult abundance and escapement in future years than would otherwise occur without the actions.

To determine if VAMP has been successful in targeting the migration period of naturally produced juvenile salmon, catches of unmarked salmon in the Kodiak trawl at Mossdale and in salvage at the CVP and SWP facilities were compared prior to, during, and after the VAMP period.

Unmarked and Marked Salmon Captured at Mossdale

The general time period for VAMP of about mid-April to mid-May was chosen based on historical data that indicated a high percentage of the salmon smolts emigrating from the San Joaquin tributaries passed into the Delta at Mossdale during that time. The 2009 VAMP period was April 19th - May 19th and trawl sampling at Mossdale was conducted three days/week January 5th – March 30th; five days per week April 1st – June 5th; and three days per week during the remainder of June. Densities (catch per 10,000 cubic meters) of unmarked juvenile salmon captured at Mossdale during January through June are shown in Figure 5-15. Unmarked salmon do not have an adipose clip or any other external mark (i.e., Panjet or Bismark brown) and can be juveniles from natural spawning or unmarked hatchery fish from the MRH. However, no adipose fin clipped salmon were released from MRH during 2009 and all unmarked hatchery fish were released in the San Joaquin River at Jersey Point, 43.9 miles downstream of Mossdale. There were three acoustic-tagged salmon from VAMP study releases that were caught at Mossdale and measured on April 23rd (Fig. 5-16). A total of ten other acoustic-tagged salmon were caught from April 27th – May 14th, but were not measured.

A peak density of unmarked juvenile salmon at Mossdale occurred on May 6th and 7th immediately following a major storm event (Figure 5-15). That was a time of increasing flows in the Tuolumne and Merced rivers and following a peak flow in the Stanislaus River (tributary flows are shown in Figure 6-1). Densities may have been as high or higher on days when no sampling was conducted (i.e., sampling was only conducted 5 days/week in April-May). The size of the juvenile salmon captured in the Mossdale trawl during January through June is shown in Figure 5-16.

Salmon Salvage and Losses at Delta Export Pumps

Fish salvage operations at the CVP and SWP export facilities capture juvenile salmon and transport them by tanker truck to release sites in the north Sacramento-San Joaquin Delta away from the pumps. The untagged salmon are potentially from any source in the Central Valley. It is not certain which unmarked salmon recovered are of San Joaquin basin origin, although the timing of salvage and fish size can be compared with Mossdale trawl data and recovery data for tagged smolts at the salvage facilities to provide some general indication as to the extent of overlap.

The estimated salmon losses at the CVP and SWP are based on expanded salvage and an estimate of screen efficiency and survival through the facility and salvage

process. Recent studies suggest that screen efficiencies at the CVP louvers may be less than the current values used to calculate salvage and loss. As a result, the proportion of fish salvaged may be overestimated while those lost to the system may be underestimated. The CVP pumps divert directly from the Old River channel and direct losses using the current screening efficiencies are estimated to range from about 50 to 80% of the number salvaged. Four to five salmon are estimated to be lost per salvaged salmon at the SWP because of high predation rates in Clifton Court Forebay. The SWP losses are therefore about six to eight times higher, per salvaged salmon, than for the CVP. The loss estimates do not include any indirect mortality in the Delta due to water export operations or additional mortality associated with post-release predation.

Density of salmon encountering each of the export and fish salvage facilities off Old River is represented by the combined salvage and loss estimated per acre-foot of water pumped. The DFG and DWR maintain a database of daily, weekly, and monthly salvage data. The number and density of juvenile salmon that migrated through the system, the placement of the HORB, and the amount of water pumped by each facility are some of the factors that influence the number of juvenile salmon salvaged and lost. Density is an indicator of when concentrations of juvenile salmon may be more susceptible to the export facilities and salvage system. Additionally, salvage efficiency is lower for smaller-sized salmon (fry and parr), so their salvage numbers and estimated losses are underrepresented.

A review of weekly data for January through June indicates that salvage and losses started to increase in late March at CVP and in mid-April at SWP and remained elevated through mid-May (Figure 5-17 and Figure 5-18). Salmon densities based on combined salvage and loss estimates were also highest during much of the typical VAMP period at the CVP and SWP (Figure 5-19); the peak at both facilities occurred during late April. The combined exports in the first half of 2009 exceeded the flow at Vernalis prior to mid-April and in late June and roughly equaled Vernalis flow from mid-April to mid-Jun (Figure 5-20). As in other years, substantial numbers for salmon salvage and losses were observed outside of the VAMP period.

The size and timing distribution of unmarked salmon in the Mossdale trawl (Figure 5-16) during January through June generally overlaps with the distribution of those salvaged at the fish facilities (Figure 5-21, Source: S. Greene, DWR). Based on comparisons with Mossdale data, it appears that many salmon salvaged from late March to late May period could have been from the San Joaquin basin (Figure 5-15).

These results show that the primary 2009 San Joaquin River salmon smolt migration period from late March to mid-late May coincided with the higher salvage period of the CVP/SWP facilities and started about three weeks prior to the behavioral barrier operation. Sampling frequency at Mossdale was more limited than in many recent years, so production estimates at Mossdale could be improved by ensuring that sampling is conducted daily when most salmon smolts are emigrating.

Figure 5-15
Average Daily Densities of Unmarked Juvenile Chinook Salmon Caught in the Mossdale Kodiak Trawl in 2009 on the San Joaquin River.

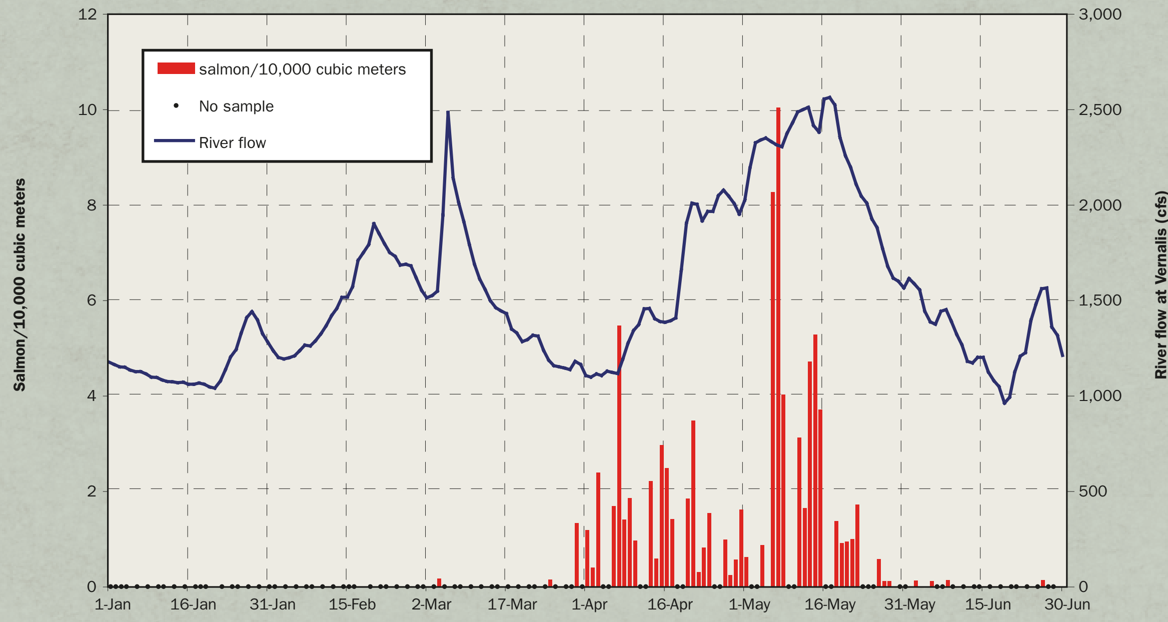


Figure 5-16
Individual Daily Forklengths of Juvenile Chinook Salmon from the Mossdale Kodiak Trawl on the San Joaquin River, January through June 2009.

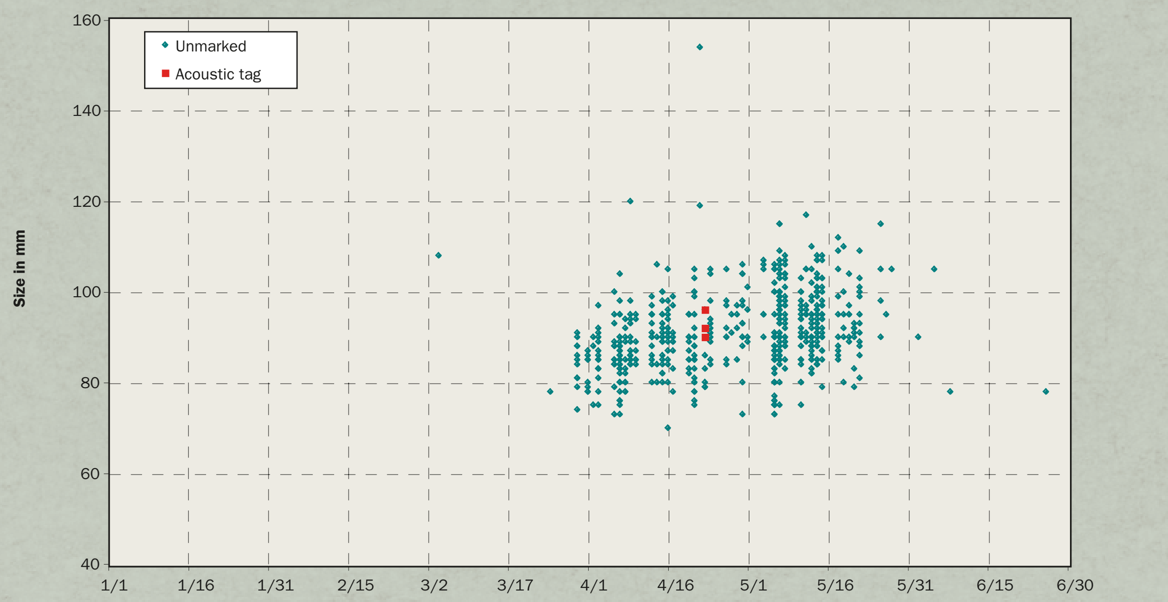


Figure 5-17
2009 Central Valley Project (CVP) Estimated Juvenile Chinook Salmon Salvage and Loss.

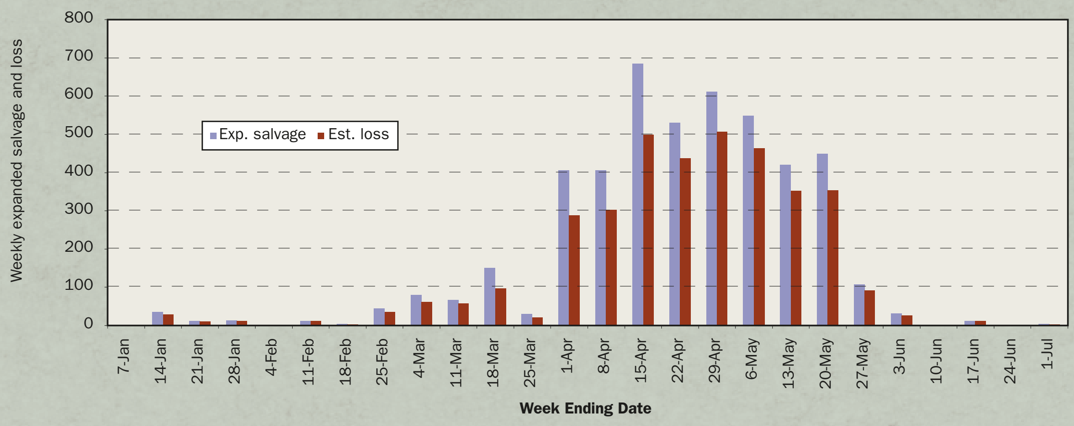


Figure 5-18
2009 State Water Project (SWP) Estimated Juvenile Chinook Salmon Salvage and Loss.

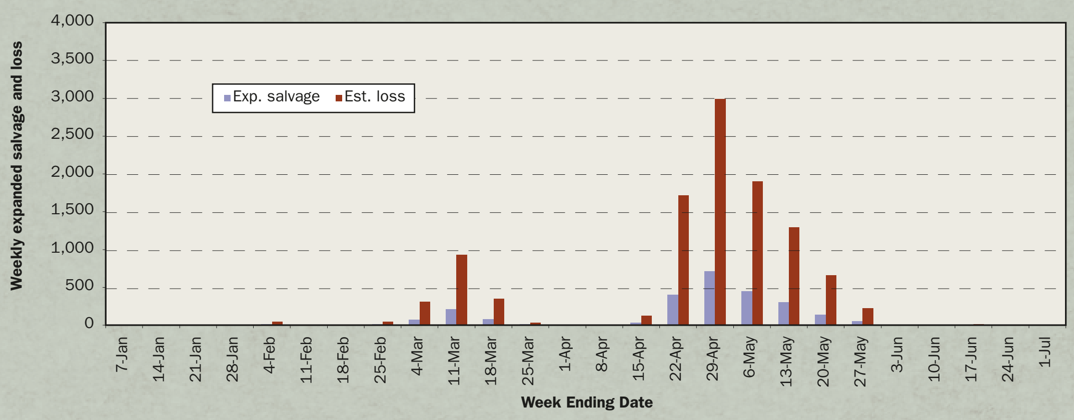


Figure 5-19

2009 State Water Project (SWP) & Central Valley Project (CVP) Combined Juvenile Chinook Salmon Salvage and Loss Density per 1,000 Acre Feet of Export.

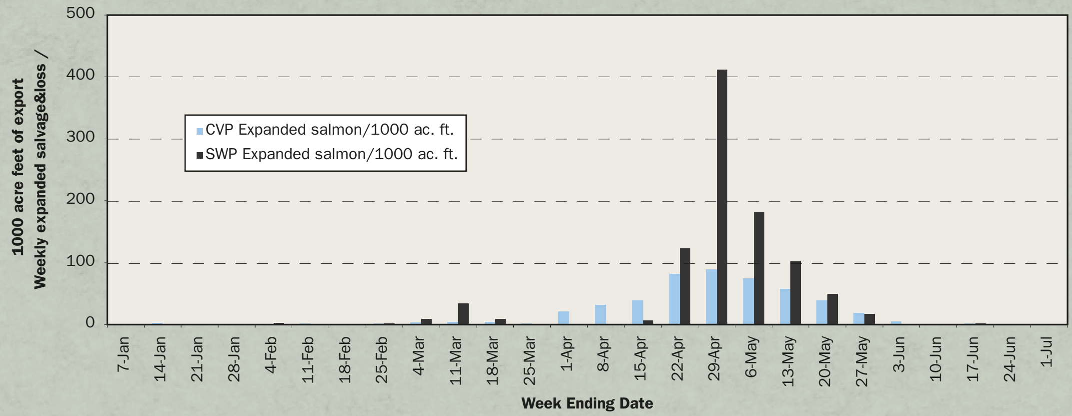


Figure 5-20

2009 Weekly Average Export Rates from the State Water Project (SWP) & Central Valley Project (CVP) and Vernalis Flow in Cubic Feet per Second (cfs).

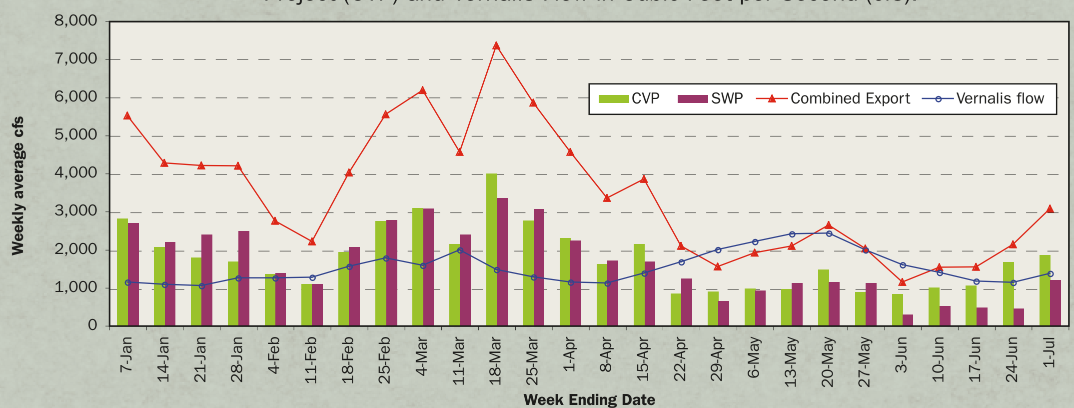
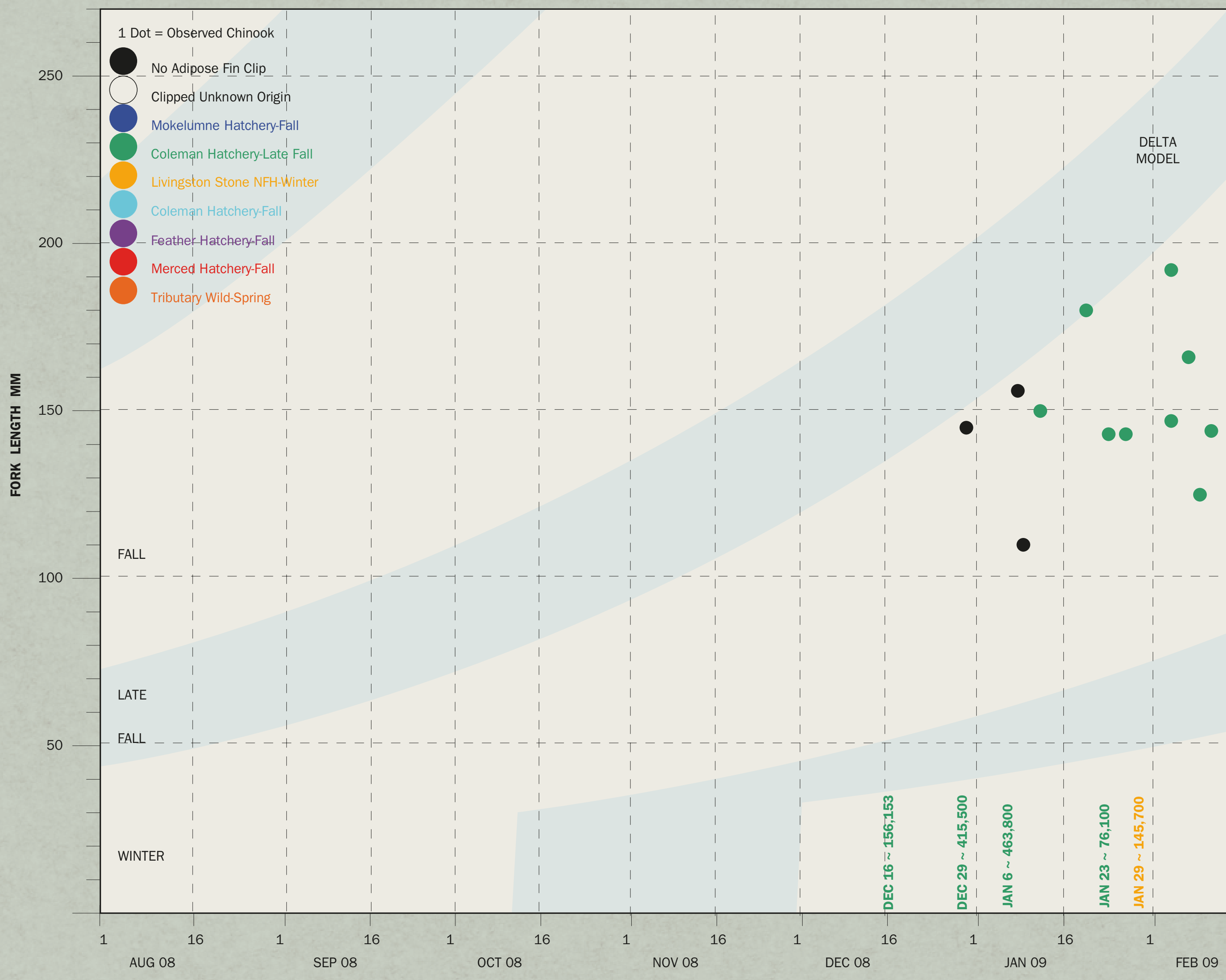
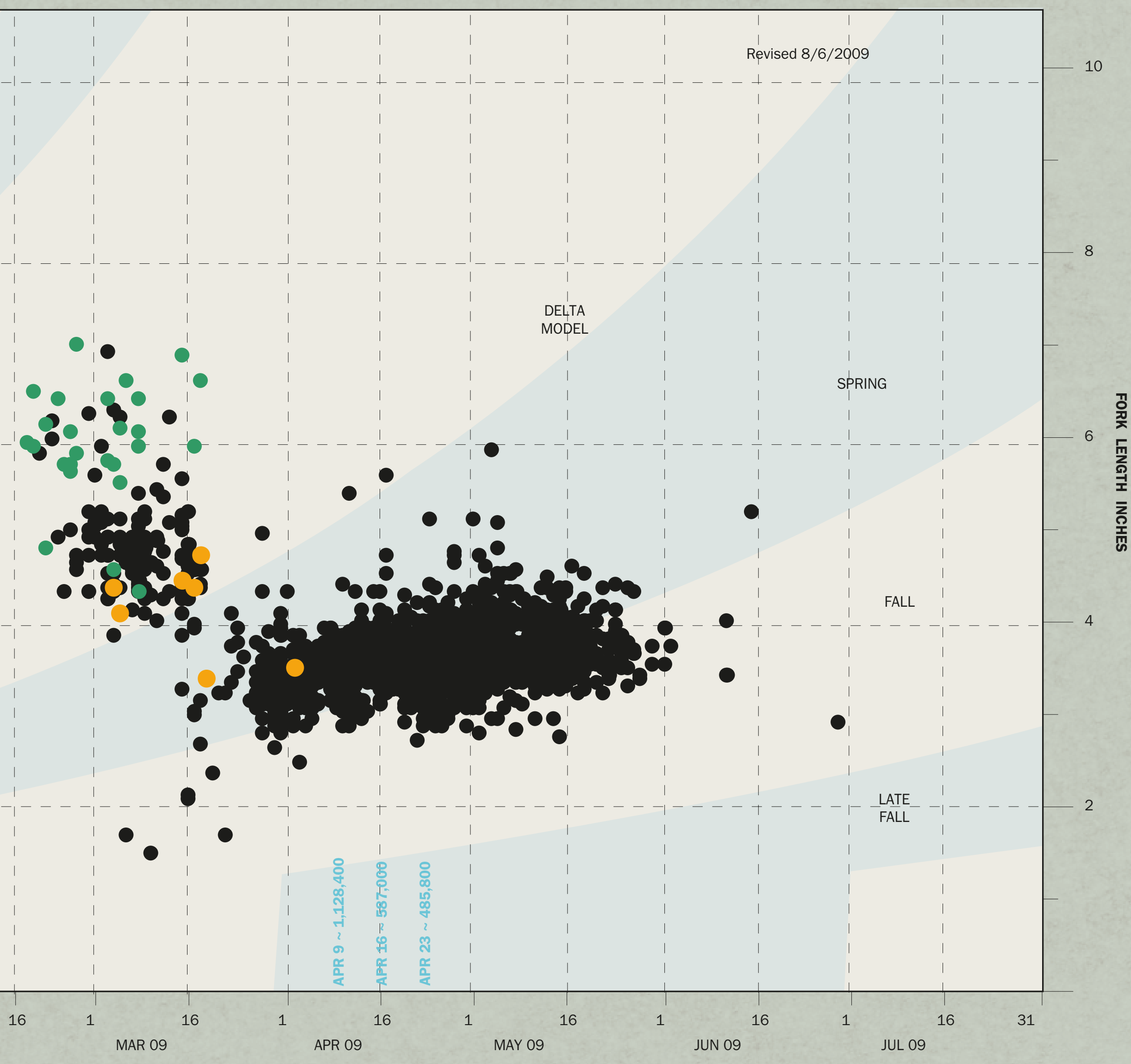


Figure 5-21
Observed Juvenile Chinook Salmon Salvage at the State Water Project (SWP) & Central Valley Project (CVP) Delta Fish Facilities from 8/1/2008 Through 7/31/2009. (Source: S. Greene, DWR)




Revised 8/6/2009
DELTA
MODEL
SPRING
FALL
LATE
FALL
APR 9 ~ 1,128,400
APR 16 ~ 587,000
APR 23 ~ 485,800
10
8
6
4
2
FORK LENGTH INCHES
16
1
16
1
16
1
16
1
16
1
16
31
MAR 09
APR 09
MAY 09
JUN 09
JUL 09

CHAPTER 6

COMPLIMENTARY STUDIES RELATED TO THE VAMP

Throughout 2009 several fishery studies were conducted to advance the understanding of juvenile salmon abundance and survival in the San Joaquin River Basin. Following are summary reports of the information developed in several of those studies. Any opinions and conclusions presented in this chapter are solely of the author(s) and are not necesarily the views of any of the VAMP Partners.

Review of Juvenile Salmon Data from the San Joaquin River Tributaries to the South Delta during January through June, 2009

Contributed by Tim Ford, Turlock and Modesto Irrigation Districts, and Chrissy Sonke, FISHBIO Environmental

The VAMP includes protective measures for San Joaquin River (SJR) smolts during an approximate 31-day period in April and May, and evaluations are conducted annually to determine how those measures (i.e., river flow, exports, and HORB) relate to delta survival. However, juvenile salmon from the spawning areas of the Stanislaus, Tuolumne, and Merced rivers (referred to here as tributaries) can migrate to the SJR and delta over a longer season that may range from January to June. Their migration and rearing patterns vary among tributaries and among years in response to flow releases, runoff events, turbidity, and other factors.

During 2009, rotary screw trapping was conducted near the confluences of the Stanislaus, Tuolumne, and Merced Rivers with the SJR. Seining was also conducted in the SJR from below the head of Old River (HOR) to upstream of the Tuolumne River confluence. This review presents data from those rotary screw traps (RST) and seining to identify the presence and movement of juvenile salmon from the tributaries into the mainstream San Joaquin River relative to observations at the Mossdale Trawl and in CVP and SWP salvage facilities. Salmon were assigned to life stage category based on a forklength scale, where <50 mm= fry, 50-69 mm= parr, and ≥ 70 mm= smolt.

Stanislaus River RST monitoring was conducted at River Mile (RM) 9 (Caswell site) between Jan 13th and June 25th; Tuolumne River RST monitoring was conducted at RM 5 (Grayson site) between Jan 8th and June 11th; and Merced River RST monitoring was conducted at RM 2 (Hatfield site) only between March 30th and May 29th. Weekly seining during Jan – June was done up to 8 sites from RM 51 (Dos Reis) to RM 83 (downstream of the Tuolumne River confluence) and biweekly seining was conducted at RM 78 and RM 90 from mid-Jan through late May. Trawling was conducted in the San Joaquin River at Mossdale near RM 54 (downstream of the three eastside tributaries, and immediately upstream of the Head of Old River) with a schedule of three days/week between Jan 5th to Mar 30th; five days per week between Apr 1st and June 5th; and three days per week during the remainder of June. Basin flow patterns, rainfall, turbidity and water temperatures are shown in Figures 6-1, 6-2 and 6-3.

Overall, Chinook outmigrant abundance in 2009 was extremely low in the San Joaquin Basin, consistent with the low number of adults that returned to spawn during fall 2008. A combined total of 1,582 juvenile Chinook salmon were captured in the RSTs (n=933) and in the Mossdale trawl (n=649). These were mainly the progeny of an estimated 1,777 spawners in the San Joaquin Basin; none were caught in the seine sampling. The escapement to the San Joaquin Basin in 2008 was a 49% increase over estimated escapement of 1,192 in 2007, which was the lowest estimate since 1992. A few relatively large juveniles in the tributary and Mossdale catch indicate some fall-run yearling outmigrants from the 2007 run or from other than fall-run timing. Fry catch was low at the RST monitoring sites, the Mossdale trawl, and the CVP and SWP salvage facilities, suggesting few fry migrated out of the tributaries during 2009.

Figure 6-1
San Joaquin River Basin Rainfall at Don Pedro Reservoir and Flow on the Stanislaus, Tuolumne, Merced and San Joaquin Rivers for Jan – June, 2009

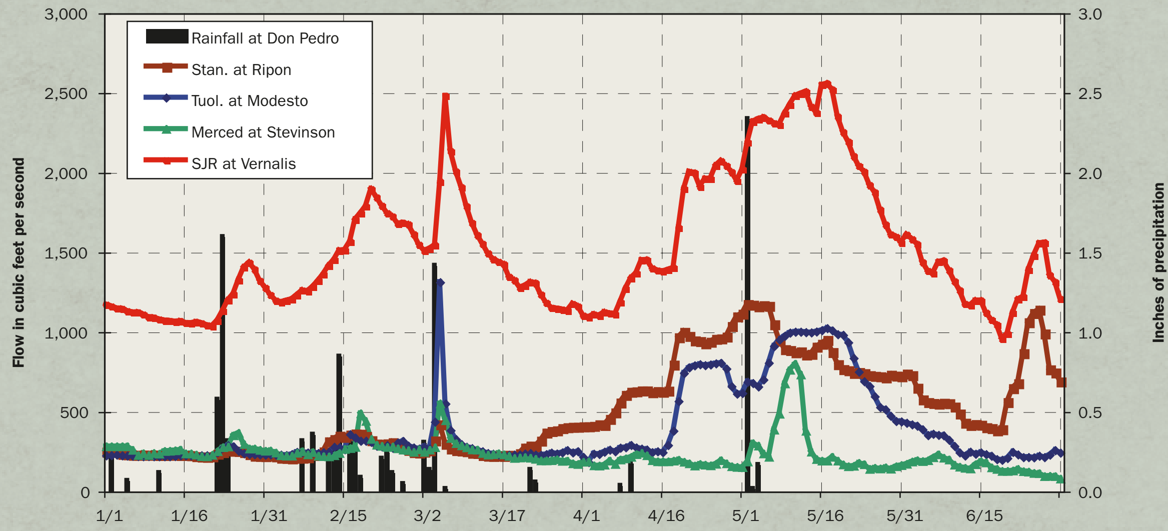


Figure 6-2
Turbidity Levels for the San Joaquin River (Daily Averages) and the Stanislaus, Tuolumne and Merced Rivers (Tributary data are instantaneous readings at the lower rotary crew trap locations) for Jan – June 2009

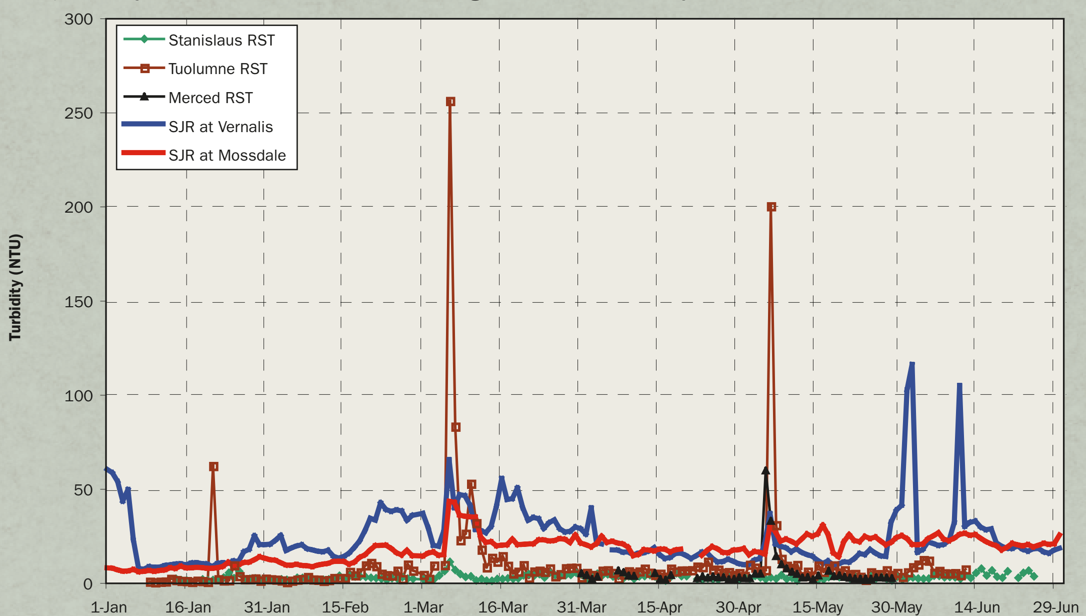


Figure 6-3
Water Temperatures (F°) for the San Joaquin River and the Stanislaus, Tuolumne and Merced Rivers for Jan – June 2009

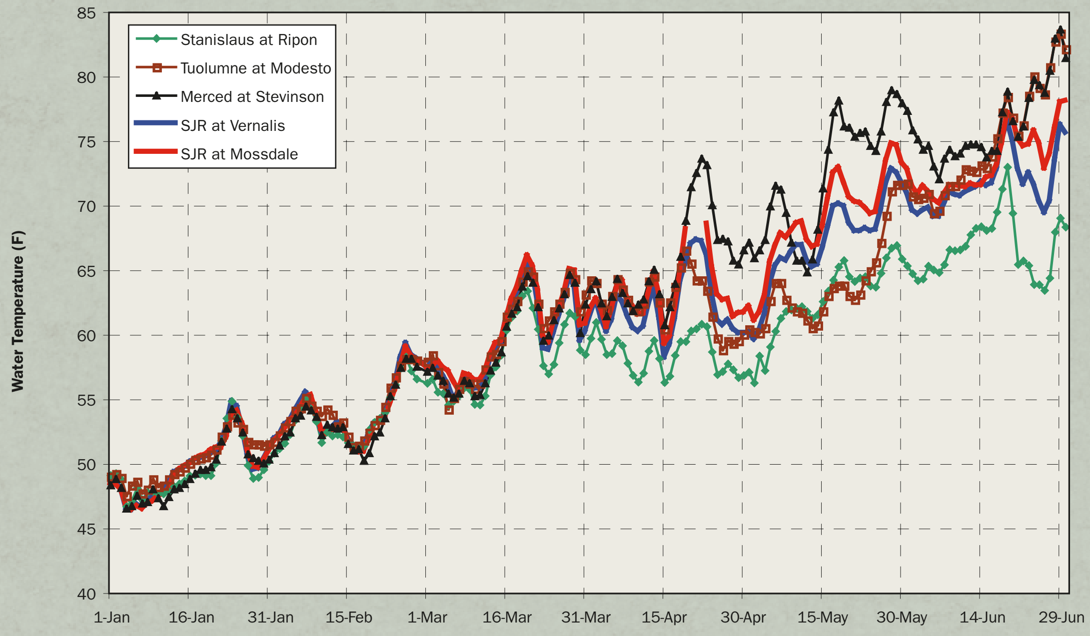
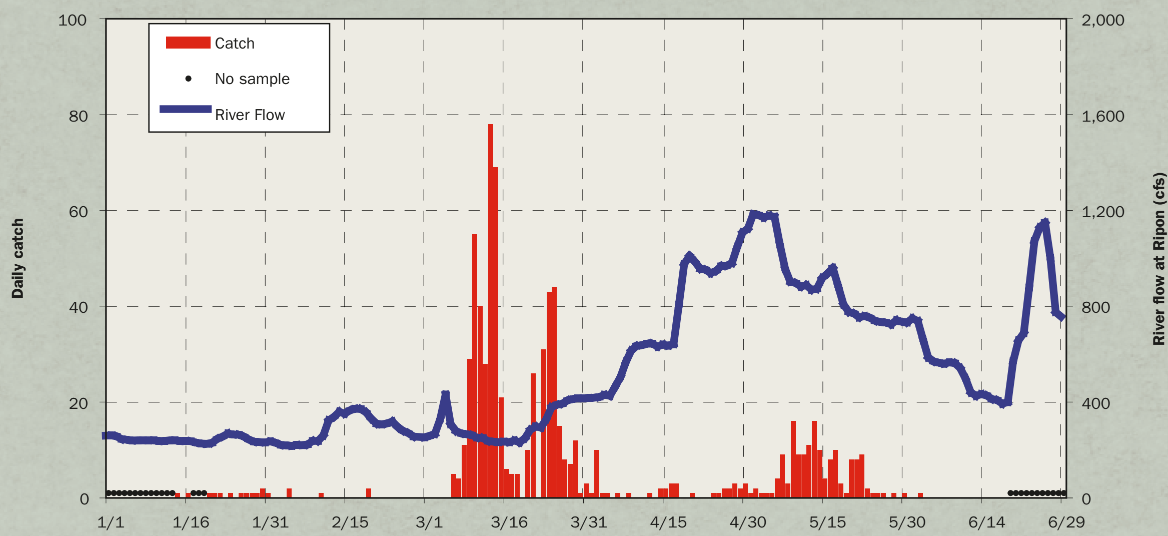


Figure 6-4
Stanislaus River Screw Trap Catch of Unmarked Juvenile Chinook Salmon for Jan – Jun 2009 as Compared with River Flow at Ripon



The seasonal peak catch of parr/smolt in the Stanislaus River RST (Figure 6-4) occurred on Mar 13th and may have been a delayed response to a rain event that occurred from Mar 1st to 5th. Catch began increasing on Mar 8th and was elevated for a 10-day period following the rain event. Another peak was observed on Mar 25th following a rain event on Mar 21st and 22nd. Neither of these peaks was detected at Mossdale indicating that juveniles may have remained in the lower San Joaquin River above Mossdale and/or that they passed Mossdale undetected due to infrequent sampling. Seasonal peak catch of parr/smolt on the Tuolumne River was observed on May 5th (Figure 6-5) and was subsequently detected at Mossdale (Figure 6-7) during May 6th – 8th; this peak was preceded by a major storm event during the spring pulse flow on the Tuolumne. The Merced River RST (Figure 6-6) sampling suggests that very few parr/smolts migrated out of the Merced River during 2009 (total catch =11). Very low catches of juvenile salmon were observed by mid-May in the Tuolumne, and by the end of May in the Stanislaus River and at Mossdale.

Average size of salmon captured in the RSTs and Mossdale trawl (Figure 6-8) shows that most fish observed prior to early March averaged <50 mm fork length (FL). In contrast, average size in the salvage prior to late March shows that most fish were substantially larger than those emigrating from the San Joaquin Basin. Although salvage operations are relatively less effective at capture of fry, the absence of fry in the salvage combined with low abundance of fry observed at upstream monitoring locations suggests that few fry of San Joaquin Basin origin were entrained by the pumps during 2009. It appears that salvage during January through March was dominated by larger fish of other races originating from the Sacramento Basin - average size at all locations typically increased by early April to >70 mm FL (Figure 6-8).

To obtain more useful information on salmon movement into the Delta, daily monitoring at the lower end of each of the three San Joaquin tributaries and at Mossdale for the entire season (roughly January through June) is a high priority. Further evaluation of the trawl and salvage efficiency on smaller juvenile salmon is necessary. These data would help to refine existing protective measures for fry to smolts, if warranted, and to identify alternative strategies that may protect a larger proportion of the juvenile salmon population migrating from the San Joaquin tributaries.

2009 Mossdale Trawl Summary

Contributed by Jennifer O'Brien
California Department of Fish and Game

Introduction

The California Department of Fish and Game has been monitoring the San Joaquin River drainage fall-run Chinook salmon (*Oncorhynchus tshasytsxha*) smolt out-migrant population since 1988. Monitoring is conducted two miles downstream of Mossdale Landing County Park (RM 56) to just upstream of the Old River confluence (Figure 6-9). This essential measurement of timing and production for out-migrating fall-run Chinook salmon smolts has been performed at this location to:

1) Determine annual salmon smolt production in the San Joaquin Basin.
2) Develop smolt production trend information.
3) Determine the timing and magnitude of smolt out-migration into the Delta from the San Joaquin tributaries.
4) Document the occurrences of other species including listed species such as steelhead (*Oncorhynchus mykiss*) and Delta Smelt (*Hypomesus transpacificus*).

Methods

Sampling is performed with a 6 x 25 foot (1.87m x 7.6m) Kodiak trawl net. The Kodiak trawl uses two boats to pull a net equipped with spreader bars, wings, and a "belly" in the throat of the net (to improve capture vulnerability). The cod end of the trawl net is secured using a rope. The sampling intensity was five days a week from March 30th to June 5th, and three days a week from June 8th to June 29th. The entire sampling period was from March 30th to June 29th with a total of 65 sample days out of the study period of 92 days. All trawling occurred during daylight hours, generally starting between 0800 and 0900 hours. Each sampling day consisted of 10 tows at 20 minutes per tow. Sampling was also conducted three days per week from July to March by the USFWS Stockton office.

All fish were identified to species and enumerated. The first 30 per tow of all species, except Chinook salmon, were also measured. Chinook salmon were checked for dye mark. All non-marked Chinook salmon were considered "natural" for the purpose of this study. All Chinook salmon were measured (fork length, mm).

Water temperature, turbidity, weather, and beginning tow time were recorded for each tow. Velocity was recorded by using a digital flow meter model 2030R that

Figure 6-5
Tuolumne River Screw Trap Catch of Unmarked Juvenile Chinook Salmon for Jan – Jun 2009 as Compared with River Flow at Modesto

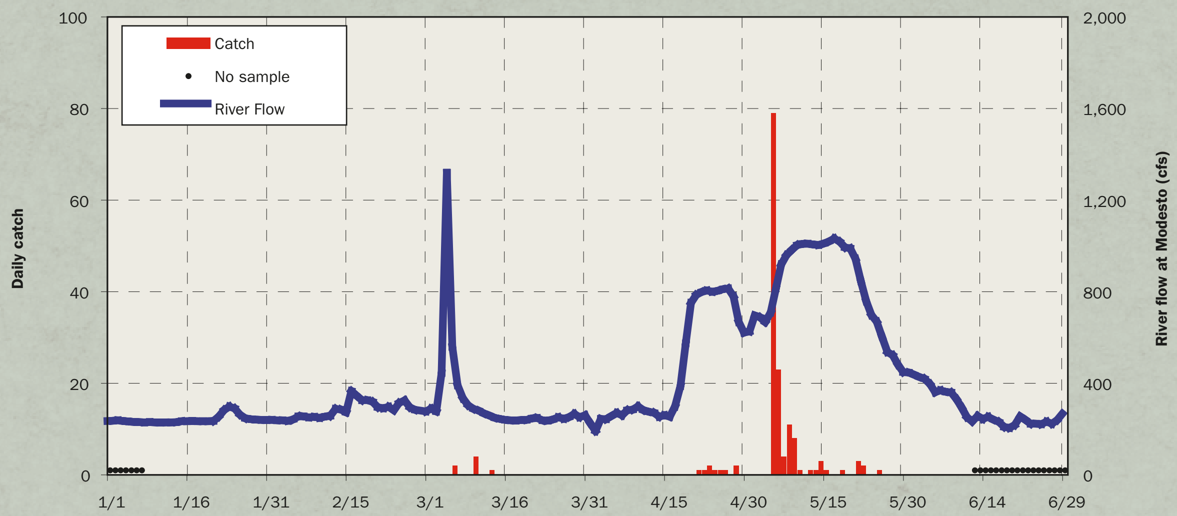
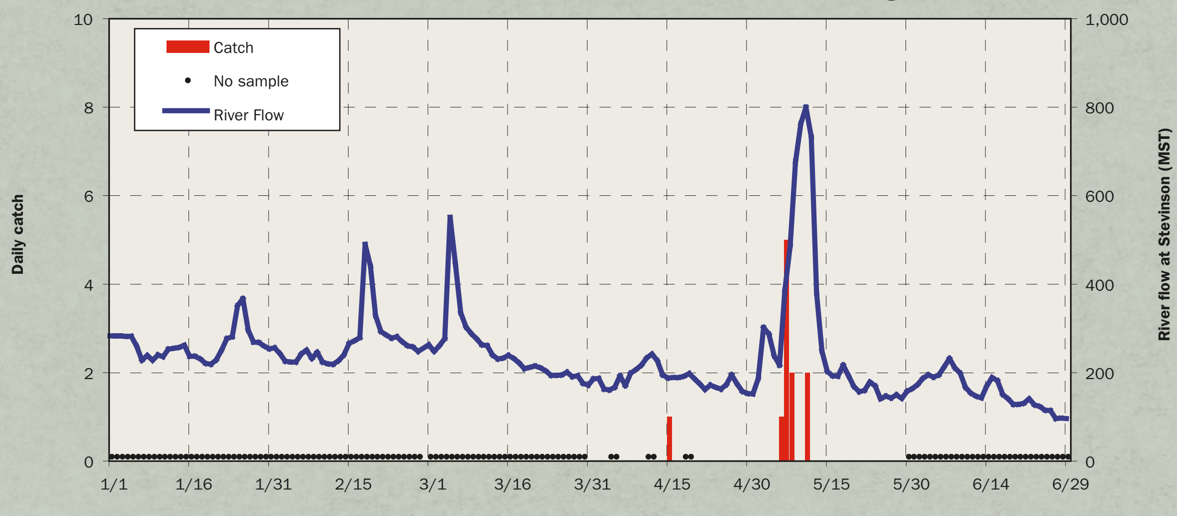


Figure 6-6
Merced River Screw Trap Catch of Unmarked Juvenile Chinook Salmon for Jan – Jun 2009 as Compared with River Flow at the Stevinson Gage (MST)



is made by General Oceanics Inc. A Garmin GPS Map 172c was used to map the location of all sampling tows. The mean daily river flow data that is used in this report was taken from the U.S. Geological Survey mean daily stream flow gauge at Vernalis (VNS) (See Figure 2-1 inside the front cover).

Analysis

Smolt Production Index Calculation (Smolt/ac-ft Method):

The 2009 natural smolt production from the San Joaquin River drainage was estimated by two different methods. The first method, smolt production index calculation (smolt/ac-ft method) involves taking the actual number of non-marked Chinook salmon and dividing by the actual volume sampled to get Chinook/ac-ft. This number is then expanded by the daily mean flow recorded at Vernalis for a 5-hour index and expanded again for a 24-hour daily estimate. These daily average smolt densities are then expanded by multiplying by the daily mean flow recorded at Vernalis. Production for days not sampled within the study period was estimated by averaging smolt/ac-ft for the two days before and two days after the non-sampled period.

The natural smolt index estimates (E_I) are calculated as follow:

$$E_I = \sum_{i=1}^{n=92}\left[\left(\frac{C_i}{V_{Ti}}\right)\left(V_{Pi}\right)\left(\frac{24}{5}\right)\right]$$

Where:

E_I = Smolt Production Index Estimation

n = days in the index period

C = daily non-marked Chinook catch

V_T = daily volume of trawl sampled

V_P = daily 5-hour volume of water passing Mossdale

i = ith Day

The 95% confidence interval around this index was calculated as +1.96 x the Standard Deviation of the mean smolt density (smolt/ac-ft) in the trawl catch over the 92 days.

Vulnerability Expansion Calculation (Multiple Years Regression Vulnerability Method):

The second estimate (regression vulnerability method), which the California Department of Fish and Game (DFG) believes to be a more accurate estimate, due to the uneven distribution of smolts in the channel, is determined based on the recapture rates of dye marked vulnerability release groups. Due to the low number of smolts produced at Merced River Hatchery (MRH), there was no vulnerability tests performed during the 2009 sampling period. Instead, vulnerability is estimated based on the natural logarithm of all vulnerability tests from previous years (1989-2008) (Figure 6-10). This number is then extrapolated out to a 5-hour index and a 24-hour seasonal estimate. Productions for days not sampled within the study period were estimated by averaging smolt catch and minutes towed for the 2 days before and 2 days after the non-sampled period.

$$E_V = \sum_{i+1}^{n=92}\left[\frac{\frac{C_i}{V_i}\left(60*24\right)}{T_i}\right]$$

Where:

n = Days in the index period

C = Daily non-marked Chinook catch

T = Minutes towed

i = ith Day

V = [Ln(F) x (-0.0102)] + 0.1098 (Figure 6-10); Daily Vulnerability Estimate

F = Mean daily flow at Vernalis

For the purpose of the analysis, vulnerability to the trawl was assumed from the beginning of the first tow detected to the end of the last tow detected on the day of release. Detection of marked fish subsequent to day of release was not used in the analysis (this was less than 5 fish total for all releases). Travel time (from release point to trawl), time vulnerable to the trawl, and the percent vulnerability as related to flow were determined for each test group.

Results

Between March 30th and June 29, 2009, 647 non-marked Chinook salmon smolts were captured in the Mossdale trawl. Daily capture of non-marked salmon ranged from 0 to 74 individuals with an average of 10 captured per day. Figure 6-11 shows the expanded daily catch of non-marked Chinook. The forklength of non-marked Chinook ranged between 70 and 154 mm. The average forklength for non-marked Chinook was 91.1 mm.

The smolt production estimate for the San Joaquin basin was 50,827 using the smolt production index estimation, and 199,973 using the vulnerability expansion estimation (Table 6-1). The vulnerability expansion estimation is thought to be more accurate than the smolt/ac-ft index method because it should account for an uneven distribution of migrating smolts in the river channel.

One Steelhead (*Oncorhynchus mykiss*) was captured and returned to the river during the 2009 sampling period.

Figure 6-7
Kodiak Trawl Catch of Unmarked Juvenile Salmon on the San Joaquin River near the Mossdale Bridge Gage for Jan – Jun 2009 as Compared with River Flow at the Vernalis Gage (VNS)

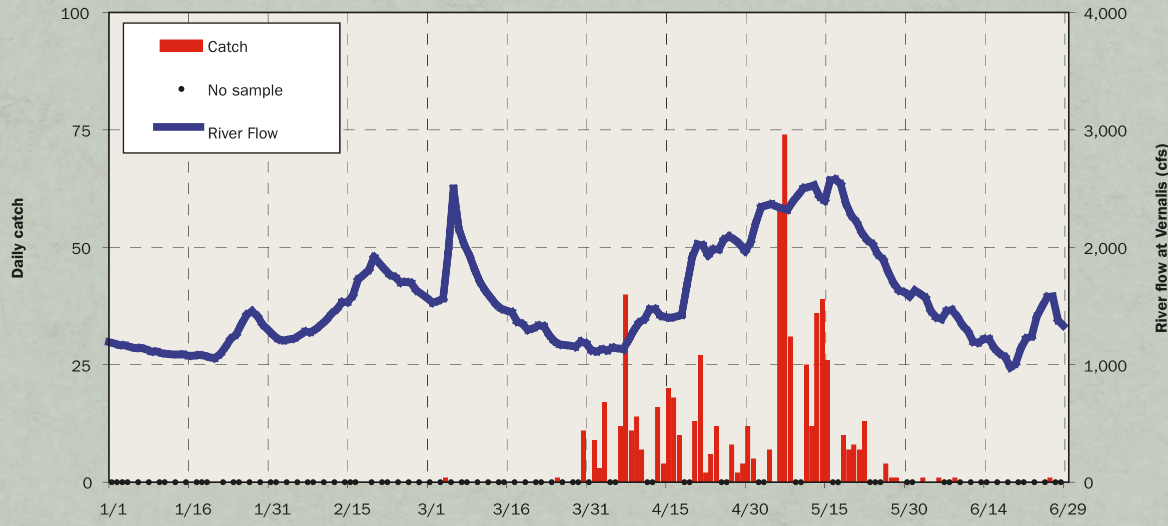


Figure 6-8
Daily Average Forklength of Unmarked Juvenile Chinook Salmon in the San Joaquin River Basin and Delta Pumping Facilities for Jan – Jun 2009

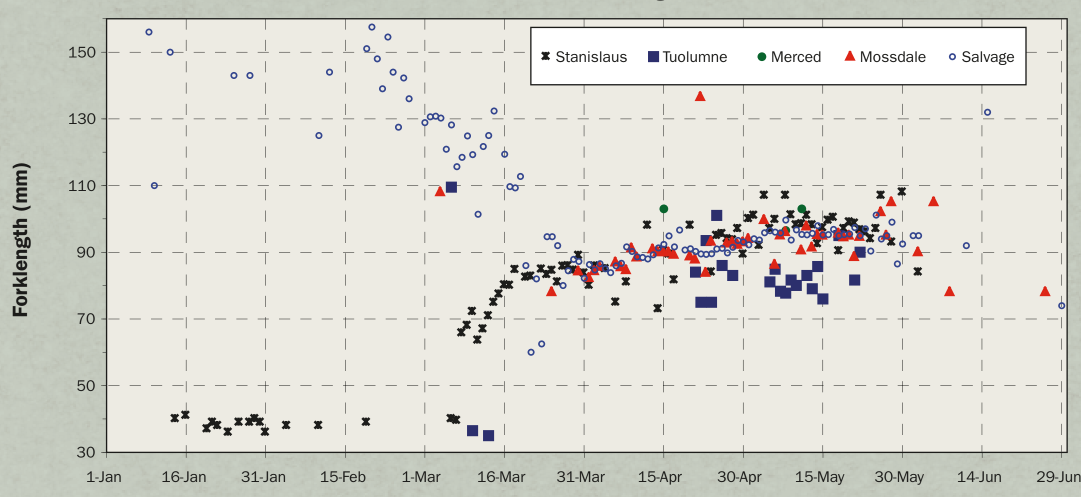


Table 6-1
Chinook Salmon Smolt Production Seasonal Estimates and Sampling Period for the Duration of the VAMP Study

Year	Sampling Period (Days)	Percentage of Days Sampled %	Smolt/ac-ft Estimate	Vulnerability Smolt Production Annually Population Ratio Method (95% confidence range)
2009	92	63	50,827+1,690	199,973****
2008	91	63.7	188,652 + 8,010	285,886 : (29,043 - 67,432)
2007	75	76	273,798 + 7,490	920,006***
2006	75	85.3	848,394 + 12,888	1,808,143 : (1,749,531- 1,866,755)
2005	89	80.9	363,800 + 14,700	621,403 : (388,884- 1,119,550)
2004	61	88.5	92,500 + 66,500	297,348 : (191,222- 665,160)
2003	88	80.7	107,500 + 60,300	368,424 : (277,626- 545,121)
2002	74	87.8	229,100 + 557,100	2,254,647 : (1,455,066- 5,179,591)
2001	103	78.6	279,800 + 286,000	928,996 : (586,790- 2,228,789)
2000	88	81.8	211,100 + 181,900	484,703**
1999	119	71.4	146,900 + 63,500	438,979**
1998	99	67.7	1,075,000 + 562,800	2,844,637**
1997	92	69.6	168,600 + 89,400	635,517**
1996	89	85.4	381,900 + 626,900	1,155,319**
1995	60	78.3	1,108,900 + 2,640,000	3,361,384**
1994	63	73	67,500 + 62,200	453,245**
1993	83	61.4	54,200 + 21,800	269,035**
1992	72	44.4	23,600 + 6,300	280,395**
1991	59	66.1	*	538,005**
1990	82	69.5	*	263,932**
1989	54	100	*	4,241,862**

* Data is currently being reevaluated.
** 1989-2000 estimates based on the natural log of all vulnerability tests (1989-2005).
*** 2007 estimates based on the natural log of all vulnerability tests (1989-2006)
**** 2009 estimates based on the natural log of all vulnerability tests (1989-2008)

The forklength of the single *O. mykiss* smolt measured 335 mm.

Health and Physiological Assessment of VAMP Release Groups

Contributed by Ken Nichols and J. Scott Foott, U. S. Fish and Wildlife Service, CA-NV Fish Health Center, 24411 Coleman Fish Hatchery Rd., Anderson, CA 96007 http://www.fws.gov/canvfhc/

Summary: In support of the 2009 VAMP survival and distribution studies, the California-Nevada Fish Health Center performed pathogen screening and bioassays. Infections with the parasite *Tetracapsuloides bryosalmonae* and bacteria in the *Aeromonas/Pseudomonas* complex were detected, but no signs of clinical disease were observed. Most of the fish had undergone or were in the process of smoltification. No differences were detected in survival, blood chemistry, or white blood cell counts. No significant tissue abnormalities were observed in histological sections of gill, kidney, or liver from all bioassay groups. The data indicates that the juvenile Chinook population used for the VAMP study was healthy, undergoing smoltification, and did not incurred overt impairment in 40 hour bioassays at either Durham Ferry or adjacent to the Stockton Wastewater Treatment Plant outfall.

Introduction

As a component of the 2009 Vernalis Adaptive Management Plan (VAMP) study on reach-specific survival and distribution of migrating Chinook salmon in the San Joaquin River and delta, the CA-NV Fish Health Center conducted a general pathogen screening and a bioassay to aid in evaluating fish performance. Pathogen screening during past VAMP studies has detected infection with the myxozoan parasite *Tetracapsuloides bryosalmonae* (causative agent of Proliferative Kidney Disease). This parasite has been shown to cause mortality in Merced River Hatchery salmon held until June (Foott, Stone and Nichols 2005). In the 2007 VAMP study, a significant number of acoustic tags from juvenile Chinook salmon were “motionless” in the San Joaquin River just upstream

Figure 6-9
Location Map of the Mossdale Trawl Area in the Lower San Joaquin River, 2009

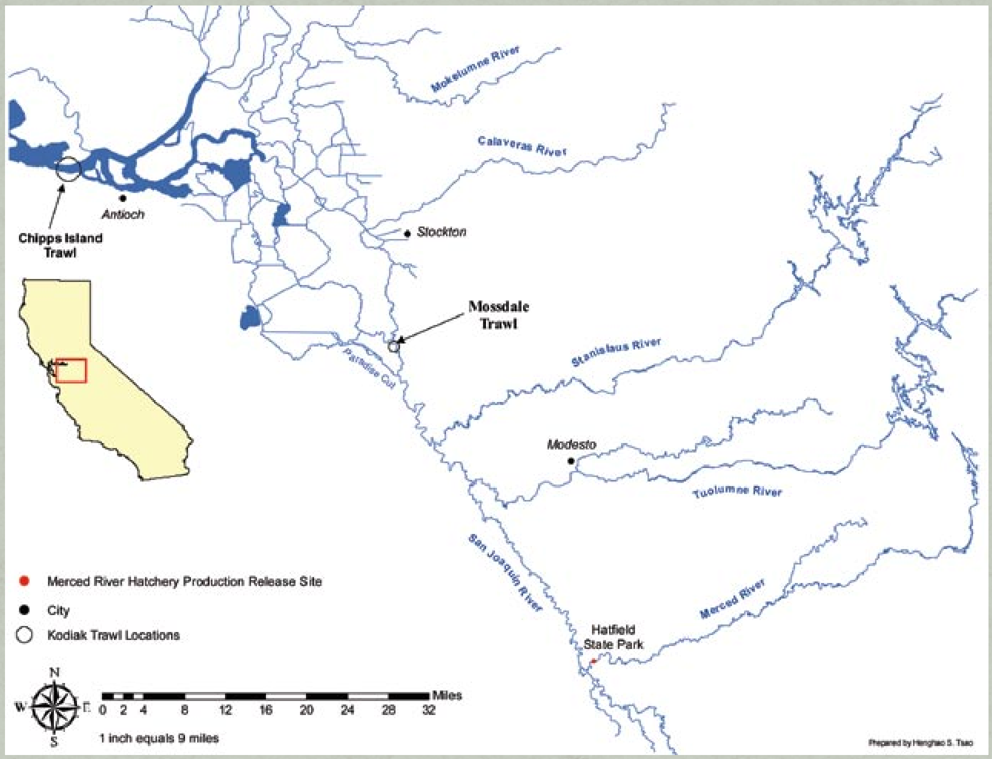


Figure 6-10
Natural Logarithm of Efficiency Tests 1989-2008 for San Joaquin River Flows at the Vernalis Gage in Cubic Feet per Second

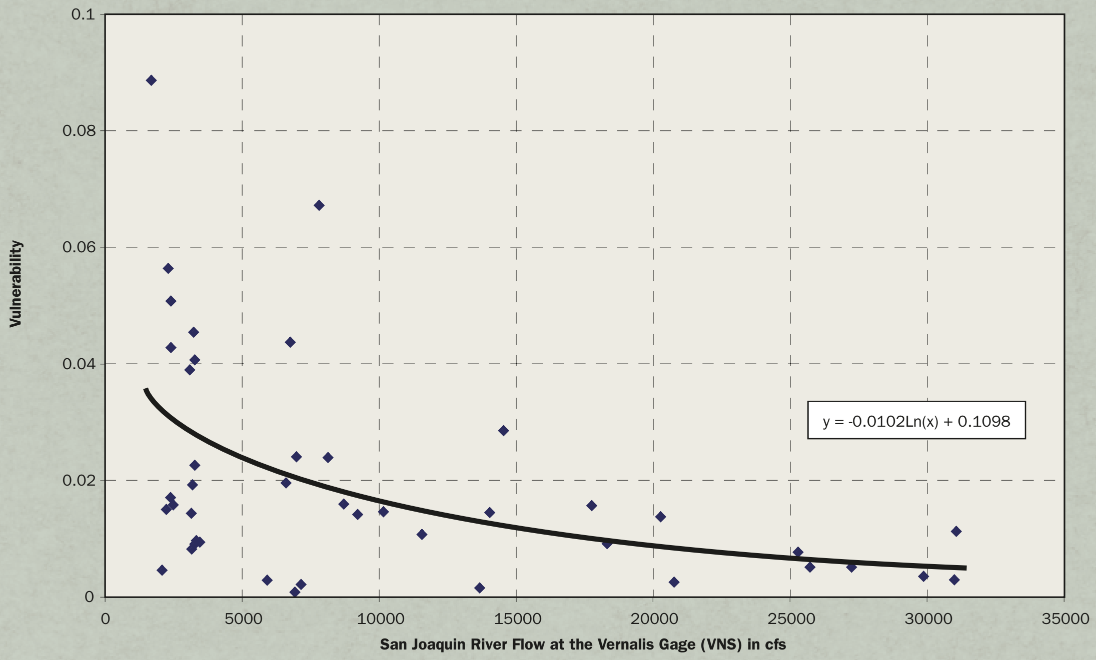


Figure 6-11
Expanded Daily Catch of Non-marked Chinook Salmon Based on Vulnerability Estimates and Flow in the San Joaquin River at the Vernalis Gage (VNS) for April – June, 2009

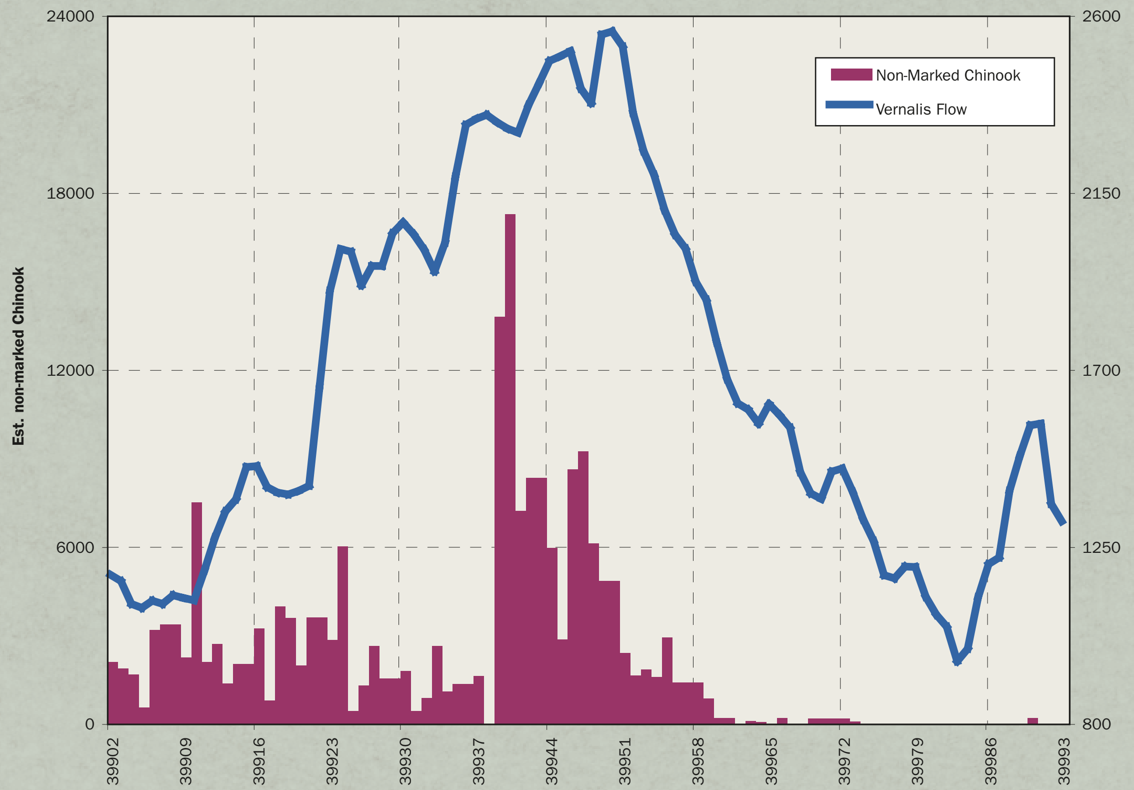
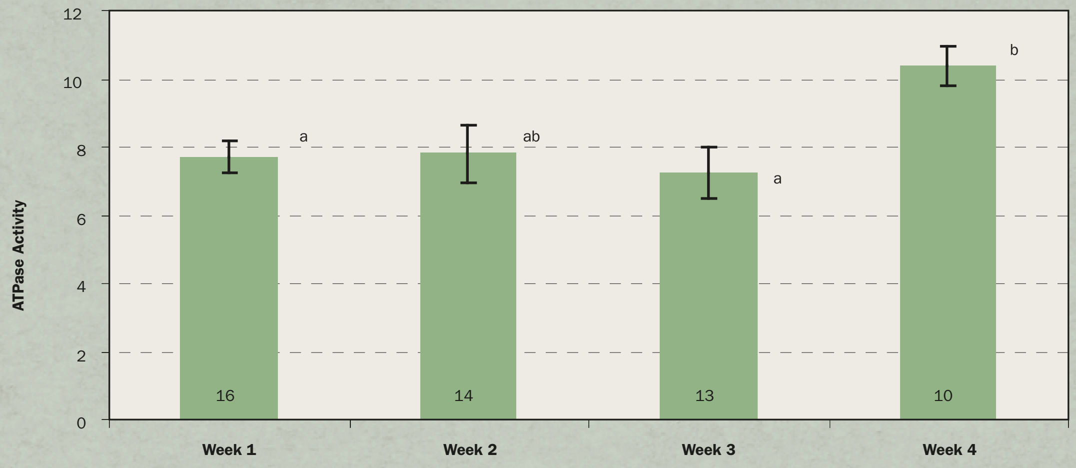


Figure 6-12
Gill Na^+, K^+-ATPase activities (μmol ADP/mg protein/hr) for cohorts of acoustic tagged Chinook salmon utilized in the 2009 VAMP study. Data presented as mean ± SE and sample number at base of each bar. Groups with letters in common are not statically different (P=0.021, ANOVA).



of the Stockton wastewater treatment facility (SJRGA 2008). The cause of the mortality was unknown, and it was recommended that the site be monitored to identify similar a mortality event during the 2009 study. The objectives of this project was: 1) survey the juvenile Chinook population used for the VAMP study for specific fish pathogens and smolt development (gill ATPase), and 2) determine if 40-hour bioassays in the San Joaquin River (SJR), at either the Durham Ferry (DF) release site or adjacent to the Stockton Wastewater Treatment Plant (WWTP) outfall, resulted in mortality, reduced white blood cell counts, or abnormalities in gill, kidney, or liver tissues.

Methods

Fish

Juvenile Chinook salmon used in this study were cohorts of acoustic tagged Chinook used in the 2009 VAMP survival and distribution studies. Fish for the pathogen screening and bioassay were held in separate live cages for approximately 40 hours in the San Joaquin River at the Durham Ferry site. An additional bioassay group went to the river near the Stockton Wastewater Treatment Facility (WWTF). Bioassays began on Tuesday of each week with fish sampled 40 hours later on Thursday. Sampling was performed each week of the VAMP study releases: April 23 (Week 1), April 30 (Week 2), May 7 (Week 3) and May 14 (Week 4).

Pathogen and Physiology

Eighteen fish held at Durham Ferry were sampled weekly for bacteriology, virology and gill ATPase assays as described below:

Bacteriology – A sample of kidney tissue was collected aseptically and inoculated onto brain-heart infusion agar. Bacterial isolates were screened by standard microscopic and biochemical tests (USFWS and AFS-FHS 2007). These screening methods would not detect *Flavobacterium columnare. Renibacterium salmoninarum* (the bacteria that causes bacterial kidney disease) was screened by fluorescent antibody test of kidney imprints.

Table 6-2
Summary of pathogen screening of 2009 VAMP study fish. Assays included: virology by tissue culture of pooled kidney and spleen samples; bacteriology by culture of individual kidney samples on BHIA media; fluorescent antibody test for *Renibacterium salmoninarum* (Rs-FAT) by individual kidney imprints using polyclonal antiserum.

Assay	Samples	Total Fish	# Pos (%)	Pathogen
Virology	14	58	0	No virus detected
Bacteriology	80	80	0	No obligate bacterial pathogens detected
			21 (26%)	Aeromonas/ Pseudomonas
Rs-FAT	58	58	0	None detected

Table 6-3
Survival of bioassay Chinook held for 48 hours in live cages adjacent to the Stockton Wastewater Treatment Facility (WWTF) or Durham Ferry release site.

Site	Week 1	Week 2	Week 3	Week 4
WTF	10/10	9/10	9/10	10/10
Durham Ferry	8/10	10/10	10/10	10/10

Virology – Four fish pooled samples of kidney and spleen were inoculated onto EPC and CHSE-214 and incubated for 24 days (including a 14 day blind pass) at 15°C. (USFWS and AFS-FHS 2007).

Gill ATPase - Gill Na^+, K^+-Adenosine Triphosphatase activity (ATPase) was assayed by the method of McCormick and Bern (1989). Briefly, gill lamellae were dissected and frozen in sucrose-EDTA-Imidazole (SEI) buffer on dry ice. The sample was later homogenized, centrifuged and the pellet sonicated prior to the assay. ATPase activity was determined by the decrease over time in optical density (340 nm) as NADH is converted to NAD+. This activity was reported as µmol ADP/mg protein/hour as 1 mol of NAD is produced for each mol of ADP generated in the reaction. Gill ATPase activity is correlated with osmoregulatory ability in saltwater and is located in the chloride cells of the lamellae. This enzyme system transports salts from the blood against the concentration gradient in saltwater. Data analysis was performed by ANOVA and Tukey multiple comparison test.

Bioassay

Each week, fish for the bioassay were surgically implanted with a non-functioning acoustic (dummy) tag which mimicked, as closely as possible, the treatment of the VAMP study groups. Groups of 10 dummy tagged fish per site were placed in live cages and transported to both the WWTF and Durham Ferry sites. Following the 40 hour exposure period, mortality was recorded and both blood and histology samples collected. Blood was collected from the severed caudal vessel using heparinized Natelson tube.

Histopathology – The gills, liver and posterior kidney were rapidly removed from the fish and immediately fixed in Davidson's fixative, processed for 5 µm paraffin sections and stained with hematoxylin and eosin (Humason 1979). All tissues for a given fish were placed on one slide and identified by a unique code number. Each slide was examined at low (40X) and high magnification (400X).

Apoptosis assay – Anterior kidney and thymus tissues were processed for histopathology as above. Apoptosis (programmed cell death) in cells within these organs was used as a potential biomarker for environmental stress (Sweet et al. 1999). Molecular changes to the DNA signifying apoptosis were visualized on the section by TUNEL assay using an *in situ* detection kit (Trevigen Inc, Gaithersburg, MD; Catalog# 4828-30-BK). Each tissue was examined and rated on a scale relative to control tissues. Five tissue sections from each site in weeks 1 and 4 were examined by this assay (5 samples x 2 sites x 2 weeks = 20 samples total).

Plasma Total Protein and Chloride - Plasma was separated in the field by centrifuge and stored at -80°C until analyzed. Total protein was measured using colorimetric analysis reagents from Point Scientific (Canton, Michigan, kit T7528) and bovine serum albumin as a standard. Plasma chloride was measured using colorimetric analysis reagents from Point Scientific (kit C7501). Data analysis was performed using the Mann-Whitney test on medians. Plasma was not collected in week 2 due to an equipment problem.

WBC Counts - Blood was diluted 200x in Rees-Ecker fluid and stored cool. White blood cell (WBC) counts were performed by hemocytometry (Manner 1992). Counts were reported as WBC/mm3 whole blood. Data analysis was performed using the Mann-Whitney test on medians.

Results

Pathogen Screening

Summary results of weekly pathogen testing are presented in Table 6-2. No obligate viral or bacterial pathogens were detected however *Aeromonas-Pseudomonas* bacteria were isolated in 26% of the

Figure 6-13
Microscopic colored spheres observed in all of the kidneys from juvenile Chinooks salmon from Week 1 of the VAMP study. The spheres above are pink, however yellow and blue were observed in other fish.

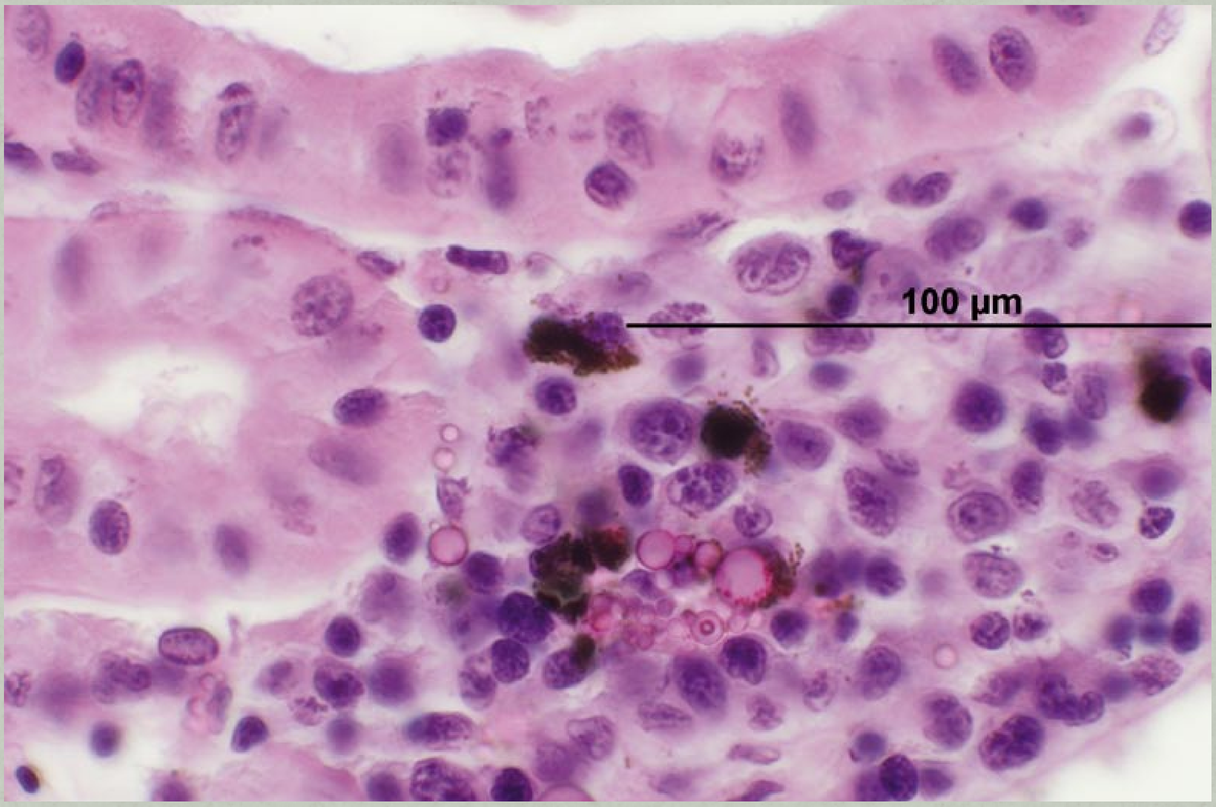


Figure 6-14
Box plots of median plasma total protein concentrations for bioassay fish groups held in the San Joaquin River near the Stockton Wastewater Treatment Facility (WWTF) and Durham Ferry release site (DF). Samples consisted of 5 fish at each site each week.

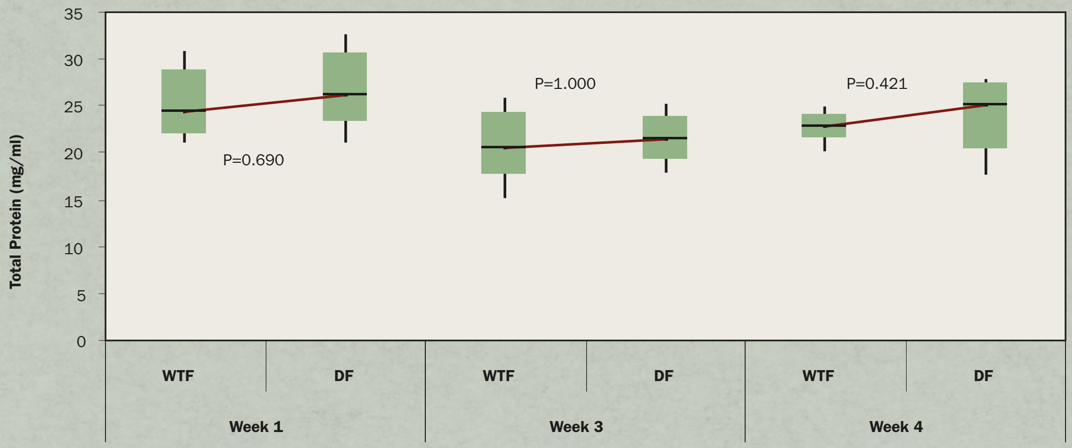


Figure 6-15

Box plots of median plasma chloride concentrations for bioassay fish groups held in the San Joaquin River near the Stockton Wastewater Treatment Facility (WWTF) and Durham Ferry release site (DF). Samples consisted of 5 fish at each site each week.

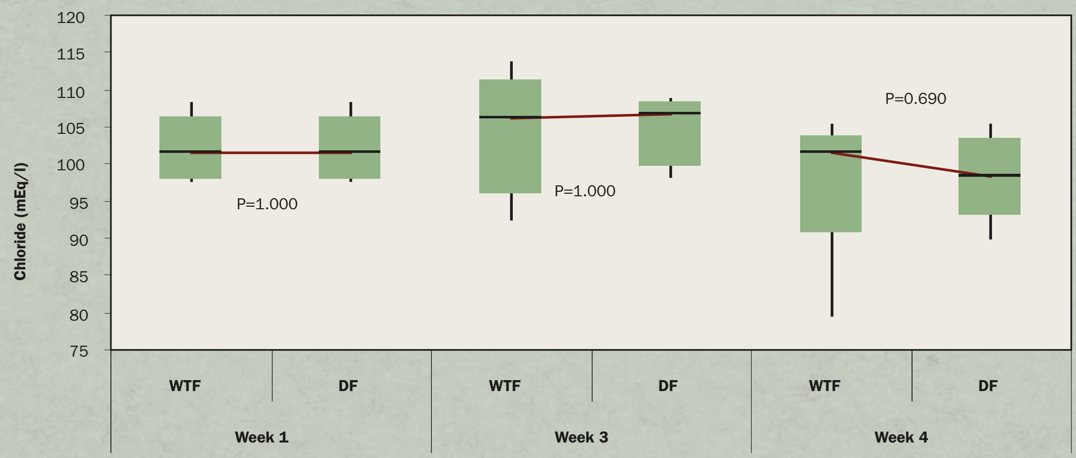
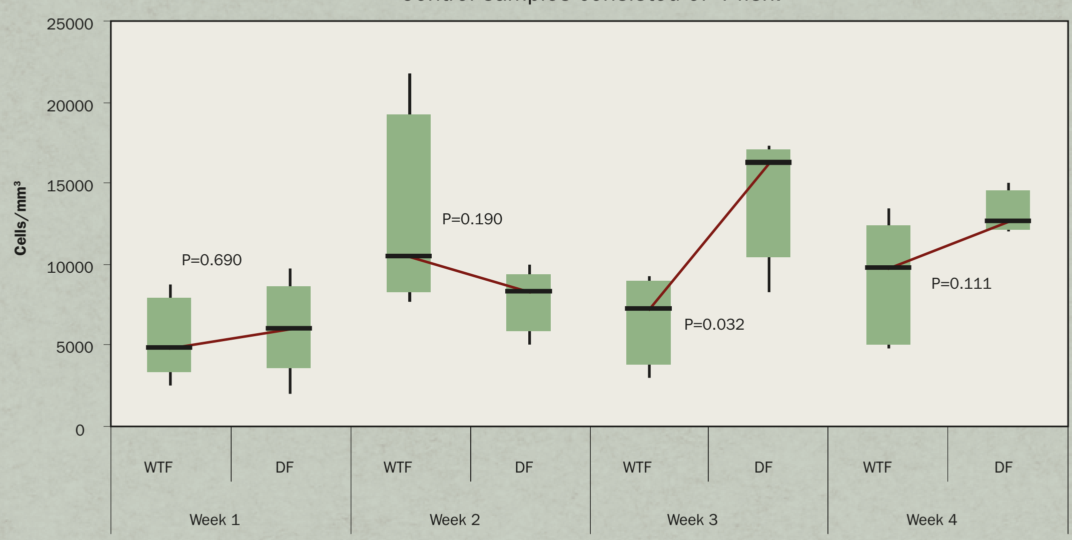


Figure 6-16

Box plots of Median WBC counts for bioassay fish groups held in the San Joaquin River adjacent to the Stockton Water Treatment Facility (WWTF) or Durham Ferry release site (DF). Sample number was 5 fish for all samples except Week 2 - WWTF and Week 4 - Control samples consisted of 4 fish.



bacterial samples. This gram-negative bacterial group is ubiquitous in soil and water as well as the intestinal tract of fish (Aoki 1999). It is often classified as an opportunistic fish pathogen. No clinical signs of bacterial septicemia were observed in these fish. Due to high winds during sampling, bacterial culture plates became contaminated with airborne bacteria and fungi. Approximately 25% of the samples were so overgrown with contaminates that they were discarded due to human health concerns. *Tetracapsuloides bryosalmonae* (the causative agent of proliferative kidney disease) was detected in 13% (10 / 76) of the kidney samples examined by histology. All of the Tb infections were in the early stages and no significant inflammation or kidney damage was associated with the infections.

Gill ATPase - Weekly mean ATPase activity ranged from 7.3 to 10.4 µmol ADP/mg protein/hr (Figure 6-12). ATPase activities in fish sampled in week 4 were higher than those observed in weeks 1 (P=0.048) and 3 (P=0.020). The majority of fish sampled (74%) had ATPase activities consistent with Chinook salmon smolts (data not presented). Other than a likely increase in ATPase activity with time, no other trends were observed.

Bioassay

There was no difference in 40 hour fish survival between WWTF and Durham Ferry sites. During the 4 weekly bioassays 95% (38/40) of the fish survived at both sites (Table 6-3). No cause of death was determined for the 4 mortalities.

Histopathology

No biologically significant differences were detected between fish held at the WWTP and Durham Ferry in any of the weeks. Fish from both locations in Week 1 had deposits of microscopic colored spheres associated with macrophages. It is believed the beads are associated with colored fin marks observed on this group of fish (Figure 6-13). No microscopic spheres were observed in fish from Weeks 2-4. Minor kidney lesions and gill edema were observed in fish from other weeks, but these changes were not likely to significantly affect fish performance or lead to acute mortality. No evidence of apoptosis was evident in any of the anterior kidney or thymus sections from the WWTF or Durham Ferry fish sampled in Weeks 1 and 4.

Plasma Total Protein

Median plasma total protein concentration in bioassay groups ranged from 21 to 26 mg/ml (Figure 6-14). No significant differences were detected between fish held at the WWTF and control sites in week 1 (P=0.690), week 3 (P=1.000), week 4 (P=0.421) or when all weeks were combined (P=0.367). No testing was done in week 2 due to an equipment problem.

Plasma Chloride

Median plasma chloride concentration in bioassay groups ranged from 102 to 107 mEq/l (Figure 6-15). No significant difference was detected between fish held at the WWTF or Control sites in week 1 (P=1.000), week 2 (P=1.000), week 3 (P=0.690) or when all weeks were combined (P=0.838).

WBC Counts

Median counts for the bioassay groups ranged from 4750 to 16250 cells/mm^3 (Figure 6-16). In week 3, the fish held at the Durham Ferry site had elevated WBC counts compared to fish held at the WWTF (P=0.032). When all weeks were combined, there was no significant difference (P=0.103) in the median WCB count at the WWTF (7750 cells/mm^3) compared to the Durham Ferry site (9750 cells/mm^3). Elevated WBC count is nonspecific, but can indicate infection (Barton, Morgan and Vijayan 2002)

Conclusions

No significant health or physiological problems were detected in the 2009 VAMP release groups. Light infections of *Tetracapsuloides bryosalmonae* were detected, but all infections were at very early stages and would not likely impact survival during the VAMP study period. It is possible that a portion of the population had asymptomatic infections from opportunistic bacteria. Most fish had undergone or were in the process of smoltification.

No differences were observed in bioassay groups held adjacent to the WWTP or Durham Ferry sites. While low mortality in the bioassay groups was observed, it occurred at both sites and was likely a result of handing and transport. No indications of significant tissue changes were observed at either site by histology. Minor gill edema was observed in fish from both locations in several weeks. It was not know if these changes were due to water quality at the site or handling of the sample groups. Blood clinical chemistry and WBC count data did not demonstrate any consistent difference between bioassay groups. The elevated WBC count observed at the Control group in Week 3 was the only exceptional observation and may have been caused by infections of *Tb* or an adverse reaction to tagging.

CHAPTER 7

CONCLUSIONS AND RECOMMENDATIONS

The 2009 VAMP moved into the third consecutive dry year and for the first time, the sequential dry-year relaxation of the San Joaquin River Agreement was initiated. This meant that there would be no Target Flow. A minimum base flow of 2,000cfs was maintained. The VAMP coordinated actions to ensure as closely as possible a stable flow rate at Vernalis during the VAMP period. The mean daily flow at Vernalis varied between 1,830 and 2,650 cubic feet per second (cfs) over the 31-day VAMP period. The observed exports during this period averaged 1,990 cfs and ranged from 1,350 cfs to 2,590 cfs. The start of the VAMP Fish experiment was again delayed from the default period to April 19th to May 19th to allow the test fish to increase in size. Flow and fish size were only two factors that presented challenges to the VAMP team to demonstrate that acoustic telemetry technology can be implemented full scale in the South Delta.

Difficulties deploying and maintaining large open-water receivers, loss of the physical barrier at the Head of Old River, tracking smolts through numerous channels, tagging near the limit on tag size for fall run San Joaquin River smolts and maintaining an acoustic receiver network under South Delta conditions presented challenges to VAMP in meeting the second goal of better defining route selection and survival between various reaches in the Delta.

The third goal of the 2009 VAMP was to demonstrate acoustic tagging and release of fall-run smolts can be accomplished without introducing bias in the survival estimates and route selection data. Reaching this goal was challenged by the time consuming data processing from numerous receivers, data interpretation for conditions in the South Delta and understanding and dealing with observed high mortality within certain reaches within the South Delta.

Table 7-1
Summary of VAMP 2009 Issues and Recommendations

CHALLENGE OR ISSUE FACED BY VAMP	RECOMMENDATIONS FOR 2010
The timing of VAMP has been designed to adaptively change with hydrologic conditions.	Continue to identify opportunities when it would be beneficial to change the VAMP period to increase protection for juvenile Chinook salmon outmigration from the San Joaquin River Basin.
Low flow conditions in 2009 emphasized the importance of the ungaged flow on the San Joaquin River and tributaries.	Maintain and increase the frequency of flow-monitoring station maintenance to ensure accurate flow records.
Flow data collected in 2009 near Lathrop, Old River at Head and near Mossdale provided valuable information on the flow split at the Head of Old River.	Continue to use the ADCM flow measurement devices to measure stage and flow at these monitoring sites.
Delays for fish growth push the study into critical water temperature periods.	Continue intensive temperature monitoring throughout the experiment.
	Work with DFG Hatchery specialists to develop strategies to enhance smolt growth prior to the VAMP period.
Deployment of large open-water receivers presents a strong technical challenge.	Develop a long-term commitment with specialist to install these stations
As much as 40% of the study cost in future years may be related to installing the large open-water receivers	Work with the technology manufacturers and other specialists to develop cheaper, long-term solutions for these sites.
Large open-water receivers are a critical component of the survival study and comparisons with prior CWT studies.	Use a consistent study design over multiple years, especially with respect to addressing large-scale questions such as survival to Chipps Island. As part of this recommendation, the large open-water receivers or an alternate technology should be located at Chipps Island each year.
There are numerous routes and channels that the smolts can take in the South Delta especially without the barrier at the head of Old River.	Continue cooperation with the South Delta Temporary Barriers study and the Non-physical barrier study to increase the number of channels VAMP can cover for route selection. Use redundant receivers at key exit points for route selection analysis.
Receiver overheating under hot spring Delta conditions.	All future telemetry sites exposed to outdoor ambient conditions should utilize the modified job boxes developed during the 2009 VAMP study (Vogel, 2010).
Importance of route selection at the head of Old River with a non-physical barrier installed.	Deployment of a four-port receiver at the head of Old River when a non-physical barrier is installed should be a priority to detail fish behavior and predatory fish behavior.
Interference from line power sources.	Discontinue the use of AC trickle chargers unless grounding and acoustic noise can be eliminated.
Use of acid batteries presents labor and safety issues.	Use of non-acid batteries should be implemented to avoid safety issues in remote areas. Development of solar panels for trickle charging should be developed and tested.
Tag life is still near the limits of time needed for travel through the Delta.	Continue the tag life studies initiated in 2008. Continue to distribute tags from all tag manufacture groups across all release groups and taggers so that any survival effect of release group (location, time) or tagger is not confounded with a potential effect of tag batch or tag life on survival.
Availability of test fish from the San Joaquin River Basin.	Develop a long-term supply source from the Merced River Hatchery (MRH) to ensure a continuous source of in-basin smolts.
High mortality being experienced after tagged smolt releases.	Continue evaluation of tagger effects. Continue health studies on release groups and tagging procedures. Consider additional live-pen studies in reaches of highest mortality with a priority in the Stockton Deep Water Ship Channel and near the Stockton WWTP. Continue dummy tagging of release fish Continue tagger training and continued development of refresher training courses for previous taggers. Work with groups to develop long-term availability of previous taggers to ensure consistency in tagging procedures. Evaluate predator effects on tagged smolts under San Joaquin River conditions. Evaluate if acoustic-tagged salmon are in "sub-standard condition" resulting from surgery and transport (Vogel, 2010) Consider conducting predator avoidance tests on representative tagged salmon using established study protocols (Vogel, 2010). Increase the intensity of mobile telemetry to locate high mortality areas or zones.

Table 7-1
Summary of VAMP 2009 Issues and Recommendations

CHALLENGE OR ISSUE FACED BY VAMP	RECOMMENDATIONS FOR 2010
Loss of data due to receiver malfunctions or vandalism.	Develop remote sensing techniques to continuously check on receiver operations. Use redundant receivers at key stations to avoid critical data loss including Mossdale, SJR at Lathrop, Old River East side and Chipps Island.
Data processing is time consuming and expensive due to labor costs.	Continue the use of a central ftp site for data downloads to avoid loss of data prior to processing. To ensure consistency in how data is processed, develop standardized procedures for how data is handled, reviewed, stored and processed. Plan precisely who will be processing data from each receiver and how the transfer of processed data will occur. Develop training programs for data processors. Develop procedures to compare manual processing with computer marking programs to evaluate accuracy under Delta conditions.
Due to high rates of predation, predator movements after consumption of tagged smolts likely biased smolt survival estimates.	Do not rely solely on the “presence/absence” data processing techniques. Develop standard terminology for data analysis including standard definitions for “near-filed, medium-filed and far-field” observations used in the 2009 VAMP study to ensure consistency in data processing and interpretation. Continue with manual data processing with an emphasis on marking predator-type movements vs. smolt type movements. Work with the acoustic tracking manufacturers to develop more rapid marking programs that identify specific types of smolt behavior.
Due to high mortality, very few smolts released upstream of Vernalis reach as far downstream as Turner Cut.	Focus future work to better define the reason for the high mortality in specific reaches of the San Joaquin River. Consider supplemental releases to determine if mortality experiences in the upper reaches of the San Joaquin River are similar to those found further downstream.
Evidence is mounting that the high mortality in certain reaches and near certain points in the river may be associated with predation and this may be limiting survival.	Evaluate acoustic-tagged salmon smolts to determine if they are in a “sub-standard” condition resulting from surgery and transport causing increased vulnerability to predation compared to untagged salmon. Increase predator tagging with an emphasis on tagging prior to the start of the tagged smolt release to allow the predators time to adjust and move to locations they are accustomed to during the out-migration period. Develop a full study plan for predator tracking to ensure consistency and allow data interpretation between studies. Tag predators in known “hot spots” such as bridges, pumping structures, scour holes, etc. to better learn about their habitats during the smolt out-migration period. Increase the intensity of mobile monitoring in known predator areas and in the main stem of the San Joaquin River as most acoustically-tagged predators may not hang out around fixed station receivers. Conduct an acoustic-tag defecation study to determine how long transmitters remain in the stomach of predators. Program predator acoustic tags with a short repetition rate as they swim faster and would move faster by a fixed receiver and also would likely be picked up more readily by mobile monitoring. Work with the tag manufacturers to develop a smolt tag that shows different characteristics when it is consumed or in the stomach of a predator.

Considerations for a Future VAMP

Drs. Bruce Herbold and Chuck Hanson developed the original Vernalis Adaptive Management Plan (VAMP) conceptual framework for protection and experimental determinations of juvenile Chinook salmon survival within the lower San Joaquin River in response to river flow and pumping exports. The VAMP experiments were designed to evaluate how juvenile Chinook salmon migration from the San Joaquin Valley is affected by different San Joaquin River flows and different export rates at the State Water Project (SWP) and Central Valley Project (CVP) exports. In addition, the value of a barrier at the head of Old River was to be evaluated. The VAMP studies were designed as a large-scale, 12-year experimental survival study. The year 2010 represents the last year of the first phase of the study. Much has been learned, but not all of the goals have been achieved and salmon populations are of even greater concern now. Thus, a Phase II VAMP is needed.

In recognition of the transition between Phases I and II of the program, Doctors Herbold and Hanson developed the following recommendations aimed at a synthesis of what has been learned during the Phase I studies and for use as part of the scientific foundation for developing the Phase II program along with consideration from the scientific peer review panel recommendations and the acoustic tagging studies recommended under the National Marine Fisheries OCAP-BO. These broader program recommendations include:

• Conduct a comprehensive statistical analysis of juvenile Chinook salmon survival data collected during the Phase I studies and identify trends in survival for juvenile Chinook salmon in regard to all environmental factors measured. Summarize the key findings of the Phase I studies in regard to flows and exports but include any evidence of the impact of other stressors such as water quality impairments and predation.

• Perform a retrospective review of the accomplishments, challenges and constraints that affect the experimental design, implementation, and analysis of the survival studies for use as part of the basis for design of the Phase II investigations.

•Survey stakeholders and agencies to develop relevant questions to be addressed in Phase II. The new Biological Opinions from USFWS and NMFS have greatly reduced the level of exports. Results of the last few years with acoustic tags have highlighted reach-specific mortality impacts. Emphasis in Phase II is likely to address how different river flow and export levels alter the impact of multiple other stressors.

• Explore the potential to include other species and wild-caught salmonids to broaden the value of VAMP, particularly in regard to steelhead.

• Design VAMP Phase II studies that can robustly address the multiple questions of interest with the funding and fish resources available, and that can fit within the framework of opportunities and constraints that have been identified in Phase I.

• Ensure that future studies examine a greater range of San Joaquin River flows than were available in Phase I, even if higher flows are provided for shorter periods of time than targeted in Phase I.

• Integrate VAMP Phase II studies with other fishery studies being conducted or designed for the San Joaquin River and its tributaries, especially the San Joaquin River restoration efforts.

Bruce Herbold

Chuck Hanson

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Signatories to The San Joaquin River Agreement

U.S. BUREAU OF RECLAMATION

U.S. FISH AND WILDLIFE SERVICE

CALIFORNIA DEPARTMENT OF WATER RESOURCES

CALIFORNIA DEPARTMENT OF FISH AND GAME

OAKDALE IRRIGATION DISTRICT*

SOUTH SAN JOAQUIN IRRIGATION DISTRICT*

MODESTO IRRIGATION DISTRICT*

TURLOCK IRRIGATION DISCTICT*

MERCED IRRIGATION DISTRICT*

SAN JOAQUIN RIVER EXCHANGE CONTRACTORS WATER AUTHORITY*

CENTRAL CALIFORNIA IRRIGATION DISTRICT

FIREBAUGH CANAL WATER DISTRICT

COLUMBIA CANAL COMPANY

SAL LUIS CANAL COMPANY

FRIANT WATER AUTHORITY*

PUBLIC UTILITIES COMMISSION OF THE CITY AND COUNTY OF SAN FRANCISCO*

NATURAL HERITAGE INSTITUTE

METROPOLITAN WATER DISTRTICT OF SOUTHERN CALIFORNIA

SAN LUIS AND DELTA-MENDOTA WATER AUTHORITY

SAN JOAQUIN RIVER GROUP AUTHORITY

*San Joaquin River Group Authority Members

2009 Useful Web Pages

Page 4 San Joaquin River Agreement
www.sjrg.org/agreement.htm

Page 4 SWRCB Decision 1641
www.waterrights.ca.gov/hearings/Decisions.htm

Page 9 VAMP Annual Technical Reports
www.sjrg.org

Page 9 VAMP Experimental Design
www.sjrg.org/agreement.htm

Page 14 CDEC Daily
http://cdec.water.ca.gov/cgi-progs/queryDgroups?s=fw2

Page 14 Vernalis, USGS Daily(USGS, station 11303500)
http://waterdata.usgs.gov/ca/nwis/dv?cb_00060=on&format=html&begin_date=2008-02-01&site_no=11303500&referred_module=sw

Page 14 Newman, USGS Daily(USGS, station 11274000)
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Page 14 LaGrange, USGS Daily
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(http://waterdata.usgs.gov/ca/nwis/dv?cb_00060=on&format=html&begin_date2008-02-01&site_no=11289650&referred_module=sw

Page 14 Goodwin, USBR Daily
(USBR, Goodwin Dam Daily Operation Report)
http://www.usbr.gov/mp/cvo/vungvari/gdwdop.pdf

Page 14 Cressey, CDEC Daily(CDEC, station CRS)
http://cdec.water.ca.gov/cgi-progs/queryDgroups?s=fw2

Page 14 Stevinson, CDEC Daily(CDEC, station MST)
http://cdec.water.ca.gov/cgi-progs/queryDgroups?s=fw2

Page 50 CVP and SWP Salvage Data
www.iep.ca.gov

Page 50 USFWS Stockton
www.delta.dfg.ca.gov/data/salvage

Page 48 Pacific States Marine Fisheries Commission
Regional Mark Information System
www.psmfc.org/Regional_Mark_Processing_Center_RMPC

Common Acronyms and Abbreviations

ADCP	Acoustic Doppler Current Meters
BAFF	Bio-Acoustic Fish Fence
Bay-Delta	Sacramento and San Joaquin Rivers, San Francisco Bay Delta
BO	Biological Opinion
CCF	Clifton Court Forebay
CCFB	Clifton Court Forebay
CDEC	California Data Exchange Center
CDFG	California Department of Fish and Game
CDRR	Combined Differential Recovery Rate
cfs	Cubic Feet per Second
CNFHC	California/Nevada Fish Health Center
CPUE	Catch Per Unit Effort
CRR	Combined Recovery Rate
CRRL	Columbia River Research Laboratory
CVP	Central Valley Project
CVPIA	Central Valley Project Improvement Act
CWT	Coded Wire Tagged
D-1641	Water Rights Decision 1641 of the SWRCB
DF	Durham Ferry
DFG	California Department of Fish and Game
DO	Dissolved Oxygen
DWR	California Department of Water Resources
EPA	United States Environmental Protection Agency
FERC	Federal Energy Regulatory Commission
FL	Fork Length
GLC	Grant Line Canal
GPS	Global Positioning System
HTI	Hydroacoustic Technology Inc
HOR	Head of Old River
HORB	Head of Old River Barrier
ID	Irrigation District
LED	Light Emitting Diode
MAL	Mallard Slough
MeID	Merced Irrigation District
MID	Modesto Irrigation District
MR	Middle River
MRH	Merced River Hatchery
MSD	San Joaquin River at Mossdale
MSL	Mean Sea Level
MST	Merced River at Stevinson
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
OH1	Head of Old River
OID	Oakdale Irrigation District
OR	Old River
ORT	Old River at Tracy
OSJ	North Old River
PKD	Proliferative Kidney Disease
RM	River Mile
RST	Rotary Screw Trap
SDIP	South Delta Improvement Project
SDWA	South Delta Water Agency
SEI	Sucrose-EDTA-Imidazole
SJL	San Joaquin River at Lathrop
SJR	San Joaquin River
SJT	San Joaquin River at Channel Markers 16 & 18 (Near Turner Cut)
SJRA	San Joaquin River Agreement
SJRECWA	San Joaquin River Exchange Contractors Water Authority
SJRGA	San Joaquin River Group Authority
SJRATC	San Joaquin River Agreement Technical Committee
SJRTC	San Joaquin River Agreement Technical Committee
SLDMWA	San Luis Delta Mendota Water Authority
SOP	Standard Operating Procedure
STP	Stockton Wastewater Treatment Plant
SSJID	South San Joaquin Irrigation District
SWC	State Water Contractors
SWP	State Water Project
SWRCB	State Water Resources Control Board
TAN	Total Ammonia Nitrogen
TBP	Temporary Barriers Project
TFF	Tracy Fish Facility
TID	Turlock Irrigation District
TRN	Turner Cut
USACE	United States Army Corps of Engineers
USB	Universal Serial Bus
USBR	United States Bureau of Reclamation
USFWS	United States Fish and Wildlife Service
USGS	United States Geological Survey
VAMP	Vernalis Adaptive Management Plan
VNS	Vernalis
WBC	White Blood Cell
WOMT	CALFED Water Operations Management Team
WQCP	Water Quality Control Plan
WWTF	Wastewater Treatment Facility
WWTP	Wastewater Treatment Plant

TABLE OF CONTENTS

APPENDIX A

Appendix A-1, Table 1

2009 VAMP DAILY OPERATION PLAN — MARCH 19, 2009
LOW UNGAGED FLOW
Target Flow Period: April 20th – May 20th * Flow Target: 3,200 cfs
Bold Numbers: observed real-time mean daily flows

	San Joaquin River near Vernalis							Merced River at Cressey				Tuolumne River at LaGrange				Stanislaus R blw Goodwin					
Date	Existing Flow (cfs)	VAMP Supple-mental Flow (cfs)	Other Supple-mental Flow (cfs)	Cumula-tive VAMP Supple-mental Flow (TAF)	VAMP Flow (cfs)	SJR above Merced R (2day lag) (cfs)	Ungaged Flow above Vernalis (cfs)	Existing Flow (cfs)	MeID VAMP Supple-mental Flow (cfs)	Exch Contr VAMP Supple-mental Flow (cfs)	VAMP Flow (3day lag) (cfs)	Existing Flow - base FERC volume (cfs)	Existing Flow - Adjusted FERC Pulse (cfs)	VAMP Supple-mental Flow (cfs)	VAMP Flow (2day lag) (cfs)	Existing Flow - Base (cfs)	Existing Flow - reshaped	VAMP Supple-mental Flow (cfs)	Other Supple-mental Flow (cfs)	VAMP Flow (2day lag) (cfs)	Maintain Priority Flow Level M=Merced T=Tuol. S=Stan.
3/15/09	1,360				1,360	486	225	267			267		167		167		207			207	
3/16/09	1,350				1,350	500	234	264			264		168		168		204			204	
3/17/09	1,330				1,330	507	203	262			262		168		168		204			204	
3/18/09	1,260				1,260	493	121	261			261		168		168		205			205	
3/19/09																					
3/20/09																					
3/21/09																					
3/22/09																					
3/23/09																					
3/24/09																					
3/25/09																					
3/26/09																					
3/27/09																					
3/28/09																					
3/29/09								250			250										
3/30/09						464		250			250	150	150		150	250	250			250	
3/31/09						460		250			250	150	150		150	250	250			250	
4/1/09	1,114				1,114	456	0	250			250	150	150		150	763	763			763	
4/2/09	1,110				1,110	452	0	250			250	150	150		150	763	763			763	
4/3/09	1,619				1,619	448	0	250			250	150	150		150	763	763			763	
4/4/09	1,615				1,615	444	0	250			250	150	150		150	763	763			763	
4/5/09	1,611				1,611	440	0	250			250	150	150		150	763	763			763	
4/6/09	1,607				1,607	436	0	250			250	150	150		150	763	763			763	
4/7/09	1,603				1,603	432	0	250			250	150	150		150	763	763			763	
4/8/09	1,599				1,599	428	0	250			250	150	150		150	763	763			763	
4/9/09	1,595				1,595	424	0	250			250	150	150		150	763	763			763	
4/10/09	1,591				1,591	420	0	250			250	150	150		150	763	763			763	
4/11/09	1,587				1,587	416	0	250			250	150	150		150	763	763			763	
4/12/09	1,583				1,583	412	0	250			250	150	150		150	763	763			763	
4/13/09	1,579				1,579	408	0	250			250	150	150		150	763	763			763	
4/14/09	1,575				1,575	404	0	250			250	150	150		150	763	763			763	
4/15/09	1,571				1,571	400	0	250			250	150	150		150	763	763			763	
4/16/09	1,567				1,567	396	0	250			250	150	150		150	763	763			763	
4/17/09	1,563				1,563	392	0	250	631	119	1,000	150	150		150	763	763			763	
4/18/09	1,559				1,559	388	0	250	631	119	1,000	648	648	237	885	763	763	237	0	1,000	
4/19/09	1,555				1,555	384	0	250	631	119	1,000	648	648	237	885	763	763	237	0	1,000	
4/20/09	2,049	1,224	0	2.43	3,273	380	0	250	631	119	1,000	648	648	237	885	763	763	237	0	1,000	
4/21/09	2,046	1,224	0	4.86	3,270	376	0	250	631	119	1,000	648	648	237	885	763	763	237	0	1,000	
4/22/09	2,042	1,224	0	7.28	3,266	372	0	250	631	119	1,000	648	648	237	885	763	763	237	0	1,000	
4/23/09	2,038	1,224	0	9.71	3,262	369	0	250	631	119	1,000	648	648	237	885	763	763	237	0	1,000	
4/24/09	2,034	1,224	0	12.14	3,258	365	0	250	631	119	1,000	648	648	237	885	763	763	237	0	1,000	
4/25/09	2,030	1,224	0	14.57	3,254	361	0	250	631	119	1,000	648	648	237	885	763	763	237	0	1,000	
4/26/09	2,026	1,224	0	16.99	3,250	357	0	250	631	119	1,000	648	648	237	885	763	763	237	0	1,000	
4/27/09	2,022	1,224	0	19.42	3,246	353	0	250	631	119	1,000	648	648	237	885	763	763	237	0	1,000	
4/28/09	2,018	1,224	0	21.85	3,242	349	0	250	631	119	1,000	648	648	237	885	763	763	237	0	1,000	
4/29/09	2,014	1,224	0	24.28	3,238	345	0	250	631	119	1,000	648	648	237	885	763	763	237	0	1,000	
4/30/09	2,010	1,224	0	26.71	3,234	341	0	250	631	119	1,000	648	648	237	885	763	763	237	0	1,000	
5/1/09	2,006	1,224	0	29.13	3,230	337	0	250	631	119	1,000	648	648	237	885	737	737	237	0	974	
5/2/09	2,002	1,224	0	31.56	3,226	333	0	250	631	119	1,000	648	648	237	885	737	737	237	0	974	
5/3/09	1,972	1,224	0	33.99	3,196	329	0	250	631	119	1,000	648	648	237	885	737	737	237	0	974	
5/4/09	1,968	1,224	0	36.42	3,192	325	0	250	631	119	1,000	648	648	237	885	737	737	237	0	974	
5/5/09	1,964	1,224	0	38.84	3,188	321	0	250	631	119	1,000	648	648	237	885	737	737	237	0	974	
5/6/09	1,961	1,224	0	41.27	3,185	317	0	250	631	119	1,000	648	648	237	885	737	737	237	0	974	
5/7/09	1,957	1,224	0	43.70	3,181	313	0	250	631	119	1,000	648	648	237	885	737	737	237	0	974	
5/8/09	1,953	1,224	0	46.13	3,177	310	0	250	631	119	1,000	648	648	237	885	737	737	237	0	974	
5/9/09	1,949	1,224	0	48.56	3,173	306	0	250	631	119	1,000	648	648	237	885	737	737	237	0	974	
5/10/09	1,945	1,224	0	50.98	3,169	302	0	250	631	119	1,000	648	648	237	885	737	737	237	0	974	
5/11/09	1,941	1,224	0	53.41	3,165	298	0	250	631	119	1,000	648	648	237	885	737	737	237	0	974	
5/12/09	1,937	1,224	0	55.84	3,161	294	0	250	631	119	1,000	648	648	237	885	737	737	237	0	974	
5/13/09	1,933	1,224	0	58.27	3,157	290	0	250	631	119	1,000	648	648	237	885	737	737	237	0	974	
5/14/09	1,929	1,224	0	60.69	3,153	286	0	250	631	119	1,000	648	648	237	885	737	737	237	0	974	
5/15/09	1,925	1,224	0	63.12	3,149	282	0	250	631	119	1,000	648	648	237	885	737	737	237	0	974	
5/16/09	1,921	1,224	0	65.55	3,145	278	0	250	631	119	1,000	648	648	237	885	737	737	237	0	974	
5/17/09	1,917	1,224	0	67.98	3,141	274	0	250	631	119	1,000	648	648	237	885	737	737	237	0	974	
5/18/09	1,913	1,224	0	70.41	3,137	270	0	250			250	648	648	237	885	737	737	237	0	974	
5/19/09	1,909	1,224	0	72.83	3,133	266	0	250			250	550	550		550	737	737			737	
5/20/09	1,905	1,224	0	75.26	3,129	262	0	250			250	450	450		450	737	737			737	
5/21/09	1,803				1,803	258	0	250			250	350	350		350	737	737			737	
5/22/09	1,699				1,699	254	0	250			250	250	250		250	737	737			737	
5/23/09	1,595				1,595	250	0	250			250	150	150		150	737	737			737	
5/24/09	1,491				1,491	246	0	250			250	150	150		150	737	737			737	
5/25/09	1,387				1,387	242	0	250			250	150	150		150	737	737			737	
5/26/09	1,383				1,383	238	0	250			250	150	150		150	737	737			737	
5/27/09	1,379				1,379	234	0	250			250	150	150		150	737	737			737	
5/28/09	1,375				1,375	230	0	250			250	150	150		150	737	737			737	
5/29/09	1,371				1,371	226	0	250			250	150	150		150	737	737			737	
5/30/09	1,367				1,367	222	0	250			250	150	150		150	737	737			737	
5/31/09	1,363				1,363	218	0	250			250	115	115		115	737	737			737	
VAMP Period																					
Avg. (cfs):	1,975	1,224	0		3,199	329	0	250	631	119	1,000	648	648	237	885	748	748	237	0	985	
Supple-mental Water (TAF):		75.26	0.00						38.80	7.32				14.57				14.57	0.00		

VAMP flow operation period

Appendix A-1, Table 2

2009 VAMP DAILY OPERATION PLAN — MARCH 19, 2009
HIGH UNGAGED FLOW
Target Flow Period: April 20th – May 20th * Flow Target: 3,200 cfs
Bold Numbers: observed real-time mean daily flows

Date	San Joaquin River near Vernalis							Merced River at Cressey				Tuolumne River at LaGrange				Stanislaus R blw Goodwin					
	Existing Flow (cfs)	VAMP Supple-mental Flow (cfs)	Other Supple-mental Flow (cfs)	Cumula-tive VAMP Supple-mental Flow (TAF)	VAMP Flow (cfs)	SJR above Merced R (2day lag) (cfs)	Ungaged Flow above Vernalis (cfs)	Existing Flow (cfs)	MeID VAMP Supple-mental Flow (cfs)	Exch Contr VAMP Supple-mental Flow (cfs)	VAMP Flow (3day lag) (cfs)	Existing Flow - base FERC volume (cfs)	Existing Flow - Adjusted FERC Pulse (cfs)	VAMP Supple-mental Flow (cfs)	VAMP Flow (2day lag) (cfs)	Existing Flow - Base (cfs)	Existing Flow - reshaped	VAMP Supple-mental Flow (cfs)	Other Supple-mental Flow (cfs)	VAMP Flow (2day lag) (cfs)	Maintain Priority Flow Level M=Merced T=Tuol. S=Stan.
3/15/09	1,360				1,360	486	225	267			267		167		167		207			207	
3/16/09	1,350				1,350	500	234	264			264		168		168		204			204	
3/17/09	1,330				1,330	507	203	262			262		168		168		204			204	
3/18/09	1,260				1,260	493	121	261			261		168		168		205			205	
3/19/09																					
3/20/09																					
3/21/09																					
3/22/09																					
3/23/09																					
3/24/09																					
3/25/09																					
3/26/09																					
3/27/09																					
3/28/09																					
3/29/09								250			250										
3/30/09						464		250			250	175	175		175	250	250			250	
3/31/09						460		250			250	175	175		175	250	250			250	
4/1/09	1,639				1,639	456	500	250			250	175	175		175	643	643			643	
4/2/09	1,635				1,635	452	500	250			250	175	175		175	643	643			643	
4/3/09	2,024				2,024	448	500	250			250	175	175		175	643	643			643	
4/4/09	2,020				2,020	444	500	250			250	175	175		175	643	643			643	
4/5/09	2,016				2,016	440	500	250			250	175	175		175	643	643			643	
4/6/09	2,012				2,012	436	500	250			250	175	175		175	643	643			643	
4/7/09	2,008				2,008	432	500	250			250	175	175		175	643	643			643	
4/8/09	2,004				2,004	428	500	250			250	175	175		175	643	643			643	
4/9/09	2,000				2,000	424	500	250			250	175	175		175	643	643			643	
4/10/09	1,996				1,996	420	500	250			250	175	175		175	643	643			643	
4/11/09	1,992				1,992	416	500	250			250	175	175		175	643	643			643	
4/12/09	1,988				1,988	412	500	250			250	175	175		175	643	643			643	
4/13/09	1,984				1,984	408	500	250			250	175	175		175	643	643			643	
4/14/09	1,980				1,980	404	500	250			250	175	175		175	643	643			643	
4/15/09	1,976				1,976	400	500	250			250	175	175		175	643	643			643	
4/16/09	1,972				1,972	396	500	250			250	175	175		175	643	643			643	
4/17/09	1,968				1,968	392	500	250	360	0	610	175	175		175	643	643			643	
4/18/09	1,964				1,964	388	500	250	360	0	610	1,080	1,080	0	1,080	643	643	0	0	643	
4/19/09	1,960				1,960	384	500	250	360	0	610	1,080	1,080	0	1,080	643	643	0	0	643	
4/20/09	2,861	360	0	0.71	3,221	380	500	250	360	0	610	1,080	1,080	0	1,080	643	643	0	0	643	
4/21/09	2,858	360	0	1.43	3,218	376	500	250	360	0	610	1,080	1,080	0	1,080	643	643	0	0	643	
4/22/09	2,854	360	0	2.14	3,214	372	500	250	360	0	610	1,080	1,080	0	1,080	643	643	0	0	643	
4/23/09	2,850	360	0	2.86	3,210	369	500	250	360	0	610	1,080	1,080	0	1,080	643	643	0	0	643	
4/24/09	2,846	360	0	3.57	3,206	365	500	250	360	0	610	1,080	1,080	0	1,080	643	643	0	0	643	
4/25/09	2,842	360	0	4.28	3,202	361	500	250	360	0	610	1,080	1,080	0	1,080	643	643	0	0	643	
4/26/09	2,838	360	0	5.00	3,198	357	500	250	360	0	610	1,080	1,080	0	1,080	643	643	0	0	643	
4/27/09	2,834	360	0	5.71	3,194	353	500	250	360	0	610	1,080	1,080	0	1,080	643	643	0	0	643	
4/28/09	2,830	360	0	6.43	3,190	349	500	250	360	0	610	1,080	1,080	0	1,080	643	643	0	0	643	
4/29/09	2,826	360	0	7.14	3,186	345	500	250	360	0	610	1,080	1,080	0	1,080	643	643	0	0	643	
4/30/09	2,822	360	0	7.85	3,182	341	500	250	150	0	400	1,080	1,080	0	1,080	643	643	0	0	643	
5/1/09	2,818	360	0	8.57	3,178	337	500	250	150	0	400	1,080	1,080	0	1,080	918	918	0	0	918	
5/2/09	2,814	360	0	9.28	3,174	333	500	250	150	0	400	1,080	1,080	0	1,080	918	918	0	0	918	
5/3/09	3,085	150	0	9.58	3,235	329	500	250	150	0	400	1,080	1,080	0	1,080	918	918	0	0	918	
5/4/09	3,081	150	0	9.88	3,231	325	500	250	150	0	400	1,080	1,080	0	1,080	918	918	0	0	918	
5/5/09	3,077	150	0	10.18	3,227	321	500	250	150	0	400	1,080	1,080	0	1,080	918	918	0	0	918	
5/6/09	3,074	150	0	10.47	3,224	317	500	250	150	0	400	1,080	1,080	0	1,080	918	918	0	0	918	
5/7/09	3,070	150	0	10.77	3,220	313	500	250	150	0	400	1,080	1,080	0	1,080	918	918	0	0	918	
5/8/09	3,066	150	0	11.07	3,216	310	500	250	150	0	400	1,080	1,080	0	1,080	918	918	0	0	918	
5/9/09	3,062	150	0	11.37	3,212	306	500	250	150	0	400	1,080	1,080	0	1,080	918	918	0	0	918	
5/10/09	3,058	150	0	11.66	3,208	302	500	250	150	0	400	1,080	1,080	0	1,080	918	918	0	0	918	
5/11/09	3,054	150	0	11.96	3,204	298	500	250	150	0	400	1,080	1,080	0	1,080	918	918	0	0	918	
5/12/09	3,050	150	0	12.26	3,200	294	500	250	150	0	400	1,080	1,080	0	1,080	918	918	0	0	918	
5/13/09	3,046	150	0	12.56	3,196	290	500	250	150	0	400	1,080	1,080	0	1,080	918	918	0	0	918	
5/14/09	3,042	150	0	12.85	3,192	286	500	250	150	0	400	1,080	1,080	0	1,080	918	918	0	0	918	
5/15/09	3,038	150	0	13.15	3,188	282	500	250	150	0	400	1,080	1,080	0	1,080	918	918	0	0	918	
5/16/09	3,034	150	0	13.45	3,184	278	500	250	150	0	400	1,080	1,080	0	1,080	918	918	0	0	918	
5/17/09	3,030	150	0	13.75	3,180	274	500	250	150	0	400	1,080	1,080	0	1,080	918	918	0	0	918	
5/18/09	3,026	150	0	14.04	3,176	270	500	250			250	1,080	1,080	0	1,080	918	918	0	0	918	
5/19/09	3,022	150	0	14.34	3,172	266	500	250			250	825	825		825	918	918			918	
5/20/09	3,018	150	0	14.64	3,168	262	500	250			250	675	675		675	918	918			918	
5/21/09	2,759				2,759	258	500	250			250	575	575		575	918	918			918	
5/22/09	2,605				2,605	254	500	250			250	475	475		475	918	918			918	
5/23/09	2,501				2,501	250	500	250			250	375	375		375	918	918			918	
5/24/09	2,397				2,397	246	500	250			250	275	275		275	918	918			918	
5/25/09	2,293				2,293	242	500	250			250	225	225		225	918	918			918	
5/26/09	2,189				2,189	238	500	250			250	175	175		175	918	918			918	
5/27/09	2,135				2,135	234	500	250			250	175	175		175	918	918			918	
5/28/09	2,081				2,081	230	500	250			250	175	175		175	918	918			918	
5/29/09	2,077				2,077	226	500	250			250	175	175		175	918	918			918	
5/30/09	2,073				2,073	222	500	250			250	175	175		175	918	918			918	
5/31/09	2,069				2,069	218	500	250			250	140	140		140	918	918			918	
VAMP Period																					
Avg. (cfs):	2,962	238	0		3,200	329	500	250	238	0	488	1,080	1,080	0	1,080	803	803	0	0	803	
Supple-mental Water (TAF):		14.64	0.00						14.64	0.00				0.00				0.00	0.00		

VAMP flow operation period

Appendix A-1, Table 3

2009 VAMP DAILY OPERATION PLAN — APRIL 19, 2009

Target Flow Period: April 19th – May 19th * Flow Target: N/A

Bold Numbers: observed real-time mean daily flows

	San Joaquin River near Vernalis							Merced River at Cressey				Tuolumne River at LaGrange				Stanislaus R blw Goodwin					
Date	Existing Flow (cfs)	VAMP Supple-mental Flow (cfs)	Other Supple-mental Flow (cfs)	Cumula-tive VAMP Supple-mental Flow (TAF)	VAMP Flow (cfs)	SJR above Merced R (2day lag) (cfs)	Ungaged Flow above Vernalis (cfs)	Existing Flow (cfs)	MeID VAMP Supple-mental Flow (cfs)	Exch Contr VAMP Supple-mental Flow (cfs)	VAMP Flow (3day lag) (cfs)	Existing Flow - base FERC volume (cfs)	Existing Flow - Adjusted FERC Pulse (cfs)	VAMP Supple-mental Flow (cfs)	VAMP Flow (2day lag) (cfs)	Existing Flow - Base (cfs)	Existing Flow - reshaped (cfs)	VAMP Supple-mental Flow (cfs)	Other Supple-mental Flow (cfs)	VAMP Flow (2day lag) (cfs)	Maintain Priority Flow Level M=Merced T=Tuol. S=Stan.
3/15/09	1,390				1,360	598	147	267			267	167	167		167	207	207			207	
3/16/09	1,380				1,350	613	157	264			264	168	168		168	204	204			204	
3/17/09	1,370				1,330	624	131	262			262	168	168		168	204	204			204	
3/18/09	1,300				1,300	609	48	261			261	168	168		168	205	205			205	
3/19/09	1,280				1,280	619	20	260			260	168	168		168	260	260			260	
3/20/09	1,230				1,230	606	-14	257			257	168	168		168	303	303			303	
3/21/09	1,240				1,240	584	-68	244			244	168	168		168	300	300			300	
3/22/09	1,260				1,260	586	-77	245			245	165	165		165	303	303			303	
3/23/09	1,260				1,260	585	-49	245			245	165	165		165	406	406			406	
3/24/09	1,190				1,190	547	-108	231			231	163	163		163	453	453			453	
3/25/09	1,140				1,140	522	-261	230			230	166	166		166	454	454			454	
3/26/09	1,110				1,110	518	-298	242			242	165	165		165	452	452			452	
3/27/09	1,100				1,100	497	-273	237			237	164	164		164	451	451			451	
3/28/09	1,100				1,100	494	-265	231			231	163	163		163	454	454			454	
3/29/09	1,090				1,090	494	-264	224			224	163	163		163	452	452			452	
3/30/09	1,130				1,130	469	-218	232			232	164	164		164	453	453			453	
3/31/09	1,120				1,120	433	-220	226			226	164	164		164	456	456			456	
4/1/09	1,060				1,060	388	-250	224			224	165	165		165	451	451			451	
4/2/09	1,050				1,050	363	-235	227			227	164	164		164	455	455			455	
4/3/09	1,070				1,070	375	-160	232			232	165	165		165	455	455			455	
4/4/09	1,060				1,060	355	-146	221			221	165	165		165	453	453			453	
4/5/09	1,080				1,080	351	-142	237			237	165	165		165	525	525			525	
4/6/09	1,070				1,070	333	-135	237			237	165	165		165	553	553			553	
4/7/09	1,060				1,060	367	-202	243			243	166	166		166	656	656			656	
4/8/09	1,100				1,100	338	-188	258			258	166	166		166	707	707			707	
4/9/09	1,180				1,180	329	-246	256			256	165	165		165	704	704			704	
4/10/09	1,250				1,250	334	-204	252			252	165	165		165	703	703			703	
4/11/09	1,280				1,280	333	-176	251			251	165	165		165	706	706			706	
4/12/09	1,370				1,370	338	-88	253			253	165	165		165	708	708			708	
4/13/09	1,370				1,370	371	-86	255			255	165	165		165	702	702			702	
4/14/09	1,320				1,320	391	-142	244			244	166	166		166	704	704			704	
4/15/09	1,391				1,391	380	-100	250			250	180	180		180	700	700			700	
4/16/09	1,416				1,416	376	-100	250	0	0	250	190	190		190	700	700			700	
4/17/09	1,404				1,404	372	-100	250	0	0	250	260	260	0	260	650	650	0	450	1,100	
4/18/09	1,416				1,416	368	-100	250	0	0	250	390	390	0	390	650	650	0	450	1,100	
4/19/09	1,432	0	450	0.00	1,882	364	-100	250	0	0	250	630	630	0	630	650	650	0	450	1,100	
4/20/09	1,558	0	450	0.00	2,008	360	-100	250	0	0	250	640	640	0	640	650	650	0	450	1,100	
4/21/09	1,794	0	450	0.00	2,244	356	-100	250	0	0	250	640	640	0	640	650	650	0	450	1,100	
4/22/09	1,800	0	450	0.00	2,250	352	-100	250	0	0	250	640	640	0	640	650	650	0	450	1,100	
4/23/09	1,796	0	450	0.00	2,246	348	-100	250	0	0	250	640	640	0	640	650	650	0	450	1,100	
4/24/09	1,792	0	450	0.00	2,242	344	-100	250	0	0	250	640	640	0	640	650	650	0	450	1,100	
4/25/09	1,788	0	450	0.00	2,238	340	-100	250	0	0	250	640	640	0	640	650	650	0	450	1,100	
4/26/09	1,784	0	450	0.00	2,234	336	-100	250	0	0	250	640	640	0	640	650	650	0	450	1,100	
4/27/09	1,780	0	450	0.00	2,230	332	-100	250	0	0	250	640	640	0	640	650	650	0	450	1,100	
4/28/09	1,776	0	450	0.00	2,226	328	-100	250	0	0	250	460	460	0	460	650	650	0	675	1,325	
4/29/09	1,772	0	450	0.00	2,222	324	-100	250	0	0	250	460	460	0	460	650	650	0	675	1,325	
4/30/09	1,588	0	675	0.00	2,263	320	-100	250	0	0	250	460	460	0	460	650	650	0	675	1,325	
5/1/09	1,584	0	675	0.00	2,259	316	-100	250	0	0	250	460	460	0	460	575	575	0	750	1,325	
5/2/09	1,580	0	675	0.00	2,255	312	-100	250	0	0	250	460	460	0	460	575	575	0	750	1,325	
5/3/09	1,501	0	750	0.00	2,251	308	-100	250	0	0	250	460	460	0	460	575	575	0	750	1,325	
5/4/09	1,497	0	750	0.00	2,247	304	-100	250	0	0	250	460	460	0	460	575	575	0	750	1,325	
5/5/09	1,493	0	750	0.00	2,243	300	-100	250	0	0	250	580	580	0	580	575	575	0	625	1,200	
5/6/09	1,489	0	750	0.00	2,239	296	-100	250	0	0	250	780	780	0	780	575	575	0	425	1,000	
5/7/09	1,605	0	625	0.00	2,230	292	-100	250	0	0	250	880	880	0	880	575	575	0	325	900	
5/8/09	1,801	0	425	0.00	2,226	288	-100	250	0	0	250	880	880	0	880	575	575	0	325	900	
5/9/09	1,897	0	325	0.00	2,222	284	-100	250	0	0	250	930	930	0	930	575	575	0	325	900	
5/10/09	1,893	0	325	0.00	2,218	280	-100	250	0	0	250	930	930	0	930	575	575	0	325	900	
5/11/09	1,939	0	325	0.00	2,264	276	-100	250	0	0	250	930	930	0	930	575	575	0	325	900	
5/12/09	1,935	0	325	0.00	2,260	272	-100	250	0	0	250	930	930	0	930	575	575	0	325	900	
5/13/09	1,931	0	325	0.00	2,256	268	-100	250	0	0	250	930	930	0	930	575	575	0	325	900	
5/14/09	1,927	0	325	0.00	2,252	264	-100	250	0	0	250	930	930	0	930	575	575	0	325	900	
5/15/09	1,923	0	325	0.00	2,248	260	-100	250	0	0	250	930	930	0	930	575	575	0	325	900	
5/16/09	1,919	0	325	0.00	2,244	256	-100	250	0	0	250	930	930	0	930	575	575	0	325	900	
5/17/09	1,915	0	325	0.00	2,240	252	-100	250			250	930	930	0	930	575	575	0	325	900	
5/18/09	1,911	0	325	0.00	2,236	248	-100	250			250	880	880		880	575	575			575	
5/19/09	1,907	0	325	0.00	2,232	244	-100	250			250	880	880		880	575	575			575	
5/20/09	1,853				1,853	240	-100	250			250	830	830		830	575	575			575	
5/21/09	1,849				1,849	236	-100	250			250	680	680		680	575	575			575	
5/22/09	1,795				1,795	232	-100	250			250	580	580		580	575	575			575	
5/23/09	1,641				1,641	228	-100	250			250	480	480		480	575	575			575	
5/24/09	1,537				1,537	224	-100	250			250	480	480		480	575	575			575	
5/25/09	1,433				1,433	220	-100	250			250	380	380		380	575	575			575	
5/26/09	1,429				1,429	216	-100	250			250	380	380		380	575	575			575	
5/27/09	1,325				1,325	212	-100	250			250	380	380		380	575	575			575	
5/28/09	1,321				1,321	208	-100	250			250	305	305		305	575	575			575	
5/29/09	1,317				1,317	204	-100	250			250	305	305		305	575	575			575	
5/30/09	1,238				1,238	200	-100	250			250	265	265		265	575	575			575	
5/31/09	1,234				1,234	196	-100	250			250	265	265		265	575	575			575	
VAMP Period																					
Avg. (cfs):	1,752	0	471		2,223	312	-100	250	0	0	250	681	681	0	681	609	609	0	471	1,080	
Supple-mental Water (TAF):		0.00	28.96						0.00	0.00				0.00				0.00	28.96		

VAMP flow operation period

Appendix A-1, Table 4

2009 VAMP DAILY OPERATION PLAN — MAY 13, 2009

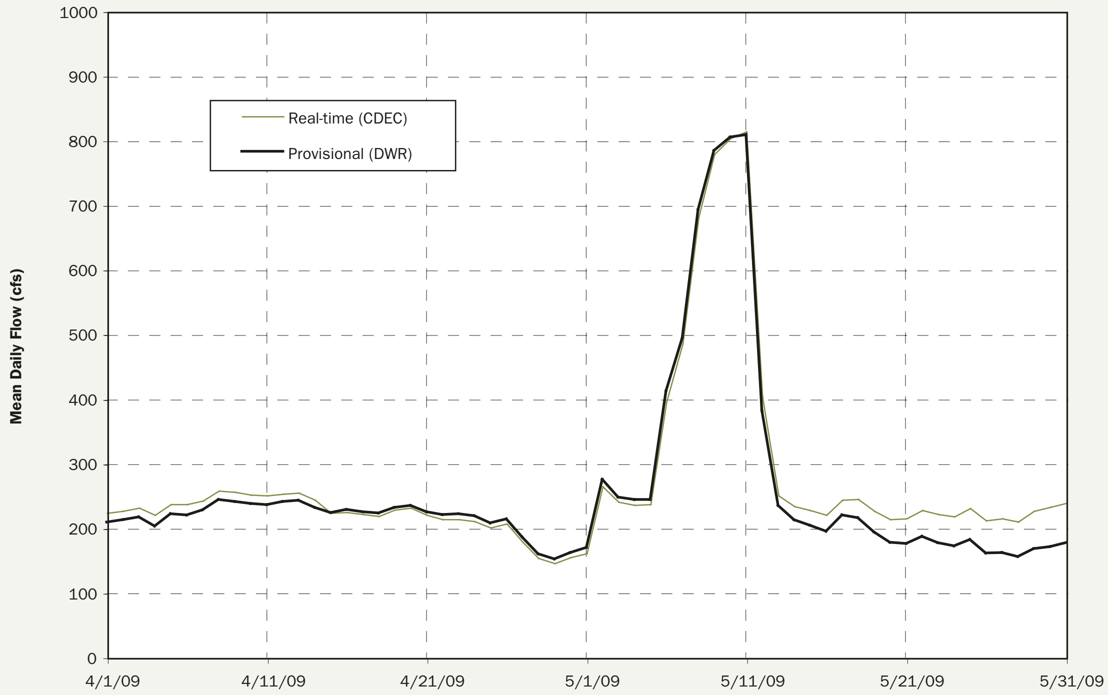
Target Flow Period: April 19th – May 19th * Flow Target: N/A

Bold Numbers: observed real-time mean daily flows

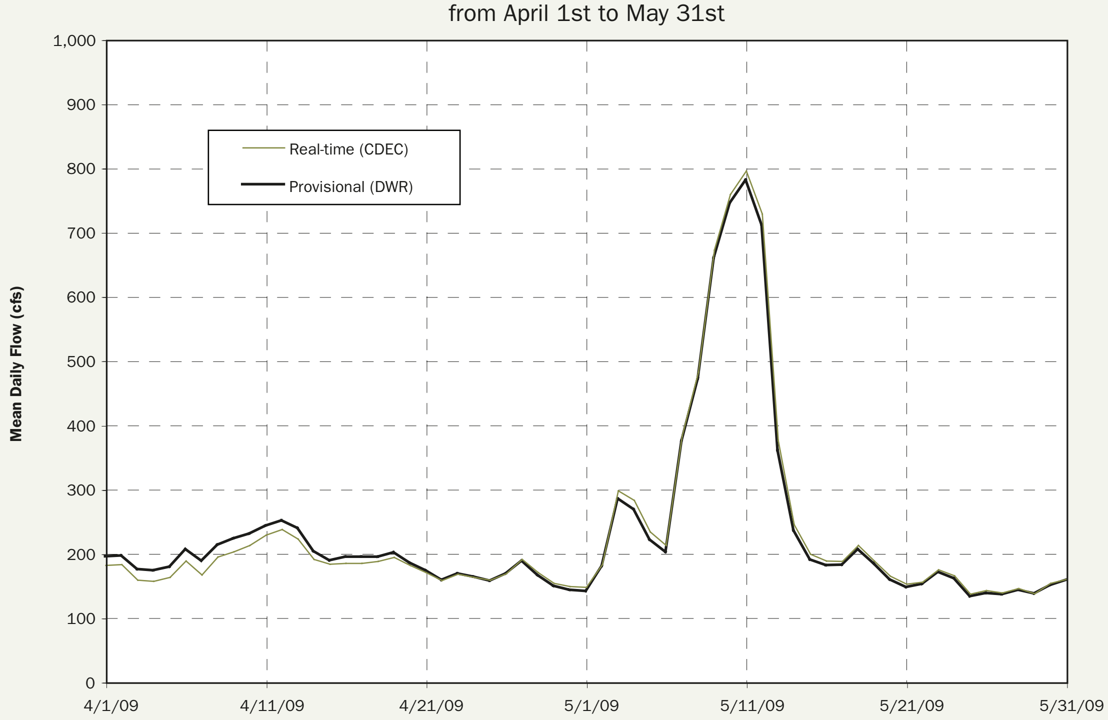
	San Joaquin River near Vernalis							Merced River at Cressey				Tuolumne River at LaGrange				Stanislaus R blw Goodwin					
Date	Existing Flow (cfs)	VAMP Supple-mental Flow (cfs)	Other Supple-mental Flow (cfs)	Cumula-tive VAMP Supple-mental Flow (TAF)	VAMP Flow (cfs)	SJR above Merced R (2day lag) (cfs)	Ungaged Flow above Vernalis (cfs)	Existing Flow (cfs)	MeID VAMP Supple-mental Flow (cfs)	Exch Contr VAMP Supple-mental Flow (cfs)	VAMP Flow (3day lag) (cfs)	Existing Flow - base FERC volume (cfs)	Existing Flow - Adjusted FERC Pulse (cfs)	VAMP Supple-mental Flow (cfs)	VAMP Flow (2day lag) (cfs)	Existing Flow - Base (cfs)	Existing Flow - reshaped (cfs)	VAMP Supple-mental Flow (cfs)	Other Supple-mental Flow (cfs)	VAMP Flow (2day lag) (cfs)	Maintain Priority Flow Level M=Merced T=Tuol. S=Stan.
3/15/09	1,390				1,390	579	163	267			267	167	167		169	207	207			207	
3/16/09	1,380				1,380	594	173	264			264	168	168		170	204	204			204	
3/17/09	1,370				1,370	605	148	262			262	168	168		170	204	204			204	
3/18/09	1,300				1,300	590	65	261			261	168	168		170	205	205			205	
3/19/09	1,280				1,280	601	37	260			260	168	168		170	260	260			260	
3/20/09	1,230				1,230	587	3	257			257	168	168		170	303	303			303	
3/21/09	1,240				1,240	566	-52	244			244	168	168		170	300	300			300	
3/22/09	1,260				1,260	567	-60	245			245	165	165		167	303	303			303	
3/23/09	1,260				1,260	567	-33	245			245	165	165		167	406	406			406	
3/24/09	1,190				1,190	530	-91	231			231	163	163		165	453	453			453	
3/25/09	1,140				1,140	505	-245	230			230	166	166		168	454	454			454	
3/26/09	1,110				1,110	501	-283	242			242	165	165		167	452	452			452	
3/27/09	1,100				1,100	480	-258	237			237	164	164		166	451	451			451	
3/28/09	1,100				1,100	478	-250	231			231	163	163		165	454	454			454	
3/29/09	1,090				1,090	477	-249	224			224	163	163		165	452	452			452	
3/30/09	1,130				1,130	453	-204	232			232	164	164		173	453	453			453	
3/31/09	1,120				1,120	418	-205	226			226	164	164		167	456	456			456	
4/1/09	1,060				1,060	373	-243	224			224	165	165		165	451	451			451	
4/2/09	1,050				1,050	348	-223	227			227	164	164		164	455	455			455	
4/3/09	1,070				1,070	360	-145	232			232	165	165		165	455	455			455	
4/4/09	1,060				1,060	341	-131	221			221	165	165		165	453	453			453	
4/5/09	1,080				1,080	337	-127	237			237	165	165		165	525	525			525	
4/6/09	1,070				1,070	319	-121	237			237	165	165		165	553	553			553	
4/7/09	1,060				1,060	352	-188	243			243	166	166		166	656	656			656	
4/8/09	1,100				1,100	323	-174	258			258	166	166		166	707	707			707	
4/9/09	1,180				1,180	314	-231	256			256	165	165		165	704	704			704	
4/10/09	1,250				1,250	320	-189	252			252	165	165		165	703	703			703	
4/11/09	1,280				1,280	318	-161	251			251	165	165		165	706	706			706	
4/12/09	1,370				1,370	323	-74	253			253	165	165		165	708	708			708	
4/13/09	1,370				1,370	355	-71	255			255	165	165		165	702	702			702	
4/14/09	1,320				1,320	376	-127	244			244	166	166		166	704	704			704	
4/15/09	1,300				1,300	370	-175	224			224	186	186		186	702	702			702	
4/16/09	1,300				1,300	372	-201	225	0	0	225	234	234		234	703	703			703	
4/17/09	1,310				1,310	373	-192	222	0	0	222	260	340	0	340	650	650	0	350	1,000	
4/18/09	1,320				1,320	335	-213	219	0	0	219	390	524	0	524	650	650	0	550	1,200	
4/19/09	1,210	0	350	0.00	1,560	304	-378	229	0	0	229	630	674	0	674	650	650	0	558	1,208	
4/20/09	1,260	0	550	0.00	1,810	303	-471	232	0	0	232	640	681	0	681	650	650	0	490	1,140	
4/21/09	1,362	0	558	0.00	1,920	286	-485	221	0	0	221	640	680	0	680	650	650	0	454	1,104	
4/22/09	1,440	0	490	0.00	1,930	271	-423	214	0	0	214	640	680	0	680	650	650	0	458	1,108	
4/23/09	1,406	0	454	0.00	1,860	263	-442	214	0	0	214	640	679	0	679	650	650	0	450	1,100	
4/24/09	1,462	0	458	0.00	1,920	260	-360	211	0	0	211	640	675	0	675	650	650	0	452	1,102	
4/25/09	1,480	0	450	0.00	1,930	252	-326	201	0	0	201	640	670	0	670	650	650	0	456	1,106	
4/26/09	1,568	0	452	0.00	2,020	241	-231	207	0	0	207	640	671	0	671	650	650	0	449	1,099	
4/27/09	1,594	0	456	0.00	2,050	240	-189	179	0	0	179	640	630	0	630	650	650	0	461	1,111	
4/28/09	1,591	0	449	0.00	2,040	237	-172	154	0	0	154	460	510	0	510	650	650	0	589	1,239	
4/29/09	1,559	0	461	0.00	2,020	242	-168	146	0	0	146	460	482	0	482	650	650	0	652	1,302	
4/30/09	1,381	0	589	0.00	1,970	254	-195	155	0	0	155	460	483	0	483	650	650	0	653	1,303	
5/1/09	1,388	0	652	0.00	2,040	261	-140	161	0	0	161	460	484	0	484	575	575	0	733	1,308	
5/2/09	1,527	0	653	0.00	2,180	257	-6	265	0	0	265	460	483	0	483	575	575	0	735	1,310	
5/3/09	1,547	0	733	0.00	2,280	230	72	241	0	0	241	460	482	0	482	575	575	0	730	1,305	
5/4/09	1,545	0	735	0.00	2,280	291	69	236	0	0	236	460	526	0	526	575	575	0	737	1,312	
5/5/09	1,520	0	730	0.00	2,250	324	-32	237	0	0	237	580	679	0	679	575	575	0	668	1,243	
5/6/09	1,493	0	737	0.00	2,230	329	-140	396	0	0	396	780	838	0	838	575	575	0	498	1,073	
5/7/09	1,542	0	668	0.00	2,210	233	-272	486	0	0	486	880	900	0	900	575	575	0	369	944	
5/8/09	1,702	0	498	0.00	2,200	204	-277	681	0	0	681	880	918	0	918	575	575	0	329	904	
5/9/09	1,901	0	369	0.00	2,270	126	-203	779	0	0	779	930	955	0	955	575	575	0	334	909	
5/10/09	1,991	0	329	0.00	2,320	108	-192	804	0	0	804	930	951	0	951	575	575	0	330	905	
5/11/09	2,046	0	334	0.00	2,380	109	-291	814	0	0	814	930	951	0	951	575	575	0	327	902	
5/12/09	2,070	0	330	0.00	2,400	168	-343	404	0	0	404	930	951	0	951	575	575	0	325	900	
5/13/09	2,089	0	327	0.00	2,416	164	-350	250	0	0	250	930	930	0	930	575	575	0	325	900	
5/14/09	2,158	0	325	0.00	2,483	160	-350	250	0	0	250	930	930	0	930	575	575	0	325	900	
5/15/09	1,723	0	325	0.00	2,048	156	-350	250	0	0	250	930	930	0	930	575	575	0	325	900	
5/16/09	1,565	0	325	0.00	1,890	152	-350	250	0	0	250	930	930	0	930	575	575	0	325	900	
5/17/09	1,561	0	325	0.00	1,886	148	-350	250			250	930	930	0	930	575	575	0	325	900	
5/18/09	1,557	0	325	0.00	1,882	144	-350	250			250	880	880		880	575	575			575	
5/19/09	1,553	0	325	0.00	1,878	140	-350	250			250	880	880		880	575	575			575	
5/20/09	1,649				1,649	136	-200	250			250	830	830		830	575	575			575	
5/21/09	1,745				1,745	132	-100	250			250	680	680		680	575	575			575	
5/22/09	1,691				1,691	128	-100	250			250	580	580		580	575	575			575	
5/23/09	1,537				1,537	124	-100	250			250	480	480		480	575	575			575	
5/24/09	1,433				1,433	120	-100	250			250	480	480		480	575	575			575	
5/25/09	1,329				1,329	116	-100	250			250	380	380		380	575	575			575	
5/26/09	1,325				1,325	112	-100	250			250	380	380		380	575	575			575	
5/27/09	1,221				1,221	108	-100	250			250	380	380		380	575	575			575	
5/28/09	1,217				1,217	104	-100	250			250	305	305		305	575	575			575	
5/29/09	1,213				1,213	100	-100	250			250	305	305		305	575	575			575	
5/30/09	1,134				1,134	96	-100	250			250	265	265		265	575	575			575	
5/31/09	1,130				1,130	92	-100	250			250	265	265		265	575	575			575	
VAMP Period																					
Avg. (cfs):	1,606	0	476		2,082	235	-260	308	0	0	308	681	714	0	714	609	609	0	476	1,085	
Supple-mental Water (TAF):		0.00	29.28						0.00	0.00				0.00				0.00	29.28		

VAMP flow operation period

Appendix A-2, Figure 1
Mean Daily Flow in the Merced River at Cressey in Cubic Feet per Second (cfs)
from April 1st to May 31st

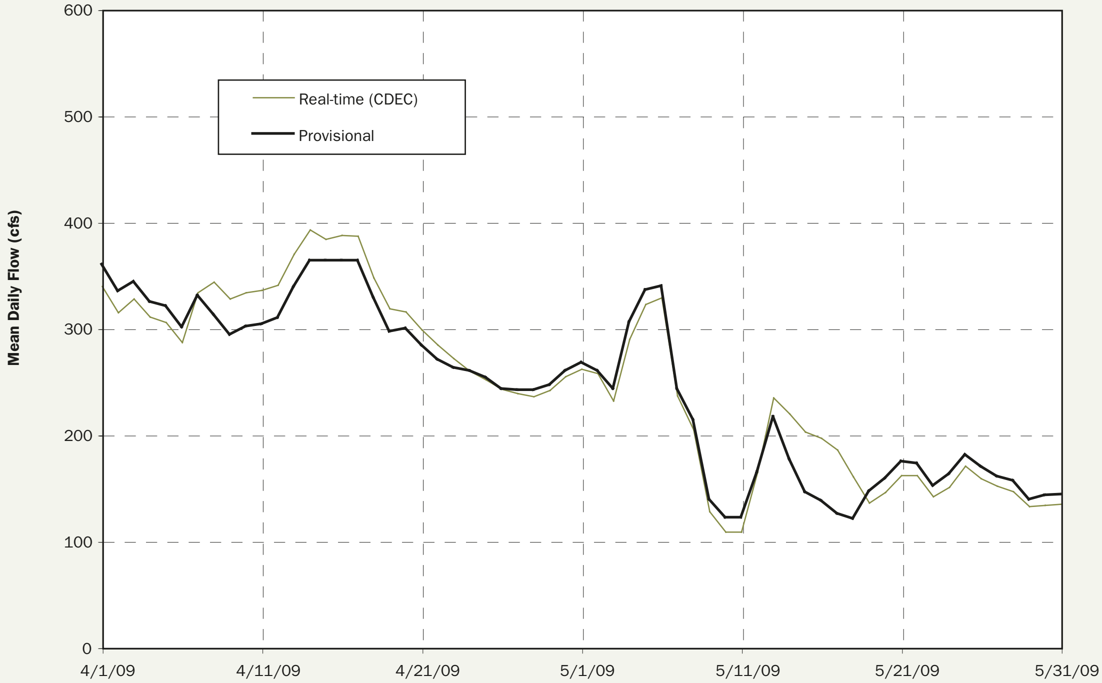


Appendix A-2, Figure 2
Mean Daily Flow in the Merced River at Stevinson in Cubic Feet per Second (cfs)
from April 1st to May 31st



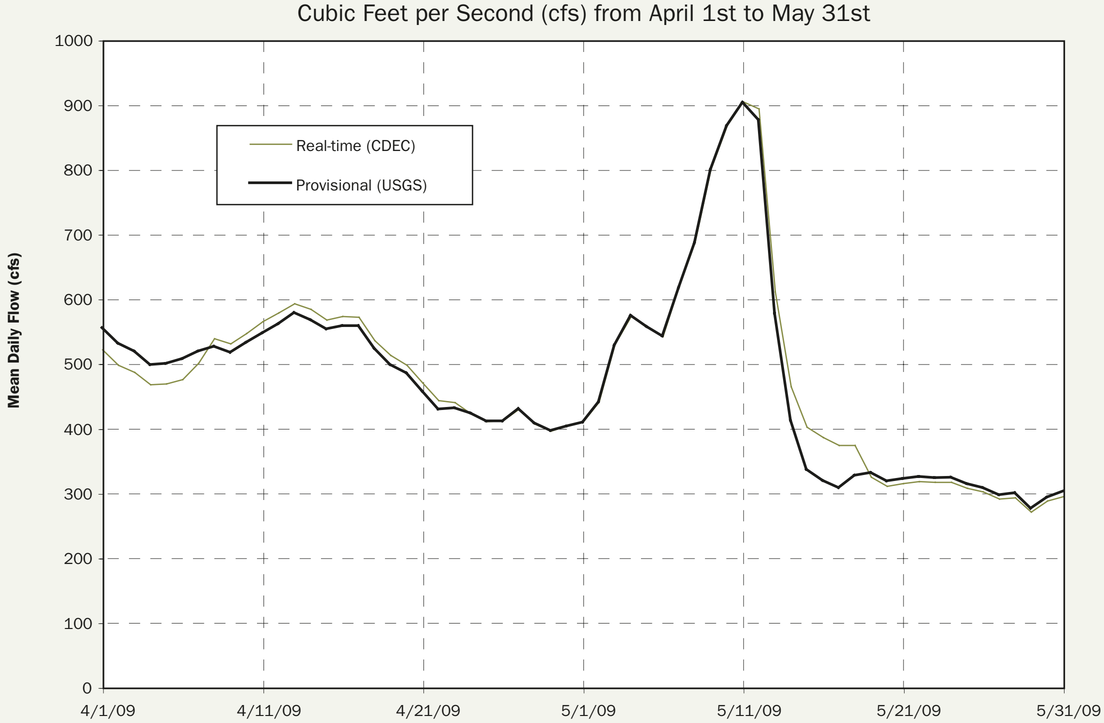
Appendix A-2, Figure 3

Mean Daily Flow in the San Joaquin River above the Merced River Inflow in Cubic Feet per Second (cfs) from April 1st to May 31st



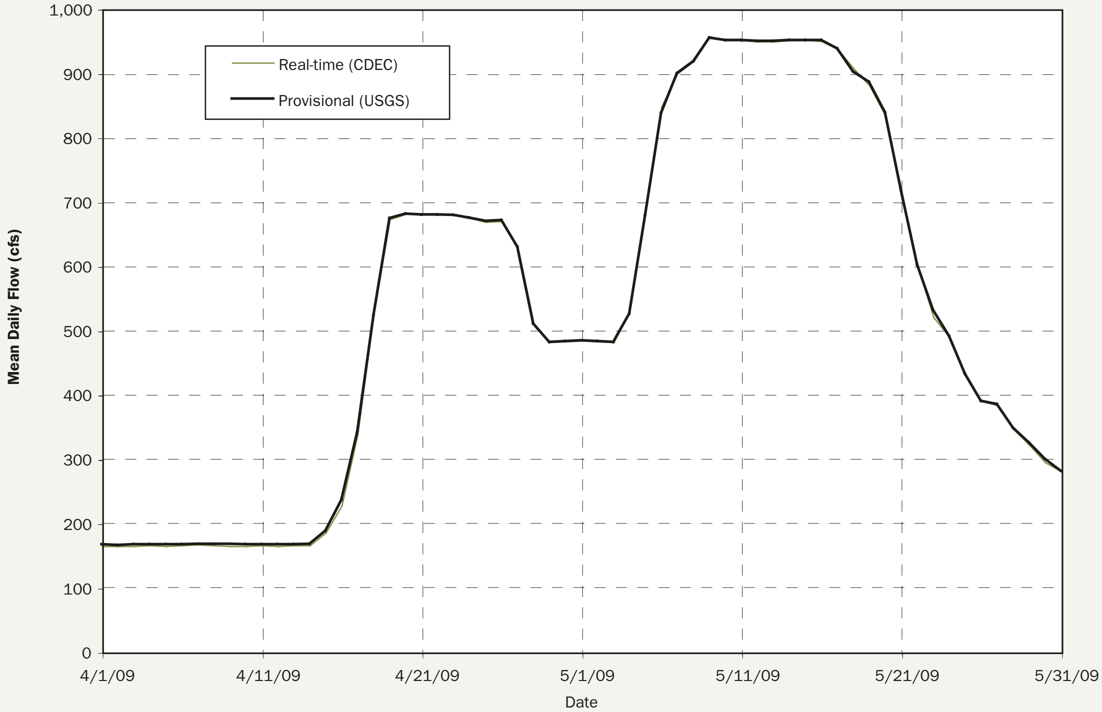
Appendix A-2, Figure 4

Mean Daily Flow in the San Joaquin River below the Merced River Inflow near Newman in Cubic Feet per Second (cfs) from April 1st to May 31st



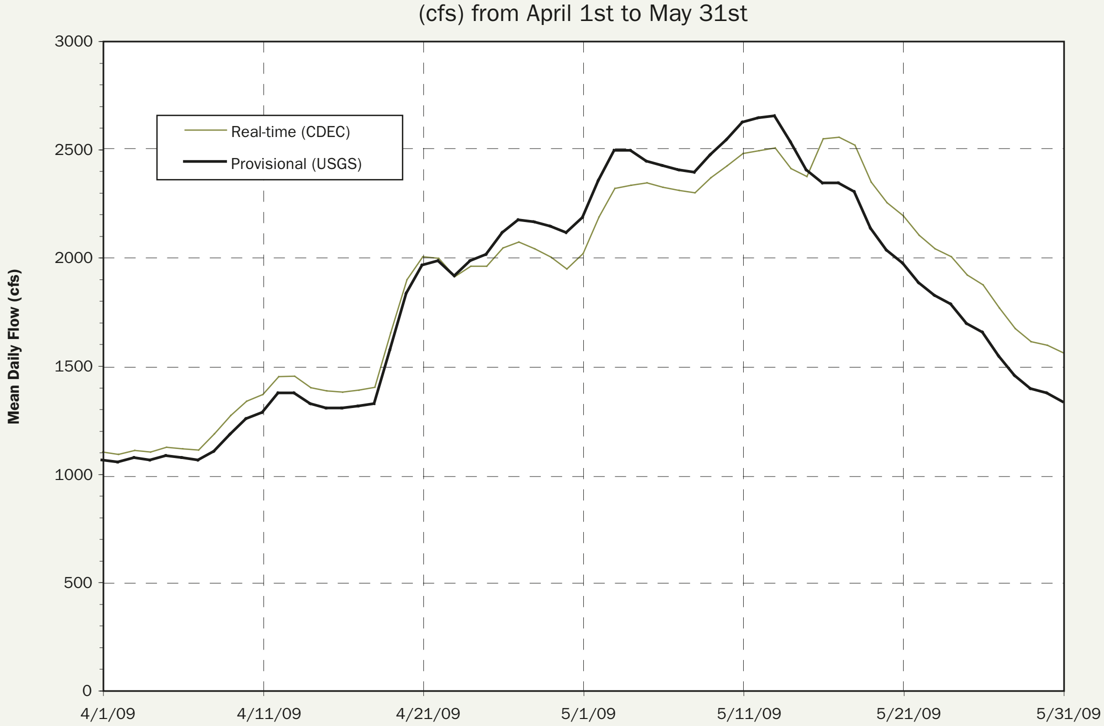
Appendix A-2, Figure 5

Mean Daily Flow in the Tuolumne River below La Grange Dam in Cubic Feet per Second (cfs) from April 1st to May 31st



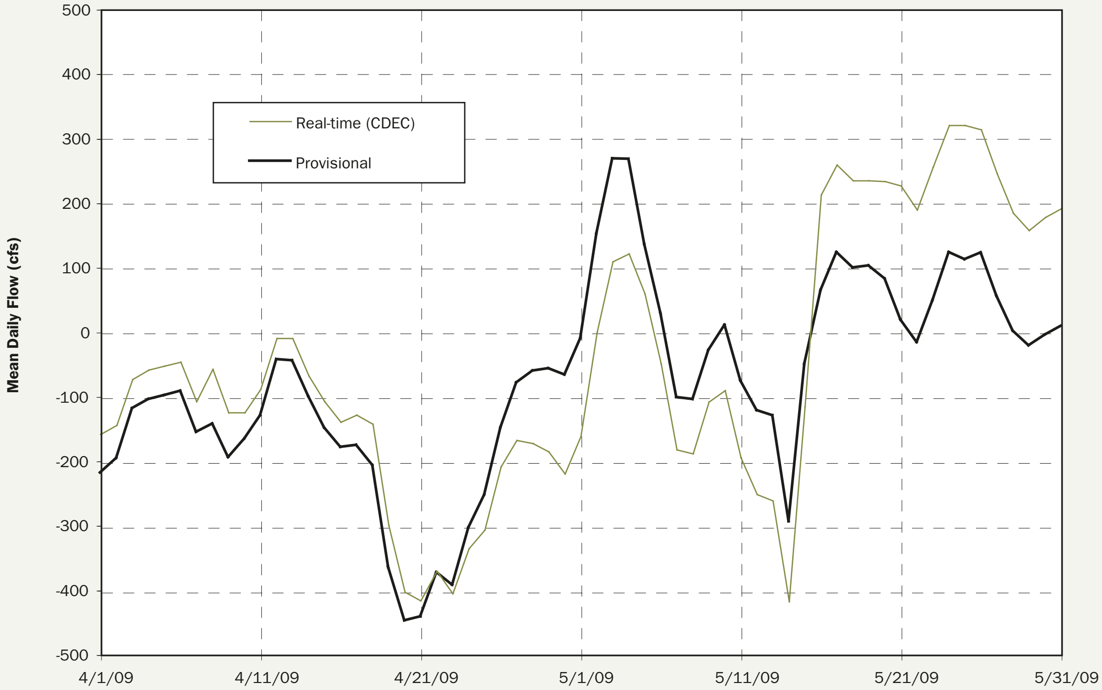
Appendix A-2, Figure 6

Mean Daily Flow in the San Joaquin River near Vernalis (VNS) in Cubic Feet per Second (cfs) from April 1st to May 31st



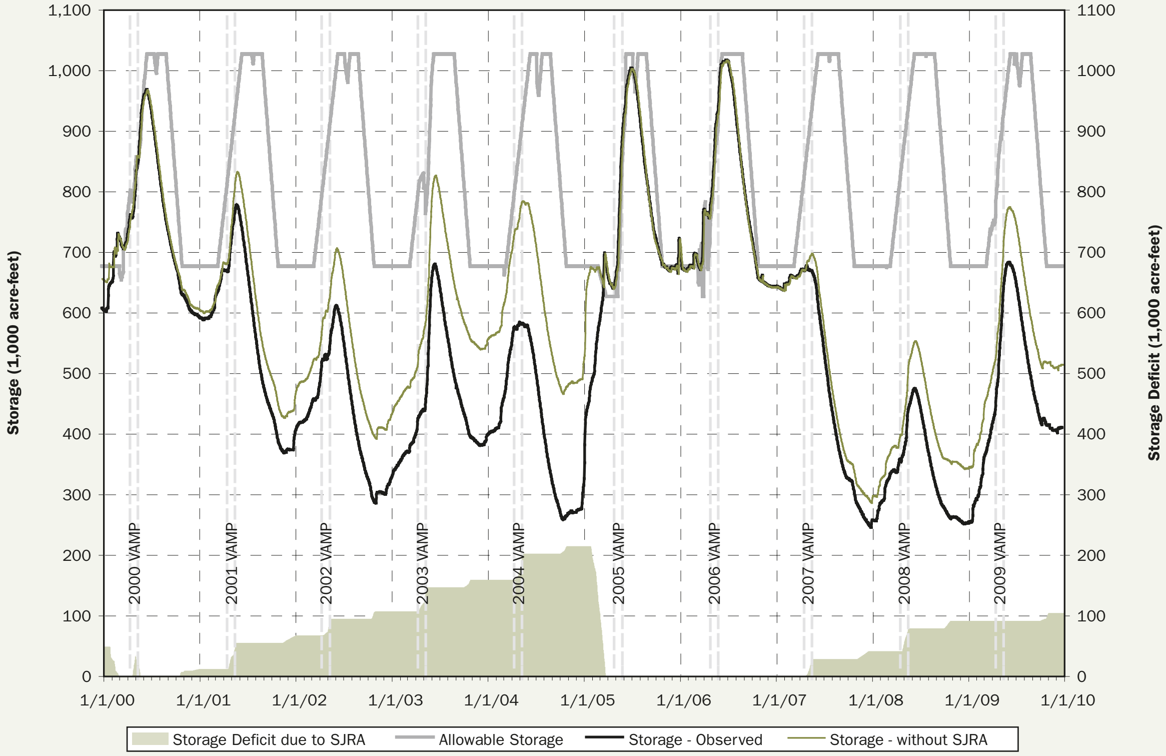
Appendix A-2, Figure 7

Mean Daily Ungaged Flow in the San Joaquin River near Vernalis (VNS) in Cubic Feet per Second (cfs) from April 1st to May 31st

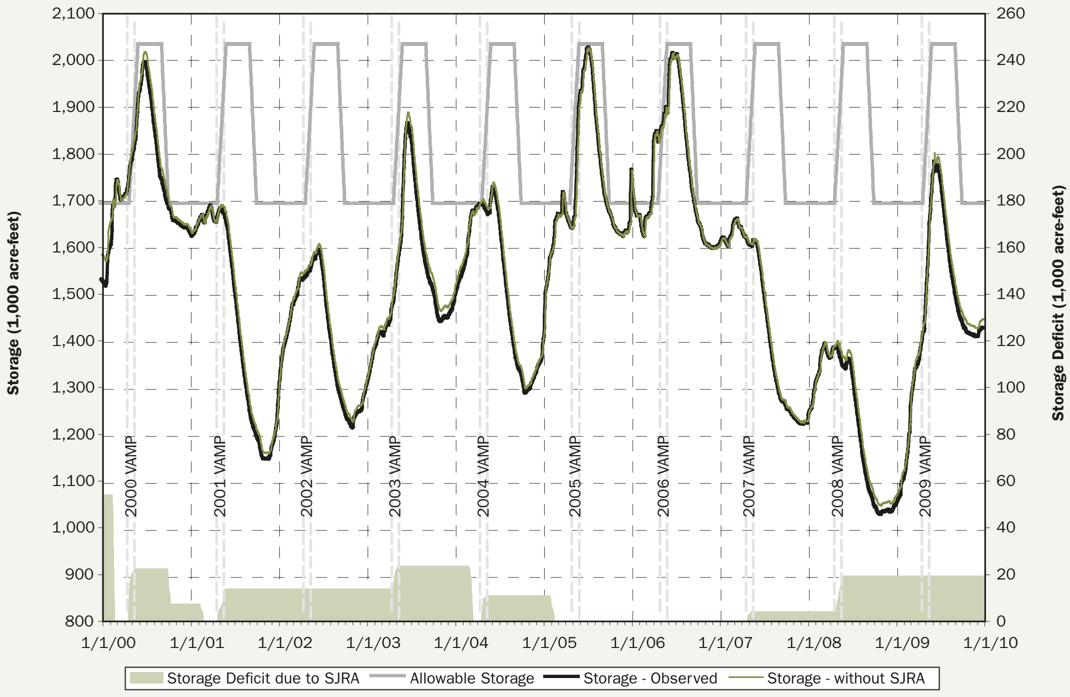


APPENDIX B

Appendix B, Figure 1
San Joaquin River Agreement (SJRA) Storage Impacts in Acre-Feet on Lake McClure (Merced River) from 2000-2009

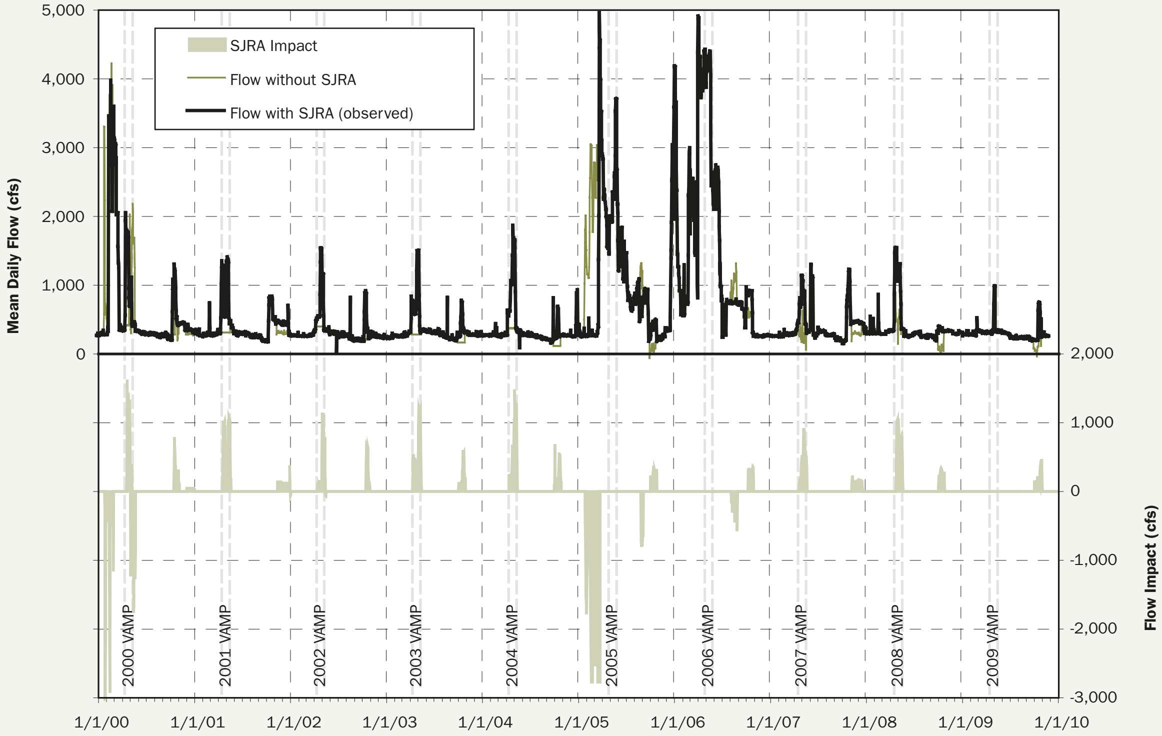


Appendix B, Figure 2
San Joaquin River Agreement (SJRA) Storage Impacts in Acre-Feet on Don Pedro Reservoir (Tuolumne River) from 2000-2009



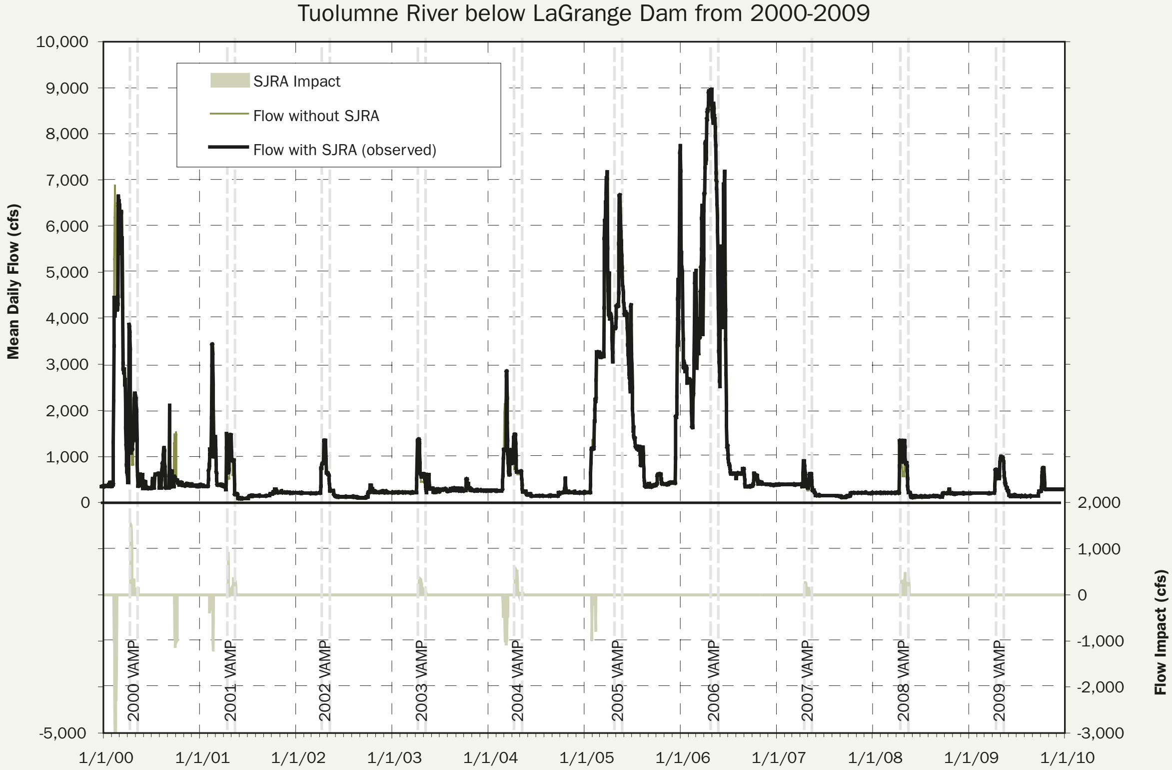
Appendix B, Figure 3

San Joaquin River Agreement (SJRA) Flow Impacts in Cubic Feet per Second (cfs) on the Merced River below Crocker-Huffman Dam from 2000-2009



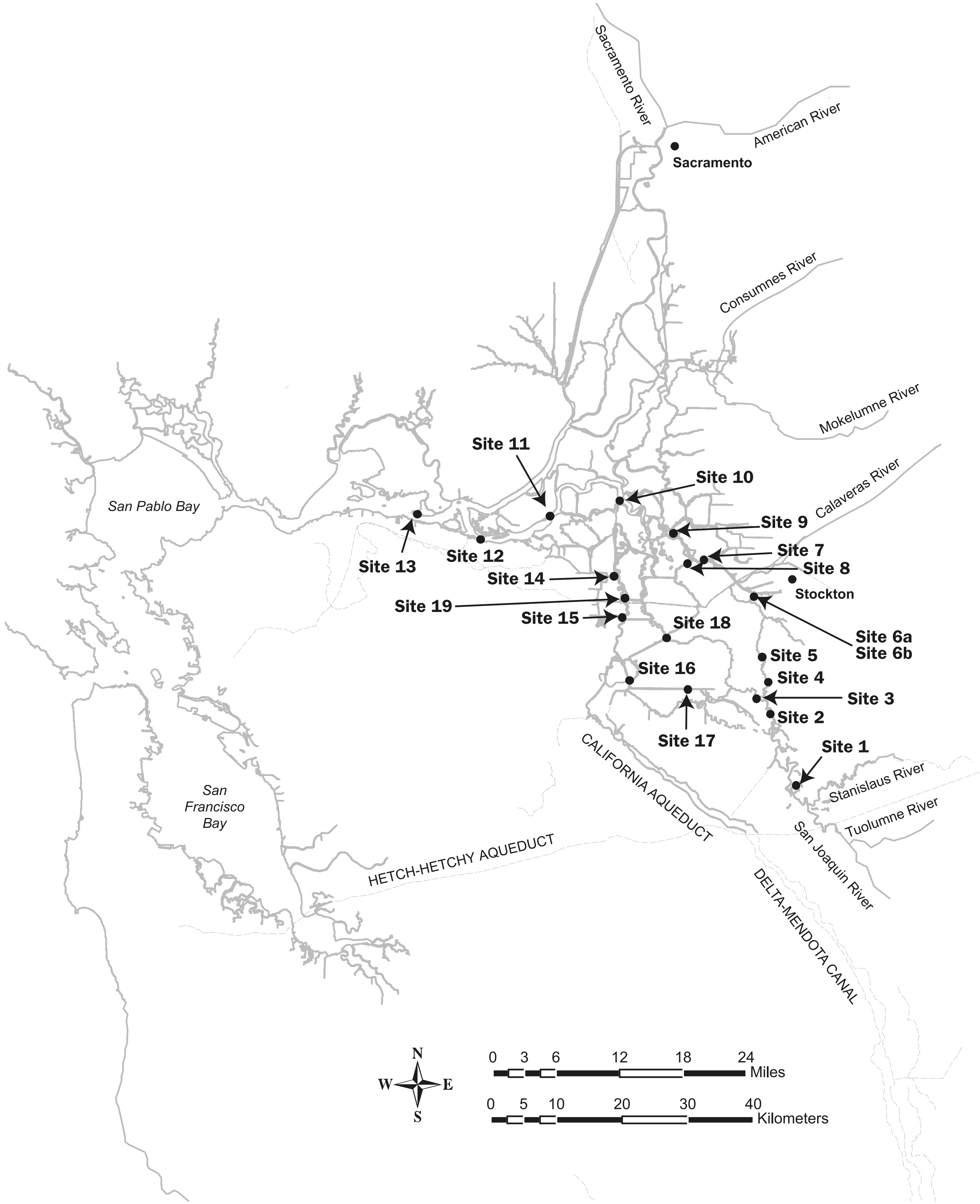
Appendix B, Figure 4

San Joaquin River Agreement (SJRA) Flow Impacts in Cubic Feet per Second (cfs) on the Tuolumne River below LaGrange Dam from 2000-2009



APPENDIX C

Figure C-1
Overview of Water Temperature Monitoring Locations in the Lower San Joaquin River and Delta as Part of the 2009 Vernalis Adaptive Management Program (VAMP)



Appendix C-1
Site Descriptions for Water Temperature Monitoring Locations in the San Joaquin River and Delta as Part of the 2009 Vernalis Adaptive Management Program (VAMP)

Site #	Logger Number	Temperature Monitoring Location	Lat	Long	Date Deployed	Date Retrieved
A	1293972	Merced River Fish Hatchery Raceway - 1	n/a	n/a	not deployed	not deployed
B	1293988	Merced River Fish Hatchery Raceway - 2	N/A	N/A	not deployed	not deployed
1	1259798	Durham Ferry	N 37 41.263	W 121 15.609	4/3/09	6/16/09
2	1259808	Mossdale	N 37 47.142	W 121 18.383	4/3/09	6/16/09
3	1259797	Old River at HORB	N 37 48.633	W 121 19.232	4/3/09	6/16/09
4	1284085	Dos Reis	N 37 49.956	W 121 18.791	4/3/09	6/16/09
5	1259804	DWR Monitoring Station at Lathrop	N 37 51.874	W 121 19.388	4/3/09	6/16/09
6a	1293979	Confluence – Top	N 37 56.817	W 121 20.293	4/3/09	6/16/09
6b	1259806	Confluence-Bottom	N 37 56.817	W 121 20.293	4/3/09	6/16/09
7	1293991	Upstream of Channel Marker 33	N 37 59.682	W 121 24.699	4/3/09	6/16/09
8	1292416	Turner Cut (Channel Marker 21-22)	N 38 00.339	W121 27.095	4/3/09	6/16/09
9	1259807	1/2 mile upstream of Channel Marker 13 (“Q” Piling)	N 38 01.949	W 121 28.770	4/3/09	6/16/09
10	1259796	All Pro abandoned boat	N 38 04.497	W 121 34.399	4/3/09	6/16/09
11	1293973	USGS Gaging Station at Jersey Point	N 38 03.177	W121 41.623	4/3/09	6/16/09
12	1293995	Antioch Marina	N 38 01.370	W121 48.689	4/3/09	6/16/09
13	1284083	Chipps Island	N 38 03.011	W 121 55.038	4/3/09	6/16/09
14	1271938	Holland Riverside Marina	N 37 58.324	W 121 34.900	4/3/09	6/16/09
15	1027504	Old River and Indian Slough Confluence	N 37 54.985	W 121 34.038	4/3/09	6/16/09
16	1292420	CCF Radial Gates	N 37 49.898	W 121 33.238	4/3/09	6/16/09
17	1293975	Grant Line Canal at Tracy Blvd. Bridge	N 37 49.194	W 121 26.988	4/3/09	logger malfunction
18	1292418	Union Point	N37 53.427	W121 29.359	4/3/09	6/16/09
19	1027502	Werner Cut (Channel above Woodward Isle)	N 37 56.381	W 121 32.467	4/3/09	6/16/09

Figure C-2
Daily Water Temperature Fluctuations (°C) in the San Joaquin River at Durham Ferry During the 2009 Vernalis Adaptive Management Program (VAMP)

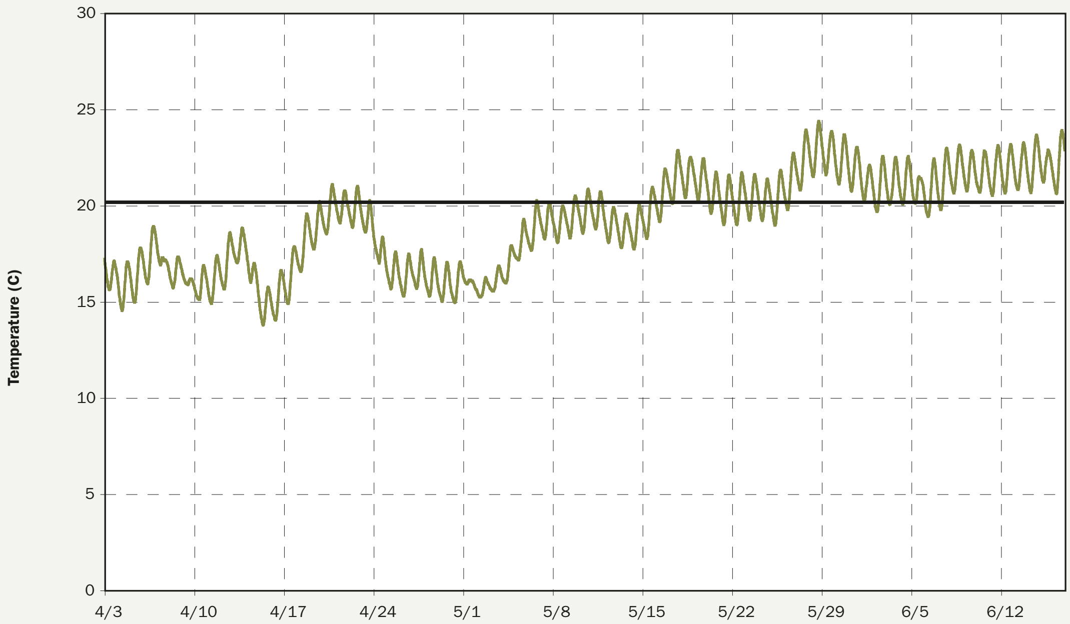


Figure C-3
Daily Water Temperature Fluctuations (°C) in the San Joaquin River at Mossdale Bridge During the 2009 Vernalis Adaptive Management Program (VAMP)

Figure C-4
Daily Water Temperature Fluctuations (°C) in Old River at the Head of Old River Barrier
During the 2009 Vernalis Adaptive Management Program (VAMP)

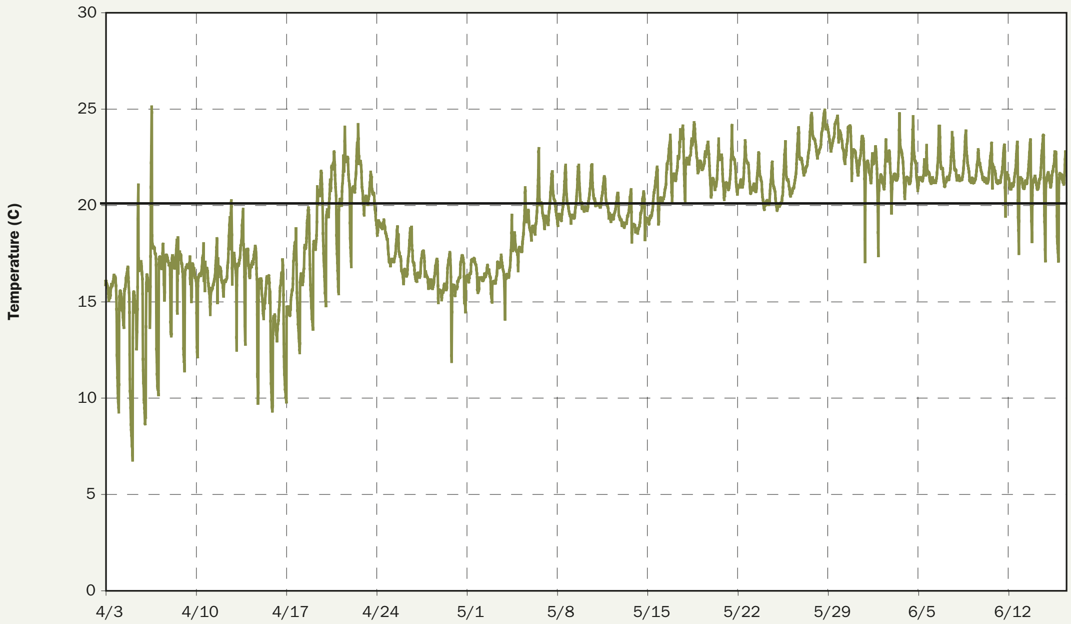


Figure C-5
Daily Water Temperature Fluctuations (°C) in the San Joaquin River at Dos Reis County Park
During the 2009 Vernalis Adaptive Management Program (VAMP)

Figure C-6
Daily Water Temperature Fluctuations (°C) in the San Joaquin River at the DWR Flow Monitoring Station Near Lathrop During the 2009 Vernalis Adaptive Management Program (VAMP)

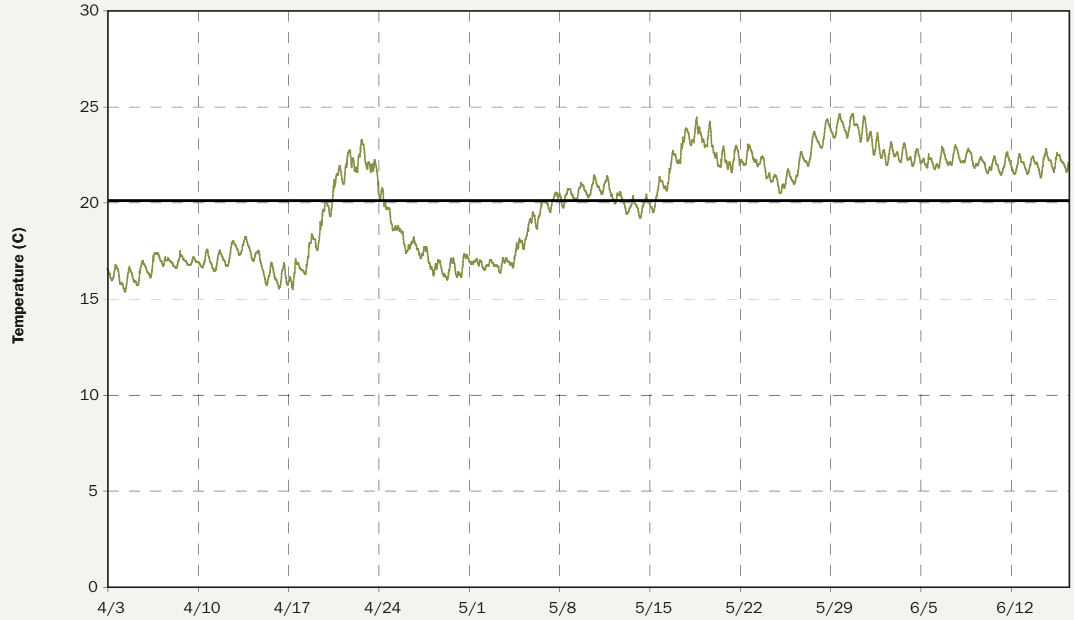


Figure C-7
Daily Water Temperature Fluctuations (°C) in the San Joaquin River at the Top of the Confluence Near Stockton During the 2009 Vernalis Adaptive Management Program (VAMP)

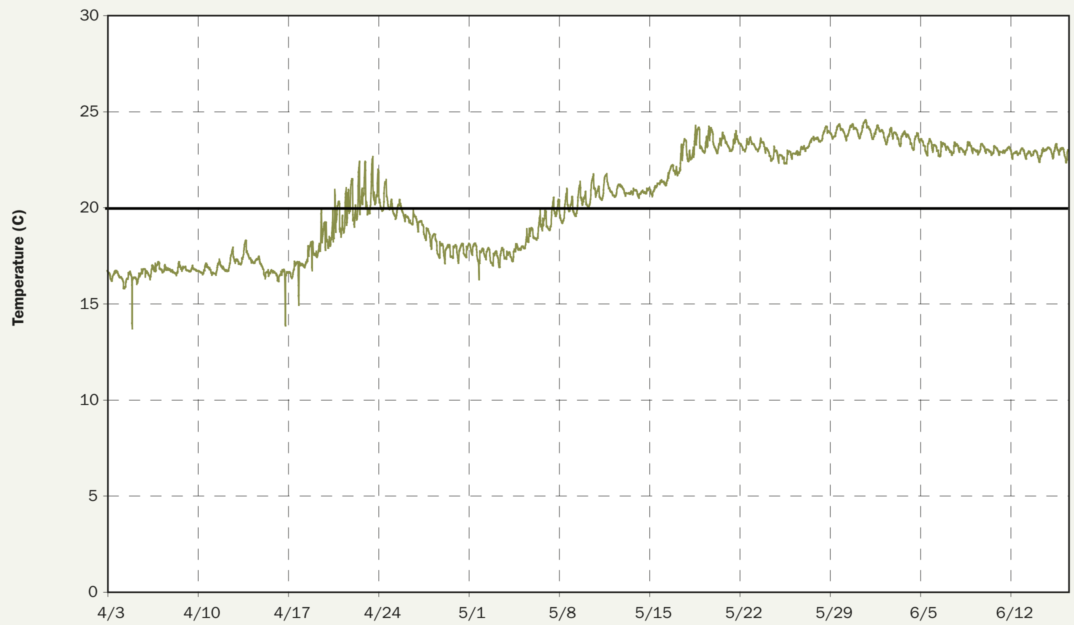


Figure C-8
Daily Water Temperature Fluctuations (°C) in the San Joaquin River at the Bottom of the Confluence Near Stockton During the 2009 Vernalis Adaptive Management Program (VAMP)

Figure C-9
Daily Water Temperature Fluctuations (°C) in the San Joaquin River Upstream of Channel Marker No 33 During the 2009 Vernalis Adaptive Management Program (VAMP)

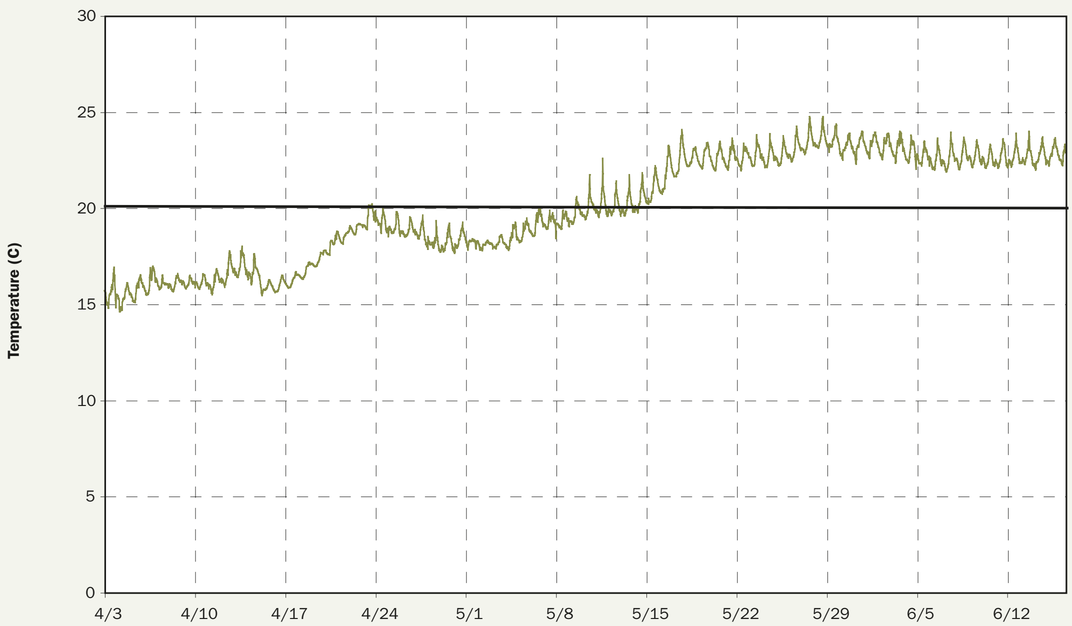


Figure C-10
Daily Water Temperature Fluctuations (°C) in the San Joaquin River at Turner Cut During the 2009 Vernalis Adaptive Management Program (VAMP)

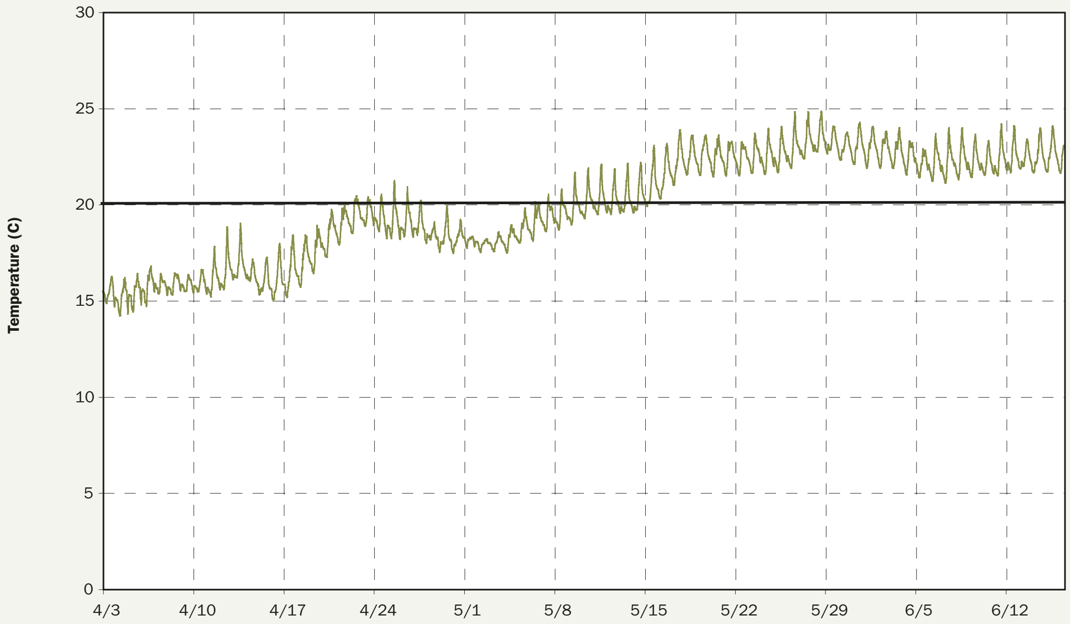


Figure C-11
Daily Water Temperature Fluctuations (°C) in the San Joaquin River ½ Mile Upstream of Channel Marker No 13 During the 2009 Vernalis Adaptive Management Program (VAMP)

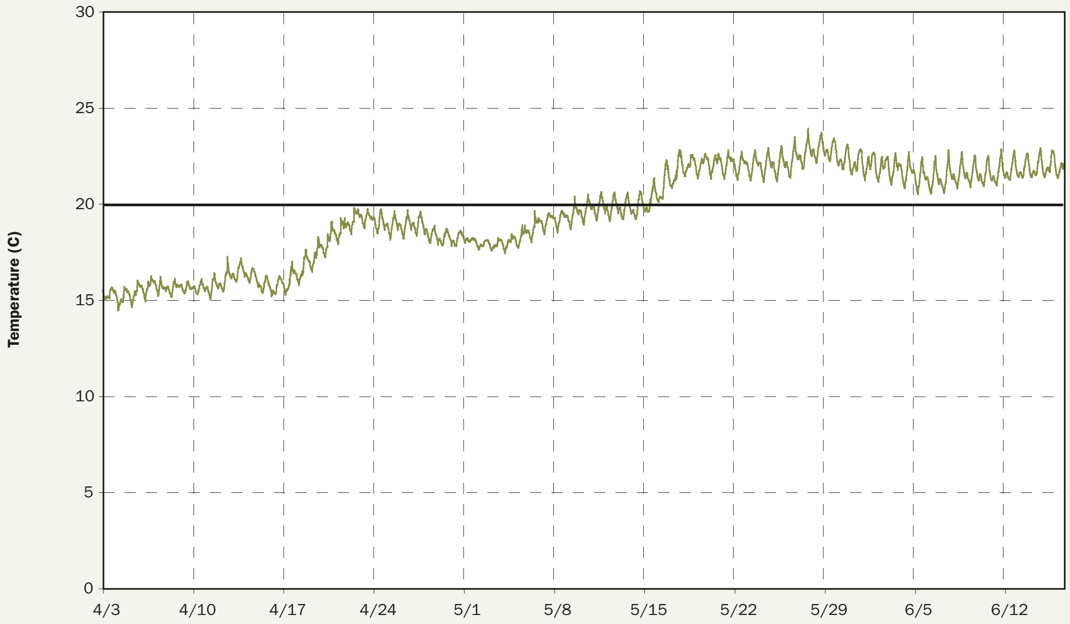


Figure C-12
Daily Water Temperature Fluctuations (°C) in the San Joaquin River at the All Pro Abandoned Boat During the 2009 Vernalis Adaptive Management Program (VAMP)

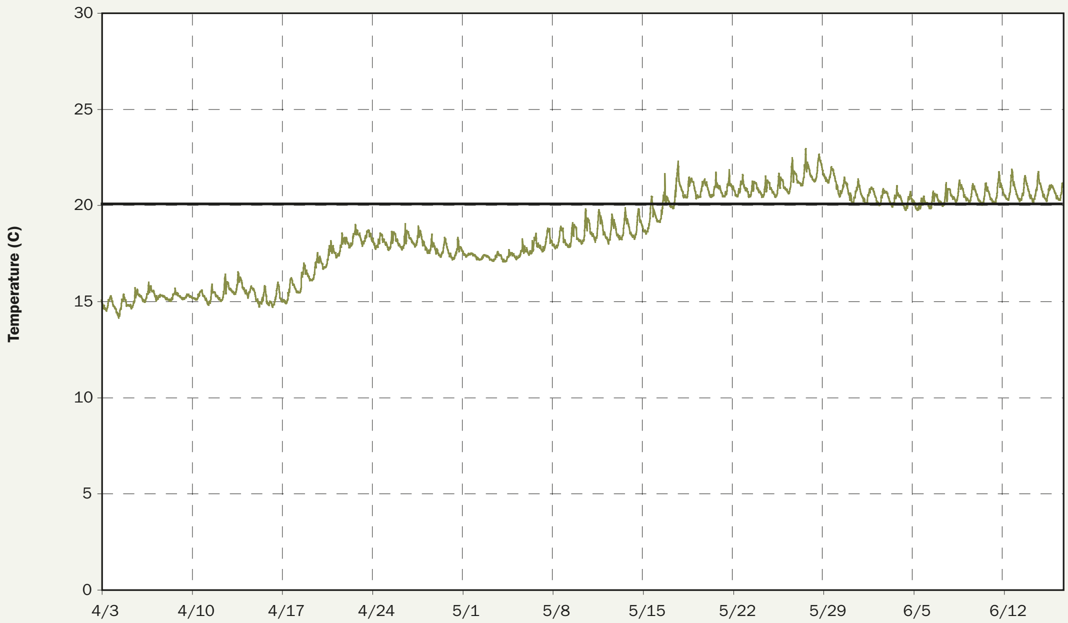


Figure C-13
Daily Water Temperature Fluctuations (°C) in the San Joaquin River at the USGS Gauging Station at Jersey Point During the 2009 Vernalis Adaptive Management Program (VAMP)

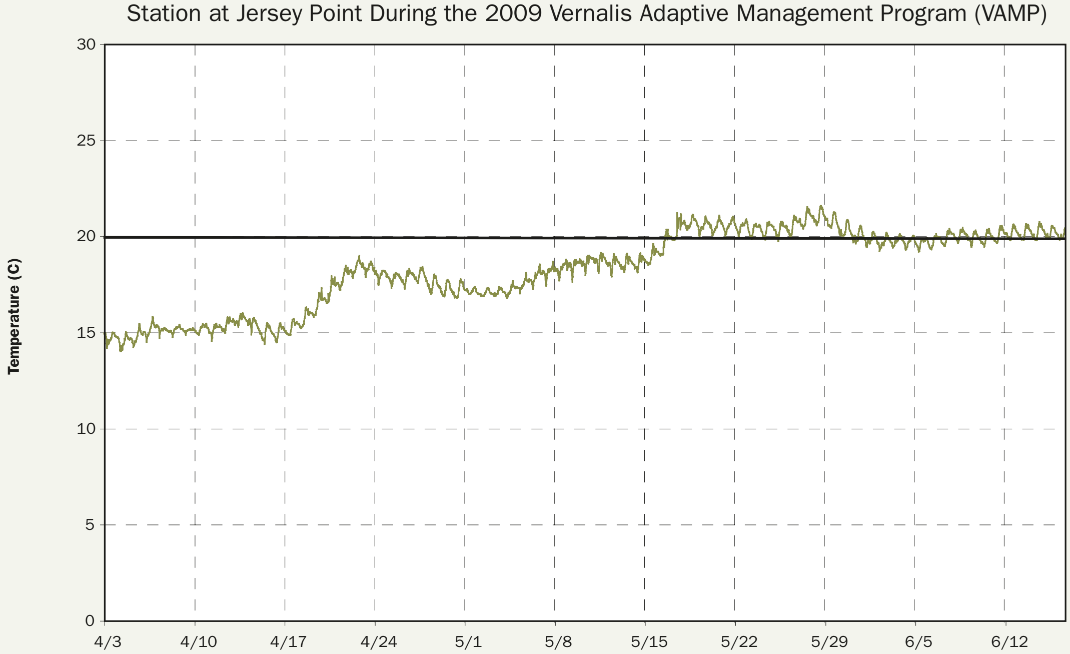


Figure C-14
Daily Water Temperature Fluctuations (°C) in the San Joaquin River Near the Antioch Marina During the 2009 Vernalis Adaptive Management Program (VAMP)

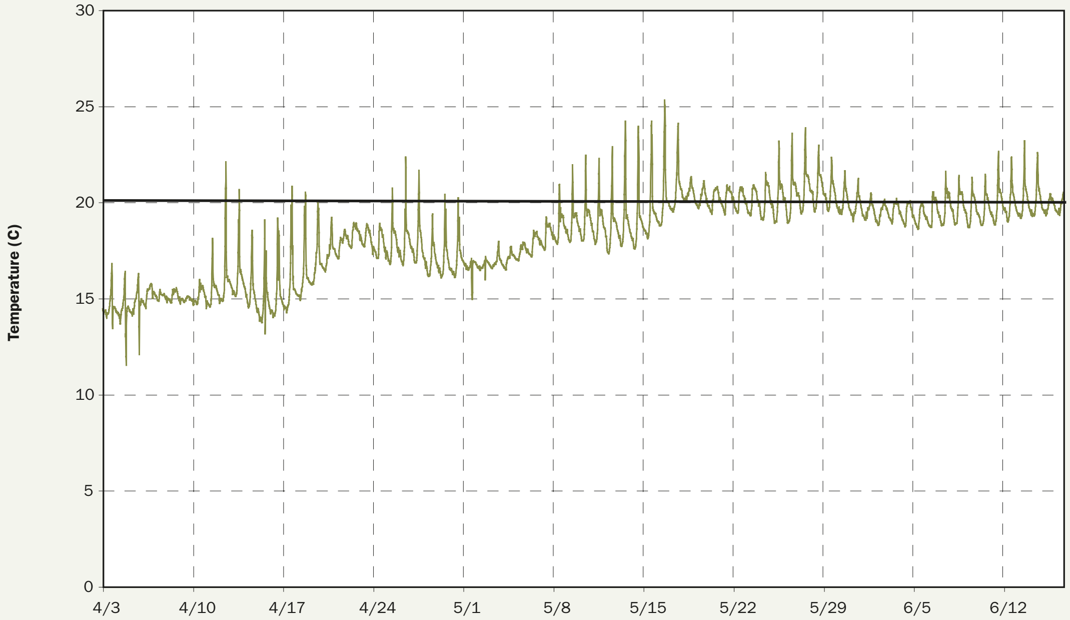


Figure C-15
Daily Water Temperature Fluctuations (°C) in the San Joaquin River Near Chipps Island During the 2009 Vernalis Adaptive Management Program (VAMP)

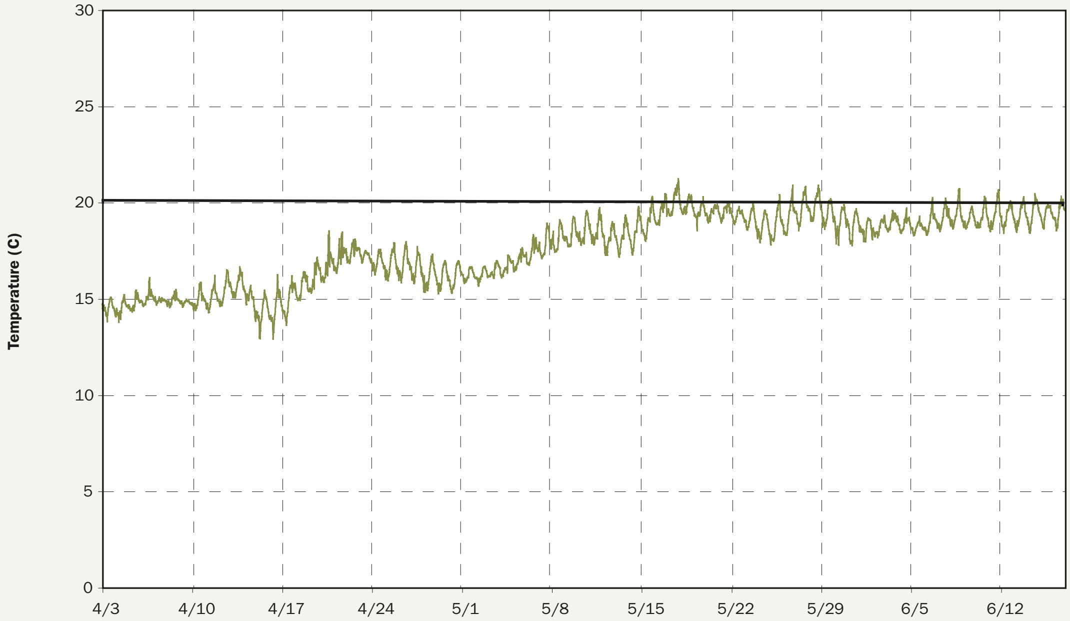


Figure C-16
Daily Water Temperature Fluctuations (°C) in the South Delta Near the Holland Riverside Marina During the 2009 Vernalis Adaptive Management Program (VAMP)

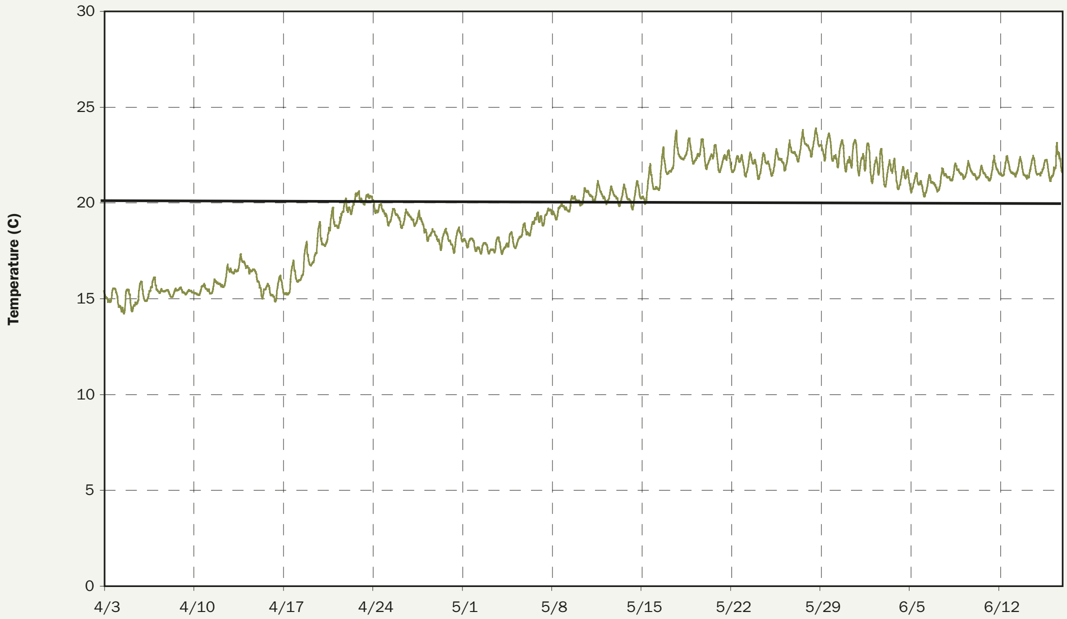


Figure C-17
Daily Water Temperature Fluctuations (°C) in the South Delta Near the Old River/Indian Slough Confluence During the 2009 Vernalis Adaptive Management Program (VAMP)

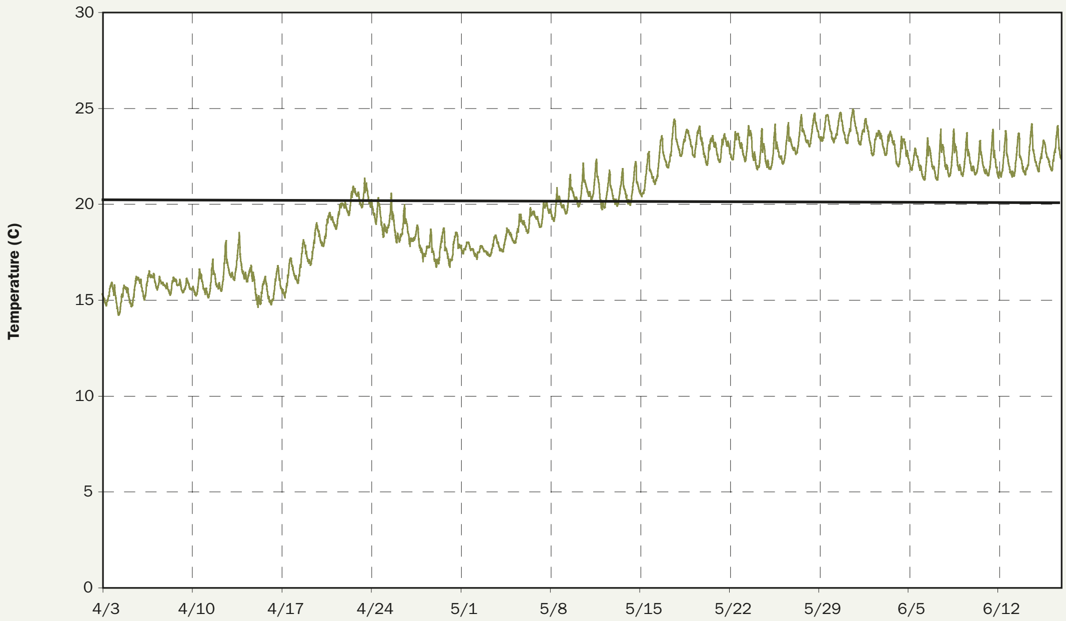


Figure C-18
Daily Water Temperature Fluctuations (°C) in the South Delta Near the CCF Radial Gates During the 2009 Vernalis Adaptive Management Program (VAMP)

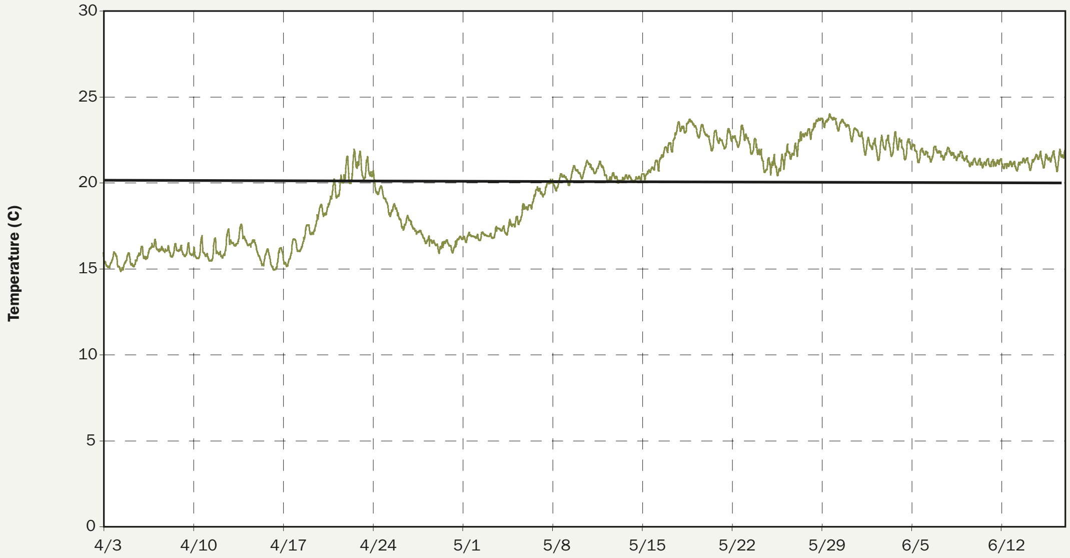
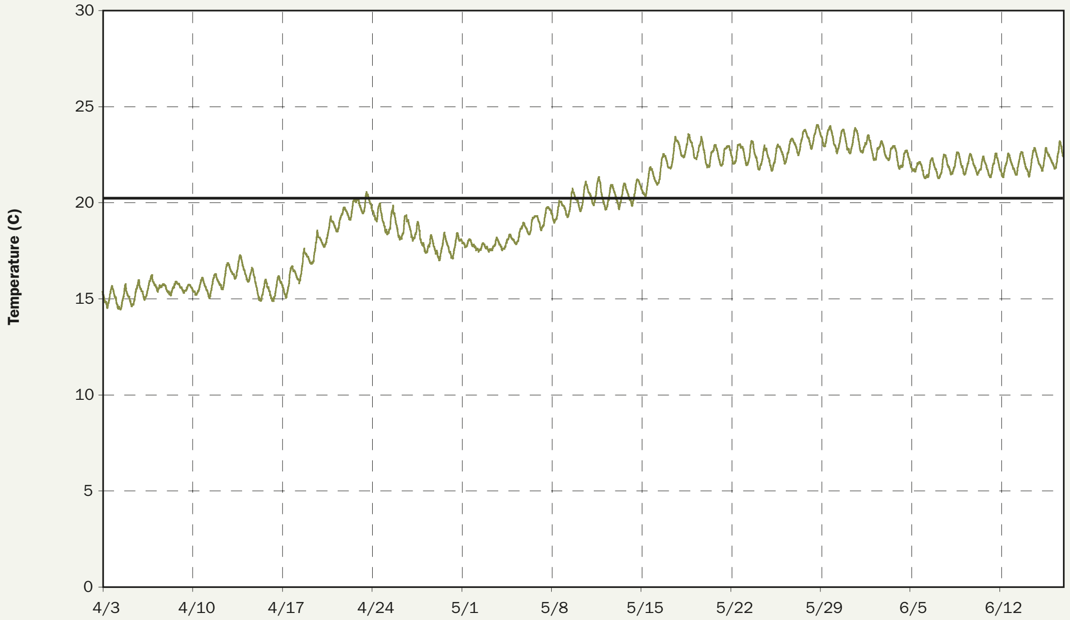


Figure C-19
Daily Water Temperature Fluctuations (°C) in the South Delta Near Union Point During the 2009 Vernalis Adaptive Management Program (VAMP)

Figure C-20
Daily Water Temperature Fluctuations (°C) in the South Delta Near Werner Cut During the 2009 Vernalis Adaptive Management Program (VAMP)



APPENDIX D

Table D-1
Definitions of Parameters Used in the Release-recapture Survival Model Shown in Chapter 5

Parameter	Definition
S_{A1}	Probability of survival from release at Durham Ferry to Mossdale (SJO(s))
S_{A2}	Probability of survival from Mossdale (SJO(s)) to Lathrop (SJO(n)) or Old River East (OLD(e))
S_{A3}	Probability of survival from Lathrop (SJO(n)) to Stockton USGS Gauge (STP(s))
S_{A4}	Probability of survival from Stockton USGS Gauge (STP(s)) to Stockton Navy Bridge (STP(n))
S_{A5}	Probability of survival from Stockton Navy Bridge (STP(n)) to Shipping Channel Marker 18 (SJT(se)) or Turner Cut North East (TRN(ne))
S_{B1}	Probability of survival from Old River East (OLD(e)) to head of Middle River (OM(fs))
S_{B2}	Probability of survival from head of Middle River (OM(fs)) to Old River North upstream (OLD(nu)), Middle River North upstream (MID(nu)), Clifton Court Forebay Access Channel (CCG(e)), or Central Valley Project trash rack (CVP(ne), CVP(sw))
ψ_{A1}	Probability of remaining in the San Joaquin River at the Old River-San Joaquin River junction; $=1-\psi_{B1}$
ψ_{B1}	Probability of entering the Old River at the Old River-San Joaquin River junction; $=1-\psi_{A1}$
ψ_{A2}	Probability of remaining in the San Joaquin River at the Turner Cut-San Joaquin River junction; $=1-\psi_{F2}$
ψ_{F2}	Probability of entering Turner Cut at the Turner Cut-San Joaquin River junction; $=1-\psi_{A2}$
$\phi_{B2,B3}$	Joint probability of moving from OM(fs) toward OLD(nu), and surviving from OM(fs) to OLD(nu)
$\phi_{B2,C1}$	Joint probability of moving from OM(fs) toward MID(nu), and surviving from OM(fs) to MID(nu)
$\phi_{B2,D1}$	Joint probability of moving from OM(fs) toward CCG(e), and surviving from OM(fs) to CCG(e)
$\phi_{B2,E1}$	Joint probability of moving from OM(fs) toward CVP, and surviving from OM(fs) to CVP(ne) or CVP(sw)
P_{A2}	Conditional probability of detection at Mossdale (SJO(s))
P_{A3}	Conditional probability of detection at Lathrop (SJO(n))
P_{A4}	Conditional probability of detection at Stockton USGS Gauge (STP(s))
P_{A5}	Conditional probability of detection at Stockton Navy Bridge (STP(n))
P_{A6a}	Conditional probability of detection at Shipping Channel Marker 18 (SJT(se))
P_{B1}	Conditional probability of detection at Old River East (OLD(e))
P_{B2}	Conditional probability of detection at head of Middle River (OM(fs))
P_{B3a}	Conditional probability of detection at Old River North upstream (OLD(nu))
P_{C1a}	Conditional probability of detection at Middle River North upstream (MID(nu))
P_{E1a}	Conditional probability of detection at Central Valley Project trash rack (CVP(ne), CVP(sw))
P_{F1a}	Conditional probability of detection at Turner Cut North East (TRN(ne))
λ_{A6}	Joint probability of surviving from Shipping Channel Marker 18 (SJT(se)) to Shipping Channel Marker 16 (SJT(nw)), and being detected at SJT(nw)
λ_{B3}	Joint probability of surviving from Old River North upstream (OLD(nu)) to Old River North downstream (OLD(nd)), and being detected at OLD(nd)
λ_{C1}	Joint probability of surviving from Middle River North upstream (MID(nu)) to Middle River North downstream (OLD(nd)), and being detected at MID(nd)
λ_{E1}	Joint probability of surviving from the Central Valley Project trash rack (CVP(ne), CVP(sw)) to the Central Valley Project holding tank (CVP(tank)), and being detected at CVP(tank)
λ_{F1}	Joint probability of surviving from Turner Cut North East (TRN(ne)) to Turner Cut Resort (TRN(sw)), and being detected at TRN(sw)

Table D-2
Parameter Estimates (standard error in parentheses) with 95% Profile Likelihood Confidence Intervals (CI) for Tagged Juvenile Chinook Salmon Released at Durham Ferry in 2009, Omitting the Predator-type Detections. Parameters Without Standard Errors or Confidence Intervals Were Set to Fixed Values in the Model. Population-level Estimates are Weighted Averages of the Release Group Estimates. Some Parameters Were Not Estimable Because of Sparse Data.

Parameter	Release Groups 1 – 2		Release Groups 3 – 6		Release Group 7		Population	
	Estimate (SE)	95% CI	Estimate (SE)	95% CI	Estimate (SE)	95% CI	Estimate (SE)	95% CI
S_{A1}			0.46 (0.02)	0.42, 0.51	0.47 (0.04)	0.39, 0.56	0.47 (0.02)	0.43, 0.50
S_{A2}			0.83 (0.03)	0.77, 0.87			0.83 (0.03)	0.77, 0.87
S_{A3}	0.50 (0.07)	0.37, 0.63	0.63 (0.05)	0.53, 0.72			0.59 (0.04)	0.51, 0.66
S_{A4}	0.81 (0.08)	0.63, 0.93	0.77 (0.05)	0.66, 0.86	0.70 (0.14)	0.39, 0.92	0.78 (0.04)	0.68, 0.85
S_{A5}	0.04 (0.04)	0.00, 0.18	0.13 (0.05)	0.06, 0.24	0.00		0.09 (0.03)	0.04, 0.16
S_{B1}	0.70 (0.05)	0.61, 0.78	0.78 (0.04)	0.69, 0.86			0.75 (0.03)	0.69, 0.81
S_{B2}	0.26 (0.05)	0.16, 0.37	0.12 (0.04)	0.06, 0.20	0.16 (0.08)	0.04, 0.36	0.16 (0.03)	0.11, 0.23
ψ_{A1}	0.36 (0.04)	0.29, 0.44	0.52 (0.04)	0.45, 0.59			0.47 (0.03)	0.42, 0.52
ψ_{B1}	0.64 (0.04)	0.56, 0.71	0.48 (0.04)	0.41, 0.55			0.53 (0.03)	0.48, 0.58
ψ_{A2}	1.00		1.00				1.00	
ψ_{F2}	0.00		0.00				0.00	
$\phi_{B2,B3}$	0.00		0.01 (0.01)	0.00, 0.06	0.00		0.01 (0.01)	0.00, 0.03
$\phi_{B2,C1}$	0.00		0.00		0.00		0.00	
$\phi_{B2,D1}$	0.21 (0.05)	0.13, 0.32	0.11 (0.04)	0.05, 0.19	0.00		0.12 (0.02)	0.08, 0.18
$\phi_{B2,E1}$	0.04 (0.02)	0.01, 0.11	0.00		0.16 (0.08)	0.04, 0.36	0.03 (0.01)	0.01, 0.07
P_{A2}			0.99 (0.01)	0.97, 1.00	1.00		0.99 (0.01)	0.98, 1.00
P_{A3}	1.00		0.96 (0.03)	0.89, 1.22			0.97 (0.02)	0.93, 1.03
P_{A4}	0.91 (0.06)	0.75, 0.98	0.98 (0.02)	0.92, 1.00	0.88 (0.12)	0.55, 0.99	0.95 (0.03)	0.88, 0.96
P_{A5}	1.00		1.00		1.00		1.00	
P_{A6a}	1.00		1.00				1.00	
P_{B1}	1.00		0.93 (0.03)	0.86, 0.98			0.96 (0.02)	0.91, 0.98
P_{B2}	1.00		1.00		1.00		1.00	
P_{B3a}			1.00				1.00	
P_{C1a}								
P_{E1a}	1.00				1.00		1.00	
P_{F1a}								
λ_{A6}	1.00		1.00				1.00	
λ_{B3}			0.00				0.00	
λ_{C1}								
λ_{E1}	0.00				0.33 (0.27)	0.02, 0.84	0.11 (0.09)	0.01, 0.28
λ_{F1}								

Table D-3
Parameter Estimates (standard error in parentheses) with 95% Profile Likelihood Confidence Intervals (CI) for Tagged Juvenile Chinook Salmon Released at Durham Ferry in 2009, Including the Predator-type Detections. Parameters Without Standard Errors or Confidence Intervals Were Set to Fixed Values in the Model. Population-level Estimates are Weighted Averages of the Release Group Estimates. Some Parameters Were Not Estimable Because of Sparse Data.

Parameter	Release Groups 1 – 2		Release Groups 3 – 6		Release Group 7		Population	
	Estimate (SE)	95% CI	Estimate (SE)	95% CI	Estimate (SE)	Parameter	Estimate (SE)	95% CI
S_{A1}			0.69 (0.02)	0.65, 0.73	0.77 (0.04)	0.70, 0.84	0.71 (0.02)	0.65, 0.74
S_{A2}			0.86 (0.02)	0.82, 0.90			0.86 (0.02)	0.82, 0.90
S_{A3}	0.59 (0.07)	0.45, 0.72	0.74 (0.04)	0.66, 0.80			0.69 (0.03)	0.62, 0.75
S_{A4}	0.88 (0.06)	0.73, 0.97	0.93 (0.02)	0.88, 0.97	0.83 (0.08)	0.65, 0.95	0.91 (0.03)	0.86, 0.94
S_{A5}	0.08 (0.05)	0.01, 0.22	0.16 (0.04)	0.10, 0.25	0.00		0.12 (0.03)	0.07, 0.18
S_{B1}	0.89 (0.03)	0.82, 0.94	0.90 (0.02)	0.84, 0.94			0.89 (0.02)	0.85, 0.93
S_{B2}	0.62 (0.05)	0.52, 0.71	0.75 (0.07)	0.65, 1.46	0.66 (0.08)	0.50, 0.79	0.70 (0.04)	0.63, 1.10
ψ_{A1}	0.30 (0.04)	0.23, 0.37	0.46 (0.03)	0.41, 0.52			0.41 (0.02)	0.36, 0.45
ψ_{B1}	0.70 (0.04)	0.63, 0.77	0.54 (0.03)	0.48, 0.59			0.59 (0.02)	0.55, 0.64
ψ_{A2}	1.00		0.94 (0.06)	0.76, 0.99	1.00		0.96 (0.04)	0.84, 1.00
ψ_{F2}	0.00		0.06 (0.06)	0.00, 0.24	0.00		0.04 (0.04)	0.00, 0.16
$\phi_{B2,B3}$	0.06 (0.02)	0.02, 0.11	0.06 (0.05)	0.02, 0.77	0.03 (0.03)	0.00, 0.11	0.06 (0.03)	0.03, 0.46
$\phi_{B2,C1}$	0.00		0.00		0.00		0.00	
$\phi_{B2,D1}$	0.23 (0.04)	0.16, 0.32	0.32 (0.04)	0.25, 0.40	0.13 (0.05)	0.05, 0.26	0.27 (0.03)	0.22, 0.32
$\phi_{B2,E1}$	0.33 (0.05)	0.24, 0.42	0.37 (0.06)	0.28, 0.54	0.50 (0.08)	0.34, 0.66	0.37, (0.04)	0.31, 0.48
P_{A2}			0.99 (<0.01)	0.98, 1.02			0.99 (<0.01)	0.98, 1.00
P_{A3}	1.00		0.95 (0.02)	0.90, 0.98			0.97 (0.01)	0.94, 0.99
P_{A4}	0.88 (0.06)	0.73, 0.97	0.99 (0.01)	0.96, 1.00	0.95 (0.05)	0.81, 1.00	0.95 (0.02)	0.91, 0.98
P_{A5}	1.00		1.00		1.00		1.00	
P_{A6a}	1.00		0.90 (0.09)	0.63, 0.99			0.93 (0.06)	0.75, 1.00
P_{B1}	1.00		0.95 (0.02)	0.91, 0.98			0.97 (0.01)	0.94, 0.98
P_{B2}	1.00		1.00		1.00		1.00	
P_{B3a}	1.00		0.50 (0.35)	0.04, 0.96	1.00		0.71 (0.20)	0.45, 0.98
P_{C1a}								
P_{E1a}	1.00		0.89 (0.10)	0.59, 0.99	1.00		0.94 (0.06)	0.77, 1.00
P_{F1a}								
λ_{A6}	1.00		0.64 (0.13)	0.38, 0.85			0.76 (0.09)	0.59, 0.90
λ_{B3}	0.67 (0.19)	0.28, 0.94	0.2 (0.18)	0.01, 0.63			0.45 (0.12)	0.27, 0.71
λ_{C1}								
λ_{E1}	0.18 (0.07)	0.07, 0.33	0.16 (0.05)	0.08, 0.28	0.21 (0.09)	0.07, 0.42	0.17 (0.04)	0.11, 0.25
λ_{F1}								

APPENDIX E

Distribution and Joint Fish-Tag Survival of Juvenile Chinook Salmon Migrating through the Sacramento-San Joaquin River Delta, California, 2008

By Christopher M. Holbrook, Russell W. Perry, and Noah S. Adams

Prepared in cooperation with the Technical Committee of the Vernalis Adaptive Management Plan and the San Joaquin River Group Authority

Open-File Report 2009–1204

U.S. Department of the Interior
U.S. Geological Survey

Distribution and Joint Fish-Tag Survival of Juvenile Chinook Salmon Migrating through the Sacramento-San Joaquin River Delta, California, 2008

By Christopher M. Holbrook, Russell W. Perry, and Noah S. Adams

Abstract

Acoustic telemetry was used to obtain the movement histories of 915 juvenile fall-run Chinook salmon (*Oncorhynchus tshawytscha*) through the lower San Joaquin River and Sacramento-San Joaquin Delta, California, in 2008. Data were analyzed within a release-recapture framework to estimate survival, route distribution, and detection probabilities among three migration pathways through the Delta. The pathways included the primary route through the San Joaquin River and two less direct routes (Old River and Turner Cut). Strong inferences about survival were limited by premature tag failure, but estimates of fish distribution among migration routes should be unaffected by tag failure. Based on tag failure tests (N = 66 tags), we estimated that only 55–78 percent of the tags used in this study were still functioning when the last fish was detected exiting the study area 15 days after release. Due to premature tag failure, our "survival" estimates represent the joint probability that both the tag and fish survived, not just survival of fish. Low estimates of fish-tag survival could have been caused by fish mortality or fish travel times that exceeded the life of the tag, but we were unable to differentiate between the two. Fish-tag survival through the Delta (from Durham Ferry to Chipps Island by all routes) ranged from 0.05 ± 0.01 (SE) to 0.06 ± 0.01 between the two weekly release groups. Among the three migration routes, fish that remained in the San Joaquin River exhibited the highest joint fish-tag survival (0.09 ± 0.02) in both weeks, but only 22–33 percent of tagged fish used this route, depending on the week of release. Only 4–10 percent (depending on week) of tagged fish traveled through Turner Cut, but no tagged fish that used this route were detected exiting the Delta. Most fish (63–68 percent, depending on week of release) migrated through Old River, but fish-tag survival through this route (0.05 ± 0.01) was only about one-half that of fish that remained in the San Joaquin River. Once tagged fish entered Old River, only fish collected at two large water conveyance projects and transported through the Delta by truck were detected exiting the Delta, suggesting that this route was the only successful migration pathway for fish that entered Old River. The rate of entrainment of tagged juvenile salmon into Old River was similar to the fraction of San Joaquin River discharge flowing into Old River, which averaged 63 percent but varied tidally and ranged from 33 to 100 percent daily. Although improvements in transmitter battery life are clearly needed, this information will help guide the development of future research and monitoring efforts in this system.

Evaluation of Acoustic-Tagged Juvenile Chinook Salmon Movements in the Sacramento – San Joaquin Delta during the 2009 Vernalis Adaptive Management Program

March 2010

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Evaluation of Acoustic-Tagged Juvenile Chinook Salmon Movements in the Sacramento – San Joaquin Delta during the 2009 Vernalis Adaptive Management Program

Executive Summary

The spring of 2009 was the fourth year of experiments evaluating the movements of acoustic-tagged juvenile Chinook salmon (*Oncorhynchus tshawytscha*) released in the San Joaquin River during the Vernalis Adaptive Management Program (VAMP). It was hypothesized that the study may provide salmon survival estimates in some key reaches of the Delta and fish route "selection" probabilities at critical flow splits (i.e., head of Old River and Turner Cut). This plan was also intended to become adaptive by continuing the testing of the acoustic receiver network and equipment, refining logistical approaches to field implementation, and assessing other potential improvements should a study of this nature continue in future years. The project was considered to be an ongoing effort to determine the efficacy of using this technology for Delta fish studies.

A total of 933 acoustic-tagged salmon was released in the lower San Joaquin River at Durham Ferry during seven separate releases in late April and early May 2009. Passage of those fish at 19 acoustic receivers strategically positioned in various Delta channels was monitored from the time of first fish release until early June. Additionally, mobile telemetry was used in some of the key fish migration channels to potentially locate areas of high salmon mortality and where predatory

fish may have defecated smolt tags. To improve our understanding of how potential effects of non-native fish predation may influence survival results and interpretation of smolt telemetry data, small numbers of predatory fish were also tagged with transmitters to monitor trends in behavior and movements within the VAMP acoustic telemetry array.

We employed elaborate, painstaking techniques to evaluate the extensive acoustic telemetry data and spatiotemporal history of each tagged fish acquired during the VAMP study. We chose this approach because simple reporting of fish tag presence/absence information may cause widespread misinterpretation and negate the potential for scientifically sound results. These highly detailed assessments of acoustic tag movements included: 1) a near-field environment within the fish transmitter detection range of each of the 19 acoustic hydrophones, 2) medium-field observations of tag movements in a fine-time scale between receivers in close proximity, and 3) far-field examinations of movements of transmitters throughout the study-wide telemetry array. Manual processing of the acoustic telemetry data, although time consuming, provided critically important information on fish behavior to assist in interpreting the 2009 study results.

All of the fish telemetry data were integrated with: 1) flow measurements recorded in relevant Delta channels; 2) site-specific characteristics in fish migration corridors; and 3) knowledge acquired from numerous prior juvenile salmon telemetry studies conducted in the Delta. Furthermore, the analyses included results of a concurrent independent evaluation of acoustic tag movements at a two-dimensional acoustic receiver with four hydrophones positioned at the head of Old River and a dual-frequency identification sonar camera to study a potential fish behavioral barrier (“bubble curtain”). This latter study provided a means to develop a separate independent method to estimate predation on VAMP study fish and compare with our analyses.

It appears that we were frequently tracking dead salmon (or the transmitters) inside predatory fish during the 2009 VAMP study, not live salmon. Although reasonably accurate numerical estimates of salmon smolt survival were not feasible, fish survival as observed from all seven releases of acoustic-tagged salmon was extremely low. Both independent methods of data evaluation, although not definitive, suggest that there was a very high level of predation on acoustic-tagged salmon. Mobile telemetry surveys found a total of 173 acoustic tags believed to be dead acoustic-tagged salmon or tags defecated by predatory fish in the reaches surveyed (approximately 19% of those fish released at Durham Ferry).

Although the proximal cause of the fish mortality appeared to be a result of predation, the circumstances causing predation remain unknown and warrant further study. While remaining speculative, some of the conditions enhancing predation on salmon are hypothesized to be a result of one or more of the following: 1) flow and/or water quality (including temperature) conditions; 2) in-channel artificial structures (e.g., bridge piers, pump stations, docks); 3) channel geometry (e.g., scour holes) providing favorable habitat conditions for predatory fish; and/or 4) the possible substandard condition of tagged salmon.

Acoustic-tagged striped bass frequently moved throughout the telemetry array and empirical evidence corroborating assumptions of predation on acoustic-tagged salmon was observed. These complex circumstances significantly affect how juvenile salmon telemetry data can be interpreted. Due to a large number of acoustic-tagged salmon possibly being eaten by non-native predatory fish in the Delta, the ability to accurately estimate salmon survival is likely severely compromised because of incorrect assumptions on tag detections (i.e., live salmon versus dead salmon). Differentiating between live acoustic-tagged salmon and predatory fish that had eaten acoustic-tagged salmon makes it very difficult to estimate overall salmon survival, salmon survival by reach, and fish route selection at key flow splits, all of which were (and continue to be) key objectives of the VAMP study.

Acoustic telemetry technology has been amply demonstrated to be a powerful analytical tool to study juvenile salmon movements in the Delta, but only if it is appropriately implemented and the results are properly analyzed and understood. Information developed from the 2009 VAMP study indicates that attempts to accurately estimate salmon survival in the Delta using acoustic telemetry will require a new approach, perhaps by seeking changes in the technology to determine predation. In the absence of a technological breakthrough, highly detailed data on the behavior of predatory fish movements as compared to juvenile salmon movements is critically necessary.

Most importantly, because of the well-documented low salmon smolt survival in the lower San Joaquin River and Delta, efforts should focus on determining site-specific causes of mortality with the objectives of developing and implementing remedial actions to increase fish survival.

This report contains numerous recommendations to improve the execution and scientific integrity of future acoustic telemetry studies in the Delta.

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Modesto Irrigation District
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Oakdale Irrigation District
Merced Irrigation District
Friant Water Authority
City and County of San Francisco
South San Joaquin Irrigation District
San Joaquin River Exchange Contractors Water Authority

Web site: www.SJRG.org