2010 ANNUAL TECHNICAL REPORT

San Joaquin River Agreement

VERNALIS ADAPTIVE MANAGEMENT PLAN

SAN JOAQUIN RIVER GROUP AUTHORITY

Figure 1-1

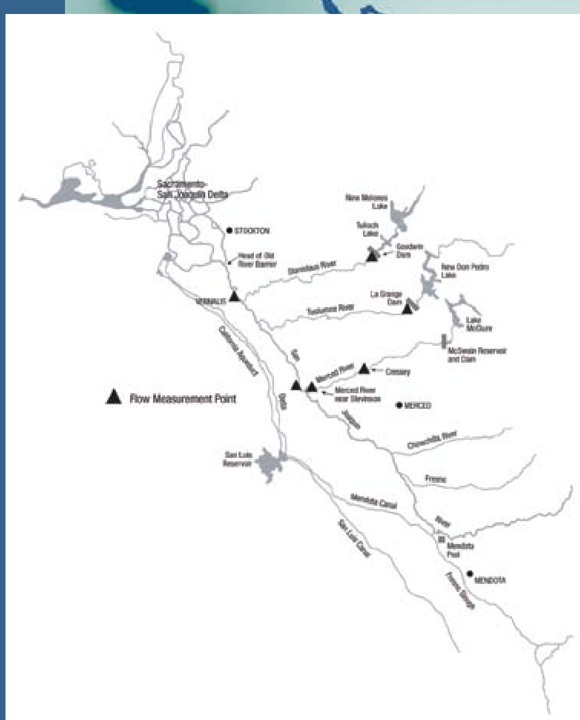
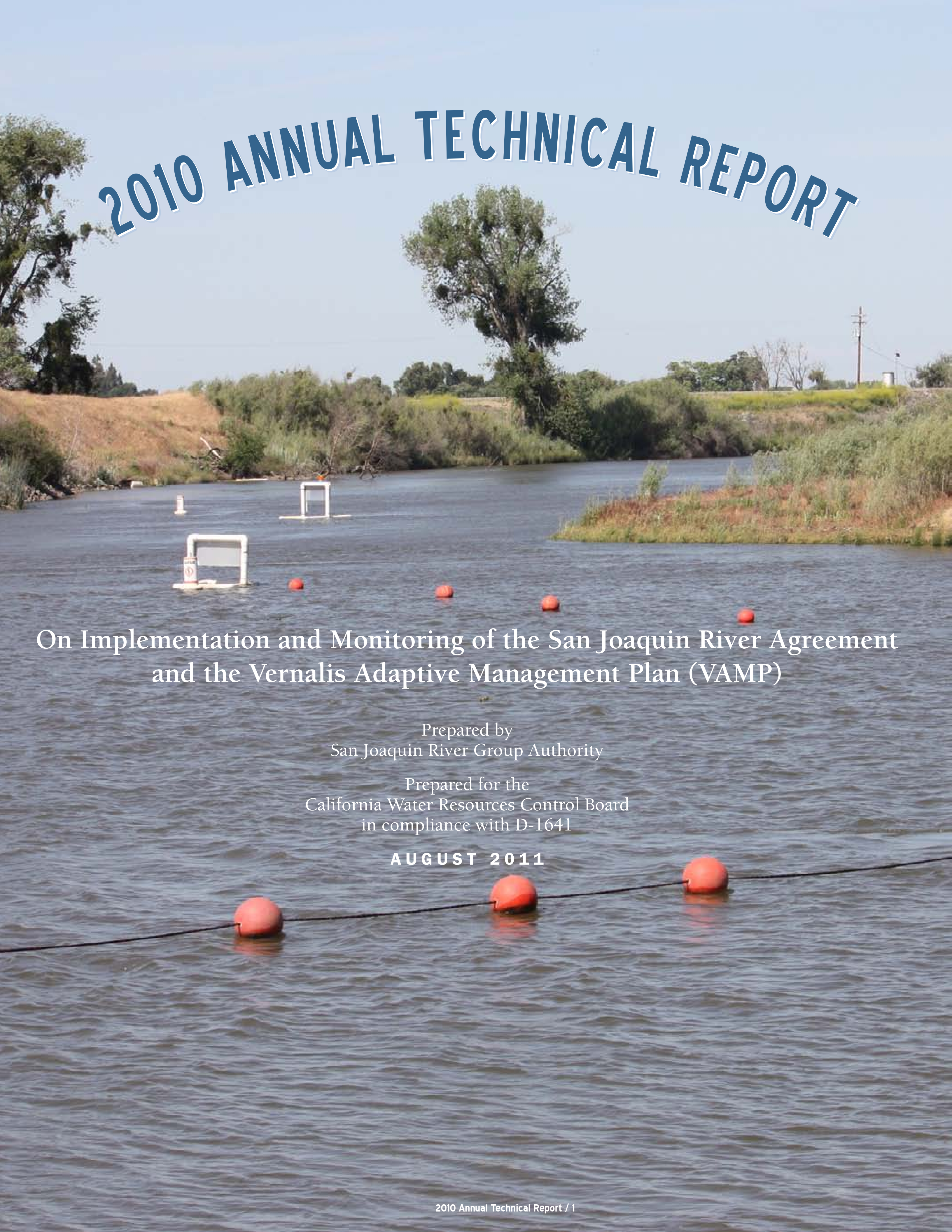


Figure 2-1



2010 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

AUGUST 2011

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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 changes in response to alterations in San Joaquin River flows and State Water Project (SWP)/Central Valley Project (CVP) exports with the installation of a physical Head of Old River Barrier (HORB). As in 2009, a physical HORB was not installed in 2010 and a Non-Physical Barrier was again tested instead.

The VAMP design provides for a 31-day pulse flow (target flow) in the San Joaquin River at Vernalis 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 facilitated communication and coordination for both the VAMP Chinook salmon smolt survival experiment and for scheduling stream flow releases on the Tuolumne, Merced, and Stanislaus rivers.

The 2010 Technical Report consolidates the annual SJRA Operations and the VAMP Hydrology and Fish Monitoring Reports. The 2010 VAMP program represents the eleventh 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 2010 report includes the following information on the implementation of the SJRA: the hydrologic chronicle; management of any additional SJRA water; the experimental design and results of the juvenile salmon acoustic tag study; flow and fisheries monitoring in the lower San Joaquin River, Old River, and Delta; discussion of complementary investigations; conclusions and recommendations

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 has not been installed at the head of Old River since 2008. In 2010, similar to 2009, the Department of Water Resources (DWR), in cooperation with the Bureau of Reclamation (USBR), conducted the second year of testing of a non-physical behavior barrier at the head of Old River. In addition, DWR conducted a complimentary study on the effects of south Delta temporary barriers on juvenile salmon and a specialized study on tracking of tagged predator fish in the South Delta. Some of the receivers used in these studies complemented those in place for 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 other studies to ensure that the maximum amount of data was available to all three studies and that no duplication of effort took place. In addition, the VAMP fish releases were coordinated to meet the needs of the head of Old River non physical barrier evaluation. A discussion of the two barrier studies is included in Chapter 4 of the 2010 Annual Report.

Hydrology

The seasonal precipitation in the San Joaquin Hydrologic Region (Cosumnes, Mokelumne, Stanislaus, Tuolumne, Merced and San Joaquin Rivers) measured 100% of average on April 1, 2010. The forecasted April-July runoff as of April 1st in the four basins above Vernalis (Stanislaus, Tuolumne, Merced and San Joaquin) ranged from 93% to 107% of average. Water Year 2010 was classified as "below normal" based on the April 1st-90% probability of exceedence forecast of the San Joaquin Valley Water Year Type Index (60-20-20 Index) with a numerical indicator of 3. The numerical indicators for 2008 and 2009 were 1 ("critical") and 2 ("dry"), respectively. The sum of the 2009 and 2010 numerical indicators was 5 so the "double step" condition, which occurs when that sum is 7 or greater, was not in effect. Conversely, the sum of the 2008, 2009 and 2010 numerical indicators was 6 so the "sequential dry-year relaxation" condition, which occurs when that sum is 4 or less, was not in effect. Therefore, a "single-step" condition was in effect of the 2010 VAMP operation (see Chapter 2 for further explanation).

The planning process for the VAMP operation differed from that of prior VAMP years due to the introduction of the following factors:

1. The National Marine Fisheries Service (NMFS) Reasonable and Prudent Alternatives (RPAs) for the Stanislaus and San Joaquin Rivers. The RPAs specified required flows on the Stanislaus and San Joaquin Rivers depending on time of year and hydrologic conditions; and

2. The one-year extension of the SJRA under which the VAMP supplemental water and accompanying operation would be determined prior to the VAMP period and no adjustments to the supplemental water or operation would be made during the VAMP period. The consequence of this is that if the NMFS RPAs required more flow than was required for the VAMP operation, the flow in the San Joaquin River at Vernalis would likely exceed the VAMP flow target.

An additional factor for 2010 that was not present previously was the San Joaquin River Restoration Program (Restoration Program) which requires additional releases from Millerton Lake to restore flows and salmon populations between Millerton Lake and the Merced River. The initial releases under this program commenced in October 2009. The effect of the Restoration Program on the VAMP operation is to potentially increase the uncertainty associated with the estimate of flow in the San Joaquin River at the Merced River.

The initial March daily operation plan forecasted a VAMP Target Flow of 3,200 cfs with supplemental water requirements of about 20,500 acre-feet for the wetter condition and 60,000 acre-feet for a drier condition. As a result of cool and wet conditions in late March and early April and a corresponding increase in the run-off volume, the VAMP Target Flow increased to 4,450 cfs with a supplemental water requirement of 21,840 acre-feet. As stipulated by the SJRA Division Agreement the 21,840 acre-feet of supplemental water would be on the Merced River. A key factor in the increased target flow was the need for increased flood control releases on the Tuolumne River. The uncertainty associated with flood control operations increased the uncertainty of achieving a stable flow for 31 days at Vernalis.

The mean daily flow at Vernalis averaged 5,140 cfs during the VAMP target-flow period (April 25th – May 25th). The mean daily flow at Vernalis varied between 4,210 cfs and 5,890 cfs during the target-flow period. The deviation from the target flow of 4,450 cfs was caused by flood control operations on the Tuolumne River. Additionally, flows coming from upstream of the Merced River were generally higher than expected, possibly the result of less loss from the restoration flows than expected.

The combined CVP and SWP Delta export target during the VAMP period was 1,500 cfs. The observed exports during this period averaged 1,520 cfs and ranged from 1,320 cfs to 1,560 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 2010 VAMP represented the fifth year of using acoustic telemetry technology. The first year (2006) was a pilot trial, followed in the second year by a slightly extended receiver network in 2007 with 2008 being 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, primarily tag failure that made survival estimates potentially biased. Even though unbiased survival estimates could not be determined from the 2008 experiment, valuable information was collected on smolt movement (smolt distribution, migration timing and predator problems) and on methods of implementing an acoustic telemetry study under South Delta conditions to Chipps Island. For 2009, the VAMP experimental design followed the same structural setup as the 2008 VAMP study but limited resources and the lack of key project staff resulted in a modified plan that did not include receivers at Jersey Point and Chipps Island. Instead it focused on 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). While survival could be determined to the most downstream receivers near Turner Cut, survival through the Delta could not be estimated because of the missing receivers at Chipps Island.

The 2010 VAMP study refocused on installing these key downstream receivers and estimating survival through the Delta. Because of budgetary limitations, only the downstream receivers at Chipps Island were added back into the program in 2010. The receiver sites at Jersey Point were not in place in 2010. Within the resources that were available, the VAMP study team developed a study plan that called for nineteen acoustic receivers at twelve sites in the lower San Joaquin River and Southern Delta. By developing the program cooperatively with the DWR South Delta Temporary Barriers study and the joint DWR/USBR Non-physical Barrier evaluation, the VAMP team was able to expand the number of receiver sites in the south Delta by eight. This final layout of the nineteen receivers from the VAMP program and the ones deployed by DWR and USBR provided good coverage of the South Delta migration routes that may be used by salmon smolts.

Specific experimental objectives of VAMP 2010 included:

- Quantification of Chinook salmon smolt survival along individual San Joaquin River segments to Chipps Island using acoustic tags implanted in test fish and a dual array of receivers at Chipps Island. Tagged fish were released at Durham Ferry, although estimates of survival started at Mossdale with supplemental releases made at Stockton.

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

- Evaluation of migration path selection at the San Joaquin River – Old River flow split at the Head of Old River under the 2010 flow conditions and the use of the non-physical barrier.

- Evaluation of how survival for tagged salmon varies between routes (San Joaquin River versus Old River) as a function of flow.

- Evaluation of areas of high relative mortality as tagged juvenile salmon migrate through the Delta by various routes.

- 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.

- Health and physiology testing of dummy tagged VAMP fish to evaluate the incidence of disease in test fish.

- Evaluation of areas of high relative mortality occuring on the San Joaquin River downstream of the City of Stockton.

Study Implementation

During the 2010 study, Chinook salmon smolts were acoustically tagged with Hydroacoustic Technology, Inc (HTI) tags and released into the San Joaquin River at Durham Ferry with supplemental releases on the San Joaquin River near Stockton and in Old River just downstream of its junction with the mainstem San Joaquin River. A total of 21 releases were made between April 27th and May 19th, with 7 releases at each of the 3 separate sites. At Durham Ferry between 70 and 74 fish were released per release period, while at Old River and at Stockton, between 34 and 36 fish were released at each location per release period.

The study design was intended to obtain an "average" survival rate for juvenile salmon migrating through the Delta to Chipps Island. Given that survival through the Delta can be low, the supplemental releases at Old River and near Stockton were made to augment the numbers of fish that survived to those two locations from releases made at Durham Ferry and to assure some fish would be recovered at Chipps Island. In addition, the seven sets of releases at Durham Ferry were also used to meet the study needs of the joint DWR / USBR evaluation of a non-physical barrier (NPB) at the head of Old River often called the Bio-Acoustical Fish Fence or BAFF.

Each tag was detected and uniquely identified as it passed acoustic receivers placed on key migration routes 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 were analyzed to help interpret the survival estimates.

In order to evaluate the effects of tagging, transportation and holding, several randomly selected groups of fish were implanted with inactive or dummy transmitters.

There was little apparent effect of tagging or handling of these fish. A general pathogen and physiological screening conducted on dummy-tagged fish and release group cohorts remaining at Merced River Hatchery (MRH) found no viral or bacterial pathogens. No mortality or evidence of physiological impairment was observed in either the tagged or MRH groups.

As in prior years computerized temperature recorders were employed 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 monitor the failure rate of the acoustic tags and identify any premature failure. Survival estimates were adjusted for the small amount of premature tag failure observed. There were no clear differences in tag life between manufacturing lots. No effect of tagger was found in estimates of fish survival.

Acoustic-tagged salmon smolts were tracked through a series of receivers located on key migration routes. Several of the receivers were moved in 2010 to avoid noise interference encountered in 2009. While there were periodic receiver non-operational periods in 2010, the use of redundant receivers at critical points minimized or eliminated data loss. The total receiver network worked very well during 2010.

Survival Study Results

Data from most fixed receiver sites in 2010 were processed using two automarking algorithms (FishCount and MarkTags) that were developed by USGS or by HTI and modified by USGS. Limited manual data processing was also used at key detection sites to (1) assess the performance of the automarking algorithms, and (2) attempt to differentiate between acoustic signals coming from live salmon and those coming from predators that had eaten tagged salmon. Manual processing focused on sites critical to estimating route selection and survival through the Delta (Old River, Lathrop, Chipps Island and Mossdale). Complete manual processing of all data is impractical because of the large number of data files. Most of the errors found in the two methods (manual and auto-processing) were missed detections, but in general the two processes were similar with few apparent errors that neither found. Because probability of detection is estimated for each receiver, missed detections are less problematic than tags that are misread or false positives. The statistical survival model used the probability of detection at each receiver to adjust for missed detections when estimating survival. The use of redundant receivers at critical sites also limited the impact of missed detections because it was unlikely that an individual fish was missed at both receivers.

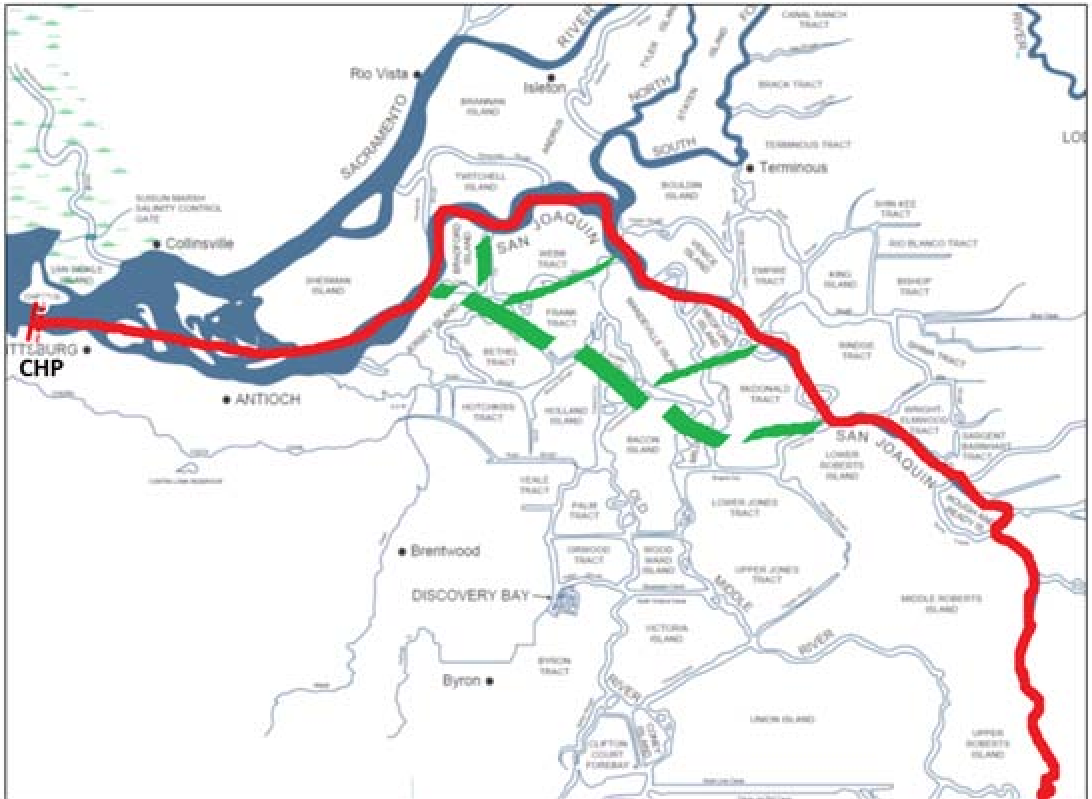
The manual processing also provided an assessment of near-field tag movements, used in assessing predation of tagged smolts (see below). This information was most useful at Chipps Island. At other sites, predation assessment was based primarily on larger-scale analysis available from the auto-processed data.

A multi-state statistical release-recapture model was developed and used to estimate salmon smolt survival and migration route parameters throughout the study area to a single exit point at Chipps Island. The model assumed two route possibilities beyond the split at Old River. The first was the San Joaquin River route (Figure ES-1) from Mossdale to Chipps Island. Fish taking this route had several possible migration pathways downstream of Stockton, all of which lead to the receivers at Chipps Island. The second route was via Old River through the interior Delta channels or fish recovery facilities at the federal and state projects (Figure ES-2).

The possibility of predatory fish eating tagged study fish and then moving past one or more fixed-site receivers complicated analysis of the detection data. Without removing the detections that came from predators, the salmon survival model would produce positively biased estimates of juvenile salmon survival through the Delta. Prior to analyzing the data in the survival model, all detection data were reviewed to determine whether detections appeared to be "smolt-like" or "predator-like" using the criteria developed by the program over the last two years. A total of 602 of the 993 tags (61%) released at Durham Ferry and the two supplemental release points (Stockton and Old River) were classified as being detected in a predator at some point during the study. Two data sets were then constructed: the full data set that included all detections, including those classified as coming from predators (i.e., "predator-type"), and a reduced data set that was restricted to those detections classified as coming from live smolts (i.e., "smolt-type"). The survival model was fit to both data sets separately, and the resulting survival estimates were compared to assess the differences in survival between our best estimate of survival (without predator-type detections) and that using the uncorrected dataset.

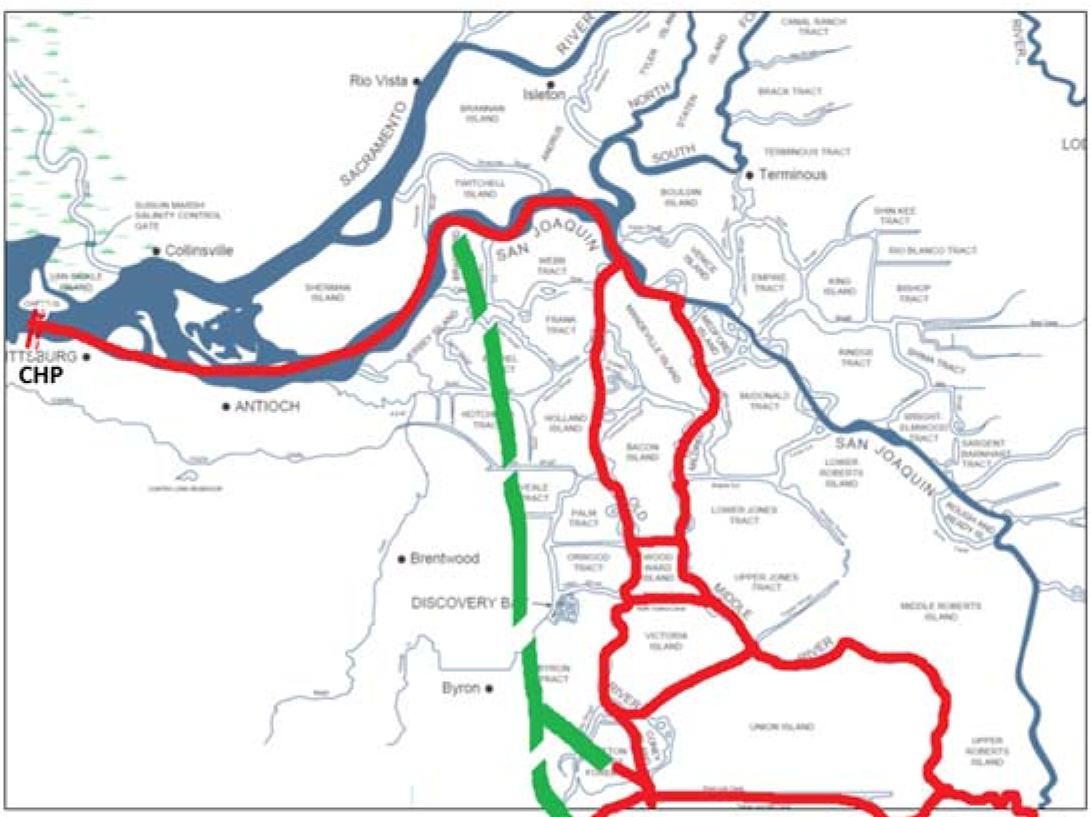
Of the 504 tags released in juvenile Chinook salmon at Durham Ferry, 500 were detected on one or more receivers downstream of the release site, with 59 eventually detected at Chipps Island, including the "predator-type" detections. Without predator-type detections, only 29 Durham Ferry tags were detected at

Figure ES-1
Survival to Chipps Island San Joaquin Route



Prepared by University of Washington

Figure ES-2
Survival to Chipps Island Old River Route



Prepared by University of Washington

Chipps Island, 19 of which were previously detected at the Central Valley Project. All 247 of the tags released in salmon in the Old River supplemental release groups were detected on one or more receivers downstream of the release site, including predator-type detections; 28 of these tags were detected at Chipps Island, including predator-type detections. Without predator-type detections, only 16 Old River tags were detected at Chipps Island. Of the 242 tags released in salmon in the Stockton supplemental release groups, 235 were detected on one or more receivers downstream of the release site, with 27 detected at Chipps Island, including predator-type detections. Without predator-type detections, only 12 Stockton tags were detected at Chipps Island. Overall, a total of 114 tags were detected at Chipps Island from all release groups, including predator-type detections. Without predator-type detections, the total number of tags detected at Chipps Island dropped to 57.

Using only those tags that showed "smolt-like" behavior, total salmon smolt survival from Mossdale to Chipps Island was estimated to be $\hat{S}_{Total}$= 0.05 ($\widehat{SE}$ =0.01). Estimated survival from Mossdale to Chipps Island through the San Joaquin River route was $\hat{S}_A$ = 0.04 ($\widehat{SE}$ =0.01), while estimated survival from Mossdale to Chipps Island through the Old River route was $\hat{S}_B$ = 0.07 ($\widehat{SE}$ =0.01). The estimated survival in the Old River route ($\hat{S}_B$) included survival to the entrances of the water export facilities followed by facility salvage and trucking and release near Jersey Point, upstream of the Chipps Island receiver. These estimates of survival were lower than the estimates including predator-like detections, indicating that ignoring predation may result in positive biases in overall salmon survival estimates.

Durham Ferry fish appeared to use the San Joaquin River route (Figure ES-1) and the Old River route (Figure ES-2) in approximately equal proportions. The estimated route entrainment probability was 0.47 ($\widehat{SE}$ =0.02) for the San Joaquin River route and 0.53 ($\widehat{SE}$ =0.02) for the Old River route. Route selection at the Head of Old River was largely unaffected by predator-type detections. During the 2010 VAMP fish release and tracking period (April 25th – June 25th), the average flow split was 42:58% (San Joaquin River main stem : Old River).

Survival (without predator-like detections) was also estimated through the portion of the study area that matched the 2009 study area, with survival considerably higher in 2010 than in 2009. Estimates of survival in the San Joaquin River route from Mossdale to the Shipping Channel Markers or Turner Cut in 2010 averaged 0.32 ($\widehat{SE}$ =0.02) compared to 0.05 ($\widehat{SE}$ = 0.02) in 2009. Estimated survival from Mossdale to the entrances of the water export facilities or the northern Old River receivers at Highway 4 averaged 0.77 ($\widehat{SE}$ =0.05) in 2010, compared to 0.08 ($\widehat{SE}$= 0.02) in 2009. Overall survival through the southern region of the Delta (from Mossdale to the Channel Markers and Turner Cut junction on the San Joaquin, and in Old River to the entrances of the export facilities or northern Old River receivers) averaged 0.56 ($\widehat{SE}$ =0.03) in 2010, compared to 0.06 ($\widehat{SE}$ =0.01) in 2009 (excluding predator-type detections).

Mobile telemetry surveys were also conducted in 2010 from the fish release point to Stockton and to Clifton Court. Based on the 2010 mobile monitoring, predation did not appear to be a problem near the Head of Old River or near the railroad bridge in Stockton but predation did still appear to be an issue in front of the Central Valley Project trash racks, with a total of 37 acoustic tags detected near this location. The Stockton Deep Water Ship Channel (DWSC) also appeared to be a continuing problem area with 68% of the detected immobile tags on the San Joaquin River between Old River and Turner Cut found at this location. In contrast, only a few tags were observed on the San Joaquin River between Banta Carbona and Old River where the majority were found in 2009. These findings were consistent with fixed receiver data, which found that the shipping channel in the San Joaquin downstream of Stockton had the largest number (57) of first-time predator-type detections. The Central Valley Project trash rack receivers had the next largest number (49) of first-time predator classifications.

High mortality in Old River is supported by data from the Old River supplemental releases where a total of 162 (of 247) tags were eventually classified as coming from a predator rather than a smolt. The large majority of predator-type detections in the Old River route occurred at the Central Valley Project trash racks, the radial gates at the entrance to Clifton Court Forebay and the Old River North site. However, it is noteworthy that of the 29 salmon-type tags detected at Chipps Island from the Durham Ferry releases, 19 of these tags had previously been detected at the Central Valley Project, with only 9 that had previously been detected in the San Joaquin River at Lathrop or farther downstream. None were observed moving from Clifton Court Forebay directly to Chipps Island.

The problem of detections of predatory fish on tags that were originally placed in salmon introduces additional uncertainty to the survival estimates. To account for this uncertainty, the VAMP team attempted to identify and remove detections coming from predators. However, the decision process used to identify predator detections has uncertainty, as well. Based on perceived behavioral differences between salmon and predatory fish, it is only as good as our understanding of fish behavior in a variety of different hydrologic environments. It may misclassify detections from individuals that acted differently than expected. Further review and refinement will improve the process and reduce uncertainty in future years.

Despite the uncertainty in the decision process, the resulting survival estimates based only on data classified as salmon detections represent the best estimates of salmon survival. The estimates of survival based on all detections, including obvious predator detections, are positively biased, and are presented to demonstrate the degree of sensitivity of the results on the decision process. In future years, it will be important to improve how we 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.

It is clear that survival was low in 2010, regardless of whether or not only smolt-like detections were used in the model (0.05 with only smolt-type detections or 0.11 with predator-type detections) relative to many of the past years when survival was measured from Mossdale to Jersey Point using coded wire tagged fish. However, the data show regional survival in 2010 was higher than for comparable estimates in 2009 both with and without predator-type detections. In addition, the relative proportion of predator detections to all detections for this area was lower in 2010 than in 2009. The reason for the continued low survival rates and the change in predation rates in some river reaches or routes remains unknown. More evaluation of the role of flow and predation and their interaction on survival through the Delta is planned for 2011.

Lastly, the objective of the VAMP is to be protective of the natural juvenile salmon originating from the San Joaquin basin that migrate through the Delta. Trawling at Mossdale indicated many of the juvenile salmon were caught during the VAMP period (April 25th – May 25th), although there was a spike in early June shortly after the VAMP period ended. Thus it appears that a large proportion of the unmarked fish originating from the San Joaquin River basin passed through the Delta during the VAMP period. Further analyses will be conducted in 2011 to continue to assess the roles of flow and exports and a non-physical barrier at the head of Old River on juvenile salmon survival through the Delta.

CHAPTER 1
INTRODUCTION

Actions associated with the Vernalis Adaptive Management Plan (VAMP) were implemented between April 25 and May 25, 2010 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 fourth straight year, the 2010 VAMP relied on acoustic telemetry and tracking methodology to monitor the survival and migration of salmon smolts through the Delta. The VAMP Fish Monitoring Experiment start date was delayed ten days to April 25th from the default start date of April 15th to allow for additional growth of the experimental fish. A total 993 fish were tagged and released for the experiment. A total of seven releases were made between April 26th and May 20th at three separate sites; on the San Joaquin River at Durham Ferry, Old River near its junction with the San Joaquin River and on the San Joaquin River near the Stockton Wastewater Treatment Facility (SWWTF) (Figure 5-2). At Durham Ferry, releases were done every six hours over a 24-hour period while at the two other sites release times varied based on the tide.

The VAMP experiment was designed to assess salmon smolt survival through the Delta in relation to two factors; flow in the San Joaquin River at Vernalis and export rates at the State Water Project and Central Valley Project with a physical 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 had 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 in 2008. In 2010, as in 2009, 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.

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, and State and federal water project (SWP/CVP) export rates, with 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 implementable CWT study. The primary reason was that an adequate number of smolts were not produced at the MRH, due to low adult returns the previous fall. In addition, the CWT study was further constrained by recent concerns for delta smelt that potentially could have 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 11 days (Holbrook et al., 2009). 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 a Channel marker in the San Joaquin River near McDonald Island and to Old River at the Highway 4 Bridge. Survival was also estimated for intermediate reaches along various migration paths.

Because of a continuing shortage of test fish from the MRH in 2008, a full study program using acoustic telemetry was initiated in 2008 to include a number of acoustic receivers to better understand the survival of salmon smolts to Jersey Point and Chipps Island (the exit of the Delta). In 2009, a similar study was conducted although receivers at Jersey Point and Chipps Island were not deployed so estimates of survival were limited to south Delta channels. The study design was expanded in the 2010 VAMP study to reinstate the receiver array near Chipps Island (although not Jersey Point due to budget constraints). This report describes the experimental design used in 2010, the hydrologic planning and implementation during the first average year following three years 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 assessment of a non-physical barrier at the head of Old River. Conclusions and recommendations for future VAMP studies are also included.

2010 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 unbiased survival estimates could not be determined from the 2008 experiment, valuable information was collected on smolt movement (smolt distribution, migration timing and predator problems) and on methods of implementing an acoustic telemetry study under South Delta conditions to Chipps Island. In 2009, the VAMP experimental design followed the structural setup of the 2008 study but limited resources and key project staff non-availability resulted in a modified plan that did not include receivers at Jersey Point and Chipps Island and instead was focused on 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). This experimental design however left the VAMP without the key open-water receiver locations near Jersey Point and Chipps Island which are key to estimating survival through the Delta. While survival could be determined to the most downstream receivers near Turner Cut, survival through the Delta could not be estimated because of the missing open-water receivers at Chipps Island. This continues to be a long-term goal of the VAMP study team.

In the 2010 VAMP study, a major effort was made to refocus on these key downstream receivers and estimate survival through the Delta. Because of budgetary limitations, only the downstream receivers at Chipps Island were added back into the program in 2010. The receiver sites at Jersey Point were not in place in 2010. Within the resources that were available, the VAMP study team developed a study plan that called for nineteen acoustic receivers at twelve sites in the lower

San Joaquin River and Southern Delta. By developing the program cooperatively with the California Department of Water Resources South Delta Temporary Barriers study and the Non-physical Barrier evaluation being conducted by scientists from the U. S. Bureau of Reclamation, the VAMP was able to expand the number of receiver sites in the south Delta by eight. This final layout of the nineteen receivers from the VAMP program and the ones deployed by DWR and USBR provided good coverage of the South Delta migration routes that may be used by salmon smolts. This layout is described in Chapter 5 and shown Figure 5-2.

The 2010 VAMP represents the eleventh year of the approved twelve-year VAMP experiment. This report summarizes the efforts made during the 2010 VAMP flow and fish monitoring programs. Chapter 2 of this report describes the hydrologic planning and implementation during what was to be the first average year following three years of drought in the San Joaquin River Basin. Thus the flow regime was different than found in the previous three years. Chapter 3 describes the additional water supply arrangement and deliveries that occurred during the 2010 VAMP, including the fall attraction water following the three years 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 2010 VAMP.

Salmon smolt survival investigations are presented in Chapter 5. These include discussions on fish transport and releases 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. As in 2009, the 2010 study also included the development and execution of a survival model, with and without estimates of predation on tagged fish, and how well the receiver network and data development allowed an estimate of survival. Also included in this year's report in Chapter 6 is a discussion of fish health during the 2010 VAMP.

As in previous years, the report also includes a summary of complementary studies (Chapter 6) that were conducted at the same time as VAMP or were related to VAMP. These included salmon data from the tributaries, the 2010 Mossdale Trawl and, as mentioned above, 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 2010, 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.

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.

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 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 during any given year. 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.

2010 VAMP Year

The hydrologic conditions for the Water Year 2010[1] winter were very close to average 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 100% of average on April 1, 2010[2]. The forecasted April-July runoff as of April 1st in the four basins above Vernalis (Stanislaus, Tuolumne, Merced and San Joaquin) ranged from 93% to 107% of average[2]. The April 1st-90% probability of exceedence forecast of the San Joaquin Valley Water Year Type Index (60-20-20 Index) is used to define the current year's numerical indicator for use in determining whether a "double-step", "single-step" or "sequential dry-year relaxation" condition exists. For this April 1st forecast, Water Year 2010 was classified as "below normal" with a numerical indicator of 3. The numerical indicators for 2008 and 2009 were 1 ("critical") and 2 ("dry"), respectively (Table 2-3). The sum of the 2009 and 2010 numerical indicators was 5 so the "double step" condition, which occurs when that sum is 7 or greater, was not in effect. Conversely, the sum of the 2008, 2009 and 2010 numerical indicators was 6 so the "sequential dry-year relaxation" condition, which occurs when that sum is 4 or less, was not in effect. Therefore, the "single-step" condition was in effect of the 2010 VAMP operation.

The planning process for the VAMP operation differed from that of prior VAMP years due to the introduction of the following factors:

1. The National Marine Fisheries Service (NMFS) Reasonable and Prudent Alternatives (RPAs) for the Stanislaus and San Joaquin Rivers. The RPAs specified required flows on the Stanislaus and San Joaquin Rivers depending on time of year and hydrologic conditions. Both of these flow requirements would be met through additional releases of flow from New Melones Reservoir on the Stanislaus River.

2. The one-year extension of the SJRA. Under this extension agreement the VAMP supplemental water and accompanying operation would be determined prior to the VAMP period and no adjustments to the supplemental water or operation would be made during the VAMP period. The agreement specifies that the Existing Flow for the Stanislaus River would be determined for VAMP planning purposes as if the New Melones Interim Plan of Operation were in effect. The consequence of this is that if the NMFS RPAs require more flow than is required for the VAMP operation, the flow in the San Joaquin River at Vernalis would likely exceed the VAMP flow target.

Table 2-3
Prior Year San Joaquin Valley Water Year Hydrologic Classifications Numerical Indicators Used in VAMP Planning

Year	60-20-20 Water Year Hydrologic Classification	VAMP Numerical Indicator
2000	Above Normal	4
2001	Dry	2
2002	Dry	2
2003	Below Normal	3
2004	Dry	2
2005	Wet	5
2006	Wet	5
2007	Critical	1
2008	Critical	1
2009	Dry	2
2010	Above Normal [a]	4

[a] Final Determination of the 60-20-20 Water Year Classification is not determined until July 1st of each year, after the VAMP period and may differ from the classification used during the April 1st, 90% exceedence forecast used for VAMP flow planning. The final determination of the 60-20-20 Water Year Clasificatiion will be used in next year's planning of VAMP flows.

An additional factor for 2010 that was not present previously was the San Joaquin River Restoration Program (Restoration Program). The Restoration Program requires additional releases from Millerton Lake to restore flows and salmon fishery between Millerton Lake and the Merced River. The initial releases under this program commenced in October 2009. The effect of the Restoration Program on the VAMP operation is to potentially reduce the uncertainty associated with the estimate of flow in the San Joaquin River at the Merced River. There was still some uncertainty with regard to how much of the Restoration Program flows would reach the Merced River in this initial year of the program, but the information gathered this year should prove helpful for future VAMP planning.

[1] *Water Year 2010 is October 2009 through September 2010.*

[2] *Water Conditions in California, California Cooperative Snow Surveys Bulletin 120, Report 3, April 1, 2010. California Department of Water Resources.*

Hydrologic Planning for 2010 VAMP

The SJRTC Hydrology Group held its initial meeting for the 2010 VAMP planning on February 24, 2010. The SJRTC Hydrology Group met two additional times in combination with the SJRTC Biology Group on March 17th and April 13th. At these meetings, forecasts of hydrologic and operational conditions on the San Joaquin River and its tributaries were discussed and refined. A telephone conference of the SJRTC was held on April 16, 2010 to finalize the VAMP period daily operation plan.

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 24th SJRTC Hydrology Group meeting. The 90 percent probability of exceedence forecast indicated a VAMP target flow of 2,000 cfs and the 50 percent probability of exceedence forecast indicated a VAMP target flow of 3,200 cfs.

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 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).

A review of historical ungaged flows was made when the VAMP experiment was initially being developed to determine if there were any correlations between the ungaged flow and the 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.

Table 2-4
Summary of Daily Operation Plans for the 2010 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	3/16/10	3/9/10	April 25 - May 25	Single	600	2,870	3,200	20,480
					100	2,220	3,200	60,110
	4/12/10	3/23/10	April 25 - May 25	Single	300	3,020	3,200	11,010
Final	4/16/10	4/12/10	April 25 - May 25	Single	500	4,100	4,450	21,840

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 25th to May 25th for 2010 to allow the test salmon smolts to mature to the desirable size.

The initial daily operation plan was prepared on March 16th for the March 17th Hydrology Group meeting. Two versions of this plan were developed to account for hydrologic uncertainty, one considering wetter conditions and one considering drier conditions. Both conditions forecasted a VAMP Target Flow of 3,200 cfs with supplemental water requirements of about 20,500 acre-feet for the wetter condition and 60,000 acre-feet for the drier condition.

A second daily operation plan was prepared on April 12th. The DWR April 1st run-off forecast was not yet available when this plan was prepared, so it was based on the March 23rd interim runoff forecast. A single plan was developed at this time since the hydrologic condition uncertainty was much less due to the nearness of the VAMP flow period. The April 12th operation plan forecasted a VAMP Target Flow of 3,200 cfs, no change from the March 16th operation plan, but with a reduced supplemental water requirement of about 11,000 acre-feet.

The final daily operation plan was prepared on April 16th. As a result of cool and wet conditions in late March and early April and a corresponding increase in the run-off volume from the March 23rd forecast to the April 1st forecast the VAMP Target Flow increased to 4,450 cfs with a supplemental water requirement of 21,840 acre-feet. As stipulated by the SJRA Division Agreement the 21,840 acre-feet of supplemental water would be provided by Merced Irrigation District.

A key factor in the increased target flow from the April 12th operation plan to the April 16th operation plan was the need for increased flood control releases on the Tuolumne River. The uncertainty associated with flood control operations increased the uncertainty of achieving a stable flow for 31 days at Vernalis.

Table 2-4 provides a summary of the daily operation plans developed during the VAMP planning process. The daily operation plans are provided in their entirety in Appendix A, Tables 1 through 4.

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 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.

Implementation

Since the one year SJRA extension agreement stipulated that no changes to the proposed VAMP operation plan would be made once the VAMP operation commenced, the implementation phase of the VAMP hydrologic operation consisted mainly of monitoring the flow conditions during the VAMP period.

Table 2-5 Real-time Mean Daily Flow Data Sources Used in the 2010 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=2010-01-01&end_date=&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=2010-01-01&end_date=&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=2010-01-01&end_date=&site_no=11274000&referred_module=sw)

Table 2-6 Summary of USGS Flow Measurements at the San Joaquin River near Vernalis (VNS) Gage During the 2010 VAMP				
Date	**Time**	**Gage Height (ft.)**	**Measured Flow (cfs)**	**Rating Curve Shift (ft.)**
2/11/10	10:58	10.63	2,560	-0.08
4/19/10	12:29	12.80	4,460	-0.34
4/26/10	11:29	13.82	5,530	-0.34
5/18/10	12:22	12.55	4,410	-0.31
7/13/10	12:18	9.13	1,530	+0.10

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 2-5. 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.

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. 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. The results of these measurements are summarized in Table 2-6. There were no significant rating curve shifts experienced during the 2010 VAMP target flow period.

Results of Operations

The final record of flows during the VAMP period is based on the provisional mean daily flow data available from USGS, DWR and USBR as of October 1, 2010. 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, Figures 1 through 6, 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 5,140 cfs during the VAMP target flow period (April 25th – May 25th). 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 4,210 cfs and 5,890 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 2-7. The primary reason for the deviation of the observed flow from the target flow was the flood control operations on the Tuolumne River, which required higher releases from Don Pedro Reservoir than anticipated during the development of the VAMP daily operation plan. Additionally, flows in the San Joaquin River upstream of the Merced River were generally higher than expected, possibly the result of less loss from the restoration flows than expected.

Merced Irrigation District provided 23,980 acre-feet of supplemental water during the VAMP flow period. The deviation from the forecasted supplemental water contribution of 21,840 acre-feet is likely due to operational limitations and error and uncertainty in real-time gage flow data.

The mean daily ungaged flow at Vernalis averaged 190 cfs during the VAMP period, ranging from a minimum of -312 cfs to a maximum of 667 cfs. A plot of the ungaged flow is provided in Figure 2-3.

The combined CVP and SWP Delta export rate target during the VAMP period was 1,500 cfs. The observed exports during this period, shown in Figure 2-4, averaged 1,520 cfs and ranged from 1,320 cfs to 1,560 cfs.

Hydrologic Impacts

The MeID 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.

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 entering the 2010 VAMP operation was -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. Following the 2010 VAMP flow period flood control releases from Lake McClure were required resulting in the elimination of the aforementioned hypothetical storage deficit. 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 entering into 2010 was -19,650 acre-feet (see Figure 2-6). This storage deficit was eliminated by the flood control operations made in 2010.

Summary of Historical VAMP Operations

The year 2010 marks the eleventh year of VAMP operation in compliance with State Water Board Decision 1641 (D-1641). A summary of the VAMP target flows for these first eleven years is provided in Table 2-8. A summary of the SJRGA supplemental water contributions is provided in Table 2-9. 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 eleven years of VAMP operation are provided in Appendix B, Figures 1 through 4.

Over the eleven 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.

State Water Board D-1641 Reservoir Refill

Reservoir refill, or replenishment, is noted in three places in D-1641:

The first description of reservoir refill or replenishment is noted in condition 7 on page 168 of D-1641 which states that:

IT IS FURTHER ORDERED that Licenses 990, 2684, 2685, 6047, 11395, and 11396 (Applications 1221, 1222, 1224, 10572, 16186, and 16187, respectively) of the Merced Irrigation District, Licenses 7856 and 7860 (Applications 10872 and 13310, respectively) of the Oakdale and South San Joaquin Irrigation Districts, and Licenses 5417 and 11058 (Applications 1233 and 14127, respectively) of the Turlock and Modesto Irrigation Districts shall be amended *by adding the following conditions which shall expire on December 31, 2011 or at such time as the San Joaquin River Agreement (SJRA) is terminated, whichever occurs first.*

Condition 7 specifically states that (bold emphasis added for those related to reservoir refill):

(7.) Annually, Licensees shall submit an operations report to the Executive Director of the SWRCB by January 30 of the year following each year of operation under the SJRA. The report shall identify (a) the source and quantity of water released from storage, or storage and direct diversions foregone to meet the April-May pulse flow objective in the San Joaquin River at Airport Way Bridge in Vernalis; (b) the time period when this water was released from storage, or not diverted; ***(c) a monthly accounting of reservoir operations to refill reservoir storage;*** *(d) the source and quantity of water transferred to the USBR pursuant to the terms of the SJRA; (e) the quantity, timing, and location of groundwater extractions made to maintain water supply deliveries due to the SJRA; (f) the time period in which water sold to the USBR was released from storage or not diverted; and* ***(g) an analysis showing that all storage releases, storage and direct diversions foregone, and replenishment operations listed above were performed within the limits, terms and conditions of these licenses.***

The second description of reservoir refill or replenishment is noted in condition 3 on page 169 of D-1641 which states that:

IT IS FURTHER ORDERED that Licenses 990, 2684, 2685, 6047, 11395, and 11396 (Applications 1221, 1222, 1224, 10572, 16186, and 16187, respectively) of the Merced Irrigation District be amended by adding the following conditions which shall expire on December 31, 2011 or at such time as the San Joaquin River Agreement (SJRA) is terminated, whichever occurs first.

Condition 3 specifically states that:

(3.) At times when the USBR is releasing water from New Melones Reservoir for the purpose of meeting the Vernalis salinity objective, or when Standard Permit Term 93 is in effect, or when salinity objectives at Vernalis are not being met, Licensee shall not replenish (1) stored water or foregone diversions provided for the April-May pulse flow or the October target flow at Vernalis, or (2) water transferred to the USBR pursuant to the SJRA. The Executive Director of the SWRCB is delegated authority to ensure that this condition is not used by the USBR to increase the obligation of Licensee.

The third description of reservoir refill or replenishment is noted on page 170 of D-1641 which states that:

IT IS FURTHER ORDERED that Licenses 5417 and 11058 (Applications 1233 and 14127, respectively) of the Modesto and Turlock Irrigation Districts shall be amended by adding the following conditions which shall expire on December 31, 2011 or at such time as the San Joaquin River Agreement (SJRA) is terminated, whichever occurs first.

At times when the USBR is releasing water from New Melones Reservoir for the purpose of meeting the Vernalis salinity objective, or when Standard Permit Term 93 is in effect, or when salinity objectives at Vernalis are not being met, Licensees shall not replenish (1) stored water or foregone diversions provided for the April/May pulse flow at Vernalis, or (2) water transferred to the USBR pursuant to the San Joaquin River Agreement. The Executive Director of the SWRCB is delegated authority to ensure that this condition is not used by the USBR to increase the obligation of Licensee.

Tables 2-10 and 2-11 summarize when supplemental water was provided and when the storage was theoretically replenished for Lake McClure and Don Pedro Reservoir (refill), respectively. It should be noted that, contrary to the implication in the D-1641 conditions noted above, one does not choose when to replenish or refill. Refill occurs when reservoir releases under the hypothetical "without D-1641" scenario would be less than those that actually occur. There are two conditions that would cause this: 1) when the reservoir fills (i.e. when storage reaches the top of the allowable conservation storage), and 2) when the reservoir empties.

Another factor that would affect the size of the "hole" in the reservoir that would eventually be refilled is conservation by the irrigation districts that reduces diversions from the rivers downstream of the reservoirs that is a direct result of the SJRA. In other words, if a district provides 10,000 ac-ft of supplemental water from storage and subsequently has no changes in diversions from the river downstream of the reservoir, then the "hole" in the reservoir would be 10,000 ac-ft. However, if the district were paid for providing that supplemental water and used those funds to improve their efficiency (as is the case with the SJRA) which in turn results in reduced diversions from the river, which would back up the amount of reduction into the reservoir, reducing the "hole" that would need to be refilled. Since the effects of SJRA related conservation have not yet been quantified, the refill analysis presented herein assumes that demands on the rivers are the same both with and without D-1641.

As shown in Tables 2-10 and 2-11, even without accounting for the reduced river diversions due to SJRA-related conservation projects, reservoir refill has not occurred during times when *"the USBR is releasing water from New Melones Reservoir for the purpose of meeting the Vernalis salinity objective or when Standard Permit Term 93 is in effect, or when salinity objectives at Vernalis are not being met."*

Plots comparing the theoretical without D-1641 storage and release for Lake McClure and Don Pedro Reservoir with the observed, or with D-1641, storage and release for the reservoir refill periods are provided in Appendix E. These plots illustrate the determination of the refill periods. Plots showing the Vernalis water quality condition during the refill periods and the corresponding Stanislaus River flow are provided in Appendix F. These plots provide the support for determining whether or not *"the USBR is releasing water from New Melones Reservoir for the purpose of meeting the Vernalis salinity objective, or when Standard Permit Term 93 is in effect, or when salinity objectives at Vernalis are not being met".*

Table 2-7
2010 Vernalis Adaptive Management Plan (VAMP)
Final Flows and Accounting of Supplemental Water Contributions
VAMP Target Flow Period: April 25th – May 25th · Target Flow: 4,450 cfs

Date	Merced R. at Cressey				Tuolumne R. blw LaGrange Dam			Stanislaus R. blw Goodwin Dam			San Joaquin R. above Merced R. Flow [2] (cfs)	Ungaged Flow at Vernalis (cfs)	San Joaquin River at Vernalis		
	(3 day Travel Time to Vernalis) Existing Flow [1] (cfs)	Observed Flow (cfs)	Merced ID Supple-mental Flow (cfs)	Exchange Contrac-tors Supple-mental Flow (cfs)	(2 day Travel Time to Vernalis) Existing Flow [1] (cfs)	Observed Flow (cfs)	MID/TID Supple-mental Flow (cfs)	(2 day Travel Time to Vernalis) Existing Flow [1] (cfs)	Observed Flow (cfs)	OID/ SSJID Supple-mental Flow (cfs)			Existing Flow [1] (cfs)	Observed Flow (cfs)	VAMP Supple-mental Water (cfs)
04/01/10	232	232			480	480		1,274	1,274		882	360	1,920	1,920	
04/02/10	189	189			634	634		1,354	1,354		853	377	2,040	2,040	
04/03/10	171	171			652	652		1,355	1,355		847	(171)	2,700	2,700	
04/04/10	163	163			652	652		1,359	1,359		861	(33)	3,040	3,040	
04/05/10	213	213			651	651		1,365	1,365		897	307	3,350	3,350	
04/06/10	203	203			653	653		1,353	1,353		952	457	3,500	3,500	
04/07/10	194	194			652	652		1,356	1,356		1,052	494	3,570	3,570	
04/08/10	198	198			652	652		1,358	1,358		1,101	459	3,630	3,630	
04/09/10	188	188			707	707		1,170	1,170		1,075	297	3,560	3,560	
04/10/10	178	178			759	759		1,005	1,005		1,068	195	3,500	3,500	
04/11/10	206	206			760	760		1,006	1,006		1,050	290	3,440	3,440	
04/12/10	227	227			1,080	1,080		1,014	1,014		1,079	610	3,630	3,630	
04/13/10	268	268			1,270	1,270		1,006	1,006		1,108	696	3,690	3,690	
04/14/10	251	251			1,260	1,260		999	999		1,136	691	4,070	4,070	
04/15/10	231	231			1,330	1,330		1,007	1,007		1,246	569	4,180	4,180	
04/16/10	218	218			1,580	1,580		1,022	1,022		1,291	567	4,230	4,230	
04/17/10	200	200			1,770	1,770		1,006	1,006		1,235	526	4,360	4,360	
04/18/10	205	205			1,950	1,950		1,008	1,008		1,146	366	4,490	4,490	
04/19/10	211	211			1,980	1,980		1,007	1,007		1,091	291	4,520	4,520	
04/20/10	221	221			2,140	2,140		1,010	1,010		1,074	366	4,670	4,670	
04/21/10	267	267			2,150	2,150		1,004	1,004		1,055	717	5,000	5,000	
04/22/10	250	567	317	0	2,130	2,130		1,000	1,000		1,087	595	5,030	5,030	
04/23/10	250	728	478	0	2,160	2,160	0	1,006	1,006	0	1,110	660	5,090	5,090	
04/24/10	250	907	657	0	1,990	1,990	0	1,007	1,007	0	1,190	826	5,310	5,310	
04/25/10	250	965	715	0	1,770	1,770	0	1,008	1,008	0	1,190	667	5,193	5,510	317
04/26/10	250	965	715	0	1,750	1,750	0	1,004	1,004	0	1,140	635	5,072	5,550	478
04/27/10	250	965	715	0	1,750	1,750	0	1,003	1,003	0	1,100	605	4,823	5,480	657
04/28/10	250	961	711	0	1,740	1,740	0	1,003	1,003	0	1,040	501	4,645	5,360	715
04/29/10	250	725	475	0	1,770	1,770	0	1,005	1,005	0	1,010	472	4,575	5,290	715
04/30/10	250	493	243	0	2,090	2,090	0	1,003	1,003	0	1,023	342	4,375	5,090	715
05/01/10	250	416	166	0	2,350	2,350	0	1,005	1,005	0	1,027	224	4,259	4,970	711
05/02/10	250	427	177	0	2,340	2,340	0	1,001	1,001	0	963	159	4,525	5,000	475
05/03/10	250	414	164	0	2,560	2,560	0	1,005	1,005	0	938	105	4,737	4,980	243
05/04/10	250	503	253	0	3,300	3,300	0	1,015	1,015	0	942	40	4,594	4,760	166
05/05/10	250	786	536	0	3,280	3,280	0	1,005	1,005	0	895	210	4,963	5,140	177
05/06/10	250	776	526	0	3,280	3,280	0	1,012	1,012	0	831	(161)	5,346	5,510	164
05/07/10	250	773	523	0	3,290	3,290	0	1,025	1,025	0	905	(63)	5,367	5,620	253
05/08/10	250	768	518	0	3,290	3,290	0	1,017	1,017	0	924	(289)	5,084	5,620	536
05/09/10	250	582	332	0	3,280	3,280	0	1,018	1,018	0	878	(276)	5,194	5,720	526
05/10/10	250	412	162	0	3,290	3,290	0	1,015	1,015	0	919	(114)	5,367	5,890	523
05/11/10	250	364	114	0	3,300	3,300	0	1,025	1,025	0	924	(164)	5,262	5,780	518
05/12/10	250	356	106	0	3,120	3,120	0	1,011	1,011	0	877	(216)	5,258	5,590	332
05/13/10	250	344	94	0	2,680	2,680	0	1,028	1,028	0	790	(241)	5,258	5,420	162
05/14/10	250	470	220	0	2,580	2,580	0	1,017	1,017	0	667	(312)	4,946	5,060	114
05/15/10	250	641	391	0	2,440	2,440	0	1,016	1,016	0	547	(134)	4,614	4,720	106
05/16/10	250	650	400	0	2,230	2,230	0	876	876	0	448	112	4,626	4,720	94
05/17/10	250	655	405	0	2,160	2,160	0	790	790	0	473	87	4,340	4,560	220
05/18/10	250	646	396	0	2,160	2,160	0	818	818		478	95	3,899	4,290	391
05/19/10	250	662	412	0	2,150	2,150	0	824	824		476	137	3,810	4,210	400
05/20/10	250	647	397	0	2,140	2,140	0	811	811		504	99	3,805	4,210	405
05/21/10	250	635	385	0	2,150	2,150	0	806	806		441	184	3,884	4,280	396
05/22/10	250	632	382	0	3,060	3,060	0	814	814		413	133	3,838	4,250	412
05/23/10	417	417			3,140	3,140	0	688	688		428	566	4,213	4,610	397
05/24/10	342	342			3,150	3,150		384	384		468	148	4,685	5,070	385
05/25/10	343	343			3,140	3,140		206	206		520	42	4,548	4,930	382
05/26/10	335	335			3,160	3,160		209	209		536	341	4,760	4,760	
05/27/10	350	350			2,610	2,610		214	214		555	532	4,740	4,740	
05/28/10	351	351			2,250	2,250		206	206		663	362	4,610	4,610	
05/29/10	339	339			2,050	2,050		203	203		745	676	4,390	4,390	
05/30/10	345	345			2,040	2,040		204	204		816	721	4,190	4,190	
05/31/10	346	346			2,040	2,040		202	202		854	741	4,090	4,090	
							VAMP Period								
Average (cfs):	244	557	388	0	2,449	2,449	0	999	999	0	950	190	4,831	5,144	389
Supplemental Water (ac-ft):			23,980	0			0			0					23,980

■ 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, Water Data Library, 9/14/10
Merced River near Stevinson (CA DWR B05125): California DWR, USDAY V71 Output 8/25/10
Tuolumne River below LaGrange Dam near LaGrange (USGS 11289650): USGS, provisional data as of 9/14/10
Stanislaus River below Goodwin Dam: USBR, Goodwin Reservoir Daily Operations Report - OID/SSJID/Tri-Dams, 5/1/10 (April report) and 6/1/10 (May report)
San Joaquin River near Vernalis (USGS 11303500): USGS, provisional data as of 9/14/10
San Joaquin River at Newman (USGS 11274000): USGS, provisional data as of 9/14/10

Table 2-8
Summary of VAMP Flows, 2000-2010

Year	VAMP Target Flow Period	VAMP Target Flow Condition	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	4/15 - 5/15	Double-step	5,700	5,869	4,800	77,680	2,250	2,155
2001	4/20 - 5/20	Single-step	4,450	4,224	2,909	78,650	1,500	1,420
2002	4/15 - 5/15	Single-step	3,200	3,301	2,757	33,430	1,500	1,430
2003	4/15 - 5/15	Single-step	3,200	3,235	2,290	58,065	1,500	1,446
2004	4/15 - 5/15	Single-step	3,200	3,155	2,088	65,591	1,500	1,331
2005	5/1 - 5/31	na [a]	>7,000	10,390	10,390	0	2,250	2,986 [b]
2006	5/1 - 5/31	na [a]	>7,000	26,220/24,262 [c]	26,020	0	1,500/6,000	1,559/5,748 [c]
2007	4/22 - 5/22	Single-step	3,200	3,263	2,721	33,330	1,500	1,486
2008	4/22 - 5/22	Single-step	3,200	3,163	1,939	75,250	1,500	1,520
2009	4/19 - 5/19	Off-ramp	na	2,260	2,260	0	na	1,990
2010	4/25 - 5/25	Single-step	4,450	5,140	4,830	23,980	1,500	1,515

[a] Existing flow greater than maximum VAMP Target Flow of 7,000 cfs
[b] 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.
[c] "First fish release-recapture period"/"Second fish release-recapture period"

Table 2-9
Summary of VAMP Supplemental Water Contributions, 2000 - 2010

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	7300 [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
2010	23,980	Observed:	23,980	0	0	0	0	0
		Division Agreement:	23,980	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.

Table 2-10
Summary of When Supplemental Water Was Provided and When Storage Was Theoretically Replenished for Lake McClure on the Merced River as Required Under D-1641

Date Range	D-1641 Supplemental Water [SJRA year] (ac-ft)	Reservoir Refill (ac-ft)	Storage Impact (ac-ft)	Vernalis Status [1]
4/18/00 - 5/11/00	46,750 [2000]		-46,750	
5/13/00 - 5/29/00		46,750	0	N
10/15/00 - 12/31/00	12,500 [2000]		-12,500	
4/17/01 - 5/19/01	42,120 [2001]		-54,620	
11/12/01 - 12/31/01	12,500 [2001]		-67,120	
4/13/02 - 5/15/02	25,840 [2002]		-92,960	
10/15/02 - 10/31/02	12,470 [2002]		-105,430	
4/11/03 - 5/16/03	38,260 [2003]		-143,690	
10/1/03 - 10/27/03	12,500 [2003]		-156,190	
4/12/04 - 5/13/04	42,680 [2004]		-198,870	
10/1/04 - 10/26/04	12,500 [2004]		-211,370	
1/25/05 - 3/23/05		211,370	0	N
8/26/05 - 9/3/05		12,500	12,500	N
10/1/05 - 10/26/05	12,500 [2005]		0	
10/8/06 - 10/28/06	12,500 [2006]		-12,500	
4/19/07 - 5/19/07	28,960 [2007]		-41,460	
11/6/07 - 12/17/07	12,500 [2007]		-53,960	
4/22/08 - 5/19/08	38,150 [2008]		-92,110	
10/1/08 - 10/24/08	12,500 [2008]		-104,610	
10/1/09 - 10/31/09	12,500 [2009]		-117,110	
4/22/10 - 5/22/10	23,970 [2010]		-141,080	
4/13/10 - 5/23/10		141,080	0	N
10/15/10 - 11/8/10	12,500 [2010]		-12,500	
11/27/10 - 12/8/10		12,500	0	N

[1] Y = USBR releasing water from New Melones Reservoir for Vernalis WQ
N = USBR not releasing water from New Melones Reservoir for Vernalis WQ

Table 2-11
Summary of When Supplemental Water Was Provided and When Storage Was Theoretically Replenished for Don Pedro Reservoir on the Tuolumne River as Required Under D-1641

Date Range	(ac-ft)	Reservoir Refill (ac-ft)	Storage Impact (ac-ft)	Vernalis Status [1]
4/13/00 - 5/12/00	22,650 [2000]		-22,650	
9/27/00 - 10/7/00		14,950	-7,700	N
3/23/01 - 3/28/01		4,610	-3,090	N
4/18/01 - 5/18/01	14,060 [2001]		-17,150	
4/13/03 - 5/13/03	9,730 [2003]		-26,880	
3/10/04 - 3/16/04		12,590	-14,290	N
3/27/04 - 4/1/04		14,290	0	N
4/13/04 - 5/13/04	11,150 [2004]		-11,150	
3/21/05 - 3/24/05		11,150	0	N
4/20/07 - 5/6/07	4,370 [2007]		-4,370	
4/20/08 - 5/20/08	15,280 [2008]		-19,650	
4/8/10 - 4/17/10		19,650	0	N

[1]
Y = USBR releasing water from New Melones Reservoir for Vernalis WQ
N = USBR not releasing water from New Melones Reservoir for Vernalis WQ

Figure 2-2

Recorded Flows during the 2010 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

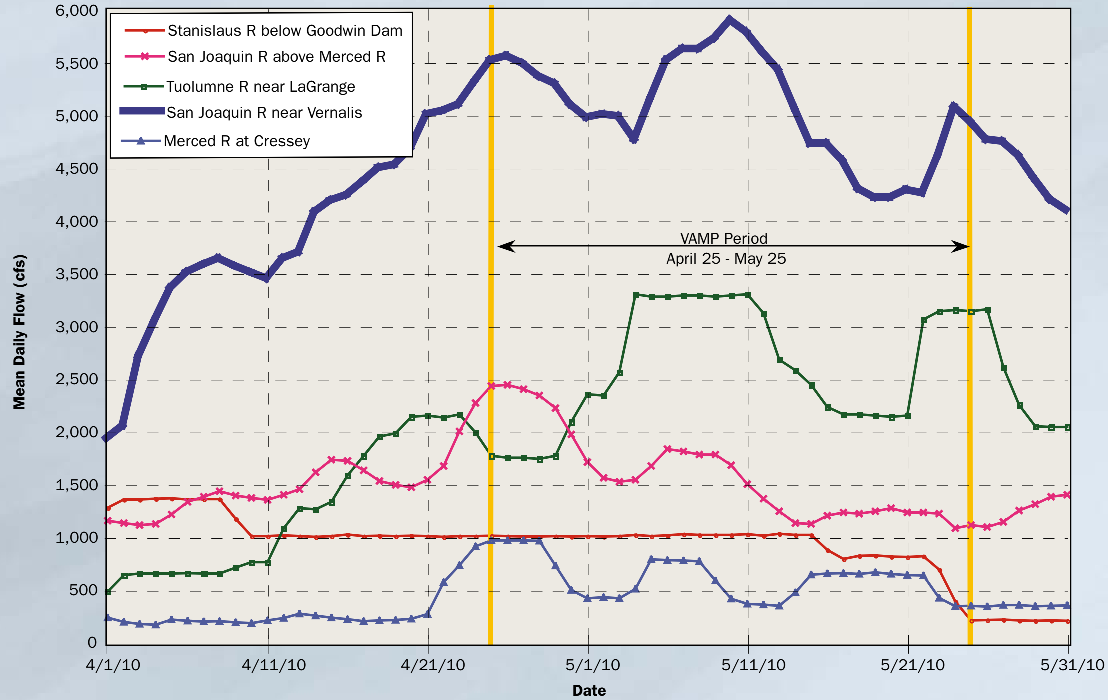


Figure 2-3

Ungaged Flow in the San Joaquin River at Vernalis (VNS) during the 2010 VAMP

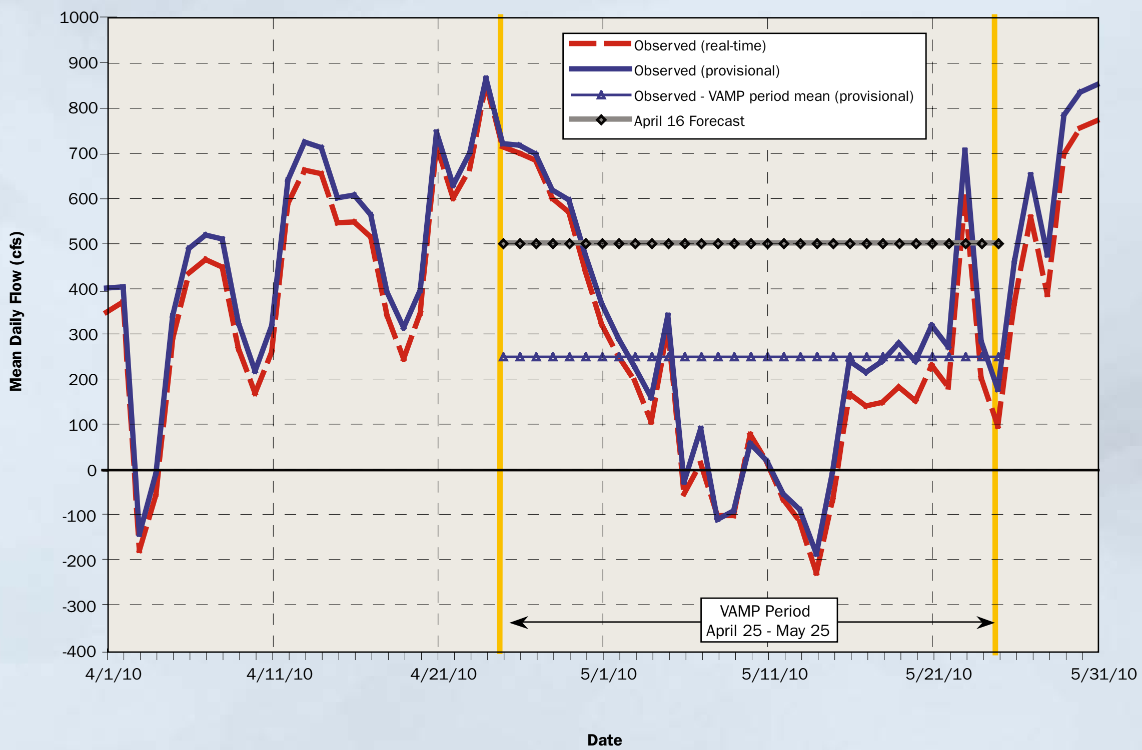


Figure 2-4
Federal and State Delta Exports during the 2010 VAMP

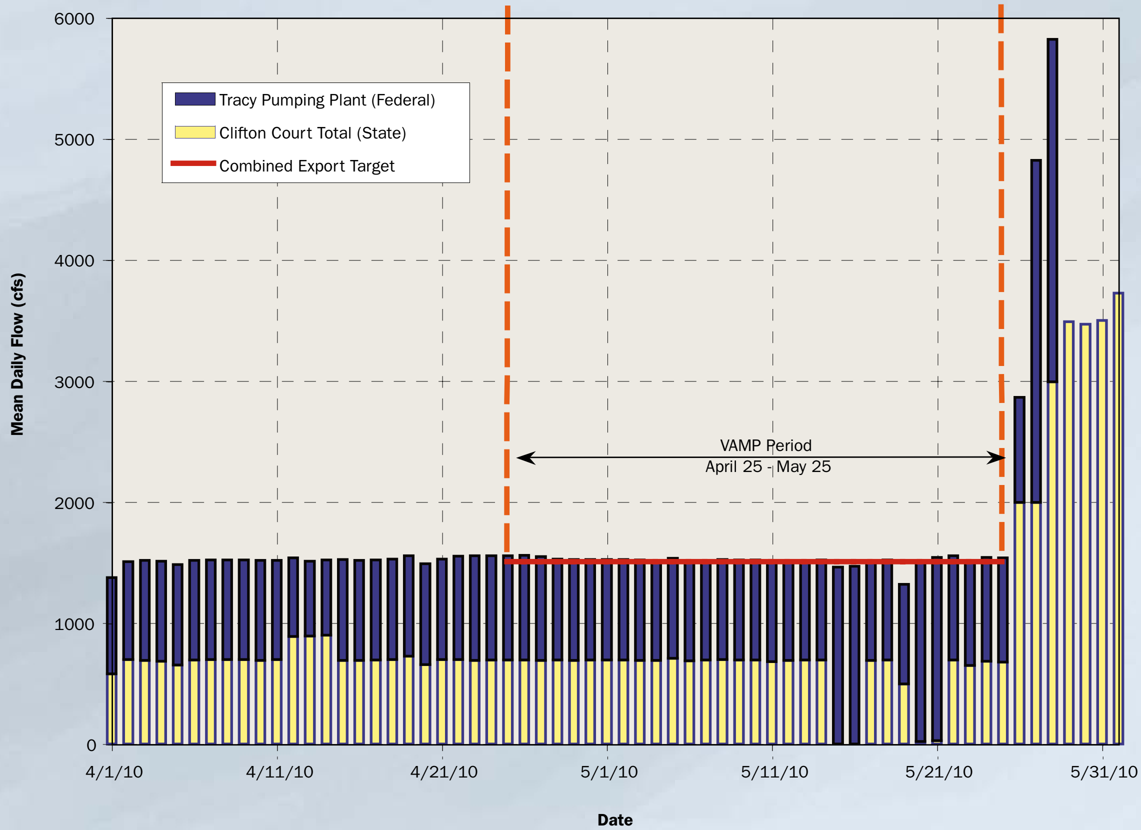


Figure 2-5
San Joaquin River Agreement (SJRA) Storage and Flow Impacts
Merced River – Lake McClure Storage and Release - 2010

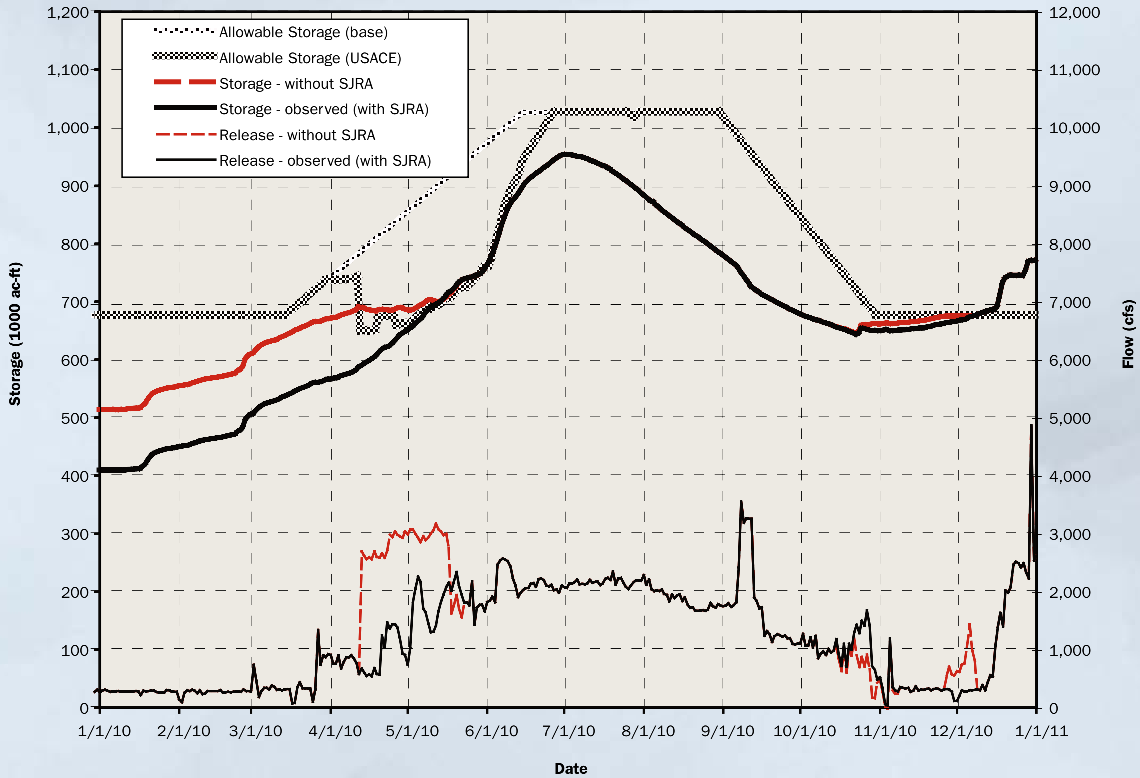
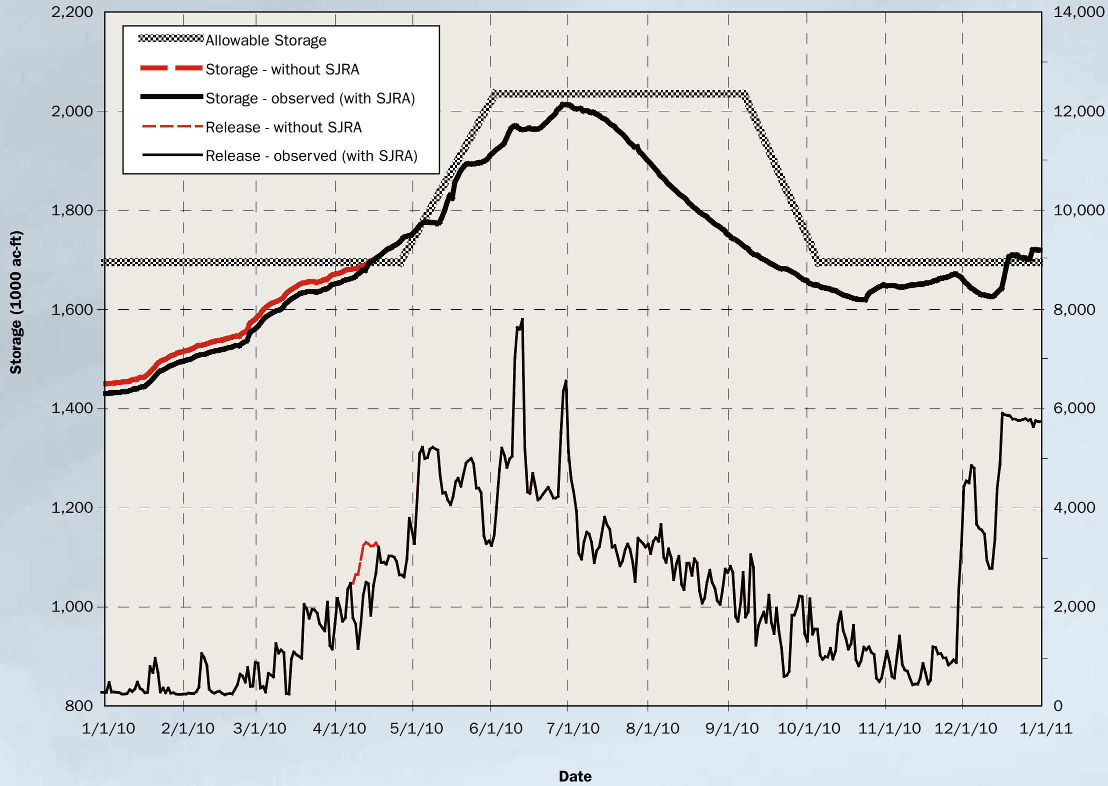


Figure 2-6
San Joaquin River Agreement (SJRA) Storage and Flow Impacts on the Tuolumne River –
New Don Pedro Reservoir Storage and Release - 2010



CHAPTER 3
ADDITIONAL WATER SUPPLY ARRANGEMENTS & 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 by MeID was finalized on September 30, 2010, with the water to be provided from October 15th through November 8th as shown in Table 3-1 and Figure 3-1. Table 3-1 also includes an accounting of the observed Fall SJRA Water Transfer.

Oakdale Irrigation District (OID)

The combined Paragraph 8.5 water is referred to as the OID Additional Water. 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). OID did not provide any supplemental water for the 2010 VAMP, therefore OID made available 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

Table 3-1
2010 Merced Irrigation District SJRA Fall Water Transfer Daily Summary

		SCHEDULED			OBSERVED				
		SJRA Transfer Water						SJRA Transfer Water	
Date	Merced River Base Flow at Shaffer Br/ Cressey (cfs)	SJRA Transfer Water Flow (cfs)	Cumulative SJRA Transfer Water Volume (acre-ft)	Merced River Target Flow at Shaffer Br/Cressey (cfs)	Merced River Flow at Shaffer Br/Cressey [Merced ID1] (cfs)	Merced River Flow at Cressey [DWR2] (cfs)	Observed Flow for Transfer 3 (cfs)	SJRA Transfer Daily Flow Rate (cfs)	Cumulative SJRA Transfer Water Volume (acre-ft)
1-Oct	30	0	0	30	148	128	148	0	0
2-Oct	30	0	0	30	155	120	155	0	0
3-Oct	30	0	0	30	158	138	158	0	0
4-Oct	30	0	0	30	158	145	158	0	0
5-Oct	30	0	0	30	158	147	158	0	0
6-Oct	30	0	0	30	168	146	168	0	0
7-Oct	30	0	0	30	155	151	155	0	0
8-Oct	30	0	0	30	172	143	172	0	0
9-Oct	30	0	0	30	176	151	176	0	0
10-Oct	30	0	0	30	165	161	165	0	0
11-Oct	30	0	0	30	161	156	161	0	0
12-Oct	30	0	0	30	145	141	145	0	0
13-Oct	30	0	0	30	148	128	148	0	0
14-Oct	30	0	0	30	158	132	158	0	0
15-Oct	30	50	99	80	172	135	172	142	282
16-Oct	85	40	179	125	172	154	172	87	454
17-Oct	85	65	307	150	176	158	176	91	635
18-Oct	85	90	486	175	176	161	176	91	815
19-Oct	85	115	714	200	179	178	179	94	1,002
20-Oct	85	160	1,031	245	179	176	179	94	1,188
21-Oct	85	165	1,359	250	191	179	191	106	1,398
22-Oct	85	365	2,083	450	857	191	191	106	1,609
23-Oct	85	515	3,104	600	829	609	609	524	2,648
24-Oct	85	615	4,324	700	897	674	674	589	3,816
25-Oct	85	615	5,544	700	980	712	712	627	5,060
26-Oct	85	615	6,764	700	1,035	788	788	703	6,454
27-Oct	85	615	7,983	700	1,016	841	841	756	7,954
28-Oct	85	615	9,203	700	705	842	842	757	9,455
29-Oct	85	415	10,026	500	679	628	628	543	10,532
30-Oct	85	415	10,850	500	557	568	568	483	11,490
31-Oct	85	315	11,474	400	442	497	497	56	11,601
1-Nov	220	130	11,732	350	425	402	402	57	11,714
2-Nov	220	80	11,891	300	350	382	382	58	11,829
3-Nov	220	55	12,000	275	358	326	326	59	11,946
4-Nov	220	55	12,109	275	358	323	323	60	12,065
5-Nov	220	55	12,218	275	362	325	325	61	12,186
6-Nov	220	55	12,327	275	358	326	326	62	12,309
7-Nov	220	55	12,436	275	309	315	315	63	12,434
8-Nov	220	30	12,496	250	297	275	297	33	12,500
9-Nov	220			220	273	284	273		
10-Nov	220			220	281	264	281		
11-Nov	220			220	261	261	261		
12-Nov	220			220	241	251	241		
13-Nov	220			220	253	233	253		
14-Nov	220			220	249	242	249		
15-Nov	220			220	253	231	253		
16-Nov	220			220	229	236	229		
17-Nov	220			220	217	221	217		

1 Merced Irrigation District Daily Water Tabulation and Use Report
2 California Department of Water Resources, B05155 Merced River at Cressey, USDAY V91 Output 01/14/11
3 The Technical Appendix to the San Joaquin River Group Division Agreement states that "[T]he Merced River at Shaffer Bridge…will be used for flows between 0 and 300 cfs. …[F]or the flows above 300 cfs, measurements will be provided at the gage on the Merced River located near Cressey."

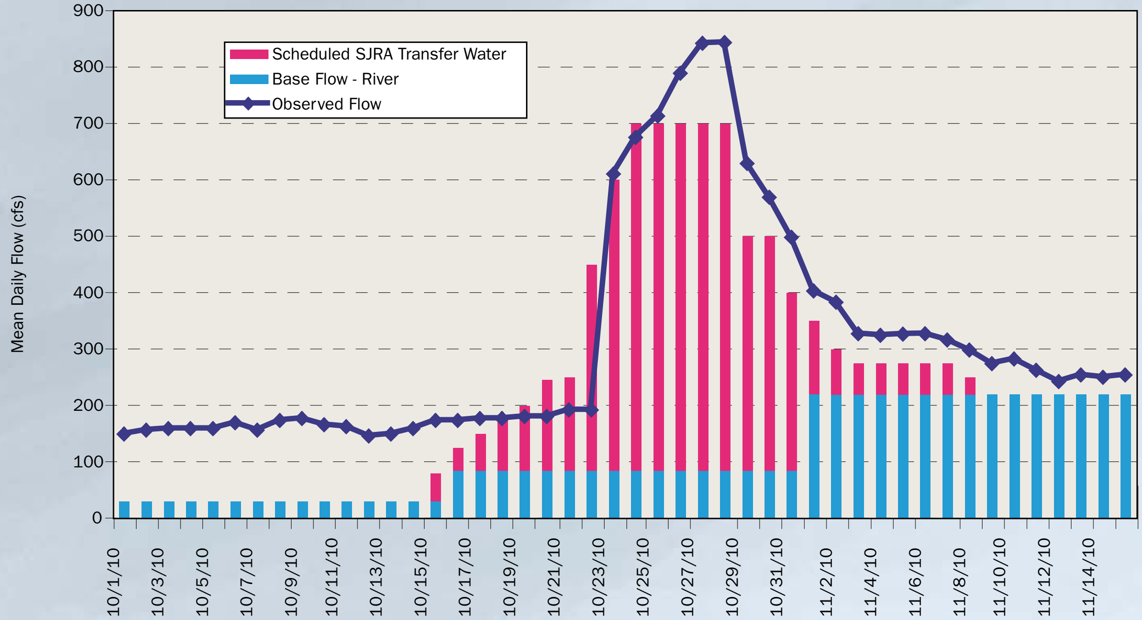
under Paragraph 8.5 of the SJRA was 26,000 acre-feet (15,000 acre-feet plus 11,000 acre-feet of Difference Water). The OID additional water is made available in New Melones Reservoir for use by the USBR for any authorized purpose of the New Melones project.

The 11,000 ac-ft of Difference Water and the 15,000 ac-ft of additional water was used to supplement river flow in the Stanislaus River for fishery purposes during October of 2010 as shown in Table 3-2.

Table 3-2
2010 Oakdale Irrigation District SJRA Additional and Difference Water Daily Release Summary

Date of Release	Estimated Flow in cubic feet per second (cfs)	Cumulative Flow in acre-feet (ac-ft)
10/15/10	177	351
10/16/10	463	1,269
10/17/10	717	2,692
10/18/10	972	4,620
10/19/10	1050	6,702
10/20/10	1050	8,785
10/21/10	1218	11,201
10/22/10	1297	13,773
10/23/10	686	15,134
10/24/10	1210	17,534
10/25/10	1100	19,716
10/26/10	1084	21,866
10/27/10	949	23,748
10/28/10	690	25,117
10/29/10	445	26,000

Figure 3-1
Merced Irrigation District Fall 2010 Water Transfer as
Shown by Merced River Flow at Shaffer Bridge/Cressey

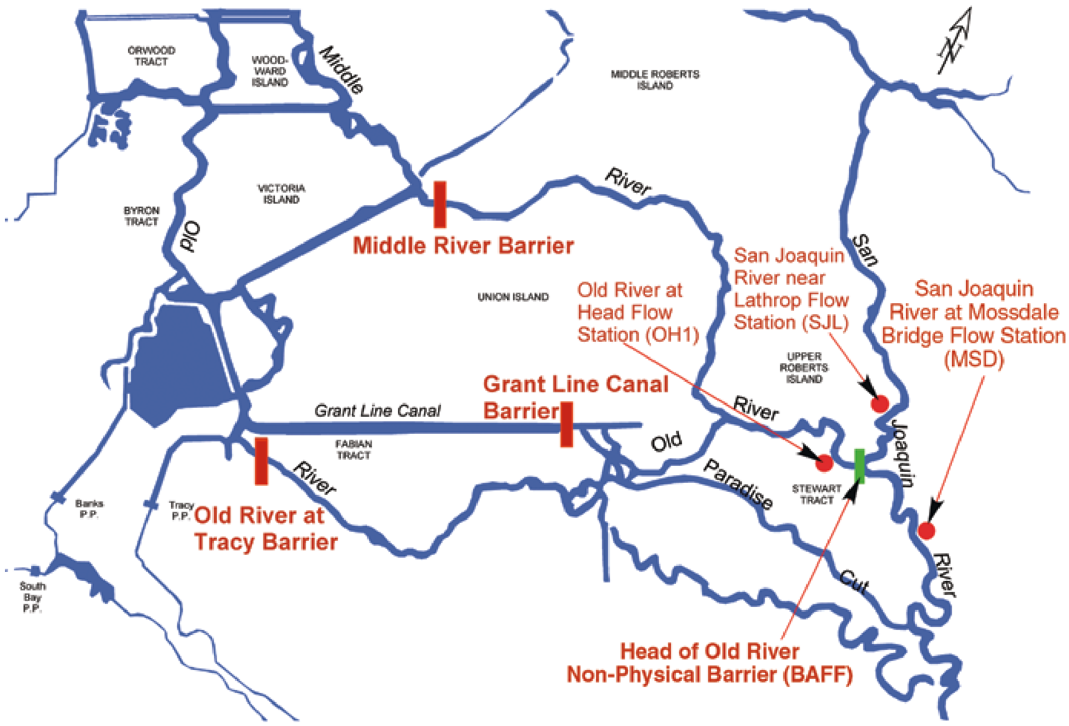


CHAPTER 4

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 2010 was again prohibited in a Federal Court decision by United States Fresno District Court Judge Wanger for increased protection for delta smelt. To provide equivalent protection in 2010, several agencies and groups designed, implemented and monitored a non-physical barrier call a Bio-Acoustic Fish Fence (BAFF). The first installation of the BAFF occurred in 2009 and 2010 was the second year of evaluation of this barrier.

Figure 4-1
Location Map – South Delta Agricultural and Non-Physical Barriers



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 head of Old River as shown in Figure 4-1. One is 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 acoustical Doppler was installed in 2006 in the main stem 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, 2010 through June 30, 2010 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.

In contrast to 2009 which was a sequential dry-year relaxation (no VAMP Target flows provided because of the continued drought), the 2010 VAMP year provided

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.

a Target flow of 4,450 cfs. The impact of these 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 (April 25th – June 25th), on average 58% of the flow recorded in the San Joaquin River at Mossdale Bridge (MSD) was moving into Old River (OH1) and 42% was continuing downstream in the main stem San Joaquin River toward the gage near Lathrop (SJL). This is in contrast to the 75:25% split that occurred during the low flow period of 2009. During the entire period of record for 2010 shown in Table 4-1, the average flow split remained at a 58:42% split.

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 1,500 cfs as required in the NMFS and USFWS BiOps. During the VAMP Target (Pulse) flow period, exports averaged 1,430 cfs and also during most of the fish release and tracking period (April 25th – June 25th). Exports also averaged 1,460 cfs during the 60-day period beginning on April 1st. As shown in Table 4-2, exports flows fluctuated from 10 – 40% and averaged only 30% (<0.3 : 1) of the flow recorded at the San Joaquin River at Vernalis (VNS) gage. Analysis of the data from the San Joaquin River at Mossdale Bridge (MSD) gage was not conducted as there seem to be a serious discrepancy between the gage at Vernalis (VNS) and the one at Mossdale Bridge (MSD). An analysis provided by MBK Engineers shows there may have been a rating curve adjustment on or about June 4th (Figure 4-5). Prior to that time, the flow at Mossdale was about 125% of the flow at Vernalis (VNS). After the rating curve adjustment, the flow at Vernalis and Mossdale appear to be the same. This was further verified by taking the sum of the gage Old River at Head (OH1) and San Joaquin River below Old River near Lathrop (SJL) which should essentially equal the Mossdale Bridge gage but it appears to agree with Vernalis instead (Figure 4-6). During the entire time period shown in Table 4-2 (April 1st – June 30th), exports flows averaged 77% of the flow recorded at the San Joaquin River at Vernalis (VNS) gage for a ratio of 0.8 : 1.

Table 4-1
Measured Flows in San Joaquin River at Mossdale, Old River at Head and San Joaquin River below Old River.

Date	Old River at Head (OH1)			San Joaquin River below Old River (SJL)			San Joaquin River at Mossdale (MSD)		
	Minimum Flow	Maximum Flow	Mean Daily Flow	Minimum Flow	Maximum Flow	Mean Daily Flow	Minimum Flow	Maximum Flow	Mean Daily Flow
	(cfs)	(cfs)	(cfs)	(cfs)	(cfs)	(cfs)	(cfs)	(cfs)	(cfs)
4/1/10	241	2,220	1,408	-1,380	2,130	550	686	3,710	2,561
4/2/10	207	2,170	1,412	-1,270	1,970	538	655	3,590	2,561
4/3/10	780	2,310	1,659	-1,030	2,260	969	1,780	4,510	3,457
4/4/10	1,150	2,390	1,863	-641	2,340	1,164	2,680	4,770	3,866
4/5/10	1,210	2,480	1,931	-210	2,560	1,509	3,120	5,200	4,319
4/6/10	1,410	2,470	1,997	542	2,440	1,715	3,880	4,910	4,377
4/7/10	1,530	2,500	2,034	524	2,350	1,697	3,550	4,700	4,192
4/8/10	1,530	2,500	2,078	127	2,430	1,683	3,540	4,730	4,216
4/9/10	1,520	2,580	2,082	70	2,430	1,634	3,450	4,730	4,175
4/10/10	1,470	2,660	2,131	-172	2,550	1,460	3,170	4,860	4,070
4/11/10	1,440	2,700	2,136	-787	2,560	1,438	2,930	4,840	4,077
4/12/10	1,450	2,870	2,159	-491	2,660	1,502	3,100	5,080	4,238
4/13/10	1,490	2,880	2,180	-201	2,790	1,688	3,270	5,090	4,415
4/14/10	1,650	2,890	2,308	-264	2,870	1,781	3,310	5,390	4,681
4/15/10	1,690	3,060	2,389	67	3,040	1,981	3,920	5,600	4,930
4/16/10	1,680	2,990	2,410	-299	3,220	1,956	3,750	5,750	4,934
4/17/10	1,660	3,010	2,459	141	3,100	2,061	3,840	5,960	5,122
4/18/10	1,760	3,050	2,515	338	3,390	2,204	4,120	6,270	5,370
4/19/10	1,790	3,060	2,502	513	3,220	2,275	4,400	6,200	5,454
4/20/10	1,830	3,130	2,545	374	3,630	2,376	4,710	6,490	5,693
4/21/10	2,020	3,240	2,666	1,460	3,440	2,643	5,180	6,850	6,134
4/22/10	2,210	3,220	2,725	1,690	3,380	2,662	5,660	6,870	6,286
4/23/10	2,280	3,180	2,751	1,660	3,330	2,683	5,720	7,020	6,416
4/24/10	2,390	3,240	2,823	1,570	3,370	2,768	5,710	7,390	6,615
4/25/10	2,500	3,360	2,936	1,700	3,480	2,863	6,070	7,540	6,825
4/26/10	2,380	3,400	2,904	1,620	3,570	2,844	5,900	7,350	6,747
4/27/10	2,230	3,410	2,883	1,480	3,560	2,717	5,590	7,230	6,578
4/28/10	2,180	3,440	2,856	1,420	3,540	2,688	5,670	7,300	6,494
4/29/10	2,070	3,410	2,837	1,130	3,640	2,708	5,360	7,260	6,515
4/30/10	2,010	3,290	2,763	1,290	3,670	2,683	5,430	7,170	6,329
5/1/10	2,020	3,180	2,711	1,210	3,420	2,517	5,320	6,840	6,160
5/2/10	1,860	3,200	2,660	1,300	3,450	2,575	5,050	6,960	6,209
5/3/10	2,180	3,110	2,738	1,740	3,300	2,601	5,640	6,960	6,312
5/4/10	2,070	3,010	2,602	1,630	3,080	2,487	5,400	6,570	6,033
5/5/10	2,270	3,200	2,695	1,570	3,260	2,599	5,370	7,040	6,244
5/6/10	2,590	3,310	2,963	2,060	3,480	3,009	6,120	7,490	6,804
5/7/10	2,790	3,400	3,101	2,340	3,410	3,046	6,300	7,470	6,947
5/8/10	2,700	3,390	3,074	2,160	3,390	2,945	6,360	7,470	6,930
5/9/10	2,740	3,470	3,105	2,110	3,520	2,957	6,320	7,580	6,985
5/10/10	2,720	3,560	3,185	2,150	3,620	3,037	6,500	7,720	7,193
5/11/10	2,650	3,550	3,124	2,190	3,760	3,076	6,320	7,880	7,197
5/12/10	2,590	3,410	3,010	2,080	3,660	2,939	6,260	7,460	6,905
5/13/10	2,400	3,350	2,928	1,670	3,520	2,828	5,760	7,390	6,700
5/14/10	2,130	3,300	2,791	1,340	3,550	2,688	5,630	7,180	6,464
5/15/10	1,910	3,110	2,628	913	3,380	2,462	5,100	6,660	5,997
5/16/10	1,820	3,080	2,596	373	3,410	2,345	4,700	6,750	5,949
5/17/10	1,810	3,120	2,584	459	3,460	2,318	4,840	6,740	5,849
5/18/10	1,730	2,990	2,451	588	3,080	2,174	4,570	6,210	5,502
5/19/10	1,670	2,870	2,369	785	2,860	2,096	4,490	6,060	5,362
5/20/10	1,800	2,870	2,379	940	2,890	2,098	4,610	5,880	5,295
5/21/10	1,930	2,940	2,435	633	2,710	1,991	4,510	5,770	5,255
5/22/10	1,950	2,930	2,447	117	2,760	2,040	4,310	5,860	5,239
5/23/10	1,960	3,130	2,548	187	2,910	2,167	4,320	6,280	5,544
5/24/10	2,250	3,250	2,812	757	3,240	2,519	5,060	6,770	6,153
5/25/10	2,250	3,240	2,781	1,150	3,350	2,562	5,280	6,840	6,096
5/26/10	1,960	3,240	2,756	517	2,750	1,995	4,760	6,530	5,844
5/27/10	2,160	3,740	2,851	-31	2,740	1,865	4,670	6,440	5,749
5/28/10	2,030	3,490	2,827	151	2,650	1,877	4,750	6,470	5,743
5/29/10	2,010	3,390	2,788	-32	2,580	1,750	4,560	6,220	5,497
5/30/10	1,970	3,430	2,727	-88	2,480	1,636	4,130	6,140	5,261
5/31/10	1,740	3,120	2,590	12	2,410	1,532	3,990	5,960	5,106
6/1/10	1,770	3,040	2,532	-37	2,290	1,487	4,170	5,790	5,031
6/2/10	1,750	2,970	2,504	-27	2,190	1,491	4,110	5,430	4,881
6/3/10	1,880	3,040	2,476	-161	2,100	1,480	3,320	5,200	4,339
6/4/10	1,930	2,960	2,443	-230	2,060	1,512	3,300	4,110	3,815
6/5/10	2,050	3,050	2,492	-317	2,130	1,567	3,110	4,390	3,931
6/6/10	2,430	3,200	2,803	129	2,380	1,846	3,850	5,010	4,677
6/7/10	2,340	3,160	2,698	527	2,470	1,858	3,990	5,070	4,607
6/8/10	2,060	3,160	2,535	-159	2,330	1,456	3,380	4,560	4,034
6/9/10	1,970	3,010	2,480	-814	2,300	1,295	2,880	4,450	3,847
6/10/10	1,730	2,970	2,401	-950	2,290	1,192	2,700	4,370	3,704
6/11/10	1,840	3,190	2,667	-852	2,440	1,456	2,760	4,990	4,166
6/12/10	2,510	3,620	3,188	85	2,810	2,054	4,280	5,800	5,230
6/13/10	2,710	3,780	3,348	756	2,920	2,225	4,910	6,120	5,617
6/14/10	2,860	3,940	3,453	887	2,970	2,308	5,040	6,220	5,757
6/15/10	2,980	3,960	3,578	1,250	2,960	2,410	5,540	6,530	6,037
6/16/10	2,760	3,880	3,372	1,420	2,860	2,317	4,850	6,020	5,538
6/17/10	2,640	3,630	3,191	774	2,690	2,055	4,280	5,300	4,939
6/18/10	2,150	3,400	2,860	-240	2,260	1,653	3,200	4,740	4,239
6/19/10	1,840	3,140	2,564	-698	2,060	1,290	2,740	4,050	3,554
6/20/10	2,050	3,080	2,484	-808	2,030	1,127	2,550	3,790	3,304
6/21/10	1,860	2,830	2,358	-769	1,930	962	2,240	3,710	3,107
6/22/10	1,550	2,790	2,241	-1,040	1,940	779	1,810	3,580	2,852
6/23/10	1,410	2,790	2,160	-1,220	1,860	653	1,520	3,450	2,688
6/24/10	1,350	2,680	2,031	-1,200	1,920	646	1,350	3,590	2,629
6/25/10	1,010	2,720	2,022	-1,290	1,940	611	1,250	3,480	2,570
6/26/10	1,100	2,640	1,982	-1,320	1,850	580	1,280	3,400	2,514
6/27/10	1,240	2,630	2,059	-1,230	1,960	753	1,420	3,560	2,739
6/28/10	1,540	2,830	2,308	-1,010	2,090	857	2,050	3,810	3,061
6/29/10	1,380	3,000	2,250	-1,000	2,070	869	1,930	3,820	3,038
6/30/10	1,440	2,990	2,385	-564	2,120	1,148	2,560	3,990	3,439

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) Pumping Facilities for the Period April 1 to June 30, 2010

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(VSN)	Exports as a Ratio of SJR Flow near Vernalis (VSN)	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 : VSN	Exports : MSD
4/1/2009	1,910	2,561	676	796	134	0.8 : 1	0.6 : 1
4/2/2009	2,052	2,561	919	807	125	0.8 : 1	0.7 : 1
4/3/2009	2,789	3,457	677	826	124	0.5 : 1	0.4 : 1
4/4/2009	3,181	3,866	615	826	122	0.5 : 1	0.4 : 1
4/5/2009	3,556	4,319	661	827	121	0.4 : 1	0.3 : 1
4/6/2009	3,718	4,377	662	823	118	0.4 : 1	0.3 : 1
4/7/2009	3,803	4,192	675	822	110	0.4 : 1	0.4 : 1
4/8/2009	3,861	4,216	676	823	109	0.4 : 1	0.4 : 1
4/9/2009	3,781	4,175	674	824	110	0.4 : 1	0.4 : 1
4/10/2009	3,723	4,070	658	824	109	0.4 : 1	0.4 : 1
4/11/2009	3,650	4,077	656	822	112	0.4 : 1	0.4 : 1
4/12/2009	3,874	4,238	760	649	109	0.4 : 1	0.3 : 1
4/13/2009	3,934	4,415	833	618	112	0.4 : 1	0.3 : 1
4/14/2009	4,353	4,681	829	623	108	0.3 : 1	0.3 : 1
4/15/2009	4,468	4,930	657	833	110	0.3 : 1	0.3 : 1
4/16/2009	4,538	4,934	662	826	109	0.3 : 1	0.3 : 1
4/17/2009	4,682	5,122	654	827	109	0.3 : 1	0.3 : 1
4/18/2009	4,827	5,370	660	827	111	0.3 : 1	0.3 : 1
4/19/2009	4,866	5,454	657	829	112	0.3 : 1	0.3 : 1
4/20/2009	5,013	5,693	662	830	114	0.3 : 1	0.3 : 1
4/21/2009	5,359	6,134	671	829	114	0.3 : 1	0.2 : 1
4/22/2009	5,378	6,286	661	853	117	0.3 : 1	0.2 : 1
4/23/2009	5,383	6,416	664	862	119	0.3 : 1	0.2 : 1
4/24/2009	5,377	6,615	660	862	123	0.3 : 1	0.2 : 1
4/25/2009	5,595	6,825	661	862	122	0.3 : 1	0.2 : 1
4/26/2009	5,635	6,747	664	862	120	0.3 : 1	0.2 : 1
4/27/2009	5,551	6,578	660	854	118	0.3 : 1	0.2 : 1
4/28/2009	5,378	6,494	680	831	121	0.3 : 1	0.2 : 1
4/29/2009	5,295	6,515	638	831	123	0.3 : 1	0.2 : 1
4/30/2009	5,081	6,329	653	831	125	0.3 : 1	0.2 : 1
5/1/2009	4,968	6,160	665	831	124	0.3 : 1	0.2 : 1
5/2/2009	5,000	6,209	664	832	124	0.3 : 1	0.2 : 1
5/3/2009	4,973	6,312	662	829	127	0.3 : 1	0.2 : 1
5/4/2009	4,736	6,033	663	827	127	0.3 : 1	0.2 : 1
5/5/2009	5,156	6,244	659	825	121	0.3 : 1	0.2 : 1
5/6/2009	5,537	6,804	666	823	123	0.3 : 1	0.2 : 1
5/7/2009	5,655	6,947	809	822	123	0.3 : 1	0.2 : 1
5/8/2009	5,651	6,930	1,524	823	123	0.4 : 1	0.3 : 1
5/9/2009	5,760	6,985	1,001	824	121	0.3 : 1	0.3 : 1
5/10/2009	5,933	7,193	429	826	121	0.2 : 1	0.2 : 1
5/11/2009	5,813	7,197	0	820	124	0.1 : 1	0.1 : 1
5/12/2009	5,619	6,905	0	823	123	0.1 : 1	0.1 : 1
5/13/2009	5,430	6,700	0	825	123	0.2 : 1	0.1 : 1
5/14/2009	5,055	6,464	0	826	128	0.2 : 1	0.1 : 1
5/15/2009	4,697	5,997	0	1,462	128	0.3 : 1	0.2 : 1
5/16/2009	4,698	5,949	0	1,468	127	0.3 : 1	0.2 : 1
5/17/2009	4,539	5,849	0	826	129	0.2 : 1	0.1 : 1
5/18/2009	4,264	5,502	0	825	129	0.2 : 1	0.1 : 1
5/19/2009	4,183	5,362	0	823	128	0.2 : 1	0.2 : 1
5/20/2009	4,193	5,295	0	1,488	126	0.4 : 1	0.3 : 1
5/21/2009	4,253	5,255	437	1,512	124	0.5 : 1	0.4 : 1
5/22/2009	4,226	5,239	1,493	860	124	0.6 : 1	0.4 : 1
5/23/2009	4,610	5,544	809	858	120	0.4 : 1	0.3 : 1
5/24/2009	5,068	6,153	656	859	121	0.3 : 1	0.2 : 1
5/25/2009	4,923	6,096	791	860	124	0.3 : 1	0.3 : 1
5/26/2009	4,741	5,844	3,629	867	123	0.9 : 1	0.8 : 1
5/27/2009	4,723	5,749	1,136	2,825	122	0.8 : 1	0.7 : 1
5/28/2009	4,583	5,743	2,182	2,829	125	1.1 : 1	0.9 : 1
5/29/2009	4,348	5,497	3,403	2,824	126	1.4 : 1	1.1 : 1
5/30/2009	4,161	5,261	4,011	2,837	126	1.6 : 1	1.3 : 1
5/31/2009	4,068	5,106	4,273	2,829	126	1.7 : 1	1.4 : 1

continued on next page

Table 4-2 Continued							
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(VSN)	Exports as a Ratio of SJR Flow near Vernalis (VSN)	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 : VSN	Exports : MSD
6/3/2009	3,819	4,339	3,425	3,138	114	1.7 : 1	1.5 : 1
6/4/2009	3,760	3,815	3,797	3,509	101	1.9 : 1	1.9 : 1
6/5/2009	4,079	3,931	3,714	3,503	96	1.8 : 1	1.8 : 1
6/6/2009	4,664	4,677	3,774	3,515	100	1.6 : 1	1.6 : 1
6/7/2009	4,280	4,607	3,960	3,506	108	1.7 : 1	1.6 : 1
6/8/2009	3,899	4,034	3,961	3,516	103	1.9 : 1	1.9 : 1
6/9/2009	3,712	3,847	4,004	3,519	104	2.0 : 1	2.0 : 1
6/10/2009	3,623	3,704	4,006	3,525	102	2.1 : 1	2.0 : 1
6/11/2009	4,331	4,166	3,504	3,045	96	1.5 : 1	1.6 : 1
6/12/2009	5,452	5,230	3,378	2,838	96	1.1 : 1	1.2 : 1
6/13/2009	5,652	5,617	3,520	2,838	99	1.1 : 1	1.1 : 1
6/14/2009	5,875	5,757	3,502	2,842	98	1.1 : 1	1.1 : 1
6/15/2009	6,109	6,037	3,046	2,839	99	1.0 : 1	1.0 : 1
6/16/2009	5,306	5,538	2,235	2,837	104	1.0 : 1	0.9 : 1
6/17/2009	4,711	4,939	2,791	2,823	105	1.2 : 1	1.1 : 1
6/18/2009	3,984	4,239	3,291	2,821	106	1.5 : 1	1.4 : 1
6/19/2009	3,428	3,554	3,823	2,829	104	1.9 : 1	1.9 : 1
6/20/2009	3,216	3,304	3,833	3,306	103	2.2 : 1	2.2 : 1
6/21/2009	3,040	3,107	3,995	3,518	102	2.5 : 1	2.4 : 1
6/22/2009	2,799	2,852	3,184	3,529	102	2.4 : 1	2.4 : 1
6/23/2009	2,693	2,688	2,966	3,530	100	2.4 : 1	2.4 : 1
6/24/2009	2,661	2,629	2,136	3,408	99	2.1 : 1	2.1 : 1
6/25/2009	2,563	2,570	2,531	2,831	100	2.1 : 1	2.1 : 1
6/26/2009	2,585	2,514	2,186	2,612	97	1.9 : 1	1.9 : 1
6/27/2009	2,904	2,739	2,193	2,610	94	1.7 : 1	1.8 : 1
6/28/2009	3,147	3,061	2,396	2,644	97	1.6 : 1	1.6 : 1
6/29/2009	3,045	3,038	3,404	2,665	100	2.0 : 1	2.0 : 1
6/30/2009	3,622	3,439	4,327	3,267	95	2.1 : 1	2.2 : 1

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

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 86-68290-10-07 by the USBR. Contact persons for further information is Mark Bowen or Ray Bark, USBR 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 on the main stem San Joaquin River (Newman, 2008 and Holbrook et al., 2009). Each spring a physical temporary spring Head of Old River Barrier (HORB) had been used up until 2007 when it was prohibited in a Federal Court decision by United States Fresno District Court Judge Wanger for increased protection for delta smelt. This prohibition continued into the 2010 VAMP. The U. S. Bureau of Reclamation (USBR) in Denver and the California Department of Water Resources (DWR) in Sacramento working in coordination with Fish Guidance Systems (Southampton, England), Ovivo USA, LLC in Salt Lake City Utah formerly 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.

In 2009, the first BAFF was installed with the goal to deter anadromous salmonid juveniles from entering Old River. The 2009 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 4-7. This layout was to allow the BAFF to maximize fish guidance down the main stem of the San Joaquin River and away from Old River as depicted in Figure 4-8.

It was thought that the 2009 alignment, while being efficient in deterring acoustically tagged salmon smolts from entering Old River, it may have guided the smolts into or near the large scour hole immediately downstream of the divergence of Old River and the

Figure 4-2
Daily Flow Range in Cubic Feet per Second (cfs) – Old River at Head (OH1)

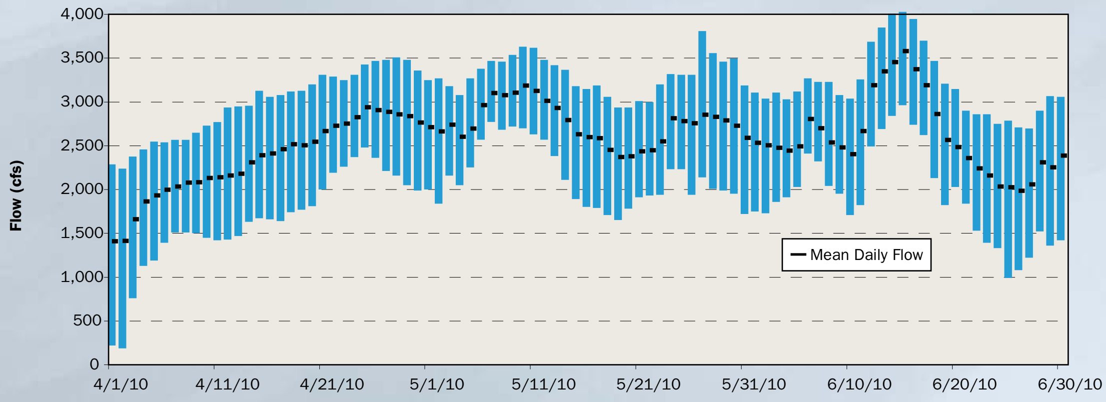


Figure 4-3
Daily Flow Range in Cubic Feet per Second (cfs) –
San Joaquin River below Old River near Lathrop (SJL)

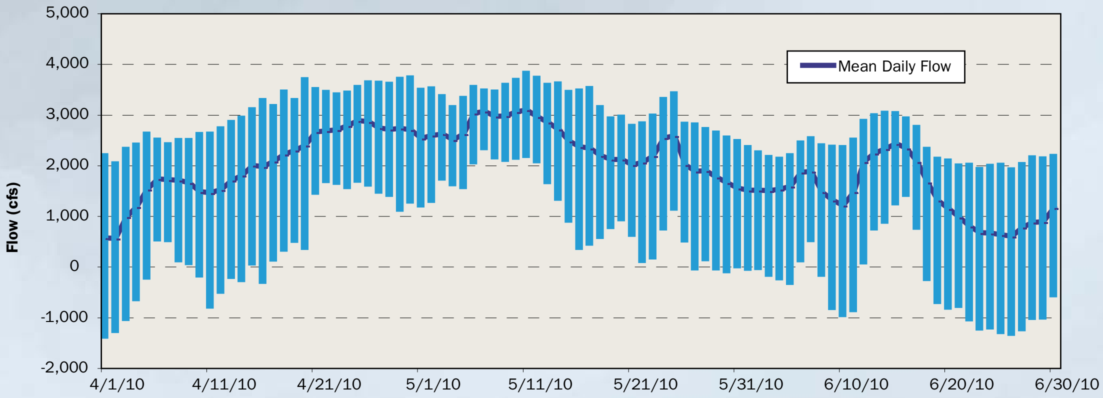


Figure 4-4
Daily Flow Range in Cubic Feet per Second (cfs) –
San Joaquin River at Mossdale Bridge (MSD

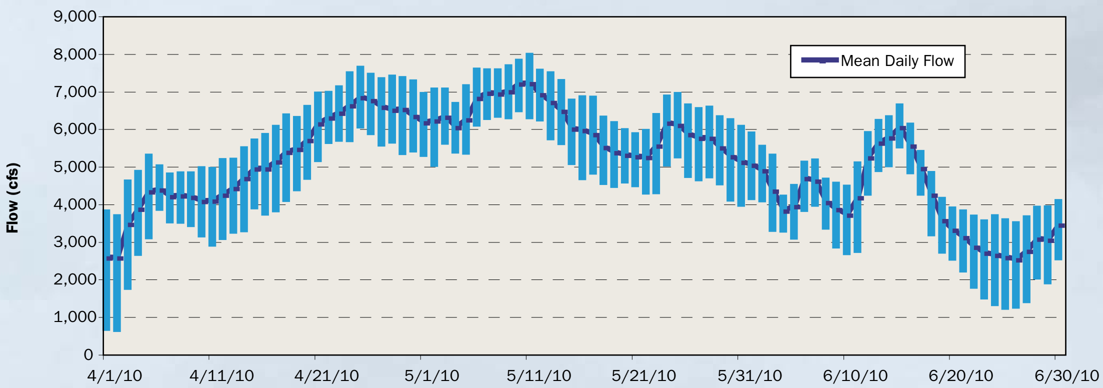


Figure 4-5
San Joaquin River Flow in Cubic Feet per Second (cfs)
near Vernalis (VNS) and at Mossdale Bridge (MSD)

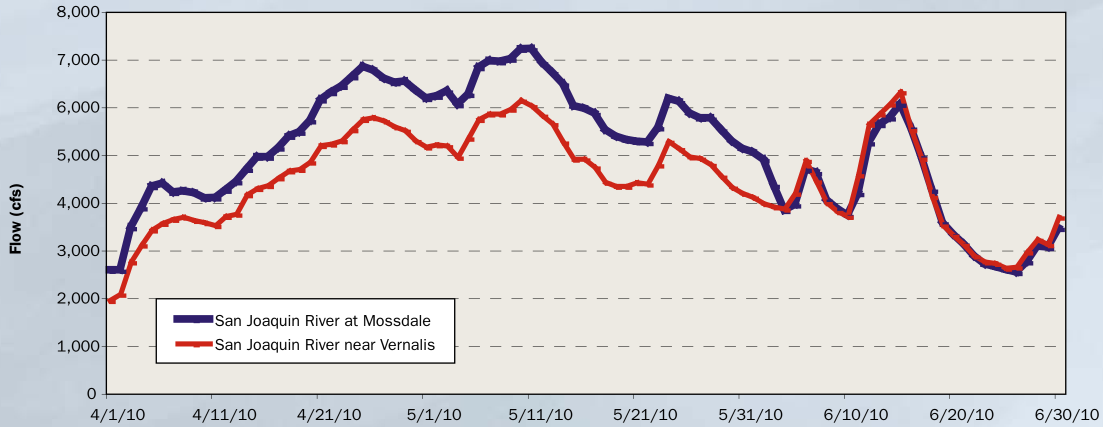


Figure 4-6
Comparison of the Gage Recordings on the San Joaquin River at Mossdale Bridge (MSD) and at Vernalis (VNS) for the VAMP Target Flow and Fish Tracking Periods in 2010.Flow Data Provided by California Department of Water Resources (DWR) and United States Geological Survey (USGS) Websites. (Figure Courtesy of MBK Engineers)

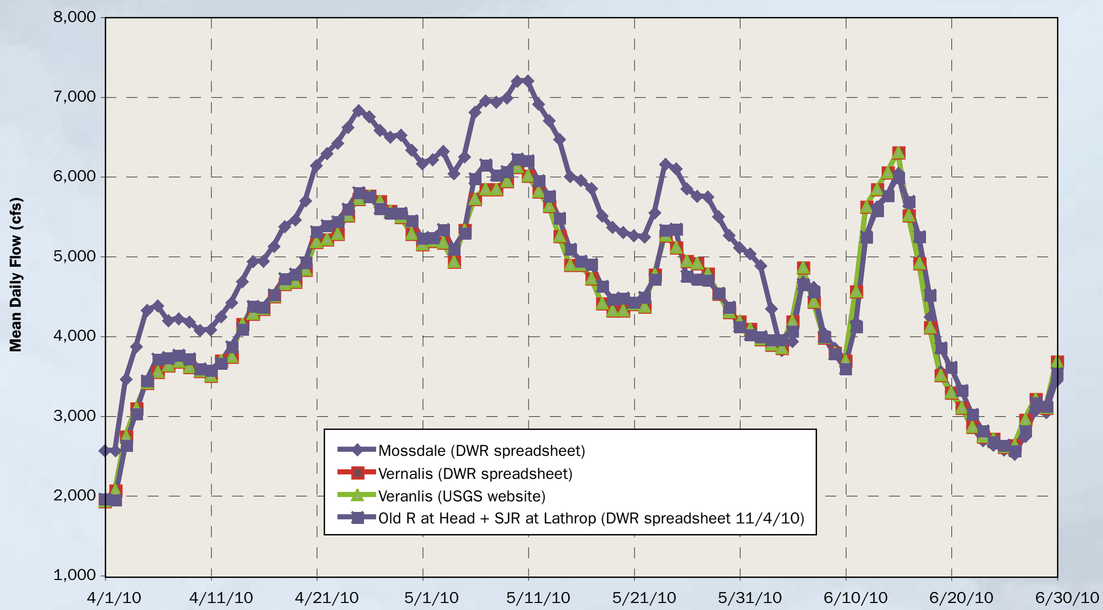


Figure 4-7
Approximate Location of the 2010 Bio-Acoustic Fish Fence (BAFF) (Shown as a Bold Black Line) at the Divergence of San Joaquin River (SJR) and Old River (OR). Locations of the Underwater Hydrophones are Shown by the Numbers near the Colored Circles. The Approximate Location of the 2009 BAFF is Shown by a Lighter Black Line Immediately to the Left (Downstream) of the 2010 Alignment. (Data and Figure From Bowen and Bark, 2010)

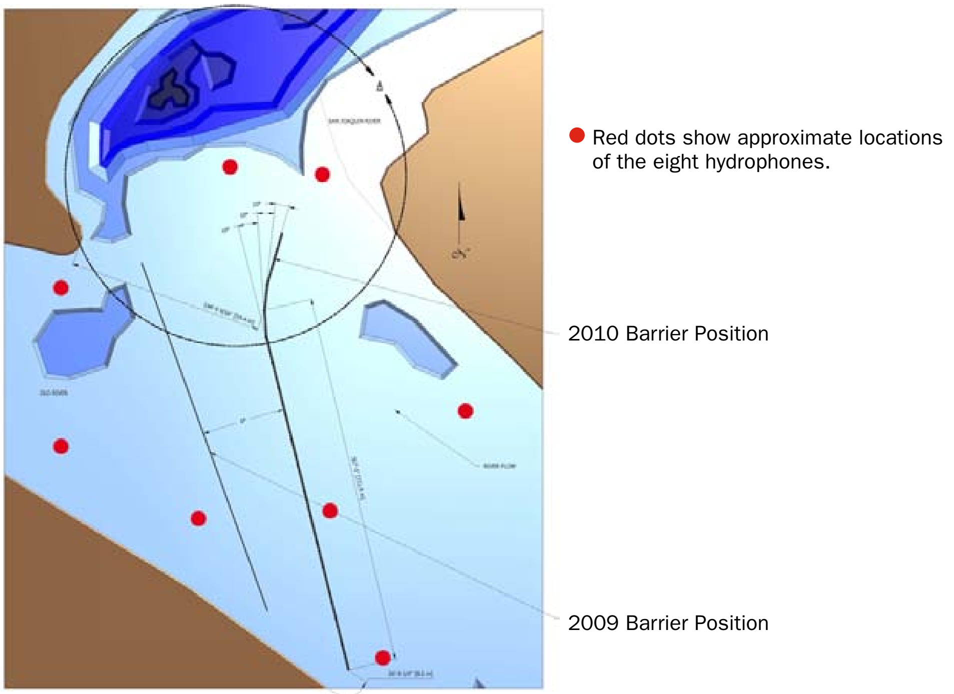


Figure 4-8
Schematic of Probable Operation of the Bio-Acoustic Fish Fence (BAFF) planned and developed for deployment at the Divergence of San Joaquin River (SJR) and Old River (OR). (Figure Courtesy of EIMCO Water Technologies)

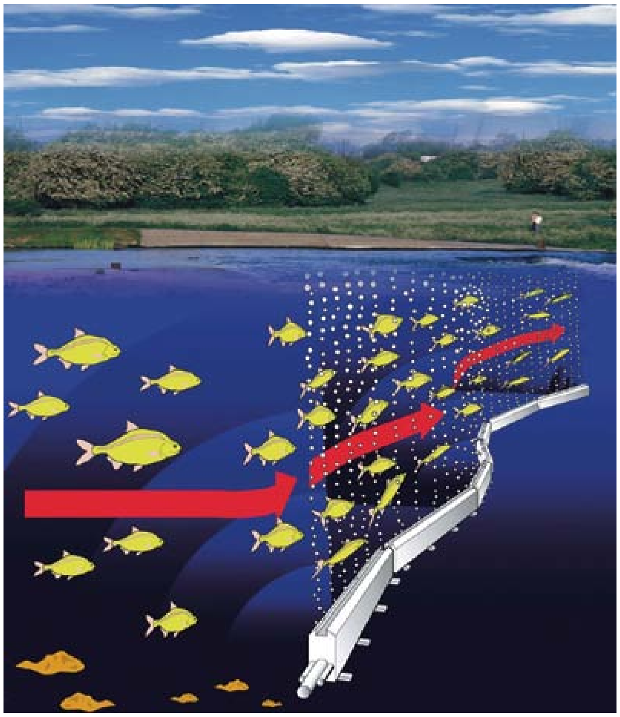


Figure 4-9
Basic Components of the Bio-Acoustic Fish Fence (BAFF) Planned and Developed for Deployment at the Divergence of San Joaquin River (SJR) and Old River (OR) in 2009 and 2010. (Figure Courtesy of EIMCO Water Technologies)

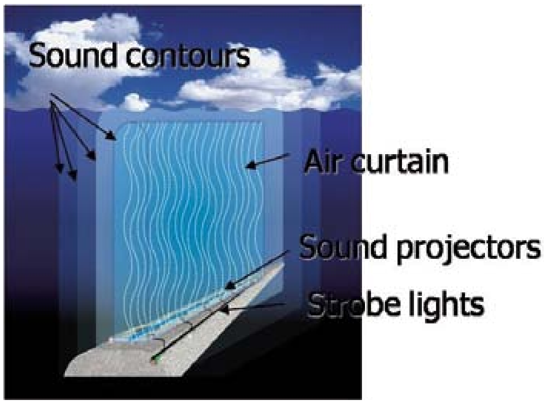


Figure 4-10
Physical Structure of the Bio-Acoustic Fish Fence (BAFF) Similar to that Deployed at the Divergence of the San Joaquin River and Old River During the 2009 and 2010 VAMP.

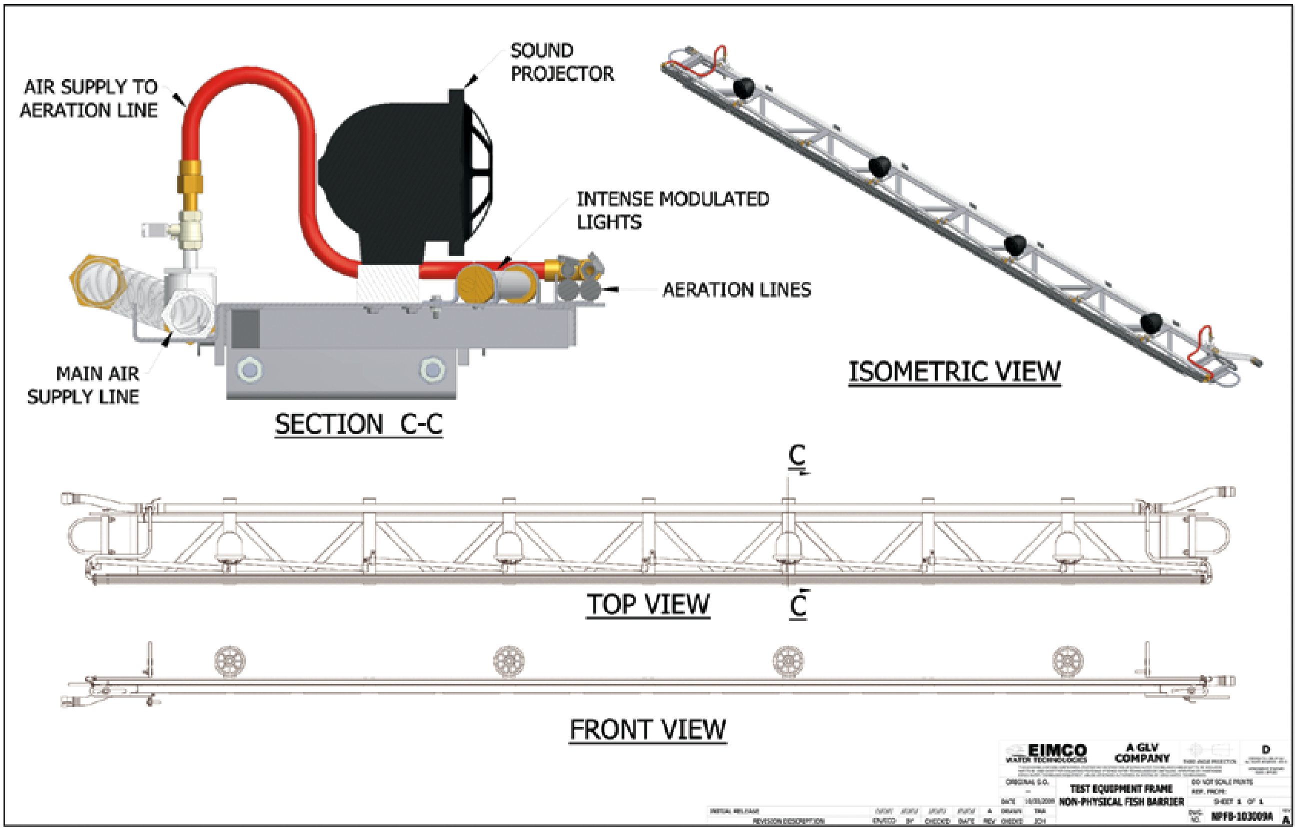
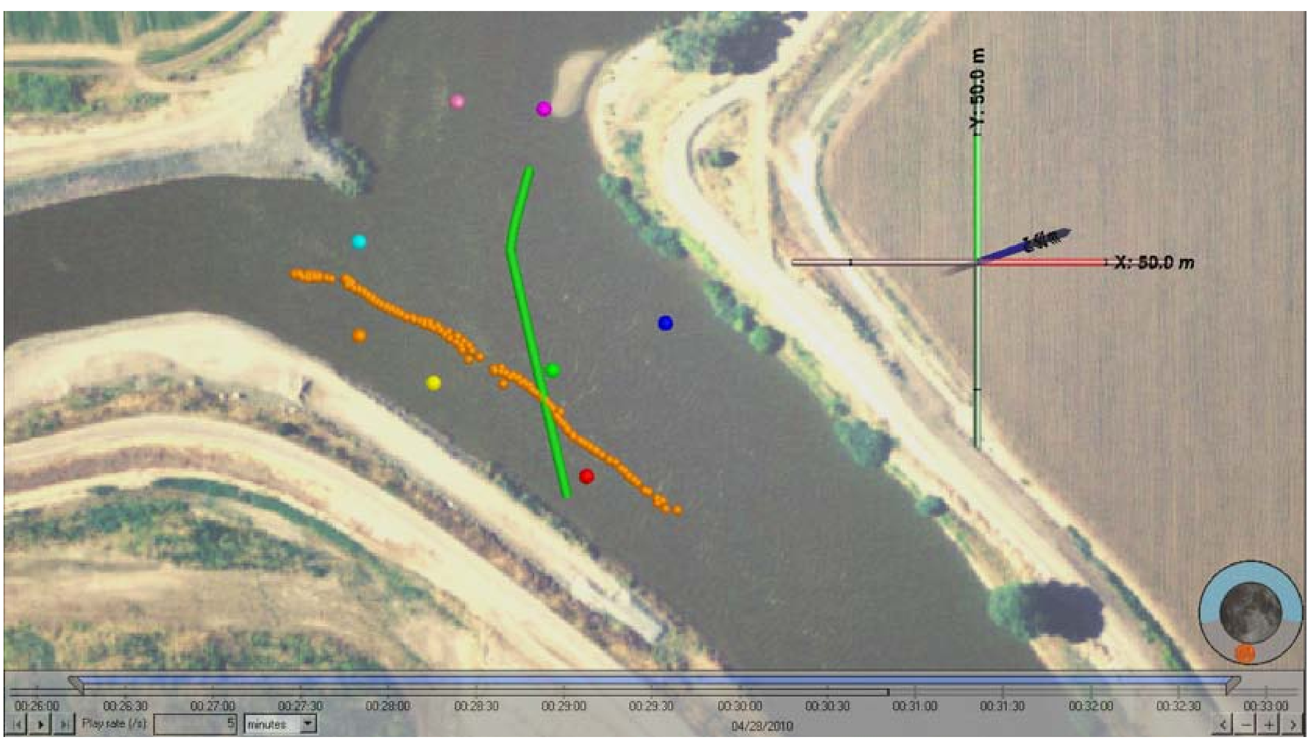


Figure 4-11
Approximate Location of the 2010 Bio-Acoustic Fish Fence (BAFF) (Shown as a Green Line) at the Divergence of San Joaquin River (SJR) and Old River (OR). Locations of the Underwater Hydrophones are Shown by the Colored Circles. The Yellow Dotted Line is 2010 VAMP Fish Tag 5437 as the Fish Approached and Passed Through the BAFF on 4/28/10 while the barrier was on. (Figure and Data From Bowen and Bark, 2010)



main stem San Joaquin River. It is unclear whether the deterrence increased the predation rate as the scour hole is a known area of high predator activity or the predation losses were simply related to the low flow conditions that occurred in 2009.

In an attempt to minimize or eliminate the role of the scour hole, the alignment of the BAFF was changed. The 2010 BAFF was set out further in the channel, lengthened to 136 m, the angle change to 34 degrees and the downstream end of the BAFF changed from a straight layout to a "hockey stick" configuration (Figure 4-7) (Bowen and Bark, 2010). The figure also shows the 8 hydrophones deployed to provide 2-D tacking in the vicinity of the BAFF.

The 2010 BAFF, as in 2009, was made up of three components: sound, bubble curtain, and hi-intensity light-emitting diode (LED) strobe lights as depicted in Figure 4-9. The BAFF components, air, sound and light are attached to a truss style frame mounted about 0.5 meter 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 4-10.

The main 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 any saturation of the area surrounding the BAFF with sound. Sound levels are expected to fall to ambient levels within a distance 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 was completed on April 16th. After the BAFF was deployed, eight (8) underwater hydrophones were deployed (Figure 4-7) 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 identical to those used in the VAMP receiver network. Each VAMP acoustic tagged fish transmits an underwater signal or acoustic "ping" that send identification information about the tagged fish to the hydrophones. The hydrophones were deployed at known locations within the array to maximize spacing of the hydrophones in two (or three) dimensions. For three dimensional tracking, tags must be received on at least four hydrophones; for two dimensional tracking, tags must be received on at least three hydrophones. Figure 4-11 shows a typical tracking of one tagged salmon smolt as it approaches the BAFF. The smolt shown in Figure 4-11 passed through the BAFF while the BAFF was on. The hydrophones can not pick up the "pings" of any tagged fish that passes through the BAFF in either direction however the layout of the hydrophones this year allowed the fish to be tracked separately by hydrophones on each side of the BAFF to observe tagged fish passing in both directions through the BAFF.

A full report on the efficiency of the BAFF has been prepared and is available on the USBR Denver Library website (Bowen and Bark, 2010). It is recommended that the readers consult the full report on the BAFF. The authors feel that several interactions were taking place during 2010. These may be the result of the change in the layout of the BAFF or in the flow velocity which greatly exceeded that seen in the 2009 dry year.

Even though predation in and near the HOR still was an issue in 2010, it was not a great a factor as seen in 2009. The authors state that *"It now seems even more likely, given the results of 2010 monitoring, that the high 2009 predation rates we observed were a function of the dry year in the San Joaquin River. Smolts and predators might have been concentrated into a smaller volume of water than in average or wet years. Such a concentration could result in higher encounter rates between predators and smolts leading to an increased predation rate. In addition, lower velocities in drier years may lead to a bioenergetically advantageous situation for large-bodied predators in the open channels near the Divergence.*

We recommend that the DWR, determine the hydrologic forecast for the San Joaquin River in March. Then, if a dry year is predicted with the resulting low discharges and low velocities then we recommend that if the BAFF is installed in 2011 that predator relocation be employed in the ORB area. For example, striped bass and largemouth bass could be moved from the Divergence to San Luis Reservoir. Failure to do so could lead to a similar situation to that we observed in 2009. That is, the BAFF's deterrence may be offset by the heavy predation."

The BAFF was faced with higher flows 2010 that also led to higher velocities through the BAFF. The greatest decrease in flow and velocity occurred with VAMP Fish Releases 6 and 7 and as a result, the average velocity through the BAFF came down. The authors showed that *"when discharge and velocity decreased Proportion Deterred improved; the Chinook smolts may have had more time to avoid the BAFF. Of course, we constantly conducted maintenance on the BAFF in 2010. And, we thought that the BAFF was in its best condition during Release 7. So, it is possible that it was BAFF maintenance, velocity reduction, or an interaction of both that led to improved deterrence in Release 7.*

Another phenomenon of interest occurred simultaneously with the flow and velocity decrease in Release 6: the proportion of smolts eaten in the vicinity of the ORB increased. And as flow and resulting velocity continued to decrease in Release 7, the proportion of smolts eaten in the vicinity of the ORB increased and there was an increase in the proportion of smolts never arriving at the Divergence. These results suggest that predation from Durham Ferry to the Divergence and in the vicinity of the Divergence may be correlated with velocity. Higher discharges in 2010, and resulting high velocities, in the first five releases could have curtailed predation on Chinook smolts.

The authors also observed large differences in Protection Efficiency (deterrence) depending upon whether the BAFF was on or off. This may also be related to flow velocity or the angle of the BAFF. The authors stated *"in 2010, the BAFF angle was 30° when in 2009 it was 24°. The steeper angle and higher velocities may have behaved synergistically to give fish less time to evaluate the barrier and avoid it. So, when velocities are high, the fish may pass through it before they can travel the full length of the barrier. Many of these fish will not be successfully deterred by our definition. Never the less, they may swim some meters (many 2D tracks showed this effect) before passing through the BAFF. That distance improved the probability that that smolt will enter the San Joaquin River. Thus, we observed poor deterrence but significant improvement in protection efficiency, survival, down into the San Joaquin River.*

For a 2011 installation, we recommend the BAFF angle be reduced from 30 to 24 degrees. Many fish passed through the barrier because they did not have sufficient time, this was evident from the 2D tracks. And we recommend that the curved elements near the distal end of the 2010 ORB be removed. Many Chinook smolts passed through the BAFF in these curved sections."

South Delta Temporary Agricultural Barriers Project

(The following section is a summary of work conducted by the California Department of Water Resources (DWR) with support from the US Bureau of Reclamation (USBR) and guidance from the National Marine Fisheries Service (NMFS). In 2010, this project included evaluating the movement of salmon 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 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 (BAFF) 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. A full scale experimental design is to be implemented in spring 2010. 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 and acoustic tagged salmon and steelhead in a manner similar to that done in the 2009 VAMP (see Figure 5-2). 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.

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, were used as part of the technical foundation for the 2010 full-scale study. 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 at 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 2010 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 2010 study, Chinook salmon smolts were acoustically tagged with Hydroacoustic Technology, Incorporated (HTI) tags and released into the San Joaquin River at Durham Ferry and supplemental releases on the San Joaquin River near Stockton and in Old River just downstream of the mainstem San Joaquin River. A total of twenty-one releases were made between April 27th and May 19th, with seven releases at each of the three separate sites. At Durham Ferry between 70 and 74 fish were released per release period, while at Old River and at Stockton, between 34 and 36 fish were released at each location per release period.

The study design was intended to provide estimates of survival to Chipps Island given that survival through the Delta was low. The releases at Old River and near Stockton were made to augment the numbers of fish that survived to those two locations from releases made at Durham Ferry and to assure some fish would be recovered at Chipps Island. In addition, the seven sets of releases at Durham Ferry were also used to meet the study needs of the joint California Department of Water Resources (DWR) and the United States Bureau of Reclamation (USBR) evaluation of a non-physical barrier (NPB) at the head of Old River often called the Bio-Acoustical Fish Fence or BAFF. 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 were analyzed to help interpret the survival estimates.

Study Design and Methods

Study Fish

All fish used in the VAMP 2010 study originated from Merced River Fish Hatchery (MRH). Approximately 1,750 juvenile fall run Chinook salmon were transferred by California Department of Fish and Game (CDFG) from MRH to the Tracy Fish Collection Facility (TFCF) on April 15th (n=500), April 22nd (n=500), April 29th (n=500), and May 6th (n=250). Fish were held at TFCF for 11-15 days prior to tagging to allow for acclimation to Delta water quality and temperature prior to release. During the first 7-11 days water temperature in the holding tanks at TFCF was held at approximately 14-15°C (57-59°F) using a water chiller to reduce the temperature of ozonated Delta water. During the last 3-4 days prior to tagging, the water supply was switched to ozonated Delta water at ambient Delta water temperatures (i.e., not passed through the water chiller). Fish were not held at ambient temperatures for the duration of holding at TFCF because Proliferative Kidney Disease (PKD) is progressive at temperatures greater than 15°C (59°F).

Transmitter Programming

Transmitters were programmed according to modified guidelines developed during the 2008 VAMP. Transmitters were programmed the day prior to tagging which was two days prior to the beginning of each release. Transmitters were soaked for approximately 24 hours prior to programming. Tag programming files were developed by HTI which provided the tag period and pulse width to be used for each tag in each release group. Tag periods used during the 2010 study ranged from 4 seconds to 10 seconds, with a pulse width of

2 milliseconds. The HTI tag programming software provided programming history files which contained the date, time, tag period, and pulse width for each tag that was programmed. On a datasheet the manufacturing lot was also recorded for each tag programmed.

After programming, tags were sniffed in a cup of water using a HTI sniffer and monitored through at least three transmission cycles. At most 5 attempts were made to program each tag. If the tag could not be programmed after 5 attempts, a new tag was selected, and the tag that would not program was returned to HTI. During the 2008 VAMP some tags that passed activation and sniffing could not be heard after fish tagging. To address this issue in 2009 and 2010, each activated tag was briefly listened to within a few hours after programming and prior to surgical implantation in study fish to confirm tag function and programming. A total of 36 tags failed to initialize and all programmed tags were heard during validation immediately after programming in 2010.

Transmitter Implantation and Validation

The 2010 training and tagging operations were conducted at the TFCF as was done in 2009. In 2007 and 2008 training occurred at the Mokelumne River Fish Hatchery and tagging occurred at Merced River Fish Hatchery (MRH). The TFCF was selected in 2009 as a preferred alternative to MRH for tagging due to the proximity and similar water temperature conditions to the release sites at Durham Ferry, Old River, and Stockton. Transit time to the release site and large differences in temperature between MRH and the release sites posed significant challenges 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 the TFCF.

Tagging operations occurred at the TFCF between April 26th and May 17th. Study fish were withheld food for 24 hours prior to transmitter implantation. During each tagging session 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 had an average weight of 0.65 g in air (range: 0.61 g to 0.73 g), was 16.4 mm long, with a diameter of 6.7 mm.

The challenges with fish size and tag weight that occurred during 2009 (San Joaquin River Group Authority, 2010) were not encountered during 2010. A minimum fish weight criterion of 12.1 g was used to ensure a maximum tag weight to body weight ratio of 5.4%. The same criteria was also used during 2008, but could not be achieved during 2009 (San Joaquin River Group Authority, 2010). All fish tagged and released during the 2010 VAMP met the minimum weight criterion of 12.1 g. Most fish had tag weight to body weight ratios of 3-4%, far below the 5.4% maximum criterion (Figure 5-1). Although the minimum weight criteria was met for all fish, 10 fish ranging in weight from 12.1 to 12.7 grams had a maximum tag weight to body weight ratio which slightly exceeded the 5.4% criteria (range 5.5-5.8%) due to tag weights ranging from 0.68 to 0.71 grams. These fish however represented less than 1% of the total number of fish tagged and released during the 2010 VAMP.

Standard operating procedures (SOP) for tagging (Appendix G) were largely based on methods 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, fork length (FL) measured 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 minutes. Fish were then placed into perforated 19 L (5 gal) 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 (1.8 gal) of water to allow transfer without complete dewatering. Each holding container was stocked with three tagged fish and 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 adjust their buoyancy and compensate for the weight of the transmitter. The approximate tagging times are listed in Table 5-1.

After surgery, tagged fish were monitored by hydrophones gently placed in the recovery buckets at TFCF to confirm the operational status of each transmitter prior to transportation to the release sites. In the 21 separate releases, a total of 17 transmitters were found to be non-functional during this evaluation and these fish were removed from the study.

Figure 5-1
Frequency Distribution of Tag Weight to Body Weight (TW:BW) Ratio of Live Study Fish Released During the 2010 VAMP Study

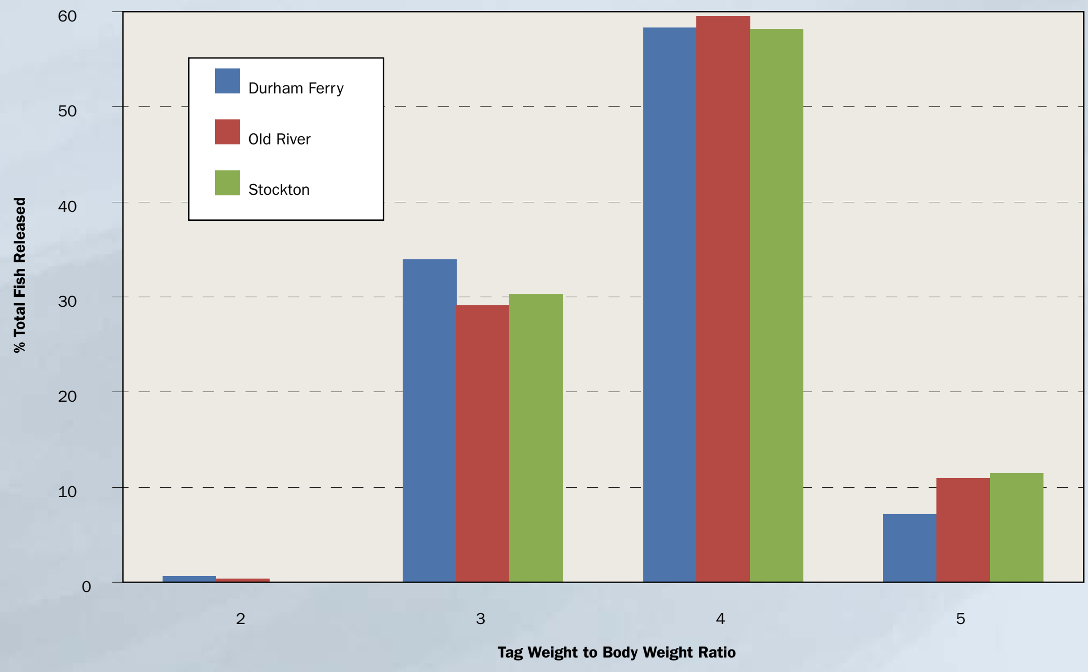


Figure 5-2
Locations of Acoustic Receivers and Release Sites Utilized for the 2010 VAMP Study Including Locations of Acoustic Receivers the California Department of Water Resources (DWR) Deployed for the South Delta Temporary Barriers Study (figure compliments of University of Washington)

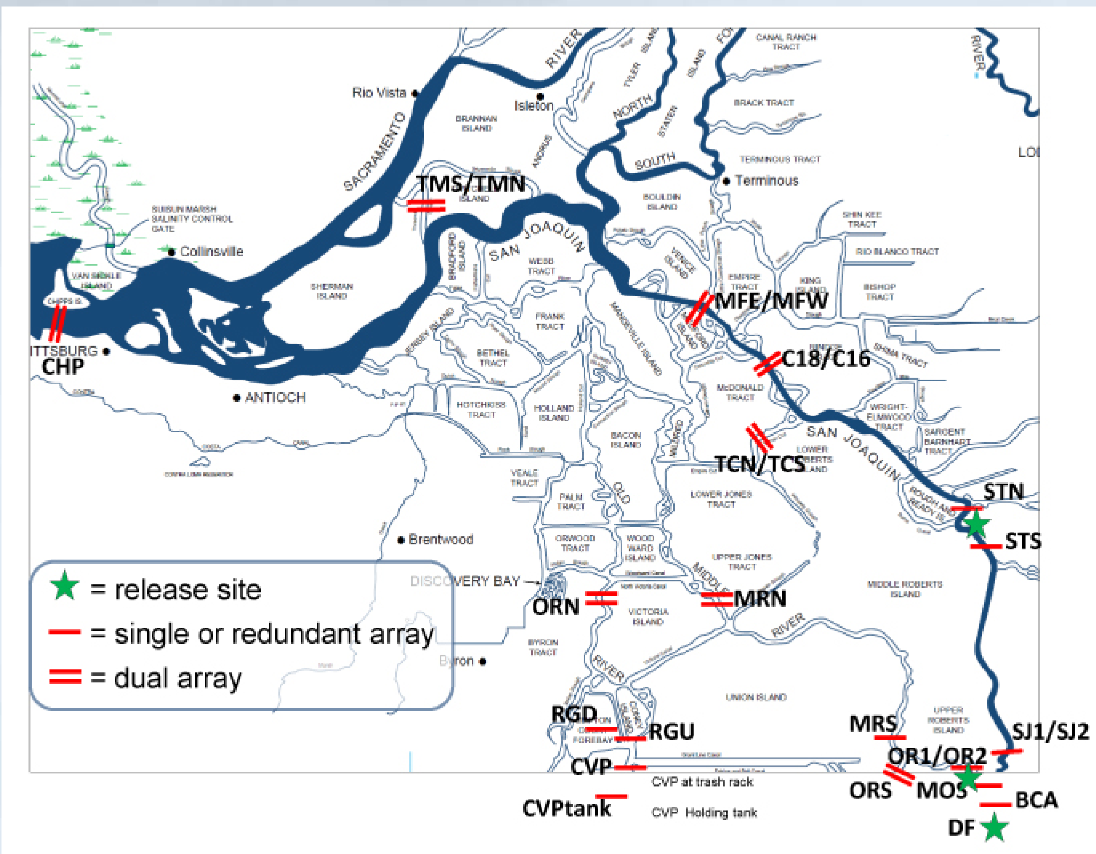


Table 5-1
Tagging, Transport, Holding and Release Information for the Seven Sets of Fish Releases (released approximately every 6 hours over a 24 hour period) for VAMP in 2010

Durham Ferry

Tagging	Transport	Holding	Total released (A+B+C+D)	Release A Date/Time	Release A Number released	Release B Date/Time	Release B Number released	Release C Date/Time	Release C Number released	Release D Date/time	Release D Number released	Fish Health Dummy tagged
Mon 4/26 0800 - 1252	Mon 4/26 1301 - 1340	4/26 1415 - 4/27 1400	74	4/27 1402, 1411	18	4/27 1954, 2001	18	4/28 0211	18	4/28 0809, 0812	20	10
Thurs 4/29 0800 - 1245	Thurs 4/29 1300 -1350	4/29 1415 - 4/30 1400	74	4/30 1407, 1408	18	4/30 1958, 1959	18	5/1 0200, 0201	18	5/1 0759, 0800	20	10
Mon 5/3 0800 - 1215	Mon 5/3 1230 -1315	5/3 1330 - 5/4 1400	73	5/4 1355, 1402	18	5/4 1958, 2004	18	5/5 0159, 2000	18	5/5 0759, 0800	19	10
Thurs 5/6 0800 - 1215	Thurs 5/6 1235 - 1315	5/6 1335 - 5/7 1400	70	5/7 1404, 1408	18	5/7 2004, 2005	18	5/8 0202, 0204	16	5/8 0802, 0803	18	10
Mon 5/10 0800- 1200	Mon 5/10 1215 -1258	5/10 1314 - 5/11 1400	70	5/11 1402	17	5/11 1959	17 *	5/12 0158, 0159	17	5/12 0759, 0801	19	10
Thurs 5/13 0800 - 1200	Thurs 5/13 1210 - 1255	5/13 1310 - 5/14 1400	73	5/14 1402	17	5/14 1959	18	5/15 0201, 0202	18	5/15 0759, 0801	20*	10
Mon 5/17 0800 - 1215	Mon 5/17 1225 - 1310	5/17 1330 - 5/18 1400	73	5/18 1401, 1402, 1403	17 (+3 intentional morts)	5/18 2000	18	5/19 0159, 0200	17	5/19 0759, 0801	18	10

* one mortality observed after transport but not included in the number released

Old River

Tagging	Transport	Holding	Total released (A+B+C+D)	Release A Date/Time	Release A Number released	Release A Tidal condition at release	Release B Date/ Time	Release B Number released	Release B Tidal condition at release	Release C Date/Time	Release C Number released	Release C Tidal condition at release	Release D Date/ Time	Release D Number released	Release D Tidal condition at release	Fish Health Dummy tagged
Tues 4/27 0800 - 1115	Tues 4/27 1123 -1215	4/27 1249 - 4/28 1100	36	4/28 1103	9	slack before ebb	4/28 1703	9	slack before flood	4/28 2300	9	slack before ebb	4/29 0505	9	slack before flood	10
Fri 4/30 0800 -1115	Fri 4/30 1130 - 1200	4/30 1239 - 5/1 1300	36	5/1 1305	9	slack before ebb	5/1 1903	9	slack before flood	5/2 0059	9	slack before ebb	5/2 0700	9	slack before flood	10
Tues 5/4 0800 - 1124	Tues 5/4 1140 - 1218	5/4 1237 - 5/5 1600	36	5/5 1603	9	slack before ebb	5/5 2207	9	slack before flood	5/6 0404	9	slack before ebb	5/6 0958	9	slack before flood	10
Fri 5/7 0800 - 1052	Fri 5/7 1109 - 1146	5/7 1204 - 5/8 1430	36	5/8 1434	9	slack before flood	5/8 2035	9	slack before ebb	5/9 0230	9	slack before flood	5/9 0830	9	slack before ebb	10
Tues 5/11 0800 - 1045	Tues 5/11 1105 - 1140	5/11 1157 - 5/12 1000	36	5/12 1002	9	slack before ebb	5/12 1559	9	slack before flood	5/12 2159	9	slack before ebb	5/13 0356	9	slack before flood	10
Fri 5/14 0800 - 1037	Fri 5/14 1045 - 1126	5/14 1138 - 5/15 1130	35	5/15 1135	9	slack before ebb	5/15 1733	9	slack before flood	5/15 2335	9	slack before ebb	5/16 0532	8	slack before flood	10
Tues 5/18 0800 - 1040	Tues 5/18 1100 - 1135	5/18 1200 - 5/19 1030	35	5/19 1027, 1028	9 (+3 intentional morts)	slack before flood	5/19 1629	9	slack before ebb	5/19 2239	8	slack before flood	5/20 0434	6	slack before ebb	10

Table 5-1 (Continued)																
Stockton																
				Release A			Release B			Release C			Release D			
Tagging	Transport	Holding	Total released (A+B+C+D)	Date/Time	Number released	Tidal condition at release	Date/ Time	Number released	Tidal condition at release	Date/Time	Number released	Tidal condition at release	Date/ Time	Number released	Tidal condition at release	Fish Health Dummy tagged
Tues 4/27 1200 - 1345	Tues 4/27 1353 - 1455	4/27 1600 - 4/28 1500	36	4/28 1457	9	slack before flood	4/28 2102	9	slack before ebb	4/29 0311	9	slack before flood	4/29 0901	9	slack before ebb	10
Fri 4/30 1200 - 1345	Fri 4/30 1355 - 1450	4/30 1520 - 5/1 1630	36	5/1 1630	9	slack before flood	5/1 2232	9	slack before ebb	5/2 0432	9	slack before flood	5/2 1042	9	slack before ebb	10
Tues 5/4 1200 - 1340	Tues 5/4 1352 - 1445	5/4 1510 - 5/5 1400	35	5/5 1958	9	slack before ebb	5/6 0202	8	slack before flood	5/6 0801	9	slack before ebb	5/6 1401	9	slack before flood	10
Fri 5/7 1200 - 1325	Fri 5/7 1340 - 1430	5/7 1500 - 5/8 1800	36	5/8 1801	9	slack before ebb	5/8 0002	9	slack before flood	5/9 0600	9	slack before ebb	5/9 1200	9	slack before flood	10
Tues 5/11 1200 - 1421	Tues 5/11 1425 - 1524	5/11 1600 - 5/12 1400	35	5/12 1400	9	slack before flood	5/12 1953	9	slack before ebb	5/13 0206	8	slack before flood	5/13 0804	9	slack before ebb	10
Fri 5/14 1200 - 1347	Fri 5/14 1354 - 1445	5/14 1520 - 5/15 1600	34	5/15 1556	8	slack before flood	5/15 2159	9	slack before ebb	5/16 0415	9	slack before flood	5/16 1001	8	slack before ebb	10
Tues 5/18 1200 -1303	Tues 5/18 1315- 1502	5/18 1522 - 5/19 1300	35	5/19 1253, 1254	9 (+3 intentional morts)	slack before ebb	5/19 1901	9	slack before flood	5/20 0102	9	slack before ebb	5/20 0701	5	slack before flood	10

Transportation to Release Sites

In order to minimize the stress associated with moving fish, specially designed transport tanks were used to move fish from TFCF to the release sites. The tanks were designed to securely hold a series of 19 L (5 gal) containers (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. Each transport tank was mounted on the bed of a flatbed truck that was equipped with an oxygen tank and hosing to deliver oxygen to the tanks during transport.

Buckets were removed from holding tank at the TFCF and loaded into the transport tanks. Immediately prior to loading, all fish were visually inspected for mortalities or signs of poor recovery from tagging (e.g. erratic swimming behavior). Only one fish was removed for signs of poor recovery from the 21 release groups tagged at the TFCF. The approximae transport times are listed in Table 5-1. Temperature and DO in the transport tanks were recorded after loading buckets into transport tanks but before leaving the TFCF for the release site and at the release site prior to unloading (Table 5-2).

Perforated buckets were removed from the transport tanks and carried to the river. For the releases at Old River, perforated buckets were placed into “sleeves” and transferred to a small boat for moving fish to the holding location. Perforated buckets were carried to the river at the Durham Ferry site, usually without a “sleeve”. The buckets were transferred from the truck at the Stockton release site using a similar procedure to that used at Old River; where they were placed in sleeves and transported by boat a short distance to the holding location. Water temperature and dissolved oxygen levels were measured in the river near the holding locations at each of the release sites prior to placing the fish into perforated plastic garbage cans in the river (Table 5-2).

The tagged fish were transferred from buckets to 120 L (32 gal), perforated, plastic garbage cans for the 24-hour holding period. The perforated garbage cans had hole sizes of 0.95 or 0.64 cm. Three buckets, with usually three fish per bucket, were emptied into each trash can. Fish were held in the garbage cans for a minimum of 24 hours prior to release (Table 5-1). Dummy tagged fish were treated similarly but were held for 48 hours. 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.

Table 5-2
Water Temperature (ºC) and Dissolved Oxygen (mg/L) at the Tracy Fish Collection Facility Prior to Transport to the Three Release Sites, in the Transport Tank after Transport, and in the River Immediately Prior to Placing the Fish in Holding Containers for each of the Seven Release Groups and the Number of Mortalities after Transport, Just Prior to Release after the 24-hour Holding Period and for Dummy-tagged Fish after the 48-hour Holding Period

2010 VAMP Fish Releases into the San Joaquin River at Durham Ferry

Transport Date	At Tracy Fish Collection Facility		Tank after loading		Tank after transport		# morts after transport	San Joaquin River at Durham Ferry			Dummy tag morts after 48 hrs
	Temp (˚C)	DO (mg/L)	Temp (˚C)	DO (mg/L)	Temp (˚C)	DO (mg/L)		Temp (˚C)	DO (mg/L)	# morts just prior to release	
4/26/10	19.6	-	18.8	13.92	20.1	11.48	0	18.8	6.54	0	0
4/29/10	17.4	14.18	17.3	14.5	17.4	13.25	0	15.6	9.12	0	0
5/3/10	18.1	14.21	18.1	15.12	18.9	13.82	0	17.3	9.56	0	0
5/6/10	18.3	12.23	17.7	12	18.1	13.83	0	15.9	10.4	0	0
5/10/10	15.5	-	15	-	16.0	-	1	12*	-	0	0
5/13/10	17.5	11.34	17.7	15.35	18.3	15.33	1	16.0	11.5	0	0
5/17/10	18.4	8.5	16.5	12.27	16.5	14.11	0	16.8	9.8	0	0
Average	17.83	12.09	17.3	13.86	17.90	13.64		16.73	9.49		

2010 VAMP Fish Releases into Old River just Downstream of the Head of Old River

Transport Date	At Tracy Fish Collection Facility		Tank after loading		Tank after transport		# morts after transport	Old River just Downstream of its Confluence with the Mainstem San Joaquin River			Dummy tag morts after 48 hrs
	Temp (˚C)	DO (mg/L)	Temp (˚C)	DO (mg/L)	Temp (˚C)	DO (mg/L)		Temp (˚C)	DO (mg/L)	# morts just prior to release	
4/27/10	18.1	12.5	18	14.52	17.9	6.35	0	17.5	8.44	0	0
4/30/10	17	14.22	16.8	13.97	16.8	11.32	0	15.3	9.32	0	0
5/4/10	18.4	13.43	17.8	12.31	18.7	8.5	0	17.3	9.0	0	0
5/7/10	-	-	17.8	13.42	20.8	7.5	0	15.7	9.4	0	1
5/11/10	16.4	11.45	16.6	-	16.8	11.8	0	14.2	10.2	0	0
5/14/10	17.9	9.32	16.5	12.7	17.7	7.67	0	16.8	10.2	0	0
5/18/10	18.4	7.23	16.6	16	16.8	-	0	16.8	-	0	0
Average	17.70	11.36	17.16	13.82	17.93	8.86		16.23	9.43		

2010 VAMP Releases into the San Joaquin River near Stockton Waste Water Treatment Facility (STWWTF)

Transport Date	At Fish Facility		Tank after loading		Tank after transport		# morts after transport	San Joaquin River near Stockton Wastewater Treatment Plant			Dummy tag morts after 48 hrs
	Temp (˚C)	DO (mg/L)	Temp (˚C)	DO (mg/L)	Temp (˚C)	DO (mg/L)		Temp (˚C)	DO (mg/L)	# morts just prior to release	
4/27/10	18.2	13.72	18.2	14.6	18.3	10.89	0	18.1	7.49	0	0
4/30/10	18.4	13.17	18.1	12.9	18.7	14.07	0	16.8	9.39	0	0
5/4/10	19.3	13.38	17.9	13.24	18.2	14.07	0	18.3	7.74	0	0
5/7/10	18.4	14	16.9	13.84	18.1	15.2	0	17.2	9.67	0	0
5/11/10	18.1	8.41	17.5	15.35	17.8	12.63	0	15.6	8.94	0	0
5/14/10	18.7	10.3	17.2	15.19	17.9	12.04	0	18.1	10.50	0	0
5/18/10	19.2	6.9	18.1	11.29	18.8	9.35	0	18.5	8.52	0	0
Average	18.61	11.41	17.70	13.77	18.26	12.61		17.51	8.89		

* - Potentially an error in reading

During the holding and recovery period tagged fish were also monitored by a hydrophone installed at each of the release sites. This monitoring period allowed confirmation of the operational status of each transmitter prior to release. There were four tags not detected during the monitoring at the release sites; one from the 5th release into the San Joaquin River at Durham Ferry, one from the 6th release at Durham Ferry, one from the 1st release into the San Joaquin River near the Stockton Waste Water Treatment Facility (SWWTF) and one from the 7th release at the SWWTF. The undetected tags were noted in the database but were not used in the survival analysis (essentially removed from the release groups).

Releases

Seven releases were made between April 27th and May 19th at three separate sites; on the San Joaquin River at Durham Ferry (approximate river mile (RM) 66), Old River near its junction with the San Joaquin River (approximate RM 48) and on the San Joaquin River near the Stockton Wastewater Treatment Facility (SWWTF) (approximate RM 39) (Figure 5-2). At Durham Ferry a total of approximately 74 fish were released per release period, while at Old River and San Joaquin River near the SWWTF, a total of approximately 36 fish were released per release period (Table 5-1).

After the fish had been held for a 24 hour period, releases were done every six hours until all fish were released. Release times for Durham Ferry were set for 1400, 2000, 0200 and 0800 hours, while releases at Old River and SWWTF varied based on the tide (Table 5-1). Releases at Old River and at the SWWTF were conducted three or nine hours after the high slack to release fish in the middle of the tide phase for each release. It was assumed that releasing fish during the middle of the tidal cycle would allow fish to move out of the release area before tides moved them too far upstream (flood tides) or downstream (ebb tides).

To assure the fish from the Durham Ferry releases did not experience mortality or differential mortality associated with potential operation of an agricultural pump located directly upstream of the release site and to minimize their exposure to predators that potentially congregated near the holding locations, a boat was used to transport tagged fish in the perforated 120 L (32 gal) containers downstream about 275 m (300 yds) before releasing them at RM 69.5. At the Old River and SWWTF release sites, boats were also used to move release groups downstream from the holding location prior to release; at the Old River release site the fish were moved downstream around the bend in Old River and the fish released near the Stockton WWTF were released about 60 m (200 ft) downstream of the holding area.

Prior to release, individual garbage cans were attached to the gunnel of the Jon boat and transported to the center of the river channel. In addition, a sleeve (either another slightly larger un-perforated garbage can or a large plastic bag) was placed around the perforated garbage can to minimize the amount of water from within the perforated garbage can that seeped into the river as the can was being transported downstream to avoid having any potential predators, that had congregated near the holding area from following the cans downstream and eating the fish just moments after release. All releases were made in the center of each channel.

Once the release site was reached, the perforated garbage cans were lifted to the surface to allow most of the water to drain. This allowed the tagged fish to be observed just prior to release. Observations were conducted to determine if there was any mortality of tagged fish after the holding period and just prior to release. The time was noted for each release. Dead or impaired fish were collected and identified by tag period.

To determine the “behavior” of dead fish, a total of nine tagged salmon, three at each release location, were intentionally sacrificed immediately before release and released with the live study fish. The nine tagged salmon were euthanized by pithing the fish (inserting a dissecting probe through the top surface of the fish’s head between and directly behind the eyes and pushing the probe back and forth) and using scissors to cut through all the gill arches on the left side of each fish. The intent of releasing dead fish with the live release groups was to evaluate how far downstream a dead fish could travel since detection of dead fish at a receiver would be perceived in the model as survival of a live fish. The shorter the distance that a dead fish travels, 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 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. Dummy-tagged fish were evaluated for condition and mortality after being held at the release site for approximately 48 hours.

After dummy-tagged fish were held for 48 hours, they were euthanized with MS-222, measured (FL to nearest mm) and examined qualitatively for percent scale

Table. 5-3
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)

Table 5-4
Descriptions and Locations of Acoustic Hydrophone and Receiver Sites used in the 2010 VAMP Study, with Receiver Codes used in Figure 5-2, Survival Model (Figure 5-5), and in Data Processing at the Columbia River Research Lab (CRRL) of the United States Geological Survey (USGS) in Cook, Washington (Latitude and longitude measurements refer to hydrophone locations)

Receiver Location and Description	Hydrophone Location		Receiver Code shown in Figure 5-2	Survival Model Code Shown in Figure 5-5	Data Processing Code Used in Figures 5-3 and 5-4
	Latitude (°N)	Longitude (°W)			
San Joaquin River at Banta Carbona	37.72765	121.29860	BCA	A2	901
San Joaquin River at Mossdale	38.02502	121.46580	MOS	A3	902
San JoaquinRiver near Lathrop	37.82191	121.31868	SJ1	A4	903
San JoaquinRiver near Lathrop	37.82231	121.31734	SJ2	A4	904
San Joaquin River at Stockton USGS gauge	37.93341	121.32853	STS	A5	905
San Joaquin River at Stockton Navy Bridge	37.94656	121.33933	STN	A6	906
San Joaquin River at Shipping Channel Marker 18	38.02278	121.33490	C18	A7a	907
San Joaquin River at Shipping Channel Marker 16	38.02616	121.47000	C16	A7b	908
San Joaquin River at Medford Island, east	38.05221	121.51095	MFE	A8a	909
San Joaquin River at Medford Island, west	38.05318	121.51317	MFW	A8b	910
Old River near junction with San Joaquin River	37.81247	121.33541	OR1	B1	921
Old River near junction with San Joaquin River	37.81226	121.33532	OR2	B1	920
Old River South, upstream	37.82037	121.37796	ORSU	B2a	922
Old River South, downstream	37.81874	121.37992	ORSD	B2b	923
Old River North, upstream	37.89015	121.57244	ORNU	B3a	990
Old River North, downstream	37.89160	121.56845	ORND	B3b	991
Middle River South	37.83481	121.38370	MRS	C1	980
Middle River North, upstream	37.89002	121.48942	MRNU	C2a	983
Middle River North, downstream	37.89258	121.49063	MRND	C2b	984
Radial Gate at Clifton Court Forebay, upstream (in entrance channel to forebay)	37.82961	121.55695	RGU	D1	950
Radial Gate at Clifton Court Forebay, downstream (inside forebay)	37.82985	121.55769	RGD	D2	951/952
Central Valley Project trashracks	37.81669	121.55856	CVP	E1	961/962
Central Valley Project holding tank	37.81594	121.56140	CVPtank	E2	960
Turner Cut, northeast (upstream)	37.82187	121.31867	TCN	F1a	930
Turner Cut, southwest (downstream)	37.98997	121.46038	TCS	F1b	931
Chipps Island, east	38.04634	121.89076	CHPe	G1a	800
Chipps Island, west	38.04743	121.89697	CHPw	G1b	810/915
Threemile Slough, south (not used in survival model)	38.09721	121.68549	TMS	T1a	940
Threemile Slough, north (not used in survival model)	38.11105	121.68351	TMN	T1b	941

loss, body color, fin hemorrhaging, eye quality, gill coloration and vigor (Table 5-3). Any mortality was also documented. Ten dummy-tagged fish from three groups (first, third and last) from each release location were examined for bacteriology, virology and gill ATPase (see fish health discussion in chapter 6).

Receiver Deployment

The hydrophone receiver network shown in Figure 5-2 was developed as part of a series of VAMP biology group meetings involving SJRA partners along with agency representatives (NOAA, EPA, CDFG, USBR, DWR, USGS, etc.) and fishery specialists from the University of Washington. This also involved the other agencies conducting similar studies within the Lower San Joaquin River and Delta in an effort to maximize the data use between all these groups. A hierarchy of study objectives was discussed in relation to the tradeoffs associated with a variety of different hydrophone placement scenarios. Principal objectives of the hydrophone layout for 2010 were to: (1) obtain fish survival estimates through the Delta from Durham Ferry and Mossdale to Chipps Island; (2) obtain estimates of fish survival in some key reaches of the Delta; the Old River and San Joaquin River mainstem routes; and (3) obtain fish route "selection" probabilities at critical flow splits (i.e., head of Old River and Turner Cut) (Figure 5-2).

In past years VAMP relied on Natural Resource Scientists, Inc (NRS) to install and maintain the HTI acoustic equipment. However, in 2010, NRS could not provide this service so the United States Fish and Wildlife Service (USFWS), Stockton office took the primary responsibility for the installation and maintenance of the receivers with support from Normandeau and Associates (Stevenson, WA) and the United States Geological Survey (USGS) Columbia River Research Lab (CRRL). The USGS-Sacramento office installed and maintained the receivers located at Chipps Island during the 2010 VAMP study. Equipment at DWR and USBR facilities was installed and maintained by their own personnel.

As part of the 2010 VAMP program, nineteen acoustic receivers were deployed at 11 sites within the San Joaquin River and Delta (Figure 5-2). Sixteen of these receivers at ten locations were installed between March 21st and March 28th. The remaining three receivers were deployed by the USGS-Sacramento Office at Chipps Island. There were an additional eight receivers deployed at six other locations as part of the DWR temporary barriers study which were coordinated with the 2010 VAMP study in order to allow the use of the data from these receivers by both studies.

For the sixteen receivers deployed between March 21st and 28th, hydrophones were deployed in key areas, based on channel width, depth and in-water noise interference. Tag drags were conducted to make sure that each hydrophone was able to pick up a signal from an acoustic tag. Hydrophone locations were marked with an onboard GPS unit (Lowrance HDS-5). Each site contained a hydrophone, receiver, input/output box and 12V deep-cycle battery to power the equipment. All equipment was housed in a metal 'jobox' which was fabricated with a divider to facilitate holding the receiver in a water bath to eliminate overheating. The joboxes were modified using similar techniques to those described in Vogel (2010): 1) incorporating a water bath inside the joboxes, 2) cutting ventilation holes in the bottom and top for convection cooling, and 3) painting the exterior of the metal boxes with a ceramic heat-reflecting paint.

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 activated on April 17th.

The location of some sites in 2010 differed slightly from 2009 to reduce noise observed in the data files at some locations in 2009. Sites that were moved for the 2010 VAMP study included San Joaquin River at Mossdale Bridge, San Joaquin River near Lathrop and San Joaquin River near Stockton Wastewater Treatment Facility. Additional sites were installed for 2010 VAMP study that were not part of the 2009 VAMP study. These included a single receiver in the San Joaquin River just downstream of the Banta Carbona intake structure and dual arrays at Medford Island and Threemile Slough. A dual array at Chipps Island was also added in 2010. A listing of sites and their locations along with the site number assigned during data processing and survival modeling can be found in Table 5-4.

Receiver Maintenance

Receiver sites were visited three days per week (Mon,Wed, Fri) from April 19th through June 15th. At each site, the receiver 'jobox' was opened and the battery was removed. Used batteries were recharged for use the following maintenance day. Maintenance of the receivers consisted of accessing the box, replacing the 12-volt battery with a fully charged battery, making sure the I/O box was functioning and determining if the beacon tag was present. Also, data already stored on the receivers was downloaded on each visit to a laptop using HTI software. For most of the sites, data were uploaded to a FTP site soon after collection.

Ten of the receivers (at six locations) were maintained by the USFWS, Stockton Office. These six locations were located on the San Joaquin River between Stockton and Threemile Slough. Five receivers (at three locations) were maintained by the CDFG, Region 4 office (Mossdale, Old River, and San Joaquin River near Lathrop). FISHBIO maintained the single receiver at Banta Carbona. Personnel from USGS, Sacramento Office deployed and maintained two four-port receivers and one single-port receiver near Chipps Island (3 receivers at one location). An additional twelve receivers at eight locations were maintained by DWR as part of their south Delta temporary barriers program and included receivers in and outside of Clifton Court Forebay, Old and Middle River north and near the Old and Middle River confluence (Figure 5-2). In addition, the two sites upstream and downstream of the trash rack at the CVP intake pumps were also maintained by personnel from DWR. An additional receiver was placed in the holding tank at the CVP Tracy Fish Facility and was maintained by USBR personnel.

Several of these sites required field crews to utilize boats to change batteries and retrieve data. Sites that were maintained using a boat were; San Joaquin River at Mossdale (MOS), Old River (OR1 and OR2), San Joaquin River at Lathrop (SJ1 and SJ2), Navy Drive Bridge (STN), Stockton Wastewater Treatment Facility (SWWTF), channel markers 16 (C16) and 18 (C18), Medford Island ((MFE) and (MFW)) and Turner Cut ((TCS) and (TCN)). Three sites were accessible by vehicle. These sites included San Joaquin River at Banta Carbona (BCA), Threemile Slough south (TMS) and Threemile Slough north (TMN).

Temperature Monitoring

Water temperature was monitored during the 2010 VAMP 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 (Appendix C). Depth of the measurements varied from water level to approximately 4 feet below water level. As part of the 2010 VAMP monitoring program, additional temperature recorders were deployed in the south and central Delta (Appendix C) 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 instantaneously at 24-minute intervals throughout the period of the 2010 VAMP investigations.

Two temperature recorders deployed as part of the 2010 VAMP temperature monitoring activities were vandalized making the data irretrievable. This resulted in missing temperature data for the Jersey Point USGS Gauging Station and Werner Cut temperature monitoring sites.

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 2010 VAMP study following similar methods employed by the CRRL during the 2008 VAMP and FISHBIO during the 2009 VAMP (San Joaquin River Group Authority, 2010). A stratified random sample of 55 tags was taken across 1,078 successfully programmed model 795 Lm tags acquired from HTI which were comprised of seven manufacturing lots. Tags were programmed with periods ranging from 4 to 10 seconds (sec), with a pulse width of 2 milliseconds (ms). The tag life study began May 26th 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.

A recording thermograph was placed in the tank prior to tag initialization and temperature readings were logged every 60 minutes for the duration of the study.

Data Processing for Survival Analysis

Data collected at individual monitoring sites were transferred to the Columbia River Research Lab (CRRL) of the United States Geological Survey (USGS) in Cook, Washington. A multiple-step process was used to identify and verify detections of fish in the data files. The first step in identifying valid detections can be done using the vendor's software (hereafter referred to as MarkTags) to visually inspect each hourly data file from each monitoring receiver. When the number of tagged fish is relatively small, this can be a reasonable way to process the data. However, when the number of tagged fish is large, as was the case in this study, it becomes impractical to visually identify the fish detections.

For example, for a 30-day study with 20 receivers and 1000 tagged fish, visual inspection of each file using MarkTags would require 14.4 million (1000 tags in each of 24 hourly files for each of 30 days for each of 20 receivers) page-views in the MarkTags software. At an ambitious rate of 1 page viewed per second, it would require 4,000 hours of continuous, uninterrupted work to visually identify valid detections. The use of an automated process to identify fish detections clearly saved a tremendous amount of time when processing data. However, the savings in time does not come without a cost. While improvements to the accuracy of the automated process will continue, it was not, nor is it likely to be, 100% accurate at correctly identifying all fish detections all the time. If 100% accuracy must be achieved, then all the data must be processed manually. Manual processing of all the data was not an option for this study; however, the results of the automated processed files were compared to manually processed files for a limited number of sites to assess the accuracy of the auto processed files and to determine the need for manual processing in the future.

Two independent automated processes (hereafter referred to as automarking) were implemented to identify fish detections. Automarking utilizes algorithms to identify valid fish detections. For one of the automarking processes CRRL used the algorithms and parameter settings within MarkTags. Over the past 15 years, USGS, CRRL has developed procedures to determine the optimal study-specific parameter specifications to optimize the use of MarkTags. The second automarking process (hereafter referred to as FishCount) used algorithms and parameters developed by USGS. During development of this new process, CRRL assessed the accuracy of finding fish detections by comparing the results against data that had been manually processed. While automarking greatly reduces the number of hours it takes to identify valid detections, the algorithms are complex and the accuracy in identifying all possible valid detections in the data can vary. To ensure that the automated process was correctly identifying valid detections, all detections identified by MarkTags and all the detections identified by FishCount were manually verified, with the exception of the data collected at the five sites in the Clifton Court area (site numbers 950, 951, 952, 961, and 962 used in data processing[1]). Due to the nature of the data collected at the Clifton Court sites, the MarkTags process identified a relatively large number of false positive detections (over 190,000). Since all false positive detections required manual verification, the number of false positive detections generated using MarkTags precluded manual verification of all of these detections. When the data from these sites were processed using the FishCount process, fewer false positives were identified (under 16,000). For the five sites in the Clifton Court area, FishCount was the only automated process used to identify valid detections, and all false positive detections were manual verified. Because two independent automated processes were used to identify detections in the data from all but 5 of the receiver sites, USGS conducted further analysis to compare the accuracy of the two processes. CRRL found that FishCount consistently found more valid detections (Figure 5-3) and fewer false positive detections than MarkTags (Figure 5-4).

In addition to the autoprocessing, data from a subset of sites were manually processed: Old River (OR1 and OR2) (2 receivers), San Joaquin River at Lathrop (SJ1 and SJ2) (2 receivers), Chipps Island (CHPe and CHPw) (1 four port receiver and 1 single node) and San Joaquin River at Mossdale (MOS) (1 receiver). The objective of manually processing a subset of the stations was to 1) determine differences in tag detections using autoprocessing versus manually processing to gauge the effectiveness of the autoprocessing, and 2) characterize the acoustic signal pattern of detections for use in classifying detections as salmon or predator detections (described below).

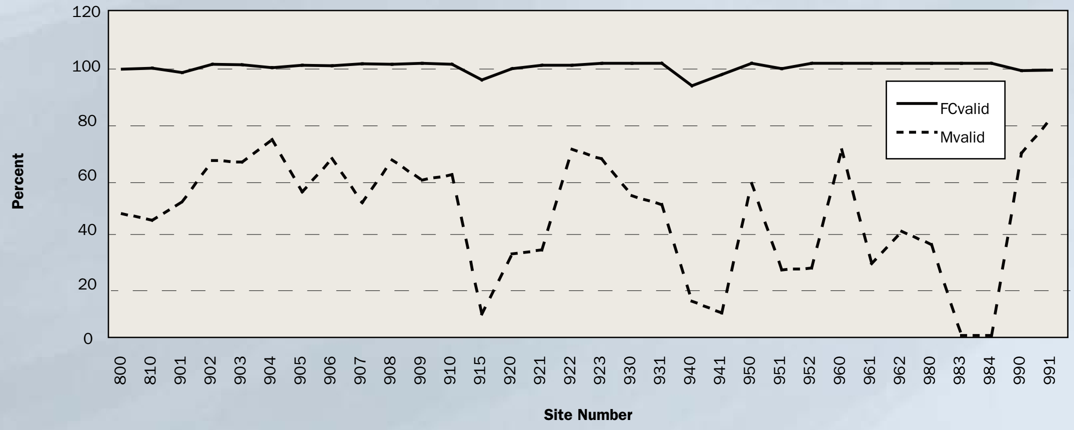
Tag code detections were compared between the manually processed and autoprocessed databases. Where differences in tag codes were apparent, tag codes were verified and these results were the basis of the comparisons at each receiver that was manually processed. Each method of processing was used to identify false negatives and false positives arising from the other processing method. While this provided some assessment of the error rate in both the autoprocessed and manually processed data, it did not identify errors made by both the autoprocessor and the manual processer. Other than at random, it is possible but unlikely both methods resulted in the same mistakes. Manual mistakes were also found in manual transcription but were counted as an error only if there was an error in the electronic database (bookmarks not properly constructed or erroneously constructed in database). Lastly, tag detections of the autoprocessed data were compared between redundant sets of receivers, taking into account any down time of the receivers.

The University of Washington received the primary database of autoprocessed detection data from the USGS-CRRL. These data included the date, time, location, and

[1] *Various site identities were used during the 2010 VAMP study for receiver placement, data storage, data analysis and survival modeling. A listing of all identifiers used during the 2010 VAMP study is shown in Table 5-4.*

Figure 5-3

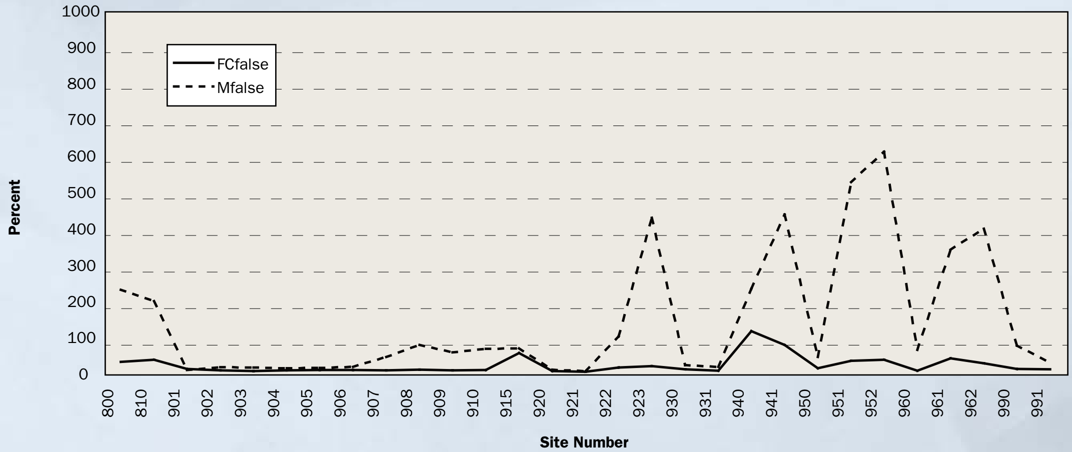
Plot Showing the Percent (%) of Valid Detections Found by FishCount (solid line) and MarkTags (dashed line) for Each Receiver Site Number (see Table 5-4 for comparison of site numbers with actual receiver site locations).



Site Numbers 980, 983, and 984 were Removed from this Comparison Due to Low Sample Size (n < 6). Sample Size was also Relatively Low at Site 915 (n = 64), 940 (n=24), and 941 (n=24) which Accounts for the Slight Decrease in Performance of FishCount. For example, FishCount Found 60 of 64 Valid Detections at Site 915, 22 of 24 at Site 940, and 23 of 24 at Site 941.

Figure 5-4

Plot Showing the Percent (%) of False Detections Found by FishCount (solid line) and MarkTags (dashed line) for each Receiver Site Number (see Table 5-4 for comparison of site numbers with actual receiver site locations).



Site numbers 980, 983, and 984 were Removed from this Comparison Due to Low Sample Size (n < 6). Sample Size was also Relatively Low at Site 915 (n = 64), 940 (n=24), and 941 (n=24) which Accounts for the Slight Increase in the Relative Percentage of False Positive Detections Found Using the FishCount Process.

tag period and subcode of each valid detection of the acoustic salmon 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.

The autoprocessed and manually processed databases were both cleaned to remove obvious invalid detections. In addition to the diagnostic comparisons between the two databases described above, the University of Washington identified potentially invalid detections based on unreasonable travel times or unlikely transitions between detections. The processor (USGS-CRRL or manual processor) then manually examined the raw data for the suspect detections to determine their validity. After cleaning both the autoprocessed and the manually processed databases, the two databases were merged to form the complete database of detections. All subsequent analysis was based on this merged database.

The information for each tag in the merged database included the date and time of the beginning and end of the period within the hourly '.RAT' file when the tag was detected. The cleaned hourly detections were converted to detections denoting the beginning and end of receiver "visits," with consecutive visits to a receiver separated either by a gap of 12 hours or more between detections on the receiver, or by detection on a different receiver. Detections from receivers in dual or redundant arrays were pooled for this purpose.

Distinguishing Between Detections of Salmon and Predators

The possibility of predatory fish eating tagged study fish and then moving past one or more fixed site receivers complicated analysis of the detection data. 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 that temporarily had a salmon tag in their gut. Without removing the detections that came from predators, the survival model would produce positively biased estimates of juvenile salmonid survival through the Delta. The size of the bias would depend on the amount of predation by predatory fish and the spatial range of the predatory fish after eating the tagged salmon. In order to minimize bias, a decision process was used to classify detections as either likely to have come from live salmon smolts, or likely to have come from predatory fish. This decision process was applied to all detections of all tags. Two data sets were then constructed: the full data set included all detections, including those classified as coming from predators (i.e., "predator-type"), while the reduced data set was restricted to those detections classified as coming from live smolts (i.e., "smolt-type"). The survival model was fit to both data sets separately, and the resulting survival estimates were used as "bookends" of the true survival.

The decision process used three levels of analysis: near-field, mid-field, and far-field (Vogel, 2010). The near-field analysis focused on movements of the tag within a short time period (no longer than one hour) within the detection range of the receiver. The mid-field analysis focused on movements of the tag among neighboring receivers and over a time scale of several hours to a day. Far-field analysis considered the movement of the tag throughout the study area. As part of the decision process, environmental data including river flow, river stage, and water velocity were examined from several points throughout the Delta (Table 5-5). Environmental data were downloaded from the California Data Exchange Center website (http://cdec.water.ca.gov/selectQuery.html) on January 4, 2011. River flow and water velocity were highly correlated at most environmental monitoring sites. All detections were considered when implementing the decision process, including detections from Threemile Slough that were otherwise excluded from the survival analysis, and detections at the Bio-Acoustical Fish Fence (BAFF) at the head of Old River.

For each tag detection, several steps were performed to determine if it should be classified as predator or salmon. Initially, all detections were assumed to be of live smolts. Once a detection was classified as coming from a predator, all subsequent detections of that tag were likewise classified as predator detections. The assignment of predator status to a detection was made conservatively, with doubtful detections classified as coming from live salmon. In general, the decision process was based on the assumption that (1) salmon smolts were unlikely to move against the flow, and (2) salmon smolts were actively migrating and thus wanted to move downriver, although they may temporarily move upstream with the flow.

Movements and transitions between detection sites on the far-field scale were considered first. Tags that moved between sites quicker than a salmon would be able were classified as predators upon arrival at the destination site. Conversely, tags were classified as predators upon arrival if they were observed moving very slowly between sites where most tags were observed to move quickly. The range of migration rates considered reasonable for a salmon smolt was selected based on conversations with Dave Vogel (Natural Resource Scientists, Inc.) and Brent Bridges (U.S. Bureau of Reclamation), and varied depending on location, water velocity, and flow volume (Table 5-6). Abrupt changes in migration rate were also used to identify possible predator detections, if there

Table 5-5
Environmental Monitoring Sites for River Flow, River Stage and Water Velocity that Were Used in Predator Decision Rule

Enivonmental Monitoring Site			Detection Site	Data Available		
Site Name	Latitude (°N)	Longitude (°W)		River Flow	Water Velocity	River Stage
OH1	37.8080	121.3290	OR1/OR2	Yes	Yes	Yes
OH4	37.8911	121.5692	ORN	Yes	Yes	Yes
OLD	37.8050	121.4490	ORS	No	No	Yes
ORI	37.8280	121.5526	CVP, RGU	Yes	Yes	No
MAL	38.0440	121.9190	CHP	No	No	Yes
MSD	37.7860	121.3060	MOS	Yes	Yes	Yes
PRI	38.0594	121.5572	C18/C16, MFE/MFW	Yes	Yes	Yes
SJG	37.9350	121.3290	STS, STN	Yes	Yes	Yes
SJL	37.8100	121.3230	SJ1/SJ2	Yes	Yes	Yes
TRN	37.9928	121.4542	TCN/TCS	Yes	Yes	Yes
VNI	38.0500	121.4960	C18/C16	No	No	Yes

was no alternative explanation for such a change (e.g., change in flow dynamics). A tag's regional residence time was considered, as well. For example, a tag that remained in the western Old River region, moving among the Central Valley Project Trash racks, Clifton Court Forebay access channel, and Old River at Highway 4 for more than one or two days would be classified as being in a predator upon one or more of those detections. The tag was first classified as a predator upon the first exhibition of predator-type behavior, with the acknowledged uncertainty that the salmon smolt may actually have been eaten sometime before the first obvious predator-type detection. River flow and water velocity were considered when assessing the tag migration rate and travel time for predator classification.

The mid-field analysis focused on the arrival and residence of a tag in the vicinity of a detection site, with all receivers comprising a dual or redundant array considered jointly. It was assumed that salmon would be more likely to be influenced by the river flow than predators, and less likely to move against the flow. Arrival timing at the San Joaquin River sites and some of the Old River sites was compared to the magnitude, direction, and rate of change of the river flow or water velocity measured every 15 minutes at the nearest monitoring site, if available. Tags that moved against the flow were classified as being in predators at the first detection after such a movement. An exception was made for tags that moved against low magnitude flow, or were observed to arrive or depart from a receiver immediately before or after a change in flow direction. Because of the complex hydrologic environment around the Central Valley Project Trash racks and the Clifton Court Forebay entrance, the flow patterns were not considered in assessing detections at these sites. Residence time at a site was also examined as part of the mid-field analysis, with very long residence times interpreted as indicative of predators. The prospect of a salmon being pushed back into range of a receiver by the flow, thus prolonging its perceived residence time at the site, was taken into account. On the other hand, a tag that was continuously within range of a receiver over a long period of time (e.g., multiple tidal cycles) was assumed to be in a predator upon departure from the receiver.

The near-field analysis focused on the movements of the tag in the vicinity of a single receiver. These movements were identified by the pattern of the acoustic signal, with signals characterized using the following coding scheme:

- 1 = Inverted signal < 30 minutes
  - 12 = Wavy signal < 30 minutes
  - 13 = Flat line signal < 30 minutes
- 2 = Inverted signal > 30 minutes
- 3 = Wavy signal > 30 minutes
- 4 = Combination of wavy and flat line signal > 30 minutes
- 5 = Flat line signal > 30 minutes
- 6 = Unknown

Codes 1 and 2 were interpreted as consistent with the directed behavior of a migrating salmon. Codes 4 and 5 were interpreted as consistent with the hovering or circling behavior of a predatory fish (e.g., striped bass) or a defecated tag that would indicate predation. A wavy signal (codes 12, 3) may indicate predator behavior, especially in a high flow setting, or smolt behavior in a

Table 5-6
Cutoff Values Used in the Predator Decision Rule (Values Past the Cutoff Indicate a Predator)

Release Site	Detection Site	Previous Site	Residence Time[a] (hr)	Travel Time (hr)		Migration Rate[b] (km/hr)		Flow at arrival[c] (cfs)	Comment
			Maximum	Minimum	Maximum	Minimum	Maximum		
DF	BCA	DF	1	3	20	0.5	3.5		
DF	MOS	BCA	1	3	33	0.3	3.5		
		DF	1	6	70	0.3	3.5		
DF	SJ1/SJ2	MOS	2	1.7	20	0.3	3.5		If not classified as predator at BAFF
		MOS	2	1.7	3	2	3.5	> 2800	If also classified as predator at BAFF
		MOS	2	2.5	20	0.3	2.5	< 2800	If also classified as predator at BAFF
		SJ1/SJ2	0	100[d]	0	100[d]	NA		
STK	SJ1/SJ2	STS	2	100[d]	0	100[d]	NA	> 50	
		SJ1/SJ2	0	100[d]	0	100[d]	NA		
DF	STS	SJ1/SJ2	2	NA	NA	NA	NA	> 3000	Flood tide after arrival: max residence time = 10
		SJ1/SJ2	NA	5	50	0.3	3		
		STS	NA	NA	NA	NA	NA		
STK	STS	STK	8.5	0	3.5	0.12	NA		STS is near STK
		STN	0	100[d]	0	100[d]	0		
DF	STN	STS	2	0.7	10	0.3	4		Flood tide after arrival: max residence time = 9
		STN	NA	NA	NA	NA	NA		
		SJ1/SJ2	2	10	60	0.3	4		
STK	STN	STK	10	0.5	9	0.3	3		Increasing tide after arrival: max residence time = 6
		STN	0	100[d]	0	20	0	> 500	
DF	C18/C16	C18/C16	0	100[d]	0	NA	NA		
		MFE/MFW	0	100[d]	0	NA	NA		
		STN	24	10	52	0.3	3.5		
		STS	24	12	61	0.3	3.5		
STK	C18/C16	STK	24	20	70	0.3	1		
		STN	24	7	52	0.3	2		
DF	MFE/MFW	C18/C16	24	NA	17	0.3	4		Maximum migration rate not firm cutoff
		MFE/MFW	0	100[d]	0	NA	NA		
STK	MFE/MFW	C18/C16	24	7	52	0.3	4		Maximum migration rate not firm cutoff
		MFE/MFW	0	100[d]	0	NA	NA		
DF	TCN/TCS	C18/C16	24	NA	NA	NA	NA	> 500	Positive flow = into San Joaquin
		STN	24	10	9	0.3	3.5	> 500	Positive flow = into San Joaquin
		STS	24	12	0	20	3.5	> 500	Positive flow = into San Joaquin
DF	TMN/TMS	MFE/MFW	10	NA	55	0.4	1		
STK		MFE/MFW	10	NA	55	0.4	1		
DF	OR1/OR2	MOS	0.5	1	4	1	4		Migration rate range depends on flow
		SJ1/SJ2	0.5	1	4	1	4		Migration rate range depends on flow
OR	OR1/OR2	OR	0.5	NA	1	0.4	NA		
		OR1/OR2	0	100[d]	0	100[d]	0		
		ORS	0	100[d]	0	100[d]	0		
DF	ORS	OR1/OR2	4	1.2	6	1	5		Lower migration rate ok if ebb changes to flood
		MOS	4	2	10	1	5		Lower migration rate ok if ebb changes to flood
OR	ORS	OR1/OR2	4	1.2	6	1	5		Lower migration rate ok if ebb changes to flood
		OR	4	2	7	1	5		Lower migration rate ok if ebb changes to flood
DF	MRN	TCN/TCS	5	NA	50	0.4	NA		
		MFE/MFW	0	100[d]	0	100[d]	0		Unlikely transition if migrating
		C18/C16	0	100[d]	0	100[d]	0		
STK	MRN	TCN/TCS	5	NA	50	0.4	NA		
		MFE/MFW	0	100[d]	0	100[d]	0		Unlikely transition if migrating
		C18/C16	0	100[d]	0	100[d]	0		
DF, OR	CVP	ORS	4[d]	NA	50	0.4	NA		
		ORN	4[d]	NA	24	0.4	NA		
		RGU	4[d]	NA	15	0.1	NA		
		CVP	0	100[d]	0	100[d]	0		
DF, OR	CVPtank	CVP	NA	NA	1	0.25	NA		
		ORS	NA	NA	53	0.3	NA		
		RGU	NA	NA	17	0.1	NA		
		ORN	NA	NA	30	0.3	NA		
DF, OR	ORN	ORS	24[e]	NA	85	0.3	NA		
		RGU	24[e]	NA	24	0.3	NA		
		ORN	48[e]	NA	NA	NA	NA		Regional residence time (multiple visits)
DF, OR	RGU	RGU	24[e]	NA	NA	NA	NA		Regional residence time (multiple visits)
		ORS	4[e]	NA	24	0.3-0.4	NA		
		ORN	4[e]	NA	12	0.6	NA		Expect transition on single tidal stage if pushed upriver
		CVP	4[e]	NA	15	0.1	NA		
DF, OR	RGD[f]	RGU	4	NA	5	NA	NA		
DF, STK	CHP	MFE/MFW	24[e]	20	150	0.3	2		
		C18/C16	24[e]	25	170	0.3	2		
DF, OR, STK	CHP	TMN/TMS	24[e]	14	95	0.3	2		
DF, OR	CHP	CVPtank	24[e]	5	NA	NA	NA		Lower travel time ok if with flow, smolt behavior
		ORN	24[e]	25	240	0.3	2		
DF, OR, STK	CHP	CHP	24[e]	NA	NA	NA	NA		Regional residence time (multiple visits)

a = residence time includes up to 12 hours missing between detections
b = Approximate migration rate was calculated on most direct pathway.
c = Flow condition, if any, must be exceeded for predator classification.
d = values of 100 were used as default cutoff values of minimum travel time and migration rate for transitions deemed unlikely for salmon smolts
e = look at raw observation data when interpreting residence time; was tag present continually, or moving with tide?
f = if concurrent detections at RGU and RGD, use migration rate to RGU and residence time at RGU to determine predation

low flow setting. Likewise, a short flat line signal (code 13) was deemed more likely to indicate a predator than a smolt. Near-field signal characteristics were considered in cases where classifications from the mid-field and far-field scales were uncertain. Near-field analysis using these codes was restricted to manually processed data from the Mossdale (MOS), Old River (OR1/OR2), and Chipps Island (CHPe/CHPw) receivers.

Additional near-field analysis was available for tags detected at the BAFF located at the head of Old River. As part of the non-physical barrier study, tags detected on the eight receivers located at the BAFF at the head of Old River were categorized as being in either salmon or predators upon leaving the barrier based on 2-dimensional tag tracks within the barrier region (similar to the near-field analysis described above), and on tag detections downstream of the barrier region. These designations were considered in conjunction with flow magnitude and direction measured on the stream flow gauges at OH1 and SJL, tag migration rate through the reach including the non-physical barrier (i.e., Mossdale to either Lathrop or Old River sites OR1/OR2), and detections of the tag elsewhere in the study area. A tag with an especially low migration rate through the HORB area during a period of high flow, and classified as a predator in the non-physical barrier study, was classified as a predator for the survival study upon arrival at the downstream end of the reach. Conversely, a tag with an especially high migration rate through that area during a period of low flow and classified as a predator in the non-physical barrier study, was also classified as a predator upon arrival downstream for the survival analysis.

A tag could be given a predator classification at a detection site either on arrival or on departure from the site. A tag classified as being in a predator because of long travel time or movement against the flow was generally given a predator classification upon arrival at the detection site. On the other hand, a tag classified as being in a predator because of long residence time was given a predator classification upon departure from the detection site. Because the survival analysis estimated survival within reaches between sites, and not survival during detection at a site, the predator classifications on departure from a site did not result in removal of detection at that site from the reduced data set. However, all subsequent detections were removed from the reduced data set.

All detections on the receivers in the western part of the Delta (CVP, RGU/RGD, ORNU, MRNU, MRS), at Threemile Slough (TMS), and at Chipps Island were examined in detail. Detections at ORS, OR1/OR2, and the San Joaquin receivers were examined only if the travel time or residence time was markedly different from the majority of detections at those sites. Criteria used as cutoff values for travel times, migration rates, and residence times for salmon smolts (Table 5-6) were determined based on conversations with Dave Vogel of Natural Resource Scientists and Brent Bridges of the U.S. Bureau of Reclamation.

Constructing Detection Histories

For each tag, the detection data summarized on the "visit" scale were converted to a detection history ("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 detection history represented the final route of the tagged fish past the receiver or river junction. Detections were pooled from the two receivers located near Lathrop in the San Joaquin River (SJ1 and SJ2), from the two receivers located at the head of Old River (OR1 and OR2), from the two receivers located at the Central Valley Project trash racks (CVP), and from the two receivers located inside the Clifton Court Forebay outside the State Water Project (RGD).

Survival Model

A multi-state statistical 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 the model developed for the 2009 VAMP study (San Joaquin River Group Authority, 2010). Figure 5-5 shows the layout of the receivers with the labels used in the survival model (Table 5-4)[2]. The survival model represented movement and survival throughout the study area to a single exit point at Chipps Island (Figure 5-6). Individual receivers comprising dual arrays were identified separately, with "a" representing the upstream receiver and "b" representing the downstream receiver. Fish moving through the Delta toward Chipps Island may use any of several routes. The simplest route followed the San Joaquin River until it joins the Sacramento River just upstream of Chipps Island (Route A). An alternative route used Old River, from its head on the San Joaquin River just upstream of Lathrop to its confluence with the San Joaquin River just downstream of Mandeville Island (Route B). Route C entered Middle River from Old River. Two possible routes used the water export facilities off of Old River; fish entering either the State Water Project

[2] *Various site identities were used during the 2010 VAMP study for receiver placement, data storage, data analysis and survival modeling. A listing of all identifiers used during the 2010 VAMP study is shown in Table 5-4.*

Figure 5-5
Locations of Acoustic Receivers ("Detection Sites") Used in the Statistical Survival Model for the 2010 VAMP Study Including Locations of Acoustic Receivers Installed and Maintained by the California Department of Water Resources for the South Delta Temporary Barriers Study. Site A1 is the Release Site at Durham Ferry. Site T1 was Excluded from the Survival Model. (see Table 5-4 for a complete listing of codes used in the survival model)

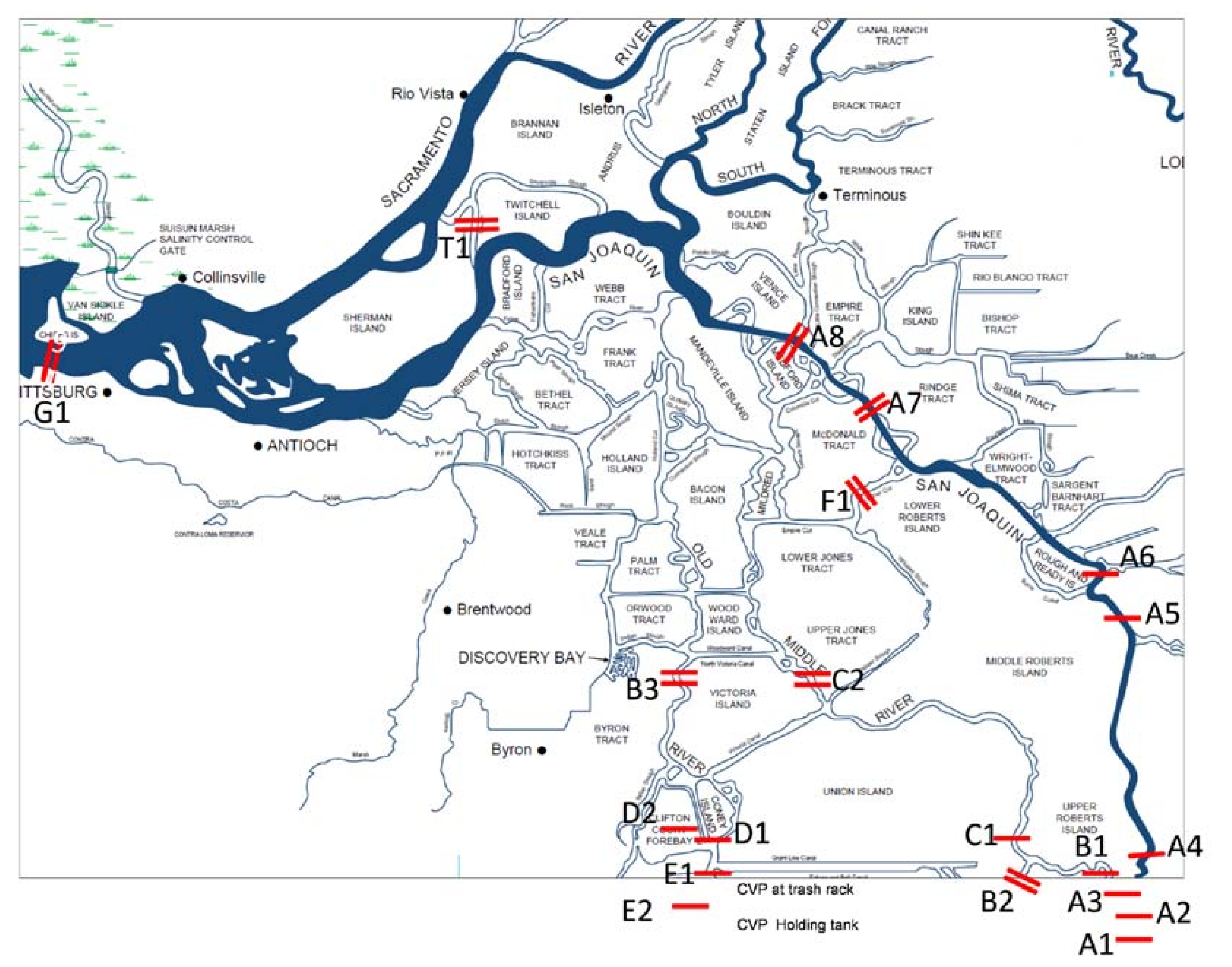
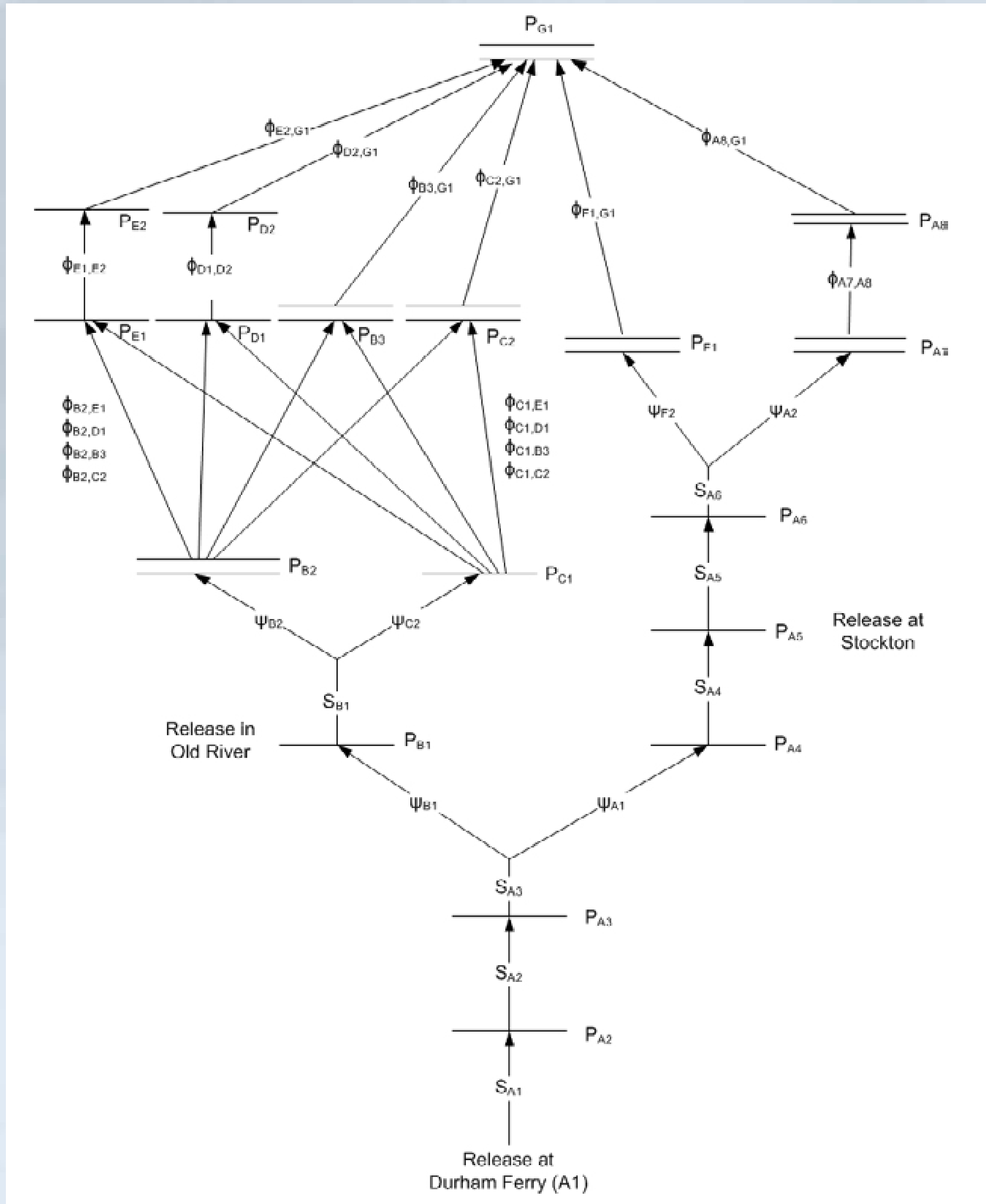


Figure 5-6

Schematic of Mark-Recapture Model Showing Estimable Parameters for Acoustically Tagged Juvenile Chinook Salmon Tagged and Released in the 2010 VAMP, using the Layout of Telemetry Stations in Figure 5-5. Parameters include: Probabilities of Survival (S_{hi}), Route Entrainment (ψ_{hl}), Transition ($\phi_{hi,kj}$), Detection (P_{hi}), and the Joint Event of Survival and Detection in the Last Reach of Each Route (λ_{hi}). Single Lines Denote Single-array Telemetry Stations and Double Lines Denote Double-array Telemetry Stations. Names of Telemetry Stations Correspond to Site Labels in Figure 5-5. Parameters $\phi_{B2,D1}$, $\phi_{C1,D1}$, P_{D1}, and $\phi_{D1,D2}$ were Estimated Separately for Arrival at D1 When the Radial Gates were Open Versus Closed



(Route D) or the Central Valley Project (Route E) had the possibility of being trucked from those sites and released just upstream of Chipps Island. Finally, fish that remained in the San Joaquin River past Stockton may have entered Turner Cut and maneuvered to Chipps Island through the interior of the Delta (Route F). Fish in routes B, C, and F all had multiple unmonitored pathways available for passing through the Delta toward Chipps Island. The survival model named detection sites (receivers) according to route, with Chipps Island assigned its own route name (G). An additional set of receivers located in Threemile Slough (Route T) was not used in the survival model. The routes and the study area exit point are summarized as follows:

A = San Joaquin River: survival

B = Old River: survival

C = Middle River: survival

D = State Water Project: survival

E = Central Valley Project: survival

F = Turner Cut: survival

G = Chipps Island: exit point

T = Threemile Slough: not used in survival model

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 ($\phi_{kj,hi}$) (Figure 5-6, and Appendix D, Table D-1). Unique detection probabilities were estimated for the individual receivers in a dual array, with P_{hia} representing the detection probability of the upstream array at station i in route h, and P_{hib} representing the detection probability of the downstream array. The full model consisted of 113 parameters for each release occasion: 44 detection probabilities, 8 survival probabilities, 18 route entrainment probabilities, and 43 transition probabilities.

The model parameters were:

P_{hi} = probability of detection at telemetry station i within route h, conditional on surviving to station i; for a dual array, $i = ia, ib$ for the upstream, downstream receivers in the dual array, respectively.

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.

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

The transition and detection parameters involving the receiver outside Clifton Court Forebay (site D1, RGU) depended on the status of the radial gates upon tag arrival at D1. Although fish that arrived at D1 when the gates were closed could not immediately enter the gates to reach site D2 (RGD), they could linger in the area until the gates opened, and many appeared to do so. Thus, parameters $\phi_{B2,\,D1O}$ $\phi_{C1,\,D1O}$ $\phi_{D1O,\,D2}$ *and* P_{D1O} represented transition to and from site D1 and detection at D1 when the gates were open, and parameters $\phi_{B2,\,D1C}$ $\phi_{C1,\,D1C}$ $\phi_{D1C,D2}$ and P_{D1C} represented transition to and from D1 and detection at D1 when the gates were closed. It was not possible to estimate unique detection probabilities for the open and closed status, so only a single detection probability was estimated for site D1, regardless of gate status: $P_{D1O} = P_{D1C} = P_{D1}$. Additionally, it was assumed that the detection probability was 100% at both RGD (the radial gate receivers inside Clifton Court Forebay; P_{D2} = 1) and CVPtank (the receiver in the holding tank at the Central Valley Project; P_{E2} = 1). These assumptions were necessary in the absence of receivers located downstream of those detection sites and unique to those routes.

In some cases, it was not possible to separately estimate the transition or survival probability to a site and the detection probability at the site. This occurred for CVP (Trash rack receiver at the Central Valley Project, site E1) when no tags were detected at both CVP and CVPtank (site E2), and for RGU (outside the radial gates in the entrance channel to the Clifton Court Forebay, site D1) when no tags were detected at both RGU and RGD (site D2). In these cases, a "last reach" parameter was estimated in place of $\phi_{kj,hi}$ and P_{hi}:

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 using the Old River route (Route B) was $\psi_B = \psi_{B1}\,\psi_{B2}$. The probability of using the Middle River route (Route C) was $\psi_C = \psi_{B1}\,\psi_{C2}$. The probability of surviving from the entrance of the Delta (site A3, MOS) through an entire migration pathway to Chipps Island was estimated as the product of survival probabilities that trace each pathway:

$$S_A = S_{A3}S_{A4}S_{A5}S_{A6,G1}$$
$$S_B = S_{A3}S_{B1}S_{B2}$$
$$S_C = S_{A3}S_{B1}S_{C1}$$

The survival probability $S_{A6,G1}$ represented the overall survival from site A6 (STN) on the San Joaquin River to Chipps Island (CHP, site G1). Fish at site A6 either remained in the San Joaquin River at the flow split with Turner Cut with probability ψ_{A2}, or entered Turner Cut with probability $\psi_{F2} = 1\text{-}\psi_{A2}$ (Figure 5-5, Figure 5-6). Thus, the overall probability of surviving from A6 to Chipps Island was defined as

$$S_{A6,G1} = S_{A6}\,(\psi_{A2}S_{A7,G1} + \psi_{F2}\phi_{F1,G1}).$$

There were multiple migration routes between site A7 (C16/C18) and Chipps Island, and most of these routes were unmonitored. Thus, it was not possible to estimate route selection and route-specific survival along each individual route. However, it was possible to estimate the overall survival from site A7 to Chipps Island ($S_{A7,G1}$), and this survival probability was used to define SA6,G1 above. Site A8 (Medford Island) on the San Joaquin River provided estimation of the joint probability of remaining in the San Joaquin River after site A7, and surviving to Chipps Island: $S_{A7,G1} = \phi_{A7,A8}\phi_{A8,G1}$.

Survival probabilities S_{B2} and S_{C1} represented survival of fish that remained in Old River at B2 (ORS), or entered Middle River at C1 (MRS), respectively. Fish in both of these routes may have subsequently moved toward the State Water Project (D1), Central Valley Project (E1), or the downstream receivers on Old River (B3) or Middle River (C2) (Figure 5-5, Figure 5-6). Each of these routes leads eventually to Chipps Island (G1). Because there were many unmonitored river junctions within the "reach" between sites B2 or C1 and Chipps Island, it was impossible to separate the probability of taking a specific pathway from the probability of surviving to a given receiver. Thus, only the joint probability of movement and survival could be estimated to the next receivers (i.e., the $\phi_{kj,hi}$ parameters defined above and in Figure 5-6). However, the overall survival from B2 (S_{B2}) or C1 (S_{C1}) to Chipps Island could be defined by summing products of the $\phi_{kj,hi}$ parameters:

$$S_{B2} = (\phi_{B2,D1O}\phi_{D1O,D2} + \phi_{B2,D1C}\phi_{D1C,D2})\phi_{D2,G1} + \phi_{B2,E1}\phi_{E1,E2}\phi_{E2,G1} + \phi_{B2,B3}\phi_{B3,G1} + \phi_{B2,C2}\phi_{C2,G1}$$

$$S_{C1} = (\phi_{C1,D1O}\phi_{D1O,D2} + \phi_{C1,D1C}\phi_{D1C,D2})\phi_{D2,G1} + \phi_{C1,E1}\phi_{E1,E2}\phi_{E2,G1} + \phi_{C1,B3}\phi_{B3,G1} + \phi_{C2,C2}\phi_{C2,G1}$$

For fish that reached the interior receivers at the State Water Project (D2) or the Central Valley Project (E2), the parameters $\phi_{D2,G1}$ and $\phi_{E2,G1}$, respectively, represented the joint probability of migrating and surviving to Chipps Island, including survival during and after collection and transport.

Using the estimated migration-route probabilities and route-specific survival for these three routes (A, B, and C), survival of the population from A3 (Mossdale) to Chipps Island was estimated as:

$$S_{total} = \psi_A S_A + \psi_B S_B + \psi_C S_C.$$

In order to compare 2010 VAMP study results with results from the 2009 VAMP study, when no detections were available from Chipps Island, "regional" survival was also estimated through the southern portion of the Delta, both within each route and overall:

$$S_{A(region)} = S_{A3}S_{A4}S_{A5}S_{A6}$$
$$S_{B(region)} = S_{A3}S_{B1}\left(\phi_{B2,B3} + \phi_{B2,D1O} + \phi_{B2,D1C} + \phi_{B2,E1} + \phi_{B2,C2}\right)$$
$$S_{C(region)} = S_{A3}S_{B1}\left(\phi_{C1,B3} + \phi_{C1,D1O} + \phi_{C1,D1C} + \phi_{C1,E1} + \phi_{C1,C2}\right)$$
$$S_{total(region)} = \psi_A S_{A(region)} + \psi_B S_{B(region)} + \psi_C S_{C(region)}$$

Individual capture histories were constructed for each tag as described above. Each capture history consisted of one or more fields representing initial release (field 1) and the sites where the tag was detected, in chronological order. Detection on both receivers in a dual array was denoted by the code "ab", detection on only the upstream receiver was denoted "a0", and detection on only the downstream receiver was denoted "b0." For example, the detection history DF A3 A4 A5 A7ab A8b0 G1a0 represented a tag that was released at Durham Ferry and detected at Mossdale (MOS, site A3), and then moved through the San Joaquin River to Chipps Island with detections on the receivers at Lathrop (SJ1/SJ2, A4), the USGS gauge in Stockton (STS, A5), the shipping channel markers in the San Joaquin River just downstream of the junction with Turner Cut (C16/C18, sites A7a and A7b), and the Medford Island west receiver (MFW, A8b). The tag was finally detected on the eastern string of receivers at Chipps Island (G1a). This tag evaded detection at some receivers, namely Banta Carbona (BCA, site A2), the receiver at the Navy Bridge in Stockton (STN, A6), the eastern receiver at Medford Island (MFE, A8a), and the western receiver at Chipps Island (CHPw, G1b). The probability of having this detection history was

$$S_{A1}\left(1-P_{A2}\right)S_{A2}P_{A3}S_{A3}\,\psi_{A1}P_{A4}S_{A4}P_{A5}S_{A5}\left(1-P_{A6}\right)S_{A6}\,\psi_{A2}P_{A7a}P_{A7b} \times \phi_{A7,A8}\left(1-P_{A8a}\right)P_{A8b}\phi_{A8,G1}P_{G1a}\left(1-P_{G1b}\right).$$

A second example is the detection history STK A6 F1ab. This detection history represented a tag that was released in a supplemental release at Stockton, and detected on the Navy Bridge receiver in Stockton (STN, A6) and on both receivers in Turner Cut (TCN and TCS, F1a and

F1b). This tag was not detected again after detection in Turner Cut. The next available detection site after Turner Cut was Chipps Island, and the tag was not detected there either because it did not reach Chipps Island (mortality), or because it evaded detection as it passed Chipps Island (imperfect detection). Thus, this detection history has probability

$$\phi_{STK,A6} P_{A6} S_{A6} \left(1-\psi_{A2}\right) P_{F1a} P_{F1b} \left[1-\phi_{F1,G1} + \phi_{F1,G1}\left(1-P_{G1a}\right)\left(1-P_{G1b}\right)\right].$$

A third example is the detection history OR B1 B2a0 E1 E2 G1ab. This tag was released in a supplemental release in Old River, and was observed moving past receivers in the Old River route to Chipps Island. The tag was detected at the receivers just downstream from the head of Old River (OR1/OR2, site B1), the upstream receiver of the pair located in Old River just past the junction with Middle River (ORSU, B2a), the receivers at both the Central Valley Project trash rack (CVP, E1) and the Central Valley Project holding tank (CVPtank, E2), and finally at both receivers at Chipps Island (G1a, G1b). The tag was not detected on the downstream receiver at the ORS station (site B2b), but was assumed to be present there because of detection on the upstream receiver. This detection history has probability

$$\phi_{OR,B1} P_{B1} S_{B1} \psi_{B2} P_{B2a} \left(1-P_{B2b}\right) \phi_{B2,E1} P_{E1} \phi_{E1,E2} \phi_{E2,G1} P_{G1a} P_{G1b}.$$

A final example of a detection history is DF A2 A3 C1 D1O D2. This tag was released at Durham Ferry and detected at both Banta Carbona (A2) and Mossdale (A3) before entering Old River, moving to Middle River (C1), and finally being detected on the receivers both outside and inside the radial gates at the Clifton Court Forebay (D1 and D2). The tag arrived at the outside receiver when the gate was open, denoted by D1O in the capture history. The tag evaded detection at the Old River receivers just downstream of the head of the river (B1), but was assumed to have passed those receivers because it was detected both upstream and downstream. This detection history has probability

$$S_{A1} P_{A2} S_{A2} P_{A3} S_{A3} \left(1-\psi_{A1}\right)\left(1-P_{B1}\right) S_{B1} \left(1-\psi_{B2}\right) P_{C1} \phi_{C1,D1O} P_{D1} \phi_{D1O,D2}$$
$$\times \left[1-\phi_{D2,G1} + \phi_{D2,G1}\left(1-P_{G1a}\right)\left(1-P_{G1b}\right)\right].$$

Under the assumptions of common survival, route entrainment, and detection probabilities and independent detections among the tagged fish in each release group, the likelihood function for the survival model for each release group was a multinomial likelihood with individual cells denoting each possible capture history.

Parameter Estimation

The multinomial likelihood model (described above) was numerically fit to the observed 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 and standard errors were computed for each parameter. Standard errors of derived performance measures were estimated using the delta method (Seber, 2002). Sparse data meant that some parameters could not be estimated for some release strata. Transition, survival, and detection probabilities were fixed to 1.0 or 0.0 as appropriate, based on the observed detections. The model was fit separately for each release occasion, consisting of the initial release at Durham Ferry and the associated supplemental releases at Stockton and in Old River. For each release occasion, the complete data set that included possible detections from predatory fish was analyzed separately from the reduced data set that was restricted to detections classified as salmon smolt detections.

Several steps were used to find the most parsimonious model that sufficiently represented the observed data. In all steps, the Akaike Information Criterion (AIC) was used to select between competing models, with a difference of $\Delta AIC \geq = 2$ used to indicate a significant difference in model fit (Burnham and Anderson, 2002). First, the significance of the radial gates status on arrival at the outside receiver (RGU, site D1) was tested for all release groups pooled, with supplemental releases modeled separately from Durham Ferry releases. If the effect of the gates was found to be insignificant (α = 0.05), then a simplified model was used for parameter estimation in which h $\phi_{B2,D1O}=\phi_{B2,D1C,}$ $\phi_{C1,D1O}=\phi_{C1,D1C,}$ and $\phi_{D1O,D2=}\phi_{D1C,D2.}$

Subsequent analysis focused on unique release occasions, with the Durham Ferry, Old River, and Stockton releases from a single release occasion analyzed jointly. A unique sequence of models was fit for each release occasion:

Model 1: The supplemental releases at Old River and Stockton were modeled with unique parameters compared to the initial release at Durham Ferry.

Model 2a: Unique parameters were used to model the supplemental releases, with the exception that the Stockton supplemental release group and the Durham Ferry release group were modeled with common detection probabilities at common detection sites.

Model 2b: Either Model 1 or Model 2a, as selected by AIC, was modified to use common detection probabilities for the Durham Ferry release group and the Old River supplemental release group.

Model 3a[*i*]: The model selected by AIC among the above models was modified sequentially to use common survival, route entrainment, and transition probabilities for parameter *i* for the Durham Ferry release and the Stockton supplemental release group, starting with downstream parameters and sequentially working back upstream. For example, Model 3a[$\phi_{A8,G1}$] used unique survival, route entrainment, and transition probabilities for all parameters except for $\phi_{A8,G1}$, which was equated between the Durham Ferry release group and the Stockton supplemental release group. If Model 3a[$\phi_{A8,G1}$] was selected, then Model 3a[$\phi_{A7,A8}$] was tested, in which the transition parameter $\phi_{A7,A8}$ was equated for the Durham Ferry and Stockton releases. If Model 3a[$\phi_{A8,G1}$] was not selected by AIC, then Model 3a[$\phi_{A7,A8}$] was not tested, under the assumption that differences in survival in a downstream reach imply differences in survival in all upstream reaches. All survival, route entrainment, and transition probabilities were sequentially tested working upstream until either a significant difference was found or until the parameter S_{A6} was tested.

Model 3b[*i*]: The model selected from the sequence of 3a[*i*] models was modified sequentially to use common survival, route entrainment, and transition probabilities among reaches for the Durham Ferry release and the Old River supplemental release group. Again, downstream reaches were tested first, with upstream reaches tested only if models equating downstream parameters were selected over models with unique parameters. The farthest upstream parameters to be tested were $\phi_{B2,i}$ and $\phi_{C1,i,}$ for *i* = B3, C2, D1O, D1C, and E1. The parameters S_{B1} and ψ_{B2} were not tested because the reach between B1 and the B2/C1 receivers was very close to the site of the Old River supplemental release.

Final estimation of the parameters used the result of the model sequence described above, with AIC used in model selection. For each model, goodness-of-fit was assessed visually using Anscombe residuals (McCullagh and Nelder, 1989). For each release occasion, derived parameters $S_{A6,G1}$, S_{B2}, and S_{C1} were estimated for the supplemental releases and for the Durham Ferry release separately using the selected model, and then combined in a weighted average over the initial and supplemental releases. In particular, if $\hat{\theta}_i$ is the estimate of the measure θ for release group *i* (*i* = *DF* or *STK*) for a specific release occasion, then the occasion-specific measure was estimated as

$$\hat{\theta} = w_{DF}\hat{\theta}_{DF} + w_{STK}\hat{\theta}_{STK},$$

where w_i is the proportion of all fish estimated to have arrived at site A6 that came from release *i* (*i* = DF or STK). Similarly, if $\hat{\theta}_i$ is the estimate of measure θ for release group *i* (*i* = DF or OR) for a release occasion, then the occasion-specific measure was estimated as

$$\hat{\theta} = w_{DF}\hat{\theta}_{DF} + w_{OR}\hat{\theta}_{OR},$$

where w_i is the proportion of all fish estimated to have arrived at site B1 that came from release *i* (*i* = DF or OR). Standard errors were estimated using the delta method (Seber, 2002: 7-9). Population-level estimates of parameters and performance measures were estimated as a weighted average of the release-occasion estimates, with weights proportional to total release size for a given occasion (i.e., total of Durham Ferry, Old River, and Stockton releases).

For each release group, the effect of route (San Joaquin River or Old River) on estimates of survival to Chipps Island was tested with a two-sided Z-test on the log scale:

$$Z = \frac{\ln\left(\hat{S}_A\right) - \ln\left(\hat{S}_B\right)}{\sqrt{\hat{V}}},$$

where

$$V = \frac{Var\left(\hat{S}_A\right)}{\hat{S}_A^2} + \frac{Var\left(\hat{S}_B\right)}{\hat{S}_B^2} - \frac{2Cov\left(\hat{S}_A, \hat{S}_B\right)}{\hat{S}_A \hat{S}_B}$$

The parameter V was estimated using Program USER. It was also tested whether tagged Durham Ferry fish showed a preference for either the San Joaquin River route or the Old River route using a one-sided Z-test with the test statistic:

$$Z = \frac{\left|\hat{\psi}_A - 0.5\right|}{SE\left(\hat{\psi}_A\right)}$$

Statistical significance was tested at the 5% level (α=0.05).

Analysis of Tag Failure

The estimated survival and transition probabilities were adjusted for premature tag failure using methods adapted from Townsend et al. (2006). Tag survival was modeled using the 4-parameter vitality curve (Li and Anderson, 2009) together with results from the tag-life study. Two tags in the tag-life study were observed to die within 25 hours of tag activation (see tag life study results in a later section). Because these deaths occurred within the recovery period allowed for the tagged fish between tagging, tag activation, and release to the river, all tagged salmon smolts that were released were known to have tags that had survived this initial period of premature tag death. Thus, these two tags were omitted from the tag-life data when fitting the tag-survival model. Additionally, because all detection events of tagged fish in the study area began before Day 40, the final 5 tag death times were omitted from the tag-life study because they reduced the fit of the tag survival model (see tag life study results in a later section).

In Townsend et al. (2006), the probability of tag survival through a reach is estimated based on the average observed travel time of tagged fish through that reach. In order to account for possible differences in travel time to Chipps Island using the various routes (i.e., San Joaquin route [A] and Old River route [B]), travel time and the probability of tag survival to Chipps Island were estimated separately for the two routes. Standard errors of the tag-adjusted fish survival and transition probabilities were estimated using the inverse Hessian matrix of the fitted joint fish-tag survival model. The additional uncertainty introduced by variability in tag survival parameters was not estimated, with the result that standard errors may be slightly low. In previous studies, however, variability in tag-survival parameters has been observed to contribute little to the uncertainty in the fish survival estimates when compared with other, modeled sources of variability (Townsend et al., 2006); thus, the resulting bias in the standard errors is expected to be small.

Analysis of Tagger Effects

Tagger effects were analyzed by fitting the release-recapture model to the detection data from each tagger separately, pooling over release occasion. The significance of the tagger effect on model fit was assessed using a Likelihood Ratio Test (α=0.05) (Sokal and Rohlf, 1995). Additionally, estimates of cumulative survival throughout the study area were compared visually among taggers. The reduced data set (without predator detections) was used for this analysis.

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 last detection at the first site and the first detection at the second site. In cases where the tagged fish was observed to make multiple visits to a site, the final visit was used for travel time calculations. The arithmetic mean was used to summarize travel times.

Comparison of NPB Fate Assignment and VAMP Detections

Salmon tags that were released at Durham Ferry were available to pass both the non-physical barrier (NPB) at the head of Old River (sometimes called the Bio-Acoustical Fish Fence (BAFF)) and either the Lathrop receivers (SJ1/SJ2) in the San Joaquin River or the Old River receivers OR1/OR2. Detections of these tags at the Lathrop and Old River receivers were compared to the fate classification given to each fish observed in the NPB study at the Old River Barrier (ORB) area. Both the NPB study and the 2010 VAMP study independently identified route selection (San Joaquin River or Old River) at the head of Old River for all fish detected passing through this area; these independent route assignments were compared. Additionally, the survival model assumes 100% survival from the head of Old River to the receivers at Lathrop and Old River (OR1/OR2), or alternatively equal survival in each route to the detection sites. This assumption was also assessed using detections from the NPB study and the VAMP receivers downstream of the HORB area. Differences in predator classification were taken into account for these comparisons. The assessment of survival focused only on those tags classified as both entering the HORB area in smolts (based on VAMP classifications) and also leaving the HORB area in smolts (based on NPB classifications).

Mobile Telemetry Monitoring

Mobile telemetry surveys were used to determine where fish may have been lost in reaches between the fixed receiver stations. The majority of mobile monitoring effort was dedicated to systematic coverage of three reaches: (1) the San Joaquin River from Banta Carbona to the Head of Old River split, (2) Old River from the split to the federal pumping facilities and CCFB, and (3) the San Joaquin River from Old River downstream to Turner Cut (Figure 5-2). Weekly surveys were conducted in each reach between May 3rd and June 3rd with the exception that the reach between Banta Carbona and Old River was not surveyed during the week of May 3rd due to the reported high survival rates down to the non-physical barrier at Old River. The reach of the San Joaquin River between Durham Ferry and Banta Carbona was surveyed on May 24th after all tagged fish had been released.

A HTI Model 295G datalogger and omni-directional HTI model 590-Series hydrophone were used to record acoustic data. The datalogger was attached to a laptop computer and data files were reviewed in real-time using HTI's AcousticTag program. Every 0.25 mi. of river length (to stay within minimum tag detection ranges) the boat was turned to face upstream, anchor in the center of the channel, the engine was turned off, and the boat remained stationary for a minimum of 5 minutes to detect tags in smolts that may have been moving downstream, holding, or immobile (deceased). At locations where multiple tags or excessive background noise was detected, sampling was extended for an additional 5 minutes. The Model 295G datalogger is equipped with an integrated GPS receiver which provided coordinates where the receiver was located for each holding point, which was used as an estimator of tag location.

Data files generated during mobile tracking were manually processed to identify tag detections.

Study Results and Discussion

Transportation

Average water temperature in the transport tank, after buckets were loaded and prior to transport, was around 17 °C (range between 15 and 18.8 °C) and dissolved oxygen was around 13 mg/l (range between 11.3 and 15.4 °C). Over the course of the 45-60 minute drive from TFCF to the release sites, water temperatures in the transport tanks changed by -0.1 to 1.3 °C (Table 5-2).

Water temperatures in the river were about 17 °C and ranged between 12.0 and 18.8 °C (Table 5-2). The temperature reading of the 12.0 ºC recorded during the Durham Ferry 5th release was much lower than other temperatures and the reading may have been faulty; although the 5th release for all three release locations had the lowest river temperatures recorded during the release periods. The dissolved oxygen levels were between 6 and 11 mg/L in the river at all the release sites.

There were two fish identified as mortalities after transport. One was from the transport on May 10th to the Durham Ferry release and one was from the transport on May 13th to the Durham Ferry release. These mortalities were likely due to poor recovery from tagging. There were no dead fish observed after the holding period prior to the release, with the exception of one of the dummy-tagged fish.

Intentional Mortalities

Of the nine intentional mortalities released, none were detected at fixed receiver stations and five were detected during mobile tracking surveys. All tags detected during the mobile monitoring had moved less than 0.25 miles downstream of the release sites indicting a low probability of bias in the survival estimates due to potential misclassification of drifting mortalities as survivors to a given point.

Dummy-Tagged Fish

One fish was found dead of the 210 dummy-tagged fish evaluated after 48 hours (Table 5-7). The fish was from the group of dummy-tagged fish examined on May 9th from the Old River release group. Only two fish had abnormal body color or light colored gill filaments. The fish observed with the faded-body color was examined on May 20th at the Stockton release location. The fish with the light-red colored gill filaments was examined on May 2nd at Old River. All remaining fish were found swimming vigorously, had normal gill coloration, normal eye quality, normal body coloration and no fin hemorrhaging. Mean scale loss for all fish assessed ranged from 1.0 to 3.0%. Roughly 1% of the examined fish had loose sutures or slight hemorrhaging around the sutures (Figure 5-7). Mean fork length (FL) of fish ranged from 104.9 to 114.4mm. Short-term survival was 99% within the trashcan containers. These data indicate that the fish used for the VAMP in 2010 were in generally good condition (Table 5-7). A general pathogen and physiological screening was conducted on dummy-tagged fish from three of the seven 2010 VAMP release (tagged) groups and cohorts of release groups remaining at Merced River Hatchery (MRH) (see Chapter 6 for a discussion of the fish health evaluation).

Receiver performance

Receiver performance was much improved in 2010 over receiver performance in 2009. The use of modified 'joboxes' was continued because it seemed to eliminate the suspected overheating problems that occurred in previous years (Vogel, 2010). There were additional problems that occurred in 2009 that were eliminated in 2010. Several receivers in 2009 had periods during the study where the acoustic receiver did not function properly (SJRGA, 2010). The longest 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 in 2009. For VAMP 2010, these sites were moved to avoid both grounding and noise interference issues as suggested by NRS (Vogel, 2010).

While most of the issues from 2009 were eliminated, there were a few sites that had periods of non-operation in 2010. Most of the sites that had non-operation periods were due to pre-mature battery failure. A number of batteries that were used in 2010 had been used in 2009 and while all batteries were load tested and fully charged during the project, some batteries did not maintain an adequate charge and caused the loss of a limited number of files (Table 5-8). The use of a redundant receiver at Old River provided data from a second receiver when the other receiver was down.

The only other issue that was encountered regarding loss of files seems to have been related to when the '.RAT' files were downloaded. Files were to be downloaded during the time between 10 minutes after the top of the hour to 10 minutes before the hour. This was done to allow the receiver time to download all files. While this was done the majority of the time, there were a limited number of single files that were not retrieved

Table 5-7
Results of Dummy Tagged Juvenile Chinook Salmon Evaluated After Being Held for 48 Hours at the Release Sites as Part of the 2010 VAMP Study

Holding Site	Examination Date, Time	Mean (sd) Forklength (mm)	Mortality	Mean (sd) scale loss	Normal Body Color	No Fin Hemorrhaging	Normal Eye Quality	Normal Gill Color
Durham Ferry	4/28/10, 0810	109.7 (1.9)	0/10	1.9 (0.8)	10/10	10/10	10/10	10/10
Old River	4/29/10, 0528	106.8 (1.8)	0/10	1.0 (0.0)	10/10	10/10	10/10	10/10
Stockton	4/29/10, 0908	104.9 (2.6)	0/10	1.0 (0.0)	10/10	10/10	10/10	10/10
Durham Ferry	5/01/10, 0810	110.1 (2.4)	0/10	2.1 (0.3)	10/10	10/10	10/10	10/10
Old River	5/02/10, 0710	108.2 (2.4)	0/10	2.4 (1.3)	10/10	10/10	10/10	9/10
Stockton	5/02/10, 1052	108.9 (2.5)	0/10	1.4 (0.5)	10/10	10/10	10/10	10/10
Durham Ferry	5/05/10, 0800	107.7 (4.1)	0/10	3.0 (2.4)	10/10	10/10	10/10	10/10
Old River	5/06/10, 1018	107.8 (2.6)	0/10	2.3 (1.1)	10/10	10/10	10/10	10/10
Stockton	5/06/10, 1416	107.7 (2.6)	0/10	2.2 (0.9)	10/10	10/10	10/10	10/10
Durham Ferry	5/08/10, 0823	111.0 (3.8)	0/10	2.1 (1.2)	10/10	10/10	10/10	10/10
Old River	5/09/10, 0830	109.3 (4.3)	1/10	2.9 (2.5)	9/9	9/9	9/9	9/9
Stockton	5/09/10, 1205	107.4 (3.7)	0/10	1.2 (0.4)	10/10	10/10	10/10	10/10
Durham Ferry	5/12/10, 0825	111.2 (3.1)	0/10	2.6 (0.7)	10/10	10/10	10/10	10/10
Old River	5/13/10, 0410	108.2 (5.1)	0/10	1.5 (0.7)	10/10	10/10	10/10	10/10
Stockton	5/13/10, 0816	108.7 (4.7)	0/10	1.6 (0.7)	10/10	10/10	10/10	10/10
Durham Ferry	5/15/10, 0816	111.6 (4.0)	0/10	2.0 (0.8)	10/10	10/10	10/10	10/10
Old River	5/16/10, 0550	113.5 (5.1)	0/10	2.1 (1.2)	10/10	10/10	10/10	10/10
Stockton	5/16/10, 1011	112.4 (3.7)	0/10	2.0 (1.2)	10/10	10/10	10/10	10/10
Durham Ferry	5/19/10, 0830	112.6 (3.4)*	0/10	2.8 (0.9)	10/10	10/10	10/10	10/10
Old River	5/20/10, 0453	114.4 (3.3)	0/10	1.5 (0.7)	10/10	10/10	10/10	10/10
Stockton	5/20/10, 0712	112.6 (4.1)	0/10	2.0 (1.2)	9/10	10/10	10/10	9/10

*Mean and SD was based on 7 fish

Table 5-8
Periods of Non-operation of Acoustic Receivers During the 2010 VAMP Study. Refer to Figure 5-2 for Receiver Locations

Site Name		Receiver Location	Start Down Time	End Down Time	Reason for down time
BCA		Banta Carbona	4/28/10 0300 hrs	4/28/10 1400 hrs	Downloaded data to close to the hour
MOS		Mossdale	5/27/10 0600 hrs	5/27/10 1400 hrs	Premature battery failure
OR1		Old River	6/5/10 1900 hrs	6/5/10 2000 hrs	Downloaded data to close to the hour
OR2		Old River	4/28/10 1000 hrs	4/30/10 1300 hrs	Premature battery failure
MFW		Medford Island	5/3/10 0800 hrs	5/3/10 0900 hrs	Was not written due to datalogger switch
MRNU		Middle River North Upstream	5/3/10 1100 hrs	5/4/10 0500 hrs	Unknown. Receiver light flashing
MRND		Middle River North Downstream	5/31/10 1900 hrs	6/1/10 1000 hrs	Low voltage problem; too long between battery changes
RGU		Radial Gates Upstream	3/30/10 1100 hrs	3/31/10 0900 hrs	Not able to log into node. Node was swapped out
RGU		Radial Gates Upstream	4/16/10 1000 hrs	4/18/10 0900 hrs	Possible improper settings change
RGU		Radial Gates Upstream	5/10/10 0600 hrs	5/10/10 0900 hrs	Unknown. No receiver check that day
RGU		Radial Gates Upstream	5/13/10 0000 hrs	5/14/10 1114 hrs	Unknown. No receiver check that day
RGU		Radial Gates Upstream	5/24/10 1400 hrs	5/25/10 0900 hrs	Low voltage problem; too long between battery changes
CHP	S810	Chipps Island	4/26/10 1200 hrs	4/26/10 1542 hrs	mechanical problem with receiver
CHP		Chipps Island	4/27/10 1600 hrs	4/27/10 2041 hrs	mechanical problem with receiver
CHP		Chipps Island	5/4/10 1300 hrs	5/5/10 0852 hrs	software problem
CHP	S915	Chipps Island	5/9/10 0900 hrs	5/9/10 1100 hrs	equipment failure
CHP		Chipps Island	5/19/10 1300 hrs	5/19/10 1500 hrs	equipment failure
CHP		Chipps Island	5/29/10 1800 hrs	5/29/10 2000 hrs	equipment failure
CHP		Chipps Island	6/8/10 2200 hrs	6/8/10 0000 hrs	equipment failure

Table 5- 9
Comparison of Data Processing Errors Using Auto-processed and Manually-processed Data for Seven Acoustic Receivers Stations During the 2010 VAMP

Receiver	Autoprocessed					Manually processed				
	Missed Detection	Tag Misread	Duplicated Detection	Fractional Read	False Positive	Missed Detection	Tag Misread	Fractional Read	False Positive	Unclear
OR 1	21	0	1	0	0	26	4	11	0	1
OR 2	10	1	2	0	0	16	1	0	1	1
Chipps 915	10	1	0	0	0	10	2	0	0	0
SJ1	0	0	0	1	0	56	0	2	0	0
SJ2	6	1	4	0	0	27	1	2	0	3
Chipps 800	16	1	3	0	1	0	3	1	0	1
Mossdale	2	0	0	0	0	27	0	4	0	0

Figure 5-7
Loose Sutures on a Dummy-tagged Fish from the Durham Ferry Release Site during the 2010 VAMP Study

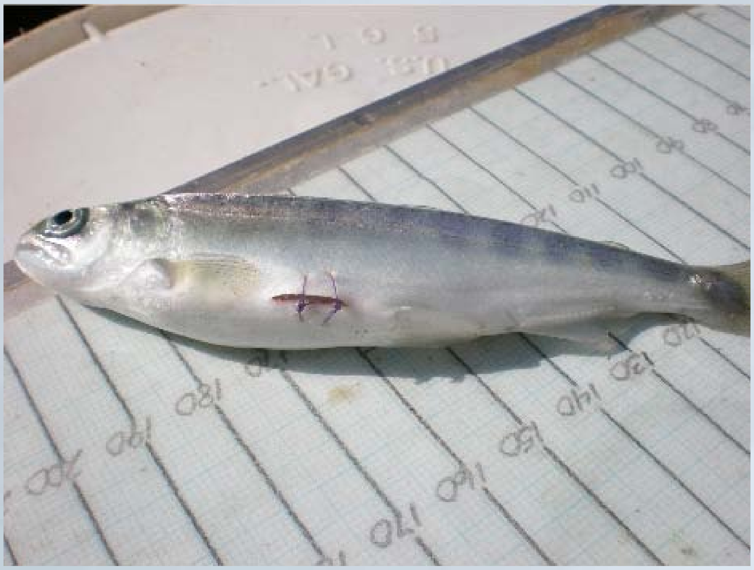
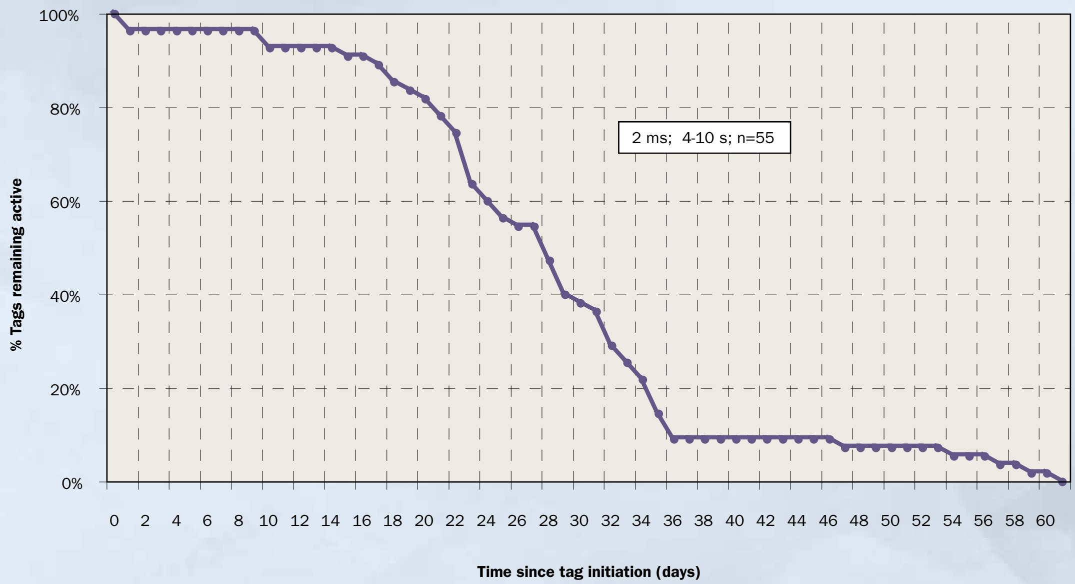


Figure 5-8
Acoustic Tag Extinction Rate for the Hydroacoustic Technology, Inc. Model 795Lm Tag Evaluated During the 2010 VAMP Study



due to downloading within the restricted time period. A number of files from sites maintained by DWR had a substantial number of '.RAT' files missing. Most of the failures were due to the receiver hard drive filling up resulting in an automatic shut down of the receiver.

Fish Health

No viral or bacterial pathogens were detected in the release groups. The most significant health problem observed was Tetracapsuloides bryosalmonae infection, with majority of salmon examined exhibiting early stages of clinical Proliferative Kidney Disease (PKD). No mortality or evidence of physiological impairment was observed in either the tagged or MRH groups (Nichols, 2010) (see Chapter 6 for an in-depth discussion of the fish health evaluation).

Temperature Monitoring

Results of water temperature monitoring at Durham Ferry, Old River at HORB, and CCF Radial Gates during the April-June fall-run Chinook salmon smolt emigration from the San Joaquin River through the Delta are shown in Appendix C, Figures C-4, C-6 and C-19, respectively. Water temperatures measured within the lower San Joaquin River and Delta are shown in Appendix C with a description of the monitoring sites shown in Figure C-1 and C-2 with data plots for 19 sites within the River and Delta shown in Figure C-3 through C-21. The plots in Appendix C show that all sites in the mainstem San Joaquin River (e.g., Durham Ferry, Mossdale, and Old River at HORB) were within a range considered to be suitable (typically < 20º C; 68º F) during April and May of the 2010 VAMP. Temperatures were slightly higher, but still usually under 20º C (68º F) further downstream within the Delta (e.g., Old River/Indian Slough Confluence, CCF Radial Gates). Results of the 2010 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 river and downstream within the Delta during April-May would not be expected to result in adverse effects or reduced survival of emigrating juvenile Chinook salmon released as part of the 2010 VAMP investigations. However, temperatures during early June were within the range considered to be stressful for juvenile Chinook salmon.

Tag Life Study

A stratified random sample of 55 tags was taken across 1,078 successfully programmed HTI model 795 Lm tags acquired in seven manufacturing lots from Hydroacoustic Technology, Inc (HTI) in Seattle, Washington. Results from the tag life study demonstrated that the tags used this year were reliable and none of the challenges with tag performance encountered during 2008 were identified in 2010. However, tag life during 2010 was more variable than in 2009, with a shorter minimum observed tag life and longer maximum observed tag life (San Joaquin River Group Authority, 2010). Most of this difference is likely due to the wider range of tag periods used in 2010 (4-10 seconds) than in 2009 (5-7 seconds). Tag life in 2009 ranged from 21 days to 29 days, whereas tag life in 2010 ranged from 12 hours to 60 days, with 96% of tags lasting 10 days or more (Figure 5-8). By the 20th day in 2010, 82% of the tags remained viable. In 2009, as soon as tags began to fail after the 20th day, the rate of attrition was high and all tags were dead by the end of the 29th day following initialization. In 2010 almost 40% of the tags were still viable on the 29th day. There were no clear differences in tag life between manufacturing lots (Figure 5-9).

As expected, tag life generally increased as the interval between pulse transmissions, the tag period, increased (Figure 5-9). Longer intervals between pulse transmissions result in fewer pulses, and reduced energy consumption which increases the expected life of the tag.

About 16% of the 2010 tags (n=9) used in the tag-life study intermittently transmitted signals for 1 to 12 hours after the initial failure, whereas intermittent transmission was observed in approximately one-third of the tags used in the 2009 tag life study.

Water temperature in the tag-testing tank averaged 17 °C during the 60-day 2010 study, and generally ranged between 11°C and 18°C which was similar to river conditions during the 2010 survival experiment. However, water temperatures ranged between 24°C and 34°C during days 16 through 20 due to failure of the water chiller which controlled temperatures in the tank. At the time of this temperature spike, 82-90% of the tags were still functioning and potentially affected. Since tags are expected to last longer under higher water temperatures, tag life may have been slightly extended due to this event.

Data Processing

Data from all fixed receiver sites were processed using two automarking algorithms: FishCount, an algorithm developed by Aaron Blake and Scott Brewer of CRRL of the USGS; and MarkTags, an algorithm developed by HTI and modified by CRRL of the USGS (Noah Adams, USGS-CRRL, Personal Communication).

The manually processed data identified some tags that were missed in the autoprocessing. In addition, the autoprocessor picked up detections that the manual processing missed. The subset of sites that were

Table 5- 9
Comparison of Data Processing Errors Between Using Auto-processed and Manually-processed Data for Seven Acoustic Receivers Stations During the 2010 VAMP

Receiver	Autoprocessed					Manually Processed				
	Missed Detection	Tag Misread	Duplicated Detection	Fractional Read	False Positive	Missed Detection	Tag Misread	Fractional Read	False Positive	Unclear
OR 1	21	0	1	0	0	26	4	11	0	1
OR 2	10	1	2	0	0	16	1	0	1	1
Chipps 915	10	1	0	0	0	10	2	0	0	0
SJ1	0	0	0	1	0	56	0	2	0	0
SJ2	6	1	4	0	0	27	1	2	0	3
Chipps 800	16	1	3	0	1	0	3	1	0	1
Mossdale	2	0	0	0	0	27	0	4	0	0

manually processed were Old River (OR1/OR2) (2 receivers), Lathrop (SJ1/SJ2) (2 receivers), Chipps Island (CHP) (1 four port receiver and 1 single node) and Mossdale (MOS) (1 receiver). For the receiver at Old River (OR1), the autoprocessor missed 21 detections, the manual processing missed 26 detections (Table 5-9). In addition, 4 detections were manually misidentified and 11 additional detections were in error because they were fractionals of true tag codes. The autoprocessor duplicated one detection and gave it an incorrect code. One auto-processed detection could not be confirmed through manual processing. For the receiver at Old River (OR2), fewer errors were identified both in the auto-processed and manual-processed data, but again with most of the errors being missed detections for both the manual and auto-processed data. Examination of the auto-processed detections independent of the manual processed data identified additional errors (Table 5-10). The largest number of errors occurred on the Central Valley Project trash rack receivers (CVP), with 4 misread tags, 5 duplicate reads, and 26 false positives. The large number of detections at this site complicated any type of data processing, making impractical both manual processing and in-depth comparisons between the two auto-processing algorithms (FishCount and MarkTags). These additional errors were only those that were obvious when comparing the medium and far-field movement through-out the Delta for the tagged fish. It is likely there are additional errors in the data that we were not able to identify with the processes we used.

In some respects, missed detections are less of a problem than tags that are misread, fractionals, duplicated detections or false positives. The model is designed to determine the probability of detection and is robust enough to correct for missed detections at most receivers. Where 100% probability of detection is desired or necessary, missed detections are also problematic. In some ways missed detections are addressed using redundant receivers at key locations (Old River 1 and 2 (OR1 and OR2) and San Joaquin at Lathrop 1 and 2 (SJ1 and SJ2)) as it is unlikely that the same fish would be missed at both receivers within a redundant array. Although the receivers at Old River each had down times in 2010, there was at least one receiver operating there at all times, so it is unlikely that any fish were missed at that site. For the redundant San Joaquin River receivers, there was no down time.

Table 5-10
Summary of Auto-processing Errors Identified Independent of the Manual Data Processing

Receiver	Tag Misread	Duplicate Read	Fractional	False Positive
BCA	0	0	0	4
MOS	0	0	0	1
SJ2	1	0	0	0
STN	1	1	0	0
C16	0	1	0	4
C18	0	1	0	1
MFW	0	1	0	0
OR1	0	0	0	2
ORS	0	1	0	1
ORN	2	8	0	3
RGD	2	2	0	6
RGU	0	0	0	3
CVP	4	5	0	26
TMS	0	1	0	0
CHP-800	0	0	0	1
CHP-810	0	0	0	2

Detections of Acoustic-Tagged Fish

Of the 504 tags released in juvenile Chinook salmon at Durham Ferry, 500 were detected on one or more receivers downstream of the release site (Table 5-11), including the predator-type detections. In general, the number of tags detected at each site in the San Joaquin route declined with distance from Durham Ferry,

Table 5-11
Number of Tags from each Release Group that were Detected Downstream of the Release Site in 2010, Including Predator-type Detections

Durham Ferry Releases								
Release Group	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**Total**
Number Released	74	74	73	70	70	73	70	504
Total Number Detected	72	74	72	70	70	73	69	500
Old River Releases								
Release Group	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**Total**
Number Released	36	36	36	36	36	35	32	247
Total Number Detected	36	36	36	36	36	35	32	247
Stockton Releases								
Release Group	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**Total**
Number Released	35	36	35	36	35	34	31	242
Total Number Detected	34	35	34	34	35	33	30	235

with 477 tags detected at Mossdale, 232 tags detected at Lathrop, 188 tags detected at the Navy Bridge in Stockton, and 69 tags detected at Medford Island. Only 19 tags were detected at Turner Cut (Table 5-12). Approximately an equal number of tags were detected in the Old River route as in the San Joaquin route, with 245 tags detected on the Old River receivers located near the head of the river. Only one tagged fish was observed to use the Middle River (MRS)route rather than the Old River route at the head of Middle River. Because detection probability could not be estimated based on a single tag, the detection history for this tag was censored at its previous detection (at OR1/OR2), and the MRS site was not included in the survival model. Without the MRS site, it was no longer possible to separately estimate the survival probability from the first Old River receivers (OR1/OR2) to the head of Middle River (SB1) and the route entrainment probability at the head of Old River (ψ_{B2}). Instead, the joint probability of migrating from OR1/OR2 toward the Old River South receivers (ORS) and surviving through that reach was estimated as:

$$\phi_{B1,B2} = S_{B1}\psi_{B2}.$$

Many tags were observed moving among the receivers at the Central Valley Project Trash rack (CVP), radial gates at the Clifton Court Forebay (RGU), and Old River North receivers (ORN). Among these three sites, the route with the final tag detection was used in the survival model. Approximately equal numbers of tags were detected finally moving from Old River South (ORS) to the Central Valley Project as to the radial gates at the Clifton Court Forebay, with fewer moving to the Old River North receivers (Table 5-12). Data gaps at the Central Valley Project trash rack receivers (CVP) prevented estimation of the detection probability at that site for the 4th Durham Ferry release group, so those receivers were omitted from the survival model for that release group. No tags were observed at the Middle River North sites (MRNU, MRND) after passing the southern Old River receivers. Thus, all Middle River receivers were omitted from the survival model for the Durham Ferry release groups. Of the 504 tags released in juvenile Chinook salmon at Durham Ferry, 59 were eventually detected at Chipps Island, including detections of tags classified as being in predators.

All 247 of the tags released in salmon in the Old River supplemental release groups were detected on one or more receivers downstream of the release site, including predator-type detections (Table 5-11). None of these tags was detected using the Middle River route, so the Middle River receivers were omitted from the survival model for the Old River releases. As with the Durham Ferry release groups, more tags released at Old River were finally detected at the Central Valley Project trash racks and the Clifton Court Forebay radial gates than at the Old River North receivers. Data gaps at the Central Valley Project trash rack receivers (CVP) prevented estimation of the detection probability at that site for the 4th Old River release group, so those receivers were omitted from the survival model for that release group. Of the 247 tags released at Old River, 28 were detected at Chipps Island, including predator-type detections (Table 5-12).

Of the 242 tags released in salmon in the Stockton supplemental release groups, 235 were detected on one or more receivers downstream of the release site, including predator-type detections (Table 5-11). The majority of the detections downstream of the Stockton Navy Bridge (STN) were detected in the San Joaquin

Table 5-12
Number of Tags Observed from each Release Group at each Detection Site in 2010 and Release Location and Used in the Survival Analysis, Including Predator-type Detections

Detection Site	Site Code	Survival Model Code	Durham Ferry Release Group							
			1	2	3	4	5	6	7	Total
Banta Carbona	BCA	A2	70	65	64	65	68	70	66	468
Mossdale	MOS	A3	68	74	68	67	68	72	60	477
Lathrop	SJ1/SJ2	A4	34	32	26	37	32	35	36	232
Stockton USGS Gauge	STS	A5	33	28	24	33	30	31	27	206
Stockton Navy Bridge	STN	A6	24	29	22	30	29	30	24	188
Shipping Channel Marker 18	C18	A7a	17	18	12	17	20	10	17	111
Shipping Channel Marker 16	C16	A7b	18	22	13	17	19	10	19	118
Medford Island East	MFE	A8a	11	8	8	11	14	6	10	68
Medford Island West	MFW	A8b	12	8	8	11	14	6	10	69
Turner Cut Northeast	TCN	F1a	2	1	1	6	5	2	1	18
Turner Cut Southwest	TCS	F1b	3	1	1	6	5	2	1	19
Old River	OR1/OR2	B1	34	42	42	31	36	36	24	245
Old River South Upstream	ORSU	B2a	31	41	38	28	36	37	23	234
Old River South Downstream	ORSD	B2b	0	41	37	20	14	0	0	112
Middle River South	MRS	C1	0	0	1*	0	0	0	0	1*
Old River North Upstream	ORNU	B3a	8	11	4	2	6	7	1	39
Old River North Downstream	ORND	B3b	8	12	3	1	5	6	1	36
Middle River North Upstream	MRNU	C2a	0	0	0	0	0	0	0	0
Middle River North Downstream	MRND	C2b	0	0	0	0	0	0	0	0
Radial Gates Upstream	RGU	D1	12	13	15	15	10	6	0	71
Radial Gates Downstream	RGD	D2	11	10	12	9	8	5	0	55
Central Valley Project trashrack	CVP	E1	11	16	12	5*	11	9	10	74
Central Valley Project tank	CVPtank	E2	2	3	3	4	10	8	5	35
Chipps Island East	CHPe	G1a	6	2	4	7	15	14	11	59
Chipps Island West	CHPw	G1b	6	2	4	7	14	12	11	56
Detection Site	**Site Code**	**Survival Model Code**	**Old River Release Group**							
			1	**2**	**3**	**4**	**5**	**6**	**7**	**Total**
Old River	OR1/OR2	B1	35	35	36	36	36	35	32	245
Old River South Upstream	ORSU	B2a	36	35	34	35	30	35	32	237
Old River South Downstream	ORSD	B2b	1	28	35	9	9	0	0	82
Middle River South	MRS	C1	0	0	0	0	0	0	0	0
Old River North Upstream	ORNU	B3a	13	3	7	5	5	7	1	41
Old River North Downstream	ORND	B3b	13	6	9	3	5	7	1	44
Middle River North Upstream	MRNU	C2a	0	0	0	0	0	0	0	0
Middle River North Downstream	MRND	C2b	0	0	0	0	0	0	0	0
Radial Gates Upstream	RGU	D1	12	15	12	7	6	11	0	63
Radial Gates Downstream	RGD	D2	10	13	11	4	8	9	0	55
Central Valley Project trashrack	CVP	E1	6	10	14	11*	7	5	19	72
Central Valley Project tank	CVPtank	E2	1	5	4	8	4	0	8	30
Chipps Island East	CHPe	G1a	1	6	3	8	3	0	7	28
Chipps Island West	CHPw	G1b	1	6	3	7	3	0	6	26
Detection Site	**Site Code**	**Survival Model Code**	**Stockton Release Group**							
			1	**2**	**3**	**4**	**5**	**6**	**7**	**Total**
Stockton Navy Bridge	STN	A6	27	30	33	34	35	33	30	222
Shipping Channel Marker 18	C18	A7a	21	22	14	16	21	7	17	118
Shipping Channel Marker 16	C16	A7b	21	23	15	17	24	8	18	126
Medford Island East	MFE	A8a	13	16	13	11	13	6	8	80
Medford Island West	MFW	A8b	13	17	13	11	13	6	8	81
Turner Cut Northeast	TCN	F1a	4	0	1	4	3	1	3	16
Turner Cut Southwest	TCS	F1b	4	0	1	4	3	2	3	17
Chipps Island East	CHPe	G1a	3	1	5	6	5	2	3	25
Chipps Island West	CHPw	G1b	4	0	5	6	6	2	3	26

*=not used in survival model.

River, with 128 detected at one or the other, or both of the channel markers (C18/C16); only 17 tags were detected in Turner Cut, none of which was detected at Chipps Island (Table 5-12). Twenty-seven tags from the Stockton release groups were detected at Chipps Island, all of which migrated past the shipping channel markers and Medford Island (Table 5-12). All predator-type detections were included in these detections.

Some tag detections were not used in the survival analysis, either because the tags were assigned to a different migration route, or because the receivers where they were detected were not intended to be included in the survival model. For example, tag 8305.02 (period and subcode) was detected at the Middle River South receiver (MRS). However, because this tag was later detected at an Old River South receiver (ORS), it was assigned to the Old River route rather than to the Middle River route, and so the MRS detection was omitted. A total of eight tags were detected on the Middle River North receivers (MRN) throughout the study period, with four coming from the Durham Ferry releases and four from the Stockton supplemental releases. Three of these eight tags were last seen at Turner Cut before being detected at Middle River North, one was last detected at Medford Island, and four were last detected at the channel markers in the San Joaquin shipping channel (site C18/C16). Thus, all eight of these tags were assigned the San Joaquin River route rather than the Old River route, and so the Middle River North detections were not used in the survival analysis. Twenty tags were detected at the Threemile Slough receivers (TMN, TMS): ten tags from Durham Ferry, nine from the Stockton supplemental releases, and one from the Old River supplemental releases. Of these 20 tags detected at Threemile Slough, 11 were eventually detected at Chipps Island. However, some of these detections were classified as coming from predators. Threemile Slough was not included in the survival model.

The decision process used to distinguish between detections of Chinook salmon smolts and detections of predatory fish that had eaten the tagged smolts classified 602 of the 993 tags (61%) released as being detected in a predator at some point during the study (Table 5-13). Of the 504 tags released in juvenile Chinook salmon at Durham Ferry, 312 were classified as being detected in a predator at some point. The detection site with the largest number of first-time predator-type detections was the shipping channel markers in the San Joaquin downstream of Stockton (site C18/C16), where 42 tags released at Durham Ferry were first labeled as predators upon arrival at the receivers, and 16 were first classified as predators upon departure from the receivers. Being classified as a predator upon arrival was usually the result of unusual travel time or migration rate, while being classified as a predator only upon departure was usually the result of long residence time at a site. The Central Valley Project trash rack receivers (CVP) had the next largest number of first-time predator classifications, with 18 tags first classified as being in predators upon arrival at the site, and 31 tags classified as predators upon departure from the site. Among the Old River releases, a total of 162 tags were eventually classified as coming from a predator rather than a smolt, with the majority (88%) of such classifications occurring at the receivers at the Central Valley Project trash racks (CVP), the radial gates at the entrance to Clifton Court Forebay (RGU, RGD), and the Old River North site (ORN) (Table 5-11). A total of 128 tags that were released in salmon smolts in the Stockton supplemental releases were classified as being in predators at some point (Table 5-13). The Stockton release site was located between the receiver at the USGS gauge (STS) and the receiver near the Navy Bridge (STN) in Stockton. Thus, some tags released at Stockton were observed at the USGS gauge receiver (STS), and a few as far upstream as Lathrop (SJ1/SJ2). Several of these detections (6 of 37; 16%) were classified as coming from predators, based on travel time and travel in relation to river flow. Most of the first-time predator classifications occurred at the channel markers in the shipping channel downstream of Stockton (site C18/C16) (Table 5-13). None of the Stockton tags was observed at the eastern or southern receivers in the Old River route (i.e., OR1/OR2 and ORS). However, several Stockton tags were observed in the central Delta, at one or more of the Middle River, radial gate, and Central Valley Project receivers. These tags were generally classified as predators upon arrival at those sites based on long transition times. Even if they had not been classified as predators, they would not have contributed to the survival analysis because they were all previously assigned to the San Joaquin River route for survival analysis. One Stockton tag was classified as a predator upon arrival at the receivers in Threemile Slough (Table 5-13).

When the detections classified as coming from predators were removed from the detection data, fewer detections were available for the survival analysis (Table 5-14 and Table 5-15). Nevertheless, a large proportion of the tags released were detected at least once, suggesting high initial survival. Of the 504 tags released in juvenile Chinook salmon at Durham Ferry, 496 were detected on downriver receivers with smolt-type detections (Table 5-14). Of these 496 tags, 202 were detected using the San Joaquin River route, and 229 were detected using the Old River route. Only six smolts were detected at Turner Cut, and none of these smolts was subsequently detected at Chipps Island. Only one tag was detected

Table 5-13
Number of Tags from each Release Group and Release Location First Classified as in a Predator at each Detection Site in 2010 as a Result of the Predator-Smolt Decision Process

Detection Site and Codes			Durham Ferry Release Groups															
			Classified as predator on arrival at site								Classified as predator on departure from site							
			1	2	3	4	5	6	7	Total	1	2	3	4	5	6	7	Total
Detection Site	Site Code	Survival Model Code																
Banta Carbona	BCA	A2	4	0	2	0	0	0	2	8	0	0	0	0	0	0	0	0
Mossdale	MOS	A3	1	0	0	0	0	1	2	4	0	1	0	0	0	1	0	2
Lathrop	SJ1/SJ2	A4	3	0	2	8	3	6	4	26	0	0	2	0	0	2	0	4
Stockton USGS Gauge	STS	A5	1	0	1	3	0	1	0	6	0	1	1	1	0	0	1	4
Stockton Navy Bridge	STN	A6	0	0	0	0	0	1	2	3	1	1	0	0	4	2	0	8
Shipping Channel Marker	C18/C16	A7	5	13	8	6	5	3	2	42	1	0	2	5	4	1	3	16
Medford Island	MFE/MFW	A8	5	1	0	0	1	0	0	7	1	0	1	0	1	1	0	4
Turner Cut	TCN/TCS	F1	1	0	0	3	3	1	0	8	0	0	0	0	0	0	0	0
Old River	OR1/OR2	B1	3	1	4	3	0	1	1	13	0	0	0	0	0	0	1	1
Old River South	ORS	B2	2	1	2	2	2	5	0	14	1	0	0	0	0	0	0	1
Middle River South	MRS	C1	0	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0
Old River North	ORN	B3	3	3	2	1	1	3	1	14	2	5	2	0	4	3	0	16
Middle River North	MRN	C2	0	0	0	0	0	0	2	2	0	0	0	0	0	1	0	1
Radial Gates Upstream	RGU	D1	1	2	5	1	1	2	0	12	5	4	3	5	3	0	1	21
Radial Gates Downstream	RGD	D2	1	1	1	0	2	0	0	5	4	1	2	5	3	0	0	15
Central Valley Project trashrack	CVP	E1	2	2	0	2	3	5	4	18	5	9	8	1	1	1	6	31
Central Valley Project tank	CVPtank	E2	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0
Chipps Island	CHP	G1	0	0	0	0	0	0	1	1	0	0	0	0	0	0	3	3
Threemile Slough	TMS/TMN		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total Tags			32	24	27	30	22	29	21	185	20	22	21	17	20	12	15	127

Detection Site and Codes			Old River Release Groups															
			Classified as predator on arrival at site								Classified as predator on departure from site							
			1	2	3	4	5	6	7	Total	1	2	3	4	5	6	7	Total
Detection Site	**Site Code**	**Survival Model Code**																
Old River	OR1/OR2	B1	0	0	0	1	2	1	1	5	0	0	0	0	1	0	0	1
Old River South	ORS	B2	0	1	1	0	0	1	1	4	1	0	0	0	0	0	0	1
Middle River South	MRS	C1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Old River North	ORN	B3	2	0	0	5	1	4	0	12	4	4	3	0	2	5	3	21
Middle River North	MRN	C2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Radial Gates Upstream	RGU	D1	2	0	3	3	0	2	0	10	10	5	6	4	0	1	2	28
Radial Gates Downstream	RGD	D2	0	2	1	0	1	2	0	6	5	8	5	2	6	2	0	28
Central Valley Project trashrack	CVP	E1	0	1	2	5	4	2	8	22	2	4	5	0	2	1	2	16
Central Valley Project tank	CVPtank	E2	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0
Chipps Island	CHP	G1	0	1	1	3	0	0	1	6	0	0	0	1	0	0	0	1
Threemile Slough	TMS/TMN		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total Tags			4	6	8	17	8	12	11	66	22	21	19	7	11	9	7	96

Detection Site and Codes			Stockton Release Groups															
			Classified as predator on arrival at site								Classified as predator on departure from site							
			1	2	3	4	5	6	7	Total	1	2	3	4	5	6	7	Total
Detection Site	**Site Code**	**Survival Model Code**																
Lathrop	SJ1/SJ2	A4	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0
Stockton USGS Gauge	STS	A5	1	1	0	1	0	2	0	5	0	1	0	0	0	2	0	3
Stockton Navy Bridge	STN	A6	1	2	5	1	1	2	4	16	2	1	1	1	1	4	2	12
Shipping Channel Marker	C18/C16	A7	5	6	9	6	10	4	4	44	2	1	0	4	3	1	2	13
Medford Island	MFE/MFW	A8	1	1	0	2	1	0	0	5	1	2	2	1	2	0	1	9
Turner Cut	TCN/TCS	F1	2	0	2	2	1	1	1	9	0	1	0	0	1	1	0	3
Middle River South	MRS	C1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Old River North	ORN	B3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Middle River North	MRN	C2	0	1	0	0	0	0	1	2	0	0	0	0	0	0	0	0
Radial Gates Upstream	RGU	D1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Radial Gates Downstream	RGD	D2	0	1	1	0	0	0	0	2	0	0	0	0	0	0	0	0
Central Valley Project trashrack	CVP	E1	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
Central Valley Project tank	CVPtank	E2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Chipps Island	CHP	G1	0	0	0	0	1	0	0	1	0	0	0	0	1	0	0	1
Threemile Slough	TMS/TMN		0	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0
Total Tags			11	12	17	13	14	9	11	87	5	6	3	6	8	8	5	41

Table 5-14
Number of Tags from each Release Group at the Three Release Locations that were Detected Downstream during the 2010 VAMP, Without Predator-type Detections

Durham Ferry Releases								
Release Group	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**Total**
Number Released	74	74	73	70	70	73	70	504
Total Number Detected	71	74	70	70	70	73	68	496
Old River Releases								
Release Group	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**Total**
Number Released	36	36	36	36	36	35	32	247
Total Number Detected	36	36	36	36	36	34	31	245
Stockton Releases								
Release Group	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**Total**
Number Released	35	36	35	36	35	34	31	242
Total Number Detected	32	31	33	33	35	29	25	218

using the Middle River route; because this was too few detections for use in the survival model, the Middle River route was not included in the survival model for Durham Ferry releases. With predator-type detections omitted, approximately equal numbers of fish were observed to eventually move to the Old River North receivers (ORN) as to the Central Valley Project and Clifton Court Forebay receivers (Table 5-15). A total of 29 tags were detected at Chipps Island with only smolt-type detections, with 19 of these tags previously detected at the Central Valley Project and only 9 previously detected in the San Joaquin River at Lathrop or farther downstream.

Even without the predator-type detections, nearly all (245) of the 247 tags released in the Old River supplemental releases were detected on downriver receivers (Table 5-14). The close proximity of the Old River release site to the first Old River receivers (OR1/OR2) may explain the high proportion of tags detected. No tag from the Old River releases was detected using the Middle River route, so that route was omitted from the survival model for the Old River release groups. More salmon were detected using the Clifton Court Forebay route (sites RGU, RGD) than the Old River North route (site ORN) or the Central Valley Project route (sites CVP, CVPtank), although most fish detected on the receiver located outside the radial gate (RGU) were not subsequently detected on the receivers inside the gate (RGD) (Table 5-15). Of the 247 tags released at Old River, only 16 were eventually detected at Chipps Island and classified as in salmon smolts (Table 5-15).

Of the 242 tags released in salmon in the Stockton supplemental release groups, 218 were detected on downriver receivers with salmon-type detections. Most of these tags were last detected at the Stockton Navy Bridge (STN), with only 78 tags detected at the channel markers (sites C18 and C16) or downstream, and only 8 detected at Turner Cut (Table 5-14). Twelve of the 242 tags released were detected at Chipps Island, classified as in salmon smolts (Table 5-15).

Survival Effect of Tagger

Fish in the release groups were evenly distributed across tagger (Table 5-16). A chi-squared test found good distribution of taggers across all Durham Ferry release groups (P=1.0), and across all supplemental releases at both Old River and Stockton (P=1.0 in each case).

A likelihood ratio test found no significant effect of tagger on model fit to data from all release occasions pooled (P=0.9702). Additionally, estimated smolt survival through each river reach showed no consistent evidence of a tagger effect on survival (Table 5-17). Cumulative survival to Chipps Island via the San Joaquin route (Figure 5-10) and via the Old River route (Figure 5-11) 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

Two of the 55 tags in the tag life study died within 25 hours of tag activation, and 5 tags survived more than 45 days (Figure 5-8). The initial two tag deaths were omitted from the tag survival analysis because all tagged juvenile salmon released to the river were observed to have live tags more than 25 hours after tag activation. The tag life data were truncated at 40 days because all detections of tagged fish were observed prior to Day 40, and the tag survival model fit better without the last 5 tag failures (Figure 5-12).

Table 5-15
Number of Tags from each Release Group at the Three Release Locations that Were Observed at each Detection Site in 2010 and Used in the Survival Analysis, Without Predator-type Detections

Detection Site	Site Code	Survival Model Code	Durham Ferry Release Group							
			1	2	3	4	5	6	7	Total
Banta Carbona	BCA	A2	68	65	62	65	68	70	65	463
Mossdale	MOS	A3	65	74	67	67	68	71	60	472
Lathrop	SJ1/SJ2	A4	29	32	24	29	29	27	32	202
Stockton USGS Gauge	STS	A5	27	28	19	24	27	22	22	169
Stockton Navy Bridge	STN	A6	20	28	17	21	26	20	20	152
Shipping Channel Marker 18	C18	A7a	14	16	6	9	12	4	14	75
Shipping Channel Marker 16	C16	A7b	13	16	5	8	10	4	14	70
Medford Island East	MFE	A8a	10	5	3	2	2	2	4	28
Medford Island West	MFW	A8b	10	5	2	2	1	2	4	26
Turner Cut Northeast	TCN	F1a	1	0	0	0	3	1	1	6
Turner Cut Southwest	TCS	F1b	1	0	0	0	3	1	1	6
Old River	OR1/OR2	B1	31	40	37	27	36	35	22	228
Old River South Upstream	ORSU	B2a	27	39	33	22	34	31	20	206
Old River South Downstream	ORSD	B2b	0	39	33	18	14	0	0	104
Middle River South	MRS	C1	0	0	0	1*	0	0	0	1*
Old River North Upstream	ORNU	B3a	11	13	10	0	11	9	3	57
Old River North Downstream	ORND	B3b	10	14	6	0	7	2	2	41
Middle River North Upstream	MRNU	C2a	0	0	0	0	0	0	0	0
Middle River North Downstream	MRND	C2b	0	0	0	0	0	0	0	0
Radial Gates Upstream	RGU	D1	9	9	8	12	11	1	1	51
Radial Gates Downstream	RGD	D2	5	3	2	5	4	0	0	19
Central Valley Project trashrack	CVP	E1	7	16	11	3	7	2	7	53
Central Valley Project tank	CVPtank	E2	0	3	1	3	6	7	3	23
Chipps Island East	CHPe	G1a	3	2	0	2	7	8	7	29
Chipps Island West	CHPw	G1b	3	2	0	2	6	6	7	26
Detection Site	**Site Code**	**Survival Model Code**	**Old River Release Group**							
			1	**2**	**3**	**4**	**5**	**6**	**7**	**Total**
Old River	OR1/OR2	B1	35	35	36	36	36	34	31	243
Old River South Upstream	ORSU	B2a	36	34	33	35	29	33	30	230
Old River South Downstream	ORSD	B2b	0	27	34	9	9	0	0	79
Middle River South	MRS	C1	0	0	0	0	0	0	0	0
Old River North Upstream	ORNU	B3a	10	6	8	2	10	11	6	53
Old River North Downstream	ORND	B3b	9	7	8	2	7	6	4	43
Middle River North Upstream	MRNU	C2a	0	0	0	0	0	0	0	0
Middle River North Downstream	MRND	C2b	0	0	0	0	0	0	0	0
Radial Gates Upstream	RGU	D1	20	17	14	14	7	7	3	82
Radial Gates Downstream	RGD	D2	9	8	6	2	6	2	0	33
Central Valley Project trashrack	CVP	E1	3	5	11	2	4	2	8	35
Central Valley Project tank	CVPtank	E2	0	1	4	7	2	0	7	21
Chipps Island East	CHPe	G1a	0	0	1	7	2	0	6	16
Chipps Island West	CHPw	G1b	0	0	1	7	2	0	6	16
Detection Site	**Site Code**	**Survival Model Code**	**Stockton Release Group**							
			1	**2**	**3**	**4**	**5**	**6**	**7**	**Total**
Stockton Navy Bridge	STN	A6	26	27	33	33	35	29	25	208
Shipping Channel Marker 18	C18	A7a	17	13	6	11	17	2	12	78
Shipping Channel Marker 16	C16	A7b	17	12	6	11	15	1	12	74
Medford Island East	MFE	A8a	10	8	5	5	7	0	8	43
Medford Island West	MFW	A8b	10	8	5	5	7	0	7	42
Turner Cut Northeast	TCN	F1a	2	1	0	1	2	1	1	8
Turner Cut Southwest	TCS	F1b	2	1	0	1	2	1	1	8
Chipps Island East	CHPe	G1a	2	1	1	2	4	0	2	12
Chipps Island West	CHPw	G1b	2	1	1	2	4	0	2	12

*=not used in survival model.

Table 5-16
Number of Juvenile Chinook Salmon Tagged by Tagger in each Release Group and Release Location During the 2010 VAMP Study

Durham Ferry Release Group	Tagger			Total Tags
	A	B	C	
1	24	25	25	74
2	25	25	24	74
3	24	24	25	73
4	24	24	22	70
5	23	24	23	70
6	25	24	24	73
7	0	47	23	70
Total Durham Ferry Tags	145	193	166	504
Old River Release Group	**Tagger**			**Total Tags**
	A	B	C	
1	12	12	12	36
2	12	12	12	36
3	12	12	12	36
4	12	12	12	36
5	12	12	12	36
6	12	12	11	35
7	10	10	12	32
Total Old River Tags	82	82	83	247
Stockton Release Group	**Tagger**			**Total Tags**
	A	B	C	
1	12	11	12	35
2	12	12	12	36
3	11	12	12	35
4	12	12	12	36
5	12	12	11	35
6	10	12	12	34
7	11	11	9	31
Total Stockton Tags	80	82	80	242
Total Tags	307	357	329	993

Table 5-17
Estimates (and standard errors) of Survival Probabilities (S_{Ai}) and Transition Probabilities ($\phi_{kj,hi}$) by Tagger for the VAMP 2010 study.

Parameter	Tagger A	Tagger B	Tagger C
S_{A1}	0.98 (0.01)	1.00 (0.01)	0.99 (0.01)
S_{A2}	0.96 (0.02)	0.93 (0.02)	0.96 (0.02)
S_{A3}	0.93 (0.02)	0.89 (0.02)	0.92 (0.02)
S_{A4}	0.84 (0.05)	0.80 (0.04)	0.91 (0.04)
S_{A5}	1.01 (0.06)	0.94 (0.04)	0.98 (0.05)
S_{A6}	0.43 (0.05)	0.39 (0.04)	0.43 (0.04)
$\phi_{A7,A8}$	0.55 (0.07)	0.45 (0.07)	0.47 (0.06)
$\phi_{A8,G1}$	0.14 (0.06)	0.4551 (0.11)	0.26 (0.09)
$\phi_{F1,G1}$	0.00 (0)	0.00 (0)	0.00 (0)
$\phi_{B1,B2}$	0.88 (0.04)	0.91 (0.03)	0.93 (0.03)
$\phi_{B2,B3}$	0.26 (0.04)	0.23 (0.03)	0.29 (0.04)
$\phi_{B3,G1}$	0.00 (0)	0.03 (0.03)	0.00 (0)
$\phi_{B2,D10}$	0.22 (0.03)	0.21 (0.03)	0.21 (0.04)
$\phi_{B2,D1C}$	0.11 (0.03)	0.12 (0.03)	0.10 (0.03)
$\phi_{D10,D2}$	0.35 (0.09)	0.45 (0.11)	0.38 (0.09)
$\phi_{D1C,D2}$	0.34 (0.13)	0.38 (0.12)	0.23 (0.11)
$\phi_{D2,G1}$	0.00 (0)	0.00 (0)	0.00 (0)
$\phi_{B2,E1}$	0.26 (0.06)	0.59 (0.18)	0.44 (0.17)
$\phi_{E1,E2}$	0.42 (0.11)	0.20 (0.08)	0.26 (0.08)
$\phi_{E2,G1}$	0.77 (0.11)	0.81 (0.10)	0.85 (0.09)

The complete set of detection data, including the detections classified as coming from predators, included many detections that occurred well after the tags began dying in the tag life study (Figure 5-13, Figure 5-14). A sizeable number of late detections occurred at the Channel Markers in the San Joaquin River just past the junction with Turner Cut, and at the Lathrop receivers just downstream of the junction with Old River (Figure 5-13). In the Old River route, the trash rack at the Central Valley Project had the largest proportion of late detections (Figure 5-14). The very long detection histories and late detections observed at these sites were interpreted as coming from predatory fish that had eaten the study fish. When the detections classified as coming from predators were removed, the remaining detections occurred before most of the tag failure observed in the tag life study (Figure 5-15, Figure 5-16). Tag life corrections were made to survival estimates for both sets of detections (with and without detections classified as predators). Because of the prolonged detections observed in the complete data set, the tag-life adjustments to survival estimates were more extreme for the detection set that included the predator detections.

Survival and Route Entrainment Probabilities

The model selection process identified the most parsimonious model that adequately fit the data, based on AIC and visual analysis of the Anscombe residuals. For the reduced data set that excluded detections classified as coming from predators, estimating unique transition parameters to and from the radial gates at the Clifton Court Forebay (RGU, RGD) based on gate status (open and closed) significantly improved the fit of the model ($\Delta AIC = 6.755$), so all models fit to the reduced data set used unique parameters based on gate status. However, for the full data set that included detections classified as coming from predators, the simpler model without a gate effect fit the model nearly as well as the model using unique gate parameters ($\Delta AIC = 0.283$). Thus, the models fit to the full data set used the simpler model that did not distinguish between open and closed gate states.

Figure 5-10
Estimated Cumulative Survival from the Release at Durham Ferry to Chipps Island along the San Joaquin River Route, by Tagger during the 2010 VAMP Study

Figure 5-11
Estimated Cumulative Survival from the Release at Durham Ferry to Chipps Island along the Old River Route, by Tagger during the 2010 VAMP Study

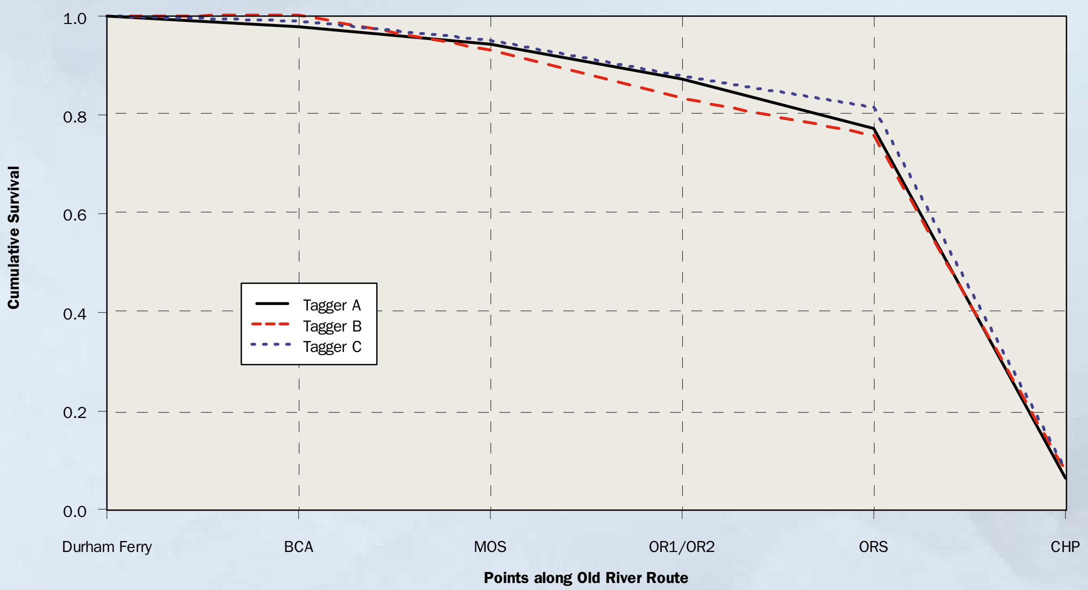


Figure 5-12
Observed Tag Failure Times from the 2010 Tag-life Study, and Fitted Four-Parameter Vitality Curve. The First Two and Last Five Tag Failures were Omitted

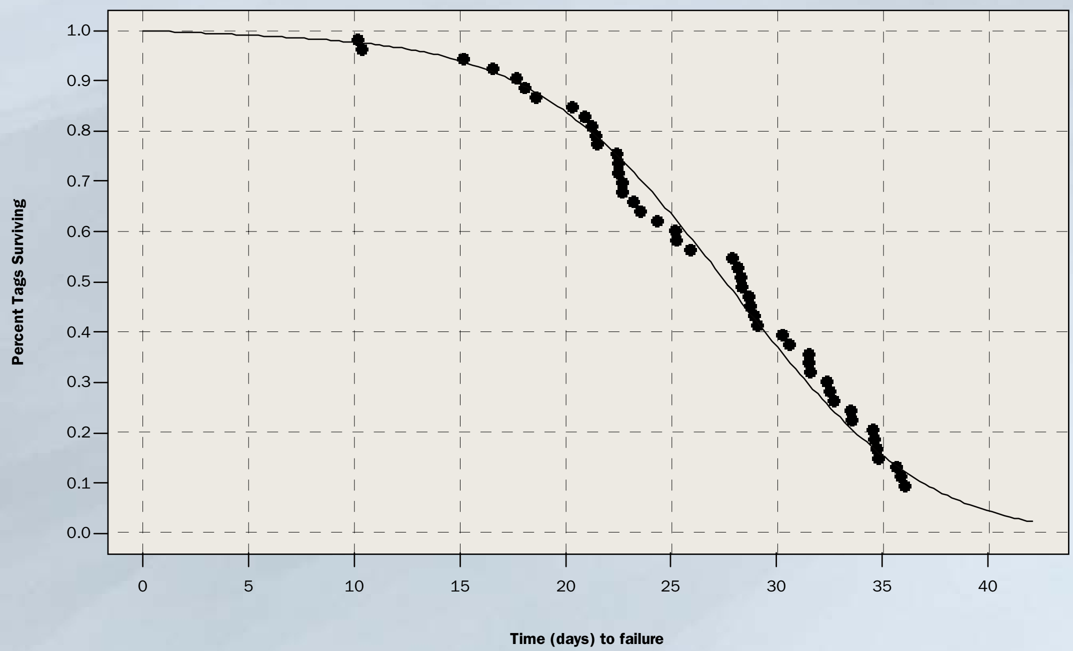


Figure 5-13
Four-Parameter Vitality Curve Survivorship Curve for Tag Life, and the Timing of Detections of Acoustic-tagged Chinook Salmon Smolts at Receivers Located in the San Joaquin River Route to Chipps Island. Only Tags Released at Durham Ferry are Shown, Including Detections Classified as Predator Detections

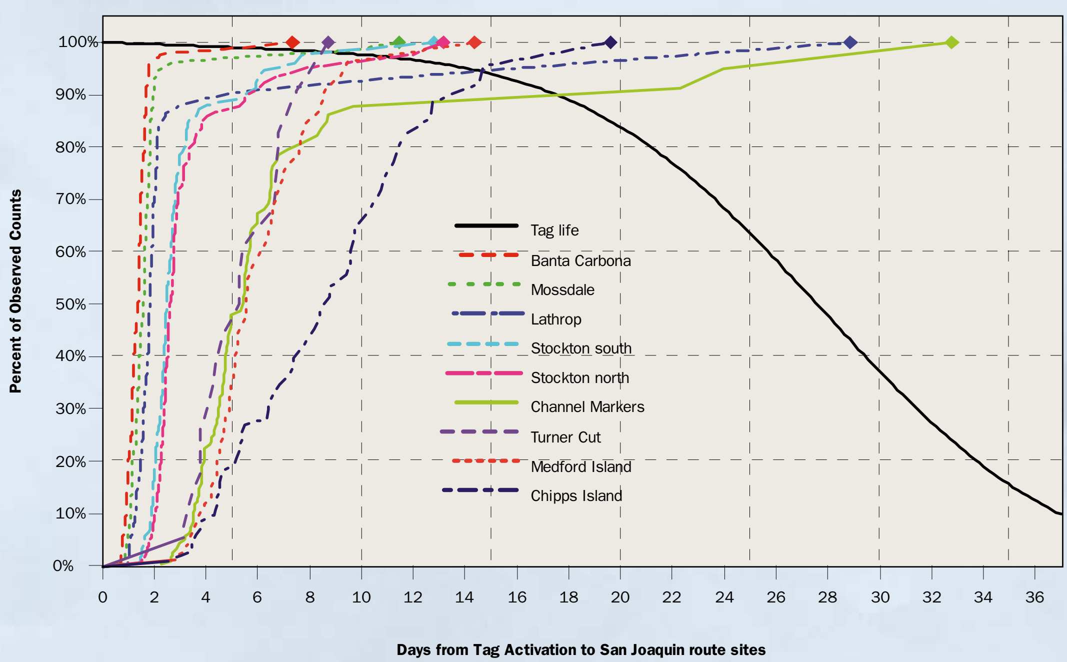


Figure 5-14
Four-Parameter Vitality Curve Survivorship Curve for Tag Life, and the Timing of Detections of Acoustic-tagged Chinook Salmon Smolts at Receivers Located in the Old River Route to Chipps Island. Only Tags Released at Durham Ferry are Shown, Including Detections Classified as Predator Detections

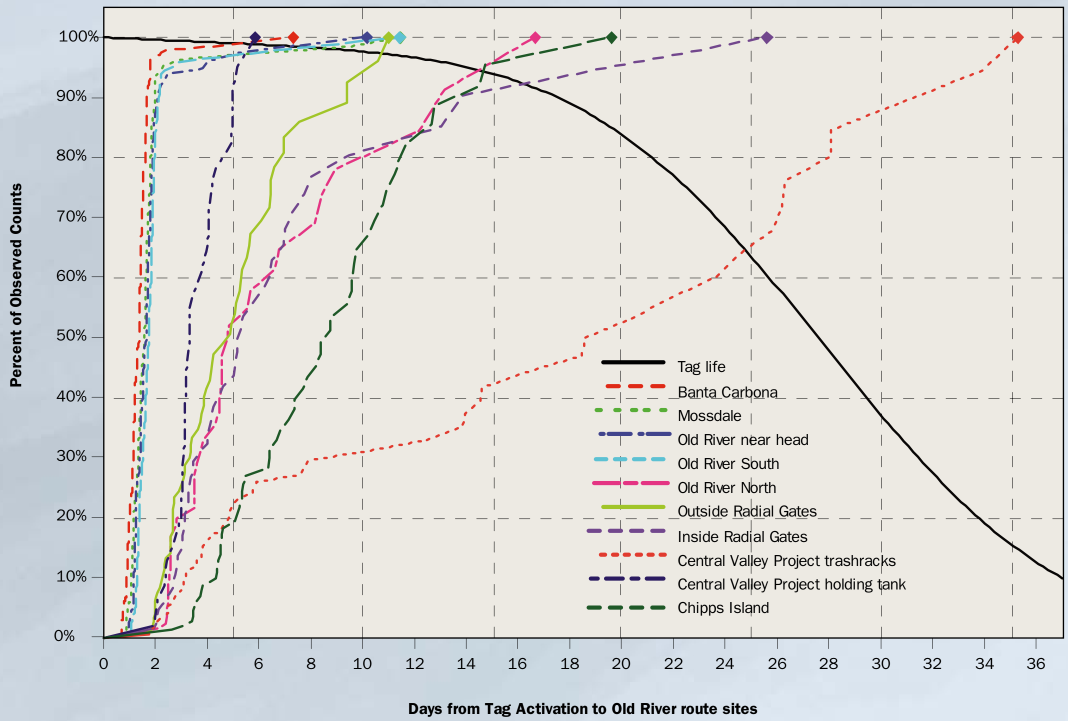


Figure 5-15
Four-Parameter Vitality Curve Survivorship Curve for Tag Life, and the Timing of Detections of Acoustic-tagged Chinook Salmon Smolts at Receivers Located in the San Joaquin River Route to Chipps Island. Only Tags Released at Durham Ferry are Shown, Omitting Detections Classified as Predator Detections

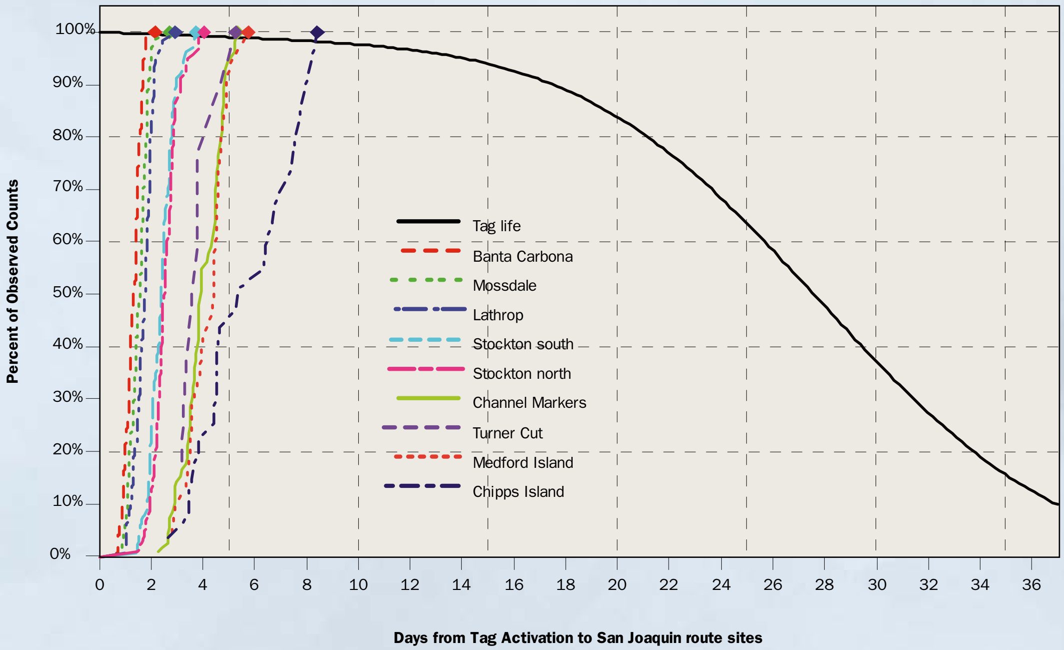
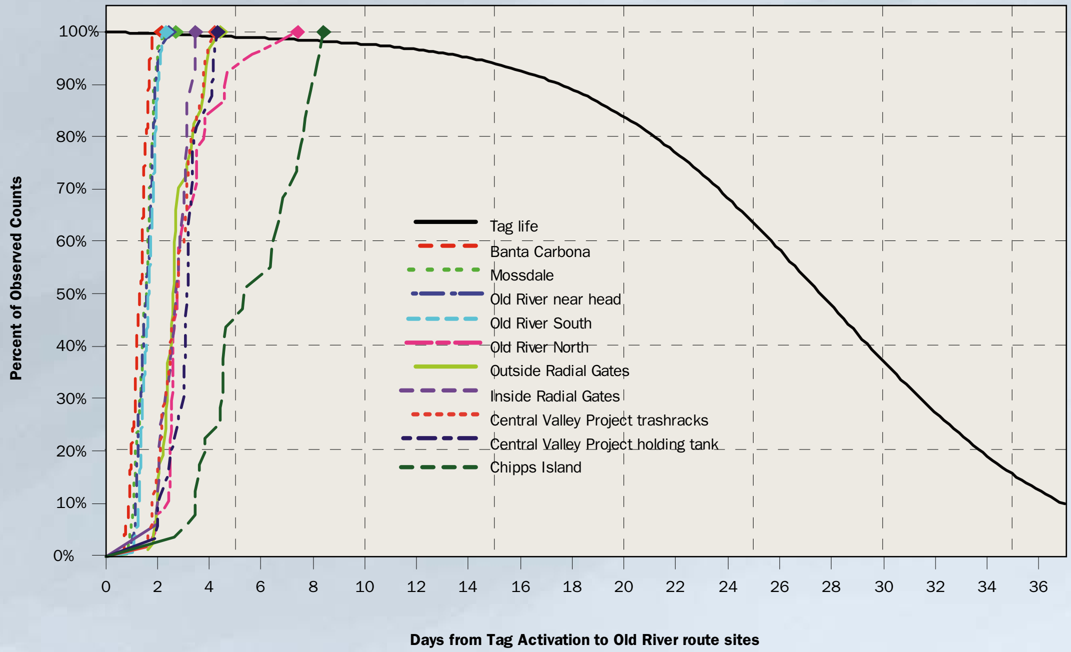


Figure 5-16

Four-Parameter Vitality Curve Survivorship Curve for Tag Life, and the Timing of Detections of Acoustic-tagged Chinook Salmon Smolts at Receivers Located in the San Joaquin River Route to Chipps Island. Only Tags Released at Durham Ferry are Shown, Omitting Detections Classified as Predator Detections



For most release occasions, the selected model used common detection, survival, route entrainment, and transition probabilities among the primary release group at Durham Ferry and the supplemental releases at Old River and Stockton (Table 5-18, Appendix D - Tables D-2 and D-3). All models considered used unique values of $\phi_{B1,B2}$ for the Durham Ferry and Old River releases, because of the close proximity of the Old River release site to the OR1/OR2 receivers. Some parameters were unable to be estimated for certain release groups or release occasions because of sparse data. For example, without the predator-type detections, no information was available on the transition probability between the receivers at the radial gates at Clifton Court Forebay (RGU, RGD) and Chipps Island ($\phi_{D2,G1}$) because no non-predator type detections on the radial gate receivers were used in the survival analysis. Also without the predator-type detections, it was not possible to separately estimate $\phi_{B2,E1}$ and P_{E1} for the first release occasion (both Durham Ferry and Old River release groups) because no tags were observed at site E2 (CVPtank). For the 7th release occasion, it was not possible to separately estimate $\phi_{B2,D1C}$ and P_{D1} because no tags were observed at site D2 (RGD) (both Durham Ferry and Old River release groups). In these cases, the joint probability of transition and detection were estimated as: $\lambda_{B2,E1} = \phi_{B2,E1}P_{E1}$ and $\lambda_{B2,D1C} = \phi_{B2,D1C}P_{D1}$, respectively. If the detection probability was less than 1.0, then $\lambda_{ij} < \phi_{ij}$, and the survival probability from the Old River South receivers (ORS) to the water export facilities (CVP, RGU) and Old River North (ORN) would be underestimated. However, the overall probability of survival to Chipps Island through the Old River Route (S_B) would not be affected by the detection probability at sites E1 (CVP) and D1 (RGU), because the estimated transition probabilities from those sites onward was zero in each case.

Using only those detections classified as coming from salmon and excluding the predator-type detections, the estimates of the total survival from Mossdale to the receivers at Chipps Island, S_{Total}, ranged from 0.01 ($\widehat{SE}$=0.01) for Release 3 to 0.10 ($\widehat{SE}$ = 0.03) for both Release 5 and Release 7, with a population estimate of 0.05 ($\widehat{SE}$ =0.01) (Table 5-19; Appendix D – Table D-2). Estimates of the probability of remaining in the San Joaquin River at the junction with Old River (ψ_A) ranged from 0.39 ($\widehat{SE}$=0.06) for Release 3 to 0.59 ($\widehat{SE}$=0.07) for Release 7, with a population-level estimate of 0.47 ($\widehat{SE}$ =0.02). The only significant preference for either route was observed in Release 3, where the Old River route was used more than the San Joaquin River route ($\hat{\psi}_A$=0.39, $\widehat{SE}$ = 0.06; P=0.0443). Estimates of survival from Mossdale to Chipps Island through the San Joaquin River route (S_A) ranged from 0.01 ($\widehat{SE}$ =0.01) for releases 2, 3, and 6 to 0.07 ($\widehat{SE}$ =0.04) for releases 1 and 7, with an average estimate of 0.04 ($\widehat{SE}$ =0.01) over all releases (Table 5-19). Estimates of survival from Mossdale to Chipps Island through the Old River route (S_B) ranged from 0.00 ($\widehat{SE}$ =0.00) for Release 1 to 0.15 ($\widehat{SE}$ =0.05) for Release 7, with an average of 0.07 ($\widehat{SE}$ =0.01) (Table 5-19). Only Release 1 showed a significant (α=0.05) difference in survival to Chipps Island through the two routes, with a significantly higher estimated probability of surviving to Chipps Island through the San Joaquin route (P=0.0100). Lack of significance for other releases may be a result of low statistical power. Pooled over all release groups, however, survival to Chipps Island was estimated be significantly higher through the Old River route than through the San Joaquin River route (P=0.0133, one-sided Z-test on the lognormal scale).

Survival was also estimated through the portion of the study area that matched the 2009 study area. Estimates of survival in the San Joaquin River route from Mossdale to the Shipping Channel Markers (C18/C16) or Turner Cut (TCN/TCS) ($S_{A(region)}$) ranged from 0.11 ($\widehat{SE}$=0.04) for Release 6 to 0.49 ($\widehat{SE}$=0.06) for Release 5 (population-level average = 0.32; $\widehat{SE}$ =0.02) (Table 5-19). Estimates of survival from Mossdale to the entrances of the water export facilities (CVP, RGU) or the northern Old River receivers at Highway 4 (ORN) ($S_{B(region)}$) ranged from 0.56 ($\widehat{SE}$=0.09) for Release 4 to 0.90 ($\widehat{SE}$=0.04) for Release 2 (population-level average=0.77 ($\widehat{SE}$=0.05)) (Table 5-19). Overall survival through the southern region of the Delta (comparable to the study region in the 2009 study) was estimated to range from 0.39 ($\widehat{SE}$=0.06) for Release 4 to 0.71 ($\widehat{SE}$ =0.05) for Release 5 (average = 0.56; $\widehat{SE}$=0.03) (Table 5-19). These survival estimates were considerably higher than comparable estimates from the 2009 VAMP study, where average survival through this region (both routes) was estimated to be 0.06 ($\widehat{SE}$=0.01) (without predator-type detections), with survival in the San Joaquin River route estimated at 0.05 ($\widehat{SE}$= 0.02), and survival through the Old River route estimated at 0.08 ($\widehat{SE}$= 0.02) (SJRGA, 2010).

When predator-type detections were included in the analysis, estimates of total survival from Mossdale to Chipps Island (S_{Total}) ranged from 0.06 ($\widehat{SE}$=0.02) for Release 2 to 0.18 ($\widehat{SE}$=0.03) for Release 5, with a population-level average estimate of 0.11 ($\widehat{SE}$ =0.01) (Table 5-20; Appendix D - Table D-3). Using the full data set with the predator-type detections, estimates of the route entrainment probability into the San Joaquin River route (ψ_A) ranged from 0.38 ($\widehat{SE}$ =0.06) for Release 3 to 0.60 ($\widehat{SE}$=0.06) for Release 7 (average = 0.49; $\widehat{SE}$=0.02). As with the reduced data set, only Release 3 showed a statistically significant route

Table 5-18
Results of Model Selection Process for Detection Data, With and Without Predator-type Detections. Release Occasion Consists of Primary Release Group at Durham Ferry and Supplemental Release Groups at both Old River and Stockton. Final Model Description: Unique Parameters are Identified Among Release Sites. DF = Durham Ferry, OR = Old River, and STK = Stockton. All Models Estimated Unique Values of $\phi_{B1,B2}$ for the DF and OR release sites. N_{par} = number of unique parameters estimated

With Predators	Release Occasion	Final Model Unique Parameters		Log-Likelihood	N_{par}	AIC
		DF vs. OR	DF vs. STK			
Yes	1	[none]	[none]	-69.74429	44	227.4886
Yes	2	$P_{B2b, PB3a}$	P_{A6} P_{G1b} $\phi_{A7, A8}$ ψ_{A2} S_{A6}	-69.7423	50	239.4846
Yes	3	[none]	[none]	-65.42396	44	218.8479
Yes	4	P_{B2b}	[none]	-76.61694	43	239.2339
Yes	5	[none]	P_{A7a} P_{A7b}	-91.67242	45	273.3446
Yes	6	$\phi_{E1,E2}$	[none]	-61.41989	44	210.8398
Yes	7	[none]	[none]	-57.08281	40	194.1656
No	1	[none]	[none]	-62.10735	44	212.2147
No	2	P_{B2b} $\phi_{B2,D1C}$ $\phi_{B2,E1}$	P_{A6}	-67.23123	47	228.4625
No	3	[none]	P_{B3b}	-57.11298	44	202.2260
No	4	$\phi_{B2,E1}$ $\phi_{E1,E2}$ $\phi_{E2,G1}$	P_{B2b}	-68.73799	50	237.4760
No	5	[none]	[none]	-92.77070	46	277.5414
No	6	$\phi_{B2,D1C}$ $\phi_{B2,E1}$ $\phi_{E1,E2}$	[none]	-48.70236	49	195.4047
No	7	[none]	S_{A6} ψ_{A2} $\phi_{A7,A8}$ $\phi_{A8,G1}$	-55.50728	49	209.0146

Table 5-19
Performance Metric Estimates (standard error in parentheses) for Tagged Juvenile Chinook Salmon Released in the 2010 VAMP Study, Omitting the Predator-type Detections. Release Occasion Includes Primary Release at Durham Ferry and Supplemental Releases at Old River and Stockton. "Regional" Survival Extended to the Shipping Channel Markers and Turner Cut in Route A, and the Central Valley Project Trash Rack, Exterior Radial Gate Receiver at Clifton Court Forebay, and Old River North Receivers in Route B. (Population-level estimates are weighted averages of release group estimates)

Parameter	Release Occasion							Population Estimate
	1	2	3	4	5	6	7	
S_A	0.07[a] (0.03)	0.01 (0.01)	0.01 (0.01)	0.04 (0.02)	0.06 (0.03)	0.01 (0.01)	0.07 (0.03)	0.04 (0.01)
S_B	0.00[a] (0.00)	0.03 (0.02)	0.01 (0.01)	0.10 (0.03)	0.13 (0.04)	0.07 (0.02)	0.15 (0.05)	0.07 (0.01)
ψ_A	0.48 (0.06)	0.44 (0.06)	0.39[a] (0.06)	0.52 (0.07)	0.45 (0.06)	0.43 (0.06)	0.59 (0.07)	0.47 (0.02)
ψ_B	0.52 (0.06)	0.56 (0.06)	0.61[a] (0.06)	0.48 (0.07)	0.55 (0.06)	0.57 (0.06)	0.41 (0.07)	0.53 (0.02)
S_{Total}	0.03 (0.02)	0.02 (0.01)	0.01 (0.01)	0.06 (0.02)	0.10 (0.03)	0.05 (0.02)	0.10 (0.03)	0.05 (0.01)
$SA_{(region)}$	0.47 (0.07)	0.40 (0.06)	0.16 (0.04)	0.24 (0.05)	0.49 (0.06)	0.11 (0.04)	0.35 (0.06)	0.32 (0.02)
$SB_{(region)}$	0.78 (0.06)	0.90 (0.04)	0.75 (0.06)	0.56 (0.09)	0.88 (0.08)	0.68 (0.29)	0.83 (0.21)	0.77 (0.05)
$S_{Total(region)}$	0.63 (0.05)	0.68 (0.05)	0.52 (0.06)	0.39 (0.06)	0.71 (0.06)	0.43 (0.17)	0.55 (0.10)	0.56 (0.03)

[a] = significant difference between route A and route B estimate (α=0.05).

Table 5-20
Performance Metric Estimates (standard error in parentheses) for Tagged Juvenile Chinook Salmon Released in the 2010 VAMP Study, Including the Predator-type Detections. Release Occasion Includes Primary Release at Durham Ferry and Supplemental Releases at Old River and Stockton. "Regional" Survival Extended to the Shipping Channel Markers and Turner Cut in Route A, and the Central Valley Project Trash Rack, Exterior Radial Gate Receiver at Clifton Court Forebay, and Old River North Receivers in Route B. (Population-level estimates are weighted averages of release group estimates)

Parameter	Release Occasion							Population Estimate
	1	2	3	4	5	6	7	
S_A	0.11 (0.04)	0.01[a] (0.03)	0.12 (0.04)	0.15 (0.04)	0.18 (0.05)	0.10 (0.03)	0.12 (0.04)	0.11 (0.01)
S_B	0.04 (0.02)	0.10[a] (0.03)	0.06 (0.03)	0.15 (0.04)	0.18 (0.05)	0.11 (0.03)	0.21 (0.05)	0.12 (0.01)
ψ_A	0.50 (0.06)	0.43 (0.06)	0.38[a] (0.06)	0.55 (0.06)	0.47 (0.06)	0.49 (0.06)	0.60 (0.06)	0.49 (0.02)
ψ_B	0.50 (0.06)	0.57 (0.06)	0.62[a] (0.06)	0.45 (0.06)	0.53 (0.06)	0.51 (0.06)	0.40 (0.06)	0.51 (0.02)
S_{Total}	0.07 (0.02)	0.06 (0.02)	0.08 (0.02)	0.15 (0.03)	0.18 (0.03)	0.10 (0.02)	0.16 (0.03)	0.11 (0.01)
$SA_{(region)}$	0.64 (0.07)	0.63 (0.07)	0.49 (0.07)	0.59 (0.06)	0.77 (0.06)	0.30 (0.05)	0.54 (0.07)	0.57 (0.02)
$SB_{(region)}$	0.93 (0.05)	0.98 (0.02)	0.93 (0.07)	0.52[b] (0.06)	1.09 (0.10)	1.43 (0.57)	1.11 (0.25)	1.00 (0.09)
$S_{Total(region)}$	0.79 (0.04)	0.83 (0.04)	0.76 (0.06)	0.56[b] (0.05)	0.94 (0.06)	0.88 (0.30)	0.77 (0.11)	0.79 (0.05)

[a] = significant difference between route A and route B estimate (a=0.05).
[b] = survival to Central Valley Project trashracks not included.

preference (P=0.0229), with $\hat{\Psi}_A$= 0.38 ($\widehat{SE}$= 0.06) for that release group. Route-specific survival estimates from Mossdale to Chipps Island through the San Joaquin River route (S_A), including predator-type detections, ranged from 0.01 ($\widehat{SE}$=0.03) for Release 2 to 0.18 ($\widehat{SE}$ =0.05) for Release 5, with a population-level average of 0.11 ($\widehat{SE}$=0.01) (Table 5-20). Survival to Chipps Island through the Old River route (S_B) had estimates ranging from 0.04 ($\widehat{SE}$=0.02) for Release 1 to 0.21 ($\widehat{SE}$ =0.05) for Release 7 with a population-level average of 0.12; ($\widehat{SE}$=0.01) (Table 5-20). There was a statistically significant (α=0.05) difference in estimated survival between the two routes only for Release 2, for which the Old River route had a significantly higher probability of survival to Chipps Island than the San Joaquin River route (P = 0.0289).

Including the predator-type detections, estimates of regional survival in the San Joaquin River route from Mossdale to the Shipping Channel Markers (C18/C16) or Turner Cut (TCN/TCS) ($S_{A(region)}$) ranged from 0.30 ($\widehat{SE}$=0.05) for Release 6 to 0.77 ($\widehat{SE}$=0.06) for Release 5, with a population-level average of 0.57 ($\widehat{SE}$=0.02) (Table 5-20). In the Old River route, estimates of regional survival to the entrances of the water export facilities (CVP, RGU) or the northern Old River receivers at Highway 4 (ORN) ($S_{B(region)}$) ranged from 0.93 ($\widehat{SE}$=0.05-0.07) for both releases 1 and 3, to 1.43 ($\widehat{SE}$=0.57) for Release 6 with a population-level average of 1.00; ($\widehat{SE}$=0.09) (Table 5-20). These estimates exceeded the comparable estimates from 2009 by approximately 0.4-0.5 for both routes, with $\hat{S}_{A(region)}$=0.10 and $\hat{S}_{B(region)}$=0.58 in 2009 (including predator-type detections).

For most releases, the largest component of the estimated Old River route survival through the southern Delta ($S_{B(region)}$) came from the transition to the Central Valley Project trash rack ($\phi_{B2,E1}$) when predator-type detections were included. It was not possible to estimate the transition probability to the trash rack for Release 4 when predator-type detections were included in the model, probably because of failure of the assumption that all tags observed at the trash rack had the same probability of moving on to the holding tank (with predators less likely to move to the holding tank). Without that component of overall survival through the southern Delta, the estimate of the Old River survival through that region was only 0.52 ($\widehat{SE}$=0.06) for Release 4, considerably lower than the estimates for the other releases, in which the transition probability to the trash rack was included (Table 5-20). The very high point estimate of $S_{B(region)}$ observed for Release 6 resulted from the long travel times observed among tags classified as being in predators, in particular long travel times to the Central Valley Project trash rack. These long travel times resulted in large corrections in survival estimates due to tag failure, producing impractical point estimates of survival in the Old River route through the southern portion of the Delta. Estimates of the total survival through the southern portion of the Delta, including both routes, ($S_{Total(region)}$) ranged from 0.76 ($\widehat{SE}$=0.06) for Release 3 to 0.94 ($\widehat{SE}$=0.06) for Release 5, with a population-level average of 0.79 ($\widehat{SE}$=0.05) (Table 5-20). Again, the estimate for Release 4 (0.56, $\widehat{SE}$=0.05) was lower than the others, but did not include survival to the Central Valley Project trash rack. The 2010 estimates of overall survival through the 2009 study area were considerably higher than the comparable estimates from 2009: $\hat{S}_{Total\ (region)}$= 0.34 for 2009, including predator-type detections. Estimates of survival through both the Old River region ($S_{B(region)}$) and through the entire southern region ($S_{Total(region)}$) must be interpreted with caution, especially when based on detections classified as coming from predators, because of likely violation of model assumptions.

The point estimates of the overall survival to Chipps Island (S_{Total}) were consistently higher for the full data set that included the predator-type detections than for the reduced data set that excluded those detections (Table 5-19 vs. Table 5-20), with the releases 1 and 2 showing the smallest differences (0.04) and releases 4 and 5 showing the largest differences (0.09 and 0.08, respectively). Exclusion of the predator-type detections had little effect on estimates of the route entrainment probability at the head of Old River (ψ_A). Exclusion of the predator-type detections had no effect on the route-specific survival to Chipps Island through the San Joaquin River route (S_A) for Release 2; both the full data set, including predator-type detections, and the reduced data set, including only smolt-type detections, produced a very low estimate of S_A for Release 2 (0.01, $\widehat{SE}$=0.01-0.03). However, for all other releases, including the predator-type detections increased the point estimate of survival through the San Joaquin River route by a range of 0.04 to 0.12 (Table 5-19 vs. Table 5-20). The increase in the point estimates of survival to Chipps Island through the Old River route (S_B) was more stable, ranging from 0.04 (releases 1 and 6) to 0.07 (Release 2). On the smaller, regional scale, comparable to the study area in the 2009 study, the increase in point estimates of survival through the southern Delta ($S_{Total(region)}$) ranged from 0.15 (Release 1) to 0.45 (Release 6). As noted above, the very large increase in survival for Release 6 that was seen using all detections relative to only smolt-type detections is likely due to long travel times within the western Old River region that artificially increased the point estimates of the transition probabilities, and that were interpreted as evidence of predation.

Travel Time

For tags released at Durham Ferry and classified as being in salmon smolts, average travel time through the reaches ranged from 0.15 days ($\widehat{SE}$=0.01) from the Stockton USGS gauge (STS) to the Navy Bridge in Stockton (STN) (approximately 3 km), to 3.14 days ($\widehat{SE}$ =0.36) from Medford Island (MFE/MFW) to Chipps Island (CHP) (Table 5-21). There were multiple paths between Medford Island and Chipps Island; the path that used only the San Joaquin River was approximately 46 km. When all detections were considered, including those classified as being in predators, there was little change in travel times through the southern part of the Delta (e.g., through Stockton; Table 5-21). However, as the distance from Durham Ferry increased, the difference in average travel time associated with predator-type detections generally increased as well. The longest travel times for Durham Ferry tags (including predator-type detections) were observed between the Old River South receivers (ORS) and the Central Valley Project trash rack (CVP), with an average travel time of 7.15 days ($\widehat{SE}$ =1.07), and from Turner Cut (TCN/TCS) to Chipps Island, with an average travel time of 9.43 days ($\widehat{SE}$ =1.46). Without the predator-type detections, no tags were observed to move from Turner Cut to Chipps Island, and the average transition from Old River South to the Central Valley Project trash racks was only 1.03 days ($\widehat{SE}$ =0.07) (Table 5-21). It is not surprising that travel times were longer on average when the predator-type tags were included, because the decision process used to identify predator detections was partly based on travel time.

Tags released at Old River and classified as being in salmon had travel times ranging from 0.10 days ($\widehat{SE}$ <0.01) for the transition from the first Old River receivers (OR1/OR2) to Old River South, to 1.75 days ($\widehat{SE}$ =0.11) from the Central Valley Project holding tank to Chipps Island (Table 5-21). In general, average travel times were longer when predator-type detections were included, although the difference was not consistently significant (α=0.05). Tags released at Stockton and classified as being in salmon had travel times that were very similar to those observed for the Durham Ferry releases (Table 5-21). When predator-type detections were included, average travel times tended to be longer.

Comparison of NPB Fate Assignment and VAMP Detections

The NPB fate assignment and the VAMP decision rule used to distinguish between detections of salmon smolts and detections of predators focused on different sets of information. The NPB analysis focused mainly on near-field movements of the tag in the presence of the 2-dimensional array of receivers located at the Head of Old River Barrier, with secondary attention paid to downstream tag detections. The VAMP analysis, on the other hand, focused on mid-field and far-field tag movements in conjunction with observations of river flow and water velocity. The VAMP decision rule used the NPB predator classifications in cases where migration rates seemed counter to flow patterns (i.e., fast migration rates during low flow, or slow migration rates during high flow). Thus, it is not expected that the two methods agree perfectly on predator classification. The VAMP analysis classified 39 tags as in predators for the first time after leaving the NPB area, corresponding to predator mortality of 9% in that region. The draft NPB analysis estimated a higher rate of mortality due to predation in the NPB area, based on detections of VAMP fish at the Old River barrier in 2010 (Bowen et al., 2010) however Bowen's estimate will be reduced when the draft NPB report is finalized based in part, on the information provided by the far field observations from the VAMP study (M. Bowen, personal communication).

After accounting for differences in predation classification, there were only five conflicts in route assignment between the NPB analysis and the VAMP analysis. For three tags, the barrier data assigned the San Joaquin River and VAMP detections assigned Old River; for two tags, the barrier data assigned Old River and VAMP detections assigned the San Joaquin River. For each of these five tags, the tag was not detected on the VAMP receiver in the route assigned in the barrier data. It is possible that after initially moving in one direction, the fish eventually turned to go down the other river without being detected on the ORB receivers.

A total of 316 tags were detected on the HORB receivers and classified as both entering the area (i.e., leaving Mossdale) in smolts in the VAMP analysis and also leaving the area in smolts by the NPB study (draft analysis). Of these 316 tags, 100% were detected on downriver receivers, including those that were newly classified as being in predators between leaving the HORB area and being detected on downriver receivers. Without these "new predator" detections, 309 of the 316 tags (98%, $\widehat{SE}$ =1%) were detected on downriver receivers. Each of the 7 tags (out of 316) not treated as survivors in the "smolt-only" data set were detected in Old River at OR1/OR2, but were newly classified as in predators there because of either unexpectedly long or unexpectedly short transition times from Mossdale. Assuming that these 7 new predator classifications at OR1/OR2 were appropriate, the difference between the assumed (100%) and estimated (98%) survival from the head of Old River to the Old River receivers would have a negligible effect on estimates of route entrainment probability at the head of Old River, with differences considerably smaller than the standard error on route entrainment estimates ($\widehat{SE}$ estimates ranged from 0.06-0.07). Thus, the assumption of 100% survival from the head of Old River to the Lathrop or Old River receivers was acceptable.

Mobile Telemetry

Mobile tracking efforts in previous years identified three sites of high juvenile salmon mortality or tag defecation: in the deep scour hole in the San Joaquin River near the head of Old River, near a railroad bridge in Stockton, and in front of the Tracy Fish Facility trash racks (Vogel, 2007b and Vogel, 2010). Based on the 2010 mobile monitoring, predation did not appear to be a problem near the Head of Old River or near the railroad bridge in Stockton. However, predation did still appear to be an issue in front of the Tracy Fish Facility trash racks, with a total of 37 acoustic tags detected near this location (Figure 5-17).

Survival in the San Joaquin River between Banta Carbona and Old River was high during the 2010 VAMP. Of the few tags lost in this reach that had been released at Durham Ferry, five were detected by mobile tracking and were found to be distributed evenly throughout the reach with no apparent hot spots (Figure 5-18).

A total of 128 tags from marked salmon were detected in the San Joaquin River between Old River and Turner Cut. Nine of these tags were later detected at a downstream fixed acoustic station, indicating that the tag was in a live fish (smolt or predator) that moved out of the reach sometime after detection by the mobile array. The remaining 119 detections represent the last known location for those tags. Precise hotspots were not detected. Sixty-eight percent (68%) of the detected immobile tags in this reach of the San Joaquin River were found in the Stockton Deep Water Ship Channel (DWSC) (n=87), while 18% (n=23) were detected between its junction with Old River and the Stockton release site, and 14% (n=18) were detected between the Stockton release site and the DWSC (Figure 5-18).

A total of 120 tags were detected in Old River and Grant Line Canal between the Head of Old River and the State and federal pumping facilities. Twenty-six of these tags were later detected at a downstream fixed acoustic station, indicating that the tag was in a live fish (smolt or predator) that moved out of the reach sometime after detection by the mobile array. The remaining 94 tag detections represent the last known location for those tags. Precise hotspots were not detected. The highest concentration of the tags detected by mobile monitoring in this reach were found in the vicinity of the State and federal Pumping facilities 44% (n=87), while 28% (n=33) were detected in Old River upstream of Grant Line Canal, and 28% (n=34) were detected in Grant Line Canal. In general, there was a trend of increased tag detections as distance to the State and federal pumping facilities decreased (Figure 5-17 and Figure 5-18).

San Joaquin River Salmon Protection - Comparison with Past Years

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 has been hypothesized that actions aimed at improving conditions for the juveniles will translate into greater adult abundance and escapement in future years.

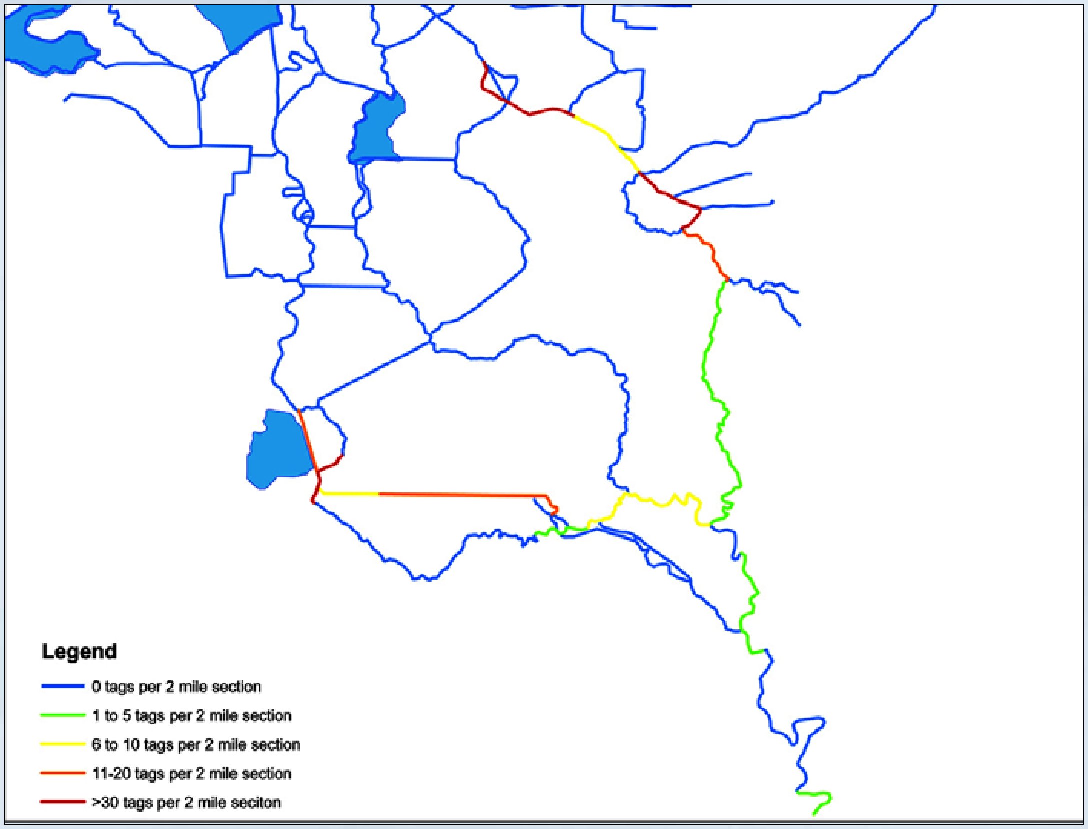
To determine if VAMP has been successful in targeting the migration period of naturally produced juvenile salmon, catches of unmarked salmon in the Kodiak trawl at Mossdale and in salvage at the CVP and SWP facilities were compared prior to, during, and after the 2010 VAMP period.

Table 5-21
Average Travel Time in Days of Acoustic-tagged Juvenile Chinook Salmon Through the San Joaquin River Delta During the 2010 VAMP Study.
(Average travel time is an arithmetic mean)

Reach		Durham Ferry Release Groups					
		Without Predator-Type Detections			With Predator-Type Detections		
Upstream Boundary	Downstream Boundary	N	Travel Time	SE	N	Travel Time	SE
Durham Ferry Release Site	Banta Carbona (BCA)	463	1.22	0.01	468	1.25	0.02
Banta Carbona (BCA)	Mossdale (MOS)	439	0.2	<0.01	444	0.25	0.03
Mossdale (MOS)	Lathrop (SJ1/SJ2)	202	0.18	0.01	232	0.31	0.12
	Old River (OR1/OR2)	228	0.09	<0.01	244	0.14	0.02
Lathrop (SJ1/SJ2)	Stockton USGS Gauge (STS)	169	0.69	0.02	206	0.82	0.05
Stockton USGS Gauge (STS)	Stockton Navy Bridge (STN)	150	0.15	0.01	186	0.26	0.06
Stockton Navy Bridge (STN)	Shipping Channel Markers (C18/C16)	69	1.44	0.06	110	2.93	0.37
	Turner Cut (TCN/TCS)	5	1.87	0.35	18	2.69	0.33
Shipping Channel Markers (C18/C16)	Medford Island (MFE/MFW)	28	0.33	0.06	69	0.91	0.16
Old River (OR1/OR2)	Old River South (ORS)	205	0.11	<0.01	233	0.14	0.01
Old River South (ORS)	Old River North (ORN)	58	1.35	0.13	40	3.16	0.5
	Clifton Court Forebay Access Channel (RGU)	50	1.03	0.08	70	2.37	0.25
	Central Valley Project trashrack (CVP)	53	1.03	0.07	74	7.15	1.07
Clifton Court Forebay Access Channel (RGU)	Clifton Court Forebay Interior (RGD)	18	0.31	0.08	53	1.02	0.39
Central Valley Project trashrack (CVP)	Central Valley Project Holding Tank (CVPtank)	11	0.18	0.09	19	0.3	0.08
Medford Island (MFE/MFW)	Chipps Island (CHP)	8	3.14	0.36	24	4.05	0.35
Turner Cut (TCN/TCS)		0	NA	NA	2	9.43	1.46
Old River North (ORN)		1	3.84	NA	3	4.6	1.74
Clifton Court Forebay Interior (RGD)		0	NA	NA	0	NA	NA
Central Valley Project Holding Tank (CVPtank)		19	1.02	0.16	28	1.02	0.12
Reach		**Old River Release Groups**					
		Without Predator-Type Detections			**With Predator-Type Detections**		
Upstream Boundary	**Downstream Boundary**	**N**	**Travel Time**	**SE**	**N**	**Travel Time**	**SE**
Old River Release Site	Old River (OR1/OR2)	243	1.07	0.02	245	1.11	0.03
Old River (OR1/OR2)	Old River South (ORS)	229	0.1	<0.01	236	0.1	<0.01
Old River South (ORS)	Old River North (ORN)	55	1.4	0.1	51	1.74	0.7
	Clifton Court Forebay Access Channel (RGU)	82	0.96	0.07	63	1.21	0.14
	Central Valley Project trashrack (CVP)	35	1.25	0.1	72	9.6	0.99
Clifton Court Forebay Access Channel (RGU)	Clifton Court Forebay Interior (RGD)	31	0.16	0.03	50	0.4	0.08
Central Valley Project trashrack (CVP)	Central Valley Project Holding Tank (CVPtank)	12	0.19	0.05	18	0.38	0.14
Old River North (ORN)	Chipps Island (CHP)	0	NA	NA	1	20.65	NA
Clifton Court Forebay Interior (RGD)		0	NA	NA	1	1.42	NA
Central Valley Project Holding Tank (CVPtank)		16	1.75	0.11	26	1.45	0.22
Reach		**Stockton Release Groups**					
		Without Predator-Type Detections			**With Predator-Type Detections**		
Upstream Boundary	**Downstream Boundary**	**N**	**Travel Time**	**SE**	**N**	**Travel Time**	**SE**
Stockton Release Site	Stockton Navy Bridge (STN)	208	1.37	0.02	222	1.64	0.09
Stockton Navy Bridge (STN)	Shipping Channel Markers (C18/C16)	69	1.43	0.06	117	2.73	0.26
	Turner Cut (TCN/TCS)	7	1.54	0.25	15	2.64	0.5
Shipping Channel Markers (C18/C16)	Medford Island (MFE/MFW)	43	0.34	0.06	81	0.87	0.11
Medford Island (MFE/MFW)	Chipps Island (CHP)	11	3.68	0.31	26	4.83	0.44
Turner Cut (TCN/TCS)		0	NA	NA	0	NA	NA

Figure 5-17
Approximate Last Known Location of Ninety–four Acoustic Tags Detected as Immobile by Mobile Monitoring in Old River and Grant Line Canal between the Head of Old River and the State and Federal Pumping Facilities

Figure 5-18
Approximate Density of Observed Immobile Acoustic Tags per Two-mile Reach of the Main Stem San Joaquin River from Old River Ferry to Turner Cut and from the Head of Old River to the State and Federal Pumping Facilities. Immobile Tags were defined as the Last Known Location of Acoustic Tags that were Found to be Immobile by Mobile Monitoring Conducted by Boat Throughout the 2010 VAMP Program



Unmarked and Marked Salmon Captured at Mossdale

The general time period for VAMP of 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 pass Mossdale during this time. The 2010 VAMP period was April 25th - May 25th, and trawl sampling at Mossdale was conducted three days/week January – March; five days per week April – May; and three days per week in June. Densities (catch per 10,000 cubic meters) of unmarked juvenile salmon captured at Mossdale from January through June are shown in Figure 5-19. Unmarked salmon do not have a clipped adipose fin or any other external mark (i.e., Panjet or Bismark brown) and may be juveniles from natural spawning or unmarked hatchery fish from the MRH. However during 2010, all unmarked hatchery fish from MRH were released in the San Joaquin River at Jersey Point, 43.9 miles downstream of Mossdale. Zero adipose fin-clipped or acoustically tagged fish were captured, and the only externally marked fish captured in the Mossdale trawl during 2010 were Panjet marked fish released immediately upstream of the trawl to estimate capture efficiency.

A peak density of unmarked juvenile salmon at Mossdale occurred on April 8th, (Figure 5-19) several days after reservoir releases were increased on both the Stanislaus and Tuolumne Rivers. Densities may have been as high or higher on days when no sampling was conducted (sampling was only conducted 5 days/week in April-May). The size of juvenile salmon captured in the Mossdale trawl between January and June is shown in Figure 5-20.

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 away from the pumps in the northern Sacramento-San Joaquin Delta. The untagged salmon are potentially from any source in the Central Valley. It is uncertain which of the 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 a general indication as to the extent of potential overlap. The combined exports in 2010 exceeded the flow at Vernalis prior to early-April and during the majority of June, and ranged from 47 to 76% less than Vernalis flow from early April to early June (Figure 5-21) (see Chapter 4 for more discussion of Vernalis flow and export rates).

The 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 Delta, the placement of the HORB, and the amount of water pumped by each facility are a few of the factors that influence the number of juvenile salmon salvaged and lost. Salmon density at the facilities can be an indicator of periods of time when more juvenile salmon may be susceptible to the export and salvage system. However, salvage efficiency is likely lower for smaller-sized salmon (fry and parr), so their salvage numbers and estimated losses are underrepresented.

Weekly salvage and loss data for the CVP and SWP were provided by CDFG Delta Fish Salvage Monitoring Project. A review of weekly data for January through June indicates that salvage and losses started to increase in April at CVP and in late-April at SWP and remained elevated through mid-May (Figure 5-22 and Figure 5-23). Additionally, there were three weeks of elevated levels of estimated loss (> 500 salmon) at SWP in late-January and early-February. Salmon densities based on combined salvage and loss estimates divided by 1,000 acre feet of export were also highest during much of the typical VAMP period at both facilities (Figure 5-24). Densities at the SWP had a distinct peak in mid-May, in contrast the CVP did not show a defined peak during the VAMP period.

The size and timing distributions of unmarked salmon in the Mossdale trawl (Figure 5-19) during January through June corresponds well with the distributions of the fish salvaged at the facilities during this same time period (Figure 5-25). Based on comparisons with Mossdale data, it appears that many salmon salvaged from late March to late May period could have originated from the San Joaquin basin.

These results demonstrate that the primary 2010 San Joaquin River salmon smolt migration period from the beginning of April to mid-late May coincided with the higher salvage period of the CVP/SWP facilities. In addition, the timing corresponded with the operation of the Non-Physical Barrier (NPB) (often called the Bio-Acoustical Fish Fence or BAFF), which was installed April 15th through June 16th. Sampling frequency at Mossdale in 2010 was more limited than in most recent years during the VAMP period and occurred only 5 days a week while in past years, sampling occurred 7 days per week in April and May. Production estimates at Mossdale could be improved by ensuring that sampling is conducted daily when most salmon smolts are emigrating.

Figure 5-19
Average Daily Densities of Unmarked Juvenile Chinook Salmon Caught in the Mossdale Kodiak Trawl in 2010 on the San Joaquin River

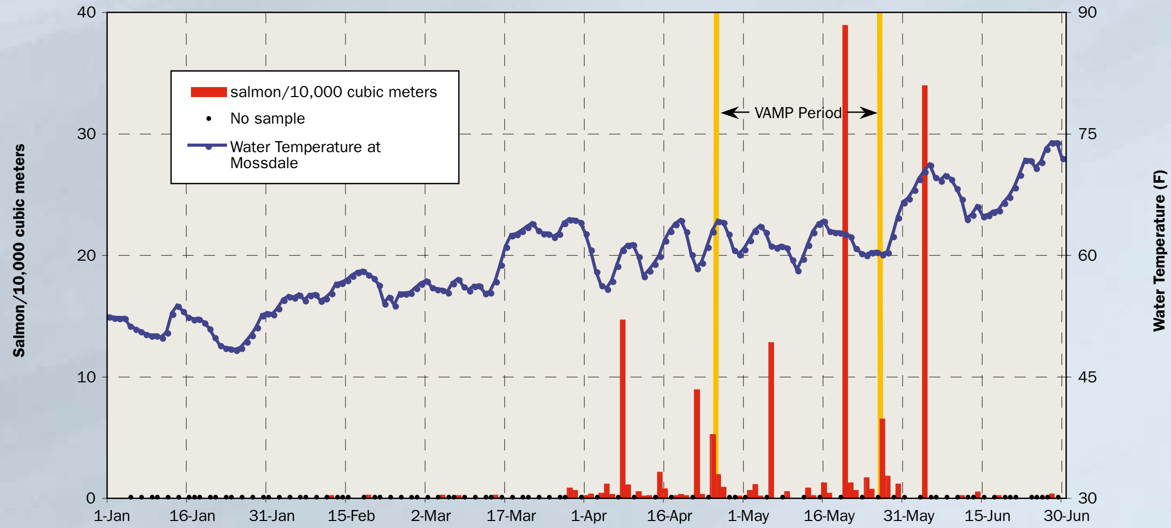


Figure 5-20
Individual Daily Forklengths (FL) in millimeters of Juvenile Chinook Salmon from the Mossdale Kodiak Trawl on the San Joaquin River, January through June 2010

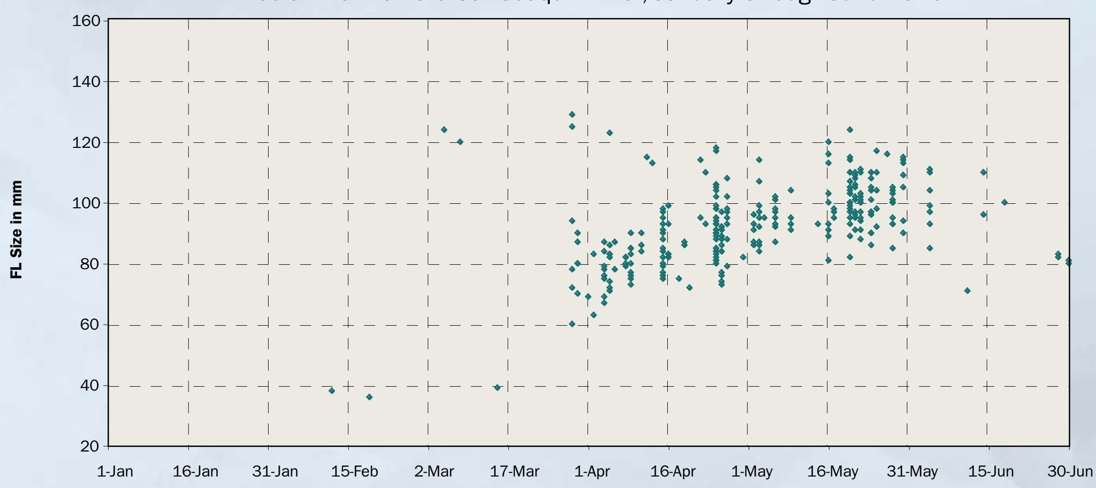


Figure 5-21
Weekly Average Export Rates from January through June 2010 from the State Water Project (SWP) & Central Valley Project (CVP) and Vernalis Flow in Cubic Feet per Second (cfs)

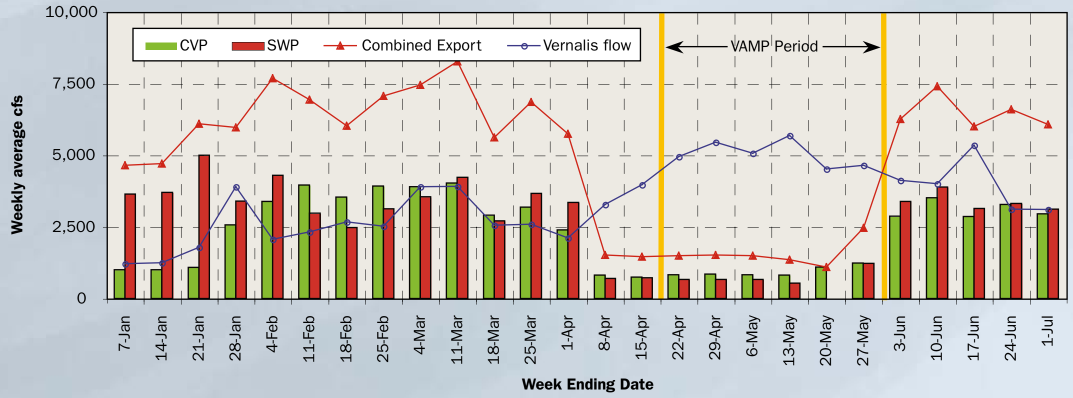


Figure 5-22
Central Valley Project (CVP) Estimated Juvenile Chinook Salmon Salvage and Loss from January through June 2010

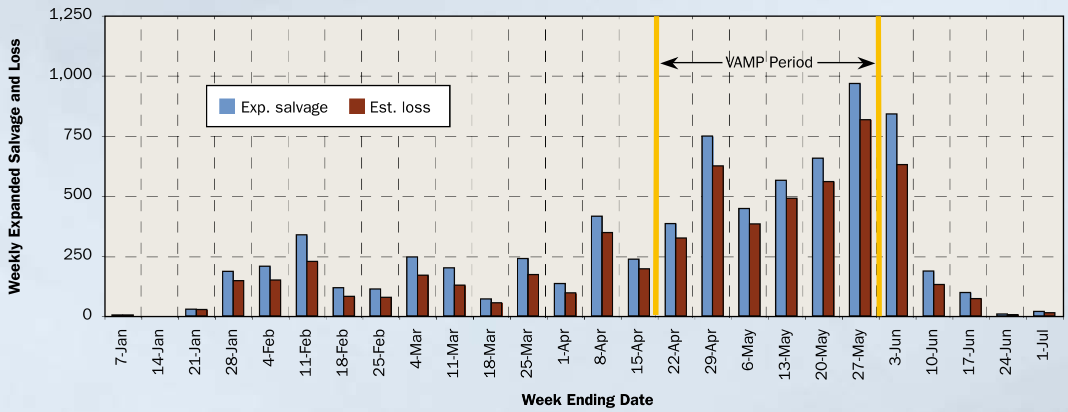


Figure 5-23
State Water Project (SWP) Estimated Juvenile Chinook Salmon Salvage and Loss from January through June 2010

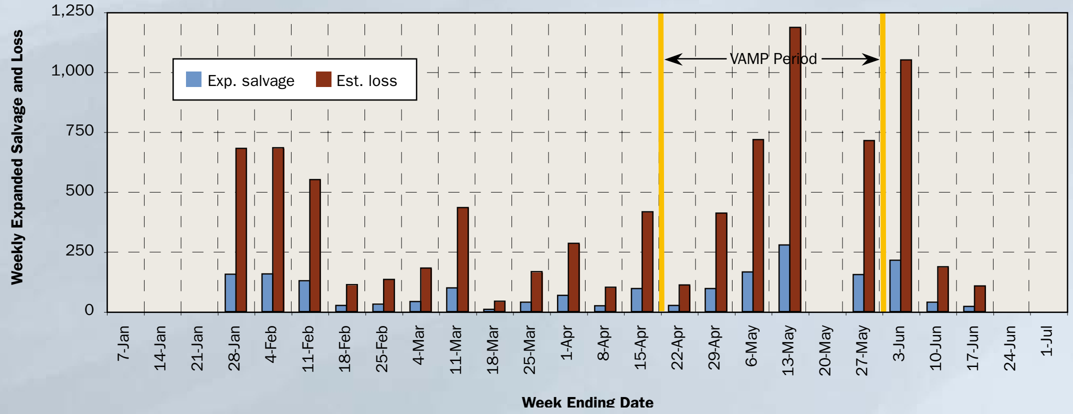


Figure 5-24
State Water Project (SWP) & Central Valley Project (CVP) Combined Juvenile Chinook Salmon Salvage and Loss Density Estimates per 1,000 Acre Feet of Export from January through June 2010

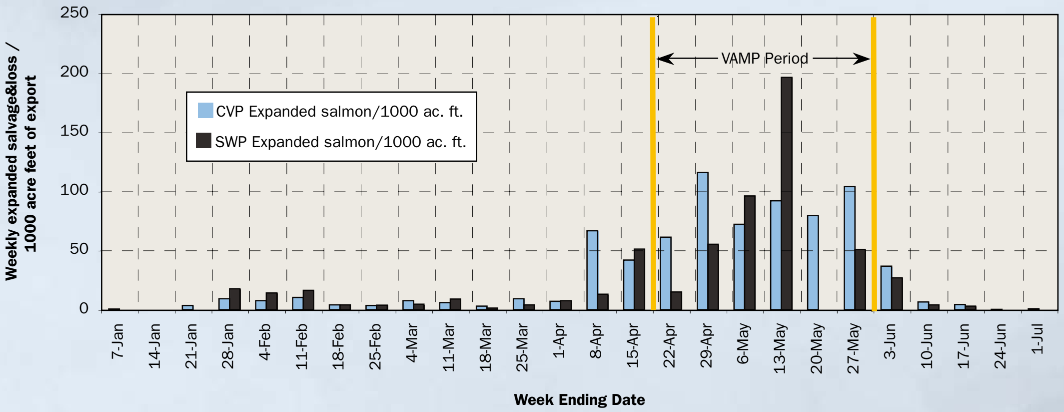
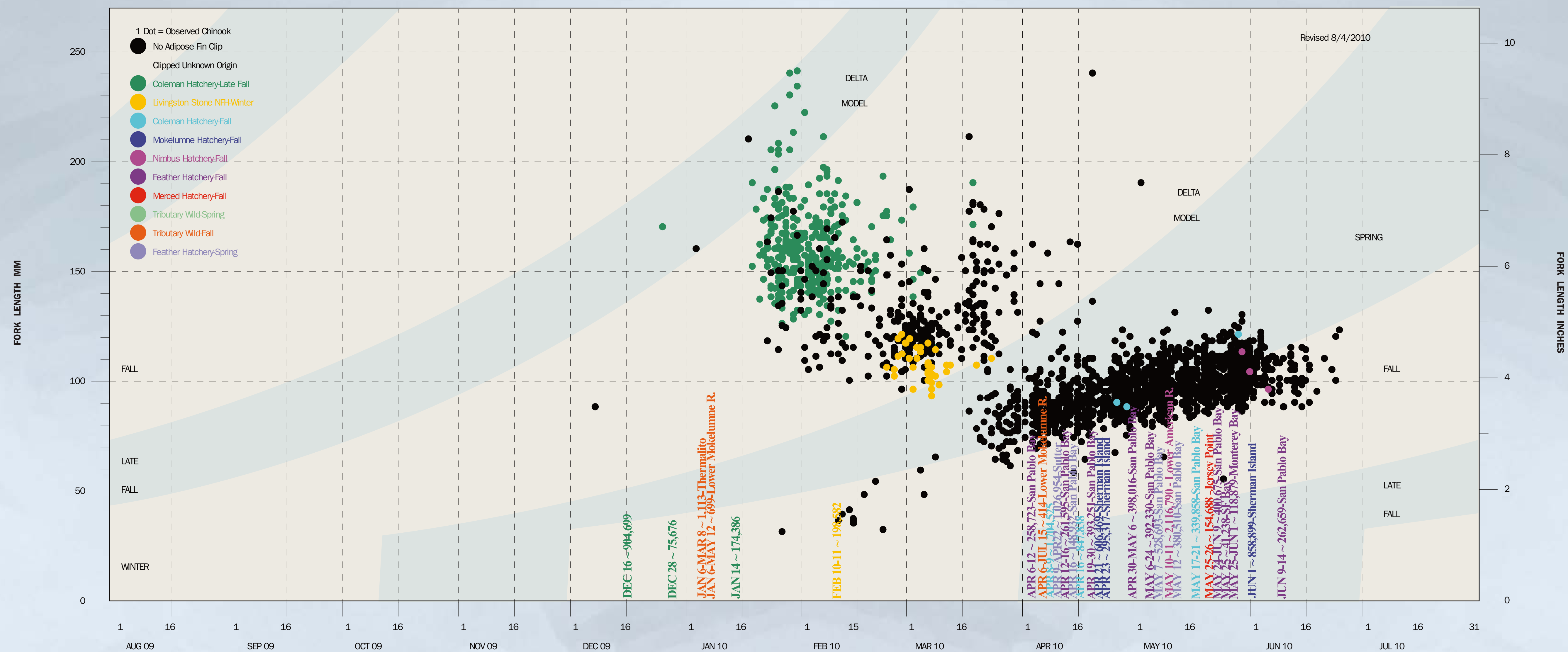


Figure 5-25
Observed Juvenile Chinook Salmon Salvage at the State Water Project (SWP)
& Central Valley Project (CVP) Delta Fish Facilities from 8/1/2009 Through 7/31/2010
(Source: S Greene, DWR)



CHAPTER 6

COMPLIMENTARY STUDIES RELATED TO THE VAMP

Throughout 2010 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 a selection of those studies. Any opinions and conclusions presented in this chapter are solely of the author(s) and are not necessarily 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, 2010

Contributed by 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 flows, exports, and a barrier at the head of Old River) relate to survival through the Delta. 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. Basin flow patterns and rainfall for the first half of 2010 are shown in Figure 6-1 while turbidity and water temperatures for the first half of 2010 are shown in Figures 6-2 and 6-3, respectively.

During 2010, sampling with rotary screw traps (RST) was conducted near the confluences of the Stanislaus and Tuolumne Rivers with the SJR. Rotary screw trapping was not conducted in the Merced River in 2010. Seining was carried out in the SJR from below the head of Old River (HOR) to upstream of the Tuolumne River confluence. This review presents data from these monitoring projects to identify the presence and movement of juvenile salmon from the tributaries into the mainstem San Joaquin River relative to observations at the Mossdale Trawl and in Central Valley Project (CVP) and State Water Project (SWP) salvage facilities.

Salmon were assigned to lifestage categories based on a forklength (FL) scale, where <50 mm= fry, 50-69 mm= parr, and ≥ 70 mm= smolt.

RST monitoring was conducted on the Stanislaus River at River Mile (RM) 9 (Caswell site) from January 12th – June 17th. During 2010, there were eight non-sampling periods that ranged from three to seven days on the Stanislaus River. RST monitoring was conducted continuously (7 days per week) from January 6th – June 17th on the Tuolumne River at RM 5 (Grayson site). Weekly seining was conducted from January through June at up to 8 sites on the mainstem San Joaquin River from RM 51 (Dos Reis below the HOR) to RM 83 (downstream of the Tuolumne River confluence) and biweekly seining was conducted at RM 78 and RM 90 from mid-January through late May. Trawling was conducted on the San Joaquin River at Mossdale near RM 54 (downstream of the tributaries, and just upstream of the Head of Old River) with a schedule of three days/week January through March; five days per week April through May; and three days per week during June.

Overall, Chinook outmigrant abundance in 2010 was low in the San Joaquin Basin, consistent with the low number of adults that returned to spawn during fall 2009. A combined total of 2,410 juvenile Chinook salmon (excluding Merced River outmigrants) were captured in the RSTs (n=1,056) and in the Mossdale trawl (n=1,354); none were caught in the seine sampling. These fish were mainly the progeny of an estimated 2,156 spawners in the San Joaquin Basin the previous fall. The escapement to the San Joaquin Basin in 2009 was a 21% increase over estimated escapement of 1,777 in 2008, and an 81% increase over estimated escapement of 1,192 in 2007, which was the lowest

Figure 6-1
San Joaquin River Basin Rainfall at Don Pedro Reservoir and Flow on the Stanislaus, Tuolumne, Merced and San Joaquin Rivers for January – June, 2010

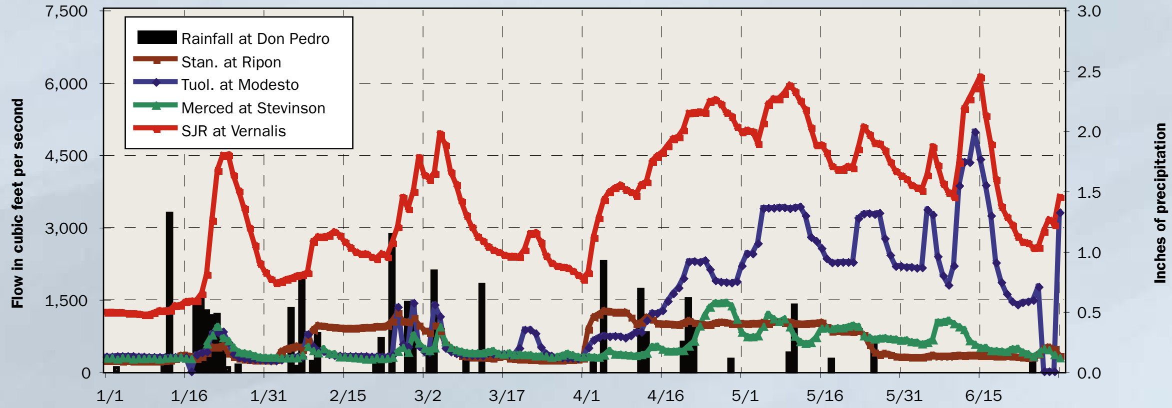


Figure 6-2
Turbidity Levels for the San Joaquin River (Daily Averages) and the Stanislaus and Tuolumne Rivers (Tributary data are instantaneous readings at the most downstream rotary crew trap locations) for January – June, 2010

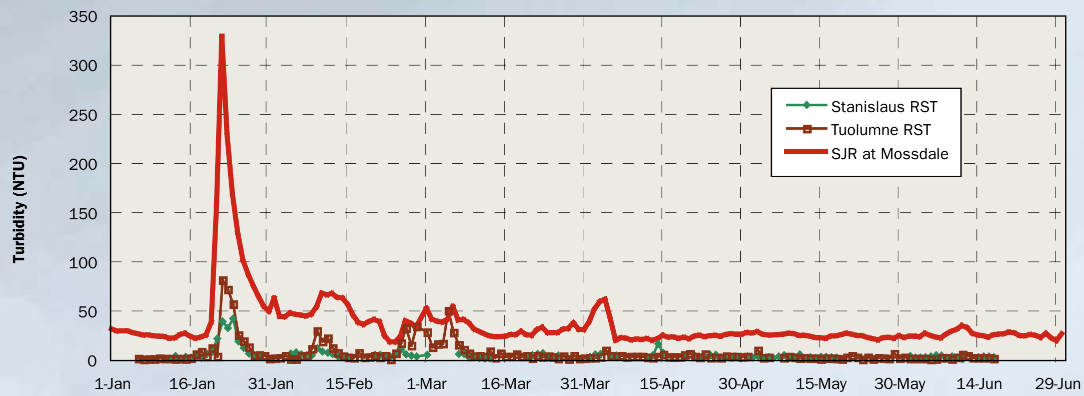


Figure 6-3
Water Temperatures (F°) for the San Joaquin River and the Stanislaus, Tuolumne and Merced Rivers for January – June, 2010

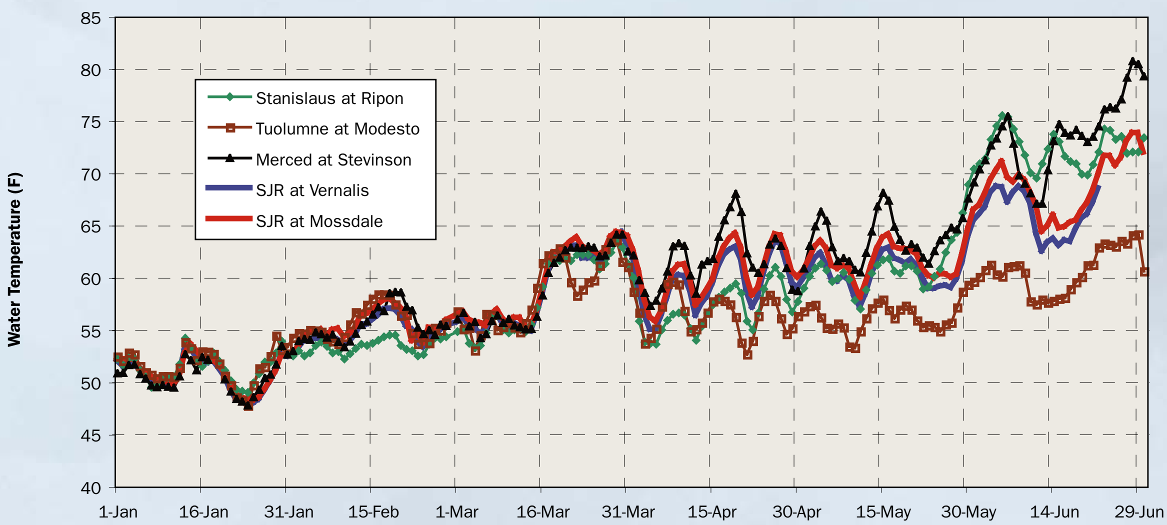


Figure 6-4
Tuolumne River Screw Trap Catch of Unmarked Juvenile Chinook Salmon for January – June, 2010 as Compared with River Flow at Modesto

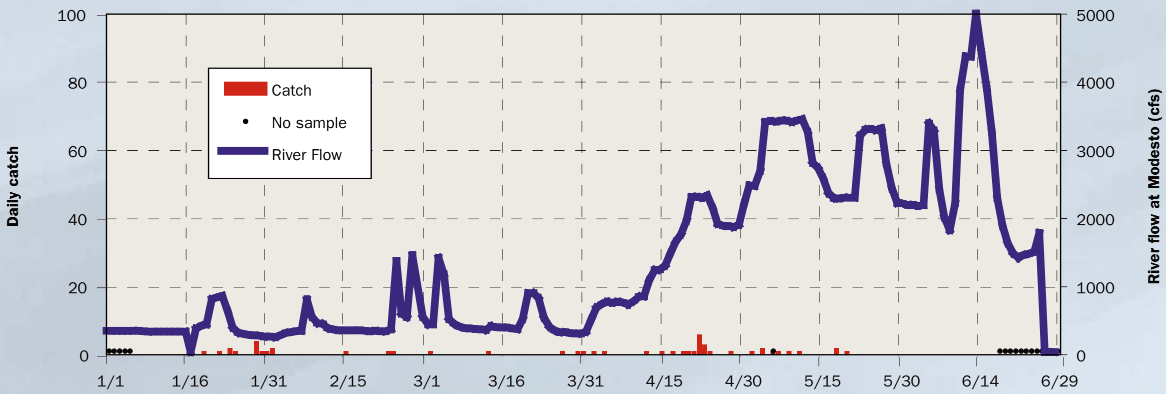


Figure 6-5
Stanislaus River Screw Trap Catch of Unmarked Juvenile Chinook Salmon for January – June, 2010 as Compared with River Flow at Ripon

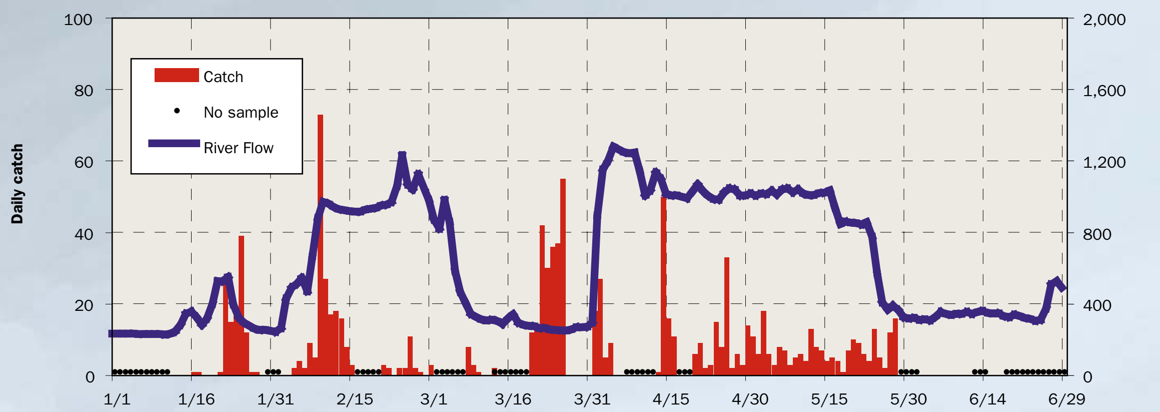
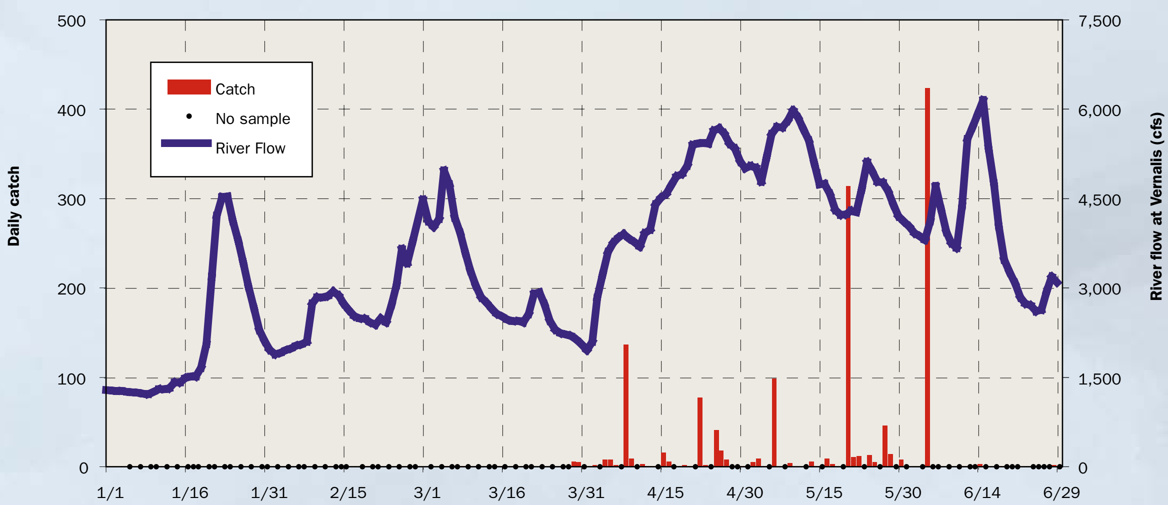


Figure 6-6
Kodiak Trawl Catch of Unmarked Juvenile Salmon on the San Joaquin River near the Mossdale Bridge Gage for January – June, 2010 as Compared with River Flow at the Vernalis Gage (VNS)



estimate since 1992. A few relatively large juveniles in the tributary and Mossdale catch indicate the presence of fall-run yearling outmigrants from the 2008 run or from races other than fall-run. Fry catch was relatively low at the RST monitoring sites, the Mossdale trawl, and the CVP and SWP salvage facilities compared to previous years, suggesting few fry migrated out of the tributaries during 2010.

At the Tuolumne River RST, there were no obvious peaks in fry movement (Figure 6-4) and fry catch never exceeded four fish per day. A seasonal peak catch of fry (n=73) at the Stanislaus River RST (Figure 6-5) occurred on February 9th, during the initial increase in reservoir releases beginning on February 1, 2010. Stanislaus River flows remained around 1,000 cfs for the entire month of February. Only three salmon fry (i.e. <50 mm) were captured in the Mossdale trawl, which was consistent with the low numbers of fry that migrated out of the Stanislaus and Tuolumne (Figure 5-b). Further, the number of fry salvaged at the CVP and SWP facilities (n=10) was low compared to years of high outmigrating fry abundance. It is unknown if fry migrated out of the Merced River, however based on the trends observed on the other two tributaries, the Mossdale trawl, and the salvage from the CVP and SWP facilities, it is likely that fry outmigration was low.

The seasonal peak catch of parr/smolt in the Stanislaus River RST (Figure 6-5) occurred on March 26th (n=55) during a period of relatively low flows, which took place during the entire month of March. This peak in catch may have extended for a longer period, however there was a gap in sampling between March 14th and 19th, just after a short period of rainfall on March 13th. During this non-sampling period there was a relatively slight increase in flow on March 17th. An additional peak in catch (n=50) occurred on April 14th, following a short period of non-sampling, which occurred just after a peak in flows. Salmon were captured at the Stanislaus RST each day during the VAMP period (April 25th – May 25th) and daily catch ranged from 1 to 33 fish. Due to the timing of the periods of non-sampling at the Stanislaus RST, it is difficult to examine the relationship between environmental variables, such as flow and rainfall, and Chinook catch. Neither of two peaks noted above were detected immediately after in the sampling at Mossdale, however, a peak was detected on April 8th, thirteen days after the main Stanislaus peak (Figure 6-6). This may indicate there was a substantial lag in timing between these sites, or may reflect a peak in salmon from the Merced River, which was not sampled with a RST. Very low catches of parr/smolt salmon were observed at the Tuolumne River RST throughout the spring and daily catch never exceeded six fish (Figure 6-4). The highest catch (n=6) occurred on April 22nd, during a peak in flow due to a rain event from April 20th to 22nd.

Average size of salmon captured in the RSTs and Mossdale trawl prior to early March (Figure 6-7) was less than 50 mm fork length (FL). In contrast, average size in the salvage prior to late March indicates that most salvaged 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, indicates that few fry of San Joaquin Basin origin were likely entrained by the pumps during 2010. It appears that salvage during January through March was dominated by larger fish, which were likely of other races originating from the Sacramento Basin - average size at the RSTs and Mossdale typically increased by early April to >70 mm FL (Figure 6-7).

To obtain more useful information on the timing of salmon movement into the Delta, daily monitoring for the entire outmigration season (roughly January through June) in the lower end of each of the three San Joaquin tributaries and at Mossdale is a high priority. Further evaluation of the trawl and salvage efficiency for sampling and capture of smaller juvenile salmon is necessary. These data would help to refine existing protective measures for fry, parr and 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.

2010 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 tshawytscha*) 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 6-8). 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.

Figure 6-7
Daily Average Forklength (FL) of Unmarked Juvenile Chinook Salmon in the San Joaquin River Basin and Delta Pumping Facilities for January – June, 2010

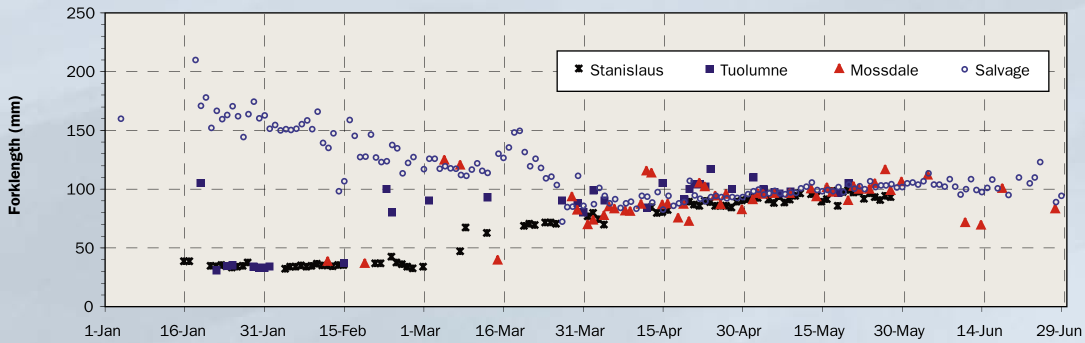
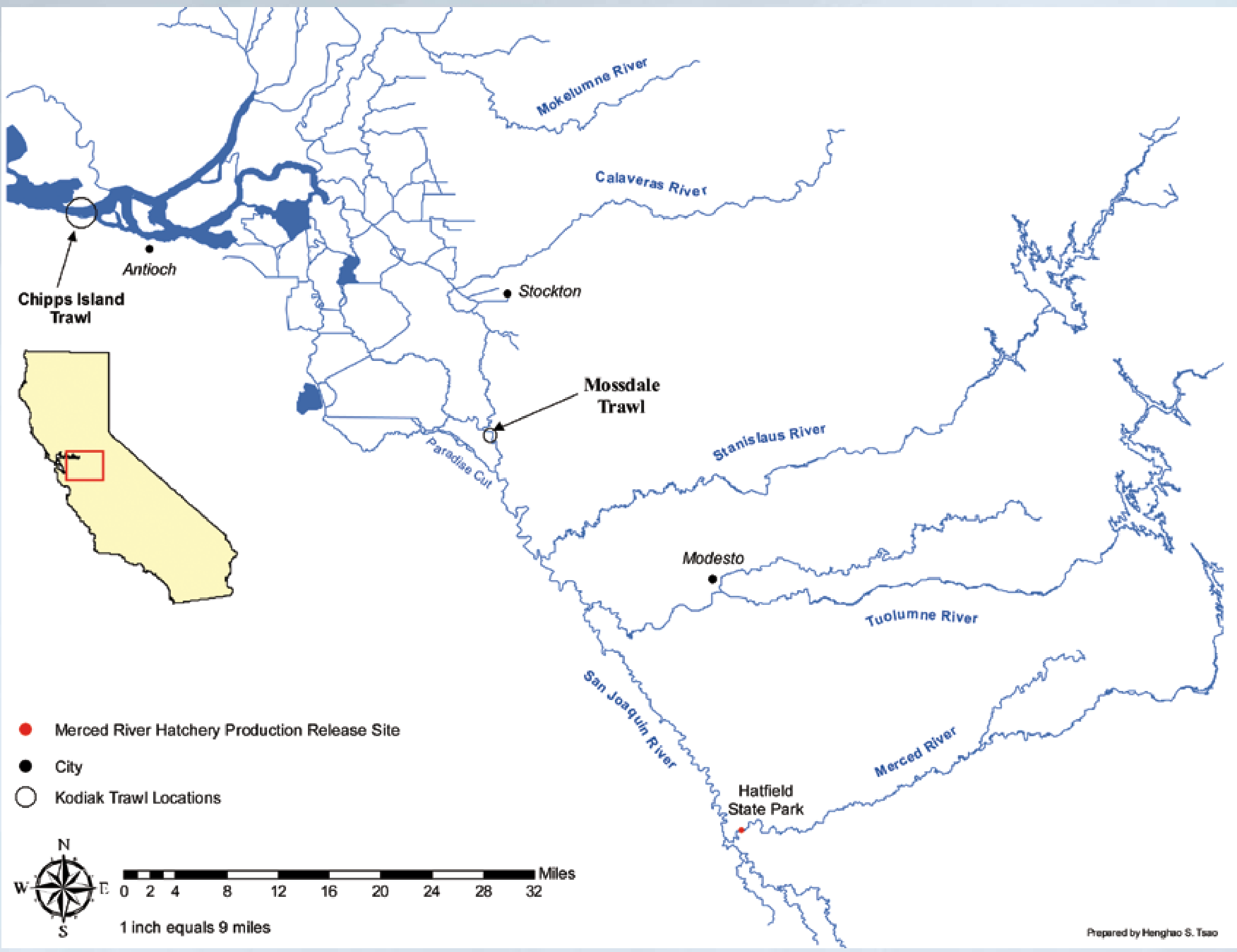


Figure 6-8
Location Map of the Mossdale Trawl Area in the Lower San Joaquin River, 2010



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 29th to May 30th, and three days a week from May 31st to June 20th and two days a week from June 21st to June 30th. During 2010, the entire sampling period was from March 29th to June 30th with a total of 59 sample days out of the study period of 94 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 days were extended on days when efficiency tests were conducted. 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 (FL), 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 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 2010 natural smolt production from the San Joaquin River drainage was estimated by three 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

Figure 6-9
Natural Logarithm of Efficiency Tests 1989-2010 for San Joaquin River Flows at the Vernalis Gage (VNS) in Cubic Feet per Second

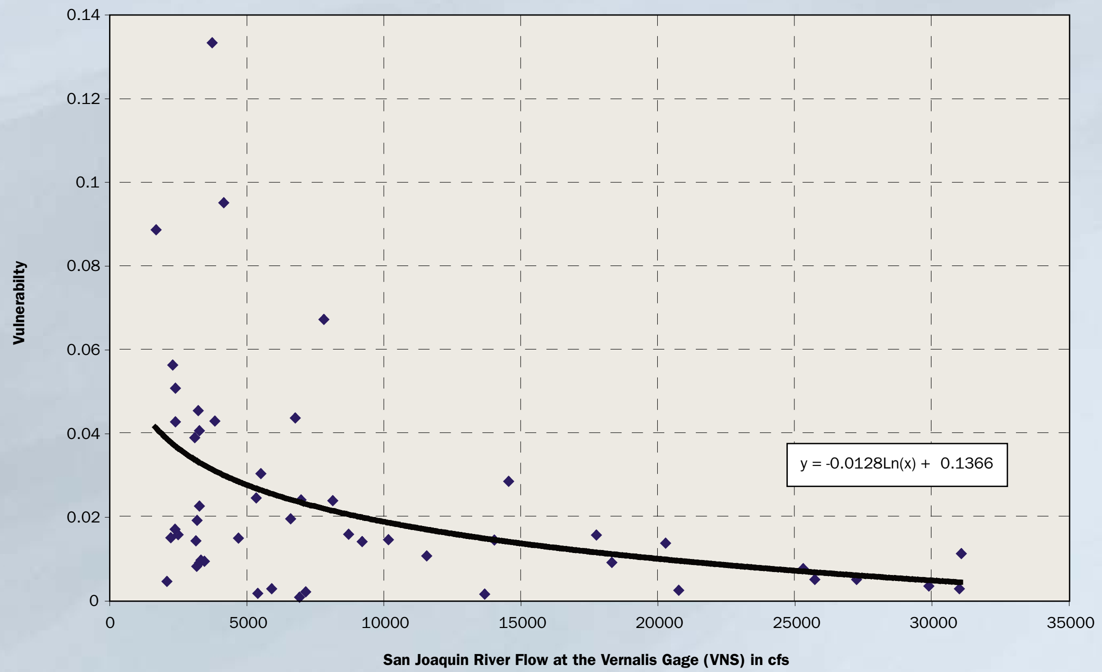
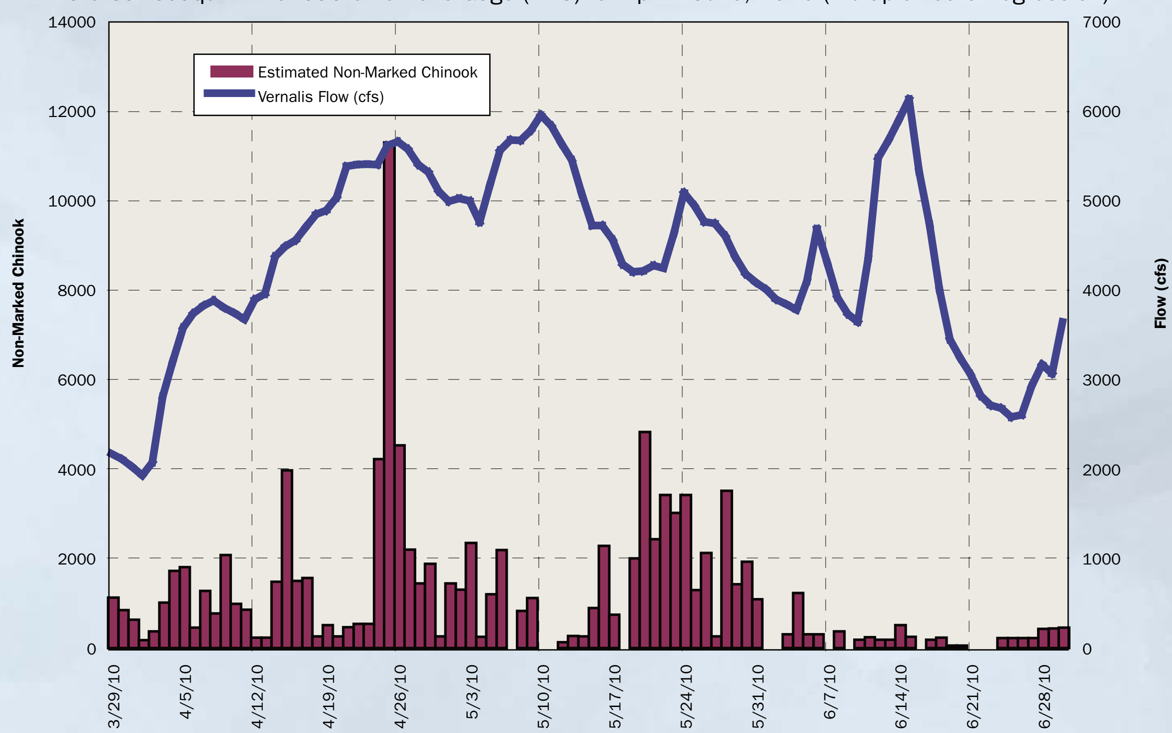


Figure 6-10
Expanded Daily Catch of Non-marked Chinook Salmon Based on Vulnerability Expansion Estimates and Flow in the San Joaquin River at the Vernalis Gage (VNS) for April – June, 2010 (Multiple Years Regression)



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 smolt production index estimates (E_I) are calculated as follows:

$$E_I = \sum_{i=1}^{n=94} \left[\left(\frac{C_i}{V_{Ti}} \right) \left(V_{Pi} \right) \left(\frac{24}{5} \right) \right]$$

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 = *i*th 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 94 days.

Vulnerability Expansion Estimate (Single Year Population Ratio Method):

The second estimate: Vulnerability Expansion Estimate (Single Year Population Ratio Method) is determined based on the recapture rates of dye marked vulnerability release groups. There were 7 vulnerability test groups in 2010 (Table 6-1). A population ratio is calculated based on these 7 test groups. The population ratio is used to calculate a 5-hour index, and extrapolated into 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.

The single year population ratio (r) is calculated as follows:

$$r = \frac{\sum_{i=1}^{n} y}{\sum_{i=1}^{n} x} = \frac{\overline{y}}{\overline{x}}$$

Where:

r = population ratio

n = number of vulnerability test groups

y = number of marked fish captured

x = number of marked fish released (effective release)

i = *i*th day

The vulnerability Expansion Estimation is then calculated by:

$$E_V = \sum_{i=1}^{N=94} \left\{ \left[\frac{(C_i / r)}{(T_i / 300)} \right] \left(\frac{24}{5} \right) \right\}$$

Where:

E_V = vulnerability Expansion Estimation

r = population ratio

C = daily non-marked Chinook catch

T = tow duration

i = *i*th day

N = number of days sampled

For the purpose of the analysis, vulnerability to the trawl was assumed from the beginning of the first tow with test fish 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. 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 (Table 6-1).

Vulnerability Expansion Estimate (Multiple Years Regression Method):

The third estimate: Vulnerability Expansion Estimate (Multiple Years Regression Method) is also determined based on the recapture rates of dye marked vulnerability release groups. Vulnerability is estimated based on the natural logarithm of all vulnerability tests from previous years (1989-2010) (Figure 6-9). This number is then extrapolated to a 5-hour index and a 24-hour seasonal estimate. Production for days not sampled within the study period was estimated by averaging smolt catch and minutes towed for the 2 days before and 2 days after the non-sampled period.

$$E_V = \sum_{i+1}^{n=94} \left[\frac{\frac{C_i}{V_i}(60*24)}{T_i} \right]$$

Where:

n = Days in the index period

C = Daily non-marked Chinook catch

T = Minutes towed

i = ith Day

V = $[Ln(F) \times (-0.0128)] + 0.1366$ (Figure 6-9); Daily Vulnerability Estimate

F = Mean daily flow for the San Joaquin River at the Vernalis (VNS) Gage

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

There were 296 non-marked Chinook salmon smolts captured in the Mossdale trawl between March 29 and June 30, 2010. An additional 11 Chinook were captured, but escaped the net before being brought onto the boat. Daily capture of non-marked salmon ranged from 1 to 41 individuals with an average of 5.0 captured per day. Figure 6-10 shows the Vulnerability Expansion Estimate (Multiple Years Regression Method) of non-marked Chinook. The forklength (FL) of non-marked Chinook ranged between 60 and 192 mm. The average forklength (FL) for non-marked Chinook was 93.5 mm.

The smolt production estimate for the San Joaquin basin was 53,093 using the smolt production index calculation, 62,176 using the vulnerability expansion estimate (single year population ratio method), and 104,385 using the vulnerability expansion estimate (multiple years regression method) (Table 6-2).

Three Steelhead (*Oncorhynchus mykiss*) were captured and returned to the river during the 2010 sampling period. All three individuals were in the stage of smolting and had forklengths (FL) ranging between 275-360mm (310mm average). One deceased Delta smelt (*Hypomesus transpacificus*) (FL 25mm) was removed from the net on June 14th. Species identification was confirmed by both CDFG and USFWS biologists.

Table 6-1
Dye Marked Hatchery Smolt Release for Vulnerability Studies in the San Joaquin River at Mossdale Landing, April through June 2010

Release Date /Time	Water Temp. (°C) Truck/River	Effective # Released	Number Recovered	Streamflow (cfs) at Vernalis	Beginning and Ending Recovery Time
8-Apr-10	11˚C/13.5˚C	3037	133	3861	11:18
8:24					12:58
22-Apr-10	11˚C/13.5˚C	3055	75	5378	10:01
8:13					11:42
6-May-10	N/A	2992	91	5537	10:07
8:30					10:57
13-May-10	11˚C/16˚C	3081	5	5430	10:11
8:10					12:48
20-May-10	9.5˚C/15˚C	3044	292	4193	10:09
8:40					11:23
27-May-10	10.5˚C/14.5˚C	3016	45	4723	9:11
8:00					11:27
4-Jun-10	12˚C/19˚C	3123	416	3760	9:45
8:22					14:25

Table 6-2
Chinook Salmon Smolt Production Seasonal Estimates and Sampling Period for Before and During the VAMP Study

Year	Sampling Period (Days)	Percentage of Day Sampled (%)	Smolt Production Index Calculation (Smolt/ac-ft Estimate)	Vulnerability Expansion Estimate Single Year Population Ratio Method (95% confidence range)	Vulnerability Expansion Estimate Multiple Years Regression Method (1989-2010)
2010	94	63	53,093+1,640	62,176 : (29,393 - 166,754)	104,385
2009	92	63	50,827+1,690	**	168,574
2008	91	63.7	188,652 + 8,010	285,886 : (139,406 - 323,675)	470,665
2007	75	76	273,798 + 7,490	**	755,812
2006	75	85.3	848,394 + 12,888	1,808,143 : (1,025,096- 5,423,123)	2,074,469
2005	89	80.9	363,800 + 14,700	621,403 : (388,884- 1,119,550)	667,301
2004	61	88.5	92,500 + 66,500	297,348 : (191,222- 665,160)	275,721
2003	88	80.7	107,500 + 60,300	368,424 : (277,626- 545,121)	455,574
2002	74	87.8	229,100 + 557,100	2,254,647 : (1,455,066- 5,179,591)	607,553
2001	103	78.6	279,800 + 286,000	928,996 : (586,790- 2,228,789)	703,509
2000	88	81.8	211,100 + 181,900	*	403,629
1999	119	71.4	146,900 + 63,500	*	366,427
1998	99	67.7	1,075,000 + 562,800	*	2,497,345
1997	92	69.6	168,600 + 89,400	*	528,070
1996	89	85.4	381,900 + 626,900	*	968,742
1995	60	78.3	1,108,900 + 2,640,000	*	2,993,015
1994	63	73	67,500 + 62,200	*	374,035
1993	83	61.4	54,200 + 21,800	*	223,453
1992	72	44.4	23,600 + 6,300	*	230,694
1991	59	66.1	*	*	441,785
1990	82	69.5	*	*	316,903
1989	54	100	*	*	3,497,682

* Data is currently being reevaluated.
** No hatchery juvenile Chinook salmon available for efficiency test

Health and Physiological Assessment of VAMP Release Groups

Contributed by Ken Nichols, U. S. Fish and Wildlife Service, CA-NV Fish Health Center, 24411 Coleman Fish Hatchery Rd., Anderson, CA 96007
http://www.fws.gov/canvfhc/ (Nichols, K. 2010)

Summary:

A general pathogen and physiological screening was conducted on three of the seven 2010 VAMP release (tagged) groups and cohorts of release groups remaining at Merced River Hatchery (MRH). No viral or bacterial pathogens were detected in the release groups.
The most significant health problem observed was *Tetracapsuloides bryosalmonae* infection, with majority of salmon examined exhibiting early stages of clinical Proliferative Kidney Disease. No mortality or evidence of physiological impairment was observed either the tagged or MRH groups.

Introduction

As a component of the 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 smolt physiological assessment. The health and physiological condition of the fish helps explain their performance and survival during the study. Pathogen screening during past VAMP studies has regularly found infection with the myxozoan parasite *Tetracapsuloides bryosalmonae*, the causative agent of Proliferative Kidney Disease (PKD). This parasite has been shown to cause mortality in Merced River Hatchery salmon with increased mortality and faster disease progression in fish at higher water

Table 6-3
Fish Sampled for VAMP 2010 for Health and Physiological Assessment. Groups Included Dummy-tagged Fish Held for 48 Hours at the Release Sites (Tagged) and Unmarked Cohorts Held at Merced River Hatchery (MRH)

Release	Dates	Tagged	MRH
1st Release	April 28th-29th	30	30
3rd Release	May 5th-6th	30	30
7th Release	May 19th-20th	30	No sample

Table 6-4
Severity of Clinical Proliferative Kidney Disease in Chinook Salmon Used in the 2010 VAMP Studies. Data Presented as the Number of Fish with Kidney Inflammation Rated as Normal, Focal, Multifocal or Diffuse in Histological Examination. Fish were 48-hour Dummy-tagged (Tagged) or Merced River Hatchery (MRH) Groups Sampled on the 1st, 3rd or 7th Releases

Release	Group	Normal	Focal	Multifocal	Diffuse
1st Rel	Tagged	1	19	6	3
	MRH	14	12	3	1
3rd Rel	Tagged	1	17	10	2
	MRH	2	20	7	1
7th Rel	Tagged	0	4	13	13

Table 6-5
Intensity of T. bryosalmonae Infection in Chinook Salmon Used in the 2010 VAMP Studies. Data Presented as the Number of Fish with Zero (None), <10 (Low), 11-30 (Moderate) or >30 (High) T. bryosalmonae Parasites Observed in Histological Examination of Kidney Tissue. Fish were 48-hour Dummy-tagged (Tagged) or Merced River Hatchery (MRH) Groups Sampled on the 1st, 3rd or 7th Releases

Release	Group	None	Low	Moderate	High
1st Rel	Tagged	0	0	17	12
	MRH	1	13	11	5
3rd Rel	Tagged	0	0	10	20
	MRH	0	6	20	4
7th Rel	Tagged	0	1	1	28

temperatures (Ferguson 1981; Foott, Stone and Nichols 2007). The objectives of this project was 1) survey the juvenile Chinook population used for the VAMP study for specific fish pathogens including *Tetracapsuloides bryosalmonae*, 2) assess smolt development (gill Na^+-K^+ ATPase) and 3) determine if holding and tagging fish in delta water had any detrimental effect on the health.

Methods

Sample Groups

Two groups of Juvenile Chinook salmon were examined. The first groups were dummy-tagged fish, held in pens for 48 hours in the San Joaquin River at the Durham Ferry, Old River, and Stockton release sites (tagged). The second group was unmarked cohorts held at the Merced River Hatchery (MRH). Health monitoring was performed during three of the seven 2010 VAMP release periods (Table 6-3). For tagged groups, 10 fish at each of the 3 release sites were sampled during the 1st, 3rd and 7th releases. For the MRH groups, 30 fish were sampled directly from the hatchery tanks on April 28th and May 5th (1st and 3rd releases).

Sample Collection

Fish were euthanized in groups of 3 or 4 fish, any abnormalities were noted, and tissue samples for pathology and physiology assays were collected. Field collection and lab assays are briefly 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*

Figure 6-11

Micrographs of Hepatic Glycogen Reserves (Clear White Vacuoles) in 48-hour Dummy-tagged (Tagged) and Merced River Hatchery (MRH) Salmon Livers. Note the Dense Cytoplasm in Smaller Hepatocytes of Tagged Groups vs. Enlarged, Vacuolated Hepatocytes Typical of MRH Groups

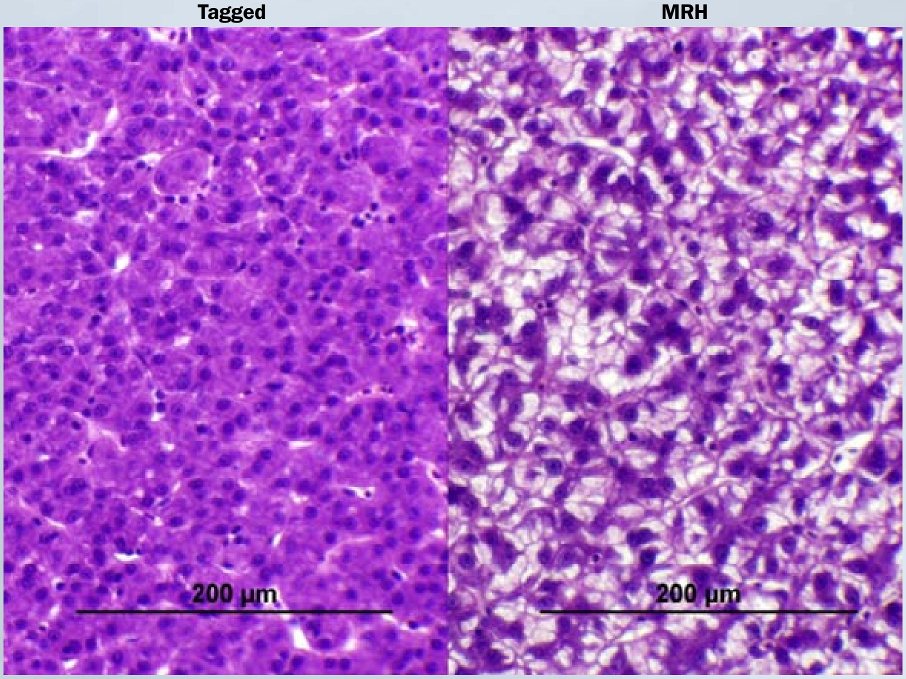
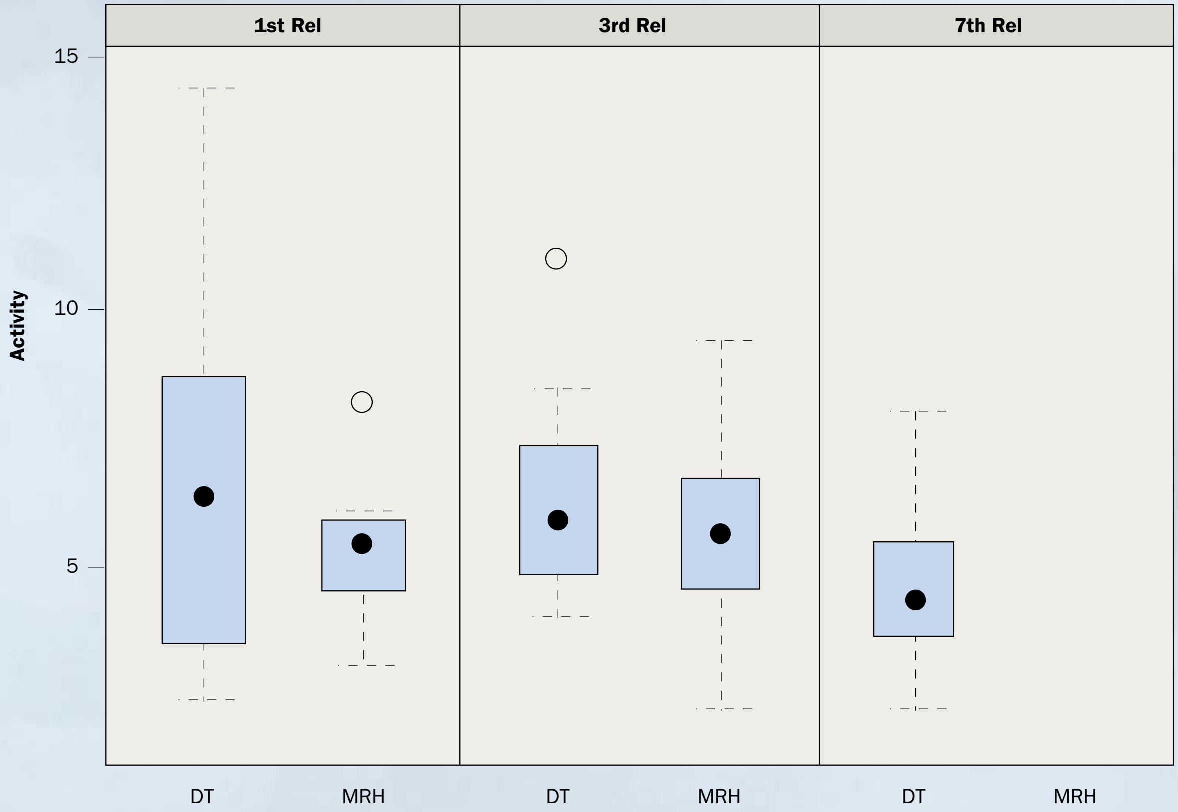


Figure 6-12

Gill Na+, K+-Adenosine Triphosphatase Activity (µmol ADP/mg protein/hour) in Chinook Salmon Which were Dummy Tagged and Held for 48 hours at the Release Site (DT) or Cohorts of Tagged Fish Held at the Merced River Hatchery (MRH). Sampling was Performed on the First (1st Rel), Third (3rd Rel) and Seventh (7th Rel) of the 7 Release Periods



(the bacteria that causes bacterial kidney disease) was screened by fluorescent antibody test of kidney imprints.

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).

Histopathology –The gill, liver, intestine 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 under a light microscope. Infections of the myxozoan parasite *T. bryosalmonae* were rated for intensity of parasite infection and associated tissue inflammation. Intensity of infections was rated as None (zero), Low (<10), Moderate (11-30) or High (>30) based on number of *T. bryosalmonae* parasites observed. Kidney inflammation rated as normal, focal, multifocal or diffuse. Data analysis was performed using R version 2.11.1 using Fisher's Exact Test for Count Data.

Gill ATPase - Gill Na^+, K^+-Adenosine Triphosphatase activity (ATPase) was assayed by the method of McCormick and Bern (1989). Gill ATPase activity is correlated with osmoregulatory ability in saltwater and is located in the chloride cells of the lamellae. Data analysis was performed using R version 2.11.1 by Wilcoxon rank sum and Kruskal-Wallis rank sum tests.

Results

Summary results of pathogen testing are presented in Table 6-3. No obligate viral or bacterial pathogens were detected however *Aeromonas-Pseudomonas* bacteria were isolated in 11% of the bacterial samples. This group of gram-negative bacterial 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.

Histopathology – Infections with *T. bryosalmonae* were observed 99% (148/149) of the fish examined. Clinical PKD was observed in both Tagged and MRH fish groups. In tagged sample groups, the incidence of clinical PKD (multifocal or diffuse kidney inflammation, Table 6-4) increased from 31% (9/29) during the 1st release, to 40% (12/30) during the 3rd release and 87% (26/30) during the 7th release ($p<0.001$). No difference in incidence of clinical PKD (disease state) was observed between tagged and MRH fish groups in either the 1st ($p=0.125$) or 3rd ($p=0.412$) releases. The intensity of *T. bryosalmonae* infection (number of parasites) was significantly lower in MRH fish compared to tagged fish groups in both the 1st and 3rd releases (Table 6-5, $p<0.001$ both releases). The intensity of infection increased with later releases in tagged groups ($p<0.001$), but no difference was detected in fish sampled at MRH between the 1st and 3rd release periods ($p=0.072$). An apparent difference in liver glycogen reserves was noted between tagged and MRH fish groups. In histological examination of the liver, fish from the MRH groups appeared to have higher hepatic glycogen reserves compared to tagged fish (Figure 6-11). No significant external parasitic infections or evidence of adverse environmental conditions were identified in any of the gill sections examined.

Gill ATPase activity values ranged from 2.1 to 14.4 µmol ADP/mg protein/hr. No difference was observed between tagged and MRH fish groups in the 1st and 3rd Releases ($p=0.283$ and $P=0.546$). A slight decline in ATPase activity between releases was observed in tagged groups ($p=0.017$, Figure 6-12).

Discussion

Most of the 2010 VAMP study fish were in early stage PKD. High incidences of *T. bryosalmonae* infection are not unusual in juvenile Chinook from MRH. The onset of clinical disease in these fish normally occurs after the VAMP studies have concluded (Foott, Stone and Nichols 2007; Foott and Stone 2008). In 2010, clinical PKD was observed in 31% of the tagged fish from 1st release and by the 7th release 87% of these fish had clinical infections. In 2005 and 2008, VAMP study fish were held in the CA-NV Fish Health Center wet lab and observed through the typical PKD period, and total mortality due to the disease was low at 20%-27% (Foott, Stone and Nichols 2007; Foott and Stone 2008). These studies also found that fish with clinical PKD continued to perform well until late into the disease. No mortality was observed in the tagged fish groups sampled in this study suggesting VAMP study fish had not entered late stage disease by the time fish were released. Proliferative Kidney Disease is progressive and some of the study fish would eventually become impaired due to the disease; however, this study did not follow fish condition or mortality after release. In the future, it would be possible to estimate performance of study fish after release by tracking mortality in cohorts of the tagged fish held in tanks for the expected study period.

Compared to MRH cohorts, tagged fish groups had higher parasite intensity and lower hepatic glycogen reserves. While there was a higher intensity of T. bryosalmonae infections in tagged groups compared to cohorts at held at MRH, no significant difference in disease severity was detected. Replication of this parasite within the fish host is temperature dependent (Ferguson 1981). It was expected that PKD progression would follow the same pattern as parasite intensity. The histological rating system used may not have been sensitive enough to detect the change. A rating system based on several tissues may better summarize overall disease state. A difference in hepatic glycogen reserves between tagged and MRH fish groups was also noted. While it was not quantified the difference between the groups was readily apparent in histological examination of the liver (Figure 6-11). It is not unusual to find high hepatic glycogen in hatchery fish which are fed a high energy diet. The lower glycogen stores in tagged groups was a possible indicator of short term starvation or stress (Phillips 1969; Barton, Morgan and Vijayan 2002) and was observed in all tagged fish groups. In the future it would be of interest to monitor energy storage to determine if any release groups were at a disadvantage.

Gill ATPase activity in salmonids typically increases and peaks near the time of most active migratory behavior (Duston, Saunders and Knox 1991; Ewing, Ewing and Satterthwaite 2001; Wedemeyer 1996). Median activity levels measured in this study (5.8 µmol ADP/mg protein/hr) were lower than activity levels measured in the 2009 VAMP study (7.3-10.4 µmol ADP/mg protein/hr, Nichols and Foott 2009). Due to differences in sampling conditions and assay conditions between years these values will have some variability. However, the data also suggests activity levels were declining in the later release groups. It is possible 2010 VAMP release groups had already reach peak smolt status and were beginning parr-reversion. Decreases in ATPase activity can also occur due to increases in water temperature (Duston et al. 1991). Once fish reach salt water gill ATPase activity levels can rapidly increase.

CHAPTER 7

CONCLUSIONS AND RECOMMENDATIONS

The 2010 VAMP was the first year after three consecutive dry years and the 2009 implementation of the sequential dry-year relaxation of the San Joaquin River Agreement. During 2009, there was no Target Flow. A minimum base flow of 2,000 cfs was maintained in 2009. In contrast, 2010 saw a Target Flow of 4,450 cfs but often flows were higher due to late spring rainfall and cooler than average weather. The VAMP coordinated actions to ensure as closely as possible a stable flow rate at Vernalis during the 2010 VAMP period. The hydrologic conditions for the Water Year 2010 winter were very close to average 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 100% of average on April 1, 2010. The mean daily flow at Vernalis varied between 4,210 cfs and 5,890 cfs over the 31-day VAMP period (April 25th to May 25th). The observed exports during this period averaged 1,520 cfs and ranged from 1,320 cfs to 1,560 cfs. The start of the VAMP Fish experiment was delayed to April 25th to May 25th to allow the test fish to increase in size. Flow and fish size were two factors that presented challenges to the VAMP team in meeting their primary goal of demonstrating that acoustic telemetry technology can be implemented full scale in the South Delta.

Many of the difficulties encountered in 2009 were overcome in 2010 and the VAMP team had greater success in deploying and maintaining the large open-water receivers at Chipps Island, tracking smolts through numerous channels, obtaining larger fish for tagging and maintaining an acoustic receiver network throughout the South Delta that has in the past presented challenges to VAMP team in meeting the second goal of better defining route selection and survival between various reaches in the Delta.

The third goal of the 2010 VAMP was to acoustically tag and release fall-run smolts for estimating survival and route selection in various South Delta channels and to Chipps Island. Reaching this goal was still challenged by the time consuming data processing from numerous receivers, data interpretation for smolts that potentially have been consumed by predators in the modeling of the survival through the South Delta and understanding and dealing with observed high mortality within certain reaches within the South Delta. The VAMP Team however made great progress in 2010 in improving the reliability of the data processing procedures and minimized lost data during receiver malfunctions.

Table 7-1
Summary of VAMP 2010 Issues and Recommendations

CHALLENGE OR ISSUE FACED BY VAMP	RECOMMENDATIONS FOR 2011
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 and high spring flows in 2010 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.
The San Joaquin River Restoration Flows were first encountered in 2010 and made flow prediction at Vernalis more difficult.	Continue to coordinate with the SJRRP to develop more reliable methods for flow estimation of releases made before and during the VAMP period.
Flow data collected in 2010 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 in fish growth push the study start later than the April 15th – May 15th default period as was used in many of the past years with CWTs.	Continue intensive temperature monitoring throughout the experiment. Work with DFG Hatchery specialists to develop strategies to enhance smolt growth prior to the VAMP period. Continue to improve the use of the TFCF for holding and tagging of smolts as the environmental conditions are similar to Delta conditions
Deployment of large open-water receivers continues to present a strong technical challenge to the VAMP Team.	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 maximize the coverage of migration routes with shared acoustic receivers. Use redundant and dual receivers at key locations for route selection analysis and end points for the survival modeling.
Receiver overheating under hot spring Delta conditions.	All future telemetry sites exposed to outdoor ambient conditions should utilize the modified joboxes developed during the 2009 VAMP study (Vogel, 2010). Work should continue on other modifications to help improve internal temperatures within the joboxes.
Assessing the importance of route selection at the head of Old River with a non-physical barrier installed and assessing associated predation.	Deployment of a four-port receiver at the head of Old River whether a non-physical barrier is installed or not should be a priority to assess detailed fish behavior and predatory fish behavior.
Interference from line power sources.	Continue to restrict 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 in 2011.
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. Discontinue the use of Feather River Hatchery Fish as were used in 2009 as they may not be representative of the survival of juvenile salmon originating from the San Joaquin River Basin.

Table 7-1 (continued)
Summary of VAMP 2010 Issues and Recommendations

CHALLENGE OR ISSUE FACED BY VAMP	RECOMMENDATIONS FOR 2011
Minimizing mortality after tagging and smolt releases.	Evaluate the benefits of supplemental releases near Stockton and in Old River to supplement the number of tagged fish that make it to Chipps Island
	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.
Loss of data due to receiver malfunctions or vandalism.	Develop remote log-in techniques to continuously check on receiver operations.
	Work with the University of Washington and others to identify critical receiver locations and assure data is gathered with minimal downtime.
	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.
Difficulty in distinguishing between tags in live smolts versus those in predators for the 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 to assess the benefits of classifying detections as 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.
	Conduct modeling using both all detections and only those characterized as being in smolts.

Table 7-1 (continued)
Summary of VAMP 2010 Issues and Recommendations

CHALLENGE OR ISSUE FACED BY VAMP	RECOMMENDATIONS FOR 2011
Due to high mortality, very few tagged smolts released upstream of Vernalis reach as far downstream as Turner Cut, Jersey Point or Chipps Island.	Focus future work to better define the reason for the high mortality in specific reaches of the Delta and 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 and to ensure that enough tagged smolts reach Chipps Island to allow a more robust survival modeling effort.
Continued high mortality in certain reaches and near certain points in the river that may or may not be associated with predation.	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. 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.

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The entire VAMP team would like to extend our appreciation to the U.S. Bureau of Reclamation, the U.S. Fish and Wildlife Service, the California Department of Fish and Game and the California Department of Water Resources for the vast support they provided in implementing this experiment.

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SAN JOAQUIN RIVER GROUP AUTHORITY[1]

[1] *Signatory to the one-year extension of the agreement in 2010*

[2] *San Joaquin River Group Authority Members*

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
BCA	San Joaquin River near the Banta Carbona Intake Structure
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
CDRR	Cubic Feet Per Second
C16	San Joaquin River at Shipping Channel Marker C16 Acoustic Receiver Location
C18	San Joaquin River at Shipping Channel Marker C18 Acoustic Receiver Location
CHPe	Chipps Island East Acoustic Receiver Location
CHPw	Chipps Island West Acoustic Receiver Location
CNFHC	California/Nevada Fish Health Center
CPUE	Catch Per Unit Effort
CRR	Combined Recovery Rate
CRRL	Columbia River Research Laboratory
CVP	Central Valley Project or Central Valley Project Trash Rack
CVPTank	Central Valley Project Holding Tank
CVPIA	Central Valley Project Improvement Act
CWT	Coded Wire Tagged
D-1641	Water Rights Decision 1641 of the SWRCB
DF	San Joaquin River at Durham Ferry - Acoustic Receiver Location
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
MFE	San Joaquin River at Medford Island, East Acoustic Receiver Location
MFW	San Joaquin River at Medford Island, West Acoustic Receiver Location
MID	Modesto Irrigation District
MR	Middle River
MRN	Middle River North Acoustic Reciever Location (2 Receivers)
MRND	Middle River North, Downstream Acoustic Receiver Location
MRNU	Middle River North, Upstream Acoustic Receiver Location
MRS	Middle River South Acoustic Reciever Location
MRH	Merced River Fish Hatchery
MSD	San Joaquin River at Mossdale
MOS	San Joaquin River at Mossdale Acoustic Receiver Location
MSL	Mean Sea Level
MST	Merced River at Stevinson
NEW	San Joaquin River at Newman
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
OH1	Head of Old River
OID	Oakdale Irrigation District
OR	Old River
OR1/OR2	Old River at the junction with San Joaquin River (2 Receivers)
ORN	Old River North Acoustic Reciever Location (2 Receivers)
ORND	Old River North, Downstream Acoustic Reciever Location

ORNU	Old River North, Upstream Acoustic Reciever Location
ORS	Old River South Acoustic Reciever Location (2 Receivers)
ORSD	Old River South, Downstream Acoustic Reciever Location
ORSU	Old River South, Upstream Acoustic Reciever Location
ORT	Old River at Tracy
OSJ	North Old River
PKD	Proliferative Kidney Disease
RGD	Radial Gates at Clifton Court Forebay, Interior Acoustic Reciever Location (2 Receivers)
RGU	Radial Gates at Clifton Court Forebay, Entrance Channel Acoustic Reciever Location
RM	River Mile
RPA	Reasonable and Prudent Alternatives
RST	Rotary Screw Trap
SDIP	South Delta Improvement Project
SDWA	South Delta Water Agency
SEI	Sucrose-EDTA-Imidazole
SJ1/SJ2	San Joaquin River at Lathrop Acoustic Reciever Location (2 Receivers)
SJL	San Joaquin River at Lathrop
SJR	San Joaquin River
SJT	San Joaquin River at Channel Markers 16 & 18
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
STK	San Joaquin River Near Stockton Acoustic Reciever Location
STN	San Joaquin River at Navy Bridge near Stockton Acoustic Reciever Location
STP or SWWTP or SWWTF	Stockton Wastewater Treatment Plant / Facility
STS	San Joaquin River at USGS Gauge at Stockton
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
TCN/TCS	San Joaquin River at Turner Cut Acoustic Reciever Location (2 Receivers)
TFCF	Tracy Fish Collection Facility
TID	Turlock Irrigation District
TMN/TMS	Threemile Slough Acoustic Reciever Location (2 Receivers)
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
VSN	Vernalis
WBC	White Blood Cell
WOMT	CALFED Water Operations Management Team
WQCP	Water Quality Control Plan
WWTP	Wastewater Treatment Plant

APPENDIX TABLE OF CONTENTS

APPENDIX A

Appendix A, Table 1

2010 VAMP DAILY OPERATION PLAN – MARCH 16, 2010

LOW UNGAGED FLOW

Target Flow Period: April 25th- May 25th * Flow Target: 3,200 cfs

Bold Numbers: observed real-time mean daily flows

Date	San Joaquin River near Vernalis: Existing Flow (cfs)	San Joaquin River near Vernalis: VAMP Supplemental Flow (cfs)	San Joaquin River near Vernalis: Other Supplemental Flow (cfs)	San Joaquin River near Vernalis: Cumulative VAMP Supplemental Flow (TAF)	San Joaquin River near Vernalis: VAMP Flow (cfs)	SJR above Merced R (2day lag) (cfs)	Ungaged Flow above Vernalis (cfs)	Merced River at Cressey: Existing Flow (cfs)	Merced River at Cressey: MeID VAMP Supplemental Flow (cfs)	Merced River at Cressey: Exch Contr VAMP Supplemental Flow (cfs)	Merced River at Cressey: VAMP Flow (3day lag) (cfs)	Tuolumne River at LaGrange: Existing Flow - base FERC volume (cfs)	Tuolumne River at LaGrange: Existing Flow - Adjusted FERC Pulse (cfs)	Tuolumne River at LaGrange: VAMP Supplemental Flow (cfs)	Tuolumne River at LaGrange: VAMP Flow (2day lag) (cfs)	Stanislaus R blw Goodwin: Existing Flow - Base (cfs)	Stanislaus R blw Goodwin: Existing Flow - reshaped	Stanislaus R blw Goodwin: VAMP Supplemental Flow (cfs)	Stanislaus R blw Goodwin: Other Supplemental Flow (cfs)	Stanislaus R blw Goodwin: VAMP Flow (2day lag) (cfs)	Maintain Priority Flow Level M=Merced T=Tuol. S=Stan.
3/20/10																					
3/21/10																					
3/22/10																					
3/23/10																					
3/24/10																					
3/25/10																					
3/26/10																					
3/27/10																					
3/28/10																					
3/29/10																					
3/30/10																					
3/31/10								250			250										
4/1/10						595	100	250			250	220	220		220	746	746			746	
4/2/10						590	100	250			250	220	220		220	746	746			746	
4/3/10	1,911				1,911	585	100	250			250	220	220		220	746	746			746	
4/4/10	1,906				1,906	580	100	250			250	220	220		220	746	746			746	
4/5/10	1,901				1,901	575	100	250			250	220	220		220	746	746			746	
4/6/10	1,896				1,896	570	100	250			250	220	220		220	746	746			746	
4/7/10	1,891				1,891	565	100	250			250	220	220		220	746	746			746	
4/8/10	1,886				1,886	560	100	250			250	220	220		220	746	746			746	
4/9/10	1,881				1,881	555	100	250			250	220	220		220	746	746			746	
4/10/10	1,876				1,876	550	100	250			250	220	220		220	746	746			746	
4/11/10	1,871				1,871	545	100	250			250	220	220		220	746	746			746	
4/12/10	1,866				1,866	540	100	250			250	220	220		220	746	746			746	
4/13/10	1,861				1,861	535	100	250			250	220	220		220	746	746			746	
4/14/10	1,856				1,856	530	100	250			250	220	220		220	746	746			746	
4/15/10	1,851				1,851	525	100	250			250	220	220		220	746	746			746	
4/16/10	1,846				1,846	520	100	250			250	220	220		220	746	746			746	
4/17/10	1,841				1,841	515	100	250			250	220	220		220	746	746			746	
4/18/10	1,836				1,836	510	100	250			250	250	250		250	746	746			746	
4/19/10	1,831				1,831	505	100	250			250	250	250		250	746	746			746	
4/20/10	1,856				1,856	500	100	250			250	250	250		250	746	746			746	
4/21/10	1,851				1,851	496	100	250			250	250	250		250	746	746			746	
4/22/10	1,846				1,846	491	100	250	260	81	591	500	500		500	746	746			746	
4/23/10	1,842				1,842	487	100	250	264	81	595	950	950	163	1,113	746	746	163	0	909	
4/24/10	2,087				2,087	483	100	250	269	81	600	950	950	163	1,113	746	746	163	0	909	
4/25/10	2,533	667	0	1.32	3,200	478	100	250	273	81	604	950	950	163	1,113	746	746	163	0	909	
4/26/10	2,529	671	0	2.66	3,200	474	100	250	278	81	609	950	950	163	1,113	746	746	163	0	909	
4/27/10	2,524	676	0	4.00	3,200	469	100	250	432	81	763	950	950	163	1,113	746	746	163	0	909	
4/28/10	2,520	680	0	5.34	3,200	465	100	250	636	81	967	800	800	163	963	746	746	163	0	909	
4/29/10	2,515	685	0	6.70	3,200	461	100	250	791	81	1,122	600	600	163	763	746	746	163	0	909	
4/30/10	2,361	839	0	8.37	3,200	456	100	250	834	81	1,165	450	450	163	613	746	746	163	0	909	
5/1/10	2,157	1,043	0	10.44	3,200	452	100	250	838	81	1,169	450	450	163	613	707	707	163	0	870	
5/2/10	2,002	1,198	0	12.81	3,200	448	100	250	343	81	674	450	450	163	613	707	707	163	0	870	
5/3/10	1,959	1,241	0	15.27	3,200	443	100	250	347	81	678	950	950	163	1,113	707	707	163	0	870	
5/4/10	1,955	1,245	0	17.74	3,200	439	100	250	352	81	683	950	950	163	1,113	707	707	163	0	870	
5/5/10	2,450	750	0	19.23	3,200	435	100	250	356	81	687	950	950	163	1,113	707	707	163	0	870	
5/6/10	2,446	754	0	20.73	3,200	430	100	250	360	81	691	950	950	163	1,113	707	707	163	0	870	
5/7/10	2,442	759	0	22.23	3,200	426	100	250	515	81	846	950	950	163	1,113	707	707	163	0	870	
5/8/10	2,437	763	0	23.74	3,200	421	100	250	719	81	1,050	800	800	163	963	707	707	163	0	870	
5/9/10	2,433	767	0	25.27	3,200	417	100	250	873	81	1,204	600	600	163	763	707	707	163	0	870	
5/10/10	2,278	922	0	27.09	3,200	413	100	250	878	81	1,209	450	450	163	613	707	707	163	0	870	
5/11/10	2,074	1,126	0	29.33	3,200	408	100	250	882	81	1,213	450	450	163	613	707	707	163	0	870	
5/12/10	1,920	1,280	0	31.87	3,200	404	100	250	386	81	717	450	450	163	613	707	707	163	0	870	
5/13/10	1,915	1,285	0	34.41	3,200	400	100	250	391	81	722	950	950	163	1,113	707	707	163	0	870	
5/14/10	1,911	1,289	0	36.97	3,200	395	100	250	395	81	726	950	950	163	1,113	707	707	163	0	870	
5/15/10	2,407	793	0	38.54	3,200	391	100	250	400	81	731	950	950	163	1,113	707	707	163	0	870	
5/16/10	2,402	798	0	40.13	3,200	386	100	250	404	81	735	950	950	163	1,113	707	707	163	0	870	
5/17/10	2,398	802	0	41.72	3,200	382	100	250	608	81	939	950	950	163	1,113	707	707	163	0	870	
5/18/10	2,393	807	0	43.32	3,200	378	100	250	713	81	1,044	750	750	163	913	707	707	163	0	870	
5/19/10	2,389	811	0	44.93	3,200	373	100	250	817	81	1,148	650	650	163	813	707	707	163	0	870	
5/20/10	2,185	1,015	0	46.94	3,200	369	100	250	921	81	1,252	550	550	163	713	707	707	163	0	870	
5/21/10	2,080	1,120	0	49.16	3,200	365	100	250	1,025	81	1,356	450	450	163	613	707	707	163	0	870	
5/22/10	1,976	1,224	0	51.59	3,200	361	100	250	1,129	81	1,460	350	350	163	513	707	707	163	0	870	
5/23/10	1,872	1,328	0	54.22	3,200	357	100	250			250	250	250	163	413	707	707	163	0	870	
5/24/10	1,768	1,432	0	57.06	3,200	353	100	250			250	200	200		200	707	707			707	
5/25/10	1,664	1,536	0	60.11	3,200	349	100	250			250	150	150		150	707	707			707	
5/26/10	1,610	0	0		1,610	345	100	250			250	150	150		150	707	707			707	
5/27/10	1,556	0	0		1,556	341	100	250			250	150	150		150	707	707			707	
5/28/10	1,552	0	0		1,552	337	100	250			250	150	150		150	707	707			707	
5/29/10	1,548	0	0		1,548	333	100	250			250	150	150		150	707	707			707	
5/30/10	1,544	0	0		1,544	329	100	250			250	150	150		150	707	707			707	
5/31/10	1,540	0	0		1,540	325	100	250			250	150	150		150	707	707			707	
VAMP Period																					
Avg. (cfs):	2,222	978	0		3,200	421	100	250	571	81	902	734	734	163	897	717	717	163	0	880	
Supplemental Water (TAF):		60.11	0.00						35.08	4.98				10.02				10.02	0.00		

VAMP flow operation period

Appendix A, Table 2

2010 VAMP DAILY OPERATION PLAN – MARCH 16, 2010
HIGH UNGAGED FLOW
Target Flow Period: April 25th – May 25th * 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.
3/20/10																					
3/21/10																					
3/22/10																					
3/23/10																					
3/24/10																					
3/25/10																					
3/26/10																					
3/27/10																					
3/28/10																					
3/29/10																					
3/30/10																					
3/31/10								250			250										
4/1/10						595	600	250			250	220	220		220	458	458			458	
4/2/10						590	600	250			250	220	220		220	458	458			458	
4/3/10	2,123				2,123	585	600	250			250	220	220		220	458	458			458	
4/4/10	2,118				2,118	580	600	250			250	220	220		220	458	458			458	
4/5/10	2,113				2,113	575	600	250			250	220	220		220	458	458			458	
4/6/10	2,108				2,108	570	600	250			250	220	220		220	458	458			458	
4/7/10	2,103				2,103	565	600	250			250	220	220		220	458	458			458	
4/8/10	2,098				2,098	560	600	250			250	220	220		220	458	458			458	
4/9/10	2,093				2,093	555	600	250			250	220	220		220	458	458			458	
4/10/10	2,088				2,088	550	600	250			250	220	220		220	458	458			458	
4/11/10	2,083				2,083	545	600	250			250	220	220		220	458	458			458	
4/12/10	2,078				2,078	540	600	250			250	220	220		220	458	458			458	
4/13/10	2,073				2,073	535	600	250			250	220	220		220	458	458			458	
4/14/10	2,068				2,068	530	600	250			250	220	220		220	458	458			458	
4/15/10	2,063				2,063	525	600	250			250	220	220		220	458	458			458	
4/16/10	2,058				2,058	520	600	250			250	220	220		220	458	458			458	
4/17/10	2,053				2,053	515	600	250			250	220	220		220	458	458			458	
4/18/10	2,048				2,048	510	600	250			250	250	250		250	458	458			458	
4/19/10	2,043				2,043	505	600	250			250	250	250		250	458	458			458	
4/20/10	2,068				2,068	500	600	250			250	250	250		250	458	458			458	
4/21/10	2,063				2,063	496	600	250			250	515	515		515	458	458			458	
4/22/10	2,058				2,058	491	600	250	430	0	680	975	975		975	458	458			458	
4/23/10	2,319				2,319	487	600	250	434	0	684	975	975	0	975	458	458	0	0	458	
4/24/10	2,774				2,774	483	600	250	439	0	689	975	975	0	975	458	458	0	0	458	
4/25/10	2,770	430	0	0.85	3,200	478	600	250	443	0	693	975	975	0	975	458	458	0	0	458	
4/26/10	2,766	434	0	1.71	3,200	474	600	250	598	0	848	975	975	0	975	458	458	0	0	458	
4/27/10	2,761	439	0	2.59	3,200	469	600	250	752	0	1,002	825	825	0	825	458	458	0	0	458	
4/28/10	2,757	443	0	3.46	3,200	465	600	250	906	0	1,156	675	675	0	675	458	458	0	0	458	
4/29/10	2,602	598	0	4.65	3,200	461	600	250	911	0	1,161	525	525	0	525	458	458	0	0	458	
4/30/10	2,448	752	0	6.14	3,200	456	600	250	633	0	883	525	525	0	525	458	458	0	0	458	
5/1/10	2,294	906	0	7.94	3,200	452	600	250	137	0	387	525	525	0	525	740	740	0	0	740	
5/2/10	2,289	911	0	9.74	3,200	448	600	250	142	0	392	1,025	1,025	0	1,025	740	740	0	0	740	
5/3/10	2,567	633	0	11.00	3,200	443	600	250	146	0	396	1,025	1,025	0	1,025	740	740	0	0	740	
5/4/10	3,063	137	0	11.27	3,200	439	600	250	151	0	401	1,025	1,025	0	1,025	740	740	0	0	740	
5/5/10	3,058	142	0	11.55	3,200	435	600	250	155	0	405	1,025	1,025	0	1,025	740	740	0	0	740	
5/6/10	3,054	146	0	11.84	3,200	430	600	250	309	0	559	1,025	1,025	0	1,025	740	740	0	0	740	
5/7/10	3,050	151	0	12.14	3,200	426	600	250	414	0	664	875	875	0	875	740	740	0	0	740	
5/8/10	3,045	155	0	12.45	3,200	421	600	250	568	0	818	775	775	0	775	740	740	0	0	740	
5/9/10	2,891	309	0	13.06	3,200	417	600	250	572	0	822	625	625	0	625	740	740	0	0	740	
5/10/10	2,786	414	0	13.88	3,200	413	600	250	577	0	827	625	625	0	625	740	740	0	0	740	
5/11/10	2,632	568	0	15.01	3,200	408	600	250	56	0	306	625	625	0	625	740	740	0	0	740	
5/12/10	2,628	572	0	16.15	3,200	404	600	250	60	0	310	1,150	1,150	0	1,150	740	740	0	0	740	
5/13/10	2,623	577	0	17.29	3,200	400	600	250	65	0	315	1,150	1,150	0	1,150	740	740	0	0	740	
5/14/10	3,144	56	0	17.40	3,200	395	600	250	69	0	319	1,150	1,150	0	1,150	740	740	0	0	740	
5/15/10	3,140	60	0	17.52	3,200	391	600	250	74	0	324	1,150	1,150	0	1,150	740	740	0	0	740	
5/16/10	3,135	65	0	17.65	3,200	386	600	250	228	0	478	1,150	1,150	0	1,150	740	740	0	0	740	
5/17/10	3,131	69	0	17.79	3,200	382	600	250	382	0	632	1,000	1,000	0	1,000	740	740	0	0	740	
5/18/10	3,126	74	0	17.93	3,200	378	600	250	387	0	637	850	850	0	850	740	740	0	0	740	
5/19/10	2,972	228	0	18.38	3,200	373	600	250	66	0	316	850	850	0	850	740	740	0	0	740	
5/20/10	2,818	382	0	19.14	3,200	369	600	250	70	0	320	1,175	1,175	0	1,175	740	740	0	0	740	
5/21/10	2,813	387	0	19.91	3,200	365	600	250	74	0	324	1,175	1,175	0	1,175	740	740	0	0	740	
5/22/10	3,134	66	0	20.04	3,200	361	600	250	78	0	328	1,175	1,175	0	1,175	740	740	0	0	740	
5/23/10	3,130	70	0	20.18	3,200	357	600	250			250	1,175	1,175	0	1,175	740	740	0	0	740	
5/24/10	3,126	74	0	20.33	3,200	353	600	250			250	1,025	1,025		1,025	740	740			740	
5/25/10	3,122	78	0	20.48	3,200	349	600	250			250	850	850		850	740	740			740	
5/26/10	2,968	0	0		2,968	345	600	250			250	700	700		700	740	740			740	
5/27/10	2,789	0	0		2,789	341	600	250			250	625	625		625	740	740			740	
5/28/10	2,635	0	0		2,635	337	600	250			250	575	575		575	740	740			740	
5/29/10	2,556	0	0		2,556	333	600	250			250	525	525		525	740	740			740	
5/30/10	2,502	0	0		2,502	329	600	250			250	475	475		475	740	740			740	
5/31/10	2,448	0	0		2,448	325	600	250			250	425	425		425	740	740			740	
VAMP Period																					
Avg. (cfs):	2,867	333	0		3,200	421	600	250	333	0	583	928	928	0	928	667	667	0	0	667	
Supplemental Water (TAF):		20.48	0.00						20.48	0.00				0.00				0.00	0.00		

VAMP flow operation period

Appendix A, Table 3

2010 VAMP DAILY OPERATION PLAN – APRIL 12, 2010

Target Flow Period: April 25th- May 25th * Flow Target: 3,200 cfs

Bold Numbers: observed real-time mean daily flows

Date	San Joaquin River near Vernalis					SJR above Merced R (2day lag) (cfs)	Ungaged Flow above Vernalis (cfs)	Merced River at Cressey				Tuolumne River at LaGrange				Stanislaus R blw Goodwin					Maintain Priority Flow Level M=Merced T=Tuol. S=Stan.
	Existing Flow (cfs)	VAMP Supple-mental Flow (cfs)	Other Supple-mental Flow (cfs)	Cumula-tive VAMP Supple-mental Flow (TAF)	VAMP Flow (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)	
3/20/10	2,380					1,178	527	271				761	761								
3/21/10	2,510					1,181	451	278				759	759								
3/22/10	2,860					1,160	443	273				694	694								
3/23/10	2,880					1,144	465	274				400	400								
3/24/10	2,690					1,111	347	271				277	277								
3/25/10	2,410					1,080	394	257				242	242								
3/26/10	2,260					1,050	393	251				224	224								
3/27/10	2,200					990	400	256				224	224								
3/28/10	2,170					964	435	263				222	222								
3/29/10	2,150					909	479	259				223	223								
3/30/10	2,090					906	442	260				225	225								
3/31/10	2,010					917	412	261			261	268	268								
4/1/10	1,910					894	317	258			258	480	480		480	617	617			617	
4/2/10	2,040					868	339	220			220	634	634		634	617	617			617	
4/3/10	2,780				2,123	855	-129	205			205	652	652		652	617	617			617	
4/4/10	3,170				2,433	921	56	197			197	652	652		652	617	617			617	
4/5/10	3,540				2,802	924	458	245			245	651	651		651	617	617			617	
4/6/10	3,710				2,968	963	573	240			240	653	653		653	617	617			617	
4/7/10	3,800				3,052	1,086	663	233			233	652	652		652	617	617			617	
4/8/10	3,860				3,124	1,149	646	236			236	652	652		652	617	617			617	
4/9/10	3,780				3,041	1,118	446	229			229	707	707		707	617	617			617	
4/10/10	3,720				2,979	1,100	328	220			220	759	759		759	617	617			617	
4/11/10	3,650				3,097	1,094	419	244			244	760	760		760	617	617			617	
4/12/10	3,005				3,005	1,087	300	250			250	220	220		220	617	617			617	
4/13/10	2,991				2,991	1,080	300	250			250	220	220		220	617	617			617	
4/14/10	2,468				2,468	1,073	300	250			250	220	220		220	617	617			617	
4/15/10	2,467				2,467	1,066	300	250			250	220	220		220	617	617			617	
4/16/10	2,460				2,460	1,059	300	250			250	220	220		220	617	617			617	
4/17/10	2,453				2,453	1,052	300	250			250	220	220		220	617	617			617	
4/18/10	2,446				2,446	1,045	300	250			250	250	250		250	617	617			617	
4/19/10	2,439				2,439	1,038	300	250			250	250	250		250	617	617			617	
4/20/10	2,462				2,462	1,031	300	250			250	250	250		250	617	617			617	
4/21/10	2,455				2,455	1,024	300	250			250	515	515		515	617	617			617	
4/22/10	2,448				2,448	1,017	300	250	48	0	298	975	975		975	617	617			617	
4/23/10	2,706				2,706	1,010	300	250	55	0	305	975	975	0	975	617	617	0	0	617	
4/24/10	3,159				3,159	1,003	300	250	62	0	312	975	975	0	975	617	617	0	0	617	
4/25/10	3,152	48	0	0.10	3,200	996	300	250	69	0	319	975	975	0	975	617	617	0	0	617	
4/26/10	3,145	55	0	0.20	3,200	989	300	250	226	0	476	975	975	0	975	617	617	0	0	617	
4/27/10	3,138	62	0	0.33	3,200	982	300	250	383	0	633	825	825	0	825	617	617	0	0	617	
4/28/10	3,131	69	0	0.46	3,200	975	300	250	540	0	790	675	675	0	675	617	617	0	0	617	
4/29/10	2,974	226	0	0.91	3,200	968	300	250	547	0	797	525	525	0	525	617	617	0	0	617	
4/30/10	2,817	383	0	1.67	3,200	961	300	250	526	0	776	525	525	0	525	617	617	0	0	617	
5/1/10	2,660	540	0	2.74	3,200	954	300	250	33	0	283	525	525	0	525	645	645	0	0	645	
5/2/10	2,653	547	0	3.83	3,200	947	300	250	40	0	290	1,025	1,025	0	1,025	645	645	0	0	645	
5/3/10	2,674	526	0	4.87	3,200	940	300	250	47	0	297	1,025	1,025	0	1,025	645	645	0	0	645	
5/4/10	3,167	33	0	4.94	3,200	933	300	250	54	0	304	1,025	1,025	0	1,025	645	645	0	0	645	
5/5/10	3,160	40	0	5.02	3,200	926	300	250	61	0	311	1,025	1,025	0	1,025	645	645	0	0	645	
5/6/10	3,153	47	0	5.11	3,200	919	300	250	218	0	468	1,025	1,025	0	1,025	645	645	0	0	645	
5/7/10	3,146	54	0	5.22	3,200	912	300	250	325	0	575	875	875	0	875	645	645	0	0	645	
5/8/10	3,139	61	0	5.34	3,200	905	300	250	482	0	732	775	775	0	775	645	645	0	0	645	
5/9/10	2,982	218	0	5.77	3,200	898	300	250	489	0	739	625	625	0	625	645	645	0	0	645	
5/10/10	2,875	325	0	6.41	3,200	891	300	250	496	0	746	625	625	0	625	645	645	0	0	645	
5/11/10	2,718	482	0	7.37	3,200	884	300	250	0	0	250	625	625	0	625	645	645	0	0	645	
5/12/10	2,711	489	0	8.34	3,200	877	300	250	0	0	250	1,150	1,150	0	1,150	645	645	0	0	645	
5/13/10	2,704	496	0	9.32	3,200	870	300	250	0	0	250	1,150	1,150	0	1,150	645	645	0	0	645	
5/14/10	3,222	0	0	9.32	3,222	863	300	250	0	0	250	1,150	1,150	0	1,150	645	645	0	0	645	
5/15/10	3,215	0	0	9.32	3,215	856	300	250	6	0	256	1,150	1,150	0	1,150	645	645	0	0	645	
5/16/10	3,208	0	0	9.32	3,208	849	300	250	163	0	413	1,150	1,150	0	1,150	645	645	0	0	645	
5/17/10	3,201	0	0	9.32	3,201	842	300	250	320	0	570	1,000	1,000	0	1,000	645	645	0	0	645	
5/18/10	3,194	6	0	9.34	3,200	835	300	250	327	0	577	850	850	0	850	645	645	0	0	645	
5/19/10	3,037	163	0	9.66	3,200	828	300	250	9	0	259	850	850	0	850	645	645	0	0	645	
5/20/10	2,880	320	0	10.29	3,200	821	300	250	16	0	266	1,175	1,175	0	1,175	645	645	0	0	645	
5/21/10	2,873	327	0	10.94	3,200	814	300	250	23	0	273	1,175	1,175	0	1,175	645	645	0	0	645	
5/22/10	3,191	9	0	10.96	3,200	807	300	250	30	0	280	1,175	1,175	0	1,175	645	645	0	0	645	
5/23/10	3,184	16	0	10.99	3,200	800	300	250			250	1,175	1,175	0	1,175	645	645	0	0	645	
5/24/10	3,177	23	0	11.04	3,200	793	300	250			250	1,025	1,025		1,025	645	645			645	
5/25/10	3,170	30	0	11.10	3,200	786	300	250			250	850	850		850	645	645			645	
5/26/10	3,013	0	0		3,013	779	300	250			250	700	700		700	645	645			645	
5/27/10	2,831	0	0		2,831	772	300	250			250	625	625		625	645	645			645	
5/28/10	2,674	0	0		2,674	765	300	250			250	575	575		575	645	645			645	
5/29/10	2,592	0	0		2,592	758	300	250			250	525	525		525	645	645			645	
5/30/10	2,535	0	0		2,535	751	300	250			250	475	475		475	645	645			645	
5/31/10	2,478	0	0		2,478	744	300	250			250	425	425		425	645	645			645	
VAMP Period																					
Avg. (cfs):	3,021	180	0		3,201	905	300	250	180	0	430	928	928	0	928	638	638	0	0	638	
Supplemental Water (TAF):		11.10	0.00						11.10	0.00				0.00				0.00	0.00		

VAMP flow operation period

Appendix A, Table 4

2010 VAMP DAILY OPERATION PLAN – APRIL 16, 2010

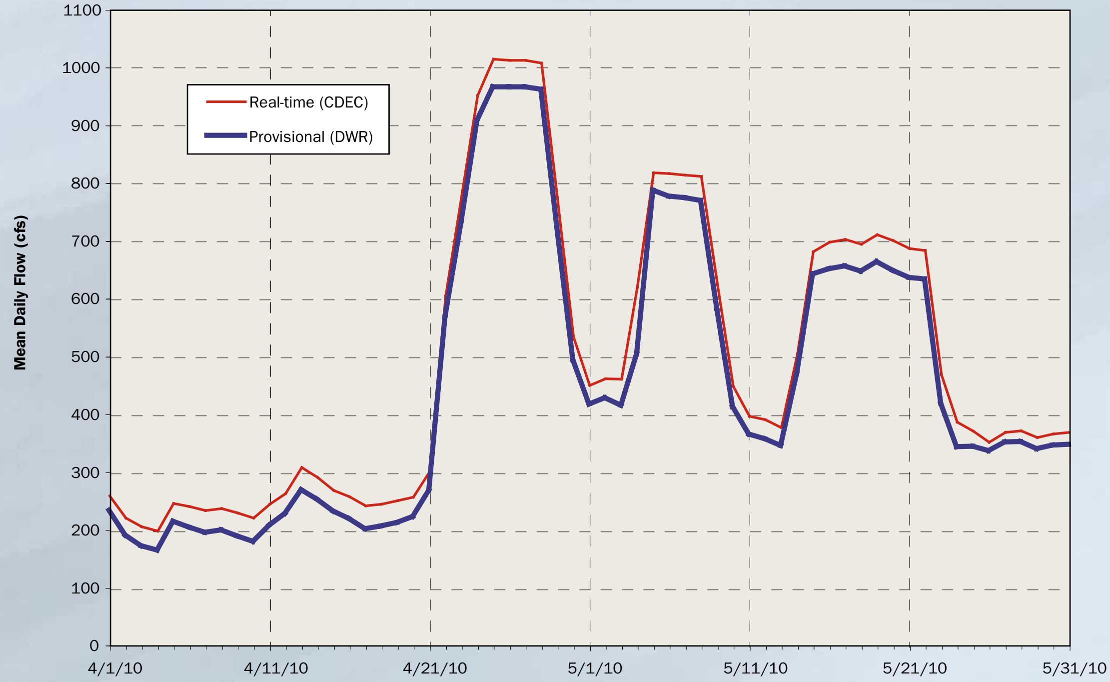
Target Flow Period: April 25th - May 25th * Flow Target: 4,450 cfs

Bold Numbers: observed real-time mean daily flows

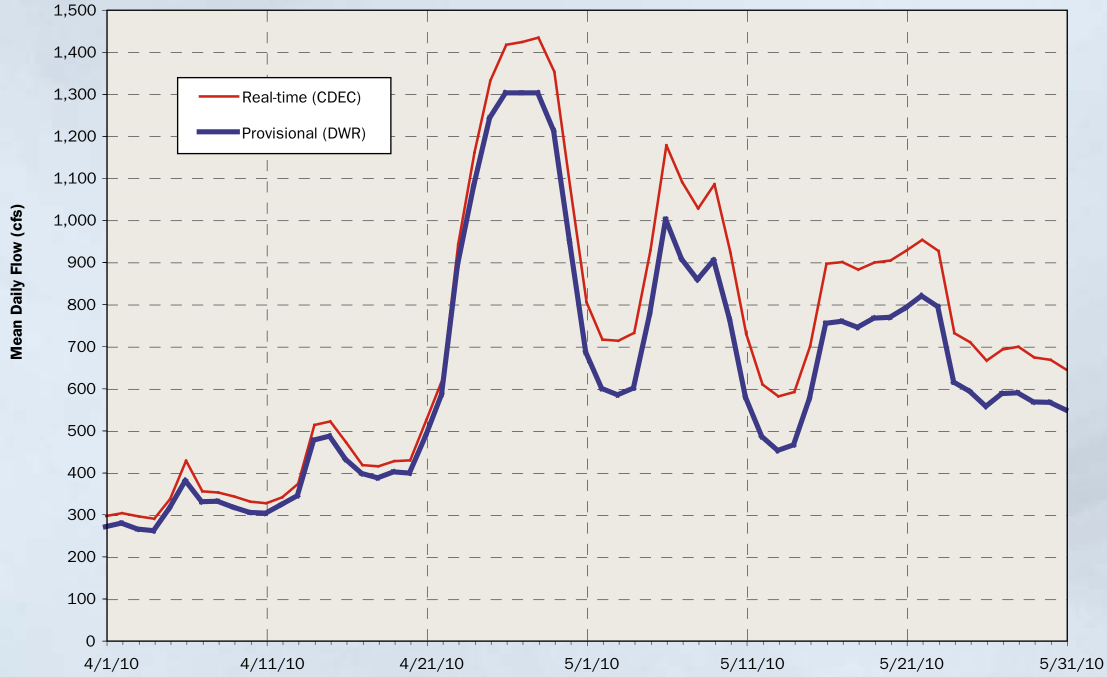
	San Joaquin River near Vernalis							Merced River at Cressey				Tuolumne River at LaGrange				Stanislaus R blw Goodwin					
Date	Existing Flow (cfs)	VAMP Supple-mental Flow (cfs)	Other Supple-mental Flow (cfs)	Cumula-tive VAMP Supple-mental Flow (TAF)	VAMP Flow (cfs)	SJR above Merced R (2day lag) (cfs)	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.
3/20/10						1,178	527	271				761	761								
3/21/10						1,181	451	278				759	759								
3/22/10						1,160	443	273				694	694								
3/23/10						1,144	465	274				400	400								
3/24/10						1,111	347	271				277	277								
3/25/10						1,080	394	257				242	242								
3/26/10						1,050	393	251				224	224								
3/27/10						990	400	256				224	224								
3/28/10						964	435	263				222	222								
3/29/10						909	479	259				223	223								
3/30/10						906	442	260				225	225								
3/31/10						917	412	261			261	268	268								
4/1/10						894	317	258			258	480	480		480	617	617			617	
4/2/10						868	339	220			220	634	634		634	617	617			617	
4/3/10	2,123				2,123	855	-129	205			205	652	652		652	617	617			617	
4/4/10	2,433				2,433	921	56	197			197	652	652		652	617	617			617	
4/5/10	2,802				2,802	924	458	245			245	651	651		651	617	617			617	
4/6/10	2,968				2,968	963	573	240			240	653	653		653	617	617			617	
4/7/10	3,052				3,052	1,086	663	233			233	652	652		652	617	617			617	
4/8/10	3,124				3,124	1,149	646	236			236	652	652		652	617	617			617	
4/9/10	3,041				3,041	1,118	446	229			229	707	707		707	617	617			617	
4/10/10	2,979				2,979	1,100	328	220			220	759	759		759	617	617			617	
4/11/10	3,097				3,097	1,094	419	244			244	760	760		760	617	617			617	
4/12/10	3,482				3,482	1,130	777	262			262	1,080	1,080		1,080	617	617			617	
4/13/10	3,541				3,541	1,148	850	307			307	1,270	1,270		1,270	617	617			617	
4/14/10	3,943				3,943	1,188	872	290			290	1,260	1,260		1,260	617	617			617	
4/15/10	4,081				4,081	1,320	784	268			268	1,330	1,330		1,330	617	617			617	
4/16/10	4,112				4,112	1,300	740	250			250	1,500	1,500		1,500	617	617			617	
4/17/10	4,157				4,157	1,000	600	250			250	1,700	1,700		1,700	617	617			617	
4/18/10	4,185				4,185	900	500	250			250	1,900	1,900		1,900	617	617			617	
4/19/10	4,067				4,067	850	500	250			250	1,900	1,900		1,900	617	617			617	
4/20/10	4,167				4,167	800	500	250			250	2,100	2,100		2,100	617	617			617	
4/21/10	4,117				4,117	750	500	250			250	2,100	2,100		2,100	617	617			617	
4/22/10	4,267				4,267	700	500	250	290	0	540	2,100	2,100		2,100	617	617			617	
4/23/10	4,217				4,217	695	500	250	490	0	740	2,100	2,100	0	2,100	617	617	0	0	617	
4/24/10	4,167				4,167	690	500	250	700	0	950	1,900	1,900	0	1,900	617	617	0	0	617	
4/25/10	4,162	290	0	0.58	4,452	685	500	250	700	0	950	1,700	1,700	0	1,700	617	617	0	0	617	
4/26/10	3,957	490	0	1.55	4,447	680	500	250	700	0	950	1,700	1,700	0	1,700	617	617	0	0	617	
4/27/10	3,752	700	0	2.94	4,452	675	500	250	700	0	950	1,700	1,700	0	1,700	617	617	0	0	617	
4/28/10	3,747	700	0	4.32	4,447	670	500	250	700	0	950	1,700	1,700	0	1,700	617	617	0	0	617	
4/29/10	3,742	700	0	5.71	4,442	665	500	250	380	0	630	1,700	1,700	0	1,700	617	617	0	0	617	
4/30/10	3,737	700	0	7.10	4,437	660	500	250	70	0	320	2,000	2,000	0	2,000	617	617	0	0	617	
5/1/10	3,732	700	0	8.49	4,432	655	500	250	70	0	320	2,300	2,340	0	2,340	645	645	0	0	645	
5/2/10	4,027	380	0	9.24	4,407	650	500	250	70	0	320	2,300	2,340	0	2,340	645	645	0	0	645	
5/3/10	4,390	70	0	9.38	4,460	645	500	250	70	0	320	2,300	2,340	0	2,340	645	645	0	0	645	
5/4/10	4,385	70	0	9.52	4,455	640	500	250	300	0	550	2,300	2,340	0	2,340	645	645	0	0	645	
5/5/10	4,380	70	0	9.66	4,450	635	500	250	540	0	790	2,100	2,100	0	2,100	645	645	0	0	645	
5/6/10	4,375	70	0	9.80	4,445	630	500	250	540	0	790	1,900	1,900	0	1,900	645	645	0	0	645	
5/7/10	4,130	300	0	10.39	4,430	625	500	250	540	0	790	1,900	1,900	0	1,900	645	645	0	0	645	
5/8/10	3,925	540	0	11.46	4,465	620	500	250	540	0	790	1,900	1,900	0	1,900	645	645	0	0	645	
5/9/10	3,920	540	0	12.54	4,460	615	500	250	250	0	500	1,900	1,900	0	1,900	645	645	0	0	645	
5/10/10	3,915	540	0	13.61	4,455	610	500	250	0	0	250	2,200	2,200	0	2,200	645	645	0	0	645	
5/11/10	3,910	540	0	14.68	4,450	605	500	250	0	0	250	2,500	2,460	0	2,460	645	645	0	0	645	
5/12/10	4,205	250	0	15.17	4,455	600	500	250	0	0	250	2,500	2,460	0	2,460	645	645	0	0	645	
5/13/10	4,460	0	0	15.17	4,460	595	500	250	0	0	250	2,500	2,460	0	2,460	645	645	0	0	645	
5/14/10	4,455	0	0	15.17	4,455	590	500	250	170	0	420	2,500	2,460	0	2,460	645	645	0	0	645	
5/15/10	4,450	0	0	15.17	4,450	585	500	250	400	0	650	2,300	2,300	0	2,300	645	645	0	0	645	
5/16/10	4,445	0	0	15.17	4,445	580	500	250	400	0	650	2,100	2,100	0	2,100	645	645	0	0	645	
5/17/10	4,280	170	0	15.51	4,450	575	500	250	400	0	650	2,100	2,100	0	2,100	645	645	0	0	645	
5/18/10	4,075	400	0	16.30	4,475	570	500	250	400	0	650	2,100	2,100	0	2,100	645	645	0	0	645	
5/19/10	4,070	400	0	17.10	4,470	565	500	250	400	0	650	2,100	2,100	0	2,100	645	645	0	0	645	
5/20/10	4,065	400	0	17.89	4,465	560	500	250	400	0	650	2,100	2,100	0	2,100	645	645	0	0	645	
5/21/10	4,060	400	0	18.68	4,460	555	500	250	400	0	650	2,100	2,100	0	2,100	645	645	0	0	645	
5/22/10	4,055	400	0	19.48	4,455	550	500	250	390	0	640	2,100	2,100	0	2,100	645	645	0	0	645	
5/23/10	4,050	400	0	20.27	4,450	545	500	250			250	2,100	2,100	0	2,100	645	645	0	0	645	
5/24/10	4,045	400	0	21.06	4,445	540	500	250			250	1,700	1,700		1,700	645	645			645	
5/25/10	4,040	390	0	21.84	4,430	535	500	250			250	1,500	1,500		1,500	645	645			645	
5/26/10	3,635	0	0		3,635	530	500	250			250	1,350	1,350		1,350	645	645			645	
5/27/10	3,430	0	0		3,430	525	500	250			250	1,200	1,200		1,200	645	645			645	
5/28/10	3,275	0	0		3,275	520	500	250			250	1,000	1,000		1,000	645	645			645	
5/29/10	3,120	0	0		3,120	515	500	250			250	900	900		900	645	645			645	
5/30/10	2,915	0	0		2,915	510	500	250			250	800	800		800	645	645			645	
5/31/10	2,810	0	0		2,810	505	500	250			250	700	700		700	645	645			645	
VAMP Period																					
Avg. (cfs):	4,095	355	0		4,450	620	500	250	355	0	605	2,087	2,087	0	2,087	638	638	0	0	638	
Supplemental Water (TAF):		21.84	0.00						21.84	0.00				0.00				0.00	0.00		

VAMP flow operation period

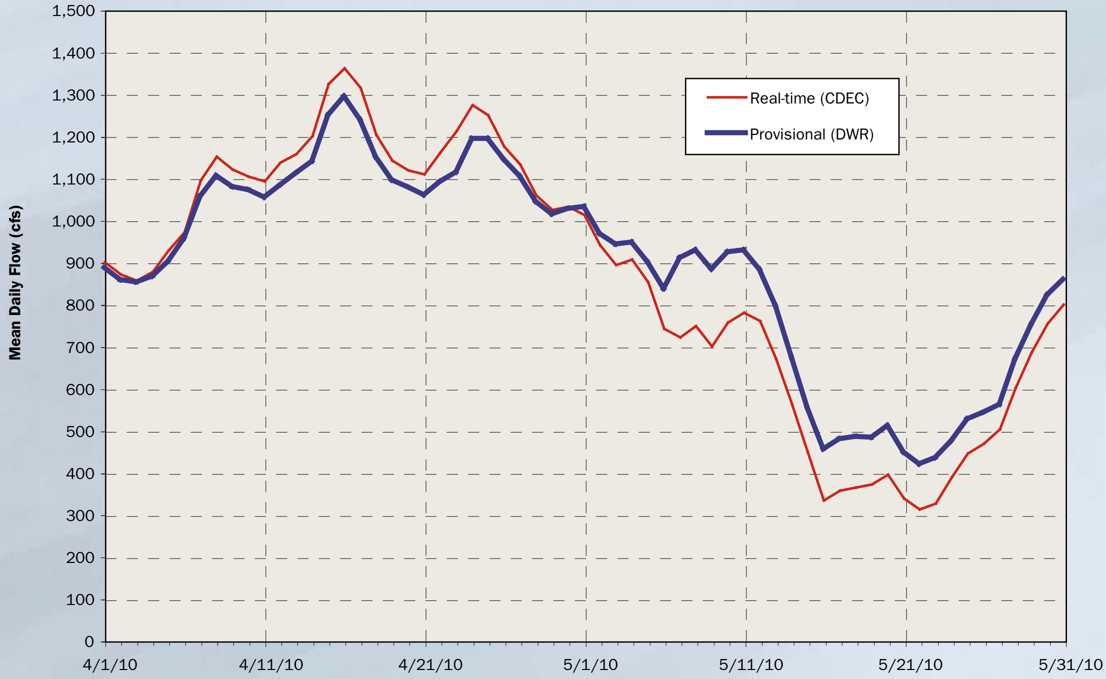
Appendix A, Figure 1
Mean Daily Flow in the Merced River at Cressey
in Cubic Feet per Second (cfs) from April 1st to May 31st



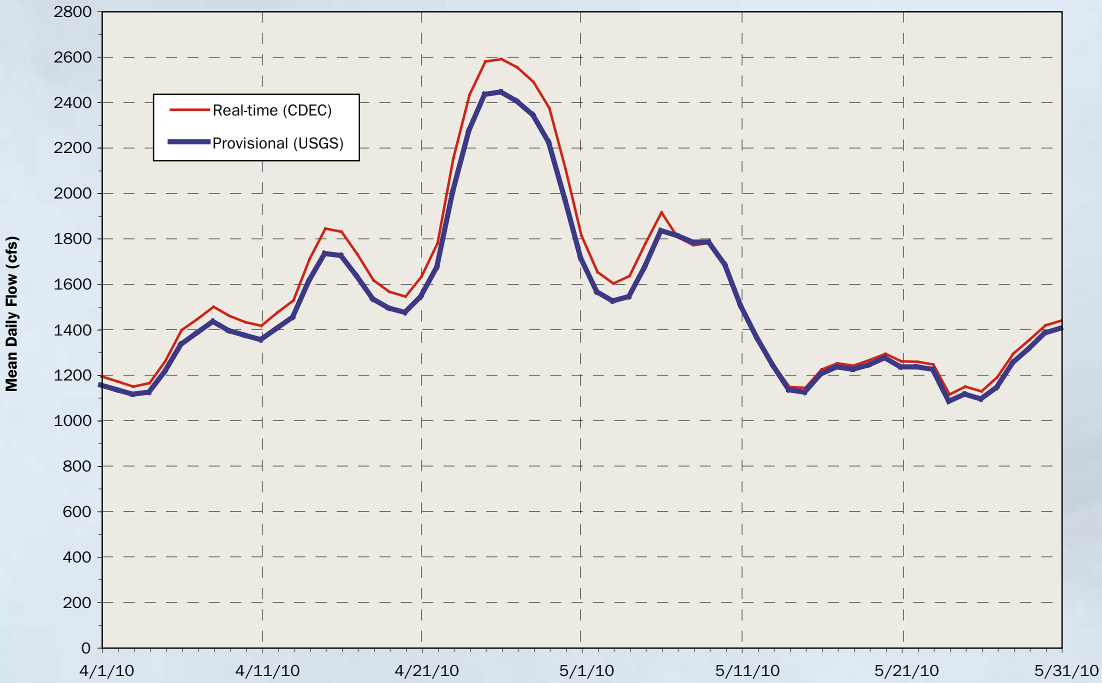
Appendix A, Figure 2
Mean Daily Flow in the Merced River at Stevinson
in Cubic Feet per Second (cfs) from April 1st to May 31st



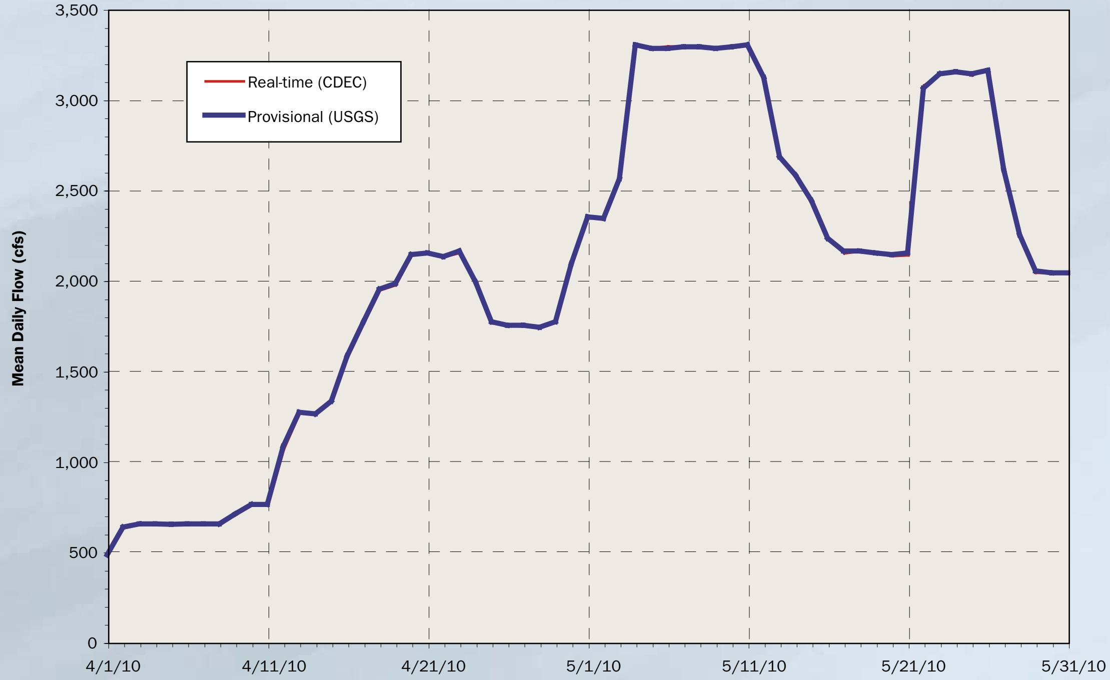
Appendix A, Figure 3
Mean Daily Flow in the San Joaquin River above the Merced River Inflow
in Cubic Feet per Second (cfs) from April 1st to May 31st



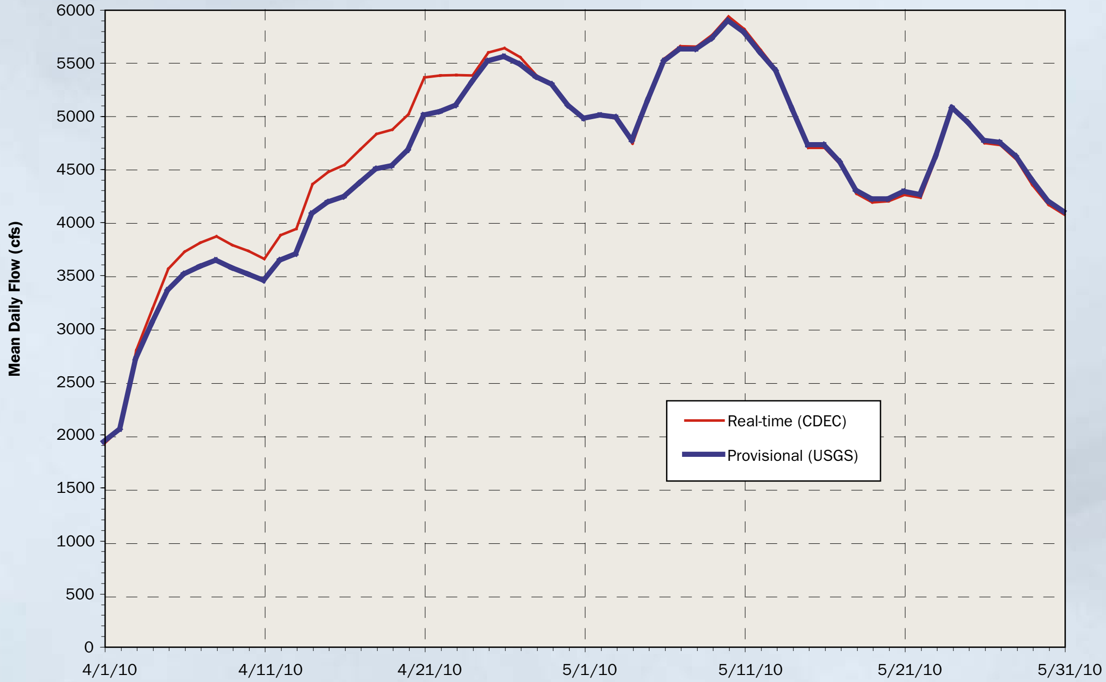
Appendix A, Figure 4
Mean Daily Flow in the San Joaquin River below the Merced River Inflow near Newman
in Cubic Feet per Second (cfs) from April 1st to May 31st



Appendix A, 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

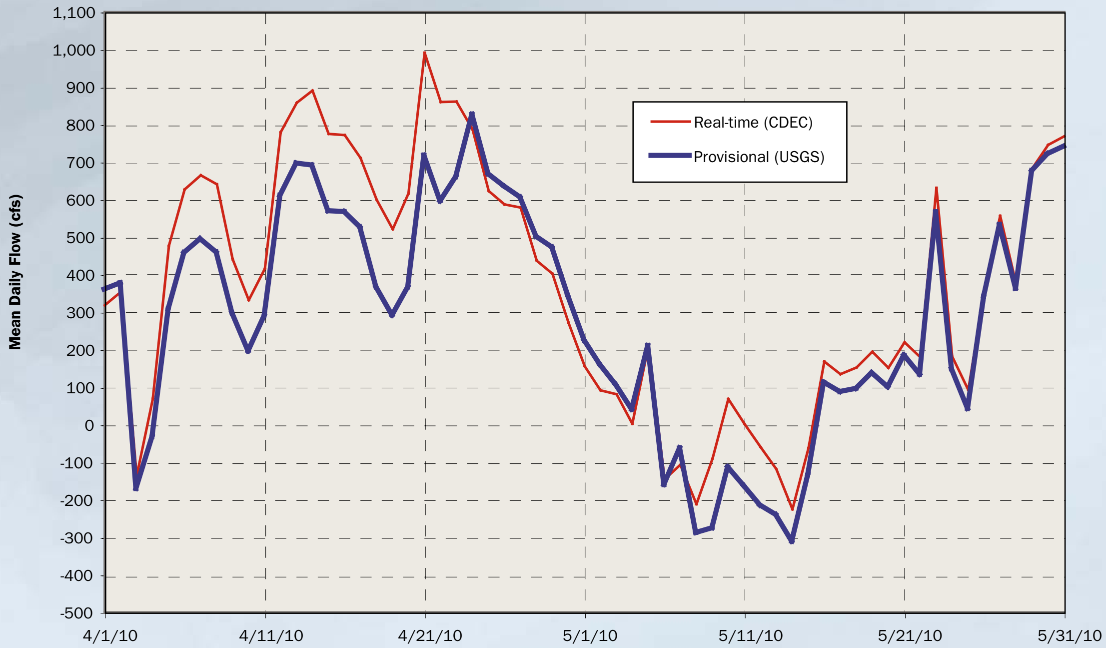


Appendix A, Figure 6
Mean Daily Flow in the San Joaquin River near Vernalis (VSN)
in Cubic Feet per Second (cfs) from April 1st to May 31st



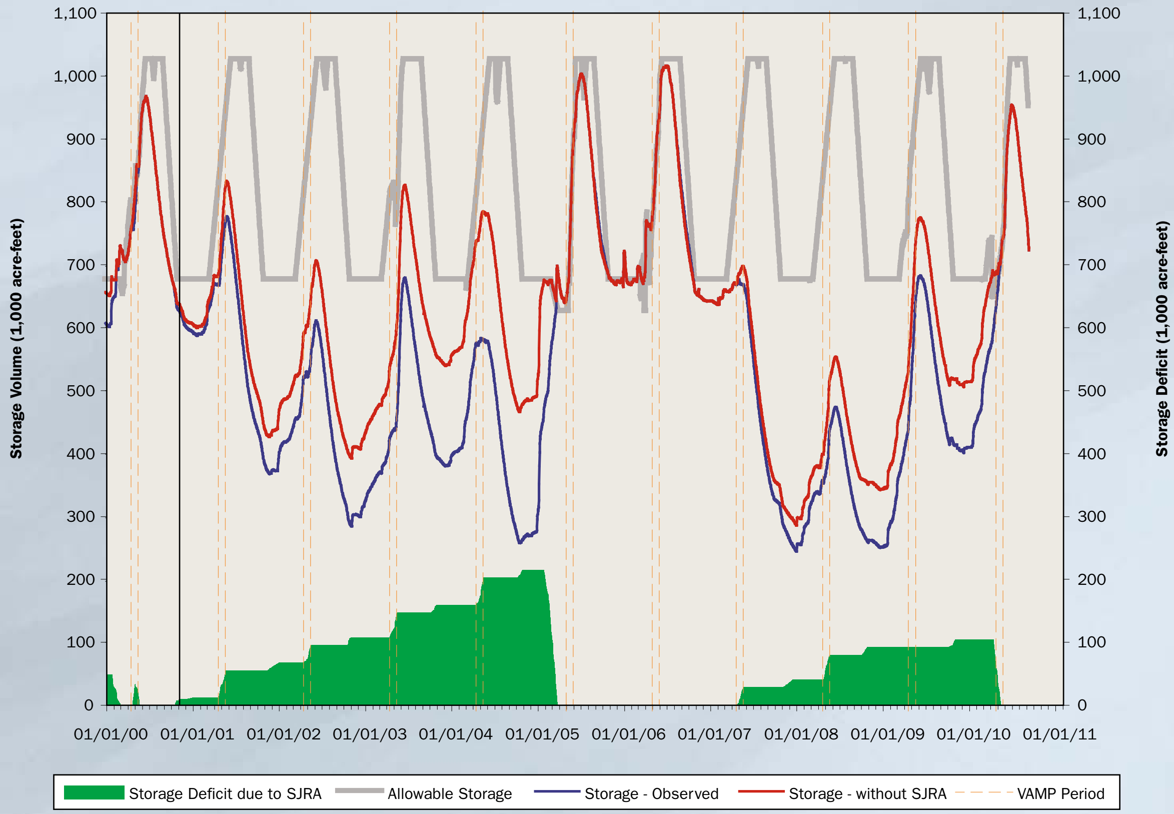
Appendix A, Figure 7

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

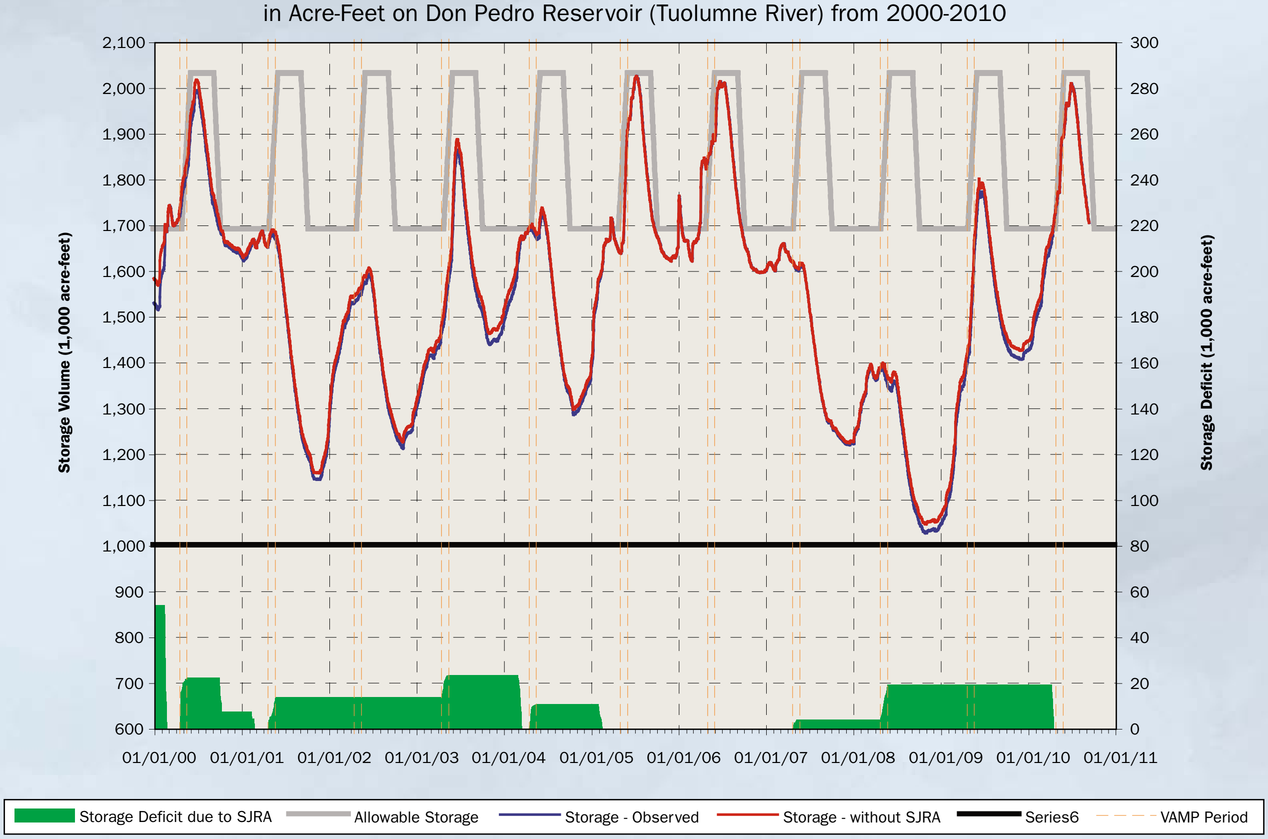


APPENDIX B

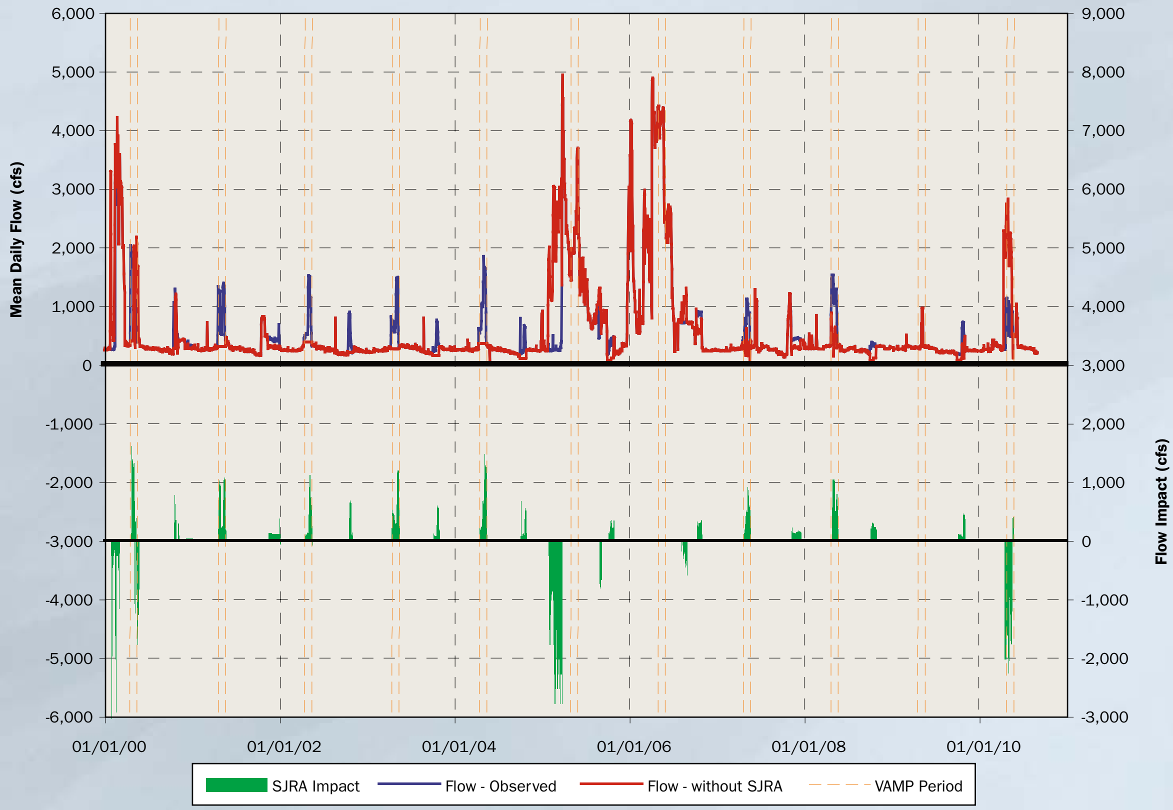
Appendix B, Figure 1
San Joaquin River Agreement (SJRA) Storage Impacts
in Acre-Feet on Lake McClure (Merced River) from 2000-2010



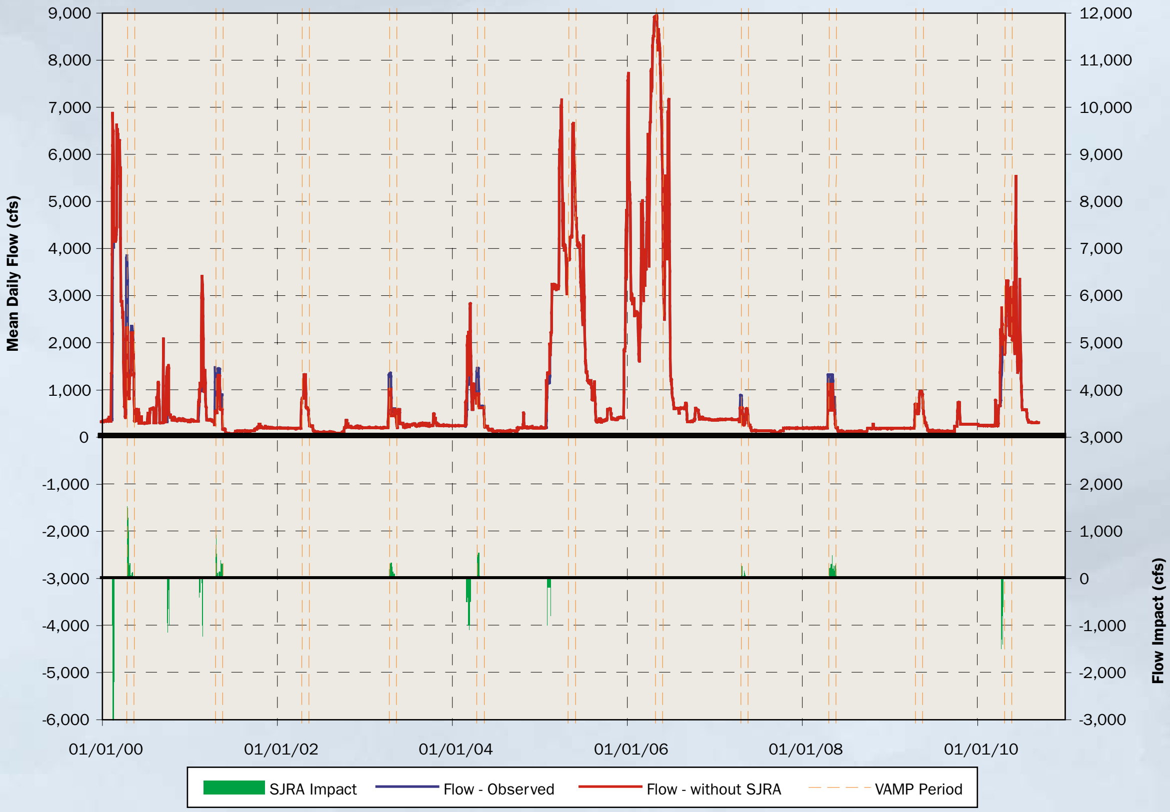
Appendix B, Figure 2
San Joaquin River Agreement (SJRA) Storage Impacts
in Acre-Feet on Don Pedro Reservoir (Tuolumne River) from 2000-2010



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 2000-2010



Appendix B, Figure 4
San Joaquin River Agreement (SJRA) Flow Impacts
in Cubic Feet per Second (cfs) on the Tuolumne River below La Grange Dam from 2000-2010



APPENDIX C

Table C-1
Site Descriptions for Water Temperature Monitoring Locations in the San Joaquin River and Delta as Part of the 2010 Vernalis Adaptive Management Program (VAMP)

Site #	Logger Number	Temperature Monitoring Location	Lat	Long	Date Deployed	Date Retrieved
A	1259811	Stockton Release Site	N 37 56.103	W 121 19.831	4/17/10	6/19/10
B	1271943	Old River Release Site	N 37 48.513	W 121 20.062	4/17/10	6/19/10
1	1292418	Durham Ferry	N 37 41.263	W 121 15.609	4/16/10	6/19/10
2	1259808	Mossdale Landing	N 37 47.142	W 121 18.383	4/16/10	6/19/10
3	1293998	Old River at HORB	N 37 48.633	W 121 19.232	4/16/10	6/19/10
4	1027504	Dos Reis	N 37 49.956	W 121 18.791	4/16/10	7/30/10
5	1027502	DWR Monitoring Station	N 37 51.874	W 121 19.388	4/16/10	6/19/10
6a	1027490	Confluence – Top	N 37 56.817	W 121 20.293	4/16/10	7/30/10
6b	1027492	Confluence-Bottom	N 37 56.817	W 121 20.293	4/16/10	7/30/10
7	1271938	Upstream of Channel Marker 33	N 37 59.682	W 121 24.699	4/16/10	6/19/10
8	1259804	Turner Cut - Channel Marker 21-22	N 38 00.339	W121 27.095	4/16/10	6/19/10
9	1293982	"Q" Piling 1/2 mile upstream of channel marker 13	N 38 01.949	W 121 28.770	4/16/10	6/19/10
10	2400407	All Pro boat	N 38 04.497	W 121 34.399	4/16/10	6/19/10
11	1027493	Jersey Point USGS Gauging Station	N 38 03.177	W121 41.623	4/16/10	Not Retrieved
12	1027501	Antioch Marina	N 38 01.370	W121 48.689	4/16/10	6/20/10
13	1271939	Chipps Island	N 38 03.011	W 121 55.038	4/16/10	6/20/10
14	1284083	Holland Riverside Marina	N 37 58.324	W 121 34.900	4/16/10	6/19/10
15	1292420	Old River / Indian Slough Confluence	N 37 54.985	W 121 34.038	4/17/10	6/19/10
16	1292417	CCF Radial Gates	N 37 49.898	W 121 33.238	4/17/10	6/19/10
17	1293975	Grant Line Canal at Tracy Blvd Bridge	N 37 49.194	W 121 26.988	4/17/10	6/19/10
18	1293985	Union Pt.	N37 53.427	W121 29.359	4/17/10	6/19/10
19	1259798	Werner Cut: Channel above Woodward Isle	N 37 56.381	W 121 32.467	4/17/10	Not Retrieved

Figure C-1
Overview of Water Temperature Monitoring Locations in the Lower San Joaquin River and Delta as Part of the 2010 Vernalis Adaptive Management Program (VAMP)

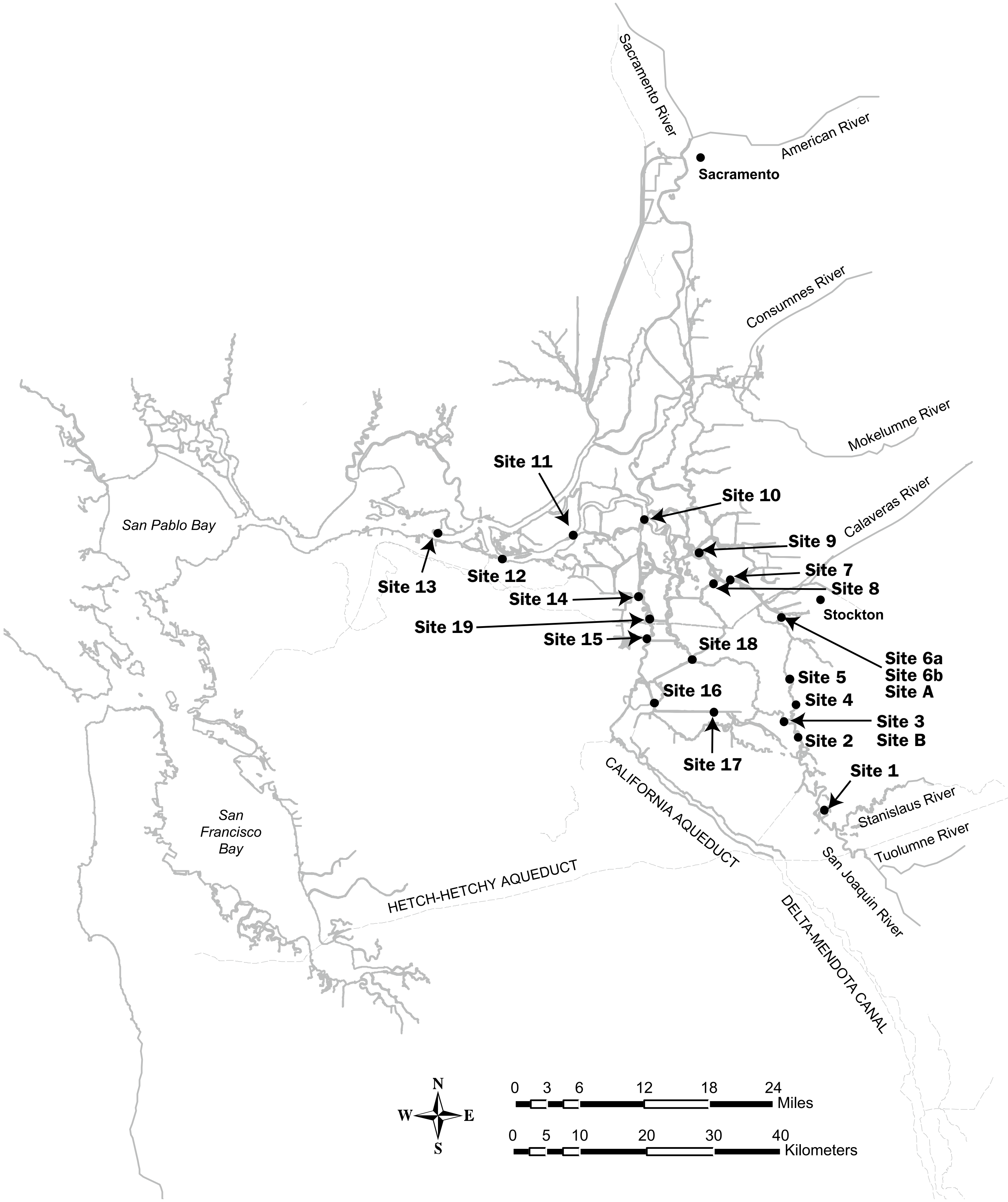


Figure C-2
Daily Water Temperature Fluctuations (°C) in the San Joaquin River at the Stockton Fish Release Site During the 2010 Vernalis Adaptive Management Program (VAMP)

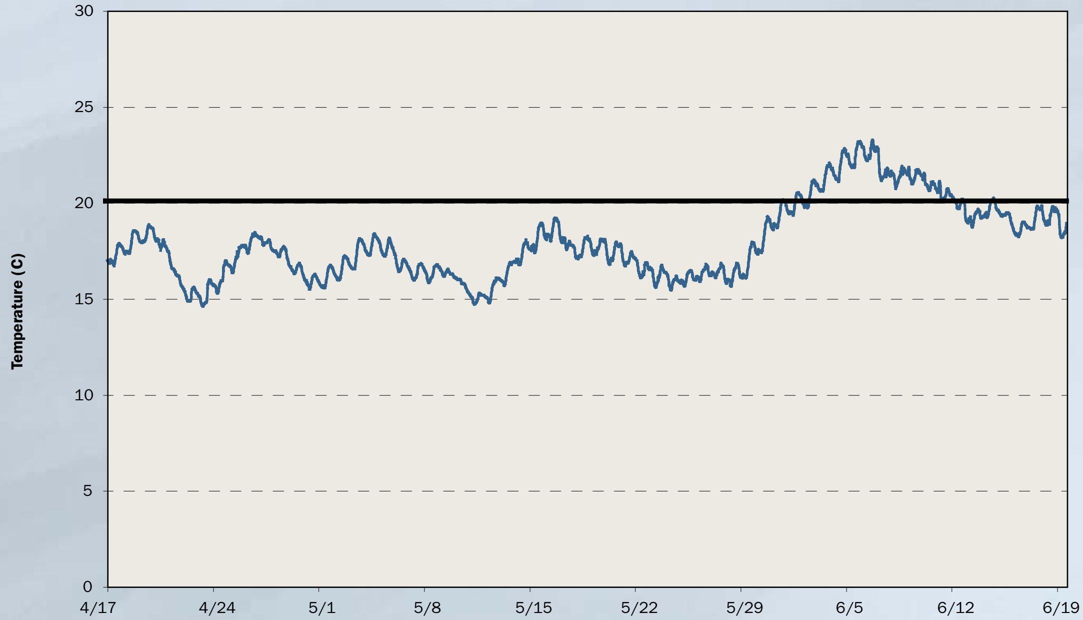


Figure C-3
Daily Water Temperature Fluctuations (°C) in the San Joaquin River at the Old River Fish Release Site During the 2010 Vernalis Adaptive Management Program (VAMP)

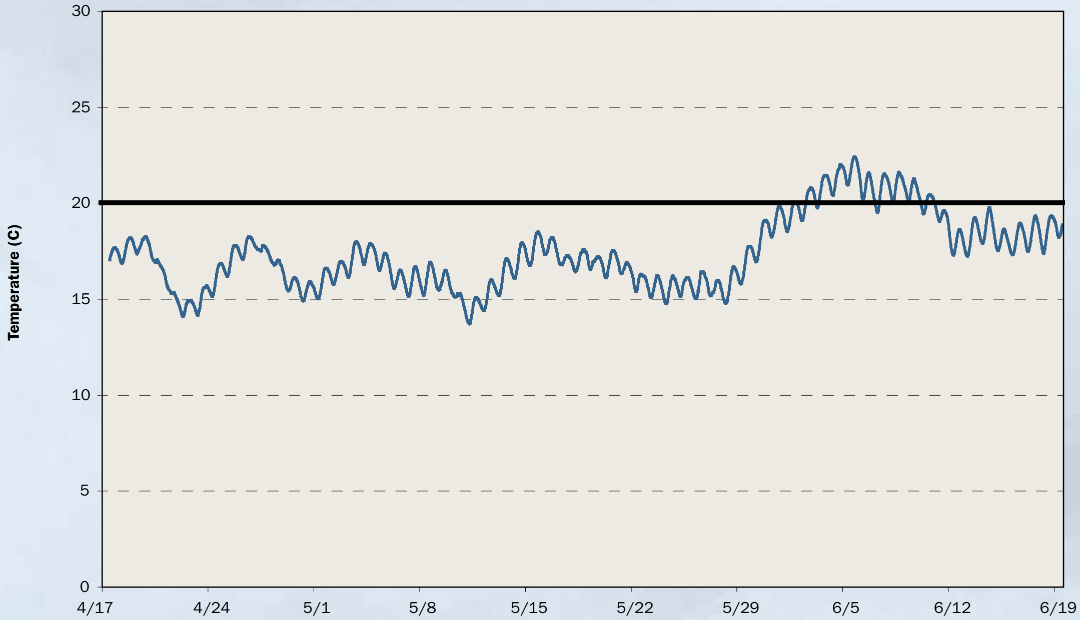


Figure C-4
Daily Water Temperature Fluctuations (°C) in the San Joaquin River at Durham Ferry
During the 2010 Vernalis Adaptive Management Program (VAMP)

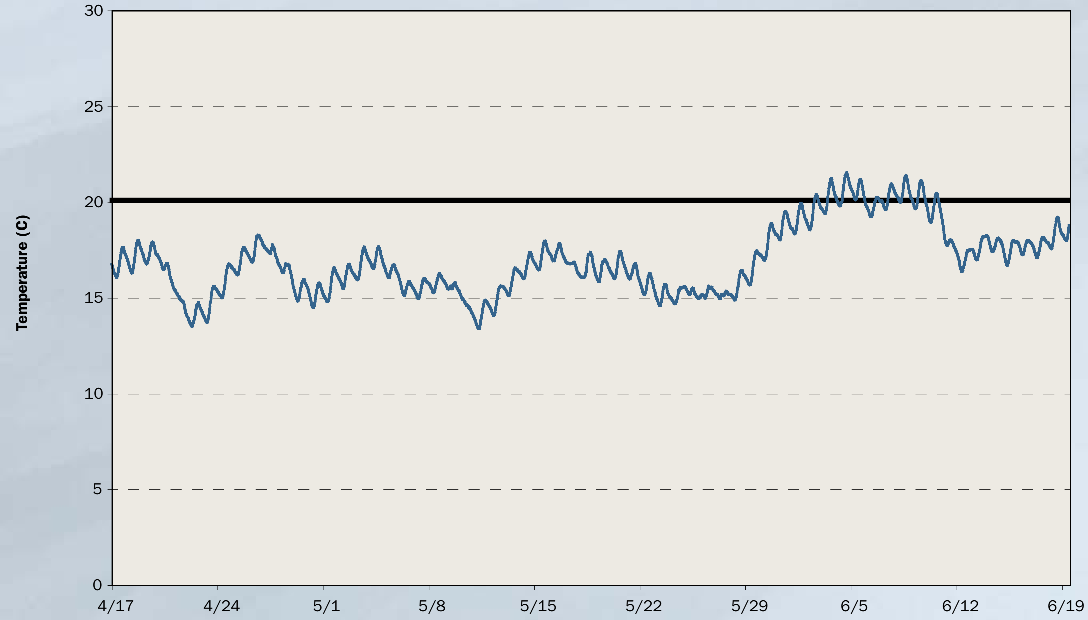


Figure C-5
Daily Water Temperature Fluctuations (°C) in the San Joaquin River at Mossdale Bridge
During the 2010 Vernalis Adaptive Management Program (VAMP)

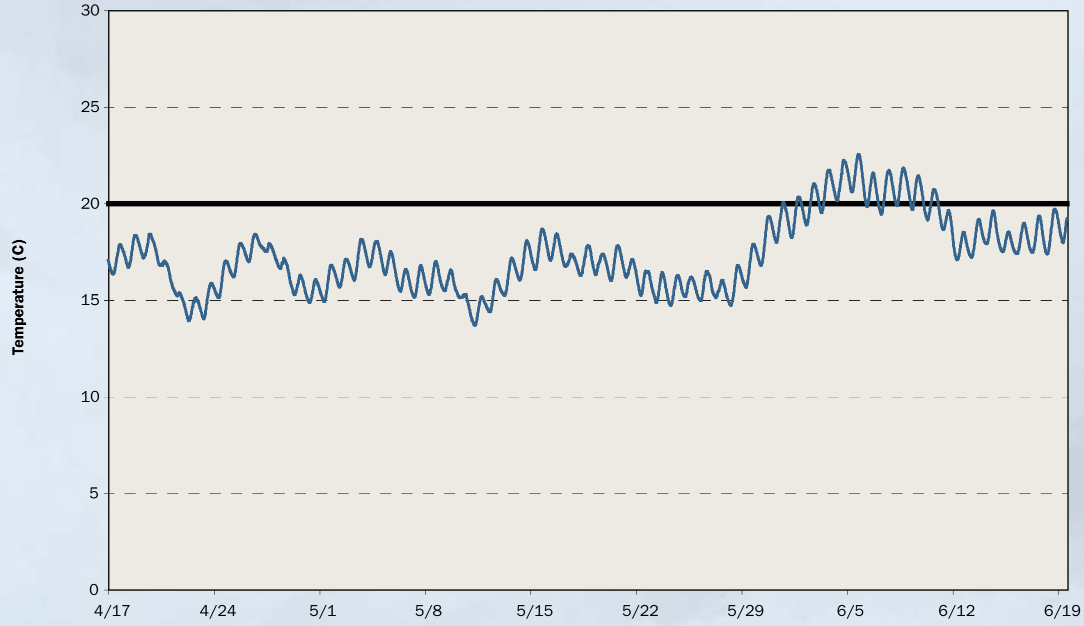


Figure C-6
Daily Water Temperature Fluctuations (°C) in Old River at the Head of Old River Barrier During the 2010 Vernalis Adaptive Management Program (VAMP)

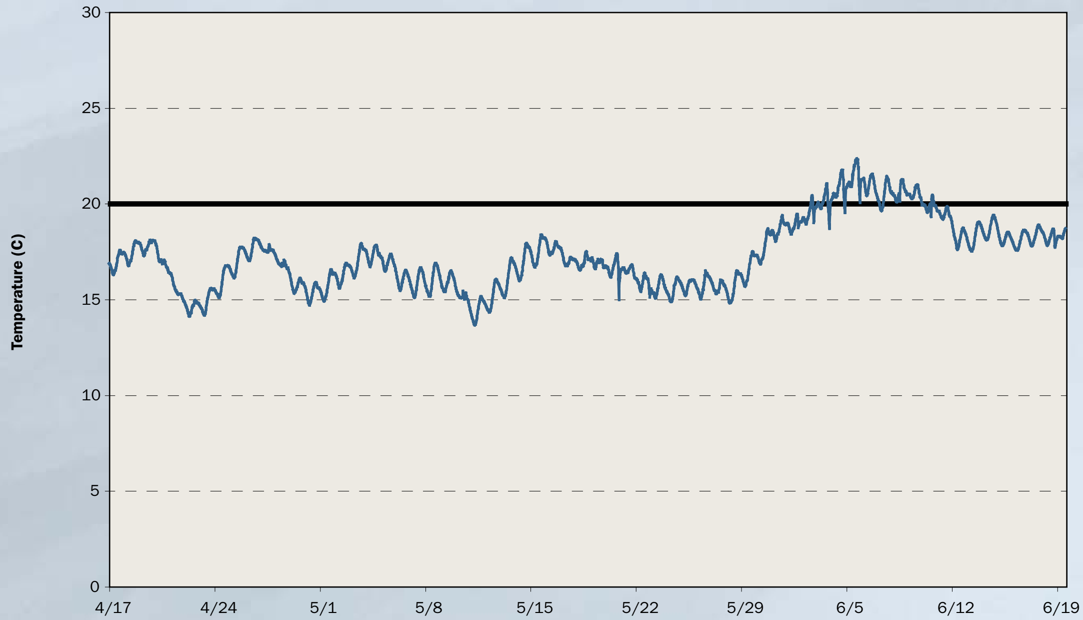


Figure C-7
Daily Water Temperature Fluctuations (°C) in the San Joaquin River at Dos Reis County Park During the 2010 Vernalis Adaptive Management Program (VAMP)

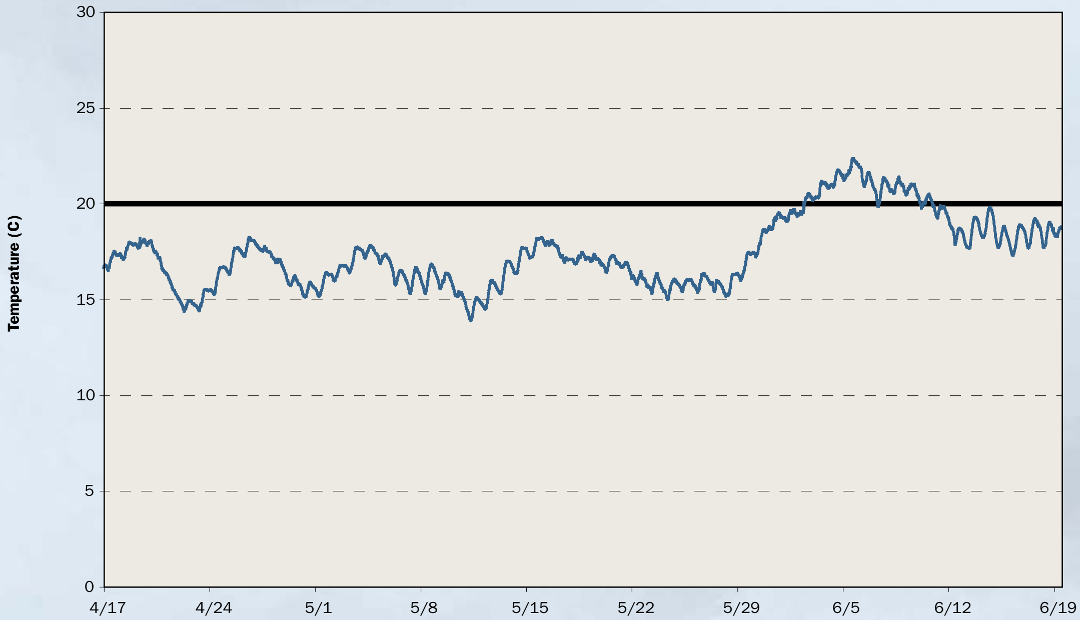


Figure C-8

Daily Water Temperature Fluctuations (°C) in the San Joaquin River at the DWR Flow Monitoring Station Near Lathrop During the 2010 Vernalis Adaptive Management Program (VAMP)

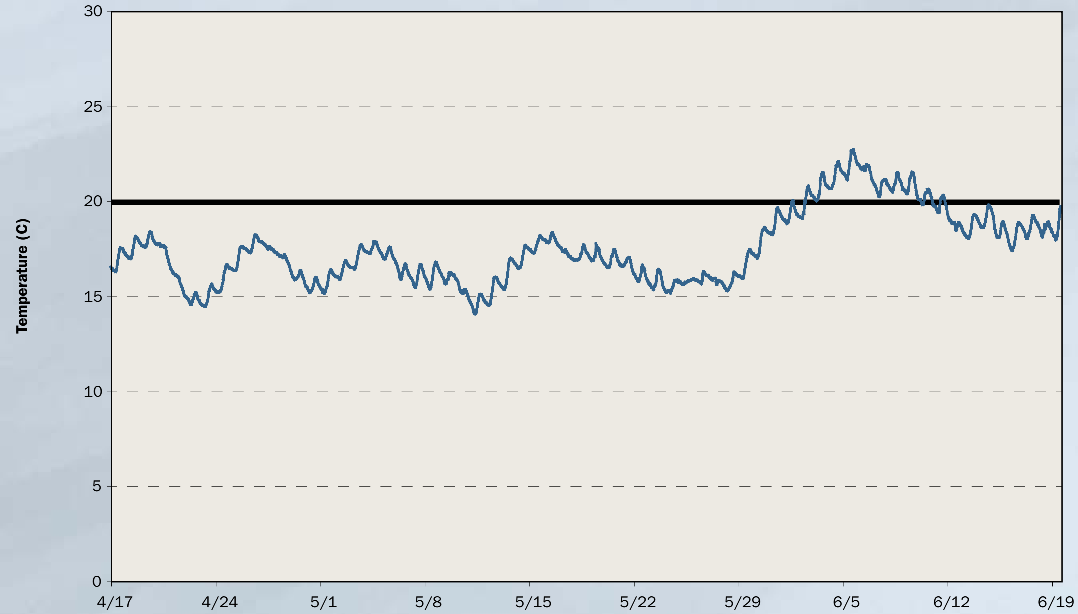


Figure C-9

Daily Water Temperature Fluctuations (°C) in the San Joaquin River at the Top of the Confluence Near Stockton During the 2010 Vernalis Adaptive Management Program (VAMP)

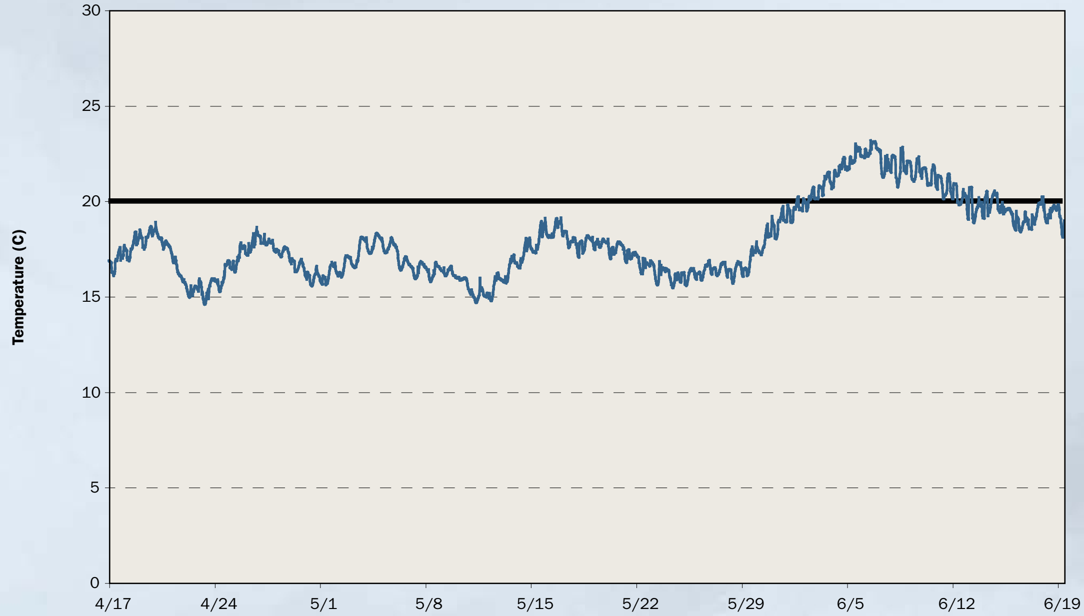


Figure C-10
Daily Water Temperature Fluctuations (°C) in the San Joaquin River at the Bottom of the Confluence Near Stockton During the 2010 Vernalis Adaptive Management Program (VAMP)

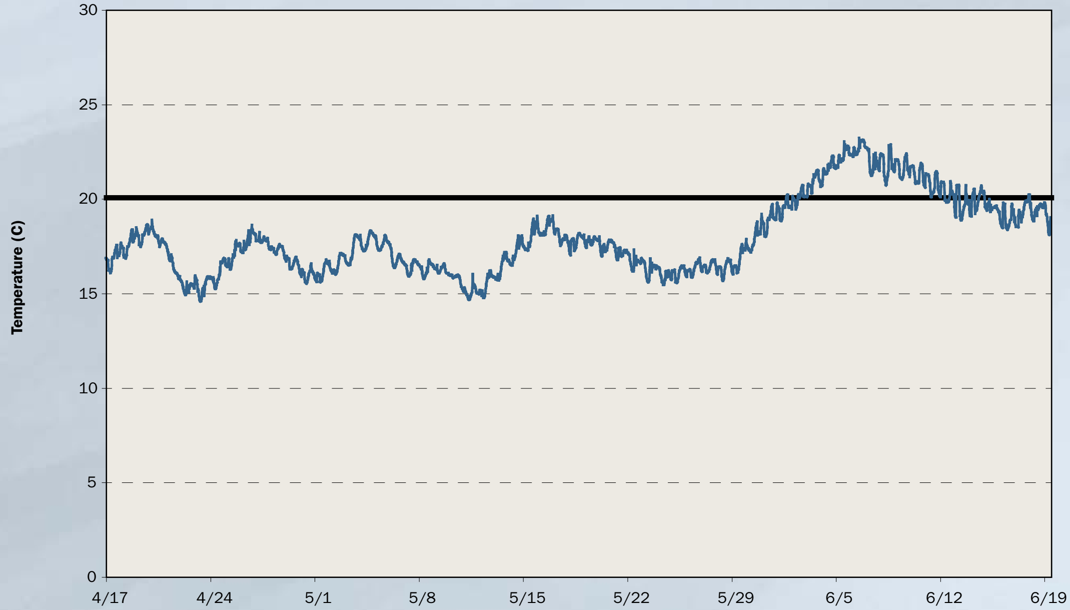


Figure C-11
Daily Water Temperature Fluctuations (°C) in the San Joaquin River Upstream of Channel Marker No 33 During the 2010 Vernalis Adaptive Management Program (VAMP)

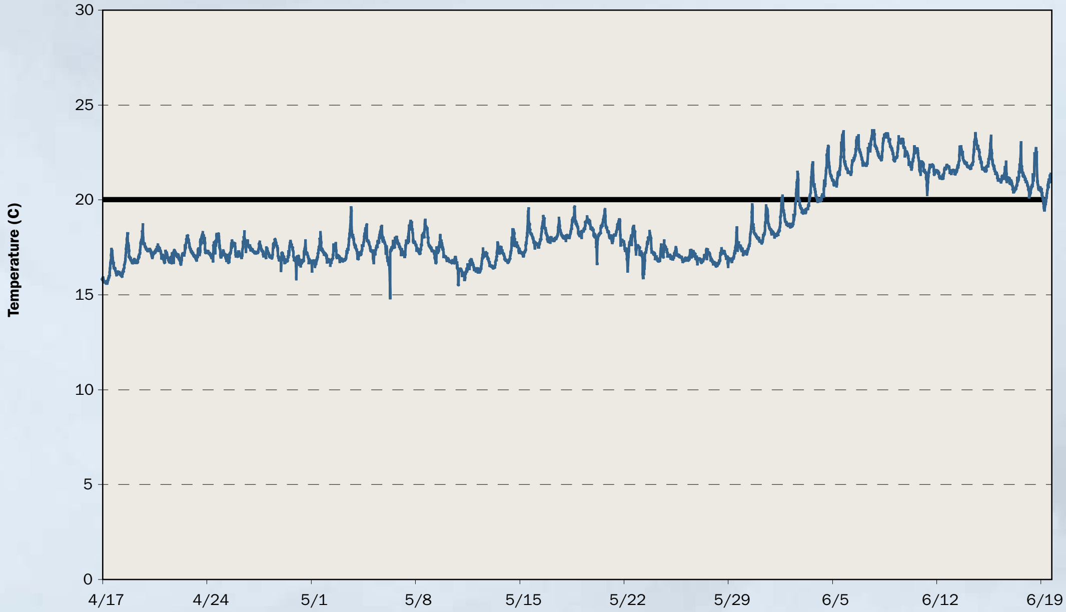


Figure C-12

Daily Water Temperature Fluctuations (°C) in the San Joaquin River at Turner Cut (Channel Marker 21-22) During the 2010 Vernalis Adaptive Management Program (VAMP)

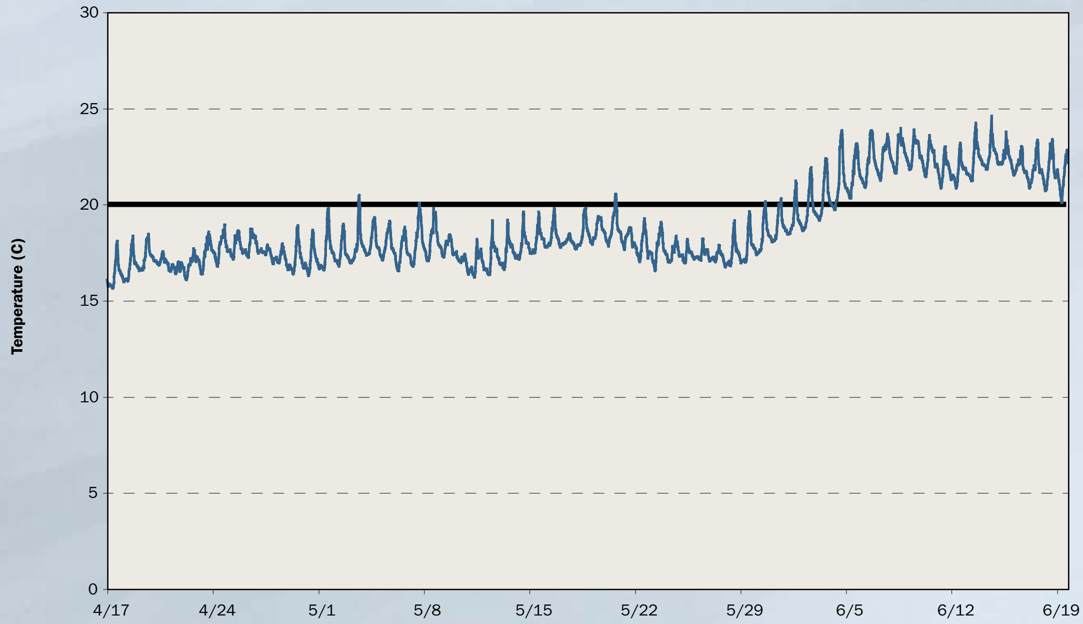


Figure C-13

Daily Water Temperature Fluctuations (°C) in the San Joaquin River ½ Mile Upstream of Channel Marker No 13 (“Q” Piling) During the 2010 Vernalis Adaptive Management Program (VAMP)

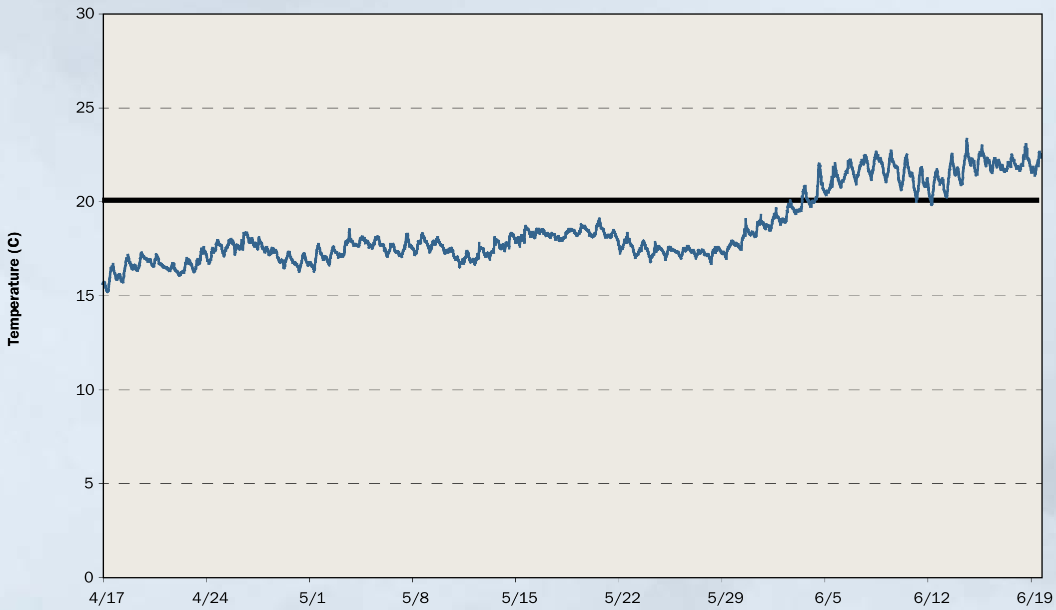


Figure C-14
Daily Water Temperature Fluctuations (°C) in the San Joaquin River at the All Pro Abandoned Boat During the 2010 Vernalis Adaptive Management Program (VAMP)

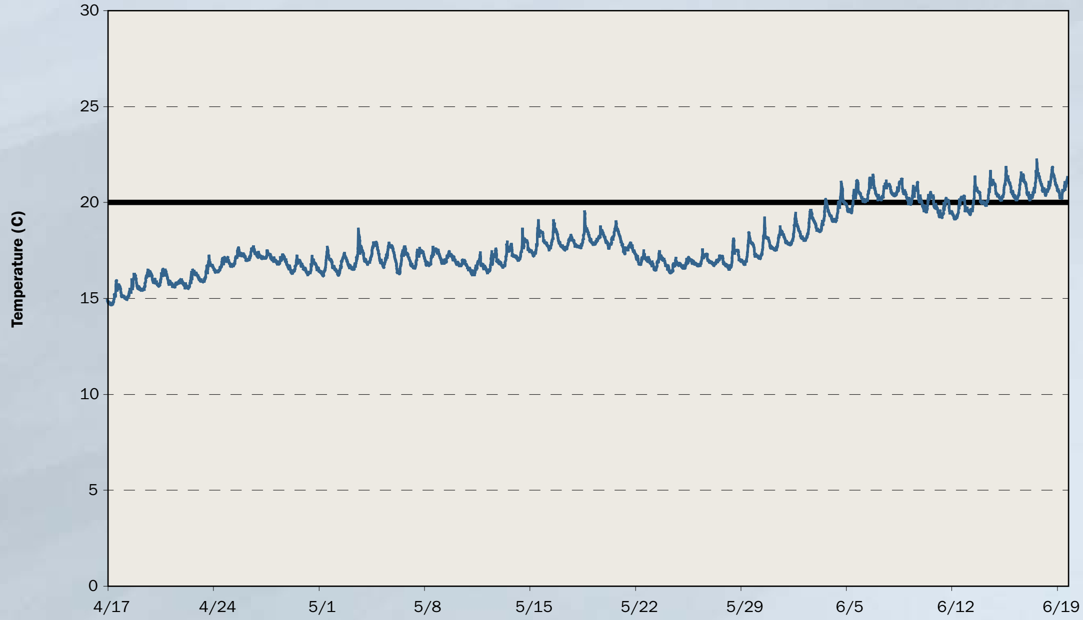


Figure C-15
Daily Water Temperature Fluctuations (°C) in the San Joaquin River Near the Antioch Marina During the 2010 Vernalis Adaptive Management Program (VAMP)

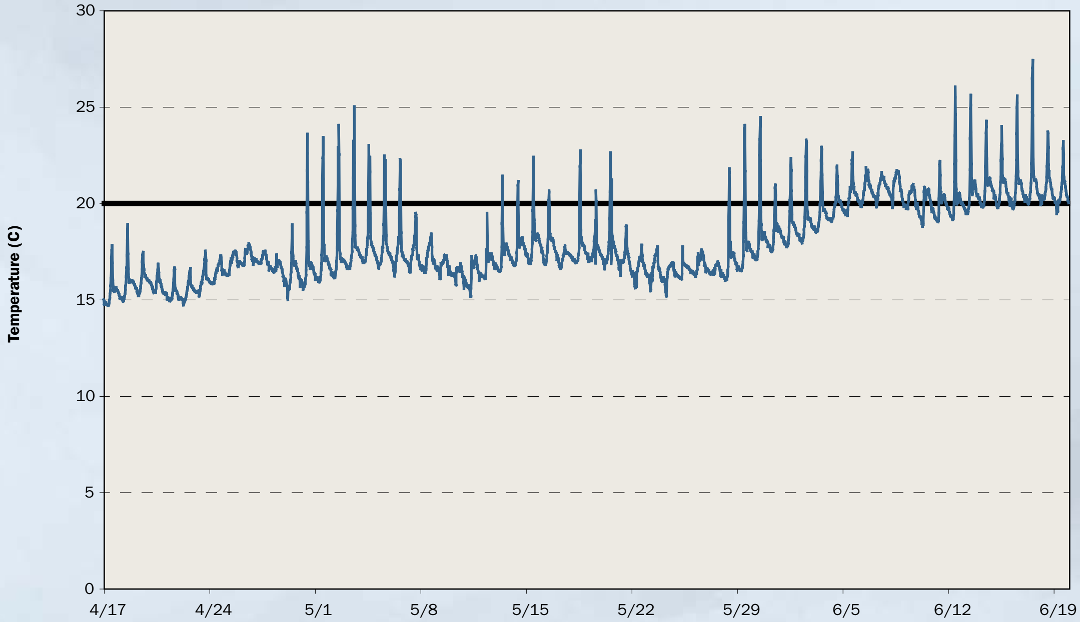


Figure C-16
Daily Water Temperature Fluctuations (°C) in the South Delta Near Chipps Island During the 2010 Vernalis Adaptive Management Program (VAMP)

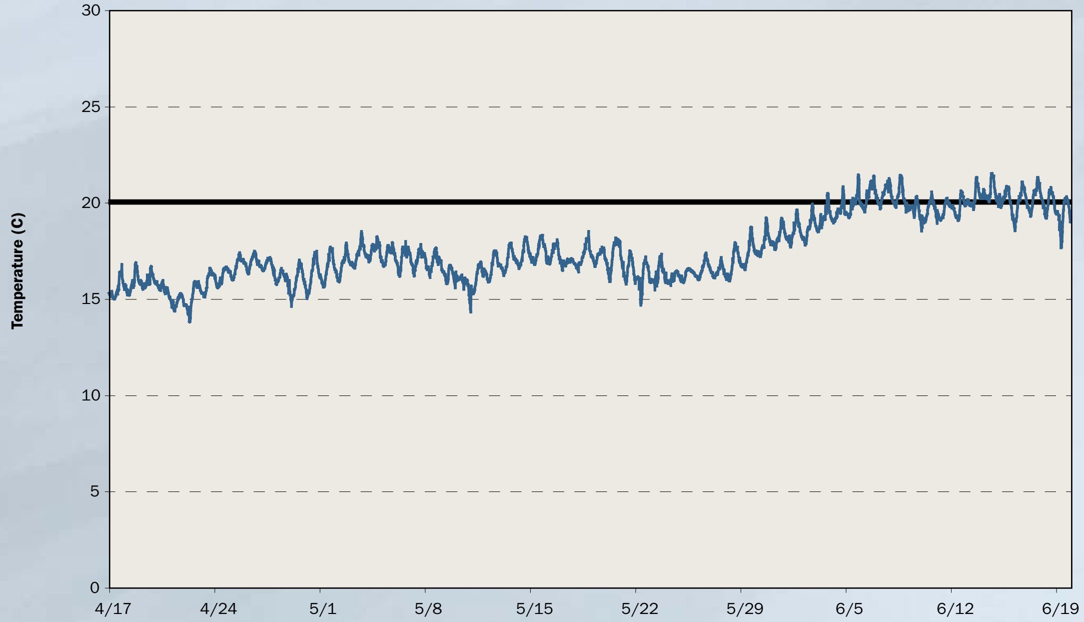


Figure C-17
Daily Water Temperature Fluctuations (°C) in the South Delta Near the Holland Riverside Marina During the 2010 Vernalis Adaptive Management Program (VAMP)

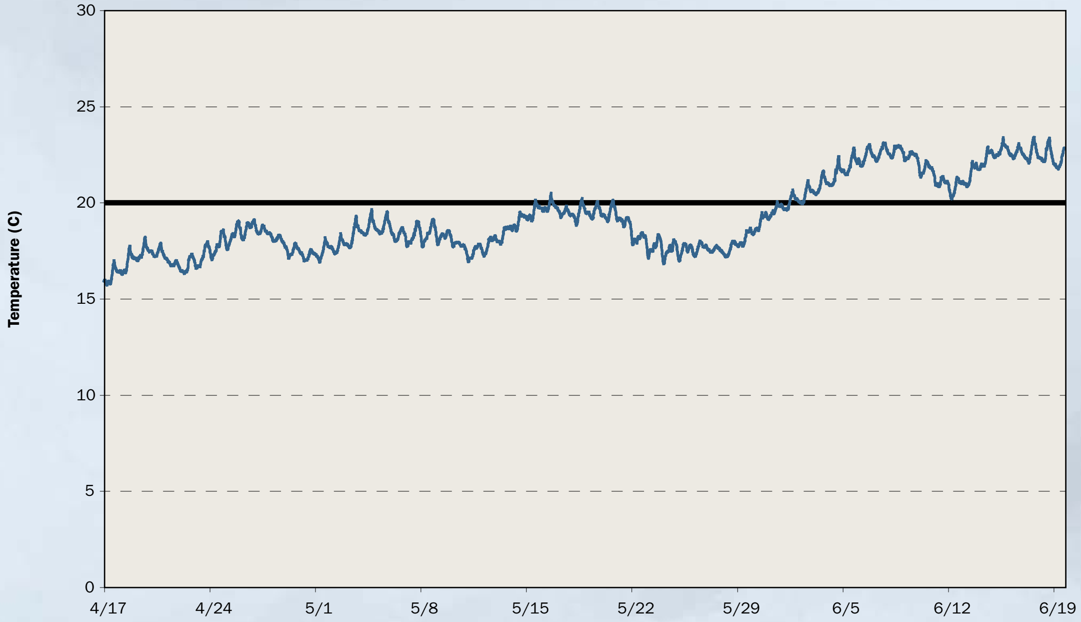


Figure C-18
Daily Water Temperature Fluctuations (°C) in the South Delta Near the Old River/Indian Slough Confluence During the 2010 Vernalis Adaptive Management Program (VAMP)

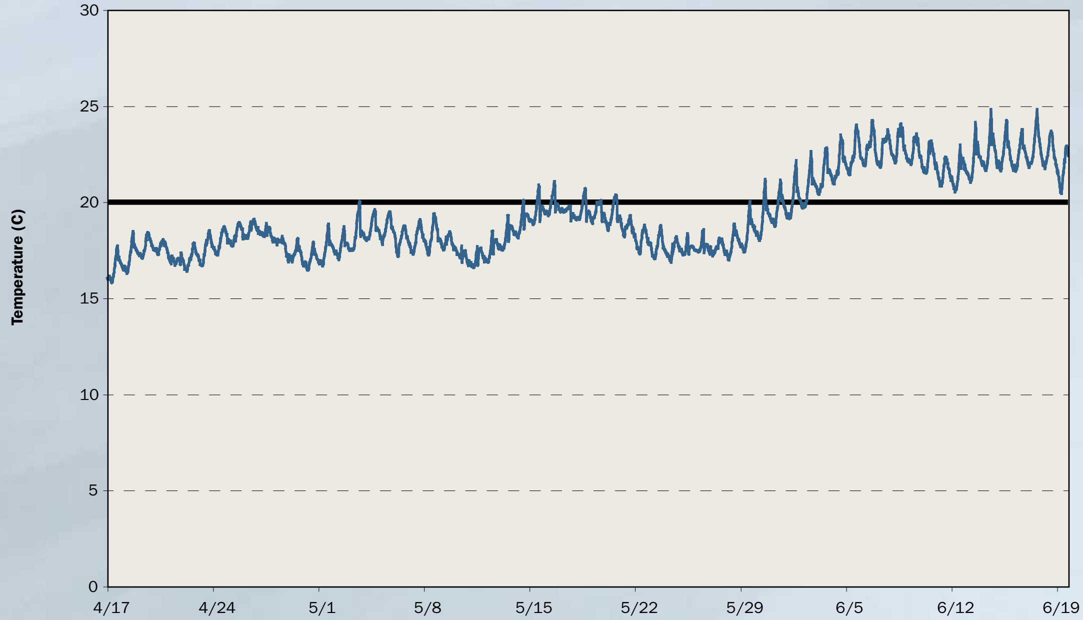


Figure C-19
Daily Water Temperature Fluctuations (°C) in the South Delta Near the CCF Radial Gates During the 2010 Vernalis Adaptive Management Program (VAMP)

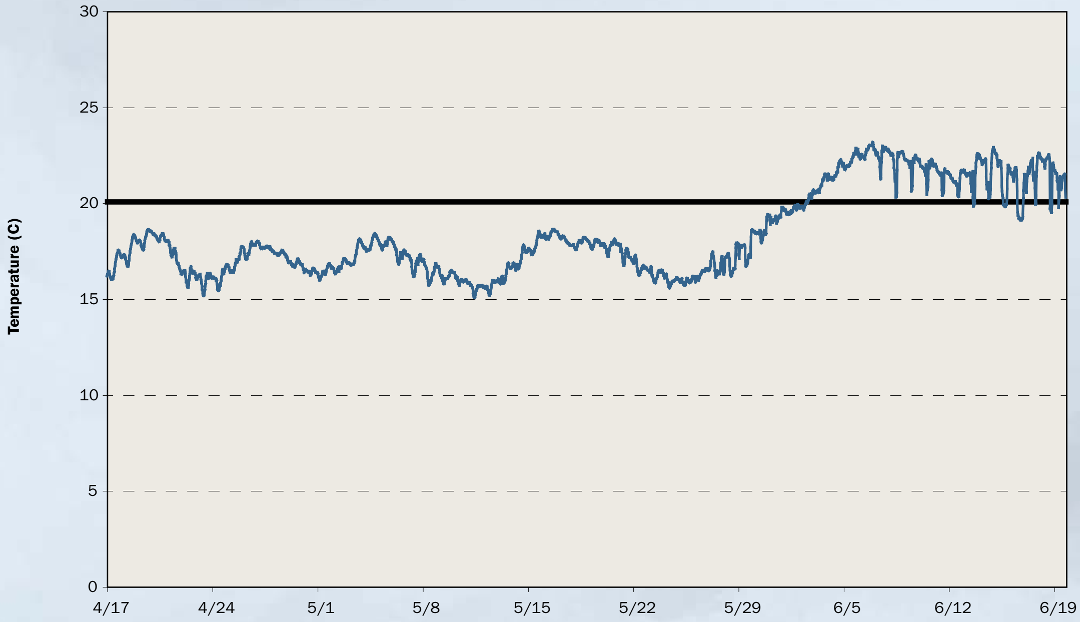


Figure C-20
DDaily Water Temperature Fluctuations (°C) in the South Delta in the Grant Line Canal at Tracy Blvd Bridge During the 2010 Vernalis Adaptive Management Program (VAMP)

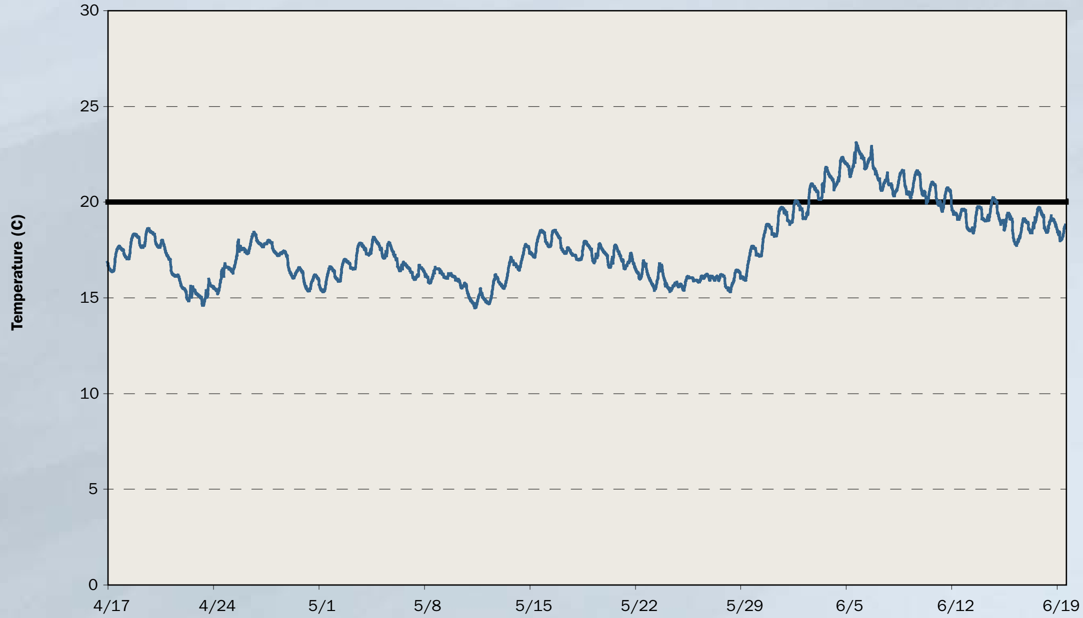
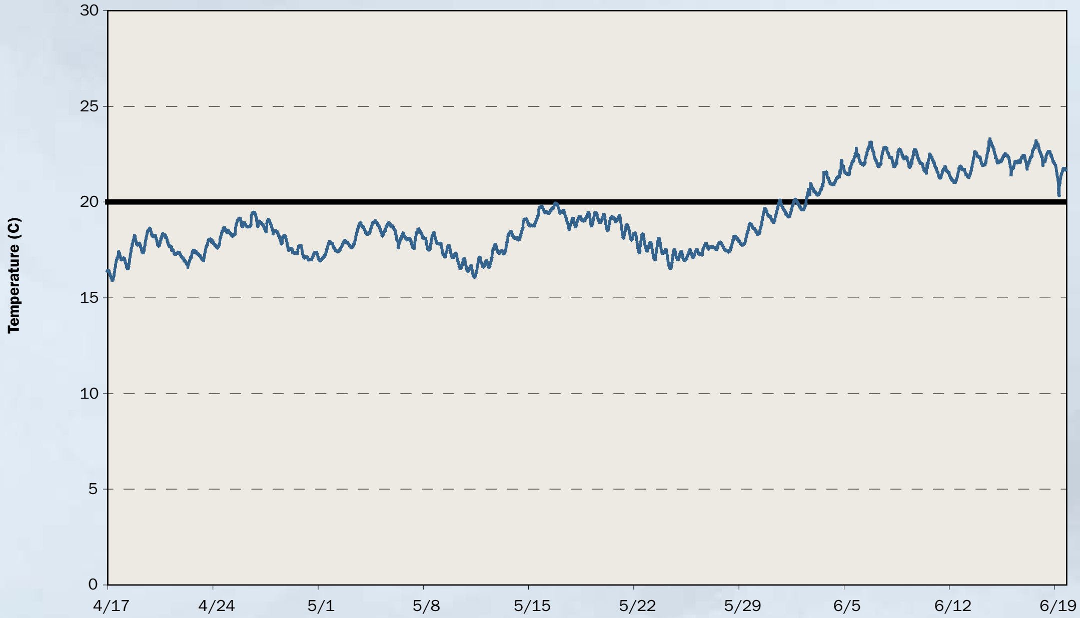


Figure C-21
Daily Water Temperature Fluctuations (°C) in the South Delta Near Union Point During the 2010 Vernalis Adaptive Management Program (VAMP)



APPENDIX D

Acronyms and Abbreviations Used in Appendix D

BCA	San Joaquin River at Banta Carbona
C18/C16	San Joaquin River at Shipping Channel Markers (2 Receivers)
CHP	Chipps Island
CHPe	Chipps Island East Receivers
CHPw	Chipps Island West Receivers
CVP	Central Valley Project Trash Rack
CVPTank	Central Valley Project Holding Tank
DF	San Joaquin River at Durham Ferry
MFE	San Joaquin River at Medford Island, East Receiver
MFW	San Joaquin River at Medford Island, West Receiver
MOS	San Joaquin River at Mossdale
MRN	Middle River North (2 Receivers)
MRND	Middle River North, Downstream Receiver
MRNU	Middle River North, Upstream Receiver
MRS	Middle River South
OR	Old River
OR1/OR2	Old River at the junction with San Joaquin River (2 Receivers)
ORN	Old River North (2 Receivers)
ORND	Old River North, Downstream Receiver
ORNU	Old River North, Upstream Receiver
ORS	Old River South (2 Receivers)
ORSD	Old River South, Downstream Receiver
ORSU	Old River South, Upstream Receiver
RGD	Radial Gates at Clifton Court Forebay, Interior (2 Receivers)
RGU	Radial Gates at Clifton Court Forebay, Entrance Channel
SJ1/SJ2	San Joaquin River at Lathrop (2 Receivers)
STK	San Joaquin River at Stockton
STN	San Joaquin River at Navy Bridge near Stockton
STS	San Joaquin River at USGS Gauge at Stockton
TCN/TCS	San Joaquin River at Turner Cut (2 Receivers)
TMS	Threemile Slough (South Receiver)
TMN	Threemile Slough (North Receiver)

Table D-1
Definitions of Parameters Used in the Release-Recapture Survival Model Shown in Chapter 5. Unique Parameters Were Defined for each Release Site: DF = Durham Ferry, OR = Old River, STK = Stockton.

Parameter	Release Site	Definition
S_{A1}	DF	Probability of survival from Durham Ferry release site to Banta Carbona (BCA)
S_{A2}	DF	Probability of survival from Banta Carbona (BCA) to Mossdale (MOS)
S_{A3}	DF	Probability of survival from Mossdale (MOS) to Lathrop (SJ1/SJ2) or Old River (OR1/OR2)
S_{A4}	DF	Probability of survival from Lathrop (SJ1/SJ2) to Stockton USGS Gauge (STS)
S_{A5}	DF	Probability of survival from Stockton USGS Gauge (STS) to Stockton Navy Bridge (STN)
S_{A6}	DF, STK	Probability of survival from Stockton Navy Bridge (STN) to Shipping Channel Markers (C18/C16) or Turner Cut (TCN/TCS)
S_{B1}	DF, OR	Probability of survival from Old River (OR1/OR2) to Old River South (ORS)
ψ_{A1}	DF	Probability of remaining in the San Joaquin River at the junction with Old River;
ψ_{B1}	DF	Probability of entering Old River at the junction with the San Joaquin River;
ψ_{A2}	DF, STK	Probability of remaining in the San Joaquin River at the junction with Turner Cut;
ψ_{F2}	DF, STK	Probability of entering Turner Cut at the junction with the San Joaquin River;
ψ_{B2}	DF, OR	Probability of remaining in Old River at the junction with Middle River;
ψ_{C2}	DF, OR	Probability of entering Middle River at the junction with Old River;
$\phi_{A7,A8}$	DF, STK	Joint probability of moving from C18/C16 toward MFE/MFW, and surviving from C18/C16 to MFE/MFW
$\phi_{A8,G1}$	DF, STK	Joint probability of moving from MFE/MFW toward CHP, and surviving from MFE/MFW to CHP
$\phi_{B1,B2}$	DF, OR	Joint probability of moving from OR1/OR2 toward ORN, and surviving from OR1/OR2 to ORN;
$\phi_{B2,B3}$	DF, OR	Joint probability of moving from ORS toward ORN, and surviving from ORS to ORN;
$\phi_{B2,C2}$	DF, OR	Joint probability of moving from ORS toward MRN, and surviving from ORS to MRN
$\phi_{B2,D1O}$	DF, OR	Joint probability of moving from ORS toward RGU when the gate was open, and surviving from ORS to RGU
$\phi_{B2,D1C}$	DF, OR	Joint probability of moving from ORS toward RGU when the gate was closed, and surviving from ORS to RGU
$\phi_{B2,E1}$	DF, OR	Joint probability of moving from ORS toward CVP, and surviving from ORS to CVP
$\phi_{B3,G1}$	DF, OR	Joint probability of moving from ORN toward CHP, and surviving from ORN to CHP
$\phi_{C1,B3}$	DF, OR	Joint probability of moving from MRS toward ORN, and surviving from MRS to ORN
$\phi_{C1,C2}$	DF, OR	Joint probability of moving from MRS toward MRN, and surviving from MRS to MRN
$\phi_{C1,D1O}$	DF, OR	Joint probability of moving from MRS toward RGU when the gate was open, and surviving from MRS to RGU
$\phi_{C1,D1C}$	DF, OR	Joint probability of moving from MRS toward RGU when the gate was closed, and surviving from MRS to RGU
$\phi_{C1,E1}$	DF, OR	Joint probability of moving from MRS toward CVP, and surviving from MRS to CVP
$\phi_{C2,G1}$	DF, OR	Joint probability of moving from MRN toward CHP, and surviving from MRN to CHP
$\phi_{D1O,D2}$	DF, OR	Joint probability of moving from RGU toward RGD, and surviving from RGU to RGD, conditional on arriving at RGU when the gate was open
$\phi_{D1C,D2}$	DF, OR	Joint probability of moving from RGU toward RGD, and surviving from RGU to RGD, conditional on arriving at RGU when the gate was closed
$\phi_{D2,G1}$	DF, OR	Joint probability of moving from RGD toward CHP, and surviving from RGU to CHP
$\phi_{E1,E2}$	DF, OR	Joint probability of moving from CVP toward CVPtank, and surviving from CVP to CVPtank
$\phi_{E2,G1}$	DF, OR	Joint probability of moving from CVPtank toward CHP, and surviving from CVPtank to CHP
$\phi_{F1,G1}$	DF, STK	Joint probability of moving from TCN/TCS toward CHP, and surviving from TCN/TCS to CHP
$\phi_{OR,B1}$	OR	Joint probability of moving from the Old River release site toward OR1/OR2, and surviving from the release site to OR1/OR2
$\phi_{STK,A6}$	STK	Joint probability of moving from the Stockton release site toward STN, and surviving from the release site to STN
P_{A2}	DF	Conditional probability of detection at BCA
P_{A3}	DF	Conditional probability of detection at MOS
P_{A4}	DF	Conditional probability of detection at SJ1/SJ2
P_{A5}	DF	Conditional probability of detection at STS
P_{A6}	DF, STK	Conditional probability of detection at STN
P_{A7a}	DF, STK	Conditional probability of detection at C18
P_{A7b}	DF, STK	Conditional probability of detection at C16
P_{A8a}	DF, STK	Conditional probability of detection at MFE
P_{A8b}	DF, STK	Conditional probability of detection at MFW
P_{B1}	DF, OR	Conditional probability of detection at OR1/OR2
P_{B2a}	DF, OR	Conditional probability of detection at ORSU
P_{B2b}	DF, OR	Conditional probability of detection at ORSD
P_{B3a}	DF, OR	Conditional probability of detection at ORNU
P_{B3b}	DF, OR	Conditional probability of detection at ORND
P_{C1}	DF, OR	Conditional probability of detection at MRS
P_{C2a}	DF, OR	Conditional probability of detection at MRNU
P_{C2b}	DF, OR	Conditional probability of detection at MRND
P_{D1}	DF, OR	Conditional probability of detection at RGU
P_{E1}	DF, OR	Conditional probability of detection at CVP
P_{F1a}	DF, STK	Conditional probability of detection at TCN
P_{F1b}	DF, STK	Conditional probability of detection at TCS
P_{G1a}	DF, OR, STK	Conditional probability of detection at CHPe
P_{G1b}	DF, OR, STK	Conditional probability of detection at CHPw

Table D-2
Parameter Estimates (standard errors in parentheses) for Tagged Juvenile Chinook Salmon Released in 2010, Excluding Predator-type Detections. Parameters Without Standard Errors Were Estimated at Fixed Values in the Model. Estimates of Parameters Used for Multiple Release Sites are Weighted Averages of the Site-specific Estimates. Population-level Estimates are Weighted Averages of Release Group Estimates. Some Parameters Were Not Estimable Because of Sparse Data. Release Sites are Defined as: DF = Durham Ferry, OR = Old River, STK = Stockton.

Parameter	Release Site	Release Occasion							Population Estimate
		1	2	3	4	5	6	7	
S_{A1}	DF	0.97 (0.02)	1.00	0.97 (0.02)	1.00	1.00	1.00	0.98 (0.02)	0.99 (0.00)
S_{A2}	DF	0.91 (0.03)	1.00	0.95 (0.03)	0.96 (0.02)	0.97 (0.02)	0.97 (0.02)	0.88 (0.04)	0.95 (0.01)
S_{A3}	DF	0.92 (0.03)	0.97 (0.02)	0.91 (0.03)	0.84 (0.05)	0.96 (0.02)	0.89 (0.04)	0.90 (0.04)	0.91 (0.01)
S_{A4}	DF	0.93 (0.05)	0.91 (0.05)	0.79 (0.08)	0.83 (0.07)	0.93 (0.05)	0.82 (0.07)	0.72 (0.08)	0.85 (0.02)
S_{A5}	DF	1.03 (0.09)	0.96 (0.04)	0.90 (0.07)	0.95 (0.07)	1.00	0.91 (0.06)	0.92 (0.06)	0.95 (0.02)
S_{A6}	DF, STK	0.52 (0.07)	0.47 (0.07)	0.24 (0.06)	0.37 (0.07)	0.55 (0.06)	0.16 (0.05)	0.59 (0.07)	0.41 (0.02)
S_{B1}	DF, OR								
ψ_{A1}	DF	0.48 (0.06)	0.44 (0.06)	0.39 (0.06)	0.52 (0.07)	0.45 (0.06)	0.43 (0.06)	0.59 (0.07)	0.47 (0.02)
ψ_{B1}	DF	0.52 (0.06)	0.56 (0.06)	0.61 (0.06)	0.48 (0.07)	0.55 (0.06)	0.57 (0.06)	0.41 (0.07)	0.53 (0.02)
ψ_{A2}	DF, STK	0.91 (0.05)	0.97 (0.03)	1.00	0.95 (0.05)	0.85 (0.06)	0.75 (0.15)	0.93 (0.05)	0.91 (0.03)
ψ_{F2}	DF, STK	0.09 (0.05)	0.03 (0.03)	0.00	0.05 (0.05)	0.15 (0.06)	0.25 (0.15)	0.07 (0.05)	0.09 (0.03)
ψ_{B2}	DF, OR								
ψ_{C2}	DF, OR								
$\phi_{A7,A8}$	DF, STK	0.65 (0.09)	0.45 (0.09)	0.67 (0.14)	0.35 (0.11)	0.35 (0.09)	0.33 (0.19)	0.54 (0.1)	0.48 (0.05)
$\phi_{A8,G1}$	DF, STK	0.25 (0.1)	0.08 (0.07)	0.13 (0.12)	0.43 (0.19)	0.40 (0.16)	0.51 (0.36)	0.48 (0.12)	0.32 (0.07)
$\phi_{B1,B2}$	DF	0.90 (0.05)	0.97 (0.03)	0.89 (0.05)	0.85 (0.07)	0.94 (0.04)	0.86 (0.06)	0.91 (0.06)	0.90 (0.02)
$\phi_{B2,B3}$	DF, OR	0.33 (0.06)	0.30 (0.05)	0.27 (0.05)	0.04 (0.02)	0.33 (0.06)	0.31 (0.06)	0.18 (0.05)	0.25 (0.02)
$\phi_{B2,C2}$	DF, OR	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
$\phi_{B2,D1O}$	DF, OR	0.33 (0.06)	0.27 (0.05)	0.18 (0.05)	0.30 (0.06)	0.27 (0.08)	0.09 (0.04)	0.00a	0.21 (0.02)
$\phi_{B2,D1C}$	DF, OR	0.13 (0.04)	0.08 (0.03)	0.15 (0.04)	0.16 (0.05)	0.14 (0.05)	0.04 (0.02)	0.08a (0.04)	0.11 (0.02)
$\phi_{B2,E1}$	DF, OR		0.28 (0.05)	0.33 (0.06)	0.29 (0.11)	0.23 (0.06)	0.45 (0.38)	0.75 (0.26)	0.38 (0.08)
$\lambda_{B2,E1}$	DF, OR	0.16 (0.05)							
$\phi_{B3,G1}$	DF, OR	0.00	0.00	0.00	0.00	0.05 (0.05)	0.00	0.00	0.01 (0.01)
$\phi_{C1,B3}$	DF, OR								
$\phi_{C1,C2}$	DF, OR								
$\phi_{C1,D1O}$	DF, OR								
$\phi_{C1,D1C}$	DF, OR								
$\phi_{C1,E1}$	DF, OR								
$\phi_{C2,G1}$	DF, OR								
$\phi_{D1O,D2}$	DF, OR	0.52 (0.11)	0.45 (0.11)	0.17 (0.11)	0.35 (0.12)	0.33 (0.14)	0.33 (0.19)		0.36 (0.05)
$\phi_{D1C,D2}$	DF, OR	0.37 (0.17)	0.33 (0.19)	0.6 (0.16)	0.11 (0.1)	0.5 (0.2)	0.00	0.00	0.28 (0.05)
$\phi_{D2,G1}$	DF, OR	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
$\phi_{E1,E2}$	DF, OR	0.00	0.19 (0.09)	0.23 (0.09)	0.6 (0.21)	0.55 (0.15)	0.50 (0.35)	0.27 (0.11)	0.33 (0.07)
$\phi_{E2,G1}$	DF, OR		0.50 (0.25)	0.20 (0.18)	0.33 (0.27)	1.00	1.00	0.90 (0.1)	0.65 (0.07)
$\phi_{F1,G1}$	DF, STK	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
$\phi_{OR,B1}$	OR	1.00	1.00	1.00	1.00	1.00	0.98 (0.03)	0.97 (0.03)	0.99 (0.01)
$\phi_{STK,A6}$	STK	1.07 (0.08)	0.99 (0.09)	0.95 (0.04)	0.95 (0.06)	1.00	0.86 (0.06)	0.82 (0.07)	0.95 (0.02)
P_{A2}	DF	0.95 (0.03)	0.88 (0.04)	0.88 (0.04)	0.93 (0.03)	0.97 (0.02)	0.96 (0.02)	0.95 (0.03)	0.93 (0.01)
P_{A3}	DF	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
P_{A4}	DF	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
P_{A5}	DF	1.00	0.96 (0.04)	1.00	1.00	1.00	1.00	0.95 (0.05)	0.99 (0.01)
P_{A6}	DF, STK	0.71 (0.08)	0.76 (0.1)	1.00	0.95 (0.05)	0.98 (0.02)	1.00	0.96 (0.04)	0.91 (0.02)
P_{A7a}	DF, STK	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
P_{A7b}	DF, STK	0.97 (0.03)	0.97 (0.03)	0.92 (0.08)	0.95 (0.05)	0.86 (0.06)	0.83 (0.15)	1.00	0.93 (0.03)
P_{A8a}	DF, STK	1.00	1.00	1.00	1.00	0.89 (0.11)	1.00	0.92 (0.08)	0.97 (0.02)
P_{A8b}	DF, STK	1.00	1.00	0.87 (0.12)	0.82 (0.08)	0.79 (0.13)	1.00	0.84 (0.1)	0.90 (0.03)
P_{B1}	DF, OR	0.98 (0.02)	0.99 (0.01)	1.00	1.00	1.00	0.98 (0.02)	1.00	0.99 (0.00)
P_{B2a}	DF, OR	0.98 (0.02)	1.00	0.99 (0.01)	1.00	1.00	1.00	1.00	1.00 (0.00)
P_{B2b}	DF, OR	0.00	0.90 (0.03)	1.00	0.47 (0.06)	0.37 (0.06)	0.00	0.00	0.40 (0.01)
P_{B3a}	DF, OR	1.00	0.86 (0.07)	1.00	1.00	1.00	1.00	1.00	0.98 (0.01)
P_{B3b}	DF, OR	0.90 (0.06)	0.95 (0.05)	0.60 (0.15)	1.00	0.67 (0.1)	0.40 (0.11)	0.67 (0.16)	0.74 (0.04)
P_{C1}	DF, OR								
P_{C2a}	DF, OR								
P_{C2b}	DF, OR								
P_{D1}	DF, OR	1.00	1.00	1.00	1.00	0.70 (0.14)	1.00	1.00a	0.96 (0.02)
P_{E1}	DF, OR		1.00	1.00	0.30 (0.14)	0.75 (0.15)	0.14 (0.13)	0.40 (0.15)	0.60 (0.05)
P_{F1a}	DF, STK	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00 (0.00)
P_{F1b}	DF, STK	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00 (0.00)
P_{G1a}	DF, OR, STK	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00 (0.00)
P_{G1b}	DF, OR, STK	1.00	1.00	1.00	1.00	0.92 (0.07)	0.75 (0.15)	1.00	0.95 (0.02)

a = Under assumption that pD1aO=1.

Table D-3
Parameter Estimates (standard errors in parentheses) for Tagged Juvenile Chinook Salmon Released in 2010, Including Predator-type Detections. Parameters Without Standard Errors Were Estimated at Fixed Values in the Model. Estimates of Parameters Used for Multiple Release Sites are Weighted Averages of the Site-specific Estimates. Population-level Estimates are Weighted Averages of Release Group Estimates. Some Parameters Were Not Estimable Because of Sparse Data. Release Sites are Defined as: DF = Durham Ferry, OR = Old River, STK = Stockton.

Parameter	Release Site	Release Occasion							Population Estimate
		1	2	3	4	5	6	7	
S_{A1}	DF	0.99 (0.01)	1.00	1.00 (0.01)	1.00	1.00	1.00	1.00 (0.02)	1.00 (0.00)
S_{A2}	DF	0.93 (0.03)	1.00	0.94 (0.03)	0.96 (0.02)	0.97 (0.02)	0.99 (0.01)	0.86 (0.04)	0.95 (0.01)
S_{A3}	DF	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
S_{A4}	DF	0.97 (0.03)	0.91 (0.05)	0.92 (0.05)	0.89 (0.05)	0.94 (0.04)	0.87 (0.05)	0.78 (0.07)	0.90 (0.02)
S_{A5}	DF	0.97 (0.07)	1.00	0.99 (0.05)	0.95 (0.04)	1.00	0.97 (0.03)	0.99 (0.04)	0.98 (0.02)
S_{A6}	DF, STK	0.68 (0.07)	0.69 (0.06)	0.54 (0.07)	0.7 (0.06)	0.82 (0.05)	0.35 (0.06)	0.71 (0.06)	0.64 (0.02)
S_{B1}	DF, OR								
ψ_{A1}	DF	0.5 (0.06)	0.43 (0.06)	0.38 (0.06)	0.55 (0.06)	0.47 (0.06)	0.49 (0.06)	0.6 (0.06)	0.49 (0.02)
ψ_{B1}	DF	0.5 (0.06)	0.57 (0.06)	0.62 (0.06)	0.45 (0.06)	0.53 (0.06)	0.51 (0.06)	0.4 (0.06)	0.51 (0.02)
ψ_{A2}	DF, STK	0.85 (0.05)	0.96 (0.04)	0.94 (0.04)	0.78 (0.06)	0.85 (0.05)	0.82 (0.08)	0.9 (0.05)	0.87 (0.02)
ψ_{F2}	DF, STK	0.15 (0.05)	0.04 (0.04)	0.06 (0.04)	0.22 (0.06)	0.15 (0.05)	0.18 (0.08)	0.1 (0.05)	0.13 (0.02)
ψ_{B2}	DF, OR								
ψ_{C2}	DF, OR								
$\phi_{A7,A8}$	DF, STK	0.63 (0.08)	0.58 (0.07)	0.72 (0.08)	0.62 (0.08)	0.62 (0.07)	0.73 (0.11)	0.51 (0.08)	0.63 (0.03)
$\phi_{A8,G1}$	DF, STK	0.32 (0.09)	0.04 (0.04)	0.35 (0.11)	0.47 (0.11)	0.44 (0.1)	0.47 (0.14)	0.48 (0.12)	0.36 (0.04)
$\phi_{B1,B2}$	DF	0.94 (0.04)	0.98 (0.02)	0.93 (0.04)	0.93 (0.05)	1.00	1.00	0.96 (0.04)	0.96 (0.01)
$\phi_{B2,B3}$	DF, OR	0.36 (0.06)	0.24 (0.05)	0.18 (0.05)	0.11 (0.04)	0.19 (0.05)	0.21 (0.05)	0.04 (0.03)	0.19 (0.02)
$\phi_{B2,C2}$	DF, OR	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
$\phi_{B2,D1}$	DF, OR	0.35 (0.06)	0.38 (0.06)	0.37 (0.06)	0.45 (0.06)	0.39 (0.08)	0.24 (0.05)	0.00	0.31 (0.02)
$\phi_{B2,E1}$	DF, OR	0.27 (0.06)	0.38 (0.06)	0.44 (0.13)		0.51 (0.11)	0.98 (0.58)	1.12 (0.26)	0.61 (0.11)
$\phi_{B2,E1}$					0.19 (0.05)				
$\phi_{B3,G1}$	DF, OR	0.00	0.00	0.00	0.15 (0.14)	0.08 (0.08)	0.13 (0.09)	0.00	0.05 (0.03)
$\phi_{C1,B3}$	DF, OR								
$\phi_{C1,C2}$	DF, OR								
$\phi_{C1,D1}$	DF, OR								
$\phi_{C1,E1}$	DF, OR								
$\phi_{C2,G1}$	DF, OR								
$\phi_{D1,D2}$	DF, OR	0.87 (0.07)	0.79 (0.08)	0.88 (0.07)	0.46 (0.09)	0.63 (0.12)	0.82 (0.09)		0.74 (0.04)
$\phi_{D2,G1}$	DF, OR	0.00	0.04 (0.04)	0.00	0.00	0.00	0.00		0.01 (0.01)
$\phi_{E1,E2}$	DF, OR	0.15 (0.08)	0.27 (0.08)	0.21 (0.08)		0.41 (0.11)	0.19 (0.12)	0.21 (0.07)	0.24 (0.04)
$\phi_{E2,G1}$	DF, OR	1.00	0.88 (0.12)	0.72 (0.17)	0.77 (0.13)	0.79 (0.11)	0.88 (0.12)	0.93 (0.07)	0.85 (0.04)
$\phi_{F1,G1}$	DF, STK	0.00	0.00	0.00	0.10 (0.1)	0.00	0.25 (0.22)	0.00	0.05 (0.03)
$\phi_{OR,B1}$	OR	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
$\phi_{STK,A6}$	STK	1.07 (0.05)	1.07 (0.06)	1.01 (0.04)	0.96 (0.04)	1.00	0.98 (0.03)	0.99 (0.04)	1.01 (0.02)
P_{A2}	DF	0.96 (0.02)	0.88 (0.04)	0.88 (0.04)	0.93 (0.03)	0.97 (0.02)	0.96 (0.02)	0.95 (0.03)	0.93 (0.01)
P_{A3}	DF	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
P_{A4}	DF	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
P_{A5}	DF	1.00	0.97 (0.03)	1.00	1.00	1.00	1.00	0.96 (0.04)	0.99 (0.01)
P_{A6}	DF, STK	0.74 (0.06)	0.78 (0.09)	0.94 (0.04)	0.98 (0.02)	0.98 (0.02)	1.00	0.93 (0.04)	0.91 (0.02)
P_{A7a}	DF, STK	0.97 (0.03)	0.89 (0.05)	0.9 (0.06)	0.94 (0.04)	0.91 (0.04)	0.94 (0.05)	0.92 (0.04)	0.92 (0.02)
P_{A7b}	DF, STK	1.00	1.00	0.96 (0.03)	0.97 (0.03)	0.95 (0.03)	1.00	1.00	0.98 (0.01)
P_{A8a}	DF, STK	0.96 (0.04)	0.96 (0.04)	1.00	1.00	0.96 (0.03)	0.92 (0.06)	0.95 (0.04)	0.96 (0.01)
P_{A8b}	DF, STK	1.00	1.00	1.00	1.00	0.96 (0.03)	0.92 (0.06)	0.95 (0.04)	0.98 (0.01)
P_{B1}	DF, OR	0.99 (0.01)	0.99 (0.01)	1.00	1.00	1.00	0.99 (0.01)	1.00	1.00 (0.00)
P_{B2a}	DF, OR	0.98 (0.02)	1.00	0.99 (0.01)	1.00	1.00	1.00	1.00	1.00 (0.00)
P_{B2b}	DF, OR	0.01 (0.01)	0.91 (0.03)	0.97 (0.03)	0.71 (0.09)	0.35 (0.06)	0.00	0.00	0.43 (0.02)
P_{B3a}	DF, OR	0.86 (0.08)	0.72 (0.1)	0.82 (0.12)	1.00	0.90 (0.09)	0.92 (0.07)	1.00	0.89 (0.03)
P_{B3b}	DF, OR	0.86 (0.08)	1.00	0.67 (0.26)	0.57 (0.19)	0.82 (0.12)	0.86 (0.09)	1.00	0.82 (0.05)
P_{C1}	DF, OR								
P_{C2a}	DF, OR								
P_{C2b}	DF, OR								
P_{D1}	DF, OR	1.00	0.96 (0.04)	1.00	1.00	0.63 (0.12)	1.00		0.93 (0.02)
P_{E1}	DF, OR	1.00	0.92 (0.06)	0.74 (0.21)		0.57 (0.13)	0.25 (0.15)	0.53 (0.14)	0.67 (0.05)
P_{F1a}	DF, STK	0.86 (0.13)	1.00	1.00	1.00	1.00	0.75 (0.22)	1.00	0.94 (0.04)
P_{F1b}	DF, STK	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
P_{G1a}	DF, OR, STK	0.91 (0.09)	1.00	1.00	1.00	0.96 (0.04)	1.00	1.00	0.98 (0.01)
P_{G1b}	DF, OR, STK	1.00	0.89 (0.00)	1.00	0.95 (0.05)	0.96 (0.04)	0.88 (0.08)	0.95 (0.05)	0.95 (0.02)

APPENDIX E

Figure E-1

Impact of SWRCB D-1641 Storage and Flow Conditions on Lake McClure Storage and Release (Merced River) for 2000. (Refill period: May 13 – 29, 2000)

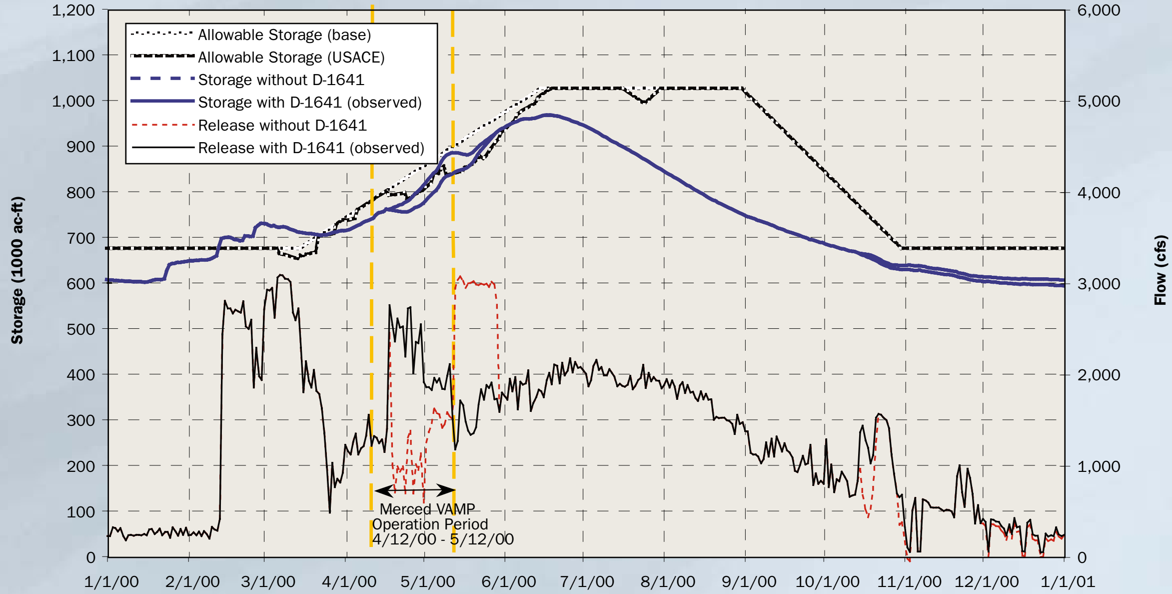


Figure E-2

Impact of SWRCB D-1641 Storage and Flow Conditions on Don Pedro Reservoir Storage and Release (Tuolumne River) for 2000. (Refill period: September 27 – October 7, 2000)

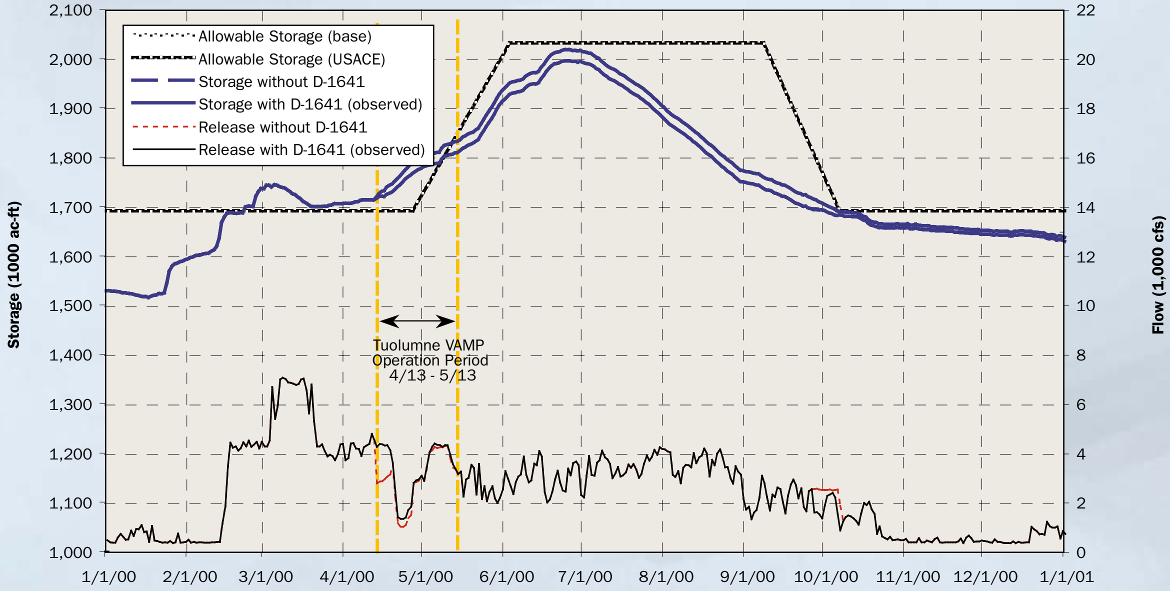


Figure E-3

Impact of SWRCB D-1641 Storage and Flow Conditions on Don Pedro Reservoir Storage and Release (Tuolumne River) for 2001. (Refill period: March 23 – 28, 2001)

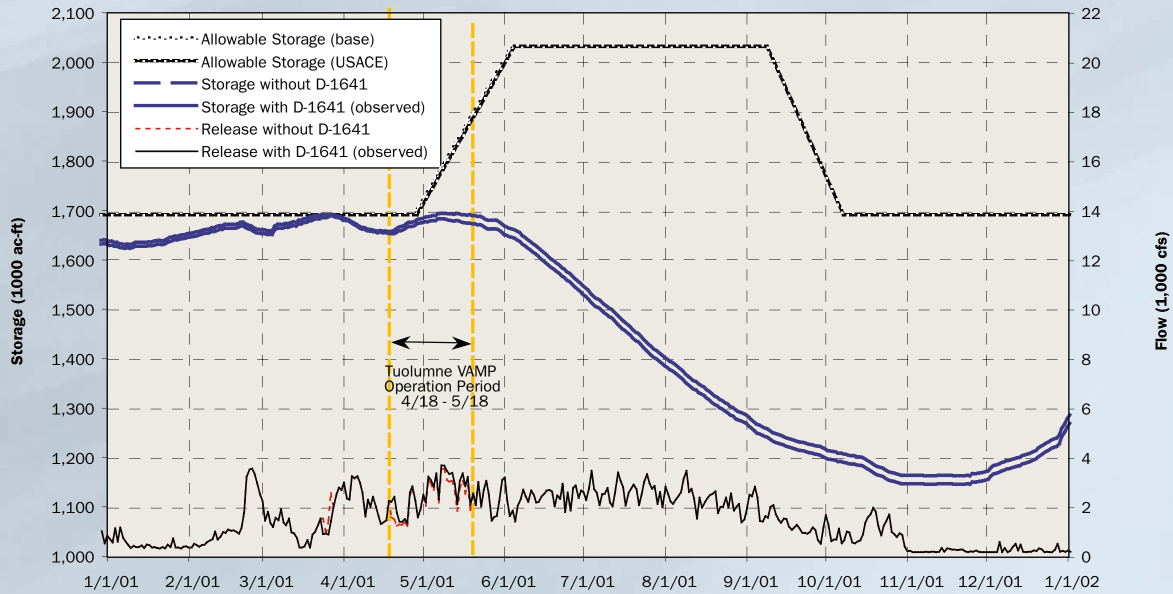


Figure E-4

Impact of SWRCB D-1641 Storage and Flow Conditions on Don Pedro Reservoir Storage and Release (Tuolumne River) for 2004. (Refill period: March 10 – 16, 2004 and March 27 – April 1, 2004)

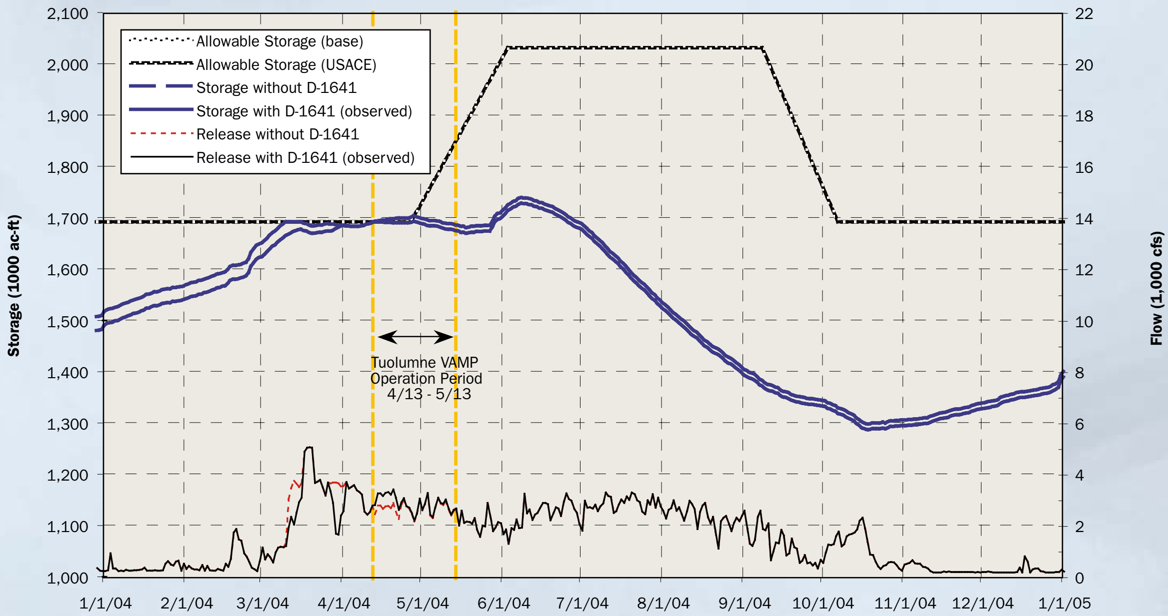


Figure E-5

Impact of SWRCB D-1641 Storage and Flow Conditions on Lake McClure Storage and Release (Merced River) for 2005. (Refill period: January 25 - March 23, 2005 and August 26 – September 3, 2005)

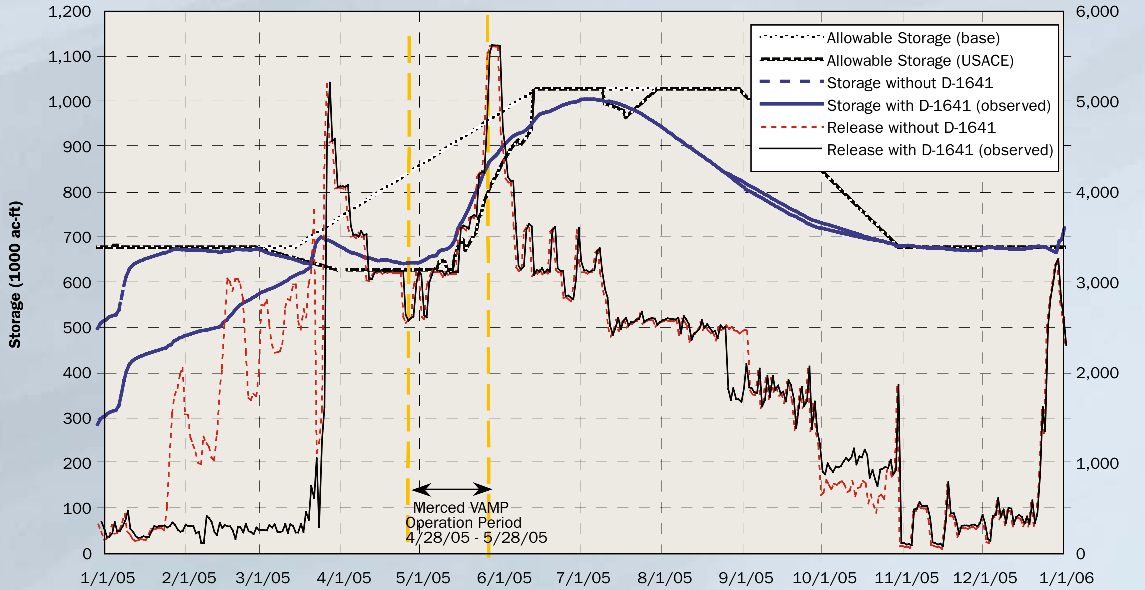


Figure E-6

Impact of SWRCB D-1641 Storage and Flow Conditions on Don Pedro Reservoir Storage and Release (Tuolumne River) for 2005. (Refill period: March 21 – 24, 2005)

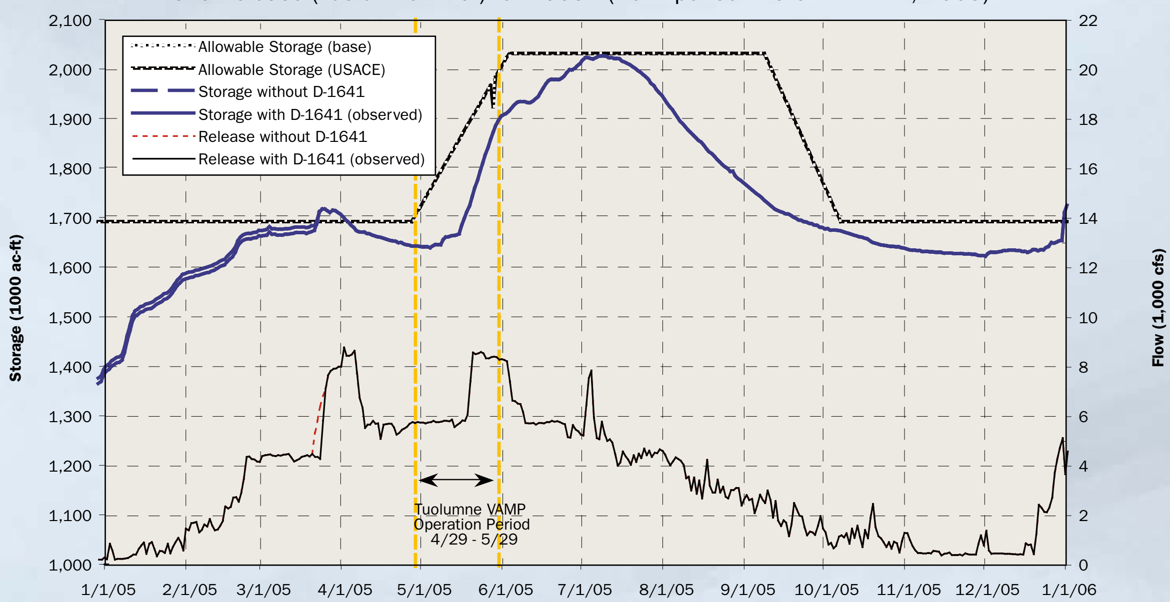


Figure E-7

Impact of SWRCB D-1641 Storage and Flow Conditions on Lake McClure Storage and Release (Merced River) for 2010. (Refill period: April 13 – May 23, 2010 and November 27 – December 8, 2010)

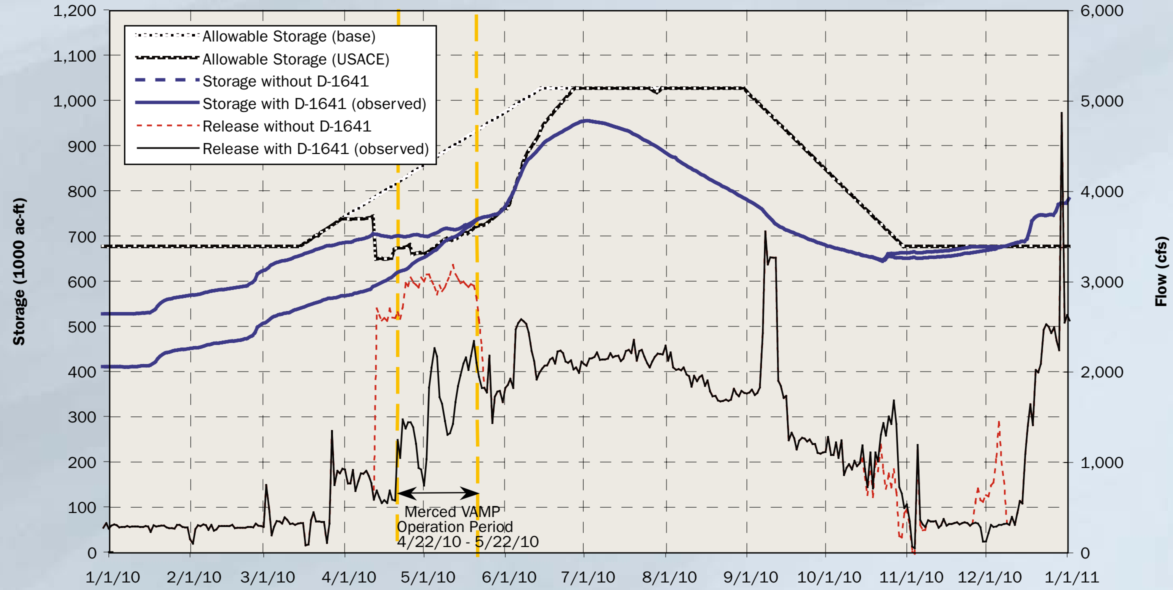
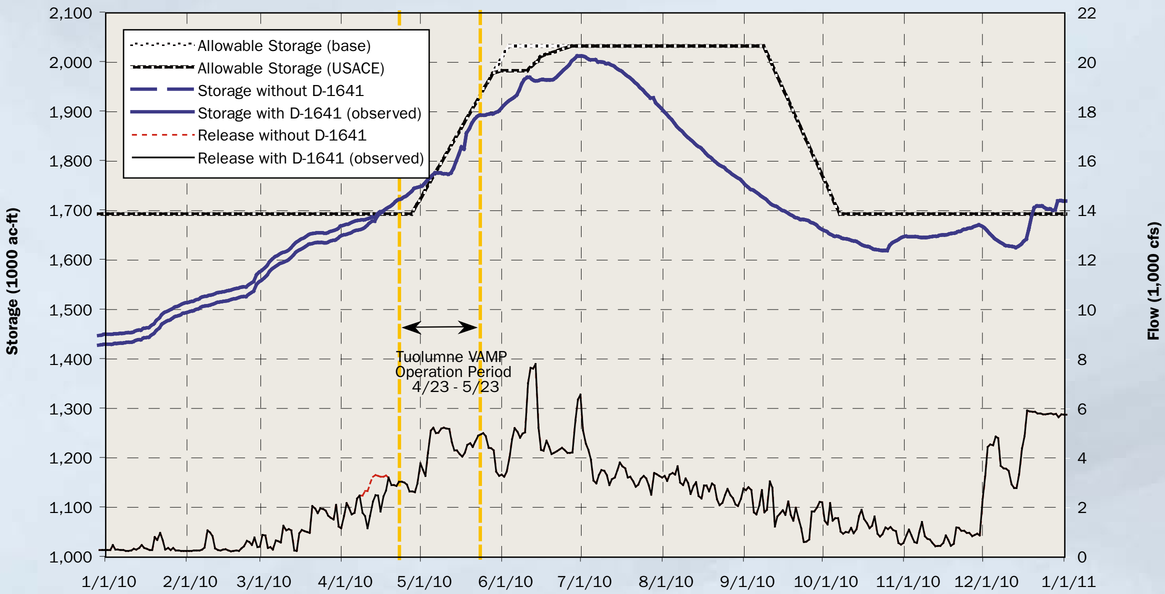


Figure E-8

Impact of SWRCB D-1641 Storage and Flow Conditions on Don Pedro Reservoir Storage and Release (Tuolumne River) for 2010. (Refill period: April 8 – 17, 2010)



APPENDIX F

Figure F-1

Impact of SWRCB D-1641 Storage and Flow Conditions on Vernalis Water Quality and Goodwin Dam Release to Stanislaus River, May 2000

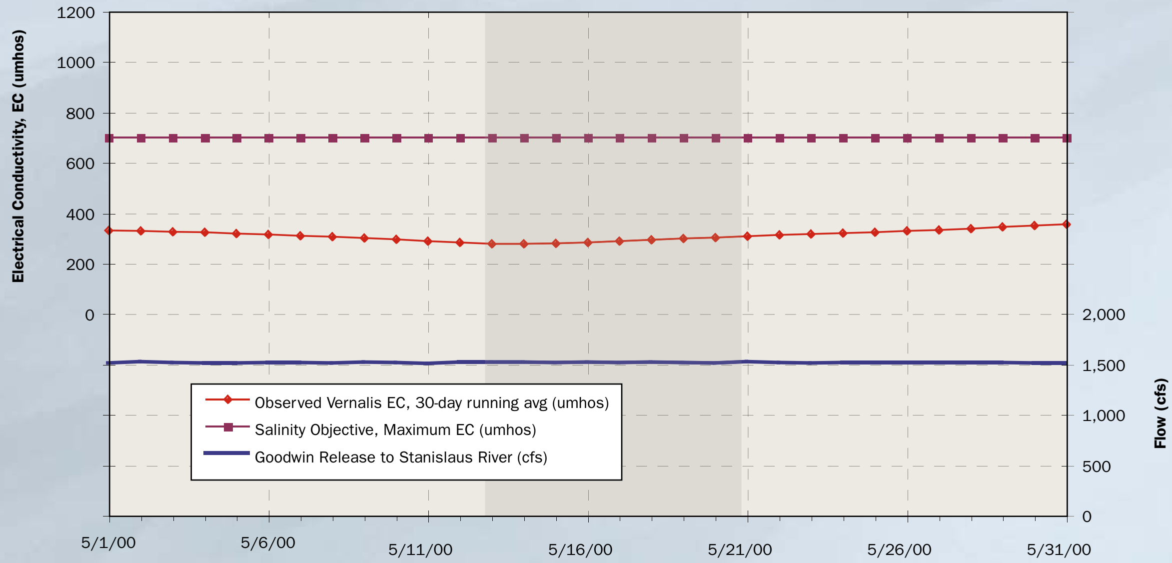


Figure F-2

Impact of SWRCB D-1641 Storage and Flow Conditions on Vernalis Water Quality and Goodwin Dam Release to Stanislaus River, September - October 2000 (Reservoir Refill Period: September 27 – October 7, 2000)

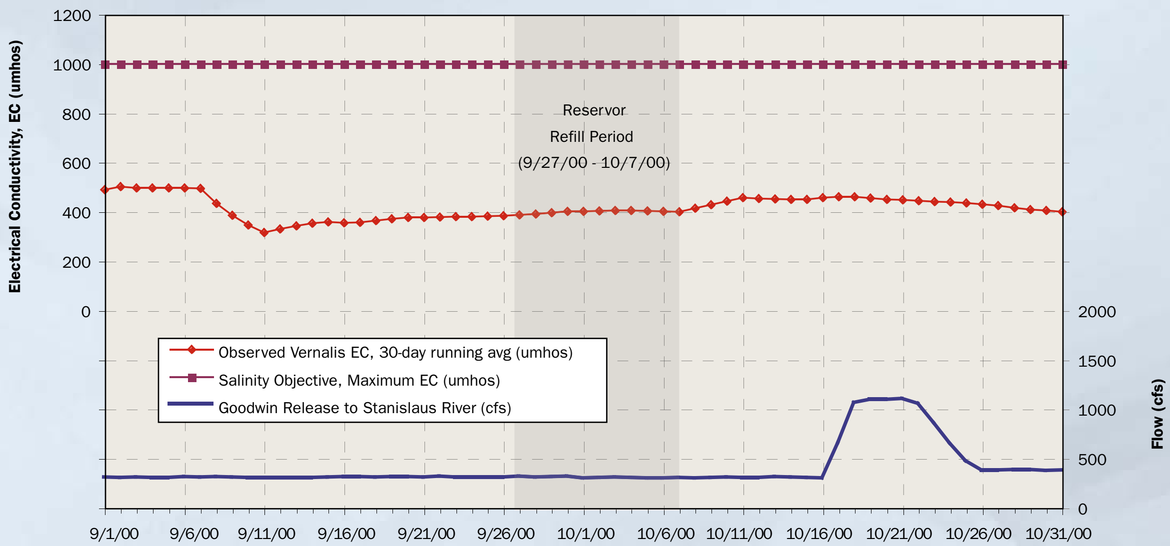


Figure F-3

Impact of SWRCB D-1641 Storage and Flow Conditions on Vernalis Water Quality and Goodwin Dam Release to Stanislaus River, March 2001 (Reservoir Refill Period: March 23 – 28, 2001)

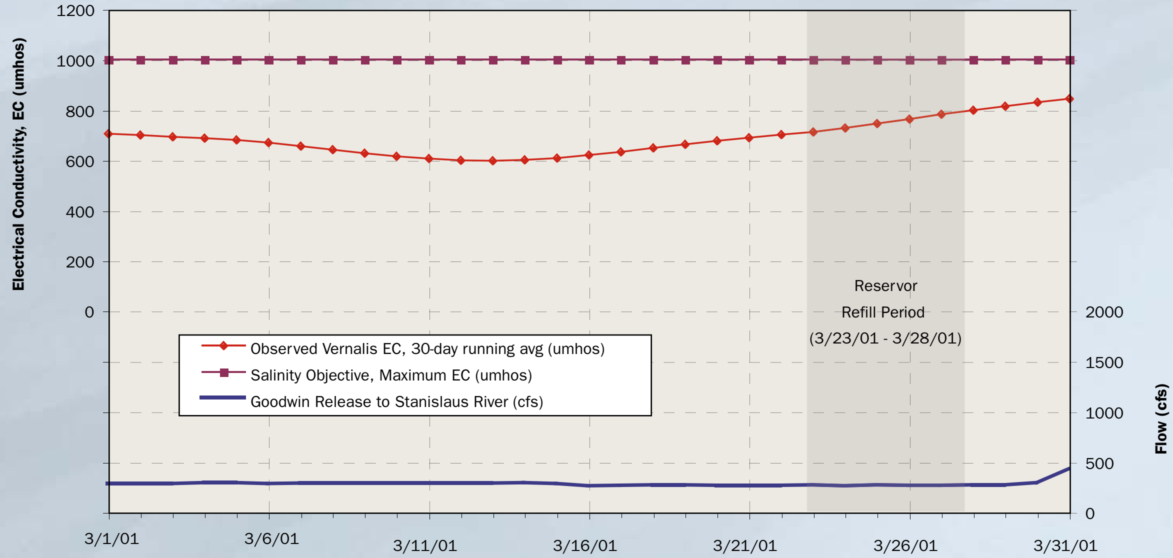


Figure F-4

Impact of SWRCB D-1641 Storage and Flow Conditions on Vernalis Water Quality and Goodwin Dam Release to Stanislaus River, March – April, 2004 (Reservoir Refill Period: March 10 – 16, 2001 and March 27 – April 1, 2001)

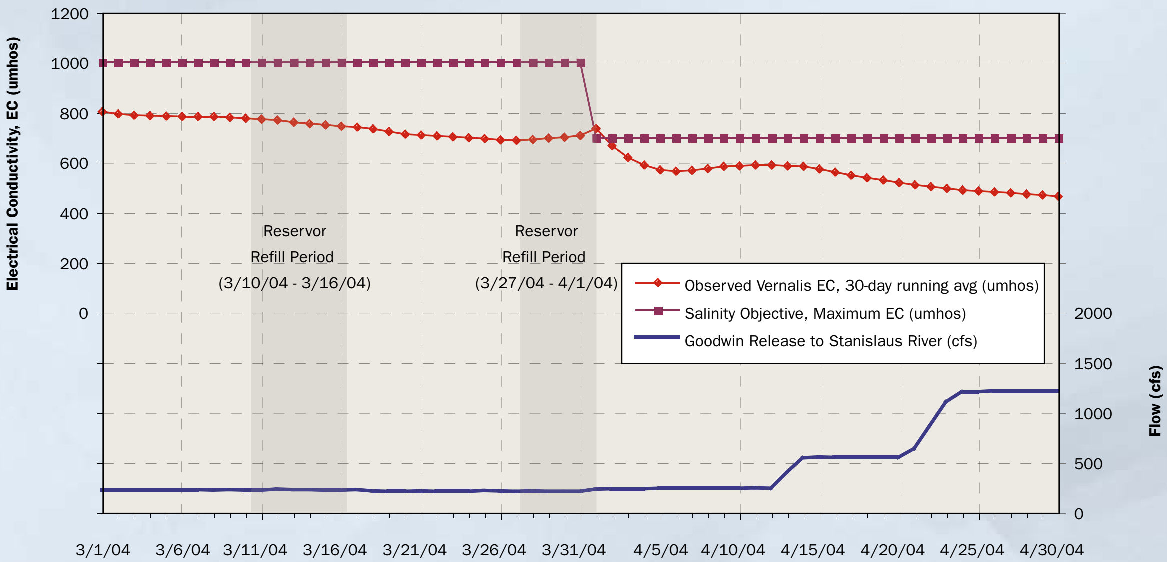


Figure F-5

Impact of SWRCB D-1641 Storage and Flow Conditions on Vernalis Water Quality and Goodwin Dam Release to Stanislaus River, January - March 2005 (Reservoir Refill Period: January 25 - March 24, 2005)

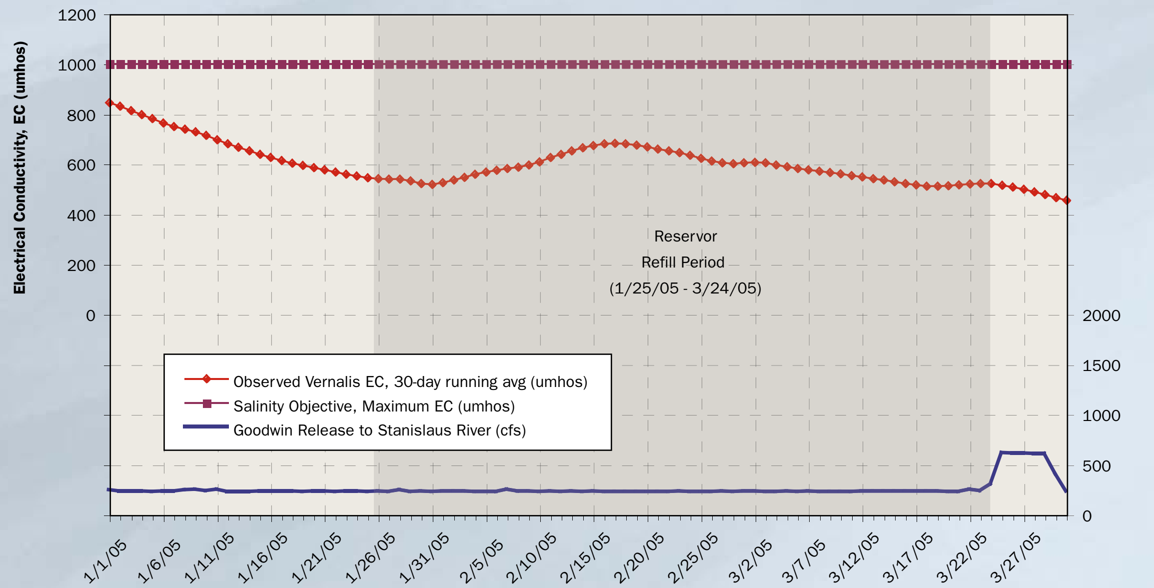


Figure F-6

Impact of SWRCB D-1641 Storage and Flow Conditions on Vernalis Water Quality and Goodwin Dam Release to Stanislaus River, August - September 2005 (Reservoir Refill Period: August 26 – September 3, 2005)

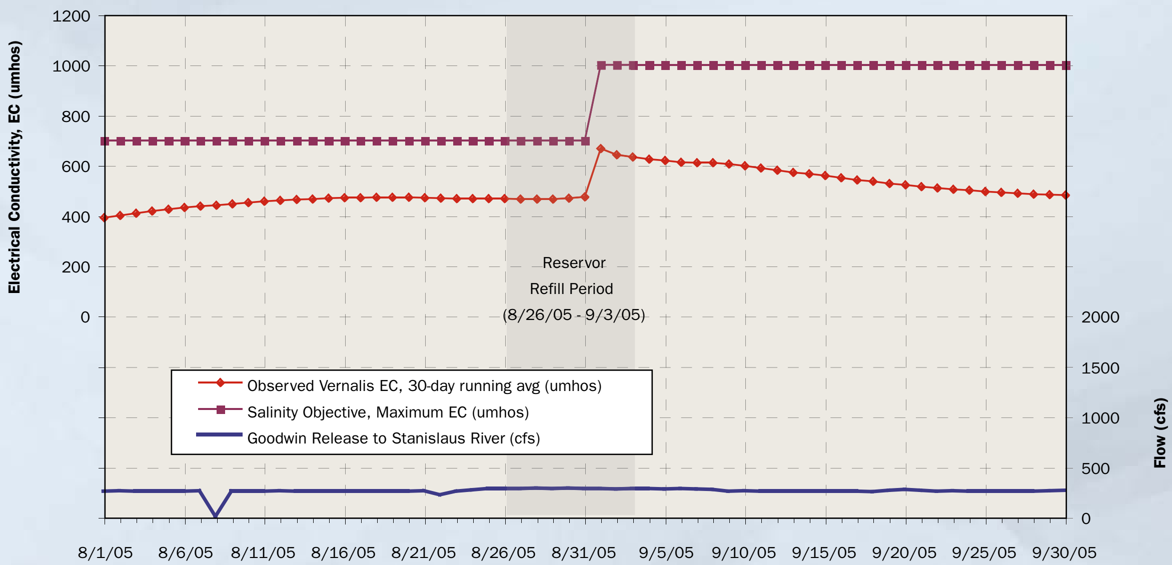


Figure F-7
Impact of SWRCB D-1641 Storage and Flow Conditions on Vernalis Water Quality and Goodwin Dam Release to Stanislaus River, March - May 2010 (Reservoir Refill Period: March 8 – May 23, 2010)

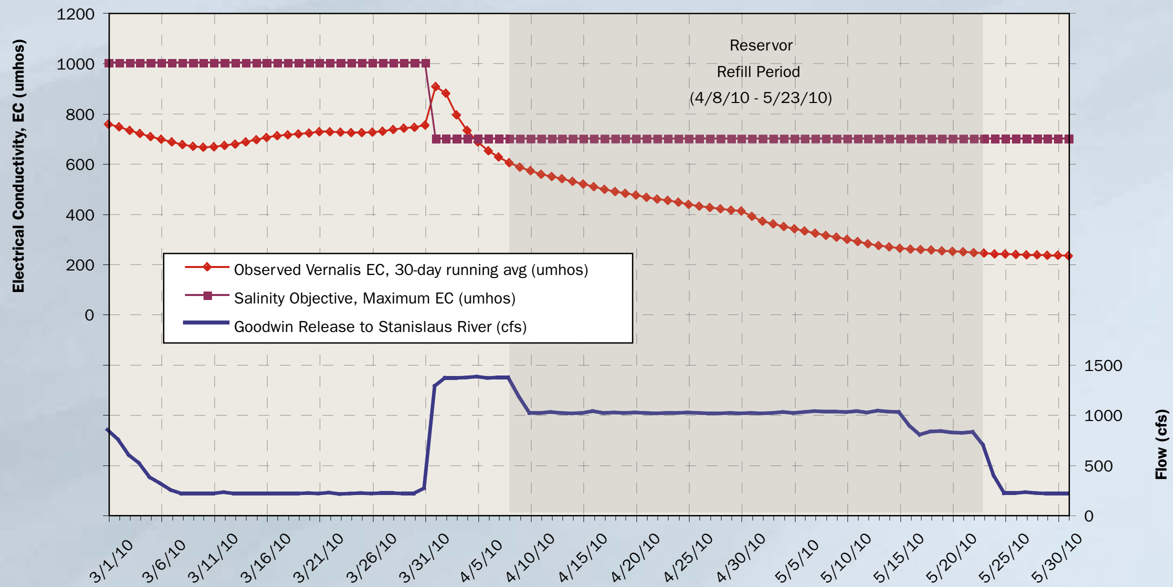
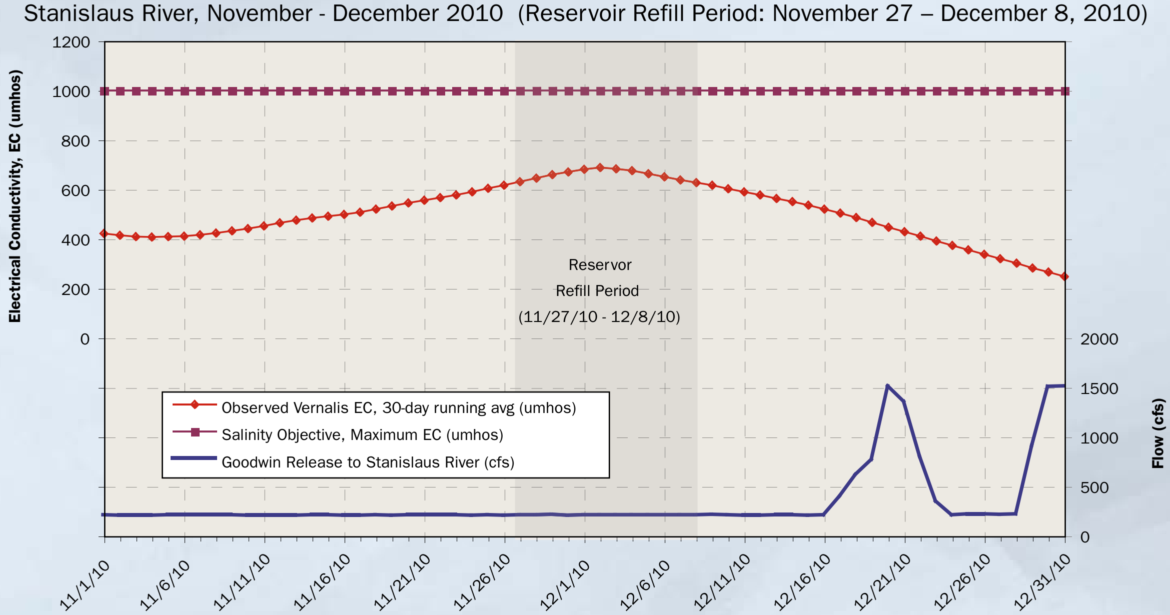


Figure F-8
Impact of SWRCB D-1641 Storage and Flow Conditions on Vernalis Water Quality and Goodwin Dam Release to Stanislaus River, November - December 2010 (Reservoir Refill Period: November 27 – December 8, 2010)



APPENDIX G

ACOUSTIC TAGGING SOP – VAMP 2010
(Version 041910)

Equipment Set up

- Fill disinfection trays for surgical instruments with Novalsan
- Fill rinse tray with de-ionized or distilled water.
- Set up scale, measuring board, and surgery tray.
- Fill fresh carboy with water from source tank and fill MS-222 carboy to the line with water from the same source tank. Add 2ml MS-222 and 2ml bicarb to the water in the MS-222 carboy.
- Fill anesthesia bucket to line with water from source tank. Add 7ml MS-222 and 7ml bicarb. Cover with a lid.
- Place a study fish recovery bucket in a sleeve and fill with water from source tank. Check to be sure that the bucket is labeled on the handle and that the label on the lid matches. Both should correspond to the release group that is being tagged. Buckets for Durham Ferry will begin with "DF", for Old River will begin with "OR", and for Stockton will begin with "STK".
- Place a dummy fish recovery bucket in a sleeve and fill with water from source tank. Check to be sure that the bucket is labeled on the handle and that the label on the lid matches. Dummy buckets should have red lids and will begin with "X"
- Check that a reject bucket has been filled with water from the source tank and is available nearby.
- Start a data sheet.
- Obtain tags and place the first tag and its vial in disinfectant solution. Record the Tube ID on the datasheet. Tags should be used in sequential order. Move the tag and vial to the rinse water before implanting the tag.

Surgery

- Anesthetize fish
  - Net one fish from source tank and place directly into the anesthesia bucket. Start your stopwatch immediately to track how long the fish is in the anesthesia bucket and place a lid on the bucket.
  - Remove the lid after about 1 minute to observe the fish for loss of equilibrium. Keep the fish in the water for an additional 30-60 seconds after it has lost equilibrium. Time of sedation should normally be 2-4 minutes, with an average of about 3 minutes. If loss of equilibrium takes less than 1 minute or if a fish is in the anesthesia bucket for more than 5 minutes, reject that fish. If after sedating a few fish they are consistently losing equilibrium in more or less time than typical, the anesthesia concentration may need to be adjusted. This should only be done after consultation with the coordinator.
  - If a fish is unacceptable for tagging, place the fish in the "Reject" bucket and inform the data recorder.
- Recording fish length, weight, and condition
  - Transfer the fish to the scale and weigh to the nearest 0.1g.
  - Transfer the fish to the measuring board and determine forklength (FL) to the nearest mm.
  - Check for any abnormalities and descaling.
  - Data must be vocally relayed to the recorder and the recorder should repeat the information back to the tagger to avoid miscommunication.
  - Any fish dropped on the floor should be rejected.
- Tag implantation
  - Place the fish into the surgical tray ventral side up. Immediately start a stopwatch to track surgery time.
  - Anesthesia should be administered through the gravity feed tube as soon as the fish is on the surgery table. Using the in-line valve, adjust the flow as needed so that the gilling rate of the fish is steady.
  - Using a scalpel, make an incision approximately 5 mm in length beginning a few mm in front of the pelvic girdle. The incision should ne just deep enough to penetrate the peritoneum, avoiding the internal organs. The spleen is generally near the incision point so pay close attention to the depth of the incision.
  - Use forceps to open the incision to check that you did not damage any internal organs or cause excessive bleeding. If you observe damage or think you damaged an organ, do not implant the tag – reject that fish.
  - One scalpel blade can be used on about 5-7 fish. If the scalpel is pulling rough or making jagged

incisions, it needs to be changed prior to tagging the next fish.

- Gently push the tag into the body cavity and position it so that it lies directly beneath the incision and the ceramic head is facing forward. This positioning will provide a barrier between the suture needle and internal organs.
- Suture the incision with two to three interrupted stitches.
- Transfer the fish from the surgical table to the appropriate recovery bucket.
- Three fish will be placed in each recovery bucket. Call out the count of fish in the recovery bucket to the recorder for confirmation. Put the lid back on the bucket. Once 3 fish are in a bucket, place the datasheet on top of the lid and signal to the tag validating crew for the bucket to be removed.
- Confirm the tube ID with the recorder and place the empty vial into the lid of the tray which holds the tags.
- Between surgeries the tagger should replace the tools that we just used into the disinfectant bath. Each tagger will have 3 sets of surgical instruments to rotate through to ensure that tools get a thorough soaking in disinfectant between uses. Once disinfected, tools should be rinsed in distilled or de-ionized water. Organic debris in the disinfectant bath reduced effectiveness so be sure to change the bath regularly.

Tag Validation

- Obtain bucket and datasheet from tagging crew and gently place hydrophone in bucket.
- Set display for that hydrophone to the first tag period on the datasheet and confirm the signal. Record the time of confirmation on the datasheet. Repeat for the other two tag periods.
- Once all tags in a bucket have been heard, remove the hydrophone, securely fasten the lid, and transfer the bucket to the flume.
- Return the datasheet to the tagging crew.

Loading

- Begin a fish loading, transport, and release data sheets.
- Fill hauling tank with water at same temperature as source tank. Allow water to sit in the tank for at least 15 minutes before purging.
- Re-fill tank with water at the same temperature as the source tank. Record temperature.
- Turn on oxygen and record DO.
- Bring buckets to the truck and check each for morts before placing into the tank. If a mort is found, the recovery bucket containing the mort should be returned to the tagging area. The tag should be removed and identified by the validation crew. The tag should be implanted into a new fish with a new entry on a datasheet and comment should read re-tagged from mort. The original entry should be crossed out in the data sheet with a comment of mort at loading.
- Call out the number of the bucket to the recorder and the number of fish in the bucket.
- Once all buckets have been loaded, confirm that the number of buckets matches the number that should be loaded and that there are no buckets remaining in the flume or the tagging area.
- Secure the tank.
- Send datasheets with transport crew.

Cleanup

- Return tag tray with empty vials and datasheets to coordinator at end of each tagging session.
- Wipe down or spray all surfaces with ETOH to disinfect
- Soak surgical instruments in Novalsan for at least 15 minutes. Scrub with small brush. Rinse with water and dry thoroughly. To prevent rusting. Leave on a dry towel.
- Rinse buckets with hose and place upside down to dry.

Important things to remember:

- Anesthesia and fresh carboys and buckets should be filled just prior to tagging to avoid temperature changes and should be changed often. Check levels of carboys before each surgery to be certain that you will not run out of water during a surgery.
- Keep a lid on any bucket that contains fish.
- Any fish dropped on the floor should be rejected. If a fish is dropped on the floor after it has been tagged, euthanize the fish, remove the tag, and place it into another fish.
- Carefully handle buckets. Try not to bang them around, slam the handles, or otherwise handle in a rough manner as this can stress fish.

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Modesto Irrigation District
Turlock Irrigation District
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