2011

ANNUAL TECHNICAL REPORT

San Joaquin River Agreement

VERNALIS ADAPTIVE MANAGEMENT PLAN

San Joaquin River Group Authority

Figure 1-1

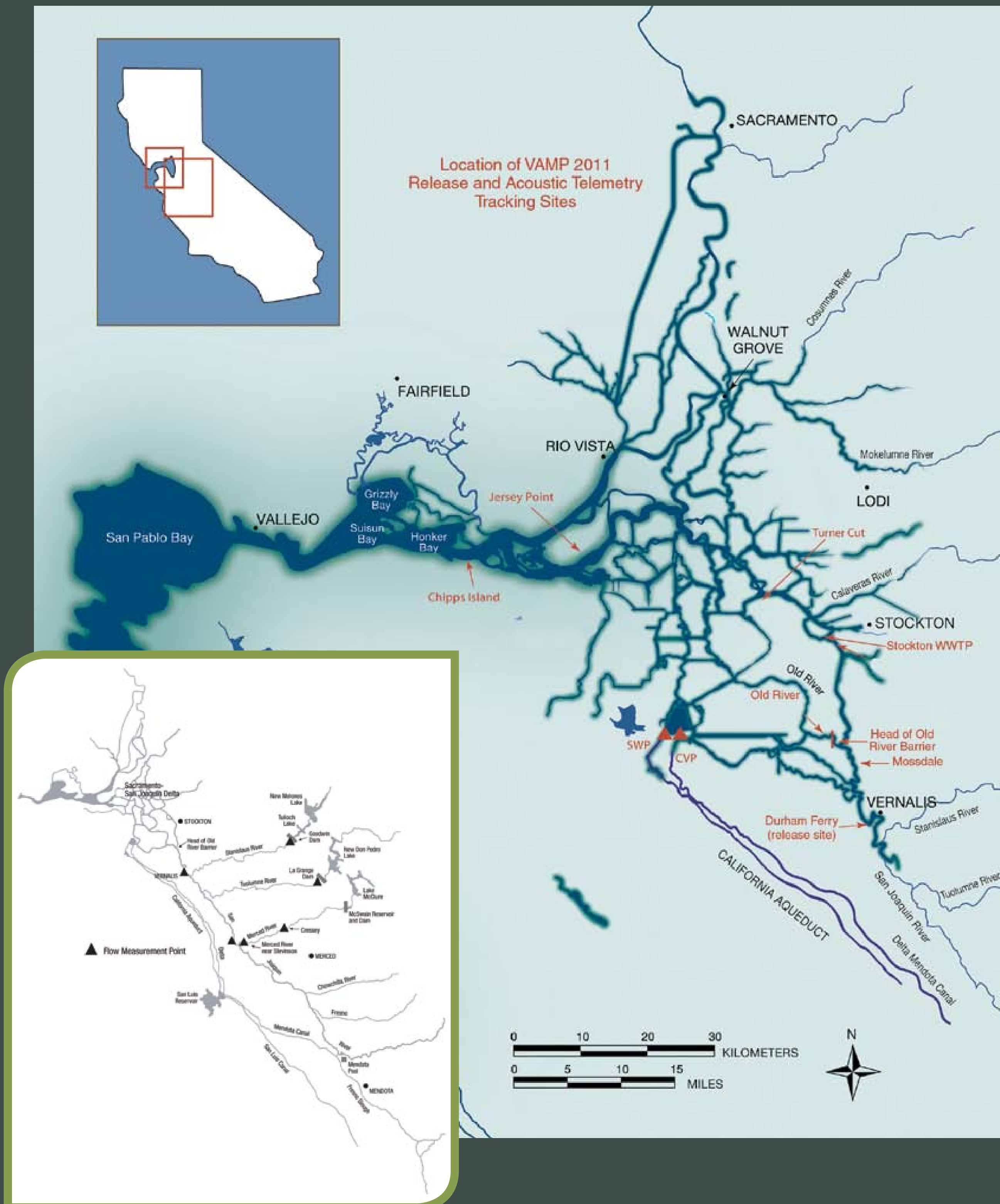

Figure 2-1

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

FEBRUARY 2013

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EXECUTIVE SUMMARY




The San Joaquin River Agreement (SJRA) was 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, was 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 was 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 and 2010, a physical HORB was not installed in 2011. A Non-Physical Barrier was planned for testing again in 2011 but high flows prior to VAMP and during the VAMP period made it unsafe to install any type of barrier at the head of Old River.

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 during the spring of 2011 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 2011 Technical Report consolidates the annual SJRA Operations and the VAMP Hydrology and Fish Monitoring Reports. The 2011 VAMP program represents the twelfth and final 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 2011 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, and discussion of complementary investigations.

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 mainstem 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 2011, similar to 2009 and 2010, the Department of Water Resources (DWR), in cooperation with the United States Bureau of Reclamation (USBR), planned for the third year of testing of a non-physical barrier called the Bio-Acoustic Fish Fence (BAFF) at the head of Old River. The VAMP study was designed to be coordinated with the 2011 BAFF study planned for the head of Old River. Unfortunately high flows in the San Joaquin River made installation of the BAFF too dangerous and therefore the 2011 BAFF study did not occur.

Hydrology

The seasonal precipitation in the San Joaquin Hydrologic Region (Cosumnes, Mokelumne, Stanislaus, Tuolumne, Merced and San Joaquin Rivers) measured 160% of average on April 1, 2011. The forecasted April-July runoff as of April 1st in the four basins above Vernalis (Stanislaus, Tuolumne, Merced and San Joaquin) ranged from 165 to 168% of average. Water Year 2011 was classified as "wet" 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 5. The numerical indicators for 2009 and 2010 were 2 ("dry") and 4 ("above normal"), respectively. The sum of the 2010 and 2011 numerical indicators was 9 so the "double step" condition, which occurs when that sum is 7 or greater, was in effect. Conversely, the sum of the 2009, 2010 and 2011 numerical indicators was 11 so the "sequential dry-year relaxation" condition, which occurs when that sum is 4 or less, was not in effect. Therefore, a "double-step" condition was in effect for the 2011 VAMP operation (see Chapter 2 for further explanation).

The planning process for the 2011 VAMP Hydrologic Planning and operation had to consider two additional 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. An additional factor for 2011 that was not present prior to the 2010 VAMP 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 7,000 cfs with a supplemental water requirement of about 60,000 acre-feet for a wetter condition and a target flow of 4,450 cfs with a supplemental water requirement of 110,000 acre-feet for a drier condition. As a result of continued cool and wet conditions the March 28th operation plan forecasted a VAMP target flow of 20,400 cfs, significantly greater than the maximum VAMP Target flow of 7,000 cfs. The daily operations plan was updated several times; as well the VAMP Target flow period was moved back to May 1st to May 31st. Due to the continued wet conditions, the 2011 VAMP was driven by flood control operations with the VAMP Target Flow being greater than 7,000 cfs. All efforts were then focused on achieving a stable flow at Vernalis as best could be accomplished with the flood control operations.

The mean daily flow at Vernalis averaged 12,650 cfs during the VAMP target-flow period (May 1st – May 31st). The mean daily flow at Vernalis varied between 10,100 cfs and 18,200 cfs during the target-flow period. The deviation from the 7,000 cfs target flow was caused by flood control operations on all the tributaries and from upstream of the Merced River.

The combined CVP and SWP Delta export target during the VAMP period was 3,000 cfs. The observed exports during this period averaged 3,360 cfs and ranged from 2,420 cfs to 5,160 cfs.

Fish Monitoring Experimental Design

The 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 2011 VAMP represented the sixth year that acoustic telemetry technology was used to estimate juvenile salmon survival in the southern Sacramento-San Joaquin Delta and the third year where survival was estimated through the Delta to Chipps Island (2008, 2010 and 2011). The first year acoustic telemetry was used (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 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. The 2011 VAMP study plan called for a similar layout to that of 2010 but added receivers sites at Jersey Point and False River. To increase the extent of the VAMP study, the VAMP team coordinated their study plan with those of four other studies: 1) a South Delta Temporary Barrier Project (TBP) study, to assess the survival of Chinook salmon and steelhead with the South Delta temporary barriers installed; 2) a 6-year steelhead study as part of the NMFS OCAP Biological Opinion to determine if salmon could be used as surrogates for estimating steelhead survival in the San Joaquin River basin; 3) a HOR study to evaluate fish routing and predation at the HOR without a physical or non-physical barrier installed; and 4) a pre-screen loss study at the CVP using a 2-D acoustic array. 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 studies and that no duplication of effort took place. In addition, the VAMP fish releases were coordinated to meet the needs of all these studies. Additional Chinook salmon and steelhead releases were made as part of these four studies and are either summarized in the survival analysis and discussion, reported in other sections of this report (Chapter 6) or will be forthcoming in independent reports. Of the four release groups of acoustic-tagged Chinook salmon discussed in this report, the first two groups were released during the 2011 VAMP and the last two were released after the end of the 2011 VAMP but as part of the South Delta TBP study.

Study Implementation

During the 2011 study, Chinook salmon smolts were tagged with Hydroacoustic Technology, Inc (HTI) acoustic tags and released into the San Joaquin River at Durham Ferry on the mainstem San Joaquin River. The study design in 2011 was simplified from that used in 2010 by releasing all tagged fish at Durham Ferry, rather than at the three release locations used in 2010 (Durham Ferry, Stockton and in Old River). Because survival through the Delta is estimated starting at Mossdale, tagged fish released at Durham Ferry have the distance between the receiver at Durham Ferry and Mossdale (21 rkm) to express any potential handling mortality that occurs, reducing its effect on survival through the Delta. Releasing all groups at Durham Ferry in 2011 reduced any impact of handling mortality on survival through the Delta and standardized the reach where it was expressed. The numbers of fish released at Durham Ferry were increased to accommodate the study design change in 2011.

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 on 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 20° C for the entire VAMP period which is considered suitable for salmon smolts. Temperatures did exceed 20° C during the later part of June which coincided with later part of the survival studies for the South Delta TBP.

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. While there were occasional periods when some receivers were not operating in 2011, the use of redundant receivers at critical points minimized or eliminated data loss. The total receiver network worked very well during 2011.

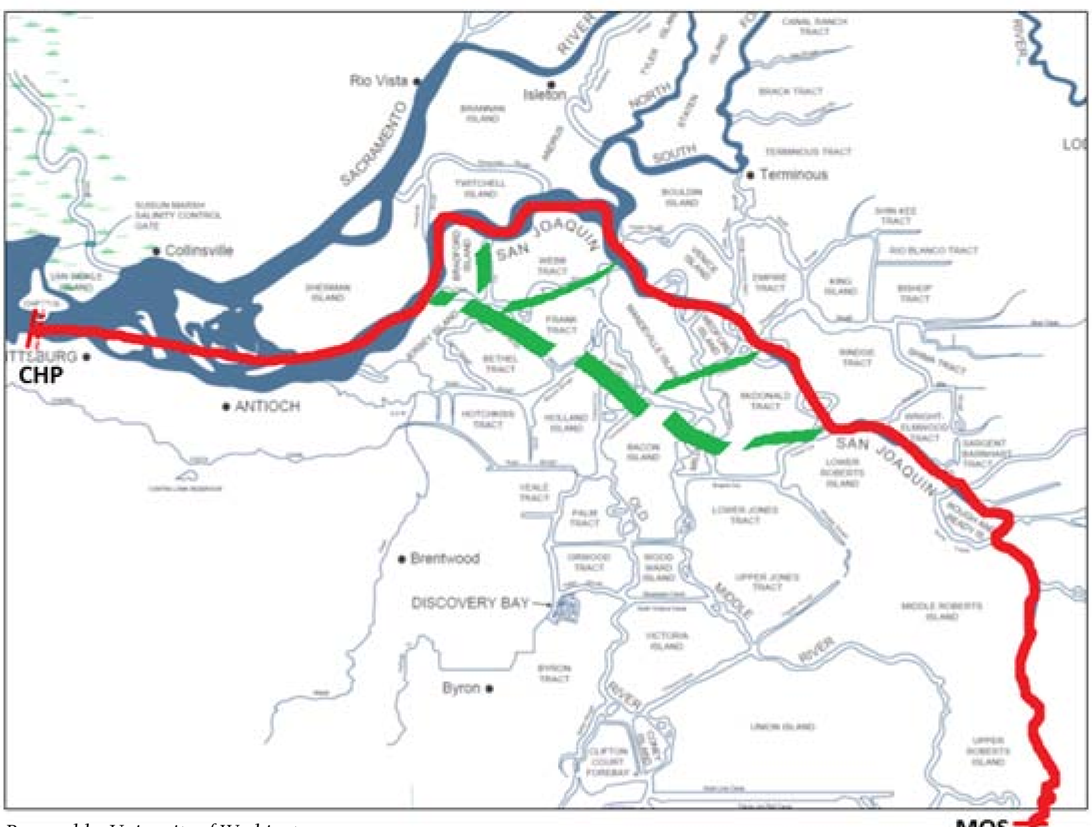
Survival Study Results

Data from the fixed receiver sites in 2011 were processed using automarking algorithms (FishCount) developed by USGS. Manual data processing was also used at Chipps Island to attempt to differentiate between acoustic signals coming from live salmon and those coming from predators that had eaten tagged salmon. Complete manual processing of all data was impractical because of the large number of data files.

The manual processing provided an assessment of near-field tag movements, used in assessing predation of tagged smolts. This information was available only from 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 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. It is also possible that fish migrating down the San Joaquin River also entered the interior Delta through Turner Cut or other channels downstream of Old River. The second route was via Old River through the interior Delta channels or fish facilities at the federal and state projects (Figure ES-2). The model is similar to the one used in the 2010 VAMP study.

Figure ES-1
Survival to Chipps Island San Joaquin Route



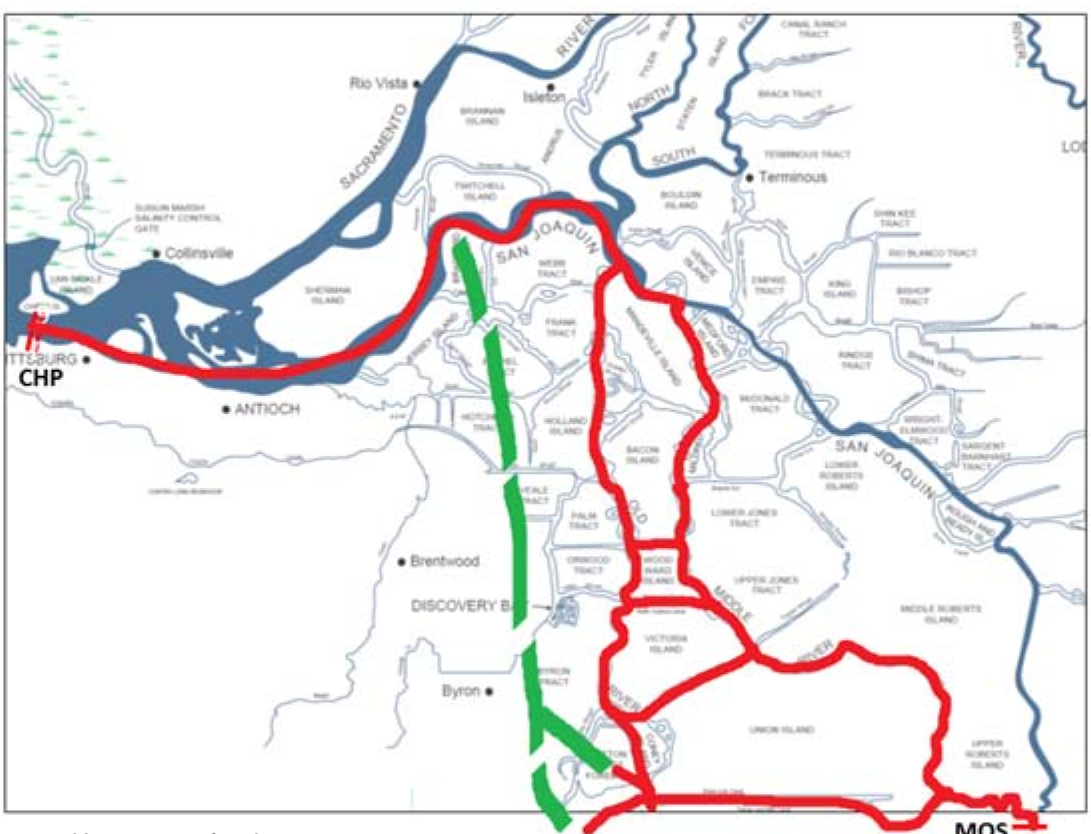
Prepared by University of Washington

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 three years. A total of 297 of the 948 tags (31%) released during the VAMP period at Durham Ferry were classified as being detected in a predator at some point during the study. Similar levels (31%) were detected in a predator (296 of the 947 tags) at some point during the two releases that occurred after the VAMP period as part of the South Delta TBP study. Both levels were less than last year (2010) which showed 61% classified as being detected in a predator at some point during the VAMP study period.

The detection sites with the largest number of first-time predator-type detections were the receiver near the Navy Drive Bridge in Stockton (STN) and the receivers at the radial gates inside the Clifton Court Forebay (RGD). A total of 7 tags were classified as being in predators upon arrival at the Navy Drive Bridge receivers, with 109 tags classified as being predators upon departure from that receiver. Only one tag was classified as in a predator on arrival at RGD, but 106 tags were classified as in a predator on departure from RGD. The other site that stands out with many first-time predator detections was the Central Valley Project trashracks (CVP), with 104 tags first classified as in predators there. A total of 37 tags were classified as predators upon arrival at CVP with 67 tags classified as predators upon departure from CVP.

Two data sets were constructed using a combined data set from releases 1 and 2 (during the VAMP) and releases 3 and 4 (after the VAMP): 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 the best estimate of survival without predator-type detections and that using the uncorrected dataset.

Figure ES-2
Survival to Chipps Island Old River Route



Prepared by University of Washington

Of the 1,895 tags released in juvenile Chinook salmon at Durham Ferry both during and after the VAMP period, 1,847 (97%) were detected on one or more receivers downstream of the release site, with 35 eventually detected at Chipps Island, including the "predator-type" detections. Without predator-type detections, only 33 Durham Ferry tags were detected at Chipps Island, 21 of which (64%) were previously detected at the Central Valley Project.

Using only those tags that showed "smolt-like" behavior, total salmon smolt survival from Mossdale to Chipps Island was estimated to be $\hat{S}_{Total}$= 0.02 ($\widehat{SE}$ =<0.01) ranging from 0.01 during the VAMP period to 0.03 after the VAMP period. Estimated survival from Mossdale to Chipps Island through the San Joaquin River route was $\hat{S}_A$= 0.01 ($\widehat{SE}$ =0.01), while estimated survival from Mossdale to Chipps Island through the Old River route was $\hat{S}_B$ = 0.04 ($\widehat{SE}$ =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 or Decker Island, upstream of the Chipps Island receiver. The small number of tags detected at Chipps Island limited the precision with which survival could be estimated, especially for the San Joaquin River route. Despite that limitation, survival to Chipps Island was significantly higher ($P<0.0001$) through the Old River route than in the San Joaquin River route. This may be due to the salvage operations at the CVP as the majority of the tags detected at Chipps Island (64%) came through the CVP holding tanks in the Old River route.

Tagged Chinook salmon released at Durham Ferry appeared to use the San Joaquin River route (Figure ES-1) to a greater degree than the Old River route (Figure ES-2). The estimated route entrainment probability was 0.58 ($\widehat{SE}$ =0.01) for the San Joaquin River route and 0.42 ($\widehat{SE}$ =0.01) for the Old River route during the VAMP period releases with later releases for the South Delta TBP study showing the same trend. Route selection estimation at the Head of Old River was largely unaffected by predator-type detections. During the 2011 VAMP fish release and tracking period (May 1st – June 30th), the average flow split was 48:52% (San Joaquin River mainstem: Old River).

Survival (without predator-like detections) was also estimated through the portion of the study area that matched the 2009 study area and referred to as the Southern Delta. The Southern Delta region starts at Mossdale, with endpoints at: 1) the entrances to Clifton Court Forebay and the CVP; 2) Old River North and Middle River North receivers near Highway 4, and 3) the receivers in the San Joaquin River and in Turner Cut just downstream of the Turner Cut junction. Overall estimated survival in the Southern Delta region was 0.06 and 0.56, respectively for 2009 and 2010. Estimated survival in 2011 through the same Southern Delta area remained high at 0.56 ($\widehat{SE}$ ≤ 0.03) compared to survival through the entire Delta estimated to be $\hat{S}_{Total}$= 0.02 ($\widehat{SE}$ =<0.01). Estimates of survival in the San Joaquin River route from Mossdale to the Shipping Channel Markers or Turner Cut in 2011 averaged 0.48 ($\widehat{SE}$ = 0.02) compared to 0.05 ($\widehat{SE}$ = 0.02) in 2009 and 0.32 ($\widehat{SE}$ = 0.02) in 2010. Estimated survival from Mossdale to the entrances of the water export facilities or the northern Old River receivers at Highway 4 averaged 0.66 ($\widehat{SE}$ = 0.02) in 2011, compared to 0.08 ($\widehat{SE}$ = 0.02) in 2009 and 0.77 ($\widehat{SE}$ = 0.05) in 2010.

Survival in the Delta downstream of the Southern Delta region endpoints was generally much lower than upstream, and contributed to the low survival to Jersey Point and Chipps Island regardless of which pathway the juveniles took. One mechanism for the low survival in the San Joaquin River route may be diversion into the interior and south Delta as the tagged fish move downstream. Averaged over all releases (VAMP and non-VAMP), approximately 21% of the tagged fish that approached the Turner Cut junction on the San Joaquin River entered Turner Cut: 23% during the VAMP releases vs. 18% after VAMP. However, none of those tagged fish entering the interior Delta via Turner Cut were subsequently detected at Chipps Island. The data also suggest that once tagged fish enter the interior Delta from the San Joaquin River they do not re-enter the San Joaquin River, but move further into the south/southwestern Delta. It appears that survival to Chipps Island is low for fish entering the interior Delta from the San Joaquin River. This is further supported by the low estimated joint probability of fish successfully moving from Old River north (ORN) to Jersey Point.

Mobile telemetry surveys were also conducted in 2011 from the fish release point to Stockton and to Clifton Court. Based on the 2011 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 the Grant Line Canal leading to the CVP and in front of the CVP trash racks. A total of 162 Chinook tags were detected in Old River and Grant Line Canal between the Head of Old River and the State and federal pumping facilities. The highest concentration of the tags detected by mobile monitoring in this reach were detected in Grant Line Canal at 54%, while 29% were found in the vicinity of the State and federal Pumping facilities, and the remaining 17% were detected in Old River upstream of Grant Line Canal. The number of tags detected in Grant Line Canal was much higher than in previous years. It is unknown whether the fish were preyed upon in this location, or if the smolts were eaten at other locations and later deposited where the tags were detected.

The Stockton Deep Water Ship Channel (DWSC) also appeared to be a continuing problem area with 73% 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. These findings were consistent with fixed receiver data, which found that the DWSC downstream of Stockton had the largest number (102) of first-time predator-type detections of the San Joaquin River receiver sites.

The problem of detections in predatory fish from 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 the 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. During 2011, the University of Washington specialists utilized several criteria to distinguish between detections of salmon smolts and predators. The various criteria used were fish speed, residence time, upstream transitions, unexpected transitions, travel time since release and movements against flow. Although no one single criterion is perfect, it is expected that using the various criteria will improve detection histories to better reflect detections coming from salmon smolts.

Despite the uncertainty in the decision process, the resulting survival estimates based only on data classified as smolt-type 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 on how to distinguish between acoustic signals from live salmon smolts and those from predators that have eaten study fish in order to minimize bias in the survival estimates that is introduced by predation.

It is clear that survival through the entire Delta to Chipps Island and Jersey Point was low in 2011, regardless of whether or not only smolt-type detections were used in the model (0.02 with only smolt-type detections and 0.02 with predator-type detections) relative to past years when survival was measured from Mossdale to Jersey Point using CWT fish. However, the data show regional survival throughout the Southern Delta in 2011 was higher than in 2009 (a low flow year) both with and without predator-type detections and similar to the levels seen in 2010. In contrast, survival in the Delta downstream of the Southern Delta endpoints was generally much lower than upstream, and contributed to the low survival to Jersey Point and Chipps Island regardless of which pathway the juvenile Chinook salmon took. In addition, the relative proportion of predator detections to all detections for the Southern Delta area was lower in 2011 than in 2009 or 2010. 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 needs to be studied in future years.

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 (May 1st – May 31st). Densities began to rise in late-April, as river flows began to decrease, and remained elevated through mid-June. Juvenile Chinook salmon emigrated from the San Joaquin Basin later than usual due to higher flows and lower water temperatures in 2011 and this later migration coincided with the VAMP target flow period. 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.

CHAPTER 1

INTRODUCTION

In 1994 a long process of developing new water quality standards for the Sacramento-San Joaquin Delta culminated in an agreement, the Delta Accord, among many interested parties. This Delta Accord was proposed to the State Water Resources Control Board and became the basis for their 1995 Water Quality Control Plan (WQCP). This plan specified a variety of San Joaquin River flows at Vernalis and limited total State Water Project (SWP) and Central Valley Project (CVP) exports to 100 percent of the flow of the San Joaquin River at Vernalis.

Although flows on the lower San Joaquin River were a part of the Delta Accord, many water right holders in the San Joaquin River Basin had not been involved in the agreement and their concerns threatened the viability of the plan. In addition, both the National Marine Fisheries Service (NMFS) and the US Fish and Wildlife Service (USFWS) were concerned that the conditions specified in the Delta Accord might not adequately protect species listed under the federal Endangered Species Act. In particular the USFWS, in their Biological Opinion (BiOp), specified that total exports should be no more than half of the San Joaquin River flow requirement.

Developing the VAMP

Many studies had been done to examine the survival of salmon in the delta, but the results did not provide much detail for management recommendations. For most studies, flows had been either the minimum required under earlier rules or had been very high as a result of flood operations. Export rates had varied in most studies in ways that made statistical conclusions about their effects difficult.

To address these concerns Drs. Bruce Herbold of the US EPA and Charles Hanson of Hanson Environmental, Inc. were asked by the United States Bureau of Reclamation (USBR) and the Metropolitan Water District of Southern California to develop a plan that would address the various concerns surrounding the lower San Joaquin River conditions in a scientific fashion that could be appended to the earlier agreement. Generally Dr. Herbold led the effort in experimental design aspects and Dr. Hanson developed field sampling aspects.

The result of the Hanson-Herbold effort was an adaptive management plan to protect both San Joaquin River Basin salmon and delta smelt in keeping with the scientific knowledge at the time and to simultaneously develop scientific information that would fill the missing gaps in regard to flow and export impacts on salmon. The Hanson-Herbold experimental design became known as the Vernalis Adaptive Management Plan (VAMP). The San Joaquin River Agreement (SJRA) provided the funding and framework to implement VAMP. The original experimental design is described in Appendix A and B of the SJRA. The SJRA and Appendices A and B of the SJRA can be found at the website http://www.sjrg.org or in Appendix K to this report.

The goal of the VAMP was to assess the relative impacts of changes in San Joaquin River flow at Vernalis (VNS) and SWP and CVP export rates on the survival of San Joaquin River Basin salmon smolts passing through the delta. The objectives of VAMP were to measure the recapture rates of salmon smolts released upstream of Vernalis to sampling locations in the western delta under consistent flow and export conditions that would vary from year to year. As part of the design of VAMP, a barrier at the Head of Old River (HORB) was assumed to be in place, although it was recognized that in some years the barrier would not be in place but that valuable data could still be collected.

Experimental design of VAMP was constrained by a number of factors. Earlier studies had developed considerable support for the construction of a HORB to keep salmon smolts away from the export facilities. The 1995 WQCP supported the concept of such a barrier but did not require its installation. The

Table 1-1 Original Experimental San Joaquin River at Vernalis Flow and Export Target Rates for the Combined Central Valley Project and State Water Project Pumping Facilities in Cubic Feet per Second (cfs)		
VAMP San Joaquin River Target Flow Rate at Vernalis	Combined Delta Export Target Rate (cubic feet per second)	
	1,500	3,000
3,200	X	
7,000	X	X

reasoning was that such a barrier could cause flood risks at river flows over 7,000 cubic feet per second (cfs) and could not be installed at river flows over 5,000 cfs due to safety concerns. In addition, some export water was required by local cities without any storage capacity, particularly the City of Tracy, to meet their needs for municipal safety.

Thus, maximum experimental flows were set at 7,000 cfs and minimal exports were set at 1,500 cfs. These constraints, coupled with the BiOp requirement that flows should be at least double export rates, resulted in maximum export rates of 3,000 cfs and minimum flows of 3,200 cfs. These maxima and minima yielded three experimental conditions that would compare the effects on survival for two levels of export at one flow and for two levels of flow at one export rate (Table 1-1).

Consultation with project operators, agency biologists, consultants and university statisticians led to two important conclusions:

- a wider range of flow conditions was desirable from a statistical viewpoint and was achievable within a range of variability of about 10 percent, and
- an intermediate combination of flows and exports was needed to discern any curvilinear responses to either parameter.

These conclusions led to a re-design of Table 1-1 to a final set of 5 targeted experimental conditions (Table 1-2).

To implement this study plan, triggering criteria to set flow targets were developed. The VAMP flow target was determined (forecasted) by estimating the mean flow that would occur at Vernalis (VNS) during the VAMP target flow period without the VAMP. This was referred to as "existing flow". The existing flow was then adjusted based on the forecasted flow for that year. For example, a forecasted existing flow at Vernalis on April 1st of 3,400 cfs is increased to a VAMP Target Flow of 4,450 cfs based on a "single step" increase. The forecasted "existing flows" at Vernalis on April 1st could be an additional step higher based on the previous water-year type. Each water-year type was assigned a numerical indicator and if the sum of the present forecast and the previous water year numerical indicators was 7 or greater, this was a general indication of either abundant reservoir storage levels or a high probability of abundant runoff. Conversely when the sum of the numerical indicators from the current year forecast and the two previous years is 4 or less this is a strong indication of extended drought conditions and the supplemental water requirement could be eliminated entirely. Such a condition occurred in 2009 (SJRGA, 2010). See Chapter 2 for a more in-depth discussion of how the VAMP target flows are determined and achieved. In addition, flood years were anticipated which did not explicitly fall into the targets within the VAMP study design. Comparison with the historical record of Vernalis flows suggested that all of the flow conditions would be achieved over a span of ten to twelve years.

Table 1-2 Redesigned Experimental San Joaquin River at Vernalis Flow and Export Target Rates for the Combined Central Valley Project and State Water Project Pumping Facilities in Cubic Feet per Second (cfs)			
VAMP San Joaquin River Target Flow Rate at Vernalis (cfs)	Combined Delta Export Target Rate (cfs)		
	1,500	2,250	3,000
3,200	X		
4,450	X		
5,700		X	
7,000	X		X

Table 1-3 VAMP Flow and Delta Export Target Flow Rates as Described in the San Joaquin River Agreement (SJRA) in Cubic Feet per Second (cfs)			
Forecasted Existing Flow (cfs)	**SJRGA Supplemental Water Target Flow (cfs)**	**VAMP Target Flow (cfs)**	**Delta Export Target Rate (cfs)**
Less than 2,000 [1]	2,000		1,500
2,000 to 3,199	3,200	3,200	1,500
3,200 to 4,449	4,450	4,450	1,500
4,450 to 5,699	5,700	5,700	2,250
5,700 to 7,000	7,000	7,000	1,500 or 3,000
Greater than 7,000	N/A	Provide stable flow to extent possible	1,500, 2,250 or 3,000 [2]

[1] If the Existing Flow is less than 2,000 cfs, then the SJRGA is required to provide supplemental water to achieve a target flow rate of 2,000 cfs with the USBR responsible for obtaining water to fulfill the requirement of existing biological opinions.

[2] Suggested rates

Export rates in most years were set by the VAMP target flows. For years when flow targets would be 7,000 cfs, two export rates were available. For years with flow targets of 7,000 cfs, it was agreed that export targets would alternate between 1,500 and 3,000 cfs, starting with the lower value.

To meet these flow targets the San Joaquin River Group Authority (SJRGA) members, the State Water Contractors (SWC), the San Luis and Delta Mendota Water Authority (SLDMWA), the USBR, and other water and environmental organizations developed and signed the San Joaquin River Agreement (SJRA). The SJRA assigned responsibilities and payments for providing the target flows, with the understanding that payment was intended to fund irrigation improvements that would reduce the economic impacts of any future regulations. When necessary the costs of export reductions were covered through use of Central Valley Project Improvement Act (CVPIA) and Environmental Water Account (EWA) water. The redesigned flow and export rates as shown in Table 1-2 were included in the SJRA as shown in Table 1-3.

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 original VAMP experimental design measured salmon smolt survival through the Delta under five different combinations of flow and export rates (Table 1-2) with the presence of a physical barrier at the head of Old River. However the hydrologic conditions during the twelve-year VAMP did not yield the higher experimental flow condition (7,000 cfs) within the study period. During all of the years of the VAMP (2000- 2011) only three of the five experimental conditions were achieved; flows of 3,200 and 4,450 cfs with an export of 1,500 cfs was achieved in seven of the twelve years; and a flow of 5,700 cfs with an export level of 2,250 cfs was achieved during one year. Three of the remaining four years were flood years with flows greater than 7,000 cfs and one year was an off-ramp year due to low flows and extended drought conditions. Achievement of the experimental conditions is summarized in Table 2-8 along with a more in-depth discussion of the VAMP flows throughout Chapter 2.

During the twelve VAMP years, the water districts coordinated their operations in order to maintain stable flows as much as possible, even in high flow years, 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. The physical barrier was installed at the head of Old River as part of the VAMP between 2000 and 2004 and in 2007. Flows in 2005 and 2006 were too high to allow the installation of the physical barrier. In 2008, a Federal Court decision for the protection of delta smelt halted the installation of the physical barrier at the head of Old River during the VAMP for that year. In 2009 and 2010, the California Department of Water Resources (DWR), in cooperation with the USBR began the initial testing of a non-physical behavior barrier at the head of Old River. In 2011 flows were too high to install either a physical or non-physical barrier.

Experimental Design Elements

The original experimental design described in the SJRA included two mark-recapture studies performed each year during the April-May juvenile salmon outmigration period that were to provide estimates of salmon survival under each set of conditions. The technique used to mark the fish was coded wire tagging (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) and are summarized in this report (SJRGA 2001; 2002; 2003; 2004; 2005; 2006; and 2007). 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 1995a; 1995b; 1997; 1998; 1999; and 2001) (SJRGA, 1999). These pre-VAMP studies will also be summarized as part of this report.

In 2007, due to a combination of events, test fish were not available from the Merced River Fish Hatchery (MRH) to allow a CWT study. The primary reason was that an inadequate number of smolts were produced at the MRH, due to low adult returns the previous fall. However, additional concerns included the potential for the curtailment or constraints relative to the freshwater recovery of the CWT's at Antioch and Chipps Island due to take concerns for delta smelt. To address these concerns a newer method using acoustic telemetry to estimate survival was started in 2007. While there had been a pilot study using acoustic tags as part of the VAMP in 2006, 2007 was the first year the acoustic studies were conducted without a CWT study. For the 2007 VAMP studies, a group of study fish from the MRH was 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. Without receivers at Chipps Island, survival was not measured through the Delta to Chipps Island as had been done with previous VAMP CWT studies.

Because of a continuing shortage of test fish from the MRH and the continued concern about possible curtailments in trawl sampling at Chipps Island, acoustic telemetry continued to be used in 2008 and for the remaining years of the VAMP. Compared to traditional mark-recapture techniques, acoustic telemetry has provided greater temporal and spatial coverage of the outmigration process. Further, continuous, simultaneous monitoring at several locations allowed estimation of routing 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 certain aspects of the uncertainty associated with estimates of survival, detection, and routing probabilities. In 2008, a full study program using acoustic telemetry was conducted and included acoustic receivers at Jersey Point and Chipps Island (the exit of the Delta) to allow an estimate of survival through the whole Delta similar to what had been done using the CWT studies. Unfortunately, tag malfunction resulted in biased estimates of survival (SJRG, 2009, Holbrook et al., 2009 and Holbrook et al., 2013).

In 2009, a similar acoustic study was conducted although receivers at Jersey Point and Chipps Island were not deployed due to staff limitations, so estimates of survival were limited to south Delta channels. The study design was expanded in 2010 to reinstate the receiver array near Chipps Island (although not Jersey Point due to budget constraints). In 2011, the study design was expanded further to include Jersey Point as well as Chipps Island.

This report describes the experimental design and results of the VAMP salmon survival study conducted in 2011. In addition, the results of past VAMP studies are summarized. The report also describes the hydrologic planning and implementation and the additional water supply arrangements and deliveries during the twelve years of the VAMP. Experimental and complementary studies related to VAMP and conducted in 2011 are also included.

2011 VAMP Experimental Design

The 2011 VAMP represents the twelfth and last year of the approved twelve-year VAMP experiment. This report summarizes the efforts made during the VAMP period to conduct the salmon survival study. Chapter 2 of this report describes the hydrologic planning and implementation during 2011 and conditions during the previous VAMP years (2000-2010). Chapter 3 describes the additional water supply arrangement and deliveries that occurred during the 2011 VAMP, including the fall attraction water. Although no physical or non-physical barrier was deployed at the head of Old River in 2011, Chapter 4 covers the proportion of water moving into Old River from the San Joaquin River and reports on the 2011 evaluation of the South Delta temporary barriers.

Salmon smolt survival investigations are presented in Chapter 5. These include the results from 2011 as well as a summary of past results from the VAMP and earlier south Delta studies that was part of the foundation for the VAMP. The discussion also includes the development and operation of the 2011 receiver network and the data processing from the receivers as well as results from mobile tracking conducted simultaneously. As in the 2008-2010 studies, the development and execution of a survival model is included, both with and without estimates of predator-type detections. In addition, the detection probabilities (how well the receiver network detected tagged fish for estimating survival) are also included in Appendices. Route entrainment probabilities were also analyzed in Chapter 5. Also included in Chapter 5 and 6 is a discussion of fish health during the 2011 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. In 2011, these included additional Chinook and steelhead releases at Durham Ferry as part of the 6-year steelhead study and the South Delta temporary barriers study to estimate survival through the Delta at different times during the season. Additional complementary studies included salmon catch in the tributaries and in the Mossdale Trawl and, as mentioned above, the complete report of the health studies done on tagged fish to determine if condition of the experimental fish impacted the 2011 survival results. Also included in Chapter 6 is an initial study of juvenile salmon survival and migration in the San Joaquin River Restoration Area during the spring of 2011, a summary of water temperatures seen during the 12 years of VAMP and a behavior study for fish in the vicinity of the HOR during the 2011 VAMP.

One aspect of the VAMP study in 2011, was its integration with four other studies being conducted simultaneously: 1) a South Delta Temporary Barrier Project (TBP) study, to assess the survival of Chinook salmon with the South Delta temporary barriers installed; 2) the 6-year steelhead study as part of the OCAP Biological Opinion to determine if salmon could be used as surrogates for steelhead in the San Joaquin River basin; 3) a head of Old River study to evaluate fish routing and predation at the head of Old River without a physical or non-physical barrier installed; and 4) a pre-screen loss study at the CVP to assess loss at the Tracy Fish Collection Facility (Central Valley Project) behind the trashracks using a 2-D acoustic array. Additional Chinook salmon and steelhead releases were made as part of these studies. The survival of Chinook salmon groups released as part of the South Delta TBP Study are reported in Chapter 5 as are the groups of salmon released as part of the VAMP. These estimates of Chinook salmon survival are reported in Chapter 5 both by release period and with the estimates pooled to obtain averages of population-level survival. Results of the steelhead releases as part of the 6-year study will be provided in a separate report, as will the assessment of the pre-screen loss at the CVP and evaluation of

predation of the head of Old River (HOR). As previously mentioned, an analyses of the route entrainment probabilities at the HOR in 2011 was presented in Chapter 5, with an analyses of the route entrainment probabilities during the 2009 and 2010 VAMP presented in Chapter 7. Chapter 8 is an itial analysis of salmon smolt survival in and near the South Delta Temporary Agricultural Barriers.

The integration of these studies provided for better comparisons between studies and cost-savings for each project. The integration was apparent in many aspects of the studies. Tagging for all the salmon and steelhead for the four studies was done by the same individuals and tagging crews. The tagged fish were all handled and released in a similar manner. All fish were detected on the same receivers and the same people did the data processing and analyses. Integration at all stages of the projects enhanced our ability to compare results across projects. The integration of the projects also resulted in labor and supply efficiencies which reduced costs for each of the individual projects. Furthermore, the integration resulted in obtaining more estimates of survival through the Delta, over a longer period of time, with multiple species, than would not have been possible without the partnership. We would recommend such integration for others as acoustic telemetry studies are costly at the scale needed to estimate survival through the Delta.

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 was 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 2011, 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 (VNS) gage on the San Joaquin River (see Figure 2-1 inside front cover) during the months of April and May, along with a corresponding reduction in State Water Project (SWP) and Central Valley Project (CVP) Sacramento-San Joaquin Delta exports. The VAMP target flow and reduced Delta export are determined based on a forecast of the San Joaquin River flow that would occur during the target flow period absent the VAMP (Existing Flow) as shown in Table 2-1. The Existing Flow is defined in the SJRA as "the forecasted flows in the San Joaquin River at Vernalis during the Pulse Flow Period that would exist absent the VAMP or water acquisitions," including such flows as minimum in-stream flows, water quality or scheduled fishery releases from New Melones Reservoir on the Stanislaus River, flood control releases, uncontrolled reservoir spills, and/or local runoff. Achieving the target flow requires the coordinated operation of the three major San Joaquin River tributaries upstream of Vernalis: the Merced River, the Tuolumne River and the Stanislaus River.

As part of the development of the VAMP experimental design, the SJRTC had identified a level of variation in San Joaquin River flow and SWP/CVP export rate thought to be within an acceptable range for specific VAMP test conditions. In developing the criteria, the SJRTC examined both the ability to effectively monitor and manage flows and exports within various ranges (e.g., the ability to accurately manage and regulate export rates is substantially greater than the ability to manage San Joaquin River flows) and the flow and export differences among VAMP targets (Table 2-1). Through these discussions, the SJRTC agreed that SWP/CVP export rates would be managed to a level of plus or minus 2.5 percent 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 was 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 percent 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 percent flow variation at the Vernalis (VNS) 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 percent of the Vernalis flow target. It was recognized by the SJRTC that these guidelines are not absolute conditions, but were to be used in the implementation of the flow and export targets to limit the variation when evaluating the potential effect of flow and export on fall-run 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.

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[a]

[a] Suggested rates at higher flows.

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, was used to define the SJRGA supplemental water obligation limit when Existing Flow was 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 was less than 2,000 cfs, the target flow would be 2,000 cfs and the USBR, in accordance with the SJRA, would act to purchase additional water from willing sellers to fulfill the requirements of existing biological opinions.

When the Existing Flow exceeded 7,000 cfs, the parties to the SJRA would 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 would 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 were dependent on the hydrologic year type as defined by the 60-20-20 Index, which was 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.

Under the SJRA, the maximum amount of supplemental water to be provided to meet VAMP target flows in any given year was 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 was needed, the USBR would attempt to acquire the needed additional water on a willing seller basis. In accordance with the SJRA, the SJRGA agreed to extend a "favored purchaser" offer to the USBR through each current year's VAMP period.

2011 VAMP Year

The hydrologic conditions for the Water Year 2011[1] winter were very wet 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 160 percent of average on April 1, 2011[2]. The San Joaquin River watershed experienced the wettest October, the 3rd wettest December, a dry January, and the 6th wettest March on record. The forecasted April-July runoff as of April 1st in the four basins above Vernalis (Stanislaus, Tuolumne, Merced and San Joaquin) ranged from 165 to 168 percent of average[2].

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 Hydrologic Classification	VAMP Numerical Indicator
Wet	5
Above Normal	4
Below Normal	3
Dry	2
Critical	1

Table 2-3

Year	San Joaquin Valley Water Year Hydrologic Classification	VAMP Numerical Indicator
2009	Dry	2
2010	Above Normal	4
2011	Wet [1]	5

[1] The current year's Classification is based on the April 1st 90% exceedence forecast and may differ from the official Classification which is based on the May 1st forecast and is therefore not available for VAMP planning. The current year's official Classification will be used in next year's planning of VAMP flows.

The April 1st-90 percent probability of exceedence forecast of the San Joaquin Valley Water-Year Type Classification, based on the 60-20-20 Index, was 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 existed. For this April 1st forecast, Water Year 2011 was classified as "wet" with a VAMP numerical indicator of 5. The numerical indicators for 2009 and 2010 were 2 ("dry") and 4 ("above normal"), respectively (Table 2-3). The sum of the 2010 and 2011 numerical indicators was 9 so the "double step" condition, which occurs when that sum is 7 or greater, was in effect. Conversely, the sum of the 2009, 2010 and 2011 numerical indicators was 11 so the "sequential dry-year relaxation" condition, which occurs when that sum is 4 or less, was not in effect. Therefore, the "double-step" condition was in effect of the 2011 VAMP operation.

[1] *Water Year 2011 is October 2010 through September 2011.*

[2] *Water Conditions in California, California Cooperative Snow Surveys Bulletin 120, Report 3, April 1, 2011. California Department of Water Resources.*

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 second one-year extension of the SJRA (the first one-year extension of the SJRA occurred in year 2010). Under this extension agreement, the VAMP supplemental water and accompanying operation would be determined prior to the VAMP period and coordinated 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.

An additional factor for 2011 that was not present prior to the 2010 VAMP was the San Joaquin River Restoration Program (Restoration Program). The Restoration Program requires additional releases from Millerton Lake to restore flows and salmon fishery on the upper San Joaquin River 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 was to potentially reduce the uncertainty associated with the estimate of flow in the San Joaquin River at the Merced River. There was some uncertainty with regard to the Restoration Program flows due to seepage concerns.

Hydrologic Planning for 2011 VAMP

The SJRTC Hydrology Group held its initial meeting for the 2011 VAMP planning on February 23, 2011. The SJRTC Hydrology Group met three additional times: on March 16th, March 29th and April 21st . The March 29th and April 21st meetings were in combination with the SJRTC Biology Group. 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 29th 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 23rd SJRTC Hydrology Group meeting. The 90 percent probability of exceedence forecast indicated a VAMP target flow of (a likely double-step) 7,000 cfs and the 50 percent probability of exceedence forecast indicated an existing flow greater than the maximum VAMP target flow of 7,000 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 was 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 provided a forecast of the daily flows expected during the HORB installation period. The daily operation plan calculated 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 (VNS) gage were used in the development of the daily operation plan. Whole day increments were used because the daily operation plan was 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 was 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 (VNS) gage and the upstream measuring points and was 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
CRSv	=	Merced River at Cressey lagged 3 days
$USJR_{lag}$	=	San Joaquin River above Merced River lagged 2 days

(USJR is represented by the measured flow at the USGS San Joaquin River at Fremont Ford Bridge (11261500) which is located 7 miles upstream of the Merced River confluence).

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 was developed assuming a constant ungaged flow throughout the target flow period essentially equal to the value entering the target flow period.

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

The initial daily operation plan was prepared on March 15th for the March 16th Hydrology Group meeting. Two versions of this plan were developed to account for hydrologic uncertainty, one considering wetter conditions and one considering drier conditions. The wetter condition forecasted a VAMP Target Flow of 7,000 cfs with supplemental water requirements of about 60,000 acre-feet. The drier condition forecasted a VAMP Target Flow of 4,450 cfs with supplemental water requirements of about 110,000 acre-feet.

A second daily operation plan was prepared on March 28th for the March 29th meeting. The DWR April 1st run-off forecast was not yet available when this plan was prepared, so it was based on the March 22nd interim runoff forecast. In March the Upper San Joaquin, Tuolumne, Merced, and Stanislaus Rivers had received significant rainfall runoff and reservoirs were managing for flood control. 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 March 28th operation plan forecasted a VAMP Target Flow of 20,400 cfs, significantly greater than the maximum VAMP Target Flow of 7,000 cfs.

Due to changing conditions, the daily operation plan was updated numerous times. The final daily operation plan was prepared on April 29th after the VAMP Period was set as May 1st to May 31st. The daily operation plan was modified to again adjust the tributary flow estimates due to flood control operations, however, the VAMP Target flow of greater than 7,000 cfs (targeting stable flows) remained the same. 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 14.

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 consulted with DFG and the tributary biological teams to determine periods when pulse flows and stable flows were desirable on the tributaries, what flow rates were desired, what rates of change were acceptable, and what minimum and maximum flows were acceptable.

Implementation

Since flows throughout the San Joaquin River basin during the 2011 VAMP period were being driven by flood control operations, the implementation phase of the VAMP hydrologic operation consisted mainly of monitoring the flow conditions during the VAMP period. Attempts were made during the operation

Table 2-4
Summary of Daily Operation Plans for the 2011 VAMP

Phase	VAMP Forecast Date	DWR Runoff Forecast Date	VAMP Target Flow Period	Single or Double Step	Assumed Ungaged Flow at Vernalis - VAMP Period Average (cfs)	Existing Flow - VAMP Period Average (cfs)	VAMP Target Flow (cfs)	SJRGA Supplemental Water Requirement (acre-feet)
Planning	3/16/11	3/8/11	April 15 - May 15	Double	400	2,630	4,450	110,000
					1,000	6,030	7,000	59,350
	3/28/11	3/22/11	April 15 - May 15	n/a	1,000	20,440	n/a	0
	4/15/11	4/1/11	May 1 - May 31	n/a	500	18,090	n/a	0
	4/20/11	4/12/11	May 1 - May 31	n/a	500	17,750	n/a	0
	4/27/11	4/19/11	May 1 - May 31	n/a	2,000	17,580	n/a	0
	4/29/11	4/19/11	May 1 - May 31	n/a	3,000	17,260	n/a	0
Implementation	5/10/11	5/1/11	May 1 - May 31	n/a	3,000	14,300	n/a	0
	5/12/11	5/1/11	May 1 - May 31	n/a	2,500	13,350	n/a	0
	5/12/11	5/1/11	May 1 - May 31	n/a	2,500	13,740	n/a	0
	5/19/11	5/10/11	May 1 - May 31	n/a	730	11,960	n/a	0
	5/20/11	5/10/11	May 1 - May 31	n/a	650	12,050	n/a	0

Table 2-5
Real-time Mean Daily Flow Data Sources Used in the 2011 VAMP

Measurement Location	Source
San Joaquin River near Vernalis	USGS, station 11303500 (http://waterdata.usgs.gov/ca/nwis/dv?cb_00060=on&format=html&begin_date=2011-01-01&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=2011-01-01&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)
San Joaquin River at Fremont Ford Bridge	USGS, station 11261500 (http://waterdata.usgs.gov/ca/nwis/dv?cb_00060=on&format=html&begin_date=2011-01-01&end_date=&site_no=11261500&referred_module=sw)

Table 2-6
Summary of USGS Flow Measurements at the San Joaquin River near Vernalis (VNS) Gage During the 2011 VAMP

Date	Time	Gage Height (ft.)	Measured Flow (cfs)	Rating Curve Shift (ft.)
3/3/11	11:19	18.08	11,600	0
3/3/11	11:54	18.08	11,700	0
4/1/11	13:44	27.17	31,100	+0.80
4/25/11	14:22	24.68	22,100	-0.40
5/2/11	13:02	22.48	16,900	-0.75
5/9/11	11:16	20.79	14,200	-0.75
5/16/11	12:20	19.21	11,200	-0.75
5/23/11	14:21	18.58	11,200	-0.75

planning to provide a steady flow during the VAMP Target Flow period, as stipulated by the SJRA when Existing Flow exceeds 7,000 cfs. However, due to the changing conditions and needs of the flood control operation to respond to these conditions, it was not possible to maintain a steady flow during the VAMP Target Flow period.

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 were continuously monitored. Similarly, the computed ungaged flow at Vernalis and the flow in the San Joaquin River upstream of the Merced River were 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. The measurements resulted in rating shifts just prior to and at the beginning of the 2011 VAMP target flow period, however these rating shifts did not affect the VAMP operation due to the ongoing flood control operations.

Results of Operations

The final record of flows during the VAMP period was based on the provisional mean daily flow data available from USGS, DWR and USBR as of January 19, 2012. 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 5, 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 12,650 cfs during the VAMP target flow period (May 1st – May 31st). 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 10,100 cfs and 18,200 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 mean daily ungaged flow at Vernalis averaged 840 cfs during the VAMP period, ranging from a minimum of 310 cfs to a maximum of 1,650 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 restricted by the NMFS RPA to a 4:1 Delta inflow to export ratio. The observed exports during this period, shown in Figure 2-4, averaged 3,360 cfs and ranged from 2,420 cfs to 5,160 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.

Entering the 2011 VAMP target flow period there was no storage impact in Lake McClure on the Merced River (Figure 2-5) or in Don Pedro Reservoir on the Tuolumne River (Figure 2-6). Since no supplemental water was provided for the 2011 VAMP operation there was also no storage impact in these reservoirs following the VAMP target flow period.

Summary of Historical VAMP Operations

The year 2011 marks the twelfth year of VAMP operation in compliance with State Water Board Decision 1641 (D-1641). A summary of the VAMP target flows for these twelve 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 monitored the cumulative impact of the SJRA on reservoir storage

Table 2-7
2011 Vernalis Adaptive Management Plan (VAMP)
Final Flows and Accounting of Supplemental Water Contributions
VAMP Target Flow Period: May 1st – May 31st · Target Flow: n/a

Date	Merced R. at Cressey (3-day Travel Time to Vernalis)				Tuolumne R. blw LaGrange Dam (2-day Travel Time to Vernalis)			Stanislaus R. blw Goodwin Dam (2-day Travel Time to Vernalis)			San Joaquin R. above Merced R. Flow [2]	Ungaged Flow at Vernalis	San Joaquin River at Vernalis		
	Existing Flow [1]	Observed Flow	Merced ID Supple-mental Flow	Exchange Contrac-tors Supple-mental Flow	Existing Flow [1]	Observed Flow	MID/TID Supple-mental Flow	Existing Flow [1]	Observed Flow	OID/SSJID Supple-mental Flow			Existing Flow [1]	Observed Flow	VAMP Supple-mental Water
	(cfs)	(cfs)	(cfs)	(cfs)	(cfs)	(cfs)	(cfs)	(cfs)	(cfs)	(cfs)	(cfs)	(cfs)	(cfs)	(cfs)	(cfs)
04/01/11	3,390	3,390			8,350	8,350		1,301	1,301		13,900	2,482	30,700	30,700	
04/02/11	3,710	3,710			8,380	8,380		1,307	1,307		12,900	2,867	30,800	30,800	
04/03/11	3,830	3,830			8,340	8,340		1,307	1,307		12,800	3,719	30,700	30,700	
04/04/11	3,790	3,790			8,320	8,320		1,310	1,310		12,800	4,123	30,100	30,100	
04/05/11	4,000	4,000			8,350	8,350		1,726	1,726		12,900	3,443	29,600	29,600	
04/06/11	4,120	4,120			8,350	8,350		2,000	2,000		12,700	3,040	29,300	29,300	
04/07/11	4,330	4,330			7,580	7,580		2,002	2,002		12,100	2,634	29,400	29,400	
04/08/11	4,410	4,410			7,740	7,740		2,028	2,028		11,600	2,350	29,400	29,400	
04/09/11	4,580	4,580			8,330	8,330		2,026	2,026		11,300	3,098	28,900	28,900	
04/10/11	4,680	4,680			8,340	8,340		2,022	2,022		10,900	2,902	28,600	28,600	
04/11/11	4,730	4,730			8,340	8,340		2,043	2,043		10,800	2,334	28,400	28,400	
04/12/11	4,770	4,770			8,310	8,310		2,655	2,655		10,500	2,358	28,200	28,200	
04/13/11	4,800	4,800			8,340	8,340		3,066	3,066		10,300	2,137	28,000	28,000	
04/14/11	4,830	4,830			8,360	8,360		3,113	3,113		10,100	1,805	28,000	28,000	
04/15/11	4,860	4,860			8,330	8,330		3,061	3,061		9,670	1,424	27,900	27,900	
04/16/11	3,760	3,760			8,320	8,320		3,017	3,017		9,450	1,427	27,800	27,800	
04/17/11	3,420	3,420			8,340	8,340		3,018	3,018		9,110	1,709	27,600	27,600	
04/18/11	3,430	3,430			8,170	8,170		3,048	3,048		8,750	1,553	27,200	27,200	
04/19/11	3,420	3,420			7,710	7,710		3,019	3,019		8,550	2,272	26,500	26,500	
04/20/11	3,460	3,460			7,330	7,330		2,637	2,637		8,430	2,312	25,700	25,700	
04/21/11	3,520	3,520			7,040	7,040		2,532	2,532		8,300	2,191	24,900	24,900	
04/22/11	3,550	3,550			6,770	6,770		2,552	2,552		8,140	2,083	23,900	23,900	
04/23/11	3,590	3,590			6,440	6,440		2,525	2,525		7,950	1,868	23,200	23,200	
04/24/11	3,630	3,630			6,140	6,140		2,560	2,560		7,730	1,618	22,600	22,600	
04/25/11	3,670	3,670			5,810	5,810		2,568	2,568		7,560	1,535	22,000	22,000	
04/26/11	3,100	3,100			5,690	5,690		2,543	2,543		7,500	1,480	21,500	21,500	
04/27/11	2,980	2,980			5,680	5,680		2,529	2,529		7,420	1,332	20,900	20,900	
04/28/11	3,000	3,000	0	0	5,610	5,610		2,546	2,546		7,360	897	20,300	20,300	
04/29/11	2,980	2,980	0	0	4,970	4,970	0	2,174	2,174	0	7,280	1,071	19,800	19,800	
04/30/11	2,530	2,530	0	0	4,210	4,210	0	2,003	2,003	0	7,040	704	19,200	19,200	
05/01/11	2,500	2,500	0	0	3,590	3,590	0	2,014	2,014	0	6,700	776	18,200	18,200	0
05/02/11	2,510	2,510	0	0	3,510	3,510	0	2,014	2,014	0	6,250	867	17,100	17,100	0
05/03/11	2,510	2,510	0	0	3,500	3,500	0	2,040	2,040	0	6,030	1,366	16,200	16,200	0
05/04/11	2,480	2,480	0	0	3,490	3,490	0	2,025	2,025	0	5,900	1,226	15,500	15,500	0
05/05/11	2,420	2,420	0	0	3,670	3,670	0	2,012	2,012	0	5,760	820	14,900	14,900	0
05/06/11	2,410	2,410	0	0	3,890	3,890	0	2,022	2,022	0	5,570	575	14,500	14,500	0
05/07/11	2,420	2,420	0	0	3,890	3,890	0	2,017	2,017	0	5,320	578	14,500	14,500	0
05/08/11	2,430	2,430	0	0	3,890	3,890	0	2,001	2,001	0	5,070	498	14,400	14,400	0
05/09/11	2,420	2,420	0	0	3,890	3,890	0	2,036	2,036	0	4,750	663	14,300	14,300	0
05/10/11	2,430	2,430	0	0	3,840	3,840	0	2,028	2,028	0	4,390	519	13,900	13,900	0
05/11/11	2,180	2,180	0	0	3,670	3,670	0	2,058	2,058	0	4,090	394	13,500	13,500	0
05/12/11	2,390	2,390	0	0	3,370	3,370	0	2,043	2,043	0	3,910	422	13,100	13,100	0
05/13/11	2,380	2,380	0	0	3,130	3,130	0	2,021	2,021	0	3,650	452	12,700	12,700	0
05/14/11	2,350	2,350	0	0	3,130	3,130	0	2,009	2,009	0	3,020	797	12,300	12,300	0
05/15/11	2,440	2,440	0	0	3,110	3,110	0	2,001	2,001	0	2,490	909	12,100	12,100	0
05/16/11	2,440	2,440	0	0	3,100	3,100	0	2,042	2,042	0	2,490	1,361	11,900	11,900	0
05/17/11	2,450	2,450	0	0	3,140	3,140	0	2,032	2,032	0	2,570	1,649	11,600	11,600	0
05/18/11	2,460	2,460	0	0	3,130	3,130	0	2,037	2,037	0	2,480	1,428	11,500	11,500	0
05/19/11	2,440	2,440	0	0	3,110	3,110	0	2,039	2,039	0	2,400	1,218	11,400	11,400	0
05/20/11	2,430	2,430	0	0	3,120	3,120	0	2,042	2,042	0	2,410	1,203	11,300	11,300	0
05/21/11	2,400	2,400	0	0	3,120	3,120	0	2,022	2,022	0	2,450	1,191	11,200	11,200	0
05/22/11	2,400	2,400	0	0	3,130	3,130	0	1,998	1,998	0	2,390	988	11,000	11,000	0
05/23/11	2,440	2,440	0	0	3,140	3,140	0	2,004	2,004	0	2,250	978	11,000	11,000	0
05/24/11	3,150	3,150	0	0	3,110	3,110	0	2,021	2,021	0	2,190	882	10,800	10,800	0
05/25/11	3,230	3,230	0	0	3,130	3,130	0	2,040	2,040	0	2,070	806	10,600	10,600	0
05/26/11	3,270	3,270	0	0	3,120	3,120	0	2,027	2,027	0	1,860	939	10,700	10,700	0
05/27/11	3,280	3,280	0	0	3,100	3,100	0	1,684	1,684	0	1,690	310	10,700	10,700	0
05/28/11	3,260	3,260	0	0	3,120	3,120	0	1,512	1,512	0	1,580	363	10,600	10,600	0
05/29/11	3,290	3,290			3,180	3,180	0	1,510	1,510	0	1,490	556	10,300	10,300	0
05/30/11	3,260	3,260			3,680	3,680		1,511	1,511		1,440	708	10,200	10,200	0
05/31/11	3,220	3,220			4,290	4,290		1,531	1,531		1,420	660	10,100	10,100	0
							VAMP Period								
Average (cfs):	2,595	2,595	0	0	3,435	3,435	0	1,985	1,985	0	3,792	842	12,648	12,648	0
Supplemental Water (ac-ft):			0	0			0			0					0

■ VAMP Period

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

[2] San Joaquin River at Fremont Ford Bridge, USGS 11261500 (~7 miles upstream of the Merced River)

Observed Flow Sources:

Merced River at Cressey (CA DWR B05155): California DWR, Water Data Library, 1/19/12

Tuolumne River below LaGrange Dam near LaGrange (USGS 11289650): USGS, provisional data as of 1/19/12

Stanislaus River below Goodwin Dam: USBR, Goodwin Reservoir Daily Operations Report - OID/SSJID/Tri-Dams, 5/1/11 (April report) and 6/1/11 (May report)

San Joaquin River near Vernalis (USGS 11303500): USGS, provisional data as of 1/19/12

San Joaquin River at Fremont Ford Bridge (USGS 11261500): USGS, provisional data as of 1/19/12

Table 2-8
Summary of VAMP Flows, 2000-2011

Year	VAMP Target Flow Period	VAMP Target Flow Condition	Target Flow at Vernalis - VAMP Period Mean (cfs)	Observed Flow at Vernalis - VAMP Period Mean (cfs)	Existing Flow - VAMP Period Mean (cfs)	VAMP Supplemental Water Volume (acre-feet)	Delta Export Target (cfs)	Observed Delta Exports - VAMP Period Mean (cfs)
2000	4/15 - 5/15	Double-step	5,700	5,870	4,820	77,680	2,250	2,160
2001	4/20 - 5/20	Single-step	4,450	4,220	2,920	78,650	1,500	1,420
2002	4/15 - 5/15	Single-step	3,200	3,300	2,760	33,430	1,500	1,430
2003	4/15 - 5/15	Single-step	3,200	3,240	2,290	58,070	1,500	1,450
2004	4/15 - 5/15	Single-step	3,200	3,160	2,090	65,590	1,500	1,330
2005	5/1 - 5/31	n/a [a]	>7,000	10,390	10,390	0	2,250	2,990 [b]
2006	5/1 - 5/31	n/a [a]	>7,000	27,900/24,260 [c]	26,020	0	1,500/6,000 [c]	1,560/5,750 [c]
2007	4/22 - 5/22	Single-step	3,200	3,260	2,720	33,330	1,500	1,490
2008	4/22 - 5/22	Single-step	3,200	3,160	1,940	75,250	1,500	1,520
2009	4/19 - 5/19	Off-ramp	na	2,280	2,280	0	n/a	1,990
2010	4/25 - 5/25	Single-step	4,450	5,140	4,830	23,980	1,500	1,520
2011	5/1 - 5/31	n/a [a]	>7,000	12,650	12,650	0	[d]	3,360

[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" (5/1 - 5/15 for Vernalis, 5/3 - 5/17 for Delta Exports)/"Second fish release-recapture period" (5/16 - 5/31 for Vernalis, 5/18 - 6/2 for Delta Exports)

[d] Restricted to 4:1 Delta inflow to export ratio, NMFS Reasonable and Prudent Alternative

and stream flows. Plots of storage and flow impacts throughout the twelve years of VAMP operation are provided in Appendix B, Figures 1 through 4.

Over the twelve 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*

Table 2-9
Summary of VAMP Supplemental Water Contributions, 2000 - 2011

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
2011	0 [e]	Observed:	0	0	0	0	0	0
		Division Agreement:	0	0	0	0	0	0
		Deviation:	0	0	0	0	0	0

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

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 C. 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 C. 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 2-10
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	SJRA Supplemental Water Provided from Storage (ac-ft)	Reservoir Storage Replenishment (ac-ft)	Storage Impact Balance (ac-ft)	Vernalis Status [1]	Appendix C Figures
4/18/00 - 5/11/00	46,750		-46,750		
5/13/00 - 5/29/00		46,750	0	N	1, 2
10/15/00 - 12/31/00	12,500		-12,500		
4/17/01 - 5/19/01	42,120		-54,620		
11/12/01 - 12/31/01	12,500		-67,120		
4/13/02 - 5/15/02	25,840		-92,960		
10/15/02 - 10/31/02	12,470		-105,430		
4/11/03 - 5/16/03	38,260		-143,690		
10/1/03 - 10/27/03	12,500		-156,190		
4/12/04 - 5/13/04	42,680		-198,870		
10/1/04 - 10/26/04	12,500		-211,370		
1/25/05 - 3/23/05		211,370	0	N	3, 4
10/8/06 - 10/28/06	12,500		-12,500		
4/19/07 - 5/19/07	28,960		-41,460		
11/6/07 - 12/17/07	12,500		-53,960		
4/22/08 - 5/19/08	38,150		-92,110		
10/1/08 - 10/24/08	12,500		-104,610		
10/1/09 - 10/31/09	12,500		-117,110		
4/22/10 - 5/22/10	23,970		-141,080		
4/13/10 - 5/23/10		141,080	0	N	5, 6
10/15/10 - 11/8/10	12,500		-12,500		
11/27/10 - 12/8/10		12,500	0	N	7, 8

[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	SJRA Supplemental Water Provided from Storage (ac-ft)	Reservoir Storage Replenishment (ac-ft)	Storage Impact Balance (ac-ft)	Vernalis Status [1]	Appendix C Figures
4/13/00 - 5/12/00	22,650		-22,650		
9/27/00 - 10/7/00		14,950	-7,700	N	9, 10
3/23/01 - 3/28/01		4,610	-3,090	N	11, 12
4/18/01 - 5/18/01	14,060		-17,150		
4/13/03 - 5/13/03	9,730		-26,880		
3/10/04 - 3/16/04		12,590	-14,290	N	13, 14
3/27/04 - 4/1/04		14,290	0	N	13, 14
4/13/04 - 5/13/04	11,150		-11,150		
3/21/05 - 3/24/05		11,150	0	N	15, 16
4/20/07 - 5/6/07	4,370		-4,370		
4/20/08 - 5/20/08	15,280		-19,650		
4/8/10 - 4/17/10		19,650	0	N	17, 18

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

Figure 2-2
Observed Flow during the 2011 VAMP in the San Joaquin River near Vernalis (VNS), in the San Joaquin River above the Merced River confluence and in the Three Tributaries (Stanislaus, Tuolumne and Merced Rivers) Flowing into the San Joaquin River above Vernalis

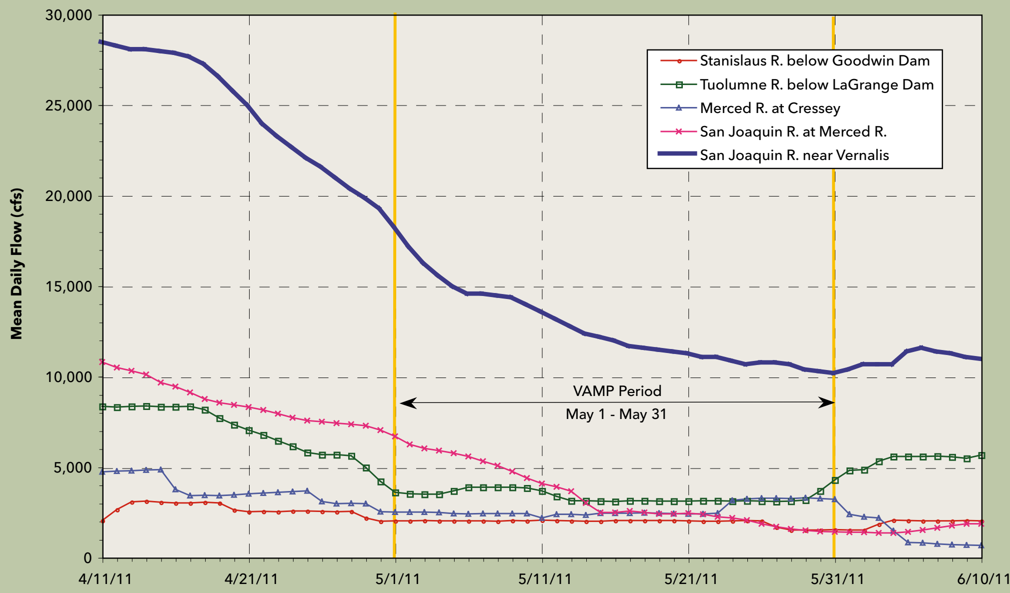


Figure 2-3
Ungaged Flow in the San Joaquin River near Vernalis (VNS) during the 2011 VAMP

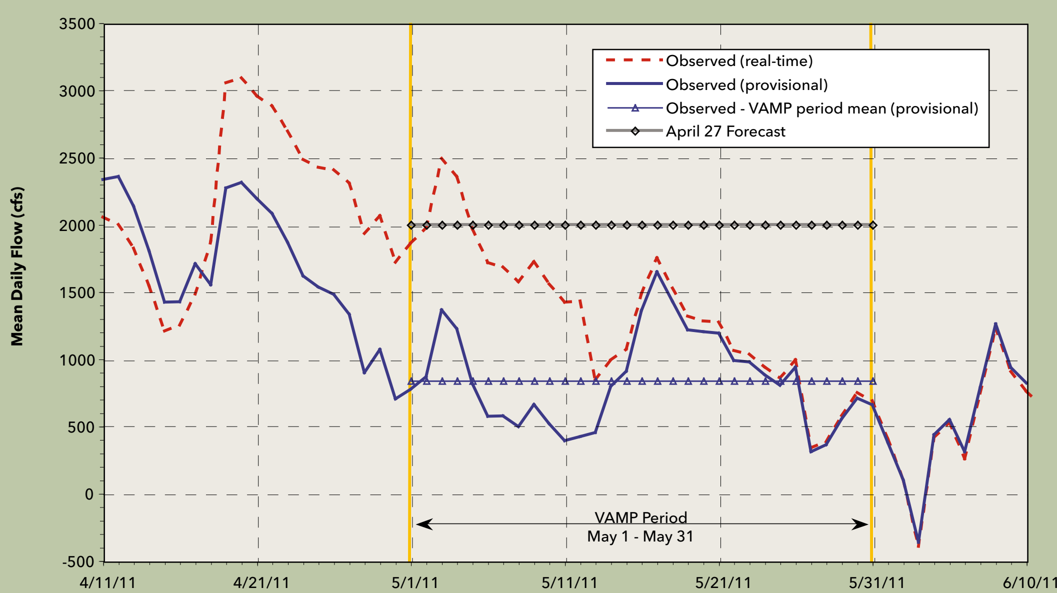


Figure 2-4
Federal and State Delta Exports during the 2011 VAMP

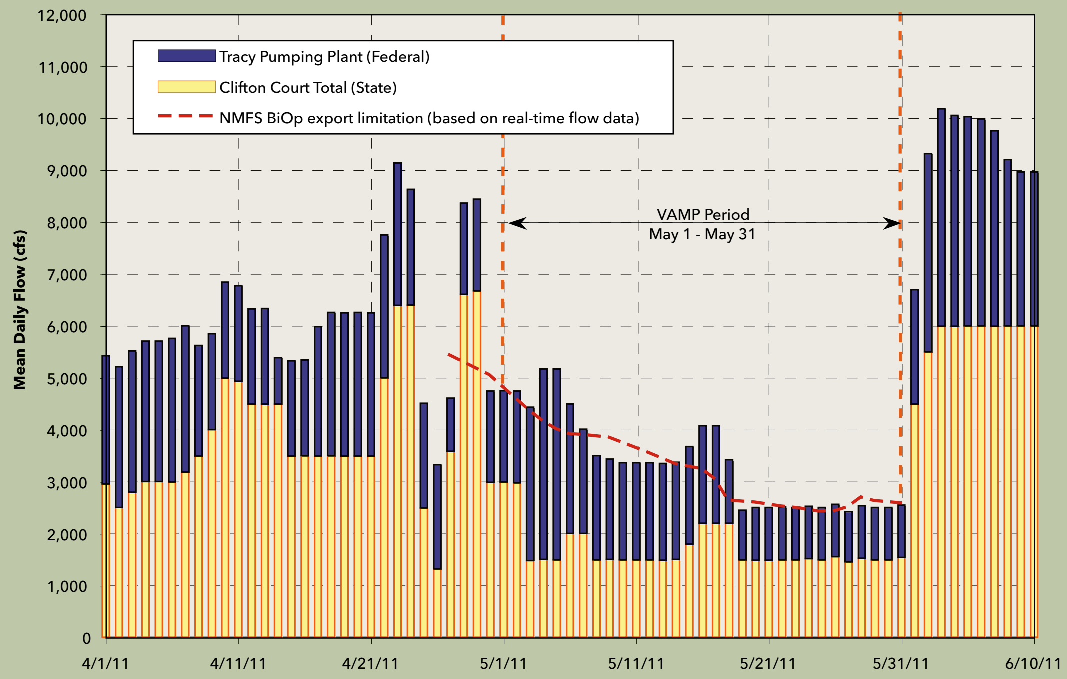


Figure 2-5
San Joaquin River Agreement (SJRA) Storage and Flow Impacts Merced River – Lake McClure Storage and Release - 2011

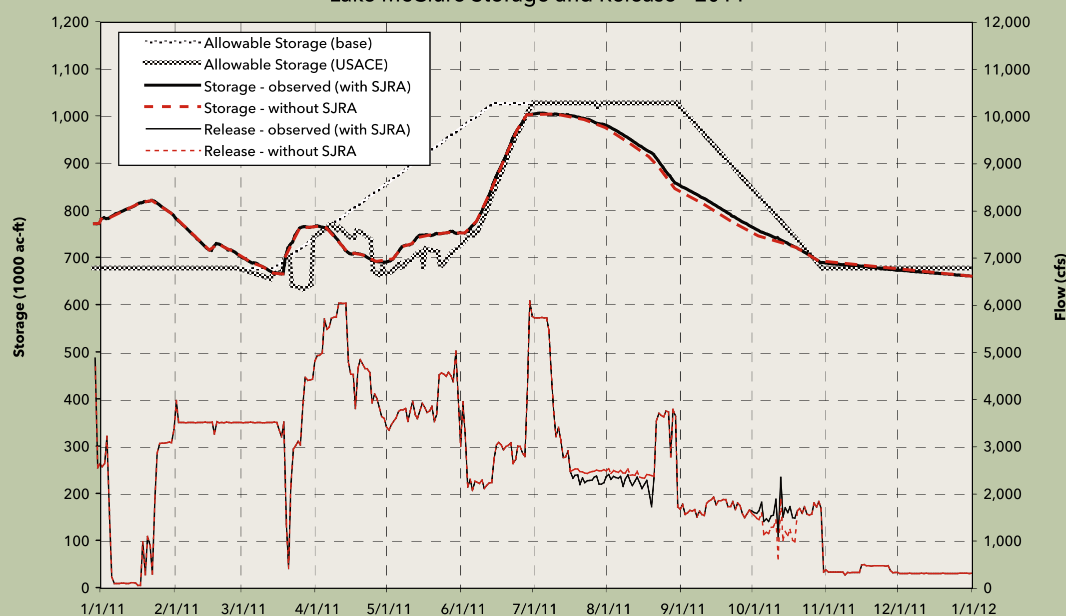
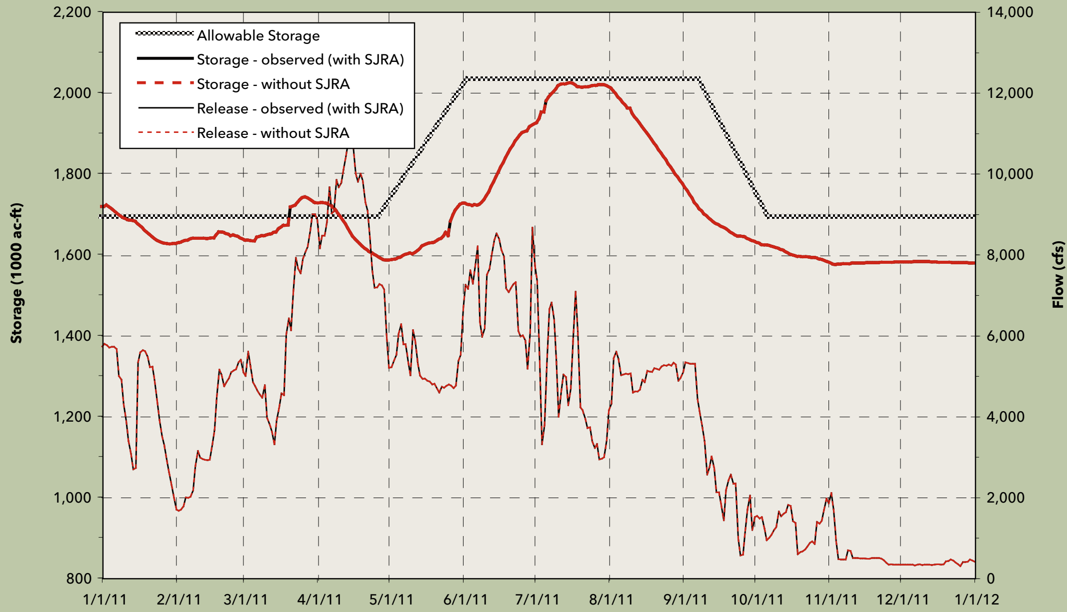


Figure 2-6
San Joaquin River Agreement (SJRA) Storage and Flow Impacts on the Tuolumne River
New Don Pedro Reservoir Storage and Release - 2011

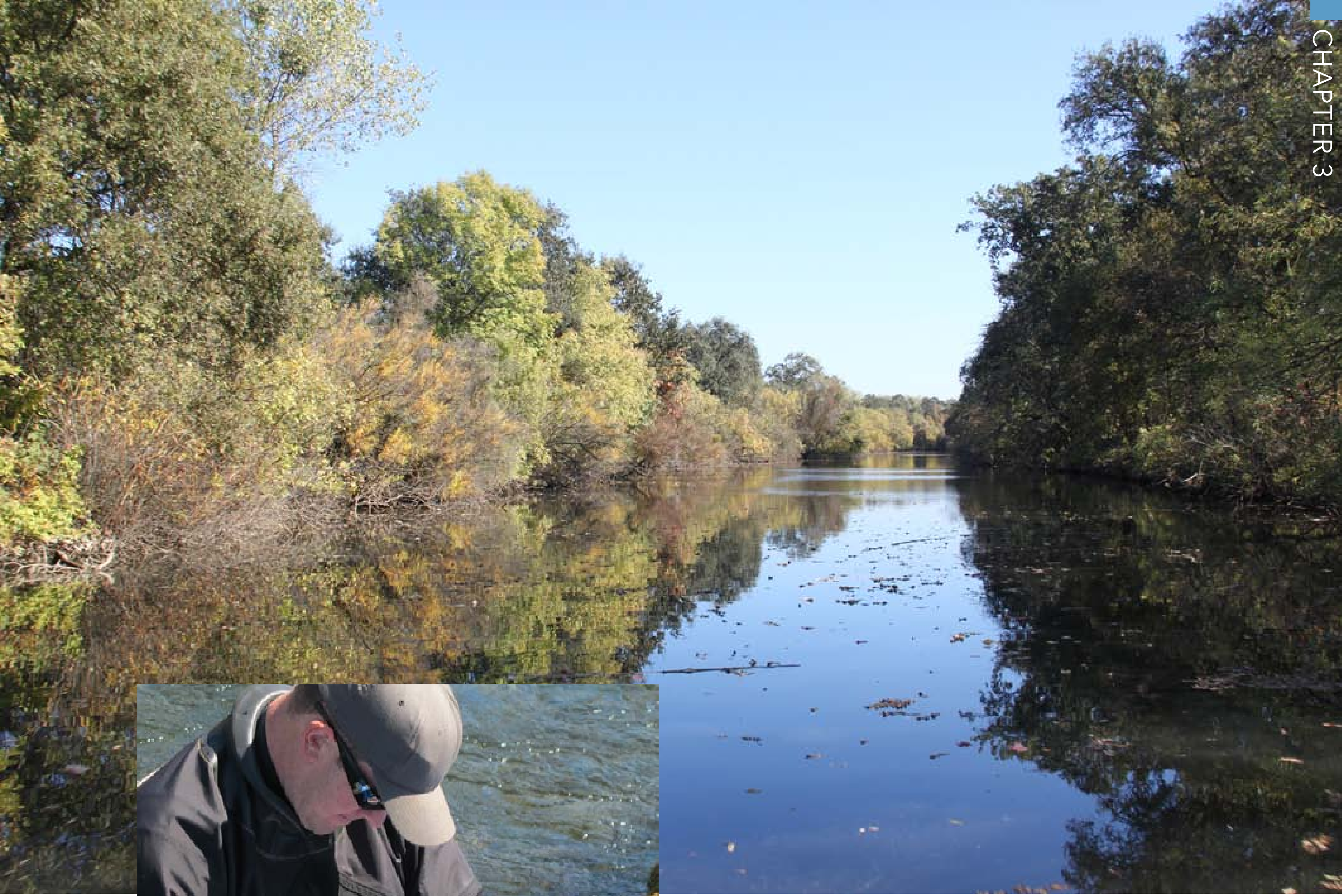


CHAPTER 3

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 in late September, with the water being provided from October 1st through October 20th as shown in Table 3-1 and Figure 3-1.

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 2011 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 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.

Due to high storage levels and ongoing flood control operations at New Melones Reservoir, the USBR did not schedule the release of the 2011 OID Additional water.

Table 3-1
2011 Merced Irrigation District SJRA Fall Water Transfer - Daily Summary

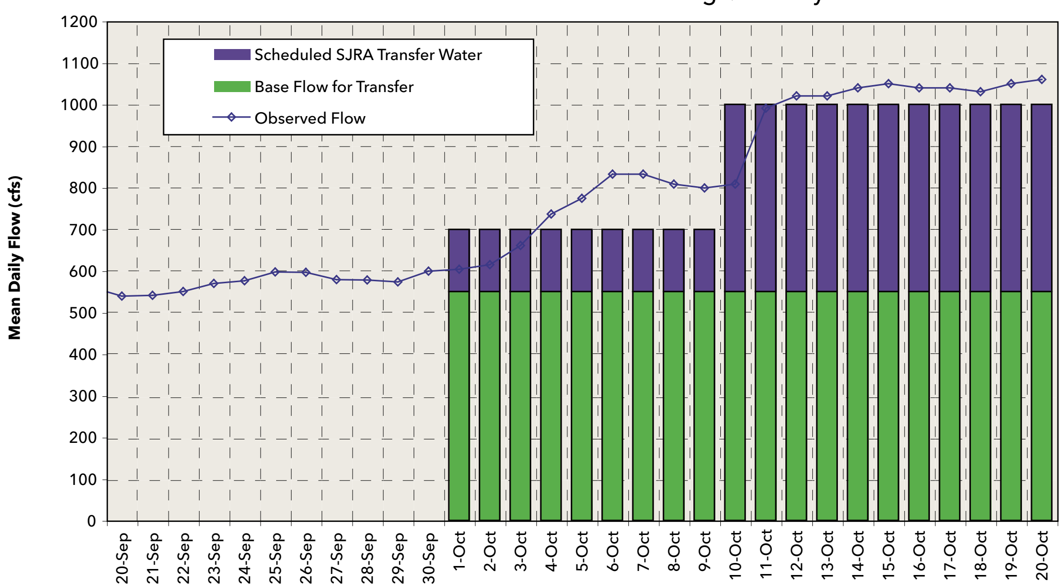
		SCHEDULED			OBSERVED				
		SJRA Transfer Water						SJRA Transfer Water	
Date	Merced River Base Flow (cfs)	SJRA Transfer Water Flow (cfs)	Cumulative SJRA Transfer Water Volume (ac-ft)	Merced River Target Flow (cfs)	Merced River at Shaffer Bridge Flow [1] (cfs)	Merced River at Cressey Flow [2] (cfs)	Merced River Flow for Transfer [3] (cfs)	SJRA Transfer Water Flow (cfs)	Cumulative SJRA Transfer Water Volume (ac-ft)
1-Oct	550	150	298	700	605	604	604	54	107
2-Oct	550	150	595	700	615	615	615	65	236
3-Oct	550	150	893	700	690	661	661	111	456
4-Oct	550	150	1,190	700	721	736	736	186	825
5-Oct	550	150	1,488	700	763	774	774	224	1,269
6-Oct	550	150	1,785	700	790	832	832	282	1,829
7-Oct	550	150	2,083	700	763	832	832	282	2,388
8-Oct	550	150	2,380	700	742	808	808	258	2,900
9-Oct	550	150	2,678	700	742	799	799	249	3,394
10-Oct	550	450	3,570	1,000	962	808	808	258	3,905
11-Oct	550	450	4,463	1,000	986	991	991	441	4,780
12-Oct	550	450	5,355	1,000	974	1,020	1,020	470	5,712
13-Oct	550	450	6,248	1,000	986	1,020	1,020	470	6,645
14-Oct	550	450	7,140	1,000	992	1,040	1,040	490	7,617
15-Oct	550	450	8,033	1,000	992	1,050	1,050	500	8,608
16-Oct	550	450	8,926	1,000	986	1,040	1,040	490	9,580
17-Oct	550	450	9,818	1,000	974	1,040	1,040	490	10,552
18-Oct	550	450	10,711	1,000	992	1,030	1,030	480	11,504
19-Oct	550	450	11,603	1,000	998	1,050	1,050	500	12,496
20-Oct	550	450	12,496	1,000	998	1,060	1,060	2	12,500

[1] Merced Irrigation District Daily Water Tabulation and Use Report

[2] California Department of Water Resources, B05155 Merced River at Cressey, USDAY V91 Output 01/23/12

[3] The Technical Appendix to the San Joaquin River Group Division Agreement states "The first location is the Merced River at Shaffer Bridge which will be used for flows between 0 and 300 cfs. For flows in the Merced River above 300 cfs, the rating at the Shaffer Bridge gage is not valid. Therefore, for the flows above 300 cfs, measurements will be provided at the gage on the Merced River located near Cressey."

Figure 3-1
Merced Irrigation District Fall 2011 Water Transfer as Shown by Merced River Flow at Shaffer Bridge/Cressey

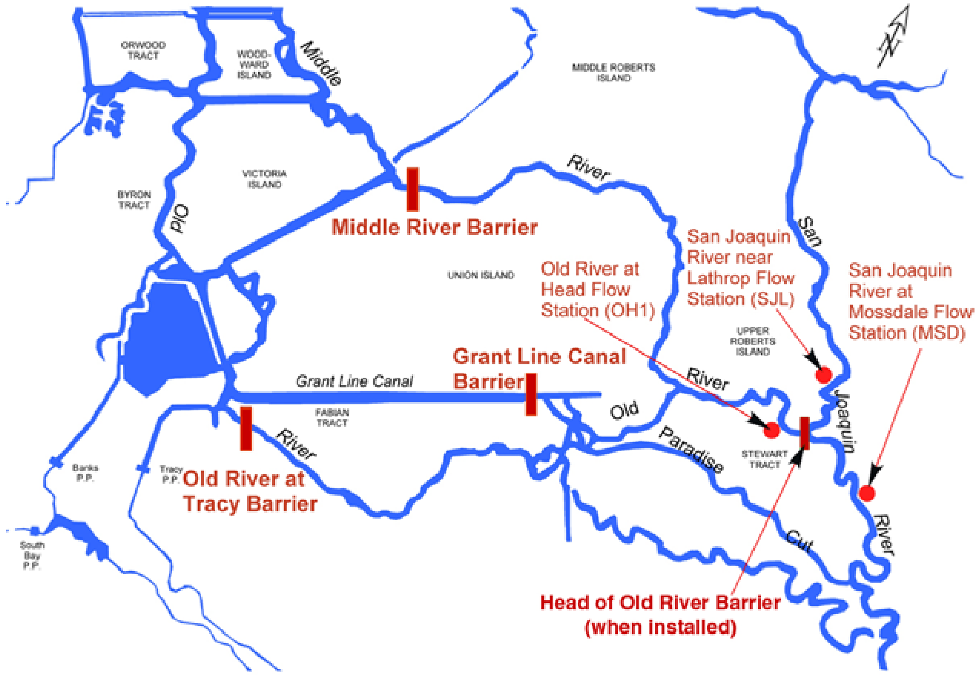


CHAPTER 4

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) was not planned for 2011 due to concerns for its potential negative effects on delta smelt. However, a non-physical barrier at the head of Old River, called the Bio-Acoustic Fish Fence (BAFF), was planned for 2011 similar to the one tested in 2009 and 2010. The goal of the BAFF is to determine if salmon smolts could be deterred from entering Old River where juvenile salmon survival has been shown to be less than if they had remained in the main stem San Joaquin River, downstream of Old River. Unfortunately due to high flows in the San Joauin River, installation of the BAFF was too dangerous and therefore plans for its installation were halted prior to the VAMP fish releases.

Figure 4-1
Location Map – South Delta Agricultural and Head of Old River 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 (Figure 4-1). One is in the San Joaquin River 460 m (1,500 ft) downstream of Old River (San Joaquin River below Old River near Lathrop, SJL) and another located in Old River 260 m (840 ft) 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 3,050 m (10,000 ft) upstream from the head of Old River. In 2011, the SJL flow monitoring site was discontinued and it was replaced by another ADCM-flow station at Brandt Bridge (BDT) approximately 5,600 m (3.5 miles) downstream of the confluence of the main stem San Joaquin River the Old River. The reason for the replacement was reoccurring inaccurate measurements due to bottom shifting at the SJL gage site. In the 2011 VAMP report, the BDT station will replace the SJL site for the flow data analysis. The river stretch between SJL and BDT has no tributary contributing to the flow or any significant diversion points. As with the previous SJL gage site, the flow measured at the BDT site will be used to calculate the flow split between Old River and the main stem San Joaquin 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, 2011 through June 30, 2011 period for the three ADCMs. Figures 4-2, 4-3, and 4-4 show the daily flow range and the mean for the San Joaquin River at the Mossdale gage, the Old River at Head gage and the San Joaquin River at Brandt Bridge gage, respectively.

Table 4-2 shows the mean daily flow of the San Joaquin River gage at Mossdale and the San Joaquin River near Vernalis (VNS) for the April 1st through June 30th period. 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 2010 which provided a VAMP Target flow of 4,450 cfs, 2011 did not provide a Target flow as the reservoirs were in flood operations during the entire VAMP period (May 1st - 31st). The impact of these high flows in the San Joaquin River in the absence of the 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 (May 1st – June 30th), on average 52% of the flow recorded in the San Joaquin River at Mossdale Bridge (MSD) was moving into Old River (OH1) and 48% was continuing downstream in the main stem San Joaquin River toward the gage at Brandt Bridge (BDT). This is

Table 4-1
Measured Flows in San Joaquin River near Mossdale (MSD), Old River at Head (OH1) and San Joaquin River at Brandt Bridge (BDT) (below Old River) for the Period April 1 to June 30, 2011

Date	San Joaquin River above Old River (San Joaquin River at Mossdale gage, MSD)			Old River below San Joaquin River (Old River at Head gage, OH1)			San Joaquin River below Old River (San Joaquin River at Brandt Bridge gage, BDT)			San Joaquin River-Old River Flow Split (% of total flow)	
	Minimum Flow (cfs)	Maximum Flow (cfs)	Mean Daily Flow (cfs)	Minimum Flow (cfs)	Maximum Flow (cfs)	Mean Daily Flow (cfs)	Minimum Flow (cfs)	Maximum Flow (cfs)	Mean Daily Flow (cfs)	OH1	BDT
4/1/11	23300	24500	24000	10400	11400	10900	10100	10800	10500	50.9%	49.1%
4/2/11	23100	24400	23900	10600	11400	11100	10200	10900	10500	51.4%	48.6%
4/3/11	23500	24600	23900	10400	11400	10900	10300	11000	10600	50.7%	49.3%
4/4/11	22900	24200	23600	10500	11400	10900	10300	10800	10500	50.9%	49.1%
4/5/11	22600	23700	23100	10500	12700	11500	10000	10700	10300	52.8%	47.2%
4/6/11	22200	23200	22800	11700	12500	12300	9950	10700	10300	54.4%	45.6%
4/7/11	22300	23600	22900	11900	12700	12300	9800	10700	10200	54.7%	45.3%
4/8/11	22300	23600	23100	11800	12900	12400	10000	10800	10400	54.4%	45.6%
4/9/11	22100	23400	22800	12000	12600	12300	9910	10600	10300	54.4%	45.6%
4/10/11	22100	23200	22600	12100	12600	12300	9810	10500	10100	54.9%	45.1%
4/11/11	22100	23100	22600	11900	12700	12300	9860	10500	10100	54.9%	45.1%
4/12/11	21800	23000	22500	12000	12700	12400	9850	10300	10100	55.1%	44.9%
4/13/11	22000	23100	22500	11900	12700	12300	9740	10200	9990	55.2%	44.8%
4/14/11	22100	23500	22800	11600	12700	12300	9850	10400	10200	54.7%	45.3%
4/15/11	22200	23400	22900	11700	12800	12400	9950	10600	10200	54.9%	45.1%
4/16/11	22100	23300	22700	12100	12900	12500	9830	10500	10200	55.1%	44.9%
4/17/11	22100	23200	22600	12200	12800	12500	9650	10400	10000	55.6%	44.4%
4/18/11	22400	23300	22900	11700	12800	12400	9760	10400	10100	55.1%	44.9%
4/19/11	22100	23200	22600	11700	12500	12200	9670	10300	10000	55.0%	45.0%
4/20/11	21800	23000	22400	11600	12500	12100	9410	10100	9760	55.4%	44.6%
4/21/11	21700	22600	22200	11400	12300	11900	9230	10100	9620	55.3%	44.7%
4/22/11	21200	22500	21700	11200	12100	11700	8990	9890	9440	55.3%	44.7%
4/23/11	20500	21700	21200	11000	11700	11300	8980	9600	9280	54.9%	45.1%
4/24/11	20200	21100	20600	11000	11500	11200	8780	9400	9070	55.3%	44.7%
4/25/11	19800	20600	20300	10600	11300	11000	8600	9280	8910	55.2%	44.8%
4/26/11	19600	20500	20200	10200	11200	10800	8590	9150	8890	54.9%	45.1%
4/27/11	19200	20100	19700	10200	11100	10600	8380	9010	8700	54.9%	45.1%
4/28/11	18900	19700	19300	10100	10800	10400	8190	8740	8440	55.2%	44.8%
4/29/11	18700	19700	19200	9210	10500	9790	8250	8670	8430	53.7%	46.3%
4/30/11	18000	19300	18700	9230	10100	9630	8060	8520	8260	53.8%	46.2%
5/1/11	17100	18500	17900	9000	9760	9400	7800	8330	8040	53.9%	46.1%
5/2/11	16100	17500	16800	8120	9330	8920	7270	8020	7640	53.9%	46.1%
5/3/11	14900	16400	15600	7980	8880	8400	7040	7650	7350	53.3%	46.7%
5/4/11	14000	15300	14700	7450	8400	7890	6600	7380	6990	53.0%	47.0%
5/5/11	13500	14400	14000	6950	7760	7380	6320	7130	6720	52.3%	47.7%
5/6/11	13400	13900	13700	6770	7500	7180	6100	6860	6480	52.6%	47.4%
5/7/11	13400	14000	13700	6770	7360	7140	5990	6750	6410	52.7%	47.3%
5/8/11	13400	14400	13900	6990	7510	7240	6040	6790	6420	53.0%	47.0%
5/9/11	13500	14300	14000	6500	7340	6980	6210	6820	6500	51.8%	48.2%
5/10/11	13300	14200	13800	6510	7190	6870	5990	6680	6370	51.9%	48.1%
5/11/11	13100	13900	13400	6490	7020	6780	5680	6420	6130	52.5%	47.5%
5/12/11	12400	13400	12800	6000	6820	6430	5580	6370	6010	51.7%	48.3%
5/13/11	12000	12700	12300	5750	6420	6070	5230	6200	5770	51.3%	48.7%
5/14/11	11200	12200	11700	5500	6190	5930	4960	6000	5570	51.6%	48.4%
5/15/11	10900	11700	11300	5410	6190	5800	4620	5950	5430	51.6%	48.4%
5/16/11	10800	11600	11200	5290	5850	5600	4800	5860	5380	51.0%	49.0%
5/17/11	10500	11300	10900	5130	5660	5440	4310	5690	5150	51.4%	48.6%
5/18/11	10500	11500	11100	5160	5820	5500	4220	5930	5220	51.3%	48.7%
5/19/11	10700	11600	11200	5070	5730	5440	4380	5840	5230	51.0%	49.0%
5/20/11	10600	11500	11100	5170	5730	5420	4350	5780	5180	51.1%	48.9%
5/21/11	10800	11600	11100	5120	5610	5340	4450	5690	5120	51.1%	48.9%
5/22/11	10800	11400	11100	5080	5480	5270	4490	5550	5080	50.9%	49.1%
5/23/11	10600	11200	10900	5010	5420	5230	4490	5450	5030	51.0%	49.0%
5/24/11	10500	11000	10800	4690	5300	5070	4480	5360	5020	50.2%	49.8%
5/25/11	10300	10800	10600	4670	5170	4940	4410	5250	4890	50.3%	49.7%
5/26/11	10200	10900	10600	4630	5190	4940	4350	5260	4910	50.2%	49.8%
5/27/11	10500	11300	11000	4800	5220	5080	4290	5390	4920	50.8%	49.2%
5/28/11	10600	11300	11000	4700	5340	5060	4240	5440	4880	50.9%	49.1%
5/29/11	10200	10900	10500	4600	5260	4890	4180	5340	4790	50.5%	49.5%
5/30/11	10100	10800	10400	4580	5170	4870	4040	5210	4700	50.9%	49.1%
5/31/11	9790	10700	10300	4480	4990	4710	3960	5140	4640	50.4%	49.6%
6/1/11	10000	11100	10600	4560	5100	4930	3950	5260	4680	51.3%	48.7%
6/2/11	10500	11300	11000	4820	5480	5120	4120	5460	4870	51.3%	48.7%
6/3/11	10600	11400	11000	4840	5480	5090	4160	5380	4860	51.2%	48.8%
6/4/11	10500	11500	11100	4780	5290	5060	4050	5270	4790	51.4%	48.6%
6/5/11	11200	12400	11800	5010	6000	5530	4450	5720	5140	51.8%	48.2%
6/6/11	11700	12500	12100	5330	6130	5710	4720	5850	5360	51.6%	48.4%
6/7/11	11700	12200	11900	5250	5900	5650	4720	5730	5360	51.3%	48.7%
6/8/11	11400	12100	11800	5260	5820	5630	4630	5600	5250	51.7%	48.3%
6/9/11	11100	11800	11500	5270	5800	5550	4450	5600	5210	51.6%	48.4%
6/10/11	10700	11400	11100	5360	5740	5540	4420	5500	5090	52.1%	47.9%
6/11/11	10700	11300	11000	5280	5850	5520	4290	5450	5000	52.5%	47.5%
6/12/11	10800	11800	11400	5230	5910	5630	4170	5640	5130	52.3%	47.7%
6/13/11	11200	12200	11700	5580	6120	5870	4450	5860	5360	52.3%	47.7%
6/14/11	11100	11900	11600	5330	5920	5690	4350	5810	5320	51.7%	48.3%
6/15/11	11000	11700	11300	5210	6080	5560	4400	5800	5220	51.6%	48.4%
6/16/11	10400	11400	10900	5070	5920	5440	4100	5610	4930	52.5%	47.5%
6/17/11	10100	10800	10500	4980	5740	5350	3790	5440	4740	53.0%	47.0%
6/18/11	10200	11000	10700	5060	5690	5340	3970	5350	4740	53.0%	47.0%
6/19/11	10300	11100	10800	4960	5730	5260	4130	5390	4820	52.2%	47.8%
6/20/11	10100	11000	10600	4880	5550	5210	4070	5250	4750	52.3%	47.7%
6/21/11	10100	10700	10400	4770	5250	4990	3950	5080	4650	51.8%	48.2%
6/22/11	10100	10800	10500	4690	5170	4920	3930	5040	4620	51.6%	48.4%
6/23/11	10200	11000	10600	4750	5190	4980	4040	5110	4680	51.6%	48.4%
6/24/11	10600	11200	10900	4820	5290	5070	4090	5180	4800	51.4%	48.6%
6/25/11	10700	11200	10900	4910	5280	5110	4240	5280	4840	51.4%	48.6%
6/26/11	10700	11200	11000	4860	5380	5140	4210	5430	4930	51.0%	49.0%
6/27/11	10700	11400	11100	4960	5490	5250	4290	5490	4930	51.6%	48.4%
6/28/11	10900	11400	11100	4980	5590	5240	4290	5520	4980	51.3%	48.7%
6/29/11	10700	11400	11100	5200	5720	5420	4080	5500	4930	52.4%	47.6%
6/30/11	10300	11100	10700	4950	5530	5220	4170	5450	4900	51.6%	48.4%

Table 4-2
Measured Flows in San Joaquin River near Vernalis (VNS) and near Mossdale (MSD) 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, 2011

Date	San Joaquin River near Vernalis (VNS) [A]	San Joaquin River at Mossdale Bridge (MSD) [B]	State Water Project (SWP) at Harvey O Banks Pumping Plant (HRO)	Central Valley Project (CVP) at Tracy Pumping Plant (TRP)	San Joaquin River Flow at Mossdale Bridge(MSD) as % of Flow Measured near Vernalis(VNS)	Exports as a Ratio of SJR Flow near Vernalis (VNS)	Exports as a Ratio of SJR Flow at the Mossdale Bridge (MSD)
	Mean Daily Flow[1] (cfs)	Mean Daily Flow[1] (cfs)	Mean Daily Flow[1] (cfs)	Mean Daily Flow** (cfs)	(%)	VNS : Exports	MSD : Exports
4/1/2011	24,000	30,700	2,467	2,953	128	4.4 : 1	5.7 : 1
4/2/2011	23,900	30,800	2,712	2,496	129	4.6 : 1	5.9 : 1
4/3/2011	23,900	30,700	2,714	2,794	128	4.3 : 1	5.6 : 1
4/4/2011	23,600	30,100	2,703	2,998	128	4.1 : 1	5.3 : 1
4/5/2011	23,100	29,600	2,704	2,995	128	4.1 : 1	5.2 : 1
4/6/2011	22,800	29,400	2,760	2,991	129	4.0 : 1	5.1 : 1
4/7/2011	22,900	29,400	2,820	3,180	128	3.8 : 1	4.9 : 1
4/8/2011	23,100	29,500	2,128	3,490	128	4.1 : 1	5.3 : 1
4/9/2011	22,800	29,000	1,848	3,999	127	3.9 : 1	5.0 : 1
4/10/2011	22,600	28,600	1,842	4,992	127	3.3 : 1	4.2 : 1
4/11/2011	22,600	28,500	1,841	4,927	126	3.3 : 1	4.2 : 1
4/12/2011	22,500	28,200	1,832	4,490	125	3.6 : 1	4.5 : 1
4/13/2011	22,500	28,000	1,837	4,493	124	3.6 : 1	4.4 : 1
4/14/2011	22,800	28,000	890	4,493	123	4.2 : 1	5.2 : 1
4/15/2011	22,900	27,900	1,833	3,490	122	4.3 : 1	5.2 : 1
4/16/2011	22,700	27,800	1,838	3,497	122	4.3 : 1	5.2 : 1
4/17/2011	22,600	27,600	2,486	3,494	122	3.8 : 1	4.6 : 1
4/18/2011	22,900	27,200	2,756	3,499	119	3.7 : 1	4.3 : 1
4/19/2011	22,600	26,500	2,757	3,489	117	3.6 : 1	4.2 : 1
4/20/2011	22,400	25,700	2,758	3,494	115	3.6 : 1	4.1 : 1
4/21/2011	22,200	24,900	2,758	3,491	112	3.6 : 1	4.0 : 1
4/22/2011	21,700	23,900	2,750	4,994	110	2.8 : 1	3.1 : 1
4/23/2011	21,200	23,200	2,744	6,388	109	2.3 : 1	2.5 : 1
4/24/2011	20,600	22,600	2,228	6,399	110	2.4 : 1	2.6 : 1
4/25/2011	20,300	22,000	2,013	2,491	108	4.5 : 1	4.0 : 1
4/26/2011	20,200	21,500	2,003	1,318	106	6.1 : 1	6.5 : 1
4/27/2011	19,700	20,900	1,024	3,581	106	4.3 : 1	4.5 : 1
4/28/2011	19,300	20,300	1,757	6,600	105	2.3 : 1	2.4 : 1
4/29/2011	19,200	19,800	1,759	6,672	103	2.3 : 1	2.3 : 1
4/30/2011	18,700	19,200	1,759	2,982	103	3.9 : 1	4.0 : 1
5/1/2011	17,900	18,200	1,757	2,993	102	3.8 : 1	3.8 : 1
5/2/2011	16,800	17,100	1,761	2,978	102	3.5 : 1	3.6 : 1
5/3/2011	15,600	16,200	2,949	1,477	104	3.5 : 1	3.7 : 1
5/4/2011	14,700	15,500	3,664	1,498	105	2.8 : 1	3.0 : 1
5/5/2011	14,000	14,900	3,672	1,492	106	2.7 : 1	2.9 : 1
5/6/2011	13,700	14,500	2,493	1,996	106	3.1 : 1	3.2 : 1
5/7/2011	13,700	14,500	2,007	1,995	106	3.4 : 1	3.6 : 1
5/8/2011	13,900	14,400	2,009	1,491	104	4.0 : 1	4.1 : 1
5/9/2011	14,000	14,300	1,927	1,500	102	4.1 : 1	4.2 : 1
5/10/2011	13,800	13,900	1,870	1,495	101	4.1 : 1	4.1 : 1
5/11/2011	13,400	13,500	1,871	1,494	101	4.0 : 1	4.0 : 1
5/12/2011	12,800	13,100	1,869	1,489	102	3.8 : 1	3.9 : 1
5/13/2011	12,300	12,700	1,868	1,481	103	3.7 : 1	3.8 : 1
5/14/2011	11,700	12,300	1,874	1,498	105	3.5 : 1	3.6 : 1
5/15/2011	11,300	12,100	1,877	1,793	107	3.1 : 1	3.3 : 1

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(VNS)	Exports as a Ratio of SJR Flow near Vernalis (VNS)	Exports as a Ratio of SJR Flow at the Mossdale Bridge (MSD)
	Mean Daily Flow[1] (cfs)	Mean Daily Flow[1] (cfs)	Mean Daily Flow[1] (cfs)	Mean Daily Flow[1] (cfs)	(%)	VNS : Exports	MSD : Exports
5/16/2011	11,200	11,900	1,876	2,195	106	2.8:1	2.9:1
5/17/2011	10,900	11,600	1,878	2,193	106	2.7:1	2.8:1
5/18/2011	11,100	11,500	1,221	2,196	104	3.2 : 1	3.4 : 1
5/19/2011	11,200	11,400	959	1,490	102	4.6 : 1	4.7 : 1
5/20/2011	11,100	11,300	1,013	1,483	102	4.4 : 1	4.5 : 1
5/21/2011	11,100	11,200	1,012	1,483	101	4.4 : 1	4.5 : 1
5/22/2011	11,100	11,000	1,012	1,491	99	4.4 : 1	4.4 : 1
5/23/2011	10,900	11,000	1,009	1,490	101	4.4 : 1	4.4 : 1
5/24/2011	10,800	10,800	1,007	1,514	100	4.3 : 1	4.3 : 1
5/25/2011	10,600	10,600	1,007	1,495	100	4.2 : 1	4.2 : 1
5/26/2011	10,600	10,700	1,007	1,549	101	4.1 : 1	4.2 : 1
5/27/2011	11,000	10,700	965	1,453	97	4.5 : 1	4.4 : 1
5/28/2011	11,000	10,600	1,005	1,520	96	4.4 : 1	4.2 : 1
5/29/2011	10,500	10,300	1,008	1,489	98	4.2 : 1	4.1 : 1
5/30/2011	10,400	10,200	1,006	1,489	98	4.2 : 1	4.1 : 1
5/31/2011	10,300	10,100	1,007	1,536	98	4.1 : 1	4.0 : 1
6/1/2011	10,600	10,300	2,207	4,489	97	1.6 : 1	1.5 : 1
6/2/2011	11,000	10,600	3,822	5,493	96	1.2 : 1	1.1 : 1
6/3/2011	11,000	10,600	4,187	5,990	96	1.1 : 1	1.0 : 1
6/4/2011	11,100	10,600	4,055	5,990	95	1.1 : 1	1.1 : 1
6/5/2011	11,800	11,300	4,032	5,994	96	1.2 : 1	1.1 : 1
6/6/2011	12,100	11,500	3,981	5,998	95	1.2 : 1	1.2 : 1
6/7/2011	11,900	11,300	3,764	5,987	95	1.2 : 1	1.2 : 1
6/8/2011	11,800	11,200	3,195	5,994	95	1.3 : 1	1.2 : 1
6/9/2011	11,500	11,000	2,956	5,998	96	1.3 : 1	1.2 : 1
6/10/2011	11,100	10,900	2,953	6,000	98	1.2 : 1	1.2 : 1
6/11/2011	11,000	10,800	2,962	5,473	98	1.3 : 1	1.3 : 1
6/12/2011	11,400	11,100	2,965	6,520	97	1.2 : 1	1.2 : 1
6/13/2011	11,700	11,400	2,967	5,998	97	1.3 : 1	1.3 : 1
6/14/2011	11,600	11,200	2,969	5,990	97	1.3 : 1	1.3 : 1
6/15/2011	11,300	11,000	2,972	5,993	97	1.3 : 1	1.2 : 1
6/16/2011	10,900	10,500	2,973	6,670	96	1.1 : 1	1.1 : 1
6/17/2011	10,500	10,300	2,977	6,678	98	1.1 : 1	1.1 : 1
6/18/2011	10,700	10,300	2,975	6,670	96	1.1 : 1	1.1 : 1
6/19/2011	10,800	10,200	2,973	6,670	94	1.1 : 1	1.1 : 1
6/20/2011	10,600	10,100	2,963	6,677	95	1.1 : 1	1.0 : 1
6/21/2011	10,400	9,940	2,962	6,677	96	1.1 : 1	1.0 : 1
6/22/2011	10,500	10,000	2,968	6,663	95	1.1 : 1	1.0 : 1
6/23/2011	10,600	10,200	3,828	6,670	96	1.0 : 1	1.0 : 1
6/24/2011	10,900	10,400	4,194	6,737	95	1.0 : 1	1.0 : 1
6/25/2011	10,900	10,400	4,194	6,668	95	1.0 : 1	1.0 : 1
6/26/2011	11,000	10,400	4,197	6,674	95	1.0 : 1	1.0 : 1
6/27/2011	11,100	10,600	4,201	6,678	95	1.0 : 1	1.0 : 1
6/28/2011	11,100	10,600	4,144	6,679	95	1.0 : 1	1.0 : 1
6/29/2011	11,100	10,500	4,203	6,679	95	1.0 : 1	1.0 : 1
6/30/2011	10,700	10,500	4,129	6,675	98	1.0 : 1	1.0 : 1

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

Figure 4-2
Daily Flow Range in Cubic Feet per Second (cfs) – San Joaquin River above Old River (San Joaquin River at Mossdale Gage)

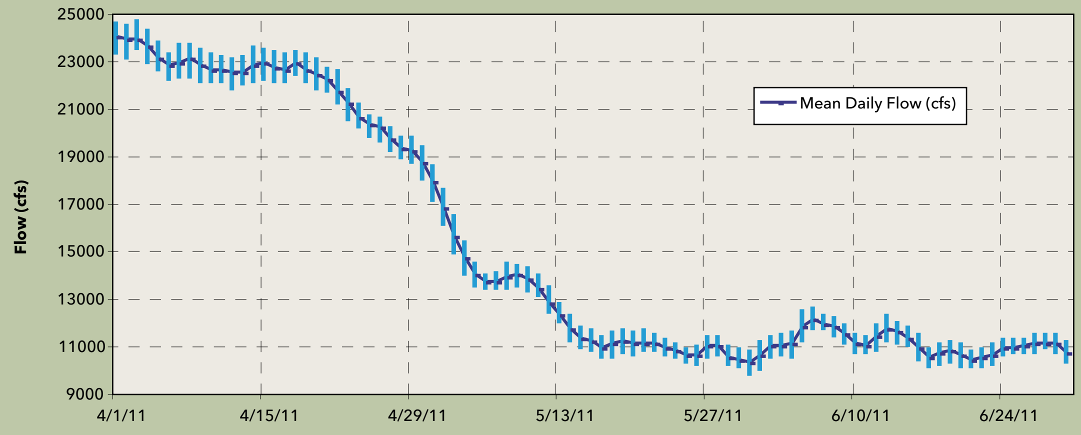


Figure 4-3
Daily Flow Range in Cubic Feet per Second (cfs) – Old River below the Confluence with the San Joaquin River (Old River at Head Gage (OH1))

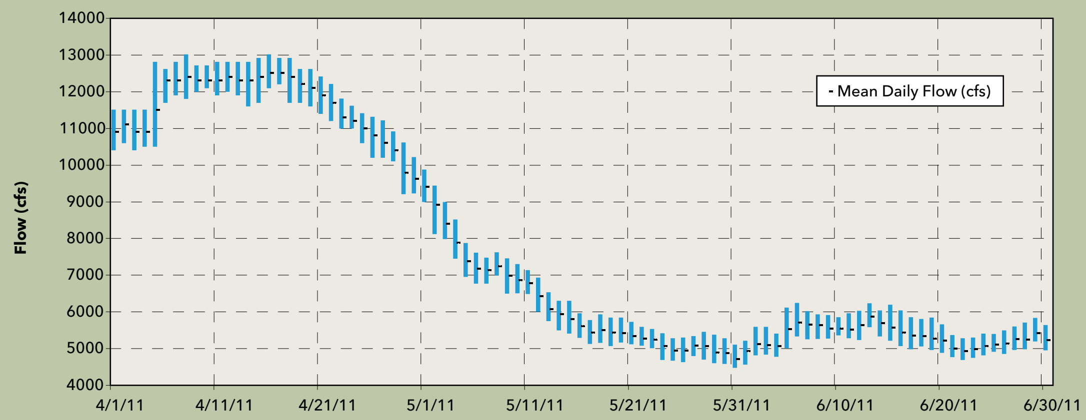


Figure 4-4
Daily Flow Range in Cubic Feet per Second (cfs) – San Joaquin River below the Old River Confluence at Brandt Bridge (BDT)

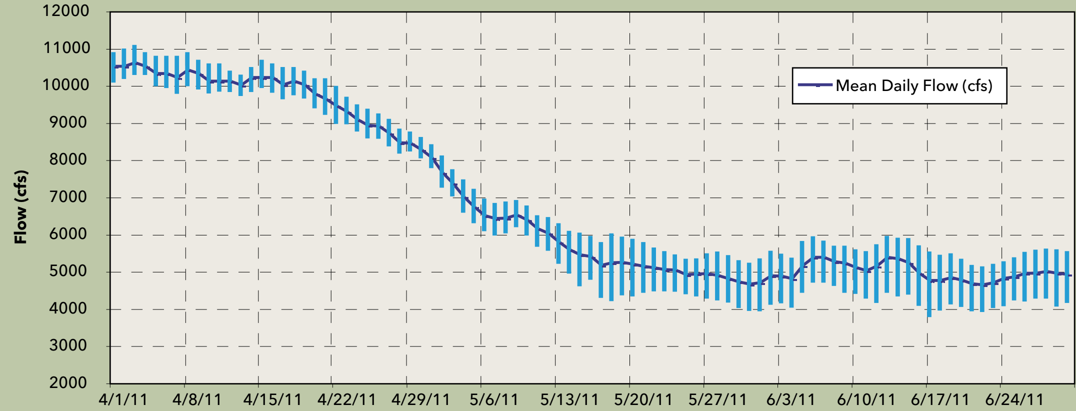
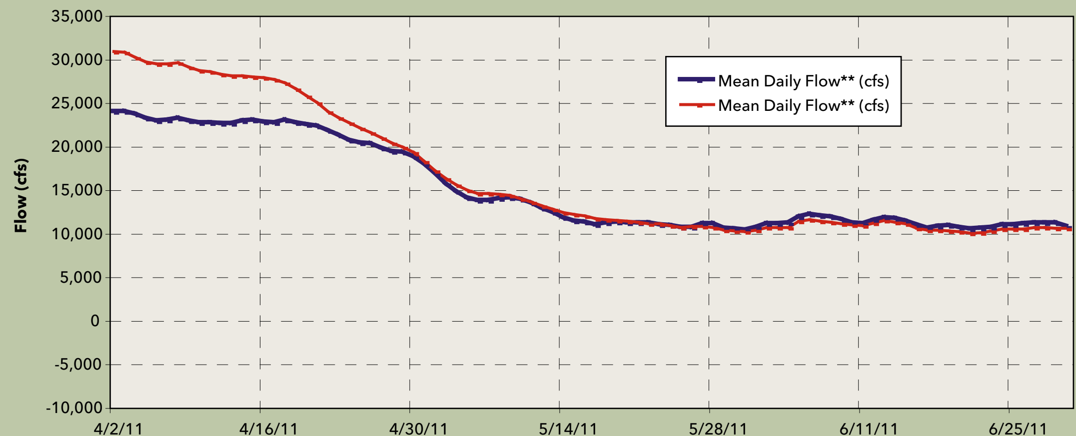


Figure 4-5
San Joaquin River Flow in Cubic Feet per Second (cfs) near Vernalis (VNS) and at Mossdale Bridge (MSD)



in contrast to the 58:42 split that occurred during the 2010 Target flow of 4,450 cfs and the 75:25% split that occurred during the low flow period of 2009. During the entire period of record for 2011 (April 1st – June 30th) shown in Table 4-1, the average flow split remained at a 52:48% 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 levels defined in the 2011 amendments to the 2009 NMFS RPA (Table 4-3). For 2011, daily Vernalis flow from April 1st to April 21st was above 21,750 cfs thus the export limitation was unrestricted. The combined exports during this period averaged 5,906 cfs with an average flow to export ratio of 4:1. On April 22nd flows at Vernalis (VNS) fell below the 21,750 cfs limitation defined in the 2011 amendments to the 2009 NMFS RPA and continued below 21,750 but above 6,000 cfs until the end of June. Daily combined exports during the April 1st to May 31st period averaged 4,716 cfs with a Vernalis flow to export ratio of during the VAMP period (May 1st to 31st) averaging 3.7:1 and ranged from 2.7:1 – 4.6:1. The daily Vernalis flow to export ratio during the entire April 1st to May 31st period averaged 3.6:1 (Table 4-2).

Development of a Barrier at the Head of Old River

(The following section is a summary of work planned by DWR and the U. S. Bureau of Reclamation (USBR) in cooperation with VAMP but was not implemented due to the very high flow in 2011 and the danger of installing the barrier at such flows. Contact person for further information is Jacob McQuirk, Bay-Delta Office, California Department of Water Resources, Sacramento, California)

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 Head of Old River Barrier (HORB) had been used until 2008 when a Federal Court decision by United States Fresno District Court Judge Wanger increased concern for protection of delta smelt. In 2009 and 2010 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 4-6. 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 described in SJRGA, 2011.

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 main stem San Joaquin River. It is unclear whether the deterrence increased the predation rate as the scour hole

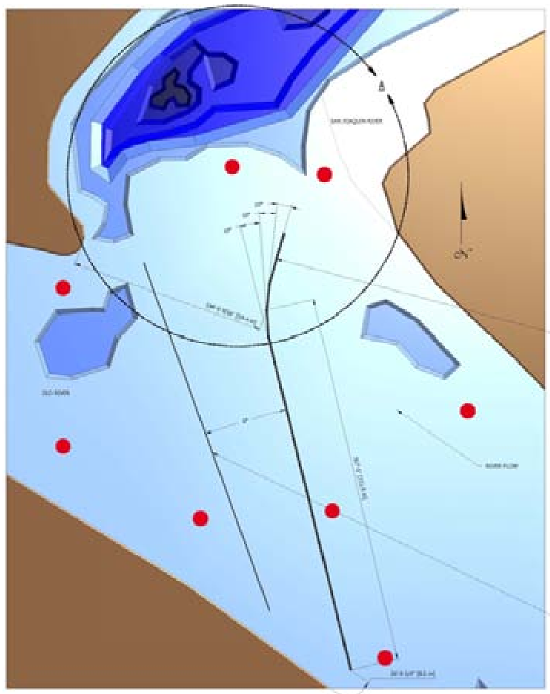
Photo 4-1
Bubble Barrier Being Tested at the Divergence of the San Joaquin River and Old River During the 2010 VAMP. Photo taken from the North Bank.

Table 4-3
Restrictions to the Combined Central Valley Project (CVP) and State Water Project (SWP) Exports For the Period April 1st through May 31st as Defined in the 2011 Amendments to the 2009 NMFS RPA

Flows at Vernalis Gage (VNS) (cfs)	Combined CVP and SWP Export
0 – 6,000	1,500 cfs
6,000 – 21,750[1]	4:1 ratio (Vernalis (VNS) flow : export flow)
21,750 or greater	Unrestricted until flood recedes below 21,750 cfs

[1] Flood warning stage at Vernalis is 24.5 feet, flow is 21,750 cfs at this point. Flood stage is 29 feet with a corresponding flow of 34,500 cfs. Data from CDEC looking at April 8-9, 2006 period. As such, recognizing that the flows associated with these stages do vary, the trigger allowing unrestricted exports will be a Vernalis stage of 24.5 feet.

Figure 4-6
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 in 2010 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)



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 4-6) (Bowen and Bark, 2010). The figure also shows the 8 hydrophones deployed in 2010 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 described in SJRGA, 2011. 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 described in SJRGA, 2011.

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.

Bowen and Bark (2010) observed differences in the 2010 Protection Efficiency with the BAFF off depending on the release, tide, and discharge. Protection Efficiency, with BAFF off, was as low as 0.1000 and as high as 0.3750. It was felt that at least some of these differences may result from differences in flow fields that change with the tide and subsequent discharge.

Bowen and Bark (2010) were also of the opinion that the sound deterred the fish and the bubble curtain contained the sound. The Modulated Intense Lights (MIL) enabled the fish to identify the source of the sound. The fish saw the barrier because of the MILs and they heard the sound as they approached the BAFF. The risk of passing through the barrier to an uncertain future was greater than the risk of swimming away and passing into a different uncertain future but avoiding the source of that sound. In addition in 2010, the BAFF angle was 30° when in 2009 it was 24° (Figure 4-6). The steeper angle and higher velocities may have behaved synergistically to give fish less time to evaluate the barrier and avoid it. Bowen and Bark (2010) felt that 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. Many however were observed swimming 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, they observed poor deterrence but significant improvement in protection efficiency, survival, down into the San Joaquin River.

For the 2011 installation, Bowen and Bark (2010) recommended the BAFF angle be reduced from 30 back to 24 degrees as they felt that many fish passed through the barrier because they did not have sufficient time as was evident from the 2D tracks. They also recommend that the curved elements near the distal end of the 2010 BAFF be removed as they observed many Chinook smolts passing through the BAFF in these curved sections.

Finally, Bowen and Bark (2010) recommended any new BAFF deployments emphasize that all components of the barrier be fully operational at all times to avoid inconsistencies in deterrence.

Unfortunately due to the high flows in the San Joaquin River, installation of the BAFF was too dangerous and therefore plans for its installation were scraped prior to the VAMP fish releases. The testing of the efficiency of the BAFF was to be a component of the VAMP and coordinated smolt releases were to occur. The releases were continued and are reported upon in Chapter 5.

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 2011, 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 and are also discussed in Chapter 5 and in Chapter 7. Contact person for further information is Mark Holderman or Kevin Clark, California Department of Water Resources, Bay-Delta Office, Sacramento, California).

CHAPTER 5

SALMON SMOLT SURVIVAL INVESTIGATIONS

The 2011 VAMP is the 6th year that acoustic technology was used to estimate juvenile salmon survival in the southern Sacramento-San Joaquin Delta (2006-2011), and the third year where survival was estimated through the Delta to Chipps Island (2008, 2010 and 2011). Prior to 2007, coded wire tag studies were used to estimate survival through the Delta. As part of the background for reporting the results of the 2011 study, the previous coded wire tag studies conducted in the south Delta and through the Delta prior to the VAMP (1994-1999), during the VAMP (2000-2006) and results of the previous acoustic studies (2006-2010) are summarized below. More detail on each annual study is provided in previous reports and specific references are shown in Table 5-1.











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Table 5-1
Reference Citations for Past Reports that Have Reported on Annual South Delta Salmon Smolt Survival Since 1994. Full Reference Citations are Found in the Reference List at the End of this Report

Study Type	Study Year	Reference List Citation
Pre-VAMP	1982-1995	USFWS, 1987
		Brandes and McLain, 2001
Pre-VAMP	1996	Brandes and McLain, 2001
		IEP 1996
Pre-VAMP	1997	Brandes and McLain, 2001
		IEP 1998
		DWR, 1998
Pre-VAMP	1998	IEP, 1999c
Pre-VAMP	1999	Brandes, 2000
		DWR, 2001
VAMP	2000	SJRGA, 2001
VAMP	2001	SJRGA, 2002
VAMP	2002	SJRGA, 2003
		DWR, 2003
	2003	SJRGA, 2004
VAMP	2004	SJRGA, 2005
VAMP	2005	SJRGA, 2006
VAMP	2006	SJRGA, 2007
VAMP	2007	SJRGA, 2008
VAMP	2008	SJRGA, 2009
		Holbrook et al, 2009
		Holbrook et al., 2013
VAMP	2009	SJRGA, 2010
		Buchanan et al., 2013
VAMP	2010	SJRGA, 2011
		Buchanan et al., 2013

Conceptual Model

The main objective of the VAMP was to better understand the relationship between Chinook salmon smolt survival through the Delta and San Joaquin River flows, combined Central Valley Project (CVP) and State Water Project (SWP) exports and installation of the head of Old River barrier (HORB). Survival during the smolt life-stage was assumed to be the mechanism associated with two statistically significant linear regressions between escapement and 1) San Joaquin River flow at Vernalis and 2) the ratio of San Joaquin River flow to CVP and SWP exports, 2 ½ years earlier (Figures 5-20 and 5-21 in SJRGA, 2007). It is these relationships between flow and flow/exports and escapement that are the basis for the hypothesis that increasing flow and decreasing exports during the smolt outmigration would increase adult escapement and production in the San Joaquin River basin.

Pre-VAMP and VAMP CWT studies

Between 1985 and 2006, juvenile salmon from Feather River Hatchery (FRH) or Merced River Hatchery (MRH) were marked and released to estimate survival in, or through, the Delta. The marked salmon were released at various locations in the Delta and reflect the evolution of different hypotheses and study designs. Coded wire tagged (CWT) fish used in the pre-VAMP studies were from FRH in study years 1989-1998 and from MRH in 1986-1989 and 1996-1999. Between 1996 and 1998, hatchery fish from MRH were paired with those from FRH and after 1999 only MRH stock were used in the experiments. Pre-VAMP studies were also conducted in 1985 using fish from MRH, but were marked using spray-dye.

The first pre-VAMP studies compared survival between marked FRH smolts released into upper Old River to FRH smolts released on the mainstem San Joaquin River at Dos Reis. These studies were conducted between 1985 and 1990 and suggested that survival was higher for fish released on the mainstem San Joaquin River at Dos Reis than for fish released into Old River (Brandes and McLain, 2001). The results of these studies were the basis for recommending a rock barrier at the head of Old River (HOR) to prevent juvenile salmon from migrating down Old River where survival appeared to be less.

Starting in 1994, survival was estimated through the Delta by pairing upstream releases to control releases at Jersey Point. This allowed absolute survival to be estimated between the upstream release location and Jersey Point using the relative recovery rate of marked fish from the upstream group relative to the control/ downstream group. Recoveries were made at Chipps Island and in the ocean fishery and later, as part of the VAMP, at Antioch. Survival was estimated as part of the pre-VAMP studies between 1994 and 1999, with two of those years (1994 and 1997) measuring survival when the physical rock barrier was installed at the head Old River. The VAMP studies began in 2000 and continued until 2006 using juvenile salmon from MRH marked with CWTs. Marked fish were released both upstream (Mossdale and/or Durham Ferry) and downstream (Jersey Point) to estimate survival through the Delta. In 2006, acoustic tags were also used in the south Delta, as part of a pilot study. Between 2007 and 2011, acoustic tags were used to estimate survival in the south Delta (2007, 2009) or through the Delta to Chipps Island (2008, 2010 and 2011).

Between 1994 and 1999 marked fish were released on the San Joaquin River at Mossdale and Jersey Point. Starting in 2000, releases were also, or alternatively, made at Durham Ferry to allow the fish more distance to distribute naturally in the river channel prior to reaching the junction with Old River. To assess the mortality between Durham Ferry and Mossdale, releases were made at both locations in most years between 2000 and 2005. In 2006, releases were made only at Mossdale because San Joaquin River flows were so high that part of the flow was diverted into Paradise Cut (a flood bypass), which is upstream of Mossdale, but downstream of Durham Ferry. To better compare results to other VAMP years, when San Joaquin River flow was not diverted into Paradise Cut, the release site was changed from Durham Ferry to Mossdale in 2006. The releases at Jersey Point were generally made on a flood tide to increase fish dispersion throughout the channel before the tagged fish migrated downstream and encountered the recovery trawls at Antioch and Chipps Island. Releases at other locations generally did not incorporate the tides for determining release times.

In some years CWT releases were also made at Dos Reis which is located on the San Joaquin River downstream of the head of Old River and was used to help assess the mortality of marked salmon on the San Joaquin River downstream of Old River. Although it is assumed that fish released at Dos Reis migrated downstream via the mainstem San Joaquin River, there is the potential for fish released at Dos Reis to have moved upstream into Old River on flood tides, especially during periods of low San Joaquin River flows and high exports or into the interior Delta via Turner or Columbia Cuts or other downstream connections to the interior Delta.

For the releases of CWT fish, the water temperature in the hatchery truck was usually about 10 degrees lower than at the release site. This differential in water temperature between the hatchery truck and release sites potentially could have affected the survival of the study fish. To assess how these differences in water temperature might affect the short term survival of the study fish, a subset of the study fish were held for 48 hours and evaluated for health and physiological state starting in 1996 and has continued throughout the VAMP. The holding of fish for 48 hours also was used to determine if the handling, transport, and release processes affected the immediate and short-term (48 hour) survival and general condition of the experimental fish used in the VAMP and pre-VAMP experiments.

The purpose of the physiological and health assessments was to rule out survival differences due to differential health between release groups and between years. Sub-samples of fish held in net pens for all years were generally in good condition. In years where CWT fish were released, between 0 and 19 total mortalities were observed in the subsets of approximately 1,200 fish per year, after the 48-hour holding period. Mortality in 1998 was higher and was estimated to be as great as 9.2% for the Jersey Point release made on April 28, 1998, (IEP 1999a), which may have biased survival high in that year. In contrast, the health assessments conducted in 1998 concluded that the overall health of the fish examined as part of the pre-VAMP study appeared good (IEP, 1999b).

Table 5-2
Prevalence of *Tetracapsuloides bryosalmonae* (Tb) Detected in Merced River Hatchery Smolts 1996 – 2011. All Samples Were Taken from VAMP (and Precursor Project) Release Groups [1].

Year	Sample Dates	Tb Prevalence	Additional Information
1996	1 May	63% (5/8)	38% of Merced River Hatchery fish with kidney inflammation.
1997	1 May	0% (0/10)	
1998	17 Apr	0% (0/6)	No histopathology this study. No swollen or hemorrhaging organs reported
1999	20 Apr	0% (0/6)	Histopathology from only 1 release group
2000	18 Apr - 2 May	4% (2/45)	No kidney inflammation observed
2001	1 - 12 May	100% (34/34)	Increased kidney inflammation in second set of releases
2002	19 Apr - 1 May	46% (93/201)	Kidney inflammation observed in 2/201 fish examined
2003	21 Apr - 2 May	63% (30/48)	Increased gross clinical signs of PKD in later release groups
2004	22 - 26 Apr	50% (33/66)	Kidney inflammation in 5-14% of fish
2005	2 - 20 May	38% (6/16)	Overall mild PKD observed
2006	4 - 22 May	0% (0/20)	
2007	3 - 11 May	100% (30/30)	All early infections. No kidney inflammation observed.
2008	29 Apr - 8 May	79% (86/109)	Less than 30% with kidney inflammation
2009	23 Apr - 14 May	13% (10/76)	No kidney inflammation observed
2010	28 Apr - 20 May	100% (89/89)	31%-87% of fish with kidney inflammation
2011	19 May - 16 Jun	4% (3/78)	No kidney inflammation observed

[1] Fish were Assessed by Histopathological Examination of Posterior Kidney by the USFWS CA-NV Fish Health Center to Determine if Tetracapsuloides bryosalmonae Infections were Severe Enough to Influence Survival of the Study Groups During the Out-migration (2 – 3 Weeks Post Release). A Difference in Kidney Inflammation Between Upstream and Jersey Point Groups Could Help Explain Reduced Survival During Out-migration, but There was No Evidence There was Differential Infection Rates Within Paired Releases. Starting in 2007, Acoustic-tagged Fish were Used for the Studies and a High Prevalence of PKD Could Affect the Survival Rates of Acoustic-Tagged Fish Used in These Studies, as the Acoustic Tag Methodology Does Not Pair Upstream and Downstream Groups for Estimating Survival but There was no Evidence There was an Effect.

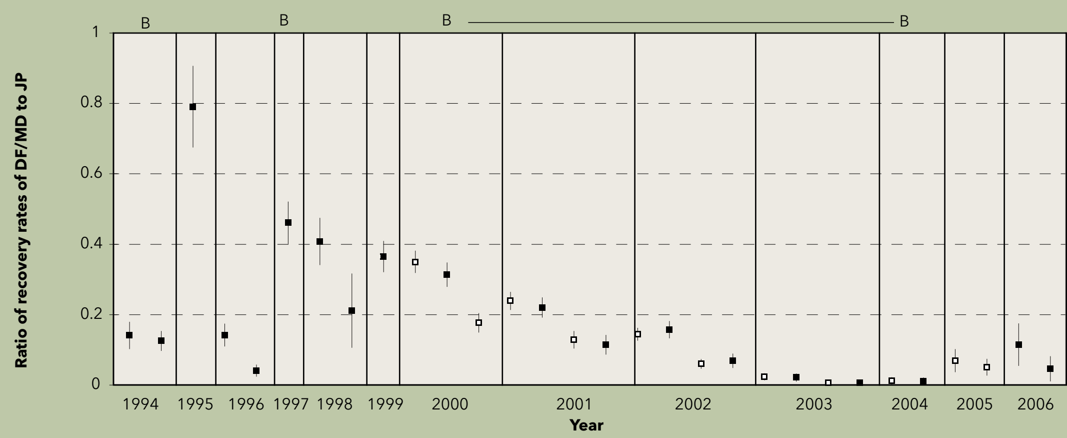
The USFWS California-Nevada Fish Health Center looked at health (bacterial, viral, and parasitic infections), smolt development, and stress response to determine if there were significant differences between CWT groups within a year that might affect survival estimates. While differences in smolt development and stress response were noted in some years, the most significant factor affecting survival for the fish used in the VAMP and pre-VAMP studies was infection with *Tetracapsuloides bryosalmonae* (the myxosporean parasite which causes Proliferative Kidney Disease (PKD))(Table 5-2). PKD is a progressive disease at water temperatures greater than 15° C and at water temperatures of 9° C the parasite can infect fish but it cannot multiply. The primary host for the parasite is bryozoan (Okamura and Wood, 2002). *T. bryosalmonae* infection can reduce a fish's performance due to associated kidney dysfunction and anemia. However, infection with the parasite does not necessarily kill the fish. *T. bryosalmonae* has been reported at MRH since the 1980's (Hedrick et al., 1986, as cited in Nichols and Foott, 2002) and in California since at least 1966 (Hedrick et al., 1985 as cited in Nichols and Foott, 2002). In 2001, *T. bryosalmonae* was found in over 90% of the samples tested from naturally spawned Chinook salmon on the Merced River (Nichols and Foott, 2002). T. bryosalmonae was present in fish used for the VAMP (Table 5-2).

To estimate survival through the Delta for CWT smolts released at Durham Ferry or Mossdale, recoveries from upstream groups were compared to releases made at Jersey Point to obtain a differential recovery rate between the two groups. The survival between the upstream and downstream location, estimated by dividing the recovery rate of the upstream group by the recovery rate of the downstream group, theoretically standardizes for differences in catch efficiency of recovery locations within and between years. Tagged fish were recovered at Chipps Island and as adults in the ocean fishery. Tagged fish were also recovered at Antioch starting in 2000.

Smolt survival between Durham Ferry or Mossdale and Jersey Point has varied considerably between 1994 and 2006 with differential recovery rates ranging from 0.01 to 0.79 (Figure 5-1). The year with the highest survival was 1995 and the years with the lowest survival were 2003 and 2004. Since 1997, there has been a general decline in survival (Figure 5-1). Survival rebounded slightly in 2005 and 2006 (Figure 5-1).

A statistically significant relationship between survival in the reach between Mossdale or Durham Ferry and Jersey Point and San Joaquin River flow at Vernalis has been observed with the HORB in place (1994, 1997, 2000-2004) ($r^2 = 0.73$, $p<0.01$; Figure 5-11 in SJRGA,

Figure 5-1
Estimates of Smolt Survival (+/- two Standard Errors) from Mossdale (Closed Squares) or Durham Ferry (Open Squares) to Jersey Point Between 1994 and 2006 Using Coded-wire-tagged Fish. Years with the Physical Head of Old River Barrier Installed are Denoted with B and are in 1994, 1997 and 2000 – 2004



2007). In addition, survival between Dos Reis and Jersey Point, between 1989 -1991 and 1995-1999 appeared to be related to San Joaquin River flow downstream of the HOR (r^2 = 0.54, p<0.01; Figure 5-14 in SJRGA, 2007) but the relationship no longer remained statistically significant (p<0.05) when results from 2005 and 2006 were added (r^2 = 0.22, p<0.10; Figure 5-13 in SJRGA, 2007).

In addition, the relationship between flow at Vernalis and the recovery rates of the Durham Ferry and Mossdale releases relative to those at Jersey Point without the HORB was much more variable with no apparent trend (Figure 5-12 in SJRGA, 2007). The 2005 and 2006 estimates were much lower than previous estimates at similar flow levels. Tagged fish released at Mossdale or Durham Ferry without a HORB could migrate either down upper Old River or via the mainstem San Joaquin River. It is not surprising that there is more variability associated with smolt survival at any given flow at Vernalis without the HORB since the flow and proportion of marked fish moving into HOR would vary more without the HORB. The proportion of juvenile salmon that migrated down HOR relative to the number that stayed in the mainstem San Joaquin River was a critical uncertainty for many years when CWT fish were used. However, based on the relationships above, fish that remained in the San Joaquin River at the HOR, when there was no HORB in place, were thought to experience higher survival at higher flows.

Another goal of the VAMP program was to identify the role of exports on juvenile salmon survival through the Delta. The relationship between San Joaquin River flow relative to exports and survival between Durham Ferry or Mossdale and Jersey Point, with the HORB in place, while statistically significant (p<0.05, Figure 5-15 in SJRGA, 2007), does not appear to explain the variability in CWT smolt survival as well as flow alone with the HORB in place. One potential explanation for these results is the low levels of exports and lack of variation in exports during these CWT experiments. During the studies, exports ranged between 1,450 and 2,350 cfs which were much lower than those incorporated into the adult escapement and flow relationship. Another complication is that exports and San Joaquin River flows were correlated during the VAMP studies with the HORB installed; higher exports were observed during times of higher flows (Figure 5-16 in SJRGA, 2007). As conditions did not provide a 7,000 cfs flow to test a

1,500 and 3,000 cfs export with a HORB, identifying the role of exports on survival was limited.

However, in 2006, an experiment was conducted to isolate the role of exports on survival during the VAMP. In 2006, flows were high and two levels of exports were tested (1,500 and 6,000 cfs) to determine if differences in survival could be detected at the two different export levels. Such an experiment was feasible in 2006 because flows were deemed high enough to provide adequate protection for delta smelt even with the 6,000 cfs exports. Results indicated that point estimates of survival were higher for the lower export period, but standard errors were large and lower temperatures during the low export period may have confounded the results (SJRGA, 2007). The 2006 data were limited in its precision because it relied primarily on recoveries at Chipps Island and Antioch as the ocean fishery south of Cape Falcon, Oregon was closed in 2008 and 2009 due to anticipated low Sacramento River fall-run adult returns (NOAA, 2008, 2009). Three and four year old adult salmon would have been recovered in the ocean fishery in 2008 and 2009 from the 2006 releases if the fishery had not been closed.

Bayesian hierarchical models were used to fit the VAMP and pre-VAMP CWT data (Newman, 2008). For the various models fitted, two robust conclusions were identified: 1) flow is positively related to survival between Dos Reis and Jersey Point; and 2) survival is higher from Dos Reis to Jersey Point relative to that from upper Old River to Jersey Point. However, the most recent "best model" does not incorporate flow or exports for either of the routes but survival was higher in the San Joaquin River than in Old River (K. B. Newman, U.S. Fish and Wildlife Service, personal communication).

In 2007, it was determined that not enough fish were available at MRH to conduct a CWT study for VAMP. In addition, there was the possibility that the trawling at Antioch and Chipps Island could be interrupted due to high incidental catches of delta smelt and reduce the effort for recovering CWT fish. These two circumstances prompted the transition away from CWT studies to acoustic telemetry. Acoustic telemetry provides a greater temporal and spatial coverage of the outmigration process than CWT studies. Furthermore, continuous, simultaneous monitoring at several locations allows estimation of distribution probabilities at junctions and reach-specific survival throughout the study region. In addition, 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.

Past acoustic studies

Acoustic tag studies between 2006 and 2010 used Hydroacoustic Technology, Incorporated (HTI) tags. Tag models and battery life of the tags varied across years.

During the 2006 VAMP, a pilot study was initiated to test whether acoustic tags could be used to monitor the migration of juvenile Chinook salmon smolts in the south Delta. A total of 100 acoustically tagged MRH fish were released at Mossdale (67) and Dos Reis (33), with the installation of five stationary receivers (see Table 1 and Figure 1 in Appendix D) (SJRGA, 2007). Receivers were not installed at Jersey Point or Chipps Island in 2006; thus survival through the Delta could not be estimated using the acoustic tags. The HORB was not in place during the 2006 VAMP studies as Vernalis flows were substantially greater than 5,000 to 7,000 cfs necessary for HORB installation (see Table 1 in Appendix D). During the 2006 study, it was estimated that 83% and 56% of the acoustically tagged smolts released at Mossdale and surviving to the HOR junction were diverted into Old River during the two releases, respectively. (Those fish assumed to be lost due to predation were subtracted from the total prior to estimating the proportion splitting at the junction) At the times when the tagged fish approached the flow split, it was estimated that approximately 53 and 51% of the mainstem San Joaquin River flow was diverted into Old River during the first and second release, respectively (SJRGA, 2007). In addition, limited mobile tracking found five of the 61 tags released at Mossdale in the scour hole near the junction with Old River, suggesting tagged fish had been preyed upon at that location.

In 2007, MRH smolts implanted with acoustic transmitters were released at five locations and movement of tagged smolts was monitored at 10 stationary receiver locations in the south and central Delta (see Table 1 and Figure 2 in Appendix D) (SJRGA, 2008). Due to logistical challenges, stationary receivers could not be installed at Chipps Island and Jersey Point which precluded estimation of survival through the Delta. Detections at the stationary receiver locations during 2007 indicated an average loss of 45% between Durham Ferry and Bowman Road (just north of Lathrop). The largest area of mortality was identified in an area adjacent to a railroad bridge (Navy Drive Bridge) near the Stockton Waste Water Treatment Plant (WWTP). Mobile tracking found fifteen percent (n=116) of 776 tags released, from four upstream sites, motionless at this location indicating that the tags were either in dead fish or had been defecated by a predator (SJRGA, 2008).

In 2008, the acoustic study design was revised and expanded to provide estimates of survival through the Delta and route selection probabilities at several junctions. The HORB was not installed in 2008. MRH smolts with surgically implanted acoustic transmitters were released at Durham Ferry and Stockton and movement of tagged smolts was monitored at 16 stationary receiver locations (see Table 1 and Figure 3 in Appendix D) (SJRGA, 2009). Unfortunately, tag life tests indicated that only 55-78% of tags used in the study were still functioning after 15 days which precluded generating unbiased estimates of survival (Holbrook et al., 2009, 2013). Estimates of survival in 2008 included both the probability that the tag was working and that the fish survived and estimates were potentially biased low. Joint fish and tag survival was estimated to be 0.06 ± 0.01 ($\widehat{SE}$) and 0.07 ± 0.02 ($\widehat{SE}$) from Mossdale to Chipps Island for the two weeks of releases made in 2008. Fish remaining in the San Joaquin River had a higher relative fish tag survival rate (0.07± 0.02 ($\widehat{SE}$) and 0.10± 0.02 ($\widehat{SE}$) for the first and second releases, respectively (C. M. Holbrook, U.S. Geological Survey, personal communication), but only about a 1/3 of the tagged fish (0.22 and 0.33) used this route (Holbrook et al., 2009). Most of the tagged fish (63-68%) released at Durham Ferry migrated through Old River where fish tag survival was less. Survival from Mossdale to Chipps Island using the Old River route was 0.05 ±0.02 ($\widehat{SE}$) and 0.06±0.02 ($\widehat{SE}$) for the first and second releases, respectively (C. M. Holbrook, U.S. Geological Survey, personal communication). In addition, none of the tagged fish that entered Turner Cut (49) were detected at Chipps Island (Holbrook et al., 2009).

Water quality monitoring near the Stockton WWTP was conducted in 2008 and found that all measured nitrogen compounds (total Ammonia Nitrogen, unionized ammonia, nitrate and nitrite) showed a significant increase in concentration downstream of the WWTP discharges into the San Joaquin River, although levels were below the chronic concentration established by EPA (SJRGA, 2009).

The VAMP study in 2009 was a scaled-back version of the 2008 VAMP study, due to the inability to install receivers at Chipps Island and Jersey Point (see Figure 4 in Appendix D). Study fish were fall/spring hybrids from FRH and all were released at Durham Ferry. In recognition of the potential bias associated with predators ingesting a tagged smolt, survival in the south Delta was estimated in two ways in 2009; one with all the detections and one by removing detections thought to be from a tagged smolt eaten by a predator and the predator moving by a downstream receiver with the tag inside its digestive track. For the survival estimates in 2009, detected tags that had a wavy or flat signal in the Raw Acoustic Tag (RAT) files were considered to be in predators (SJRGA, 2010). Typical "smolt" like behavior was assumed to be a signal with a distinct or muted peak past the receiver (SJRGA, 2010). While these behaviors are not able to truly determine if a tag was in a predator or not, it gives information on how survival may be different, given that these detection characteristics are able to differentiate between a real smolt and one that has been preyed upon.

Survival was estimated to be 0.06 ($\widehat{SE}$ = 0.01) in 2009, without predator-type detections, from Mossdale to six end points in the south Delta ($S_{Total\ (SD)}$) and based on release groups 3 -7 (see Table 1 in Appendix D) (SJRGA, 2010). Survival from Mossdale through the San Joaquin River to Turner Cut or the Channel Marker receivers (partial San Joaquin route ($S_{A(SD)}$) was 0.05 ($\widehat{SE}$ = 0.02), removing predator-type detections (see Table 1 in Appendix D) (SJRGA, 2010). Survival from Mossdale to the entrances of the water export facilities (CVP, RGU) or the northern Old River receivers at Highway 4 (ORN) (partial Old River route ($S_{B(SD)}$) was 0.08 ($\widehat{SE}$ = 0.02) without predator-type detections (see Table 1 in Appendix D) (SJRGA, 2010). Route specific survival was only calculated for release groups 3-6, because of missing data, due to receiver malfunction. Estimates of survival were 0.34 ($\widehat{SE}$ = 0.03) from Mossdale to the six end points, 0.10 ($\widehat{SE}$ =0.02) for $S_{A(SD)}$ and 0.58 ($\widehat{SE}$ = 0.06) for $S_{B(SD)}$(SJRGA, 2010) using all detections (see Table 1 in Appendix D).

The effect of water quality on juvenile salmon near the Stockton WWTP was also investigated in 2009 using paired sets of dummy tagged fish. No detectable differences in mortality between the Stockton and Durham Ferry groups were observed in 2009 (Nichols and Foott, 2009 and SJRGA, 2010).

The VAMP study in 2010 incorporated receivers at Chipps Island, but did not include receivers at Jersey Point due to budgetary constraints (see Figure 5 in Appendix D). During the 2010 study, MRH Chinook salmon smolts were acoustically tagged and released into the San Joaquin River at Durham Ferry and near Stockton and in Old River just downstream of the mainstem San Joaquin River (see Table 1 and Figure 5 in Appendix D). The releases at Old River and near Stockton were made to augment the number 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. A non-physical barrier was tested at the HOR by the Department of Water Resources (DWR) and the United States Bureau of Reclamation (USBR) using fish from the VAMP.

Survival was low at 0.05 ($\widehat{SE}$ =0.01) between Mossdale and Chipps Island in 2010 with predator-type detections removed, relative to past CWT estimates (Figure 5-1); (see also Table 1 in Appendix D); (SJRGA, 2011). Average population-level survival between Mossdale and Chipps Island was somewhat higher in 2010 when using all detections (0.11, $\widehat{SE}$ = 0.01) (see Table 1 in Appendix D) (SJRGA, 2011). Estimates of the probability of remaining in the San Joaquin River at the junction with Old River (ψ_A) averaged 0.47 ($\widehat{SE}$ =0.02) with predator-type detections removed (SJRGA, 2011). Survival from Mossdale to Chipps Island through the San Joaquin River route (S_A) was estimated to be 0.04 ($\widehat{SE}$ =0.01) and through the Old River route (S_B) was estimated to be 0.07 ($\widehat{SE}$ =0.01) when removing predator-type detections (see Table 1 in Appendix D) (SJRGA, 2011). Survival was slightly higher when all detections were used with survival through S_A estimated at 0.11 ($\widehat{SE}$ =0.01) and survival through S_B estimated at 0.12 ($\widehat{SE}$ = 0.01) (see Table 1 in Appendix D) (SJRGA, 2011). 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 mainstem San Joaquin River route (P=0.0100) (SJRGA, 2011). Lack of significance for other releases may have been a result of low statistical power. However, when survival was pooled over all release groups, survival to Chipps Island was estimated to 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) (SJRGA, 2011).

Survival was also estimated through the portion of the study area in 2010 that matched the 2009 study area. Average survival in the San Joaquin River route through the 2009 study area ($S_{A(SD)}$) without predator-type detections was estimated to be 0.32 ($\widehat{SE}$ =0.02) in 2010 (see Table 1 in Appendix D) (SJRGA, 2011). Average survival in the Old River route through this region ($S_{B(SD)}$), without predator-type detections, was estimated to be 0.77 ($\widehat{SE}$ =0.05) (SJRGA, 2011) in 2010. $S_{Total\ (SD)}$ in 2010 was estimated at 0.56 ($\widehat{SE}$ =0.03) (SJRGA, 2011) without predator-type detections. These survival estimates in 2010 were considerably higher than comparable estimates from 2009, when $S_{A(SD)}$ was estimated at 0.05 ($\widehat{SE}$ = 0.02), $S_{B(SD)}$ was estimated at 0.08 ($\widehat{SE}$ = 0.02) and $S_{Total(SD)}$ was estimated to be 0.06 ($\widehat{SE}$ =0.01) (SJRGA, 2010 and 2011) without predator-type detections (see Table 1 in Appendix D).

2011 Acoustic study

For the 2011 study, Chinook salmon smolts from MRH were acoustically tagged with Hydroacoustic Technology, Incorporated (HTI) tags and released into the San Joaquin River at Durham Ferry on the mainstem San Joaquin River about 21 rkm (13 miles) upstream of the Delta (Mossdale Bridge). This study design in 2011 was changed from that used in 2010 to allow all tagged fish in 2011 to express any potential handling mortality before they entered the Delta at Mossdale. In 2010, supplemental releases were made in Old River and at Stockton, for each of the seven releases made at Durham Ferry, thus the Stockton and Old River groups expressed the potential handling mortality in a river reach within the Delta. Because survival through the Delta is estimated starting at the Mossdale receiver location, tagged fish released at Durham Ferry have the distance between Durham Ferry and the Mossdale receiver location (21 rkm or 13 miles) to express any potential handling mortality that occurs, reducing its effect on survival through the Delta. Releasing all groups at Durham Ferry in 2011 reduced any impact of handling mortality on survival through the Delta and standardized the reach where it was expressed. The number of fish released at Durham Ferry was increased from 2010 samples sizes to accommodate the study design change in 2011. A sample size analysis was completed to determine appropriate samples size (Appendix E).

The VAMP releases in 2011 were also used to meet the study needs of four other studies: 1) a South Delta Temporary Barrier Project (TBP) study, to assess the survival of Chinook salmon and steelhead with the South Delta temporary barriers installed; 2) a 6-year steelhead study as part of the NMFS OCAP Biological Opinion to determine if salmon could be used as surrogates for estimating steelhead survival in the San Joaquin River basin; 3) a HOR study to evaluate fish routing and predation at the HOR without a physical or non-physical barrier installed; and 4) a pre-screen loss study at the CVP using a 2-D acoustic array. Additional Chinook salmon and steelhead releases were made as part of these four studies and are either summarized here, reported in other sections of this report (Chapter 6) or will be forthcoming in independent reports. Of the four releases groups of acoustic-tagged Chinook salmon discussed in this chapter, the first two groups were released during the 2011 VAMP and the last two were released after the end of the 2011 VAMP.

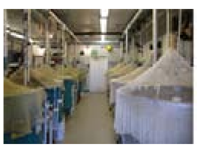
[1] *The name of the California Department of Fish and Game was changed on January 1, 2013 to California Department of Fish and Wildlife (CDFW)*

Each tagged fish released, as part of all of these acoustic studies, 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 survival estimates.

Study Design and Methods

Study Fish

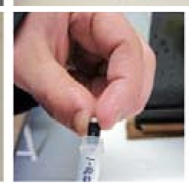
Study fish were obtained from the Merced River Hatchery. A total of 3,178 juvenile fall run Chinook salmon were transferred by California Department of Fish and Game[1] (DFG) from MRH to the CVP Tracy Fish Collection Facility (TFCF) on April 25th (n=1,139), May 9th (n=778), May 18th (n=610), June 3rd (n=568), and June 16th (83). Approximately half of the salmon delivered on April 25th were used for training, and the remaining fish were to be tagged on May 2nd and 3rd. However, due to cool water temperatures, fish growth at MRH during 2011 was relatively slow and fish did not meet minimum weight criteria by the target date. Tagging was postponed to May 16th and 17th to allow fish additional time to grow to adequate size.



Fish were generally held at TFCF for one week prior to tagging to allow for acclimation to Delta water quality and temperature prior to release; however, fish delivered on April 25th were held for three weeks due to the delay in tagging. Water temperatures in the holding tanks at TFCF were held at approximately 14-15° C until 3-4 days prior to tagging when water temperatures in the holding tanks were adjusted to ambient Delta condition. Fish were not held at ambient temperatures for the duration of holding at TCFC because PKD is progressive at temperatures greater than 15° C, and ambient Delta temperatures often exceed 15° C.

Transmitter Programming

Transmitters were programmed according to modified guidelines developed during the 2008 VAMP. Programming occurred the day prior to tagging which was two days prior to the start of each release. Transmitters were soaked for approximately 24 hours prior to programming. After programming, tags were sniffed in a cup of water using an HTI sniffer and monitored through at least three transmission cycles. At least 5 attempts were made to program each tag. Following successful programming, each tag was placed in a uniquely coded vial. Since the tags have no external identifiers, the codes on the vials were used to track the specifications (e.g., manufacturing lot, tag weight, period, sub-code, and pulse width) of individual tags.

During 2008 some tags passed activation and sniffing, but then failed shortly thereafter. To address this potential issue, a hydrophone was used during 2011 to listen to all activated tags immediately after each group of tags was programmed. This practice allowed for removal of any dead tags prior to surgical implantation in study fish.

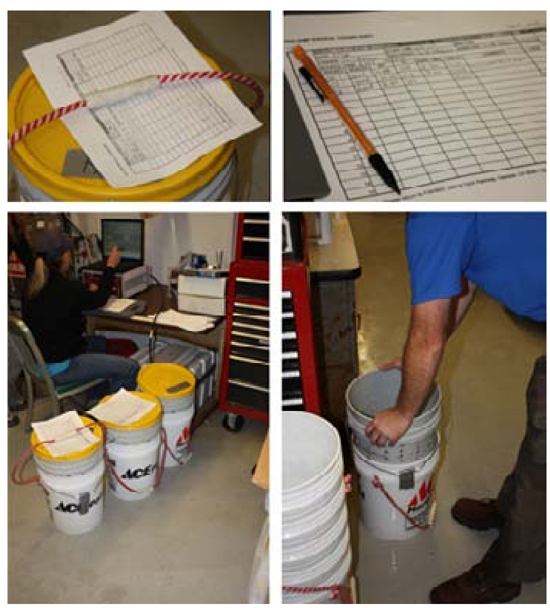
Transmitter Implantation and Validation

During 2011, training and tagging operations continued at the TFCF which was selected in 2009 as a preferred alternative to MRH for tagging (SJRGA, 2011). Tagging operations occurred at TFCF between May 16th and May 24th for VAMP and between June 6th and June 17th for the South Delta TBP study. 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 based on a standard operating procedure (SOP) developed by the Columbia River Research Lab (CRRL) of the United States Geological Survey (USGS). The SOP (Appendix F) directed all aspects of the tagging operation, and several quality assurance checks were made during each tagging session to ensure compliance with the SOP guidance.

Prior to transmitter implantation, fish were anesthetized in 70 mg/L tricane methanesulfonate buffered with an equal concentration of sodium bicarbonate until they lost equilibrium. Fish were removed from anesthesia, and were measured (fork length (FL) to nearest mm) and weighed (to nearest 0.1 g). The HTI Model 795 Lm micro acoustic tag used for this study weighed 0.65 g in air (range: 0.58 g to 0.73 g), was 16.4 mm long, with a diameter of 6.7 mm. A minimum fish weight criterion of 12.1 g was used to ensure a maximum tag weight to body weight ratio of 5.4%.

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) buckets with high dissolved oxygen concentrations (110-130%) to recover from anesthesia effects. Each bucket was labeled with a unique code. Buckets were perforated, starting 15 cm from the bottom, to allow water exchange. The non-perforated section of the bucket held 7 L of water to allow transfer without complete dewatering. Each bucket was stocked with three tagged fish, and was covered with a snap-on lid. Buckets were held in a flume at the TFCF facility until loaded for transport to the release site. Water levels were adjusted in the flume to ensure that tagged fish had access to air to adjust their buoyancy to compensate for the weight of the transmitter.



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. A total of ten transmitters were found to be non-functional during evaluation of the fish tagged for VAMP and three were found in fish tagged from the South Delta TBP study. All fish with non-functional tags were removed from the study and were euthanized at the TFCF.

In 2011, groups of 475 and 473 Chinook salmon were tagged for the VAMP and released at Durham Ferry in late May (Table 5-3). Similar sized groups (473 and 474) of Chinook salmon were tagged for the South Delta TBP study in June (Table 5-4). Each group of fish was tagged over a consecutive 4-day period and thus contained four separate sub-groups of approximately 120 fish (Tables 5-3 and 5-4). Tagging occurred in either the morning or afternoon (Table 5-3 and Table 5-4). Steelhead were tagged for the 6-year steelhead study on opposite shifts from the Chinook salmon as part of the integrated nature of the studies (see Chapter 6 for a discussion of the 6-year steelhead study program).

After tagging and tag validation, the 19L (5 gal) perforated buckets usually containing three tagged Chinook were held in the flume at the TFCF until they were loaded into the transport tanks. Water temperatures in the flume were set to match conditions at Durham Ferry or to be 1-2° C cooler than the river to allow for warming of water in the transport tanks during transport to the release site. Water temperatures in the flume were adjusted using a chiller at TFCF. The overall goal was to maintain water temperatures within a 1-2° C range from the holding tanks, to the flume, to the transport tanks, and to the release site to minimize stress to study fish.

Transport to Release Sites

In order to minimize the stress associated with moving fish and for tracking smaller groups of individual tagged fish, two specially designed transport tanks were used to move Chinook salmon from the TFCF where the tagging occurred, to the release site on the San Joaquin River at Durham Ferry. The transport tanks for Chinook salmon were designed to securely hold a series of 19 L (5 gal) perforated, 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. Both transport tanks were mounted on the bed of an 8 m (26') flatbed truck that was equipped with an oxygen tank and hosing to deliver oxygen to each of the tanks during transport.

As with the flume, water temperatures in the transport tanks were set to match conditions at Durham Ferry or to be 1-2° C cooler than the river to allow for warming during transport to the release site. Water temperatures in the transport tanks were adjusted using water from the chiller at TFCF and by adding ice to the transport tanks after loading as necessary.

Immediately prior to loading, all fish were visually inspected for mortalities or signs of poor recovery from tagging (e.g. erratic swimming behavior). Temperature and dissolved oxygen (DO) in the transport tanks were recorded after loading buckets into the transport tanks but before leaving the TFCF, and at the release site prior to unloading. Depending on water temperature conditions at Durham Ferry and ambient weather conditions, non-chlorinated ice was placed in the tanks as needed to minimize warming during transport to the release site.

Once at the release site, water temperature and dissolved oxygen levels were measured in the river and in the transport tanks. After recording water temperature and dissolved oxygen levels, tagged Chinook salmon were removed from the transport tanks and moved to the river. For all releases, perforated buckets were placed into "sleeves", transferred to a pick-up truck, and driven a short distance to the river's edge. A "sleeve" is a slightly larger non-perforated bucket that allows more water to stay in the perforated bucket than would be the case without placing it in a "sleeve."

Table 5-3
Tagging, Transport and Holding Date and Times and the Number Released for Chinook Salmon as Part of the 2011 Vernalis Adaptive Management Program (VAMP) Over a 24-hour Period after Being Held for a Minimum of 24 Hours at the Central Valley Project Tracy Fish Collection Facility (TFCF)

Tagging Date/Time	Transport Date/ Time	Start Holding Time	Total released (A+B+C+D)	Release A		Release B		Release C		Release D		Fish Health	Survival Model Release group
				Date/ Time	Number released	Date/ Time	Number released	Date/ Time	Number released	Date/ time	Number released	Dummy tagged	
5/16/2011 - morning	5/16/11; 1325-1412	5/16; 1514	120	5/17; 1500	30	5/17; 2100	30	5/18: 0300, 0301	30	5/18; 0900	30	12	1
5/17/2011-afternoon	5/17/11; 1800-1915	5/17; 2000	119	5/18; 1800	30	5/19; 0000, 0002	30	5/19; 0601	29	5/19; 1200	30	24[a]	1
5/18/2011 - morning	5/18/11; 1230-1330	5/18; 1410	117	5/19; 1500	28	5/19; 2100	30	5/20; 0300	29	5/20; 0902, 0903	30	12	1
5/19/2011 - afternoon	5/19/11; 1650-1737	5/19; 1815	119	5/20; 1800, 1802	29	5/21; 0000	30	5/21; 0559	30	5/21; 1200	30	12	1
Total			**475**										
5/21/2011-afternoon	5/21/11; 1605-1705	5/21; 1756	119	5/22; 1800	29	5/22; 2358	30	5/23; 0559	30	5/23; 1201, 1202	30	12	2
5/22/2011-morning	5/22/11; 1130-1215	5/22; 1303	119	5/23; 1500	30	5/23; 2100	30	5/24; 0300	30	5/24; 0902	29	12	2
5/23/2011-afternoon	5/23/11; 1530-1620	5/23; 1705	115	5/24; 1801	30	5/24; 2358	29	5/25; 0601	28	5/25; 1200, 1201	28	12[a]	2
5/24/2011-morning	5/24/11; 1139-1235	5/24; 1338	120	5/25; 1500	30	5/25; 2100	30	5/26; 0259	30	5/26; 0901, 0902	30	24[a]	2
Total			**473**										

[a] Given to USFWS CA-NV Fish Health Center for fish health study

Table 5-4
Tagging, Transport and Holding Date and Times and the Number Released (and Mortaltites) for Chinook Salmon as Part of South Delta Temporary Barriers Project (TBP) Study Over a 24-hour Period after Being Held for a Minimum of 24 Hours at the Central Valley Project Tracy Fish Collection Facility (TFCF)

Tagging Date/Time	Transport Date/ Time	Start Holding Time	Total released (A+B+C+D)	Release A		Release B		Release C		Release D		Fish Health	Survival Model Release group
				Date/Time	Number released	Date/ Time	Number released	Date/ Time	Number released	Date/ time	Number released	Dummy tagged	
6/6/11 - afternoon;	6/6/11; 1530-1604	6/6/11; 1645	119	6/7; 1800, 1081	29	6/8; 0000, 0001	30	6/8; 0601	30	6/8; 1201	30	12	3
6/7/11 - morning;	6/7/11; 1203-1250	6/7/11; 1335	116	6/8; 1500	28	6/8; 2100, 2101	30	6/9; 0259	30	6/9; 0900	28 (1)	12	3
6/8/11-afternoon;	6/8/11; 1555-1638	6/8/11; 1717	119	6/9; 1800	30	6/10; 0000	30	6/10; 0559	29	6/10; 1200	30	12	3
6/9/11 - morning;	6/9/11; 1131-1210	6/9/11; 1300	119	6/10: 1500	29	6/10; 2100	30	6/11; 0300	30	06/11; 0900	30	12	3
Total			**473**										
6/14/11 - morning;	6/14/11; 1217-1314	6/14/11; 1410	119	6/15; 1501, 1502	30	6/15; 2100, 2101	30	6/16; 0300	30	6/16; 0900, 0901	29	23[a]	4
6/15/11-afternoon;	6/15/11; 1624-1710	6/15/11; 1813	118	6/16; 1800	30	6/17; 0000	30	6/17; 0600	29	6/17; 1200	29	12[b]	4
6/16/11-morning;	6/16/11; 1130-1230	6/16/11; 1320	117	6/17; 1500, 1501	30	6/17; 2101, 2102	29	6/18; 0300	30	6/18; 0900	28	12	4
6/17/11-afternoon;	6/17/11; 1645-1735	6/17/11; 1828	120	6/18; 1800	30	6/19; 0000	30	6/19; 0600	30	6/19; 1200	30	12	4
Total			**474**										

[a] Given to USFWS CA-NV Fish Health Center for fish health study, [b] processed 3 hour early

Perforated buckets in sleeves were unloaded from the pick-up truck and carried to the river. Perforated buckets were separated from the sleeves at the shore and carried to the holding containers in the river about two to three feet from the shore. Fish were transferred from 19L buckets to 120 L (32 gal), perforated, plastic garbage cans held in the river. Perforations were drilled in the garbage cans to allow free flow of water through the can while fish were held at the release site. Each hole was 0.64 cm diameter. Five buckets, usually containing three salmon per bucket, were emptied into each perforated garbage can. Each bucket and each garbage can was labeled to track the specific tag codes and assure fish were transferred to the correct holding can for later release at the correct time. Tagged salmon were held in the perforated garbage cans for a minimum of approximately 24 hours prior to release.

Dummy tagged Chinook salmon were tagged and transported similarly as fish with live tags but were held for a minimum of 48 hours. A security guard or release crew remained onsite for the duration of the holding period for both the tagged and dummy-tagged Chinook salmon to ensure that study fish and equipment were not vandalized or otherwise tampered with.

Releases

For the VAMP in 2011, groups of 475 and 473 tagged Chinook salmon were released at Durham Ferry over a two-week period in mid to late May. Each group of tagged fish was released over a consecutive 5-day period and contained four separate sub-groups of approximately 120 fish (Table 5-3). Each of the four separate subgroups were released over a 24-hour period, with approximately one fourth of each subgroup (~30 tagged fish) released every 6 hours (Table 5-3).

A similar release strategy was used for Chinook salmon released as part of the South Delta TBP study. Chinook salmon for the South Delta TBP study were released later in the season than the VAMP fish, between June 7th and 19th (Table 5-4). As mentioned previously, all Chinook salmon released as part of these two studies were released at Durham Ferry on the San Joaquin River.

Specific releases times were based on the fish tagging period (morning or afternoon). Two set release schedules were used for the Chinook salmon releases in 2011; either a release schedule of 1500, 2100, 0300, 0900 hours for fish tagged in the morning or a release schedule of 1800, 0000, 0600, 1200 hours for fish tagged in the afternoon.

The releases of Chinook salmon were made from shore due to the high flows. Fish were to be released in the middle of the channel, downstream of the holding location, but flows were too high in 2011 to safely allow field personnel to use a boat to tow the release containers to mid-channel. Fish were to be released in the middle of the channel, downstream of the holding site, to potentially reduce initial predation of tagged fish immediately after release. The high flows in 2011 may have reduced this concern as it may have been more difficult for predators to congregate near the holding location with the high flows.

At the release time the lid was removed and the holding container was rotated to look for any dead or impaired fish. The container was then inverted to allow the fish to be released into the river. After the holding container was inverted, the time was recorded. As the holding containers were flipped back over, they were inspected to make sure that none of the released fish swam back into the container. During 2011, flows were very high, thus there were many times the holding containers remained clipped to the anchor rope so that they would not be lost in the current. Once the release was completed, the information on any dead fish was recorded and the tags were removed. The tags were bagged and labeled and returned to the tagging location or office to have the individual tag identified.

In 2011, no tagged fish were intentionally killed to determine the "behavior" of dead fish. In 2009 and 2010, dead fish with active tags were released as part of the study design to verify that dead fish did not move far enough downstream to be detected on receivers downstream and assumed to be in live fish. In 2009, two of the five dead fish with live tags were found in mobile monitoring approximately 300 m (1000 ft) downstream. One additional dead fish was detected approximately 5 km (3 miles) downstream. It is not clear whether this fish was eaten by a predator, had been defecated or had drifted this far downstream. In 2010, of the 3 intentional mortalities released at Durham Ferry, two were found within 0.2 km (0.1 mile) of the release site. At Old River, of the three fish intentionally killed, two were detected within 0.4 km (0.25 miles) of the release site. Of the three fish intentionally killed and released at Stockton in 2010, only one was located by mobile tracking and was within 0.3 km (0.2 miles) of the release site. The first receiver downstream of the release site (with the exception of the dual receiver at the release site) was at Banta Carbona in 2011, approximately 10 km (6 miles) downstream of the release site. Given this information, and with releases only at Durham Ferry in 2011, the technical team recommended discontinuing this evaluation in 2011.

Dummy-tagged fish

In order to evaluate the effects of tagging and transport on survival, several groups of Chinook salmon were implanted with inactive or dummy transmitters. Dummy tags in 2011 were interspersed randomly into the tagging order for each release group. For each day of VAMP releases, 12 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 approximately 48 hours, they were examined for mortality, then euthanized with MS-222, measured (FL to nearest mm) and qualitatively examined for condition: percent scale loss, body color, fin hemorrhaging, eye quality, and gill coloration (Table 5-5). After assessment of the dummy-tagged fish, dummy tags were removed for reuse.

In addition, twenty-four dummy-tagged fish from two tagging days (May 17th and May 24th) were transported to the U.S. Fish and Wildlife Service California/Nevada Fish Health Center (FHC) after the fish were held for 48 hours. An additional 12 dummy-tagged fish, tagged on May 23rd were taken to FHC after they had been held for approximately 72 hours. Once at the FHC the dummy-tagged fish were held for 30 days. The primary purpose of these dummy-tagged groups was to monitor and diagnose mortality over a 30-day holding period. An additional 60 non-tagged Chinook salmon were obtained as a control for surgery effects and to increase sample numbers without tagging additional dummy-tagged fish. The non-tagged fish were transferred directly to the FHC from the tagging facility and sampled at two time points after they arrived at the FHC: after an overnight acclimation (1d) and after approximately 30 days (30d). The dummy-tagged fish were only sampled after 30 days.

At the FHC, temperature of the single-pass water supply was allowed to fluctuate with ambient conditions. Once temperatures began to exceed 18° C (July 29th), the water supply was switched to a constant 17° C source due to concerns of *Flavobacterium columnare* infection. Fish were fed a pelleted salmon diet daily. Tanks were checked daily for dead or moribund fish. Diagnostic sampling was performed on sick or dead fish to identify any associated pathology. In addition, a reference sample of 30 unmarked Chinook was sampled at MRH on May 18th. For more detail on the methods used for the fish health evaluations see Chapter 6.

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

Characteristic	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)

Figure 5-2
Locations of Acoustic Receivers and Release Site Used for the 2011 VAMP Study Including Locations of Acoustic Receivers Deployed by the California Department of Water Resources (DWR) for the South Delta Temporary Barriers Project Study. Site Descriptions, Locations and Codes are Shown in Table 5-6

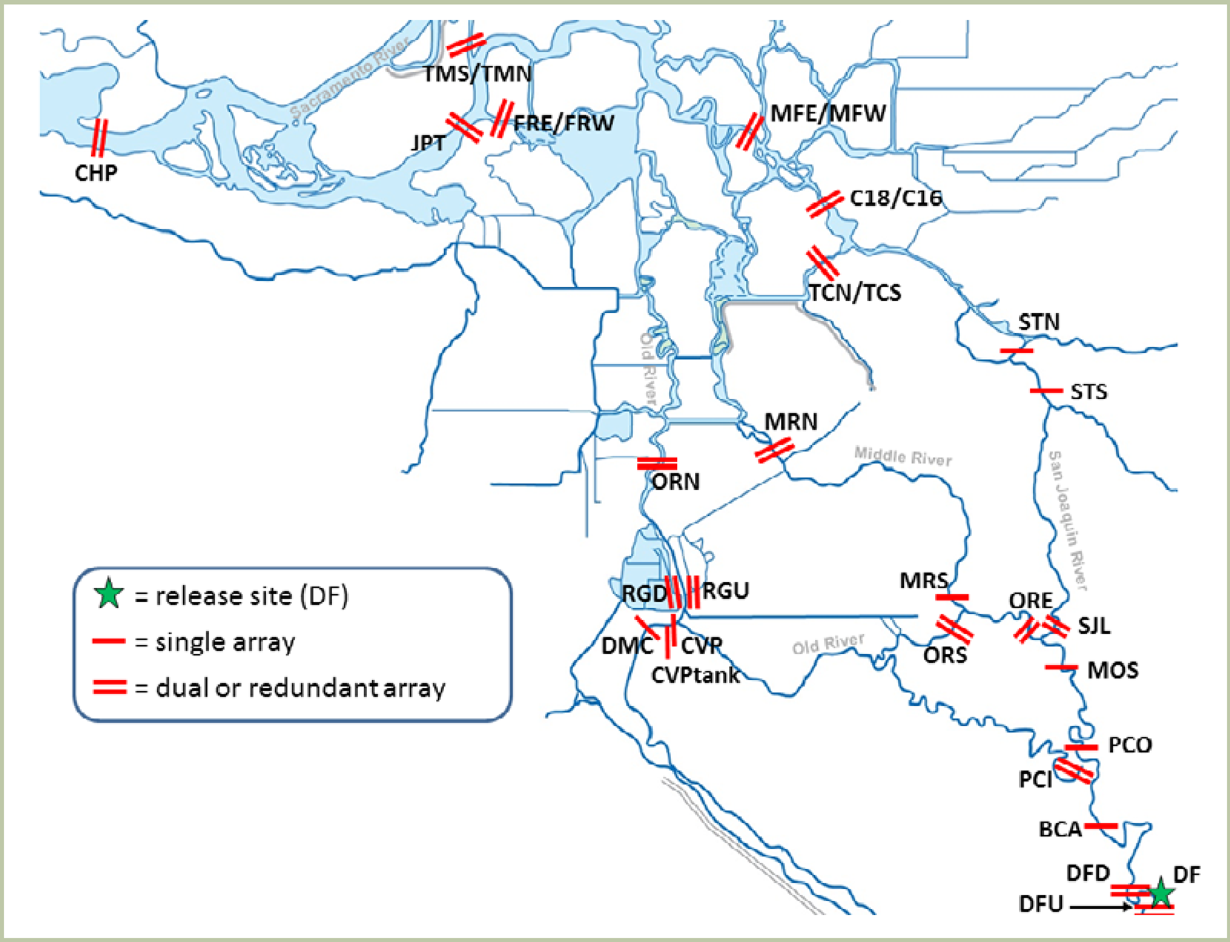


Table 5-6
Names and Descriptions of Receivers and Hydrophones Used in the 2011 VAMP Study, with Receiver Codes Used in Figure 5-2, Survival Model (Figures 5-4 and 5-5), and in Data Processing at the Columbia River Research Lab (CRRL) of the United States Geological Survey (USGS) in Cook, Washington. The Release Site was Located at Durham Ferry.

Individual Receiver Name and Description	Hydrophone Location		Receiver Code shown in Figure 5-2	Survival Model Code Shown in Figure 5-3	Data Processing Code Used in Figures 5-4 and 5-5
	Latitude (°N)	Longitude (°W)			
San Joaquin River near Durham Ferry upstream of the release site, upstream node	37.685333	121.256389	DFU1	A0a	901
San Joaquin River near Durham Ferry upstream of the release site, downstream node	37.687617	121.258150	DFU2	A0b	902
San Joaquin River near Durham Ferry; release site (no acoustic hydrophone located here)	37.686991	121.268258	DF	A1	
San Joaquin River near Durham Ferry downstream of the release site, upstream node	37.687550	121.271117	DFD1	A2a	903
San Joaquin River near Durham Ferry downstream of the release site, downstream node	37.688950	121.275667	DFD2	A2b	904
San Joaquin River near Banta Carbona	37.728183	121.298550	BCA	A3	905
San Joaquin River downstream of Paradise Cut	37.761650	121.309300	PCO	A4	937
San Joaquin River near Mossdale Bridge	37.794000	121.310900	MOS	A5	906
San Joaquin River near Lathrop, upstream	37.811167	121.319283	SJLU	A6a	909
San Joaquin River near Lathrop, downstream	37.811650	121.318683	SJLD	A6b	910
San Joaquin River at Stockton USGS gauge	37.933367	121.328667	STS	A7	911
San Joaquin River at Stockton Navy Drive Bridge	37.946550	121.339633	STN	A8	912
San Joaquin River at Shipping Channel Marker 18	38.021933	121.465983	C18	A9a	915
San Joaquin River at Shipping Channel Marker 16	38.026083	121.470817	C16	A9b	916
San Joaquin River near Medford Island, east	38.052767	121.510917	MFE	A10a	917
San Joaquin River near Medford Island, west	38.053200	121.513517	MFW	A10b	918
Old River East, near junction with San Joaquin, upstream	37.812217	121.335467	OREU	B1a	907
Old River East, near junction with San Joaquin, downstream	37.812600	121.335450	ORED	B1b	908
Old River South, upstream	37.819709	121.379215	ORSU	B2a	802
Old River South, downstream	37.818843	121.379814	ORSD	B2b	803
Old River North, upstream	37.889961	121.572875	ORNU	B3a	814
Old River North, downstream	37.892072	121.567887	ORND	B3b	815
Middle River South	37.824913	121.380829	MRS	C1	801
Middle River North, upstream	37.890200	121.489479	MRNU	C2a	816
Middle River North, downstream	37.892264	121.490199	MRND	C2b	817
Radial Gate at Clifton Court Forebay, upstream (in entrance channel to forebay), array 1	37.829600	121.556949	RGU1	D1a	810
Radial Gate at Clifton Court Forebay, upstream, array 2	37.829591	121.556949	RGU2	D1b	811
Radial Gate at Clifton Court Forebay, downstream (inside forebay), array 1	37.829852	121.557694	RGD1	D2a	812
Radial Gate at Clifton Court Forebay, downstream, array 2	37.829906	121.557670	RGD2	D2b	813
Central Valley Project trashracks	37.816658[a]	121.558690[a]	CVP	E1	701 - 713
Central Valley Project holding tank (all holding tanks pooled)	37.815910[a]	121.559090[a]	CVPtank	E2	715/716
Delta Mendota Canal (not used in survival model)	37.816240	121.560367	DMC	E3	714
Turner Cut, north (closer to San Joaquin)	37.991383	121.455200	TCN	F1a	914
Turner Cut, south (farther from San Joaquin)	37.989850	121.460017	TCS	F1b	913
San Joaquin River at Jersey Point, east (upstream)	38.056085[a]	121.686341[a]	JPTE	G1a	600
San Joaquin River at Jersey Point, west (downstream)	38.050615[a]	121.692585[a]	JPTW	G1b	610
False River, west (closer to San Joaquin)	38.056217	121.668150	FRW	H1a	922
False River, east (farther from San Joaquin)	38.056100	121.661467	FRE	H1b	921
Chipps Island, east (upstream)	38.047540[a]	121.890599[a]	CHPE	G2a	500/517
Chipps Island, west (downstream)	38.046090[a]	121.896439[a]	CHPW	G2b	510/516
Chipps Island, north (near Spoonbill Creek - not used in the survival model)	38.052640	121.889735	CHPN		515
Paradise Cut inside, east (upstream)[b]	37.760061	121.310481	PCIE	P1a	935
Paradise Cut inside, west (downstream)[b]	37.760897	121.315811	PCIW	P1b	936
Threemile Slough, south (not used in survival model)	38.097333	121.685200	TMS	T1a	920
Threemile Slough, north (not used in survival model)	38.111133	121.683067	TMN	T1b	919

[a] Average latitude and longitude given for sites with multiple hydrophones
[b] Not used in the survival model

Health assessments were also conducted on cohorts of acoustically tagged Chinook salmon used in the South Delta TBP study tagged on June 14th.

Receiver Deployment

The hydrophone receiver network in 2011 was similar to that developed in 2010 but added receiver sites at Jersey Point (JPT) and False River (FRE/FRW) (Figure 5-2). Principal objectives of the hydrophone layout for 2011 were to: (1) obtain fish survival estimates through the Delta from 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 (ORE and SJL) and Turner Cut (TCN/TCS)) (Figure 5-2). In addition, receivers were added just upstream and downstream of the release site (DFU and DFD, respectively) (Figure 5-2). A dual receiver was deployed upstream of the release site to remove any Chinook tags that moved upstream, presumably in a predator, prior to estimating survival. The dual receiver deployed just downstream of the release site was an attempt to verify that tags were still working at the time of release by detecting each tagged fish as it passed the receivers just downstream of the release site.

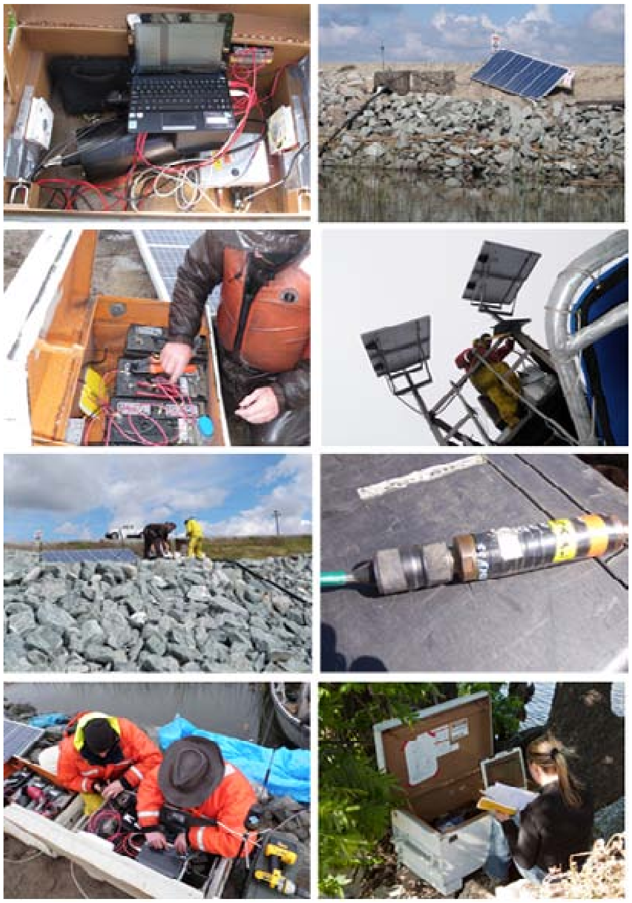
Due to the extremely high river flows during the VAMP 2011 study period, the need arose for additional receivers to be installed in, and downstream of Paradise Cut (PCI and PCO) (Figure 5-2), a location where fish passage is not normally possible. When flows at Vernalis rose above approximately 18,000 cfs, water from the San Joaquin River was able to flow over the weir at the head of Paradise Cut. Three additional receivers were added in, and around, Paradise Cut in mid-April, but by mid-May flows were no longer overtopping the weir.

In 2011, receivers were deployed as in the past but three new components were added: the use of solar power, remote access to the receivers and telemetry of data to an FTP (File Transfer Protocol) site. The use of solar power allowed the sites to run continuously throughout the experiment without changing batteries as had been done over the last 5 years, while the ability to remotely access all receivers allowed us to monitor operational parameters and telemetry allowed us to determine whether data was being collected and if the equipment was working correctly.

Receiver sites were deployed and maintained by personnel from multiple agencies. The USFWS office in Stockton, with support from the USGS-CRRL, took primary responsibility for deploying and maintaining in-Delta receivers during 2011. With the assistance of personnel from USGS-CRRL, the FWS Stockton office initially set up 22 acoustic receiver sites within the San Joaquin River and Delta, and added 3 more later in Paradise Cut for a total of 25 receiver sites (Figure 5-2 and Table 5-6). The USGS-Sacramento office installed and maintained two four-port receivers (CHPE and CHPW), and two single-node receivers near Chipps Island (517 and 516), and a second set of four port receivers at Jersey Point (JPTE and JPTW) during the 2011 VAMP study (Table 5-6). One additional hydrophone (515) was deployed near Chipps Island, just upstream of Spoonbill Slough, but was not used in the modeling as a similar receivers was not deployed in 2010. Additional sites associated with the South Delta TBP study (ORSU, ORSD, ORNU, ORND, MRS, MRNU, and MRND), were maintained by personnel from DWR (Table 5-6). Receivers inside (RGD1 and RGD2) and outside (RGU1 and RGU2) of Clifton Court Forebay were also maintained by staff from DWR while the receivers at the CVP and in the CVP holding tanks (CVPtank) were maintained by USBR staff. One additional receiver in the Delta Mendota Canal (DMC) was also maintained by USBR staff (Table 5-6).

One of the receiver location sites was changed in 2011 relative to where it had been in 2010. The two redundant receivers (one site) on the mainstem San Joaquin River below the HOR (SJL, systems 909 and 910, Table 5-6) were relocated to a site closer to the flow split to decrease the probability that mortality would occur between the junction and the receiver. The assumption of 100% survival of the tagged fish between the flow split and the receiver is necessary for determining the route entrainment probability at this location.

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. 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. Hydrophone locations were marked with an onboard GPS unit (Lowrance HDS-5). Each site contained an acoustic hydrophone, acoustic receiver, input/output box and four, 12V deep-cycle batteries to power the equipment. These batteries were attached to a four-panel solar array. The solar panels used were Sharp 80 watt off-module solar panels mounted on 1 ½" x 1 ½" x 10' angle iron. Sites that were co-located (redundant arrays) shared a four-panel solar array. The solar panels maintained the charge on the batteries and ran the electronic components. All equipment was housed in two metal joboxes. In past years, receivers were cooled by water; however, with the addition of sensitive electronic equipment, small 4" electric fans were added to the job boxes housing the electronics instead. A phidget box was installed to monitor the condition of all electronic components. Continuously pinging "beacon" tags were programmed and anchored underwater near each site throughout the study period in order to verify that each receiver was operating properly. Receivers were turned on for the 6-year steelhead study on March 3, 2011. Receivers had been operating for over two months when the Chinook salmon were released as part of the VAMP study.



In previous years of the VAMP, each site would have to be visited three to four times a week to download data and to change batteries. For VAMP 2011, the use of telemetry equipment allowed data from each site to be uploaded automatically. A laptop computer (netbook) was connected to each receiver for automatic downloading from the receiver to the computer. The data was then uploaded from the computer to a FTP site, via a modem using an antenna and air card. The RAT files could then be accessed and examined to assure the equipment was working and files were being generated. This set-up also allowed personnel to remotely access the sites through the computer and phidget control program. The phidget control supplied solar panel charging information and allowed for temperature control through adjustment of the cooling fans. If a problem was observed, personnel were dispatched to the site to correct the issue. While this system worked,

the remoteness of sites created intermittent air card connectivity, leading to crews having to go out, almost daily, to check the receivers. A booster antenna and a software program to reboot the computer helped to solve some of these problems. In addition, some equipment was replaced during the course of the season (solar module controller). Due to the high flows, beacon tags and hydrophones needed to be moved on occasion.

Temperature Monitoring

Water temperature was monitored during the VAMP 2011 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 (Figure 1 and Table 1 in Appendix G). Depths of the measurements varied from near the water surface to approximately 4 feet below the water surface. As part of the 2011 VAMP monitoring program, additional temperature recorders were deployed in the south and central Delta (Figure 1 and Table 1 in Appendix G) to provide geographic coverage for characterizing water temperature conditions while juvenile salmon emigrated from the lower San Joaquin River through the Delta. Water temperature was recorded instantaneously at 24-minute intervals throughout the period of the 2011 VAMP investigations.

Tag life study

Two in-tank tag-life studies were conducted by FISHBIO and DWR to quantify the rate of tag extinction under the operating parameters used for the study (i.e., encoding, range, and pulse width). Each study used tag periods representative of the tag periods used in the salmon survival study, with periods ranging from approximately 5000 to approximately 11000 in both studies. A stratified random sample of 50 tags per study was taken across all of the model 795 Lm tags purchased from HTI which were comprised of four manufacturing lots. Tags were programmed according to the same procedures used for the field study.

Tags were secured in a mesh bag that was placed into the study tank the day after programming. A hydrophone was suspended in the tank to continuously monitor tag function. 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. The lifespan of each tag in the tag-life study was calculated as the difference between the time of tag programming and the time of last detection in the tank.

Data Processing

Data collected at individual monitoring sites were transferred to the USGS-CRRL 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 (HTI) 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 the combined studies of 90 days with 66 receivers and 4,000 tagged fish, visual inspection of each file using MarkTags would require 570 million (4000 tags in each of 24 hourly files for each of 90 days for each of 66 receivers) page-views in the MarkTags software. To compound this further, four of the sites were 4-port (Acoustic Tag Receiver) ATR and one was a 16-port ATR (CVP trashracks) which increases the number of files that need to be visually inspected. At an ambitious rate of 1 page viewed per second, it would require about 160,000 hours of continuous, uninterrupted work to visually identify valid detections. Based on an 8-hour work day and a 5-day-a-week work schedule, it would take one person 4,000 weeks to visually inspect all the files. Clearly, an automated way of selecting valid detections was needed to process the data in a timely manner.

A combination of automated processing and manually proofing was used to identify fish detections. A tag list was compiled to isolate the locations and time frames that a given fish would be present within the system. This list was used in conjunction with RAT files, input parameters, and algorithms for the automated process (hereafter referred to as FishCount). During the processing of the 2011 data, it was necessary to make modifications to FishCount to accommodate a 7-millisecond period spacing between tags. When tags are spaced this closely, it makes it difficult to separate valid detections from one another and from the ambient background noise. The modifications made to accommodate the 7-millisecond period spacing were tested on a number of data sets from previous studies that included similar tag spacing. After FishCount completed processing the 2011 data a detection history output was compiled and manually proofed for a final cleaning of the data. After the data were manually verified, it was sent to the University of Washington to determine survival probabilities.

The use of an automated process to identify fish detections clearly saves 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. Until automated algorithms are developed closer to 100% accuracy there will always be a small portion of missed detections: this is similar to what has been found with manual proofing. Due to the amount of data collected in 2011, manual processing of all the data was not an option and the probability of missing a few valid detections using the automated process was determined to be an acceptable cost to delivering the results in a timely manner. The effect of missing detections on the survival estimation results was mitigated by the survival model, which takes into account imperfect detection probabilities.

Documentation of the validation of FishCount was outside the scope of activities for this project. However, the USGS-CRRL have continued to refine the process and have applied it to data from a number of other studies. For example, the USGS-CRRL applied FishCount to data collected during the Department of Water Resources (DWR) implementation of the 2011 and 2012 Georgiana Slough Non-Physical Barrier (GSNPB) Study to test the effectiveness of using a nonphysical barrier to prevent out-migrating juvenile Chinook salmon and steelhead from entering Georgiana Slough in the Sacramento River portion of the Delta. As part of these studies USGS is working collaboratively with HTI Inc. to compare the results of using FishCount and MarkTags to identify echoes in the RAT files. The methods, results, and discussion of the comparison of

FishCount and MarkTag will be submitted for inclusion in the 2013 Final Report to DWR. Based on the initial comparisons of the two processes, the vendor (HTI) suggested that the data used in the final report should be based on the data that is processed with FishCount, not their MarkTag software.

The University of Washington received the primary database of autoprocessed detection data from the USGS lab in Cook, WA, and the manually processed detection data from the USFWS office in Stockton, CA. These data included the date, time, location, and tag period and subcode of each valid detection of the acoustic salmon tags on the fixed-site receivers. The period and subcode indicate 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 obviously invalid detections. The University of Washington identified potentially invalid detections based on unreasonable travel times or unlikely transitions between detection sites, and queried the processor (USGS or USFWS) about the discrepancy. All corrections were noted and made to the database. 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 interval 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 Smolts 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 potentially biased estimates of juvenile salmon 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, the detection data were filtered for predator detections, and detections assumed to come from predators were removed from the data set.

The predator filter was based on the predator analyses presented by Vogel (2010 and 2011), as well as conversations with fisheries biologists familiar with the San Joaquin River and Delta regions and the predator decision processes used in previous years (SJRGA, 2010 and 2011). The predator filter was applied to all detections of all tags. Two data sets were then constructed: the full data set including all detections, including those classified as coming from predators (i.e., "predator-type"), and the reduced data set, restricted to those detections classified as coming from live smolts (i.e., "smolt-type"). The survival model was fit to both data sets separately. The results from the analysis of the reduced "smolt-type" data set are presented as the final results of the VAMP 2011 study. Results from analysis of the full data set including "predator-type" detections were used to indicate the degree of uncertainty in survival estimates arising from the predator decision process.

The predator filter was based on assumed behavioral differences between salmon smolts and predators such as striped bass and channel catfish. 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 5-7), as available, downloaded from the California Data Exchange Center (CDEC) website (http://cdec.water.ca.gov/selectQuery.html) on April 10, 2012. All detections were considered when implementing the decision process, including detections from acoustic receivers that were not otherwise used in the survival model.

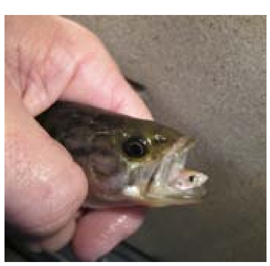
For each tag detection, several steps were performed to determine if it should be classified as predator or salmon. Initially, all detections were assumed to be of live smolts. Once a detection was classified as coming from a predator, all subsequent detections of that tag were likewise classified as 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 have temporarily moved upstream with the flow.

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

Table 5-7
Environmental Monitoring Sites Used in Predator Decision Rule

Enivonmental Monitoring Site				Data Available				
Site Name	Latitude (°N)	Longitude (°W)	Detection Site	River Flow	Water Velocity	River Stage	Pumping	Reservoir Inflow
CLC	37.8298	121.5574	RGU, RGD	No	No	No	No	Yes
FAL	38.0555	121.6672	FRE/FRW	Yes	Yes	Yes	No	No
GLC	37.8201	121.4497	ORS	Yes	Yes	Yes	No	No
HLT	38.0031	121.5108	C18/C16, MFE/MFW	Yes	Yes	No	No	No
MAL	38.0428	121.9201	CHP	No	No	Yes	No	No
MDM	37.9425	121.534	MRN	Yes	Yes	Yes	No	No
MSD	37.7860	121.3060	BCA, PCO, MOS	Yes	Yes	Yes	No	No
ODM	37.8101	121.5419	CVP, DMC	Yes	Yes	Yes	No	No
OH1	37.8080	121.3290	ORE	Yes	Yes	Yes	No	No
OH4	37.8900	121.5697	ORN	Yes	Yes	Yes	No	No
ORI	37.8280	121.5526	RGU, RGD	Yes	Yes	No	No	No
SJG	37.9351	121.3295	STS, STN	Yes	Yes	Yes	No	No
SJJ	38.0520	121.6891	JPT	Yes	Yes	Yes	No	No
SJL	37.8100	121.3230	SJL	Yes	Yes	Yes	No	No
TRN	37.9927	121.4541	TCN/TCS	Yes	Yes	Yes	No	No
TRP	37.8165	121.5596	CVP, DMC	No	No	No	Yes	No
TSL	38.1004	121.6866	TMS/TMN	Yes	Yes	Yes	No	No
VNI	38.0500	121.4960	C18/C16	No	No	Yes	No	No
VNS	37.6670	121.2670	DFU, DFD, BCA	Yes	No	Yes	No	No

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, rather than 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.



The predator filter considered various criteria on several spatial and temporal scales. Criteria fit under several categories, described in more detail below: fish speed, residence time, upstream transitions, other unexpected transitions, travel time since release, and movements against flow. Each criterion was applied to each tag detection on the "visit" time scale (Table 5-8). The visit time scale was used in the survival model, with consecutive visits at a given detection site separated by a time gap of at least 12 hours or by detection elsewhere. For each visit detection, a "predator score" was assigned based on the number of criteria yielding a positive predator classification. Separate scores were assigned depending on whether the tag was classified as a predator on arrival or on departure from the detection site. The final predator classification for a given visit-level detection was based on the "arrival" and "departure" predator scores. The detection was classified as coming from a predator on arrival at the detection site if the "arrival" predator score was ≥ 2. Likewise, the detection was classified as coming from a predator on departure from the detection site if the total predator score ("arrival" + "departure") was ≥ 2, or if the detection was previously classified as coming from a predator on arrival. All detections of a tag subsequent to its first predator designation were also classified as coming from a predator.

Table 5-8
Cutoff Values Used in Predator Filter. Observed Values Past Cutoff or Unmet Conditions Indicate a Predator

Detection Site	Previous Site	Residence Time[a] (hr)	Migration Rate[b, c] (km/hr)		Number of Visits	Flow[d] (cfs)		Water Velocity[d] (ft/sec)			Extra conditions	Comment
		Maximum	Minimum	Maximum	Maximum	At arrival	At departure[e]	At arrival	At departuree	Average during transition		
DFU	DF	50	0.01	4	1	< 15,000						No repeat visits allowed.
	DFD	10	0.3	4	1	< 15,000						No repeat visits allowed.
DFD	DF	20	0.01	4	1							
	DFU	20	0.3	4	2							
	DFD, BCA	0	100	NA	0							Not allowed.
BCA	DF	5	0.5	4	1							
	DFU, DFD	5	0.5	4	1							
	BCA, PCO	0	100	NA	0							Not allowed.
PCO	DF	1	0.3	5.5	1							
	DFU, DFD, BCA	1	0.3	5.5	1							
	PCO, MOS	0	100	NA	0							
MOS	DF	15	0.3	5.5	1							
	DFU, DFD, BCA, PCO	15	0.3	5.5	1							
	SJL, ORE	10	0.3	4	2	< 5,000	< 3,000	< 0.1	< -0.1	< 0.1		
	MOS	0	100	NA	0							Not allowed.
SJL	DFD - MOS	5	0.3	5.5	1[f]							Allow 2 visits, upstream forays coming from MOS
	ORE	5	0.3	5.5	1		< 0		< -0.1	> -0.1		
	STS	5	0.3	4	2	< -500	< -500	< -0.5	< -0.5	< -0.2		
	SJL	0	100	NA	0							Not allowed.
STS	BCA, MOS, SJL	12	0.3	5	1 (2 from SJL)			< 0.5			Arrive at beginning of flood tide	Allow 2 (3) upstream forays coming from MOS (SJL)
	BCA, MOS, SJL	6	0.3	5	1 (2 from SJL)						Do not arrive at beginning of flood tide	Allow 2 (3) upstream forays coming from MOS (SJL)
	STN	6 (4)[f]	0.2	4	2	< 1,700	< 4,000	< 0.5	< 1	< 0.5		Alternative value if arrive at beginning of flood tide
	STS	3			2	< -300 (> -300)[g]	> -300 (< -300)[g]	< -0.5 (> -0.5)[g]	> -0.5 (<-0.5)[g]	< 0.2		
STN	DF	15	0.3	5	1			< -0.1			Arrive at beginning of flood tide	
	MOS, SJL, STS	15	0.3	5	1 (2 from STS)			< -0.1			Arrive at beginning of flood tide	
	DF	6	0.1	5	1						Do not arrive at beginning of flood tide	
	MOS, SJL, STS	6	0.1	5	1 (2 from STS)						Do not arrive at beginning of flood tide	
	STN	4			2	< -1,500 (> -1,500)[g]	> -1,500 (< -1,500)[g]	< -0.1 (> -0.1)[g]	> -0.1 (<-0.1)[g]	< 0.2		
C18/C16	DF	30	0.15	4	1							
	SJL, STS, STN	30	0.15	4	1							
	TCN/TCS	30	0.15	4	1		> -500	> -0.4	> -0.1	> -0.4		
	MFE/MFW	15	0.4	4	2			< -0.4	< 0.2	< 0.2		
	C18/C16	12			2			< -0.1 (> -0.1)[g]	> -0.1 (<-0.1)[g]	-0.2 to 0.2		
MFE/MFW	C18/C16	24	0.1	4	2			> -0.4				
	MFE/MFW	12			2			< -0.1 (> -0.1)[g]	> -0.1 (<-0.1)[g]	-0.2 to 0.2		
TCN/TCS	DF	30	0.15	4	1	< 1,200		< 0.2				
	SJL, STS, STN	30	0.15	4	1	< 1,200		< 0.2				
	C18/C16	30	0.15	4	2	< 1,200		< 0.2	< 0.2	< 0.2		
	TCN/TCS	12			2	< 500 (> 500)[g]	> 500 (< 500)[g]	< -0.1 (> -0.1)[g]	> -0.1 (<-0.1)[g]	-0.2 to 0.2		
TMN/TMS	MFE/MFW, CVPtank	10	0.1	3 (5)[f]	1							Alternative residence time if coming from CVPtank
	CHP, JPT	10	2.1 (0.5)[f]	3	1		< -7,000f		< -0.1[f]			Alternative migration rate, flow and velocity limits if coming from JPT
ORE	DF	3	0.3	5.5	1	> 0		> -0.1				
	DFD, BCA, PCO, MOS	3	0.3	5.5	1 (2 from MOS)	> 0		> -0.1				
	SJL	3	0.3	5.5	1	> 0	< -200	> -0.1	< -0.1	> -0.1		
	STN	3	0.3	5.5	1		< -300		< -0.5			
	ORS	3	0.3	4	2	< 0	< -2,500	< -0.1	< -0.5	< 0		
	ORE	0	100	NA	0							Not allowed.
ORS	BCA - ORE	12	0.2	5	1 (2 from ORE)	> -2,500		> -0.5				Allow 2 (3) upstream forays if coming from MOS (ORE)
	CVP	4	1.5	4	2	< -2,500	< -900	< -0.5	< -0.5		CVP pumping < 1,500 cfs at departure[e]	
	ORS	4			2	< -2,500 (> -2,500)[g]	> -2,500 (< -2,500)[g]	< -0.5 (> -0.5)[g]	> -0.5 (<-0.5)[g]			
MRS	MOS, ORE	12	0.2	5	2 (1 from MOS)							
MRN	ORS, MRS	40	0.2	5	2	> -6, 000	> -0.5					
	C18/C16, TCN/TCS, MFE/MFW	40	0.2	5	1					> -0.1		
	CVP[f], ORN	40	0.2	5	1	< -5,500		< -0.5			CVP pumping < 1,500 cfs at departure[e]	See "extra conditions" if coming from CVP
	MRN	20			2	< -2,500 (> -2,500)[g]	> -2,500 (< -2,500)[g]	< -0.5 (> -0.5)[g]	> -0.5 (<-0.5)[g]			
CVP	BCA, ORE, ORS	80 (40)[f]	0.2	4	1 (2 from ORS)	> -900		> -0.5				Alternative values if arrive at CVP after end of VAMP
	ORN	40 (20)[f]	0.8	5	2		< -700		< -0.3	< 0		Alternative values if arrive at CVP after end of VAMP
	RGU/RGD	40 (20)[f]	0.2	5	2		< -1,500		< -0.3	< 0	CCFB inflow < 2,500 cfs at departure[e]	Alternative values if arrive at CVP after end of VAMP
	MRN	40	1.1	5	2							Alternative values if arrive at CVP after end of VAMP
	SJL, STN[f]	0	100	0	0							Arrive at CVP during VAMP
	SJL[f]	40	0.3	2.2	1						CVP pumping > 1,000 at arrival	Arrive at CVP after end of VAMP
	STN[f]	40	0.6	3.8	1						CVP pumping > 1,000 at arrival	Arrive at CVP after end of VAMP
	CVPtank	8 (4)[f]	0.02	0.3	2							Alternative values if arrive at CVP after end of VAMP
	CVP	40 (20)[f]			2						Pumping < 1,500 at departure, > 1,000 at arrival	Alternative values if arrive at CVP after end of VAMP
CVPtank	CVP	20	0	NA	1							
DMC	CVP	12 (0)[f]			2 (0)[f]						CVP pumping < 1,500 cfs at departure[e]	Alternative values if arrive at CVP after end of VAMP
	DMC	12 (0)[f]			2 (0)[f]						CVP pumping < 1,500 cfs at departure[e]	Alternative values if arrive at CVP after end of VAMP
ORN	MOS, ORE, ORS	40	0.15	4	1	> -700		> -0.3				
	MRN, RGU/RGD	40	0.15	4	2	> -700[f]	> -1,500[f]	> -0.3[f]	> -0.3[f]			Flow and water velocity limits only if coming from RGU/RGD
	CVP	40	0.15	4	2	> -700	> -900	> -0.3	> -0.5		CVP pumping < 1,500 cfs at departure[e]	
	STN, C18/C16	40	0.5 (0.3)[f]	4	1							Alternative value if arrive from C18/C16
	ORN	25			2	< -700 (> -700)[g]	> -700 (< -700)[g]	< -0.3 (> -0.3)[g]	> -0.3 (<-0.3)[g]			
RGU/RGD	ORE, ORS, MRN	10 (80)[h]	0.2	4	1							
	ORN	10 (80)[h]	0.2	4	2	< -750	< -700	< -0.1	< -0.3	< 0.2		
	CVP	10 (80)[h]	0.2	4	2	> -750		> -0.1		> -0.2	CVP pumping < 1,500 cfs at departure[e]	
JPT	C18/C16, MFE/MFW, ORS	40	0.1	5	1							
	CVPtank, RGU/RGD	40	0.1	5	1							Trucking release sites are downstream of JPT
	TMN/TMS	40	0.1	5	2							
	FRE/FRW	30	0.1	5	3							
FRE/FRW	MFE/MFW, ORN	40	0.1	5	1							
	JPT	30	0.1	5	3							
CHP	Any site except CHP	40	0.1	5	1 (2)[f]		> -1,500[f]	> -0.1[f]				Flow, velocity limits only if coming from STN; alternative values coming from JPT, TMN/TMS
	CHP	30			3							

[a] Near field residence time includes up to 12 hours missing between detections.

[b] Approximate migration rate was calculated on most direct pathway.

[c] Missing values for transitions to and from single site (or between CVP and DMC): travel times must be 12 to 24 hours.

[d] Flow or velocity condition, if any, must be violated for predator classification.

[e] Condition at departure from previous site.

[f] See comments for alternative criteria.

[g] High flow/velocity on departure requires low values on arrival (and vice versa).

[h] If present in detection range < 70% of residence time, and most detections were at RGU (not RGD).

The scoring method was used to avoid placing undue weight on any single criterion. However, extra weight was given to the residence time criteria at the radial gates into the Clifton Court Forebay (sites RGU and RGD, model codes D1 and D2) in scoring, because very long residence time at these sites was both considered to be a strong indicator of predation and unlikely to be accompanied by other predation indicators. Several methods of final predator classification using the predator scores were considered, and results were compared against the full detection histories of numerous tags with a variety of types of detection histories before settling on the above method.

Criterion: Fish Speed

Fish speed was measured in two ways for each transition between detection sites and for each tag: average migration rate through the reach, and average body lengths per second through the reach. Migration rate was measured for all transitions except for return visits to the same site. Body lengths per second was based on migration rate, but accounted for water velocity and fish length at tagging.

Migration rate was defined as distance traveled divided by travel time (km/hr). Reach distances were approximated using hydrophone latitude and longitude locations and the ruler tool in Google Earth. For transitions with multiple possible pathways, the pathway deemed most likely was used. Travel time was measured as the difference between the time of final detection at the prior detection site and the time of first detection at the later detection site. The range of acceptable migration rate values was specified for each observed tag transition, allowing for a wider range in reaches with more complicated hydrology (e.g., downstream reaches and those near the water export facilities) (Table 5-8). For upstream-directed transitions, the acceptable minimum migration rate was calculated based on the joint assumptions that (1) smolts moving upstream on the scale of the study reaches were pushed upstream by reverse flow caused primarily by incoming tide, and (2) it was unlikely that tidal influences would affect smolt migration over a long time period. Thus, maximum travel times on upstream-directed transitions were set at 12 – 15 hours, allowing for non-linear or punctuated smolt movement. The minimum migration rate for upstream-directed transitions was calculated based on this maximum travel time.

Fish speed may be affected by water velocity. Thus, the perceived migration rate (as defined above) was adjusted first by the average measured water velocity in the reach during the fish transition through the reach, and then by the size of the fish at tagging. The adjusted fish velocity (V_{FA}) was estimated by $V_{FA} = m_r - V_w$, where m_r is the signed (i.e., +/-) migration rate and V_w is the signed average water velocity through the reach during the tag transition through the reach. Both migration rate and water velocity were signed (e.g., assigned + or -) to represent direction, with downstream (toward the ocean) assigned the positive direction and upstream negative. A fish that moves downstream slower than the water velocity would have $V_{FA} < 0$, while a fish that moves downstream faster than the water velocity would have $V_{FA} > 0$. Water velocity was measured at the nearest fixed-point environmental monitoring station, using data available from CDEC at http://cdec.water.ca.gov. In some cases, this station was adjacent to the acoustic receivers located at the upstream or downstream boundary of the reach; in other cases, this station was in the vicinity of the reach, but not actually in it. Each value of V_{FA} was then divided by measured body length of the study fish at tagging to produce body lengths per second (BL/S): $BL / S = V_{FA}/FL$, where FL = fish length at tagging. The values of BL/S may be either positive or negative, depending on whether the fish moved downstream or upstream and whether it moved faster than the observed water velocity. Observed measures of BL/S ranged from -13.1 to 65.5 (mean = 1.4). Hawkins and Quinn (1996) reported critical swimming speeds up to 7.5 – 7.9 BL/S for steelhead measuring approximately 100 mm. The maximum absolute value of BL/S suitable for salmon smolts was set at 8 (i.e., -8 ≤ BL/S ≤ 8), to account for uncertainty in the actual water velocity through the reach in question.

Criterion: Residence Time

Residence time was measured on three spatio-temporal scales. The near-field residence time was the duration of the visit-level detection event, where consecutive visits at a given acoustic array (i.e., a dual or redundant array, or a single line of hydrophones) were separated by either a time gap of ≥ 12 hours, or by detection elsewhere. The near-field residence time allowed for short-term delays in migration due to tidal influence (e.g., being pushed back into range of the receiver by reverse flow). Near-field behavior within the detection range of the receivers at Chipps Island was also considered, with flat line signals indicating predation (either predator or deposited tag). Maximum allowed near-field residence times for smolts were set by reviewing observed residence times in comparison with criteria used in previous years (Table 5-8; SJRGA, 2011). In addition, the hydraulic conditions upon arrival at the site were considered, with longer residence times allowed for smolts that arrived during flood tide or encountered reverse flow conditions. Discussions with salmon biologists familiar with the Delta also informed the near-field residence time criteria.

The mid-field residence time was the time delay from the first detection at a site to the time of the last detection there before detection elsewhere. That is, the mid-field residence time removed the 12-hour limit on detection gaps at a site used to define near-field residence time. Whereas the near-field residence time measured the time a tagged fish spent in or near the detection field of a receiver array, the mid-field residence time measured the time the tagged fish spent in the neighborhood of the site without detection elsewhere. Criteria for mid-field residence time were determined by near-field residence time criteria and the number of visits allowed.

The far-field residence time measured the time a tagged fish spent in the broader region of the study area. Regions were:

San Joaquin River upstream of the head of Old River,

San Joaquin River from the head of Old River through the Stockton receivers,

San Joaquin River from the Turner Cut junction through Medford Island,

Old River from its head to the Middle River junction,

Old River from the head of Middle River to Highway 4 (including the water export facilities),

Middle River from its head to Highway 4, and

San Joaquin or Sacramento River from Threemile Slough to Chipps Island, including Jersey Point and False River.

Maximum regional residence times allowed for smolts were set at 48 hours for the San Joaquin River upstream of the head of Old River (6 hours if returning from downstream of the head of Old River), and 360 hours in all other regions.

Criterion: Upstream Transitions

Salmon smolts were assumed to be migrating toward the ocean. Upstream transitions were generally considered evidence of predation. Exceptions were made to allow for initial confusion immediately after release at Durham Ferry, temporary upstream movement in the presence of reverse river flow, and multi-directional movement in the neighborhood of the water export facilities in the southwestern portion of the study area. Based on conversations with salmon biologists, it was assumed that juvenile salmon would not make lengthy or numerous upstream forays large enough to be detected by the network of acoustic receivers used in the 2011 VAMP study. A maximum of 3 upstream forays and 15 upstream river kilometers was imposed. Upstream detection sites generally had stricter upstream foray requirements (e.g., maximum of 1 or 2).

Criterion: Unexpected Transitions

Certain transitions were observed in the data but were unexpected for salmon smolts. Such unexpected transitions included those from the CVP holding tank to the receivers located near the CVP trashracks or to the hydrophone in the Delta Mendota Canal, as well as transitions from the Delta Mendota Canal back to the CVP trashrack receivers. Several tags were observed moving from the release site at Durham Ferry to the Stockton receivers in a short time period with no intervening detections. Some such transitions may have come from predators, possibly including avian predators.

Criterion: Travel Time Since Release

Overall travel time since release at Durham Ferry was considered under the expectation that smolts would complete their migration through the Delta in 15 days or less (360 hours). This assumption was assessed by comparisons with observed detection histories. Tags with longer detection histories typically violated multiple predator filter criteria. Stricter criteria for upstream detection sites were determined by criteria for migration rate, residence time, and the number of visits allowed.

Criterion: Movements Against Flow

It was assumed that salmon smolts usually moved with downstream-directed flow, or during periods of slack or flood tide. Arrival at a detection site or departure from a detection site against relatively strong flow (i.e., not near slack or flood tide) was considered evidence of predation. Dual or redundant acoustic arrays aided in determination of fish direction, but depended on high detection probabilities and non-identical detection areas.

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 (Figure 5-2, Table 5-6). 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 13 receivers located between the trash racks and the trash boom at the Central Valley Project (CVP), and from the two receivers located within the holding tanks at CVP (CVPtank). Detections were also pooled from the receivers located in the San Joaquin River just downstream of the release site (DFD), the San Joaquin

River receivers near Lathrop (SJL), the San Joaquin River receivers at the channel markers just downstream of the Turner Cut Junction (C18/C16), the Old River receivers located near the head of the river (ORE), and the receivers located just outside the radial gates in the entrance channel to Clifton Court Forebay (RGU).

Survival Model

A multi-state statistical release-recapture model was developed and used to estimate salmon smolt survival and migration route entrainment probabilities throughout the study area to a single exit point at Chipps Island (Figures 5-3, 5-4 and 5-5). The release-recapture model was similar to the model developed by Perry et al. (2010) and the model developed for the 2009 VAMP study (SJRGA, 2010) and the 2010 VAMP study (SJRGA, 2011).

Fish moving through the Delta toward Chipps Island may have used any of several routes (Figure 5-3). The two primary routes modeled were the San Joaquin River route (Route A) and the Old River route (Route B). Route A followed the San Joaquin River until it joined the Sacramento River just upstream of Chipps Island. Route A included the possibility of exiting the San Joaquin River downstream of the city of Stockton and migrating to Chipps Island through the interior Delta. Route B used Old River from its head on the San Joaquin River just upstream of Lathrop through to Chipps Island, either via the Old River confluence with the San Joaquin River just west of Mandeville Island, or through Middle River or the state and federal water export facilities. Additional subroutes were monitored for fish use, but were contained in either Route A or Route B. Subroute C consisted of Middle River from its head on Old River to its confluence with the San Joaquin west of Medford Island, as well as the water export facilities. The water export facilities formed two subroutes: fish entering the State Water Project via Clifton Court Forebay (subroute D) or the Central Valley Project (subroute E) had the possibility of being trucked from those facilities and released in either the Sacramento River or the San Joaquin River upstream of Chipps Island. Subroutes D and E were both contained in subroute C (Middle River), while subroutes C, D, and E were all contained in route B (Old River). Finally, fish that remained in the San Joaquin River past Stockton may have exited the San Joaquin River via Turner Cut and migrated to Chipps Island via the interior Delta either through the confluence of Middle River or Old River with the San Joaquin River, or through the water export facilities (subroute F). Although subroute F included trucking from the water export facilities, passage of subroute F fish through subroutes D and E was not modeled directly. Fish in routes A, B, C, and F all had multiple unmonitored pathways available for passing through the Delta to Chipps Island.

Several exit points from the mainstem San Joaquin River were monitored and given route names for convenience, although these location did not actually determine a unique route to Chipps Island. The first encountered was Paradise Cut (Route P), which is accessible from the San Joaquin River between Durham Ferry and Banta Carbona in high water conditions. In low or normal water conditions, Paradise Cut is inaccessible. Fish that entered Paradise Cut may have entered Old River downstream of the junction with Middle River, and have moved either to the water export facilities or to downstream reaches of Old River or Middle River. Because Paradise Cut originates upstream of Mossdale Bridge, it was located outside of the study area, and was monitored to account for entry to Old River via that route. Another departure point from the San Joaquin River was False River, just east of Jersey Point. Fish entering False River from the San Joaquin River would have entered the interior Delta headed away from Chipps Island, and would not be expected to reach Chipps Island without detection in another route. Thus, False River was considered an exit point of the study area, rather than a waypoint on a route to Chipps Island. Although departure at False River was unexpected for a live migrating salmon smolt, the presence of reverse tidal flows in this region combined with potentially high mortality made this type of detection history possible. False River was given a route name (H) for convenience. Both Jersey Point and Chipps Island were included in multiple routes. Jersey Point was included in many of the previously named routes (in particular, routes A, B, C, and F), while Chipps Island (the final exit point) was included in all previously named routes and subroutes except routes P and H. Thus, Jersey Point and Chipps Island were given their own route name (G). An additional set of receivers located in Threemile Slough (Route T) and a single receiver in the Delta Mendota Canal (accessed via Route E) were not used in the survival model. The routes and the study area exit points 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 = Jersey Point, Chipps Island: survival, exit point

H = False River: exit point

P = Paradise Cut: survival

T = Threemile Slough: not used in survival model

Figure 5-3
Locations of Acoustic Receivers ("Detection Sites") Used in the Statistical Survival Model for the 2011 VAMP Study, Including Locations of Acoustic Receivers Deployed by the California Department of Water Resources for the South Delta Temporary Barriers Project Study. Site A1 is the Release Site at Durham Ferry. Sites A0, E3, P1, and T1 Were Excluded from the Survival Model.

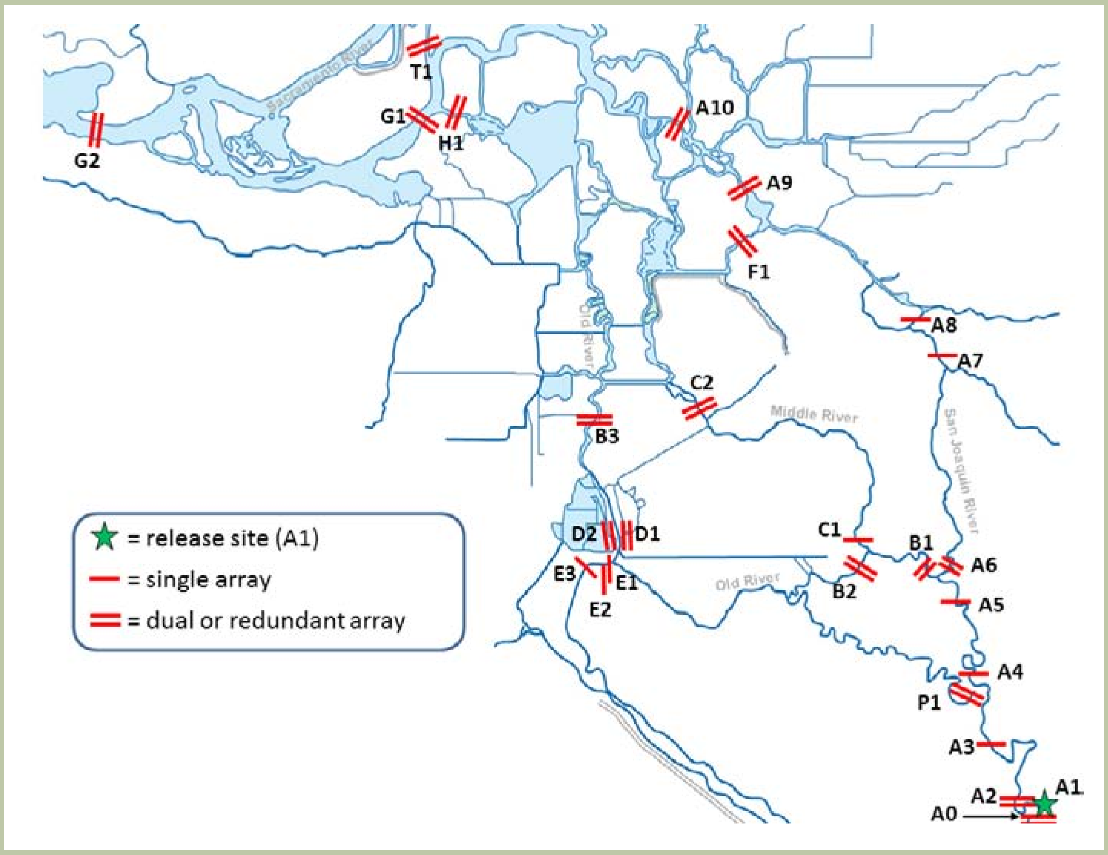


Figure 5-4

Schematic of Mark-Recapture Model Showing Estimable Parameters for Acoustic-Tagged Juvenile Chinook Salmon Tagged and Released in the 2011 VAMP Study, Using the Layout of Telemetry Stations in Figure 5-3. Parameters Include: Probabilities of Survival (S_{hi}), Route Entrainment (ψ_{hl}), Transition ($\phi_{kj,hi}$), and Detection (P_{hi}). Single Lines Denote Single-Array or Pooled Telemetry Stations, and Double Lines Denote Double-Array Telemetry Stations. Names of Telemetry Stations Correspond to Site Labels in Figure 5-3. Migration Pathways to Sites B3 (ORN), C2 (MRN), D1 (RGU), and E1 (CVP) are Color-Coded by Departure Site.

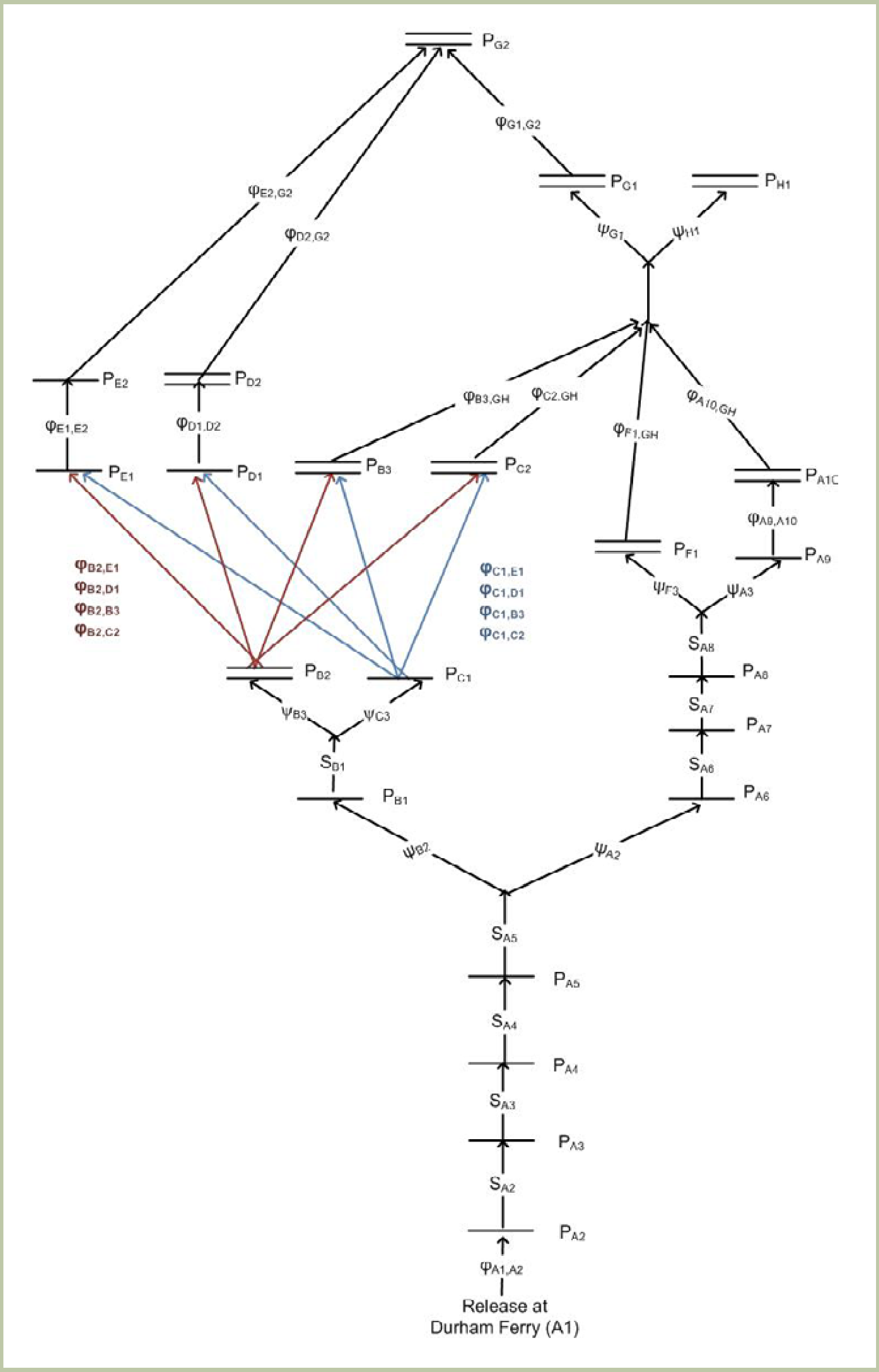


Figure 5-5

Schematic of Simplified Mark-Recapture Model Showing Estimatble Parameters for Acoustical-Tagged Juvenile Chinook Salmon in Release Group 3 of 2011 VAMP Study, Using the Layout of Telemetry Stations in Figure 5-3. Parameters Include: Probabilities of Survival (S_{hi}), Route Entrainment (ψ_{hl}), Transition ($\phi_{kj,hi}$), and Detection (P_{hi}). Single Lines Denote Single-Array or Pooled Telemetry Stations, and Double Lines Denote Double-Array Telemetry Stations. Names of Telemetry Stations Correspond to Site Labels in Figure 5-3

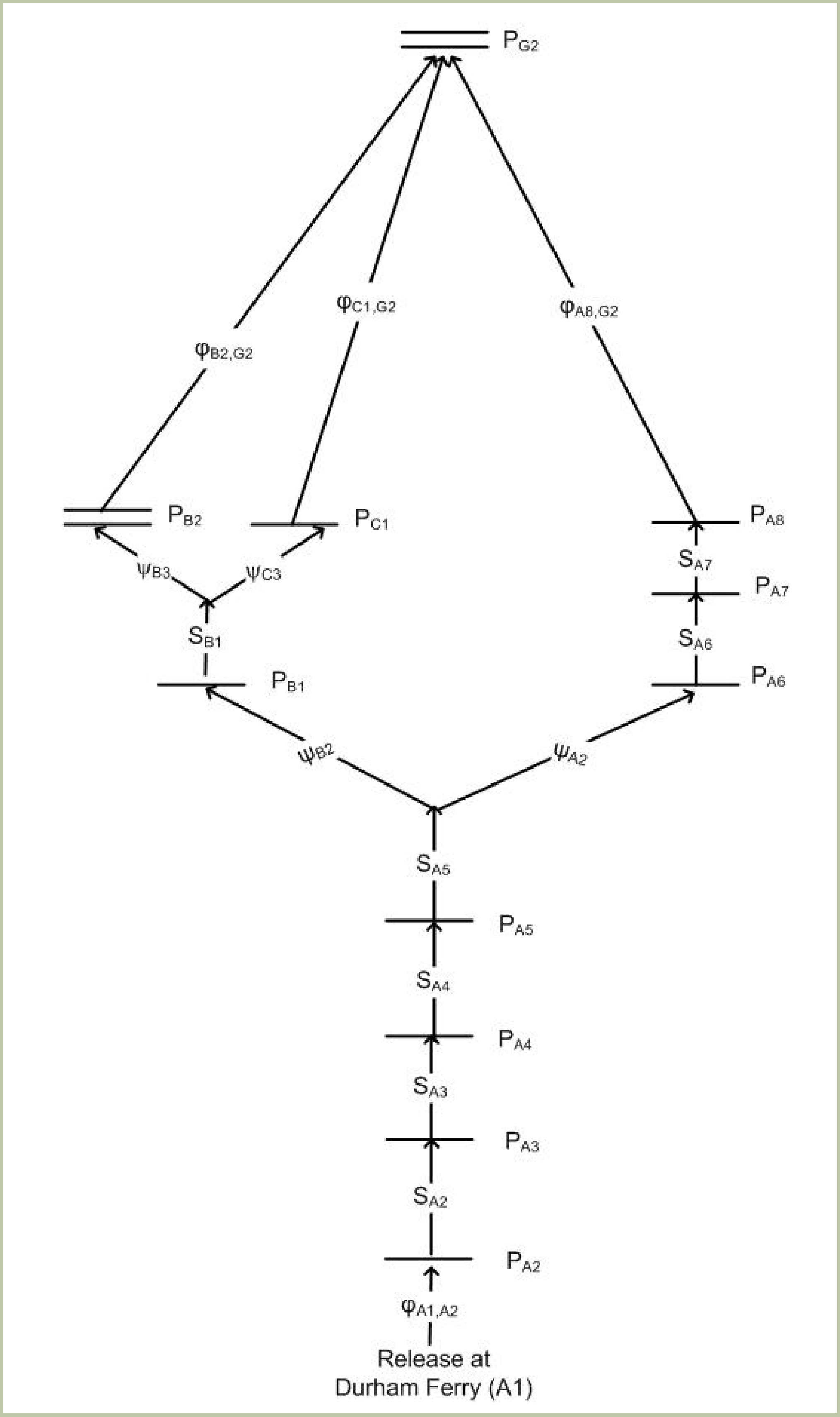


Figure 5-3 shows the layout of the receivers with the labels used in the survival model and in the predator filter. Each site is identified by route (A – G, P, or T) and the index of site within the route (0 – 10). Individual receivers comprising dual arrays were identified separately, with "a" representing the upstream receiver and "b" representing the downstream receiver.

Some detection sites (receivers) were used in the predator filter but were omitted from the survival model. These sites were the dual receivers located just upstream of the release site (A0a, A0b), the receivers located inside Paradise Cut (P1a, P1b), the single receiver located inside the Delta Mendota Canal (E3), and the dual receivers in Threemile Slough (T1a, T1b). The Paradise Cut dual array was omitted because no detections were recorded on those receivers from any release groups. This was consistent with the assumption that reduced river flow had closed access to Paradise Cut by the time of the first Chinook salmon release in mid-May. Detections were omitted from the receivers just upstream of the release site (A0a, A0b) because very few tags were detected there (22 out of 1,895), and these detections did not contribute to survival estimation through the study area. Additionally, detections from the single hydrophone located nearest the north shore in the eastern acoustic receiver line at Chipps Island (CHPn, system 515; Table 5-6) were omitted from the survival model because the entrance to Spoonbill Creek, just west of this hydrophone, violated the closure assumption of the dual array at Chipps Island. The locations of the remaining hydrophones at Chipps Island were deemed far enough from the entrance to Spoonbill Creek to make detections on those receivers unlikely to violate the closure assumption.

The release-recapture model used parameters denoting 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 ($\phi_{kj,hi}$) (Figures 5-4, 5-4 and Table 2 in Appendix H). 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 80 parameters for each release occasion: 39 detection probabilities, 8 survival probabilities, 5 route entrainment probabilities, and 28 transition probabilities. The model parameters were:

P_{hi} = detection probability: probability of detection at telemetry station i within route h, conditional on surviving to station i, where i = *ia, ib* for the upstream, downstream receivers in a 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, 3), 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 parameter ψ_{A1} is the probability of remaining in the San Joaquin River at the head of Paradise Cut. Because no Chinook salmon tags were actually detected on the receivers located inside Paradise Cut in 2011, it was assumed that Paradise Cut was inaccessible by the time of the first Chinook salmon releases. Thus, it was assumed that ψ_{A1} =1, and this parameter was omitted from the survival model and from Figures 5-4 and 5-5.

The transition and detection parameters involving the receivers 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), these fish could linger in the area until the gates open. Thus, parameters $\phi_{B2,D1O}$, $\phi_{C1,D1O}$ and $\phi_{D1O,D2}$ represented transition to and from site D1 when the gates were open, and parameters $\phi_{B2,D1C}$, $\phi_{C1,D1C}$, and $\phi_{D1C,D2}$ represented transition to and from D1 when the gates were closed. It was not possible to estimate unique detection probabilities at D1 for times when the gates were closed versus when the gates were open. Differences in D1 transition probabilities attributable to gate status were assessed using the Akaike Information Criterion (AIC), with an AIC ≥ 2 indicating a significant effect of gate status (Burnham and Anderson, 2002). In the case where there was no significant effect of gate status, common transition probabilities at D1 were used regardless of gate status. It was also not possible to estimate the detection probability at CVPtank (in the holding tanks at the Central Valley Project) because there were no receivers located downstream of this detection site and unique to subroute E. Therefore, it was necessary to assume that the detection probability at this site was 100% (i.e., P_{E2} = 1). Because site E2 consisted of receivers located in the constrained environment of the holding tanks, this assumption was deemed reasonable as long as the monitoring equipment was operating. Records of receiver performance indicated no outages at site E2 during the 2011 tagging study.

A variation on the parameter naming convention was used for parameters representing the transition probability to the junction of False River with the San Joaquin River (site H1), just upstream of Jersey Point (Figure 5-3). This river junction marks the distinction between routes G and H, so transition probabilities to this junction were named $\phi_{kj,GH}$, for the joint probability of surviving and moving from station *j* in route *k* to the False River junction. Once at the junction between the San Joaquin River and False River, fish in the San Joaquin River may have either exited to False River or else remained in the San Joaquin River to reach Jersey Point. Alternatively, fish that approached the San Joaquin River from the interior Delta through False River may have either moved downstream in the San Joaquin River to Jersey Point, or else moved upstream away from Jersey Point (deemed less likely for migrating smolts). The complex tidal forces present in this region precluded distinguishing between smolts using False River as an exit from the San Joaquin River and smolts using False River as an entrance to the San Joaquin River. Thus, the available information included whether a fish was at False River, but not its direction of movement there. Regardless of which approach the fish used to reach this junction, the $\phi_{kj,GH}$ parameter (i.e., $\phi_{A10,GH}$, $\phi_{B3,GH}$, $\phi_{C2,GH}$ or $\phi_{F1,GH}$) was the transition probability to the junction of False River with the San Joaquin River, via any route; ψ_{G1} was the probability of moving downstream toward Jersey Point from the junction; and $\psi_{H1} = 1\text{-}\psi_{G1}$ was the probability of exiting (or re-exiting) the San Joaquin River to False River from the junction (Figure 5-4).

For fish that reached the interior receivers at the Clifton Court Forebay (D2) or the Central Valley Project (E2), the parameters $\phi_{D2,G2}$ and $\phi_{E2,G2}$, respectively, represented the joint probability of migrating and surviving to Chipps Island, including survival during and after collection and transport (Figure 5-4). The parameter $\phi_{D2,G2}$ also included survival through the Clifton Court Forebay and into the holding tank at the State Water Project. Some salvaged and transported smolts were released in the San Joaquin River between Jersey Point and Chipps Island, and others were released in the Sacramento River upstream of the confluence with the San Joaquin River. Only the overall probability of making the transition to Chipps Island was estimated for fish passing through the water export facilities.

In addition to the model parameters, derived performance metrics measuring migration route probabilities and survival were estimated as functions of the model parameters. Both route entrainment (i.e., route use or route selection) and route-specific survival were estimated for the two primary routes determined by routing at the head of Old River (routes A and B). Route entrainment and route-specific survival were also estimated on a finer spatial scale, in particular for the major subroutes of routes A and B. These subroutes were identified by a two-letter code, with the first letter indicating the route used at the head of Old River (A or B), and the second letter indicating the route used at the next river junction encountered: A or F at the Turner Cut Junction, and B or C at the head of Middle River. Thus, the route entrainment probabilities for the subroutes were:

$\psi_{AA} = \psi_{A2}\psi_{A3}$: probability of remaining in the San Joaquin River past the head of Old River and the Turner Cut Junction,

$\psi_{AF} = \psi_{A2}\psi_{F3}$: probability of remaining in the San Joaquin River past the head of Old River, and exiting to the interior Delta at Turner Cut,

$\psi_{BB} = \psi_{B2}\psi_{B3}$: probability of entering Old River at the head of Old River, and remaining in Old River past the head of Middle River,

$\psi_{BC} = \psi_{B2}\psi_{C3}$: probability of entering Old River at the head of Old River, and entering Middle River at the head of Middle River,

where $\psi_{B2} = 1\text{-}\psi_{A2}$, $\psi_{F3} = 1\text{-}\psi_{A3}$, and $\psi_{C3} = 1\text{-}\psi_{B3}$. The probability of surviving from the entrance of the Delta near Mossdale Bridge (site A5, MOS) through an entire migration pathway to Chipps Island was estimated as the product of survival probabilities that trace that pathway:

$S_{AA} = S_{A5}S_{A6}S_{A7}S_{A8}\phi_{A9,\,A10}\phi_{A10,G2}$: Delta survival for fish that remained in the San Joaquin River past the head of Old River and Turner Cut,

$S_{AF} = S_{A5}S_{A6}S_{A7}S_{A8}\phi_{F1,G2}$: Delta survival for fish that entered Turner Cut from the San Joaquin River,

$S_{BB} = S_{A5}S_{B1}S_{B2}$: Delta survival for fish that entered Old River at its head, and remained in Old River past the head of Middle River,

$S_{BC} = S_{A5}S_{B1}S_{C1}$: Delta survival for fish that entered Old River at its head, and entered Middle River at its head.

The parameters $\phi_{A10,G2}$ and $\phi_{F1,G2}$ represent the probability of getting from A10 and F1, respectively, to Chipps Island. Both parameters represent multiple pathways around or through the Delta to Chipps Island (Figure 5-3). For example, for fish that reached the Medford Island receivers on the San Joaquin River (site A10), the simplest pathway was to remain in the San Joaquin past Jersey Point to Chipps Island (Figure 5-3).

Alternatively, these fish may have reached Jersey Point via the confluence of Old River with the San Joaquin River, Frank's Tract, and False River on their way to Chipps Island. In either case, the probability of getting from the Medford Island receivers to Chipps Island is written as $\phi_{A10,G2} = \phi_{A10,GH}\psi_{G1}\phi_{G1,G2}$. Fish that left the San

Joaquin River at Turner Cut also had multiple ways of reaching Chipps Island. One option was to use interior, unmonitored channels to reach False River, Jersey Point, and Chipps Island, with probability $\phi_{F1,G2} = \phi_{F1,GH}\psi_{G1}\phi_{GH,G2}$. The parameter $\phi_{F1,GH}$ represents all ways of getting to the False River junction via the unmonitored channels of the northern interior Delta, as well as returning to the San Joaquin River downstream of Medford Island and migrating to Jersey Point in the river. Other migration options for Turner Cut fish used monitored routes (e.g., the water export facilities), but were nevertheless not modeled directly.

Survival probabilities S_{B2} and S_{C1} represented survival of fish that remained in the Old River at B2 (ORS), or entered the 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) (Figures 5-3 and 5-4). Each of these routes leads eventually to Chipps Island (G2). 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 5-4). However, the overall survival probability from B2 (S_{B2}) or C1 (S_{C1}) to Chipps Island could be defined by summing products of the $\phi_{kj,hi}$ parameters:

$$S_{B2} = \left(\phi_{B2,D1O}\phi_{D1O,D2} + \phi_{B2,D1C}\phi_{D1C,D2}\right)\phi_{D2,G2} + \phi_{B2,E1}\phi_{E1,E2}\phi_{E2,G2} + \left(\phi_{B2,B3}\phi_{B3,GH} + \phi_{B2,C2}\phi_{C2,GH}\right)\psi_{G1}\phi_{G1,G2}$$

$$S_{C1} = \left(\phi_{C1,D1O}\phi_{D1O,D2} + \phi_{C1,D1C}\phi_{D1C,D2}\right)\phi_{D2,G2} + \phi_{C1,E1}\phi_{E1,E2}\phi_{E2,G2} + \left(\phi_{C1,B3}\phi_{B3,GH} + \phi_{C1,C2}\phi_{C2,GH}\right)\psi_{G1}\phi_{G1,G2}$$

Fish leaving the southern Delta in Old River or Middle River past the Highway 4 receivers (B3 or C2, respectively) may have used any of several routes to reach Chipps Island. These fish may have remained in Old or Middle rivers until these rivers rejoined the San Joaquin River downstream of Medford Island, and then migrated in the San Joaquin River. Alternatively these fish may have passed through Frank's Tract and False River or Fisherman's Cut to rejoin the San Joaquin River. Although these routes were largely unmonitored, all fish moving from Highway 4 to Chipps Island must have passed Jersey Point (site G1), located on the San Joaquin River just downstream of the junction with False River (site H1). Thus, both S_{B2} and S_{C1} used the transition probabilities $\phi_{B3,GH}$ and $\phi_{C2,GH}$ to represent the probability of moving from site B3 or C2, respectively, to the False River junction with the San Joaquin River.

In cases where the use of unique D1 transition probabilities by gate status introduced no significant improvement to model fit (according to AIC < 2), the S_{B2} and S_{C1} parameters were defined as follows:

$$S_{B2} = \phi_{B2,D1}\phi_{D1,D2}\phi_{D2,G2} + \phi_{B2,E1}\phi_{E1,E2}\phi_{E2,G2} + \left(\phi_{B2,B3}\phi_{B3,GH} + \phi_{B2,C2}\phi_{C2,GH}\right)\psi_{G1}\phi_{G1,G2}$$

$$S_{C1} = \phi_{C1,D1}\phi_{D1,D2}\phi_{D2,G2} + \phi_{C1,E1}\phi_{E1,E2}\phi_{E2,G2} + \left(\phi_{C1,B3}\phi_{B3,GH} + \phi_{C1,C2}\phi_{C2,GH}\right)\psi_{G1}\phi_{G1,G2}$$

Both route entrainment and route-specific survival were estimated on the large routing scale, as well, focusing on routing only at the head of Old River. The route entrainment parameters were defined as:

$\psi_A = \psi_{A2}$: probability of remaining in the San Joaquin River at the head of Old River

$\psi_B = \psi_{B2}$: probability of entering Old River at the head of Old River.

The probability of surviving from the entrance of the Delta (site A5, MOS) through an entire large-scale migration pathway to Chipps Island can be written as a function of the finer-scale route-specific survival probabilities and route-entrainment probabilities:

$S_A = \psi_{A3}S_{AA} + \psi_{F3}S_{AF}$: Delta survival (from Mossdale to Chipps Island) for fish that remained in the San Joaquin River at the head of Old River, and

$S_B = \psi_{B3}S_{BB} + \psi_{C3}S_{BC}$: Delta survival for fish that entered Old River at the head of Old River.

Using the estimated migration route probabilities and route-specific survival for these two primary routes (A and B), survival of the population from A5 (Mossdale) to Chipps Island was estimated as:

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

Survival was also estimated from Mossdale to the Jersey Point/False River junction, both by route and overall. Survival through this region ("Mid-Delta" or MD) was estimated only for fish that migrated entirely in-river, without being trucked from either of the water export facilities. Thus, the route-specific Mid-Delta survival for the large-scale San Joaquin River and Old River routes was defined as follows:

$S_{A(MD)} = S_{A5}S_{A6}S_{A7}S_{A8}\left(\psi_{A3}\phi_{A9,A10}\phi_{A10,GH} + \psi_{F3}\phi_{F1,GH}\right)$: Mid-Delta survival for fish that remained in the San Joaquin River past the head of Old River, and

$S_{B(MD)} = \psi_{B3}S_{BB(MD)} + \psi_{C3}S_{BC(MD)}$:

Mid-Delta survival for fish that entered Old River at its head, and remained in Old River past the head of Middle River, where

$$S_{BB(MD)} = S_{A5}S_{B1}\left(\phi_{B2,B3}\phi_{B3,GH} + \phi_{B2,C2}\phi_{C2,GH}\right), \text{ and}$$

$$S_{BC(MD)} = S_{A5}S_{B1}\left(\phi_{C1,B3}\phi_{B3,GH} + \phi_{C1,C2}\phi_{C2,GH}\right).$$

Total Mid-Delta survival (i.e., from Mossdale to the Jersey Point/False River junction) was defined as $S_{Total(MD)} = \psi_A S_{A(MD)} + \psi_B S_{B(MD)}$. Mid-Delta survival was estimated only for those release groups with sufficient tag detections to model transitions through the entire south Delta and to the Jersey Point/False River junction.

In order to compare 2011 results with results from the 2009 study, when no detections were available from Chipps Island, regional survival ("Southern Delta", or SD) was also estimated through the southern portion of the Delta, both within each primary route and overall:

$$S_{A(SD)} = S_{A5}S_{A6}S_{A7}S_{A8}, \text{ and}$$

$$S_{B(SD)} = S_{A5}S_{B1}\left(\psi_{B3}S_{B2(SD)} + \psi_{C3}S_{C1(SD)}\right)$$

where $S_{B2(SD)}$ and $S_{C1(SD)}$ are defined as:

$$S_{B2(SD)} = \phi_{B2,B3} + \phi_{B2,C2} + \phi_{B2,D1O} + \phi_{B2,D1C} + \phi_{B2,E1}, \text{ and}$$

$$S_{C1(SD)} = \phi_{C1,B3} + \phi_{C1,C2} + \phi_{C1,D1O} + \phi_{C1,D1C} + \phi_{C1,E1}.$$

In the absence of a gate effect on transitions probabilities at D1, $S_{B2(SD)}$ and $S_{C1(SD)}$ were defined as:

$$S_{B2(SD)} = \phi_{B2,B3} + \phi_{B2,C2} + \phi_{B2,D1} + \phi_{B2,E1}, \text{ and}$$

$$S_{C1(SD)} = \phi_{C1,B3} + \phi_{C1,C2} + \phi_{C1,D1} + \phi_{C1,E1}.$$

Total survival through the Southern Delta was defined as:

$$S_{Total(SD)} = \psi_A S_{A(SD)} + \psi_B S_{B(SD)}.$$

In some cases (i.e., release group 3), sparse detections on receivers in the interior Delta or downstream San Joaquin River receivers prevented fitting the full survival model to the detection histories. In these cases, the model was simplified to estimate Delta survival on a larger spatial scale than in the full model. In particular, subroute F was not distinguished from the primary San Joaquin River Route (A), and the routes through the interior Delta were not modeled. Instead, the overall probability of transition from the northern Stockton receiver (A8, STN) to Chipps Island was estimated directly (parameter $\phi_{A8,G2}$), along with transition probabilities from ORS (B2) and MRS (C1) to Chipps Island (parameters $\phi_{B2,G2}$ and $\phi_{C1,G2}$, respectively) (Figure 5-5). Although transition probabilities to the Central Valley Project trashracks (E1) and the radial gates at the Clifton Court Forebay (D1) could not be estimated, it was possible to use the tags detected at those sites to estimate transition probabilities through the CVP and Clifton Court Forebay to Chipps Island. This approach provided for relatively robust estimation of parameters in the southern Delta along with total Delta survival and route-specific survival in the primary routes.

In other cases (i.e., release group 2), sparse detections on receivers located at Jersey Point and False River prevented fitting the full survival model through that region. In these cases, the model was simplified to estimate Delta survival without the Jersey Point and False River parameters for routes A, B, C, and F. Instead, transition probabilities were estimated directly from the final sites in these routes to Chipps Island. For example, the transition probability $\phi_{A10,G2}$ was estimated directly from the model, replacing the product $\phi_{A10,GH}\psi_{G1}\phi_{G1,G2}$. Likewise, the parameters $\phi_{B3,G2}$, $\phi_{C2,G2}$, and $\phi_{F1,G2}$ were estimated from the model directly.

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 A2 A4 A6 A7 A8 A9 G1a0 G2ab represented a tag that was released at Durham Ferry and detected just downstream of the release site (A2), on the San Joaquin River receiver just downstream of Paradise Cut (A4), at Lathrop (A6), on both receivers near Stockton (A7, A8), at the channel marker array in the San Joaquin River just downstream of Turner Cut (A9), on the first receiver located at Jersey Point (G1a0), and at both receivers at Chipps Island (G2ab). This detection history had probability

$$\phi_{A1,A2}P_{A2}S_{A2}(1-p_{A3})S_{A3}P_{A4}S_{A4}(1-P_{A5})S_{A5}\psi_{A2}P_{A6}S_{A6}P_{A7}S_{A7}P_{A8}S_{A8}$$
$$\times\ \psi_{A3}P_{A9}\phi_{A9,A10}\left(1-P_{A10}\right)\phi_{A10,GH}\psi_{G1}P_{G1a}\left(1-P_{G1b}\right)\phi_{G1,G2}P_{G2a}P_{G2b}.$$

A second example was the detection history DF A3 A4 A5 B2ab D1O D2b0. A fish with this detection history was released at Durham Ferry, migrated downstream without detection on the receivers just downstream of Durham Ferry but with detection at Banta Carbona (A3), the San Joaquin site just downstream of Paradise Cut (A4), and at the site near Mossdale Bridge (A5), entered Old River without detection until the array in Old River just past the head of Middle River (B2ab), and then moved to Clifton Court Forebay with detection at the receivers outside the radial gates when the gates were open (D1O), and finally on the downstream receiver inside the radial gates (D2b0). The tag was not detected again after passing the inside receiver. The probability of having this detection history was

$$\phi_{A1,A2}(1-P_{A2})S_{A2}P_{A3}S_{A3}P_{A4}S_{A4}P_{A5}S_{A5}\psi_{B2}(1-P_{B1})S_{B1}\psi_{B3} \times P_{B2a}P_{B2b}\phi_{B2,D1O}P_{D1O}\phi_{D1O,D2}\left(1-P_{D2a}\right)P_{D2b}\chi_{D2},$$

where

$$\chi_{D2}=1-\phi_{D2,G2}+\phi_{D2,G2}(1-P_{G2a})(1-P_{G2b})$$

was the probability of not being detected again after reaching site D2.

A third example of a detection history was DF A2 A3 A5 B1 C1 B3ab H1a0. A fish with this detection history moved downstream after release at Durham Ferry, with detection on the receivers at the downstream Durham Ferry site (A2), at Banta Carbona (A3), and at Mossdale (A5). The fish then entered Old River with detection at ORE (B1), entered Middle River (C1), moved to the Old River site near Highway 4 and was detected on both receivers there (B3ab), and was last detected on the first receiver of the dual array located at False River (H1a0). The probability of this detection history occurring was parameterized as

$$\phi_{A1,A2}P_{A2}S_{A2}P_{A3}S_{A3}(1-P_{A4})S_{A4}P_{A5}S_{A5}\psi_{B2}P_{B1}S_{B1}\psi_{C3}P_{C1} \times \phi_{C1,B3}P_{B3a}P_{B3b}\phi_{B3,GH}\psi_{H1}P_{H1a}\left(1-P_{H1b}\right).$$

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

Release and detection data were organized by tag into four release groups, ranging in size from 473 to 475. The first two release groups were released on the San Joaquin River at Durham Ferry during the VAMP period (Table 5-3), and the last two release groups were released at Durham Ferry after the VAMP period (Table 5-4). For each release group, 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, software developed at the University of Washington (Lady and Skalski, 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: 7-9). Sparse data meant that some parameters could not be freely estimated for some release groups. For example, for release group 1, only 2 tags were detected at the Middle River South receiver (MRS, site C1). Such few detections prevented estimation of the detection probability at that site, thus site C1 was removed from the model and performance metrics were redefined accordingly. In all cases, 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. For each release, the complete data set that included possible detections from predatory fish was analyzed separately from the reduced data set restricted to detections classified as salmon smolt detections. Population-level estimates of parameters and performance measures were estimated from fitting the survival model to the pooled data set, using all four release groups. This is approximately equivalent to calculating a weighted average of the release-specific estimates, with weights proportional to release size, in the case where all releases provide each parameter estimate. In the event that some parameters are inestimable from particular releases because of sparse data, pooling across release groups provides more robust parameter estimates than a weighted average.

The significance of the radial gates status on arrival at the outside receiver (RGU, site D1) was assessed for all release groups pooled, using a difference in Akaike Information Criterion (AIC) ≥ 2 to indicate a significant difference in model fit (Burnham and Anderson, 2002). If the effect of the gates was found to be insignificant using this criterion, then a simplified model was used for parameter estimation in which $\phi_{B2,D1O}=\phi_{B2,D1C}$, $\phi_{C2,D1O}=\phi_{C1,D1C}$, and $\phi_{D1O,D2}=\phi_{D1C,D2}$. For each model, goodness-of-fit was assessed visually using Anscombe residuals (McCullagh and Nelder, 1989).

For each release group, the effect of primary 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

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

The parameter V was estimated using Program USER. It was also tested whether tagged Chinook salmon smolts 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:

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

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

Analysis of Tag Failure

The first of the two tag-life studies began on May 23rd, with the last tag failure recorded on July 4th. The second study began on July 12th, with the last tag failure recorded on August 21st. Observed tag survival was modeled using the 4-parameter vitality curve model (Li and Anderson, 2009).

Receiver malfunction during the May tag-life study resulted in missing failure times for three tags, resulting in interval-censored failure time data for these three tags (e.g., failure occurred sometime between day 25.9 and day 26.4). Although the precise failure times were missing, the failure time intervals for these tags were accounted for in the observed cumulative tag survival (i.e., the proportion of tags surviving to a given time). Several methods were used to account for the missing data while fitting the tag survival model, and the fit of the resulting models to the observed (non-missing) survival data was compared. One approach censored the missing values with no attempt to impute the missing failure times. An alternative method iteratively generated random failure times within the observed failure intervals, and estimated parameters of the tag survival model using averages over the iterations. The censoring method resulted in a superior model fit to the observed survival data. Thus, results from the censoring method are reported and were used to adjust fish survival estimates from the salmon survival study for tag failure.

Tag life is expected to vary with both tag period and water temperature. Differences in observed tag life were investigated both between the May and July tag-life studies, and among tags with different periods. For each tag-life study, both the observed tag survival data and the fit of the estimated tag survival model to the data were examined graphically. Two methods of stratifying the combined tag survival data from the two tag-life studies were compared: (1) stratify by study month (i.e., May vs. July) and group across all tag periods, and (2) stratify by tag period (i.e., 5000-7999 vs. 8000-11000) and group across month. Stratifying by both study month and tag period resulted in small sample sizes, and so was not considered. For the second method, data from the two tag-life studies were pooled. It was necessary to impute values for the missing data when calculating cumulative tag survival in the pooled data set. In this case, the use of randomly generated failure times was compared to the conservative approach of using the latest possible failure time from the interval of missing data. The conservative approach produced a better model fit to the observed survival data. The imputed failure times were censored for fitting of the tag survival model. Both methods of stratification were compared to the full data set that pooled across month and tag period using the AIC. The stratification method associated with the smallest AIC was used to fit the final tag survival model, and used for adjustments to the fish survival estimates for tag failure.

The resulting tag-survival model was used to adjust estimated fish survival and transition probabilities for premature tag failure using methods adapted from Townsend et al. (2006). 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 (e.g., San Joaquin route vs. Old River route), travel time and the probability of tag survival to Chipps Island were estimated separately for the different routes. Subroutes using truck transport were handled separately from subroutes using only in-river travel. 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 was expected to be small.

Analysis of Tagger Effects

Tagger effects were assessed using contingency tests of independence on the number of tag detections at key detection sites throughout the study area. Specifically, a lack of independence (i.e., heterogeneity) between the detections distribution and tagger was tested using a chi-squared test (α=0.05; Sokal and Rohlf, 1995). Lack of independence may be caused by differences in survival, route entrainment, or detection probabilities. The reduced data set (without predator detections), pooled over release groups, 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 harmonic mean was used to summarize travel times.

Route Entrainment Analysis

The effects of changes in hydrologic conditions on route entrainment at the head of Old River were explored using statistical generalized linear models (GLMs) with a binomial error structure and logit link (McCullagh and Nelder, 1989). Acoustic tag detections used in this analysis were restricted to those detected at either of the acoustic receiver arrays just downstream of the head of Old River: site SJL (model code A6) or site ORE (code B1). Predator-type detections were excluded. Detections from a total of 1,575 tags were used in this analysis.

Hydrologic conditions were represented in several ways, primarily total river flow (discharge) and water velocity. Flow and water velocity were recorded at 15-minute intervals at DWR gaging stations located just downstream of the head of Old River in both the San Joaquin River (station SJL) and Old River (station OH1) (Table 5-7). Conditions measured at the SJL station were labeled route A, and conditions at the OH1 station were labeled route B.

For each tag, conditions were measured at the estimated time of arrival of the tagged fish at the gaging station in its route. Time of arrival had to be estimated because the acoustic receivers were located at some distance from the gaging stations (0.34 to 0.93 km). Arrival time for tag i (t_i) was estimated based on the first-order assumption of constant movement during the transition from the previous detection site.

The gaging stations typically recorded flow and velocity measurements every 15 minutes. Some observations were missing. In 2011, measurements at the SJL station were sporadic before May 20th. Linear interpolation was used to estimate the flow and velocity conditions at the time of tag arrival at the gauging station:

$$Q_{ih} = w_i Q_{t_1(i)h} + (1 - w_i) Q_{t_2(i)h}$$

$$V_{ih} = w_i V_{t_1(i)h} + (1 - w_i) V_{t_2(i)h}$$

where $Q_{t_1(i)h}$ ($V_{t_1(i)h}$) and $Q_{t_2(i)h}$ ($V_{t_2(i)h}$) are the two observed measures of flow (velocity) at the gaging station in route h (h=A,B) nearest in time to the time t_i of tag i arrival such that $t_1 \leq t_i \leq t_2$. The weights w_i were defined as

$$w_i = \frac{t_{2(i)} - t_i}{t_{2(i)} - t_{1(i)}} ,$$

and resulted in weighting Q_{ih} and V_{ih} toward the closest flow or velocity observation.

In cases with a short time delay between consecutive flow and velocity observations (i.e., $t_2 - t_1 \leq 60$ minutes), the change in conditions between the two time points was used to represent the tidal stage (Perry, 2010):

$$\Delta Q_{ih} = Q_{t_2(i)h} - Q_{t_1(i)h}$$

$$\Delta V_{ih} = V_{t_1(i)h} - V_{t_1(i)h}$$

for h = route A or B and tag i.

The proportion of total flow entering each river at the time of tag arrival was measured as

$$pQ_{iA} = \frac{Q_{iA}}{Q_{iA} + Q_{iB}} \text{ into the San Joaquin River, and}$$

$$pQ_{iB} = 1 - pQ_{iA} \quad \text{into Old River.}$$

Likewise, the flow proportion into the San Joaquin River was measured at the two time points before and after tag arrival:

$$pQ_{t_1(i)A} = \frac{Q_{t_1(i)A}}{Q_{t_1(i)A} + Q_{t_1(i)B}} \quad \text{and}$$

$$pQ_{t_2(i)A} = \frac{Q_{t_2(i)A}}{Q_{t_2(i)A} + Q_{t_2(i)B}} .$$

If $t_2 - t_1 \leq 30$ minutes, then the change in flow proportion into the San Joaquin River at the time of arrival of tag i was measured by

$$\Delta pQ_{iA} = pQ_{t_2(i)A} - pQ_{t_1(i)A}.$$

In the event of negative flow into the San Joaquin River (i.e., $Q_{iA} < 0$), the flow proportion into the San Joaquin River pQ_{iA} was negative. Negative values of pQ_{iA} close to 0 indicated a small proportion of negative flow past the SJL gauging station relative to OH1 flow, while negative values farther from 0 indicated a larger proportion of negative flow past the SJL gaging station.

Flow reversal in the San Joaquin River was represented by the indicator variable U (Perry, 2010):

$$U_i = \begin{cases} 1, & Q_{iA} < 0 \\ 0, & Q_{iA} \geq 0 \end{cases}$$

Daily export rate was measured at the Central Valley Project E_{iCVP} and State Water Project E_{iSWP}, and total exports throughout the Delta E_{iTot} (data downloaded from DayFlow on October 26, 2012). Fork length at tagging L_i and release group (RG_i) were also considered. All continuous covariates were standardized, i.e.,

$$\tilde{x}_{ij} = \frac{x_{ij} - \bar{x}_j}{s(x_j)}$$

for the observation of covariate *j* from tag *i*.

The form of the generalized linear model was

$$\ln\left(\frac{\psi_{iA}}{\psi_{iB}}\right) = \beta_0 + \beta_1(\tilde{x}_{i1}) + \beta_2(\tilde{x}_{i2}) + \cdots + \beta_p(\tilde{x}_{ip}),$$

where $\tilde{x}_{i1}, \tilde{x}_{i2}, \ldots, \tilde{x}_{ip}$ are the observed values of standardized covariates for tag *i* (covariates 1, 2, …, *p*, see below), and ψ_{iA} is the predicted probability that the fish with tag *i* selected route A (San Joaquin River route), with $\psi_{iB} = 1 - \psi_{iA}$ (B = Old River route).

Single-variate regression was performed first, and covariates were ranked by P-values from the appropriate F-test (McCullagh and Nelder, 1989). Covariates found to be significant alone $\alpha = 0.05$ were then analyzed together in a series of multivariate regression models. Because of high correlation between flow and velocity, flow and velocity models were considered separately. Likewise, exports at CVP and SWP were considered separately. The general forms of the three multivariate models were:

Flow model: $Q_A + Q_B + \Delta Q_A + \Delta Q_B + U_A + E_{Tot} + L + RG$

Flow proportion model: $pQ_A + \Delta pQ_A + U_A + E_{Tot} + L + RG$

Velocity model: $V_A + V_B + \Delta V_A + \Delta V_B + U_A + E_{Tot} + L + RG.$

Backwards selection with F-tests was used to find the most parsimonious model that explained the most variation in the data (McCullagh and Nelder, 1989). AIC was used to select among the flow, flow proportion, and velocity models. Model fit was assessed by grouping data into discrete classes according to the independent covariate, and comparing predicted and observed frequencies of route entrainment into the San Joaquin using the Pearson chi-squared test (Sokal and Rohlf, 1995).

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 Clifton Court Forebay; and (3) the San Joaquin River from Old River downstream to Turner Cut. Weekly surveys were conducted in each reach between May 9th and June 10th.

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, anchored 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 processed using the Auto-Mark feature built into the HTI MarkTags program to identify tag detections. All files were then manually examined to verify marked tag codes and identify tag codes that were not identified by the auto-marking process.

Results

Transport to Release Sites

Average water temperature in the transport tanks, after buckets were loaded and prior to transport for the VAMP fish, was approximately 17° C (range between 15.7° and 17.9° C). Dissolved oxygen was between 13 and 14 mg/l (range between 12.4 and 14.9 mg/l). Over the course of the 45-60 minute drive from TFCF to the release sites, water temperatures in the transport tanks changed by -0.3° to 1.2° C and dissolved oxygen changed by -3.6 to 1.5 mg/l (Table 5-9). For the salmon released as part of the South Delta TBP study, average water temperature in the truck after loading was similar for the first group and higher for the second group than for the VAMP fish (Table 5-10). The dissolved oxygen levels were somewhat lower, for the South Delta TBP study fish than for the VAMP fish, although still relatively high, prior to transport. Water temperature and dissolved oxygen levels during transport did not change much (Table 5-10).

Water temperatures in the river were between 14° C and almost 18° C for the VAMP releases, with lower water temperatures during the first week (Table 5-9). The dissolved oxygen levels were consistently around 9 mg/l in the river at the time of release. Water temperatures in the river ranged between 15° C and almost 19° C for the South Delta TBP salmon released in June (Table 5-10).

No fish were removed for signs of poor recovery from the 948 Chinook salmon transported and released as part of VAMP in 2011. There were no dead or impaired salmon collected after transport and prior to fish being transferred to the holding containers or observed prior to release for the VAMP fish in 2011 (Table 5-3 and 5-9). There were no mortalities after transport and only one mortality prior to release from the 947 Chinook salmon released as part of the South Delta TBP study in 2011 (Table 5-4 and 5-10).

Dummy-Tagged Fish

None of the 120 fish dummy-tagged for VAMP were found dead when evaluated after 48 hours in 2011 (Table 5-11). All fish evaluated for condition were found swimming vigorously, with normal gill coloration, normal eye quality, normal body coloration and no fin hemorrhaging. Mean scale loss, for the fish dummy-tagged for VAMP, ranged from 1.0 to 8.4% (Table 5-11). None of the examined fish had loose sutures or hemorrhaging around the sutures. Mean fork length (FL) of fish examined ranged from 104.7 to 107.3 mm (Table 5-11). Short-term survival was 100% within the perforated garbage cans. These data indicate that the fish used for the VAMP in 2011 were in generally good condition.

Chinook salmon dummy-tagged for the South Delta TBP study also appeared to be in good condition, with no mortality of the fish after being held for 48 hours (Table 5-12).

Fish Health

Health assessments were conducted on cohorts of acoustic-tagged MRH juvenile Chinook salmon used in the VAMP and South Delta TBP studies corresponding to the May 19th and 26th and June 16th study fish releases. Health assessment control (HAC) groups were transferred to the CA-NV Fish Health Center wet lab, and sampled at 1 and 30 days post transfer. No obligate viral or bacterial pathogens were detected in any of the 3 HAC groups sampled 1 day post transfer. External infections with *Flavobacterium columnare* (the bacteria which causes columnaris disease) and *Ichthyophthirius multifiliis* (the protozoan which causes ich or white spot disease) were observed on fish from all 3 HAC groups sampled 30 days post transfer. *Tetracapsuloides bryosalmonae* parasites, the causative agent of proliferative kidney disease (PKD), were detected in 0-7% of fish in HAC groups at 1 day post transfer and 27-46% of fish from HAC groups sampled at 30 days post transfer. Survival for the 30-day holding periods was high and ranged from 96-100%. Gill ATPase activity levels were consistent with fish undergoing smoltification in all except the May 26th HAC group. Overall, HAC groups demonstrated low mortality and only mild PKD prevalence; indicating, fish health was not a concern in survival of 2011 VAMP and South Delta TBP study fish. The fish health study is further described in Chapter 6.

Receiver Performance

Receiver performance was much improved in 2011. The use of modified Joboxes was continued because it seemed to eliminate overheating; however, the use of water was eliminated. Instead, two fans were placed, one at each end of the Jobox and wired into a temperature sensor. As temperatures started to rise, the receivers began to overheat and shut down; resulting in data gaps. This was addressed by changing the settings in the phidget control; allowing the fans to run continuously, which seemed to minimize the overheating problem.

While most of the issues associated with receiver performance in 2010 were eliminated, there were a limited number of sites that had some non-operation issues in 2011 (Table 5-13). Most periods of down time were well after the VAMP fish were released (Table 5-13). One issue encountered was the loss of files when files were being uploaded from the netbook to the FTP sites. One explanation may be that during the uploading period from netbook to the FTP site, the FTP site may have gone offline resulting in the data gap. These data gaps were limited to one hour blocks and occurred very infrequently. In the future the use of a better air card and upgraded antenna may eliminate this occurrence.

Temperature Monitoring

Five temperature recorders deployed as part of the 2011 VAMP were taken or irretrievable. This resulted in missing data for the Confluence Top, Confluence Bottom, “Q” Piling 0.5 miles Upstream of Channel Marker 13, Jersey Point USGS Gauging Station, and Holland Riverside Marina sites. Additionally, the temperature recorder at the Dos Reis site had been occasionally dewatered, which resulted in chaotic, but still meaningful, temperature readings.

Results of water temperature monitoring at Durham Ferry, Old River at HOR, and Clifton Court Forebay Radial Gates during the April-June smolt emigration from the San Joaquin River through the Delta are shown in Figures 4, 6 and 15 in Appendix G. Water

Table 5-9
Water Temperature and Dissolved Oxygen in the Transport Tank after Loading Prior to Transport, After Transport, and in the River at the Durham Ferry Release Site, Just Prior to Placing Fish in Holding Containers 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 for Chinook Salmon Released as Part of the 2011 VAMP

Transport Date	Tank 1 after loading		Tank 2 after loading		Tank 1 after transport		Tank 2 after transport		# morts after transport	River		# morts just prior to release
	Temp (˚C)	DO (mg/L)	Temp (˚C)	DO (mg/L)	Temp (˚C)	DO (mg/L)	Temp (˚C)	DO (mg/L)		Temp (˚C)	DO (mg/L)	
5/16/11	17.2	14.9	17.2	13.7	16.9	13.8	16.9	15.2	0	15.2	9.3	0
5/17/11	16.0	14.8	16.0	14.2	15.7	13.6	15.7	---[a]	0	14	9.51	0
5/18/11	16.1	13.3	16.2	13.4	16.4	11.6	16.3	12.3	0	14.1	9.1	0
5/19/11	17.7	14.6	17.6	13.5	18.6	12.2	17.9	12.5	0	15.6	9.42	0
Average	16.8	14.4	16.8	13.7	16.9	12.8	16.7	13.3		14.7	9.3	
5/21/11	17.8	13.2	17.9	14.3	17.7	11.4	18.1	10.7	0	16.9	9.41	0
5/22/11	16.5	12.8	16.1	12.4	16.6	11.1	16.5	10.9	0	17.0	9.14	1
5/23/11	16.7	13.4	16.5	12.8	17.8	13.2	16.9	13.1	0	17.7	9.49	0
5/24/11	15.8	12.8	15.7	12.5	16.6	10.7	16.9	10.5	0	16.8	9.22	0
Average	16.7	13.0	16.6	13.0	17.2	11.6	17.1	11.3		17.1	9.3	

[a] DO meter was not operating correctly

Table 5-10
Water Temperature and Dissolved Oxygen in the Transport Tank after Loading Prior to Transport, After Transport, and in the River at the Durham Ferry Release Site, Just Prior to Placing Fish in Holding Containers and the Number of Mortalities after Transport for Chinook Salmon Released as Part of the South Delta Temporary Barrier Project Study in 2011

Transport Date	Tank 1 after loading		Tank 2 after loading		Tank 1 after transport		Tank 2 after transport		# morts after transport	River		# morts just prior to release
	Temp (˚C)	DO (mg/L)	Temp (˚C)	DO (mg/L)	Temp (˚C)	DO (mg/L)	Temp (˚C)	DO (mg/L)		Temp (˚C)	DO (mg/L)	
6/6/11	16.1	12.0	15.9	11.9	16.6	11.0	16.3	11.4	0	15.3	9.56	0
6/7/11	15.4	12.9	15.5	12.8	15.9	11.1	16.3	10.9	0	15.2	9.55	1
6/8/11	17.2	12.6	17.0	11.6	16.6	12.7	16.8	11.9	0	16.8	10.04	0
6/9/11	16.4	12.3	16.5	12.3	16.9	11.4	17.2	11.2	0	16.5	9.34	0
Average	16.3	12.5	16.2	12.1	16.5	11.6	16.7	11.3		16.0	9.6	
6/14/11	17.2	11.9	17.4	11.9	18.7	11.7	19.5	12.1	0	17.8	9.72	0
6/15/11	19.5	10.9	19.2	10.9	18.1	10.3	17.3	11.7	0	18.8	8.87	0
6/16/11	19.5	11.1	19.9	11.0	17.5	10.6	17.6	11.2	0	17.3	9.69	0
6/17/11	18.3	11.3	17.9	11.3	17.1	12.4	17.0	11.6	0	18.3	9.95	0
Average	18.6	11.3	18.6	11.3	17.9	11.3	17.9	11.7		18.1	9.6	

Table 5-11
Results of Dummy Tagged Juvenile Chinook Salmon Evaluated After Being Held for 48 Hours at the Release Sites as Part of the 2011 Vernalis Adaptive Management Program (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	5/18/11, 0905	103 (2.5)	0/12	5.25 (3.2)	12/12	12/12	12/12	12/12
Durham Ferry	5/19/11, 1200		0/24[a]					
Durham Ferry	5/20/11, 0905	104.7 (2.8)	0/12	8.4 (6.0)	12/12	12/12	12/12	12/12
Durham Ferry	5/21/11, 1207	107 (4.2)	0/12	3.3 (2.3)	12/12	12/12	12/12	12/12
Durham Ferry	5/23/11, 1210	105.8 (3.4)	0/12	1 (0)	12/12	12/12	12/12	12/12
Durham Ferry	5/24/11, 0915	107.3 (3.7)	0/12	1.1 (0.3)	12/12	12/12	12/12	12/12
Durham Ferry	5/26/11, 0912		0/36[a]					

[a]Fish given to CA/NV Fish Health Center for further evaluation, 12 of the 36 had been held since 5/23.

Table 5-12
Results of Dummy Tagged Juvenile Chinook Salmon Evaluated After Being Held for 48 Hours at the Release Sites as Part of the South Delta Temporary Barriers Project (TBP) Study in 2011

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	6/8/11, 1208	112 (3.2)	0/12	5.4 (3.3)	12/12	12/12	12/12	12/12
Durham Ferry	6/9/11, 0900	114 (2.9)	0/12	5.8 (6.0)	12/12	12/12	12/12	12/12
Durham Ferry	6/10/11, 1210	115.9 (4.8)	0/12	4.2 (3.6)	12/12	12/12	12/12	12/12
Durham Ferry	6/11/11, 0910	114.2 (3.7)	0/12	10.0 (4.2)	12/12	12/12	12/12	12/12
Durham Ferry	6/16/11, 0905		0/24[a]					
Durham Ferry	6/17/11, 0906[b]	114.5 (5.7)	0/12	6.3 (2.3)	12/12	12/12	12/12	12/12
Durham Ferry	6/18/11, 0906	113.3 (4.4)	0/12	5.8 (1.9)	12/12	12/12	12/12	12/12
Durham Ferry	6/19/11, 1201	115.3 (9.9)	0/12	13.7 (3.7)	12/12	12/12	12/12	12/12

aFish given to CA/NV Fish Health Center for further evaluation
[b] Assessed 3 hours early

Table 5-13
Periods of Non-operation of Acoustic Receivers During the 2011 VAMP Study and the South Delta Temporary Barriers Project (TBP) Study. Refer to Figure 5-2 for Receiver Locations

Study Code	System Code	Site ID	Type	Location	Non-Operational Period				Footnotes
					Start		End		
					Date	Time	Date	Time	
VAMP	909	SJLU	Node	San Joaquin River at Lathrop - Upstream (Shared)	5/11/11	0300	5/11/11	1200	2
VAMP	910	SJLD	Node	San Joaquin River at Lathrop - Downstream (Shared)	5/11/11	0300	5/11/11	1200	2
VAMP	920	TMS	Node	Threemile Slough	6/21/11	1700	6/21/11	2200	3
SD TBP	810	RGU1	Node	Radial Gates - Upstream # 1 (Shared)	7/3/11	0400	7/5/11	1000	1
SD TBP	811	RGU2	Node	Radial Gates - Upstream # 2 (Shared)	6/21/11	0700	6/21/11	0800	1
					7/3/11	0400	7/3/11	1300	
					7/4/11	0000	7/4/11	1400	
					7/5/11	0000	7/5/11	1000	
SD TBP	812	RGD1	Node	Radial Gates - Downstream # 1 (Shared)	6/1/11	1000	6/1/11	1700	4
SD TBP	813	RGD2	Node	Radial Gates - Downstream # 2 (Shared)	6/14/11	1900	6/14/11	2300	1
					6/15/11	0000	6/15/11	2000	
					6/17/11	0900	6/17/11	1100	
VAMP	603	JPTe	4prt	Jersey Point - East	7/13/11		7/14/11		1
VAMP	604	JPTw	4prt	Jersey Point - West	5/23/11		5/24/11		5
VAMP	500	CHPe	4prt	Chipps Island - East	7/11/11	1400	7/13/11	1300	1
					7/19/11	1400	7/25/11	1100	
					7/26/11	1200	7/26/11	1300	6
					7/27/11	1200	7/27/11	1300	
					7/29/11	1200	7/29/11	1300	
					7/30/11	1200	7/30/11	1300	
VAMP	504	CHPw	4prt	Chipps Island - West	7/7/11				7
VAMP	515	CHPn	Node	Chipps Island North	5/24/11	0900	5/24/11	1000	1
					6/3/11	1000	6/3/11	1100	
					6/13/11	1300	6/13/11	1400	
					7/24/11	1300	7/24/11	1400	
					8/3/11	1900	8/3/11	2000	
VAMP	516	CHPw	Node	Chipps Island West	5/21/11	0600	5/21/11	0700	1
					5/31/11	1200	5/31/11	1300	
					6/7/11	1800	6/7/11	1900	
					6/20/11	2300	6/20/11	0000	
					7/4/11	1000	7/4/11	1300	
					7/4/11	1600	7/4/11	1800	
					7/4/11	1900	7/4/11	2200	
					7/5/11	1000	7/5/11	0000	
					7/5/11	1800	7/5/11	2000	
					7/6/11	0100	7/14/11	1400	
					7/23/11	1700	7/23/11	1800	
					8/2/11	2300	8/2/11	0000	
					8/13/11	0400	8/13/11	0500	
					8/17/11	0600, 1100, 1500, 1900	8/17/11	0700, 1200, 1600, 2000	
					8/22/11	0200, 0400, 1000	8/22/11	0300, 1300, 1800	
					8/23/11	0200, 0400, 1000	8/23/11	0300, 0500, 1100	
					8/24/11	2100, 2300	8/24/11	2200, 2400	
					8/25/11	0300, 0600, 1500	8/25/11	0400, 0700, 1600	
VAMP	517	CHPe	Node	Chipps Island East	5/18/11	0300	5/18/11	0400	1
					5/20/11	0700	5/23/11	0500	
					6/4/11	0000	6/4/11	0100	
					6/14/11	0600	6/14/11	0700	
					6/17/11	0600	6/17/11	0700	

1 Unknown
2 Defective Solar Module
3 Overheating issue
4 Data Logger memory full
5 Probably battery and power failure
6 One hour off between 1200 and 1300 for two consecutive days, on for the next full day, off again for one hour (1200 to 1300) for the next two days: pattern continued until end of the season.
7 Cable was cut on 7/7/2011

temperatures measured within the lower San Joaquin River and Delta were within a range considered to be suitable (typically < 20° C; 68° F) during April and May in the mainstem San Joaquin River (e.g., Durham Ferry, Mossdale, and Old River at HOR (Figures 4, 5 and 6 in Appendix G)). Temperatures were slightly higher but still under 20° C (68° F) further downstream within the Delta (e.g., Old River/Indian Slough Confluence, CCF Radial Gates (Figures 14 and 15 in Appendix G)). Results of the 2011 water temperature monitoring showed a longitudinal gradient of temperatures that generally increased slightly as a function of distance downstream within the mainstem 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 VAMP 2011 investigations. However, temperatures during the middle of June were within the range considered to be stressful for juvenile Chinook salmon.

Detections of Acoustic-Tagged Fish

Of the 1,895 tags released in juvenile Chinook salmon at Durham Ferry in 2011, 1,847 (97%) were detected on one or more receivers downstream of the release site (Table 5-14), including the predator-type detections. In general, the number of tags detected at each site in the San Joaquin River route declined with distance from Durham Ferry, with 1,447 tags detected at Mossdale, 902 tags detected at Lathrop, 779 detected at the Navy Drive Bridge in Stockton, and 150 tags detected at Medford Island (Table 5-15). A total of 100 tags were detected leaving the San Joaquin River at Turner Cut (Table 5-15). Fewer tags were detected in the Old River route than in the San Joaquin River route, with 657 tags detected at Old River East (near the head of Old River). Only seven tags were detected leaving Old River at Middle River (MRS), with no tags detected at that receiver from the final release group (Table 5-15). Many tags were observed moving among the receivers at the Central Valley Project trashracks (CVP), radial gates at the Clifton Court Forebay (RGU, RGD), and Old River North receivers (ORN). Among these sites, the route with the final tag detection was used in the survival model (Table 5-15). Approximately equal numbers of tags from Old River South (ORS) were observed finally moving to the Central Valley Project as to the radial gates at the Clifton Court Forebay, with fewer moving to the Old River North receivers (ORN). Most of the tags detected at the Old River North receivers came from the first two release groups, with no tags detected at ORN from the final release group (Table 5-15). Very few tags were detected moving from the head of Old River to the Middle River North receivers (MRN) near Highway 4 (Table 5-15). Tag detections dropped considerably from Medford Island, Turner Cut, and Old River North (ORN) to the receivers located at Jersey Point (JPT) and False River (FRE/FRW). Twelve tags from across all release groups were detected at Jersey Point, and only one tag was detected at False River (Table 5-15). Only 35 tags were finally detected at Chipps Island (Table 5-15), including detections of tags classified as being in predators.

Some tag detections were not used in the survival model because the tags were assigned to a different migration route based on previous or subsequent tag detections. For example, tag 6311.13 (tag period and subcode) was detected at Middle River North (MRN) with subsequent detections at the radial gates receivers (RGU) and the Chipps Island receivers. Because the tag was detected at RGU after the MRN detections, it was assigned to subroute D (Clifton Court Forebay) within the primary Old River route (route B), rather than the Middle River subroute (C), and so the MRN detection was not used in the survival model. (The Chipps Island detection was used in the model.) Other tags were detected at MRN after being detected at receivers in the San Joaquin River route. For example, tag 6353.13 was detected at the Navy Drive Bridge receiver in Stockton (STN) and at Turner Cut before being detected at MRN and then at the radial gates (RGU). This tag was assigned to route A (San Joaquin River route) at the head of Old River, so the detections at both MRN and RGU were not used in the survival model. This tag was not detected at Chipps Island, but any detections from similar tags at Chipps Island would have been used in the survival model. In total, 17 tags were detected at the Middle River North (MRN) receivers (including predator-type detections), with 9 tags arriving at MRN from the Old River route (6 tags via MRS, 1 via ORN, 1 via CVP, and 1 with unknown route from ORS) and 8 tags arriving at MRN from the San Joaquin River route. Twelve of the 17 tags detected at MRN were subsequently detected at other receivers in the primary Old River route: 8 at the Clifton Court Forebay Radial Gates, 1 at the Central Valley Project trashracks (CVP), and 2 at the Old River North receivers near Highway 4. All but three of the

Table 5-14
Number of Tags from each Release Group that were Detected Downstream of the Release Site in 2011, Including Predator-type Detections

Release Group	1	2	3	4	Total
Number Released	475	473	473	474	1,895
Total Number Detected	468	465	455	459	1,847

Table 5-15
Number of Tags Observed from each Release Group at each Detection Site in 2011 and Used in the Survival Analysis, Including Predator-type Detections. Pooled Counts are Summed over all Receivers in the Array

Detection Site	Site Code	Survival Model Code	Release Group				Total
			1	2	3	4	
Durham Ferry Upstream	DFU	A0	3[a]	5[a]	4[a]	7[a]	19
Durham Ferry Downstream	DFD	A2	466	448	412	443	1,769
Banta Carbona	BCA	A3	431	417	378	396	1,622
Paradise Cut (Outside)	PCO	A4	72	186	157	179	594
Mossdale	MOS	A5	423	377	302	345	1,447
Lathrop	SJL	A6	251	240	206	205	902
Stockton USGS Gauge	STS	A7	238	205	175	171	789
Stockton Navy Drive Bridge	STN	A8	233	208	175	163	779
Shipping Channel Markers	C18/C16	A9	111	108	66[a]	88	373
Medford Island East	MFE	A10a	57	32	14[a]	38	141
Medford Island West	MFW	A10b	62	34	14[a]	38	148
Medford Island (Pooled)	MFE/MFW	A10	62	34	14[a]	40	150
Turner Cut North	TCN	F1a	39	24	26[a]	8	97
Turner Cut South	TCS	F1b	38	23	26[a]	8	95
Turner Cut (Pooled)	TCN/TCS	F1	41	24	26[a]	9	100
Old River East	ORE	B1	183	180	131	163	657
Old River South Upstream	ORSU	B2a	162	161	113	151	587
Old River South Downstream	ORSD	B2b	173	173	123	157	626
Old River South (Pooled)	ORS	B2	181	178	129	160	648
Old River North Upstream	ORNU	B3a	46	40	2[a]	0	88
Old River North Downstream	ORND	B3b	41	39	2[a]	0	82
Old River North (Pooled)	ORN	B3	52	46	2[a]	0	100
Middle River South	MRS	C1	2	3	2	0	7
Middle River North Upstream	MRNU	C2a	0	2	0[a]	1	3
Middle River North Downstream	MRND	C2b	0	2	0[a]	1	3
Middle River North (Pooled)	MRN	C2	0	2	0[a]	1	3
Radial Gates Upstream	RGU	D1	44	39	35[a]	50	168
Radial Gates Downstream #1	RGD1	D2a	40	34	44[a]	45	163
Radial Gates Downstream #2	RGD2	D2b	38	30	44[a]	46	158
Radial Gates Downstream (Pooled)	RGD	D2	41	35	44[a]	46	166
Central Valley Project Trashrack	CVP	E1	35	29	41[a]	55	160
Central Valley Project Holding Tank	CVPtank	E2	0	8	10[a]	19	37
Jersey Point East	JPTE	G1a	4	1[a]	5[a]	2	12
Jersey Point West	JPTW	G1b	3	1[a]	5[a]	2	11
Jersey Point (Pooled)	JPT	G1	4	1	5[a]	2	12
False River East	FRE	H1a	1	0[a]	0[a]	0	1
False River West	FRW	H1b	1	0[a]	0[a]	0	1
False River (Pooled)	FRE/FRW	H1	1	0	0[a]	0	1
Chipps Island East	CHPE	G2a	2	5	12	14	33
Chipps Island West	CHPW	G2b	2	6	8	11	27
Chipps Island (Pooled)	CHP	G2	3	6	12	14	35

[a] = not used in survival model.

tags detected at Middle River North were assigned to a different migration route. Only 1 of the 17 tags ever detected at MRN was subsequently detected at Chipps Island (tag 6311.13, see above), and it was assigned to the Clifton Court subroute of the primary Old River route rather to the Middle River subroute (described above). None of these 17 tags were detected at either False River or Jersey Point.

Some detection locations were used in the predator filter, but were purposely omitted from the survival model. The receiver located in the Delta Mendota Canal (DMC) recorded detections of 21 tags, 7 of which were subsequently detected on the CVP receivers. Seven tags were detected on the Threemile Slough receivers: 3 tags came directly from the San Joaquin River receivers (Medford Island, Channel Markers), 3 from Jersey Point, and 1 from CVP holding tank. One of the Threemile Slough tags from Medford Island was later detected at Chipps Island, but it was then subsequently detected at Threemile Slough a second time, by which time it was assumed to have been in a predator. A total of 24 tags were detected on the Chipps Island North receiver (CHPn; Table 5-6). Because of this receiver's proximity to the entrance to Spoonbill Creek, these detections were omitted from the survival model. All but one of the 24 tags detected at CHPn were also detected on the Chipps Island array receivers used in the survival model.

The predator filter used to distinguish between detections of Chinook salmon smolts and detections of predatory fish that had eaten the tagged smolts classified 593 of the 1,895 tags (31%) released as being detected in a predator at some point during the study (Table 5-16). Of the 1,666 tags detected in the study area (i.e., at Mossdale or points downstream), 562 tags (34%) were classified as being in a predator at some point in the study area. The detection sites with the largest number

Table 5-16
Number of Tags from each Release Group First Classified as in a Predator at each Detection Site in 2011 as a Result of the Predator Filter

Detection Site and Code			Durham Ferry Release Groups									
			Classified as Predator on Arrival at Site					Classified as Predator on Departure from Site				
Detection Site	Site Code	Survival Model Code	1	2	3	4	Total	1	2	3	4	Total
Durham Ferry Upstream	DFU	A0	2	0	0	0	2	0	0	1	0	1
Durham Ferry Downstream	DFD	A2	1	4	5	3	13	0	0	1	0	1
Banta Carbona	BCA	A3	4	1	1	3	9	1	0	0	0	1
Paradise Cut (Outside)	PCO	A4	1	0	0	1	2	1	1	0	0	2
Mossdale	MOS	A5	9	5	6	1	21	0	0	0	0	0
Lathrop	SJL	A6	0	4	2	0	6	2	1	2	3	8
Stockton USGS Gauge	STS	A7	2	1	2	3	8	6	3	2	4	15
Stockton Navy Drive Bridge	STN	A8	2	1	1	3	7	20	12	29	48	109
Shipping Channel Markers	C18/C16	A9	6	5	7	9	27	5	16	14	9	44
Medford Island	MFE/MFW	A10	3	1	1	1	6	3	4	0	2	9
Old River East	ORE	B1	0	1	1	1	3	0	0	1	1	2
Old River South	ORS	B2	0	1	0	2	3	1	3	1	1	6
Old River North	ORN	B3	15	8	1	0	24	10	13	0	0	23
Middle River South	MRS	C1	0	0	0	0	0	1	0	0	0	1
Middle River North	MRN	C2	0	0	2	1	3	0	0	0	0	0
Radial Gates Upstream	RGU	D1	6	1	0	0	7	4	0	1	1	6
Radial Gates Downstream	RGD	D2	1	0	0	0	1	21	25	30	30	106
Central Valley Project Trashrack	CVP	E1	10	11	11	5	37	15	12	17	23	67
Central Valley Project Holding Tank	CVPtank	E2	0	0	0	0	0	0	0	0	0	0
Turner Cut	TCN/TCS	F1	3	1	0	1	5	5	0	0	0	5
Jersey Point	JPT	G1	0	0	0	0	0	0	0	0	0	0
Chipps Island	CHP	G2	0	1	0	0	1	0	0	0	0	0
Chipps Island North, near Spoonbill Creek	CHPn		0	1	0	0	1	0	0	0	0	0
False River	FRE/FRW	H1	0	0	0	0	0	0	0	0	0	0
Threemile Slough	TMS/TMN	T1	0	0	0	1	1	0	0	0	0	0
Total Tags			65	47	40	35	187	95	90	99	122	406

of first-time predator-type detections were the receiver near the Navy Drive Bridge in Stockton (STN, code A8) and the receivers at the radial gates inside the Clifton Court Forebay (RGD). A total of 7 tags were classified as being in predators upon arrival at the Navy Drive Bridge receivers, with 109 tags classified as being predators upon departure from that receiver. Long nearby or regional residence time and moving against the flow were the primary indicators of predation at STN, with long residence time comprising the majority of predation indicators. Only one tag was classified as in a predator on arrival at RGD, but 106 tags were classified as in a predator on departure from RGD, all indicated by long residence time. The other site that stands out with many first-time predator detections was the Central Valley Project trashracks (CVP), with 104 tags first classified as in predators there. A total of 37 tags were classified as predators upon arrival at CVP, generally due to unusual migration rates to those receivers or moving against the flow; 67 tags were classified as predators upon departure from CVP, nearly all because of long residence times (Table 5-16).

When the detections classified as coming from predators were removed from the detection data, fewer detections were available for the survival analysis (Tables 5-17 and 5-18). Nevertheless, the number of tags from the predator-filtered data with detections downstream of the release site was nearly the same as from the unfiltered data, with 1,842 of the 1,895 tags (97%) detected (Table 5-17). Without the predator-type detections, the number of tags detected at Mossdale changed from 1,447 to 1,344 (Tables 5-15 and 5-18). The number of tag detections at Lathrop used in the survival analysis actually increased from 902 to 919 when the predator-type detections were omitted, because some tags were classified as predators after first reaching Lathrop and then appeared back upstream with predator-type detections. Most (94%) of the predator-type detections at the Navy Drive Bridge in Stockton (STN) were classified as predators only on departure, so there was little change in the number of detections at that site without those detections. Also, because most tags first classified as in predators at STN were not detected again elsewhere, the tag count at Medford Island decreased only slightly from 150 tags with predator-type detections to 141 tags without those detections. There was essentially no change in the number of detections at Old River East (ORE, near the head of Old River), Middle River South (MRS), and Middle River North (MRN) without the predator-type detections (Tables 5-15 and 5-18). Tag detections at the radial gates at the Clifton Court Forebay (RGU, RGD) and at the Central Valley Project trashrack (CVP) declined slightly after predator-type detections were removed. There was little difference in the tag count at Jersey Point and False River after the predator filter, and the number of tags detected at Chipps Island declined only by 2 to a total of 33 smolt detections. In general, a smaller proportion of tags were classified as in predators in 2011 than in 2010 (31% in 2011 vs 61% in 2010).

Tagger Effects

Fish in the release groups were evenly distributed across tagger (Table 5-19). A chi-squared test found good distribution of taggers across all release groups (P=1.0). The distribution of tags detected at various key detection sites was also well-distributed across taggers, with no evidence of a tagger effect on survival, route entrainment, and detection probabilities at these sites (P=0.8894; Table 5-20).

Tag-Survival Model and Tag-Life Adjustment

The AIC indicated that pooling data from both tag-life studies and also across all tag periods was preferable to stratifying either by study month (May or July) or by tag period. Thus, a single tag survival model was fit and used to adjust fish survival estimates for premature tag failure. The estimated mean time to tag failure was 28.8 days ($\widehat{SE} = 6.7$) (Figure 5-6). The complete set of detection data, including detections classified as coming from predators, included many detections that occurred well after the tags began dying in the tag-life study (Figures 5-7 and 5-8). In the San Joaquin River route, the Stockton North receiver near the Navy Drive Bridge (STN) and the receivers on the Channel Markers in the San Joaquin River near the Turner Cut junction (C18/C16) both had detections occurring toward the end of the observed tag life (Figure 5-7). In the Old River route, long detection histories were observed at the CVP trashracks receivers and at the Old River North receivers near Highway 4 (Figure 5-8). 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 well before most of the tag failure observed in the tag-life study (Figures 5-9 and 5-10). Tag-life corrections were made to survival estimates for both sets of detections (with and without predator-type detections).

Survival and Route Entrainment Probabilities

The model selection process identified the most parsimonious model that adequately fit the data, based on AIC. For the reduced data set that excluded predator-type detections, estimating unique transition parameters to and from the radial gates at the Clifton Court Forebay (RGU, RGD) based on gate status (open and closed) did not significantly improve model fit (AIC was smaller without gate effect; $\Delta AIC = 21.770$). A similar pattern

Table 5-17
Number of Tags from each Release Group that were Detected Downstream of the release Site During 2011, Excluding Predator-type Detections

Release Group	1	2	3	4	Total
Number Released	475	473	473	474	1,895
Total Number Detected	466	467	456	453	1,842

Table 5-18
Number of Tags Observed from each Release Group at each Detection Site in 2011 and Used in the Survival Analysis, Excluding Predator-type Detections. Pooled Counts are Summed Over all Receivers in the Array

Detection Site	Site Code	Survival Model Code	Release Group				Total
			1	2	3	4	
Durham Ferry Upstream	DFU	A0	4[a]	2[a]	3[a]	5[a]	14
Durham Ferry Downstream	DFD	A2	464	450	413	445	1,772
Banta Carbona	BCA	A3	428	419	379	397	1,623
Paradise Cut (Outside)	PCO	A4	70	186	158	180	594
Mossdale	MOS	A5	417	379	202	346	1,344
Lathrop	SJL	A6	257	247	211	204	919
Stockton USGS Gauge	STS	A7	235	205	174	170	784
Stockton Navy Drive Bridge	STN	A8	231	209	177	161	778
Shipping Channel Markers	C18/C16	A9	107	106	66[a]	82	361
Medford Island East	MFE	A10a	58	32	11[a]	33	134
Medford Island West	MFW	A10b	61	33	11[a]	33	138
Medford Island (Pooled)	MFE/MFW	A10	62	33	11[a]	35	141
Turner Cut North	TCN	F1a	40	25	26[a]	7	98
Turner Cut South	TCS	F1b	38	24	26[a]	7	95
Turner Cut (Pooled)	TCN/TCS	F1	40	25	26[a]	8	99
Old River East	ORE	B1	181	179	130	166	656
Old River South Upstream	ORSU	B2a	160	162	113	153	588
Old River South Downstream	ORSD	B2b	171	174	123	159	627
Old River South (Pooled)	ORS	B2	179	178	129	162	648
Old River North Upstream	ORNU	B3a	58	49	1[a]	0	108
Old River North Downstream	ORND	B3b	46	42	1[a]	0	89
Old River North (Pooled)	ORN	B3	58	49	1[a]	0	108
Middle River South	MRS	C1	2[a]	3	2	0	7
Middle River North Upstream	MRNU	C2a	0	2	0[a]	1	3
Middle River North Downstream	MRND	C2b	0	2	0[a]	1	3
Middle River North (Pooled)	MRN	C2	0	2	0[a]	1	3
Radial Gates Upstream	RGU	D1	36	40	38[a]	51	165
Radial Gates Downstream #1	RGD1	D2a	28	30	44[a]	45	147
Radial Gates Downstream #2	RGD2	D2b	28	27	44[a]	46	145
Radial Gates Downstream (Pooled)	RGD	D2	29	31	44[a]	46	150
Central Valley Project Trashrack	CVP	E1	31	24	39[a]	54	148
Central Valley Project Holding Tank	CVPtank	E2	0	8	9[a]	17	34
Jersey Point East	JPTE	G1a	4	1[a]	4[a]	2	11
Jersey Point West	JPTW	G1b	3	1[a]	4[a]	2	10
Jersey Point (Pooled)	JPT	G1	4	1	4[a]	2	11
False River East	FRE	H1a	1	0[a]	0[a]	0	1
False River West	FRW	H1b	1	0[a]	0[a]	0	1
False River (Pooled)	FRE/FRW	H1	1	0	0[a]	0	1
Chipps Island East	CHPE	G2a	2	5	12	13	32
Chipps Island West	CHPW	G2b	2	5	8	11	26
Chipps Island (Pooled)	CHP	G2	3	5	12	13	33

[a] = not used in survival model.

Table 5-19
Number of Juvenile Chinook Salmon Tagged by Tagger in each Release Group During the 2011 Tagging Study

Tagger	Release Group 1	Release Group 2	Release Group 3	Release Group 4	Total Tags
A	119	117	117	117	470
B	118	119	117	119	473
C	118	120	119	119	476
D	120	117	120	119	476
Total Tags	475	473	473	474	1,895

Table 5-20
Release Size and Counts of Tag Detections at Key Detection Sites by Tagger, Excluding Predator-type Detections

Detection Site	Tagger A	Tagger B	Tagger C	Tagger D
Release at Durham Ferry	470	473	476	476
Mossdale (MOS)	339	367	363	375
Lathrop (SJL)	223	228	232	236
Shipping Channel Markers (C18/C16)	84	89	83	105
Turner Cut (TCN/TCS)	29	25	23	22
Medford Island (MFE/MFW)	26	36	34	45
Old River East (ORE)	155	166	172	163
Old River South (ORS)	154	165	171	158
Old River North (ORN)	25	29	33	21
Clifton Court Forebay Interior (RGD)	40	36	44	30
Central Valley Project Holding Tank (CVPtank)	6	12	10	6
Chipps Island (CHP)	5	10	12	6

Figure 5-6
Observed Tag Failure Times from the 2011 Tag-Life Study, Color-Coded by Tag Period, and Fitted Four-Parameter Vitality Curve. Failure Times of Three Tags Were Missing

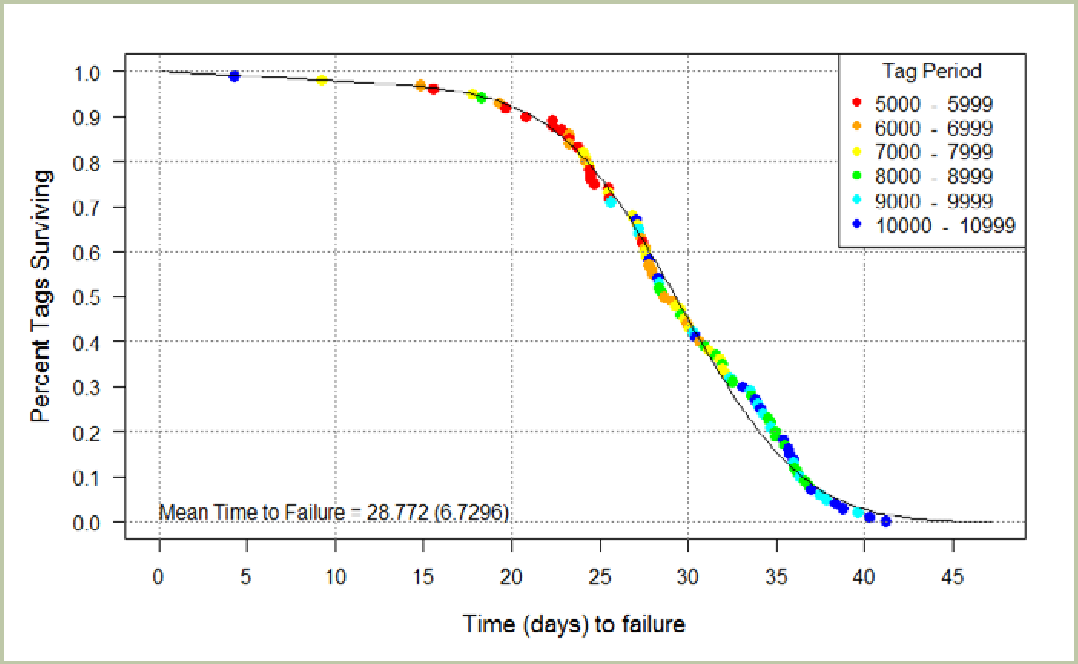


Figure 5-7
Four-Parameter Vitality Survivorship Curve for Tag Life, and the Cumulative Arrival Timing of Acoustic-Tagged Chinook Salmon Smolt at Receivers in the San Joaquin River Route to Chipps Island, Including Detections Classified as Predator Detections

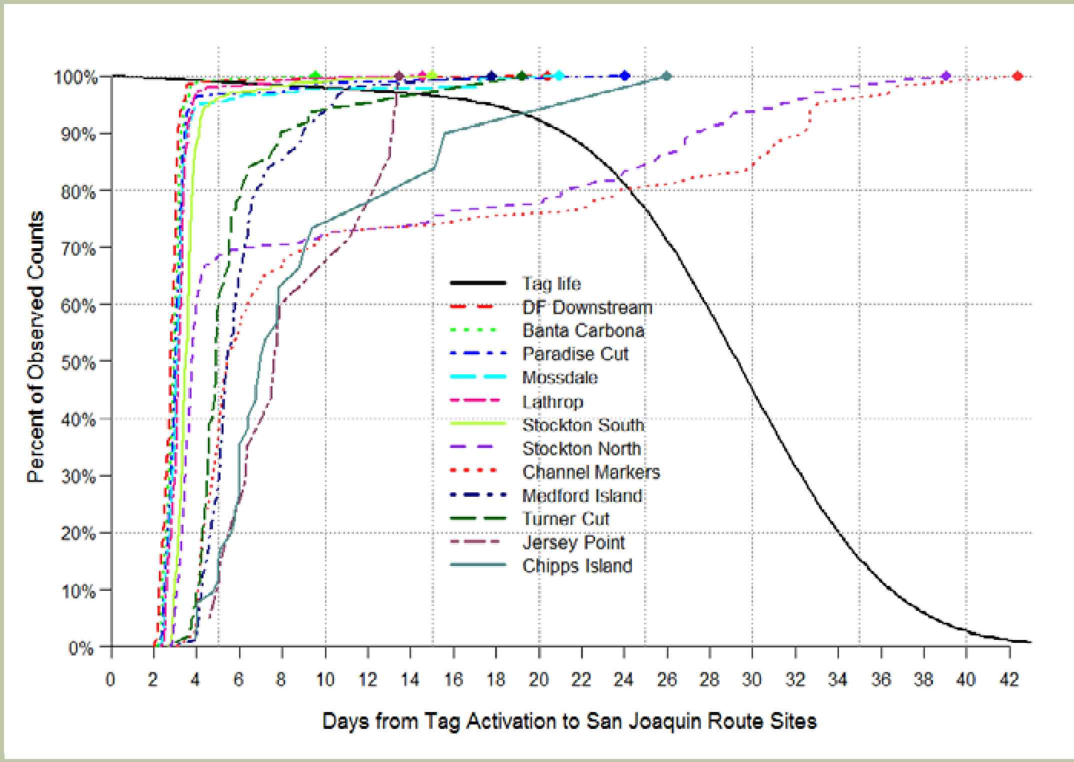


Figure 5-8
Four-Parameter Vitality Survivorship Curve for Tag Life, and the Cumulative Arrival Timing of Acoustic-Tagged Chinook Salmon Smolt at Receivers in the Old River Route to Chipps Island, Including Detections Classified as Predator Detections

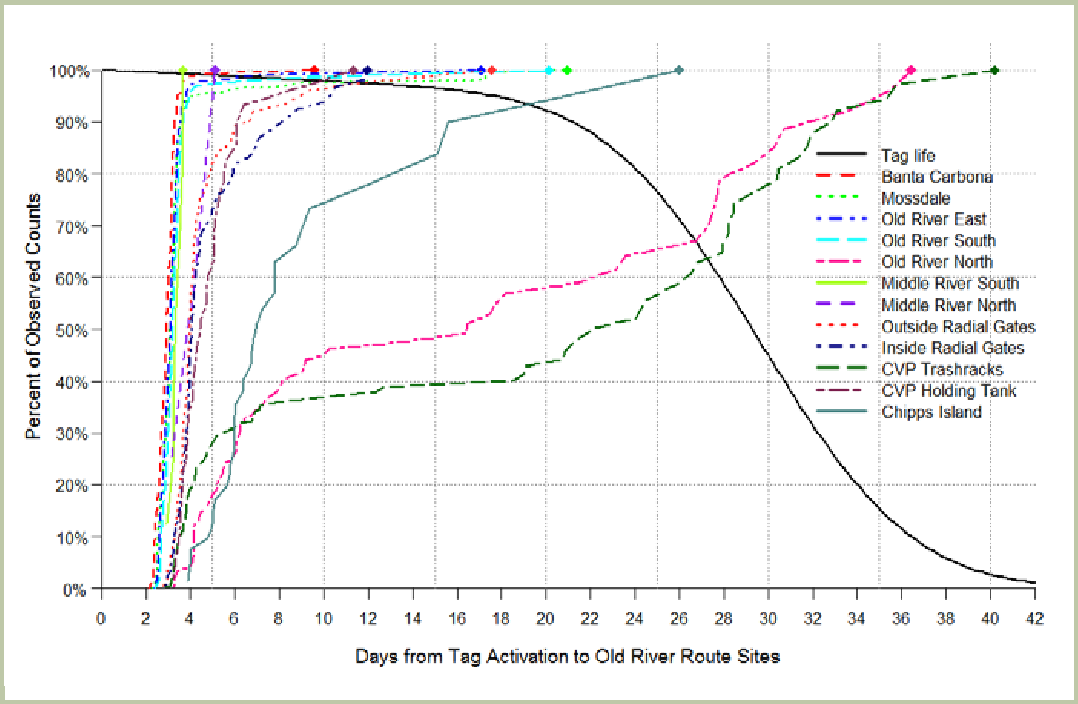


Figure 5-9
Four-Parameter Vitality Survivorship Curve for Tag Life, and the Cumulative Arrival Timing of Acoustic-Tagged Chinook Salmon Smolt at Receivers in the San Joaquin River Route to Chipps Island, Excluding Detections Classified as Predator Detections

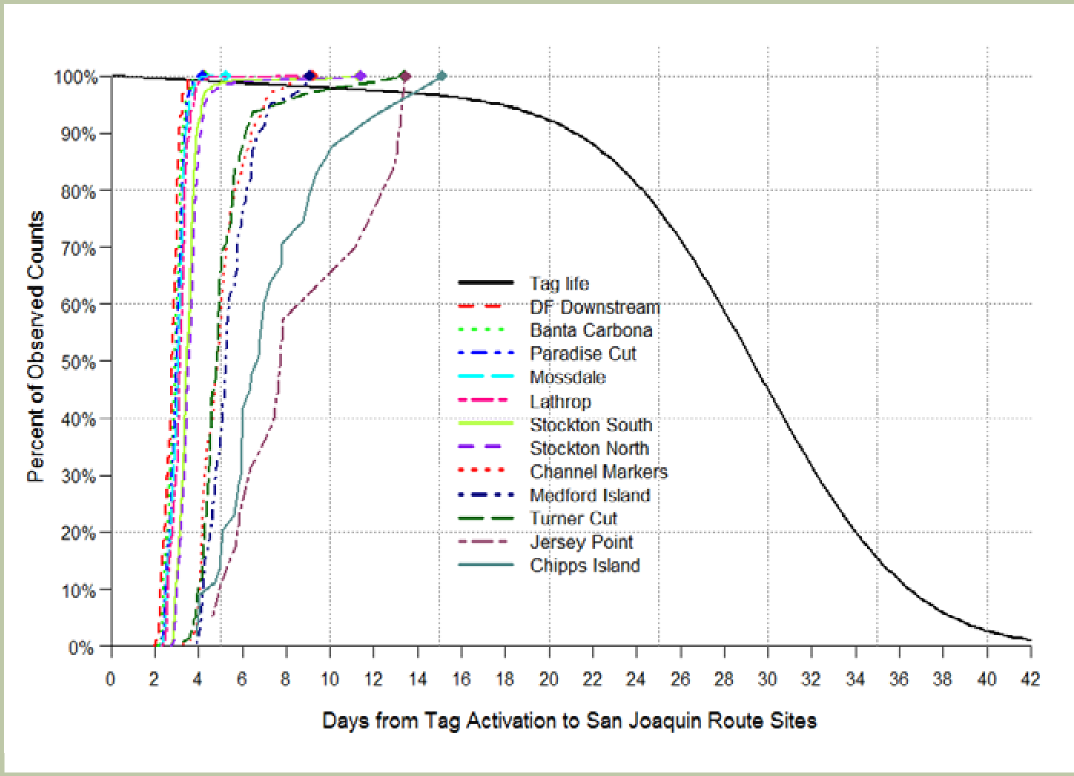
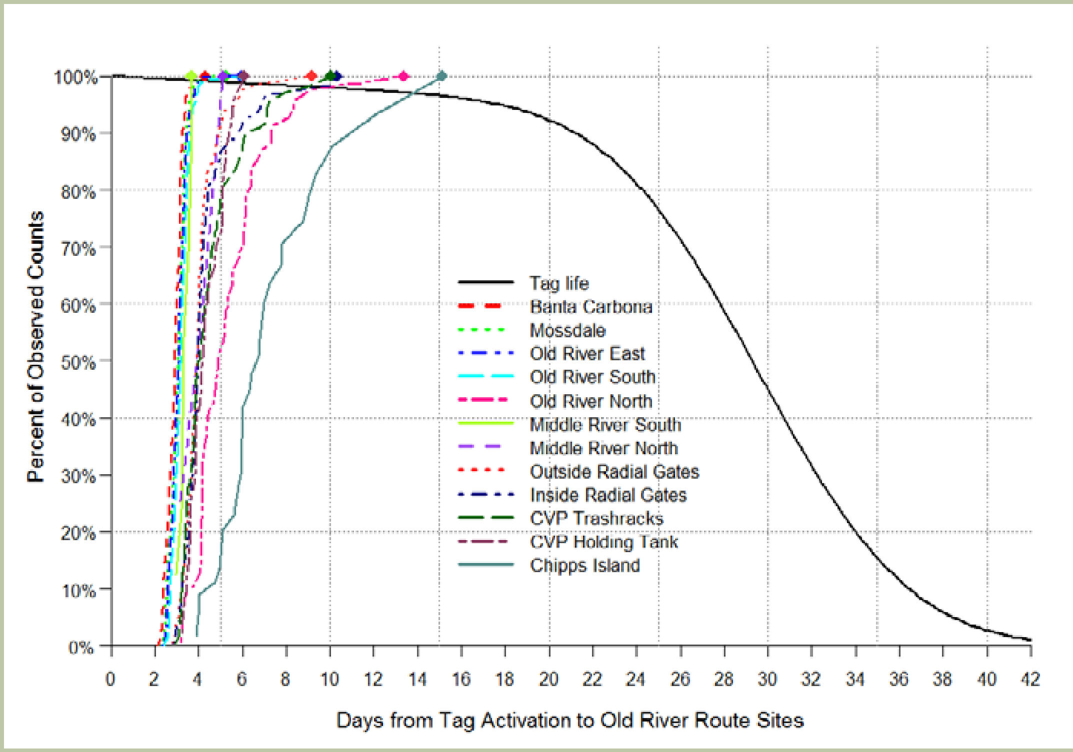


Figure 5-10
Four-Parameter Vitality Survivorship Curve for Tag Life, and the Cumulative Arrival Timing of Acoustic-Tagged Chinook Salmon Smolt at Receivers in the Old River Route to Chipps Island, Excluding Detections Classified as Predator Detections



was seen from the full data set that included predator-type detections, with the simpler non-gate model indicated (AIC was smaller without gate effect; ΔAIC = 21.587). Thus, all parameter estimation for both the reduced and the full data sets came from models using common transition parameters with respect to gate status.

Some parameters were unable to be estimated for certain release groups because of sparse data. Using the predator-filtered data from the first release group, the combination of sparse detections at the Middle River South (MRS) receiver and a lack of subsequent detections of the few tags detected at MRS prevented estimation of parameters involving that site (transition probabilities, route entrainment probability, and detection probability). This in turn meant that only the transition probability $\phi_{B1,B2} = S_{B1}\psi_{B3}$ from the Old River East receiver to the Old River South receiver could be estimated for the first release group, rather than its survival and route entrainment probability components (S_{B1} and ψ_{B3}, respectively). It was also impossible to estimate transition probabilities from MRS to downstream sites (i.e., parameters $\phi_{C1,hi}$) for this release group. Also for the first release group, it was not possible to estimate the detection probability at the CVP trashracks receivers because no tags were subsequently detected in the CVP holding tank (Table 5-18). For all other release groups, the detection probability at the CVP trashracks receivers was estimated at $\widehat{P}_{E1} = 1$, so this assumed value was used for the first release group, as well.

For the second release group, sparse detections at Jersey Point and False River prevented estimation of transition probabilities to and from those sites, and the route entrainment probability at that river junction. Instead, transition probabilities were estimated directly to Chipps Island from the Medford Island, Old River North, and Middle River North receivers (parameters $\phi_{A10,G2}$, $\phi_{B3,G2}$, and $\phi_{C3,G2}$, respectively).

Several phenomena complicated estimation and limited the spatial precision of the parameter estimation for the third release group. Sparse detection data at the Jersey Point, False River, Old River North, and Middle River North sites required removing many receivers from the survival model. Instead of reach-specific survival through the interior Delta and lower reaches of the San Joaquin River, the transition parameters to Chipps Island from the Stockton Navy Drive Bridge, Old River South, and Middle River South were estimated directly (parameters $\phi_{A8,G2}$, $\phi_{B2,G2}$, and $\phi_{C1,G2}$, respectively). See Methods: Survival Model for more information.

The limitations of the data for the individual releases were not observed when data were pooled across release groups to estimate population parameters. Total survival through the Delta was estimable for each release group, as well as route-specific survival in the primary routes at the head of Old River.

Using only those detections classified as coming from juvenile Chinook 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 releases 1 and 2 (i.e., during the VAMP), to 0.03 ($\widehat{SE}$ = 0.01) for releases 3 and 4 (i.e., after the VAMP), with a population estimate of 0.02 ($\hat{S}$ <0.01) (Table 5-21). Estimates of the probability of remaining in the San Joaquin River at the junction with Old River (ψ_{A2}) ranged from 0.55 ($\widehat{SE}$ =0.03) for release group 4 to 0.63 ($\widehat{SE}$ =0.03) for release group 3, with a population estimate of 0.58 ($\widehat{SE}$ =0.01). For all releases, there was a significant preference for the San Joaquin River route over the Old River route at the head of Old River ($P<0.05$) (Table 5-21). Estimates of survival from Mossdale to Chipps Island through the San Joaquin River route (S_A) ranged from 0.004 ($\widehat{SE}$ =0.004) for release 2 to 0.01 ($\widehat{SE}$ =0.01) for releases 1 and 3, with a population estimate of 0.01 ($\widehat{SE}$ <0.01). In the Old River route, estimates of survival from Mossdale to Chipps Island ranged from 0 for release 1 to 0.07 ($\widehat{SE}$ =0.02) for releases 3 and 4, with a population estimate of 0.04 ($\widehat{SE}$ =0.01). The small number of tags detected at Chipps Island limited the precision with which survival could be estimated, especially in the San Joaquin River route. Despite that limitation, survival to Chipps Island was significantly higher ($P<0.05$) in the Old River route than in the San Joaquin River route for releases 3 and 4 (i.e., post-VAMP release groups), although not for releases 1 and 2 (Table 5-21). For the population overall, estimated survival to Chipps Island was significantly higher in the Old River route than in the San Joaquin River route ($P<0.0001$). The majority of the tags detected at Chipps Island (21 of 33, 64%) came through the CVP holding tank in the Old River route.

Survival was estimated to the Jersey Point/False River junction for fish that did not migrate through the holding tanks at the CVP or the SWP. This survival measure ($S_{Total(MD)}$) was successfully estimated for release groups 1 and 4, with estimates of 0.01 ($\widehat{SE}$ <0.01) in each case (Table 5-21). Sparse data at Jersey Point and False River prevented estimation of survival to those sites in releases 2 and 3. In all releases, very few tags were observed leaving the San Joaquin River for False River (Table 5-18, and Table 3 in Appendix H). Survival to Jersey Point and False River was not significantly different for the two primary routes at the head of Old River (i.e., San Joaquin and Old River routes) ($P>0.05$).

Table 5-21
Performance Metric Estimates (Standard Error in Parentheses) for Tagged Juvenile Chinook Salmon Released in the 2011 Tagging Study, Excluding Predator-Type Detections. South Delta ("SD") 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 and Middle River North Receivers in Route B. (Population-level estimates were estimated from the pooled release groups.)

Parameter	Release Occasion				Population Estimate
	1	2	3	4	
ψ_{AA}	0.43 (0.03)	0.46 (0.03)		0.50 (0.03)	0.46 (0.01)
ψ_{AF}	0.16 (0.02)	0.11 (0.02)		0.05 (0.02)	0.13 (0.01)
ψ_{BB}		0.42 (0.02)	0.36 (0.03)	0.45 (0.03)	0.41 (0.01)
ψ_{BC}		0.01 (0.00)	0.01 (0.00)	0.00 (0.00)	0.01 (0.00)
S_{AA}	0.02 (0.01)	0.01 (0.00)		0.01 (0.01)	0.01 (0.00)
S_{AF}	0.00 (0.00)	0.00 (0.00)		0.00 (0.00)	0.00 (0.00)
S_{BB}		0.02 (0.01)	0.06 (0.02)	0.07 (0.02)	0.04 (0.01)
S_{BC}		0.00 (0.00)	0.48 (0.34)	0.00 (0.00)	0.01 (0.00)
ψ_A	0.59[a] (0.02)	0.57[a] (0.02)	0.63[a] (0.03)	0.55[a] (0.03)	0.58[a] (0.01)
ψ_B	0.41[a] (0.02)	0.43[a] (0.02)	0.37[a] (0.03)	0.45[a] (0.03)	0.42[a] (0.01)
S_A	0.01 (0.01)	0.004 (0.004)	0.01[b] (0.01)	0.005[b] (0.005)	0.01[b] (0.00)
S_B	0.00 (0.00)	0.02 (0.01)	0.07[b] (0.02)	0.07[b] (0.02)	0.04[b] (0.01)
S_{Total}	0.01 (0.01)	0.01 (0.01)	0.03 (0.01)	0.03 (0.01)	0.02 (0.00)
$S_{A(MD)}$	0.02 (0.01)			0.01 (0.01)	0.01 (0.00)
$S_{B(MD)}$	0.01 (0.01)			0.00 (0.00)	0.003 (0.002)
$S_{Total(MD)}$	0.01 (0.00)			0.01 (0.00)	0.01 (0.00)
$S_{A(SD)}$	0.55[b] (0.03)	0.52 (0.03)		0.42[b] (0.03)	0.48[b] (0.02)
$S_{B(SD)}$	0.68[b] (0.03)	0.61 (0.04)		0.71[b] (0.04)	0.66[b] (0.02)
$S_{Total(SD)}$	0.61 (0.02)	0.56 (0.02)		0.55 (0.03)	0.56 (0.01)

[a] = significant preference for route A (San Joaquin Route) at head of Old River (α=0.05).
[b] = significant difference between route A and route B estimate (α=0.05).

Survival was estimated through the South Delta ($S_{A(SD)}$, $S_{B(SD)}$, and $S_{Total(SD)}$) for all but the third release group. The "South Delta" corresponded to the region studied in the 2009 VAMP study (SJRGA, 2010). Estimates of survival in the San Joaquin River from Mossdale to the Shipping Channel Markers (C18/C16) or Turner Cut (TCN/TCS) ($S_{A(SD)}$) ranged from 0.42 ($\widehat{SE}$ =0.03) for release group 4 to 0.55 ($\widehat{SE}$ =0.03) for release group 1, with a population estimate of 0.48 ($\widehat{SE}$ =0.02) (Table 5-21). In the Old River route, estimated survival from Mossdale to the entrances of the water export facilities (CVP, RGU) or the northern Old River and Middle River receivers near Highway 4 (ORN, MRN) ($S_{B(SD)}$) ranged from 0.61 ($\widehat{SE}$ =0.04) for release group 2 to 0.71 ($\widehat{SE}$ =0.04) for release group 4, with an average population survival estimate of 0.66 ($\widehat{SE}$ =0.22). Total estimated survival through the entire South Delta region ($S_{Total(SD)}$) ranged from 0.55 ($\widehat{SE}$ =0.03) for release 4 to 0.61 ($\widehat{SE}$ =0.02) for release group 1, with a population estimate of 0.56 ($\widehat{SE}$ =0.01) (Table 5-21).

Including predator-type detections in the analysis produced little change in the estimates of overall survival through the Delta, with the population estimate of survival from Mossdale to Chipps Island $\hat{S}_{Total}$ = 0.02 ($\widehat{SE}$ <0.01) (Table 5-22). Route-specific survival remained higher in the Old River route than in the San Joaquin River route for releases 3 and 4, and for the population overall (P<0.0001). While individual releases exhibited minor differences in route entrainment probabilities when predators were included, there was no effect of predators on the overall population estimate (Table 5-22). There was no difference in estimated survival from Mossdale to the Jersey Point/False River junction for in-river fish (i.e., excluding those passing through the water export facilities) when predator detections were included (Tables 5-21 and 5-22). South Delta survival in the San Joaquin River route increased slightly when predator detections were included, with a population estimate of $\hat{S}_{A(SD)}$ = 0.50 ($\widehat{SE}$ =0.02). South Delta survival in the Old River route increased some when predator detections were included, to $\hat{S}_{B(SD)}$ = 0.70 ($\widehat{SE}$ =0.01) (Table 5-22). The increase may be due to the typically high density of predators at the CVP trashracks and radial gates.

Table 5-22
Performance Metric Estimates (Standard Error in Parentheses) for Tagged Juvenile Chinook Salmon Released in the 2011 Tagging Study, Including Predator-type Detections. South Delta ("SD") 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 and Middle River Receivers in Route B. (Population-level estimates were estimated from the pooled release groups)

Parameter	Release Occasion				Population Estimate
	1	2	3	4	
ψ_{AA}	0.42 (0.03)	0.46 (0.03)		0.52 (0.03)	0.46 (0.01)
ψ_{AF}	0.16 (0.02)	0.10 (0.02)		0.05 (0.02)	0.12 (0.01)
ψ_{BB}	0.42 (0.02)	0.43 (0.02)	0.37 (0.03)	0.43 (0.03)	0.41 (0.01)
ψ_{BC}	0.005 (0.003)	0.01 (0.00)	0.01 (0.00)	0.00 (0.00)	0.01 (0.00)
S_{AA}	0.02 (0.01)	0.01 (0.01)		0.01 (0.01)	0.01 (0.00)
S_{AF}	0.00 (0.00)	0.00 (0.00)		0.00 (0.00)	0.00 (0.00)
S_{BB}	0.004 (0.005)	0.03 (0.01)	0.06 (0.02)	0.07 (0.02)	0.04 (0.01)
S_{BC}	0.00 (0.00)	0.01 (0.01)	0.47 (0.33)	0.00 (0.00)	0.02 (0.01)
ψ_A	0.58[a] (0.02)	0.56[a] (0.02)	0.62[a] (0.03)	0.57[a] (0.03)	0.58[a] (0.01)
ψ_B	0.42[a] (0.02)	0.44[a] (0.02)	0.38[a] (0.03)	0.43[a] (0.03)	0.42[a] (0.01)
S_A	0.01 (0.01)	0.01 (0.01)	0.01[b] (0.01)	0.01[b] (0.01)	0.01[b] (0.00)
S_B	0.004 (0.005)	0.03 (0.01)	0.06[b] (0.02)	0.07[b] (0.02)	0.04[b] (0.01)
S_{Total}	0.01 (0.01)	0.01 (0.01)	0.03 (0.01)	0.04 (0.01)	0.02 (0.00)
$S_{A(MD)}$	0.02 (0.01)			0.01 (0.01)	0.01 (0.00)
$S_{B(MD)}$	0.01 (0.01)			0.00 (0.00)	0.004 (0.003)
$S_{Total(MD)}$	0.01 (0.00)			0.01 (0.00)	0.01 (0.00)
$S_{A(SD)}$	0.58[b] (0.03)	0.55[b] (0.03)		0.44[b] (0.03)	0.50[b] (0.02)
$S_{B(SD)}$	0.75[b] (0.04)	0.67[b] (0.04)		0.73[b] (0.04)	0.70[b] (0.02)
$S_{Total(SD)}$	0.65 (0.02)	0.6 (0.03)		0.57 (0.03)	0.58 (0.01)

[a] = significant preference for route A (San Joaquin Route) at head of Old River (α=0.05).
[b] = significant difference between route A and route B estimate (α=0.05).

Travel Time

For tags classified as being in salmon smolts, average travel time through the reaches ranged from 0.01 days ($\widehat{SE}$ < 0.01) (approximately 14 minutes) moving from the upstream receivers to the downstream receivers at the radial gates, to 3.63 days ($\widehat{SE}$ =0.06) moving from Medford Island to Chipps Island (Table 5-23). There were multiple paths between Medford Island and Chipps Island; the path that used only the San Joaquin River was approximately 41 rkm. The majority of the travel time between Medford Island and Chipps Island (2.43 days, $\widehat{SE}$ =0.03) was spent moving from Medford Island to the Jersey Point/False River junction (approximately 21.9 rkm through the San Joaquin River route).

When all detections were considered, including predator-type detections, travel times changed only slightly (Table 5-23). Tagged fish took slightly longer moving through the Old River route in the western Delta, e.g. between the Old River South and Old River North receivers (1.67 days, $\widehat{SE}$ = 0.04 including predators *vs.* 1.21 days, $\widehat{SE}$ = 0.02 without predators, Table 5-23). Likewise, the average travel time from the Old River South receivers to the CVP trashrack increased from 0.56 days ($\widehat{SE}$ = 0.01) without predator-type detections to 0.70 ($\widehat{SE}$ =0.01) with predator-type detections. These longer travel times when predator-type detections are included reflect the travel time criteria in the predator filter, which assumes that predators may move more slowly through the study area than migrating salmon smolts. For most reaches, including the predator-type detections resulted in little if any difference in observed travel times. Travel times through many reaches were shorter in 2011 than in 2010.

Route Entrainment Analysis

River flow at the San Joaquin River gauging station at Lathrop (station SJL) ranged from 4,157 cfs to 5,840 cfs (average = 5,070 cfs) during the arrival times of the tagged Chinook salmon smolts in 2011. The flow in the San Joaquin River never reversed direction during the 2011 tagging study. River flow at the Old River gauging station near the head of Old River (station OH1) ranged from 4,480 to 5,645 (average = 5,111 cfs) during the same time. There was little correlation between flow

Table 5-23
Average Travel Time in Days (Harmonic Mean) of Acoustic-tagged Juvenile Chinook Salmon Through the San Joaquin River Delta During the 2011 Tagging Study

Reach		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)	1,623	0.17	<0.01	1,622	0.17	<0.01
Banta Carbona (BCA)	Mossdale (MOS)	1,325	0.14	<0.01	1,325	0.15	<0.01
Mossdale (MOS)	Lathrop (SJL)	798	0.06	<0.01	783	0.06	<0.01
	Old River East (ORE)	581	0.06	<0.01	580	0.06	<0.01
Lathrop (SJL)	Stockton USGS Gauge (STS)	755	0.32	<0.01	759	0.32	<0.01
Stockton USGS Gauge (STS)	Stockton Navy Drive Bridge (STN)	728	0.06	<0.01	728	0.06	<0.01
Stockton Navy Drive Bridge (STN)	Shipping Channel Markers (C18/C16)	358	1.00	0.01	364	1.10	0.02
	Turner Cut (TCN/TCS)	96	1.04	0.01	96	1.09	0.01
Shipping Channel Markers (C18/C16)	Medford Island (MFE/MFW)	141	0.27	0.01	150	0.29	0.01
Medford Island (MFE/MFW)	Jersey Point/False River Junction (JPT/FRE/FRW)	8	2.43	0.03	9	2.45	0.03
Old River East (ORE)	Old River South (ORS)	631	0.10	<0.01	631	0.10	<0.01
	Middle River South (MRS)	6	0.12	<0.01	6	0.12	<0.01
Old River South (ORS)	Old River North (ORN)	105	1.21	0.02	96	1.67	0.04
	Middle River North (MRN)	2	0.68	0.01	2	0.68	0.01
	Clifton Court Forebay Access Channel (RGU)	162	0.54	0.01	163	0.56	0.01
	Central Valley Project Trashrack (CVP)	144	0.56	0.01	156	0.70	0.01
Old River North (ORN)	Jersey Point/False River Junction (JPT/FRE/FRW)	1	1.34	NA	2	0.77	0.01
Middle River South (MRS)	Old River North (ORN)	1	2.62	NA	1	2.62	NA
	Middle River North (MRN)	1	0.84	NA	1	0.84	NA
	Clifton Court Forebay Access Channel (RGU)	2	2.16	0.01	3	2.68	0.03
	Central Valley Project Trashrack (CVP)	0	NA	NA	0	NA	NA
Clifton Court Forebay Access Channel (RGU)	Clifton Court Forebay Interior (RGD)	127	0.01	<0.01	142	0.01	<0.01
Central Valley Project Trashrack (CVP)	Central Valley Project Holding Tank (CVPtank)	34	0.02	<0.01	37	0.02	<0.01
Jersey Point (JPT)	Chipps Island (CHP)	7	0.86	0.01	8	0.90	0.01
Medford Island (MFE/MFW)		6	3.63	0.06	7	3.99	0.07
Turner Cut (TCN/TCS)		0	NA	NA	0	NA	NA
Old River North (ORN)		1	1.84	NA	1	1.84	NA
Middle River North (MRN)		0	NA	NA	0	NA	NA
Clifton Court Forebay Interior (RGD)		3	1.83	0.01	4	2.25	0.03
Central Valley Project Holding Tank (CVPtank)		21	0.94	0.01	21	0.94	0.01

in the San Joaquin River and flow in Old River at the time of tag arrival at the river junction (r=-0.06). Water velocities ranged from 1.5 ft/s to 2.2 ft/s (average = 2.0 ft/s) at SJL, and from 1.7 ft/s to 2.1 ft/s (average = 1.9 ft/s) at OH1 during this time (r=0). Flow and velocity at the SJL station at the time of tag arrival were highly correlated (r=0.76), as were flow and velocity at the OH1 station at that time (r=0.73). The proportion of river flow entering the San Joaquin River averaged 0.50, ranging from 0.43 to 0.53, and was highly correlated with flow into the San Joaquin (r=0.81). Export levels were held fairly steady for the first two release groups, averaging 1,058 cfs at CVP and 1,583 cfs at SWP, with higher levels for the last two release groups, averaging 3,035 cfs at CVP and 6,287 cfs at SWP. There was moderate correlation between combined exports levels and flow at SJL (r=-0.33), and combined export levels and flow at OH1 (r=0.47).

The single-variate analyses found that the probability of remaining in the San Joaquin River at the head of Old River in 2011 was significantly related to both velocity and flow at the SJL gauging station (P<0.05, Table 5-24), with increased probability of staying in the San Joaquin River observed with increases in both flow and velocity at SJL. No other covariates had a significant effect on route entrainment into the San Joaquin River at the 5% level (Table 5-24).

Table 5-24
Results of Single-Variate Analyses of Route Entrainment at the Head of Old River

Covariate	F-test		
	F	df1, df2	P
Velocity at SJL[a]	12.4238	1, 1571	0.0004
Flow at SJL[a]	4.8088	1, 1571	0.0285
Flow proportion into San Joaquin	3.0189	1, 1571	0.0825
Velocity at OH1	2.8630	1, 1571	0.0908
Change in velocity at OH1	2.2363	1, 1569	0.1350
Change in flow proportion into San Joaquin	1.7360	1, 953	0.1880
Change in flow at OH1	1.7235	1, 1569	0.1894
Fork Length	1.1461	1, 1573	0.2845
Release Group	0.8255	3, 1571	0.4797
Change in flow at SJL	0.0938	1, 954	0.7595
Exports at SWP	0.0765	1, 1573	0.7822
Combined Exports	0.0563	1, 1573	0.8125
Change in velocity at SJL	0.0167	1, 954	0.8971
Exports at CVP	0.0113	1, 1573	0.9153
Flow at OH1	<0.0001	1, 1571	0.9936

[a] = Significant at 5% level

Table 5-25
Results of Multivariate Analyses of Route Entrainment at the Head of Old River

Model Type	Covariate[a]	Estimate	S.E.	t-Test		
				t	df	P
Velocity	Intercept	0.3407	0.0514	6.623	1,571	<0.0001
	V_A	0.2098	0.0515	4.072	1,571	<0.0001
	Goodness-of-fit: χ^2=9.3616, df=11, P=0.5886; AIC = 2123.70					
Flow	Intercept	0.3389	0.0513	6.612	1,571	<0.0001
	Q_A	0.1308	0.0514	2.547	1,571	0.0110
	Goodness-of-fit: χ^2=11.6756, df=11, P=0.3885; AIC = 2133.94					

[a] = continuous covariates (Q_A, V_A) are standardized

Multivariate analyses came to the same conclusion, with both flow and velocity at the SJL station individually explaining a significant amount of the variability in route entrainment at the head of Old River in 2011 (Table 5-25). Both models adequately fit the data (P=0.39 to 0.59), but velocity at SJL accounted for more of the variation in route entrainment than flow (ΔAIC=10.24; Table 5-25). The velocity model predicted the route entrainment probability according to:

$$\widehat{\psi_A} = \frac{\exp(-3.14 + 1.77V_A)}{1 + \exp(-3.14 + 1.77V_A)}.$$

Increases in water velocity in the San Joaquin River at Lathrop were predicted to increase the probability of route entrainment into the San Joaquin River at the head of Old River (Figure 5-11).

Mobile Telemetry Monitoring

Mobile tracking efforts in previous years identified three sites of high juvenile salmon mortality or tag defecation by predators: 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, 2007 and 2010). Based on the 2011 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. Two additional areas that appeared to be predation "hot-spots" in 2011 were around the Tracy Blvd Bridge in Grant Line canal, and in the Stockton Deep Water Ship Channel (DWSC) near Turner Cut. A total of 48 immobile tags were detected near the Tracy Blvd Bridge (Figure 5-12), and 78 tags were identified in the 2 miles above Turner Cut (Figure 5-13).

A total of 952 tag detections were recorded during the sampling period, representing detection of 668 individual tags. Of these detections, 361 had been implanted in Chinook, 290 in Steelhead, and 17 in various predators. The final location of all Chinook tag detections is shown in Figure 5-14. During one sampling event on May 25th, the GPS receiver malfunctioned so detection locations were not recorded for 34 tags.

Survival in the San Joaquin River between Banta Carbona and Old River appeared to be high during the 2011 VAMP. Of the few tags lost in this reach that had been released at Durham Ferry, eight Chinook tags were detected by mobile tracking and were found to be distributed evenly throughout the reach with no apparent hot spots.

A total of 172 tags from marked salmon were detected in the San Joaquin River between Old River and Turner Cut. Seventy-three percent (73%) of the detected Chinook tags in this reach of the San Joaquin River were found in the Stockton DWSC (n=126), while the remaining 46 were detected spread fairly evenly throughout the reach between its junction with Old River and the Stockton DWSC.

A total of 162 Chinook tags were detected in Old River and Grant Line Canal between the Head of Old River and the State and federal pumping facilities. The highest concentration of the tags detected by mobile monitoring in this reach were detected in Grant Line Canal 54% (n=88), while 29% (n=47) were found in the vicinity of the State and federal pumping facilities, and the remaining 17% (n=27) were detected in Old River upstream of Grant Line Canal. The number of tags detected in Grant Line Canal was much higher than previous years. It is unknown whether the fish were preyed upon in this location, or if they were eaten at other locations and later deposited where they were detected.

Unmarked and Marked Salmon Captured at Mossdale

The general time period for VAMP (mid-April to mid-May) was determined based on historical data, which indicates that a high percentage of salmon smolts emigrating from the San Joaquin River tributaries pass Mossdale (MOS) during this time. The 2011 VAMP period was May 1st through May 31st, and trawl sampling at Mossdale was conducted three days per week from January until March, five days per week from April to mid-June (with the exception of a two-week period from May 9th to the 22nd when the trawl was operated daily); and three days per week for the remainder of June.

Densities (catch per 10,000 cubic meters) of unmarked juvenile salmon captured at Mossdale from January through June are shown in Figure 5-15. 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 Merced River Hatchery (MRH). Unmarked hatchery fish (n=1,818) were released into the Merced River on July 15th. All other Chinook released from the MRH were either coded-wire tagged with their adipose-fin clipped (n=122,973) or released with an external Panjet mark (n=19,805)[2]. A combined total of 660 adipose fin-clipped (n=316) and Panjet marked (n=344) Chinook were captured in the trawl. The trawl captured zero acoustic-tagged fish in 2011.

Average daily densities of unmarked juvenile salmon were extremely low from January through mid-April (i.e., less than 0.2 salmon per 10,000 cubic meters). Densities began to rise in late-April, as river flows began to decrease, and remained elevated through mid-June (Figure 5-15). Juvenile Chinook emigrated from the San Joaquin Basin later than usual due to higher flows and lower water temperatures in 2011. The size of juvenile salmon captured in the Mossdale trawl between January and June is shown in Figure 5-16.

[2] *6,669 of the Panjet marked fish were also coded-wire tagged with their adipose-fin clipped. These fish were not included in the total number of CWT fish listed. These fish were released above Mossdale on May 27th and June 10th. Recaptures were designated as having either a Panjet or an ad-clip (i.e., both marks were not indicated).*

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 exact origin of these untagged salmon is unknown. It is uncertain which of the unmarked salmon recovered are of San Joaquin River basin origin, although the timing of salvage and fish size can be compared with Mossdale trawl data to provide a general indication as to the extent of potential overlap. The combined exports in 2011 exceeded the flow at Vernalis prior to April and during the majority of June, and ranged from 40 to 62% less than Vernalis flow from April to early June (Figure 5-17) (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 CDFG 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 head of Old River barrier (HORB), and the amount of water pumped by each facility are some of the factors that influence the number of juvenile salmon that are salvaged or lost. Salmon density at the facilities can be an indicator of time periods when more juvenile salmon may be susceptible to the export and salvage system. Since salvage efficiency is likely lower for smaller-sized salmon (fry and parr), their salvage numbers and estimated losses could be 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 May at CVP and in mid-May at SWP, then remained elevated through the entire month of June (Figures 5-18 and Figure 5-19). Salmon densities (based on combined salvage and loss estimates divided by 1,000 acre feet of export) were highest at both facilities following the conclusion of the VAMP period (Figure 5-20) when exports increased. Densities at the SWP had a distinct peak in late-May, whereas the CVP did not show a well-defined peak during the smolt emigration.

The size and timing distributions of unmarked salmon in the Mossdale trawl (Figure 5-16) during January through June corresponds well with the distributions of the fish salvaged at the facilities during this same time period (Figure 5-21, Source: A. Llaban, DWR). Based on comparisons with Mossdale data, it appears that many salmon salvaged from the late-May through June period could have originated from the San Joaquin River basin.

These results demonstrate that the primary 2011 San Joaquin River basin salmon smolt migration period from the beginning of May to late-June coincided with the higher salvage period of the CVP/SWP facilities. Sampling frequency at Mossdale during the smolt emigration period has decreased from 7 to 5-days per week during the last several years. In 2011, CDFG operated the Mossdale trawl 7-days per week for a two-week period beginning in mid-May when abundance began to increase. Unfortunately, the increased sampling frequency did not coincide with peak abundance, which occurred two weeks later when CDFG returned to the reduced sampling frequency (i.e., 5-days per week). Production estimates at Mossdale could be improved by ensuring that sampling is conducted daily when most salmon smolts are emigrating.

Discussion

Detections Not Used in the Survival Model

Several detections of acoustic tags at Chipps Island were not used in the survival analysis. One tag (tag ID = 6990.13) was detected at Threemile Slough after its final Chipps Island detection, and was not detected again. Using all detections (i.e., without the predator filter), this tag's detection history ignored the Chipps Island detections because the tag was detected upstream after being detected at Chipps Island; although the fish reached Chipps Island, it did not either stay there or move downstream, but rather returned to the Delta. Using the predator-filtered data, however, the tag was classified as in a predator at its Threemile Slough detection but not at its Chipps Island detection. In this case, the Chipps Island detection was used in the survival analysis, but it is unlikely that the salmon smolt survived to points downstream of Chipps Island. Another tag (tag ID = 9377.13) was detected at Chipps Island, but only on the single hydrophone closest to the entrance to Spoonbill Creek. The possibility of tagged fish leaving the river for Spoonbill Creek violated the closure assumption of the dual array at Chipps Island, so detections on this single receiver were omitted from the survival analysis. This tag had previously been classified as a predator at the Central Valley Project, so even if the Spoonbill Creek detections had been included, this tag's detection would not have contributed to estimates of survival to Chipps Island. All other detections at Chipps

Figure 5-11
Fitted Probability of Remaining in the San Joaquin River at the Head of Old River versus Water Velocity Measured at the SJL Gaging Station near Lathrop, CA, with 95% Confidence Bands, in 2011

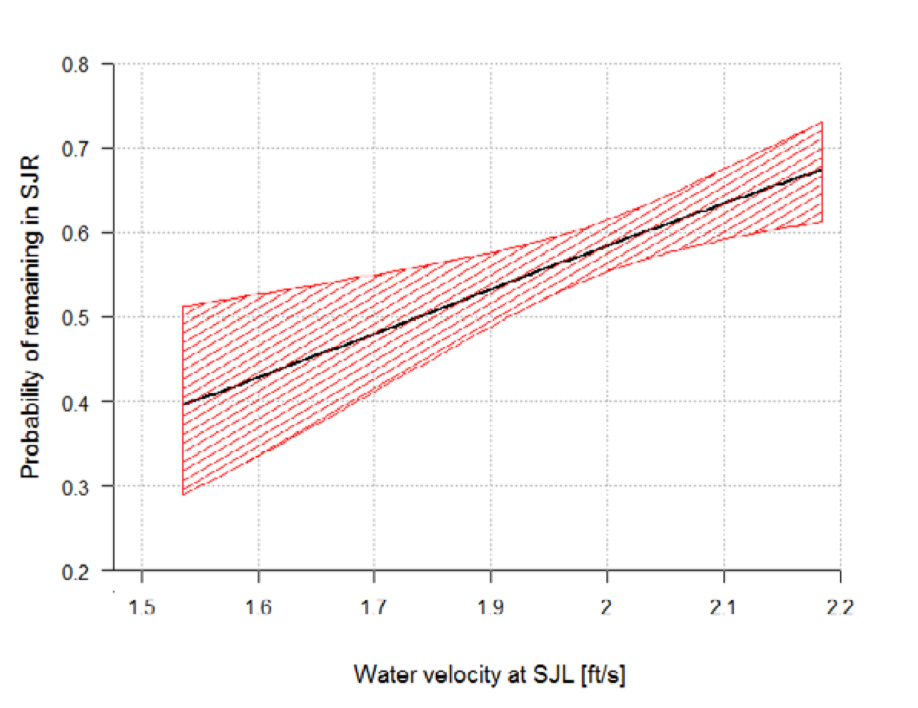


Figure 5-12
Approximate Last Known Location of Acoustic Tags Detected as Immobile in Grantline Canal Near the Tracy Boulevard Bridge Using Mobile Telemetry Monitoring During the 2011 Tagging Studies

Figure 5-13
Approximate Last Known Location of Acoustic Tags Detected as Immobile in the San Joaquin River Upstream of Turner Cut Using Mobile Telemetry Monitoring During the 2011 Tagging Studies

Figure 5-14
Approximate Last Known Location of Acoustic Chinook Tags Detected as Immobile Using Mobile Telemetry Monitoring During the 2011 Tagging Studies

Figure 5-15
Average Daily Densities of Unmarked Juvenile Chinook Salmon Caught in the Mossdale Kodiak Trawl in 2011 on the San Joaquin River

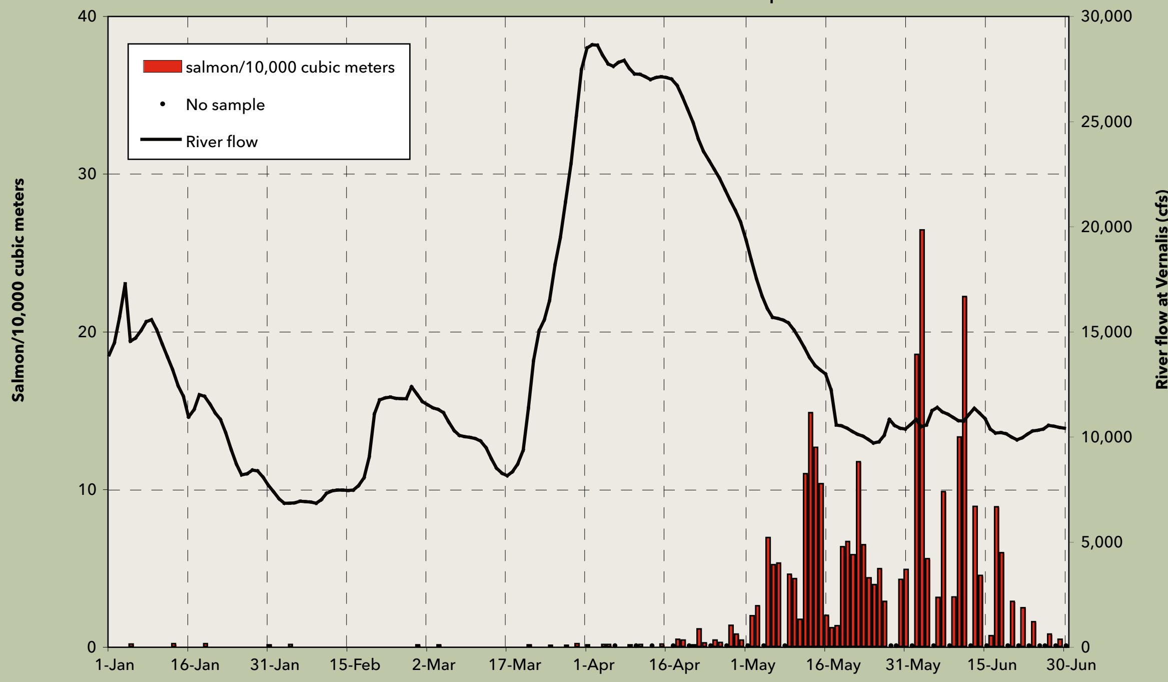


Figure 5-16
Individual Daily Forklengths (FL) in millimeters of Marked and Unmarked Juvenile Chinook Salmon from the Mossdale Kodiak Trawl on the San Joaquin River, January through June 2011

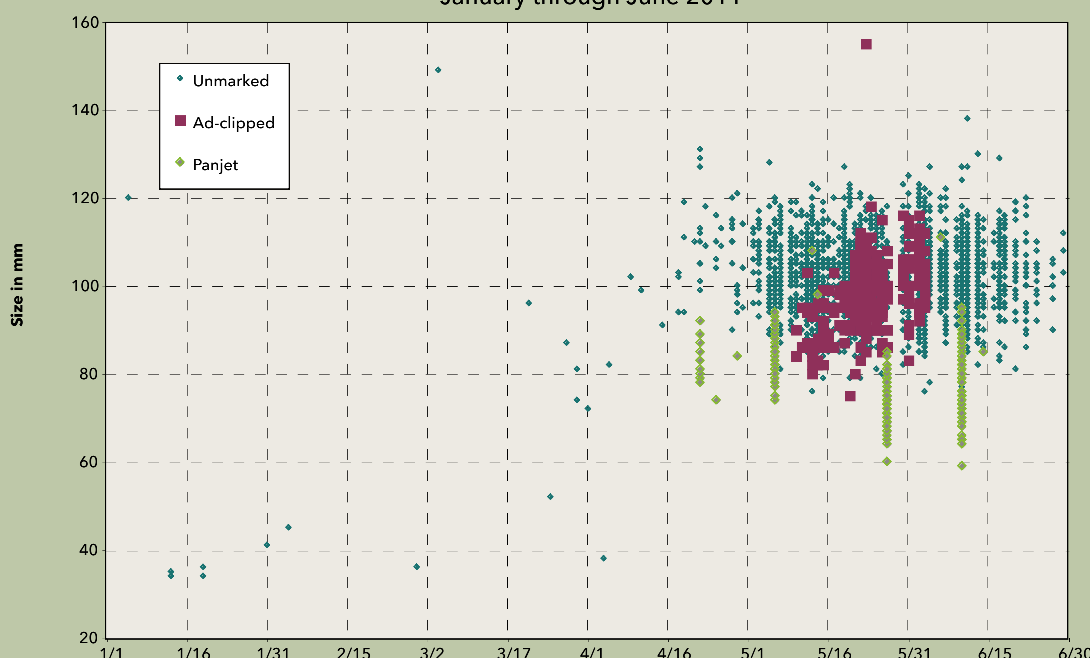


Figure 5-17
Weekly Average Export Rates from January through June 2011 from the State Water Project (SWP) & Central Valley Project (CVP) and Vernalis Flow in Cubic Feet per Second (cfs)

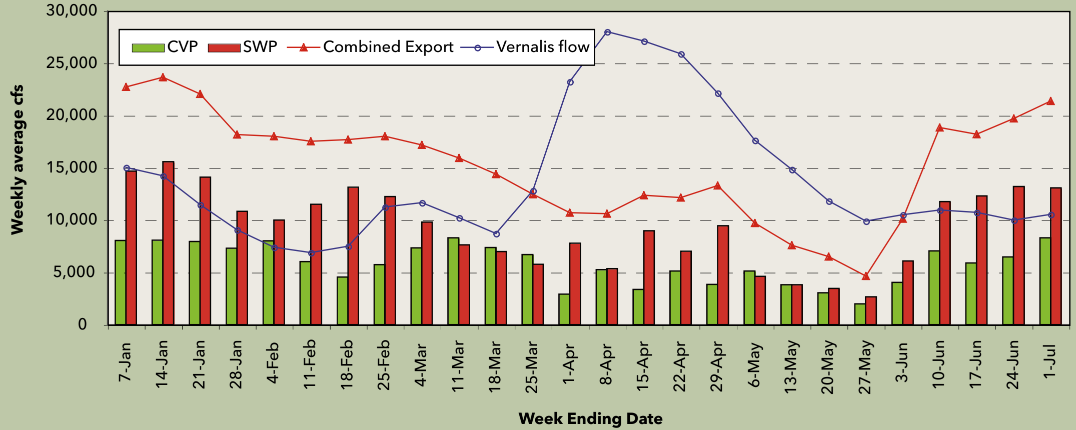


Figure 5-18
Central Valley Project (CVP) Estimated Juvenile Chinook Salmon Salvage and Loss from January through June 2011

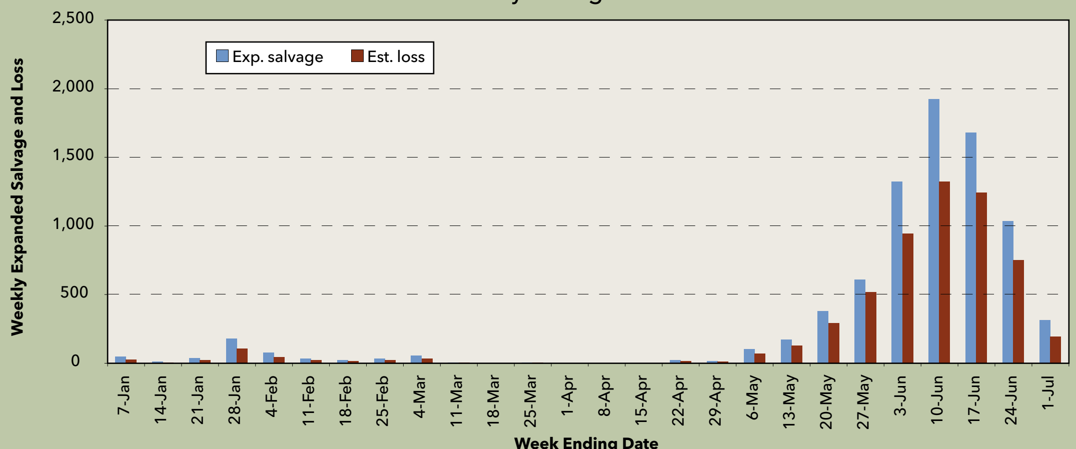


Figure 5-19
State Water Project (SWP) Estimated Juvenile Chinook Salmon Salvage and Loss from January through June 2011

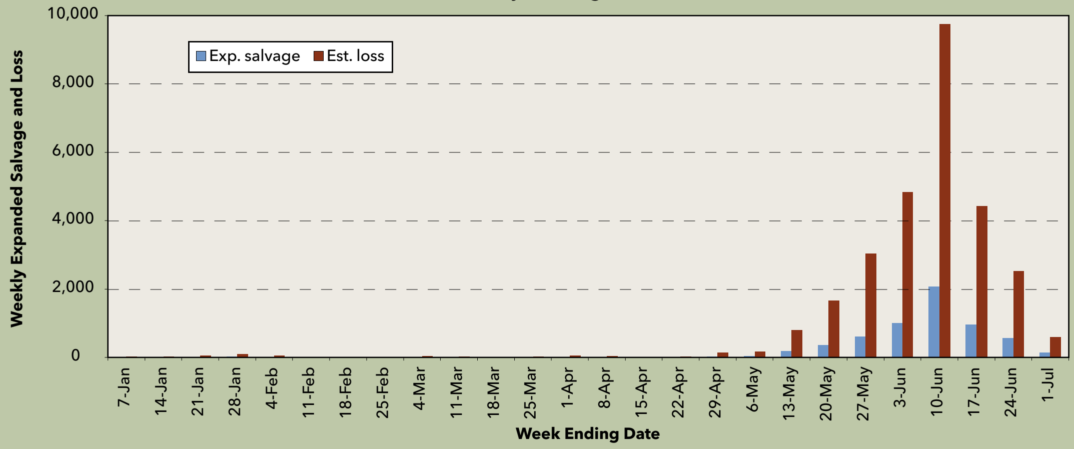


Figure 5-20
State Water Project (SWP) & Central Valley Project (CVP) Combined Juvenile Chinook Salmon Salvage and Loss Density Estimates per 1,000 Acre Feet of Export from January through June 2011

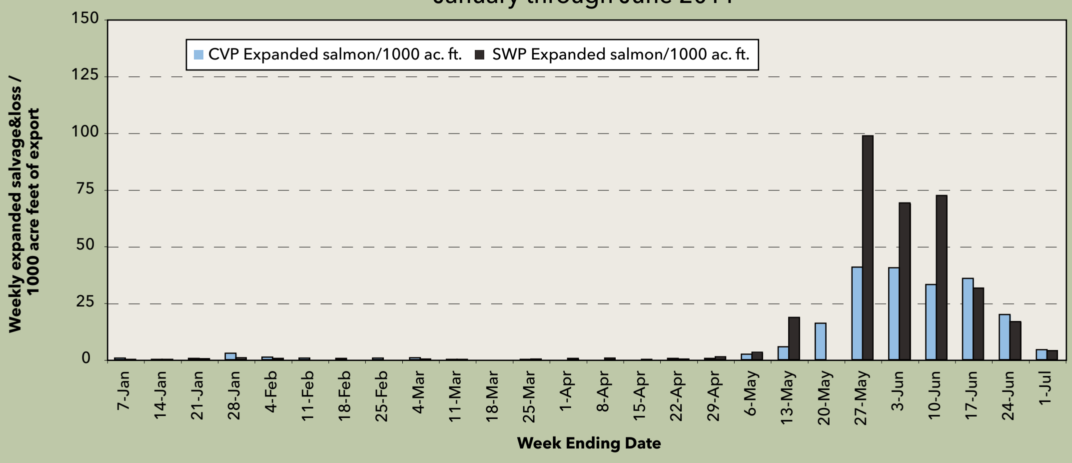
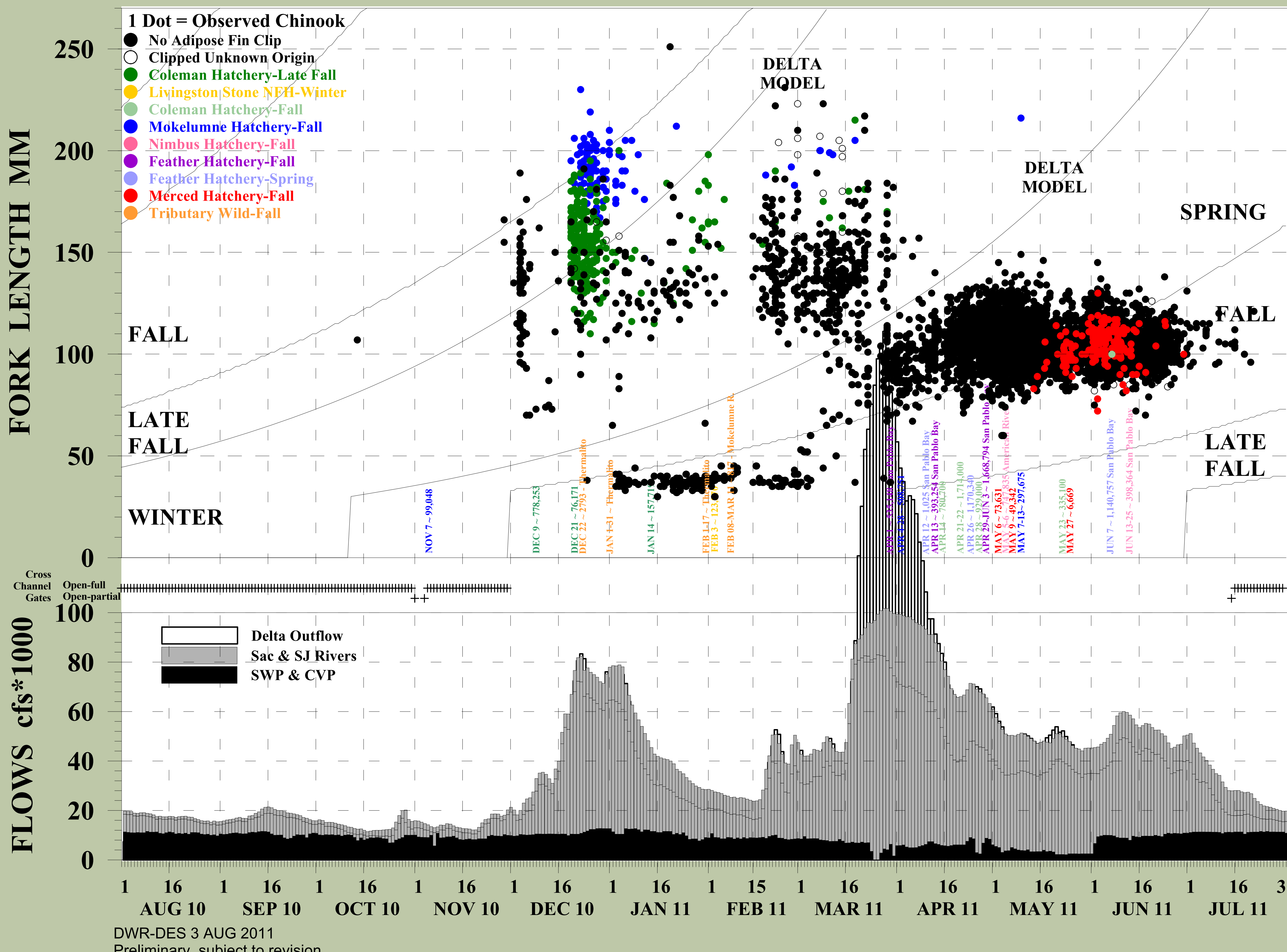


Figure 5-21
Observed Juvenile Chinook Salmon in Salvage at the State Water Project (SWP) & Central Valley Project (CVP) Delta Fish Facilities from 8/1/2009 Through 7/31/2010
(Source: A. Llaban, DWR)



Island were used in the survival model, either using the reduced "smolt-only" data or using the full data set that included the predator-type detections. If all predator-type detections, including those mentioned here, had been included along with this detection, the overall estimate of survival to Chipps Island would still have been 0.02 for the entire study period and 0.01 during the VAMP Target Flow period.

Survival in 2011

Survival through the Delta was low in 2011. Although estimated survival was observed to be higher in the Old River route (0.04, $\widehat{SE}$ = 0.01) than the San Joaquin River route (0.01, $\widehat{SE}$ = 0.00), survival in both routes was very low both during and after the VAMP period. One benefit of using acoustic tags and estimating reach and route specific survival is that it allows us to identify areas of high relative mortality as the tagged fish migrate downstream. Evaluating survival by reach may help explain why survival through the Delta using either route was so low for tagged juvenile salmon used in these studies in 2011.

The four release groups of acoustic-tagged Chinook salmon analyzed for survival and route entrainment probabilities in 2011 consisted of two groups released during the latter half of the 2011 VAMP period and two groups released within three weeks after the end of the VAMP. While survival was generally low for all four release groups, overall estimated survival to Chipps Island was slightly higher for the post-VAMP release groups than for the VAMP release groups: 0.01 ($\widehat{SE}$ =0.004) during VAMP vs. 0.03 ($\widehat{SE}$ =0.007) after VAMP (P=0.0015). The small increase in survival after the end of VAMP came from an increase in the route-specific survival to Chipps Island via the Old River route: $\bar{\hat{S}}_B = 0.01$ ($\widehat{SE}$ =0.006) during VAMP vs. $\bar{\hat{S}}_B = 0.07$ ($\widehat{SE}$ =0.014) after VAMP (P=0.0002). The increase in survival was coincident with an increase in the water export rate throughout the Delta after the VAMP ended. However, despite the increase in estimated survival after the end of the VAMP, survival estimates from the period of higher export levels remained very low.

South Delta Survival in 2011

Estimated survival in 2011 through the Southern Delta region was relatively high at 0.56 ($\widehat{SE} \leq 0.03$; without predator-like detections) compared to survival through the entire Delta. The Southern Delta region started at Mossdale, with endpoints at: 1) the entrances to Clifton Court Forebay and the CVP; 2) Old River North and Middle River North receivers near Highway 4, and 3) the receivers in the San Joaquin River and in Turner Cut just downstream of the Turner Cut junction.

Overall survival through the Southern Delta region in the Old River route was estimated at 0.66 ($\widehat{SE}$ =0.02), with the majority of the mortality occurring after fish passed Old River South (ORS, site B2). For fish that survived to ORS, approximately 23% ($\widehat{SE}$ =2%) arrived at the CVP trashracks, and another 29% ($\widehat{SE}$ =0.02) arrived at the radial gates (RGU). Approximately 16% of ORS fish ($\widehat{SE}$ =0.01) made it past those sites to the Old River North (ORN) receivers near Highway 4. Combined over these ORN, CVP, and RGU, these results indicate a survival estimate of 0.68 ($\widehat{SE}$ =0.02) in the Southern Delta region between ORS and ORN, CVP, and RGU.

In contrast, the lowest survival estimate in the Southern Delta region in the San Joaquin River route was 0.59 ($\widehat{SE}$ =0.02) for the reach from the Navy Drive Bridge (STN) to the channel markers (A8) and Turner Cut (F1). The low survival estimate in this reach resulted in lower estimates of overall survival through the Southern Delta region for the San Joaquin River route fish ($\hat{S}_{A(SD)}$ =0.48, $\widehat{SE}$ =0.02) than for the Old River route fish ($\hat{S}_{B(SD)}$ =0.66, $\widehat{SE}$ =0.02) (Table 5-21).

Survival in Downstream Reaches of the Delta

Survival in the Delta downstream of the Southern Delta endpoints was generally much lower than upstream, and contributed to the low survival to Jersey Point and Chipps Island regardless of which pathway the juveniles took. One mechanism for the low survival in the San Joaquin River route may be diversion into the interior and south Delta as the tagged fish move downstream. Averaged over all releases (VAMP and non-VAMP), approximately 21% of the tagged fish that approached the Turner Cut junction on the San Joaquin River entered Turner Cut: 23% during the VAMP releases vs. 18% after VAMP. However, none of those tagged fish entering the interior Delta via Turner Cut were subsequently detected at Chipps Island. One of the tags detected at Turner Cut (from release 2 during the VAMP) that had previously been detected at the Navy Drive Bridge receiver (STN) was later detected at Middle River North (MRN) and then at the Clifton Court Radial Gates (RGU), but it did not survive to Chipps Island. This was not an isolated case of movement from the San Joaquin River to the interior Delta as eight other tags originating from the San Joaquin River were also detected at the MRN receivers (including predator-type detections), none of which were subsequently observed at Jersey Point or Chipps Island. The majority (6 of 8) of those tags detected entering the interior Delta from the San Joaquin River came from releases made after the end of the VAMP. These detection histories appear to support the hypothesis that tagged fish leaving the San Joaquin River via Turner Cut or other junctions move further into the Southern Delta towards the SWP or CVP, either as a smolt or a predator. Only 1 fish of 17 detected at Middle River (MRN) survived to Chipps Island (by way of Clifton Court Forebay), suggesting that fish that have entered the interior Delta from the San Joaquin River tend not to re-enter the San Joaquin River, but rather move further into the south/southwestern Delta. It also suggests survival to Chipps Island is low for fish entering the interior Delta from the San Joaquin River. This is further supported by the low estimated joint probability of fish successfully moving from Old River north (ORN) to Jersey Point or False River ($\phi_{B3,GH}$ = 0.02, $\widehat{SE}$ =0.01, Table 2 and Table 3 in Appendix H).

Movement towards the interior and south Delta from the mainstem San Joaquin River may also account for the high mortality inferred by the low estimated transition probabilities between Medford Island (A10) and Jersey Point (G1). The average estimate of this transition probability ($\phi_{A10,GH}$) was 0.08, suggesting many of the fish that arrive at Medford are not successfully making it downstream to Jersey Point. Movement into the interior Delta via Old or Middle rivers or through Frank's Tract may contribute to this perceived mortality.

The estimated transition probability from the CVP trashracks to the holding tanks averaged 0.23 ($\widehat{SE}$ =0.03) over all release groups (0.15 during VAMP; 0.28 after VAMP). One mechanism for this low probability of reaching the holding tanks may be from predation between the trashracks and the holding tanks. This hypothesis is supported by the detection of 46 tags that were detected at the CVP trashracks that were later found elsewhere in the south Delta. Some of these tags were later detected back at the CVP, but none of them were detected at Chipps Island, all behavior suggesting the smolts were preyed upon between the CVP trashracks and the holding tank. In addition, some tags (14) were detected by the receiver located in the Delta Mendota Canal (DMC) and could account for some of the mortality between the CVP trashracks and the holding tanks. Furthermore, an additional seven tags were subsequently detected on the CVP trashrack receivers after being detected in the DMC, suggesting that tagged fish or predators are moving from inside the CVP to the DMC and back at a high rate. Predation was observed at the CVP with 37 tags classified as in a predator upon arrival at the CVP and 67 tags classified as predators upon departure from CVP. The mobile monitoring confirmed predation appeared to be high in front of the CVP, with a total of 37 acoustic tags detected near this location.

The joint probability of moving and surviving from the CVP holding tanks to Chipps Island was relatively high with an average estimate of 0.62 ($\widehat{SE}$ =0.08), averaged over all release groups. For the release groups during VAMP, the estimate was 0.50 ($\widehat{SE}$ =0.18); after VAMP, the estimate was 0.65 ($\widehat{SE}$ =0.09). This is in contrast to the survival through Clifton Court Forebay and the SWP, where the estimated transition probability from RGD to Chipps Island was low for all release groups (average = 0.02; $\widehat{SE}$ =0.01). This result seems consistent with previous studies (Clark et al., 2009; Gingras, 1997; SJRGA, 2011) that have identified high mortality for juvenile steelhead or salmon moving through Clifton Court Forebay and through the SWP. The VAMP team evaluated estimating the survival through the SWP more precisely, but sample sizes needed were estimated to be quite large (Appendix I).

The receivers at the radial gates inside the Clifton Court Forebay (RGD) had only one tag classified as in a predator on arrival, but 106 tags classified as in a predator on departure from RGD. The mobile tracking confirmed that several tags were found in the vicinity of the State and federal pumping facilities.

Comparison of 2011 Results to Past Years

Smolt survival through the Delta from Mossdale or Durham Ferry to Jersey Point has been extremely low over the past 10 years regardless of flow, exports, or operation of the HORB. Since 2003, at flows ranging from approximately 2,000 to 27,000 cfs, survival was consistently less than or equal to 12%. In contrast, survival between 1994 and 2001 was much higher and generally ranged between approximately 15 and 50% (Figure 5-1). These present survival levels will not produce a sustainable population. The reason for the change in survival in the last decade is unclear and more study is needed to better define what is happening.

Estimated survival in 2011 through the Southern Delta was consistent with the 2010 estimate (0.56, $\widehat{SE} \leq 0.03$ in both years) and considerably higher than the 2009 estimate (0.06, $\widehat{SE}$ =0.01) (without predator-like detections). Differences in survival between years may be due to flow, with 2009 a low-flow year and 2010 and 2011 above normal and wet flow years, respectively (Buchanan et al., 2013). However, differences between years, could also be due to differences in tag weight to body weight ratios as the minimum fish size criteria were not met in 2009; or due to differences in fish origin since Feather River Hatchery fish were used in 2009 while in 2010 and 2011 the smolts came from Merced River Hatchery. Any one or all of these factors may have contributed to the apparent differences in survival between 2009 and other years.

Between 1985 and 1991, CWT studies were conducted to estimate survival in the two main routes through the Delta; Old River and the San Joaquin River. The results of these studies indicated survival was generally higher for the fish released on the San Joaquin River at Dos Reis, downstream of Old River, than for fish released into

Old River (Brandes and McLain, 2001). These studies were the basis for installing a physical rock barrier at the head of Old River (HORB) prior to and during the VAMP studies. The physical HORB kept the majority of CWT fish (SJRGA, 2005) and flow in the San Joaquin River.

Starting in 2008, the use of acoustic tags facilitated estimating the proportion of fish taking each route (route entrainment) and estimating survival in each route. In 2008, tag failure prevented unbiased survival estimates, but survival still appeared to be higher on the San Joaquin route than for the Old River route (Holbrook et al., 2009). In contrast, the results in 2010 were mixed about which route through the Delta had higher survival. Although, survival for each of the separate release groups was not significantly different between the Old River and San Joaquin routes, with the exception of the first release group, where survival in the San Joaquin River was higher, pooling all the release groups together suggested survival was higher in the Old River route in 2010 (SJRGA, 2011). In 2011, survival appeared to be higher in Old River than in the San Joaquin River. It is not clear if survival in the San Joaquin route decreased in 2010 and 2011 or whether survival in Old River has increased, for the relative survival to be higher in Old River.

Route entrainment analysis in 2011 found that the probability of remaining in the San Joaquin River at the head of Old River was positively associated with flow and water velocity at Lathrop, with higher flows and water velocities corresponding to more salmon migrating in the San Joaquin River route. Because survival to Chipps Island in 2011 was estimated to be lower in the San Joaquin River route than in the Old River route, this meant that overall survival was lower to Chipps Island for higher flows and velocities at Lathrop.

This year was the last year for the VAMP studies. The VAMP agreement has ended and it is clear additional salmon survival monitoring is needed to estimate survival through the Delta and between the two major routes. It is clear that survival is low for juvenile salmon migrating between Mossdale and Chipps Island and has potentially gotten lower over time. Without a structured set of flow and export targets providing survival estimates in several years under the same flow and export targets, it would not have been possible to detect the shift in survival in 2003 and 2004, relative to 2002 (Figure 5-1). Estimating survival with a structured set of test conditions over a number of years allowed results from annual studies to build on one another to improve our understanding of the complexities of juvenile salmon survival in the Delta.

In addition, the change to acoustic tag methodology allows us to measure route and reach specific survival to better understand what is causing the low observed survival. There is uncertainty in estimating survival using acoustic tags due to the uncertainty of smolts being eaten by predators and tags being detected inside the predator. However, this uncertainty tends to bias survival high, and even without removing predator-type detections survival to Chipps Island has been low. There is also uncertainty of how these tags may affect the survival of acoustic-tagged fish and whether such fish are more prone to predation than untagged salmon would be. Although an effort was made to adhere to the 5% tag weight to body weight ratio, doing so has resulted in releasing the experimental fish later in the season than if smaller tags or CWTs had been used. Additional studies are needed. Pairing acoustic studies with CWT studies may help validate the survival estimates observed with the acoustic tags. In addition, there is still much to learn about what is causing, and what might reduce, the mortality through the Delta of juvenile salmon originating from the San Joaquin River basin.

CHAPTER 6

COMPLIMENTARY STUDIES RELATED TO THE VAMP

Throughout 2011 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, 2011

Contributed by Chrissy Sonke, FISHBIO

The VAMP includes protective measures for San Joaquin River (SJR) juvenile fall-run Chinook salmon smolts during a 31-day period in April and May, and evaluations are conducted annually to determine how those measures (i.e., river flows, exports rates, and a physical barrier at the head of Old River) relate to smolt 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 prolonged period that may extend from January to June. Juvenile Chinook salmon migration and rearing patterns vary among tributaries and among years in response to flow releases, runoff events, turbidity, and other factors. The San Joaquin River Basin experienced a wet year in 2011 resulting in flood control releases on all three tributaries prior to and during the VAMP period. More specifically, flood control releases began in January and lasted throughout the outmigration period (until June) in the Tuolumne and Merced Rivers, and occurred during peak smolt migration (April through June) in the Stanislaus River. Higher flows greatly reduce capture efficiencies (for most sampling methods) and result in lower than average catches. Discharge from the three tributary basins and precipitation for the first half of 2011 are shown in Figure 6-1 while turbidity and water temperatures for the first half of 2011 are shown in Figures 6-2 and 6-3, respectively.

During 2011, sampling with rotary screw traps (RST) was conducted in the Stanislaus and Tuolumne Rivers near their confluences with the SJR. No outmigration monitoring was conducted on the Merced River in 2011. Seining was conducted 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 Chinook salmon from the tributaries into the mainstem SJR 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 December 13th – July 8th. To remain consistent with previous years and between sampling locations, the RST monitoring period at Caswell has been standardized to January through June (Note: only 4 Chinook were captured outside the standardized period). No sampling occurred on 6 different occasions, each lasting from 2 to 3 days. RST monitoring was conducted on the Tuolumne River at RM 5 (Grayson site) from January 6th – June 30th. A combination of flood control releases and precipitation in late-March suspended sampling at the Grayson site for a 10-day period.

Weekly seining was conducted from January through June at up to 8 sites[1] on the mainstem SJR from RM 51 (Dos Reis below the HOR) to RM 74 (downstream of the Tuolumne River confluence) and biweekly seining was conducted at RM 78 and RM 90 (upstream of the Tuolumne River confluence) from mid-January through late May.

Trawling was conducted on the SJR at Mossdale near RM 54 (downstream of the tributaries, and just upstream of the HOR) three days per week January through March; five days per week April through mid-June (with the exception of a two-week period when the trawl was operated daily); and three days per week during the remainder of June.

Although salvage data of unmarked salmon does not distinguish where the salmon originated from, sometimes origin can be inferred by comparing timing, abundance, and size of salmon collected in the San Joaquin River Basin monitoring.

The seasonal peak catch of fry (n=132) at the Tuolumne River RST (Figure 6-4) occurred on January 26th following decreasing reservoir releases during the January 23rd - 26th period. Approximately 88% of the Chinook salmon catch moved out of the Tuolumne River as fry (n=1,454). The seasonal daily peak catch of fry (n=100) at the Stanislaus River RST (Figure 6-5) occurred on February 22nd, following rain events during February 14th – 19th. In the Stanislaus River, 67% of captured emigrating Chinook salmon were fry (n=401), which may be a result of high trapping efficiency coinciding with fry movement and low efficiency later in the season when most smolts are expected to emigrate.

Similar to 2005 and 2006, relatively few early fish were observed at the Mossdale trawl (Figure 5-15), and in

[1] *Three of the sites (Durham site at RM 68, Rte 132 at RM 77, and San Luis Refuge at RM 79) could only be sampled in June and/or July due to high river flows and there was no nearby alternative sampling site. Additionally, the site upstream the Tuolumne River confluence (RM 83) was sampled only in February and June.*

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, 2011

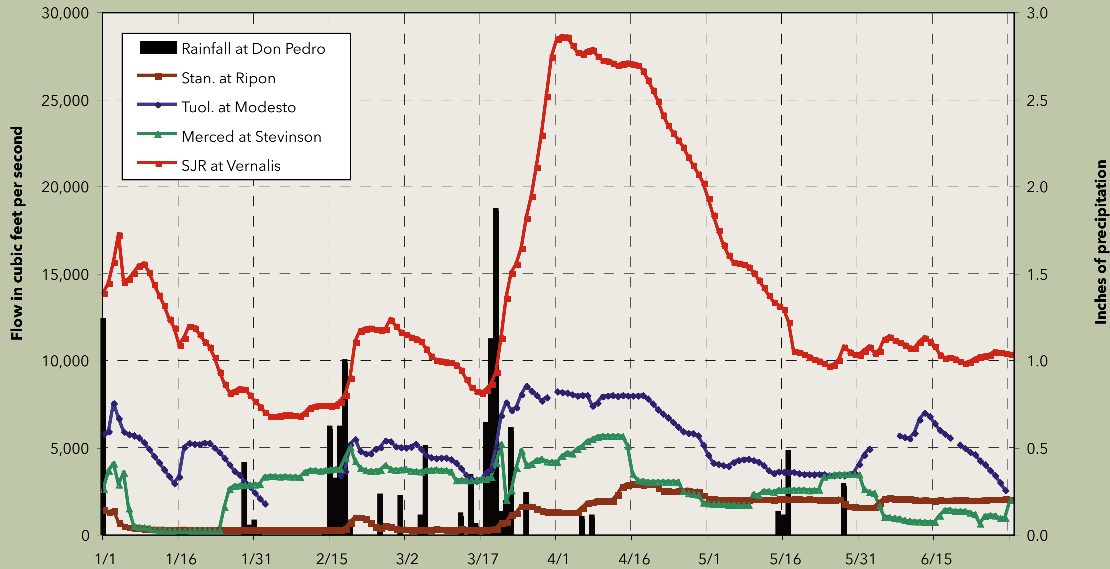


Figure 6-2
Turbidity Levels for the San Joaquin River (Daily Averages) and the Stanislaus and Tuolumne Rivers (tributary data are instantaneous readings at the most downstream rotary screw trap locations) for January – June, 2011

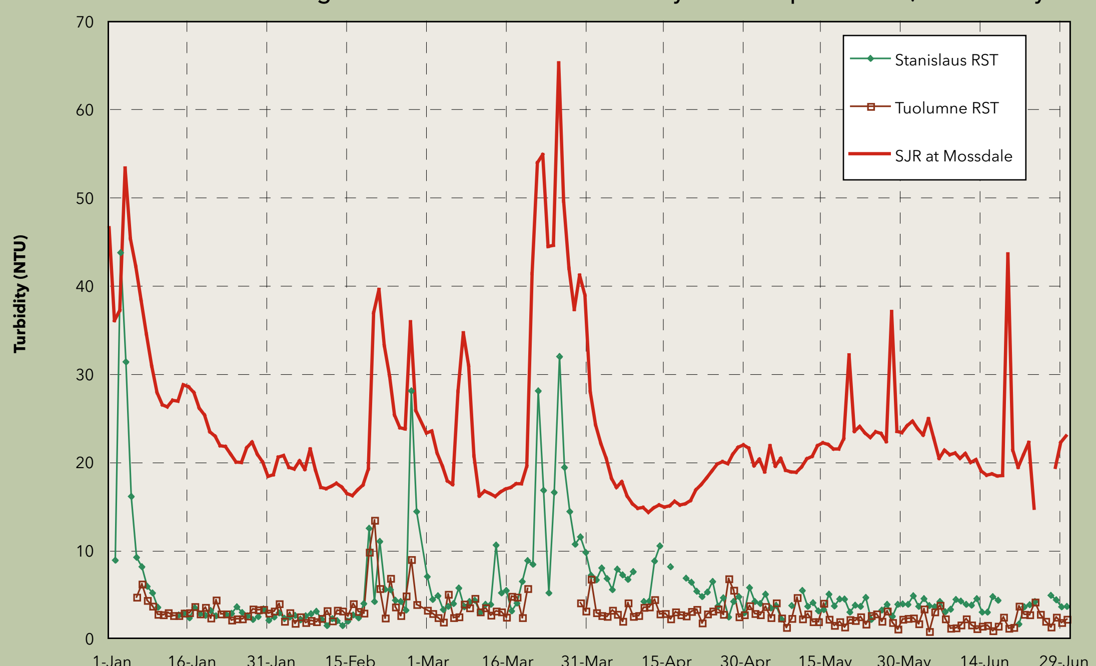


Figure 6-3
Water Temperatures (F°) for the San Joaquin River and the Stanislaus, Tuolumne and Merced Rivers for January – June, 2011

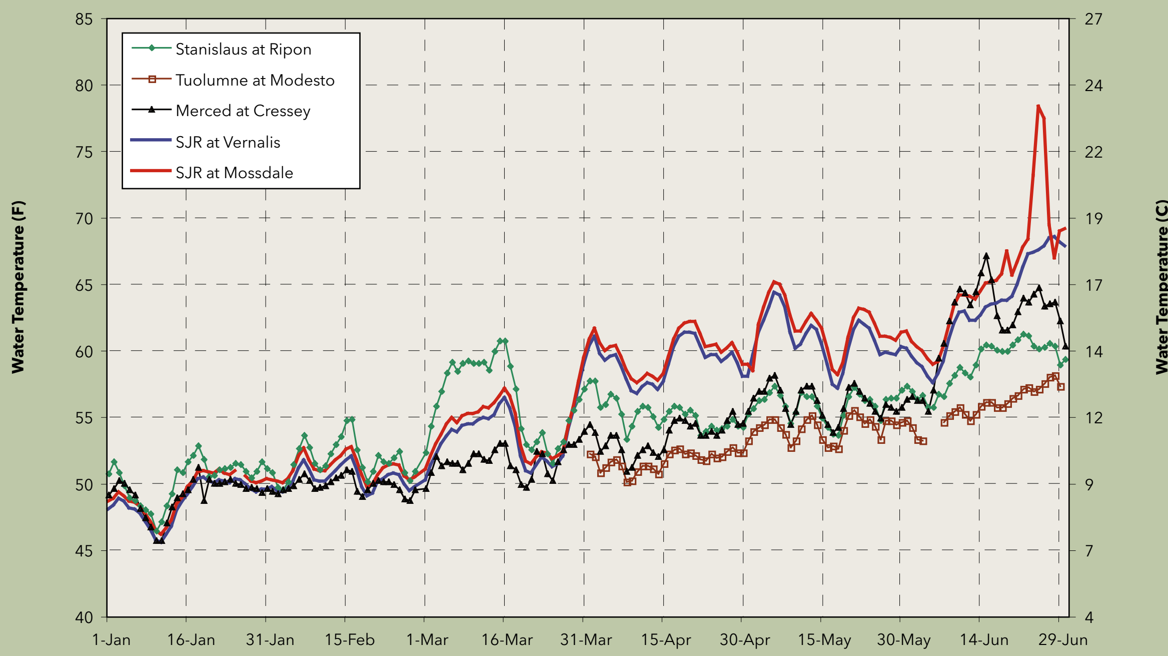


Figure 6-4
Tuolumne River Screw Trap Catch of Unmarked Juvenile Chinook Salmon for January – June, 2011 as Compared with River Flow at Modesto in cubic feet per second (cfs)

the CVP (Figure 5-18) and SWP (Figure 5-19) salvage operations. Fry that left the tributaries were not (rarely) detected at Mossdale, yet their fate after emigration from the Stanislaus and Tuolumne Rivers remains unclear. Possible explanations include further rearing in the SJR above Mossdale, incomplete temporal sampling coverage (3days/week) and low capture probability of fry caused by the 2011 high flows (Figure 6-6). Seasonal peak catch occurred at Mossdale during early June, two weeks after SJR flow began to gradually decrease from 28,000 cfs to 10,000 cfs. Figure 6-7 shows that most fish observed at Mossdale and in the tributaries prior to mid-March averaged <50 mm fork length (FL). Both the trawl and salvage are relatively ineffective at capture of fry (salmon less than 50 mm in length). It appears that salvage during January through March was dominated by larger fish, which likely originated from elsewhere in the Sacramento/San Joaquin Basin - average size at the RSTs and Mossdale typically increases by early April to >70 mm FL (Figure 6-7).

Kjelson et al. (1982) found that fry in the Delta are found in shallow water near the shoreline during daylight, but at night the fry may move off shore. Further, trawling studies have revealed that the larger fish are found toward the center of the channel. The Mossdale trawl samples in the daylight hours and in the center of the channel so it is likely that the number of fry in the San Joaquin River sampled by the trawl is underestimated. Also, the Mossdale trawl is sampled by USFWS only 3-days per week during the fry period (i.e., January-March) and it is likely that peaks in fry passage can be missed during the intermittent sampling schedule (personal communication, Jonathan Speegle, USFWS). Fry at the export facilities may be underestimated due to the high pre-screen loss caused by predation on juvenile Chinook as well as the efficiency of the screens.

Chinook salmon were captured at seven different seining sites between RM 51 and RM 90 in the SJR, with fry (<50 mm) captured until mid-March and parr/smolt (>50 mm) captured in late-March through early-May (Figure 6-8). The highest densities were recorded below the mouth of the Tuolumne River at Gardner Cove (RM 78) in mid-February and downstream of Mossdale at Dos Reis (RM 51) in late-April (Figure 6-9). The catch of fry a short distance below the confluence of the Tuolumne and SJR suggests their origination from the Tuolumne, yet it remains unclear whether fry from the Stanislaus emigrated to the SJR for rearing (seining below the Stanislaus-SJR confluence was not possible due to high flows). Fry were captured in the SJR above the confluence with the Tuolumne suggesting some salmon emigrated as fry to the SJR from the Merced River.

In order for information on the timing of salmon movement into the Delta to be sound and accurate, reliance on data from continuous daily monitoring at all three tributaries during the entire outmigration season (roughly January through June) at the lower end of each of the three San Joaquin River tributaries and at Mossdale is crucial. Unfortunately, in 2011 a combination of unusually high flows (and resulting low capture efficiencies or inability to sample) resulted in many uncertainties and the inability to draw sound conclusions. 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 Chinook salmon population migrating from the San Joaquin tributaries.

2011 Mossdale Trawl Summary

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

Introduction

The California Department of Fish and Game (CDFG) 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 6-10). This essential measurement of timing and production for out-migrating Chinook salmon smolts is performed at this location to:

1) determine annual salmon smolt production in the San Joaquin River Basin;

2) develop smolt production trend information;

3) determine the timing and magnitude of smolt out-migration into the Delta from the San Joaquin River tributaries; and

4) document the occurrences of other species including listed species such as steelhead and Delta smelt.

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 for 2011 was five days a week from April 4th to May 8th, seven days a week from May 9th to May 22nd, five days a week from

Figure 6-5
Stanislaus River Screw Trap Catch of Unmarked Juvenile Chinook Salmon for January – June, 2011 as Compared with River Flow at Ripon in cubic feet per second (cfs)

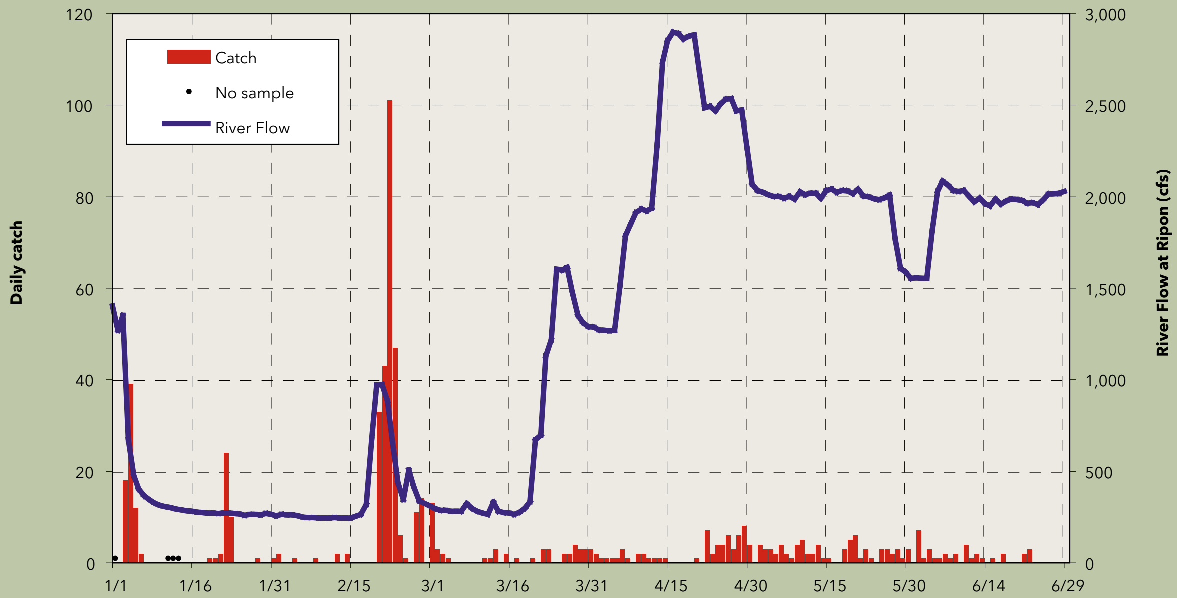


Figure 6-6
Kodiak Trawl Catch of Unmarked Juvenile Salmon on the San Joaquin River near the Mossdale Bridge Gage for January – June, 2011 as Compared with River Flow at the Vernalis Gage (VNS) in cubic feet per second (cfs)

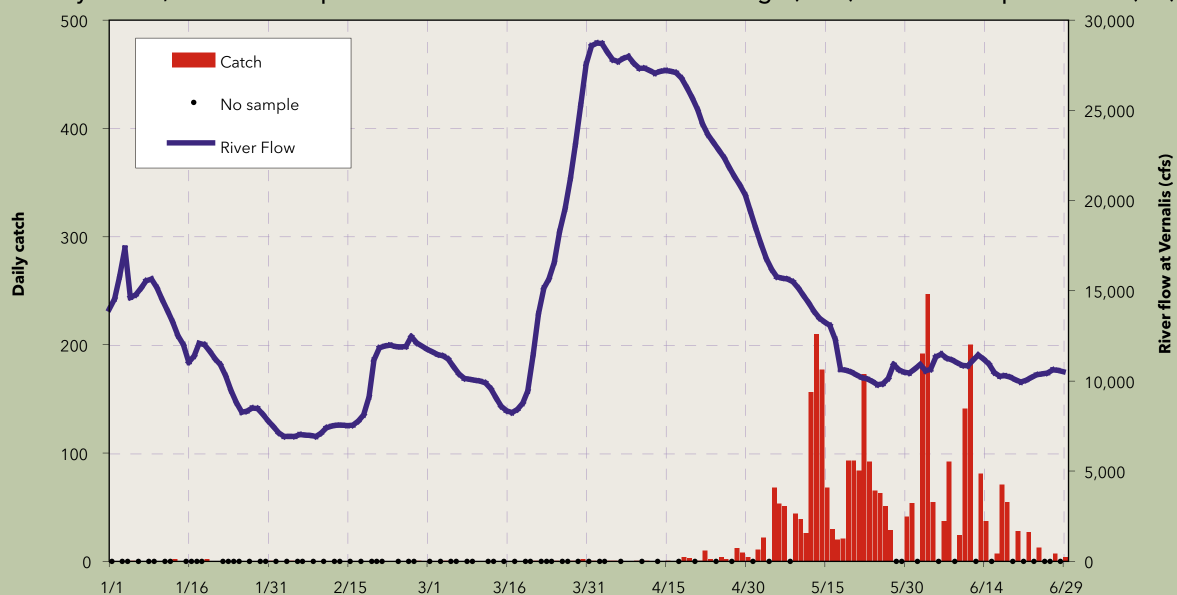


Figure 6-7
Daily Average Forklength (FL) of Unmarked Juvenile Chinook Salmon in the San Joaquin River Basin and Delta Pumping Facilities for January – June, 2011

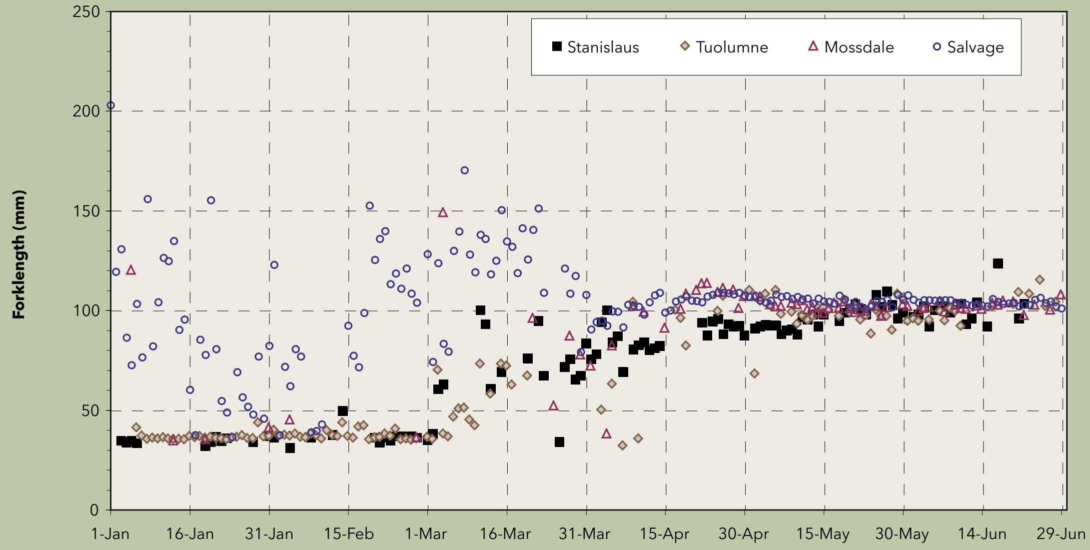


Figure 6-8
Daily Average Forklength (FL) of Unmarked Juvenile Chinnok Salmon in the San Joaquin River during 2011 Seining by the U.S. Fish and Wildlife Service and Turlock and Modesto Irrigation Districts from River Mile 51 (Dos Reis) to RM 90 (Laird)

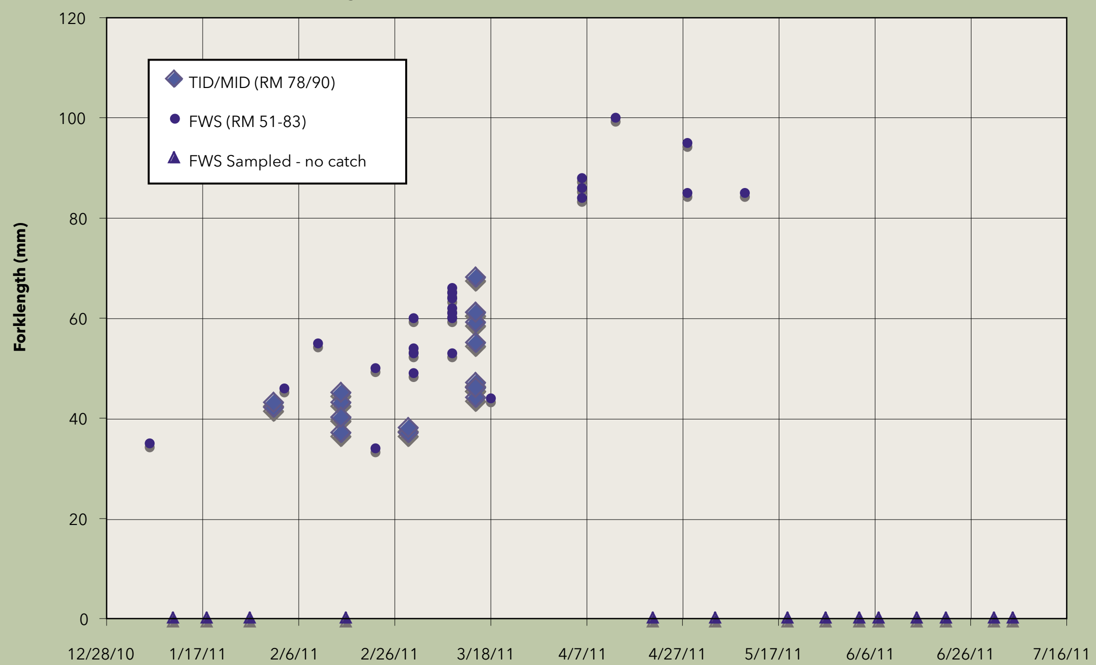


Figure 6-9
Salmon Density in San Joaquin River Seining from River Mile 51 (Dos Reis) to RM 90 (Laird) during January to June, 2011

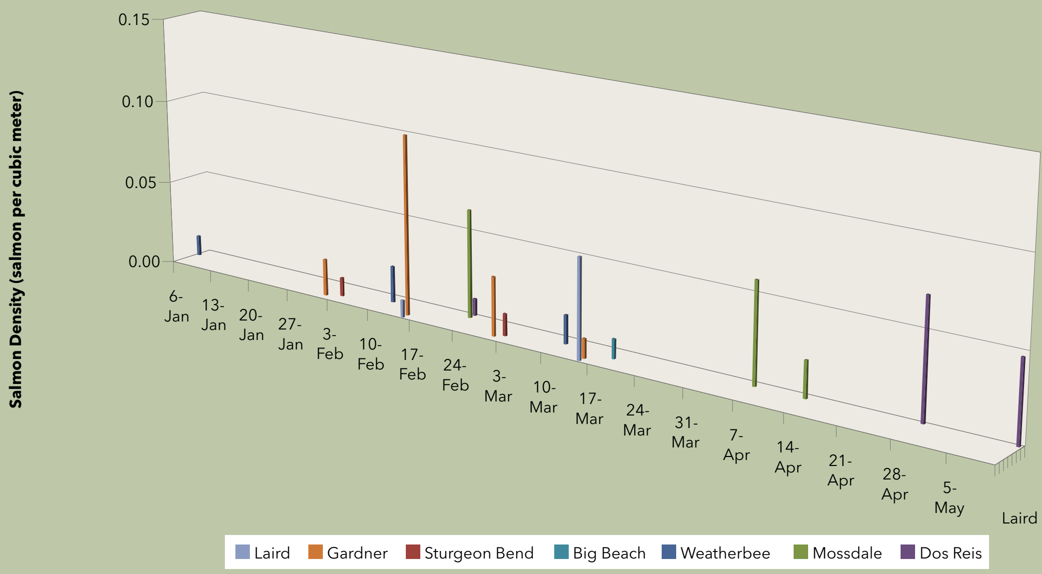
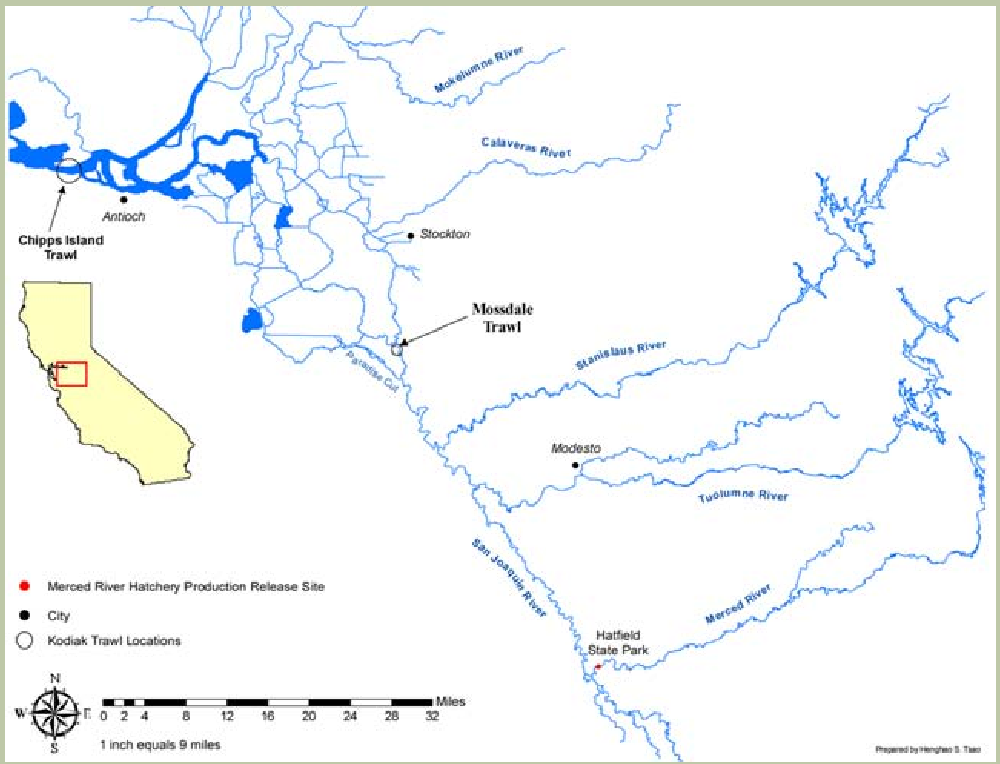


Figure 6-10
Location Map of the Mossdale Trawl Area in the Lower San Joaquin River, 2011



May 23rd to June 19th, and 3 days a week from June 20th to July 1st. The entire sampling period was from April 4th to July 1st with a total of 65 sample days out of the study period of 89 days. All trawling occurred during daylight hours, generally starting between 0800 and 0900 hours. Sampling effort usually consisted of 10 tows per day at 20 minutes per tow; however, the sampling effort was extended to 15 tows per day between May 11th and May 25th to coincide with coded-wire tag releases. 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 and adipose fin clips. All non-marked Chinook salmon were considered "natural" for the purpose of this study and were measured (fork length, mm).

Water temperature, turbidity (measured in secchi), 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 2011 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 recorded at the Vernalis (VNS) gage 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 the Vernalis (VNS) gage. 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:

$$E_I = \sum_{i=1}^{n=89} \left[\left(\frac{C_i}{V_{Ti}} \right) \left(V_{Pi} \right) \left(\frac{24}{5} \right) \right]$$

where:
E_I = smolt Production Index Estimation
n = days in the index period
C = daily non-marked Chinook salmon 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 89 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 5 vulnerability test groups in 2011 (Table 6-1). A population ratio is calculated based on these 5 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:

$$E_V = \sum_{i=1}^{N=89} \left\{ \left[\frac{(C_i/r)}{(T_i/300)} \right] \left(\frac{24}{5} \right) \right\}$$

where:
E_V = vulnerability Expansion Estimation
r = population ratio
C = daily non-marked Chinook salmon catch
T = tow duration
i = i^{th} day
N = number of days sampled.

Table 6-1 Dye Marked Smolt Release Using Merced River Hatchery Salmon for Vulnerability Studies in the San Joaquin River at Mossdale Landing, April through June 2011					
Release Date /Time	Water Temp. (°C) Truck/River	Effective # Released	Number Recovered	Streamflow (cfs) at Vernalis	Beginning and Ending Recovery Time
22-Apr-11	10°C/13.5°C	4917	9	24104	9:14
8:17					12:27
29-Apr-11	10°C/14°C	4913	0	20696	N/A
8:05					N/A
6-May-11	12.5°C/17.5°C	2993	53	15613	8:35
8:08					9:40
27-May-11	11.5°C/15.5°C	3536	123	9993	9:04
8:35					10:45
10-Jun-11	12°C/17°C	3162	153	10708	8:15
7:45					12:29

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 - 2011) (Figure 6-11). 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.

The multiple years regression estimate is calculated as follows:

$$E_V = \sum_{i+1}^{n=89} \left[\frac{\frac{C_i}{V_i}(60*24)}{T_i} \right]$$

where:
n = Days in the index period
C = Daily non-marked Chinook salmon catch
T = Minutes towed
i = i^{th} Day
V = (Figure 6-11); 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. Marked fish that were detected subsequent to the day of release (6 total for all releases) were 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.

Results

There were 3,265 non-marked Chinook salmon smolts captured in the Mossdale trawl between April 4th and July 1st. An additional 23 Chinook salmon smolts were captured, but escaped the net before being brought onto the boat. Daily capture of non-marked salmon ranged from 1 to 247 individuals with an average of 50.2 captured per day. Figure 6-12 shows the Vulnerability Expansion Estimate (Multiple Years Regression Method) of non-marked Chinook salmon smolts. The forklength of non-marked Chinook salmon smolts ranged between 38 and 142 mm. The average forklength for non-marked Chinook salmon smolts was 101.7 mm.

The smolt production estimate for the San Joaquin River basin was 1,021,701 using the smolt production index calculation, 1,524,175 using the vulnerability expansion estimate (single year population ratio method), and

Figure 6-11
Natural Logarithm of Efficiency Tests 1989-2011 for San Joaquin River Flows at the Vernalis Gage (VNS) in Cubic Feet per Second (cfs)

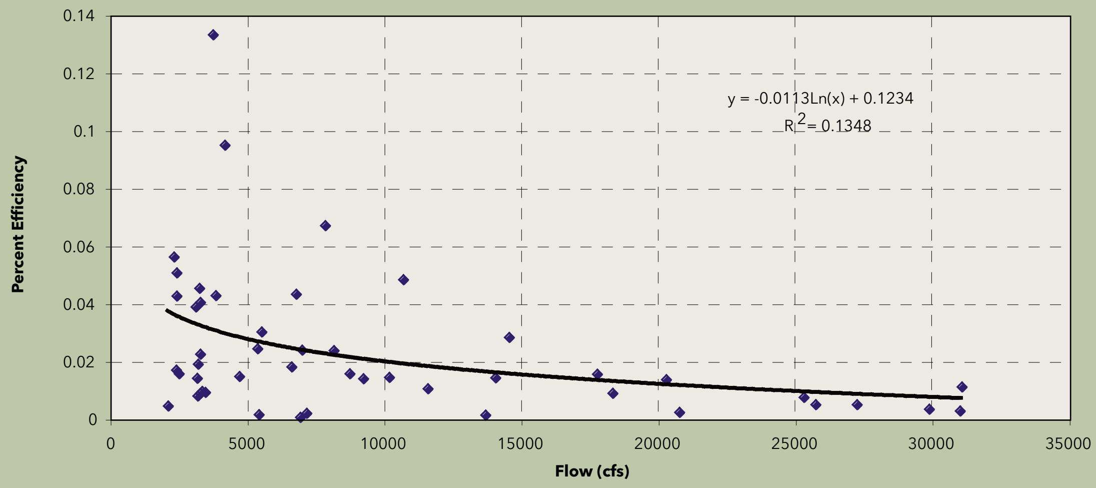


Figure 6-12
Expanded Daily Catch of Non-marked Chinook Salmon (CHN) Based on Vulnerability Expansion Estimates and Flow in the San Joaquin River at the Vernalis Gage (VNS) for April – June, 2011 (Multiple Years Regression)

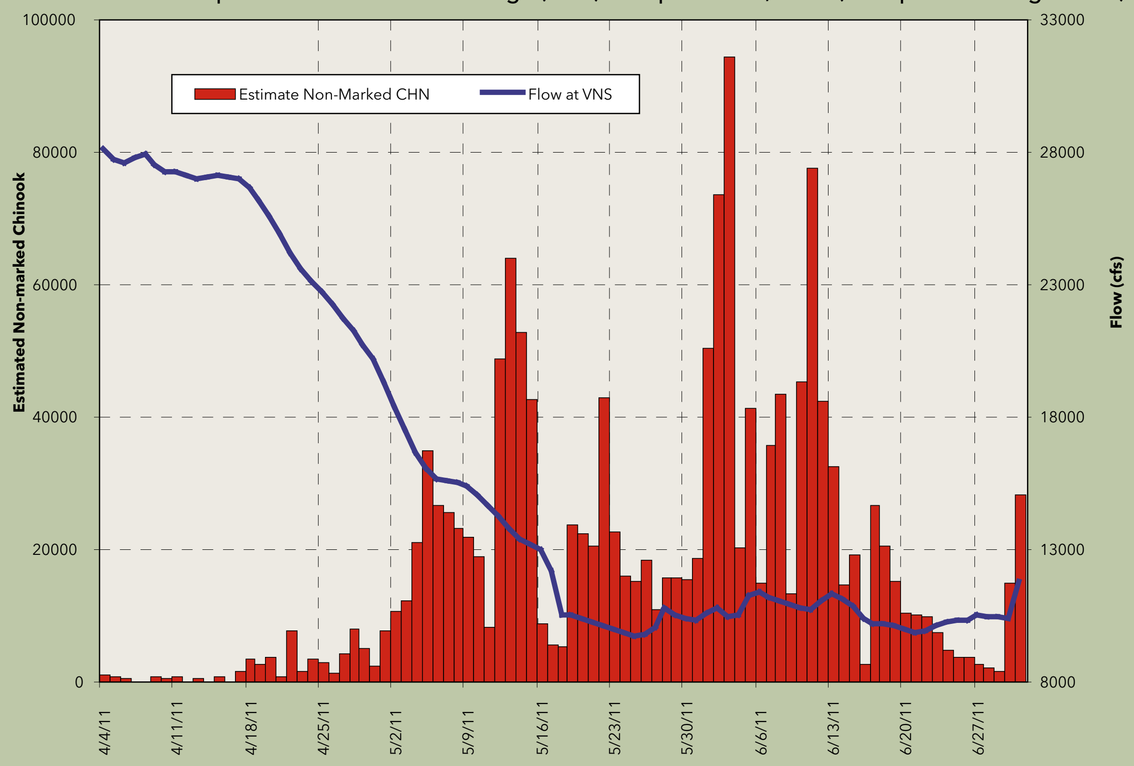


Table 6-2
Chinook Salmon Smolt Production Seasonal Estimates and Sampling Period for Before and During the VAMP Study

Year	Sampling Period (Days)	Percentage of Days 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 (1989-2011)
2011	89	73	1,021,701+24,813	1,524,175	1,536,887
2010	94	63	53,093+1,640	62,176 : (29,393 - 166,754)	106,371
2009	92	63	50,827+1,690	[b]	175,566
2008	91	63.7	188,652 + 8,010	285,886 : (139,406 - 323,675)	488,614
2007	75	76	273,798 + 7,490	[b]	783,457
2006	75	85.3	848,394 + 12,888	1,808,143 : (1,025,096-5,423,123)	1,622,492
2005	89	80.9	363,800 + 14,700	621,403 : (388,884-1,119,550)	641,377
2004	61	88.5	92,500 + 66,500	297,348 : (191,222- 665,160)	285,425
2003	88	80.7	107,500 + 60,300	368,424 : (277,626- 545,121)	471,866
2002	74	87.8	229,100 + 557,100	2,254,647 : (1,455,066-5,179,591)	628,663
2001	103	78.6	279,800 + 286,000	928,996 : (586,790-2,228,789)	724,694
2000	88	81.8	211,100 + 181,900	[a]	410,290
1999	119	71.4	146,900 + 63,500	[a]	369,845
1998	99	67.7	1,075,000 + 562,800	[a]	2,179,518
1997	92	69.6	168,600 + 89,400	[a]	540,358
1996	89	85.4	381,900 + 626,900	[a]	964,438
1995	60	78.3	1,108,900 + 2,640,000	[a]	2,515,616
1994	63	73	67,500 + 62,200	[a]	390,932
1993	83	61.4	54,200 + 21,800	[a]	228,949
1992	72	44.4	23,600 + 6,300	[a]	243,489
1991	59	66.1	[a]	[a]	468,938
1990	82	69.5	[a]	[a]	229,651
1989	54	100	[a]	[a]	3,664,884

[a] Data is currently being reevaluated.
[b] No hatchery juvenile Chinook salmon available for efficiency test

1,536,887 using the vulnerability expansion estimate (multiple years regression method) (Table 6-2).

Four Steelhead (*Oncorhynchus mykiss*) were captured and returned to the river during the 2011 sampling period. All four individuals were in the stage of smolting and had forklengths ranging between 201-330mm (265mm average).

Health and Physiological Assessment of Vernalis Adaptive Management Plan and South Delta Temporary Barriers 2011 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., 2011)

Summary

Health assessments were conducted on cohorts of acoustic tagged Merced River Hatchery fall-run juvenile Chinook salmon used in the Vernalis Adaptive Management Plan (VAMP) and South Delta Temporary Barriers Project (TBP) studies corresponding to May 19th and 26th, and June 16th, 2011 study fish releases. Health assessment control (HAC) groups were transferred to the CA-NV Fish Health Center wet lab, and sampled at 1 and 30 days post transfer. No obligate viral or bacterial pathogens were detected in any of the 3 HAC groups sampled 1 day post transfer. External infections with *Flavobacterium columnare* (the bacteria which causes columnaris disease) and *Ichthyophthirius multifiliis* (the protozoan which causes *Ichthyophthirius multifilis* (ich) or white spot disease) were observed

on fish from all 3 HAC groups sampled 30 days post transfer. *Tetracapsuloides bryosalmonae* parasites, the causative agent of proliferative kidney disease (PKD), were detected in 0-7% of fish in HAC groups at 1 day post transfer and 27-46% of fish from HAC groups sampled at 30 days post transfer. Survival for the 30-day holding periods was high and ranged from 96-100%. Gill ATPase activity levels were consistent with fish undergoing smoltification in all except the May 26th HAC group. Overall, HAC groups demonstrated low mortality and only mild PKD prevalence; indicating, fish health was not a concern in survival of 2011 VAMP and SDTB study fish.

Introduction

As a component of the 2011 Vernalis Adaptive Management Plan (VAMP) and South Delta Temporary Barrier project (TBP) studies on reach-specific survival and distribution of migrating juvenile fall-run 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 study fish can help explain their performance and survival during the studies. Pathogen screenings during past VAMP studies using Merced River Hatchery (MRH) juvenile fall-run Chinook salmon have 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 juvenile fall-run Chinook salmon with increased mortality and faster disease progression in fish at higher water temperatures (Ferguson, 1981; Foott, Stone and Nichols, 2007). The objectives of this project were to: Survey the juvenile fall-run Chinook salmon used in the two studies for specific fish pathogens including *Tetracapsuloides bryosalmonae*, assess smolt development (gill Na^{+}/ K^{+}-ATPase), and diagnose any mortality in health assessment control fish held for 30 days in the laboratory.

Methods

Sample Groups

Three health assessments were conducted on cohorts of acoustic tagged MRH juvenile fall-run Chinook salmon used in the VAMP and South Delta TBP studies corresponding to May 19th and 26th and June 16th, 2011 study-fish releases. Target sample number for each health assessment control (HAC) group consisted of 24 dummy-tagged (DT) juvenile fall-run Chinook salmon and 60 juvenile fall-run Chinook salmon that were not tagged (NT). The second (HAC2) group included an extra 12 DT fish, and limitations on available fish reduced the sample size for the third (HAC3) group (Table 6-3). The DT fish received surgical implant of a tag identical to the VAMP and SDTB acoustic tagged fish. The primary purpose of the DT groups was to monitor and diagnose mortality over a 30-day holding period. The NT group was included as a control for surgery effects and to increase sample numbers without sacrificing DT fish. Each HAC group was sampled at two time points: after an overnight acclimation (1d) and after approximately 30 days (30d).

Table 6-3
Number of Fish in Health Assessment Control (HAC) Groups Transferred to the Wet Lab. Groups Include: 1-day Untagged (1d-NT), 30-day Untagged (30d-NT) and 30-day Dummy Tagged (30d-DT)

Group	1d-NT	30d-NT	30d-DT
HAC1	30	30	24
HAC2	30	30	36
HAC3	20	14	22

Fish Handling and Holding

Fish handling attempted to shadow treatment of acoustic tagged fish used in the tracking studies. All HAC groups were split from the larger study population at tagging of the acoustic tagged cohort before transfer to the CA-NV Fish Health Center wet lab in Anderson, CA (wet lab). Each DT group was held for 48 (±12) hours in the San Joaquin River during the release period alongside their acoustic tagged cohort before transfer. The NT groups were transferred directly from the tagging facility. In the wet lab, temperature of the single-pass water supply was allowed to fluctuate with ambient conditions. Once temperatures began to exceed 18°C (July 29th), the water supply was switched to a constant 17°C source due to concerns of *Flavobacterium columnare* infection. Fish were fed a pelleted salmon diet daily. Tanks were checked daily for dead or moribund fish. Diagnostic sampling was performed on sick or dead fish to identify any associated pathology. In addition to HAC groups, a reference sample of 30 unmarked fall-run Chinook salmon was sampled at Merced River Hatchery on May 18th.

Sample Collection

For the HAC 1d and MRH samples, 30 NT fish were euthanized; forklength (FL) and any abnormalities noted; and tissue samples for bacteriology, virology, histopathology, and gill ATPase assays collected. For the HAC 30d samples, all surviving fish (both DT and NT) were euthanized; fork length, weight and any abnormalities were noted. Tissue samples for bacteriology and histopathology assays were collected from the HAC 30d-DT groups only.

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, 2010). These screening methods would not detect *Flavobacterium columnare*. *Renibacterium salmoninarum* (the bacteria that causes bacterial kidney disease) was screened by fluorescent antibody test of kidney imprints.

Virology

Four fish pooled samples of kidney and spleen were inoculated onto EPC and CHSE-214 at 15°C as described in the AFS Bluebook (USFWS and AFS-FHS, 2010) with the exception that no blind pass was performed.

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 infection was rated as none (zero), low (<10), moderate (11-30) or high (>30) based on number of *T. bryosalmonae* trophozoites observed in the kidney section. Severity of kidney inflammation was 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 (ATPase) activity was assayed by the method of McCormick (1993). 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 Kruskal-Wallis rank sum test.

Results

Holding Conditions

While the target holding period in the wet lab was 30 days, fish were sampled at 29-32 days to facilitate laboratory workflow (Table 6-4). The HAC3 group was sampled at 29 days due to concerns the fish would not survive to 32 days because of a significant external parasite infection (*I. multifiliis*). Fish were fed 1.1% to 1.8% body weight/day and average fish length increased during the 30-day monitoring period (data not shown).

Table 6-4
Holding Period and Water Temperature (T) for Health Assessment Control (HAC) Groups Held in the Wet Lab

Group	Start Date	End Date	Total (days)	T Mean (°C)	T Range (°C)
HAC1	19 May	20 June	32	14.5	11.9-16.6
HAC2	26 May	27 June	32	15.4	12.1-18.7
HAC3	16 June	15 July	29	17.3[a]	15.7-18.8

[a] The water supply for the HAC3 group was switched from an ambient temperature supply to a constant 17°C supply on June 29th.

Table 6-5
Summary of Pathogen Screening of 2011 VAMP and South Delta TBP Study Fish. Assays included: Virology by Tissue Culture; Bacteriology by Culture; Fluorescent Antibody Test for Renibacterium salmoninarum (Rs-FAT)

Assay	Samples	Total Fish	# Pos (%)	Pathogen
Virology	37	110	0	No virus detected
Bacteriology	178	178	0	No obligate bacterial pathogens
			9 (5%)	Aeromonas/ Pseudomonas
Rs-FAT	110	110	0	Rs not detected

Survival

Of the 156 fish held in the wet lab, two mortalities were observed. Survival in individual PC groups ranged from 96-100%. The first mortality occurred May 31st (day 12) in the HAC1 DT group. The second mortality occurred June 27th (day 32) in the HAC2 DT group. Both mortalities occurred overnight, so had been dead too long for a full pathology examination. No survival comparison between DT and NT groups was performed due to the low number of mortalities.

Pathogen Assays

Summary results of pathogen testing are presented in Table 6-5. No obligate viral or bacterial pathogens were detected; however, Aeromonas and Pseudomonas bacteria were isolated in 5% of the kidney samples cultured for bacteria. This group of gram-negative bacteria 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. External hemorrhaging, which may be a sign of bacterial septicemia, was observed in one fish that died during holding. This fish died overnight and was in poor

Table 6-6
Intensity of *T. bryosalmonae* Infection in Chinook Salmon. Data Presented as the Number of Fish with Zero (None), <10 (Low), 11-30 (Moderate) or >30 (High) *T. bryosalmonae* Parasites Observed in Kidney Tissue by Histopathology

Group	Time Point	None	Low	Moderate	High
MRH	--	27	0	0	0
HAC1	1d	29	0	1	0
	30d	16	6	1	0
HAC2	1d	28	2	0	0
	30d	13	10	1	0
HAC3	1d	18	0	0	0
	30d	16	5	0	1

Table 6-7
Severity of Clinical Proliferative Kidney Disease Lesion in Chinook Salmon. Data Presented as the Number of Fish with Kidney Inflammation Rated as Normal, Focal, Multifocal or Diffuse by Histopathology

Group	Time Point	Normal	Focal	Multifocal	Diffuse
MRH	--	27	0	0	0
HAC1	1d	29	1	0	0
	30d	17	5	1	0
HAC2	1d	29	1	0	0
	30d	15	3	6	0
HAC3	1d	18	0	0	0
	30d	16	5	0	1

condition; therefore, no bacterial isolation was attempted on this fish. External infections with *Flavobacterium columnare* were observed by gross examination (Figure 6-13) in 3% (2/66) of the HAC2 30d group and 2% (1/36) of the HAC3 30d-group. External infections with *Ichthyophthirius multifiliis* were observed by gross examination (Figure 6-14) in 100% of the HAC3 30d-group.

Histopathology

External infections of *I. multifiliis* (Figure 6-15) and kidney infections with *T. bryosalmonae* were observed by histopathology in all HAC 30d-groups. *Ichthyophthirius multifiliis* infections were not detected in HAC 1d-groups, but moderate to heavy infections were observed on the gills of 91 to 100% of all three HAC 30d-groups. Infections with *T. bryosalmonae* were observed in 15% (27/177) of all kidney histopathology samples. In HAC 1d-groups, no difference was detected in *T. bryosalmonae* infection intensity (P=0.32, Table 6-6) or severity of the associated lesion (P=1, Table 6-7). In HAC 30d-groups, no difference was detected in *T. bryosalmonae* infection intensity (P=0.40, Table 6-6) or severity (P=0.08, Table 6-7). Increased intensity and severity of *T. bryosalmonae* infection were observed between 1d and 30d samples in all HAC groups (P<0.05).

Gill ATPase

Activity ranged from -0.1 to 15.7 µmol ADP·mg protein $^{-1}$·hr^{-1}. Significant differences between groups were observed, with the HAC2 group having significantly lower ATPase activity levels compared to the other two HAC groups (P<0.001, Figure 6-16).

Discussion

No health problems were detected that would have a significant effect on mortality of the VAMP or SDTB study fish in 2011. *Tetracapsuloides bryosalmonae* infection intensity was very low in all groups and significant PKD lesions were observed in only a few fish. External bacterial (*F. columnare*) and parasite (*I. multifiliis*) infections necessitated water temperature control and a shorter holding period during HAC3 group. Of these pathogens, the *T. bryosalmonae* infection status provides the best insight into the health of acoustic tagged cohorts in the river.

Given the historic presence of PKD at MRH, the *T. bryosalmonae* infections most likely occurred in all MRH fish in 2011. Infections were light in 2011, and the histopathology assay likely missed low level infections in the MRH and HAC 1d-sample groups. Proliferative kidney disease is progressive and dependent on water temperature (Ferguson, 1981; Foott, Stone and Nichols, 2007). It was expected that infection intensity and PKD severity would increase during the study period. Since this parasite is not transmitted horizontally fish-to-fish, infection rates and mortality observed in the wet lab would be correlated with study fish released into the river. In past VAMP studies where fish were held for monitoring, total mortality due to the disease was low at 20 - 27% (Foott, Stone and Nichols, 2007; Foott and Stone, 2008). In 2011, incidence of *T. bryosalmonae* was lower than these previous studies and mortality due to all causes was very low (0 - 4%). There was no indication that PKD was a health concern in the 2011 VAMP or SDTB study fish.

The *I. multifiliis* and *F. columnare* infections were of concern in fish held in the wet lab. Infections were likely intensified in the HAC 30d-groups by holding conditions (confinement at high density) in the wet lab (Dickerson and Dawe, 1995). It is unclear from the limited sampling performed whether *I. multifiliis* infections impaired the health and performance of the

Figure 6-13
Juvenile Chinook Salmon with a Bacterial *F. columnare* Gill Lesion (left) and Normal Gill (right)

Figure 6-14
Example of *Ichthyophthirius multifiliis* Infection (ich or white spot disease) Observed in Health Assessment Control Group 3 (HAC3)

Figure 6-15
Example of *Ichthyophthirius multifiliis* Parasite Observed in Gill Histopathology Samples of All Health Assessment Control (HAC) Groups at the End of the 30-day Holding Period. Note the Classic Horseshoe Shaped Nucleus

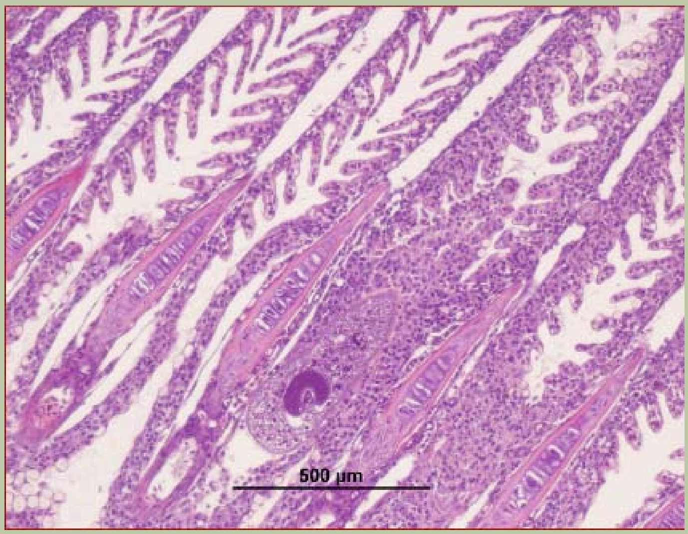
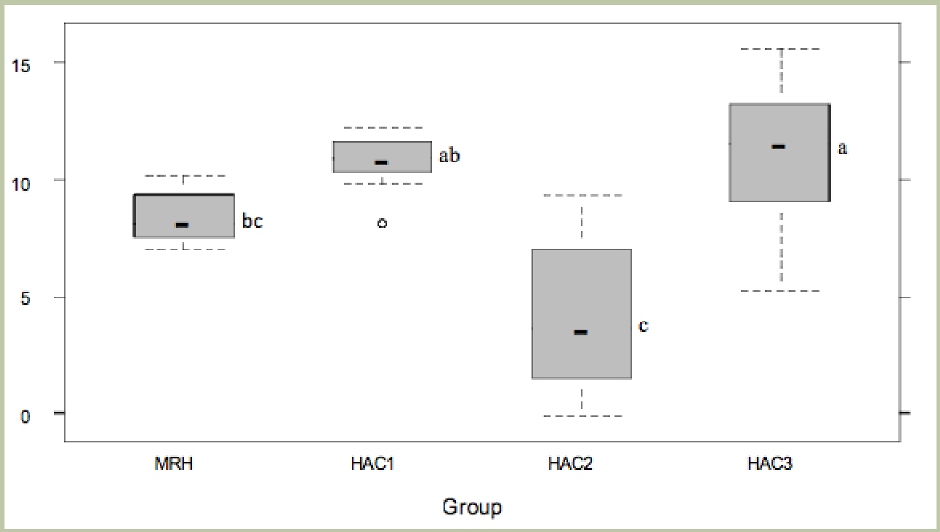


Figure 6-16
Boxplot of Median Gill ATPase Activity (µmol ADP·mg protein-1·hr-1) in Juvenile Chinook Salmon Sampled at Merced River Hatchery (MRH) or in Health Assessment Control Groups Sampled in the Wet Lab (HAC1-HAC3). Groups with Letter Subscripts in Common Were Not Significantly Different (Kruskal-Wallis rank sum test, P<0.001)



smolts prior to the 30d examination. Given the high value of each acoustic tagged fish, measures should be considered to reduce the risk of exposure to these pathogens including: cooler water temperatures during rearing and tagging; water disinfection such as high wattage UV; and formalin or antibiotic treatment.

Gill ATPase activity levels were consistent with smolting fall-run Chinook salmon except for the HAC2 group. ATPase activity appeared to be suppressed in the VAMP study group released May 25th and 26th. Gill ATPase activity in salmonids typically increases and peaks near the time of most active migratory behavior (Duston et al., 1991; Ewing et al., 2001; Wedemeyer, 1996). Decreases in ATPase activity can also occur due to increases in water temperature (Duston et al., 1991). Experience has shown that this indicator can change rapidly once fish enter salt water. Low ATPase levels will not reliably predict poor migratory performance, but may corroborate other observed differences between groups. Poor migration behavior in acoustic tagged cohorts of the HAC2 group would be consistent with the low gill ATPase observation.

Juvenile Salmonid Survival and Migration in the San Joaquin River Restoration Area during Flood Operations, Spring 2011

Contributed by Michelle Workman
U. S. Fish and Wildlife Service

Introduction

A 2006 legal settlement from a 1988 lawsuit challenging the renewal of long-term water service contracts between the United States and California's Central Valley Project Friant Division contractors, *NRDC et al. v. Kirk Rodgers et al.*, (2006) enacted the San Joaquin River Restoration Program (SJRRP) to restore flows to the San Joaquin River. One of the two primary goals of the Settlement was to restore and maintain fish populations in good condition in the mainstem San Joaquin River downstream from Friant Dam to the confluence with the Merced River (the Restoration Area), including naturally reproducing and self-sustaining populations of salmon and other fish.

The Fisheries Implementation Plan (FMWG, 2010b) for the SJRRP Fisheries Management Plan (FMWG, 2010a) forms an adaptive framework for meeting the provisions of the Settlement, including the reintroduction of salmon (NRDC vs. Rodgers, 2006). Study 20.0 in Appendix A of the 2011 Agency Plan for the SJRRP proposed a study using acoustic telemetry to identify and characterize three limiting factors for juvenile Chinook survival through the Restoration Area: predation, entrainment, and physical habitat. This summary provides information on migration characteristics and survival of juvenile fall-run Chinook salmon during their 2011 spring migration downstream through the Restoration Area. The full study results can be found in Section 24.0 of Appendix A, 2011 Final Annual Technical Report on the SJRRP website at: http://www.restoresjr.net/flows/ATR/2011_ATR/2011DF_ATR_AppA_19-25.pdf

Study Methods

The following briefly describes the methods used to deploy the receivers used to detect acoustically tagged juvenile salmon, the tagging of juvenile salmon, and the data analysis.

Study Area

The study area is on the mainstream San Joaquin River from the base of Friant Dam to the confluence of the Merced River as shown in Figure 6-17.

Acoustic Technology

Like other juvenile Chinook salmon from the San Joaquin Basin used in the VAMP and other studies, the small size of the smolts at emigration from freshwater to ocean poses a unique challenge when using acoustic technology. The study used VEMCO VR2W-180 kilohertz (kHz) receivers and V-6 acoustic transmitters. The VR2W-180 kHz receivers have a detection range of approximately 75 meters, which provided good coverage within the existing geography of the San Joaquin River in the study area. The V-6 tags weigh 1.0 gram in air (0.5 gram in water) which was within the suggested tag burden of 5 percent body weight (Adams, et al., 1998b).

Receiver Deployment

Stationary telemetry receivers were deployed at 15 sites through Reaches 1 through 5 of the Restoration Area (Figure 6-17) to assess reach specific migration patterns, and survival through mining pits, at unscreened diversions, in the bypass system, and the river channel from RM 265 at Friant Dam to RM118 at Hills Ferry just above the Merced River confluence. Receiver deployment was determined by the potential to address appropriate limiting factors (predation, entrainment, habitat), ability to access deployment sites, and risk of vandalism.

Fish Transport/Holding/Surgery

The source fish were juvenile fall-run Chinook salmon from the Feather River Annex Facility. Feather River fall-run salmon are the earliest returning fall-run salmon and provided the best opportunity to get fish to the appropriate size for acoustic tagging at the earliest date. On April 6th and 7th, 1200 fish were transported from the Feather River Annex Facility to the San Joaquin

Figure 6-17
Stationary Receiver Locations (Red Dots), Release Sites (Purple Dots) and the Designated Reaches of the San Joaquin River Restoration Area (Figure from Workman (2011))

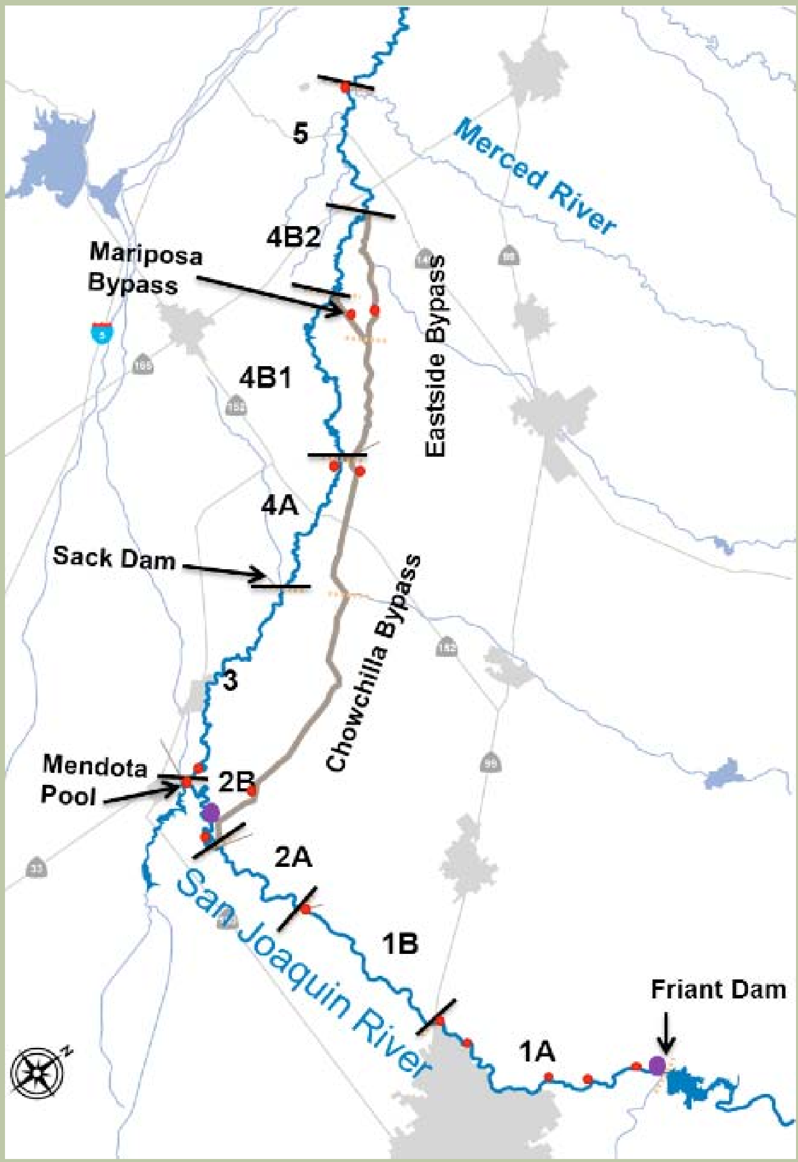


Figure 6-18
River Flow in the San Joaquin River Restoration Area During Spring 2011 Acoustic Telemetry Monitoring

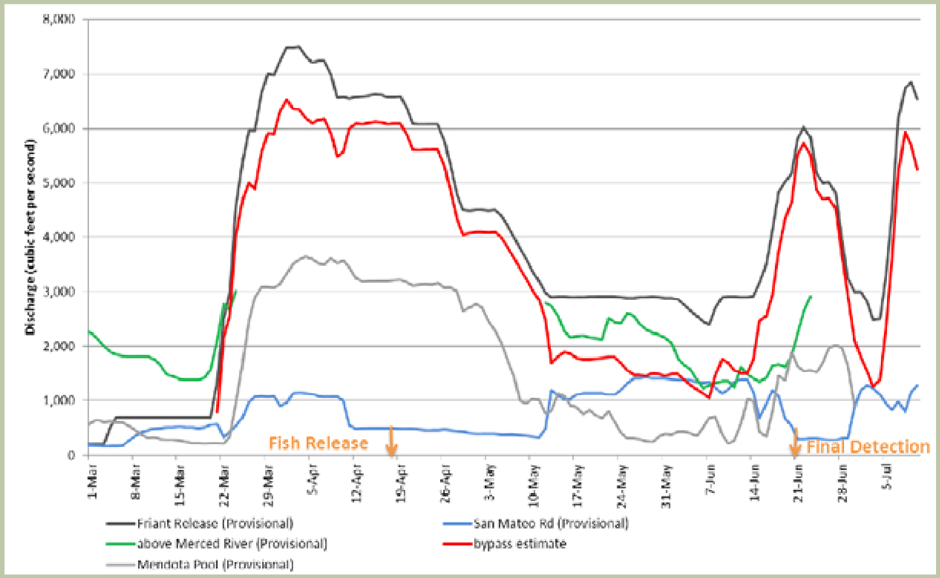


Figure 6-19
Water Temperature in the San Joaquin River Restoration Area During Spring 2011 Acoustic Telemetry Monitoring

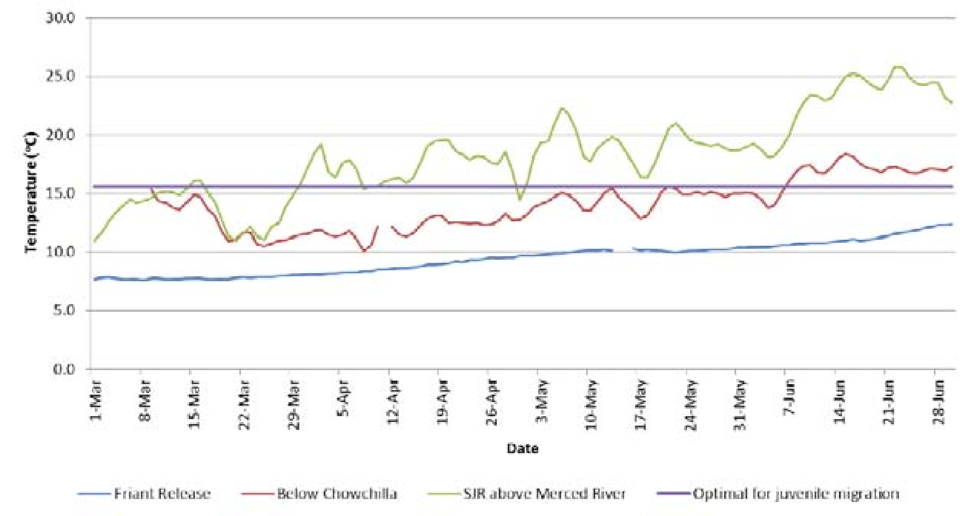


Table 6-8
Summary of Conditions Observed During Acoustic Tagged Juvenile Chinook Salmon Releases into the San Joaquin River near Friant Dam and at the San Mateo Crossing near the Mendota Pool, Spring 2011

	Release Group			
	1A-Friant	1B-Friant	2A-San Mateo Crossing	2B-San Mateo Crossing
Load Time	13:00	13:30	16:15	16:15
Release Time	14:00	14:30	17:50	17:50
Hatchery Water Temp (°C)	13.17	13.17	13.2	13.2
Tank Water Temp (°C)	11.57	11.51	13.58	13.58
River Water Temp (°C)	9.5	9.5	15.75	15.75
Acclimation Time	20 minutes	20 minutes	10 minutes	10 minutes

Table 6-9
Survival Estimates and Standard Error for Acoustic Tagged Juvenile Chinook Salmon in the San Joaquin River Restoration Area, Spring 2011

Release Group	Survival Location	Estimate of Survival	Standard Error
Friant (RM 265)	Highway 99 (RM 234)	0.78	0.02
Friant (RM 265)	Hills Ferry Barrier (RM 148)	0.55	0.04
San Mateo Crossing (RM 212)	Mendota Pool (RM 205)	0.46	0.05
San Mateo Crossing (RM 212)	Below Mendota Pool (RM 204)	0.31	0.06
San Mateo Crossing (RM 212)	Hills Ferry Barrier (RM 148)	0.27	0.08

Interim Conservation Facility located at the San Joaquin River Hatchery complex near Friant Dam. Transport was conducted in a 500-gallon, double-walled insulated aluminum tank equipped with two mechanical aerators and pure oxygen supplied through two ceramic micro-bubble diffusers. Travel time was 5 hours and 15 minutes. Six mortalities were attributed to transport and handling stress.

Fish were held from April 6th through the 21st in water temperatures ranging from 9.4 to 10.5°C (49 to 51°F) and dissolved oxygen levels between 91 - 98 % of saturation. Five mortalities were observed on April 19th due to fish health compromises and handling (i.e., fin rot, impingement, and pop eye).

Fish tagging began on April 18th. All fish were anaesthetized using Tricaine Methanesulfonate (MS-222) in a 50-milligram per liter (mg/L) solution for initial sedation and 15-mg/L solution for maintenance during surgery. Fish were anaesthetized for 45 seconds to 1 minute in the 50-mg/L solution, and then transferred to the maintenance solution for remainder of process. All fish were weighed, measured, adipose fin excised, and coded-wire tagged. A subset of 200 fish was surgically implanted with a V-6 acoustic transmitter. Approximately 250 coded-wire tagged only fish and 50 acoustic-tagged fish were held in four separate tanks. All fish were tagged by noon on April 20th and releases were conducted in the afternoon of April 21st. All fish were held for a minimum of 24 hours, with initial tag groups held 3 days. All fish tolerated sedation, surgery, and recovery well. One mortality was recorded due to impingement during collection for release. Average fish size at time of tagging was 122 mm fork length, and average weight was 18.96 grams. This resulted in an average tag burden of 5.39 percent. Release data are presented in Table 6-8. Two randomly selected acoustic tagged fish from each replicate were held back in the interim facility to monitor long-term survival from surgery and assess actual tag battery life compared to the tag battery life rating provided by VEMCO.

Data Analysis

Collected acoustic tag detection data were processed to eliminate false-positive detections following methods of Pincock (2008) and Skalski et al. (2002). A false-positive can occur when more than one tag is present within the range of a stationary receiver, and tag transmissions "collide" to produce a valid tag code that is not actually present at the monitor (Pincock, 2008; Perry et al., 2010). A detection was considered valid if a minimum of two consecutive detections occurred within a 30-minute period at a given stationary receiver and the detections were consistent with the expected downstream movements of a juvenile salmonid (Skalski et al., 2002).

Capture histories were developed for each unique tag code moving downstream through the array. Capture histories were used to determine the receiver locations that could be reliably used to develop sample statistics (i.e., if a receiver performed poorly, it was excluded from some analyses).

Survival of each release group from point of release to the terminal dual-receiver array at Hills Ferry Barrier was calculated using a Cormack-Jolly-Seber mark recapture estimate model accounting for imperfect detections following the methods of Perry et al. (2010). This estimate of survival includes an estimate of detection probability at each site to reduce bias in the survival estimate.

Evidence of suspected predation mortality did occur and was determined by examining individual capture histories. Six tag codes within Mendota Pool showed multidirectional movements (not downstream movement typical of a juvenile anadromous salmonid), and were never detected downstream. Four tags were detected over an extended time period (35-45 days) at the James Bypass (2) and Mendota Pool (2) receivers. Likely, these fish were lost to predation, and tags expelled at the receiver location until the battery died. Likewise 3 tags showed upstream movement in Mendota Pool, then were never detected again, as did one tag that went upstream from the Sand Slough receivers into the Eastside Bypass. These pool locations were the only detections that showed any definitive predation 'behavior' from the transmitters. These transmitters, assumed lost to predation, were included in the overall estimation of survival to Hills Ferry Barrier.

Results and Discussion

River Conditions

The 2011 winter/spring period was operated under flood conditions. The SJRRP has developed a series of hydrographs to determine flow regimes for Restoration. The Restoration hydrograph for normal-wet and wet years, such as 2011 only calls for 4,000 cfs in a 1-month period in late spring, with step increases from March to May, to promote smolt emigration. Significantly higher flows (Figure 6-18) were released in 2011 for flood management, and over a much longer duration than is considered in the Restoration hydrographs (SJRRP, 2010). Friant releases peaked on April 1st at 7,489 cfs, with the majority of the flood release routed down the bypass system at the Chowchilla Bifurcation Structure (RM 216). Flows receded slowly through May 10th and remained fairly stable just under 3,000 cfs until June 13th. At this time flows peaked once more to about 6,000 cfs for the remainder of the study period.

Temperature data are also collected at standard locations for the SJRRP (Figure 6-19). Conditions in the river in the spring of 2011 were relatively mild, with an abundance of water, and mild temperatures. During the 2011 spring monitoring period, Friant release temperatures were consistently below the U.S. Environmental Protection Agency (US EPA, 2003) optimal threshold to support populations of juvenile migrating salmonids (18°C). However, even under flood operations, and the high-flow volume scenario of 2011, as fish move downstream to the end of the Restoration Area, temperatures begin to degrade and exceed the threshold. Temperatures reached critical levels in Reach 5 as early as the end of March, and became lethal (with long-term exposures) by the middle of June in the same reach, and critical in the river channel below Chowchilla. This could affect survival of late emigrating smolts, or in the case of spring run, yearlings that occupy the river all year. More analysis of water year types and the effect of climate and operations on water temperature are needed.

Migration Routes

Fish were released in two separate release groups of 96 fish each: below Friant Dam (RM 266) and at San Mateo Crossing (RM 212). These two release groups were chosen because the San Joaquin River was operated under flood conditions in the spring of 2011 and the fish released at the Friant release location would have the ability to migrate downstream using either the Chowchilla Bypass or the river channel. The downstream release group was used to provide a reasonable expectation of fish migrating through the river channel Reaches 2, 3, and 4a in case all fish from the Friant release used the bypass system. The majority of the Friant release fish migrated through the Chowchilla Bypass and not the river channel.

Survival

While individual receiver locations did not perform well enough to determine site specific survival through Reach 1 and the mine pit complexes it contains, this study estimated a survival of 78 percent through this 31-mile stretch (Table 6-9). Additional losses along the remaining 116 river miles, equated to an overall survival, from release location to the end of the study area, of 55 percent. For the San Mateo release, results were lower, with an estimated survival of 46 percent from release to Mendota Pool (10 RMs), 33 percent to below the Mendota Pool receiver location, and overall 27 percent survival. Given that this was the first group of juvenile

Chinook salmon to navigate the San Joaquin River from Friant (or San Mateo Road crossing) in more than 60 years, and physical changes (other than flow releases) have not yet been implemented, survival was relatively high. The SJRGA (2010) survival estimates for fall run Chinook salmon releases on the lower San Joaquin River ranged from 0.01 to 0.10 (from Mossdale (RM 54) to Chipps Island (RM 18)).

There are a number of factors that could have contributed to high survival: fish were relatively large, smolt-sized fish upon release, to accommodate the acoustic tags, high water in many reaches may have provided cover from predators, or the higher flows may have flushed some predators out of the system. Fry-to-smolt survival in the San Joaquin tributaries has been estimated to be around 4 percent (Carl Mesick, personal communication).

NMFS Biological Opinion Action IV.2.2: Survival of Steelhead Smolts During Outmigration in the San Joaquin River and Delta[2]

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Background

The National Marine Fisheries Service's Biological Opinion (BiOp) on the Long-term Coordinated Operation of the Central Valley Project (CVP) and State Water Project (SWP) (NMFS, 2009) includes multiple management periods for San Joaquin River inflow, exports, and Old and Middle River flows. These included two actions that influence CVP/SWP export and discharges through the San Joaquin River and Old and Middle River corridors during the winter and spring seasons in addition to actions to measure the effectiveness of implementing these changes. The actions are:

- Action IV.2.1 identifies targeted levels of export volume dependent on San Joaquin River discharge at the Vernalis (VNS) gage, which may increase with San Joaquin River inflow volume during wetter periods. This action is calendar-based and occurs between April 1st and May 31st. The action hypothesizes to increase survival of emigrating salmonids by reducing the migrating fish vulnerability to entrainment into the south Delta and at the CVP/SWP facilities by increasing the San Joaquin River inflow to CVP/SWP export ratio.
- Action IV.2.2 requires the CVP/SWP operators develop and implement a Six-Year Acoustic Tag Experiment (Six-Year Study) to evaluate the results of implementing the BiOp.
- Action IV.2.3 identifies targeted discharges through the Old and Middle River corridor. Similar to Action IV.2.1, this action hypothesizes to increase survival of emigrating Sacramento and San Joaquin-origin ESA-listed salmonids by reducing their vulnerability to entrainment into the south Delta and the CVP/SWP pumps. The initial level of -5,000 cfs through Old and Middle rivers is calendar-based and runs between January 1st and June 15th, but increased entrainment of ESA-listed salmonids ESUs and steelhead can require modifying hydraulic conditions in the Old and Middle River corridor so that the net downstream flow is greater than -5,000 cfs and meets targets of -3,500 cfs and -2,500 cfs.

In 2011, to comply with the requirements of the BiOp, the U.S. Bureau of Reclamation (USBR) and the California Department of Water Resources (DWR) developed a study design for Action IV.2.2 Six-Year Acoustic Tag Experiment. The study design built upon the VAMP telemetry monitoring studies to evaluate proportional causes of mortality hypothesized to be related to operational changes in hydrology (i.e. Old and Middle rivers reverse flows, San Joaquin River inflow, export volume) and other project and non-project adverse effects on steelhead smolts out-migrating from the San Joaquin River basin and through the southern Delta. The first year of the study took place between March and June, 2011. The pilot study was designed to estimate survival and route entrainment of steelhead smolts using the same statistical model as the 2011 VAMP fish monitoring studies. In 2011, steelhead for the Six-Year Study and fall-run Chinook salmon smolts for the VAMP fish monitoring study were tagged, transported, held at the release site, and released using standardized methods to control for experimental effects in comparisons between species.

The first year of the study in 2011 was developed to provide results to assess different hypotheses surrounding mortality, and also to test hypotheses surrounding surrogacy of fall-run Chinook salmon (*Oncorhynchus tshawytscha*) for Central Valley steelhead (*Oncorhynchus mykiss*). Management questions that were to be addressed with these results include:

1. What is the survival of emigrating steelhead smolts through the mainstem of the San Joaquin River downstream to Chipps Island?

[2] *A full study plan was developed by the principal investigator and the project co-investigators (Israel, 2011). Full study plans are developed annually for this investigation by an interagency technical team and are available from the U.S. Bureau of Reclamation.*

2. What is the survival of emigrating steelhead smolts through the southern Delta to Chipps Island?

3. What influence do exports and flows have on emigrating steelhead smolt survival and route selection through the southern Delta to Chipps Island?

4. Are juvenile fall run Chinook salmon reasonable surrogates for juvenile steelhead?

5. Does quantity of predator habitat influence reach specific survival rates of juvenile steelhead?

6. What is the travel time of steelhead through different migratory routes in the San Joaquin River and southern Delta?

Results of the 2011 study will be used with the next five years of information generated from this investigation to develop performance measures for steelhead survival and management tools to evaluate how mortality and route entrainment influence attaining these quantitative targets.

Additional complementary questions will be addressed as part of Action IV.2.2 studies before the end of the study. These will examine relevant issues identified in the objectives of the study as described in the NMFS BiOp including:

1. What is the survival of emigrating steelhead smolts from the tributaries into the mainstem of the San Joaquin River?

2. Are outmigration juvenile steelhead deterred from entering Old River by placement of either a temporary physical barrier or a non-physical barrier?

3. What proportion of juvenile steelhead released during the study residualize?

Salmonid acoustic telemetry studies have occurred in the San Joaquin River and South Delta through the VAMP and the South Delta Temporary Barriers BiOp. These studies have demonstrated fall-run Chinook salmon select routes in similar proportion to the flow entering each route, low survival of juvenile salmon in the southern Delta and high rates of predation upon juvenile salmon in the San Joaquin River (Holbrook et al. 2009, Vogel 2010). The 2011 Six-Year Study was coordinated with the VAMP and South Delta TBP fish monitoring studies to simultaneous release juvenile steelhead and fall-run Chinook salmon to examine questions concerning surrogacy and species-specific route selection and survival estimates, as well as the physical and nonphysical barriers placed in the South Delta during the salmonid outmigration.

Study Design

The 2011 Six-Year Study was coordinated closely with the VAMP and South Delta TBP fish monitoring studies efforts to ensure consistency with the data and techniques used for the last several years in these studies.

Receiver Deployment and Retrieval:

During the 2011 Six-Year Study, the HTI receiver array deployed for the regional VAMP and the South Delta TBP studies was utilized for the Six-Year Study. The array was jointly operated and maintained by the three programs to ensure consistency in deployment and retrieval. The array was deployed in the late winter of 2011 in a configuration developed by the VAMP fish monitoring group to estimate salmonid survival through the lower San Joaquin River and South Delta (See Chapter 5). Several sets of dual arrays were established by the VAMP in 2011 to estimate detection probabilities and to determine the direction of fish migrations. A dual array requires there be no more than 20% spatial overlap between hydrophones if the raw signal data indicate the time when a tagged fish was nearest to array (e.g., peak signal strength) and array clocks are exactly synchronized (e.g., hydrophones are cabled). Hydrophones in dual arrays should be close enough together for survival to be 100% between them. At Chipps Island and Jersey Point, multiple hydrophones in each single array were part of the dual array. The purpose of the multiple hydrophones in each of the single arrays is to ensure that all tagged fish have a chance of being detected, regardless of where they pass the array in the channel. In these cases, detection ranges may overlap so the entire channel area is covered. The dual arrays at Chipps Island and Jersey Point were deployed and maintained by USGS-Sacramento. A full description of this array is found in Chapter 5.

Acoustic Tagging – Sample Size Estimation

Modeling of fish survival in the San Joaquin River for the 2011 VAMP study (Appendix E) was used to determine the minimum number of fish to be released at Durham Ferry for the Six-Year Study. While the parameter estimates used to determine the release sizes are from past fall-run Chinook salmon survival studies, it is assumed steelhead will show similar movement and survival patterns. Similar efforts will be undertaken during the 6-year study period to recalculate release sizes based on newer results from the previous year. To evaluate survival under different tributary flow during 2011 with varying south Delta export and flow conditions and facility operations (i.e. nonphysical barriers), the Six-Year Study plan called for three releases of 480 steelhead with an additional two releases of 480 fish per release

Table 6-10
2011 Tagging and Release Schedule for the Mokelumne River Hatchery Juvenile Steelhead (*Oncorhynchus mykiss*) Utilized During the Six-Year Study in Cooperation with the Vernalis Adaptive Management Program (VAMP) and the South Delta Temporary Barriers Project (TBP) to Evaluate Differences Due to Route Selection and Reach Specific Survival

Tagging Date	Salmon Smolt Study	Live tagged Fish, transported and released	Dummy tagged fish, transported and sacrificed for pathology study	Dummy tagged fish, transported and sacrificed to assess fish condition	Release Start Date (Releases made over a 24-hr period)	Source of Tagged Fish (Hatchery)
3/21/11	6-Year RPA	118		6	3/22/11	Mokelumne River
3/22/11	6-Year RPA	119		6	3/23/11	Mokelumne River
3/23/11	6-Year RPA	120		6	3/24/11	Mokelumne River
3/24/11	6-Year RPA	120	24	0	3/25/11	Mokelumne River
5/2/11	6-Year RPA	118		6	5/3/11	Mokelumne River
5/3/11	6-Year RPA	119		9	5/4/11	Mokelumne River
5/4/11	6-Year RPA	119		3	5/5/11	Mokelumne River
5/5/11	6-Year RPA	118		6	5/6/11	Mokelumne River
5/16/11	6-Year RPA	119		6	5/17/11	Mokelumne River
5/17/11	6-Year RPA	120	24	0	5/18/11	Mokelumne River
5/18/11	6-Year RPA	119		6	5/19/11	Mokelumne River
5/19/11	6-Year RPA	120		6	5/20/11	Mokelumne River
5/21/11	South Delta TBP	120		6	5/22/11	Mokelumne River
5/22/11	South Delta TBP	120		6	5/23/11	Mokelumne River
5/23/11	South Delta TBP	120		6	5/24/11	Mokelumne River
5/24/11	South Delta TBP	120		6	5/25/11	Mokelumne River
6/14/11	South Delta TBP	118	23	0	6/15/11	Mokelumne River
6/15/11	South Delta TBP	120		6	6/16/11	Mokelumne River
6/16/11	South Delta TBP	48		3	6/17/11	Mokelumne River
	Element Total	**2195**	**71**	**87**		

as part of the DWR South Delta TBP. The three releases under the Six-Year Study were done in coordination with the VAMP and the South Delta TBP to ensure all three programs could utilize the survival data. This approach should provide independent measures of survival under different flow, export, and facility operations and make the data available to study the surrogacy of using steelhead or salmon smolts for survival studies such as this. The release schedule for the steelhead is shown in Table 6-10.

Acoustic Tagging – Study Fish

A total of 2868 steelhead smolts from the Mokelumne River Hatchery were to be used for this study and the South Delta TBP for fish health, release groups, and the tag shedding study (Table 6-10). Fish were similar to those used in Clark et al (2009) (between 200-300mm and weighed between 75-310g). Using HTI 795LD tags (averaging 0.55g in water); the tag burden on these fish would be less than 1 percent of body weight.





Acoustic Tagging – Fish Tagging, Tag Programming and Surgery

To reduce tag effects in comparing Six-Year Study steelhead to VAMP released fall-run Chinook and the steelhead released as part of the South Delta TBP, fish surgeons and assistants working on the Six-Year Study were the taggers for the VAMP and South Delta TBP. To reduce surgery and handling effects in comparing the Six-Year Study steelhead to VAMP released fall-run Chinook and the South Delta TBP released steelhead and fall-run Chinook, the Six-Year Study tag programming procedures and fish surgeries were identical to those used for VAMP and South Delta TBP.

Acoustic Tagging – Fish Transport, Holding and Release

To reduce fish transport, holding and release effects in comparing Six-Year Study steelhead to VAMP released fall-run Chinook salmon and the South Delta TBP fall-run Chinook salmon and steelhead releases, the Six-Year Study fish transport, holding and release procedures were identical to those used for VAMP and South Delta TBP. A full discussion of the procedures used in the VAMP and South Delta TBP is found in Chapter 5.

Acoustic Tagging – Tag Shedding, Tag-Life Investigations and Fish Health

A total of 90 fish were tagged with dummy tags during the Six-Year Study to evaluate general condition after 48 hours, for physiological and pathology tests, and for evaluation of post-tagging mortality and shedding within 30 days of tagging. For each release, eighteen fish were tagged with dummy tags (6 fish per day), which were tagged during the tagging session, transported and held with the live tagged groups. Dummy tagged fish were assessed for general condition after 48 hours and used for physiological and pathology tests. Methods for randomly distributing dummy tags within the pool of live tags for each group were consistent with methods used in the 2011 VAMP study. Dummy tagged fish were assessed for general condition after 48 hours and used for physiological and pathology tests by the USFWS CA-NV Fish Health lab.

Dummy tagged fish were visually assessed for smolt status and suture health as part of every tagged fish delivery. Three fish were dummy tagged, held for 48 hours, then sacrificed to visually assess signs of smoltification and suture health. Additionally, 3 sets of 24 fish were dummy tagged, held for 48 hours, euthanized and assessed in the laboratory for pathogen infection to help determine if results associated with survival are based on the initial condition and health of test fish. These fish were evaluated as part of the first, second, and last releases. A subsample of twelve of the pathogen infection study were evaluated for gill ATPase levels. For the tag life and longer-term tag effect study, fifty fish were tagged with live tags and held at the DWR Collection, Handling, Transportation and Release Lab for 30 days to evaluate delayed mortality, tag shedding, and tag life.

Data Processing and Analysis

Data processing was conducted by the USGS Cook Laboratory using an algorithm developed specifically for the South Delta during the VAMP and South Delta TBP. Data analysis will then be consistent with the techniques used by the VAMP and South Delta TBP and reviewed by others as fitting these programs. The Six-Year Study used a mark-recapture model based on a Cormack-Jolly-Seber model in combination with a route-specific survival model of Skalski et al. (2002) to derive maximum likelihood estimates and standard errors of the parameters. The Six-Year Study used the release-recapture information derived from the 2011 VAMP receiver array to populate the mark-recapture model in a very similar framework to what was used in the 2011 VAMP fall-run Chinook survival study. A full discussion of the model, its parameters and the assumptions involved appears in Chapter 5 and in Appendix "H".

Analysis of Variables Influencing Water Temperature in the San Joaquin River and Estuary

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Background

The Vernalis Adaptive Management Plan (VAMP), officially initiated in 2000 as part of SWRCB Decision 1641, was a large-scale, long-term, experimental-management program designed to protect juvenile Chinook salmon migrating from the San Joaquin River through the Sacramento-San Joaquin Delta (SJRGA, 2011). As part of the VAMP program, water temperature has been measured at several locations throughout the San Joaquin River and Estuary for over a decade. Water temperature is an important variable for fish development, growth, health, distribution, and survival (Myrick and Cech, 2004).

The purpose of this study is to evaluate the relationship between ambient weather conditions and water temperatures recorded during VAMP periods from 2000 to 2011. An analysis is needed to better understand how air temperature and other climatic variables influence water temperature throughout the Southern Delta.

Methods

Water temperature data used in this analysis was provided by Dr. Charles H. Hanson (Hanson Environmental, Inc., Walnut Creek, CA). Dr. Hanson provided water temperature data collected in the Sacramento-San Joaquin River Delta from 1998-2011 as part of the VAMP project. Data was provided from 28 locations (Table 6-11). Data from the three hatchery sites shown in Table 6-11 were not included in this analysis. The inclusive dates for VAMP field work varied each year and the temperature monitoring start and end dates also varied, with the data generally within the period from April 1st - June 30th. The temperature loggers were placed at a depth of approximately 3 feet (~ 1 meter) below the water surface and collected measurements of temperature (°C) multiple times per hour. The data was organized by location and by year. Data for the Mossdale Landing (MO or Station 2) location (37°47.142' N, 121°18.383' W) was used in this analysis.

Historical climate data was collected from the California Irrigation Management Information System (CIMIS). Data from 2000 to 2011 was compiled from the Manteca # 70 station (70-Manteca). The CIMIS 70-Manteca station is approximately 5.7 miles northeast of the VAMP MO station (Figure 6-20). The 70-Manteca station reports solar radiation (ly/day), net solar radiation (ly/day), air temperature (°F), wind speed (mph), precipitation (inches), evapotranspiration (inches), and relative humidity (%). This data is reported at a one-hour interval.

Flow data for this analysis was collected from the San Joaquin near Vernalis (VNS) and the San Joaquin River at Mossdale Landing (MSD) stations operated by the California Department of Water Resources (DWR). Timing of flow from MSD is derived from flow at VNS and accounts for the travel time between VNS and MSD. The VAMP MO site is located at or adjacent to the MSD station. The VNS station is located approximately 8 linear miles up-stream of the MO station (Figure 6-20). Average daily flows reported by DWR for the VNS station and instantaneous flow at 15-minute intervals from the MO station were used for analysis in this report.

Bivariate and multivariate statistical analysis was conducted using JMP software (SAS Inc., Research Triangle Park, NC). Analysis was conducted and interpreted according to standard methodologies (Kleinbaum et al. 1988, Zar 1999).

Results & Discussion

A matrix analysis of the VAMP temperature data set showed a significant correlation for water temperature between all of the VAMP monitoring locations. The correlation matrix for all stations for the 2008 data is shown in Table 6-12 as an example. These results mean that each location does not need to be evaluated individually for the relationship between climatic variables and water temperature, but that results from one station can be reasonably extrapolated to other stations.

This study focused on water temperature at the MO station at Mossdale Landing (VAMP site number 2, Table 6-11). The MO site was chosen because the location corresponds to the DWR monitoring station MSD and is within six miles of the CIMIS weather station 70-Manteca, a source of high quality climate data (Figure 6-20). Additionally, the MO site is located in the region where the San Joaquin River becomes a tidal estuary and is a critical point along the salmonid migration corridor down the San Joaquin River.

Water temperature data for MO provided by Hanson Environmental, Inc. was compiled with corresponding climate data from 70-Manteca for analysis. MO water temperature data was reported on a twenty-four minute time interval and 70-Manteca climate data was reported on an hourly time interval, so data were compiled by calculating the nearest hour for each MO measurement and assigning the corresponding 70-Manteca data to each MO temperature value. All the available MO data was used in this analysis (Table 6-13). Data was not available for the MO station in 2006 and 2007, but this missing data should not compromise or bias any analysis, since the data sets for other years are complete and the data sets used includes both wet and dry water years.

The relationship between water temperature and climate was first examined using bivariate analysis (Appendix A in Stringfellow, 2012). Climate variables examined were air temperature, solar radiation, net solar radiation, relative humidity, wind speed, resultant wind speed, precipitation, and reference evapotranspiration from standardized grass (ETo). Solar radiation, net solar radiation, wind speed, resultant wind speed, precipitation, ETo, and relative humidity had a weak relationship ($r^2 < 0.100$) with MO water temperature (see Appendix A in Stringfellow, 2012 for individual results).

Water temperature at MO had a significant correlation with 70-Manteca air temperature (Figure 6-21). The observed relationship between air and water temperature ($r^2 = 0.240$) is influenced by how much each variable changes on a daily basis. Air has less thermal inertia than water and the average daily coefficient of variation was 13.6 % for air temperature. In comparison, water temperature had a mean daily coefficient of variation of 2.4% during VAMP.

Water temperature at MO also exhibits a relationship with flow. In Figure 6-22, observed water temperature at MO for all years is plotted as a function of average

Table 6-11
Locations Where Temperature Measurements were Made as Part of the 12-year VAMP (2000 – 2011)
(See Appendix G for More Information on Locations)

VAMP Site Number	Temperature Monitoring Location	Latitude	Longitude
A[3]	Merced River Fish Hatchery (MRFH-1)		
B[3]	Merced River Fish Hatchery (MRFH-2)		
C[2]	Stockton Release Site (SRL)	N 37 56.103	W 121 19.831
D[2]	Old River Release Site (ORRL)	N 37 48.513	W 121 20.062
E	Mokelumne River Fish Hatchery (MOKFH)		
1	Durham Ferry (DF)	N 37 41.263	W 121 15.609
2	Mossdale Landing (MO)	N 37 47.142	W 121 18.383
3	Old River at HORB (HORB)	N 37 48.633	W 121 19.232
4	Dos Reis (DR)	N 37 49.956	W 121 18.791
5	DWR Monitoring Station (DWR)	N 37 51.874	W 121 19.388
6a	Confluence – Top (Conf-T)	N 37 56.817	W 121 20.293
6b	Confluence- Bottom (Conf-B)	N 37 56.817	W 121 20.293
7	Upstream of Channel Marker 33 (CM33)	N 37 59.682	W 121 24.699
7a	Downstream of Channel Marker 30 (CM30)	N 37 59.776	W 121 25.569
8	Turner Cut - Channel Marker 21-22 (TC)	N 38 00.339	W 121 27.095
9	"Q" Piling 1/2 mile upstream of channel marker 13 (CM13)	N 38 01.949	W 121 28.770
10	All Pro Boat downstream of Channel Marker 36 (All Pro)	N 38 04.497	W 121 34.399
11a	Jersey Point USGS Gauging Station-Top (JP-T)	N 38 03.177	W 121 41.623
11b	Jersey Point USGS Gauging Station-Bottom (JP-B)	N 38 03.177	W 121 41.623
12	Antioch Marina (AM)	N 38 01.370	W 121 48.689
13	Chipps Island (CI)	N 38 03.011	W 121 55.038
14	Holland Riverside Marina (HRM)	N 37 58.324	W 121 34.900
15	Old River / Indian Slough Confluence (OR/IS)	N 37 54.985	W 121 34.038
16	CCF Radial Gates (CCF)	N 37 49.898	W 121 33.238
17	Grant Line Canal at Tracy Blvd Bridge (GLC)	N 37 49.194	W 121 26.988
18[1]	Union Pt./Middle River (UP)	N 37 53.427	W 121 29.359
19	Werner Cut: Channel above Woodward Isle (WC)	N 37 56.381	W 121 32.467
20[4]	Mokelumne River-Lighthouse Marina (MR/LM)	N 38 06.334	W 121 34.213

[1] Note, Site 18 (Union Point) was moved to this location in 2009 from Middle River at Victoria Canal (N37 53.323 W121 29.334

[2] Release site data collected in 2010 only

[3] In 2011, Logger A was placed with acoustic tagged fish in the hatchery building and Logger B was placed with control group fish in the outside hatchery nursery tanks. In other years, hatchery loggers were placed in the outside raceways.

[4] Lighthouse Marina site discontinued after 2005 due to no Mokelumne River releases

Table 6-12
Correlation of Water Temperature Between Various VAMP Locations Using Measured Temperature Data for the 2008 VAMP. Water Temperature was Significantly Correlated (alpha<0.05) Between All Locations (A Key to Site locations is Provided in Table 6-11)

	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6	Site 7	Site 8	Site 9	Site 10	Site 11	Site 12	Site 13	Site 14	Site 15	Site 16	Site 17	Site 18	Site 19
Site 1	1.000	0.621	0.538	0.636	0.662	0.835	0.907	0.894	0.901	0.903	0.887	0.890	0.692	0.737	0.918	0.906	0.952	0.903	0.915
Site 2	0.621	1.000	0.807	0.982	0.978	0.544	0.601	0.740	0.742	0.736	0.753	0.744	0.803	0.833	0.724	0.725	0.655	0.715	0.738
Site 3	0.538	0.807	1.000	0.851	0.831	0.480	0.523	0.668	0.671	0.663	0.666	0.651	0.685	0.725	0.632	0.651	0.576	0.623	0.658
Site 4	0.636	0.982	0.851	1.000	0.989	0.552	0.608	0.764	0.767	0.761	0.773	0.761	0.803	0.844	0.745	0.751	0.681	0.736	0.762
Site 5	0.662	0.978	0.831	0.989	1.000	0.574	0.630	0.782	0.783	0.781	0.795	0.783	0.824	0.864	0.772	0.775	0.720	0.766	0.787
Site 6a	0.835	0.544	0.480	0.552	0.574	1.000	0.961	0.868	0.852	0.888	0.890	0.901	0.770	0.818	0.877	0.877	0.837	0.877	0.877
Site 6b	0.907	0.601	0.523	0.608	0.630	0.961	1.000	0.920	0.910	0.936	0.936	0.943	0.783	0.831	0.929	0.929	0.905	0.932	0.933
Site 7	0.894	0.740	0.668	0.764	0.782	0.868	0.920	1.000	0.988	0.984	0.982	0.982	0.826	0.878	0.968	0.984	0.927	0.964	0.979
Site 8	0.901	0.742	0.671	0.767	0.783	0.852	0.910	0.988	1.000	0.980	0.976	0.973	0.800	0.857	0.967	0.983	0.927	0.959	0.979
Site 9	0.903	0.736	0.663	0.761	0.781	0.888	0.936	0.984	0.980	1.000	0.990	0.988	0.848	0.894	0.985	0.989	0.943	0.979	0.989
Site 10	0.887	0.753	0.666	0.773	0.795	0.890	0.936	0.982	0.976	0.990	1.000	0.994	0.856	0.905	0.978	0.984	0.933	0.981	0.987
Site 11a	0.890	0.744	0.651	0.761	0.783	0.901	0.943	0.982	0.973	0.988	0.994	1.000	0.857	0.905	0.973	0.981	0.929	0.979	0.982
Site 12	0.692	0.803	0.685	0.803	0.824	0.770	0.783	0.826	0.800	0.848	0.856	0.857	1.000	0.954	0.841	0.829	0.768	0.836	0.835
Site 13	0.737	0.833	0.725	0.844	0.864	0.818	0.831	0.878	0.857	0.894	0.905	0.905	0.954	1.000	0.884	0.879	0.812	0.883	0.883
Site 14	0.918	0.724	0.632	0.745	0.772	0.877	0.929	0.968	0.967	0.985	0.978	0.973	0.841	0.884	1.000	0.987	0.962	0.983	0.992
Site 15	0.906	0.725	0.651	0.751	0.775	0.877	0.929	0.984	0.983	0.989	0.984	0.981	0.829	0.879	0.987	1.000	0.956	0.986	0.994
Site 17	0.952	0.655	0.576	0.681	0.720	0.837	0.905	0.927	0.927	0.943	0.933	0.929	0.768	0.812	0.962	0.956	1.000	0.966	0.961
Site 18	0.903	0.715	0.623	0.736	0.766	0.877	0.932	0.964	0.959	0.979	0.981	0.979	0.836	0.883	0.983	0.986	0.966	1.000	0.989
Site 19	0.915	0.738	0.658	0.762	0.787	0.877	0.933	0.979	0.979	0.989	0.987	0.982	0.835	0.883	0.992	0.994	0.961	0.989	1.000

The correlations are estimated by Pairwise method.
A key to site designations is provided in Table 6-11

Table 6-13
Summary of Temporal Coverage of Water Temperature Data from VAMP Station 2 (Mossdale (MO)) Used in this Study

Year	Number of Measurements	Beginning Date & Time	Ending Date & Time
2000	3781	4/13/2000, 0009 hrs	6/15/2000, 0009 hrs
2001	3601	4/19/2001, 1207 hrs	6/18/2001, 1207 hrs
2002	4470	4/1/2002, 1236 hrs	6/15/2002, 0012 hrs
2003	3872	4/11/2003, 1141 hrs	6/15/2003, 0005 hrs
2004	2401	4/15/2004, 1254 hrs	5/25/2004, 1254 hrs
2005	3661	4/15/2005, 0000 hrs	6/15/2005, 0000 hrs
2008	4621	3/18/2008, 0012 hrs	6/3/2008, 0000 hrs
2009	4467	4/3/2009, 0000 hrs	6/16/2009, 1024 hrs
2010	3852	4/16/2010, 0948 hrs	6/19/2010, 1412 hrs
2011	5314	4/29/2011, 1100 hrs	7/27/2011, 0012 hrs

Table 6-14
Mean and Standard Deviations for Variables by Year

Year	Water Temp (°C) Mean ± Std. Dev.	Air Temp (°C) Mean ± Std. Dev.	Flow (cfs)[1] Mean ± Std. Dev.	Day of Year[2] Mean ± Std. Dev.
2000	18.4 ± 2.3	17.6 ± 6.1	4790 ± 1184	135 ± 18
2001	20.9 ± 2.7	20.4 ± 7.0	3083 ± 1223	139 ± 17
2002	19.1 ± 2.7	16.9 ± 6.2	2446 ± 779	128 ± 22
2003	19.3 ± 3.0	16.6 ± 6.3	2687 ± 544	133 ± 19
2004	19.1 ± 1.6	17.5 ± 5.9	2975 ± 442	126 ± 12
2005	16.8 ± 1.8	17.6 ± 5.6	6314 ± 2713	135 ± 18
2008	17.4 ± 2.2	15.6 ± 6.5	2498 ± 597	116 ± 22
2009	19.6 ± 2.4	17.3 ± 6.5	1709 ± 534	130 ± 21
2010	17.3 ± 1.8	16.8 ± 5.9	4957 ± 690	138 ± 19
2011	18.2 ± 2.2	19.0 ± 6.6		163 ± 26

[1] cfs = cubic feet per second
[2] Day of Year is the assignment of a number from 1 to 365 (or 366 for leap years) corresponding to each sequential day of the year in order (i.e. January 10th is the 10th DOY, February 2nd is the 33rd DOY, etc)

daily flow in the San Joaquin River at VNS. This analysis includes all available years for MO (see Table 6-13) and suggests a significant correlation between flow and temperature ($r^2 = 0.224$). In a second analysis, 24-minute water temperature data from 2008 at Mossdale Landing (MO) was compared to 15-minute flow data for the same year from the DWR Mossdale Landing station (MSD). In this analysis, the 921 data points where flow and temperature were measured at the same time (in this case on the hour) were used. In Figure 6-23, an example of a "within year" analysis, demonstrates a much less strong relationship between flow and water temperature ($r^2 = 0.023$) than was observed when multiple years are considered. These results suggest that across-years flow has a strong effect on water temperature, but that within any particular year, flows have less effect.

The difference in climate and other variables between years is analyzed in Appendix B of Stringfellow (2012) and results for select variables are shown in Table 6-14. In some cases, differences are observed between different years for major climate parameters (Appendix B in Stringfellow, 2012). For example, mean air temperature was 20.4 °C in 2002 and 15.6 °C in 2008 (Table 6-14), but in many cases, these differences between years can be attributed to differences between time periods covered by each data set (Table 6-13), since climate variables are strongly correlated with time of year (Appendix C in Stringfellow, 2012). Differences in flow between years are indicative of wet and dry years (Table 6-14) and time of year is not predictive of flow (Appendix C in Stringfellow, 2012). However, differences between years for water temperature cannot be attributed to differences in VAMP time periods between years (Appendix D in Stringfellow, 2012 and Table 6-14).

Bivariate analysis has shown a significant correlation between water temperature and major climate variables (Appendix A in Stringfellow, 2012) and water temperature and flow (Figure 6-22). Other analysis suggested that flow will affect water temperature on a different time scale than climate variables (Appendix B and C in Stringfellow, 2012 and Figures 6-22 and 6-23). Climate variables, such as solar radiation and air temperature, can change dramatically over short time periods, including hour of day (Appendix E in Stringfellow, 2012). In contrast, flow shows low daily variation, but rather varies by week, month, and year. In order to better understand the interrelationship between climate variables, flow and water temperature, multivariate analysis can be used (Kleinbaum et al. 1988, Zar 1999). Multivariate analysis, such as stepwise regression, considers the effect of more than one variable at the same time. In this report, stepwise regression is used to examine how climate variables and flow predict water temperature.

Five climate variables recorded at the 70-Manteca station were used as independent variables: air temperature, solar radiation, wind speed, relative humidity, and precipitation. Net radiation, ETo, and resultant wind speed are calculated from the independent variables. Flow is also clearly an independent variable.

A multivariate analysis was conducted to investigate the combined effect of the independent variables (air temperature, solar radiation, wind speed, relative humidity, precipitation, and flow) on water temperature and the results are shown in Appendix F in Stringfellow, 2012. The results indicate that all of the independent variables have a significant effect on water temperature. In stepwise regression, each variable is entered independently and the resultant regression coefficient (r^2)

Figure 6-20
Location of the California Irrigation Management Information Station Near Manteca, California (CIMIS 70-Manteca) in Relation to the Location of the Mossdale Flow (MSD) and Temperature (MO Station) Measuring Station on the San Joaquin River Downstream of the Vernalis (VNS) Flow Monitoring Station

Figure 6-21
Bivariate Analysis of Water Temperature at the VAMP Mossdale Temperature Measuring Station (MO Station) and Air Temperature from the California Irrigation Management Information Station Near Manteca, California (CIMIS 70-Manteca)

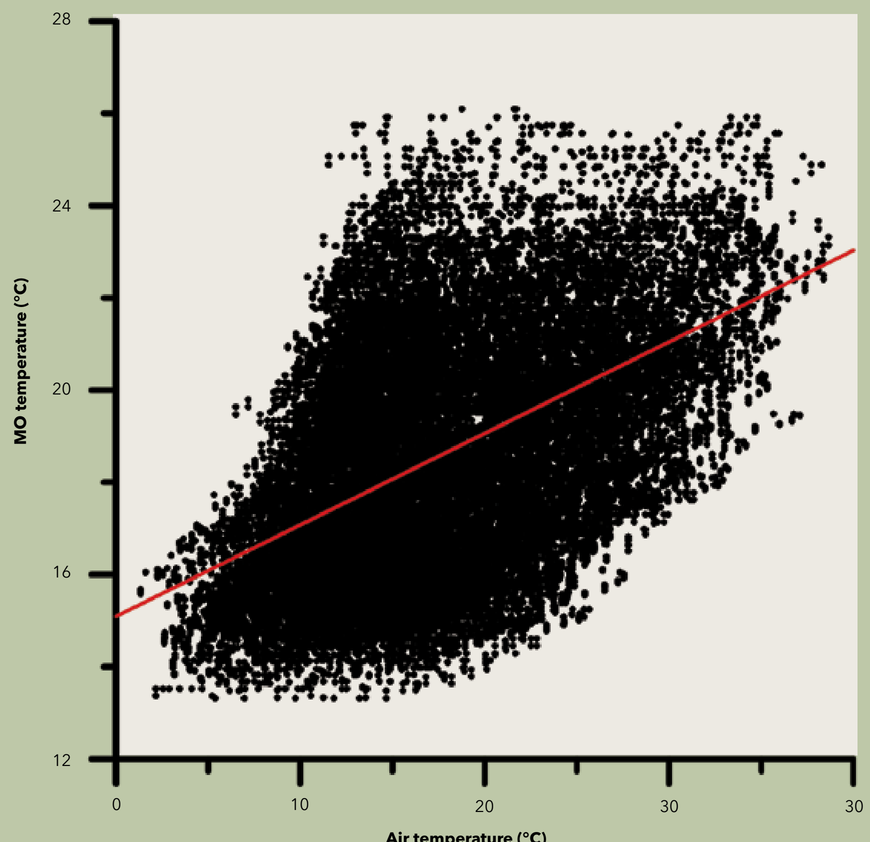


Figure 6-22
Water Temperature at the VAMP Mossdale Temperature Measuring Station (MO Station) as a Function of Average Daily Flow Recorded at the Department of Water Resources Flow Monitoring Station at Vernalis (VNS)

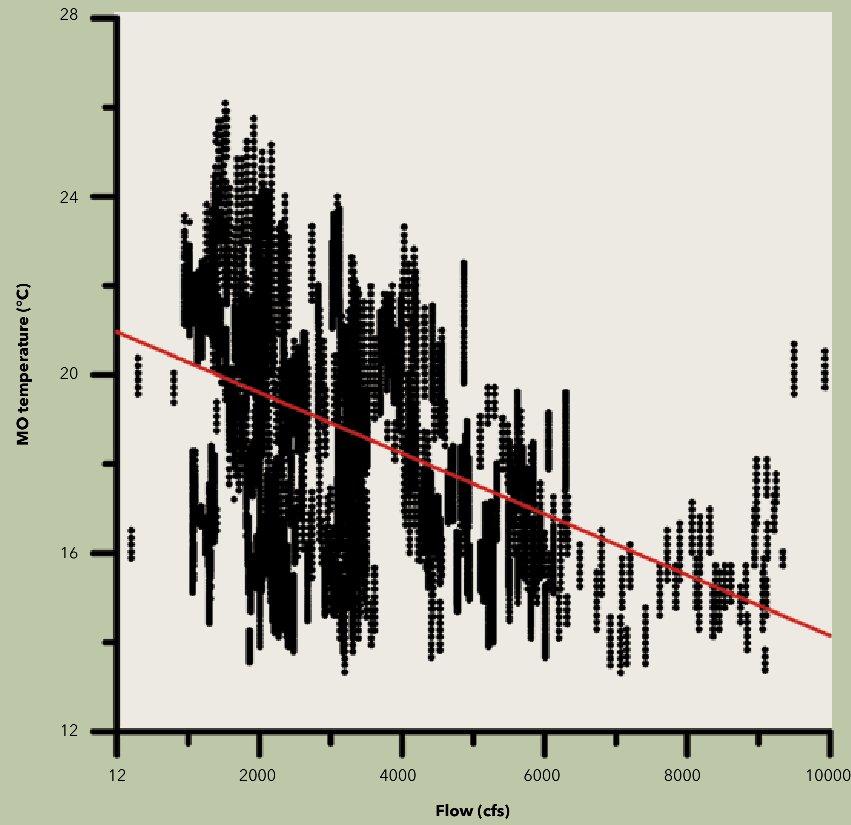
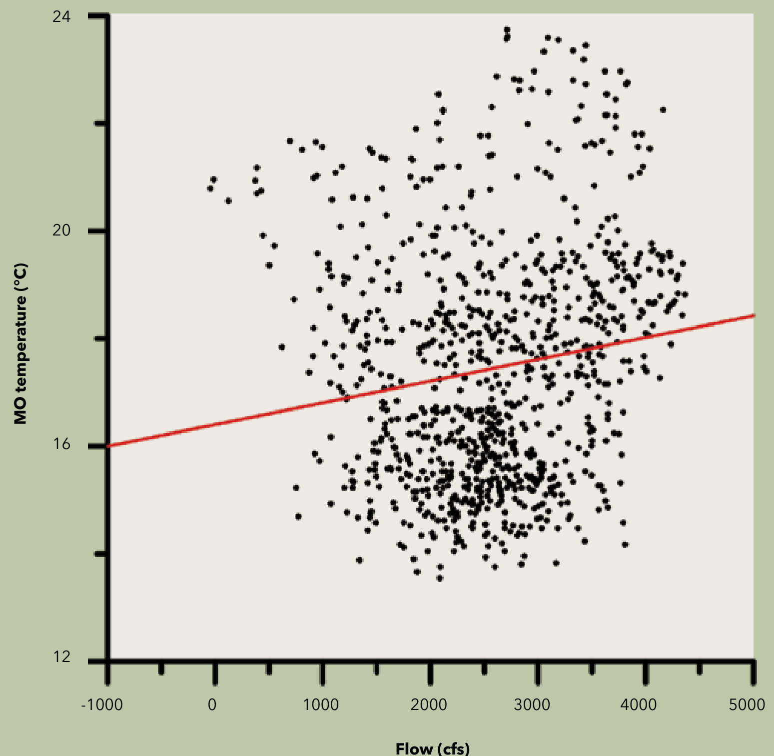


Figure 6-23
Comparison of Water Temperature and Flow for the 2008 VAMP. Water Temperature at the VAMP Mossdale Temperature Measuring Station (MO Station) as a Function of Corresponding Flow Recorded at the Department of Water Resources Flow Monitoring Station at Mossdale Landing (MSD). Due to Different Time Intervals for Data Collection, only Data Collected on the Hour are Included in this Analysis (n=921)



can be interpreted as the level of prediction provided for the dependent variable (in this case water temperature). Additionally, the order of addition is indicative of the importance of each independent variable. The analysis in Appendix F in Stringfellow, 2012 indicates that air temperature is the single most important variable predicting water temperature, followed by flow. A model containing air temperature and flow predicts approximately 43% of the variance in water temperature ($r^2 = 0.433$), the addition of solar radiation predicts over 50% ($r^2 = 0.541$), and a model including all the independent variables predicts almost 60% of the observed variance in water temperature ($r^2 = 0.581$).

Summary & Conclusions

Major climatic variables, including air temperature, solar radiation, wind speed, humidity, and precipitation, were tested for their influence on water temperature in the South Delta. All climate variables had a significant influence on ambient water temperature, however air temperature was the most important climatic driver of water temperature and predicted approximately 24% ($r^2 = 0.240$) of the variation observed in water temperature at the Mossdale Landing (MO) station. There was a strong correlation between water temperature measurements made at the VAMP MO station and other South Delta monitoring stations, indicating that results from MO are applicable to other stations in the South Delta. Water flow was also examined as a predicting variable for water temperature and was found to be in the same order as air temperature as a predicting variable ($r^2 = 0.224$) if multiple years were included in the analysis. Evaluation of climate and flow variables indicated that different variables have different time scales of influence on water temperature, for example solar radiation varies on a daily and weekly time step, whereas flow varies annually. Combined, air temperature and flow can be used to predict approximately 43% of the observed variance in water temperature.

2011 Spring Head of Old River Fish Behavior Study

Contributed by
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Background

In recent years, the Head of Old River (HOR) (Figure 6-24) has been the site of several investigations aimed

Figure 6-24
The San Joaquin River at the Divergence of Old River (shown on left) in the Southern Sacramento-San Joaquin River Delta (South Delta)

at improving the survival rate of downstream migrating salmon in the southern Sacramento-San Joaquin River Delta (South Delta). Results of several studies suggest that downstream migrating salmon have a better chance of survival if they remain in the San Joaquin River (Perry et.al, 2010 and Brandes and McLain, 2001). Beginning in spring 1992, a rock barrier was installed at the HOR which directed flows in the San Joaquin River away from the Old River. High flows precluded the installation of the rock barrier during several years (1993, 1995, 1998, 1999, 2005, 2006, and 2011), yet for years when the HOR barrier was in place, results of several studies indicated that downstream migration conditions for San Joaquin River salmon were improved (Brandes and McLain 2001, Newman and Rice 2002 and SJRGA, 2007). The rock barrier at the HOR routed smolts to a more direct migration path; the increased flows into the San Joaquin River may have reduced predation rates on downstream migrating salmon.

In 2007 growing concerns about reduced flows in the Old River lead to a re-evaluation of the HOR rock barrier. Reduced flows in the Old River resulting from the previous and 2007 installation of the HOR rock barrier were believed to have increased the effect of reverse flows toward the CVP and SWP pumping plants (also called negative Old and Middle River flows) that can occur under certain operational conditions. One of the concerns over higher negative Old and Middle River flows is the potential for increased entrainment of delta smelt at South Delta pumping facilities. These concerns lead to an order issued in 2007 that prohibited the construction of the upcoming spring HOR barrier (NRDC, 2007). This order resulted in no installation of the barrier in 2008 and the development in 2009 of a new approach for improving the survival rate of downstream migrating San Joaquin River salmon.

In 2008, laboratory testing of a non-physical barrier (NPB) to replace the HOR rock barrier was conducted by the US Department of Interior, Bureau of Reclamation (USBR). The NPB incorporated several behavioral stimuli to maximize fish guidance without altering flow. These stimuli included customized sound signals, directional strobe lighting and an air bubble curtain (Bowen et al. 2008). Results of the tests were encouraging and in spring 2009 the California Department of Water Resources (DWR) worked in coordination with Fish Guidance Systems, Ovivo USA LLC, Hydroacoustic Technology Inc., the San Joaquin River Group Authority and the USBR to design, install and monitor the NPB to replace the rock barrier at HOR. A more in-depth discussion of the installation of the NPB can be found in chapter 4 of this report and in chapter 4 of previous VAMP reports (SJRGA, 2009 and SJRGA, 2010).

In 2009 and 2010, the NPB was deployed at the divergence of the San Joaquin River immediately upstream of Old River. It was oriented and designed to discourage salmon from entering Old River. A two-dimensional fish tracking system utilizing acoustic tagging technology was used to measure the distribution and behavior of fish in the vicinity of the NPB. Compared to other more traditional tagging techniques, acoustic tag tracking technology provided very high temporal and spatial sampling coverage, assuring that each tagged fish was detected and uniquely identified as it encountered the NPB. These fish detections were used to measure the deterrence and protection efficiency of the NPB.

During both study years, the barrier performance was evaluated over the full range of light and tidal conditions with nearly equal hours of operation of the "barrier on" and "barrier off" condition. For both years, acoustic tagged fish were released upstream of the barrier at Durham Ferry. In 2009, a total of 947 tagged fish in seven release groups were released between April 22nd and May 13th (Bowen et al 2009). In 2010, a total of 508 tagged fish in seven release groups were released between April 27th and May 19th (Bowen and Bark 2010).

Results of these studies indicated 81.4 percent deterrence efficiency when the barrier was on in 2009 compared to 23.0 percent in 2010. Deterrence efficiency was significantly higher in 2009 compared to 2010. The design of the NPB was changed in 2010 and this resulted in a less effective barrier. The 2011 NPB that was never installed utilized a refined design that took into account lessons learned from 2009 and 2010. These results indicate that under certain conditions the NPB can be highly efficient at guiding Chinook smolts. In 2011, DWR planned to repeat an NPB efficiency study at the HOR; however, high flows precluded the installation of NPB in 2011.

The purpose of both the rock barrier and the NPB was to reduce the number of juvenile salmon exposed to the CVP and SWP pumping plants. In 2011 high flows precluded installation of the NPB that was designed, leased, and ready to install. The purpose of the two-dimensional fish tracking system installed at the HOR site in 2011 was to monitor the behavior of downstream migrating salmon, steelhead and tagged predators at the divergence of the San Joaquin River and the Old River without a barrier structure in place scenario.

Site Description

The HOR study site is located at the divergence of the San Joaquin and Old River, near Lathrop CA. The two-dimensional fish tracking system was installed in the area where the HOR fish barrier was constructed as part of the South Delta Temporary Barriers Project (Figure 6-25). The San Joaquin River historically flows generally northwest from the Old River divergence converging with the Sacramento near the San Francisco Estuary. Old River generally flows west from the divergence with the San Joaquin and is available for diversion to the two water conveyance systems: the State Water Project (SWP) and Central Valley Project (CVP). Flows at the San Joaquin-Old River divergence can be highly variable during spring. The high flows that precluded barrier installation in 2011 persisted during early sampling but generally decreased throughout the study period (see tables 4-1 and 4-2 in Chapter 4). Also, because the Sacramento-Sacramento-San Joaquin River Delta is at sea level, water levels, flow direction and amounts vary at this site during each tidal cycle.

Bathymetry at the San Joaquin-Old River divergence may be a factor influencing predation in the area. A deep scour hole located just downstream of the San Joaquin-Old River divergence results in an area of lower velocity flow that may provide habitat for predators (Figure 6-26).

Study Objectives and Design

The primary objective of the 2011 acoustic tag study was to measure the distribution and behavior of Chinook salmon and steelhead near the divergence of the Old and San Joaquin Rivers without a barrier installed. The data collected will be used to:

- Measure the proportion of outmigrating juvenile Chinook salmon and steelhead that continue downstream through the San Joaquin River
- Measure the proportion of outmigrating juvenile

Figure 6-25
Locations of Temporary Barriers in the South Delta including the Barrier at the Head of Old River. The Two-dimensional Fish Tracking System was Installed at the Head of Old River Barrier (indicated in green) Located at the Divergence of the San Joaquin River and Old River; however, the Head of Old River Barrier was not Installed in 2011 but the Fish Behavior 2-D Tracking Study Continued

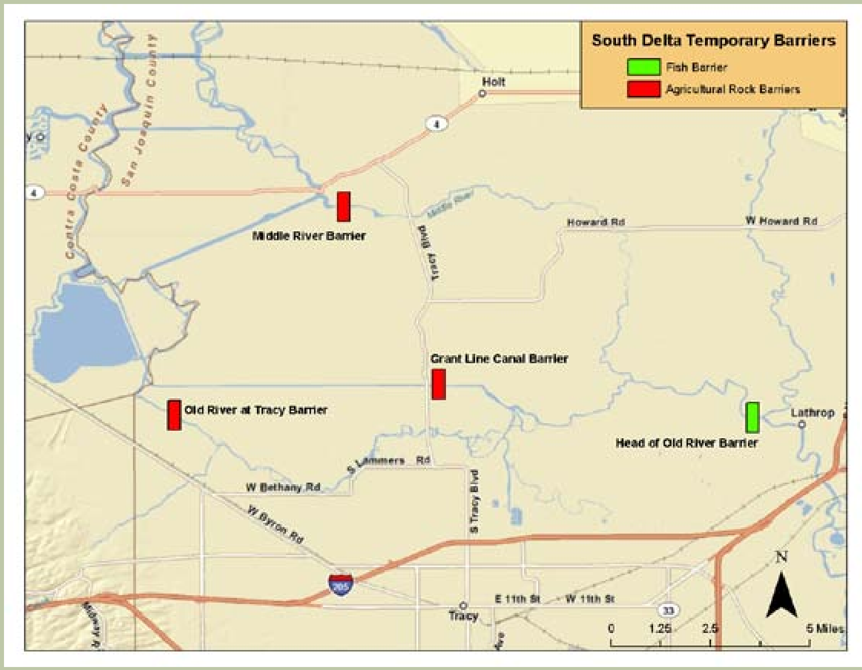


Figure 6-26
Bathymetry at the Divergence of the San Joaquin River and Old River during Positive Discharge (From: Bowen and Bark, 2010). Note the Location of the Deep Scour Hole just Downstream of the San Joaquin River-Old River Divergence

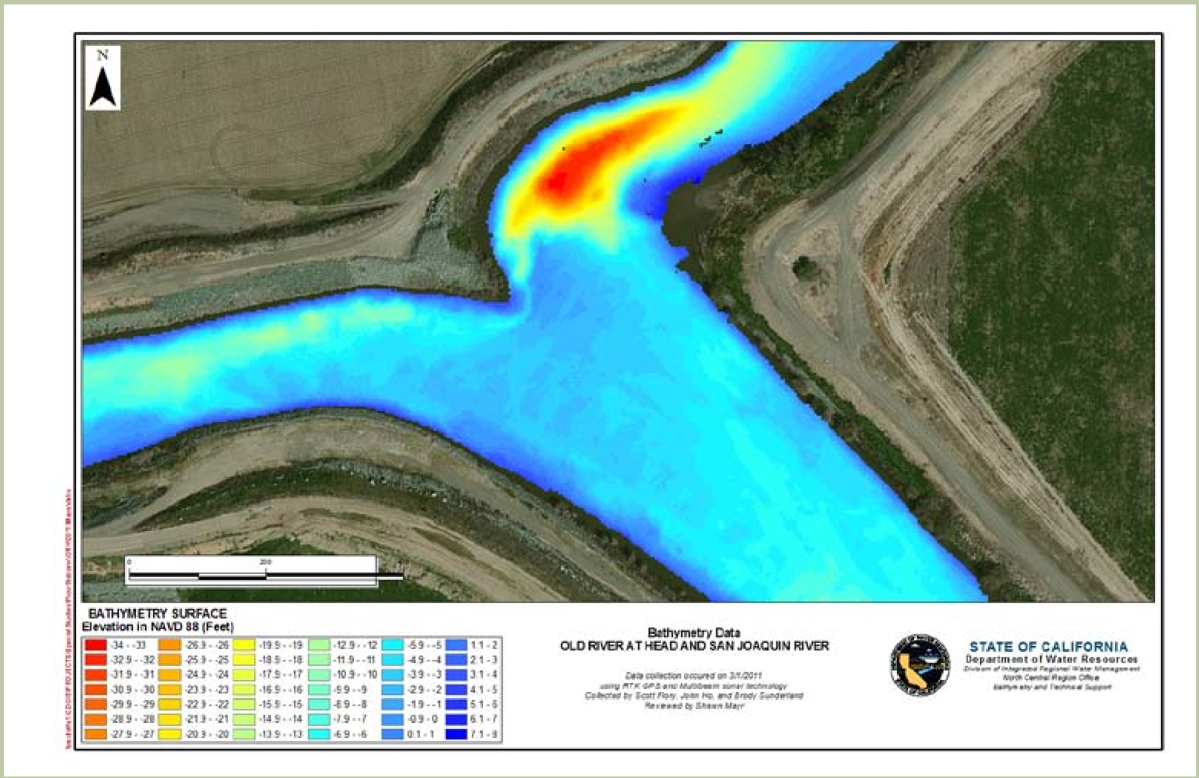


Table 6-15 Hydroacoustic Technology, Inc (HTI) Acoustic Tags Used for the Head of Old River (HOR) Fish Behavior Study in 2011				
HTI Model Number	**Diameter (mm)**	**Length (mm)**	**Weight in Air (gm)**	**Used for Tagging**
795Lm	6.8	16.5	0.65	Juvenile Chinook
795LD	6.8	20	1.1	Juvenile Steelhead
795X	16	48	13.0	Predator
795G	11	25	4.5	Predator

Chinook salmon and steelhead that continue downstream through the Old River

- Determine the behavior of tagged smolts and predators.

Acoustic Tags

The Hydroacoustic Technology, Inc (HTI) Model 795 Acoustic Tags operate at 307 kHz frequency and are encapsulated with a non-reactive, inert, low toxicity resin compound. Four different sizes of acoustic tags were used to tag juvenile Chinook, steelhead and predators (Table 6-15). The tags utilize "pulse-rate encoding" which provides increased detection range, improves the signal-to-noise ratio and pulse-arrival resolution, and decreases position variability when compared to other types of acoustic tags (Ehrenberg and Steig, 2003). Pulse-rate encoding uses the interval between each transmission to detect and identify the tag. Each tag is programmed with a unique pulse-rate encoding to detect and track the behavior of individual tagged fish moving within the array.

The pulse-rate is measured from the leading edge of one pulse to the leading edge of the next pulse in sequence. By using slightly different pulse-rates, tags can be uniquely identified. The timing of the start of each transmission is precisely controlled by a microprocessor within the tag. Each tag is programmed to have its own tag period to uniquely identify each tag.

Hydrophones

The HTI Model 590 Hydrophones operate at 307 kHz and include a low-noise preamplifier and temperature sensor. Hydrophone directional coverage is approximately 330 degrees, with equivalent sensitivity in all directions, except for a 30 degree limited sensitivity cone directly behind the hydrophone where the cable is attached. The hydrophone sensor element tip is encapsulated in specially-treated rubber with acoustic impedance close to that of water to ensure maximum sensitivity and long term reliability. The hydrophone and connector housing are made of corrosion resistant aluminum-bronze alloy. Specially designed cables incorporating twisted-pair wire and double shields for noise reduction are used to connect each deployed hydrophone to the acoustic tag receiver.

The hydrophone preamplifier circuit provides signal conditioning and background noise filtering for transmission over long cable lengths and in acoustically noisy environments such as the South Delta. A calibration circuit in the preamplifier provides a method for field testing hydrophone operation and is used to measure the signal time delays between hydrophones in the array. Measurement of the signal delays is used to verify the absolute position of each hydrophone within the sampling array, which is a critical part of the monitoring equipment deployment. This process of measuring the hydrophone positions via the signal travel times between each hydrophone is typically referred to as the "ping around" and is discussed later in this report. The HTI Model 590 Hydrophones include temperature sensors to measure water temperature at each location within the array, which is used to precisely estimate the sound velocity in water and referenced during the "ping around" procedure.

Acoustic Tag Receiver

An HTI Model 290 Acoustic Tag Receiver (ATR) can receive acoustic tag information simultaneously on up to 16 separate channels. Each ATR channel is assigned to a single hydrophone. The ATR is connected to the data collection computer, which analyzes and stores the acoustic data. An individual raw data file is automatically created for each sample hour, and contains the complete set of information describing each tag detection for all hydrophones. Data acquisition filters in the acoustic tag receiver are configured to identify the acoustic tag sound pulse and discriminate tag transmissions from background noise that may be present.

The ATR pulse measurements are automatically reported for each tag signal from each hydrophone, and are written to Raw Acoustic Tag (*.RAT suffix) files by the HTI AcousticTag® data collection software program. Each *.RAT file contains header information describing all data acquisition parameters followed by the raw tag signal data. Each raw tag signal data file contains all acoustic signals detected during the time period, including signals from tagged fish as well as some amount of unfiltered acoustic noise, which is removed during the data analysis processes.

Hydrophone Deployment

For the 2011 evaluation a total of nine hydrophones were installed near the HOR, at depths ranging from 12.0 to 41.0 ft (Figure 6-27). Hydrophones were deployed near the San Joaquin-Old River divergence using bottom mounts fabricated with railroad ties (Figure 6-28). The hydrophones were installed using tensioned aircraft cable or rope lines extending to buoys on the surface (Figure 6-29). The precise position of hydrophones in the array was examined in-situ using the hydrophone placement geometry and position calculation procedure termed the "ping-around". The effective range of detection and overlap of hydrophones in the array was also examined in-situ by actively moving a transmitting tag throughout the array and verifying consistent detection and positioning of the tag (termed the "tag drag" procedure).

Mobile Hydroacoustic Monitoring

To conduct mobile surveys a Biosonics DTX hydroacoustic system consisting of side-looking and down-looking 200khz transducers was mounted off the side of a 20' North River Aluminum boat equipped with a 150hp Honda Engine (Figure 6-30).

In 2011 a series of mobile boat surveys were used to acoustically measure densities of predator-sized targets in the vicinity of the HOR and at three reference sites. The reference sites were selected because of their similarity to the Old River junction in that they each consisted of a river bend with a large scour hole. Reference Site 1 was located just upstream of the Interstate 5 bridge over the San Joaquin River near Oakwood Lake, Reference Site 2 was a river bend midway between Reference Site 1 and the HOR, and Reference Site 3 was located on the first river bend downstream of the Head of Old River junction in the San Joaquin River. The location of the sites are shown in Figure 6-31.

GPS referenced data was obtained by connecting a Garmin GPS unit to the hydroacoustic gear. The data was collected at a -75 db threshold and a sample rate of 5 pings/sec using Biosonics Vis Acq ver 6 and data was stored on a laptop computer. Sampling at such a low threshold in the field ensured there could be no accidental filtering out of useful data; final thresholding will be done during the analysis phase. At each site a series of transects were run parallel to the river flow and an attempt was made to sample as much of the channel as possible. Typically, we moved up and down each shore and several paths were made up the center of the channel and again off to each side of river center. Each sample event, the site was sampled twice over the course of 20-30 minutes.

Table 6-16
Dates and Start Times for Mobile Surveys Conducted at the Head of Old River during the 2011 Head of Old River Fish Behavior Study

Date	Start Time
5/16/2011	1800 hrs
5/16/2011	2130 hrs
5/17/2011	0100 hrs
5/18/2011	0915 hrs
5/18/2011	1330 hrs
5/18/2011	1900 hrs
5/18/2011	2245 hrs
5/23/2011	0930 hrs
5/23/2011	1320 hrs
5/23/2011	2330 hrs
5/25/2011	0920 hrs
5/25/2011	1340 hrs
5/25/2011	1900 hrs
5/25/2011	2330 hrs
6/06/2011	1600 hrs
6/06/2011	2000 hrs
6/06/2011	2330 hrs
6/07/2011	1030 hrs
6/08/2011	1400 hrs

Data Collection

The acoustic tags analyzed for the HOR 2011 study represented a subset of the larger tag release of the 2011 VAMP study, the 2011 OCAP 6-year study and the 2011 South Delta Temporary Barriers Project (TBP) study. The releases from the combined studies began on March 22nd and continued through June 19th, releasing a total of 4,125 tagged fish. A total of 1,629 acoustic-tagged fish were analyzed at the HOR in 2011 and included Chinook salmon tagged as part of the VAMP and the South Delta TBP study (see Tables 5-3 and 5-4). An additional 150 steelhead tags are planned to be tracked for further investigations.

Releases of acoustically tagged juvenile Chinook salmon and steelhead were made into the San Joaquin River at Durham Ferry (approximate river mile (RM) 66). Releases for the Chinook salmon ranged from a minimum of 28 to a maximum of 30 tagged fish over 64 separate releases (See Tables 5-3 and 5-4 for specific details regarding the releases).

In addition to the tagged juvenile salmonids an additional 49 predatory fish (39 striped bass, 4 largemouth bass, and 6 white catfish) were captured, tagged and released in the vicinity of Old River at the San Joaquin River divergence.

Figure 6-27
Location of Hydrophones at the Head of Old River (HOR) during the 2011 VAMP

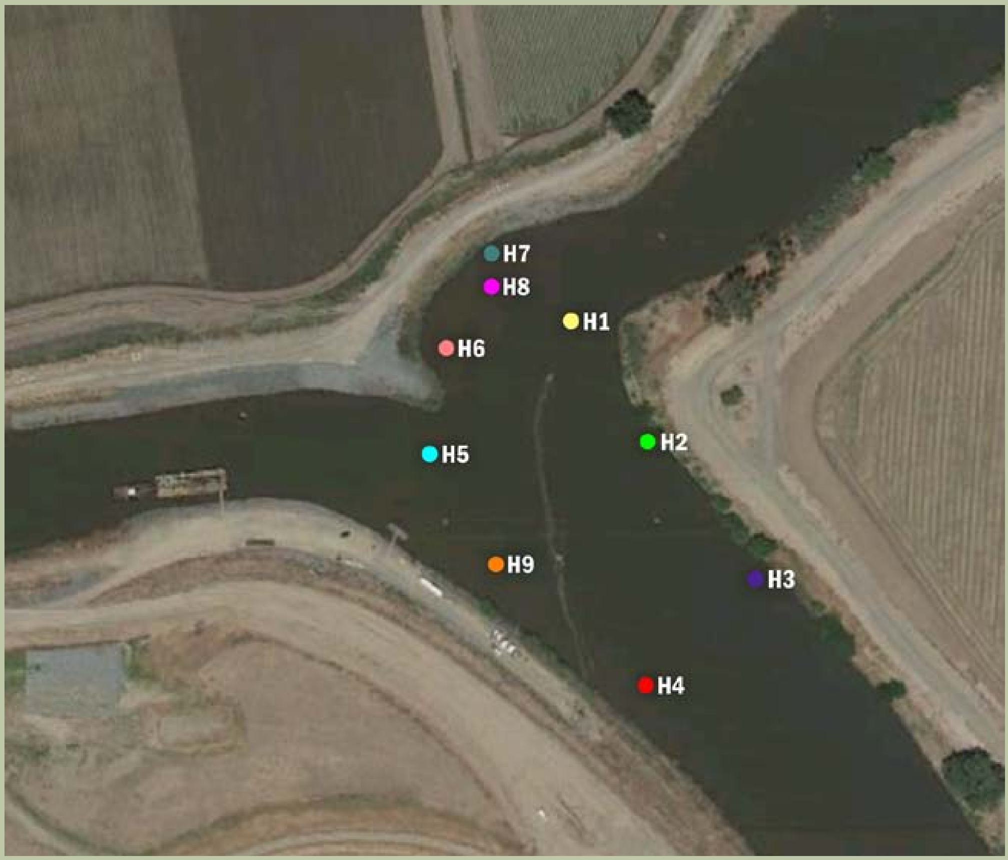


Figure 6-28
Example Hydrophone Mount used for Head of Old River (HOR) Deployments during the 2011 VAMP

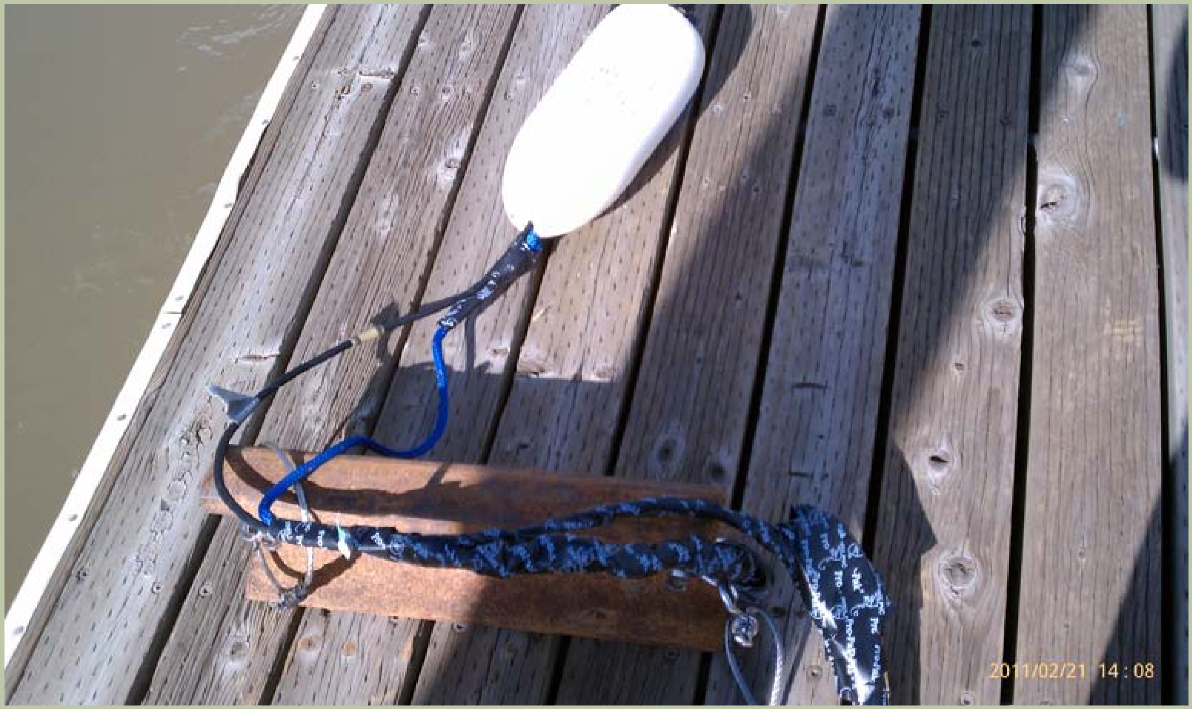


Figure 6-29
Depiction of Hydrophone Bottom Mounts with Tensioned Lines Used for the Fish Behavior Study at the Head of Old River (HOR)

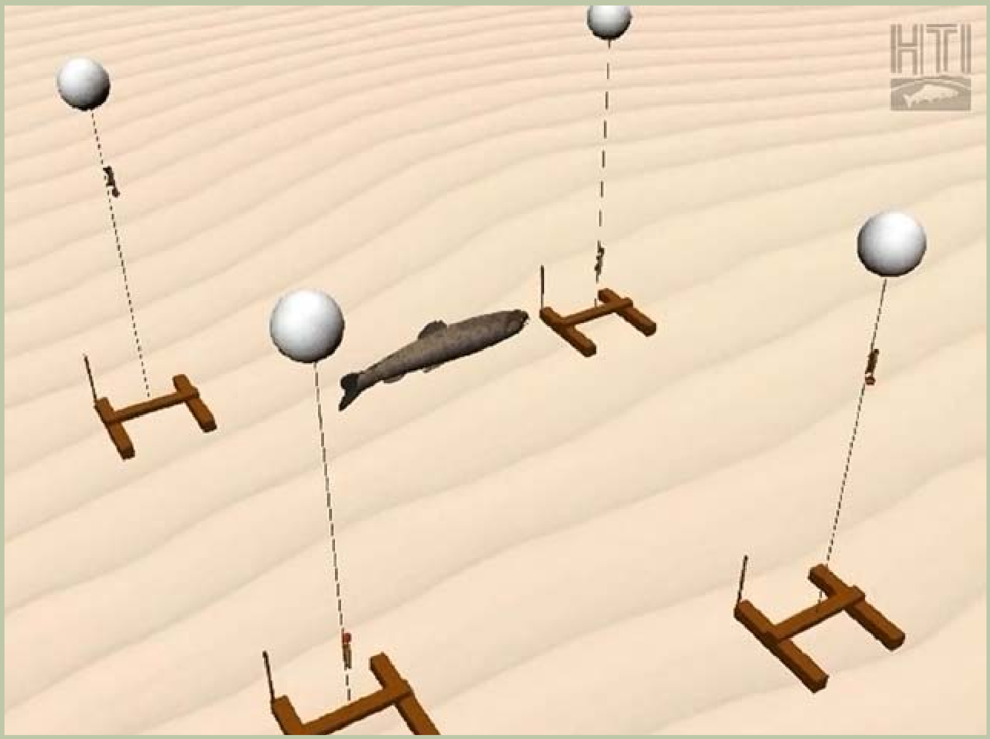
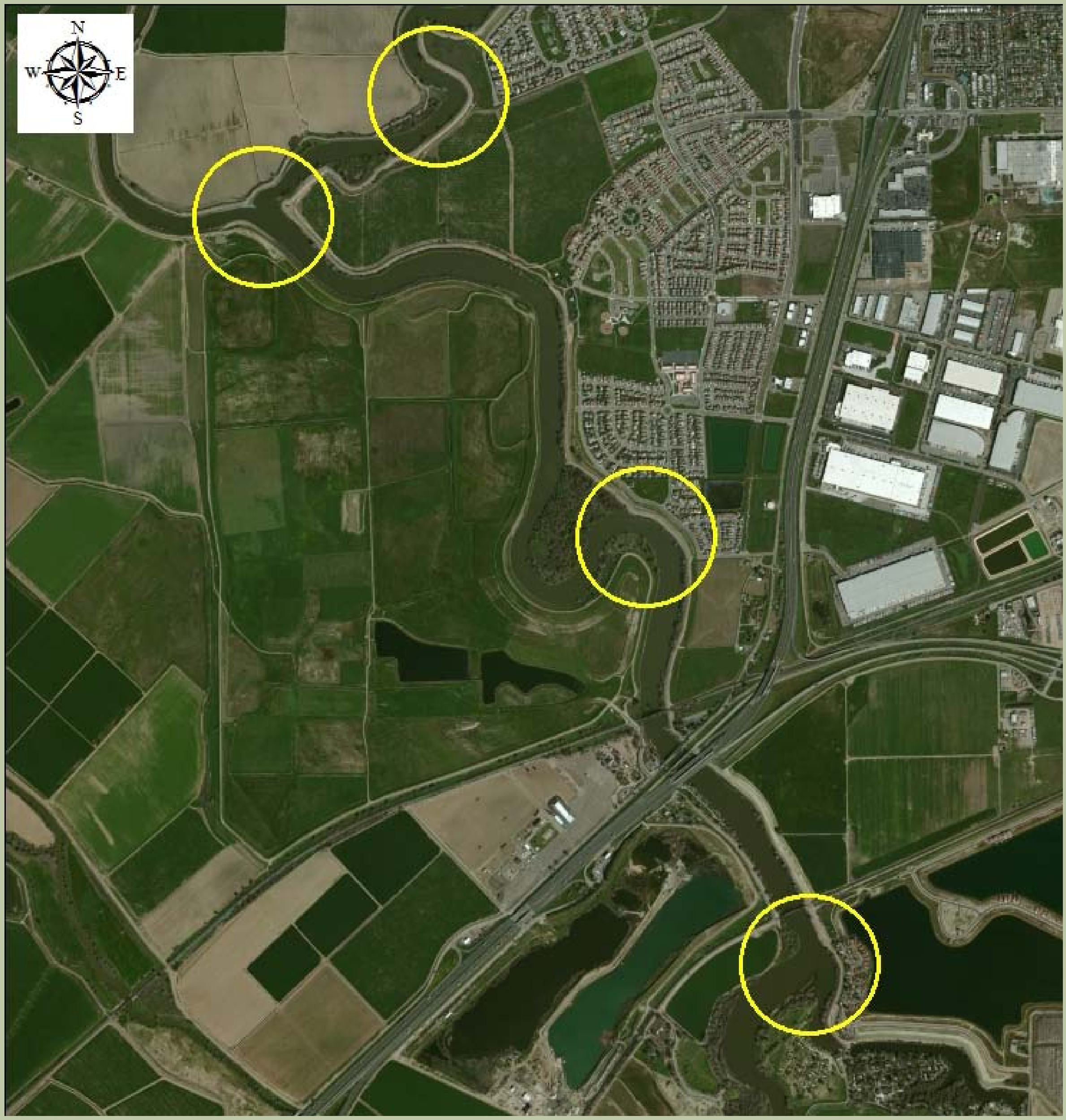


Figure 6-30
Picture of 200khz Transducers as they are being Lowered over the Side of the Boat for a Mobile Survey

Figure 6-31
Sampling Sites for Mobile Hydroacoustic Monitoring as Part of the Fish Behavior Study Conducted at the Head of Old River during 2011



Data collection at the hydrophone array at HOR was initiated on April 23rd at 1400h and continued until the system was shut down on June 22nd at 0800h. Small data collection gaps occurred and generally coincided with hydrophone maintenance and repair activities. Data gaps of less than one hour occurred on each of the following days: May 3rd, 15th, 16th, 20th and June 13th and 14th, otherwise data were collected 24 hours per day (h/d) for the duration of the study. All data were archived and stored, and were available for 2D tracking.

Mobile hydroacoustic monitoring was conducted at various times from May 16th to June 8th (Table 6-16).

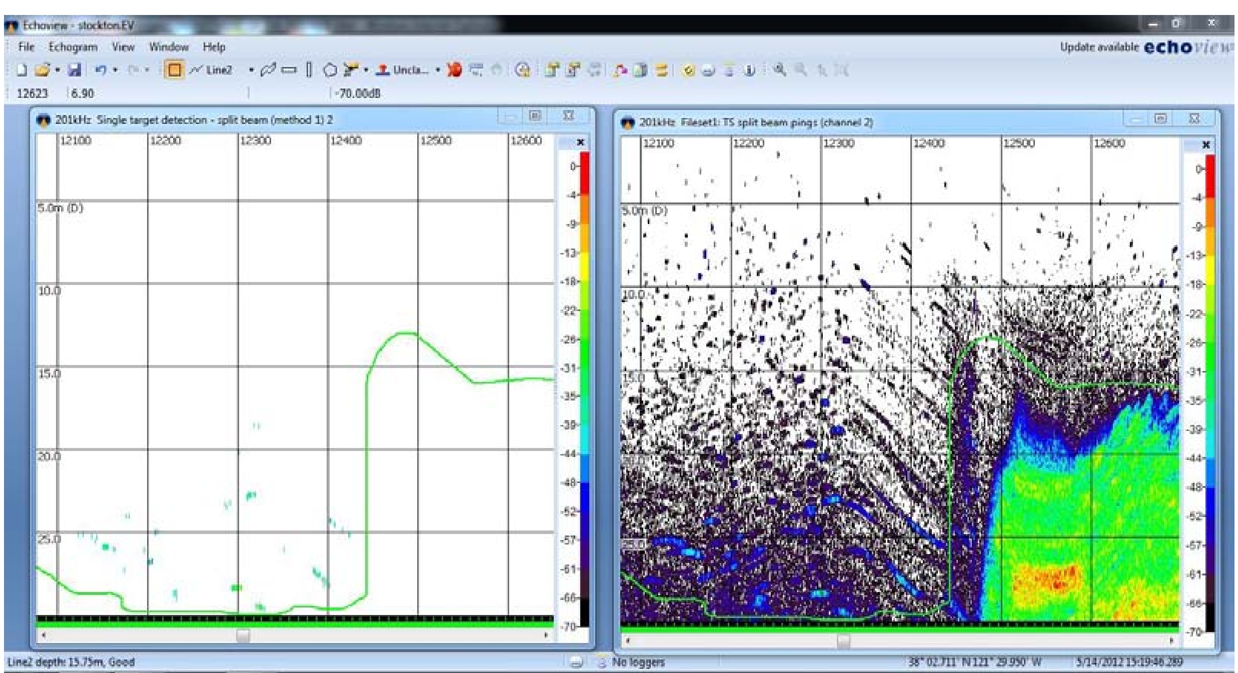
Analysis

Preliminary analysis of 2-D tracking data was conducted to determine potential predation events and to determine the route selection of tracked fish (i.e. migrated down Old River or the San Joaquin River); however, a synthesis report is being developed to reassess the determinations, to determine differences in migration route selection between various years and barrier configurations, and to better understand how the HOR barriers effect predation on juvenile salmonids. Predator tracks are planned to be utilized to determine changes in behavior and habitat usage based on barrier type and to determine key differences between steelhead, Chinook salmon and predatory fish tracks.

Echoview ® will be used for all mobile hydroacoustic data analysis. To analyze data, raw files will be imported into the software and a series of steps will be taken to develop a data analyses template that could be applied consistently across all sampling events. As a first step an artificial bottom line is created below which no data will be used. In the case of the down-looking transducer, this bottom line represented, in most instances, the actual river bed. In areas of high noise (reverberation) this bottom line could be raised up over those areas to exclude them as non-target areas. For the side-looking unit the bottom line represented the distance out the unit could see before encountering either the shore or river bottom. Once the analysis areas have been demarcated, a target echogram is developed to filter out all but the data of interest (i.e. fish) (Figure 6-32). To filter out background noise detection thresholds and target detection algorithms will be adjusted. In the final stage, fish tracking, each individual track will be assigned an id, further allowing the removal of any unwanted noise.

All data will be exported to an excel spreadsheet as a geo referenced fish track including location, time and size of target. To compare target densities among sites we will use the volume of water sampled in each event to normalize the number of targets to fish/m3. Fish will be binned out based on expected size classes of predator and prey. Due to high sediment loads in the river in 2011 our ability to detect small targets at any distance over about 10-15m was limited. Signals from larger fish were well above background noise and will not be limited during analyses.

Figure 6-32
Analysis Page of Acoustic Data. The Panel on the Right is Raw Data with an Artificial Bottom Line Drawn in. The Panel on the Left Shows the Thresholded Data Ready for Export Just Prior to Fish Tracking



CHAPTER 7

ROUTE ENTRAINMENT ANALYSIS AT HEAD OF OLD RIVER, 2009 AND 2010

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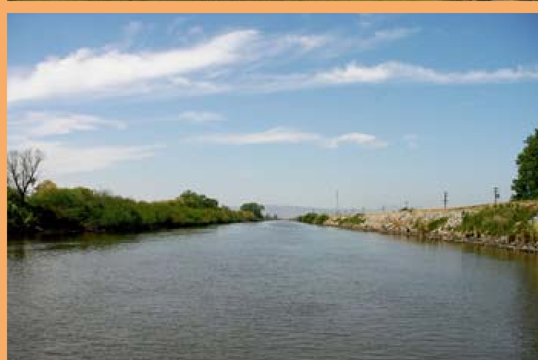
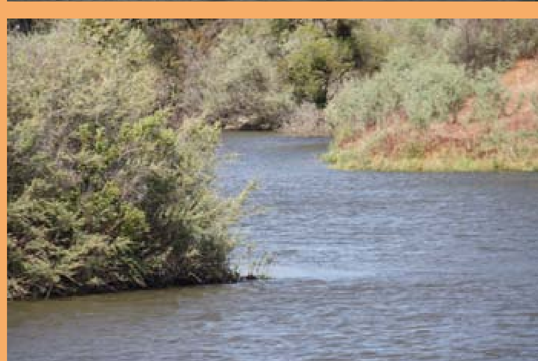



Methods

Supplementary analyses were conducted of the relationship between river conditions and the probability of remaining in the San Joaquin River at the head of Old River in 2009 and 2010. These analyses were based on the results of the data processing performed in the survival analysis of the 2009 and 2010 VAMP studies (SJRGA 2010, SJRGA 2011). Only detections classified as coming from live salmon smolts were used in this analysis. More information on data processing and the predator filter in the 2009 and 2010 studies is described in SJRGA, 2010 and SJRGA, 2011.

Analysis methods were the same as those used in the 2011 route entrainment analysis (Chapter 5). In addition to the covariates used in the 2011 route analysis, the status of the non-physical barrier at the head of Old River at the time of fish arrival at the barrier was included in the 2009 and 2010 analyses:

$$B_i = \begin{cases} 1, & \text{barrier open at arrival of tag } i \\ 0, & \text{barrier closed at arrival of tag } i \end{cases}$$

(data courtesy of the U. S. Bureau of Reclamation). Interaction effects between the barrier status and river flow, water velocity, and flow proportion were tested in the flow, velocity and flow proportion models, respectively.

Results

2009 Results

A total of 365 tags were observed passing the acoustic receivers in either the San Joaquin River or Old River near the head of Old River in 2009, with associated observations of river conditions. Of these 365 fish, 192 were observed entering Old River, while the other 173 remained in the San Joaquin River past the head of Old River. River flow and water velocity measured at the SJL gaging station in the San Joaquin River near Lathrop were very highly correlated in 2009 (r=0.99), with flow values ranging from -1,287 cfs to 2,133 cfs (average = 898 cfs) when tagged fish were passing the SJL gaging station and the OH1 gaging station in Old River just downstream of its divergence from the San Joaquin River. A description of the gaging station locations can be found in Chapter 4. Negative values of flow indicate reverse flow at the SJL gaging station. At the OH1 gaging station, flow and water velocity were also highly correlated (r=0.96), with flow values ranging from 203 cfs to 2,186 cfs (average = 1,515 cfs) when tagged fish passed the SJL and OH1 gaging stations. No reverse flow was observed at the OH1 station. Flow at the SJL station was moderately negatively correlated with flow at the OH1 gaging station (r=-0.48). Water velocity measures from the two gaging stations were also moderately negatively correlated (r=-0.37). Water velocity at the SJL station ranged from -0.88 ft/s to 1.55 ft/s (average = 0.75 ft/s), while at the OH1 station, it ranged from 0.11 ft/s to 1.58 ft/s (average = 1.03 ft/s) while tagged fish passed the gaging stations. Flow proportion into the San Joaquin River was moderately correlated with flow into the San Joaquin River (r=0.57), with negative values of flow proportion corresponding to reverse flow at the SJL gage. Flow proportion into the San Joaquin River during the time of tagged fish passage of the gaging stations (pQ_{iA}) ranged from -722% to 91% (average = 10%), omitting one extreme negative value of -2,180%. The extreme negative values occurred when flow was reversed at the SJL gage and nearly the same magnitude as the positive flow at the OH1 gage. Because flow proportion was negative only under conditions of reverse flow, the reverse flow covariate (uQ_{iA}) was omitted from the multivariate analysis with the flow proportion model.

Results of the single-variate analyses relating route entrainment at the head of Old River to river conditions found significant effect of both flow and velocity at both the SJL and the OH1 gaging stations (P<0.0005 in each case, Table 7-1). Flow proportion into the San Joaquin River and the occurrence of reverse flow at the SJL gage were also significantly correlated with route entrainment (P<0.0001 in both cases), as was change in both velocity and flow at OH1 (P<0.0001 in both cases). The status of the non-physical barrier (on versus off) was significantly correlated with route entrainment (P=0.0010), as were exports at CVP (P=0.0010) and combined exports throughout the Delta (P=0.0040). However, exports at SWP alone were not significantly correlated with route entrainment at the head of Old River (P=0.2709). Fork length, release group, change in flow and velocity at SJL, and change in flow proportion into the San Joaquin were not significantly correlated with route entrainment, either (P>0.3 in each case; Table 7-1).

The single-variate analyses may suggest possible relationships, but due to confounding among the independent covariates and the possibility of a causal relationship with an unmonitored factor, it is not possible to conclude that changes in any of the significant single-variate measures directly produce changes in route entrainment at the head of Old River. Multi-variate analysis may shed more light on which covariates are worthy of further study, although causal relationships are still not discernible.

Multivariate analyses also found significant effects of flow and velocity at both the SJL and OH1 gaging stations, as well as flow proportion into the San Joaquin River, with significantly different effects when the non-physical barrier was on (barrier = 1) than when it was off (barrier = 0) (Table 7-2). All three models (flow, velocity, and flow proportion) adequately fit the data (P>0.9), but the flow model accounted for more variation in route entrainment than either water velocity (ΔAIC=6.56) or flow proportion (ΔAIC=27.33) (Table 7-2). The flow model predicted the route entrainment probability according to:

$$\widehat{\psi_A} = \frac{exp(-1.20 + 0.002Q_A - 0.001Q_B)}{1 + exp(-1.20 + 0.002Q_A - 0.001Q_B)}$$

when the barrier was off, and

$$\widehat{\psi_A} = \frac{exp(-9.07 + 0.005Q_A + 0.002Q_B)}{1 + exp(-9.07 + 0.005Q_A + 0.002Q_B)}$$

when the barrier was on.

For flow at OH1 fixed at the mean observed value there when tagged fish were passing (1,515 cfs), increases in flow at SJL were predicted to increase the probability of a tagged fish remaining in the San Joaquin River, with a steeper increase if the barrier was on (Figure 7-1). For flow at SJL fixed at its mean observed value (893 cfs), increases in flow at OH1 were predicted to increase the probability of a tagged fish remaining in the San Joaquin River if the barrier was on, but were predicted to decrease the probability of remaining in the San Joaquin if the barrier was off (Figure 7-2).

2010 Results

A total of 430 tags were observed passing the acoustic receivers in either the San Joaquin River or Old River near the head of Old River in 2010, with associated observations of river conditions. Of these 430 tagged fish, 228 were observed entering Old River, while the other 202 fish remaining in the San Joaquin River past the head of Old River. River flow and water velocity measured at the SJL gaging station in the San Joaquin River at times when tagged fish were passing were highly correlated in 2010 (r=0.95). Observed flow values ranged from 909 cfs to 3,595 cfs (average = 2,595 cfs), and observed velocity values ranged from 0.5 ft/s to 2.3 ft/s (average = 1.6 ft/s). River flow and water velocity measured at the OH1 gaging station in Old River when tagged fish were passing were also highly correlated (r=0.92), with flow values ranging from 1,703 cfs to 3,404 cfs (average = 2,777 cfs) and velocity values ranging from 0.9 ft/s to 2.0 ft/s (average = 1.5 ft/s). There was little or no correlation between flow (r=0.04) or

Table 7-1
Results of Single-variate Analyses of Route Entrainment at the Head of Old River in 2009

Year	Covariate	F-test		
		F	df1, df2	P
2009	Velocity at SJL[a]	212.8572	1, 363	<0.0001
2009	Flow at SJL[a]	193.7478	1, 363	<0.0001
2009	Flow proportion into San Joaquin[a]	174.0139	1, 363	<0.0001
2009	Reverse flow into San Joaquin[a]	151.5927	1, 363	<0.0001
2009	Change in velocity at OH1[a]	40.8793	1, 347	<0.0001
2009	Flow at OH1[a]	22.6527	1, 363	<0.0001
2009	Change in flow at OH1[a]	16.8309	1, 347	<0.0001
2009	Velocity at OH1[a]	12.8934	1, 363	0.0004
2009	Barrier[a]	11.0410	1, 363	0.0010
2009	Exports at CVP[a]	10.9377	1, 363	0.0010
2009	Combined Exports[a]	8.3972	1, 363	0.0040
2009	Exports at SWP	1.2159	1, 363	0.2709
2009	Change in velocity at SJL	0.9906	1, 347	0.3203
2009	Fork Length	0.7137	1, 363	0.3988
2009	Release Group	0.8675	6, 358	0.5189
2009	Change in flow proportion into San Joaquin	0.3984	1, 347	0.5283
2009	Change in flow at SJL	0.0628	1, 347	0.8023

[a] Significant at 5% level

Figure 7-1
Fitted Probability of Remaining in the San Joaquin River at the Head of Old River versus River Discharge Measured at the SJL Gaging Station near Lathrop, CA, for River Discharge at OH1 Gaging Station in Old River Fixed at its Average (1,515 cfs), with 95% Confidence Bands, in 2009. Barrier is Non-Physical Barrier at Head of Old River

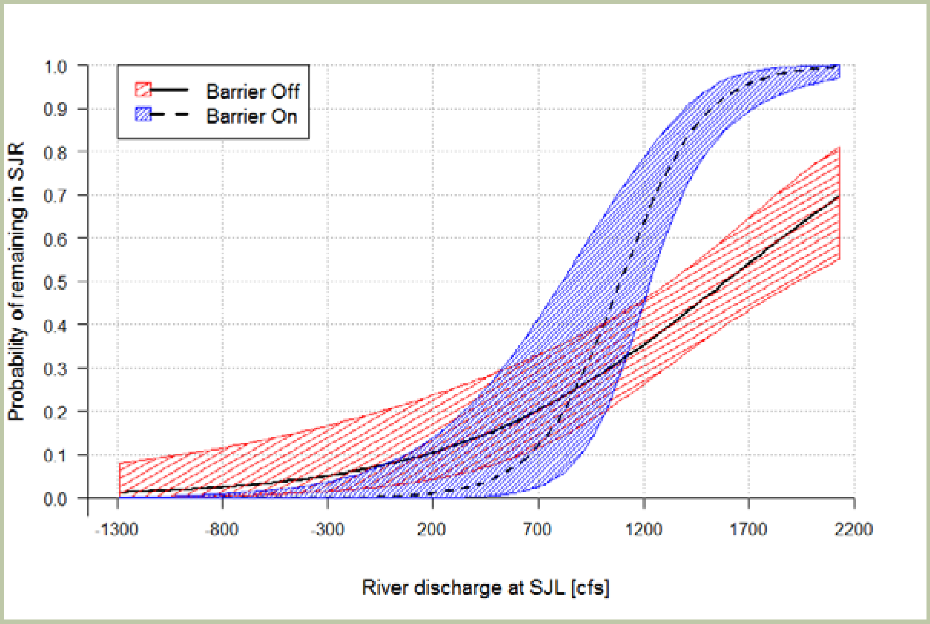


Figure 7-2
Fitted Probability of Remaining in the San Joaquin River at the Head of Old River versus River Discharge Measured at the OH1 Gaging Station in Old River, for River Discharge at SJL Gaging Station near Lathrop, CA, Fixed at its Average (893 cfs), with 95% Confidence Bands, in 2009. Barrier is Non-Physical Barrier at Head of Old River

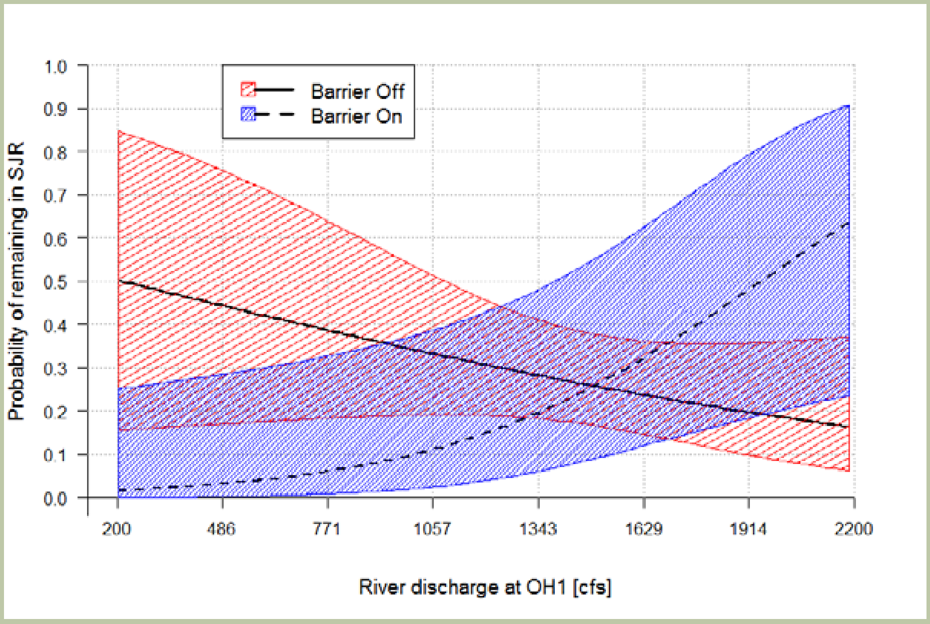


Table 7-2
Results of Multivariate Analyses of Route Entrainment at the Head of Old River in 2009

Model Type	Covariate[a]	Estimate	S.E.	t-Test		
				t	df	P
Flow	Intercept	-1.0723	0.2704	-3.966	359	<0.0001
	Q_A	1.6324	0.3647	4.476	359	<0.0001
	Q_B	-0.2749	0.209	-1.315	359	0.1893
	Barrier	0.0632	0.666	0.095	359	0.9244
	Q_A*Barrier	3.7580	1.2102	3.105	359	0.0021
	Q_B*Barrier	1.0539	0.3813	2.764	359	0.0060
Goodness-of-fit: χ^2=2.5464, df=13, P=0.9991; AIC = 289.60						
Velocity	Intercept	-1.0640	0.2808	-3.776	360	0.0002
	V_A	1.7445	0.3938	4.430	360	<0.0001
	V_B	-0.3070	0.1728	-1.776	360	0.0766
	Barrier	-0.5429	0.8145	-0.667	360	0.5052
	V_A*Barrier	3.3994	1.2618	2.694	360	0.0074
Goodness-of-fit: χ^2=2.9471, df=13, P=0.9981; AIC = 296.16						
Flow Proportion	Intercept	-1.8121	0.5039	-3.596	361	0.0004
	pQ_A	5.7413	1.4593	3.934	361	0.0001
	Barrier	-0.7723	1.3045	-0.592	361	0.5542
	pQ_A*Barrier	7.4123	4.2399	1.748	361	0.0813
Goodness-of-fit: χ^2=6.3064, df=13, P=0.9343; AIC = 316.93						

[a] continuous covariates (Q_A, Q_B, V_A, V_B, pQ_A) are standardized

Table 7-3
Results of Single-variate Analyses of Route Entrainment at the Head of Old River in 2010

Year	Covariate	F-test		
		F	df1, df2	P
2009	Barrier[a]	14.4717	1, 428	0.0002
2009	Flow proportion into San Joaquin[a]	13.5411	1, 428	0.0003
2009	Flow at SJL[a]	9.0700	1, 428	0.0027
2009	Velocity at SJL[a]	7.1774	1, 428	0.0077
2009	Flow at OH1[a]	4.8240	1, 428	0.0286
2009	Change in velocity at OH1	3.1450	1, 413	0.0769
2009	Velocity at OH1	2.8854	1, 428	0.0901
2009	Combined Exports	1.3152	1, 428	0.2521
2009	Change in flow at OH1	1.2129	1, 413	0.2714
2009	Change in velocity at SJL	0.5482	1, 428	0.4595
2009	Fork Length	0.3062	1, 428	0.5803
2009	Release Group	0.7067	6, 423	0.6444
2009	Exports at SWP	0.0752	1, 428	0.7841
2009	Change in flow proportion into San Joaquin	0.0479	1, 413	0.8268
2009	Change in flow at SJL	0.0329	1, 428	0.8562
2009	Exports at CVP	0.0223	1, 428	0.8813

[a] Significant at 5% level

Table 7-4
Results of Multivariate Analyses of Route Entrainment at the Head of Old River in 2010

Model Type	Covariate[a]	Estimate	S.E.	t-Test		
				t	df	P
Flow	Intercept	-0.5463	0.1473	-3.710	426	0.0002
	Q_A	0.3302	0.1054	3.134	426	0.0018
	Q_B	-0.2623	0.1022	-2.568	426	0.0106
	Barrier	0.7947	0.2022	3.930	426	< 0.0001
Goodness-of-fit: χ^2=17.3751, df=18, P=0.4975; AIC = 566.94						
Flow Proportion	Intercept	-0.5432	0.1471	-3.693	427	0.0003
	pQ_A	0.3944	0.1089	3.623	427	0.0003
	Barrier	0.7828	0.2018	3.880	427	0.0001
Goodness-of-fit: χ^2=13.9929, df=18, P=0.7296; AIC = 567.00						
Velocity	Intercept	-0.5470	0.1472	-3.718	426	0.0002
	V_A	0.3606	0.1099	3.282	426	0.0011
	V_B	-0.3044	0.1066	-2.856	426	0.0045
	Barrier	0.7966	0.2023	3.938	426	< 0.0001
Goodness-of-fit: χ^2=12.6394, df=18, P=0.8125; AIC = 567.80						

[a] continuous covariates (Q_A, Q_B, V_A, V_B, pQ_A) are standardized

velocity (r=0.28) at SJL and flow at OH1 during times of fish passage in 2010, although there was moderate correlation between changes in flow at SJL and observed velocity at OH1 (r=-0.48), and between changes in flow at OH1 and observed velocity at SJL (r=0.53). Observed flow proportion into the San Joaquin River at times of fish passage ranged in value from 25% to 62% (average = 48%), and was highly correlated with flow measured at SJL (r=0.91). Because flow was never reversed in the San Joaquin River during the time of fish passage in 2010, the reverse flow covariate (uQ_{iA}) was always equal to 1, and so was omitted from the analyses. There was little variation in CVP exports during fish passage through the head of Old River in 2010 (830 – 1,506 cfs, average = 928 cfs), with only slightly more variation in SWP exports (0 – 709 cfs, average = 574 cfs). Combined exports throughout the Delta ranged from 1,541 to 1,760 cfs (average = 1,663 cfs). There was little or no observed correlation between flow and velocity measures and measures of exports at either CVP, SWP, or combined (|r|<0.3).

Results of the single-variate analyses relating route entrainment at the head of Old River to river conditions found significant effects of changes in barrier status (on *vs.* off; P=0.0002), flow proportion into Old River (P=0.0003), flow (P=0.0027) and velocity (P=0.0077) measured at SJL at time of fish passage, and flow at OH1 at time of fish passage (P=0.0286) (Table 7-3). No other covariates were significant at the 5% level.

Multivariate analyses also found significant effects of flow and velocity at both the SJL and OH1 gaging stations, as well as flow proportion into the San Joaquin River and barrier status (Table 7-4). All three models (flow, velocity, and flow proportion) adequately fit the data (P>0.4). AIC detected little difference among the three models (ΔAIC $\leq$ 0.86), and estimated regression coefficients were similar among the three models (Table 7-4). The flow model had the lowest AIC, and predicted the route entrainment probability according to:

$$\widehat{\psi_A} = \frac{exp(0.35 + 0.0005Q_A - 0.0008Q_B)}{1 + exp(0.35 + 0.0005Q_A - 0.0008Q_B)}$$

when the barrier was off, and

$$\widehat{\psi_A} = \frac{exp(1.15 + 0.0005Q_A - 0.0008Q_B)}{1 + exp(1.15 + 0.0005Q_A - 0.0008Q_B)}$$

when the barrier was on.

When flow at OH1 was fixed at its mean observed value when tagged fish were passing (2,777 cfs), increases in flow at SJL were predicted to increase the probability of a tagged fish remaining in the San Joaquin River (Figure 7-3). For flow at SJL fixed at its mean observed value (2,595 cfs), increases in flow at OH1 were predicted to decrease the probability of a tagged fish remaining in the San Joaquin River (Figure 7-4). Regardless of the flow level at either

Figure 7-3
Fitted Probability of Remaining in the San Joaquin River at the Head of Old River versus River Discharge Measured at the SJL Gaging Station near Lathrop, CA, for River Discharge at OH1 Gaging Station in Old River Fixed at its Average (2,777 cfs), with 95% Confidence Bands, in 2010. Barrier is Non-Physical Barrier at Head of Old River

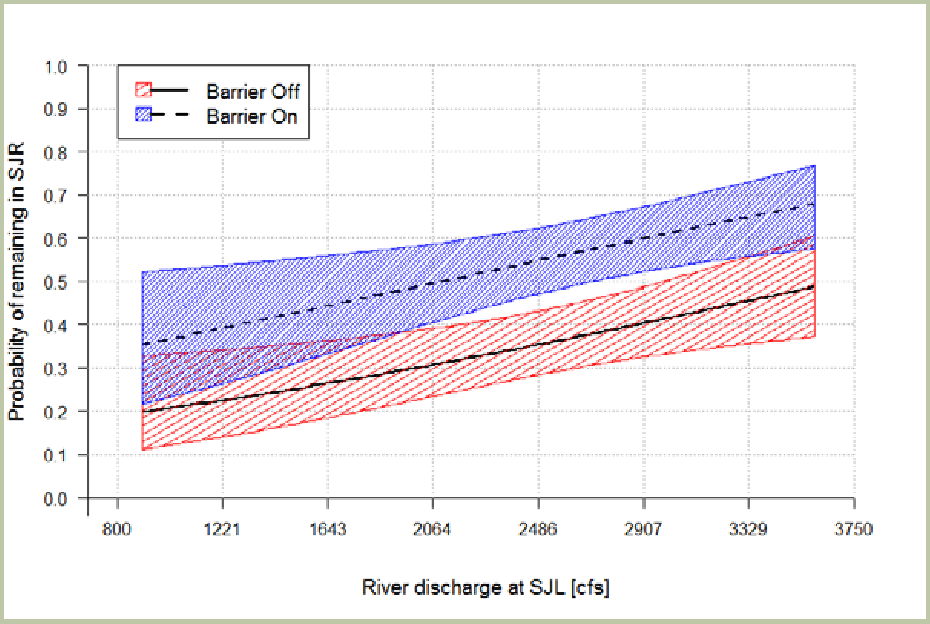
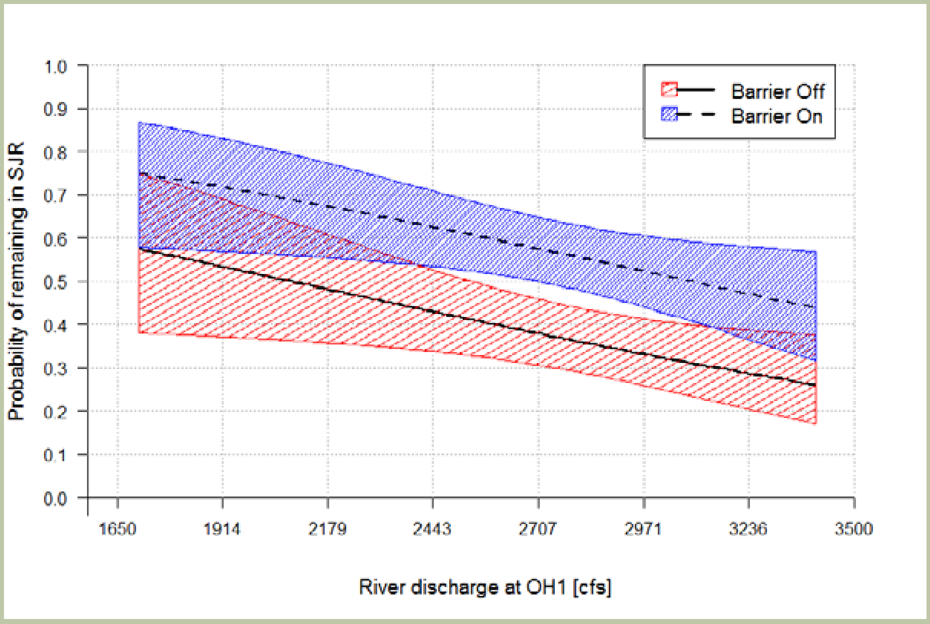


Figure 7-4
Fitted Probability of Remaining in the San Joaquin River at the Head of Old River versus River Discharge Measured at the OH1 Gaging Station in Old River, for River Discharge at SJL Gaging Station near Lathrop, CA, Fixed at its Average (2,595 cfs), with 95% Confidence Bands, in 2010. Barrier is Non-Physical Barrier at Head of Old River



OH1 or SJL, the probability of remaining in the San Joaquin River at the head of Old River was predicted to be higher when the non-physical barrier was turned on than when it was turned off (Figures 7-3 and 7-4; Table 7-4).

Summary

Both the 2009 and 2010 analyses found that increases in flow measured in the San Joaquin River near Lathrop (SJL) were associated with increased probability of remaining in the San Joaquin at the head of Old River. However, the 2009 analysis found an interaction effect between barrier status and flow measured in Old River near its head (OH1), with increases in Old River flow associated with increased probability of entering Old River when the barrier was off, but not when the barrier was on. In 2010, increases in Old River flow were associated with increased probability of entering Old River regardless of barrier status. More fish stayed in the San Joaquin River under all flow conditions in 2010 when the barrier was on than when it was off.

CHAPTER 8

SOUTH DELTA TEMPORARY AGRICULTURAL BARRIERS PROJECT

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Background

The South Delta Temporary Barriers Project (TBP) study 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. The 2011 schedule for installation, operation and removal of these three agricultural barriers is shown in Table 8-1. They are designed to: (1) improve water levels and circulation patterns for agricultural users and (2) collect data for the design of permanent barriers. They are designed to act as flow control structures, "trapping" tidal waters behind the barriers following high tide. 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 through Old River towards the Central Valley Project (CVP) and the State Water Project (SWP) export facilities (see discussion on the head of Old River Barrier in Chapter 4). A discussion of fish behavior near the head of Old River can be found in Chapter 6.

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 (*Oncorhynchus tshawytscha*), juvenile steelhead (*Oncorhynchus mykiss*), and juvenile green sturgeon (*Acipenser medirostris*). The TBP, therefore, is performed in compliance with the terms and conditions of the National Marine Fisheries Service (NMFS) Biological Opinion (BiOp) and incidental take permits. A recent NMFS (2008) BiOp requires that a fishery monitoring program be established to (1) examine the movements and survival of listed fish through channels of the South Delta and (2) examine predation effects associated with the South DeltaTBP.

To comply with the requirements of the NMFS (2008) BiOp, 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 study was a pilot study conducted March – June 2009. 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 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 and 2011 full-scale studies.

Study Design

Receiver Deployment

The 2011 South Delta TBP study used a broad receiver network (Figure 8-1) to monitor movement of acoustic tagged predators and acoustic tagged salmon and steelhead throughout the South Delta in conjunction with a larger receiver network used in the 2011 VAMP (Figure 8-2). The network of fixed-point receivers was installed in February 2011 at sites in Old River, Middle River, Grant Line Canal, Clifton Court Forebay and at the

Table 8-1
2011 Temporary Barrier Installation and Removal Schedule. For South Delta TBP Analysis Purposes, Installation Date was Taken to be 'Started' Date.

Barrier	Installation				Removal		
	Started	Closed	Completed	Notched	Started	Breached	Completed
Old River near Tracy	5/27/11	6/10/11	6/15/11	9/15/11	10/10/11	10/11/11	10/31/11
Middle River	6/1/11	6/6/11	6/6/11	9/15/11	10/10/11	10/11/11	10/18/11
Grant Line Canal	6/10/11	7/14/11	8/2/11	No Notch	10/17/11	10/19/11	11/4/11

Figure 8-1
2011 Temporary Barriers Program Receiver Array Designed to Detect Acoustic Tagged Salmonids and Acoustic Tagged Predatory Fish in the South Delta. (Red Circles Represent the Locations of the Fixed-Point Receivers)

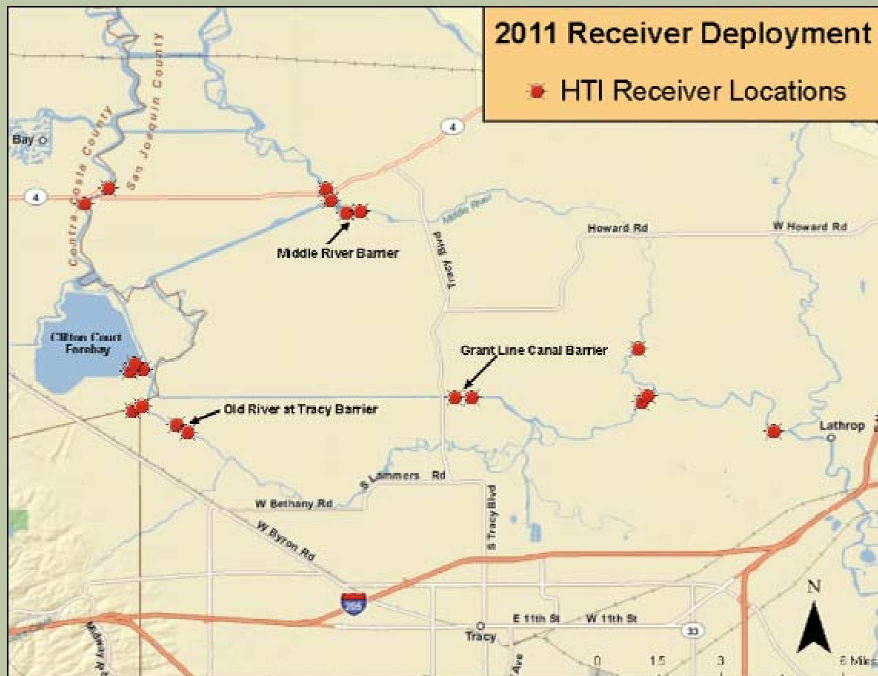


Figure 8-2
Locations of Acoustic Receivers and Release Site Used in the 2011 VAMP Study, Including Locations of Acoustic Receivers Deployed by the California Department of Water Resources for the South Delta Temporary Barriers Project Study and the Approximate Locations of the Temporary Agricultural Barriers (black bars).

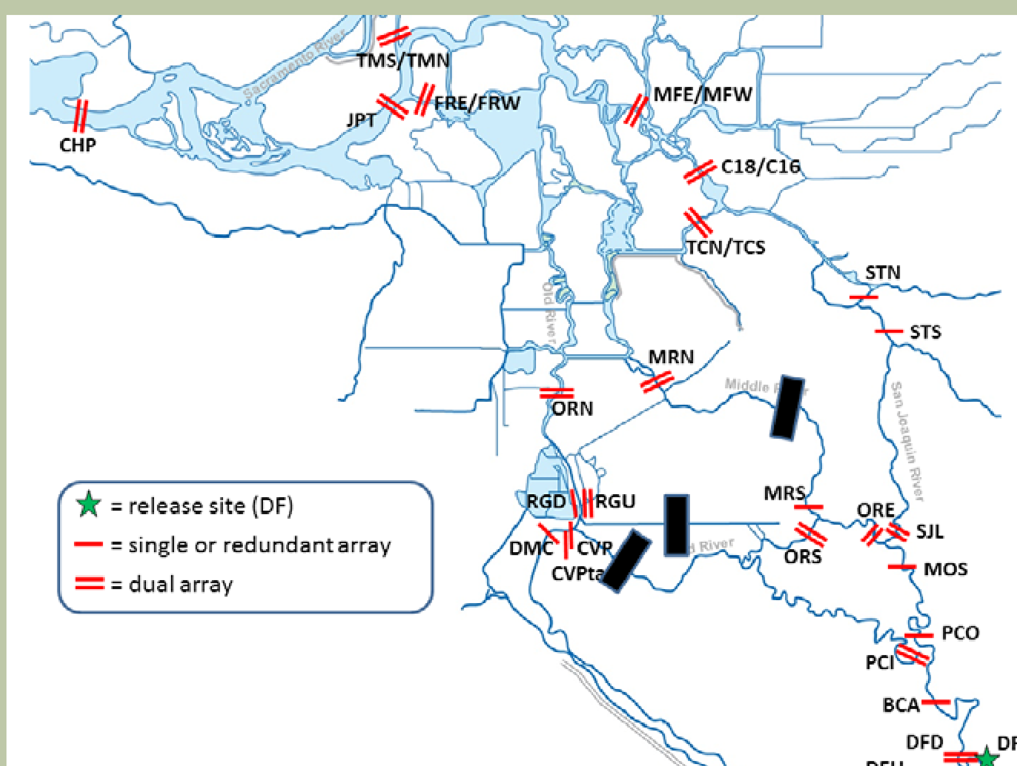


Figure 8-3
2D Acoustic Biotelemetry System Deployed at the Old River at Tracy Barrier in 2010. (The Red Circles Indicate the Location of the Hydrophones Located Upstream of the Old River at Tracy Barrier and the Blue Circles Indicate the Locations of the Hydrophones Located Downstream of the Barrier)

Central Valley Project fish facility. The receiver locations have been selected to provide data for input into an overall survival model. These receivers were placed in conjunction with those of the VAMP to limit duplication of effort and to allow maximum use of the data collected by both programs for use in the survival model.

In addition to the broader scale receiver network, a two-dimensional (2D) biotelemetry system was used to monitor both acoustic tagged predators and acoustic tagged salmon and steelhead at the Tracy at Old River Barrier, one of the agricultural barriers. Similar 2D biotelemetry systems were successfully installed near this barrier and the HOR barrier during the 2010 TBP study (Figure 8-3). In addition to the fixed station and 2D biotelemetry monitoring, mobile monitoring was conducted within the South Delta to determine the location of any salmon or steelhead tags that have been deposited on the river bottom. Other biotelemetry studies (Clark et al, 2009; SJRGA, 2010 and 2011) have shown that when predation occurs, the prey's acoustic tag can be deposited on the river bottom. Such events may be discerned by repeated mobile monitoring events.

Acoustic Tagging and Fish Releases

The South Delta TBP study team coordinated fish tagging and releases with the VAMP and OCAP 6-Year study teams (see Chapter 5 for a discussion on fish tagging and release and the coordinated study plan with VAMP, the South Delta TBP and the OCAP 6-Year study). Following the installation of the fixed-point receiver array, hatchery produced salmon and steelhead were acoustic tagged using the same surgical procedures used in the 2010 VAMP study (SJRGA, 2011). The acoustic tagged salmon and steelhead were released within the South Delta in multiple release groups. Each release group was transported to the Durham Ferry release site. After transport to the release site, the acoustic tagged fish were held for a minimum of 24 hours prior to release. The releases were intended to cover the time before, during, and after installation of the agricultural barriers. These fish were to be used to estimate survival through the South Delta past the temporary barriers and to supply a portion of the fish necessary to meet the objectives for the VAMP, HOR Bioacoustic Fish Fence (BAFF) Evaluation, and Six-Year Stealhead acoustic tag studies. The schedule for release of fish in coordination with the VAMP and OCAP 6-year study is shown in Table 8-2.

Fish Health

Dummy tagged salmon and steelhead were assessed for smolt status (gill Na+-K+-ATPase) and pathogen infection to help determine if results associated with survival were based on the initial health of test fish. Procedures for the health assessment are described in Chapter 6. Twenty-four (24) dummy-tagged fish, from each release event were assessed during the health evaluations. In addition, the dummy tagged fish were evaluated for mortality and general condition after holding for 48 hours. An additional two sets of 30 salmon from Merced River Hatchery were evaluated for physiological and pathology tests during the same weeks the experimental fish were released. A discussion of the fish health evaluation can be found in Chapter 6 under the submittal of Ken Nichols (2011) from the USFWS CA-NV Fish Health Center.

Fish Behavior and Predation

In order to examine the behavior of juvenile steelhead, juvenile salmon and predator-prey interactions directly adjacent to one of the agricultural barriers, supplemental releases of salmon and steelhead occurred upstream of the Tracy at Old River Barrier monitored by the two-dimensional (2D) biotelemetry system. Four groups of 50 salmon and four groups of 30 steelhead were released approximately five river miles upstream of this agricultural barrier (Table 8-3). The two-dimensional (2D) biotelemetry array was to provide information on passage of the temporary barrier by the tagged salmon and steelhead. In addition, the two-dimensional biotelemetry array was used to determine the areas near the temporary barrier that are utilized by the predatory fish.

To investigate predator-prey interactions near the temporary barriers, predatory fish (striped bass, largemouth bass, white catfish, channel catfish, Sacramento pikeminnow) were to be collected primarily by electrofishing with supplemental hook and line sampling. Electrofishing was to occur in Old River, Middle River, and Grant Line Canal directly adjacent to the agricultural rock barrier locations. Hook and line sampling was to occur in Old River, Middle River, Grant Line Canal, Victoria Canal, and Clifton Court Forebay. Because the electrofishing permit from National Marine Fisheries Service (NMFS) did not arrive in time, no electrofishing took place and only hook and line sampling was used throughout the study area. Predatory fish sampling began in March, prior to installation of the temporary barriers and continued into June. Predatory fish that were 2 pounds (lbs) or larger and of a size capable of consuming juvenile salmonids were externally tagged with acoustic tags following a similar procedure to that used by Clark et al. (2009). Up to 100 predatory fish were to be acoustic tagged and released in 2011. The results of the predator fish tagging are not available as of the preparation of this report but additional information on this part of the South Delta TBP study can be obtained from the technical team at the California Department of Water Resources.

Table 8-2
Merced River Hatchery Salmon Tagging and Release Schedule for the VAMP and South Delta Temporary Barriers Studies during Spring 2011[1]

Tagging Date	Salmon Smolt Study	Live tagged Fish, transported and released	Dummy tagged fish, transported, and sacrificed for pathology study	Live tagged fish, transported, and sacrificed to assess fish condition	Control fish for pathology study	Release Start Date (Releases made over a 24-hour period)	Source of Tagged Fish
5/16/2011	VAMP	120	0	12	0	5/17/2011	Merced River Hatchery
5/17/2011	VAMP	118	0	12	0	5/18/2011	Merced River Hatchery
5/18/2011	VAMP	117	24	12	90	5/19/2011	Merced River Hatchery
5/19/2011	VAMP	119	0	12	0	5/20/2011	Merced River Hatchery
5/21/2011	VAMP	119	0	12	0	5/22/2011	Merced River Hatchery
5/22/2011	VAMP	120	0	12	0	5/23/2011	Merced River Hatchery
5/23/2011	VAMP	115	0	12	30	5/24/2011	Merced River Hatchery
5/24/2011	VAMP	120	24	0	0	5/25/2011	Merced River Hatchery
6/6/2011	SDTB	119	0	12	0	6/7/2011	Merced River Hatchery
6/7/2011	SDTB	120	0	12	0	6/8/2011	Merced River Hatchery
6/8/2011	SDTB	119	0	12	0	6/9/2011	Merced River Hatchery
6/9/2011	SDTB	120	24	0	0	6/10/2011	Merced River Hatchery
6/14/2011	SDTB	119	0	12	0	6/15/2011	Merced River Hatchery
6/15/2011	SDTB	118	0	12	0	6/16/2011	Merced River Hatchery
6/16/2011	SDTB	117	12	0	30	6/17/2011	Merced River Hatchery
6/17/2011	SDTB	120	24	0	0	6/18/2011	Merced River Hatchery
2-D	SDTB	200	0	0	0	Periodic	Merced River Hatchery
	Element Total	2020	72	144	150		

[1] Refer to Table 5-3 and 5-4 for details of each release

Data Assessment

The study was designed to address 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?

Table 8-3
Release Group Sizes for Examining Two Dimensional Behavior of Salmonids at the Tracy at Old River Barrier, Spring 2011

	2D Release Totals				Total
Chinook Salmon	50	50	50	50	200
Steelhead	30	30	30	30	120

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 fishery investigation are also 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.

Data Processing and Survival Modeling

Raw acoustic data files from the receivers at the barriers were manually searched for acoustic tag detections and electronically bookmarked. In addition, tag detections from the acoustic receivers used in the VAMP study were analyzed in the VAMP survival model to test effects of barrier installation on Chinook salmon migration and survival (described further below). See Chapter 5 for more details on data processing of VAMP receiver data, coordination of study plans with VAMP and the OCAP 6-year study and the survival information.

Data Analysis Methods

Possible effects of the temporary barriers in Grant Line Canal and Old and Middle rivers on Chinook salmon smolt migration and survival were tested using the 1,895 tagged salmon smolts monitored in the 2011 Chinook salmon study (Chapter 5). Three hypotheses were tested: (1) salmon smolt survival was lower after barrier installation; (2) route entrainment probability into Old River was lower after barrier installation; and (3) travel time through the Old River corridor was longer after barrier installation.

For all three barriers the date marking the boundary of the periods before and after barrier installation was taken as the start date of barrier installation (Table 8-1), as all three barriers nearly spanned the waterway very soon after installation began. Data were then grouped by whether the release date for the tagged salmon was before or after the installation date for the barrier in question. Because the installation start dates for the Old River and Middle River barriers both occurred between the second and third release groups for Chinook salmon, the effects of these two barriers could not be measured separately. Analysis to determine possible effects of the Old River and Middle River barriers together compared summary measures of data from tagged smolts in release groups 1 and 2 combined (i.e., before Old River/Middle River barrier installation) with summary measures of data from smolts in release groups 3 and 4 combined (i.e., after Old River/Middle River barrier installation). The installation start date for the Grant Line Canal barrier was between the third and fourth release groups for Chinook, and so its effects could be measured apart from the other two barriers. For analysis of possible effects of the Grant Line Canal barrier, data from smolts in release group 3 (i.e., before Grant Line Canal barrier installation) were compared against data from smolts in release group 4 (i.e., after Grant Line Canal barrier installation). Although release groups 1 and 2 were also released before installation of the Grant Line Canal barrier, they were omitted from analysis of the Grant Line Canal barrier effects to limit confounding barrier effects with seasonal effects. Hypotheses (1) and (2) regarding survival and route entrainment were tested using parameter estimates from a multi-state statistical release-recapture model, while hypothesis (3) regarding travel time was tested using parameter estimates derived from a linear regression of individual smolt travel time data.

Survival and Route Entrainment Analysis

The multi-state statistical release-recapture model developed for the overall 2011 Chinook salmon tagging study was also used to estimate salmon smolt survival and route entrainment probabilities before and after installation of three agricultural barriers in the study area, with terminology and abbreviations for detection arrays and survival, route entrainment, and transition parameters following that outlined in Chapter 5 (Methods – Survival Model). The multinomial likelihood model was fit to the observed capture histories using Program USER. The estimated parameters of interest are maximum likelihood estimates and so are asymptotically normally distributed; thus differences in estimated survival and route entrainment parameters before and after barrier installation can be statistically assessed using a one-sided Z-test.

For hypotheses (1) and (2) regarding survival and route entrainment respectively we have as reasonable null and alternative hypotheses the following:

$$H_0: \theta_{before} \leq \theta_{after} \quad \text{vs.} \quad H_a: \theta_{before} > \theta_{after},$$

where θ_{before} is a survival or route entrainment parameter before barrier installation, θ_{after} is the same parameter after barrier installation, and we are interested in whether survival or route entrainment has decreased after a barrier was in place. The Z-statistic defined on the logarithmic scale,

$$Z(\theta) = \frac{(\ln \hat{\theta}_{before}) - \ln(\hat{\theta}_{after})}{\sqrt{CV^2(\hat{\theta}_{before}) + CV^2(\hat{\theta}_{after})}},$$

provides a means to test H_0 vs. H_a using the parameters estimated by the multinomial likelihood model described above. Here $CV^2(\hat{\theta})$ is the coefficient of variation squared, $(\hat{\sigma}/\hat{\mu})^2$. Testing at the α level rejects H_0 in favor of H_a if $1 - \Phi(Z(\theta)) < \alpha$. An α level of 0.05 was used.

In all cases sparse detections at some sites prevented fitting the full survival model. Simplified models estimating overall Delta survival provided more robust estimates, while still enabling hypothesis testing. The pooled release groups used for the Old River and Middle River barrier analysis (releases 1 and 2 compared with releases 3 and 4) required several simplifications to the likelihood model used for the full study. For the pooled release groups 1 and 2, the model was simplified to estimate Delta survival without the Jersey Point (site

Figure 8-6
Schematic of Multinomial Likelihood Mark-Recapture Model Used to Estimate Survival and Entrainment Probabilities for Chinook Salmon Smolts Released Before and After Installation of the Temporary Barriers in Old River and Middle River, 2011

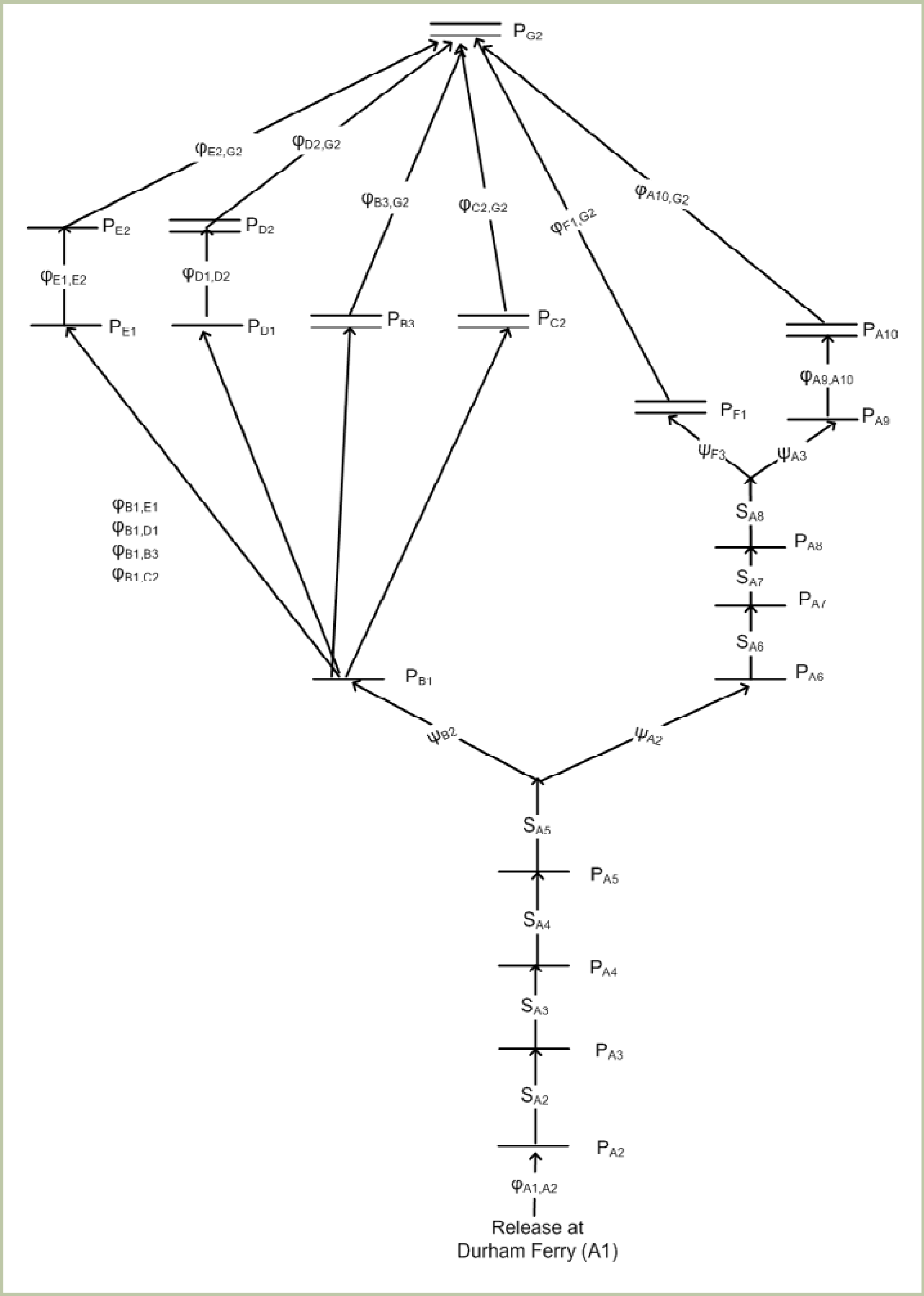
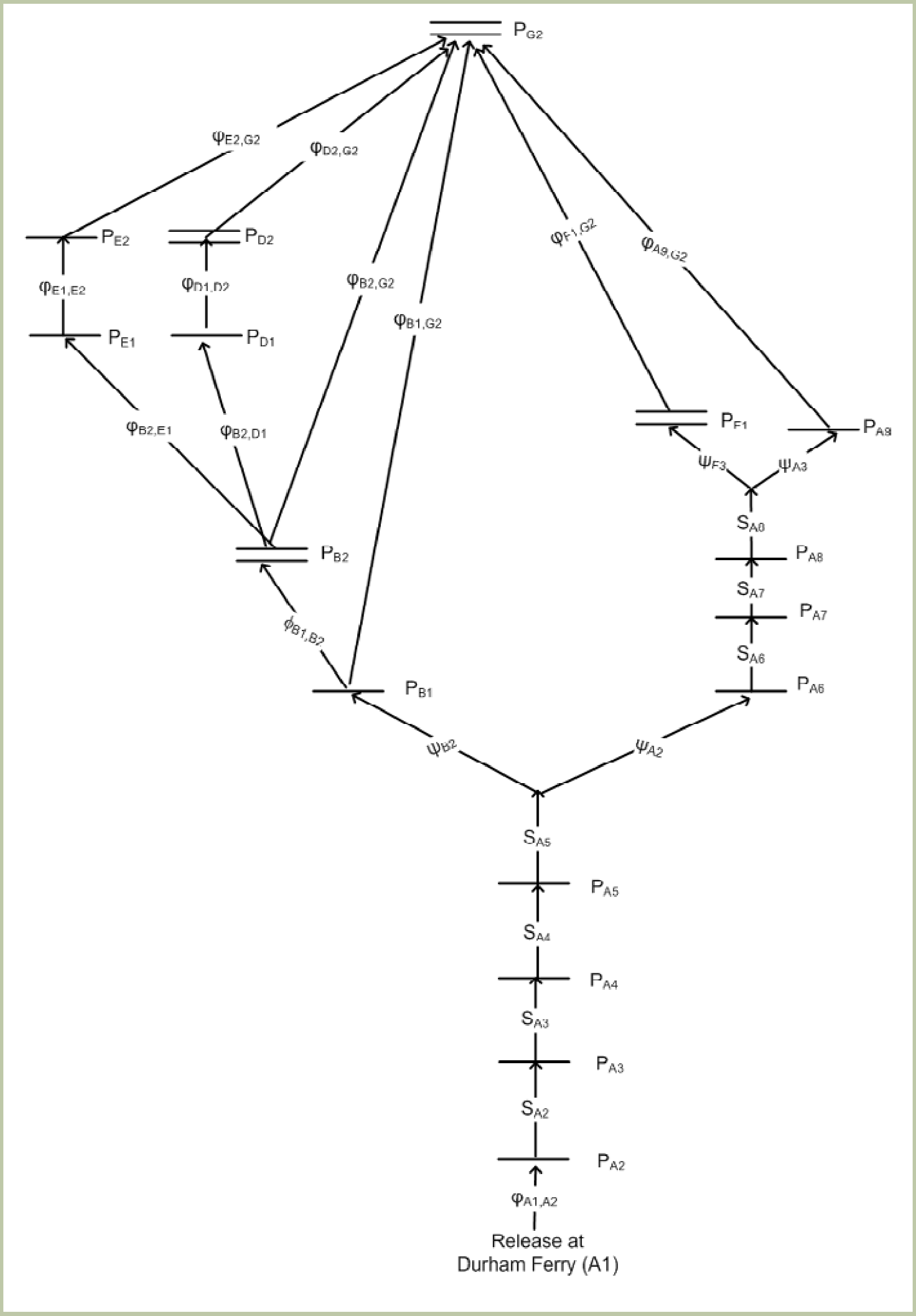


Figure 8-5
Schematic of Multinomial Likelihood Mark-Recapture Model Used to Estimate Survival and Entrainment Probabilities for Chinook Salmon Smolts Released Before and After Installation of the Temporary Barrier in Grant Line Canal, 2011



G1) and False River (site H1) parameters. Additionally, inability to estimate transition probabilities to Middle River South (site C1) and Old River South (site B2) for pooled release groups 3 and 4 forced model simplification to estimate transition probabilities to sites downstream of these two sites directly from the Old River East site (B1). The data from pooled releases 1 and 2 were fit to the same reduced model as data from pooled releases 3 and 4 so that comparisons of parameters before and after Old River and Middle River barrier installation were more robust (Figure 8-4).

Analysis of effects of the Grant Line Canal barrier required comparing release groups 3 (before) and 4 (after). Fitting these data separately required a different set of simplifications to the full likelihood model than those for the Old R./Middle R. barrier analysis described above. The model fitting data from release group 3 was simplified by removing parameters associated with sites G1, H1, and A10 (Medford Island site). Additionally, because of sparse detections in the Middle River for release group 3, the model fitting this release was further simplified, removing parameters associated with the Middle River South (C1), Middle River North (C2), and Old River North (B3) sites. Transition probabilities were estimated directly to Chipps Island from the Old River East (B1), Old River South (B2), Clifton Court Forebay (D1, D2), and Central Valley Project trashracks (E1). As above, the same reduced model was fit to both release groups 3 and 4 in order to obtain survival and route entrainment parameter estimates for before and after Grant Line Canal barrier installation (Figure 8-5).

For all release groups, detections were pooled across both receivers at the dual array sites at the San Joaquin near Lathrop (A6), the San Joaquin downstream of the Turner Cut Junction (A9), the head of Old River (B1), and the Clifton Court Forebay radial gates (upstream; D1). Finally, in all cases, transition, survival, and detection probabilities were fixed to 1.0 or 0.0 as appropriate, based on the observed detections.

Travel Time Analysis

In order to test hypothesis (3), that travel time through the Old River corridor was longer after installation of the agricultural barriers, individual smolt travel times were measured from Mossdale (site A5) to several points in the Old River and Middle River region of the Delta. Specifically, travel time was measured for fish detected at Mossdale and subsequently detected at either the Clifton Court (D1 or D2) or Central Valley (E1 or E2) Projects, or at the Old River North (B3) or Middle River North (C2) sites. Regression analysis was then performed with the logarithm of individual smolt travel times as the response variable, and covariates including a binary variable indicating presence of an agricultural barrier, a river flow measure at Mossdale at the time the smolt was detected there, total project exports on the date that the smolt was detected at Mossdale, and smolt fork length at tagging. In order to minimize the effect of both tidal and diurnal (due to pumping and agricultural diversion) fluctuations, river flow was measured as the root mean square (RMS) of river flow measurements at a site over the 24-hour period centered at the time that a smolt was detected at that site.

Although attempts were made to analyze travel times to each of the four sites listed above, several factors allowed only the analysis of travel times from Mossdale to the Clifton Court Forebay (CCFB) and Central Valley Project (CVP). Only 3 smolts of the 1,444 detected at Mossdale were subsequently detected at the Middle River North site; additionally no in-river flow data were available from near that site. Although 98 smolts detected at Mossdale were subsequently detected at the Old River North site, only 1 of these left Mossdale after installation of the Old River and Middle River barriers, and none were detected after installation of the Grant Line Canal barrier.

In all, four regression analyses were carried out. Separate analyses were carried out for travel times to the CCFB and CVP sites. Additionally, effects of the Grant Line Canal agricultural barrier on travel times were treated separately from effects of the other two barriers; because the initiation dates of construction on the Old River and Middle River barriers was so close, the effects of these two barriers could not be treated separately. For analysis of the Grant Line Canal barrier, only data from smolts detected at Mossdale after installation of the Old River and Middle River barriers were used, in order to avoid confounding the effects of the different barriers. In each of the four regressions the association between covariates dictated a single covariate model, that is

$$\log(y_i) = \beta_{oj} + \beta_{1j}x_{ij} + \varepsilon_{ij}$$

where y_i is the ith smolt's individual travel time to either the CCFB or CVP sites, x_{ij} is the jth covariate (j=1,…,4) for that smolt, ε_{ij} is a stochastic error term, and β_{oj}, β_{1j} are regression coefficients for the jth covariate in that regression. Thus, β_{1j} represents the (multiplicative) change in expected travel time from Mossdale to either the CCFB or CVP associated with a change in covariate *j*. For each single covariate regression model an F-test was performed to assess significant association between the response and covariate. AIC selection among models whose covariates were significantly associated with travel times was then used to choose which models represented a better fit to the data, and thus which covariates were most closely associated with travel time.

Barrier Region Passage Success

In addition to the analysis of Delta regional survival using detections from the VAMP receivers, barrier passage success was analyzed using detections from the receivers installed at the barriers (Figure 8-1). For each barrier, the probability of successfully passing through the barrier location, $S_{Barrier}$, was estimated for tagged fish that were detected upstream of the barrier according to

$$\hat{S}_{Barrier} = \frac{x_{Barrier}}{N_{Barrier}},$$

where $N_{Barrier}$ is the number of tagged fish detected on the fixed-site receiver located just upstream of the barrier, and $x_{Barrier}$ is the number of the $N_{Barrier}$ fish that were subsequently detected on the fixed-site receiver located just downstream of the barrier. The variance of the passage success estimate was estimated by

$$\widehat{Var}\left(\hat{S}_{Barrier}\right) = \frac{x_{Barrier}\left(N_{Barrier} - x_{Barrier}\right)}{N^3_{Barrier}}.$$

For each barrier, detections of Chinook salmon tags that had been previously classified as inside predators on the basis of the predator filter were excluded. At the time of the analysis, no predator filter had been devised for steelhead, so no steelhead tags were excluded. Barrier passage success ($S_{Barrier}$) was estimated separately for tags that arrived before the barriers were installed ("before") and for tags that arrived after installation had begun ("after"). Tags that were detected both before and after installation were assigned to the "after" category. The hypothesis that barrier presence was associated with decreased passage success was tested using a Z-test on the natural log scale:

$$Z = \frac{\ln\left(\hat{S}_{before} / \hat{S}_{after}\right)}{\sqrt{\frac{\widehat{Var}\left(\hat{S}_{before}\right)}{\hat{S}^2_{before}} + \frac{\widehat{Var}\left(\hat{S}_{after}\right)}{\hat{S}^2_{after}}}},$$

where $\hat{S}_{After}$ is the estimate of passage success before the barrier was installed, and $\hat{S}_{Before}$ is the estimate of passage success after barrier installation.

Results – Survival and Route Entrainment Analysis

The results presented here compare survival and entrainment metrics from before and after mid-season installation of three agricultural barriers. It is important to note that any differences in these metrics, however statistically significant, cannot be attributed solely to effects of these barriers. Factors such as river flow, water temperature, and water exports from the Central Valley and State Water Projects may also have an effect on smolt survival and route selection. As water temperature tends to rise later in the spring, tagged smolts released after barrier installation likely experienced higher water temperatures during migration. As is shown in the travel time analysis section of this report, both river flow at Mossdale and total Delta exports showed an association with barrier status for all three agricultural barriers as well.

Old River/Middle River Barriers

Table 8-4 shows estimates of parameters used to test hypotheses (1) and (2) regarding survival and route entrainment from before and after installation of the Old River and Middle River barriers. S_{Total} is overall smolt survival through the San Joaquin River Delta (Mossdale to Chipps Island), S_A is survival from Mossdale to Chipps Island for smolts remaining in the San Joaquin River at the head of Old River (route A), and S_B is survival from Mossdale to Chipps Island for smolts entrained into Old River at the head of Old River, regardless of subsequent route choice (Old River, Middle River, transport from CCFB or CVP, route B). The parameter ψ_{B2} is the route entrainment probability into Old River at its head. All parameter estimates are derived from the release-recapture likelihood model shown in Figure 8-4. P-values ≥ 0.3109 show that the null hypothesis cannot be rejected for any of the parameters measured. That is, smolt survival was not significantly lower either in the San Joaquin River route, the Old River/Middle River route, or across the entire Sacramento-San Joaquin River Delta, nor was entrainment into Old River significantly lower, after installation of the Old River and Middle River barriers in 2011.

In fact, testing the converse hypothesis for S_{Total} and S_B shows that survival was higher for smolts entering the Old River at Mossdale, and through the entire Sacramento-San Joaquin River Delta, after installation of the Old River and Middle River barriers ($p<0.01$ for both). Although this result is statistically significant, it is important to remember that correlation is not causation, and that the change in survival may be attributed as much or more to other seasonally-influenced factors (measured or unmeasured).

Grant Line Canal Barrier

All parameters listed in Table 8-5 represent the same as in the Old River/Middle River barrier analysis above; all were derived from the release-recapture model shown in Figure 8-5. P-values ≥ 0.1913 show that the null hypothesis cannot be rejected for any of the parameters measured. That is, smolt survival was

Table 8-4
Parameter Estimates Before and After Installation of the Old River and Middle River Temporary Barriers, 2011. Parameters and Standard Errors Estimated from Fitted Multi-state Release-recapture Model with Program USER

Parameter	Before OR/MR Barrier		After OR/MR Barrier		Z	P-value
	Estimate	SE	Estimate	SE		
S_{Total}	0.0092	0.0033	0.0330	0.0065	-3.15	0.9992
S_A	0.0060	0.0035	0.0090	0.0045	-0.53	0.7014
S_B	0.0136	0.0061	0.0674	0.0142	-3.25	0.9994
ψ_{B2}	0.4227	0.0167	0.4105	0.0181	0.49	0.3109

Table 8-5
Parameter Estimates Before and After Installation of the Grant Line Canal Temporary Barrier, 2011. Parameters and Standard Errors Estimated from Fitted Multi-state Release-recapture Model with Program USER

Parameter	Before Grant Line Canal Barrier		After Grant Line Canal Barrier		Z	P-value
	Estimate	SE	Estimate	SE		
S_{Total}	0.0320	0.0091	0.0339	0.0093	-0.15	0.5609
S_A	0.0129	0.0074	0.0047	0.0047	0.65	0.1913
S_B	0.0641	0.0207	0.0702	0.0195	-0.21	0.5848
ψ_{B2}	0.3723	0.0253	0.4461	0.0256	-2.05	0.9797

Table 8-6
Regression Cofficients, p-values, and AIC Scores for Single Regressions Modeling Fish Travel Times to the CCFB from Mossdale. Models are of the form $y=\exp(\beta0+\beta1x)+\varepsilon$, where x is the Covariate of Interest and *y* is Travel Time (days).

Covariate (x)	β0	β1	p-value (β1)	AIC
Total Exports (kcfs)	0.136	-0.058	<0.0001	202.8
Old/Middle River Barriers	-0.030	-0.384	<0.0001	204.2
Smolt Fork Length (mm)	1.724	-0.018	0.0029	225.4
Flow at Mossdale (kcfs)	-1.041	0.796	0.0229	229.1

not significantly lower either in the San Joaquin River route, the Old River/Middle River route, or through the entire Sacramento-San Joaquin River Delta, nor was entrainment into the Old River at Mossdale significantly lower, after installation of the Grant Line Canal barrier in 2011. Testing the converse hypothesis for entrainment probability ψ_{B2} , however, shows that entrainment into Old River at Mossdale was significantly higher after installation of the Grant Line Canal Barrier (p=0.0203). As with the Old River/Middle River barrier results, however, we cannot attribute this increase solely to the Grant Line Canal barrier as other variables may be as much or more of a cause.

Results – Travel Time Analysis

Of the 1,444 smolts detected at the Mossdale site (A5) during the 2011 Chinook tagging study, 171 smolts (73 detected before Old River and Middle River barrier installation, 98 after) were subsequently detected at the Clifton Court Forebay (site D1 or D2), and 124 (48 before and 76 after OR/MR barrier installation) were subsequently detected at the Central Valley Project (sites E1 or E2). Of the 98 fish travelling to the CCFB detected at Mossdale after OR/MR barrier installation, 15 were detected before and 83 after the Grant Line Canal barrier was installed. Of the 76 fish travelling to the CVP detected at Mossdale after OR/MR barrier installation, 13 were detected before and 63 after the Grant Line Canal barrier was installed. As mentioned above, sparse data at the Old River North and Middle River North sites prevented comparison of travel times to these sites.

Old River/Middle River Barriers

Travel time among tagged smolts from Mossdale to the Clifton Court Forebay was shorter after installation of the Old River and Middle River agricultural barriers (harmonic mean travel time: before=20.83 hours,

$\widehat{SE}$=0.97; after=15.03 hours, $\widehat{SE}$ =0.48). However, because seasonal trends involving each of the other covariates coincided with the installation of the barriers, the potential for confounding among covariates calls the implications of this association into question. As seen in Figure 8-6, each of the fork length, root mean square of flow at Mossdale, and total Delta exports covariates shares some association with whether the barriers were installed or not at the time that the fish was detected at Mossdale. Exports showed a particularly strong association, explained by the marked increase of project exports around June 1, nearly the same time as installation of the agricultural barriers. Regression analysis showed that each covariate on its own had a significant (α=0.05) association with travel time (Table 8-6), and both total exports and barrier status (AIC of 202.8 and 204.2 respectively) showed a better fit to the travel time data than did fork length and river flow (AIC of 225.4 and 229.1, respectively). For the Old River/Middle River barrier status covariate, exp(β0)*24=23.29 is the expected travel time (hours) from Mossdale to the CCFB sites in the absence of the Old River and Middle Riber barriers, while exp(β0+β1)*24=15.86 is the expected travel time in hours after those barriers were installed.

Clearly as travel time to CCFB was shorter after barrier installation, we cannot reject the null hypothesis (3) in favor of the alternative that travel time was longer with the barriers installed. However, the very small p-value suggests that the shorter travel time was associated with the barriers (P<0.0001, Table 8-6). Total exports showed just as strong an association with travel time from Mossdale to the CCFB sites, with exp(β1)=0.9439 representing the multiplicative change in expected travel time per additional 1,000 cfs in total exports. As an example, the average of the daily export values used in the Old River/Middle River barrier analysis was 6,683 cfs. At this export level the regression equation gives an expected travel time from Mossdale to the Clifton Court Forebay of 18.7 hours. The multiplicative effect of β1 in the regression model means that increasing exports to 7,683 cfs would yield expected travel time (18.7*0.9439)=17.6 hours; increasing to 8,683 gives expected travel time (18.7*0.94392)=16.6 hours, etc. Given the strength of association between total exports and Old River/Middle River barrier status (Figure 8-6), it is impossible to separate their effects on travel time.

Regression analysis for the effect of the Old River and Middle River barriers on travel time from Mossdale to the CVP sites used the same methods for travel to the CCFB sites. Because the time frame was the same for both analyses, total Delta exports, flow at Mossdale, and smolt fork length covariates showed a similar association with barrier status for smolts travelling to CVP sites as they did for those travelling to CCFB sites. Average travel time from Mossdale to CVP (harmonic mean) was 19.86 hours ($\widehat{SE}$=1.42) before installation of the Old and Middle River barriers, and 17.60 hours ($\widehat{SE}$=0.99) after installation. Unlike travel time to CCFB, however, linear regression models found that at the α=0.05 level, none of the covariates, taken singly, had a significant effect on travel time from Mossdale to the CVP sites (p=0.0982 for river flow at Mossdale, p>0.30 for all other covariates).

Grant Line Canal Barrier

Average travel time from Mossdale to the Clifton Court Forebay (harmonic mean) was 19.41 hours ($\widehat{SE}$=0.83) before installation of the Grant Line Canal barrier, and 15.12 hours ($\widehat{SE}$=0.53) after installation. From Mossdale to the CVP, average travel was 19.80 hours ($\widehat{SE}$=1.24) before installation and 17.23 hours ($\widehat{SE}$=1.07) after installation. Installation of the Grant Line Canal barrier was not associated with any significant effect on travel time among tagged smolts detected at Mossdale and subsequently detected at either the Clifton Court Forebay or the Central Valley Project. Total Delta exports and flow at Mossdale both again showed an association with barrier status for the Grant Line Canal, although smolt fork length did not (Figure 8-7). Neither smolt fork length, river flow at Mossdale, total Delta exports nor Grant Line Canal barrier status was significant in explaining travel time from Mossdale to either the CCFB or CVP sites (p>0.30).

Results – Barrier Region Passage Success

Middle River Barrier

Few fish were detected at the Middle River Barrier receivers, either upstream or downstream of the barrier location. Before the barrier was installed, 4 Chinook salmon and 25 steelhead were detected upstream of the barrier, with 3 and 21 of them, respectively, subsequently detected downstream of the barrier. Passage success through the barrier location before the barrier was installed was estimated at $\hat{S}_{MR}$ = 0.7500 ($\widehat{SE}$ = 0.2165) for Chinook salmon, and $\hat{S}_{MR}$ = 0.8400 ($\widehat{SE}$ = 0.0733) for steelhead (Table 8-7). After the barrier was installed, only 2 Chinook salmon and 4 steelhead were detected upstream of the barrier, with 0 Chinook salmon and 4 steelhead subsequently detected downstream; after-installation barrier passage success was $\hat{S}_{MR}$ = 0 ($\widehat{SE}$ = 0) for Chinook salmon, and $\hat{S}_{MR}$ = 1 ($\widehat{SE}$ = 0) for steelhead (Table 8-7). Because of the sparse detection data after the barrier was installed, no formal test of barrier effects was performed for either species.

Old River Barrier

There were more detections at the receivers at the Old River Barrier location than at the Middle River

Figure 8-6
(a) Total Project Exports (combined throughout Delta), (b) River Flow at Mossdale (MSD), and (c) Fork Length at Tagging Versus Status of the Old River and Middle River Barriers ("in" or "out"). Exports Were Measured for the Day of Arrival of Tagged Smolts at Mossdale; River Flow was Measured as the Root Mean Square (RMS) of River Flow over the 24-hour Period of Fish Arrival at Mossdale. Results are Shown for Tagged Fish Detected Moving from Mossdale to the Clifton Court Forebay; Analogous Plots for Smolts Traveling from Mossdale to the Central Valley Project Showed Similar Results

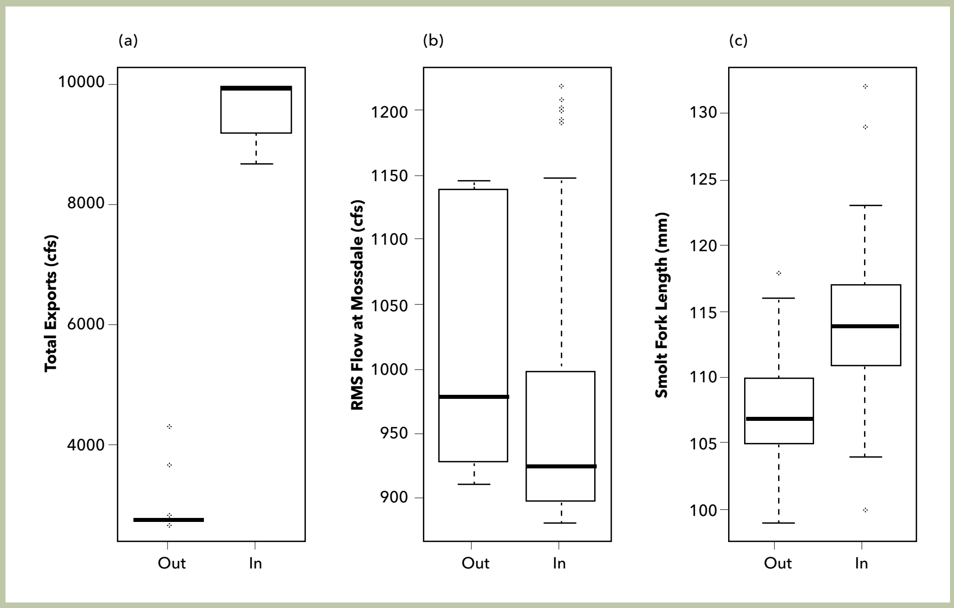


Figure 8-7
(a) Total Project Exports (combined throughout Delta), (b) River Flow at Mossdale (MSD), and (c) Fork Length at Tagging Versus Status of the Grant Line Canal Barrier ("in" or "out"). Exports Were Measured for the Day of Arrival of Tagged Smolts at Mossdale; River Flow was Measured as the Root Mean Square (RMS) of River Flow Over the 24-hour Period of Fish Arrival at Mossdale. Results are Shown for Tagged Fish Detected Moving from Mossdale to the Clifton Court Forebay; Analogous Plots for Smolts Traveling from Mossdale to the Central Valley Project Showed Similar Results

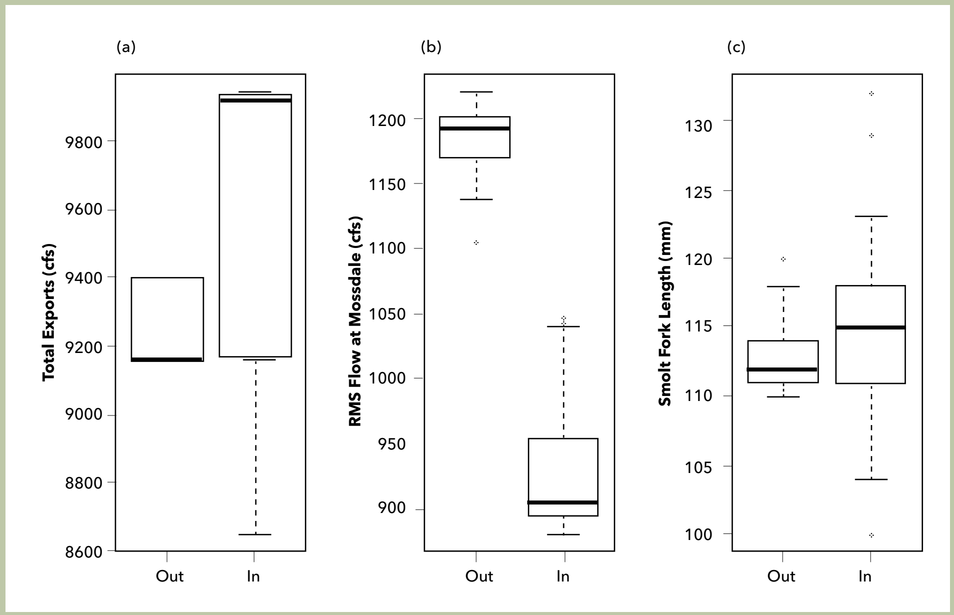


Table 8-7
Number of tagged fish detected upstream of the Middle River Barrier (N_{MR}), detected both upstream and downstream of the Middle River Barrier (x_{MR}), and the estimate of passage success ($\hat{S}_{MR}$). Standard error in parentheses. "Before" = before barrier installation began. "After" = after barrier installation began. Chinook salmon tag detections were filtered for predator-type detections.

	Chinook Salmon		Steelhead	
	Before	After	Before	After
N_{MR}	4	2	25	4
x_{MR}	3	0	21	4
$\hat{S}_{MR}$	0.7500 (0.2165)	0 (0)	0.8400 (0.0733)	1 (0)

Table 8-8
Number of tagged fish detected upstream of the Old River Barrier (N_{OR}), detected both upstream and downstream of the Old River Barrier (x_{OR}), and the estimate of passage success ($\hat{S}_{OR}$). Standard error in parentheses. "Before" = before barrier installation began. "After" = after barrier installation began. Chinook salmon tag detections were filtered for predator-type detections.

	Chinook Salmon		Steelhead	
	Before	After	Before	After
N_{OR}	39	18	30	31
x_{OR}	38	15	22	27
$\hat{S}_{OR}$	0.9744 (0.0253)	0.8333 (0.0878)	0.7333 (0.0807)	0.8710 (0.0602)

Table 8-9
Number of tagged fish detected upstream of the Grant Line Canal Barrier (N_{GLC}), detected both upstream and downstream of the Grant Line Canal Barrier (x_{GLC}), and the estimate of passage success ($\hat{S}_{GLC}$) Standard error in parentheses. "Before" = before barrier installation began. "After" = after barrier installation began. Chinook salmon tag detections were filtered for predator-type detections. * = passage success after installation was significantly lower than before installation (α=0.05).

	Chinook Salmon*		Steelhead	
	Before	After		Before
N_{GLC}	352	149	405	62
x_{GLC}	351	145	363	54
$\hat{S}_{GLC}$	0.9972 (0.0028)	0.9732 (0.0132)	0.8763 (0.0151)	0.8710 (0.0426)

Barrier, with 18 to 39 Chinook salmon and 31 to 30 steelhead detected upstream (Table 8-8). For Chinook salmon, passage success through the barrier location was estimated at $\hat{S}_{OR}$ = 0.9744 ($\widehat{SE}$ = 0.0253) before the barrier was installed, and 0.8333 (0.0878) after the barrier was installed. Although the estimated passage success was lower after installation than before, the difference was not significant at the 5% level (P=0.0747). For steelhead, passage success was $\hat{S}_{OR}$ = 0.7333 ($\widehat{SE}$ = 0.0807) before installation, and 0.8710 (0.0602) after installation (Table 8-8). For neither species did installation of the Old River Barrier result in significantly lower passage success through the barrier area. However, the lack of significance for Chinook salmon may have been a result of low statistical power.

Grant Line Canal Barrier

The receivers at the location of the barrier in Grant Line Canal had the most detections of all three barriers for both Chinook salmon and steelhead. Before barrier installation, there were 352 Chinook salmon and 405 steelhead detected upstream of the planned barrier location; after installation, 149 Chinook salmon and 62 steelhead were detected upstream of the barrier (Table 8-9). For Chinook salmon, passage success through the barrier location was estimated at $\hat{S}_{GLC}$ = 0.9972 ($\widehat{SE}$ = 0.0028) before installation, and 0.9732 (0.0132) after installation. Passage success was significantly lower after installation than before installation for Chinook salmon (P=0.0393). For steelhead, passage success was estimated at $\hat{S}_{GLC}$ = 0.8763 ($\widehat{SE}$ = 0.0151) before installation and 0.8710 (0.0426) after installation; the difference was not significant at the 5% level (P=0.4534). (Table 8-9).

Summary

Three temporary agricultural barriers were installed midway through the migration period for salmonids released as part of the Chinook salmon and steelhead acoustic-tagging studies in 2011. The barriers installed in Old River, Middle River, and Grant Line Canal in 2011 were not associated with decreases in either route-specific or total Delta survival, or with decreases in the route entrainment into Old River. Instead, installation of the Old and Middle River barriers was associated with an increase in both route-specific survival to Chipps Island through the Old River route, and in overall survival to Chipps Island. Likewise, installation of the Old and Middle River barriers was associated with a decrease in travel time from Mossdale to the Clifton Court Forebay. Installation of the Grant Line Canal barrier, on the other hand, was associated with an increase in route entrainment probability into Old River. While these results were unexpected, it is important to note that barrier installation was also associated with other changes in the river environment, including decreases in river flow and increases in exports. These other factors may have had a stronger effect on survival and route entrainment than installation of the barriers; because of the strong association between these measures and barrier presence, we cannot identify which factors were most important.

A large number of tags of both species were detected on receivers located at the Grant Line Canal barrier, with fewer tags detected at the Old River barrier, and very few tags detected at the Middle River barrier. Installation of the Grant Line Canal barrier was associated with lower passage success for Chinook salmon (P=0.0393), but not for steelhead (P=0.4534). Fewer tags were detected at the Old River Barrier near Tracy, CA. Neither species had significantly lower passage success (at the 5% significance level) in this region after barrier installation. Too few tags were detected at the Middle River Barrier for formal testing of the effect of the barrier on passage success.

Overall, steelhead demonstrated no negative effect of barrier installation on passage success; however, the steelhead data were not filtered for possible detections of predators on steelhead tags, so some of the detections may have represented predatory fish such as striped bass. Chinook salmon, on the other hand, demonstrated a negative effect of installation of the Grant Line Canal Barrier. However, passage success for Chinook salmon remained very high even after installation of the Grant Line Canal Barrier ($\hat{S}_{GLC}$=0.9732), so it is unlikely that this statistical significance translated into a biological significance, especially considering the observed increase in survival through the Delta after the barrier was installed.

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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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CALIFORNIA DEPARTMENT OF FISH AND GAME [1]

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WATER AUTHORITY [1]

SAN JOAQUIN RIVER GROUP AUTHORITY [1]

[1] *Signatory to the one-year extension of the agreement in 2011*

[2] *San Joaquin River Group Authority Members*

Common Acronyms and Abbreviations

ADCP	Acoustic Doppler Current Meters
AIC	Akaike Information Criterion
ATR	Acoustic Tag Receiver
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 or BiOp	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 Tag
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
DWSC	Deep Water Ship Channel
EPA or USEPA	United States Environmental Protection Agency
FERC	Federal Energy Regulatory Commission
FL	Fork Length
FTP	File Transfer Protocol
GLC	Grant Line Canal
GLM	Generalized Linear Model
GPS	Global Positioning System
HAC	Health Assessment Control
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 Receiver Location (2 Receivers)
MRND	Middle River North, Downstream Acoustic Receiver Location
MRNU	Middle River North, Upstream Acoustic Receiver Location
MRS	Middle River South Acoustic Receiver 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 Receiver Location (2 Receivers)
ORND	Old River North, Downstream Acoustic Receiver Location
ORNU	Old River North, Upstream Acoustic Receiver Location
ORS	Old River South Acoustic Receiver Location (2 Receivers)
ORSD	Old River South, Downstream Acoustic Receiver Location
ORSU	Old River South, Upstream Acoustic Receiver Location
ORT	Old River at Tracy
OSJ	North Old River
PKD	Proliferative Kidney Disease
RAT	Raw Acoustic Telemetry
RGD	Radial Gates at Clifton Court Forebay, Interior Acoustic Receiver Location (2 Receivers)
RGU	Radial Gates at Clifton Court Forebay, Entrance Channel Acoustic Receiver Location
RM	River Mile
RMS	Root Mean Square
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 Receiver 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
SJRRP	San Joaquin River Restoration Program
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 Receiver Location
STN	San Joaquin River at Navy Bridge near Stockton Acoustic Receiver 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 Receiver Location (2 Receivers)
TFCF	Tracy Fish Collection Facility
TID	Turlock Irrigation District
TMN/TMS	Threemile Slough Acoustic Receiver 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
VNS	Vernalis
WBC	White Blood Cell
WOMT	CALFED Water Operations Management Team
WQCP	Water Quality Control Plan
WWTP	Wastewater Treatment Plant

APPENDICES TABLE OF CONTENTS

APPENDIX A

Appendix A, Table 1

2011 VAMP DAILY OPERATION PLAN – MARCH 16, 2011
FOR DETERMINATION OF VAMP SUPPLEMENTAL WATER (WITHOUT NMFS RPA)
LOW UNGAGED FLOW
Target Flow Period: April 15th – May 15th * Flow Target: 4,450 cfs
Bold Numbers: observed real-time mean daily flows

	San Joaquin River near Vernalis							Merced River at Cressey				Tuolumne River below La Grange Dam				Stanislaus R below Goodwin Dam					Maintain Priority Flow Level M=Merced T=Tuol. S=Stan.
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)	SJREC 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)	
3/10/11	**9,920**					**745**	**1,624**	**3,642**			3,642	**3,780**	**3,780**		3,780	**210**	**210**			210	
3/11/11	**9,860**					**660**	**1,471**	**3,559**			3,559	**3,660**	**3,660**		3,660	**220**	**220**			220	
3/12/11	**9,750**					**717**	**1,365**	**3,052**			3,052	**3,280**	**3,280**		3,280	**209**	**209**			209	
3/13/11	**9,440**				9,440	**679**	**1,258**	**3,077**			3,077	**2,870**	**2,870**		2,870	**205**	**205**			205	
3/14/11	**8,930**				8,930	**655**	**1,165**	**3,063**			3,063	**2,680**	**2,680**		2,680	**203**	**203**			203	
3/15/11	**8,460**				8,460	**602**	**1,654**	**3,069**			3,069	**2,700**	**2,700**		2,700	**204**	**204**			204	
3/16/11	7,730				7,730	587	1,115	3,000			3,000	2,700	2,700		2,700	200	200			200	
3/17/11	7,659				7,659	572	1,090	2,400			2,400	2,100	2,100		2,100	200	200			200	
3/18/11	7,621				7,621	557	1,065	1,800			1,800	1,500	1,500		1,500	200	200			200	
3/19/11	6,912				6,912	542	1,040	1,800			1,800	1,150	1,150		1,150	200	200			200	
3/20/11	5,672				5,672	527	1,015	1,800			1,800	1,150	1,150		1,150	200	200			200	
3/21/11	4,682				4,682	512	990	1,800			1,800	1,150	1,150		1,150	200	200			200	
3/22/11	4,642				4,642	497	965	1,800			1,800	1,150	1,150		1,150	200	200			200	
3/23/11	4,602				4,602	482	940	1,800			1,800	1,150	1,150		1,150	200	200			200	
3/24/11	4,562				4,562	467	915	1,800			1,800	1,150	1,150		1,150	200	200			200	
3/25/11	4,522				4,522	452	890	1,800			1,800	1,150	1,150		1,150	200	200			200	
3/26/11	4,482				4,482	437	865	1,800			1,800	1,150	1,150		1,150	200	200			200	
3/27/11	4,442				4,442	422	840	1,800			1,800	1,150	1,150		1,150	200	200			200	
3/28/11	4,402				4,402	407	815	1,800			1,800	1,150	1,150		1,150	200	200			200	
3/29/11	4,362				4,362	392	790	1,800			1,800	1,150	1,150		1,150	200	200			200	
3/30/11	4,322				4,322	377	765	1,800			1,800	1,150	1,150		1,150	200	200			200	
3/31/11	4,282				4,282	362	740	1,800			1,800	1,150	1,150		1,150	200	200			200	
4/1/11	4,242				4,242	400	715	1,200			1,200	1,170	1,170		1,170	458	458			458	
4/2/11	4,202				4,202	400	690	600			600	1,170	1,170		1,170	458	458			458	
4/3/11	4,493				4,493	400	665	250			250	1,170	1,170		1,170	458	458			458	
4/4/11	3,868				3,868	400	640	250			250	1,170	1,170		1,170	458	458			458	
4/5/11	3,243				3,243	400	615	250			250	1,170	1,170		1,170	458	458			458	
4/6/11	2,868				2,868	400	590	250			250	1,170	1,170		1,170	458	458			458	
4/7/11	2,843				2,843	400	565	250			250	1,170	1,170		1,170	458	458			458	
4/8/11	2,818				2,818	400	540	250			250	1,170	1,170		1,170	458	458			458	
4/9/11	2,793				2,793	400	515	250			250	1,170	1,170		1,170	458	458			458	
4/10/11	2,768				2,768	400	490	250			250	1,170	1,170		1,170	458	458			458	
4/11/11	2,743				2,743	400	465	250			250	1,170	1,170		1,170	458	458			458	
4/12/11	2,718				2,718	400	440	250	894	179	1,323	1,170	1,170		1,170	458	458			458	
4/13/11	2,693				2,693	400	415	250	894	179	1,323	1,170	1,170	358	1,528	458	458	358	0	816	
4/14/11	2,678				2,678	400	400	250	894	179	1,323	1,170	1,170	358	1,528	458	458	358	0	816	
4/15/11	2,678	1,789	0	3.55	4,467	400	400	250	894	179	1,323	1,170	1,170	358	1,528	458	458	358	0	816	
4/16/11	2,678	1,789	0	7.10	4,467	400	400	250	894	179	1,323	1,170	1,170	358	1,528	458	458	358	0	816	
4/17/11	2,678	1,789	0	10.65	4,467	400	400	250	894	179	1,323	1,170	1,170	358	1,528	458	458	358	0	816	
4/18/11	2,678	1,789	0	14.19	4,467	400	400	250	894	179	1,323	1,170	1,170	358	1,528	458	458	358	0	816	
4/19/11	2,678	1,789	0	17.74	4,467	400	400	250	894	179	1,323	1,170	1,170	358	1,528	458	458	358	0	816	
4/20/11	2,678	1,789	0	21.29	4,467	400	400	250	894	179	1,323	1,170	1,170	358	1,528	458	458	358	0	816	
4/21/11	2,678	1,789	0	24.84	4,467	400	400	250	894	179	1,323	1,170	1,170	358	1,528	458	458	358	0	816	
4/22/11	2,678	1,789	0	28.39	4,467	400	400	250	894	179	1,323	1,170	1,170	358	1,528	458	458	358	0	816	
4/23/11	2,678	1,789	0	31.94	4,467	400	400	250	894	179	1,323	1,170	1,170	358	1,528	458	458	358	0	816	
4/24/11	2,678	1,789	0	35.48	4,467	400	400	250	894	179	1,323	1,170	1,170	358	1,528	458	458	358	0	816	
4/25/11	2,678	1,789	0	39.03	4,467	400	400	250	894	179	1,323	1,170	1,170	358	1,528	458	458	358	0	816	
4/26/11	2,678	1,789	0	42.58	4,467	400	400	250	894	179	1,323	1,170	1,170	358	1,528	458	458	358	0	816	
4/27/11	2,678	1,789	0	46.13	4,467	400	400	250	894	179	1,323	1,170	1,170	358	1,528	458	458	358	0	816	
4/28/11	2,678	1,789	0	49.68	4,467	400	400	250	894	179	1,323	1,170	1,170	358	1,528	458	458	358	0	816	
4/29/11	2,678	1,789	0	53.23	4,467	400	400	250	894	179	1,323	1,170	1,170	358	1,528	458	458	358	0	816	
4/30/11	2,678	1,789	0	56.77	4,467	400	400	250	894	179	1,323	1,170	1,170	358	1,528	458	458	358	0	816	
5/1/11	2,678	1,789	0	60.32	4,467	400	400	250	894	179	1,323	1,130	1,130	358	1,488	380	380	358	0	738	
5/2/11	2,678	1,789	0	63.87	4,467	400	400	250	894	179	1,323	1,130	1,130	358	1,488	380	380	358	0	738	
5/3/11	2,560	1,789	0	67.42	4,349	400	400	250	894	179	1,323	1,130	1,130	358	1,488	380	380	358	0	738	
5/4/11	2,560	1,789	0	70.97	4,349	400	400	250	894	179	1,323	1,130	1,130	358	1,488	380	380	358	0	738	
5/5/11	2,560	1,789	0	74.52	4,349	400	400	250	894	179	1,323	1,130	1,130	358	1,488	380	380	358	0	738	
5/6/11	2,560	1,789	0	78.07	4,349	400	400	250	894	179	1,323	1,130	1,130	358	1,488	380	380	358	0	738	
5/7/11	2,560	1,789	0	81.61	4,349	400	400	250	894	179	1,323	1,130	1,130	358	1,488	380	380	358	0	738	
5/8/11	2,560	1,789	0	85.16	4,349	400	400	250	894	179	1,323	1,130	1,130	358	1,488	380	380	358	0	738	
5/9/11	2,560	1,789	0	88.71	4,349	400	400	250	894	179	1,323	1,130	1,130	358	1,488	380	380	358	0	738	
5/10/11	2,560	1,789	0	92.26	4,349	400	400	250	894	179	1,323	1,130	1,130	358	1,488	380	380	358	0	738	
5/11/11	2,560	1,789	0	95.81	4,349	400	400	250	894	179	1,323	1,130	1,130	358	1,488	380	380	358	0	738	
5/12/11	2,560	1,789	0	99.36	4,349	400	400	250	894	179	1,323	1,130	1,130	358	1,488	380	380	358	0	738	
5/13/11	2,560	1,789	0	102.90	4,349	400	400	250			250	1,130	1,130	358	1,488	380	380	358	0	738	
5/14/11	2,560	1,789	0	106.45	4,349	400	400	250			250	1,130	1,130		1,130	380	380			380	
5/15/11	2,560	1,789	0	110.00	4,349	400	400	250			250	1,130	1,130		1,130	380	380			380	
5/16/11	2,560	0	0		2,560	400	400	250			250	1,130	1,130		1,130	380	380			380	
5/17/11	2,560	0	0		2,560	400	400	250			250	1,130	1,130		1,130	380	380			380	
5/18/11	2,560	0	0		2,560	400	400	250			250	1,130	1,130		1,130	380	380			380	
5/19/11	2,560	0	0		2,560	400	400	250			250	1,130	1,130		1,130	380	380			380	
5/20/11	2,560	0	0		2,560	400	400	250			250	1,130	1,130		1,130	380	380			380	
5/21/11	2,560	0	0		2,560	400	400	250			250	1,130	1,130		1,130	380	380			380	
5/22/11	2,560	0	0		2,560	400	400	250			250	1,130	1,130		1,130	380	380			380	
5/23/11	2,560	0	0		2,560	400	400	250			250	1,130	1,130		1,130	380	380			380	
5/24/11	2,560	0	0		2,560	400	400	250			250	1,130	1,130		1,130	380	380			380	
5/25/11	2,560	0	0		2,560	400	400	250			250	1,130	1,130		1,130	380	380			380	
5/26/11	2,560	0	0		2,560	400	400	250			250	1,130	1,130		1,130	380	380			380	
5/27/11	2,560	0	0		2,560	400	400	250			250	1,130	1,130		1,130	380	380			380	
5/28/11	2,560	0	0		2,560	400	400	250			250	1,130	1,130		1,130	380	380			380	
5/29/11	2,560	0	0		2,560	400	400	250			250	1,130	1,130		1,130	380	380			380	
5/30/11	2,560	0	0		2,560	400	400	250			250	1,130	1,130		1,130	380	380			380	
5/31/11	2,560	0	0		2,560	400	400	250			250	1,130	1,130		1,130	380	380			380	
VAMP Period																					
Avg. (cfs):	2,629	1,789	0		4,418	400	400	250	894	179	1,323	1,153	1,153	358	1,511	425	425	358	0	783	
Supplemental Water (TAF):		110.00	0.00						54.97	11.01				22.01				22.01	0.00		

VAMP flow operation period

Appendix A, Table 2

2011 VAMP DAILY OPERATION PLAN – MARCH 16, 2011
PROJECTED ACTUAL FLOWS (WITH NMFS RPA)
LOW UNGAGED FLOW
Target Flow Period: April 15th – May 15th * Flow Target: 4,450 cfs
Bold Numbers: observed real-time mean daily flows

Date	San Joaquin River near Vernalis							Merced River at Cressey				Tuolumne River below La Grange Dam				Stanislaus R below Goodwin Dam					
	Existing Flow (cfs)	VAMP Supplemental Flow (cfs)	Other Supplemental Flow (cfs)	Cumulative VAMP Supplemental Flow (TAF)	VAMP Flow (cfs)	SJR above Merced R (2day lag) (cfs)	Ungaged Flow above Vernalis (cfs)	Existing Flow (cfs)	MeID VAMP Supplemental Flow (cfs)	SJREC VAMP Supplemental Flow (cfs)	VAMP Flow (3day lag) (cfs)	Existing Flow - base FERC volume (cfs)	Existing Flow - Adjusted FERC Pulse (cfs)	VAMP Supplemental Flow (cfs)	VAMP Flow (2day lag) (cfs)	Existing Flow - Base (cfs)	Existing Flow - reshaped	VAMP Supplemental Flow (cfs)	Other Supplemental Flow (cfs)	VAMP Flow (2day lag) (cfs)	Maintain Priority Flow Level M=Merced T=Tuol. S=Stan.
3/10/11	**9,920**					**745**	**1,624**	**3,642**			3,642	**3,780**	**3,780**		3,780	**210**	**210**			210	
3/11/11	**9,860**					**660**	**1,471**	**3,559**			3,559	**3,660**	**3,660**		3,660	**220**	**220**			220	
3/12/11	**9,750**					**717**	**1,365**	**3,052**			3,052	**3,280**	**3,280**		3,280	**209**	**209**			209	
3/13/11	**9,440**				9,440	**679**	**1,258**	**3,077**			3,077	**2,870**	**2,870**		2,870	**205**	**205**			205	
3/14/11	**8,930**				8,930	**655**	**1,165**	**3,063**			3,063	**2,680**	**2,680**		2,680	**203**	**203**			203	
3/15/11	**8,460**				8,460	**602**	**1,654**	**3,069**			3,069	**2,700**	**2,700**		2,700	**204**	**204**			204	
3/16/11	8,115				8,115	587	1,500	3,000			3,000	2,700	2,700		2,700	200	200			200	
3/17/11	7,659				7,659	572	1,090	2,400			2,400	2,100	2,100		2,100	200	200			200	
3/18/11	7,621				7,621	557	1,065	1,800			1,800	1,500	1,500		1,500	200	200			200	
3/19/11	6,912				6,912	542	1,040	1,800			1,800	1,150	1,150		1,150	200	200			200	
3/20/11	5,672				5,672	527	1,015	1,800			1,800	1,150	1,150		1,150	200	200			200	
3/21/11	4,682				4,682	512	990	1,800			1,800	1,150	1,150		1,150	200	200			200	
3/22/11	4,642				4,642	497	965	1,800			1,800	1,150	1,150		1,150	200	200			200	
3/23/11	4,602				4,602	482	940	1,800			1,800	1,150	1,150		1,150	200	200			200	
3/24/11	4,562				4,562	467	915	1,800			1,800	1,150	1,150		1,150	200	200			200	
3/25/11	4,522				4,522	452	890	1,800			1,800	1,150	1,150		1,150	200	200			200	
3/26/11	4,482				4,482	437	865	1,800			1,800	1,150	1,150		1,150	200	200			200	
3/27/11	4,442				4,442	422	840	1,800			1,800	1,150	1,150		1,150	200	200			200	
3/28/11	4,402				4,402	407	815	1,800			1,800	1,150	1,150		1,150	200	200			200	
3/29/11	4,362				4,362	392	790	1,800			1,800	1,150	1,150		1,150	200	200			200	
3/30/11	4,322				4,322	377	765	1,800			1,800	1,150	1,150		1,150	200	200			200	
3/31/11	4,282				4,282	362	740	1,800			1,800	1,150	1,150		1,150	200	200			200	
4/1/11	4,242				4,242	400	715	1,200			1,200	1,170	1,170		1,170	1,500	1,500			1,500	
4/2/11	4,202				4,202	400	690	600			600	1,170	1,170		1,170	1,500	1,500			1,500	
4/3/11	5,535				5,535	400	665	250			250	1,170	1,170		1,170	1,500	1,500			1,500	
4/4/11	4,910				4,910	400	640	250			250	1,170	1,170		1,170	1,500	1,500			1,500	
4/5/11	4,285				4,285	400	615	250			250	1,170	1,170		1,170	1,500	1,500			1,500	
4/6/11	3,910				3,910	400	590	250			250	1,170	1,170		1,170	1,500	1,500			1,500	
4/7/11	3,885				3,885	400	565	250			250	1,170	1,170		1,170	1,500	1,500			1,500	
4/8/11	3,860				3,860	400	540	250			250	1,170	1,170		1,170	1,500	1,500			1,500	
4/9/11	3,835				3,835	400	515	250			250	1,170	1,170		1,170	1,500	1,500			1,500	
4/10/11	3,810				3,810	400	490	250			250	1,170	1,170		1,170	1,500	1,500			1,500	
4/11/11	3,785				3,785	400	465	250			250	1,170	1,170		1,170	1,500	1,500			1,500	
4/12/11	3,760				3,760	400	440	250	894	179	1,323	1,170	1,170		1,170	1,500	1,500			1,500	
4/13/11	3,735				3,735	400	415	250	894	179	1,323	1,170	1,170	358	1,528	1,500	1,500	358	0	1,858	
4/14/11	3,720				3,720	400	400	250	894	179	1,323	1,170	1,170	358	1,528	1,500	1,500	358	0	1,858	
4/15/11	3,720	1,789	0	3.55	5,509	400	400	250	894	179	1,323	1,170	1,170	358	1,528	1,500	1,500	358	0	1,858	
4/16/11	3,720	1,789	0	7.10	5,509	400	400	250	894	179	1,323	1,170	1,170	358	1,528	1,500	1,500	358	0	1,858	
4/17/11	3,720	1,789	0	10.65	5,509	400	400	250	894	179	1,323	1,170	1,170	358	1,528	1,500	1,500	358	0	1,858	
4/18/11	3,720	1,789	0	14.19	5,509	400	400	250	894	179	1,323	1,170	1,170	358	1,528	1,500	1,500	358	0	1,858	
4/19/11	3,720	1,789	0	17.74	5,509	400	400	250	894	179	1,323	1,170	1,170	358	1,528	1,500	1,500	358	0	1,858	
4/20/11	3,720	1,789	0	21.29	5,509	400	400	250	894	179	1,323	1,170	1,170	358	1,528	1,500	1,500	358	0	1,858	
4/21/11	3,720	1,789	0	24.84	5,509	400	400	250	894	179	1,323	1,170	1,170	358	1,528	1,500	1,500	358	0	1,858	
4/22/11	3,720	1,789	0	28.39	5,509	400	400	250	894	179	1,323	1,170	1,170	358	1,528	1,500	1,500	358	0	1,858	
4/23/11	3,720	1,789	0	31.94	5,509	400	400	250	894	179	1,323	1,170	1,170	358	1,528	1,500	1,500	358	0	1,858	
4/24/11	3,720	1,789	0	35.48	5,509	400	400	250	894	179	1,323	1,170	1,170	358	1,528	1,500	1,500	358	0	1,858	
4/25/11	3,720	1,789	0	39.03	5,509	400	400	250	894	179	1,323	1,170	1,170	358	1,528	1,500	1,500	358	0	1,858	
4/26/11	3,720	1,789	0	42.58	5,509	400	400	250	894	179	1,323	1,170	1,170	358	1,528	1,500	1,500	358	0	1,858	
4/27/11	3,720	1,789	0	46.13	5,509	400	400	250	894	179	1,323	1,170	1,170	358	1,528	1,500	1,500	358	0	1,858	
4/28/11	3,720	1,789	0	49.68	5,509	400	400	250	894	179	1,323	1,170	1,170	358	1,528	1,500	1,500	358	0	1,858	
4/29/11	3,720	1,789	0	53.23	5,509	400	400	250	894	179	1,323	1,170	1,170	358	1,528	1,500	1,500	358	0	1,858	
4/30/11	3,720	1,789	0	56.77	5,509	400	400	250	894	179	1,323	1,170	1,170	358	1,528	1,500	1,500	358	0	1,858	
5/1/11	3,720	1,789	0	60.32	5,509	400	400	250	894	179	1,323	1,130	1,130	358	1,488	1,500	1,500	358	0	1,858	
5/2/11	3,720	1,789	0	63.87	5,509	400	400	250	894	179	1,323	1,130	1,130	358	1,488	1,500	1,500	358	0	1,858	
5/3/11	3,680	1,789	0	67.42	5,469	400	400	250	894	179	1,323	1,130	1,130	358	1,488	1,500	1,500	358	0	1,858	
5/4/11	3,680	1,789	0	70.97	5,469	400	400	250	894	179	1,323	1,130	1,130	358	1,488	1,500	1,500	358	0	1,858	
5/5/11	3,680	1,789	0	74.52	5,469	400	400	250	894	179	1,323	1,130	1,130	358	1,488	1,500	1,500	358	0	1,858	
5/6/11	3,680	1,789	0	78.07	5,469	400	400	250	894	179	1,323	1,130	1,130	358	1,488	1,500	1,500	358	0	1,858	
5/7/11	3,680	1,789	0	81.61	5,469	400	400	250	894	179	1,323	1,130	1,130	358	1,488	1,500	1,500	358	0	1,858	
5/8/11	3,680	1,789	0	85.16	5,469	400	400	250	894	179	1,323	1,130	1,130	358	1,488	1,500	1,500	358	0	1,858	
5/9/11	3,680	1,789	0	88.71	5,469	400	400	250	894	179	1,323	1,130	1,130	358	1,488	1,500	1,500	358	0	1,858	
5/10/11	3,680	1,789	0	92.26	5,469	400	400	250	894	179	1,323	1,130	1,130	358	1,488	1,500	1,500	358	0	1,858	
5/11/11	3,680	1,789	0	95.81	5,469	400	400	250	894	179	1,323	1,130	1,130	358	1,488	1,500	1,500	358	0	1,858	
5/12/11	3,680	1,789	0	99.36	5,469	400	400	250	894	179	1,323	1,130	1,130	358	1,488	1,500	1,500	358	0	1,858	
5/13/11	3,680	1,789	0	102.90	5,469	400	400	250			250	1,130	1,130	358	1,488	1,500	1,500	358	0	1,858	
5/14/11	3,680	1,789	0	106.45	5,469	400	400	250			250	1,130	1,130		1,130	1,500	1,500			1,500	
5/15/11	3,680	1,789	0	110.00	5,469	400	400	250			250	1,130	1,130		1,130	1,500	1,500			1,500	
5/16/11	3,680	0	0		3,680	400	400	250			250	1,130	1,130		1,130	1,500	1,500			1,500	
5/17/11	3,680	0	0		3,680	400	400	250			250	1,130	1,130		1,130	1,500	1,500			1,500	
5/18/11	3,680	0	0		3,680	400	400	250			250	1,130	1,130		1,130	1,500	1,500			1,500	
5/19/11	3,680	0	0		3,680	400	400	250			250	1,130	1,130		1,130	1,500	1,500			1,500	
5/20/11	3,680	0	0		3,680	400	400	250			250	1,130	1,130		1,130	1,500	1,500			1,500	
5/21/11	3,680	0	0		3,680	400	400	250			250	1,130	1,130		1,130	1,500	1,500			1,500	
5/22/11	3,680	0	0		3,680	400	400	250			250	1,130	1,130		1,130	1,500	1,500			1,500	
5/23/11	3,680	0	0		3,680	400	400	250			250	1,130	1,130		1,130	1,500	1,500			1,500	
5/24/11	3,680	0	0		3,680	400	400	250			250	1,130	1,130		1,130	1,500	1,500			1,500	
5/25/11	3,680	0	0		3,680	400	400	250			250	1,130	1,130		1,130	1,500	1,500			1,500	
5/26/11	3,680	0	0		3,680	400	400	250			250	1,130	1,130		1,130	1,500	1,500			1,500	
5/27/11	3,680	0	0		3,680	400	400	250			250	1,130	1,130		1,130	1,500	1,500			1,500	
5/28/11	3,680	0	0		3,680	400	400	250			250	1,130	1,130		1,130	1,500	1,500			1,500	
5/29/11	3,680	0	0		3,680	400	400	250			250	1,130	1,130		1,130	1,500	1,500			1,500	
5/30/11	3,680	0	0		3,680	400	400	250			250	1,130	1,130		1,130	1,500	1,500			1,500	
5/31/11	3,680	0	0		3,680	400	400	250			250	1,130	1,130		1,130	1,500	1,500			1,500	
VAMP Period																					
Avg. (cfs):	3,703	1,789	0		5,492	400	400	250	894	179	1,323	1,153	1,153	358	1,511	1,500	1,500	358	0	1,858	
Supplemental Water (TAF):		110.00	0.00						54.97	11.01				22.01				22.01	0.00		

VAMP flow operation period

Appendix A, Table 3

2011 VAMP DAILY OPERATION PLAN – MARCH 16, 2011
FOR DETERMINATION OF VAMP SUPPLEMENTAL WATER (WITHOUT NMFS RPA)
HIGH UNGAGED FLOW
Target Flow Period: April 15th – May 15th * Flow Target: 4,450 cfs
Bold Numbers: observed real-time mean daily flows

	San Joaquin River near Vernalis							Merced River at Cressey				Tuolumne River below La Grange Dam				Stanislaus R below Goodwin Dam					
Date	Existing Flow (cfs)	VAMP Supplemental Flow (cfs)	Other Supplemental Flow (cfs)	Cumulative VAMP Supplemental Flow (TAF)	VAMP Flow (cfs)	SJR above Merced R (2day lag) (cfs)	Ungaged Flow above Vernalis (cfs)	Existing Flow (cfs)	MeID VAMP Supplemental Flow (cfs)	SJREC VAMP Supplemental Flow (cfs)	VAMP Flow (3day lag) (cfs)	Existing Flow - base FERC volume (cfs)	Existing Flow - Adjusted FERC Pulse (cfs)	VAMP Supplemental Flow (cfs)	VAMP Flow (2day lag) (cfs)	Existing Flow - Base (cfs)	Existing Flow - reshaped	VAMP Supplemental Flow (cfs)	Other Supplemental Flow (cfs)	VAMP Flow (2day lag) (cfs)	Maintain Priority Flow Level M=Merced T=Tuol. S=Stan.
3/10/11	**9,920**					**745**	**1,624**	**3,642**			3,642	**3,780**	**3,780**		3,780	**210**	**210**			210	
3/11/11	**9,860**					**660**	**1,471**	**3,559**			3,559	**3,660**	**3,660**		3,660	**220**	**220**			220	
3/12/11	**9,750**					**717**	**1,365**	**3,052**			3,052	**3,280**	**3,280**		3,280	**209**	**209**			209	
3/13/11	**9,440**				9,440	**679**	**1,258**	**3,077**			3,077	**2,870**	**2,870**		2,870	**205**	**205**			205	
3/14/11	**8,930**				8,930	**655**	**1,165**	**3,063**			3,063	**2,680**	**2,680**		2,680	**203**	**203**			203	
3/15/11	**8,460**				8,460	**602**	**1,654**	**3,069**			3,069	**2,700**	**2,700**		2,700	**204**	**204**			204	
3/16/11	8,261				8,261	700	1,646	3,000			3,000	2,700	2,700		2,700	200	200			200	
3/17/11	8,207				8,207	700	1,638	2,400			2,400	3,200	3,200		3,200	200	200			200	
3/18/11	8,299				8,299	700	1,630	1,800			1,800	3,600	3,600		3,600	200	200			200	
3/19/11	8,722				8,722	700	1,622	1,800			1,800	3,600	3,600		3,600	200	200			200	
3/20/11	8,514				8,514	700	1,614	1,475			1,475	3,600	3,600		3,600	200	200			200	
3/21/11	7,906				7,906	700	1,606	1,475			1,475	3,600	3,600		3,600	200	200			200	
3/22/11	7,898				7,898	700	1,598	1,475			1,475	3,600	3,600		3,600	200	200			200	
3/23/11	7,565				7,565	700	1,590	1,475			1,475	3,600	3,600		3,600	200	200			200	
3/24/11	7,557				7,557	700	1,582	1,475			1,475	3,600	3,600		3,600	200	200			200	
3/25/11	7,549				7,549	700	1,574	1,475			1,475	3,600	3,600		3,600	200	200			200	
3/26/11	7,541				7,541	700	1,566	1,475			1,475	3,600	3,600		3,600	200	200			200	
3/27/11	7,533				7,533	700	1,558	1,475			1,475	3,600	3,600		3,600	200	200			200	
3/28/11	7,525				7,525	700	1,550	1,475			1,475	3,600	3,600		3,600	200	200			200	
3/29/11	7,517				7,517	700	1,542	1,475			1,475	3,600	3,600		3,600	200	200			200	
3/30/11	7,509				7,509	700	1,534	1,475			1,475	3,600	3,600		3,600	200	200			200	
3/31/11	7,501				7,501	700	1,526	1,475			1,475	3,600	3,600		3,600	200	200			200	
4/1/11	7,493				7,493	700	1,518	1,350			1,350	2,060	2,060		2,060	900	900			900	
4/2/11	7,485				7,485	700	1,510	1,350			1,350	2,060	2,060		2,060	900	900			900	
4/3/11	6,637				6,637	700	1,502	1,350			1,350	2,060	2,060		2,060	900	900			900	
4/4/11	6,010				6,010	700	1,000	1,350			1,350	2,060	2,060		2,060	900	900			900	
4/5/11	6,010				6,010	700	1,000	1,350			1,350	2,060	2,060		2,060	900	900			900	
4/6/11	6,010				6,010	700	1,000	1,350			1,350	2,060	2,060		2,060	900	900			900	
4/7/11	6,010				6,010	700	1,000	1,350			1,350	2,060	2,060		2,060	900	900			900	
4/8/11	6,010				6,010	700	1,000	1,350			1,350	2,060	2,060		2,060	900	900			900	
4/9/11	6,010				6,010	700	1,000	1,350			1,350	2,060	2,060		2,060	900	900			900	
4/10/11	6,010				6,010	700	1,000	1,350			1,350	2,060	2,060		2,060	900	900			900	
4/11/11	6,010				6,010	700	1,000	1,350			1,350	2,060	2,060		2,060	900	900			900	
4/12/11	6,010				6,010	700	1,000	1,350	559	81	1,990	2,060	2,060		2,060	900	900			900	
4/13/11	6,010				6,010	700	1,000	1,350	559	81	1,990	2,060	2,060	163	2,223	900	900	163	0	1,063	
4/14/11	6,010				6,010	700	1,000	1,350	559	81	1,990	2,060	2,060	163	2,223	900	900	163	0	1,063	
4/15/11	6,010	966	0	1.92	6,976	700	1,000	1,350	559	81	1,990	2,060	2,060	163	2,223	900	900	163	0	1,063	
4/16/11	6,010	966	0	3.83	6,976	700	1,000	1,350	559	81	1,990	2,060	2,060	163	2,223	900	900	163	0	1,063	
4/17/11	6,010	966	0	5.75	6,976	700	1,000	1,350	559	81	1,990	2,060	2,060	163	2,223	900	900	163	0	1,063	
4/18/11	6,010	966	0	7.66	6,976	700	1,000	1,350	559	81	1,990	2,060	2,060	163	2,223	900	900	163	0	1,063	
4/19/11	6,010	966	0	9.58	6,976	700	1,000	1,350	559	81	1,990	2,060	2,060	163	2,223	900	900	163	0	1,063	
4/20/11	6,010	966	0	11.50	6,976	700	1,000	1,350	559	81	1,990	2,060	2,060	163	2,223	900	900	163	0	1,063	
4/21/11	6,010	966	0	13.41	6,976	700	1,000	1,350	559	81	1,990	2,060	2,060	163	2,223	900	900	163	0	1,063	
4/22/11	6,010	966	0	15.33	6,976	700	1,000	1,350	559	81	1,990	2,060	2,060	163	2,223	900	900	163	0	1,063	
4/23/11	6,010	966	0	17.24	6,976	700	1,000	1,350	559	81	1,990	2,060	2,060	163	2,223	900	900	163	0	1,063	
4/24/11	6,010	966	0	19.16	6,976	700	1,000	1,350	559	81	1,990	2,060	2,060	163	2,223	900	900	163	0	1,063	
4/25/11	6,010	966	0	21.08	6,976	700	1,000	1,350	559	81	1,990	2,060	2,060	163	2,223	900	900	163	0	1,063	
4/26/11	6,010	966	0	22.99	6,976	700	1,000	1,350	559	81	1,990	2,060	2,060	163	2,223	900	900	163	0	1,063	
4/27/11	6,010	966	0	24.91	6,976	700	1,000	1,350	559	81	1,990	2,060	2,060	163	2,223	900	900	163	0	1,063	
4/28/11	6,010	966	0	26.82	6,976	700	1,000	1,350	559	81	1,990	2,060	2,060	163	2,223	900	900	163	0	1,063	
4/29/11	6,010	966	0	28.74	6,976	700	1,000	1,350	559	81	1,990	2,060	2,060	163	2,223	900	900	163	0	1,063	
4/30/11	6,010	966	0	30.66	6,976	700	1,000	1,350	559	81	1,990	2,060	2,060	163	2,223	900	900	163	0	1,063	
5/1/11	6,010	966	0	32.57	6,976	700	1,000	1,100	559	81	1,740	1,750	1,750	163	1,913	1,500	1,500	163	0	1,663	
5/2/11	6,010	966	0	34.49	6,976	700	1,000	1,100	559	81	1,740	1,750	1,750	163	1,913	1,500	1,500	163	0	1,663	
5/3/11	6,300	966	0	36.40	7,266	700	1,000	1,100	559	81	1,740	1,750	1,750	163	1,913	1,500	1,500	163	0	1,663	
5/4/11	6,050	966	0	38.32	7,016	700	1,000	1,100	559	81	1,740	1,750	1,750	163	1,913	1,500	1,500	163	0	1,663	
5/5/11	6,050	966	0	40.24	7,016	700	1,000	1,100	559	81	1,740	1,750	1,750	163	1,913	1,500	1,500	163	0	1,663	
5/6/11	6,050	966	0	42.15	7,016	700	1,000	1,100	559	81	1,740	1,750	1,750	163	1,913	1,500	1,500	163	0	1,663	
5/7/11	6,050	966	0	44.07	7,016	700	1,000	1,100	559	81	1,740	1,750	1,750	163	1,913	1,500	1,500	163	0	1,663	
5/8/11	6,050	966	0	45.98	7,016	700	1,000	1,100	559	81	1,740	1,750	1,750	163	1,913	1,500	1,500	163	0	1,663	
5/9/11	6,050	966	0	47.90	7,016	700	1,000	1,100	559	81	1,740	1,750	1,750	163	1,913	1,500	1,500	163	0	1,663	
5/10/11	6,050	966	0	49.82	7,016	700	1,000	1,100	559	81	1,740	1,750	1,750	163	1,913	1,500	1,500	163	0	1,663	
5/11/11	6,050	966	0	51.73	7,016	700	1,000	1,100	559	81	1,740	1,750	1,750	163	1,913	1,500	1,500	163	0	1,663	
5/12/11	6,050	966	0	53.65	7,016	700	1,000	1,100	559	81	1,740	1,750	1,750	163	1,913	1,500	1,500	163	0	1,663	
5/13/11	6,050	966	0	55.56	7,016	700	1,000	1,100			1,100	1,750	1,750	163	1,913	1,500	1,500	163	0	1,663	
5/14/11	6,050	966	0	57.48	7,016	700	1,000	1,100			1,100	1,750	1,750		1,750	1,500	1,500			1,500	
5/15/11	6,050	966	0	59.40	7,016	700	1,000	1,100			1,100	1,750	1,750		1,750	1,500	1,500			1,500	
5/16/11	6,050	0	0		6,050	700	1,000	1,100			1,100	1,750	1,750		1,750	1,500	1,500			1,500	
5/17/11	6,050	0	0		6,050	700	1,000	1,100			1,100	1,750	1,750		1,750	1,500	1,500			1,500	
5/18/11	6,050	0	0		6,050	700	1,000	1,100			1,100	1,750	1,750		1,750	1,500	1,500			1,500	
5/19/11	6,050	0	0		6,050	700	1,000	1,100			1,100	1,750	1,750		1,750	1,500	1,500			1,500	
5/20/11	6,050	0	0		6,050	700	1,000	1,100			1,100	1,750	1,750		1,750	1,500	1,500			1,500	
5/21/11	6,050	0	0		6,050	700	1,000	1,100			1,100	1,750	1,750		1,750	1,500	1,500			1,500	
5/22/11	6,050	0	0		6,050	700	1,000	1,100			1,100	1,750	1,750		1,750	1,500	1,500			1,500	
5/23/11	6,050	0	0		6,050	700	1,000	1,100			1,100	1,750	1,750		1,750	1,500	1,500			1,500	
5/24/11	6,050	0	0		6,050	700	1,000	1,100			1,100	1,750	1,750		1,750	1,500	1,500			1,500	
5/25/11	6,050	0	0		6,050	700	1,000	1,100			1,100	1,750	1,750		1,750	1,500	1,500			1,500	
5/26/11	6,050	0	0		6,050	700	1,000	1,100			1,100	1,750	1,750		1,750	1,500	1,500			1,500	
5/27/11	6,050	0	0		6,050	700	1,000	1,100			1,100	1,750	1,750		1,750	1,500	1,500			1,500	
5/28/11	6,050	0	0		6,050	700	1,000	1,100			1,100	1,750	1,750		1,750	1,500	1,500			1,500	
5/29/11	6,050	0	0		6,050	700	1,000	1,100			1,100	1,750	1,750		1,750	1,500	1,500			1,500	
5/30/11	6,050	0	0		6,050	700	1,000	1,100			1,100	1,750	1,750		1,750	1,500	1,500			1,500	
5/31/11	6,050	0	0		6,050	700	1,000	1,100			1,100	1,750	1,750		1,750	1,500	1,500			1,500	
VAMP Period																					
Avg. (cfs):	6,035	966	0		7,001	700	1,000	1,253	559	81	1,893	1,930	1,930	163	2,093	1,152	1,152	163	0	1,315	
Supplemental Water (TAF):		59.40	0.00						34.37	4.98				10.02				10.02	0.00		

VAMP flow operation period

Appendix A, Table 4

2011 VAMP DAILY OPERATION PLAN – MARCH 16, 2011
PROJECTED ACTUAL FLOWS (WITH NMFS RPA)
HIGH UNGAGED FLOW
Target Flow Period: April 15th – May 15th * Flow Target: 4,450 cfs
Bold Numbers: observed real-time mean daily flows

Date	San Joaquin River near Vernalis							Merced River at Cressey				Tuolumne River below La Grange Dam				Stanislaus R below Goodwin Dam					
	Existing Flow (cfs)	VAMP Supplemental Flow (cfs)	Other Supplemental Flow (cfs)	Cumulative VAMP Supplemental Flow (TAF)	VAMP Flow (cfs)	SJR above Merced R (2day lag) (cfs)	Ungaged Flow above Vernalis (cfs)	Existing Flow (cfs)	MeID VAMP Supplemental Flow (cfs)	SJREC VAMP Supplemental Flow (cfs)	VAMP Flow (3day lag) (cfs)	Existing Flow - base FERC volume (cfs)	Existing Flow - Adjusted FERC Pulse (cfs)	VAMP Supplemental Flow (cfs)	VAMP Flow (2day lag) (cfs)	Existing Flow - Base (cfs)	Existing Flow - reshaped	VAMP Supplemental Flow (cfs)	Other Supplemental Flow (cfs)	VAMP Flow (2day lag) (cfs)	Maintain Priority Flow Level M=Merced T=Tuol. S=Stan.
3/10/11	**9,920**					**745**	**1,624**	**3,642**			3,642	**3,780**	**3,780**		3,780	**210**	**210**			210	
3/11/11	**9,860**					**660**	**1,471**	**3,559**			3,559	**3,660**	**3,660**		3,660	**220**	**220**			220	
3/12/11	**9,750**					**717**	**1,365**	**3,052**			3,052	**3,280**	**3,280**		3,280	**209**	**209**			209	
3/13/11	**9,440**				9,440	**679**	**1,258**	**3,077**			3,077	**2,870**	**2,870**		2,870	**205**	**205**			205	
3/14/11	**8,930**				8,930	**655**	**1,165**	**3,063**			3,063	**2,680**	**2,680**		2,680	**203**	**203**			203	
3/15/11	**8,460**				8,460	**602**	**1,654**	**3,069**			3,069	**2,700**	**2,700**		2,700	**204**	**204**			204	
3/16/11	8,261				8,261	700	1,646	3,000			3,000	2,700	2,700		2,700	200	200			200	
3/17/11	8,207				8,207	700	1,638	2,400			2,400	3,200	3,200		3,200	200	200			200	
3/18/11	8,299				8,299	700	1,630	1,800			1,800	3,600	3,600		3,600	200	200			200	
3/19/11	8,722				8,722	700	1,622	1,800			1,800	3,600	3,600		3,600	200	200			200	
3/20/11	8,514				8,514	700	1,614	1,475			1,475	3,600	3,600		3,600	200	200			200	
3/21/11	7,906				7,906	700	1,606	1,475			1,475	3,600	3,600		3,600	200	200			200	
3/22/11	7,898				7,898	700	1,598	1,475			1,475	3,600	3,600		3,600	200	200			200	
3/23/11	7,565				7,565	700	1,590	1,475			1,475	3,600	3,600		3,600	200	200			200	
3/24/11	7,557				7,557	700	1,582	1,475			1,475	3,600	3,600		3,600	200	200			200	
3/25/11	7,549				7,549	700	1,574	1,475			1,475	3,600	3,600		3,600	200	200			200	
3/26/11	7,541				7,541	700	1,566	1,475			1,475	3,600	3,600		3,600	200	200			200	
3/27/11	7,533				7,533	700	1,558	1,475			1,475	3,600	3,600		3,600	200	200			200	
3/28/11	7,525				7,525	700	1,550	1,475			1,475	3,600	3,600		3,600	200	200			200	
3/29/11	7,517				7,517	700	1,542	1,475			1,475	3,600	3,600		3,600	200	200			200	
3/30/11	7,509				7,509	700	1,534	1,475			1,475	3,600	3,600		3,600	200	200			200	
3/31/11	7,501				7,501	700	1,526	1,475			1,475	3,600	3,600		3,600	200	200			200	
4/1/11	7,493				7,493	700	1,518	1,350			1,350	2,060	2,060		2,060	400	400			400	
4/2/11	7,485				7,485	700	1,510	1,350			1,350	2,060	2,060		2,060	750	750			750	
4/3/11	6,137				6,137	700	1,502	1,350			1,350	2,060	2,060		2,060	1,000	1,000			1,000	
4/4/11	5,860				5,860	700	1,000	1,350			1,350	2,060	2,060		2,060	1,250	1,250			1,250	
4/5/11	6,110				6,110	700	1,000	1,350			1,350	2,060	2,060		2,060	1,500	1,500			1,500	
4/6/11	6,360				6,360	700	1,000	1,350			1,350	2,060	2,060		2,060	1,700	1,700			1,700	
4/7/11	6,610				6,610	700	1,000	1,350			1,350	2,060	2,060		2,060	2,000	2,000			2,000	
4/8/11	6,810				6,810	700	1,000	1,350			1,350	2,060	2,060		2,060	2,000	2,000			2,000	
4/9/11	7,110				7,110	700	1,000	1,350			1,350	2,060	2,060		2,060	2,000	2,000			2,000	
4/10/11	7,110				7,110	700	1,000	1,350			1,350	2,060	2,060		2,060	2,000	2,000			2,000	
4/11/11	7,110				7,110	700	1,000	1,350			1,350	2,060	2,060		2,060	1,500	1,500			1,500	
4/12/11	7,110				7,110	700	1,000	1,350	559	81	1,990	2,060	2,060		2,060	1,500	1,500			1,500	
4/13/11	6,610				6,610	700	1,000	1,350	559	81	1,990	2,060	2,060	163	2,223	1,500	1,500	163	0	1,663	
4/14/11	6,610				6,610	700	1,000	1,350	559	81	1,990	2,060	2,060	163	2,223	1,500	1,500	163	0	1,663	
4/15/11	6,610	966	0	1.92	7,576	700	1,000	1,350	559	81	1,990	2,060	2,060	163	2,223	1,500	1,500	163	0	1,663	
4/16/11	6,610	966	0	3.83	7,576	700	1,000	1,350	559	81	1,990	2,060	2,060	163	2,223	1,500	1,500	163	0	1,663	
4/17/11	6,610	966	0	5.75	7,576	700	1,000	1,350	559	81	1,990	2,060	2,060	163	2,223	1,500	1,500	163	0	1,663	
4/18/11	6,610	966	0	7.66	7,576	700	1,000	1,350	559	81	1,990	2,060	2,060	163	2,223	1,500	1,500	163	0	1,663	
4/19/11	6,610	966	0	9.58	7,576	700	1,000	1,350	559	81	1,990	2,060	2,060	163	2,223	2,000	2,000	163	0	2,163	
4/20/11	6,610	966	0	11.50	7,576	700	1,000	1,350	559	81	1,990	2,060	2,060	163	2,223	2,000	2,000	163	0	2,163	
4/21/11	7,110	966	0	13.41	8,076	700	1,000	1,350	559	81	1,990	2,060	2,060	163	2,223	2,000	2,000	163	0	2,163	
4/22/11	7,110	966	0	15.33	8,076	700	1,000	1,350	559	81	1,990	2,060	2,060	163	2,223	2,000	2,000	163	0	2,163	
4/23/11	7,110	966	0	17.24	8,076	700	1,000	1,350	559	81	1,990	2,060	2,060	163	2,223	1,500	1,500	163	0	1,663	
4/24/11	7,110	966	0	19.16	8,076	700	1,000	1,350	559	81	1,990	2,060	2,060	163	2,223	1,500	1,500	163	0	1,663	
4/25/11	6,610	966	0	21.08	7,576	700	1,000	1,350	559	81	1,990	2,060	2,060	163	2,223	1,500	1,500	163	0	1,663	
4/26/11	6,610	966	0	22.99	7,576	700	1,000	1,350	559	81	1,990	2,060	2,060	163	2,223	1,500	1,500	163	0	1,663	
4/27/11	6,610	966	0	24.91	7,576	700	1,000	1,350	559	81	1,990	2,060	2,060	163	2,223	1,500	1,500	163	0	1,663	
4/28/11	6,610	966	0	26.82	7,576	700	1,000	1,350	559	81	1,990	2,060	2,060	163	2,223	1,500	1,500	163	0	1,663	
4/29/11	6,610	966	0	28.74	7,576	700	1,000	1,350	559	81	1,990	2,060	2,060	163	2,223	1,500	1,500	163	0	1,663	
4/30/11	6,610	966	0	30.66	7,576	700	1,000	1,350	559	81	1,990	2,060	2,060	163	2,223	1,500	1,500	163	0	1,663	
5/1/11	6,610	966	0	32.57	7,576	700	1,000	1,100	559	81	1,740	1,750	1,750	163	1,913	1,500	1,500	163	0	1,663	
5/2/11	6,610	966	0	34.49	7,576	700	1,000	1,100	559	81	1,740	1,750	1,750	163	1,913	1,500	1,500	163	0	1,663	
5/3/11	6,300	966	0	36.40	7,266	700	1,000	1,100	559	81	1,740	1,750	1,750	163	1,913	1,500	1,500	163	0	1,663	
5/4/11	6,050	966	0	38.32	7,016	700	1,000	1,100	559	81	1,740	1,750	1,750	163	1,913	1,500	1,500	163	0	1,663	
5/5/11	6,050	966	0	40.24	7,016	700	1,000	1,100	559	81	1,740	1,750	1,750	163	1,913	1,500	1,500	163	0	1,663	
5/6/11	6,050	966	0	42.15	7,016	700	1,000	1,100	559	81	1,740	1,750	1,750	163	1,913	1,500	1,500	163	0	1,663	
5/7/11	6,050	966	0	44.07	7,016	700	1,000	1,100	559	81	1,740	1,750	1,750	163	1,913	1,500	1,500	163	0	1,663	
5/8/11	6,050	966	0	45.98	7,016	700	1,000	1,100	559	81	1,740	1,750	1,750	163	1,913	1,500	1,500	163	0	1,663	
5/9/11	6,050	966	0	47.90	7,016	700	1,000	1,100	559	81	1,740	1,750	1,750	163	1,913	1,500	1,500	163	0	1,663	
5/10/11	6,050	966	0	49.82	7,016	700	1,000	1,100	559	81	1,740	1,750	1,750	163	1,913	1,500	1,500	163	0	1,663	
5/11/11	6,050	966	0	51.73	7,016	700	1,000	1,100	559	81	1,740	1,750	1,750	163	1,913	1,500	1,500	163	0	1,663	
5/12/11	6,050	966	0	53.65	7,016	700	1,000	1,100	559	81	1,740	1,750	1,750	163	1,913	1,500	1,500	163	0	1,663	
5/13/11	6,050	966	0	55.56	7,016	700	1,000	1,100			1,100	1,750	1,750	163	1,913	1,500	1,500	163	0	1,663	
5/14/11	6,050	966	0	57.48	7,016	700	1,000	1,100			1,100	1,750	1,750		1,750	1,500	1,500			1,500	
5/15/11	6,050	966	0	59.40	7,016	700	1,000	1,100			1,100	1,750	1,750		1,750	1,500	1,500			1,500	
5/16/11	6,050	0	0		6,050	700	1,000	1,100			1,100	1,750	1,750		1,750	1,251	1,251			1,251	
5/17/11	6,050	0	0		6,050	700	1,000	1,100			1,100	1,750	1,750		1,750	1,251	1,251			1,251	
5/18/11	5,801	0	0		5,801	700	1,000	1,100			1,100	1,750	1,750		1,750	1,251	1,251			1,251	
5/19/11	5,801	0	0		5,801	700	1,000	1,100			1,100	1,750	1,750		1,750	1,251	1,251			1,251	
5/20/11	5,801	0	0		5,801	700	1,000	1,100			1,100	1,750	1,750		1,750	1,251	1,251			1,251	
5/21/11	5,801	0	0		5,801	700	1,000	1,100			1,100	1,750	1,750		1,750	1,251	1,251			1,251	
5/22/11	5,801	0	0		5,801	700	1,000	1,100			1,100	1,750	1,750		1,750	1,251	1,251			1,251	
5/23/11	5,801	0	0		5,801	700	1,000	1,100			1,100	1,750	1,750		1,750	1,251	1,251			1,251	
5/24/11	5,801	0	0		5,801	700	1,000	1,100			1,100	1,750	1,750		1,750	1,251	1,251			1,251	
5/25/11	5,801	0	0		5,801	700	1,000	1,100			1,100	1,750	1,750		1,750	1,251	1,251			1,251	
5/26/11	5,801	0	0		5,801	700	1,000	1,100			1,100	1,750	1,750		1,750	1,251	1,251			1,251	
5/27/11	5,801	0	0		5,801	700	1,000	1,100			1,100	1,750	1,750		1,750	1,251	1,251			1,251	
5/28/11	5,801	0	0		5,801	700	1,000	1,100			1,100	1,750	1,750		1,750	1,251	1,251			1,251	
5/29/11	5,801	0	0		5,801	700	1,000	1,100			1,100	1,750	1,750		1,750	1,251	1,251			1,251	
5/30/11	5,801	0	0		5,801	700	1,000	1,100			1,100	1,750	1,750		1,750	1,251	1,251			1,251	
5/31/11	5,801	0	0		5,801	700	1,000	1,100			1,100	1,750	1,750		1,750	1,251	1,251			1,251	
VAMP Period																					
Avg. (cfs):	6,448	966	0		7,414	700	1,000	1,253	559	81	1,893	1,930	1,930	163	2,093	1,565	1,565	163	0	1,728	
Supplemental Water (TAF):		59.40	0.00						34.37	4.98				10.02				10.02	0.00		

VAMP flow operation period

Appendix A, Table 5

2011 VAMP DAILY OPERATION PLAN – MARCH 28, 2011
Target Flow Period: April 15th – May 15th * Flow Target: n/a
Bold Numbers: observed real-time mean daily flows

Date	San Joaquin River near Vernalis							Merced River at Cressey				Tuolumne River below La Grange Dam				Stanislaus R below Goodwin Dam					
	Existing Flow (cfs)	VAMP Supplemental Flow (cfs)	Other Supplemental Flow (cfs)	Cumulative VAMP Supplemental Flow (TAF)	VAMP Flow (cfs)	SJR above Merced R (2day lag) (cfs)	Ungaged Flow above Vernalis (cfs)	Existing Flow (cfs)	MeID VAMP Supplemental Flow (cfs)	SJREC VAMP Supplemental Flow (cfs)	VAMP Flow (3day lag) (cfs)	Existing Flow - base FERC volume (cfs)	Existing Flow - Adjusted FERC Pulse (cfs)	VAMP Supplemental Flow (cfs)	VAMP Flow (2day lag) (cfs)	Existing Flow - Base (cfs)	Existing Flow - reshaped	VAMP Supplemental Flow (cfs)	Other Supplemental Flow (cfs)	VAMP Flow (2day lag) (cfs)	Maintain Priority Flow Level M=Merced T=Tuol. S=Stan.
3/10/11	**9,920**					**745**	**1,624**	**3,642**			3,642	**3,780**	**3,780**		3,780	**210**	**210**			210	
3/11/11	**9,860**					**660**	**1,471**	**3,559**			3,559	**3,660**	**3,660**		3,660	**220**	**220**			220	
3/12/11	**9,750**					**717**	**1,365**	**3,052**			3,052	**3,280**	**3,280**		3,280	**209**	**209**			209	
3/13/11	**9,440**				9,440	**679**	**1,258**	**3,077**			3,077	**2,870**	**2,870**		2,870	**205**	**205**			205	
3/14/11	**8,930**				8,930	**655**	**1,165**	**3,063**			3,063	**2,680**	**2,680**		2,680	**203**	**203**			203	
3/15/11	**8,460**				8,460	**602**	**1,654**	**3,069**			3,069	**2,700**	**2,700**		2,700	**204**	**204**			204	
3/16/11	**8,220**				8,220	**533**	**1,605**	**3,113**			3,113	**2,830**	**2,830**		2,830	**205**	**205**			205	
3/17/11	**8,100**				8,100	**455**	**1,531**	**3,133**			3,133	**3,320**	**3,320**		3,320	**201**	**201**			201	
3/18/11	**8,280**				8,280	**500**	**1,643**	**3,123**			3,123	**3,500**	**3,500**		3,500	**208**	**208**			208	
3/19/11	**8,640**				8,640	**344**	**1,551**	**3,244**			3,244	**4,850**	**4,850**		4,850	**205**	**205**			205	
3/20/11	**9,280**				9,280	**345**	**1,939**	**4,081**			4,081	**5,260**	**5,260**		5,260	**235**	**235**			235	
3/21/11	**11,200**				11,200	**-493**	**2,678**	**5,135**			5,135	**6,380**	**6,380**		6,380	**480**	**480**			480	
3/22/11	**13,600**				13,600	**1,865**	**4,516**	**1,935**			1,935	**7,110**	**7,110**		7,110	**1,305**	**1,305**			1,305	
3/23/11	**15,000**				15,000	**3,655**	**4,552**	**2,474**			2,474	**7,660**	**7,660**		7,660	**1,300**	**1,300**			1,300	
3/24/11	**15,500**				15,500	**5,377**	**85**	**3,774**			3,774	**7,260**	**7,260**		7,260	**1,330**	**1,330**			1,330	
3/25/11	**15,405**				15,405	**7,730**	**855**	**4,774**			4,774	**7,120**	**7,120**		7,120	**1,334**	**1,334**			1,334	
3/26/11	**17,067**				17,067	**9,130**	**626**	**3,916**			3,916	**7,140**	**7,140**		7,140	**1,344**	**1,344**			1,344	
3/27/11	**19,400**				19,400	**11,200**	**-558**	**3,998**			3,998	**7,510**	**7,510**		7,510	**1,336**	**1,336**			1,336	
3/28/11	23,388				23,388	12,400	1,000	4,500			4,500	6,000	6,000		6,000	1,400	1,400			1,400	
3/29/11	24,962				24,962	12,800	1,000	4,500			4,500	6,000	6,000		6,000	1,400	1,400			1,400	
3/30/11	24,798				24,798	13,300	1,000	4,500			4,500	6,000	6,000		6,000	1,400	1,400			1,400	
3/31/11	25,700				25,700	13,100	1,000	4,500			4,500	6,000	6,000		6,000	1,400	1,400			1,400	
4/1/11	26,200				26,200	12,900	1,000	4,500			4,500	6,000	6,000		6,000	1,400	1,400			1,400	
4/2/11	26,000				26,000	12,700	1,000	4,500			4,500	6,000	6,000		6,000	1,400	1,400			1,400	
4/3/11	25,800				25,800	12,500	1,000	4,500			4,500	6,000	6,000		6,000	1,400	1,400			1,400	
4/4/11	25,600				25,600	12,300	1,000	4,500			4,500	6,000	6,000		6,000	1,400	1,400			1,400	
4/5/11	25,400				25,400	12,100	1,000	4,500			4,500	6,000	6,000		6,000	1,400	1,400			1,400	
4/6/11	25,200				25,200	11,900	1,000	4,500			4,500	6,000	6,000		6,000	1,400	1,400			1,400	
4/7/11	25,000				25,000	11,700	1,000	4,500			4,500	6,000	6,000		6,000	1,400	1,400			1,400	
4/8/11	24,800				24,800	11,500	1,000	4,500			4,500	6,000	6,000		6,000	1,400	1,400			1,400	
4/9/11	24,600				24,600	11,300	1,000	4,500			4,500	6,000	6,000		6,000	1,400	1,400			1,400	
4/10/11	24,400				24,400	11,100	1,000	4,500			4,500	6,000	6,000		6,000	1,400	1,400			1,400	
4/11/11	24,200				24,200	10,900	1,000	4,500			4,500	6,000	6,000		6,000	1,400	1,400			1,400	
4/12/11	24,000				24,000	10,700	1,000	4,500	0	0	4,500	6,000	6,000		6,000	1,400	1,400			1,400	
4/13/11	23,800				23,800	10,500	1,000	4,500	0	0	4,500	6,000	6,000	0	6,000	1,400	1,400	0	0	1,400	
4/14/11	23,600				23,600	10,300	1,000	4,500	0	0	4,500	6,000	6,000	0	6,000	1,400	1,400	0	0	1,400	
4/15/11	23,400	0	0	0.00	23,400	10,100	1,000	4,500	0	0	4,500	6,000	6,000	0	6,000	1,400	1,400	0	0	1,400	
4/16/11	23,200	0	0	0.00	23,200	9,900	1,000	4,500	0	0	4,500	6,000	6,000	0	6,000	1,400	1,400	0	0	1,400	
4/17/11	23,000	0	0	0.00	23,000	9,700	1,000	4,500	0	0	4,500	6,000	6,000	0	6,000	1,400	1,400	0	0	1,400	
4/18/11	22,800	0	0	0.00	22,800	9,500	1,000	4,500	0	0	4,500	6,000	6,000	0	6,000	1,400	1,400	0	0	1,400	
4/19/11	22,600	0	0	0.00	22,600	9,300	1,000	4,500	0	0	4,500	6,000	6,000	0	6,000	1,400	1,400	0	0	1,400	
4/20/11	22,400	0	0	0.00	22,400	9,100	1,000	4,500	0	0	4,500	6,000	6,000	0	6,000	1,400	1,400	0	0	1,400	
4/21/11	22,200	0	0	0.00	22,200	8,900	1,000	4,500	0	0	4,500	6,000	6,000	0	6,000	1,400	1,400	0	0	1,400	
4/22/11	22,000	0	0	0.00	22,000	8,700	1,000	4,500	0	0	4,500	6,000	6,000	0	6,000	1,400	1,400	0	0	1,400	
4/23/11	21,800	0	0	0.00	21,800	8,500	1,000	4,500	0	0	4,500	6,000	6,000	0	6,000	1,400	1,400	0	0	1,400	
4/24/11	21,600	0	0	0.00	21,600	8,300	1,000	4,500	0	0	4,500	6,000	6,000	0	6,000	1,400	1,400	0	0	1,400	
4/25/11	21,400	0	0	0.00	21,400	8,100	1,000	4,500	0	0	4,500	6,000	6,000	0	6,000	1,400	1,400	0	0	1,400	
4/26/11	21,200	0	0	0.00	21,200	7,900	1,000	4,500	0	0	4,500	6,000	6,000	0	6,000	1,400	1,400	0	0	1,400	
4/27/11	21,000	0	0	0.00	21,000	7,700	1,000	4,500	0	0	4,500	6,000	6,000	0	6,000	1,400	1,400	0	0	1,400	
4/28/11	20,800	0	0	0.00	20,800	7,500	1,000	4,500	0	0	4,500	6,000	6,000	0	6,000	1,400	1,400	0	0	1,400	
4/29/11	20,600	0	0	0.00	20,600	7,300	1,000	4,500	0	0	4,500	6,000	6,000	0	6,000	1,400	1,400	0	0	1,400	
4/30/11	20,400	0	0	0.00	20,400	7,100	1,000	4,500	0	0	4,500	6,000	6,000	0	6,000	1,400	1,400	0	0	1,400	
5/1/11	20,200	0	0	0.00	20,200	6,900	1,000	4,500	0	0	4,500	6,000	6,000	0	6,000	1,500	1,500	0	0	1,500	
5/2/11	20,000	0	0	0.00	20,000	6,700	1,000	4,500	0	0	4,500	6,000	6,000	0	6,000	1,500	1,500	0	0	1,500	
5/3/11	19,900	0	0	0.00	19,900	6,500	1,000	4,500	0	0	4,500	6,000	6,000	0	6,000	1,500	1,500	0	0	1,500	
5/4/11	19,700	0	0	0.00	19,700	6,300	1,000	4,500	0	0	4,500	6,000	6,000	0	6,000	1,500	1,500	0	0	1,500	
5/5/11	19,500	0	0	0.00	19,500	6,100	1,000	4,500	0	0	4,500	6,000	6,000	0	6,000	1,500	1,500	0	0	1,500	
5/6/11	19,300	0	0	0.00	19,300	5,900	1,000	4,500	0	0	4,500	6,000	6,000	0	6,000	1,500	1,500	0	0	1,500	
5/7/11	19,100	0	0	0.00	19,100	5,700	1,000	4,500	0	0	4,500	6,000	6,000	0	6,000	1,500	1,500	0	0	1,500	
5/8/11	18,900	0	0	0.00	18,900	5,500	1,000	4,500	0	0	4,500	6,000	6,000	0	6,000	1,500	1,500	0	0	1,500	
5/9/11	18,700	0	0	0.00	18,700	5,300	1,000	4,500	0	0	4,500	6,000	6,000	0	6,000	1,500	1,500	0	0	1,500	
5/10/11	18,500	0	0	0.00	18,500	5,100	1,000	4,500	0	0	4,500	6,000	6,000	0	6,000	1,500	1,500	0	0	1,500	
5/11/11	18,300	0	0	0.00	18,300	4,900	1,000	4,500	0	0	4,500	6,000	6,000	0	6,000	1,500	1,500	0	0	1,500	
5/12/11	18,100	0	0	0.00	18,100	4,700	1,000	4,500	0	0	4,500	6,000	6,000	0	6,000	1,500	1,500	0	0	1,500	
5/13/11	17,900	0	0	0.00	17,900	4,500	1,000	4,500			4,500	6,000	6,000	0	6,000	1,500	1,500	0	0	1,500	
5/14/11	17,700	0	0	0.00	17,700	4,300	1,000	4,500			4,500	6,000	6,000		6,000	1,500	1,500			1,500	
5/15/11	17,500	0	0	0.00	17,500	4,100	1,000	4,500			4,500	6,000	6,000		6,000	1,500	1,500			1,500	
5/16/11	17,300	0	0		17,300	3,900	1,000	4,500			4,500	6,000	6,000		6,000	1,500	1,500			1,500	
5/17/11	17,100	0	0		17,100	3,700	1,000	4,500			4,500	6,000	6,000		6,000	1,500	1,500			1,500	
5/18/11	16,900	0	0		16,900	3,500	1,000	4,500			4,500	6,000	6,000		6,000	1,500	1,500			1,500	
5/19/11	16,700	0	0		16,700	3,300	1,000	4,500			4,500	6,000	6,000		6,000	1,500	1,500			1,500	
5/20/11	16,500	0	0		16,500	3,100	1,000	4,500			4,500	6,000	6,000		6,000	1,500	1,500			1,500	
5/21/11	16,300	0	0		16,300	2,900	1,000	4,500			4,500	6,000	6,000		6,000	1,500	1,500			1,500	
5/22/11	16,100	0	0		16,100	2,700	1,000	4,500			4,500	6,000	6,000		6,000	1,500	1,500			1,500	
5/23/11	15,900	0	0		15,900	2,500	1,000	4,500			4,500	6,000	6,000		6,000	1,500	1,500			1,500	
5/24/11	15,700	0	0		15,700	2,300	1,000	4,500			4,500	6,000	6,000		6,000	1,500	1,500			1,500	
5/25/11	15,500	0	0		15,500	2,100	1,000	4,500			4,500	6,000	6,000		6,000	1,500	1,500			1,500	
5/26/11	15,300	0	0		15,300	1,900	1,000	4,500			4,500	6,000	6,000		6,000	1,500	1,500			1,500	
5/27/11	15,100	0	0		15,100	1,700	1,000	4,500			4,500	6,000	6,000		6,000	1,500	1,500			1,500	
5/28/11	14,900	0	0		14,900	1,500	1,000	4,500			4,500	6,000	6,000		6,000	1,500	1,500			1,500	
5/29/11	14,700	0	0		14,700	1,300	1,000	4,500			4,500	6,000	6,000		6,000	1,500	1,500			1,500	
5/30/11	14,500	0	0		14,500	1,100	1,000	4,500			4,500	6,000	6,000		6,000	1,500	1,500			1,500	
5/31/11	14,300	0	0		14,300	900	1,000	4,500			4,500	6,000	6,000		6,000	1,500	1,500			1,500	
								VAMP Period													
Avg. (cfs):	20,442	0	0		20,442	7,500	1,000	4,500	0	0	4,500	6,000	6,000	0	6,000	1,442	1,442	0	0	1,442	
Supplemental Water (TAF):		0.00	0.00						0.00	0.00				0.00				0.00	0.00		

VAMP flow operation period

Appendix A, Table 6

2011 VAMP DAILY OPERATION PLAN – APRIL 15, 2011

Target Flow Period: May 1st – May 31st * Flow Target: n/a

Bold Numbers: observed real-time mean daily flows

Date	San Joaquin River near Vernalis							Merced River at Cressey				Tuolumne River below La Grange Dam				Stanislaus R below Goodwin Dam						
	Existing Flow (cfs)	VAMP Supplemental Flow (cfs)	Other Supplemental Flow (cfs)	Cumulative VAMP Supplemental Flow (TAF)	VAMP Flow (cfs)	SJR above Merced R (2day lag) (cfs)	Ungaged Flow above Vernalis (cfs)	Existing Flow (cfs)	MeID VAMP Supplemental Flow (cfs)	SJREC VAMP Supplemental Flow (cfs)	VAMP Flow (3day lag) (cfs)	Existing Flow - base FERC volume (cfs)	Existing Flow - Adjusted FERC Pulse (cfs)	VAMP Supplemental Flow (cfs)	VAMP Flow (2day lag) (cfs)	Existing Flow - Base (cfs)	Existing Flow - reshaped	VAMP Supplemental Flow (cfs)	Other Supplemental Flow (cfs)	VAMP Flow (2day lag) (cfs)	Maintain Priority Flow Level M=Merced T=Tuol. S=Stan.	Combined Delta Exports
3/10/11	9,920					1,050	1,240	3,642			3,642	3,780	3,780		3,780	210	210			210		7,646
3/11/11	9,860					985	1,107	3,559			3,559	3,660	3,660		3,660	220	220			220		7,660
3/12/11	9,750					905	1,080	3,052			3,052	3,280	3,280		3,280	209	209			209		7,682
3/13/11	9,440				9,450	828	943	3,077			3,077	2,870	2,870		2,870	205	205			205		8,292
3/14/11	8,930				8,940	784	987	3,063			3,063	2,680	2,680		2,680	203	203			203		7,963
3/15/11	8,470				8,470	749	1,515	3,069			3,069	2,700	2,700		2,700	204	204			204		7,019
3/16/11	8,230				8,230	730	1,486	3,113			3,113	2,830	2,830		2,830	205	205			205		7,025
3/17/11	8,110				8,110	708	1,394	3,133			3,133	3,320	3,320		3,320	201	201			201		7,011
3/18/11	8,300				8,300	710	1,466	3,123			3,123	3,500	3,500		3,500	208	208			208		7,030
3/19/11	8,660				8,660	742	1,318	3,244			3,244	4,850	4,850		4,850	205	205			205		7,024
3/20/11	9,300				9,300	852	1,749	4,081			4,081	5,260	5,260		5,260	235	235			235		7,033
3/21/11	11,300				11,300	1,150	2,380	5,135			5,135	6,380	6,380		6,380	480	480			480		7,056
3/22/11	13,600				13,600	2,880	4,009	1,935			1,935	7,110	7,110		7,110	1,305	1,305			1,305		7,999
3/23/11	15,000				15,000	4,710	2,909	2,474			2,474	7,660	7,660		7,660	1,300	1,300			1,300		5,376
3/24/11	15,600				15,600	6,610	-830	3,774			3,774	7,260	7,260		7,260	1,330	1,330			1,330		775
3/25/11	16,400				16,400	8,020	795	4,774			4,774	7,120	7,120		7,120	1,334	1,334			1,334		408
3/26/11	18,200				18,200	9,600	526	3,916			3,916	7,140	7,140		7,140	1,344	1,344			1,344		956
3/27/11	19,400				19,400	11,900	-848	3,998			3,998	7,510	7,510		7,510	1,336	1,336			1,336		3,246
3/28/11	21,100				21,100	13,800	-1,758	4,216			4,216	7,780	7,780		7,780	1,334	1,334			1,334		4,077
3/29/11	23,000				23,000	14,800	-1,662	4,287			4,287	8,110	8,110		8,110	1,328	1,328			1,328		4,310
3/30/11	25,200				25,200	14,900	-1,712	4,137			4,137	8,320	8,320		8,320	1,328	1,328			1,328		1,565
3/31/11	27,500				27,500	14,700	-954	4,121			4,121	8,310	8,310		8,310	1,323	1,323			1,323		5,036
4/1/11	28,600				28,600	13,700	-235	4,105			4,105	8,330	8,330		8,330	1,301	1,301			1,301		5,420
4/2/11	28,700				28,700	12,500	230	4,459			4,459	8,360	8,360		8,360	1,307	1,307			1,307		5,208
4/3/11	28,700				28,700	12,400	1,248	4,624			4,624	8,330	8,330		8,330	1,307	1,307			1,307		5,508
4/4/11	28,200				28,200	12,300	1,928	4,612			4,612	8,310	8,310		8,310	1,310	1,310			1,310		5,701
4/5/11	27,800				27,800	12,200	1,304	4,865			4,865	8,330	8,330		8,330	1,726	1,726			1,726		5,699
4/6/11	27,700				27,700	12,000	1,156	5,036			5,036	8,330	8,330		8,330	2,000	2,000			2,000		5,751
4/7/11	27,900				27,900	11,400	1,032	5,296			5,296	7,570	7,570		7,570	2,002	2,002			2,002		6,000
4/8/11	28,000				28,000	10,900	805	5,410			5,410	7,720	7,720		7,720	2,028	2,028			2,028		5,618
4/9/11	27,600				27,600	10,600	1,592	5,558			5,558	8,310	8,310		8,310	2,026	2,026			2,026		5,847
4/10/11	27,300				27,300	10,300	1,356	5,614			5,614	8,320	8,320		8,320	2,022	2,022			2,022		6,834
4/11/11	27,300				27,300	10,200	954	5,620			5,620	8,320	8,320		8,320	2,043	2,043			2,043		6,768
4/12/11	27,200				27,200	9,890	1,000	5,615			5,615	8,290	8,290		8,290	2,655	2,655			2,655		6,322
4/13/11	27,000				27,000	9,680	823	5,605			5,605	8,330	8,330		8,330	3,066	3,066			3,066		6,330
4/14/11	27,100				27,100	9,490	645	5,585			5,585	8,340	8,340		8,340	3,113	3,113			3,113		5,383
4/15/11	27,191				27,191	9,410	500	5,000			5,000	8,300	8,300		8,300	3,000	3,000			3,000		
4/16/11	27,048				27,048	9,330	500	5,000			5,000	8,060	8,060		8,060	3,000	3,000			3,000		
4/17/11	26,795				26,795	9,250	500	5,000			5,000	7,820	7,820		7,820	3,000	3,000			3,000		
4/18/11	25,890				25,890	9,170	500	5,000			5,000	7,580	7,580		7,580	3,000	3,000			3,000		
4/19/11	25,570				25,570	9,090	500	5,000			5,000	7,340	7,340		7,340	3,000	3,000			3,000		
4/20/11	25,250				25,250	9,010	500	5,000			5,000	7,100	7,100		7,100	3,000	3,000			3,000		
4/21/11	24,930				24,930	8,930	500	5,000			5,000	6,860	6,860		6,860	3,000	3,000			3,000		
4/22/11	24,610				24,610	8,850	500	5,000			5,000	6,620	6,620		6,620	3,000	3,000			3,000		
4/23/11	24,290				24,290	8,770	500	5,000			5,000	6,380	6,380		6,380	3,000	3,000			3,000		
4/24/11	23,970				23,970	8,690	500	5,000			5,000	6,140	6,140		6,140	3,000	3,000			3,000		
4/25/11	23,650				23,650	8,610	500	5,000			5,000	5,900	5,900		5,900	3,000	3,000			3,000		
4/26/11	23,330				23,330	8,530	500	5,000			5,000	5,660	5,660		5,660	3,000	3,000			3,000		
4/27/11	23,010				23,010	8,450	500	5,000			5,000	5,420	5,420		5,420	3,000	3,000			3,000		
4/28/11	22,690				22,690	8,370	500	3,500	0	0	3,500	5,180	5,180		5,180	3,000	3,000			3,000		
4/29/11	22,370				22,370	8,290	500	3,500	0	0	3,500	5,000	5,000	0	5,000	2,000	2,000	0	0	2,000		
4/30/11	22,050				22,050	8,210	500	3,500	0	0	3,500	5,000	5,000	0	5,000	2,000	2,000	0	0	2,000		
5/1/11	19,290	0	0	0.00	19,290	8,130	500	3,500	0	0	3,500	5,000	5,000	0	5,000	2,000	2,000	0	0	2,000		
5/2/11	19,210	0	0	0.00	19,210	8,050	500	3,500	0	0	3,500	5,000	5,000	0	5,000	2,000	2,000	0	0	2,000		
5/3/11	19,130	0	0	0.00	19,130	7,970	500	3,500	0	0	3,500	5,000	5,000	0	5,000	2,000	2,000	0	0	2,000		
5/4/11	19,050	0	0	0.00	19,050	7,890	500	3,500	0	0	3,500	5,000	5,000	0	5,000	2,000	2,000	0	0	2,000		
5/5/11	18,970	0	0	0.00	18,970	7,810	500	3,500	0	0	3,500	5,000	5,000	0	5,000	2,000	2,000	0	0	2,000		
5/6/11	18,890	0	0	0.00	18,890	7,730	500	3,500	0	0	3,500	5,000	5,000	0	5,000	2,000	2,000	0	0	2,000		
5/7/11	18,810	0	0	0.00	18,810	7,650	500	3,500	0	0	3,500	5,000	5,000	0	5,000	2,000	2,000	0	0	2,000		
5/8/11	18,730	0	0	0.00	18,730	7,570	500	3,500	0	0	3,500	5,000	5,000	0	5,000	2,000	2,000	0	0	2,000		
5/9/11	18,650	0	0	0.00	18,650	7,490	500	3,500	0	0	3,500	5,000	5,000	0	5,000	2,000	2,000	0	0	2,000		
5/10/11	18,570	0	0	0.00	18,570	7,410	500	3,500	0	0	3,500	5,000	5,000	0	5,000	2,000	2,000	0	0	2,000		
5/11/11	18,490	0	0	0.00	18,490	7,330	500	3,500	0	0	3,500	5,000	5,000	0	5,000	2,000	2,000	0	0	2,000		
5/12/11	18,410	0	0	0.00	18,410	7,250	500	3,500	0	0	3,500	5,000	5,000	0	5,000	2,000	2,000	0	0	2,000		
5/13/11	18,330	0	0	0.00	18,330	7,170	500	3,500	0	0	3,500	5,000	5,000	0	5,000	2,000	2,000	0	0	2,000		
5/14/11	18,250	0	0	0.00	18,250	7,090	500	3,500	0	0	3,500	5,000	5,000	0	5,000	2,000	2,000	0	0	2,000		
5/15/11	18,170	0	0	0.00	18,170	7,010	500	3,500	0	0	3,500	5,000	5,000	0	5,000	2,000	2,000	0	0	2,000		
5/16/11	18,090	0	0	0.00	18,090	6,930	500	3,500	0	0	3,500	5,000	5,000	0	5,000	2,000	2,000	0	0	2,000		
5/17/11	18,010	0	0	0.00	18,010	6,850	500	3,500	0	0	3,500	5,000	5,000	0	5,000	2,000	2,000	0	0	2,000		
5/18/11	17,930	0	0	0.00	17,930	6,770	500	3,500	0	0	3,500	5,000	5,000	0	5,000	2,000	2,000	0	0	2,000		
5/19/11	17,850	0	0	0.00	17,850	6,690	500	3,500	0	0	3,500	5,000	5,000	0	5,000	2,000	2,000	0	0	2,000		
5/20/11	17,770	0	0	0.00	17,770	6,610	500	3,500	0	0	3,500	5,000	5,000	0	5,000	2,000	2,000	0	0	2,000		
5/21/11	17,690	0	0	0.00	17,690	6,530	500	3,500	0	0	3,500	5,000	5,000	0	5,000	2,000	2,000	0	0	2,000		
5/22/11	17,610	0	0	0.00	17,610	6,450	500	3,500	0	0	3,500	5,000	5,000	0	5,000	2,000	2,000	0	0	2,000		
5/23/11	17,530	0	0	0.00	17,530	6,370	500	3,500	0	0	3,500	5,000	5,000	0	5,000	2,000	2,000	0	0	2,000		
5/24/11	17,450	0	0	0.00	17,450	6,290	500	3,500	0	0	3,500	5,000	5,000	0	5,000	2,000	2,000	0	0	2,000		
5/25/11	17,370	0	0	0.00	17,370	6,210	500	3,500	0	0	3,500	5,000	5,000	0	5,000	2,000	2,000	0	0	2,000		
5/26/11	17,290	0	0	0.00	17,290	6,130	500	3,500	0	0	3,500	5,000	5,000	0	5,000	2,000	2,000	0	0	2,000		
5/27/11	17,210	0	0	0.00	17,210	6,050	500	3,500	0	0	3,500	5,000	5,000	0	5,000	2,000	2,000	0	0	2,000		
5/28/11	17,130	0	0	0.00	17,130	5,970	500	3,500	0	0	3,500	5,000	5,000	0	5,000	2,000	2,000	0	0	2,000		
5/29/11	17,050	0	0	0.00	17,050	5,890	500	3,500			3,500	5,000	5,000	0	5,000	2,000	2,000	0	0	2,000		
5/30/11	16,970	0	0	0.00	16,970	5,810	500	3,500			3,500	5,000	5,000		5,000	2,000	2,000			2,000		
5/31/11	16,890	0	0	0.00	16,890	5,730	500	3,500			3,500	5,000	5,000		5,000	2,000	2,000			2,000		
											VAMP Period											
Avg. (cfs):	18,090	0	0		18,090	7,090	500	3,500	0	0	3,500	5,000	5,000	0	5,000	2,000	2,000	0	0	2,000		
Supplemental Water (TAF):		0.00	0.00						0.00	0.00				0.00				0.00	0.00			

VAMP flow operation period

Appendix A, Table 7
2011 VAMP DAILY OPERATION PLAN – APRIL 20, 2011
Target Flow Period: May 1st – May 31st * Flow Target: n/a
Bold Numbers: observed real-time mean daily flows

Date	San Joaquin River near Vernalis: 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)	Merced River at Cressey: Existing Flow (cfs)	MeID VAMP Supple-mental Flow (cfs)	SJREC VAMP Supple-mental Flow (cfs)	VAMP Flow (3day lag) (cfs)	Tuolumne River below La Grange Dam: Existing Flow - base FERC volume (cfs)	Existing Flow - Adjusted FERC Pulse (cfs)	VAMP Supple-mental Flow (cfs)	VAMP Flow (2day lag) (cfs)	Stanislaus R below Goodwin Dam: 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.	Combined Delta Exports
3/10/11	**9,920**					**1,050**	**1,240**	**3,642**			3,642	**3,780**	**3,780**		3,780	**210**	**210**			210		**7,646**
3/11/11	**9,860**					**985**	**1,107**	**3,559**			3,559	**3,660**	**3,660**		3,660	**220**	**220**			220		**7,660**
3/12/11	**9,750**					**905**	**1,080**	**3,052**			3,052	**3,280**	**3,280**		3,280	**209**	**209**			209		**7,682**
3/13/11	**9,440**				9,450	**828**	**943**	**3,077**			3,077	**2,870**	**2,870**		2,870	**205**	**205**			205		**8,292**
3/14/11	**8,930**				8,940	**784**	**987**	**3,063**			3,063	**2,680**	**2,680**		2,680	**203**	**203**			203		**7,963**
3/15/11	**8,470**				8,470	**749**	**1,515**	**3,069**			3,069	**2,700**	**2,700**		2,700	**204**	**204**			204		**7,019**
3/16/11	**8,230**				8,230	**730**	**1,486**	**3,113**			3,113	**2,830**	**2,830**		2,830	**205**	**205**			205		**7,025**
3/17/11	**8,110**				8,110	**708**	**1,394**	**3,133**			3,133	**3,320**	**3,320**		3,320	**201**	**201**			201		**7,011**
3/18/11	**8,300**				8,300	**710**	**1,466**	**3,123**			3,123	**3,500**	**3,500**		3,500	**208**	**208**			208		**7,030**
3/19/11	**8,660**				8,660	**742**	**1,318**	**3,244**			3,244	**4,850**	**4,850**		4,850	**205**	**205**			205		**7,024**
3/20/11	**9,300**				9,300	**852**	**1,749**	**4,081**			4,081	**5,260**	**5,260**		5,260	**235**	**235**			235		**7,033**
3/21/11	**11,300**				11,300	**1,150**	**2,380**	**5,135**			5,135	**6,380**	**6,380**		6,380	**480**	**480**			480		**7,056**
3/22/11	**13,600**				13,600	**2,880**	**4,009**	**1,935**			1,935	**7,110**	**7,110**		7,110	**1,305**	**1,305**			1,305		**7,999**
3/23/11	**15,000**				15,000	**4,710**	**2,909**	**2,474**			2,474	**7,660**	**7,660**		7,660	**1,300**	**1,300**			1,300		**5,376**
3/24/11	**15,600**				15,600	**6,610**	**-830**	**3,774**			3,774	**7,260**	**7,260**		7,260	**1,330**	**1,330**			1,330		**775**
3/25/11	**16,400**				16,400	**8,020**	**795**	**4,774**			4,774	**7,120**	**7,120**		7,120	**1,334**	**1,334**			1,334		**408**
3/26/11	**18,200**				18,200	**9,600**	**526**	**3,916**			3,916	**7,140**	**7,140**		7,140	**1,344**	**1,344**			1,344		**956**
3/27/11	**19,400**				19,400	**11,900**	**-848**	**3,998**			3,998	**7,510**	**7,510**		7,510	**1,336**	**1,336**			1,336		**3,246**
3/28/11	**21,100**				21,100	**13,800**	**-1,758**	**4,216**			4,216	**7,780**	**7,780**		7,780	**1,334**	**1,334**			1,334		**4,077**
3/29/11	**23,000**				23,000	**14,800**	**-1,662**	**4,287**			4,287	**8,110**	**8,110**		8,110	**1,328**	**1,328**			1,328		**4,310**
3/30/11	**25,200**				25,200	**14,900**	**-1,712**	**4,137**			4,137	**8,320**	**8,320**		8,320	**1,328**	**1,328**			1,328		**1,565**
3/31/11	**27,500**				27,500	**14,700**	**-954**	**4,121**			4,121	**8,310**	**8,310**		8,310	**1,323**	**1,323**			1,323		**5,036**
4/1/11	**28,600**				28,600	**13,700**	**-235**	**4,105**			4,105	**8,330**	**8,330**		8,330	**1,301**	**1,301**			1,301		**5,420**
4/2/11	**28,700**				28,700	**12,500**	**230**	**4,459**			4,459	**8,360**	**8,360**		8,360	**1,307**	**1,307**			1,307		**5,208**
4/3/11	**28,700**				28,700	**12,400**	**1,248**	**4,624**			4,624	**8,330**	**8,330**		8,330	**1,307**	**1,307**			1,307		**5,508**
4/4/11	**28,200**				28,200	**12,300**	**1,928**	**4,612**			4,612	**8,310**	**8,310**		8,310	**1,310**	**1,310**			1,310		**5,701**
4/5/11	**27,800**				27,800	**12,200**	**1,304**	**4,865**			4,865	**8,330**	**8,330**		8,330	**1,726**	**1,726**			1,726		**5,699**
4/6/11	**27,700**				27,700	**12,000**	**1,156**	**5,036**			5,036	**8,330**	**8,330**		8,330	**2,000**	**2,000**			2,000		**5,751**
4/7/11	**27,900**				27,900	**11,400**	**1,032**	**5,296**			5,296	**7,570**	**7,570**		7,570	**2,002**	**2,002**			2,002		**6,000**
4/8/11	**28,000**				28,000	**10,900**	**805**	**5,410**			5,410	**7,720**	**7,720**		7,720	**2,028**	**2,028**			2,028		**5,618**
4/9/11	**27,600**				27,600	**10,600**	**1,592**	**5,558**			5,558	**8,310**	**8,310**		8,310	**2,026**	**2,026**			2,026		**5,847**
4/10/11	**27,300**				27,300	**10,300**	**1,356**	**5,614**			5,614	**8,320**	**8,320**		8,320	**2,022**	**2,022**			2,022		**6,834**
4/11/11	**27,300**				27,300	**10,200**	**954**	**5,620**			5,620	**8,320**	**8,320**		8,320	**2,043**	**2,043**			2,043		**6,768**
4/12/11	**27,200**				27,200	**9,890**	**1,000**	**5,615**			5,615	**8,290**	**8,290**		8,290	**2,655**	**2,655**			2,655		**6,322**
4/13/11	**27,000**				27,000	**9,680**	**823**	**5,605**			5,605	**8,330**	**8,330**		8,330	**3,066**	**3,066**			3,066		**6,330**
4/14/11	**27,100**				27,100	**9,490**	**645**	**5,585**			5,585	**8,340**	**8,340**		8,340	**3,113**	**3,113**			3,113		**5,383**
4/15/11	**27,200**				27,200	**9,150**	**509**	**5,066**			5,066	**8,310**	**8,310**		8,310	**3,061**	**3,061**			3,061		**5,323**
4/16/11	**27,100**				27,100	**8,930**	**552**	**3,456**			3,456	**8,310**	**8,310**		8,310	**3,017**	**3,017**			3,017		**5,335**
4/17/11	**27,100**				27,100	**8,630**	**994**	**3,062**			3,062	**8,330**	**8,330**		8,330	**3,018**	**3,018**			3,018		**5,980**
4/18/11	**26,800**				26,800	**8,340**	**1,477**	**3,026**			3,026	**8,150**	**8,150**		8,150	**3,048**	**3,048**			3,048		**6,255**
4/19/11	**26,300**				26,300	**8,200**	**2,866**	**2,980**			2,980	**7,700**	**7,700**		7,700	**3,019**	**3,019**			3,019		**6,246**
4/20/11	25,600				25,600	8,150	3,000	3,500			3,500	7,430	7,430		7,430	3,000	3,000			3,000		
4/21/11	24,945				24,945	8,100	3,000	3,500			3,500	7,160	7,160		7,160	3,000	3,000			3,000		
4/22/11	24,160				24,160	8,050	2,600	3,500			3,500	6,890	6,890		6,890	3,000	3,000			3,000		
4/23/11	23,460				23,460	8,000	1,700	3,500			3,500	6,620	6,620		6,620	3,000	3,000			3,000		
4/24/11	22,840				22,840	7,950	1,400	3,500			3,500	6,350	6,350		6,350	3,000	3,000			3,000		
4/25/11	22,120				22,120	7,900	1,000	3,500			3,500	6,080	6,080		6,080	3,000	3,000			3,000		
4/26/11	21,600				21,600	7,850	800	3,500			3,500	5,810	5,810		5,810	3,000	3,000			3,000		
4/27/11	21,080				21,080	7,800	600	3,500			3,500	5,540	5,540		5,540	3,000	3,000			3,000		
4/28/11	20,660				20,660	7,750	500	3,300	0	0	3,300	5,270	5,270		5,270	3,000	3,000			3,000		
4/29/11	20,340				20,340	7,700	500	3,300	0	0	3,300	5,000	5,000	0	5,000	2,000	2,000	0	0	2,000		
4/30/11	20,020				20,020	7,650	500	3,300	0	0	3,300	5,000	5,000	0	5,000	2,000	2,000	0	0	2,000		
5/1/11	18,500	0	0	0.00	18,500	7,600	500	3,300	0	0	3,300	5,000	5,000	0	5,000	2,000	2,000	0	0	2,000		
5/2/11	18,450	0	0	0.00	18,450	7,550	500	3,300	0	0	3,300	5,000	5,000	0	5,000	2,000	2,000	0	0	2,000		
5/3/11	18,400	0	0	0.00	18,400	7,500	500	3,300	0	0	3,300	5,000	5,000	0	5,000	2,000	2,000	0	0	2,000		
5/4/11	18,350	0	0	0.00	18,350	7,450	500	3,300	0	0	3,300	5,000	5,000	0	5,000	2,000	2,000	0	0	2,000		
5/5/11	18,300	0	0	0.00	18,300	7,400	500	3,300	0	0	3,300	5,000	5,000	0	5,000	2,000	2,000	0	0	2,000		
5/6/11	18,250	0	0	0.00	18,250	7,350	500	3,300	0	0	3,300	5,000	5,000	0	5,000	2,000	2,000	0	0	2,000		
5/7/11	18,200	0	0	0.00	18,200	7,300	500	3,300	0	0	3,300	5,000	5,000	0	5,000	2,000	2,000	0	0	2,000		
5/8/11	18,150	0	0	0.00	18,150	7,250	500	3,300	0	0	3,300	5,000	5,000	0	5,000	2,000	2,000	0	0	2,000		
5/9/11	18,100	0	0	0.00	18,100	7,200	500	3,300	0	0	3,300	5,000	5,000	0	5,000	2,000	2,000	0	0	2,000		
5/10/11	18,050	0	0	0.00	18,050	7,150	500	3,300	0	0	3,300	5,000	5,000	0	5,000	2,000	2,000	0	0	2,000		
5/11/11	18,000	0	0	0.00	18,000	7,100	500	3,300	0	0	3,300	5,000	5,000	0	5,000	2,000	2,000	0	0	2,000		
5/12/11	17,950	0	0	0.00	17,950	7,050	500	3,300	0	0	3,300	5,000	5,000	0	5,000	2,000	2,000	0	0	2,000		
5/13/11	17,900	0	0	0.00	17,900	7,000	500	3,300	0	0	3,300	5,000	5,000	0	5,000	2,000	2,000	0	0	2,000		
5/14/11	17,850	0	0	0.00	17,850	6,950	500	3,300	0	0	3,300	5,000	5,000	0	5,000	2,000	2,000	0	0	2,000		
5/15/11	17,800	0	0	0.00	17,800	6,900	500	3,300	0	0	3,300	5,000	5,000	0	5,000	2,000	2,000	0	0	2,000		
5/16/11	17,750	0	0	0.00	17,750	6,850	500	3,300	0	0	3,300	5,000	5,000	0	5,000	2,000	2,000	0	0	2,000		
5/17/11	17,700	0	0	0.00	17,700	6,800	500	3,300	0	0	3,300	5,000	5,000	0	5,000	2,000	2,000	0	0	2,000		
5/18/11	17,650	0	0	0.00	17,650	6,750	500	3,300	0	0	3,300	5,000	5,000	0	5,000	2,000	2,000	0	0	2,000		
5/19/11	17,600	0	0	0.00	17,600	6,700	500	3,300	0	0	3,300	5,000	5,000	0	5,000	2,000	2,000	0	0	2,000		
5/20/11	17,550	0	0	0.00	17,550	6,650	500	3,300	0	0	3,300	5,000	5,000	0	5,000	2,000	2,000	0	0	2,000		
5/21/11	17,500	0	0	0.00	17,500	6,600	500	3,300	0	0	3,300	5,000	5,000	0	5,000	2,000	2,000	0	0	2,000		
5/22/11	17,450	0	0	0.00	17,450	6,550	500	3,300	0	0	3,300	5,000	5,000	0	5,000	2,000	2,000	0	0	2,000		
5/23/11	17,400	0	0	0.00	17,400	6,500	500	3,300	0	0	3,300	5,000	5,000	0	5,000	2,000	2,000	0	0	2,000		
5/24/11	17,350	0	0	0.00	17,350	6,450	500	3,300	0	0	3,300	5,000	5,000	0	5,000	2,000	2,000	0	0	2,000		
5/25/11	17,300	0	0	0.00	17,300	6,400	500	3,300	0	0	3,300	5,000	5,000	0	5,000	2,000	2,000	0	0	2,000		
5/26/11	17,250	0	0	0.00	17,250	6,350	500	3,300	0	0	3,300	5,000	5,000	0	5,000	2,000	2,000	0	0	2,000		
5/27/11	17,200	0	0	0.00	17,200	6,300	500	3,300	0	0	3,300	5,000	5,000	0	5,000	2,000	2,000	0	0	2,000		
5/28/11	17,150	0	0	0.00	17,150	6,250	500	3,300	0	0	3,300	5,000	5,000	0	5,000	2,000	2,000	0	0	2,000		
5/29/11	17,100	0	0	0.00	17,100	6,200	500	3,300			3,300	5,000	5,000	0	5,000	2,000	2,000	0	0	2,000		
5/30/11	17,050	0	0	0.00	17,050	6,150	500	3,300			3,300	5,000	5,000		5,000	2,000	2,000			2,000		
5/31/11	17,000	0	0	0.00	17,000	6,100	500	3,300			3,300	5,000	5,000		5,000	2,000	2,000			2,000		
VAMP Period																						
Avg. (cfs):	17,750	0	0		17,750	6,950	500	3,300	0	0	3,300	5,000	5,000	0	5,000	2,000	2,000	0	0	2,000		
Supplemental Water (TAF):		0.00	0.00						0.00	0.00				0.00				0.00	0.00			

VAMP flow operation period

Appendix A, Table 8

2011 VAMP DAILY OPERATION PLAN – APRIL 27, 2011
Target Flow Period: May 1st – May 31st * Flow Target: n/a
Bold Numbers: observed real-time mean daily flows

Date	San Joaquin River near Vernalis: Existing Flow (cfs)	VAMP Supplemental Flow (cfs)	Other Supplemental Flow (cfs)	Cumulative VAMP Supplemental Flow (TAF)	VAMP Flow (cfs)	SJR above Merced R (2day lag) (cfs)	Ungaged Flow above Vernalis (cfs)	Merced River at Cressey: Existing Flow (cfs)	MeID VAMP Supplemental Flow (cfs)	SJREC VAMP Supplemental Flow (cfs)	VAMP Flow (3day lag) (cfs)	Tuolumne River below La Grange Dam: Existing Flow - base FERC volume (cfs)	Existing Flow - Adjusted FERC Pulse (cfs)	VAMP Supplemental Flow (cfs)	VAMP Flow (2day lag) (cfs)	Stanislaus R below Goodwin Dam: Existing Flow - Base (cfs)	Existing Flow - reshaped	VAMP Supplemental Flow (cfs)	Other Supplemental Flow (cfs)	VAMP Flow (2day lag) (cfs)	Maintain Priority Flow Level M=Merced T=Tuol. S=Stan.	Combined Delta Exports
3/10/11	**9,920**					**1,050**	**1,240**	**3,642**			3,642	**3,780**	**3,780**		3,780	**210**	**210**			210		**7,646**
3/11/11	**9,860**					**985**	**1,107**	**3,559**			3,559	**3,660**	**3,660**		3,660	**220**	**220**			220		**7,660**
3/12/11	**9,750**					**905**	**1,080**	**3,052**			3,052	**3,280**	**3,280**		3,280	**209**	**209**			209		**7,682**
3/13/11	**9,440**				9,450	**828**	**943**	**3,077**			3,077	**2,870**	**2,870**		2,870	**205**	**205**			205		**8,292**
3/14/11	**8,930**				8,940	**784**	**987**	**3,063**			3,063	**2,680**	**2,680**		2,680	**203**	**203**			203		**7,963**
3/15/11	**8,470**				8,470	**749**	**1,515**	**3,069**			3,069	**2,700**	**2,700**		2,700	**204**	**204**			204		**7,019**
3/16/11	**8,230**				8,230	**730**	**1,486**	**3,113**			3,113	**2,830**	**2,830**		2,830	**205**	**205**			205		**7,025**
3/17/11	**8,110**				8,110	**708**	**1,394**	**3,133**			3,133	**3,320**	**3,320**		3,320	**201**	**201**			201		**7,011**
3/18/11	**8,300**				8,300	**710**	**1,466**	**3,123**			3,123	**3,500**	**3,500**		3,500	**208**	**208**			208		**7,030**
3/19/11	**8,660**				8,660	**742**	**1,318**	**3,244**			3,244	**4,850**	**4,850**		4,850	**205**	**205**			205		**7,024**
3/20/11	**9,300**				9,300	**852**	**1,749**	**4,081**			4,081	**5,260**	**5,260**		5,260	**235**	**235**			235		**7,033**
3/21/11	**11,300**				11,300	**1,150**	**2,380**	**5,135**			5,135	**6,380**	**6,380**		6,380	**480**	**480**			480		**7,056**
3/22/11	**13,600**				13,600	**2,880**	**4,009**	**1,935**			1,935	**7,110**	**7,110**		7,110	**1,305**	**1,305**			1,305		**7,999**
3/23/11	**15,000**				15,000	**4,710**	**2,909**	**2,474**			2,474	**7,660**	**7,660**		7,660	**1,300**	**1,300**			1,300		**5,376**
3/24/11	**15,600**				15,600	**6,610**	**-830**	**3,774**			3,774	**7,260**	**7,260**		7,260	**1,330**	**1,330**			1,330		**775**
3/25/11	**16,400**				16,400	**8,020**	**795**	**4,774**			4,774	**7,120**	**7,120**		7,120	**1,334**	**1,334**			1,334		**408**
3/26/11	**18,200**				18,200	**9,600**	**526**	**3,916**			3,916	**7,140**	**7,140**		7,140	**1,344**	**1,344**			1,344		**956**
3/27/11	**19,400**				19,400	**11,900**	**-848**	**3,998**			3,998	**7,510**	**7,510**		7,510	**1,336**	**1,336**			1,336		**3,246**
3/28/11	**21,100**				21,100	**13,800**	**-1,758**	**4,216**			4,216	**7,780**	**7,780**		7,780	**1,334**	**1,334**			1,334		**4,077**
3/29/11	**23,000**				23,000	**14,800**	**-1,662**	**4,287**			4,287	**8,110**	**8,110**		8,110	**1,328**	**1,328**			1,328		**4,310**
3/30/11	**25,200**				25,200	**14,900**	**-1,712**	**4,137**			4,137	**8,320**	**8,320**		8,320	**1,328**	**1,328**			1,328		**1,565**
3/31/11	**27,500**				27,500	**14,700**	**-954**	**4,121**			4,121	**8,310**	**8,310**		8,310	**1,323**	**1,323**			1,323		**5,036**
4/1/11	**28,600**				28,600	**13,700**	**-235**	**4,105**			4,105	**8,330**	**8,330**		8,330	**1,301**	**1,301**			1,301		**5,420**
4/2/11	**28,700**				28,700	**12,500**	**230**	**4,459**			4,459	**8,360**	**8,360**		8,360	**1,307**	**1,307**			1,307		**5,208**
4/3/11	**28,700**				28,700	**12,400**	**1,248**	**4,624**			4,624	**8,330**	**8,330**		8,330	**1,307**	**1,307**			1,307		**5,508**
4/4/11	**28,200**				28,200	**12,300**	**1,928**	**4,612**			4,612	**8,310**	**8,310**		8,310	**1,310**	**1,310**			1,310		**5,701**
4/5/11	**27,800**				27,800	**12,200**	**1,304**	**4,865**			4,865	**8,330**	**8,330**		8,330	**1,726**	**1,726**			1,726		**5,699**
4/6/11	**27,700**				27,700	**12,000**	**1,156**	**5,036**			5,036	**8,330**	**8,330**		8,330	**2,000**	**2,000**			2,000		**5,751**
4/7/11	**27,900**				27,900	**11,400**	**1,032**	**5,296**			5,296	**7,570**	**7,570**		7,570	**2,002**	**2,002**			2,002		**6,000**
4/8/11	**28,000**				28,000	**10,900**	**805**	**5,410**			5,410	**7,720**	**7,720**		7,720	**2,028**	**2,028**			2,028		**5,618**
4/9/11	**27,600**				27,600	**10,600**	**1,592**	**5,558**			5,558	**8,310**	**8,310**		8,310	**2,026**	**2,026**			2,026		**5,847**
4/10/11	**27,300**				27,300	**10,300**	**1,356**	**5,614**			5,614	**8,320**	**8,320**		8,320	**2,022**	**2,022**			2,022		**6,834**
4/11/11	**27,300**				27,300	**10,200**	**954**	**5,620**			5,620	**8,320**	**8,320**		8,320	**2,043**	**2,043**			2,043		**6,768**
4/12/11	**27,200**				27,200	**9,890**	**1,000**	**5,615**			5,615	**8,290**	**8,290**		8,290	**2,655**	**2,655**			2,655		**6,322**
4/13/11	**27,000**				27,000	**9,680**	**823**	**5,605**			5,605	**8,330**	**8,330**		8,330	**3,066**	**3,066**			3,066		**6,330**
4/14/11	**27,100**				27,100	**9,490**	**645**	**5,585**			5,585	**8,340**	**8,340**		8,340	**3,113**	**3,113**			3,113		**5,383**
4/15/11	**27,200**				27,200	**9,150**	**509**	**5,066**			5,066	**8,310**	**8,310**		8,310	**3,061**	**3,061**			3,061		**5,323**
4/16/11	**27,100**				27,100	**8,930**	**552**	**3,456**			3,456	**8,310**	**8,310**		8,310	**3,017**	**3,017**			3,017		**5,335**
4/17/11	**27,100**				27,100	**8,630**	**994**	**3,062**			3,062	**8,330**	**8,330**		8,330	**3,018**	**3,018**			3,018		**5,980**
4/18/11	**26,800**				26,800	**8,340**	**1,477**	**3,026**			3,026	**8,150**	**8,150**		8,150	**3,048**	**3,048**			3,048		**6,255**
4/19/11	**26,300**				26,300	**8,190**	**2,866**	**2,980**			2,980	**7,710**	**7,710**		7,710	**3,019**	**3,019**			3,019		**6,246**
4/20/11	**25,700**				25,700	**8,070**	**3,100**	**2,984**			2,984	**7,320**	**7,320**		7,320	**2,637**	**2,637**			2,637		**6,252**
4/21/11	**25,000**				25,000	**7,950**	**3,055**	**2,995**			2,995	**7,030**	**7,030**		7,030	**2,532**	**2,532**			2,532		**6,249**
4/22/11	**24,300**				24,300	**7,810**	**3,293**	**2,989**			2,989	**6,750**	**6,750**		6,750	**2,552**	**2,552**			2,552		**7,744**
4/23/11	**23,700**				23,700	**7,630**	**3,204**	**2,984**			2,984	**6,420**	**6,420**		6,420	**2,525**	**2,525**			2,525		**9,132**
4/24/11	**23,200**				23,200	**7,420**	**3,093**	**2,985**			2,985	**6,120**	**6,120**		6,120	**2,560**	**2,560**			2,560		**8,627**
4/25/11	**22,800**				22,800	**7,260**	**3,236**	**2,984**			2,984	**5,770**	**5,770**		5,770	**2,568**	**2,568**			2,568		**4,504**
4/26/11	**22,400**				22,400	**7,200**	**3,316**	**2,454**			2,454	**5,640**	**5,640**		5,640	**2,543**	**2,543**			2,543		**3,321**
4/27/11	21,900				21,900	7,160	3,317	2,100			2,100	5,540	5,540		5,540	2,500	2,500			2,500		
4/28/11	21,500				21,500	7,120	3,133	2,100	0	0	2,100	5,270	5,270		5,270	2,500	2,500			2,500		
4/29/11	20,654				20,654	7,080	3,000	2,100	0	0	2,100	5,000	5,000	0	5,000	2,000	2,000	0	0	2,000		
4/30/11	19,490				19,490	7,040	2,500	2,100	0	0	2,100	5,000	5,000	0	5,000	2,000	2,000	0	0	2,000		
5/1/11	18,180	0	0	0.00	18,180	7,000	2,000	2,100	0	0	2,100	5,000	5,000	0	5,000	2,000	2,000	0	0	2,000		
5/2/11	18,140	0	0	0.00	18,140	6,960	2,000	2,100	0	0	2,100	5,000	5,000	0	5,000	2,000	2,000	0	0	2,000		
5/3/11	18,100	0	0	0.00	18,100	6,920	2,000	2,100	0	0	2,100	5,000	5,000	0	5,000	2,000	2,000	0	0	2,000		
5/4/11	18,060	0	0	0.00	18,060	6,880	2,000	2,100	0	0	2,100	5,000	5,000	0	5,000	2,000	2,000	0	0	2,000		
5/5/11	18,020	0	0	0.00	18,020	6,840	2,000	2,100	0	0	2,100	5,000	5,000	0	5,000	2,000	2,000	0	0	2,000		
5/6/11	17,980	0	0	0.00	17,980	6,800	2,000	2,100	0	0	2,100	5,000	5,000	0	5,000	2,000	2,000	0	0	2,000		
5/7/11	17,940	0	0	0.00	17,940	6,760	2,000	2,100	0	0	2,100	5,000	5,000	0	5,000	2,000	2,000	0	0	2,000		
5/8/11	17,900	0	0	0.00	17,900	6,720	2,000	2,100	0	0	2,100	5,000	5,000	0	5,000	2,000	2,000	0	0	2,000		
5/9/11	17,860	0	0	0.00	17,860	6,680	2,000	2,100	0	0	2,100	5,000	5,000	0	5,000	2,000	2,000	0	0	2,000		
5/10/11	17,820	0	0	0.00	17,820	6,640	2,000	2,100	0	0	2,100	5,000	5,000	0	5,000	2,000	2,000	0	0	2,000		
5/11/11	17,780	0	0	0.00	17,780	6,600	2,000	2,100	0	0	2,100	5,000	5,000	0	5,000	2,000	2,000	0	0	2,000		
5/12/11	17,740	0	0	0.00	17,740	6,560	2,000	2,100	0	0	2,100	5,000	5,000	0	5,000	2,000	2,000	0	0	2,000		
5/13/11	17,700	0	0	0.00	17,700	6,520	2,000	2,100	0	0	2,100	5,000	5,000	0	5,000	2,000	2,000	0	0	2,000		
5/14/11	17,660	0	0	0.00	17,660	6,480	2,000	2,100	0	0	2,100	5,000	5,000	0	5,000	2,000	2,000	0	0	2,000		
5/15/11	17,620	0	0	0.00	17,620	6,440	2,000	2,100	0	0	2,100	5,000	5,000	0	5,000	2,000	2,000	0	0	2,000		
5/16/11	17,580	0	0	0.00	17,580	6,400	2,000	2,100	0	0	2,100	5,000	5,000	0	5,000	2,000	2,000	0	0	2,000		
5/17/11	17,540	0	0	0.00	17,540	6,360	2,000	2,100	0	0	2,100	5,000	5,000	0	5,000	2,000	2,000	0	0	2,000		
5/18/11	17,500	0	0	0.00	17,500	6,320	2,000	2,100	0	0	2,100	5,000	5,000	0	5,000	2,000	2,000	0	0	2,000		
5/19/11	17,460	0	0	0.00	17,460	6,280	2,000	2,100	0	0	2,100	5,000	5,000	0	5,000	2,000	2,000	0	0	2,000		
5/20/11	17,420	0	0	0.00	17,420	6,240	2,000	2,100	0	0	2,100	5,000	5,000	0	5,000	2,000	2,000	0	0	2,000		
5/21/11	17,380	0	0	0.00	17,380	6,200	2,000	2,100	0	0	2,100	5,000	5,000	0	5,000	2,000	2,000	0	0	2,000		
5/22/11	17,340	0	0	0.00	17,340	6,160	2,000	2,100	0	0	2,100	5,000	5,000	0	5,000	2,000	2,000	0	0	2,000		
5/23/11	17,300	0	0	0.00	17,300	6,120	2,000	2,100	0	0	2,100	5,000	5,000	0	5,000	2,000	2,000	0	0	2,000		
5/24/11	17,260	0	0	0.00	17,260	6,080	2,000	2,100	0	0	2,100	5,000	5,000	0	5,000	2,000	2,000	0	0	2,000		
5/25/11	17,220	0	0	0.00	17,220	6,040	2,000	2,100	0	0	2,100	5,000	5,000	0	5,000	2,000	2,000	0	0	2,000		
5/26/11	17,180	0	0	0.00	17,180	6,000	2,000	2,100	0	0	2,100	5,000	5,000	0	5,000	2,000	2,000	0	0	2,000		
5/27/11	17,140	0	0	0.00	17,140	5,960	2,000	2,100	0	0	2,100	5,000	5,000	0	5,000	2,000	2,000	0	0	2,000		
5/28/11	17,100	0	0	0.00	17,100	5,920	2,000	2,100	0	0	2,100	5,000	5,000	0	5,000	2,000	2,000	0	0	2,000		
5/29/11	17,060	0	0	0.00	17,060	5,880	2,000	2,100			2,100	5,000	5,000	0	5,000	2,000	2,000	0	0	2,000		
5/30/11	17,020	0	0	0.00	17,020	5,840	2,000	2,100			2,100	5,000	5,000		5,000	2,000	2,000			2,000		
5/31/11	16,980	0	0	0.00	16,980	5,800	2,000	2,100			2,100	5,000	5,000		5,000	2,000	2,000			2,000		
VAMP Period																						
Avg. (cfs):	17,580	0	0		17,580	6,480	2,000	2,100	0	0	2,100	5,000	5,000	0	5,000	2,000	2,000	0	0	2,000		
Supplemental Water (TAF):		0.00	0.00						0.00	0.00				0.00				0.00	0.00			

VAMP flow operation period

Appendix A, Table 9

2011 VAMP DAILY OPERATION PLAN – APRIL 29, 2011

Target Flow Period: May 1st – May 31st * Flow Target: n/a

Bold Numbers: observed real-time mean daily flows

	San Joaquin River near Vernalis							Merced River at Cressey				Tuolumne River below La Grange Dam				Stanislaus R below Goodwin Dam						
Date	Existing Flow (cfs)	VAMP Supplemental Flow (cfs)	Other Supplemental Flow (cfs)	Cumulative VAMP Supplemental Flow (TAF)	VAMP Flow (cfs)	SJR above Merced R (2day lag) (cfs)	Ungaged Flow above Vernalis (cfs)	Existing Flow (cfs)	MeID VAMP Supplemental Flow (cfs)	SJREC VAMP Supplemental Flow (cfs)	VAMP Flow (3day lag) (cfs)	Existing Flow - base FERC volume (cfs)	Existing Flow - Adjusted FERC Pulse (cfs)	VAMP Supplemental Flow (cfs)	VAMP Flow (2day lag) (cfs)	Existing Flow - Base (cfs)	Existing Flow - reshaped	VAMP Supplemental Flow (cfs)	Other Supplemental Flow (cfs)	VAMP Flow (2day lag) (cfs)	Maintain Priority Flow Level M=Merced T=Tuol. S=Stan.	Combined Delta Exports
3/10/11	**9,920**					**1,050**	**1,240**	**3,642**			3,642	**3,780**	**3,780**		3,780	**210**	**210**			210		**7,646**
3/11/11	**9,860**					**985**	**1,107**	**3,559**			3,559	**3,660**	**3,660**		3,660	**220**	**220**			220		**7,660**
3/12/11	**9,750**					**905**	**1,080**	**3,052**			3,052	**3,280**	**3,280**		3,280	**209**	**209**			209		**7,682**
3/13/11	**9,440**				9,450	**828**	**943**	**3,077**			3,077	**2,870**	**2,870**		2,870	**205**	**205**			205		**8,292**
3/14/11	**8,930**				8,940	**784**	**987**	**3,063**			3,063	**2,680**	**2,680**		2,680	**203**	**203**			203		**7,963**
3/15/11	**8,470**				8,470	**749**	**1,515**	**3,069**			3,069	**2,700**	**2,700**		2,700	**204**	**204**			204		**7,019**
3/16/11	**8,230**				8,230	**730**	**1,486**	**3,113**			3,113	**2,830**	**2,830**		2,830	**205**	**205**			205		**7,025**
3/17/11	**8,110**				8,110	**708**	**1,394**	**3,133**			3,133	**3,320**	**3,320**		3,320	**201**	**201**			201		**7,011**
3/18/11	**8,300**				8,300	**710**	**1,466**	**3,123**			3,123	**3,500**	**3,500**		3,500	**208**	**208**			208		**7,030**
3/19/11	**8,660**				8,660	**742**	**1,318**	**3,244**			3,244	**4,850**	**4,850**		4,850	**205**	**205**			205		**7,024**
3/20/11	**9,300**				9,300	**852**	**1,749**	**4,081**			4,081	**5,260**	**5,260**		5,260	**235**	**235**			235		**7,033**
3/21/11	**11,300**				11,300	**1,150**	**2,380**	**5,135**			5,135	**6,380**	**6,380**		6,380	**480**	**480**			480		**7,056**
3/22/11	**13,600**				13,600	**2,880**	**4,009**	**1,935**			1,935	**7,110**	**7,110**		7,110	**1,305**	**1,305**			1,305		**7,999**
3/23/11	**15,000**				15,000	**4,710**	**2,909**	**2,474**			2,474	**7,660**	**7,660**		7,660	**1,300**	**1,300**			1,300		**5,376**
3/24/11	**15,600**				15,600	**6,610**	**-830**	**3,774**			3,774	**7,260**	**7,260**		7,260	**1,330**	**1,330**			1,330		**775**
3/25/11	**16,400**				16,400	**8,020**	**795**	**4,774**			4,774	**7,120**	**7,120**		7,120	**1,334**	**1,334**			1,334		**408**
3/26/11	**18,200**				18,200	**9,600**	**526**	**3,916**			3,916	**7,140**	**7,140**		7,140	**1,344**	**1,344**			1,344		**956**
3/27/11	**19,400**				19,400	**11,900**	**-848**	**3,998**			3,998	**7,510**	**7,510**		7,510	**1,336**	**1,336**			1,336		**3,246**
3/28/11	**21,100**				21,100	**13,800**	**-1,758**	**4,216**			4,216	**7,780**	**7,780**		7,780	**1,334**	**1,334**			1,334		**4,077**
3/29/11	**23,000**				23,000	**14,800**	**-1,662**	**4,287**			4,287	**8,110**	**8,110**		8,110	**1,328**	**1,328**			1,328		**4,310**
3/30/11	**25,200**				25,200	**14,900**	**-1,712**	**4,137**			4,137	**8,320**	**8,320**		8,320	**1,328**	**1,328**			1,328		**1,565**
3/31/11	**27,500**				27,500	**14,700**	**-954**	**4,121**			4,121	**8,310**	**8,310**		8,310	**1,323**	**1,323**			1,323		**5,036**
4/1/11	**28,600**				28,600	**13,700**	**-235**	**4,105**			4,105	**8,330**	**8,330**		8,330	**1,301**	**1,301**			1,301		**5,420**
4/2/11	**28,700**				28,700	**12,500**	**230**	**4,459**			4,459	**8,360**	**8,360**		8,360	**1,307**	**1,307**			1,307		**5,208**
4/3/11	**28,700**				28,700	**12,400**	**1,248**	**4,624**			4,624	**8,330**	**8,330**		8,330	**1,307**	**1,307**			1,307		**5,508**
4/4/11	**28,200**				28,200	**12,300**	**1,928**	**4,612**			4,612	**8,310**	**8,310**		8,310	**1,310**	**1,310**			1,310		**5,701**
4/5/11	**27,800**				27,800	**12,200**	**1,304**	**4,865**			4,865	**8,330**	**8,330**		8,330	**1,726**	**1,726**			1,726		**5,699**
4/6/11	**27,700**				27,700	**12,000**	**1,156**	**5,036**			5,036	**8,330**	**8,330**		8,330	**2,000**	**2,000**			2,000		**5,751**
4/7/11	**27,900**				27,900	**11,400**	**1,032**	**5,296**			5,296	**7,570**	**7,570**		7,570	**2,002**	**2,002**			2,002		**6,000**
4/8/11	**28,000**				28,000	**10,900**	**805**	**5,410**			5,410	**7,720**	**7,720**		7,720	**2,028**	**2,028**			2,028		**5,618**
4/9/11	**27,600**				27,600	**10,600**	**1,592**	**5,558**			5,558	**8,310**	**8,310**		8,310	**2,026**	**2,026**			2,026		**5,847**
4/10/11	**27,300**				27,300	**10,300**	**1,356**	**5,614**			5,614	**8,320**	**8,320**		8,320	**2,022**	**2,022**			2,022		**6,834**
4/11/11	**27,300**				27,300	**10,200**	**954**	**5,620**			5,620	**8,320**	**8,320**		8,320	**2,043**	**2,043**			2,043		**6,768**
4/12/11	**27,200**				27,200	**9,890**	**1,000**	**5,615**			5,615	**8,290**	**8,290**		8,290	**2,655**	**2,655**			2,655		**6,322**
4/13/11	**27,000**				27,000	**9,680**	**823**	**5,605**			5,605	**8,330**	**8,330**		8,330	**3,066**	**3,066**			3,066		**6,330**
4/14/11	**27,100**				27,100	**9,490**	**645**	**5,585**			5,585	**8,340**	**8,340**		8,340	**3,113**	**3,113**			3,113		**5,383**
4/15/11	**27,200**				27,200	**9,150**	**509**	**5,066**			5,066	**8,310**	**8,310**		8,310	**3,061**	**3,061**			3,061		**5,323**
4/16/11	**27,100**				27,100	**8,930**	**552**	**3,456**			3,456	**8,310**	**8,310**		8,310	**3,017**	**3,017**			3,017		**5,335**
4/17/11	**27,100**				27,100	**8,630**	**994**	**3,062**			3,062	**8,330**	**8,330**		8,330	**3,018**	**3,018**			3,018		**5,980**
4/18/11	**26,800**				26,800	**8,340**	**1,477**	**3,026**			3,026	**8,150**	**8,150**		8,150	**3,048**	**3,048**			3,048		**6,255**
4/19/11	**26,300**				26,300	**8,190**	**2,866**	**2,980**			2,980	**7,710**	**7,710**		7,710	**3,019**	**3,019**			3,019		**6,246**
4/20/11	**25,700**				25,700	**8,070**	**3,100**	**2,984**			2,984	**7,320**	**7,320**		7,320	**2,637**	**2,637**			2,637		**6,252**
4/21/11	**25,000**				25,000	**7,950**	**3,055**	**2,995**			2,995	**7,030**	**7,030**		7,030	**2,532**	**2,532**			2,532		**6,249**
4/22/11	**24,300**				24,300	**7,810**	**3,293**	**2,989**			2,989	**6,750**	**6,750**		6,750	**2,552**	**2,552**			2,552		**7,744**
4/23/11	**23,700**				23,700	**7,630**	**3,204**	**2,984**			2,984	**6,420**	**6,420**		6,420	**2,525**	**2,525**			2,525		**9,132**
4/24/11	**23,200**				23,200	**7,420**	**3,093**	**2,985**			2,985	**6,120**	**6,120**		6,120	**2,560**	**2,560**			2,560		**8,627**
4/25/11	**22,800**				22,800	**7,260**	**3,236**	**2,984**			2,984	**5,770**	**5,770**		5,770	**2,568**	**2,568**			2,568		**4,504**
4/26/11	**22,400**				22,400	**7,200**	**3,316**	**2,454**			2,454	**5,640**	**5,640**		5,640	**2,543**	**2,543**			2,543		**3,321**
4/27/11	**21,800**				21,800	**7,120**	**3,217**	**2,305**			2,305	**5,630**	**5,630**		5,630	**2,529**	**2,529**			2,529		
4/28/11	**21,300**				21,300	**7,080**	**2,933**	**2,284**	0	0	2,284	**5,550**	**5,550**		5,550	**2,546**	**2,546**			2,546		
4/29/11	20,733				20,733	7,020	3,000	2,100	0	0	2,100	5,000	5,000	0	5,000	2,000	2,000	0	0	2,000		
4/30/11	20,481				20,481	6,960	3,000	2,100	0	0	2,100	4,250	4,250	0	4,250	2,000	2,000	0	0	2,000		
5/1/11	19,304	0	0	0.00	19,304	6,900	3,000	2,100	0	0	2,100	3,500	3,500	0	3,500	2,000	2,000	0	0	2,000		
5/2/11	18,310	0	0	0.00	18,310	6,840	3,000	2,100	0	0	2,100	3,500	3,500	0	3,500	2,000	2,000	0	0	2,000		
5/3/11	17,500	0	0	0.00	17,500	6,780	3,000	2,100	0	0	2,100	3,600	3,600	0	3,600	2,000	2,000	0	0	2,000		
5/4/11	17,440	0	0	0.00	17,440	6,720	3,000	2,100	0	0	2,100	3,600	3,600	0	3,600	2,000	2,000	0	0	2,000		
5/5/11	17,480	0	0	0.00	17,480	6,660	3,000	2,100	0	0	2,100	3,600	3,600	0	3,600	2,000	2,000	0	0	2,000		
5/6/11	17,420	0	0	0.00	17,420	6,600	3,000	2,100	0	0	2,100	3,700	3,700	0	3,700	2,000	2,000	0	0	2,000		
5/7/11	17,360	0	0	0.00	17,360	6,540	3,000	2,100	0	0	2,100	3,700	3,700	0	3,700	2,000	2,000	0	0	2,000		
5/8/11	17,400	0	0	0.00	17,400	6,480	3,000	2,100	0	0	2,100	3,700	3,700	0	3,700	2,000	2,000	0	0	2,000		
5/9/11	17,340	0	0	0.00	17,340	6,420	3,000	2,100	0	0	2,100	3,800	3,800	0	3,800	2,000	2,000	0	0	2,000		
5/10/11	17,280	0	0	0.00	17,280	6,360	3,000	2,100	0	0	2,100	3,800	3,800	0	3,800	2,000	2,000	0	0	2,000		
5/11/11	17,320	0	0	0.00	17,320	6,300	3,000	2,100	0	0	2,100	3,900	3,900	0	3,900	2,000	2,000	0	0	2,000		
5/12/11	17,260	0	0	0.00	17,260	6,240	3,000	2,100	0	0	2,100	3,900	3,900	0	3,900	2,000	2,000	0	0	2,000		
5/13/11	17,300	0	0	0.00	17,300	6,180	3,000	2,100	0	0	2,100	3,900	3,900	0	3,900	2,000	2,000	0	0	2,000		
5/14/11	17,240	0	0	0.00	17,240	6,120	3,000	2,100	0	0	2,100	4,000	4,000	0	4,000	2,000	2,000	0	0	2,000		
5/15/11	17,180	0	0	0.00	17,180	6,060	3,000	2,100	0	0	2,100	4,000	4,000	0	4,000	2,000	2,000	0	0	2,000		
5/16/11	17,220	0	0	0.00	17,220	6,000	3,000	2,100	0	0	2,100	4,000	4,000	0	4,000	2,000	2,000	0	0	2,000		
5/17/11	17,160	0	0	0.00	17,160	5,940	3,000	2,100	0	0	2,100	4,100	4,100	0	4,100	2,000	2,000	0	0	2,000		
5/18/11	17,100	0	0	0.00	17,100	5,880	3,000	2,100	0	0	2,100	4,100	4,100	0	4,100	2,000	2,000	0	0	2,000		
5/19/11	17,140	0	0	0.00	17,140	5,820	3,000	2,100	0	0	2,100	4,100	4,100	0	4,100	2,000	2,000	0	0	2,000		
5/20/11	17,080	0	0	0.00	17,080	5,760	3,000	2,100	0	0	2,100	4,200	4,200	0	4,200	2,000	2,000	0	0	2,000		
5/21/11	17,020	0	0	0.00	17,020	5,700	3,000	2,100	0	0	2,100	4,200	4,200	0	4,200	2,000	2,000	0	0	2,000		
5/22/11	17,060	0	0	0.00	17,060	5,640	3,000	2,100	0	0	2,100	4,200	4,200	0	4,200	2,000	2,000	0	0	2,000		
5/23/11	17,000	0	0	0.00	17,000	5,580	3,000	2,100	0	0	2,100	4,300	4,300	0	4,300	2,000	2,000	0	0	2,000		
5/24/11	16,940	0	0	0.00	16,940	5,520	3,000	2,100	0	0	2,100	4,300	4,300	0	4,300	2,000	2,000	0	0	2,000		
5/25/11	16,980	0	0	0.00	16,980	5,460	3,000	2,100	0	0	2,100	4,400	4,400	0	4,400	2,000	2,000	0	0	2,000		
5/26/11	16,920	0	0	0.00	16,920	5,400	3,000	2,100	0	0	2,100	4,400	4,400	0	4,400	2,000	2,000	0	0	2,000		
5/27/11	16,960	0	0	0.00	16,960	5,340	3,000	2,100	0	0	2,100	4,400	4,400	0	4,400	2,000	2,000	0	0	2,000		
5/28/11	16,900	0	0	0.00	16,900	5,280	3,000	2,100	0	0	2,100	4,500	4,500	0	4,500	2,000	2,000	0	0	2,000		
5/29/11	16,840	0	0	0.00	16,840	5,220	3,000	2,100			2,100	4,500	4,500	0	4,500	2,000	2,000	0	0	2,000		
5/30/11	16,880	0	0	0.00	16,880	5,160	3,000	2,100			2,100	4,000	4,000		4,000	2,000	2,000			2,000		
5/31/11	16,820	0	0	0.00	16,820	5,100	3,000	2,100			2,100	4,000	4,000		4,000	2,000	2,000			2,000		
											VAMP Period											
Avg. (cfs):	17,263	0	0		17,263	6,120	3,000	2,106	0	0	2,106	4,037	4,037	0	4,037	2,000	2,000	0	0	2,000		
Supplemental Water (TAF):		0.00	0.00						0.00	0.00				0.00				0.00	0.00			

VAMP flow operation period

Appendix A, Table 10
2011 VAMP DAILY OPERATION PLAN – MAY 10, 2011
Target Flow Period: May 1st – May 31st * Flow Target: n/a
Bold Numbers: observed real-time mean daily flows

Date	San Joaquin River near Vernalis: Existing Flow (cfs)	VAMP Supplemental Flow (cfs)	Other Supplemental Flow (cfs)	Cumulative VAMP Supplemental Flow (TAF)	VAMP Flow (cfs)	SJR above Merced R (2day lag) (cfs)	Ungaged Flow above Vernalis (cfs)	Merced River at Cressey: Existing Flow (cfs)	MeID VAMP Supplemental Flow (cfs)	SJREC VAMP Supplemental Flow (cfs)	VAMP Flow (3day lag) (cfs)	Tuolumne River below La Grange Dam: Existing Flow - base FERC volume (cfs)	Existing Flow - Adjusted FERC Pulse (cfs)	VAMP Supplemental Flow (cfs)	VAMP Flow (2day lag) (cfs)	Stanislaus R below Goodwin Dam: Existing Flow - Base (cfs)	Existing Flow - reshaped	VAMP Supplemental Flow (cfs)	Other Supplemental Flow (cfs)	VAMP Flow (2day lag) (cfs)	Maintain Priority Flow Level M=Merced T=Tuol. S=Stan.	Combined Delta Exports
3/10/11	**9,920**					**1,050**	**1,240**	**3,642**			3,642	**3,780**	**3,780**		3,780	**210**	**210**			210		**7,646**
3/11/11	**9,860**					**985**	**1,107**	**3,559**			3,559	**3,660**	**3,660**		3,660	**220**	**220**			220		**7,660**
3/12/11	**9,750**					**905**	**1,080**	**3,052**			3,052	**3,280**	**3,280**		3,280	**209**	**209**			209		**7,682**
3/13/11	**9,440**				9,450	**828**	**943**	**3,077**			3,077	**2,870**	**2,870**		2,870	**205**	**205**			205		**8,292**
3/14/11	**8,930**				8,940	**784**	**987**	**3,063**			3,063	**2,680**	**2,680**		2,680	**203**	**203**			203		**7,963**
3/15/11	**8,470**				8,470	**749**	**1,515**	**3,069**			3,069	**2,700**	**2,700**		2,700	**204**	**204**			204		**7,019**
3/16/11	**8,230**				8,230	**730**	**1,486**	**3,113**			3,113	**2,830**	**2,830**		2,830	**205**	**205**			205		**7,025**
3/17/11	**8,110**				8,110	**708**	**1,394**	**3,133**			3,133	**3,320**	**3,320**		3,320	**201**	**201**			201		**7,011**
3/18/11	**8,300**				8,300	**710**	**1,466**	**3,123**			3,123	**3,500**	**3,500**		3,500	**208**	**208**			208		**7,030**
3/19/11	**8,660**				8,660	**742**	**1,318**	**3,244**			3,244	**4,850**	**4,850**		4,850	**205**	**205**			205		**7,024**
3/20/11	**9,300**				9,300	**852**	**1,749**	**4,081**			4,081	**5,260**	**5,260**		5,260	**235**	**235**			235		**7,033**
3/21/11	**11,300**				11,300	**1,150**	**2,380**	**5,135**			5,135	**6,380**	**6,380**		6,380	**480**	**480**			480		**7,056**
3/22/11	**13,600**				13,600	**2,880**	**4,009**	**1,935**			1,935	**7,110**	**7,110**		7,110	**1,305**	**1,305**			1,305		**7,999**
3/23/11	**15,000**				15,000	**4,710**	**2,909**	**2,474**			2,474	**7,660**	**7,660**		7,660	**1,300**	**1,300**			1,300		**5,376**
3/24/11	**15,600**				15,600	**6,610**	**-830**	**3,774**			3,774	**7,260**	**7,260**		7,260	**1,330**	**1,330**			1,330		**775**
3/25/11	**16,400**				16,400	**8,020**	**795**	**4,774**			4,774	**7,120**	**7,120**		7,120	**1,334**	**1,334**			1,334		**408**
3/26/11	**18,200**				18,200	**9,600**	**526**	**3,916**			3,916	**7,140**	**7,140**		7,140	**1,344**	**1,344**			1,344		**956**
3/27/11	**19,400**				19,400	**11,900**	**-848**	**3,998**			3,998	**7,510**	**7,510**		7,510	**1,336**	**1,336**			1,336		**3,246**
3/28/11	**21,100**				21,100	**13,800**	**-1,758**	**4,216**			4,216	**7,780**	**7,780**		7,780	**1,334**	**1,334**			1,334		**4,077**
3/29/11	**23,000**				23,000	**14,800**	**-1,662**	**4,287**			4,287	**8,110**	**8,110**		8,110	**1,328**	**1,328**			1,328		**4,310**
3/30/11	**25,200**				25,200	**14,900**	**-1,712**	**4,137**			4,137	**8,320**	**8,320**		8,320	**1,328**	**1,328**			1,328		**1,565**
3/31/11	**27,500**				27,500	**14,700**	**-954**	**4,121**			4,121	**8,310**	**8,310**		8,310	**1,323**	**1,323**			1,323		**5,036**
4/1/11	**28,600**				28,600	**13,700**	**-235**	**4,105**			4,105	**8,330**	**8,330**		8,330	**1,301**	**1,301**			1,301		**5,420**
4/2/11	**28,700**				28,700	**12,500**	**230**	**4,459**			4,459	**8,360**	**8,360**		8,360	**1,307**	**1,307**			1,307		**5,208**
4/3/11	**28,700**				28,700	**12,400**	**1,248**	**4,624**			4,624	**8,330**	**8,330**		8,330	**1,307**	**1,307**			1,307		**5,508**
4/4/11	**28,200**				28,200	**12,300**	**1,928**	**4,612**			4,612	**8,310**	**8,310**		8,310	**1,310**	**1,310**			1,310		**5,701**
4/5/11	**27,800**				27,800	**12,200**	**1,304**	**4,865**			4,865	**8,330**	**8,330**		8,330	**1,726**	**1,726**			1,726		**5,699**
4/6/11	**27,700**				27,700	**12,000**	**1,156**	**5,036**			5,036	**8,330**	**8,330**		8,330	**2,000**	**2,000**			2,000		**5,751**
4/7/11	**27,900**				27,900	**11,400**	**1,032**	**5,296**			5,296	**7,570**	**7,570**		7,570	**2,002**	**2,002**			2,002		**6,000**
4/8/11	**28,000**				28,000	**10,900**	**805**	**5,410**			5,410	**7,720**	**7,720**		7,720	**2,028**	**2,028**			2,028		**5,618**
4/9/11	**27,600**				27,600	**10,600**	**1,592**	**5,558**			5,558	**8,310**	**8,310**		8,310	**2,026**	**2,026**			2,026		**5,847**
4/10/11	**27,300**				27,300	**10,300**	**1,356**	**5,614**			5,614	**8,320**	**8,320**		8,320	**2,022**	**2,022**			2,022		**6,834**
4/11/11	**27,300**				27,300	**10,200**	**954**	**5,620**			5,620	**8,320**	**8,320**		8,320	**2,043**	**2,043**			2,043		**6,768**
4/12/11	**27,200**				27,200	**9,890**	**1,000**	**5,615**			5,615	**8,290**	**8,290**		8,290	**2,655**	**2,655**			2,655		**6,322**
4/13/11	**27,000**				27,000	**9,680**	**823**	**5,605**			5,605	**8,330**	**8,330**		8,330	**3,066**	**3,066**			3,066		**6,330**
4/14/11	**27,100**				27,100	**9,490**	**645**	**5,585**			5,585	**8,340**	**8,340**		8,340	**3,113**	**3,113**			3,113		**5,383**
4/15/11	**27,200**				27,200	**9,150**	**509**	**5,066**			5,066	**8,310**	**8,310**		8,310	**3,061**	**3,061**			3,061		**5,323**
4/16/11	**27,100**				27,100	**8,930**	**552**	**3,456**			3,456	**8,310**	**8,310**		8,310	**3,017**	**3,017**			3,017		**5,335**
4/17/11	**27,100**				27,100	**8,630**	**994**	**3,062**			3,062	**8,330**	**8,330**		8,330	**3,018**	**3,018**			3,018		**5,980**
4/18/11	**26,800**				26,800	**8,340**	**1,477**	**3,026**			3,026	**8,150**	**8,150**		8,150	**3,048**	**3,048**			3,048		**6,255**
4/19/11	**26,300**				26,300	**8,190**	**2,866**	**2,980**			2,980	**7,710**	**7,710**		7,710	**3,019**	**3,019**			3,019		**6,246**
4/20/11	**25,700**				25,700	**8,070**	**3,100**	**2,984**			2,984	**7,320**	**7,320**		7,320	**2,637**	**2,637**			2,637		**6,252**
4/21/11	**25,000**				25,000	**7,950**	**3,055**	**2,995**			2,995	**7,030**	**7,030**		7,030	**2,532**	**2,532**			2,532		**6,249**
4/22/11	**24,300**				24,300	**7,810**	**3,293**	**2,989**			2,989	**6,750**	**6,750**		6,750	**2,552**	**2,552**			2,552		**7,744**
4/23/11	**23,700**				23,700	**7,630**	**3,204**	**2,984**			2,984	**6,420**	**6,420**		6,420	**2,525**	**2,525**			2,525		**9,132**
4/24/11	**23,200**				23,200	**7,420**	**3,093**	**2,985**			2,985	**6,120**	**6,120**		6,120	**2,560**	**2,560**			2,560		**8,627**
4/25/11	**22,800**				22,800	**7,260**	**3,236**	**2,984**			2,984	**5,770**	**5,770**		5,770	**2,568**	**2,568**			2,568		**4,504**
4/26/11	**22,400**				22,400	**7,200**	**3,316**	**2,454**			2,454	**5,640**	**5,640**		5,640	**2,543**	**2,543**			2,543		**3,321**
4/27/11	**21,800**				21,800	**7,120**	**3,217**	**2,305**			2,305	**5,630**	**5,630**		5,630	**2,529**	**2,529**			2,529		**4,605**
4/28/11	**21,300**				21,300	**7,080**	**2,933**	**2,284**	0	0	2,284	**5,550**	**5,550**		5,550	**2,546**	**2,546**			2,546		**8,357**
4/29/11	**20,800**				20,800	**6,990**	**3,067**	**2,241**	0	0	2,241	**4,890**	**4,890**	0	4,890	**2,174**	**2,174**	0	0	2,174		**8,431**
4/30/11	**20,300**				20,300	**6,770**	**2,819**	**1,785**	0	0	1,785	**4,110**	**4,110**	0	4,110	**2,003**	**2,003**	0	0	2,003		**4,741**
5/1/11	**19,400**	0	0	0.00	19,400	**6,440**	**3,062**	**1,728**	0	0	1,728	**3,470**	**3,470**	0	3,470	**2,014**	**2,014**	0	0	2,014		**4,750**
5/2/11	**18,500**	0	0	0.00	18,500	**6,020**	**3,376**	**1,709**	0	0	1,709	**3,380**	**3,380**	0	3,380	**2,014**	**2,014**	0	0	2,014		**4,739**
5/3/11	**17,600**	0	0	0.00	17,600	**5,810**	**3,891**	**1,708**	0	0	1,708	**3,370**	**3,370**	0	3,370	**2,040**	**2,040**	0	0	2,040		**4,426**
5/4/11	**16,800**	0	0	0.00	16,800	**5,690**	**3,658**	**1,693**	0	0	1,693	**3,360**	**3,360**	0	3,360	**2,025**	**2,025**	0	0	2,025		**5,162**
5/5/11	**16,100**	0	0	0.00	16,100	**5,560**	**3,171**	**1,643**	0	0	1,643	**3,550**	**3,550**	0	3,550	**2,012**	**2,012**	0	0	2,012		**5,164**
5/6/11	**15,700**	0	0	0.00	15,700	**5,380**	**2,917**	**1,639**	0	0	1,639	**3,780**	**3,780**	0	3,780	**2,022**	**2,022**	0	0	2,022		**4,489**
5/7/11	**15,700**	0	0	0.00	15,700	**5,140**	**2,885**	**1,650**	0	0	1,650	**3,780**	**3,780**	0	3,780	**2,017**	**2,017**	0	0	2,017		**4,002**
5/8/11	**15,600**	0	0	0.00	15,600	**4,910**	**2,775**	**1,661**	0	0	1,661	**3,780**	**3,780**	0	3,780	**2,001**	**2,001**	0	0	2,001		**3,500**
5/9/11	**15,400**	0	0	0.00	15,400	**4,600**	**2,824**	**1,661**	0	0	1,661	**3,780**	**3,780**	0	3,780	**2,036**	**2,036**	0	0	2,036		**3,427**
5/10/11	15,341	0	0	0.00	15,341	4,540	3,000	1,660	0	0	1,660	3,800	3,800	0	3,800	2,000	2,000	0	0	2,000		
5/11/11	15,077	0	0	0.00	15,077	4,480	3,000	1,660	0	0	1,660	3,560	3,560	0	3,560	2,000	2,000	0	0	2,000		
5/12/11	15,001	0	0	0.00	15,001	4,420	3,000	1,660	0	0	1,660	3,260	3,260	0	3,260	2,000	2,000	0	0	2,000		
5/13/11	14,700	0	0	0.00	14,700	4,360	3,000	1,660	0	0	1,660	2,960	2,960	0	2,960	2,000	2,000	0	0	2,000		
5/14/11	14,340	0	0	0.00	14,340	4,300	3,000	1,660	0	0	1,660	2,660	2,660	0	2,660	2,000	2,000	0	0	2,000		
5/15/11	13,980	0	0	0.00	13,980	4,240	3,000	1,660	0	0	1,660	2,360	2,360	0	2,360	2,000	2,000	0	0	2,000		
5/16/11	13,620	0	0	0.00	13,620	4,180	3,000	1,660	0	0	1,660	2,200	2,200	0	2,200	2,000	2,000	0	0	2,000		
5/17/11	13,260	0	0	0.00	13,260	4,120	3,000	1,660	0	0	1,660	2,200	2,200	0	2,200	2,000	2,000	0	0	2,000		
5/18/11	13,040	0	0	0.00	13,040	4,060	3,000	1,660	0	0	1,660	2,200	2,200	0	2,200	2,000	2,000	0	0	2,000		
5/19/11	12,980	0	0	0.00	12,980	4,000	3,000	1,660	0	0	1,660	2,200	2,200	0	2,200	2,000	2,000	0	0	2,000		
5/20/11	12,920	0	0	0.00	12,920	3,940	3,000	1,660	0	0	1,660	2,200	2,200	0	2,200	2,000	2,000	0	0	2,000		
5/21/11	12,860	0	0	0.00	12,860	3,880	3,000	1,660	0	0	1,660	2,200	2,200	0	2,200	2,000	2,000	0	0	2,000		
5/22/11	12,800	0	0	0.00	12,800	3,820	3,000	1,660	0	0	1,660	2,200	2,200	0	2,200	2,000	2,000	0	0	2,000		
5/23/11	12,740	0	0	0.00	12,740	3,760	3,000	1,660	0	0	1,660	2,200	2,200	0	2,200	2,000	2,000	0	0	2,000		
5/24/11	12,680	0	0	0.00	12,680	3,700	3,000	1,660	0	0	1,660	2,200	2,200	0	2,200	2,000	2,000	0	0	2,000		
5/25/11	12,620	0	0	0.00	12,620	3,640	3,000	1,660	0	0	1,660	2,200	2,200	0	2,200	2,000	2,000	0	0	2,000		
5/26/11	12,560	0	0	0.00	12,560	3,580	3,000	1,660	0	0	1,660	2,200	2,200	0	2,200	2,000	2,000	0	0	2,000		
5/27/11	12,500	0	0	0.00	12,500	3,520	3,000	1,660	0	0	1,660	2,200	2,200	0	2,200	2,000	2,000	0	0	2,000		
5/28/11	12,440	0	0	0.00	12,440	3,460	3,000	1,660	0	0	1,660	2,200	2,200	0	2,200	2,000	2,000	0	0	2,000		
5/29/11	12,380	0	0	0.00	12,380	3,400	3,000	1,660			1,660	2,200	2,200	0	2,200	2,000	2,000	0	0	2,000		
5/30/11	12,320	0	0	0.00	12,320	3,340	3,000	1,660			1,660	2,200	2,200		2,200	2,000	2,000			2,000		
5/31/11	12,260	0	0	0.00	12,260	3,280	3,000	1,660			1,660	2,200	2,200		2,200	2,000	2,000			2,000		
VAMP Period																						
Avg. (cfs):	14,297	0	0		14,297	4,604	3,050	1,708	0	0	1,708	2,924	2,924	0	2,924	2,012	2,012	0	0	2,012		
Supplemental Water (TAF):		0.00	0.00						0.00	0.00				0.00				0.00	0.00			

VAMP flow operation period

Appendix A, Table 11
2011 VAMP DAILY OPERATION PLAN – MAY 12, 2011
Target Flow Period: May 1st – May 31st * Flow Target: n/a
Bold Numbers: observed real-time mean daily flows

Date	San Joaquin River near Vernalis							Merced River at Cressey				Tuolumne River below La Grange Dam				Stanislaus R below Goodwin Dam						
	Existing Flow (cfs)	VAMP Supplemental Flow (cfs)	Other Supplemental Flow (cfs)	Cumulative VAMP Supplemental Flow (TAF)	VAMP Flow (cfs)	SJR above Merced R (2day lag) (cfs)	Ungaged Flow above Vernalis (cfs)	Existing Flow (cfs)	MeID VAMP Supplemental Flow (cfs)	SJREC VAMP Supplemental Flow (cfs)	VAMP Flow (3day lag) (cfs)	Existing Flow - base FERC volume (cfs)	Existing Flow - Adjusted FERC Pulse (cfs)	VAMP Supplemental Flow (cfs)	VAMP Flow (2day lag) (cfs)	Existing Flow - Base (cfs)	Existing Flow - reshaped	VAMP Supplemental Flow (cfs)	Other Supplemental Flow (cfs)	VAMP Flow (2day lag) (cfs)	Maintain Priority Flow Level M=Merced T=Tuol. S=Stan.	Combined Delta Exports
3/10/11	**9,920**					**1,050**	**1,240**	**3,642**			3,642	**3,780**	**3,780**		3,780	**210**	**210**			210		**7,646**
3/11/11	**9,860**					**985**	**1,107**	**3,559**			3,559	**3,660**	**3,660**		3,660	**220**	**220**			220		**7,660**
3/12/11	**9,750**					**905**	**1,080**	**3,052**			3,052	**3,280**	**3,280**		3,280	**209**	**209**			209		**7,682**
3/13/11	**9,440**				9,450	**828**	**943**	**3,077**			3,077	**2,870**	**2,870**		2,870	**205**	**205**			205		**8,292**
3/14/11	**8,930**				8,940	**784**	**987**	**3,063**			3,063	**2,680**	**2,680**		2,680	**203**	**203**			203		**7,963**
3/15/11	**8,470**				8,470	**749**	**1,515**	**3,069**			3,069	**2,700**	**2,700**		2,700	**204**	**204**			204		**7,019**
3/16/11	**8,230**				8,230	**730**	**1,486**	**3,113**			3,113	**2,830**	**2,830**		2,830	**205**	**205**			205		**7,025**
3/17/11	**8,110**				8,110	**708**	**1,394**	**3,133**			3,133	**3,320**	**3,320**		3,320	**201**	**201**			201		**7,011**
3/18/11	**8,300**				8,300	**710**	**1,466**	**3,123**			3,123	**3,500**	**3,500**		3,500	**208**	**208**			208		**7,030**
3/19/11	**8,660**				8,660	**742**	**1,318**	**3,244**			3,244	**4,850**	**4,850**		4,850	**205**	**205**			205		**7,024**
3/20/11	**9,300**				9,300	**852**	**1,749**	**4,081**			4,081	**5,260**	**5,260**		5,260	**235**	**235**			235		**7,033**
3/21/11	**11,300**				11,300	**1,150**	**2,380**	**5,135**			5,135	**6,380**	**6,380**		6,380	**480**	**480**			480		**7,056**
3/22/11	**13,600**				13,600	**2,880**	**4,009**	**1,935**			1,935	**7,110**	**7,110**		7,110	**1,305**	**1,305**			1,305		**7,999**
3/23/11	**15,000**				15,000	**4,710**	**2,909**	**2,474**			2,474	**7,660**	**7,660**		7,660	**1,300**	**1,300**			1,300		**5,376**
3/24/11	**15,600**				15,600	**6,610**	**-830**	**3,774**			3,774	**7,260**	**7,260**		7,260	**1,330**	**1,330**			1,330		**775**
3/25/11	**16,400**				16,400	**8,020**	**795**	**4,774**			4,774	**7,120**	**7,120**		7,120	**1,334**	**1,334**			1,334		**408**
3/26/11	**18,200**				18,200	**9,600**	**526**	**3,916**			3,916	**7,140**	**7,140**		7,140	**1,344**	**1,344**			1,344		**956**
3/27/11	**19,400**				19,400	**11,900**	**-848**	**3,998**			3,998	**7,510**	**7,510**		7,510	**1,336**	**1,336**			1,336		**3,246**
3/28/11	**21,100**				21,100	**13,800**	**-1,758**	**4,216**			4,216	**7,780**	**7,780**		7,780	**1,334**	**1,334**			1,334		**4,077**
3/29/11	**23,000**				23,000	**14,800**	**-1,662**	**4,287**			4,287	**8,110**	**8,110**		8,110	**1,328**	**1,328**			1,328		**4,310**
3/30/11	**25,200**				25,200	**14,900**	**-1,712**	**4,137**			4,137	**8,320**	**8,320**		8,320	**1,328**	**1,328**			1,328		**1,565**
3/31/11	**27,500**				27,500	**14,700**	**-954**	**4,121**			4,121	**8,310**	**8,310**		8,310	**1,323**	**1,323**			1,323		**5,036**
4/1/11	**28,600**				28,600	**13,700**	**-235**	**4,105**			4,105	**8,330**	**8,330**		8,330	**1,301**	**1,301**			1,301		**5,420**
4/2/11	**28,700**				28,700	**12,500**	**230**	**4,459**			4,459	**8,360**	**8,360**		8,360	**1,307**	**1,307**			1,307		**5,208**
4/3/11	**28,700**				28,700	**12,400**	**1,248**	**4,624**			4,624	**8,330**	**8,330**		8,330	**1,307**	**1,307**			1,307		**5,508**
4/4/11	**28,200**				28,200	**12,300**	**1,928**	**4,612**			4,612	**8,310**	**8,310**		8,310	**1,310**	**1,310**			1,310		**5,701**
4/5/11	**27,800**				27,800	**12,200**	**1,304**	**4,865**			4,865	**8,330**	**8,330**		8,330	**1,726**	**1,726**			1,726		**5,699**
4/6/11	**27,700**				27,700	**12,000**	**1,156**	**5,036**			5,036	**8,330**	**8,330**		8,330	**2,000**	**2,000**			2,000		**5,751**
4/7/11	**27,900**				27,900	**11,400**	**1,032**	**5,296**			5,296	**7,570**	**7,570**		7,570	**2,002**	**2,002**			2,002		**6,000**
4/8/11	**28,000**				28,000	**10,900**	**805**	**5,410**			5,410	**7,720**	**7,720**		7,720	**2,028**	**2,028**			2,028		**5,618**
4/9/11	**27,600**				27,600	**10,600**	**1,592**	**5,558**			5,558	**8,310**	**8,310**		8,310	**2,026**	**2,026**			2,026		**5,847**
4/10/11	**27,300**				27,300	**10,300**	**1,356**	**5,614**			5,614	**8,320**	**8,320**		8,320	**2,022**	**2,022**			2,022		**6,834**
4/11/11	**27,300**				27,300	**10,200**	**954**	**5,620**			5,620	**8,320**	**8,320**		8,320	**2,043**	**2,043**			2,043		**6,768**
4/12/11	**27,200**				27,200	**9,890**	**1,000**	**5,615**			5,615	**8,290**	**8,290**		8,290	**2,655**	**2,655**			2,655		**6,322**
4/13/11	**27,000**				27,000	**9,680**	**823**	**5,605**			5,605	**8,330**	**8,330**		8,330	**3,066**	**3,066**			3,066		**6,330**
4/14/11	**27,100**				27,100	**9,490**	**645**	**5,585**			5,585	**8,340**	**8,340**		8,340	**3,113**	**3,113**			3,113		**5,383**
4/15/11	**27,200**				27,200	**9,150**	**509**	**5,066**			5,066	**8,310**	**8,310**		8,310	**3,061**	**3,061**			3,061		**5,323**
4/16/11	**27,100**				27,100	**8,930**	**552**	**3,456**			3,456	**8,310**	**8,310**		8,310	**3,017**	**3,017**			3,017		**5,335**
4/17/11	**27,100**				27,100	**8,630**	**994**	**3,062**			3,062	**8,330**	**8,330**		8,330	**3,018**	**3,018**			3,018		**5,980**
4/18/11	**26,800**				26,800	**8,340**	**1,477**	**3,026**			3,026	**8,150**	**8,150**		8,150	**3,048**	**3,048**			3,048		**6,255**
4/19/11	**26,300**				26,300	**8,190**	**2,866**	**2,980**			2,980	**7,710**	**7,710**		7,710	**3,019**	**3,019**			3,019		**6,246**
4/20/11	**25,700**				25,700	**8,070**	**3,100**	**2,984**			2,984	**7,320**	**7,320**		7,320	**2,637**	**2,637**			2,637		**6,252**
4/21/11	**25,000**				25,000	**7,950**	**3,055**	**2,995**			2,995	**7,030**	**7,030**		7,030	**2,532**	**2,532**			2,532		**6,249**
4/22/11	**24,300**				24,300	**7,810**	**3,293**	**2,989**			2,989	**6,750**	**6,750**		6,750	**2,552**	**2,552**			2,552		**7,744**
4/23/11	**23,700**				23,700	**7,630**	**3,204**	**2,984**			2,984	**6,420**	**6,420**		6,420	**2,525**	**2,525**			2,525		**9,132**
4/24/11	**23,200**				23,200	**7,420**	**3,093**	**2,985**			2,985	**6,120**	**6,120**		6,120	**2,560**	**2,560**			2,560		**8,627**
4/25/11	**22,800**				22,800	**7,260**	**3,236**	**2,984**			2,984	**5,770**	**5,770**		5,770	**2,568**	**2,568**			2,568		**4,504**
4/26/11	**22,400**				22,400	**7,200**	**3,316**	**2,454**			2,454	**5,640**	**5,640**		5,640	**2,543**	**2,543**			2,543		**3,321**
4/27/11	**21,800**				21,800	**7,120**	**3,217**	**2,305**			2,305	**5,630**	**5,630**		5,630	**2,529**	**2,529**			2,529		**4,605**
4/28/11	**21,300**				21,300	**7,080**	**2,933**	**2,284**	0	0	2,284	**5,550**	**5,550**		5,550	**2,546**	**2,546**			2,546		**8,357**
4/29/11	**20,800**				20,800	**6,990**	**3,067**	**2,241**	0	0	2,241	**4,890**	**4,890**	0	4,890	**2,174**	**2,174**	0	0	2,174		**8,431**
4/30/11	**20,300**				20,300	**6,770**	**2,819**	**1,785**	0	0	1,785	**4,110**	**4,110**	0	4,110	**2,003**	**2,003**	0	0	2,003		**4,741**
5/1/11	**19,400**	0	0	0.00	19,400	**6,440**	**3,062**	**1,728**	0	0	1,728	**3,470**	**3,470**	0	3,470	**2,014**	**2,014**	0	0	2,014		**4,750**
5/2/11	**18,500**	0	0	0.00	18,500	**6,020**	**3,376**	**1,709**	0	0	1,709	**3,380**	**3,380**	0	3,380	**2,014**	**2,014**	0	0	2,014		**4,739**
5/3/11	**17,600**	0	0	0.00	17,600	**5,810**	**3,891**	**1,708**	0	0	1,708	**3,370**	**3,370**	0	3,370	**2,040**	**2,040**	0	0	2,040		**4,426**
5/4/11	**16,800**	0	0	0.00	16,800	**5,690**	**3,658**	**1,693**	0	0	1,693	**3,360**	**3,360**	0	3,360	**2,025**	**2,025**	0	0	2,025		**5,162**
5/5/11	**16,100**	0	0	0.00	16,100	**5,560**	**3,171**	**1,643**	0	0	1,643	**3,550**	**3,550**	0	3,550	**2,012**	**2,012**	0	0	2,012		**5,164**
5/6/11	**15,700**	0	0	0.00	15,700	**5,380**	**2,917**	**1,639**	0	0	1,639	**3,780**	**3,780**	0	3,780	**2,022**	**2,022**	0	0	2,022		**4,489**
5/7/11	**15,700**	0	0	0.00	15,700	**5,140**	**2,885**	**1,650**	0	0	1,650	**3,780**	**3,780**	0	3,780	**2,017**	**2,017**	0	0	2,017		**4,002**
5/8/11	**15,600**	0	0	0.00	15,600	**4,910**	**2,775**	**1,661**	0	0	1,661	**3,780**	**3,780**	0	3,780	**2,001**	**2,001**	0	0	2,001		**3,500**
5/9/11	**15,400**	0	0	0.00	15,400	**4,600**	**2,824**	**1,661**	0	0	1,661	**3,780**	**3,780**	0	3,780	**2,036**	**2,036**	0	0	2,036		**3,427**
5/10/11	**15,100**	0	0	0.00	15,100	**4,260**	**2,759**	**2,267**	0	0	2,267	**3,720**	**3,720**	0	3,720	**2,028**	**2,028**	0	0	2,028		**3,365**
5/11/11	**14,700**	0	0	0.00	14,700	**3,980**	**2,623**	**2,222**	0	0	2,222	**3,550**	**3,550**	0	3,550	**2,058**	**2,058**	0	0	2,058		**3,365**
5/12/11	14,269	0	0	0.00	14,269	3,830	2,600	2,400	0	0	2,400	3,260	3,260	0	3,260	2,000	2,000	0	0	2,000		
5/13/11	14,055	0	0	0.00	14,055	3,680	2,200	2,400	0	0	2,400	2,960	2,960	0	2,960	2,000	2,000	0	0	2,000		
5/14/11	13,412	0	0	0.00	13,412	3,530	2,100	2,400	0	0	2,400	2,660	2,660	0	2,660	2,000	2,000	0	0	2,000		
5/15/11	13,140	0	0	0.00	13,140	3,380	2,100	2,400	0	0	2,400	2,360	2,360	0	2,360	2,000	2,000	0	0	2,000		
5/16/11	12,690	0	0	0.00	12,690	3,230	2,100	2,400	0	0	2,400	2,200	2,200	0	2,200	2,000	2,000	0	0	2,000		
5/17/11	12,240	0	0	0.00	12,240	3,080	2,100	2,400	0	0	2,400	2,200	2,200	0	2,200	2,000	2,000	0	0	2,000		
5/18/11	11,930	0	0	0.00	11,930	2,930	2,100	2,400	0	0	2,400	2,200	2,200	0	2,200	2,000	2,000	0	0	2,000		
5/19/11	11,780	0	0	0.00	11,780	2,780	2,100	2,400	0	0	2,400	2,200	2,200	0	2,200	2,000	2,000	0	0	2,000		
5/20/11	11,630	0	0	0.00	11,630	2,630	2,100	2,400	0	0	2,400	2,200	2,200	0	2,200	2,000	2,000	0	0	2,000		
5/21/11	11,480	0	0	0.00	11,480	2,480	2,100	2,400	0	0	2,400	2,200	2,200	0	2,200	2,000	2,000	0	0	2,000		
5/22/11	11,330	0	0	0.00	11,330	2,330	2,100	2,400	0	0	2,400	2,200	2,200	0	2,200	2,000	2,000	0	0	2,000		
5/23/11	11,180	0	0	0.00	11,180	2,180	2,100	2,400	0	0	2,400	2,200	2,200	0	2,200	2,000	2,000	0	0	2,000		
5/24/11	11,030	0	0	0.00	11,030	2,030	2,100	2,400	0	0	2,400	2,200	2,200	0	2,200	2,000	2,000	0	0	2,000		
5/25/11	10,880	0	0	0.00	10,880	1,880	2,100	2,400	0	0	2,400	2,200	2,200	0	2,200	2,000	2,000	0	0	2,000		
5/26/11	10,730	0	0	0.00	10,730	1,730	2,100	2,400	0	0	2,400	2,200	2,200	0	2,200	2,000	2,000	0	0	2,000		
5/27/11	10,580	0	0	0.00	10,580	1,580	2,100	2,400	0	0	2,400	2,200	2,200	0	2,200	2,000	2,000	0	0	2,000		
5/28/11	10,430	0	0	0.00	10,430	1,430	2,100	2,400	0	0	2,400	2,200	2,200	0	2,200	2,000	2,000	0	0	2,000		
5/29/11	10,280	0	0	0.00	10,280	1,280	2,100	2,400			2,400	2,200	2,200	0	2,200	2,000	2,000	0	0	2,000		
5/30/11	10,130	0	0	0.00	10,130	1,130	2,100	2,400			2,400	2,200	2,200		2,200	2,000	2,000			2,000		
5/31/11	9,980	0	0	0.00	9,980	980	2,100	2,400			2,400	2,200	2,200		2,200	2,000	2,000			2,000		
											VAMP Period											
Avg. (cfs):	13,348	0	0		13,348	3,792	2,469	2,151	0	0	2,151	2,921	2,921	0	2,921	2,014	2,014	0	0	2,014		
Supplemental Water (TAF):		0.00	0.00						0.00	0.00				0.00				0.00	0.00			

VAMP flow operation period

Appendix A, Table 12
2011 VAMP DAILY OPERATION PLAN – MAY 12, 2011 (REVISED)
Target Flow Period: May 1st – May 31st * Flow Target: n/a
Bold Numbers: observed real-time mean daily flows

Date	San Joaquin River near Vernalis: Existing Flow (cfs)	VAMP Supplemental Flow (cfs)	Other Supplemental Flow (cfs)	Cumulative VAMP Supplemental Flow (TAF)	VAMP Flow (cfs)	SJR above Merced R (2day lag) (cfs)	Ungaged Flow above Vernalis (cfs)	Merced River at Cressey: Existing Flow (cfs)	MeID VAMP Supplemental Flow (cfs)	SJREC VAMP Supplemental Flow (cfs)	VAMP Flow (3day lag) (cfs)	Tuolumne River below La Grange Dam: Existing Flow - base FERC volume (cfs)	Existing Flow - Adjusted FERC Pulse (cfs)	VAMP Supplemental Flow (cfs)	VAMP Flow (2day lag) (cfs)	Stanislaus R below Goodwin Dam: Existing Flow - Base (cfs)	Existing Flow - reshaped	VAMP Supplemental Flow (cfs)	Other Supplemental Flow (cfs)	VAMP Flow (2day lag) (cfs)	Maintain Priority Flow Level M=Merced T=Tuol. S=Stan.	Combined Delta Exports
3/10/11	**9,920**					**1,050**	**1,240**	**3,642**			3,642	**3,780**	**3,780**		3,780	**210**	**210**			210		**7,646**
3/11/11	**9,860**					**985**	**1,107**	**3,559**			3,559	**3,660**	**3,660**		3,660	**220**	**220**			220		**7,660**
3/12/11	**9,750**					**905**	**1,080**	**3,052**			3,052	**3,280**	**3,280**		3,280	**209**	**209**			209		**7,682**
3/13/11	**9,440**				9,450	**828**	**943**	**3,077**			3,077	**2,870**	**2,870**		2,870	**205**	**205**			205		**8,292**
3/14/11	**8,930**				8,940	**784**	**987**	**3,063**			3,063	**2,680**	**2,680**		2,680	**203**	**203**			203		**7,963**
3/15/11	**8,470**				8,470	**749**	**1,515**	**3,069**			3,069	**2,700**	**2,700**		2,700	**204**	**204**			204		**7,019**
3/16/11	**8,230**				8,230	**730**	**1,486**	**3,113**			3,113	**2,830**	**2,830**		2,830	**205**	**205**			205		**7,025**
3/17/11	**8,110**				8,110	**708**	**1,394**	**3,133**			3,133	**3,320**	**3,320**		3,320	**201**	**201**			201		**7,011**
3/18/11	**8,300**				8,300	**710**	**1,466**	**3,123**			3,123	**3,500**	**3,500**		3,500	**208**	**208**			208		**7,030**
3/19/11	**8,660**				8,660	**742**	**1,318**	**3,244**			3,244	**4,850**	**4,850**		4,850	**205**	**205**			205		**7,024**
3/20/11	**9,300**				9,300	**852**	**1,749**	**4,081**			4,081	**5,260**	**5,260**		5,260	**235**	**235**			235		**7,033**
3/21/11	**11,300**				11,300	**1,150**	**2,380**	**5,135**			5,135	**6,380**	**6,380**		6,380	**480**	**480**			480		**7,056**
3/22/11	**13,600**				13,600	**2,880**	**4,009**	**1,935**			1,935	**7,110**	**7,110**		7,110	**1,305**	**1,305**			1,305		**7,999**
3/23/11	**15,000**				15,000	**4,710**	**2,909**	**2,474**			2,474	**7,660**	**7,660**		7,660	**1,300**	**1,300**			1,300		**5,376**
3/24/11	**15,600**				15,600	**6,610**	**-830**	**3,774**			3,774	**7,260**	**7,260**		7,260	**1,330**	**1,330**			1,330		**775**
3/25/11	**16,400**				16,400	**8,020**	**795**	**4,774**			4,774	**7,120**	**7,120**		7,120	**1,334**	**1,334**			1,334		**408**
3/26/11	**18,200**				18,200	**9,600**	**526**	**3,916**			3,916	**7,140**	**7,140**		7,140	**1,344**	**1,344**			1,344		**956**
3/27/11	**19,400**				19,400	**11,900**	**-848**	**3,998**			3,998	**7,510**	**7,510**		7,510	**1,336**	**1,336**			1,336		**3,246**
3/28/11	**21,100**				21,100	**13,800**	**-1,758**	**4,216**			4,216	**7,780**	**7,780**		7,780	**1,334**	**1,334**			1,334		**4,077**
3/29/11	**23,000**				23,000	**14,800**	**-1,662**	**4,287**			4,287	**8,110**	**8,110**		8,110	**1,328**	**1,328**			1,328		**4,310**
3/30/11	**25,200**				25,200	**14,900**	**-1,712**	**4,137**			4,137	**8,320**	**8,320**		8,320	**1,328**	**1,328**			1,328		**1,565**
3/31/11	**27,500**				27,500	**14,700**	**-954**	**4,121**			4,121	**8,310**	**8,310**		8,310	**1,323**	**1,323**			1,323		**5,036**
4/1/11	**28,600**				28,600	**13,700**	**-235**	**4,105**			4,105	**8,330**	**8,330**		8,330	**1,301**	**1,301**			1,301		**5,420**
4/2/11	**28,700**				28,700	**12,500**	**230**	**4,459**			4,459	**8,360**	**8,360**		8,360	**1,307**	**1,307**			1,307		**5,208**
4/3/11	**28,700**				28,700	**12,400**	**1,248**	**4,624**			4,624	**8,330**	**8,330**		8,330	**1,307**	**1,307**			1,307		**5,508**
4/4/11	**28,200**				28,200	**12,300**	**1,928**	**4,612**			4,612	**8,310**	**8,310**		8,310	**1,310**	**1,310**			1,310		**5,701**
4/5/11	**27,800**				27,800	**12,200**	**1,304**	**4,865**			4,865	**8,330**	**8,330**		8,330	**1,726**	**1,726**			1,726		**5,699**
4/6/11	**27,700**				27,700	**12,000**	**1,156**	**5,036**			5,036	**8,330**	**8,330**		8,330	**2,000**	**2,000**			2,000		**5,751**
4/7/11	**27,900**				27,900	**11,400**	**1,032**	**5,296**			5,296	**7,570**	**7,570**		7,570	**2,002**	**2,002**			2,002		**6,000**
4/8/11	**28,000**				28,000	**10,900**	**805**	**5,410**			5,410	**7,720**	**7,720**		7,720	**2,028**	**2,028**			2,028		**5,618**
4/9/11	**27,600**				27,600	**10,600**	**1,592**	**5,558**			5,558	**8,310**	**8,310**		8,310	**2,026**	**2,026**			2,026		**5,847**
4/10/11	**27,300**				27,300	**10,300**	**1,356**	**5,614**			5,614	**8,320**	**8,320**		8,320	**2,022**	**2,022**			2,022		**6,834**
4/11/11	**27,300**				27,300	**10,200**	**954**	**5,620**			5,620	**8,320**	**8,320**		8,320	**2,043**	**2,043**			2,043		**6,768**
4/12/11	**27,200**				27,200	**9,890**	**1,000**	**5,615**			5,615	**8,290**	**8,290**		8,290	**2,655**	**2,655**			2,655		**6,322**
4/13/11	**27,000**				27,000	**9,680**	**823**	**5,605**			5,605	**8,330**	**8,330**		8,330	**3,066**	**3,066**			3,066		**6,330**
4/14/11	**27,100**				27,100	**9,490**	**645**	**5,585**			5,585	**8,340**	**8,340**		8,340	**3,113**	**3,113**			3,113		**5,383**
4/15/11	**27,200**				27,200	**9,150**	**509**	**5,066**			5,066	**8,310**	**8,310**		8,310	**3,061**	**3,061**			3,061		**5,323**
4/16/11	**27,100**				27,100	**8,930**	**552**	**3,456**			3,456	**8,310**	**8,310**		8,310	**3,017**	**3,017**			3,017		**5,335**
4/17/11	**27,100**				27,100	**8,630**	**994**	**3,062**			3,062	**8,330**	**8,330**		8,330	**3,018**	**3,018**			3,018		**5,980**
4/18/11	**26,800**				26,800	**8,340**	**1,477**	**3,026**			3,026	**8,150**	**8,150**		8,150	**3,048**	**3,048**			3,048		**6,255**
4/19/11	**26,300**				26,300	**8,190**	**2,866**	**2,980**			2,980	**7,710**	**7,710**		7,710	**3,019**	**3,019**			3,019		**6,246**
4/20/11	**25,700**				25,700	**8,070**	**3,100**	**2,984**			2,984	**7,320**	**7,320**		7,320	**2,637**	**2,637**			2,637		**6,252**
4/21/11	**25,000**				25,000	**7,950**	**3,055**	**2,995**			2,995	**7,030**	**7,030**		7,030	**2,532**	**2,532**			2,532		**6,249**
4/22/11	**24,300**				24,300	**7,810**	**3,293**	**2,989**			2,989	**6,750**	**6,750**		6,750	**2,552**	**2,552**			2,552		**7,744**
4/23/11	**23,700**				23,700	**7,630**	**3,204**	**2,984**			2,984	**6,420**	**6,420**		6,420	**2,525**	**2,525**			2,525		**9,132**
4/24/11	**23,200**				23,200	**7,420**	**3,093**	**2,985**			2,985	**6,120**	**6,120**		6,120	**2,560**	**2,560**			2,560		**8,627**
4/25/11	**22,800**				22,800	**7,260**	**3,236**	**2,984**			2,984	**5,770**	**5,770**		5,770	**2,568**	**2,568**			2,568		**4,504**
4/26/11	**22,400**				22,400	**7,200**	**3,316**	**2,454**			2,454	**5,640**	**5,640**		5,640	**2,543**	**2,543**			2,543		**3,321**
4/27/11	**21,800**				21,800	**7,120**	**3,217**	**2,305**			2,305	**5,630**	**5,630**		5,630	**2,529**	**2,529**			2,529		**4,605**
4/28/11	**21,300**				21,300	**7,080**	**2,933**	**2,284**	0	0	2,284	**5,550**	**5,550**		5,550	**2,546**	**2,546**			2,546		**8,357**
4/29/11	**20,800**				20,800	**6,990**	**3,067**	**2,241**	0	0	2,241	**4,890**	**4,890**	0	4,890	**2,174**	**2,174**	0	0	2,174		**8,431**
4/30/11	**20,300**				20,300	**6,770**	**2,819**	**1,785**	0	0	1,785	**4,110**	**4,110**	0	4,110	**2,003**	**2,003**	0	0	2,003		**4,741**
5/1/11	**19,400**	0	0	0.00	19,400	**6,440**	**3,062**	**1,728**	0	0	1,728	**3,470**	**3,470**	0	3,470	**2,014**	**2,014**	0	0	2,014		**4,750**
5/2/11	**18,500**	0	0	0.00	18,500	**6,020**	**3,376**	**1,709**	0	0	1,709	**3,380**	**3,380**	0	3,380	**2,014**	**2,014**	0	0	2,014		**4,739**
5/3/11	**17,600**	0	0	0.00	17,600	**5,810**	**3,891**	**1,708**	0	0	1,708	**3,370**	**3,370**	0	3,370	**2,040**	**2,040**	0	0	2,040		**4,426**
5/4/11	**16,800**	0	0	0.00	16,800	**5,690**	**3,658**	**1,693**	0	0	1,693	**3,360**	**3,360**	0	3,360	**2,025**	**2,025**	0	0	2,025		**5,162**
5/5/11	**16,100**	0	0	0.00	16,100	**5,560**	**3,171**	**1,643**	0	0	1,643	**3,550**	**3,550**	0	3,550	**2,012**	**2,012**	0	0	2,012		**5,164**
5/6/11	**15,700**	0	0	0.00	15,700	**5,380**	**2,917**	**1,639**	0	0	1,639	**3,780**	**3,780**	0	3,780	**2,022**	**2,022**	0	0	2,022		**4,489**
5/7/11	**15,700**	0	0	0.00	15,700	**5,140**	**2,885**	**1,650**	0	0	1,650	**3,780**	**3,780**	0	3,780	**2,017**	**2,017**	0	0	2,017		**4,002**
5/8/11	**15,600**	0	0	0.00	15,600	**4,910**	**2,775**	**1,661**	0	0	1,661	**3,780**	**3,780**	0	3,780	**2,001**	**2,001**	0	0	2,001		**3,500**
5/9/11	**15,400**	0	0	0.00	15,400	**4,600**	**2,824**	**1,661**	0	0	1,661	**3,780**	**3,780**	0	3,780	**2,036**	**2,036**	0	0	2,036		**3,427**
5/10/11	**15,100**	0	0	0.00	15,100	**4,260**	**2,759**	**2,267**	0	0	2,267	**3,720**	**3,720**	0	3,720	**2,028**	**2,028**	0	0	2,028		**3,365**
5/11/11	**14,700**	0	0	0.00	14,700	**3,980**	**2,623**	**2,222**	0	0	2,222	**3,550**	**3,550**	0	3,550	**2,058**	**2,058**	0	0	2,058		**3,365**
5/12/11	14,269	0	0	0.00	14,269	3,830	2,600	2,400	0	0	2,400	3,260	3,260	0	3,260	2,000	2,000	0	0	2,000		
5/13/11	14,055	0	0	0.00	14,055	3,680	2,200	2,400	0	0	2,400	3,000	3,000	0	3,000	2,000	2,000	0	0	2,000		
5/14/11	13,412	0	0	0.00	13,412	3,530	2,100	2,400	0	0	2,400	3,000	3,000	0	3,000	2,000	2,000	0	0	2,000		
5/15/11	13,180	0	0	0.00	13,180	3,380	2,100	2,400	0	0	2,400	3,000	3,000	0	3,000	2,000	2,000	0	0	2,000		
5/16/11	13,030	0	0	0.00	13,030	3,230	2,100	2,400	0	0	2,400	3,000	3,000	0	3,000	2,000	2,000	0	0	2,000		
5/17/11	12,880	0	0	0.00	12,880	3,080	2,100	2,400	0	0	2,400	3,000	3,000	0	3,000	2,000	2,000	0	0	2,000		
5/18/11	12,730	0	0	0.00	12,730	2,930	2,100	2,400	0	0	2,400	3,000	3,000	0	3,000	2,000	2,000	0	0	2,000		
5/19/11	12,580	0	0	0.00	12,580	2,780	2,100	2,400	0	0	2,400	3,000	3,000	0	3,000	2,000	2,000	0	0	2,000		
5/20/11	12,430	0	0	0.00	12,430	2,630	2,100	2,400	0	0	2,400	3,000	3,000	0	3,000	2,000	2,000	0	0	2,000		
5/21/11	12,280	0	0	0.00	12,280	2,480	2,100	2,400	0	0	2,400	3,000	3,000	0	3,000	2,000	2,000	0	0	2,000		
5/22/11	12,130	0	0	0.00	12,130	2,330	2,100	2,400	0	0	2,400	3,000	3,000	0	3,000	2,000	2,000	0	0	2,000		
5/23/11	11,980	0	0	0.00	11,980	2,180	2,100	2,400	0	0	2,400	3,000	3,000	0	3,000	2,000	2,000	0	0	2,000		
5/24/11	11,830	0	0	0.00	11,830	2,030	2,100	2,400	0	0	2,400	3,000	3,000	0	3,000	2,000	2,000	0	0	2,000		
5/25/11	11,680	0	0	0.00	11,680	1,880	2,100	2,400	0	0	2,400	3,000	3,000	0	3,000	2,000	2,000	0	0	2,000		
5/26/11	11,530	0	0	0.00	11,530	1,730	2,100	2,400	0	0	2,400	3,000	3,000	0	3,000	2,000	2,000	0	0	2,000		
5/27/11	11,380	0	0	0.00	11,380	1,580	2,100	2,400	0	0	2,400	3,000	3,000	0	3,000	2,000	2,000	0	0	2,000		
5/28/11	11,230	0	0	0.00	11,230	1,430	2,100	2,400	0	0	2,400	3,000	3,000	0	3,000	2,000	2,000	0	0	2,000		
5/29/11	11,080	0	0	0.00	11,080	1,280	2,100	2,400			2,400	3,000	3,000	0	3,000	2,000	2,000	0	0	2,000		
5/30/11	10,930	0	0	0.00	10,930	1,130	2,100	2,400			2,400	3,000	3,000		3,000	2,000	2,000			2,000		
5/31/11	10,780	0	0	0.00	10,780	980	2,100	2,400			2,400	3,000	3,000		3,000	2,000	2,000			2,000		
VAMP Period																						
Avg. (cfs):	13,742	0	0		13,742	3,792	2,469	2,151	0	0	2,151	3,315	3,315	0	3,315	2,014	2,014	0	0	2,014		
Supplemental Water (TAF):		0.00	0.00						0.00	0.00				0.00				0.00	0.00			

VAMP flow operation period

Appendix A, Table 13

2011 VAMP DAILY OPERATION PLAN -- MAY 19, 2011

Target Flow Period: May 1st – May 31st * Flow Target: n/a

Bold Numbers: observed real-time mean daily flows

	San Joaquin River near Vernalis							Merced River at Cressey				Tuolumne River below La Grange Dam				Stanislaus R below Goodwin Dam					
Date	Existing Flow (cfs)	VAMP Supplemental Flow (cfs)	Other Supplemental Flow (cfs)	Cumulative VAMP Supplemental Flow (TAF)	VAMP Flow (cfs)	SJR above Merced R (2day lag) (cfs)	Ungaged Flow above Vernalis (cfs)	Existing Flow (cfs)	MeID VAMP Supplemental Flow (cfs)	SJREC VAMP Supplemental Flow (cfs)	VAMP Flow (3day lag) (cfs)	Existing Flow - base FERC volume (cfs)	Existing Flow - Adjusted FERC Pulse (cfs)	VAMP Supplemental Flow (cfs)	VAMP Flow (2day lag) (cfs)	Existing Flow - Base (cfs)	Existing Flow - reshaped	VAMP Supplemental Flow (cfs)	Other Supplemental Flow (cfs)	VAMP Flow (2day lag) (cfs)	Maintain Priority Flow Level M=Merced T=Tuol. S=Stan.	Combined Delta Exports
3/10/11	**9,920**					**1,050**	**1,530**	**3,642**			3,642	**3,780**	**3,780**		3,780	**210**	**210**			210		**7,646**
3/11/11	**9,860**					**985**	**1,447**	**3,559**			3,559	**3,660**	**3,660**		3,660	**220**	**220**			220		**7,660**
3/12/11	**9,750**					**905**	**1,410**	**3,052**			3,052	**3,280**	**3,280**		3,280	**209**	**209**			209		**7,682**
3/13/11	**9,440**				9,840	**828**	**1,333**	**3,077**			3,077	**2,870**	**2,870**		2,870	**205**	**205**			205		**8,292**
3/14/11	**8,930**				9,350	**784**	**1,397**	**3,063**			3,063	**2,680**	**2,680**		2,680	**203**	**203**			203		**7,963**
3/15/11	**8,920**				8,920	**749**	**1,965**	**3,069**			3,069	**2,700**	**2,700**		2,700	**204**	**204**			204		**7,019**
3/16/11	**8,710**				8,710	**730**	**1,966**	**3,113**			3,113	**2,830**	**2,830**		2,830	**205**	**205**			205		**7,025**
3/17/11	**8,621**				8,621	**708**	**1,905**	**3,133**			3,133	**3,320**	**3,320**		3,320	**201**	**201**			201		**7,011**
3/18/11	**8,850**				8,850	**710**	**2,016**	**3,123**			3,123	**3,500**	**3,500**		3,500	**208**	**208**			208		**7,030**
3/19/11	**9,260**				9,260	**742**	**1,918**	**3,244**			3,244	**4,850**	**4,850**		4,850	**205**	**205**			205		**7,024**
3/20/11	**9,960**				9,960	**852**	**2,409**	**4,081**			4,081	**5,260**	**5,260**		5,260	**235**	**235**			235		**7,033**
3/21/11	**12,000**				12,000	**1,150**	**3,080**	**5,135**			5,135	**6,380**	**6,380**		6,380	**480**	**480**			480		**7,056**
3/22/11	**14,400**				14,400	**2,880**	**4,809**	**1,935**			1,935	**7,110**	**7,110**		7,110	**1,305**	**1,305**			1,305		**7,999**
3/23/11	**15,900**				15,900	**4,710**	**3,809**	**2,474**			2,474	**7,660**	**7,660**		7,660	**1,300**	**1,300**			1,300		**5,376**
3/24/11	**16,500**				16,500	**6,610**	**70**	**3,774**			3,774	**7,260**	**7,260**		7,260	**1,330**	**1,330**			1,330		**775**
3/25/11	**17,500**				17,500	**8,020**	**1,895**	**4,774**			4,774	**7,120**	**7,120**		7,120	**1,334**	**1,334**			1,334		**408**
3/26/11	**19,400**				19,400	**9,600**	**1,726**	**3,916**			3,916	**7,140**	**7,140**		7,140	**1,344**	**1,344**			1,344		**956**
3/27/11	**20,700**				20,700	**11,900**	**452**	**3,998**			3,998	**7,510**	**7,510**		7,510	**1,336**	**1,336**			1,336		**3,246**
3/28/11	**22,510**				22,510	**13,800**	**-348**	**4,216**			4,216	**7,780**	**7,780**		7,780	**1,334**	**1,334**			1,334		**4,077**
3/29/11	**24,600**				24,600	**14,800**	**-62**	**4,287**			4,287	**8,110**	**8,110**		8,110	**1,328**	**1,328**			1,328		**4,310**
3/30/11	**27,100**				27,100	**14,900**	**188**	**4,137**			4,137	**8,320**	**8,320**		8,320	**1,328**	**1,328**			1,328		**1,565**
3/31/11	**29,500**				29,500	**14,700**	**1,046**	**4,121**			4,121	**8,310**	**8,310**		8,310	**1,323**	**1,323**			1,323		**5,036**
4/1/11	**30,700**				30,700	**13,700**	**1,865**	**4,105**			4,105	**8,330**	**8,330**		8,330	**1,301**	**1,301**			1,301		**5,420**
4/2/11	**30,800**				30,800	**12,500**	**2,330**	**4,459**			4,459	**8,360**	**8,360**		8,360	**1,307**	**1,307**			1,307		**5,208**
4/3/11	**30,700**				30,700	**12,400**	**3,248**	**4,624**			4,624	**8,330**	**8,330**		8,330	**1,307**	**1,307**			1,307		**5,508**
4/4/11	**30,100**				30,100	**12,300**	**3,828**	**4,612**			4,612	**8,310**	**8,310**		8,310	**1,310**	**1,310**			1,310		**5,701**
4/5/11	**29,500**				29,500	**12,200**	**3,004**	**4,865**			4,865	**8,330**	**8,330**		8,330	**1,726**	**1,726**			1,726		**5,699**
4/6/11	**29,300**				29,300	**12,000**	**2,756**	**5,036**			5,036	**8,330**	**8,330**		8,330	**2,000**	**2,000**			2,000		**5,751**
4/7/11	**29,400**				29,400	**11,400**	**2,532**	**5,296**			5,296	**7,570**	**7,570**		7,570	**2,002**	**2,002**			2,002		**6,000**
4/8/11	**29,400**				29,400	**10,900**	**2,205**	**5,410**			5,410	**7,720**	**7,720**		7,720	**2,028**	**2,028**			2,028		**5,618**
4/9/11	**28,900**				28,900	**10,600**	**2,892**	**5,558**			5,558	**8,310**	**8,310**		8,310	**2,026**	**2,026**			2,026		**5,847**
4/10/11	**28,500**				28,500	**10,300**	**2,556**	**5,614**			5,614	**8,320**	**8,320**		8,320	**2,022**	**2,022**			2,022		**6,834**
4/11/11	**28,400**				28,400	**10,200**	**2,054**	**5,620**			5,620	**8,320**	**8,320**		8,320	**2,043**	**2,043**			2,043		**6,768**
4/12/11	**28,200**				28,200	**9,890**	**2,000**	**5,615**			5,615	**8,290**	**8,290**		8,290	**2,655**	**2,655**			2,655		**6,322**
4/13/11	**27,900**				27,900	**9,680**	**1,723**	**5,605**			5,605	**8,330**	**8,330**		8,330	**3,066**	**3,066**			3,066		**6,330**
4/14/11	**27,900**				27,900	**9,490**	**1,445**	**5,585**			5,585	**8,340**	**8,340**		8,340	**3,113**	**3,113**			3,113		**5,383**
4/15/11	**27,900**				27,900	**9,150**	**1,209**	**5,066**			5,066	**8,310**	**8,310**		8,310	**3,061**	**3,061**			3,061		**5,323**
4/16/11	**27,700**				27,700	**8,930**	**1,152**	**3,456**			3,456	**8,310**	**8,310**		8,310	**3,017**	**3,017**			3,017		**5,335**
4/17/11	**27,590**				27,590	**8,630**	**1,484**	**3,062**			3,062	**8,330**	**8,330**		8,330	**3,018**	**3,018**			3,018		**5,980**
4/18/11	**27,100**				27,100	**8,340**	**1,777**	**3,026**			3,026	**8,150**	**8,150**		8,150	**3,048**	**3,048**			3,048		**6,255**
4/19/11	**26,390**				26,390	**8,190**	**2,956**	**2,980**			2,980	**7,710**	**7,710**		7,710	**3,019**	**3,019**			3,019		**6,246**
4/20/11	**25,590**				25,590	**8,070**	**2,990**	**2,984**			2,984	**7,320**	**7,320**		7,320	**2,637**	**2,637**			2,637		**6,252**
4/21/11	**24,800**				24,800	**7,950**	**2,855**	**2,995**			2,995	**7,030**	**7,030**		7,030	**2,532**	**2,532**			2,532		**6,249**
4/22/11	**23,690**				23,690	**7,810**	**2,683**	**2,989**			2,989	**6,750**	**6,750**		6,750	**2,552**	**2,552**			2,552		**7,744**
4/23/11	**22,990**				22,990	**7,630**	**2,494**	**2,984**			2,984	**6,420**	**6,420**		6,420	**2,525**	**2,525**			2,525		**9,132**
4/24/11	**22,290**				22,290	**7,420**	**2,183**	**2,985**			2,985	**6,120**	**6,120**		6,120	**2,560**	**2,560**			2,560		**8,627**
4/25/11	**21,690**				21,690	**7,260**	**2,126**	**2,984**			2,984	**5,770**	**5,770**		5,770	**2,568**	**2,568**			2,568		**4,504**
4/26/11	**21,190**				21,190	**7,200**	**2,106**	**2,454**			2,454	**5,640**	**5,640**		5,640	**2,543**	**2,543**			2,543		**3,321**
4/27/11	**20,590**				20,590	**7,120**	**2,007**	**2,305**			2,305	**5,630**	**5,630**		5,630	**2,529**	**2,529**			2,529		**4,605**
4/28/11	**20,000**				20,000	**7,080**	**1,633**	**2,284**	0	0	2,284	**5,550**	**5,550**		5,550	**2,546**	**2,546**			2,546		**8,357**
4/29/11	**19,400**				19,400	**6,990**	**1,667**	**2,241**	0	0	2,241	**4,890**	**4,890**	0	4,890	**2,174**	**2,174**	0	0	2,174		**8,431**
4/30/11	**18,800**				18,800	**6,770**	**1,319**	**1,785**	0	0	1,785	**4,110**	**4,110**	0	4,110	**2,003**	**2,003**	0	0	2,003		**4,741**
5/1/11	**17,800**	0	0	0.00	17,800	**6,440**	**1,462**	**1,728**	0	0	1,728	**3,470**	**3,470**	0	3,470	**2,014**	**2,014**	0	0	2,014		**4,750**
5/2/11	**16,700**	0	0	0.00	16,700	**6,020**	**1,576**	**1,709**	0	0	1,709	**3,380**	**3,380**	0	3,380	**2,014**	**2,014**	0	0	2,014		**4,739**
5/3/11	**15,700**	0	0	0.00	15,700	**5,810**	**1,991**	**1,708**	0	0	1,708	**3,370**	**3,370**	0	3,370	**2,040**	**2,040**	0	0	2,040		**4,426**
5/4/11	**14,800**	0	0	0.00	14,800	**5,690**	**1,658**	**1,693**	0	0	1,693	**3,360**	**3,360**	0	3,360	**2,025**	**2,025**	0	0	2,025		**5,162**
5/5/11	**14,100**	0	0	0.00	14,100	**5,560**	**1,171**	**1,643**	0	0	1,643	**3,550**	**3,550**	0	3,550	**2,012**	**2,012**	0	0	2,012		**5,164**
5/6/11	**13,700**	0	0	0.00	13,700	**5,380**	**917**	**1,639**	0	0	1,639	**3,780**	**3,780**	0	3,780	**2,022**	**2,022**	0	0	2,022		**4,489**
5/7/11	**13,600**	0	0	0.00	13,600	**5,140**	**785**	**1,650**	0	0	1,650	**3,780**	**3,780**	0	3,780	**2,017**	**2,017**	0	0	2,017		**4,002**
5/8/11	**13,500**	0	0	0.00	13,500	**4,910**	**675**	**1,661**	0	0	1,661	**3,780**	**3,780**	0	3,780	**2,001**	**2,001**	0	0	2,001		**3,500**
5/9/11	**13,300**	0	0	0.00	13,300	**4,600**	**724**	**1,661**	0	0	1,661	**3,780**	**3,780**	0	3,780	**2,036**	**2,036**	0	0	2,036		**3,427**
5/10/11	**13,000**	0	0	0.00	13,000	**4,260**	**659**	**2,267**	0	0	2,267	**3,720**	**3,720**	0	3,720	**2,028**	**2,028**	0	0	2,028		**3,365**
5/11/11	**12,600**	0	0	0.00	12,600	**3,980**	**523**	**2,222**	0	0	2,222	**3,550**	**3,550**	0	3,550	**2,058**	**2,058**	0	0	2,058		**3,365**
5/12/11	**12,200**	0	0	0.00	12,200	**3,800**	**531**	**2,436**	0	0	2,436	**3,240**	**3,240**	0	3,240	**2,043**	**2,043**	0	0	2,043		**3,358**
5/13/11	**11,800**	0	0	0.00	11,800	**3,570**	**-55**	**2,435**	0	0	2,435	**3,000**	**3,000**	0	3,000	**2,021**	**2,021**	0	0	2,021		**3,349**
5/14/11	**11,400**	0	0	0.00	11,400	**2,980**	**95**	**2,407**	0	0	2,407	**2,990**	**2,990**	0	2,990	**2,009**	**2,009**	0	0	2,009		**3,372**
5/15/11	**11,200**	0	0	0.00	11,200	**2,460**	**173**	**2,500**	0	0	2,500	**2,980**	**2,980**	0	2,980	**2,001**	**2,001**	0	0	2,001		**3,670**
5/16/11	**11,000**	0	0	0.00	11,000	**2,470**	**586**	**2,509**	0	0	2,509	**2,960**	**2,960**	0	2,960	**2,042**	**2,042**	0	0	2,042		**4,071**
5/17/11	**10,700**	0	0	0.00	10,700	**2,540**	**852**	**2,521**	0	0	2,521	**3,000**	**3,000**	0	3,000	**2,032**	**2,032**	0	0	2,032		**4,071**
5/18/11	**10,600**	0	0	0.00	10,600	**2,460**	**628**	**2,537**	0	0	2,537	**3,000**	**3,000**	0	3,000	**2,037**	**2,037**	0	0	2,037		**3,417**
5/19/11	10,681	0	0	0.00	10,681	2,410	600	2,400	0	0	2,400	3,000	3,000	0	3,000	2,000	2,000	0	0	2,000		
5/20/11	10,618	0	0	0.00	10,618	2,360	600	2,400	0	0	2,400	3,000	3,000	0	3,000	2,000	2,000	0	0	2,000		
5/21/11	10,547	0	0	0.00	10,547	2,310	600	2,400	0	0	2,400	3,000	3,000	0	3,000	2,000	2,000	0	0	2,000		
5/22/11	10,360	0	0	0.00	10,360	2,260	600	2,400	0	0	2,400	3,000	3,000	0	3,000	2,000	2,000	0	0	2,000		
5/23/11	10,310	0	0	0.00	10,310	2,210	600	2,400	0	0	2,400	3,000	3,000	0	3,000	2,000	2,000	0	0	2,000		
5/24/11	10,260	0	0	0.00	10,260	2,160	600	2,400	0	0	2,400	3,000	3,000	0	3,000	2,000	2,000	0	0	2,000		
5/25/11	10,210	0	0	0.00	10,210	2,110	600	2,400	0	0	2,400	3,000	3,000	0	3,000	2,000	2,000	0	0	2,000		
5/26/11	10,160	0	0	0.00	10,160	2,060	600	2,400	0	0	2,400	3,000	3,000	0	3,000	2,000	2,000	0	0	2,000		
5/27/11	10,110	0	0	0.00	10,110	2,010	600	2,400	0	0	2,400	3,000	3,000	0	3,000	2,000	2,000	0	0	2,000		
5/28/11	10,060	0	0	0.00	10,060	1,960	600	2,400	0	0	2,400	3,000	3,000	0	3,000	2,000	2,000	0	0	2,000		
5/29/11	10,010	0	0	0.00	10,010	1,910	600	2,400			2,400	3,000	3,000	0	3,000	2,000	2,000	0	0	2,000		
5/30/11	9,960	0	0	0.00	9,960	1,860	600	2,400			2,400	3,000	3,000		3,000	2,000	2,000			2,000		
5/31/11	9,910	0	0	0.00	9,910	1,810	600	2,400			2,400	3,000	3,000		3,000	2,000	2,000			2,000		
											VAMP Period											
Avg. (cfs):	11,964	0	0		11,964	3,729	734	2,169	0	0	2,169	3,313	3,313	0	3,313	2,020	2,020	0	0	2,020		
Supplemental Water (TAF):		0.00	0.00						0.00	0.00				0.00				0.00	0.00			

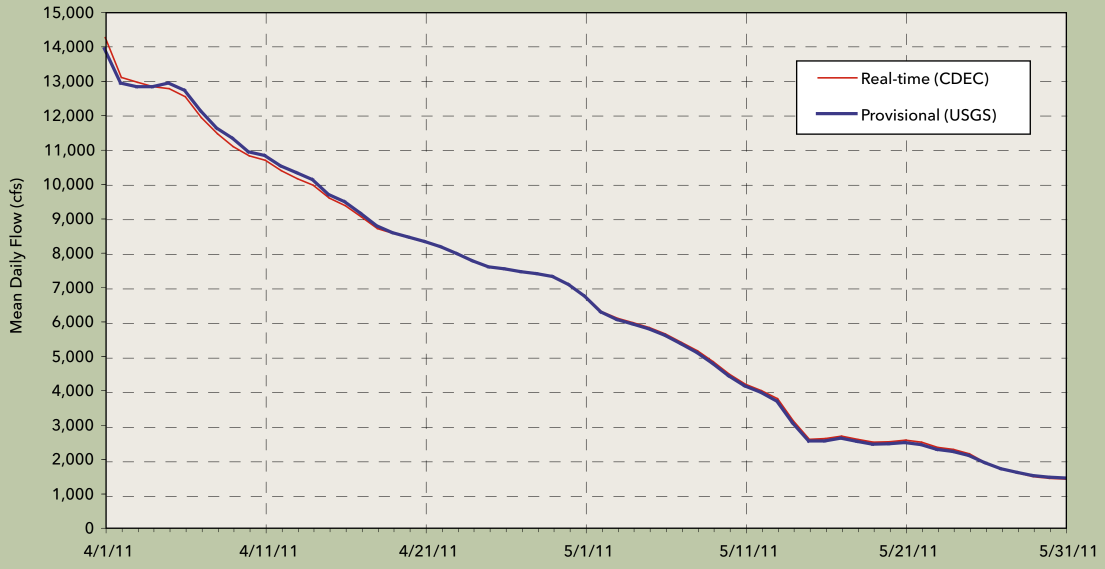
VAMP flow operation period

Appendix A, Table 14
2011 VAMP DAILY OPERATION PLAN – MAY 20, 2011
Target Flow Period: May 1st – May 31st * Flow Target: n/a
Bold Numbers: observed real-time mean daily flows

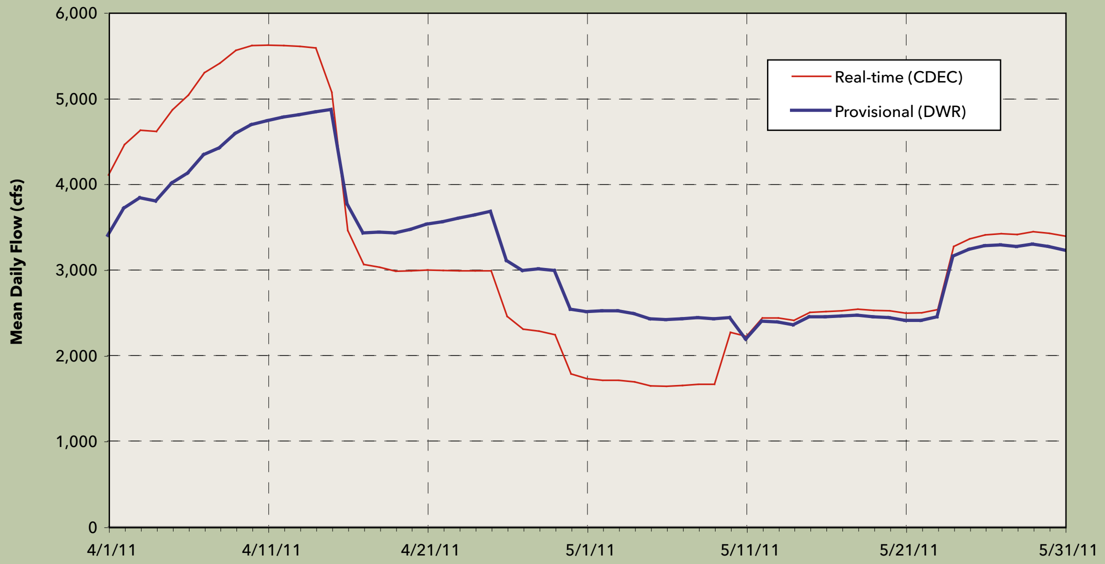
Date	San Joaquin River near Vernalis: Existing Flow (cfs)	VAMP Supplemental Flow (cfs)	Other Supplemental Flow (cfs)	Cumulative VAMP Supplemental Flow (TAF)	VAMP Flow (cfs)	SJR above Merced R (2day lag) (cfs)	Ungaged Flow above Vernalis (cfs)	Merced River at Cressey: Existing Flow (cfs)	MeID VAMP Supplemental Flow (cfs)	SJREC VAMP Supplemental Flow (cfs)	VAMP Flow (3day lag) (cfs)	Tuolumne River below La Grange Dam: Existing Flow - base FERC volume (cfs)	Existing Flow - Adjusted FERC Pulse (cfs)	VAMP Supplemental Flow (cfs)	VAMP Flow (2day lag) (cfs)	Stanislaus R below Goodwin Dam: Existing Flow - Base (cfs)	Existing Flow - reshaped	VAMP Supplemental Flow (cfs)	Other Supplemental Flow (cfs)	VAMP Flow (2day lag) (cfs)	Maintain Priority Flow Level M=Merced T=Tuol. S=Stan.	Combined Delta Exports
3/10/11	**9,920**					**1,050**	**1,530**	**3,642**			3,642	**3,780**	**3,780**		3,780	**210**	**210**			210		**7,646**
3/11/11	**9,860**					**985**	**1,447**	**3,559**			3,559	**3,660**	**3,660**		3,660	**220**	**220**			220		**7,660**
3/12/11	**9,750**					**905**	**1,410**	**3,052**			3,052	**3,280**	**3,280**		3,280	**209**	**209**			209		**7,682**
3/13/11	**9,440**				9,840	**828**	**1,333**	**3,077**			3,077	**2,870**	**2,870**		2,870	**205**	**205**			205		**8,292**
3/14/11	**8,930**				9,350	**784**	**1,397**	**3,063**			3,063	**2,680**	**2,680**		2,680	**203**	**203**			203		**7,963**
3/15/11	**8,920**				8,920	**749**	**1,965**	**3,069**			3,069	**2,700**	**2,700**		2,700	**204**	**204**			204		**7,019**
3/16/11	**8,710**				8,710	**730**	**1,966**	**3,113**			3,113	**2,830**	**2,830**		2,830	**205**	**205**			205		**7,025**
3/17/11	**8,621**				8,621	**708**	**1,905**	**3,133**			3,133	**3,320**	**3,320**		3,320	**201**	**201**			201		**7,011**
3/18/11	**8,850**				8,850	**710**	**2,016**	**3,123**			3,123	**3,500**	**3,500**		3,500	**208**	**208**			208		**7,030**
3/19/11	**9,260**				9,260	**742**	**1,918**	**3,244**			3,244	**4,850**	**4,850**		4,850	**205**	**205**			205		**7,024**
3/20/11	**9,960**				9,960	**852**	**2,409**	**4,081**			4,081	**5,260**	**5,260**		5,260	**235**	**235**			235		**7,033**
3/21/11	**12,000**				12,000	**1,150**	**3,080**	**5,135**			5,135	**6,380**	**6,380**		6,380	**480**	**480**			480		**7,056**
3/22/11	**14,400**				14,400	**2,880**	**4,809**	**1,935**			1,935	**7,110**	**7,110**		7,110	**1,305**	**1,305**			1,305		**7,999**
3/23/11	**15,900**				15,900	**4,710**	**3,809**	**2,474**			2,474	**7,660**	**7,660**		7,660	**1,300**	**1,300**			1,300		**5,376**
3/24/11	**16,500**				16,500	**6,610**	**70**	**3,774**			3,774	**7,260**	**7,260**		7,260	**1,330**	**1,330**			1,330		**775**
3/25/11	**17,500**				17,500	**8,020**	**1,895**	**4,774**			4,774	**7,120**	**7,120**		7,120	**1,334**	**1,334**			1,334		**408**
3/26/11	**19,400**				19,400	**9,600**	**1,726**	**3,916**			3,916	**7,140**	**7,140**		7,140	**1,344**	**1,344**			1,344		**956**
3/27/11	**20,700**				20,700	**11,900**	**452**	**3,998**			3,998	**7,510**	**7,510**		7,510	**1,336**	**1,336**			1,336		**3,246**
3/28/11	**22,510**				22,510	**13,800**	**-348**	**4,216**			4,216	**7,780**	**7,780**		7,780	**1,334**	**1,334**			1,334		**4,077**
3/29/11	**24,600**				24,600	**14,800**	**-62**	**4,287**			4,287	**8,110**	**8,110**		8,110	**1,328**	**1,328**			1,328		**4,310**
3/30/11	**27,100**				27,100	**14,900**	**188**	**4,137**			4,137	**8,320**	**8,320**		8,320	**1,328**	**1,328**			1,328		**1,565**
3/31/11	**29,500**				29,500	**14,700**	**1,046**	**4,121**			4,121	**8,310**	**8,310**		8,310	**1,323**	**1,323**			1,323		**5,036**
4/1/11	**30,700**				30,700	**13,700**	**1,865**	**4,105**			4,105	**8,330**	**8,330**		8,330	**1,301**	**1,301**			1,301		**5,420**
4/2/11	**30,800**				30,800	**12,500**	**2,330**	**4,459**			4,459	**8,360**	**8,360**		8,360	**1,307**	**1,307**			1,307		**5,208**
4/3/11	**30,700**				30,700	**12,400**	**3,248**	**4,624**			4,624	**8,330**	**8,330**		8,330	**1,307**	**1,307**			1,307		**5,508**
4/4/11	**30,100**				30,100	**12,300**	**3,828**	**4,612**			4,612	**8,310**	**8,310**		8,310	**1,310**	**1,310**			1,310		**5,701**
4/5/11	**29,500**				29,500	**12,200**	**3,004**	**4,865**			4,865	**8,330**	**8,330**		8,330	**1,726**	**1,726**			1,726		**5,699**
4/6/11	**29,300**				29,300	**12,000**	**2,756**	**5,036**			5,036	**8,330**	**8,330**		8,330	**2,000**	**2,000**			2,000		**5,751**
4/7/11	**29,400**				29,400	**11,400**	**2,532**	**5,296**			5,296	**7,570**	**7,570**		7,570	**2,002**	**2,002**			2,002		**6,000**
4/8/11	**29,400**				29,400	**10,900**	**2,205**	**5,410**			5,410	**7,720**	**7,720**		7,720	**2,028**	**2,028**			2,028		**5,618**
4/9/11	**28,900**				28,900	**10,600**	**2,892**	**5,558**			5,558	**8,310**	**8,310**		8,310	**2,026**	**2,026**			2,026		**5,847**
4/10/11	**28,500**				28,500	**10,300**	**2,556**	**5,614**			5,614	**8,320**	**8,320**		8,320	**2,022**	**2,022**			2,022		**6,834**
4/11/11	**28,400**				28,400	**10,200**	**2,054**	**5,620**			5,620	**8,320**	**8,320**		8,320	**2,043**	**2,043**			2,043		**6,768**
4/12/11	**28,200**				28,200	**9,890**	**2,000**	**5,615**			5,615	**8,290**	**8,290**		8,290	**2,655**	**2,655**			2,655		**6,322**
4/13/11	**27,900**				27,900	**9,680**	**1,723**	**5,605**			5,605	**8,330**	**8,330**		8,330	**3,066**	**3,066**			3,066		**6,330**
4/14/11	**27,900**				27,900	**9,490**	**1,445**	**5,585**			5,585	**8,340**	**8,340**		8,340	**3,113**	**3,113**			3,113		**5,383**
4/15/11	**27,900**				27,900	**9,150**	**1,209**	**5,066**			5,066	**8,310**	**8,310**		8,310	**3,061**	**3,061**			3,061		**5,323**
4/16/11	**27,700**				27,700	**8,930**	**1,152**	**3,456**			3,456	**8,310**	**8,310**		8,310	**3,017**	**3,017**			3,017		**5,335**
4/17/11	**27,590**				27,590	**8,630**	**1,484**	**3,062**			3,062	**8,330**	**8,330**		8,330	**3,018**	**3,018**			3,018		**5,980**
4/18/11	**27,100**				27,100	**8,340**	**1,777**	**3,026**			3,026	**8,150**	**8,150**		8,150	**3,048**	**3,048**			3,048		**6,255**
4/19/11	**26,390**				26,390	**8,190**	**2,956**	**2,980**			2,980	**7,710**	**7,710**		7,710	**3,019**	**3,019**			3,019		**6,246**
4/20/11	**25,590**				25,590	**8,070**	**2,990**	**2,984**			2,984	**7,320**	**7,320**		7,320	**2,637**	**2,637**			2,637		**6,252**
4/21/11	**24,800**				24,800	**7,950**	**2,855**	**2,995**			2,995	**7,030**	**7,030**		7,030	**2,532**	**2,532**			2,532		**6,249**
4/22/11	**23,690**				23,690	**7,810**	**2,683**	**2,989**			2,989	**6,750**	**6,750**		6,750	**2,552**	**2,552**			2,552		**7,744**
4/23/11	**22,990**				22,990	**7,630**	**2,494**	**2,984**			2,984	**6,420**	**6,420**		6,420	**2,525**	**2,525**			2,525		**9,132**
4/24/11	**22,290**				22,290	**7,420**	**2,183**	**2,985**			2,985	**6,120**	**6,120**		6,120	**2,560**	**2,560**			2,560		**8,627**
4/25/11	**21,690**				21,690	**7,260**	**2,126**	**2,984**			2,984	**5,770**	**5,770**		5,770	**2,568**	**2,568**			2,568		**4,504**
4/26/11	**21,190**				21,190	**7,200**	**2,106**	**2,454**			2,454	**5,640**	**5,640**		5,640	**2,543**	**2,543**			2,543		**3,321**
4/27/11	**20,590**				20,590	**7,120**	**2,007**	**2,305**			2,305	**5,630**	**5,630**		5,630	**2,529**	**2,529**			2,529		**4,605**
4/28/11	**20,000**				20,000	**7,080**	**1,633**	**2,284**	0	0	2,284	**5,550**	**5,550**		5,550	**2,546**	**2,546**			2,546		**8,357**
4/29/11	**19,400**				19,400	**6,990**	**1,667**	**2,241**	0	0	2,241	**4,890**	**4,890**	0	4,890	**2,174**	**2,174**	0	0	2,174		**8,431**
4/30/11	**18,800**				18,800	**6,770**	**1,319**	**1,785**	0	0	1,785	**4,110**	**4,110**	0	4,110	**2,003**	**2,003**	0	0	2,003		**4,741**
5/1/11	**17,800**	0	0	0.00	17,800	**6,440**	**1,462**	**1,728**	0	0	1,728	**3,470**	**3,470**	0	3,470	**2,014**	**2,014**	0	0	2,014		**4,750**
5/2/11	**16,700**	0	0	0.00	16,700	**6,020**	**1,576**	**1,709**	0	0	1,709	**3,380**	**3,380**	0	3,380	**2,014**	**2,014**	0	0	2,014		**4,739**
5/3/11	**15,700**	0	0	0.00	15,700	**5,810**	**1,991**	**1,708**	0	0	1,708	**3,370**	**3,370**	0	3,370	**2,040**	**2,040**	0	0	2,040		**4,426**
5/4/11	**14,800**	0	0	0.00	14,800	**5,690**	**1,658**	**1,693**	0	0	1,693	**3,360**	**3,360**	0	3,360	**2,025**	**2,025**	0	0	2,025		**5,162**
5/5/11	**14,100**	0	0	0.00	14,100	**5,560**	**1,171**	**1,643**	0	0	1,643	**3,550**	**3,550**	0	3,550	**2,012**	**2,012**	0	0	2,012		**5,164**
5/6/11	**13,700**	0	0	0.00	13,700	**5,380**	**917**	**1,639**	0	0	1,639	**3,780**	**3,780**	0	3,780	**2,022**	**2,022**	0	0	2,022		**4,489**
5/7/11	**13,600**	0	0	0.00	13,600	**5,140**	**785**	**1,650**	0	0	1,650	**3,780**	**3,780**	0	3,780	**2,017**	**2,017**	0	0	2,017		**4,002**
5/8/11	**13,500**	0	0	0.00	13,500	**4,910**	**675**	**1,661**	0	0	1,661	**3,780**	**3,780**	0	3,780	**2,001**	**2,001**	0	0	2,001		**3,500**
5/9/11	**13,300**	0	0	0.00	13,300	**4,600**	**724**	**1,661**	0	0	1,661	**3,780**	**3,780**	0	3,780	**2,036**	**2,036**	0	0	2,036		**3,427**
5/10/11	**13,000**	0	0	0.00	13,000	**4,260**	**659**	**2,267**	0	0	2,267	**3,720**	**3,720**	0	3,720	**2,028**	**2,028**	0	0	2,028		**3,365**
5/11/11	**12,600**	0	0	0.00	12,600	**3,980**	**523**	**2,222**	0	0	2,222	**3,550**	**3,550**	0	3,550	**2,058**	**2,058**	0	0	2,058		**3,365**
5/12/11	**12,200**	0	0	0.00	12,200	**3,800**	**531**	**2,436**	0	0	2,436	**3,240**	**3,240**	0	3,240	**2,043**	**2,043**	0	0	2,043		**3,358**
5/13/11	**11,800**	0	0	0.00	11,800	**3,570**	**-55**	**2,435**	0	0	2,435	**3,000**	**3,000**	0	3,000	**2,021**	**2,021**	0	0	2,021		**3,349**
5/14/11	**11,400**	0	0	0.00	11,400	**2,980**	**95**	**2,407**	0	0	2,407	**2,990**	**2,990**	0	2,990	**2,009**	**2,009**	0	0	2,009		**3,372**
5/15/11	**11,200**	0	0	0.00	11,200	**2,460**	**173**	**2,500**	0	0	2,500	**2,980**	**2,980**	0	2,980	**2,001**	**2,001**	0	0	2,001		**3,670**
5/16/11	**11,000**	0	0	0.00	11,000	**2,470**	**586**	**2,509**	0	0	2,509	**2,960**	**2,960**	0	2,960	**2,042**	**2,042**	0	0	2,042		**4,071**
5/17/11	**10,700**	0	0	0.00	10,700	**2,540**	**852**	**2,521**	0	0	2,521	**3,000**	**3,000**	0	3,000	**2,032**	**2,032**	0	0	2,032		**4,071**
5/18/11	**10,600**	0	0	0.00	10,600	**2,460**	**628**	**2,537**	0	0	2,537	**3,000**	**3,000**	0	3,000	**2,037**	**2,037**	0	0	2,037		**3,417**
5/19/11	**10,500**	0	0	0.00	10,500	**2,380**	**419**	**2,525**	0	0	2,525	**2,970**	**2,970**	0	2,970	**2,039**	**2,039**	0	0	2,039		**2,449**
5/20/11	10,418	0	0	0.00	10,418	2,360	400	2,500	0	0	2,500	3,000	3,000	0	3,000	2,000	2,000	0	0	2,000		
5/21/11	10,326	0	0	0.00	10,326	2,340	400	2,500	0	0	2,500	3,000	3,000	0	3,000	2,000	2,000	0	0	2,000		
5/22/11	10,285	0	0	0.00	10,285	2,320	400	2,500	0	0	2,500	3,000	3,000	0	3,000	2,000	2,000	0	0	2,000		
5/23/11	10,240	0	0	0.00	10,240	2,300	400	2,900	0	0	2,900	3,000	3,000	0	3,000	2,000	2,000	0	0	2,000		
5/24/11	10,220	0	0	0.00	10,220	2,280	400	3,250	0	0	3,250	3,000	3,000	0	3,000	2,000	2,000	0	0	2,000		
5/25/11	10,200	0	0	0.00	10,200	2,260	400	3,250	0	0	3,250	3,000	3,000	0	3,000	2,000	2,000	0	0	2,000		
5/26/11	10,580	0	0	0.00	10,580	2,240	400	3,250	0	0	3,250	3,000	3,000	0	3,000	2,000	2,000	0	0	2,000		
5/27/11	10,910	0	0	0.00	10,910	2,220	400	3,250	0	0	3,250	3,000	3,000	0	3,000	1,750	1,750	0	0	1,750		
5/28/11	10,890	0	0	0.00	10,890	2,200	400	3,250	0	0	3,250	3,000	3,000	0	3,000	1,500	1,500	0	0	1,500		
5/29/11	10,620	0	0	0.00	10,620	2,180	400	3,250			3,250	3,000	3,000	0	3,000	1,500	1,500	0	0	1,500		
5/30/11	10,350	0	0	0.00	10,350	2,160	400	3,250			3,250	3,000	3,000		3,000	1,500	1,500			1,500		
5/31/11	10,330	0	0	0.00	10,330	2,140	400	3,250			3,250	3,000	3,000		3,000	1,500	1,500			1,500		
VAMP Period																						
Avg. (cfs):	12,051	0	0		12,051	3,771	651	2,336	0	0	2,336	3,312	3,312	0	3,312	1,981	1,981	0	0	1,981		
Supplemental Water (TAF):		0.00	0.00						0.00	0.00				0.00				0.00	0.00			

VAMP flow operation period

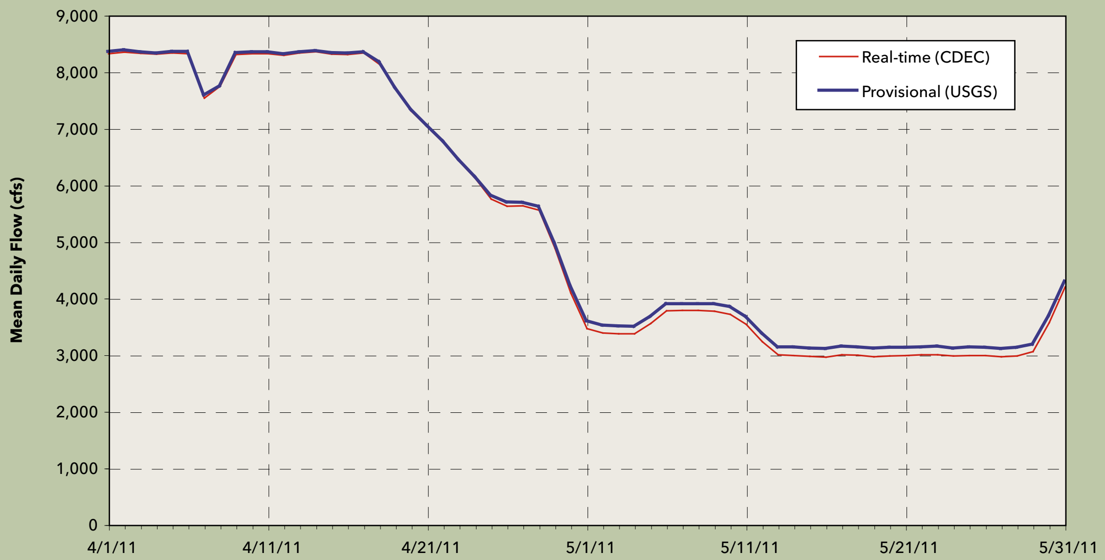
Appendix A, Figure 1
Mean Daily Flow in the San Joaquin River at Fremont Ford Bridge
in Cubic Feet per Second (cfs) from April 1st to May 31st



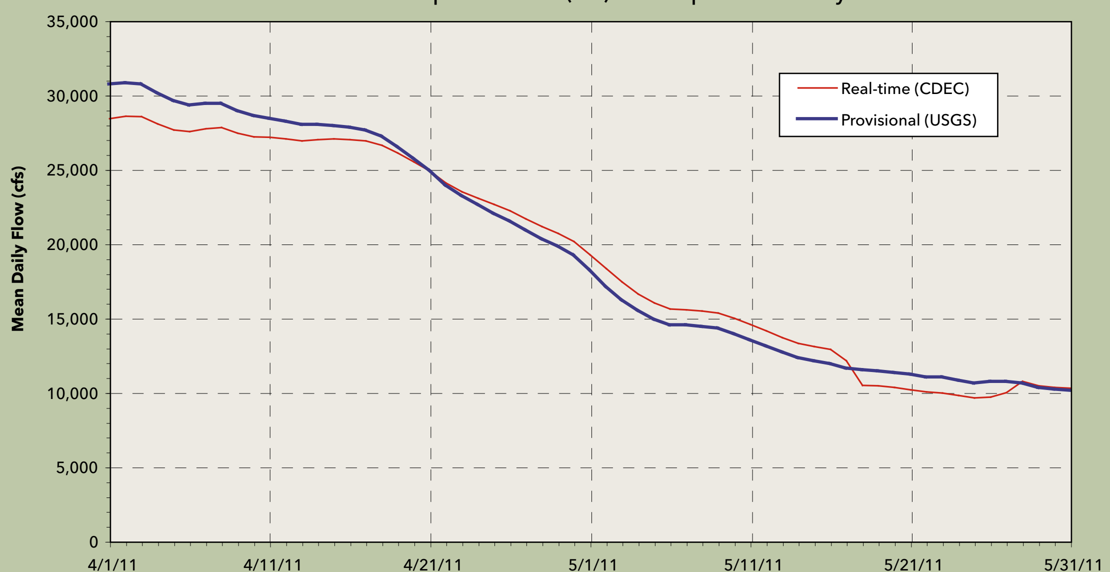
Appendix A, Figure 2
Mean Daily Flow in the Merced River at Cressey in
Cubic Feet per Second (cfs) from April 1st to May 31st



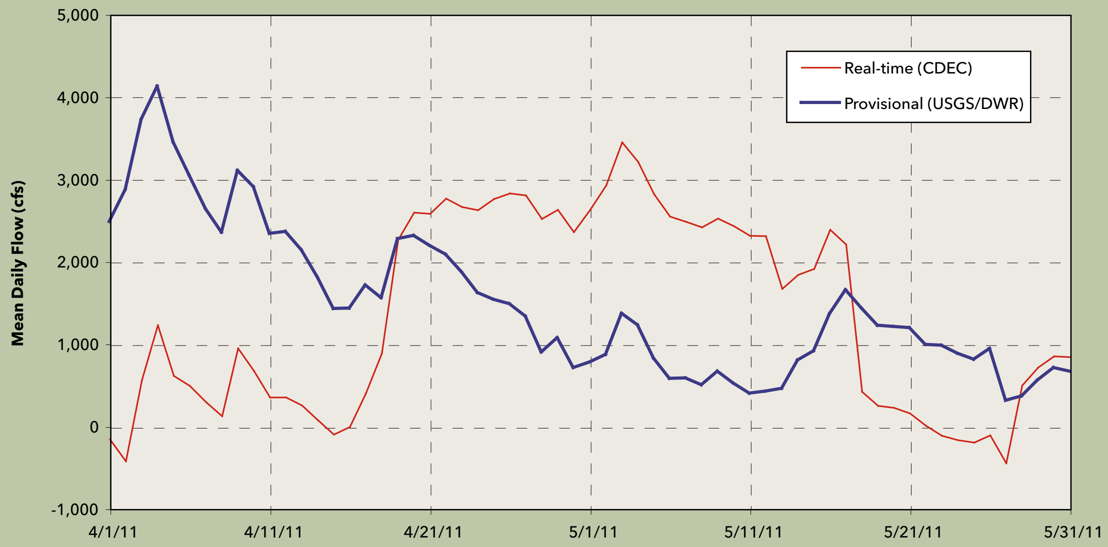
Appendix A, Figure 3
Mean Daily Flow in the Tuolumne River below La Grange Dam
in Cubic Feet per Second (cfs) from April 1st to May 31st



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

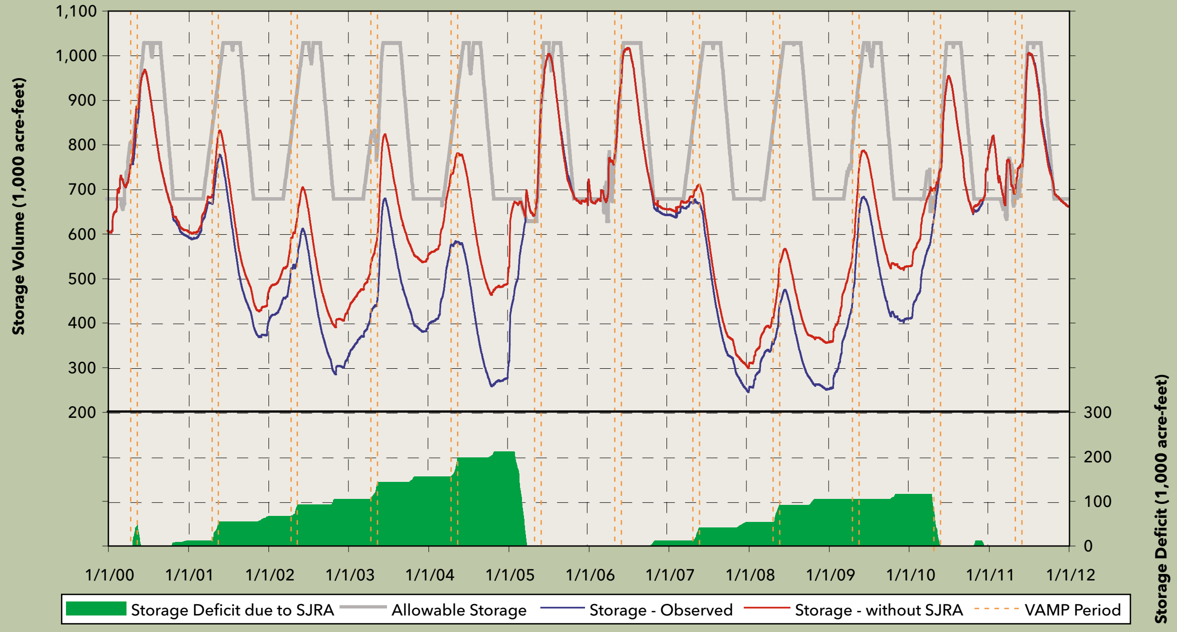


Appendix A, Figure 5
Mean Daily Ungaged Flow in the San Joaquin River near Vernalis (VNS)
in Cubic Feet per Second (cfs) from April 1st to May 31st

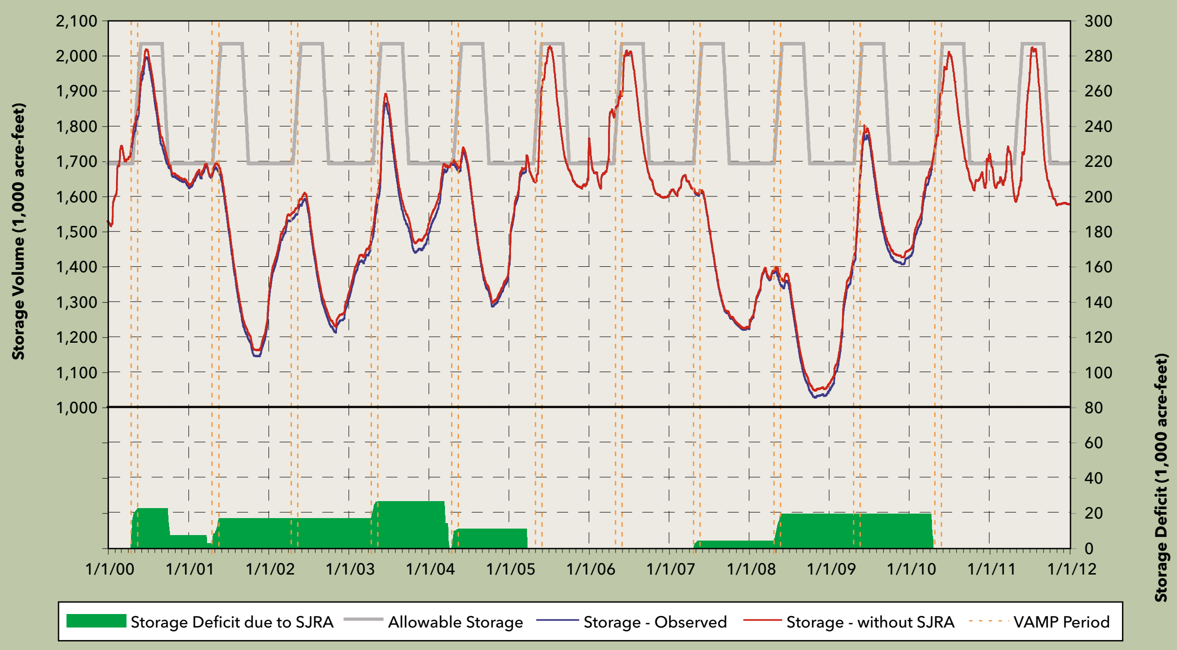


APPENDIX B

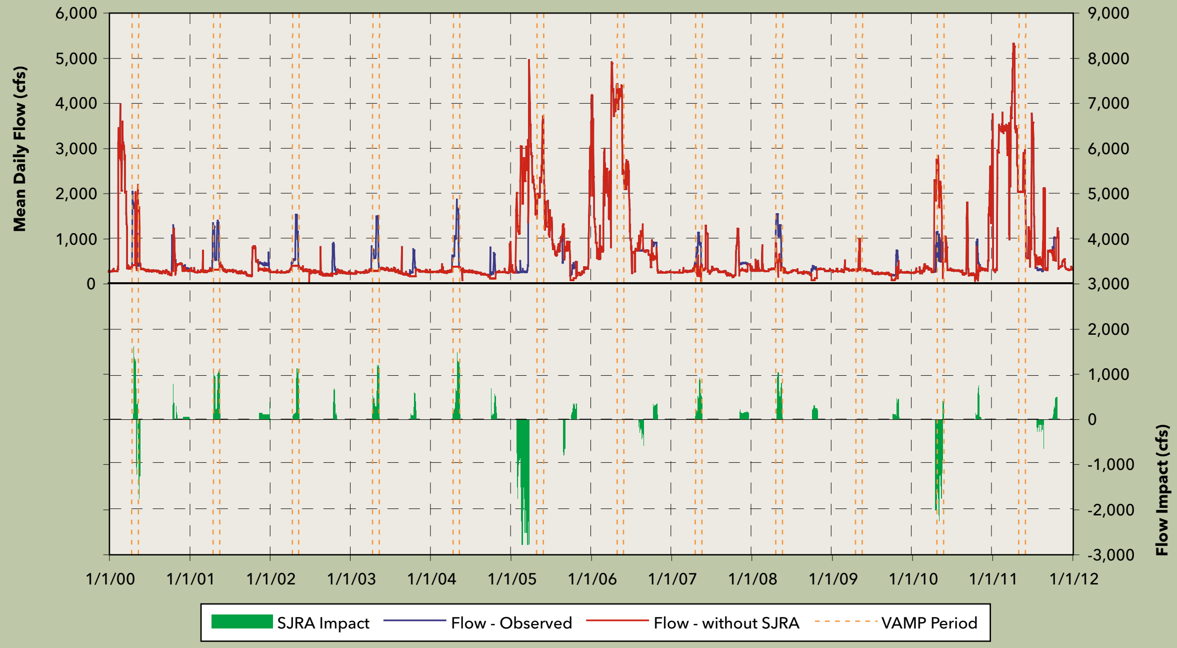
Appendix B, Figure 1
San Joaquin River Agreement (SJRA) Storage Impacts in Acre-Feet on Lake McClure (Merced River) from 2000-2011



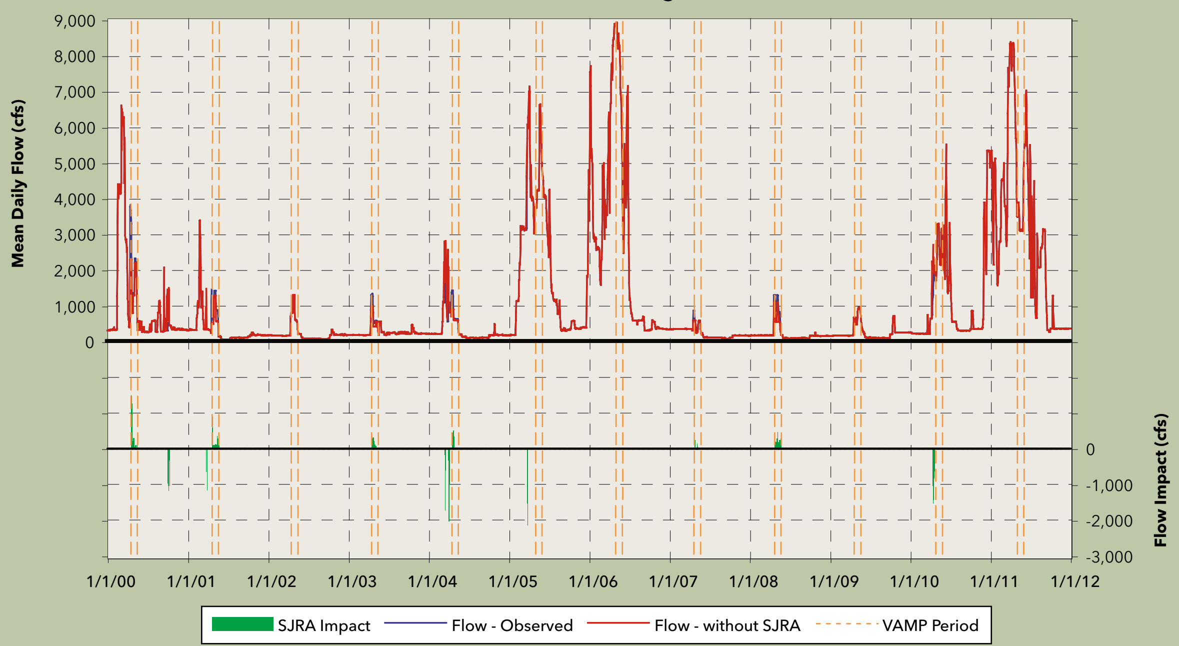
Appendix B, Figure 2
San Joaquin River Agreement (SJRA) Storage Impacts in Acre-Feet on Don Pedro Reservoir (Tuolumne River) from 2000-2011



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 2000-2011

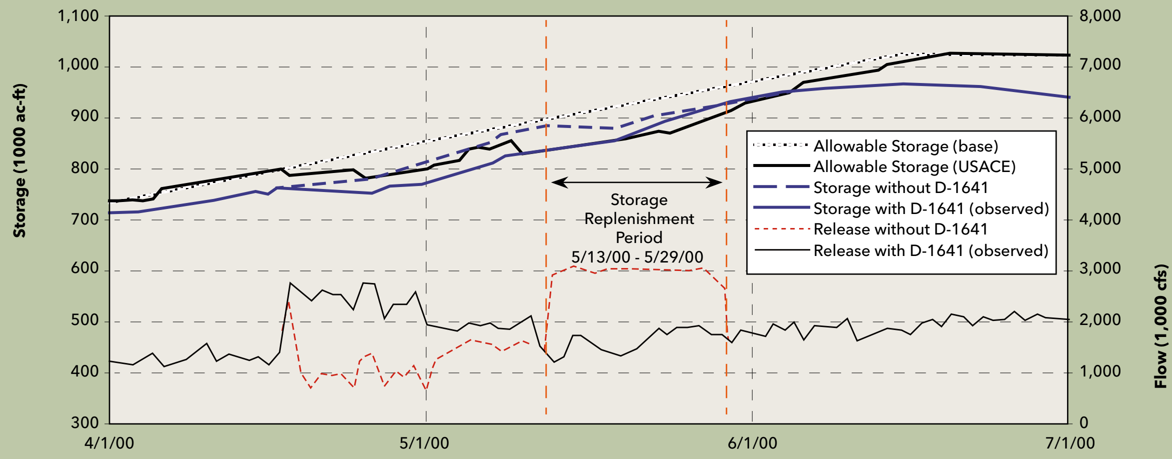


Appendix B, Figure 4
San Joaquin River Agreement (SJRA) Flow Impacts in Cubic Feet per Second (cfs) on the Tuolumne River below La Grange Dam from 2000-2011

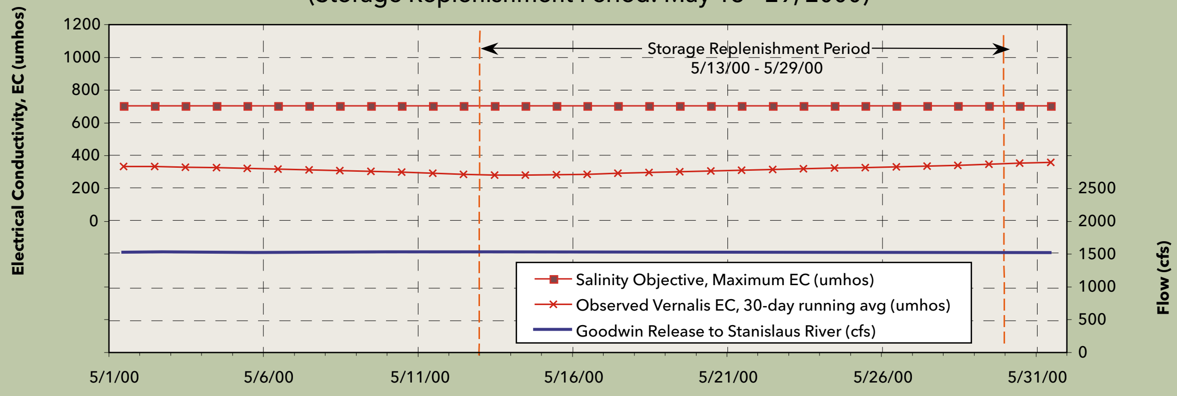


APPENDIX C

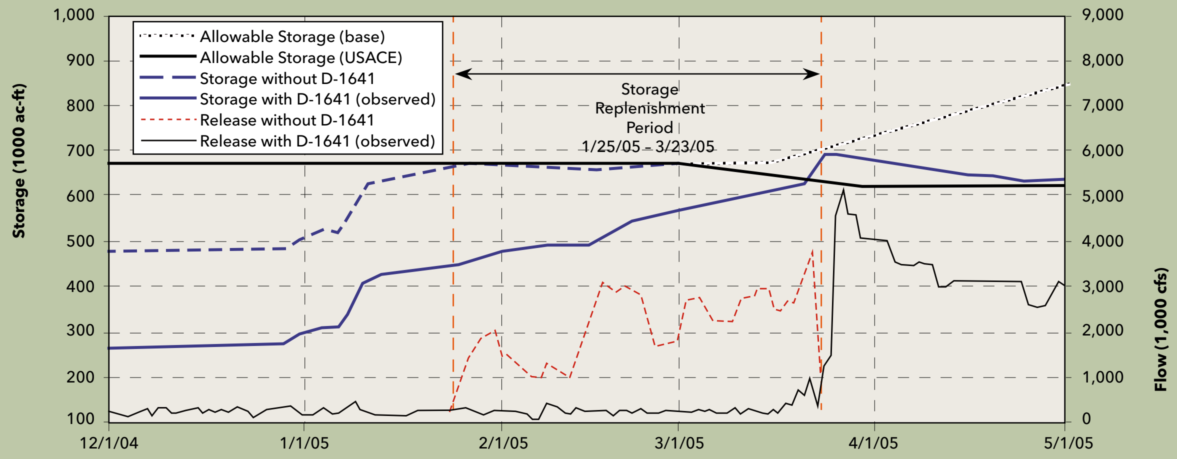
Appendix C, Figure 1
SWRCB D-1641 Reservoir Storage Replenishment in Lake McClure (Merced River)
(Storage Replenishment Period: May 13 - 29, 2000)



Appendix C, Figure 2
San Joaquin River near Vernalis (VNS) Water Quality During Lake McClure (Merced River) Storage Replenishment
(Storage Replenishment Period: May 13 - 29, 2000)

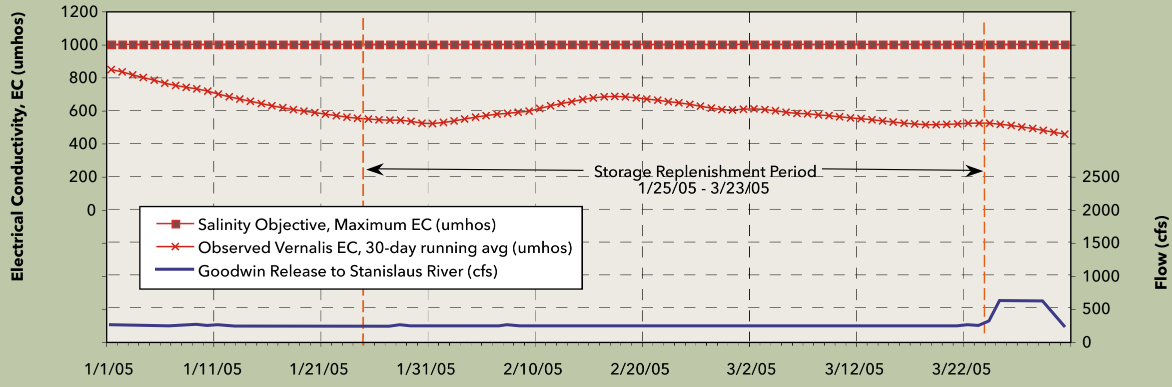


Appendix C, Figure 3
SWRCB D-1641 Reservoir Storage Replenishment in Lake McClure (Merced River)
(Storage Replenishment Period: January 25 - March 23, 2005)



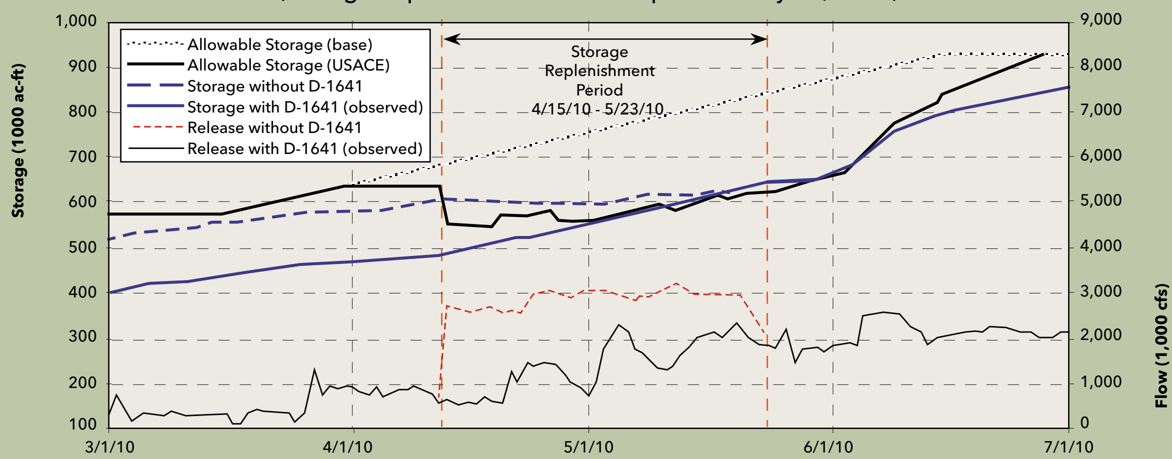
Appendix C, Figure 4

San Joaquin River near Vernalis (VNS) Water Quality During Lake McClure (Merced River) Storage Replenishment
(Storage Replenishment Period: January 25 - March 23, 2005)



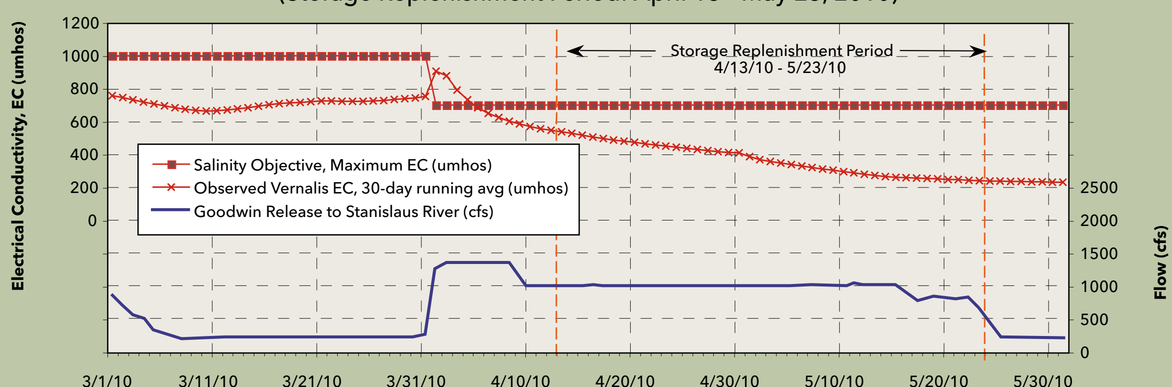
Appendix C, Figure 5

SWRCB D-1641 Reservoir Storage Replenishment in Lake McClure (Merced River)
(Storage Replenishment Period: April 13 - May 23, 2010)



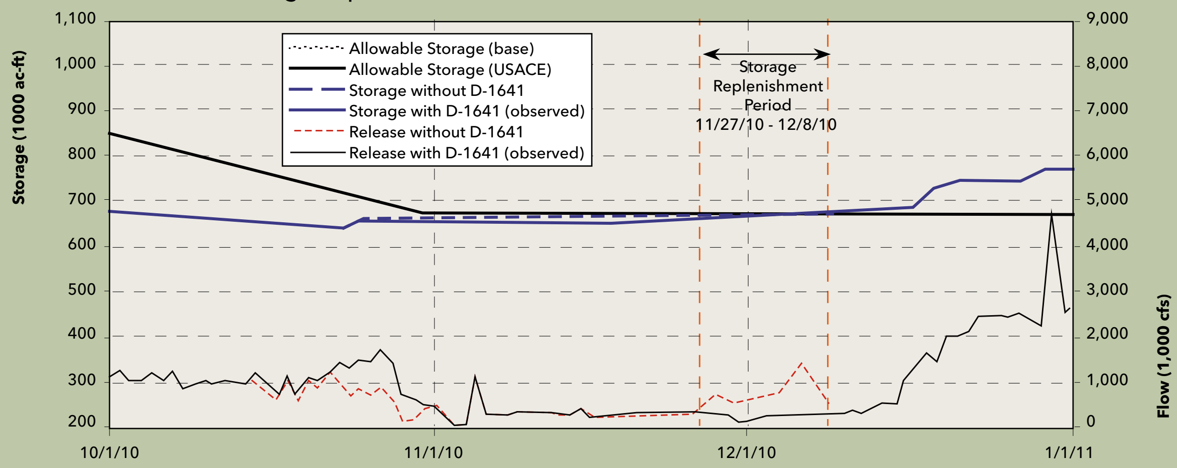
Appendix C, Figure 6

San Joaquin River near Vernalis (VNS) Water Quality During Lake McClure (Merced River) Storage Replenishment
(Storage Replenishment Period: April 13 - May 23, 2010)



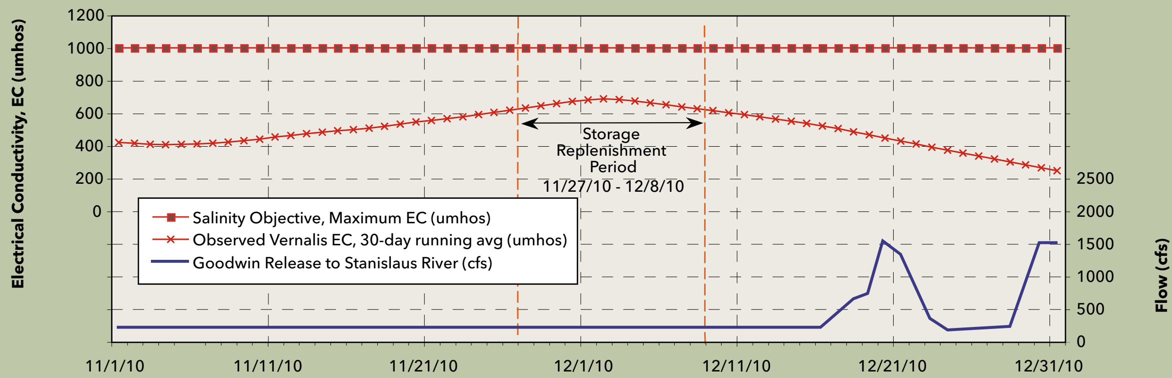
Appendix C, Figure 7

SWRCB D-1641 Reservoir Storage Replenishment in Lake McClure (Merced River)
(Storage Replenishment Period: November 27 - December 8, 2010)



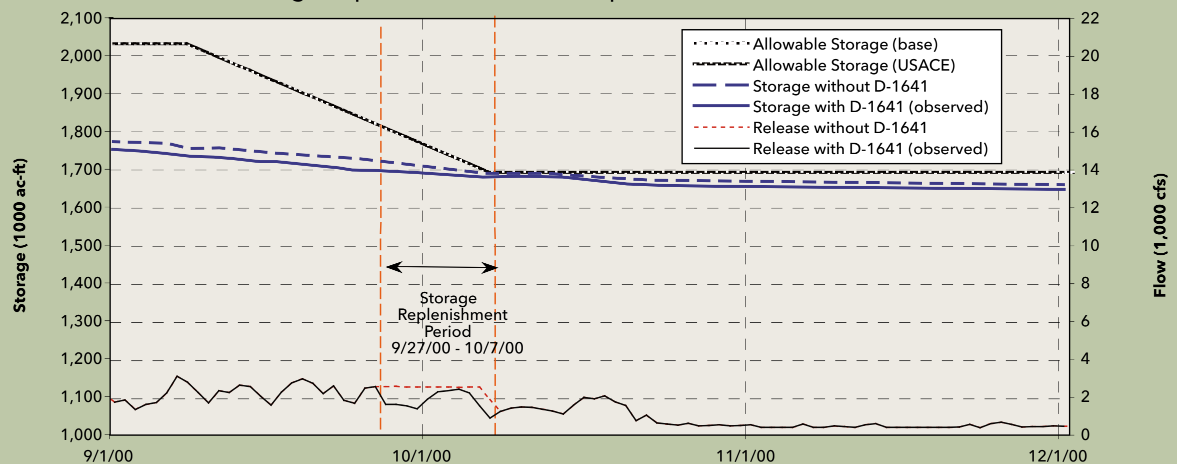
Appendix C, Figure 8

San Joaquin River near Vernalis (VNS) Water Quality During Lake McClure (Merced River) Storage Replenishment
(Storage Replenishment Period: November 27 - December 8, 2010)



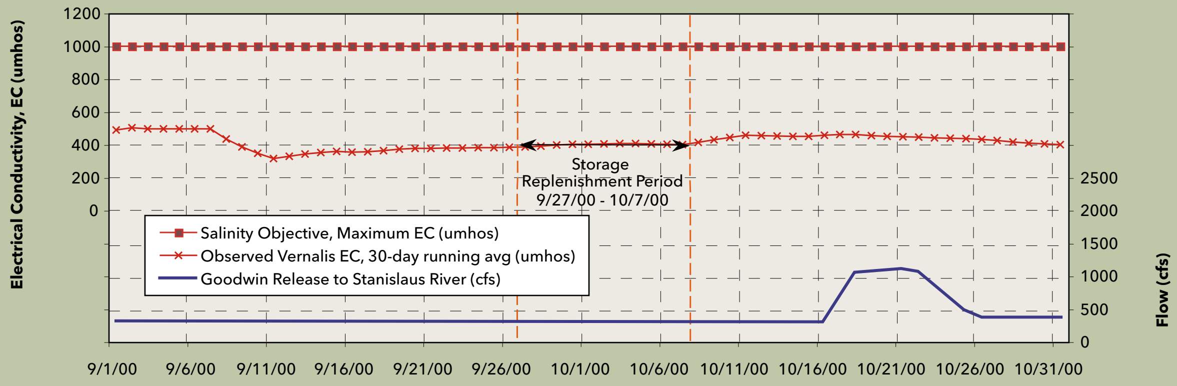
Appendix C, Figure 9

SWRCB D-1641 Reservoir Storage Replenishment in Don Pedro Reservoir (Tuolumne River)
(Storage Replenishment Period: September 27 - October 7, 2000)



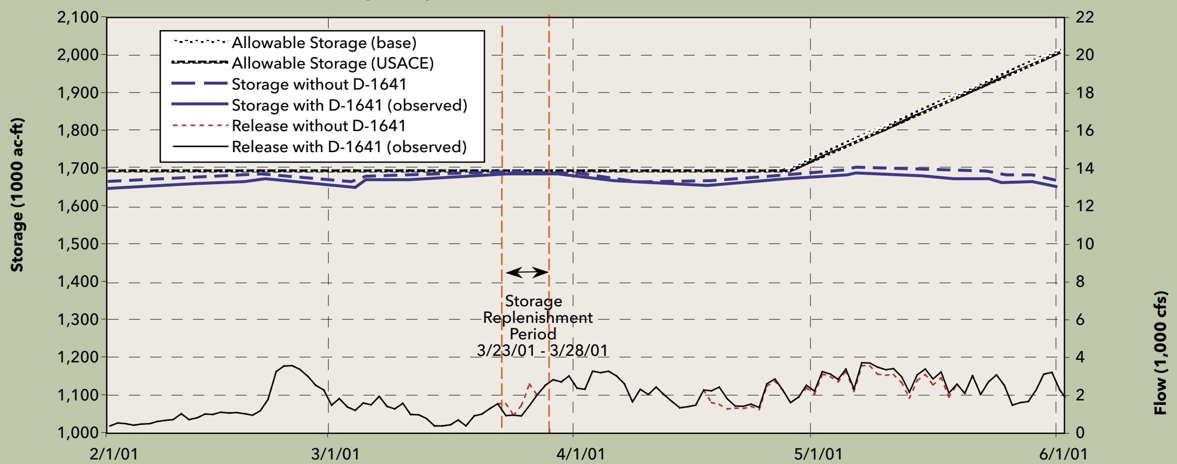
Appendix C, Figure 10

San Joaquin River near Vernalis (VNS) Water Quality During Don Pedro Reservoir (Tuolumne River) Storage Replenishment (Storage Replenishment Period: September 27 - October 7, 2000)



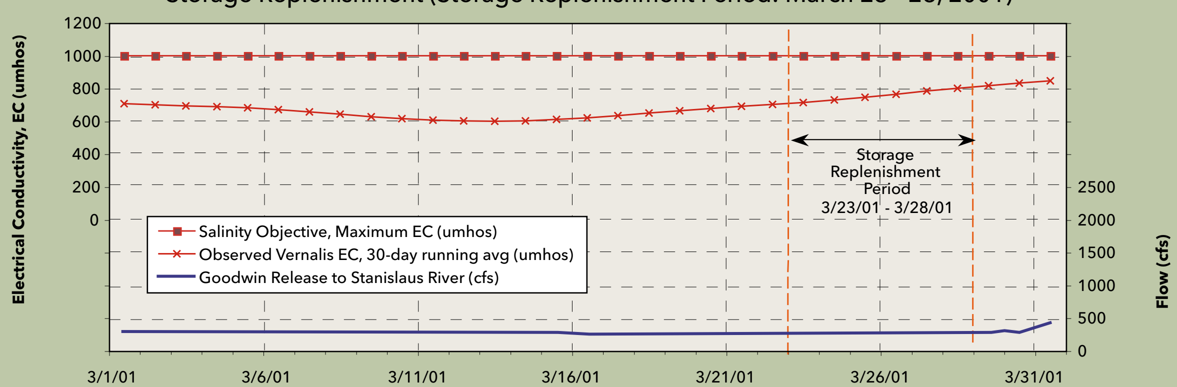
Appendix C, Figure 11

SWRCB D-1641 Reservoir Storage Replenishment in Don Pedro Reservoir (Tuolumne River) (Storage Replenishment Period: March 23 - 28, 2001)

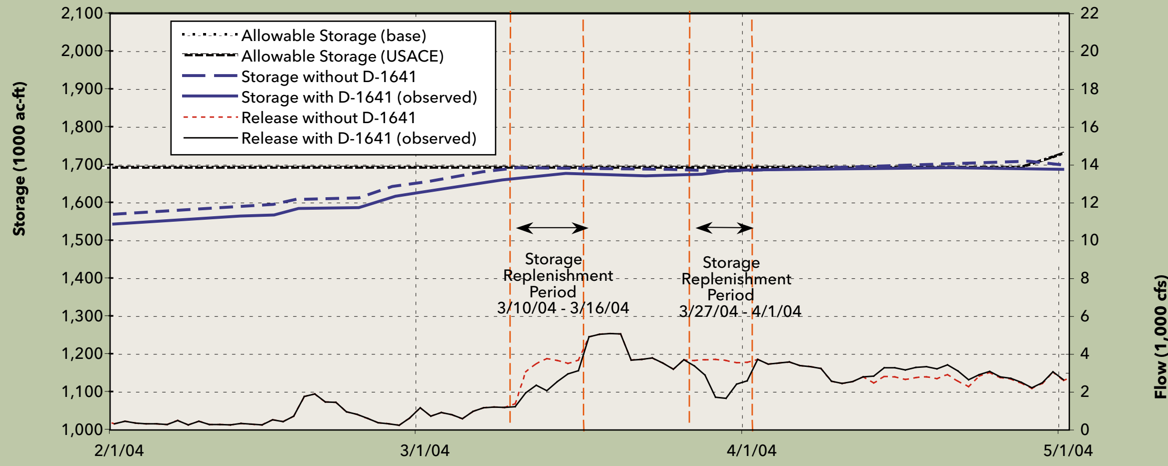


Appendix C, Figure 12

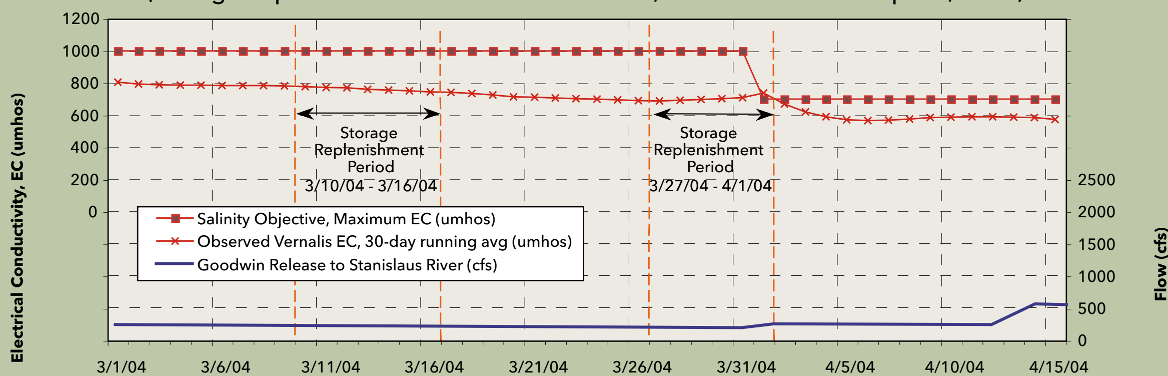
San Joaquin River near Vernalis (VNS) Water Quality During Don Pedro Reservoir (Tuolumne River) Storage Replenishment (Storage Replenishment Period: March 23 - 28, 2001)



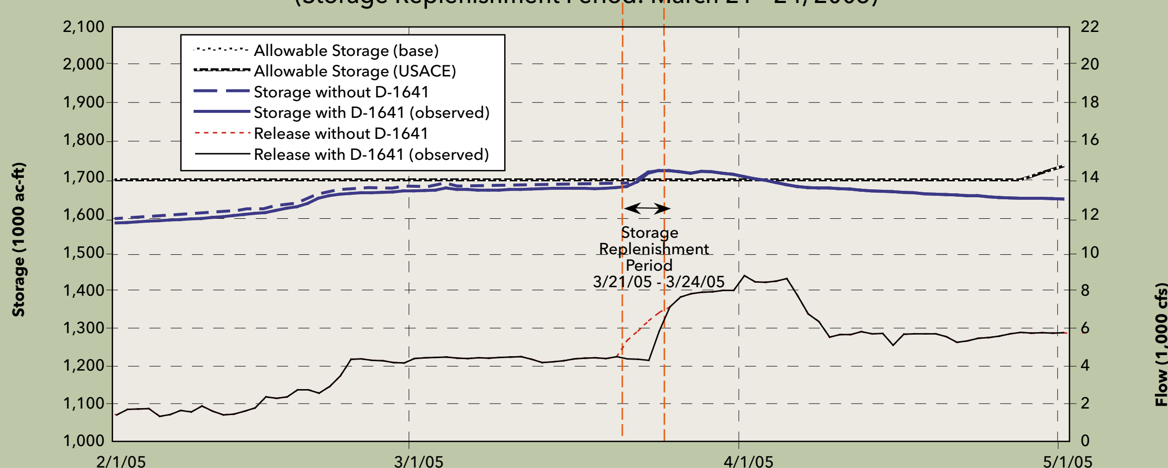
Appendix C, Figure 13
SWRCB D-1641 Reservoir Storage Replenishment in Don Pedro Reservoir (Tuolumne River)
(Storage Replenishment Period: March 10 - 16, 2004 & March 27 - April 1, 2004)



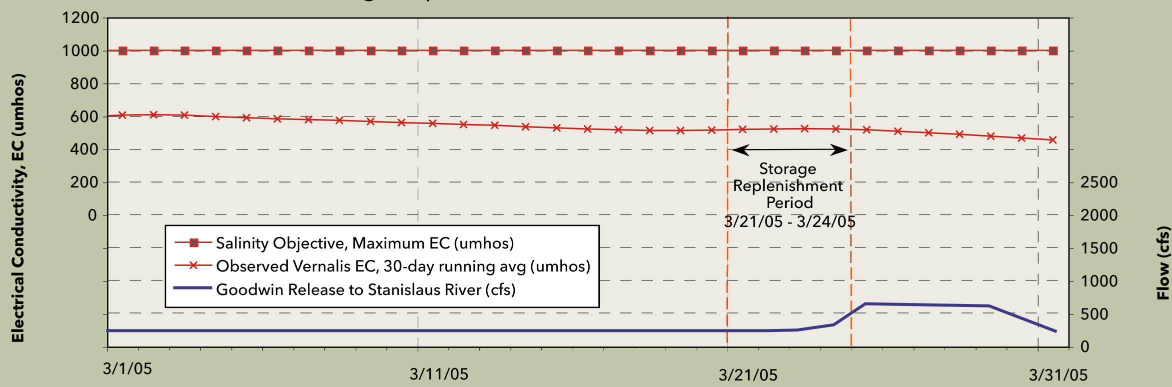
Appendix C, Figure 14
San Joaquin River near Vernalis (VNS) Water Quality During
Don Pedro Reservoir (Tuolumne River) Storage Replenishment
(Storage Replenishment Period: March 10 - 16, 2004 & March 27 - April 1, 2004)



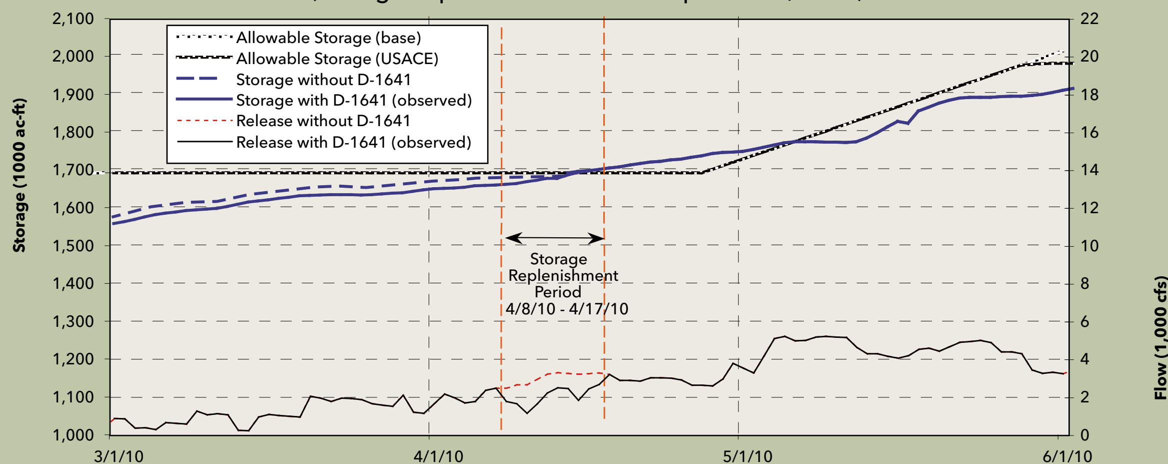
Appendix C, Figure 15
SWRCB D-1641 Reservoir Storage Replenishment in Don Pedro Reservoir (Tuolumne River)
(Storage Replenishment Period: March 21 - 24, 2005)



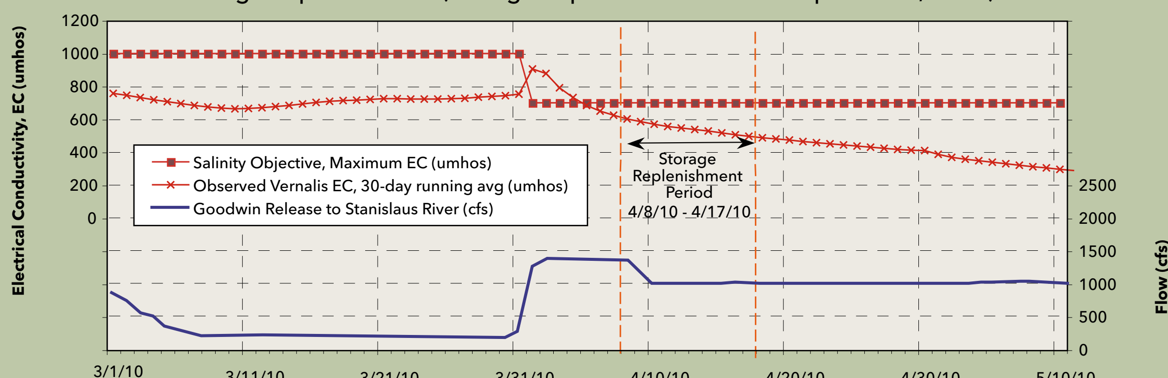
Appendix C, Figure 16
San Joaquin River near Vernalis (VNS) Water Quality During Don Pedro Reservoir (Tuolumne River) Storage Replenishment
(Storage Replenishment Period: March 21 - 24, 2005)



Appendix C, Figure 17
SWRCB D-1641 Reservoir Storage Replenishment in Don Pedro Reservoir (Tuolumne River)
(Storage Replenishment Period: April 8 - 17, 2010)



Appendix C, Figure 18
San Joaquin River near Vernalis (VNS) Water Quality During Don Pedro Reservoir (Tuolumne River)
Storage Replenishment (Storage Replenishment Period: April 8 - 17, 2010)



APPENDIX D

Appendix D, Table 1

Release Information and Survival Estimates (Standard Error (SE) in Parentheses) for Acoustically-tagged Salmon during the 2006, 2007, 2008, 2009 and 2010 Vernalis Adaptive Management Program (VAMP) Studies (SJRGA 2007, 2008, 2009, 2010 and 2011 and C.M. Holbrook, U.S. Geological Survey, personal communication).

Year	Hatchery of origin of study fish	Run of study fish	Release Date	Release Location	Number Released	Number of receiver sites	HORB	Vermalis Flows during the VAMP period [a]	CVP+SWP Exports during VAMP period [a]	Survival in the south Delta region to six end points: without predator-like detections / all detections (Standard Error in Parentheses)	Survival through the Delta to Jersey Point or Chipps Island (Delta); Route A (SJ route); and Route B (Old River route): without predator-like detections/all detections (Standard Error in Parentheses)
2006	MRH	Fall	8-May	Mossdale	32	5	No	26,220[b] / 24,262[c]	1,559/5,748	Not measured	Not Measured: no receivers at Chipps Island or Jersey Point
			15-May	Mossdale	35						
				Dos Reis	33						
				TOTAL	100						
2007	MRH	Fall	3-May	Durham Ferry	98	10	Yes	3,263	1,486	Not measured	Not Measured: no receivers at Chipps Island or Jersey Point
				Mossdale	99						
			4-May	Bowman Road	99						
				Stockton	100						
				D/S HORB	99						
			10-May	Durham Ferry	96						
				Mossdale	97						
			11-May	Bowman Road	95						
				Stockton	92						
				D/S HORB	95						
				TOTAL	970						
2008	MRH	Fall	29-Apr	Durham Ferry – Day	144	17	No	3,163	1,520	Not explictly reported: potentially biased survival estimates	Joint fish and tag survival, premature battery failure may have biased estimates. No predator-type detections removed. Mossdale to Chipps Island = .06 (0.01) and 0.07 (0.02) for first and second releases, respectively. Route A = 0.07 (0.02) and 0.10 (0.02) for first and second releases, respectively Route B = 0.05 (0.02) and 0.06 (0.02) for for first and second releases, respectively.
				Durham Ferry – Night	138						
			1-May	Stockton - Day	93						
				Stockton-night	94						
			6-May	Durham Ferry – Day	139						
				Durham Ferry-night	144						
			8-May	Stockton-Day	85						
				Stockton - night	78						
				TOTAL	915						
2009	FRH	Fall/ spring hybrids	22-Apr	Durham Ferry	136	14	Non-physical barrier tested	2,260	1,990	Mossdale to 6 end points = 0.06 (0.01) / 0.34 (0.03) based on release groups 3-7 Partial Route A (SJ route) = 0.05 (0.02) / 0.10 (0.02) for release groups 3-6 Partial Route B (Old River = 0.08 (0.02) / 0.58 (0.06)	Not Measured: no receivers at Chipps Island or Jersey Point
			25-Apr	Durham Ferry	136						
			29-Apr	Durham Ferry	135						
			2-May	Durham Ferry	136						
			6-May	Durham Ferry	136						
			9-May	Durham Ferry	133						
			13-May	Durham Ferry	135						
				TOTAL	947						

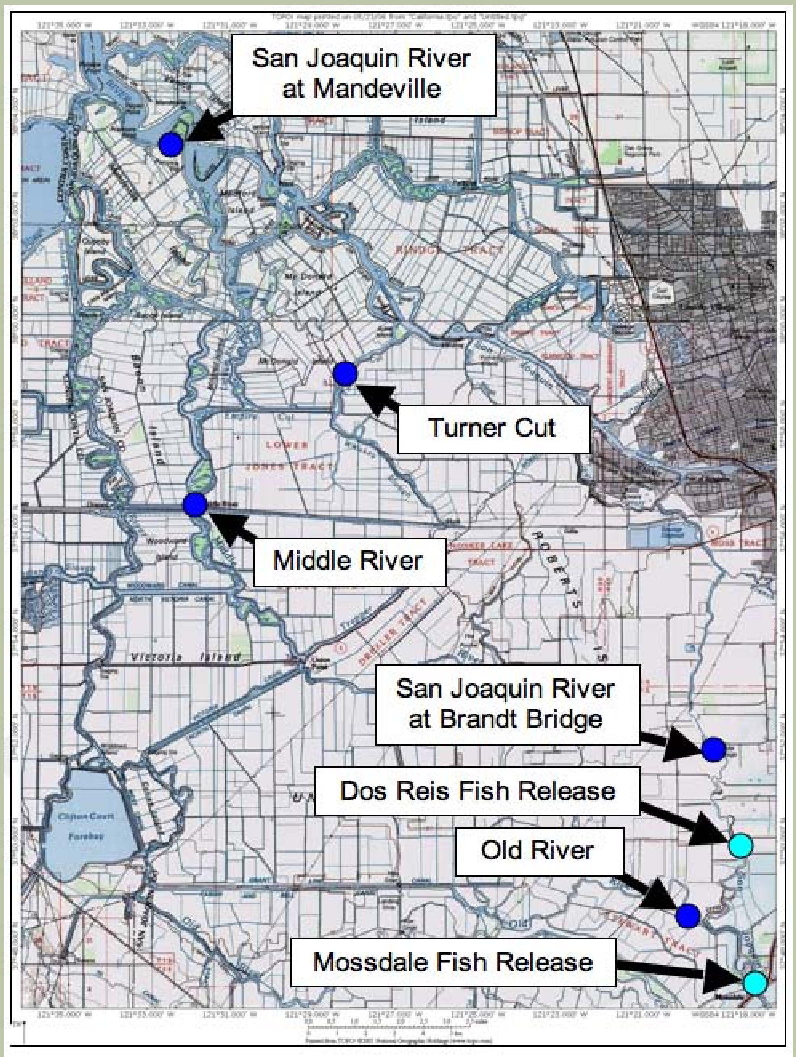
Appendix D, Table 1 (continued)
Release Information and Survival Estimates (Standard Error (SE) in Parentheses) for Acoustically-tagged Salmon during the 2006, 2007, 2008, 2009 and 2010 Vernalis Adaptive Management Program (VAMP) Studies (SJRGA 2007, 2008, 2009, 2010 and 2011 and C.M. Holbrook, U.S. Geological Survey, personal communication).

Year	Hatchery of origin of study fish	Run of study fish	Release Date	Release Location	Number Released	Number of receiver sites	HORB	Vermalis Flows during the VAMP period [a]	CVP+SWP Exports during VAMP period [a]	Survival in the south Delta region to six end points: without predator-like detections / all detections (Standard Error in Parentheses)	Survival through the Delta to Jersey Point or Chipps Island (Delta); Route A (SJ route); and Route B (Old River route): without predator-like detections/all detections (Standard Error in Parentheses)
2010	MFRH	Fall	26-Apr	Durham Ferry	74	20	Non-physical barrier tested	5,140	1,515		
			27-Apr	Old River	36					Mossdale to 6 end points = 0.56 (0.03) / 0.79 (0.04)	Mossdale to Chipps Island = 0.05 (0.01) / 0.11 (0.01)
				Stockton	36						
			29-Apr	Durham Ferry	74						
			30-Apr	Old River	36						
				Stockton	36						
			3-May	Durham Ferry	73					Partial Route A (SJ route) = 0.32 (0.02) / 0.57 (0.02)	Route A (SJ Route) = 0.04 (0.01) / 0.11 (0.01)
			4-May	Old River	36						
				Stockton	35						
			6-May	Durham Ferry	70						
			7-May	Old River	36						
				Stockton	36						
			10-May	Durham Ferry	71						
			11-May	Old River	36						
				Stockton	35						
			13-May	Durham Ferry	74					Partial Route B (Old River) = 0.77 (0.05) / 1.00 (0.09)	Route B (Old River) = 0.07 (0.01) / 0.12 (0.01)
			14-May	Old River	35						
				Stockton	35						
			17-May	Durham Ferry	70						
			18-May	Old River	35						
				Stockton	35						
				TOTAL	**1004**						

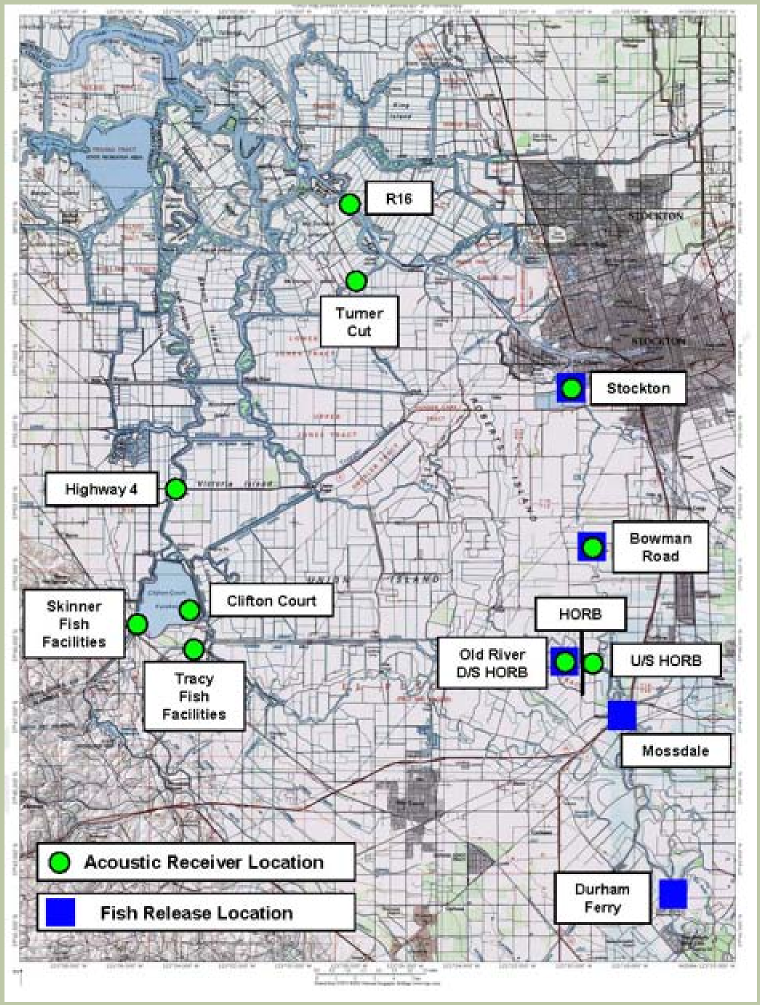
[a] Flows at Vernalis and exports during the VAMP period.
[b] During first fish release
[c] During second fish release

Appendix D, Figure 1

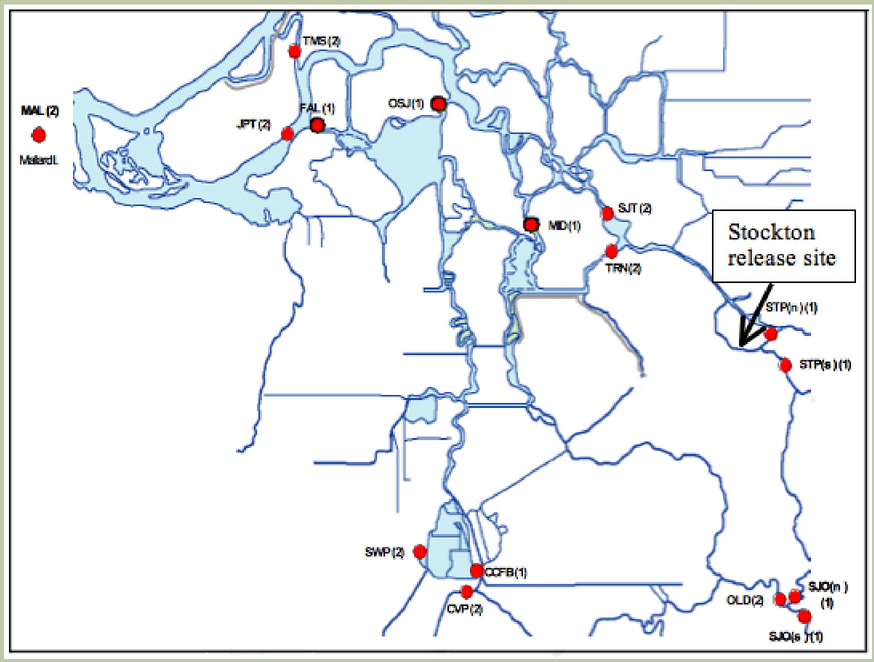
Release and Receiver Locations for Pilot Acoustic Telemetry Tag Study Conducted as Part of VAMP in 2006. A Total of 67 (Mossdale) and 33 (Dos Reis) Tagged Salmon Smolts Were Released as Part of the 2006 Pilot Program. No Receivers Were in Place at Jersey Point or Chipps Island to Estimate Survival Through the Delta.



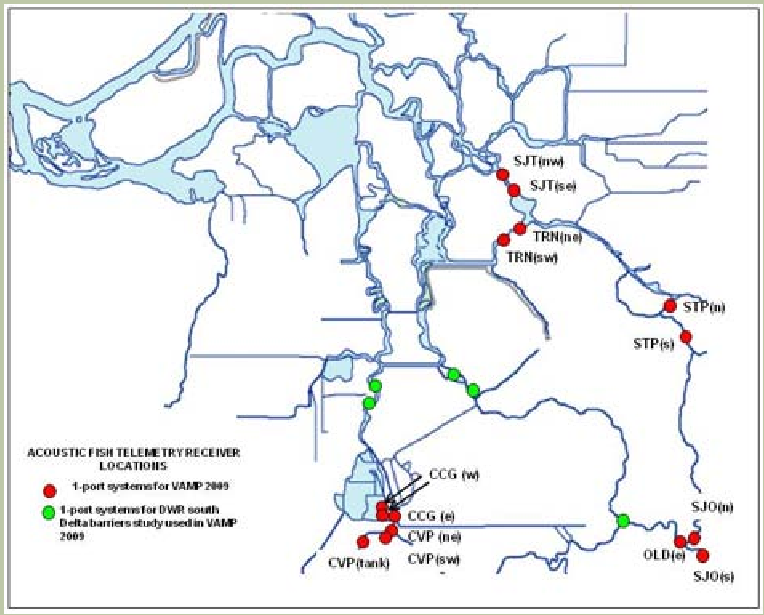
Appendix D, Figure 2
Location of Acoustic Release and Detection Sites During VAMP in 2007. Approximately 100 Acoustically-tagged Fish Were Released at Each Location, in Each of Two Release Periods in May of 2007. No Receivers Were in Place at Jersey Point or Chipps Island to Estimate Survival Through the Delta. Through Mobile Tracking, Fifteen Percent (n=116) of the 776 tags Released at Four Upstream Locations Were Found Motionless at One Location Indicating That the Tags Were Either in Dead Fish or Had Been Defecated by a Predator.



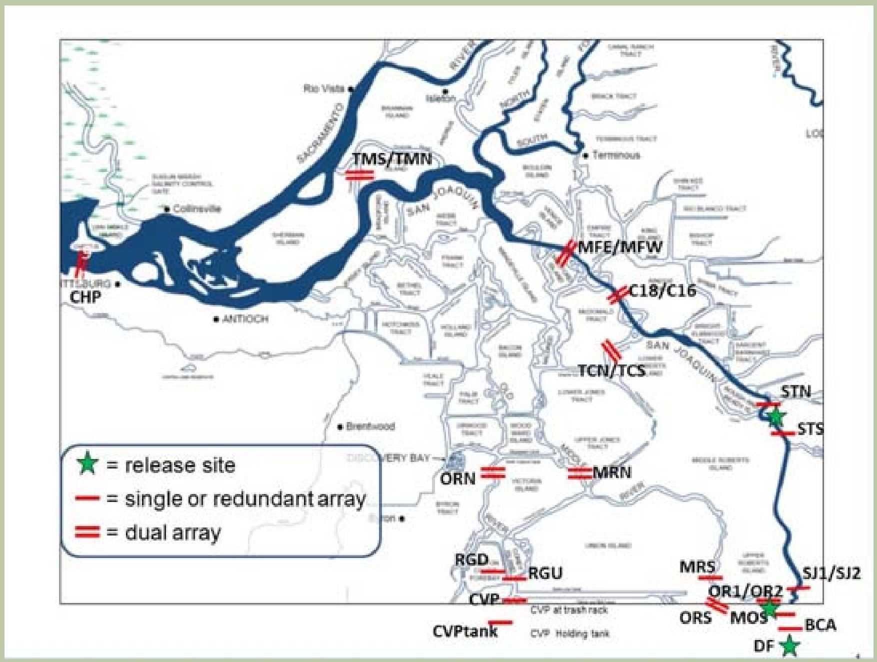
Appendix D, Figure 3
Location of Acoustic Detection Stations During the 2008 VAMP. Releases Were Made at Durham Ferry, Approximately 11 miles Upstream of the San Joaquin River Split at Old River (SJO(s)) and Just Downstream of Stockton (STP(n)). A Total of 78 (Stockton) and 144 (Durham Ferry) Acoustically-Tagged Fish Were Released at These Two Locations, for One Day and Night Release, During Two Periods in late-April – Early May in 2008.



Appendix D, Figure 4
Receiver Locations for the 2009 VAMP. Seven Releases of Approximately 133 Fish Were Made at Durham Ferry Between April 22 and May 13, 2009. No Receivers Were in Place at Jersey Point or Chipps Island to Estimate Survival Through the Delta.



Appendix D, Figure 5
Release Site and Receiver Locations for VAMP in 2010. Seven Groups of 70-74 Fish Were Released at Durham Ferry (DF), Seven Groups of 35-36 Acoustically-tagged Fish Were Released at Old River (near OR1/OR2) and Seven Groups of 34-36 Acoustically-tagged Fish Were Released at Stockton Between April 27 and May 20, 2010. Map is Not to Scale.



APPENDIX E

Sample Size for VAMP 2011: Preliminary Analysis

Prepared for:

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12 August 2010

Summary of Recommendations

Single Release at Durham Ferry

- For low/medium route-specific survival (0.05 – 0.10), high detection probability at Chipps Island
- To estimate parameters: 475 for low survival; 145 for medium survival
- To detect relative effect between routes of size Δ=1.0: 790 for low survival; 410 for medium survival
- To detect relative effect between routes of size Δ=0.5: 3,510 for low survival; 1,800 for medium survival

Primary Release at Durham Ferry with Supplemental Releases in SJR and OR downstream of the OR flow split

- For low route-specific survival, high detection probability at Chipps Island
- To estimate parameters:
  - Release at Durham Ferry: 95
  - Release in San Joaquin near Lathrop: 75
  - Release in Old River near HOR: 75
- To detect relative effect between routes of size Δ=1.0:
  - Release at Durham Ferry: 97
  - Release in San Joaquin near Lathrop: 97
  - Release in Old River near HOR: 97
- To detect relative effect between routes of size Δ=0.5:
  - Release at Durham Ferry: 510
  - Release in San Joaquin near Lathrop: 510
  - Release in Old River near HOR: 510

Other Design Considerations for Sample Size

- These recommendations are based on
  - Detection probability near 100% at the receivers in both SJR and OR just downstream of the Old River flow split
  - Detection probability of 90-97% at the dual array at Chipps Island
  - Survival from Durham Ferry to Old River = 0.5
  - Route entrainment probability into SJR at Old River = 0.3 - 0.6.
- Relative effect of size Δ=1.0 means one route has twice the survival of the other (e.g., $S_A=2S_B$)
- Relative effect of size Δ=0.5 means one route has 1.5 times the survival of the other (e.g., $S_A=1.5S_B$)
- Power to detect relative effect was calculated at 70% with probability of Type I error: α=0.10.
- With supplemental releases, could use lower sample size if release fewer fish at Durham Ferry than in the supplemental releases. But releasing fewer than 75 fish at Durham Ferry is not recommended.

Introduction

The appropriate sample size for the VAMP 2011 study refers both to the number of release groups and the size of each release group. For both the 2009 and 2010 VAMP studies, numerous releases of between 30 and 135 fish each were released at Durham Ferry and elsewhere in order to obtain information on survival and route selection throughout the VAMP period while also providing enough release groups to garner sufficient statistical power for the non-physical barrier study at the head of Old River. Both 2009 and 2010 were marked by fairly stable river conditions, with low variation in river flow and water exports during the VAMP period. The stable conditions allowed data from multiple release groups to be pooled for statistical analysis in the case where sparse data prevented estimation of model parameters for individual release groups. This was particularly necessary for the 2009 study, when both river flow and smolt survival were markedly low.

In 2011, it is expected that the river environment will be more variable, with potentially sizeable changes in both river flow and water exports during the VAMP period. In a changing environment, it is inadvisable to pool data from across release groups that migrated through the system under different conditions. If it were known ahead of time when or how often changes in the river environment (particularly flow and exports) will occur, then it might be possible to plan multiple small releases with the expectation of pooling data from all release groups that migrated under one set of river conditions, if necessary. However, without knowing the schedule and degree of environmental changes ahead of time, it is impossible to plan for multiple releases during periods of unchanging conditions, and thus impossible rely on pooling data from multiple release groups. Relying on multiple small release groups presents a danger of being unable to estimate key model parameters for one or more release groups. For this reason, it is necessary to plan release groups of sufficient size to maximize the probability that all model parameters will be estimable for each release group. With a fixed total number of tags available, this means making relatively few releases of large size, rather than many small releases. The size of each release group will depend on actual model parameters and the desired degree of precision of the estimates. The number of release groups will then depend on the total number of tags available.

This rest of this document discusses the advantages and disadvantages of various release scenarios for a single release group, and for different values of the model parameters. A simplified version of the release-recapture model is used, representing only key parameters and detection sites. It is assumed that the primary goal of the study is to estimate the route selection probability at the head of Old River (ψ_A) and survival from the head of Old River to Chipps Island through the San Joaquin route (S_A) and also through the Old River route (S_B). A secondary objective is to be able to detect a relative difference between S_A and S_B of a particular size (e.g., 30% or 50%) with a desired level of statistical power and a Type I error probability (α) of either 5% or 10%. The focus is on the size of a single release group, possibly composed of both primary and supplemental releases.

Methods

Two approaches were used to determine the necessary sample size for varying conditions, represented by different values of model parameters. The first approach was a simulation exercise that identified the release size necessary to provide informative estimates of model parameters (survival and route selection probabilities) with high probability. This approach was used to plan the 2010 VAMP study, and the results from the 2010 sample size analysis remain valid. Those results have been augmented with additional simulations here. The second approach consisted of power calculations to detect a relative difference in route survival probabilities of a particular size.

Simulations – summary of methods from 2010 proposal

A simplified study design (Figure 1) was used both to simulate detection data and to generate estimates of model parameters. The model parameters estimated were: S_{RO} = survival from Durham Ferry to the head of Old River; ψ_A = probability of selecting the San Joaquin River at the Old River flow split; S_A = survival from the San Joaquin River near Lathrop (site A1) to Chipps Island, through all possible routes; S_B = survival from the first Old River receiver (site B1) to Chipps Island, through all possible routes; P_C = detection probability at the dual array at Chipps Island. Also estimated was the overall survival from Durham Ferry to Chipps Island, $S_R = S_{RO}\left(\psi_A S_A + \psi_B S_B\right)$.

Data were simulated for different release sizes and for different values of the model parameters. Method of moments estimates were computed from each simulated data set. Parameter values used to simulate the data (Table 1) were selected based on parameter estimates reported in the 2008 VAMP draft report (Holbrook et al. 2009) and estimates from the 2009 VAMP study (SJRGA 2010). For each parameter set and release size, 5000 simulations were run. Simulations reflect sampling error but not natural variability. Release sizes considered were: 95, 145, 190, 250, 475, 750, and 1000.

Table 1. Values of parameters used for data simulation in Analysis 1 to estimate survival to Chipps Island and route selection at Old River.

Parameter	Value
S_R	0.025, 0.045, 0.08, 0.14
S_{RO}	0.5, 0.9
ψ_A	0.3, 0.5
S_A	0.05, 0.10, 0.15
S_B	0.05, 0.10, 0.15
P_{A1}	0.98
P_{B1}	0.98
P_C	0.6, 0.9

The minimum release size for each parameter set was selected based on three criteria reflecting the ability to attain a point estimate of each parameter, the reasonableness of the point estimate , and the uncertainty associated with the point estimate (Table 2). See 2010 VAMP proposal for further description of the simulations analysis.

Additional analyses were performed considering the possibility of a supplemental release in the San Joaquin River near Lathrop (site A1) and another supplemental release in Old River near site B1. See 2010 VAMP proposal for further description of these analyses.

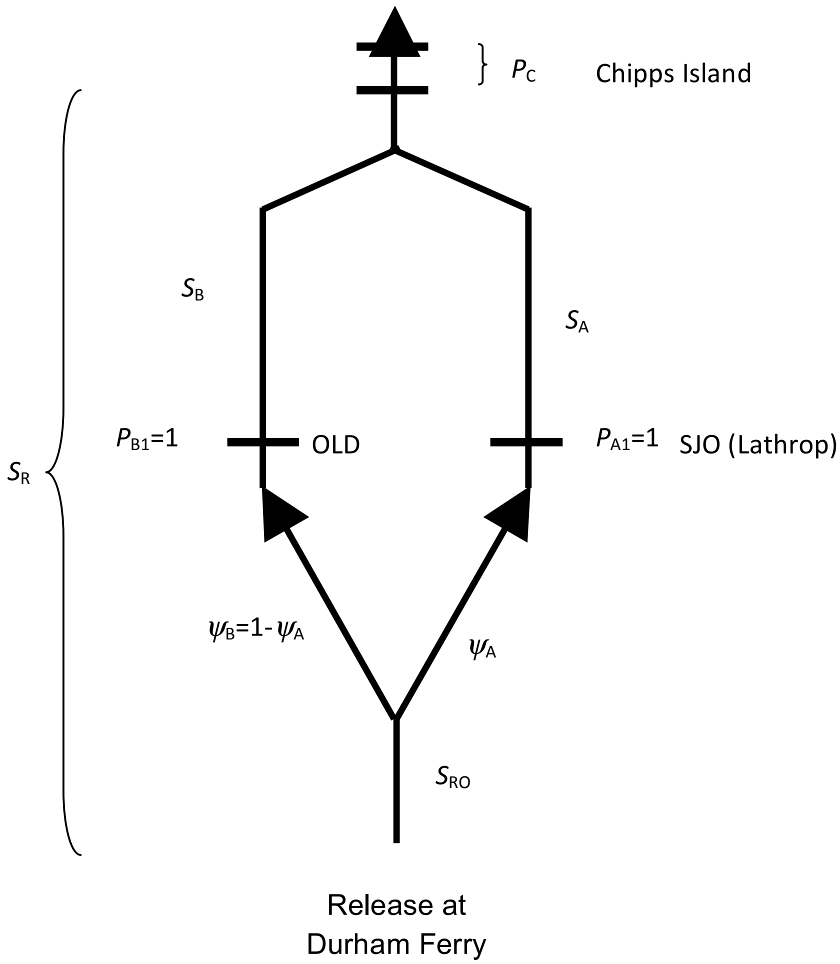

Figure 1. Schematic of model simulations and power calculations, with parameters: survival from Durham Ferry to Chipps Island (S_R), survival to Chipps Island from the head of Old River in the San Joaquin route (S_A) and in the Old River route (S_B), and the probability of remaining in the San Joaquin River at the head of Old River (ψ_A). Other parameters are survival from Durham Ferry to the head of Old River (S_{RO}), detection probabilities at site A1 (P_{A1}), site B1 (P_{B1}), and overall probability of detection on at least one receiver at Chipps Island (P_C).

Table 2. Criteria used for identification of minimum sample size necessary to estimate a model parameter, assuming 5000 simulations.

Criterion	Definition
C1	Parameter is estimable in at least 95% of simulations (4750 or more)
C2	Probability estimate is not greater than 1.1 in 95% of simulations (4750 or more)
C3	Standard error on parameter estimate is not greater than 0.10

Power Calculations – No supplemental releases

Power was calculated based on the asymptotic normal distribution of the maximum likelihood estimators of survival in both the San Joaquin and Old River routes (S_A and S_B, respectively). For a given Type I error probability (α), the probability of detecting an absolute difference between S_A and S_B of size δ is approximately

$$P(\delta) \approx \Phi\left(z_{\alpha/2} + \frac{\delta}{\sqrt{Var\left(\hat{S}_A - \hat{S}_B\right)}} \right) + \Phi\left(z_{\alpha/2} - \frac{\delta}{\sqrt{Var\left(\hat{S}_A - \hat{S}_B\right)}} \right),$$

where Φ is the cumulative distribution function of the standard normal distribution and $z_{\alpha/2}$ is the $(\alpha/2)$-th quantile of the standard normal distribution. The variance of the difference in survival estimates, $Var\left(\hat{S}_A - \hat{S}_B\right)$, can be approximated by the Delta Method (Seber 2002, pp.7-9). For a single primary release with no supplemental releases, the variance of the difference in survival estimates is (to a first-order Taylor series approximation, and ignoring covariance terms):

$$Var\left(\hat{S}_A - \hat{S}_B\right) \approx \frac{1}{RS_{RO}P_C}\left[\frac{(S_A - S_B)^2 (1 - P_C)}{\psi_A S_A + \psi_B S_B} + \xi \right],$$

where

$$\xi = \frac{S_A}{\psi_A}(1 + S_A P_C - 2S_{RO}\psi_A S_A P_C) + \frac{S_B}{\psi_B}(1 + S_B P_C - 2S_{RO}\psi_B S_B P_C)$$

and

$$\psi_B = 1 - \psi_A .$$

For a single release occasion with a primary release at Durham Ferry of size R_1, a supplemental release in the San Joaquin River (of size R_2) just downstream of the Old River flow split, and another supplemental release in Old River (of size R_3) just downstream of the Old River flow split, the variance of the difference in survival estimates is approximately:

$$Var\left(\hat{S}_A-\hat{S}_B\right) \approx \frac{\left(S_A-S_B\right)^2\left(1-P_C\right)}{P_C\left[R_1S_{RO}\left(\psi_AS_A+\psi_BS_B+R_2S_A+R_3S_B\right)\right]} + \frac{S_A}{P_C}\left[\frac{R_1S_{RO}\psi_A\left(1+S_AP_C\right)-2R_1S_{RO}^2\psi_A^2S_AP_C+R_2\left(1-S_AP_C\right)}{\left(R_1S_{RO}\psi_A+R_2\right)^2}\right] + \frac{S_B}{P_C}\left[\frac{R_1S_{RO}\psi_B\left(1+S_BP_C\right)-2R_1S_{RO}^2\psi_B^2S_BP_C+R_3\left(1-S_BP_C\right)}{\left(R_1S_{RO}\psi_B+R_3\right)^2}\right].$$

For a given value of S_A and a given value of δ, the absolute difference between S_A and S_B, the value of S_B can be found by $S_B=S_A\left(1-\delta\right)$, and the relative difference between S_A and S_B is $\Delta=S_A\delta$. Thus, although power is expressed in terms of absolute differences in survival, it can be found for any desired relative difference in survival, as well.

Power to detect a relative effect (Δ) of varying sizes was calculated for eight scenarios representing a combination of low/high survival from Durham Ferry to the receivers in both rivers just downstream of the head of Old River (S_{RO}), low/medium probability of route entrainment into the San Joaquin River at the head of Old River (ψ_A), and low/high detection probability at Chipps Island (P_C) (Table 3). For each scenario, power was calculated to detect three levels of relative effect: $\Delta=0.3$, 0.5, and 1.0. These three levels correspond to S_A being 20% higher than S_B, 50% higher than S_B, and twice as large as S_B, respectively. Values of S_A considered ranged from 0.05 to 0.8. Power was calculated for two levels of the Type I error probability: $\alpha=0.05$ and 0.10. Power was calculated for varying release sizes, both for a single primary release at Durham Ferry (Scenarios 1 – 8) and for a Durham Ferry release coupled with two supplemental releases (Scenarios 9 – 24). Scenarios 9 – 16 used equal release sizes at Durham Ferry and the two supplemental release sites, while for Scenarios 17 – 24, the Durham Ferry release group was three times the size of the supplemental releases (Table 3).

Table 3. Scenarios used in power calculations. R_1 = size of release at Durham Ferry. R_2 = size of supplemental release in the San Joaquin River near Lathrop. R_3 = size of supplemental release in Old River just downstream of the Old River flow split.

Scenario					
No Supplemental Releases	With Supplemental Releases				
	R_1=R_2=R_3	R_1 = $3R_2$ = $3R_3$	Survival from DF to head of Old River (receivers) (S_{OR})	Route entrainment probability in SJR at head of Old River (ψ_A)	Detection probability at Chipps Island (P_C)
1	9	17	0.5	0.5	0.6
2	10	18	0.5	0.5	0.9
3	11	19	0.9	0.5	0.6
4	12	20	0.9	0.5	0.9
5	13	21	0.5	0.3	0.6
6	14	22	0.5	0.3	0.9
7	15	23	0.9	0.3	0.6
8	16	24	0.9	0.3	0.9

Results

Single Release at Durham Ferry, No Supplemental Release

Simulations

Although a wide range of parameter values were considered, recommendations were based on the assumption of S_{RO} =0.5, ψ_A=0.5, P_{A1}=0.98, and P_{B1}=0.98 (Table 4). The minimum release size needed to estimate all key model parameters (S_A, S_B, ψ_A, S_R, and S_{RO}) depended on the values of survival from the head of Old River to Chipps Island through the San Joaquin River (S_A) and through the Old River route (S_B), and overall detection probability of the dual array at Chipps Island (P_C). In the case of low survival (0.05) to Chipps Island in either route, a minimum of 475 fish would need to be released at Durham Ferry to insure being able to estimate both S_A and S_B. For higher values of route-specific survival, the minimum release size necessary depended on the detection probability at Chipps Island (P_C): between 145 and 250 fish would be required at Durham Ferry if P_C =0.6, while between 95 and 145 fish would be required if P_C =0.9 (Table 4). In all cases, 95 fish were sufficient to guarantee estimation of survival from Durham Ferry to the head of Old River (S_{RO}) and the route entrainment probability at the head of Old River (ψ_A). If overall survival from Durham Ferry to Chipps Island is to be estimated without route-specific survival, then a release of 145 fish at Durham Ferry should be sufficient, unless survival through both routes and detection probability at Chipps Island are all very low.

Table 4. Minimum release size to estimate parameters S_A, S_B, ψ_A, S_{RO}, and S_R, based on simulations using a single release at Durham Ferry (no supplemental releases). Recommendations are based on the assumption of S_{RO} = 0.5, ψ_A = 0.5, P_{A1} = 0.98, and P_{B1} = 0.98.

Parameter	True Value	Minimum release size with P_C=0.6	Minimum release size with P_C=0.9
S_A	0.05	475	475
S_A	0.10	250	145
S_A	0.15	145	95
S_B	0.05	475	475
S_B	0.10	250	145
S_B	0.15	145	95

Power Calculations

Detecting a difference ("effect") in route-specific survival between the San Joaquin and Old River routes is more demanding than simply estimating the model parameters, and thus much larger sample sizes are required. In general, detecting a smaller effect (Δ), demanding a smaller Type I error probability (α), and desiring higher power all require more fish (Table 5 - Table 7; Figure A1 - Figure A8).

With route-specific survival to Chipps Island in the San Joaquin River route (S_A) equal to 0.05 and a Type I error probability of α =0.10, from 260 to nearly 1,500 fish would need to be released at Durham Ferry to detect a relative effect of Δ =1.0 (i.e., S_A=2 S_B) with approximately 70% power (Table 5). To detect an effect of only Δ=0.50 (i.e., S_A = 1.5 S_B) with 70% power, from 1,420 to 5,370 fish would be required at Durham Ferry. The range of release sizes depends on the value of survival from Durham Ferry to the head of Old River (S_{RO}), the route entrainment probability at the head of Old River (ψ_A), and the overall detection probability at the dual array at Chipps Island (P_C). Low values of any of these parameters results in nearly doubling the necessary release size (Table 5). Lower desired power values demand fewer fish (Figure A1 - Figure A8). With route-specific survival through the San Joaquin River route at 0.1, the release size necessary to detect a relative effect of Δ=1.0 with 70% power and a Type I error probability of α=0.10 ranges from 130 to 760. From 710 to 2,730 fish would be required to detect a relative error of Δ=0.5 (Table 6). With route-specific survival through the San Joaquin River route at S_A=0.15, between approximately 90 and 510 fish would be required to detect a relative effect of Δ=1.0, and between 475 and 1,850 would be required to detect a relative effect of Δ=0.5 (α=0.10, power = 0.7; Table 7).

In all cases, the only parameter that is marginally under human control is the detection probability at the dual array at Chipps Island (P_C). Low values of the detection probability (e.g., P_C=0.6) require many more fish than higher values of the detection probability (e.g., P_C=0.9). Thus, regardless of the desired power to detect an effect or the desired effect size, it is recommended that efforts be made to optimize the detection probability at Chipps Island as much as possible. Further, these power calculations were performed under the assumption of 100% detection at the first detection arrays in both the San Joaquin River and Old River just downstream of the Old River flow split (i.e., sites A1 and B1). Lower detection probabilities at these sites will lower the power to detect effects.

Table 5. Release size to detect relative effect of either Δ =0.5 or Δ =1.0 with approximately 70% power and a Type I error probability of either α=0.05 or α=1.0, for S_A=0.05, for a single primary release group with no supplemental release.

				Δ=0.5		Δ=1.0	
Scenario	S_{OR}	ψ_A	P_C	α=0.05	α=0.10	α=0.05	α=0.10
1	0.5	0.5	0.6	5,230	3,980	1,170	890
2	0.5	0.5	0.9	3,390	2,590	620	470
3	0.9	0.5	0.6	2,900	2,190	650	490
4	0.9	0.5	0.9	1,860	1,420	340	260
5	0.5	0.3	0.6	7,050	5,370	1,950	1,490
6	0.5	0.3	0.9	4,610	3,510	1,040	790
7	0.9	0.3	0.6	3,900	2,960	1,080	830
8	0.9	0.3	0.9	2,540	1,930	570	440

Table 6. Release size to detect relative effect of either Δ =0.5 or Δ =1.0 with approximately 70% power and a Type I error probability of either α=0.05 or α=1.0, for S_A=0.1, for a single primary release group with no supplemental release.

				Δ=0.5		Δ=1.0	
Scenario	S_{OR}	ψ_A	P_C	α=0.05	α=0.10	α=0.05	α=0.10
1	0.5	0.5	0.6	2,640	2,020	590	450
2	0.5	0.5	0.9	1,730	1,320	320	240
3	0.9	0.5	0.6	1,440	1,100	330	250
4	0.9	0.5	0.9	940	710	170	130
5	0.5	0.3	0.6	3,580	2,730	990	760
6	0.5	0.3	0.9	2,360	1,800	540	410
7	0.9	0.3	0.6	1,960	1,500	550	420
8	0.9	0.3	0.9	1,290	980	290	230

Table 7. Release size to detect relative effect of either Δ =0.5 or Δ =1.0 with approximately 70% power and a Type I error probability of either α=0.05 or α=1.0, for S_A=0.15, for a single primary release group with no supplemental release.

				Δ=0.5		Δ=1.0	
Scenario	S_{OR}	ψ_A	P_C	α=0.05	α=0.10	α=0.05	α=0.10
1	0.5	0.5	0.6	1,790	1,360	400	300
2	0.5	0.5	0.9	1,180	900	210	165
3	0.9	0.5	0.6	960	740	215	165
4	0.9	0.5	0.9	625	475	115	87
5	0.5	0.3	0.6	2,430	1,850	670	510
6	0.5	0.3	0.9	1,630	1,230	370	280
7	0.9	0.3	0.6	1,320	1,010	365	280
8	0.9	0.3	0.9	870	670	200	150

Release at Durham Ferry with two Supplemental Releases

Simulations

Simulation results from the sample size analysis performed for the 2010 VAMP study are summarized here. For further details, see 2010 VAMP proposal.

In general, lower detection probability at Chipps Island demanded larger release groups at Durham Ferry and also at the downstream supplemental release sites (Table 8). Under the assumption of high detection probability at Chipps Island (0.97) and fairly low survival to Chipps Island in both routes, the recommended sample sizes of the three groups are R_1 = 95 (at Durham Ferry), R_2 = 75 (in the San Joaquin near Lathrop), and R_3 = 75 (in Old River near its head). This gives a total of 245 fish released. With lower detection probability at Chipps Island (0.76), a total of 440 fish would be necessary, comparable to the number recommended for a single primary release at Durham Ferry. Using smaller release groups may require pooling data across release groups in the event of low survival or low detection. Every effort should be made to ensure that detection probability at Chipps Island is as high as possible (at least 0.75). Similarly, detection probabilities lower than 0.9 at the first receivers in the San Joaquin River or Old River just downstream of the flow split may require a larger release group at Durham Ferry.

Table 8. Parameter values used to simulated data, and minimum release size recommended at Durham Ferry (R_1), site A1 in the San Joaquin River (R_2), and site B1 in Old River (R_3) to estimate key model survival and route selection parameters. Recommendations are based on the assumption of S_{RO} = 0.5, ψ_{A1} = 0.6, P_{A3} = 0.98, and P_{B1} = 0.94.

True Values			Minimum release size at Durham Ferry (R_1) to estimate:					Minimum supplemental release size to estimate:	
S_A	S_B	P_C	S_R	S_{RO}	S_A	S_B	ψ_{A1}	S_A (R_2)	S_B (R_3)
0.1	0.06	0.76	190	95	95	250	95	100	150
0.1	0.06	0.97	95	95	95	95	95	75	75
0.1	0.06	1.00	95	95	95	95	95	25	75
0.15	0.09	0.76	190	95	95	95	95	75	150
0.15	0.09	0.97	95	95	95	95	95	25	75
0.15	0.09	1.00	95	95	95	95	95	25	25

Power Calculations

Power was calculated for two supplemental release protocols: equal weighting across all release groups (i.e., common release size across all three releases: R_1=R_1=R_3), and triple weighting for the primary release group at Durham Ferry (R_1=$3R_2$=$3R_3$).

Equal Weight across all primary and supplemental release groups: $R_1 = R_2 = R_3$

As with a single release, more fish are required to detect smaller effect sizes at higher power and with a lower Type I error probability. Using equal release sizes at Durham Ferry and the two supplemental release groups, and assuming route-specific survival in the San Joaquin River route is 0.05, between 235 and 570 fish would be necessary to detect an effect of Δ=1.0 with approximately 70% power and a Type I error probability of α=0.10. To detect an effect of size Δ=0.5, from 1,280 to 2,390 fish would be required (Table 9). A third of those fish would be released at Durham Ferry. If route-specific survival in the San Joaquin River route is 0.15, total release sizes necessary to detect an effect of Δ=1.0 range from 75 to 185, and from 410 to 680 to detect an effect of Δ=0.5 (α=0.10, power = 0.7) (Table 10). In both cases, the largest benefits to using supplemental releases instead of a single Durham Ferry release arise when survival from Durham Ferry to the head of Old River (S_{RO}) is low (0.5). Different values of S_A and different desired power levels require different release sizes (Figure A9 - Figure A16).

Table 9. Total release size to detect relative effect of either Δ =0.5 or Δ =1.0 with approximately 70% power and a Type I error probability of either α=0.05 or α=1.0, for S_A=0.05, for a primary release at Durham Ferry of size R1, a supplemental release in the San Joaquin River just downstream of the OR flow split (size R2 = R1), and a supplemental release in Old River just downstream of the OR flow split (size R3 = R1). The number in parenthesis is R1.

				Δ=0.5		Δ=1.0	
Scenario	S_{OR}	ψ_A	P_C	α=0.05	α=0.10	α=0.05	α=0.10
1	0.5	0.5	0.6	3,050 (1,017)	2,320 (773)	685 (228)	520 (173)
2	0.5	0.5	0.9	1,950 (650)	1,480 (493)	355 (118)	270 (90)
3	0.9	0.5	0.6	2,630 (877)	2,010 (670)	590 (197)	450 (150)
4	0.9	0.5	0.9	1,700 (567)	1,280 (427)	305 (102)	235 (78)
5	0.5	0.3	0.6	3,140 (1,047)	2,390 (797)	740 (247)	570 (190)
6	0.5	0.3	0.9	2,010 (670)	1,530 (510)	385 (128)	290 (97)
7	0.9	0.3	0.6	2,780 (927)	2,120 (707)	670 (223)	510 (170)
8	0.9	0.3	0.9	1,770 (590)	1,355 (452)	350 (117)	265 (88)

Table 10. Total release size to detect relative effect of either Δ =0.5 or Δ =1.0 with approximately 70% power and a Type I error probability of either α=0.05 or α=1.0, for S_A=0.15, for a primary release at Durham Ferry of size R1, a supplemental release in the San Joaquin River just downstream of the OR flow split (size R2 = R1), and a supplemental release in Old River just downstream of the OR flow split (size R3 = R1). The number in parenthesis is R1.

				Δ=0.5		Δ=1.0	
Scenario	S_{OR}	ψ_A	P_C	α=0.05	α=0.10	α=0.05	α=0.10
1	0.5	0.5	0.6	980 (327)	750 (250)	220 (73)	170 (57)
2	0.5	0.5	0.9	615 (205)	470 (157)	110 (38)	85 (28)
3	0.9	0.5	0.6	850 (283)	650 (217)	190 (63)	145 (48)
4	0.9	0.5	0.9	540 (180)	410 (137)	100 (33)	75 (25)
5	0.5	0.3	0.6	1,005 (335)	770 (257)	240 (80)	185 (62)
6	0.5	0.3	0.9	630 (210)	480 (160)	120 (40)	90 (30)
7	0.9	0.3	0.6	890 (297)	680 (227)	215 (72)	165 (55)
8	0.9	0.3	0.9	560 (187)	430 (143)	110 (37)	85 (28)

Unequal Weights across Primary and Supplemental Release Groups: $R_1 = 3R_2 = 3R_3$

Putting more fish in the primary release at Durham Ferry (R_1) and fewer in the supplemental releases tends to require more fish overall than using an equal weighting across the three release groups (compare Table 9 and Table 11, or Table 10 and Table 12). This is because most of the parameters we wish to estimate arise downstream of the Old River flow split. With low route-specific survival (S_A=0.05), a total of from 240 to 750 fish would be required to detect relative effect of size Δ=1.0, while from 1,330 to 3,020 fish would be required to detect an effect of size Δ=0.5 (α=0.10, power=0.7; Table 11). With higher route-specific survival (S_A=0.15), between 80 and 245 fish would be required to detect a relative effect of size Δ=1.0, and between 440 and 990 fish would be required to detect an effect of size Δ=0.5 (α=0.10, power = 0.7) (Table 12). Results for other values of route-specific survival and other power levels are available in the Appendix (Figure A17 - Figure A24).

Table 11. Total release size to detect relative effect of either Δ =0.5 or Δ =1.0 with approximately 70% power and a Type I error probability of either α=0.05 or α=1.0, for S_A=0.05, for a primary release at Durham Ferry of size R1, a supplemental release in the San Joaquin River just downstream of the OR flow split (size R2 = R1/3), and a supplemental release in Old River just downstream of the OR flow split (size R3 = R1/3). The number in parenthesis is R1.

				Δ=0.5		Δ=1.0	
Scenario	S_{OR}	ψ_A	P_C	α=0.05	α=0.10	α=0.05	α=0.10
1	0.5	0.5	0.6	3,660 (2,196)	2,780 (1,668)	820 (492)	630 (378)
2	0.5	0.5	0.9	2,350 (1,410)	1,790 (1,074)	425 (255)	325 (195)
3	0.9	0.5	0.6	2,750 (1,650)	2,075 (1,245)	610 (366)	470 (282)
4	0.9	0.5	0.9	1,750 (1,050)	1,330 (798)	320 (192)	240 (144)
5	0.5	0.3	0.6	3,970 (2,382)	3,020 (1,812)	985 (591)	750 (450)
6	0.5	0.3	0.9	2,550 (1,530)	1,940 (1,164)	510 (306)	390 (234)
7	0.9	0.3	0.6	3,080 (1,848)	2,350 (1,410)	790 (474)	605 (363)
8	0.9	0.3	0.9	1,985 (1,191)	1,510 (906)	415 (249)	315 (189)

Table 12. Total release size to detect relative effect of either Δ =0.5 or Δ =1.0 with approximately 70% power and a Type I error probability of either α=0.05 or α=1.0, for S_A=0.15, for a primary release at Durham Ferry of size R1, a supplemental release in the San Joaquin River just downstream of the OR flow split (size R2 = R1/3), and a supplemental release in Old River just downstream of the OR flow split (size R3 = R1/3). The number in parenthesis is R1.

				Δ=0.5		Δ=1.0	
Scenario	S_{OR}	ψ_A	P_C	α=0.05	α=0.10	α=0.05	α=0.10
1	0.5	0.5	0.6	1,195 (717)	910 (546)	270 (162)	205 (123)
2	0.5	0.5	0.9	760 (456)	580 (348)	140 (84)	105 (63)
3	0.9	0.5	0.6	890 (534)	680 (408)	200 (120)	155 (93)
4	0.9	0.5	0.9	570 (342)	440 (264)	102 (61)	80 (48)
5	0.5	0.3	0.6	1,290 (774)	990 (594)	325 (195)	245 (147)
6	0.5	0.3	0.9	820 (492)	625 (375)	165 (99)	125 (75)
7	0.9	0.3	0.6	1,010 (606)	770 (462)	260 (156)	200 (120)
8	0.9	0.3	0.9	650 (390)	500 (300)	135 (81)	100 (60)

List of References

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San Joaquin River Group Authority (SJRGA) 2010. 2009 Annual Technical Report on Implementation and Monitoring of the San Joaquin River Agreement and the Vernalis Adaptive Management Plan (VAMP). Prepared for the California Water Resources Control Board in compliance with D-1641.

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Appendix: Power Curves

No Supplemental Releases

Scenario 1: Low Survival to Old River (0.5), Route Entrainment into San Joaquin River at Old River = 0.5, Low Detection Probability at Chipps Island (0.6). No supplemental release.

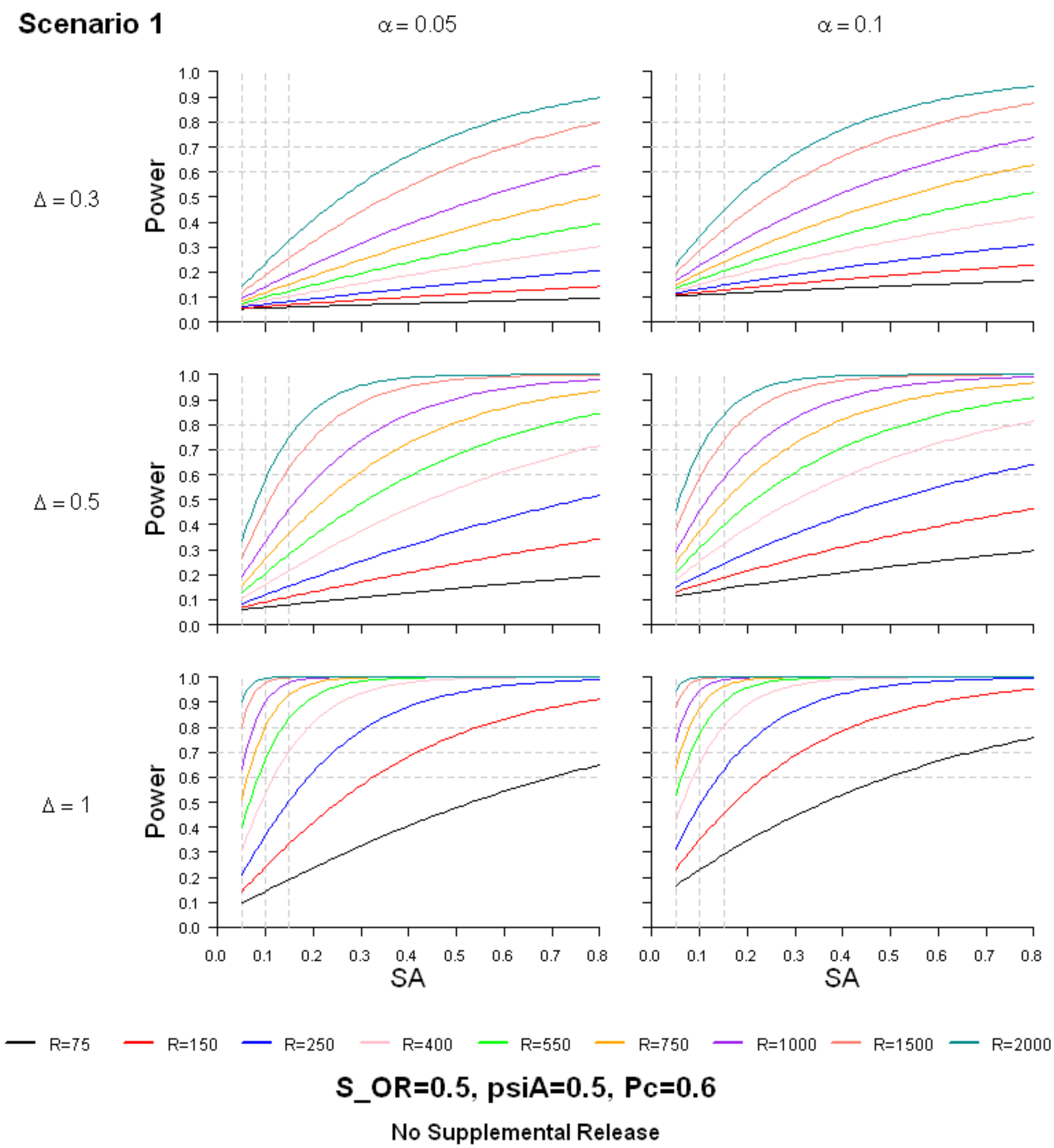


Figure A1. Power to detect relative difference of Delta between survival from the head of Old River to Chipps Island in the San Joaquin River route (SA) or in the Old River route, with a Type I error probability of alpha, and survival from Durham Ferry to the receivers just downstream of the head of Old River = 0.5, route entrainment probability into the San Joaquin River at head of Old River = 0.5, and detection probability at Chipps Island = 0.6. Detection probability at receivers in San Joaquin River and Old River just downstream of the head of Old River = 1. No supplemental release.

Scenario 2: Low Survival to Old River (0.5), Route Entrainment into San Joaquin River at Old River = 0.5, High Detection Probability at Chipps Island (0.9). No supplemental release.

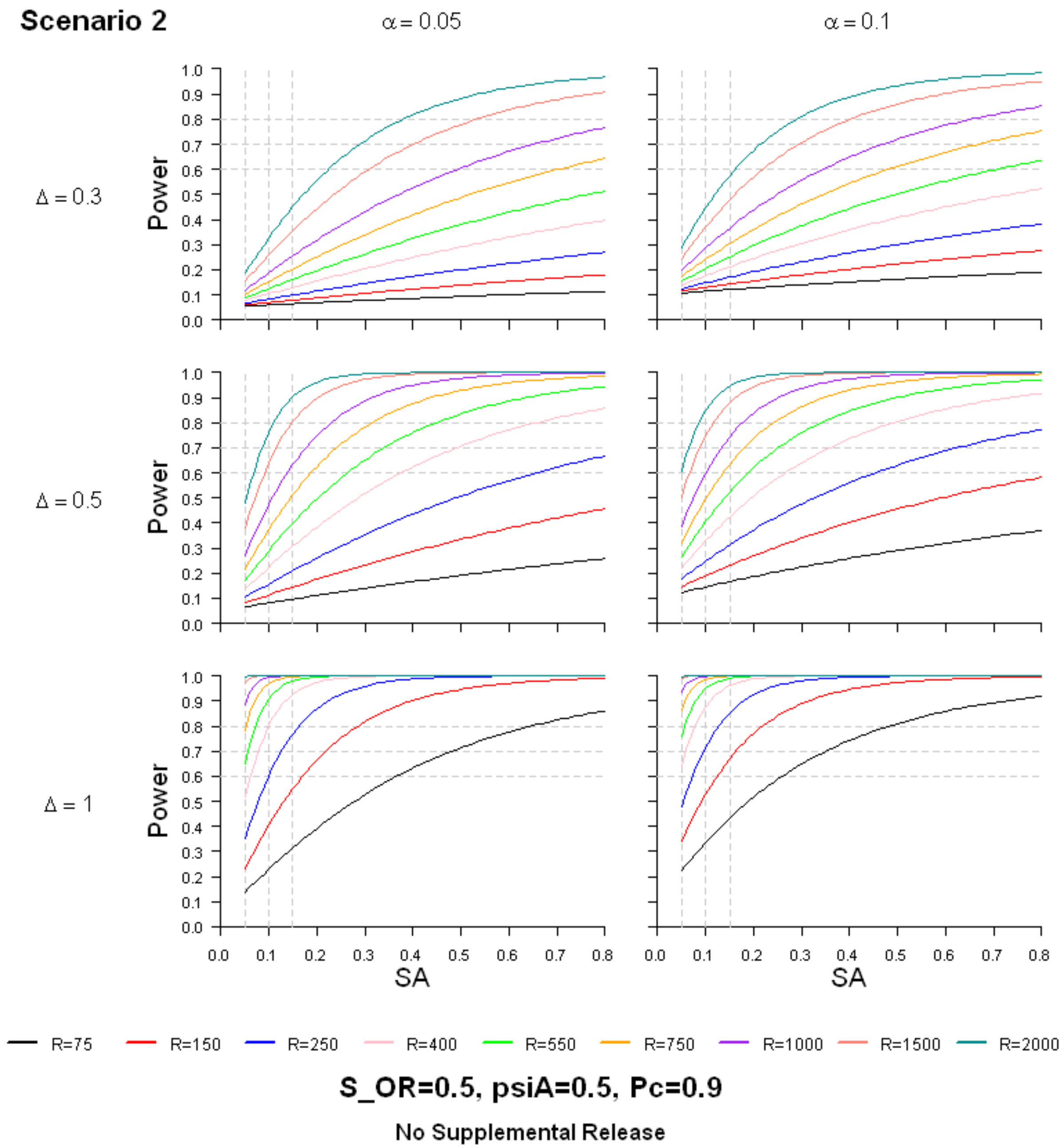


Figure A2. Power to detect relative difference of Delta between survival from the head of Old River to Chipps Island in the San Joaquin River route (SA) or in the Old River route, with a Type I error probability of alpha, and survival from Durham Ferry to the receivers just downstream of the head of Old River = 0.5, route entrainment probability into the San Joaquin River at head of Old River = 0.5, and detection probability at Chipps Island = 0.9. Detection probability at receivers in San Joaquin River and Old River just downstream of the head of Old River = 1. No supplemental release.

Scenario 3: High Survival to Old River (0.9), Route Entrainment into San Joaquin River at Old River = 0.5, Low Detection Probability at Chipps Island (0.6). No supplemental release.

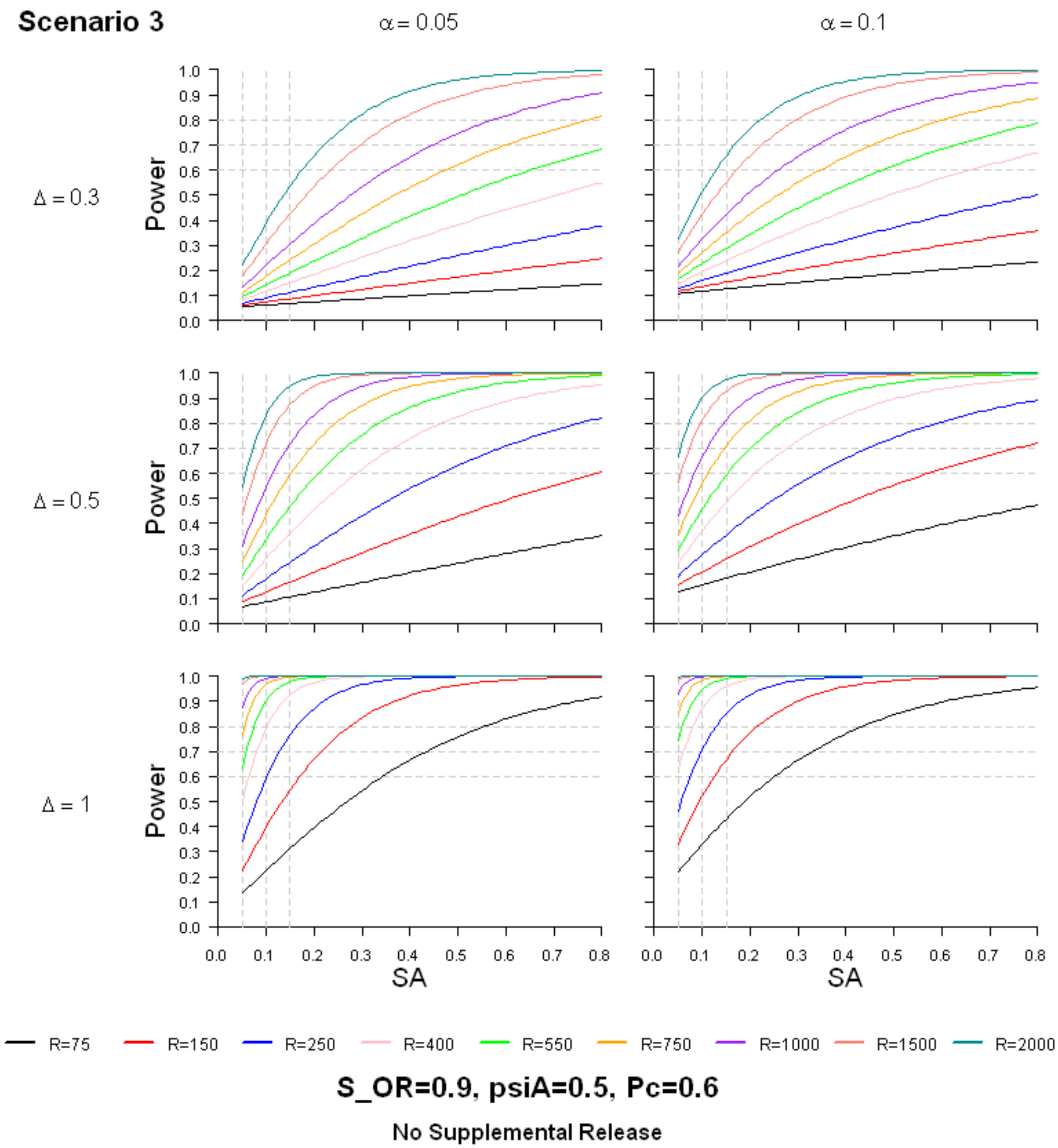


Figure A3. Power to detect relative difference of Delta between survival from the head of Old River to Chipps Island in the San Joaquin River route (SA) or in the Old River route, with a Type I error probability of alpha, and survival from Durham Ferry to the receivers just downstream of the head of Old River = 0.9, route entrainment probability into the San Joaquin River at head of Old River = 0.5, and detection probability at Chipps Island = 0.6. Detection probability at receivers in San Joaquin River and Old River just downstream of the head of Old River = 1. No supplemental release.

Scenario 4: High Survival to Old River (0.9), Route Entrainment into San Joaquin River at Old River = 0.5, High Detection Probability at Chipps Island (0.9). No supplemental release.

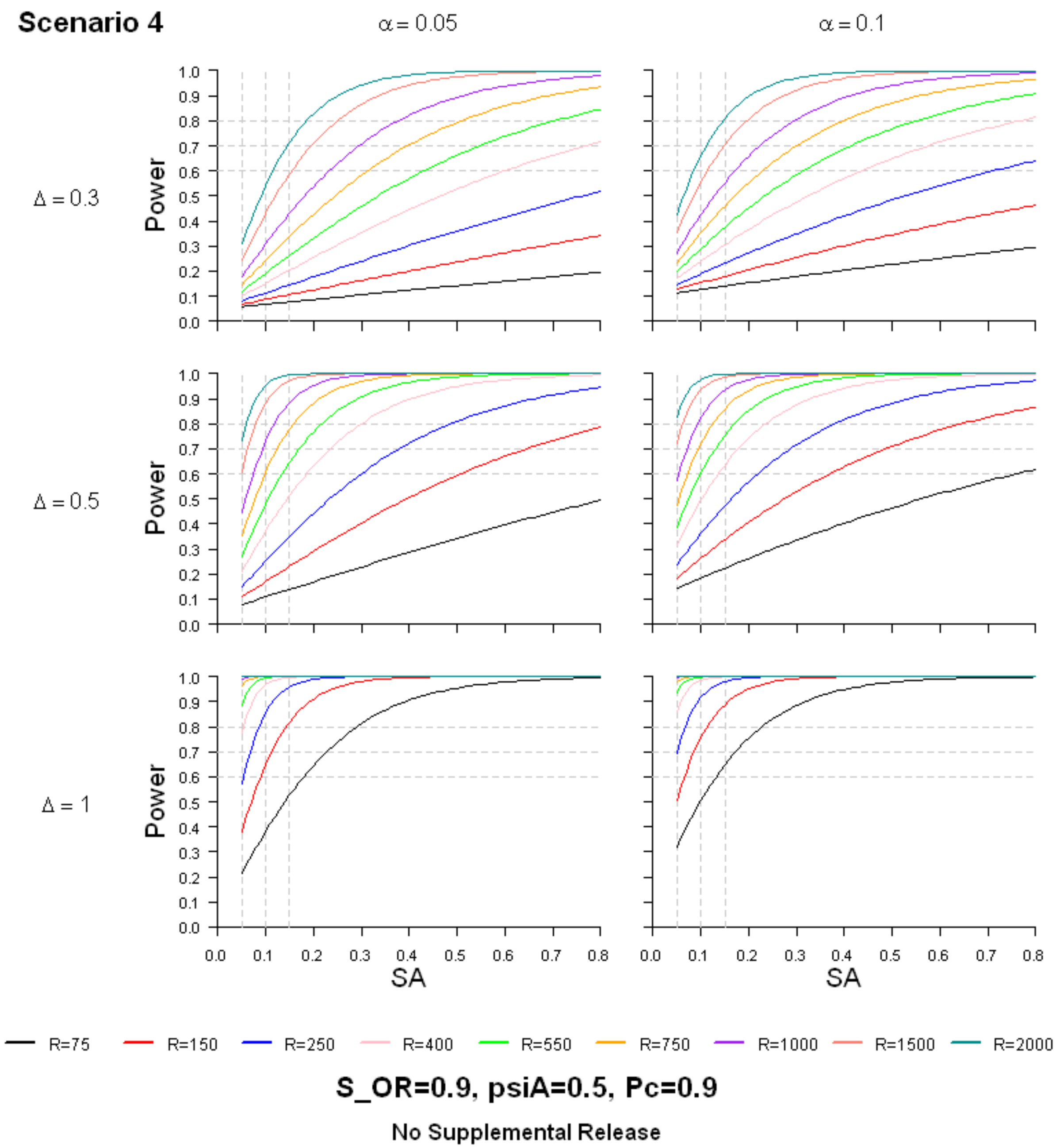


Figure A4. Power to detect relative difference of Delta between survival from the head of Old River to Chipps Island in the San Joaquin River route (SA) or in the Old River route, with a Type I error probability of alpha, and survival from Durham Ferry to the receivers just downstream of the head of Old River = 0.9, route entrainment probability into the San Joaquin River at head of Old River = 0.5, and detection probability at Chipps Island = 0.9. Detection probability at receivers in San Joaquin River and Old River just downstream of the head of Old River = 1. No supplemental release.

Scenario 5: Low Survival to Old River (0.5), Route Entrainment into San Joaquin River at Old River = 0.3, Low Detection Probability at Chipps Island (0.6). No supplemental release.

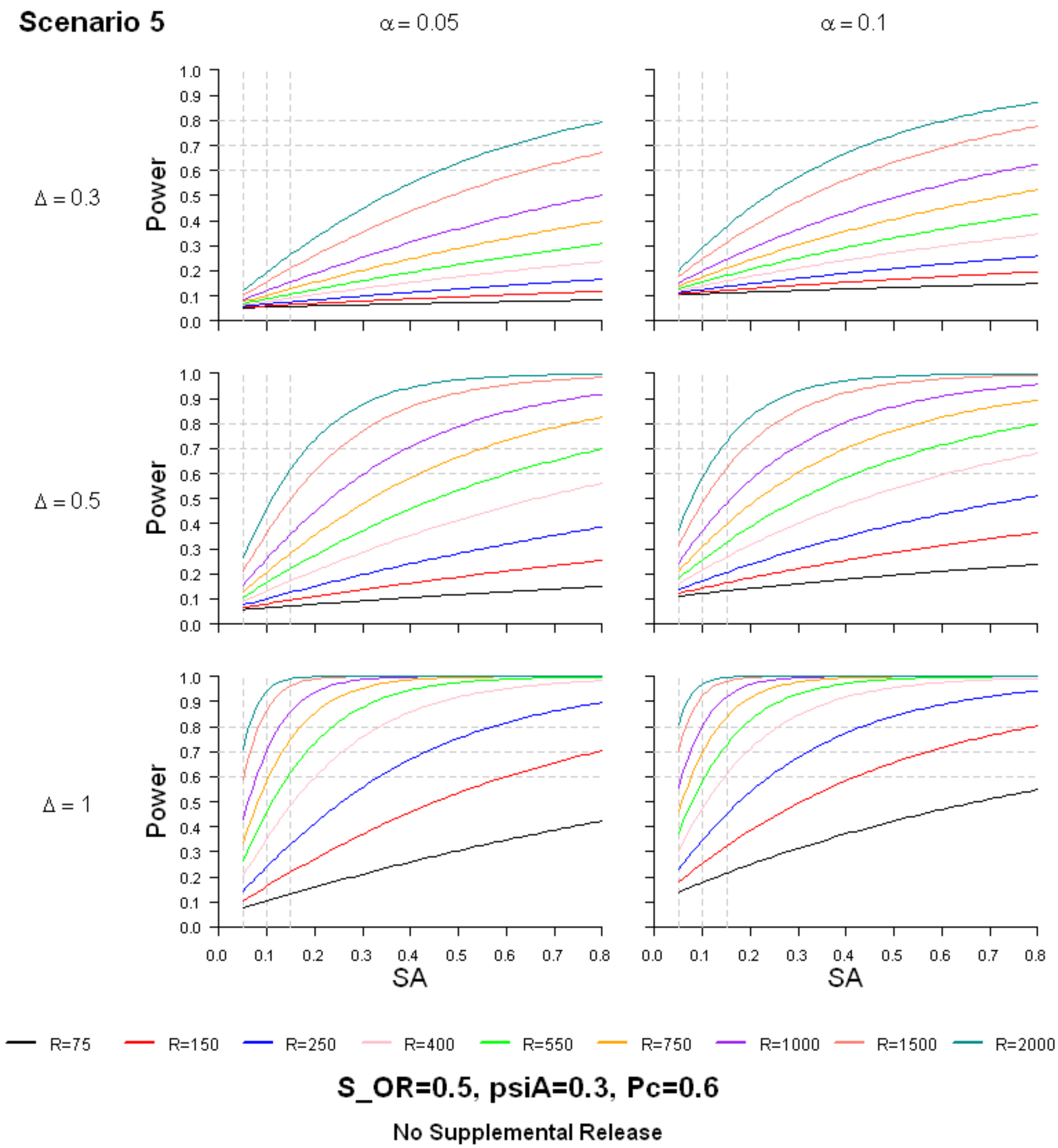


Figure A5. Power to detect relative difference of Delta between survival from the head of Old River to Chipps Island in the San Joaquin River route (SA) or in the Old River route, with a Type I error probability of alpha, and survival from Durham Ferry to the receivers just downstream of the head of Old River = 0.5, route entrainment probability into the San Joaquin River at head of Old River = 0.3, and detection probability at Chipps Island = 0.6. Detection probability at receivers in San Joaquin River and Old River just downstream of the head of Old River = 1. No supplemental release.

Scenario 6: Low Survival to Old River (0.5), Route Entrainment into San Joaquin River at Old River = 0.3, High Detection Probability at Chipps Island (0.9). No supplemental release.

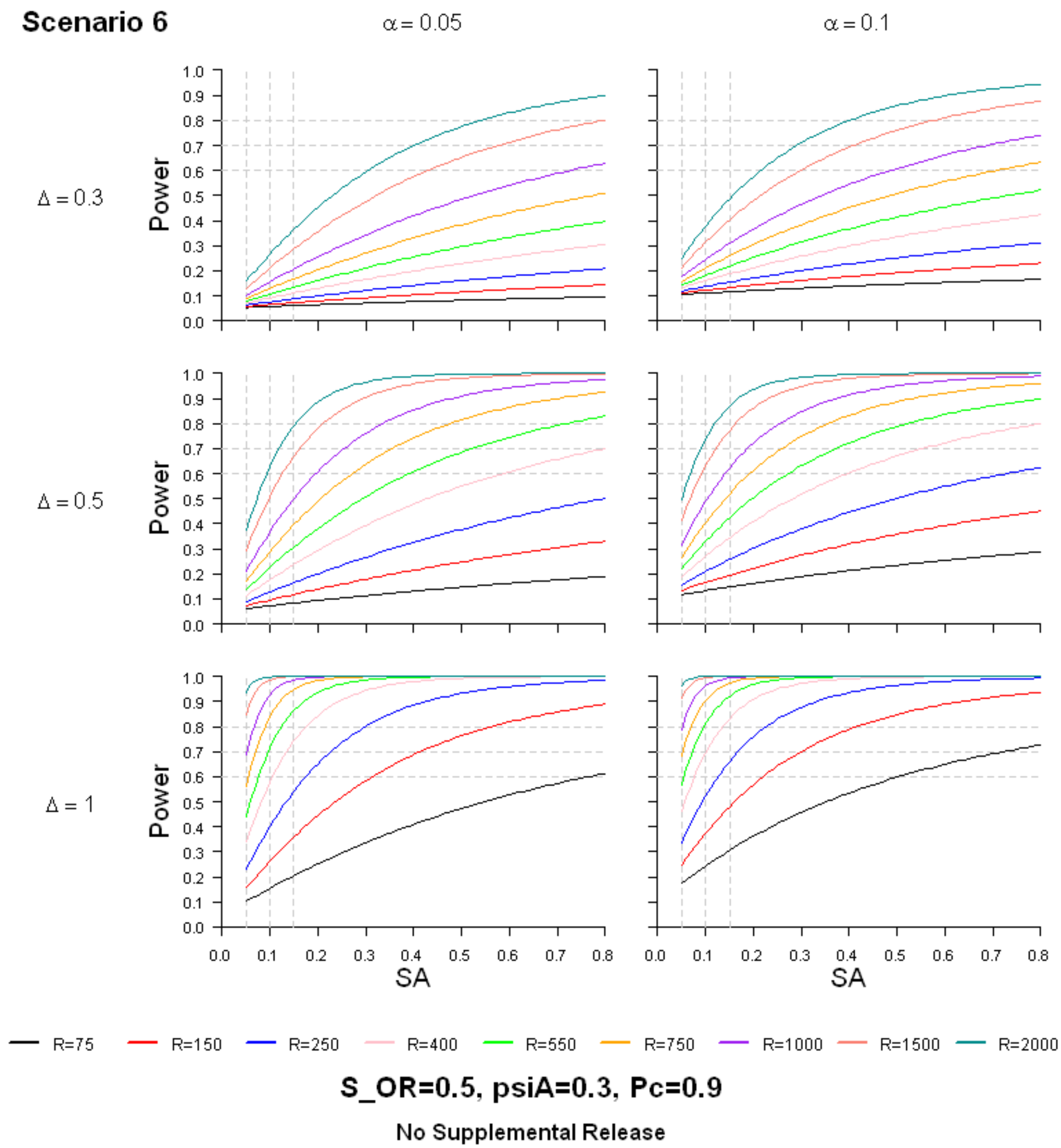


Figure A6. Power to detect relative difference of Delta between survival from the head of Old River to Chipps Island in the San Joaquin River route (SA) or in the Old River route, with a Type I error probability of alpha, and survival from Durham Ferry to the receivers just downstream of the head of Old River = 0.5, route entrainment probability into the San Joaquin River at head of Old River = 0.3, and detection probability at Chipps Island = 0.9. Detection probability at receivers in San Joaquin River and Old River just downstream of the head of Old River = 1. No supplemental release.

Scenario 7: High Survival to Old River (0.9), Route Entrainment into San Joaquin River at Old River = 0.3, Low Detection Probability at Chipps Island (0.6). No supplemental release.

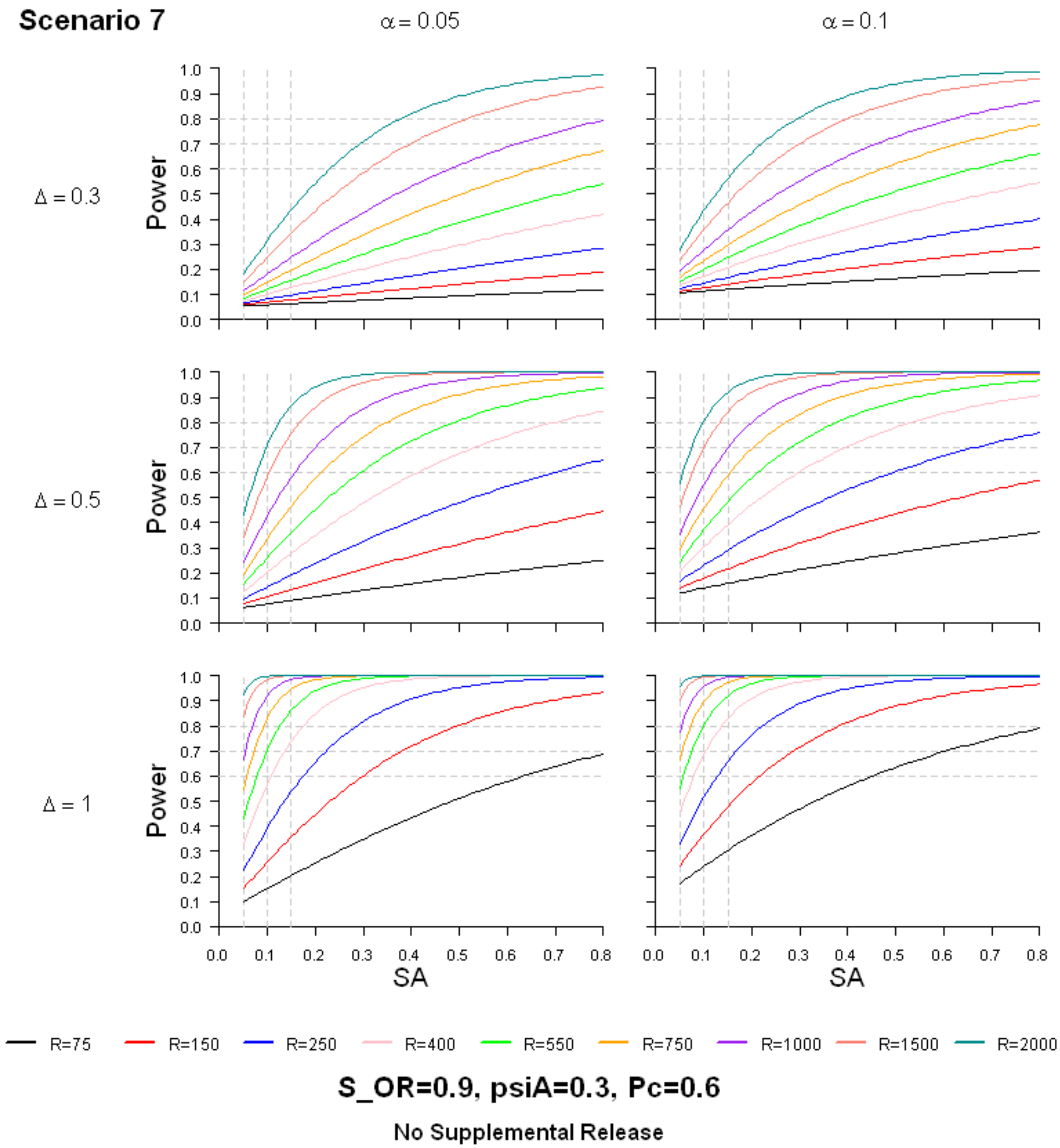


Figure A7. Power to detect relative difference of Delta between survival from the head of Old River to Chipps Island in the San Joaquin River route (SA) or in the Old River route, with a Type I error probability of alpha, and survival from Durham Ferry to the receivers just downstream of the head of Old River = 0.9, route entrainment probability into the San Joaquin River at head of Old River = 0.3, and detection probability at Chipps Island = 0.6. Detection probability at receivers in San Joaquin River and Old River just downstream of the head of Old River = 1. No supplemental release.

Scenario 8: High Survival to Old River (0.9), Route Entrainment into San Joaquin River at Old River = 0.3, High Detection Probability at Chipps Island (0.9). No supplemental release.

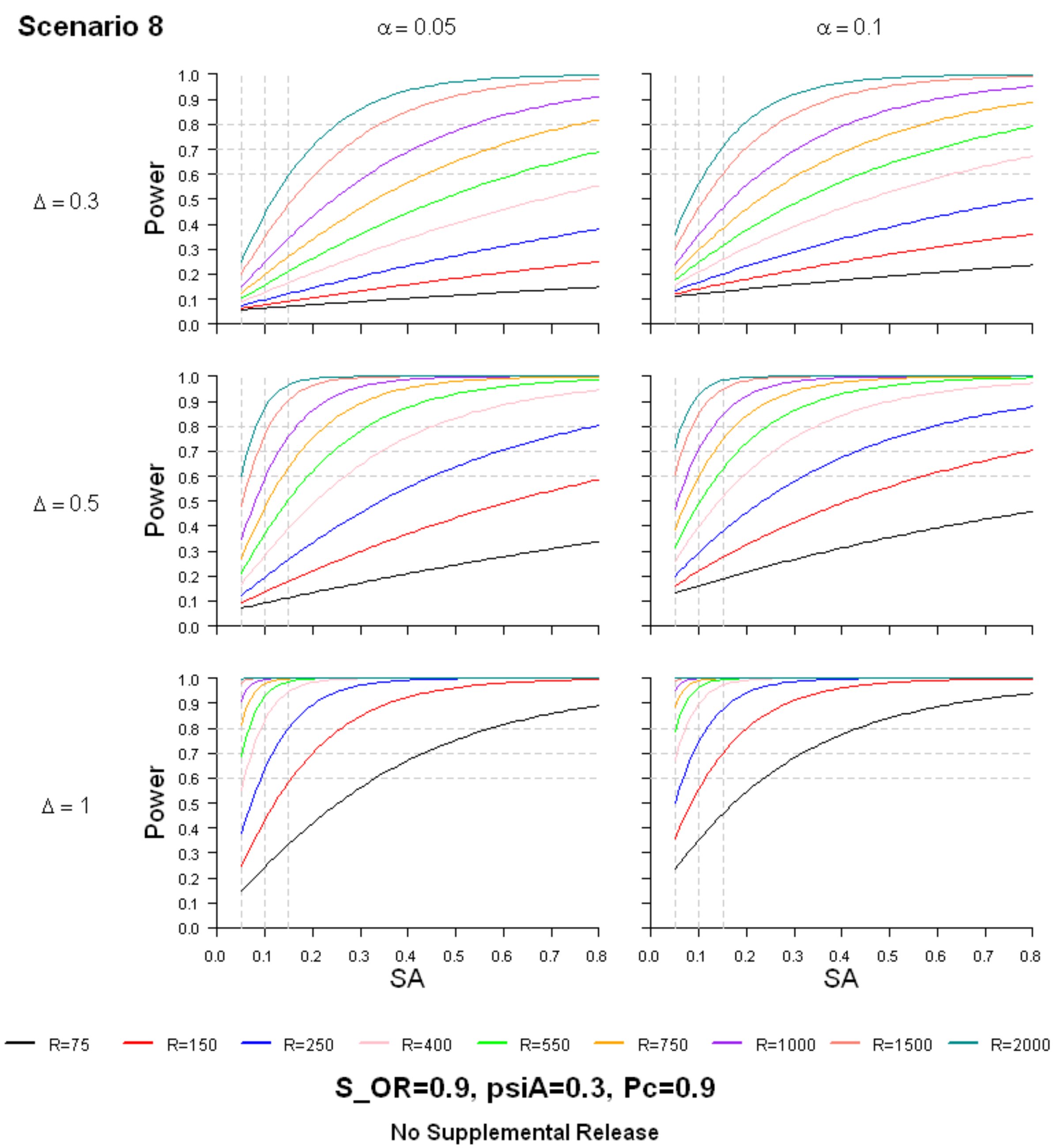


Figure A8. Power to detect relative difference of Delta between survival from the head of Old River to Chipps Island in the San Joaquin River route (SA) or in the Old River route, with a Type I error probability of alpha, and survival from Durham Ferry to the receivers just downstream of the head of Old River = 0.9, route entrainment probability into the San Joaquin River at head of Old River = 0.3, and detection probability at Chipps Island = 0.9. Detection probability at receivers in San Joaquin River and Old River just downstream of the head of Old River = 1. No supplemental release.

Equal Weights across Primary and Supplemental Release Groups: R1=R2=R3

Scenario 9: Low Survival to Old River (0.5), Route Entrainment into San Joaquin River at Old River = 0.5, Low Detection Probability at Chipps Island (0.6). Supplemental Release in SJR, OR (equal release sizes).

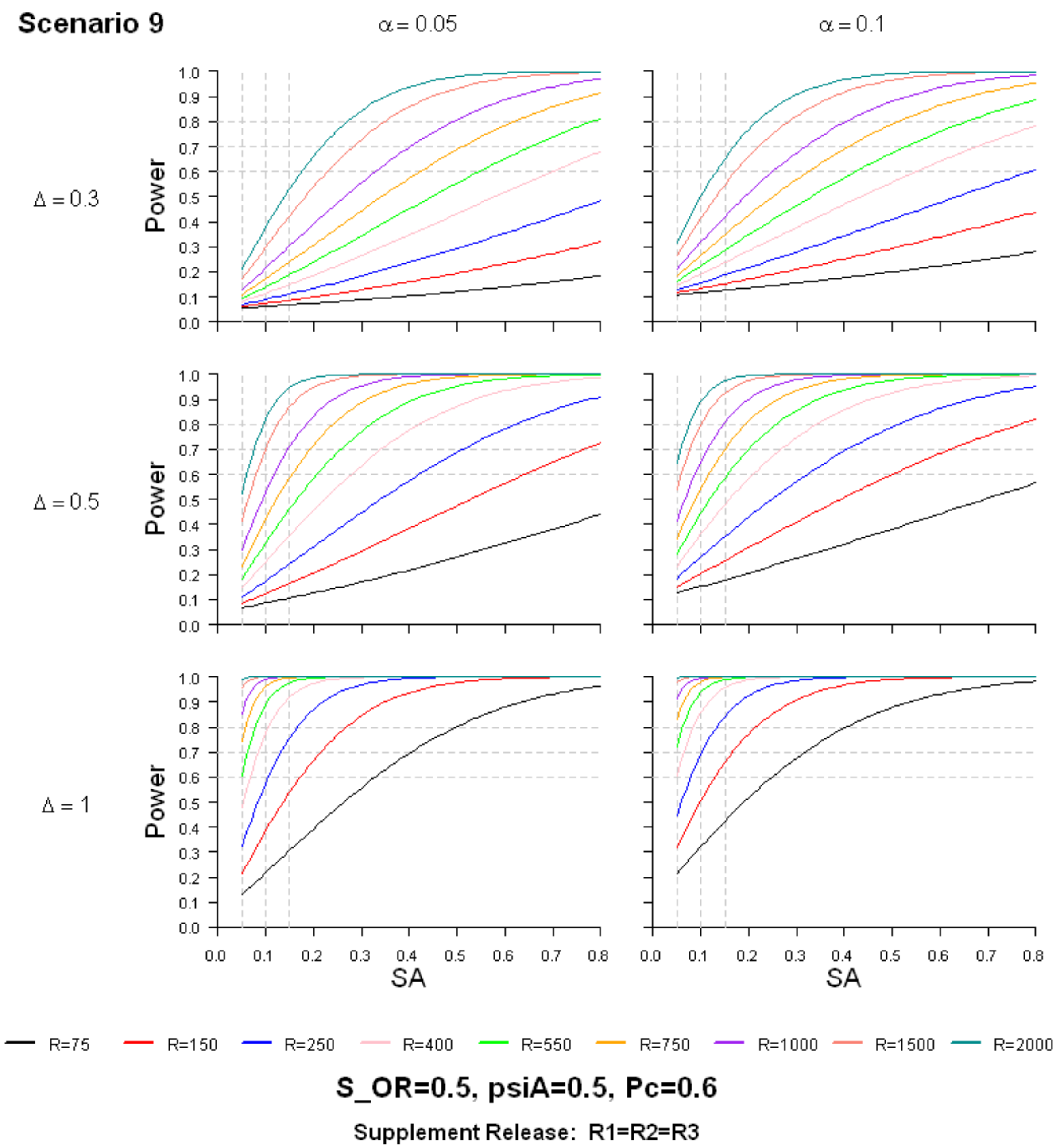


Figure A9. Power to detect relative difference of Delta between survival from the head of Old River to Chipps Island in the San Joaquin River route (SA) or in the Old River route, with a Type I error probability of alpha, and survival from Durham Ferry to the receivers just downstream of the head of Old River = 0.5, route entrainment probability into the San Joaquin River at head of Old River = 0.5, and detection probability at Chipps Island = 0.6. Detection probability at receivers in San Joaquin River and Old River just downstream of the head of Old River = 1. Primary release (R1) with supplemental releases in San Joaquin River (R2) and Old River (R3) just downstream of the Old River flow split, with R1=R2=R3 and R=R1+R2+R3.

Scenario 10: Low Survival to Old River (0.5), Route Entrainment into San Joaquin River at Old River = 0.5, High Detection Probability at Chipps Island (0.9). Supplemental Release in SJR, OR (equal release sizes).

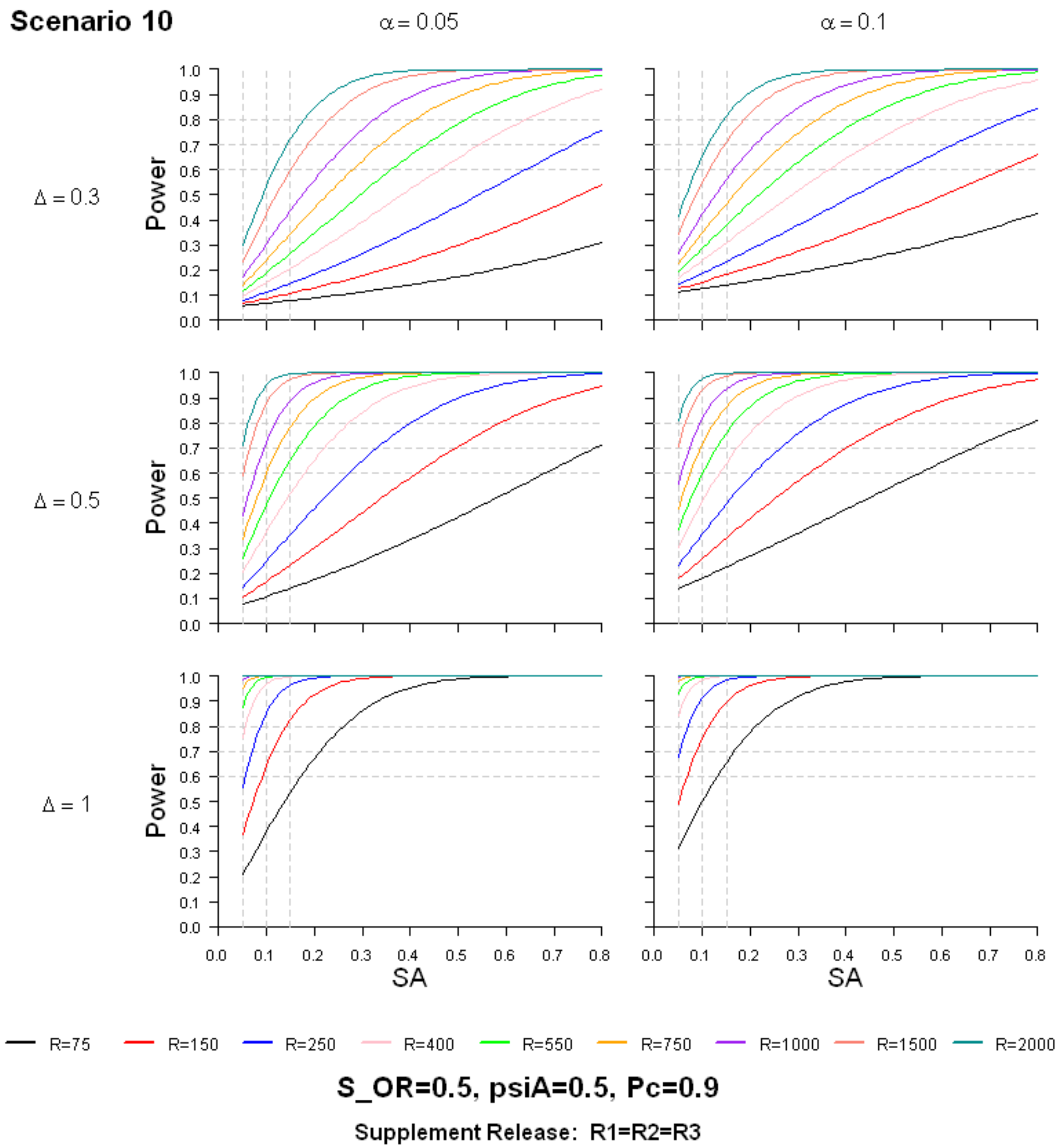


Figure A10. Power to detect relative difference of Delta between survival from the head of Old River to Chipps Island in the San Joaquin River route (SA) or in the Old River route, with a Type I error probability of alpha, and survival from Durham Ferry to the receivers just downstream of the head of Old River = 0.5, route entrainment probability into the San Joaquin River at head of Old River = 0.5, and detection probability at Chipps Island = 0.9. Detection probability at receivers in San Joaquin River and Old River just downstream of the head of Old River = 1. Primary release (R1) with supplemental releases in San Joaquin River (R2) and Old River (R3) just downstream of the Old River flow split, with R1=R2=R3 and R=R1+R2+R3.

Scenario 11: High Survival to Old River (0.9), Route Entrainment into San Joaquin River at Old River = 0.5, Low Detection Probability at Chipps Island (0.6). Supplemental Release in SJR, OR (equal release sizes).

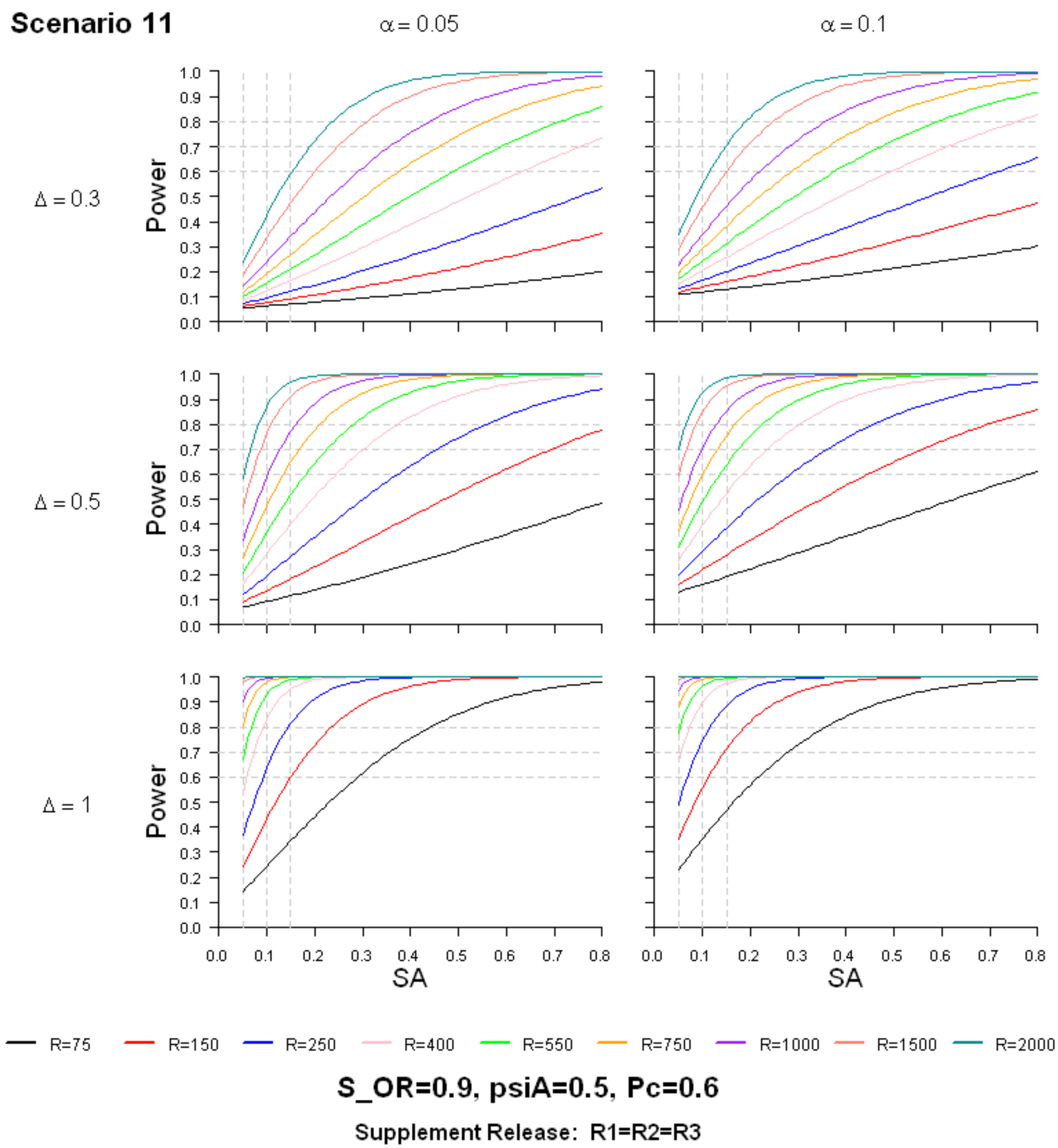


Figure A11. Power to detect relative difference of Delta between survival from the head of Old River to Chipps Island in the San Joaquin River route (SA) or in the Old River route, with a Type I error probability of alpha, and survival from Durham Ferry to the receivers just downstream of the head of Old River = 0.9, route entrainment probability into the San Joaquin River at head of Old River = 0.5, and detection probability at Chipps Island = 0.6. Detection probability at receivers in San Joaquin River and Old River just downstream of the head of Old River = 1. Primary release (R1) with supplemental releases in San Joaquin River (R2) and Old River (R3) just downstream of the Old River flow split, with R1=R2=R3 and R=R1+R2+R3.

Scenario 12: High Survival to Old River (0.9), Route Entrainment into San Joaquin River at Old River = 0.5, High Detection Probability at Chipps Island (0.9). Supplemental Release in SJR, OR (equal release sizes).

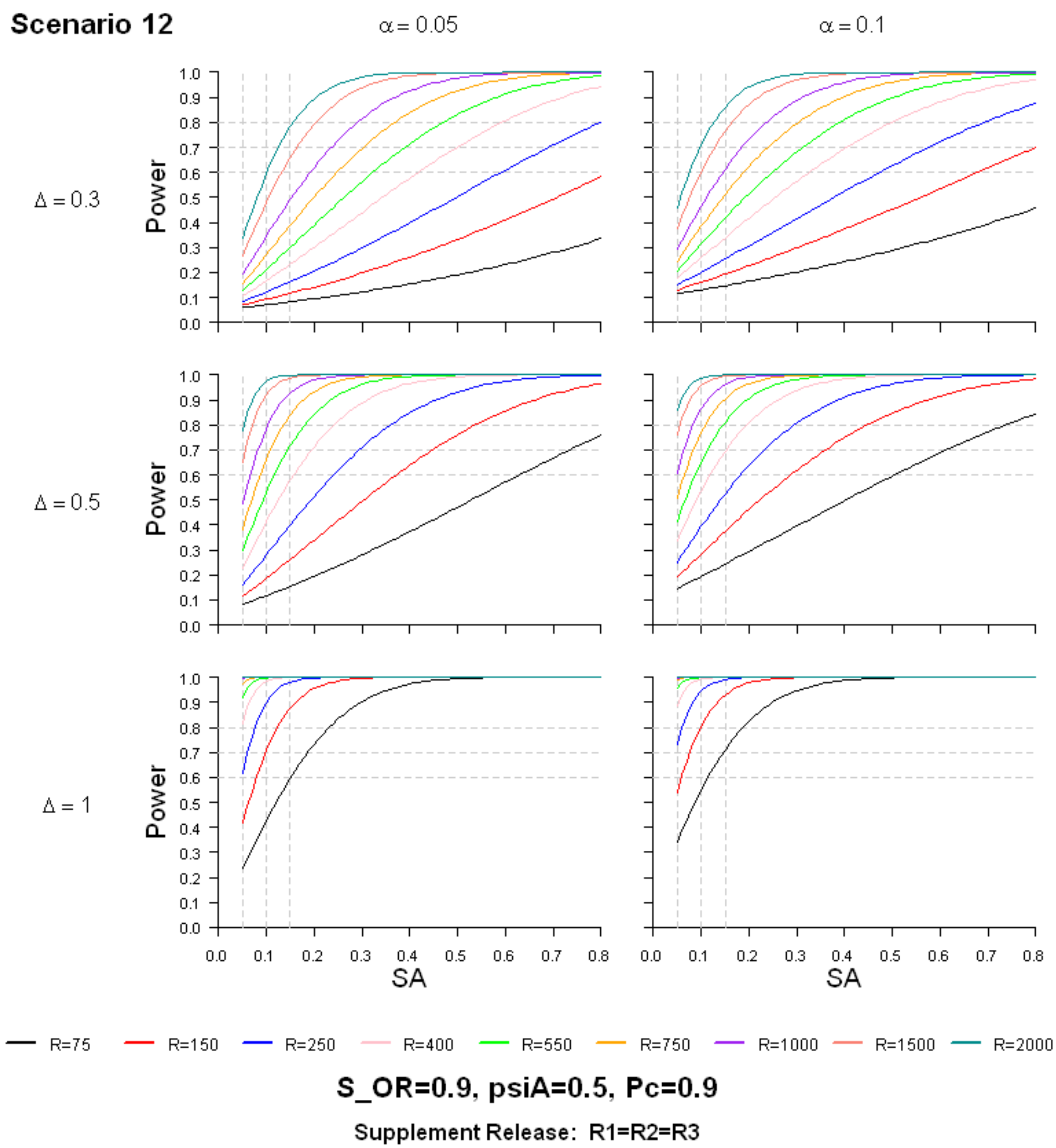


Figure A12. Power to detect relative difference of Delta between survival from the head of Old River to Chipps Island in the San Joaquin River route (SA) or in the Old River route, with a Type I error probability of alpha, and survival from Durham Ferry to the receivers just downstream of the head of Old River = 0.9, route entrainment probability into the San Joaquin River at head of Old River = 0.5, and detection probability at Chipps Island = 0.9. Detection probability at receivers in San Joaquin River and Old River just downstream of the head of Old River = 1. Primary release (R1) with supplemental releases in San Joaquin River (R2) and Old River (R3) just downstream of the Old River flow split, with R1=R2=R3 and R=R1+R2+R3.

Scenario 13: Low Survival to Old River (0.5), Route Entrainment into San Joaquin River at Old River = 0.3, Low Detection Probability at Chipps Island (0.6). Supplemental Release in SJR, OR (equal release sizes).

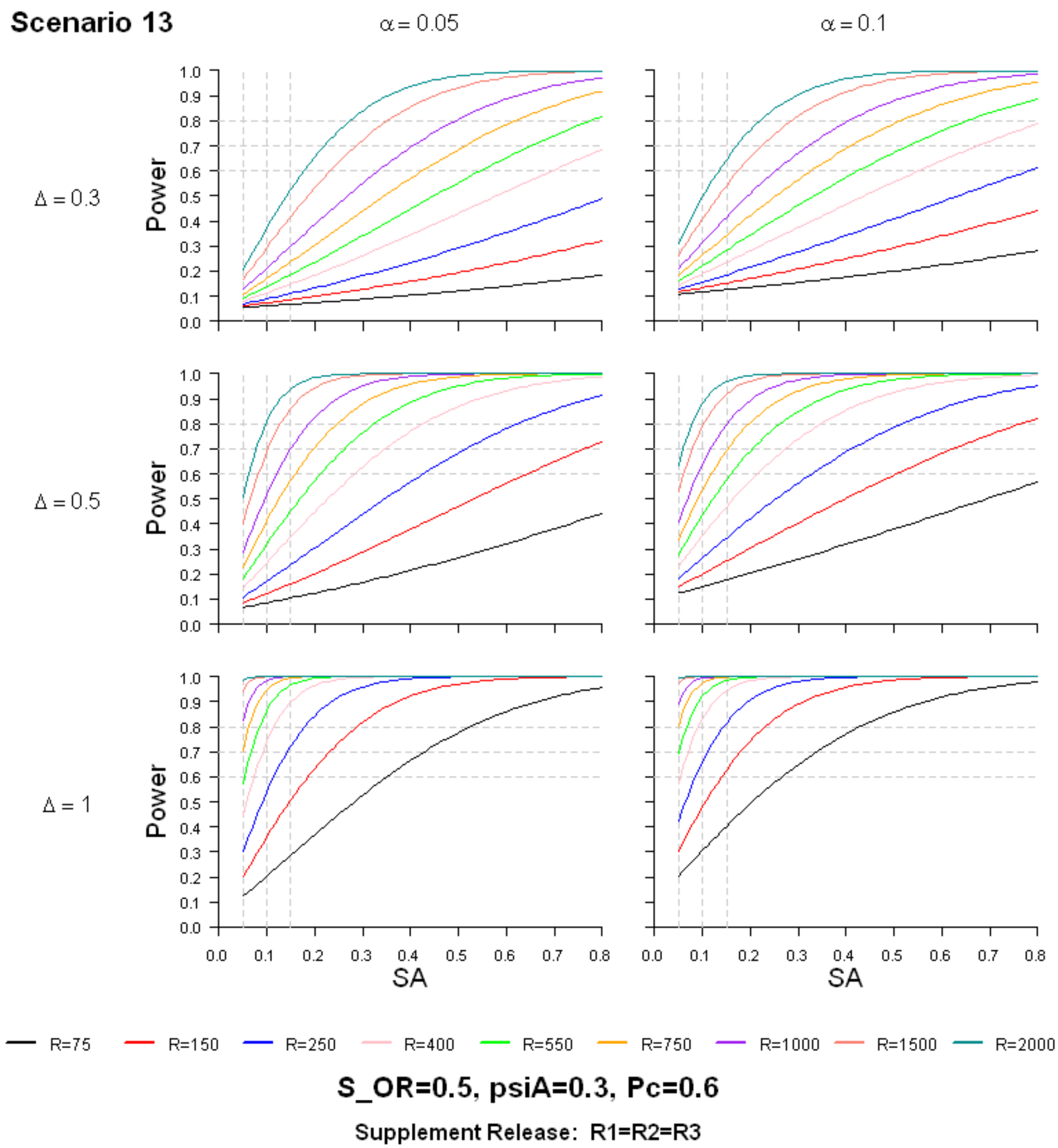


Figure A13. Power to detect relative difference of Delta between survival from the head of Old River to Chipps Island in the San Joaquin River route (SA) or in the Old River route, with a Type I error probability of alpha, and survival from Durham Ferry to the receivers just downstream of the head of Old River = 0.5, route entrainment probability into the San Joaquin River at head of Old River = 0.3, and detection probability at Chipps Island = 0.6. Detection probability at receivers in San Joaquin River and Old River just downstream of the head of Old River = 1. Primary release (R1) with supplemental releases in San Joaquin River (R2) and Old River (R3) just downstream of the Old River flow split, with R1=R2=R3 and R=R1+R2+R3.

Scenario 14: Low Survival to Old River (0.5), Route Entrainment into San Joaquin River at Old River = 0.3, High Detection Probability at Chipps Island (0.9). Supplemental Release in SJR, OR (equal release sizes).

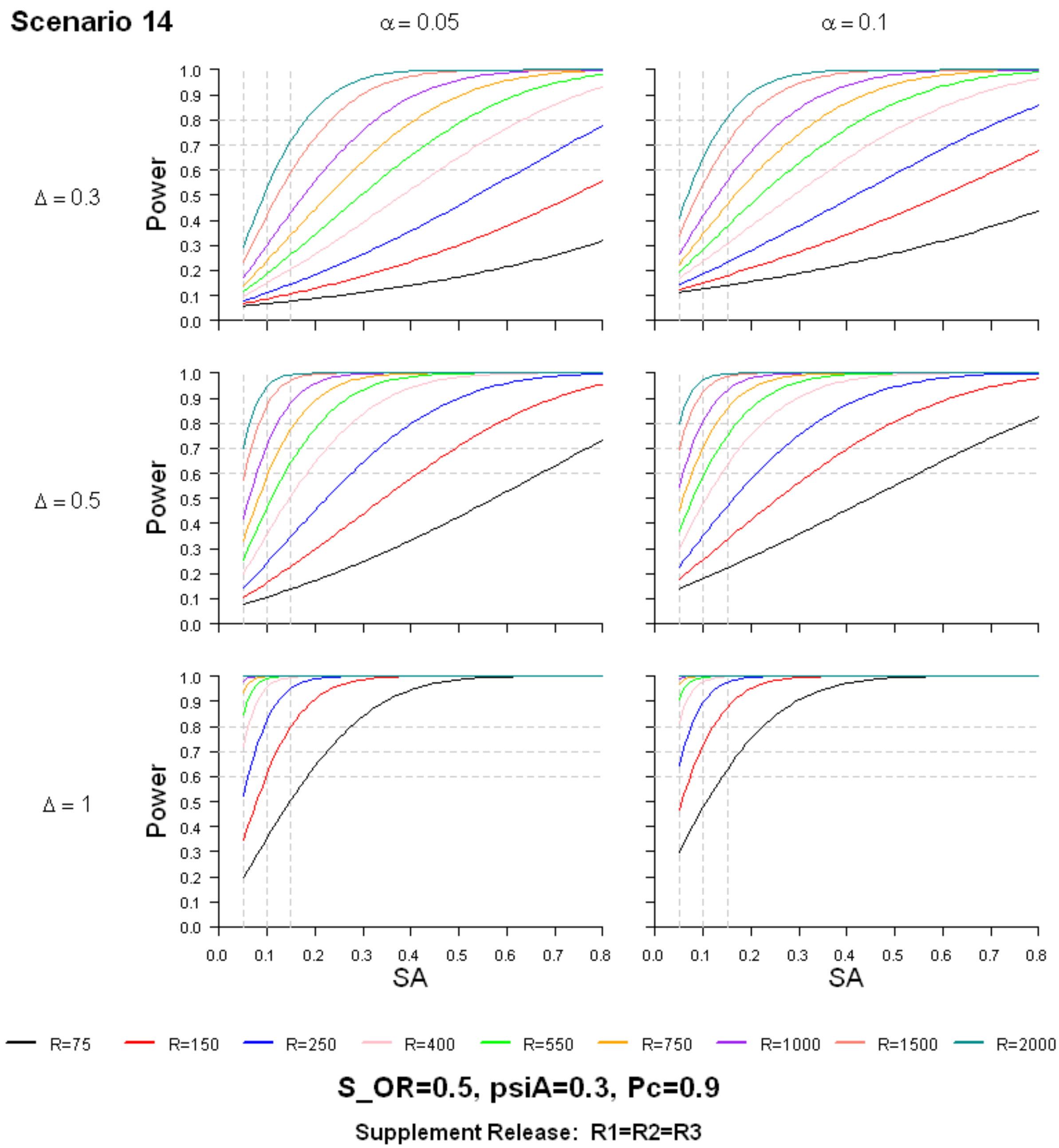


Figure A14. Power to detect relative difference of Delta between survival from the head of Old River to Chipps Island in the San Joaquin River route (SA) or in the Old River route, with a Type I error probability of alpha, and survival from Durham Ferry to the receivers just downstream of the head of Old River = 0.5, route entrainment probability into the San Joaquin River at head of Old River = 0.3, and detection probability at Chipps Island = 0.9. Detection probability at receivers in San Joaquin River and Old River just downstream of the head of Old River = 1. Primary release (R1) with supplemental releases in San Joaquin River (R2) and Old River (R3) just downstream of the Old River flow split, with R1=R2=R3 and R=R1+R2+R3.

Scenario 15: High Survival to Old River (0.9), Route Entrainment into San Joaquin River at Old River = 0.3, Low Detection Probability at Chipps Island (0.6). Supplemental Release in SJR, OR (equal release sizes).

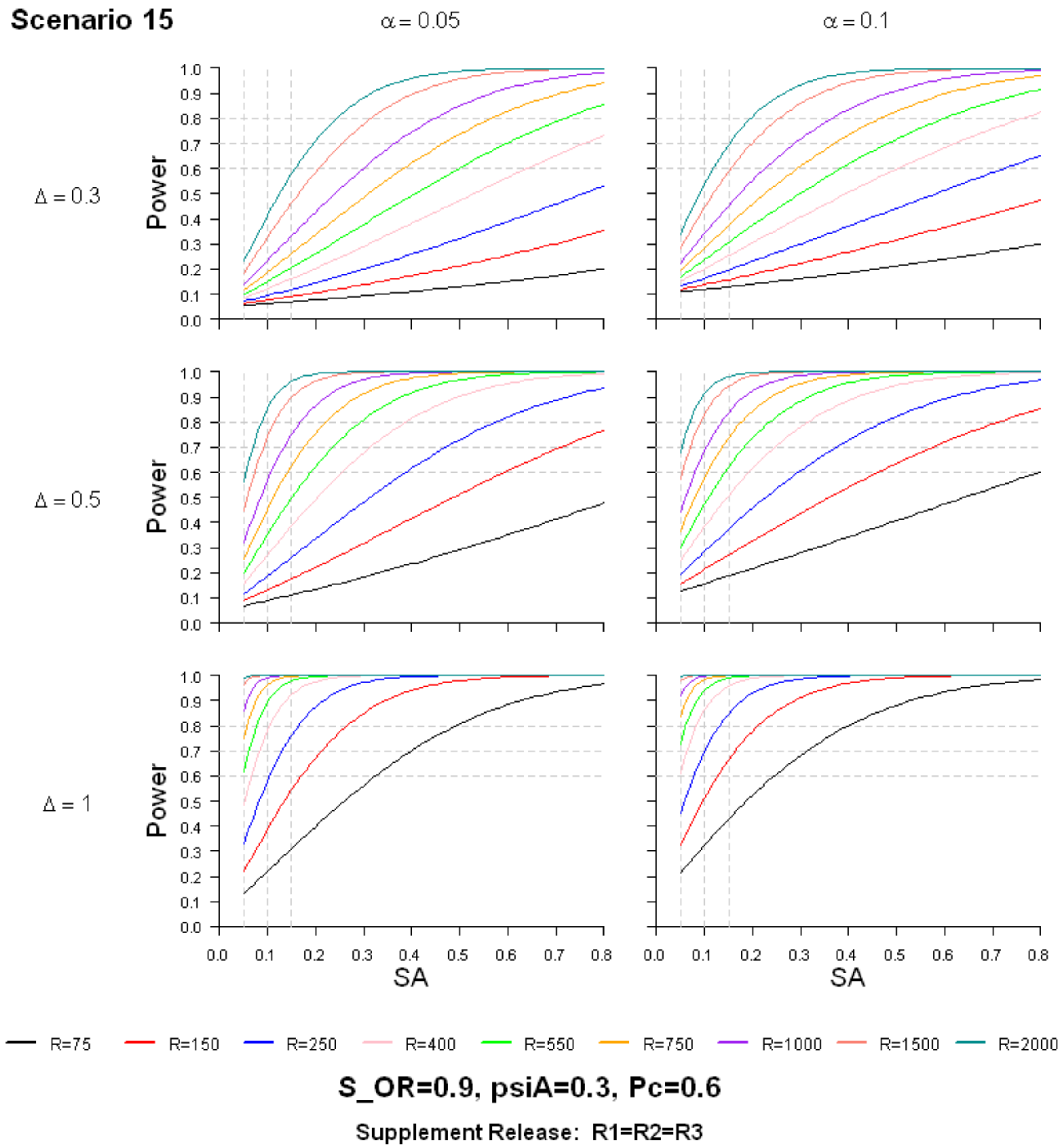


Figure A15. Power to detect relative difference of Delta between survival from the head of Old River to Chipps Island in the San Joaquin River route (SA) or in the Old River route, with a Type I error probability of alpha, and survival from Durham Ferry to the receivers just downstream of the head of Old River = 0.9, route entrainment probability into the San Joaquin River at head of Old River = 0.3, and detection probability at Chipps Island = 0.6. Detection probability at receivers in San Joaquin River and Old River just downstream of the head of Old River = 1. Primary release (R1) with supplemental releases in San Joaquin River (R2) and Old River (R3) just downstream of the Old River flow split, with R1=R2=R3 and R=R1+R2+R3.

Scenario 16: High Survival to Old River (0.9), Route Entrainment into San Joaquin River at Old River = 0.3, High Detection Probability at Chipps Island (0.9). Supplemental Release in SJR, OR (equal release sizes).

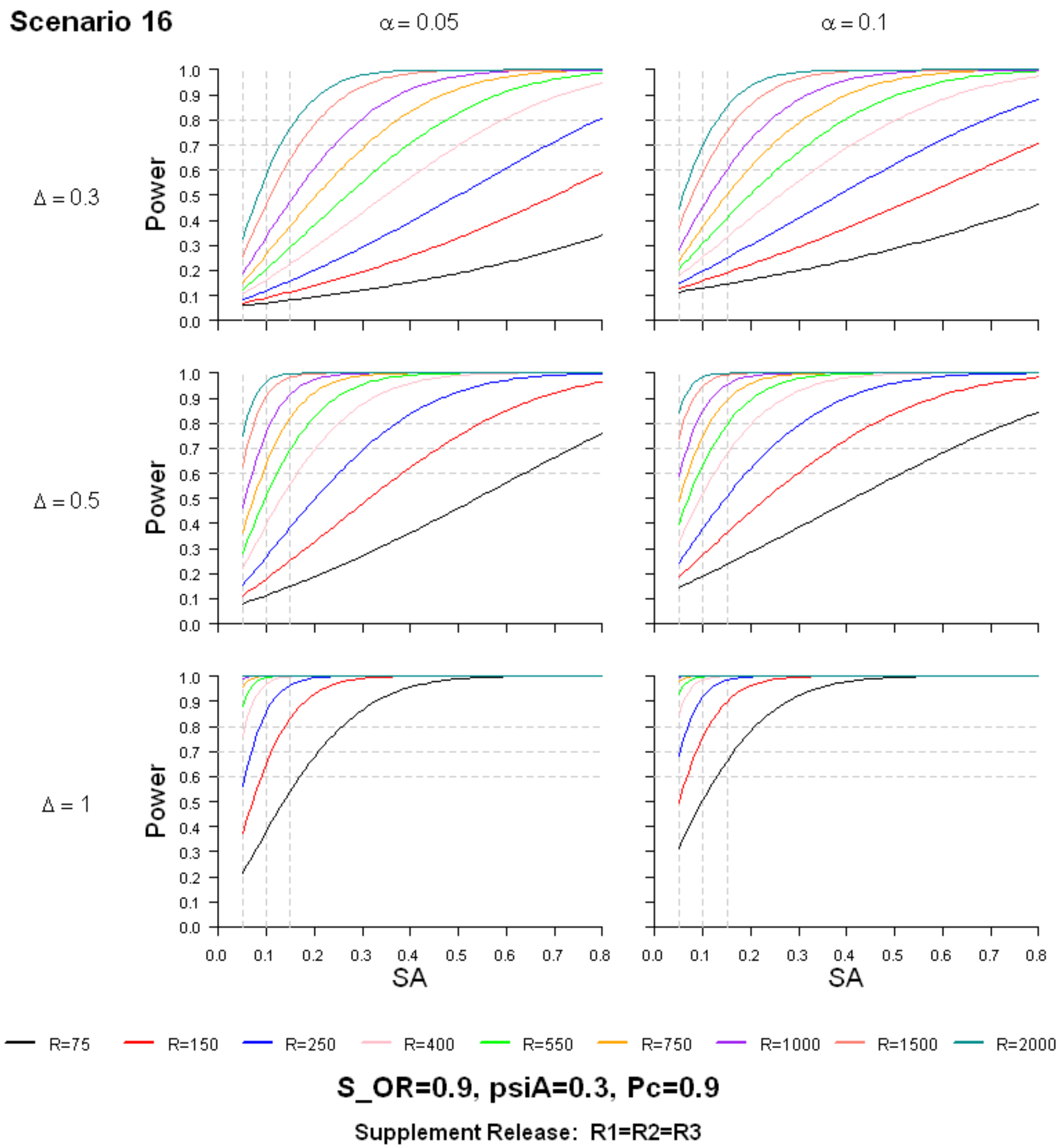


Figure A16. Power to detect relative difference of Delta between survival from the head of Old River to Chipps Island in the San Joaquin River route (SA) or in the Old River route, with a Type I error probability of alpha, and survival from Durham Ferry to the receivers just downstream of the head of Old River = 0.9, route entrainment probability into the San Joaquin River at head of Old River = 0.3, and detection probability at Chipps Island = 0.9. Detection probability at receivers in San Joaquin River and Old River just downstream of the head of Old River = 1. Primary release (R1) with supplemental releases in San Joaquin River (R2) and Old River (R3) just downstream of the Old River flow split, with R1=R2=R3 and R=R1+R2+R3.

Unequal Weights across Primary and Supplemental Release Groups: R1=3R2=3R3

Scenario 17: Low Survival to Old River (0.5), Route Entrainment into San Joaquin River at Old River = 0.5, Low Detection Probability at Chipps Island (0.6). Supplemental Release in SJR, OR (Primary release size=3 times each supplemental release size).

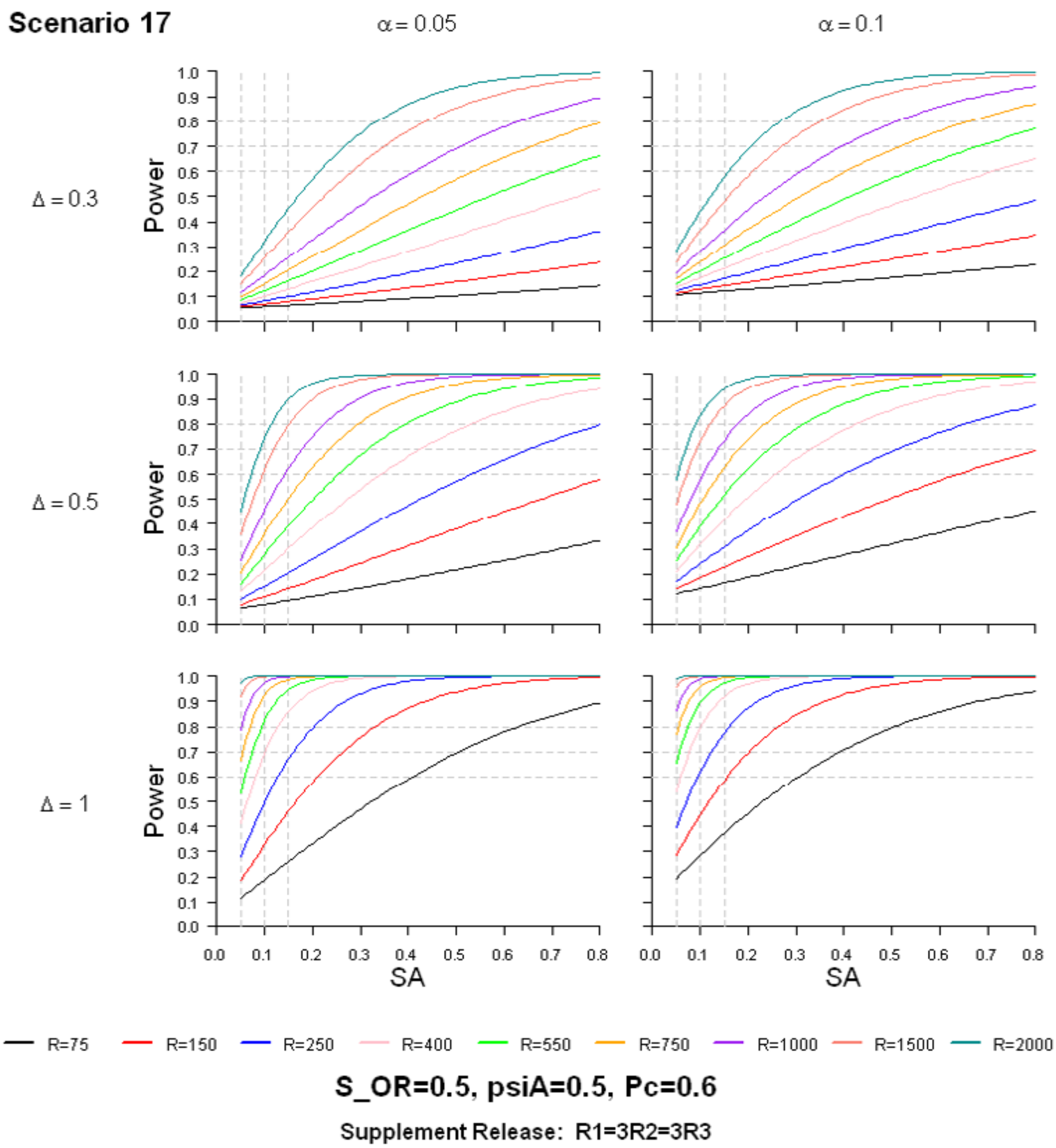


Figure A17. Power to detect relative difference of Delta between survival from the head of Old River to Chipps Island in the San Joaquin River route (SA) or in the Old River route, with a Type I error probability of alpha, and survival from Durham Ferry to the receivers just downstream of the head of Old River = 0.5, route entrainment probability into the San Joaquin River at head of Old River = 0.5, and detection probability at Chipps Island = 0.6. Detection probability at receivers in San Joaquin River and Old River just downstream of the head of Old River = 1. Primary release (R1) with supplemental releases in San Joaquin River (R2) and Old River (R3) just downstream of the Old River flow split, with R1=3R2=3R3 and R=R1+R2+R3.

Scenario 18: Low Survival to Old River (0.5), Route Entrainment into San Joaquin River at Old River = 0.5, High Detection Probability at Chipps Island (0.9). Supplemental Release in SJR, OR (Primary release size=3 times each supplemental release size).

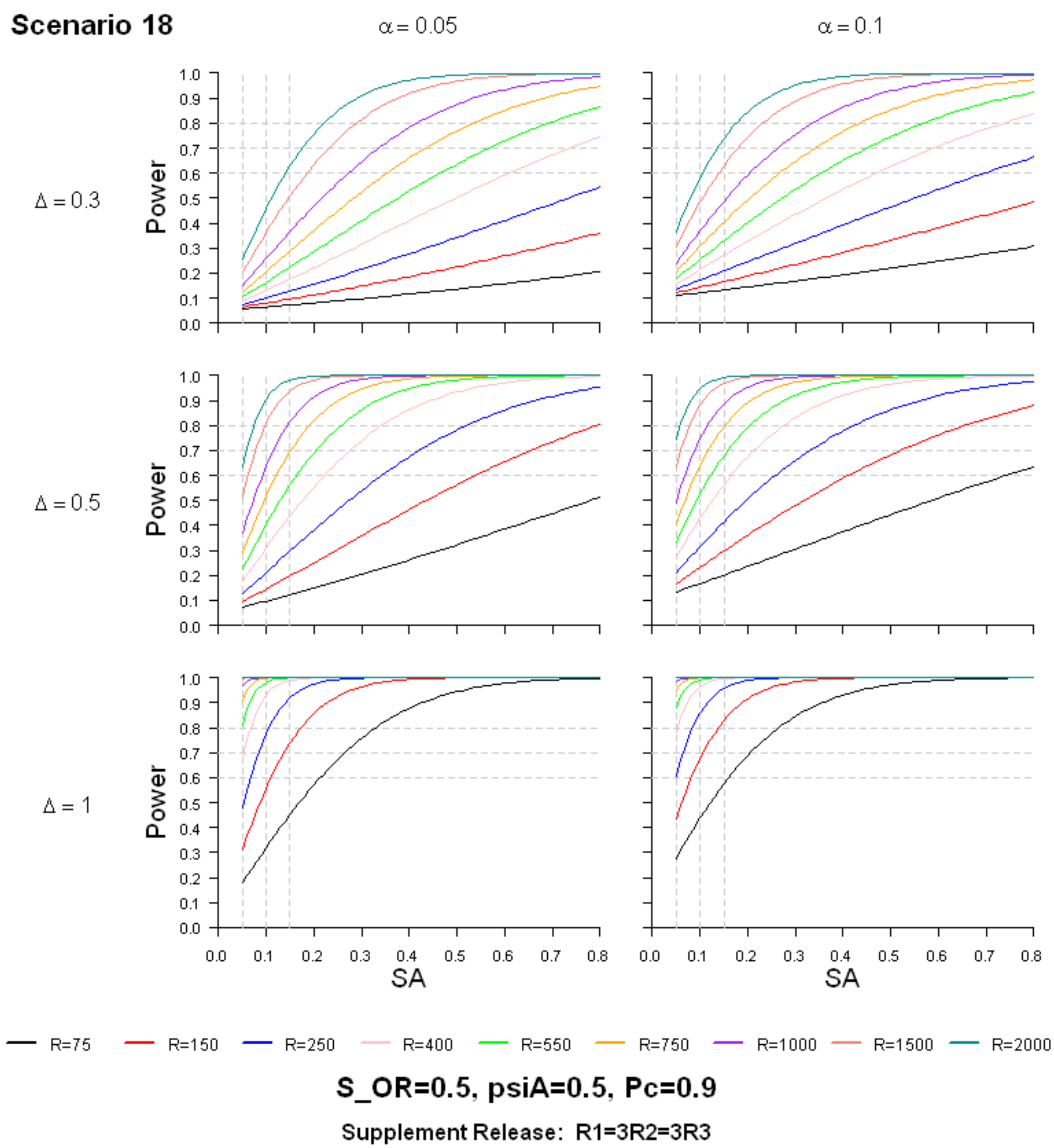


Figure A18. Power to detect relative difference of Delta between survival from the head of Old River to Chipps Island in the San Joaquin River route (SA) or in the Old River route, with a Type I error probability of alpha, and survival from Durham Ferry to the receivers just downstream of the head of Old River = 0.5, route entrainment probability into the San Joaquin River at head of Old River = 0.5, and detection probability at Chipps Island = 0.9. Detection probability at receivers in San Joaquin River and Old River just downstream of the head of Old River = 1. Primary release (R1) with supplemental releases in San Joaquin River (R2) and Old River (R3) just downstream of the Old River flow split, with R1=3R2=3R3 and R=R1+R2+R3.

Scenario 19: High Survival to Old River (0.9), Route Entrainment into San Joaquin River at Old River = 0.5, Low Detection Probability at Chipps Island (0.6). Supplemental Release in SJR, OR (Primary release size=3 times each supplemental release size).

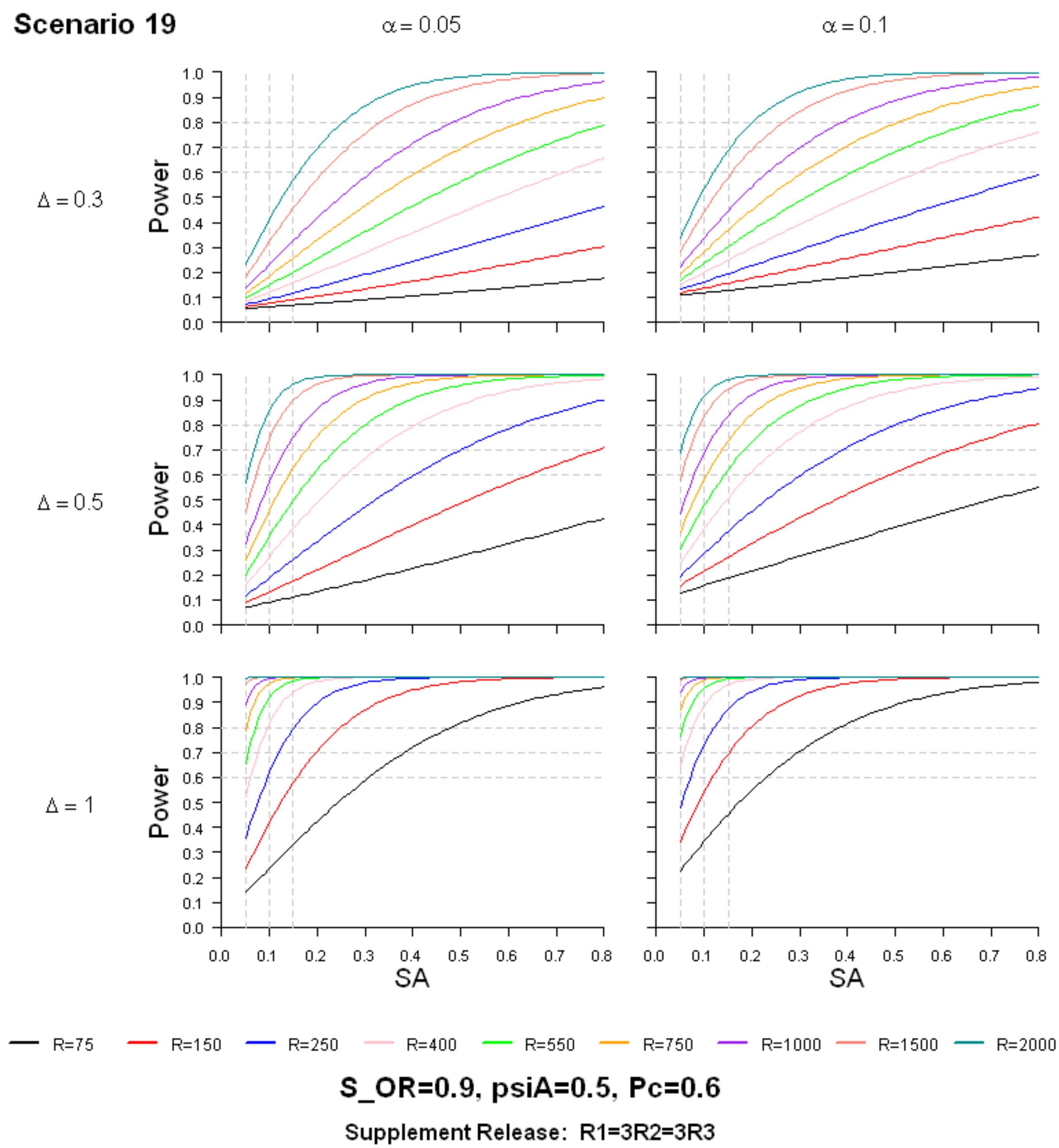


Figure A19. Power to detect relative difference of Delta between survival from the head of Old River to Chipps Island in the San Joaquin River route (SA) or in the Old River route, with a Type I error probability of alpha, and survival from Durham Ferry to the receivers just downstream of the head of Old River = 0.9, route entrainment probability into the San Joaquin River at head of Old River = 0.5, and detection probability at Chipps Island = 0.6. Detection probability at receivers in San Joaquin River and Old River just downstream of the head of Old River = 1. Primary release (R1) with supplemental releases in San Joaquin River (R2) and Old River (R3) just downstream of the Old River flow split, with R1=3R2=3R3 and R=R1+R2+R3.

Scenario 20: High Survival to Old River (0.9), Route Entrainment into San Joaquin River at Old River = 0.5, High Detection Probability at Chipps Island (0.9). Supplemental Release in SJR, OR (Primary release size=3 times each supplemental release size).

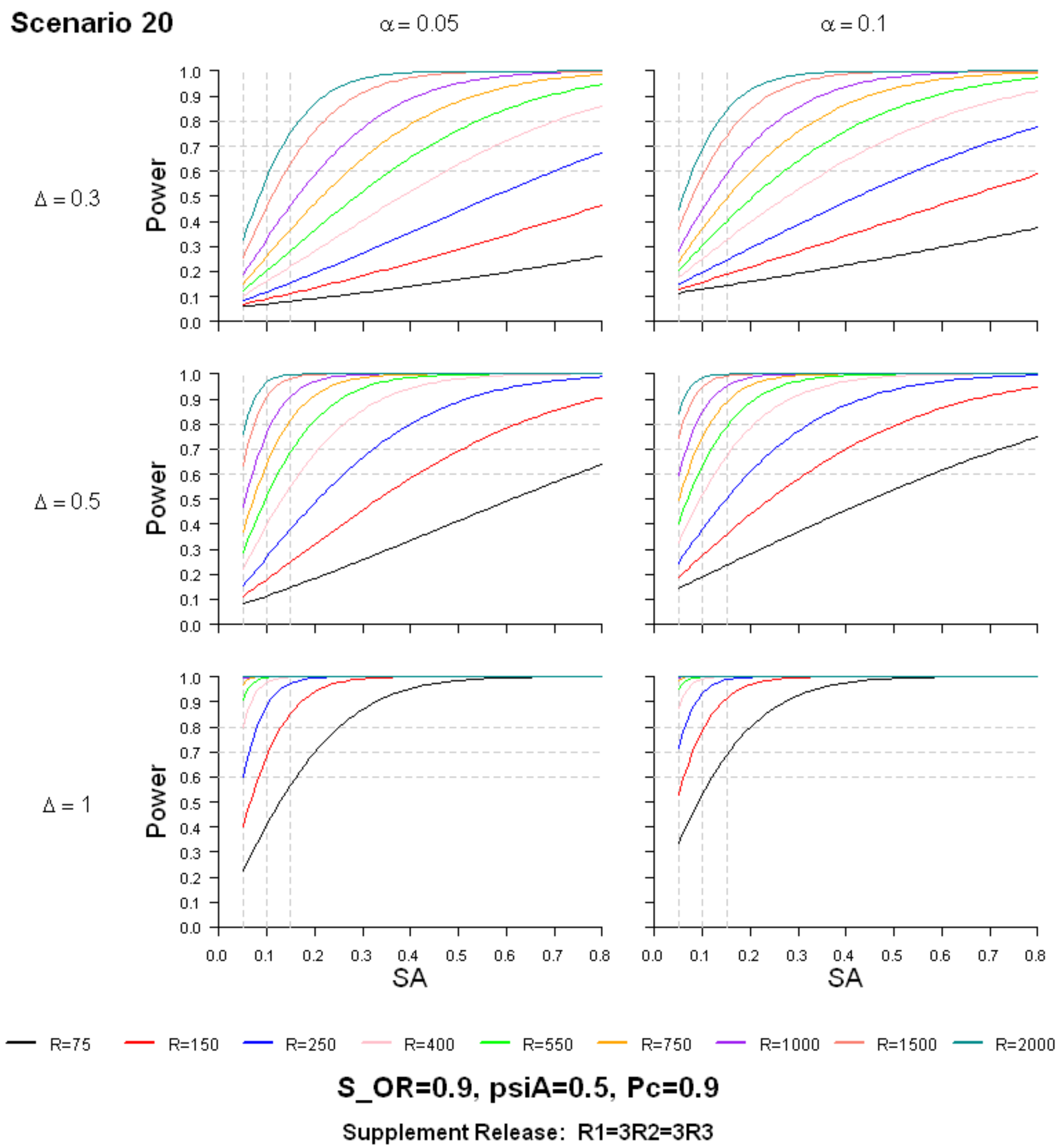


Figure A20. Power to detect relative difference of Delta between survival from the head of Old River to Chipps Island in the San Joaquin River route (SA) or in the Old River route, with a Type I error probability of alpha, and survival from Durham Ferry to the receivers just downstream of the head of Old River = 0.9, route entrainment probability into the San Joaquin River at head of Old River = 0.5, and detection probability at Chipps Island = 0.9. Detection probability at receivers in San Joaquin River and Old River just downstream of the head of Old River = 1. Primary release (R1) with supplemental releases in San Joaquin River (R2) and Old River (R3) just downstream of the Old River flow split, with R1=3R2=3R3 and R=R1+R2+R3.

Scenario 21: Low Survival to Old River (0.5), Route Entrainment into San Joaquin River at Old River = 0.3, Low Detection Probability at Chipps Island (0.6). Supplemental Release in SJR, OR (Primary release size=3 times each supplemental release size).

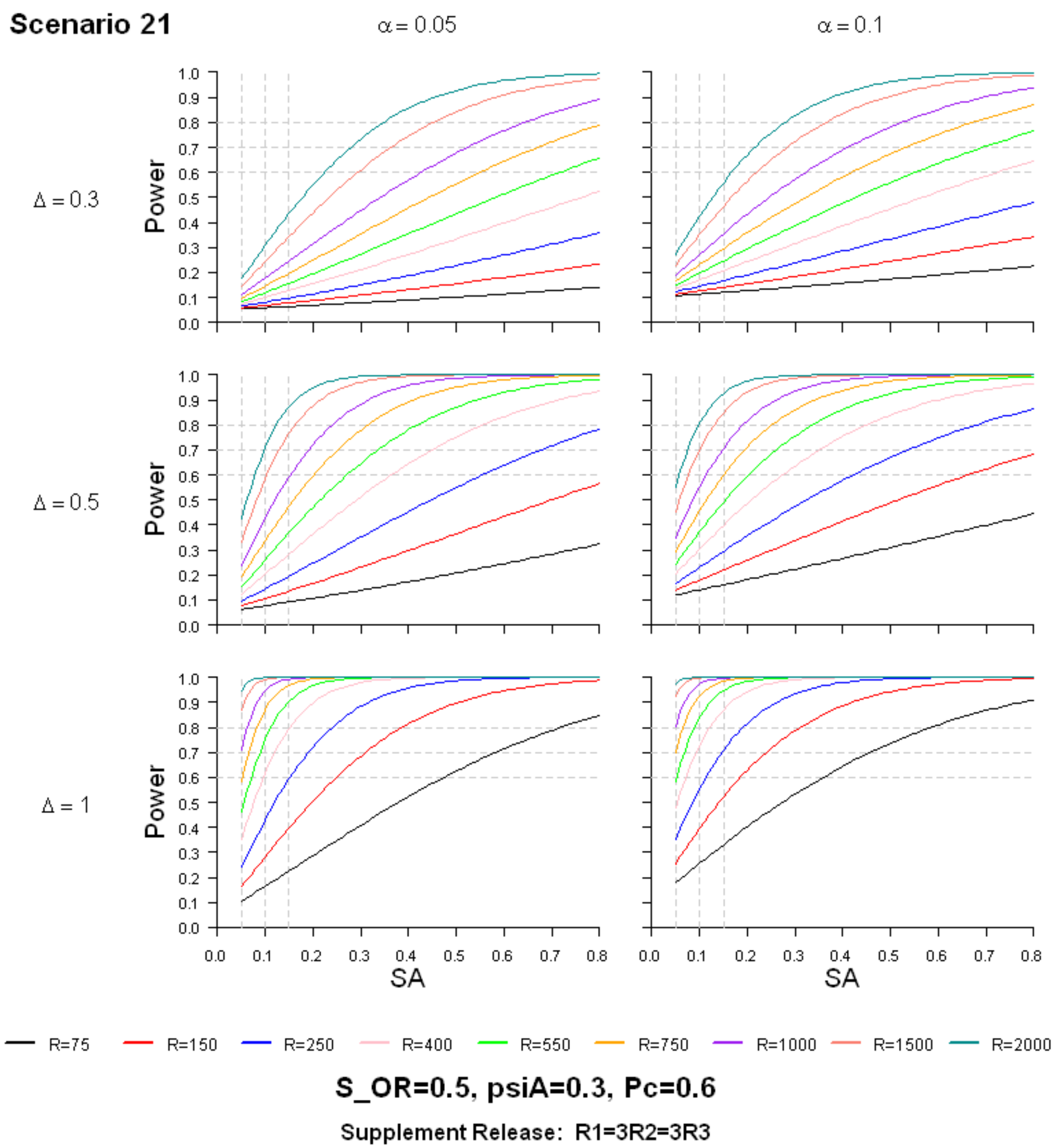


Figure A21. Power to detect relative difference of Delta between survival from the head of Old River to Chipps Island in the San Joaquin River route (SA) or in the Old River route, with a Type I error probability of alpha, and survival from Durham Ferry to the receivers just downstream of the head of Old River = 0.5, route entrainment probability into the San Joaquin River at head of Old River = 0.3, and detection probability at Chipps Island = 0.6. Detection probability at receivers in San Joaquin River and Old River just downstream of the head of Old River = 1. Primary release (R1) with supplemental releases in San Joaquin River (R2) and Old River (R3) just downstream of the Old River flow split, with R1=3R2=3R3 and R=R1+R2+R3.

Scenario 22: Low Survival to Old River (0.5), Route Entrainment into San Joaquin River at Old River = 0.3, High Detection Probability at Chipps Island (0.9). Supplemental Release in SJR, OR (Primary release size=3 times each supplemental release size).

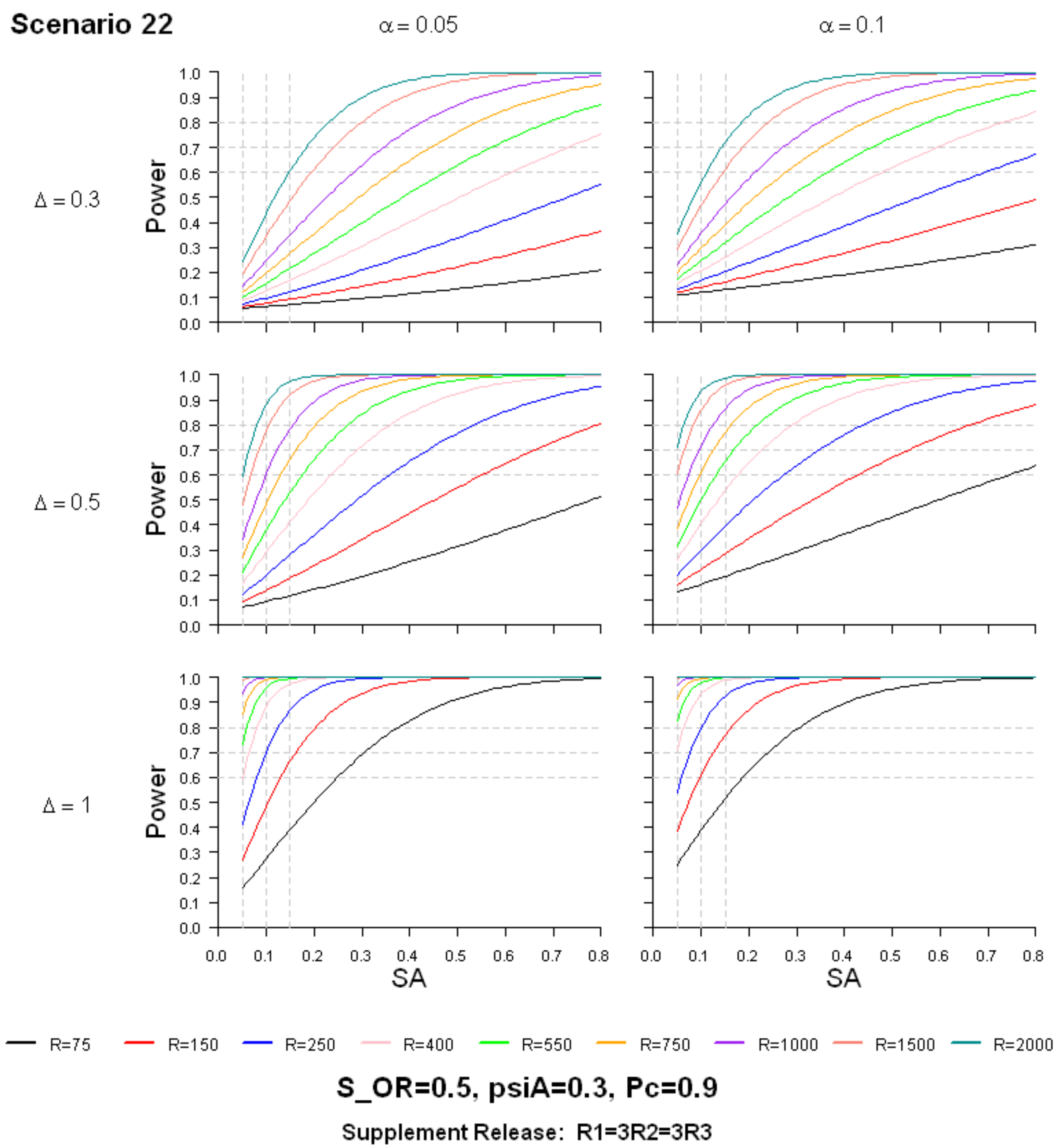


Figure A22. Power to detect relative difference of Delta between survival from the head of Old River to Chipps Island in the San Joaquin River route (SA) or in the Old River route, with a Type I error probability of alpha, and survival from Durham Ferry to the receivers just downstream of the head of Old River = 0.5, route entrainment probability into the San Joaquin River at head of Old River = 0.3, and detection probability at Chipps Island = 0.9. Detection probability at receivers in San Joaquin River and Old River just downstream of the head of Old River = 1. Primary release (R1) with supplemental releases in San Joaquin River (R2) and Old River (R3) just downstream of the Old River flow split, with R1=3R2=3R3 and R=R1+R2+R3.

Scenario 23: High Survival to Old River (0.9), Route Entrainment into San Joaquin River at Old River = 0.3, Low Detection Probability at Chipps Island (0.6). Supplemental Release in SJR, OR (Primary release size=3 times each supplemental release size).

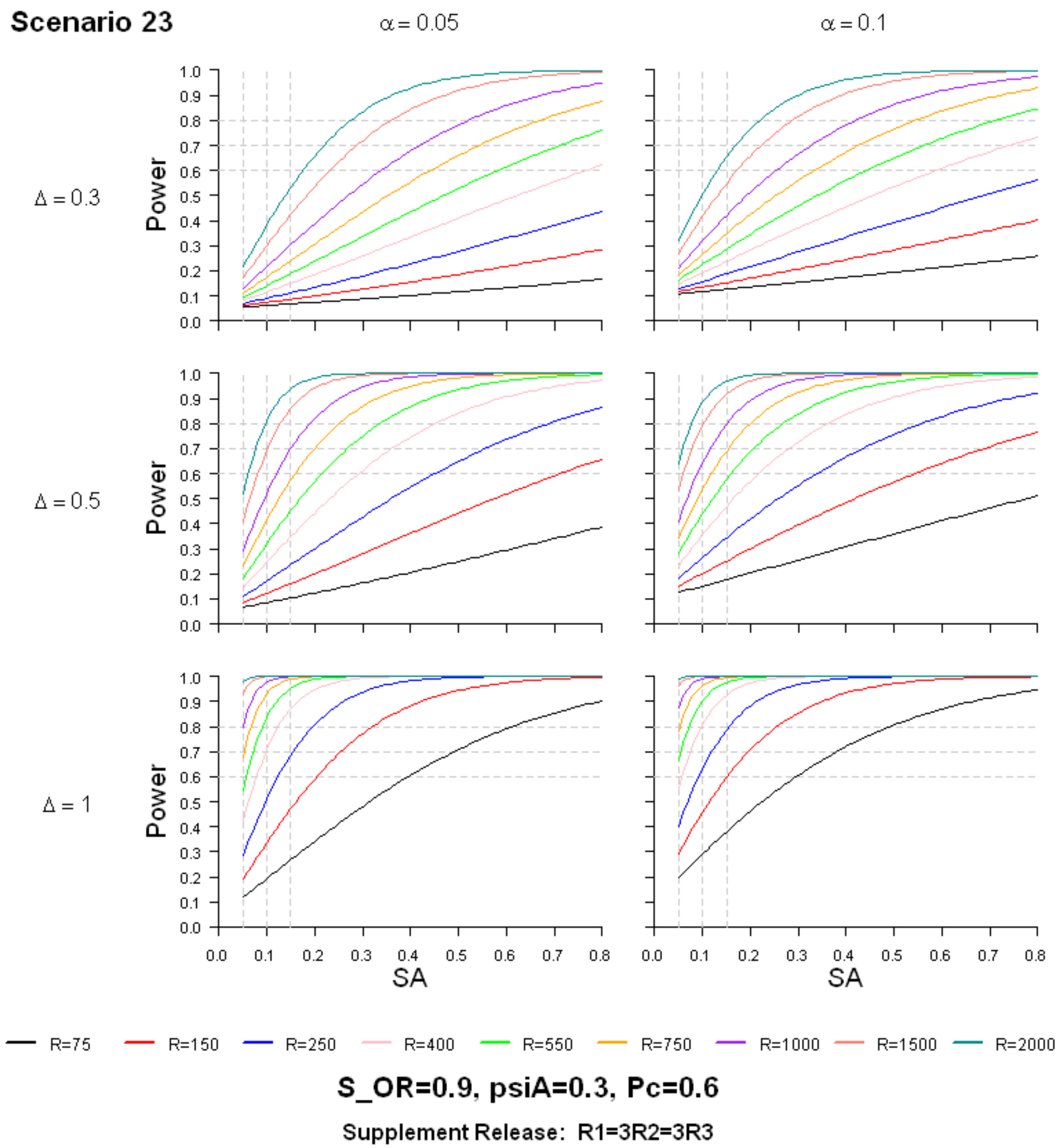


Figure A23. Power to detect relative difference of Delta between survival from the head of Old River to Chipps Island in the San Joaquin River route (SA) or in the Old River route, with a Type I error probability of alpha, and survival from Durham Ferry to the receivers just downstream of the head of Old River = 0.9, route entrainment probability into the San Joaquin River at head of Old River = 0.3, and detection probability at Chipps Island = 0.6. Detection probability at receivers in San Joaquin River and Old River just downstream of the head of Old River = 1. Primary release (R1) with supplemental releases in San Joaquin River (R2) and Old River (R3) just downstream of the Old River flow split, with R1=3R2=3R3 and R=R1+R2+R3.

Scenario 24: High Survival to Old River (0.9), Route Entrainment into San Joaquin River at Old River = 0.3, High Detection Probability at Chipps Island (0.9). Supplemental Release in SJR, OR (Primary release size=3 times each supplemental release size).

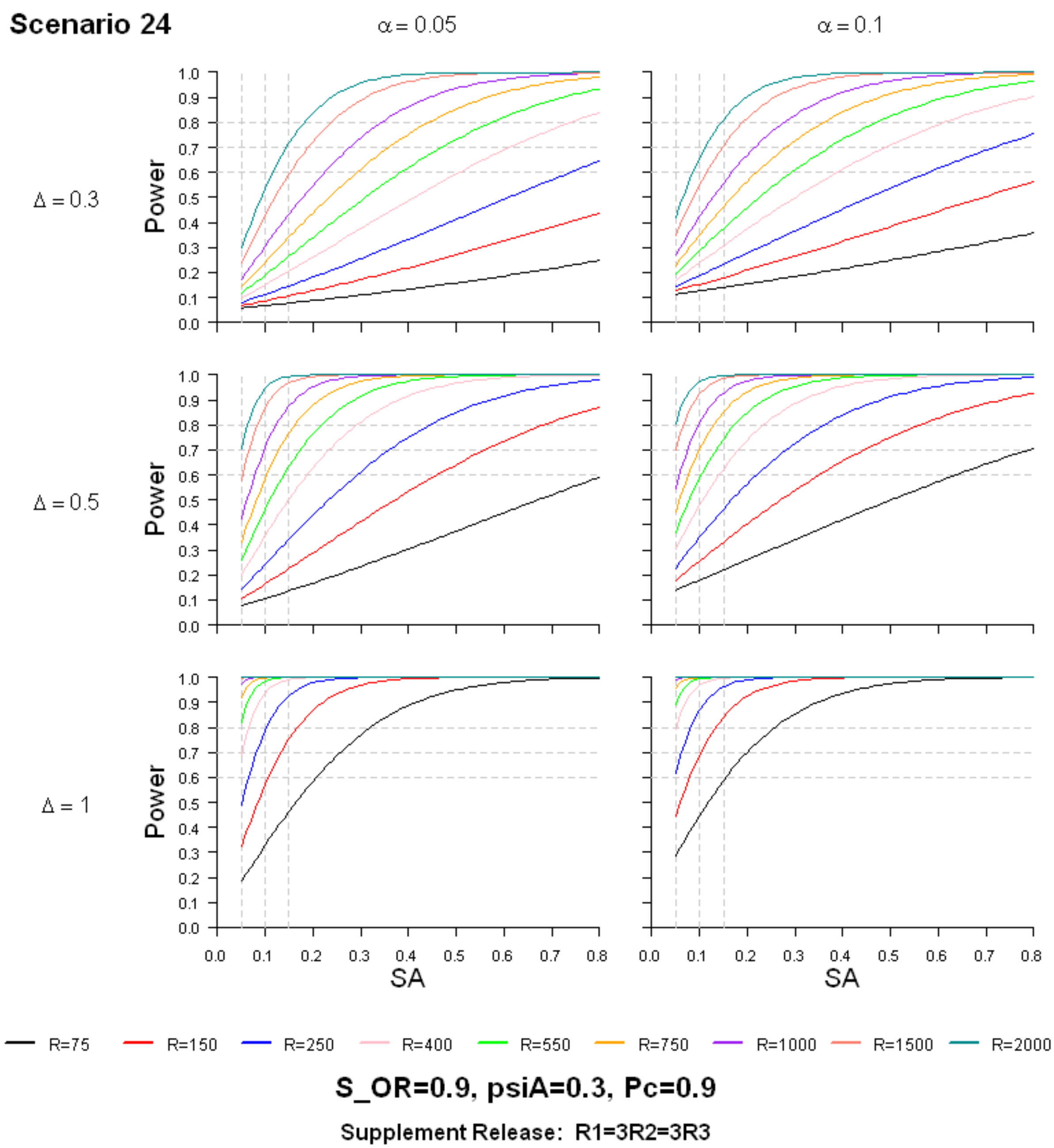


Figure A24. Power to detect relative difference of Delta between survival from the head of Old River to Chipps Island in the San Joaquin River route (SA) or in the Old River route, with a Type I error probability of alpha, and survival from Durham Ferry to the receivers just downstream of the head of Old River = 0.9, route entrainment probability into the San Joaquin River at head of Old River = 0.3, and detection probability at Chipps Island = 0.9. Detection probability at receivers in San Joaquin River and Old River just downstream of the head of Old River = 1. Primary release (R1) with supplemental releases in San Joaquin River (R2) and Old River (R3) just downstream of the Old River flow split, with R1=3R2=3R3 and R=R1+R2+R3.

APPENDIX F

ACOUSTIC TAGGING SOP – VAMP 2011

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.
- 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 "CX"
- Check that a reject bucket has been filled with water from the source tank and is available nearby.
- Check that a lethal bucket has been filled with water from the source tank and a lethal dose of MS-222, and ensure this lethal bucket 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. Move the tag and vial to the rinse water before implanting the tag.
- Prepare the flume by inserting the standpipe, and adjusting water sources to achieve the desired temperature based on temperature of the source tank and temperature at Durham Ferry. Direct the flow to circulate around the tank and use a cinder block between the standpipe and the incoming water to assist circulation. Cover the flume with lids to shade the buckets and to minimize heating of the water.

Surgery

- Anesthetize fish
    - o Net one fish from source tank and place directly into the anesthesia bucket. Place a lid on the bucket. Start your stopwatch immediately to track how long the fish is in the anesthesia bucket.
    - o Remove the lid at 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.
    - o 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
    - o Transfer the fish to the scale and weigh to the nearest 0.1g.
    - o Transfer the fish to the measuring board and determine forklength (FL) to the nearest mm.
    - o Check for any abnormalities and descaling.
    - o Data must be vocally relayed to the recorder and the recorder should repeat the information back to the tagger to avoid miscommunication.
    - o Any fish dropped on the floor must be rejected.
- Tag implantation
    - o Place the fish into the surgical tray ventral side up. Immediately start a stopwatch to track surgery time.
    - o 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.

- o Using a scalpel, make an incision approximately 5 mm in length beginning a few mm in front of the pelvic girdle. The incision should be 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.

- o 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.

- o One scalpel blade can be used on about 5 fish. If the scalpel is pulling rough or making jagged incisions, the blade needs to be changed prior to tagging the next fish.

- o 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.

- o Suture the incision with two to three interrupted stitches.

- o Transfer the fish from the surgical table to the appropriate recovery bucket.

- o 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.

- o Confirm the tube ID with the recorder and place the empty vial into the lid of the tray which holds the tags.

- o Between surgeries the tagger should move the tools 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 to the first tag periods on the datasheet and confirm the signals. Record the time of confirmation on the datasheet.

- Once all tags in a bucket have been heard, remove the hydrophone, securely fasten the lid, and transfer the bucket to the flume.

- If a tag is not heard, isolate the individual carrying the non-functioning tag, euthanize the fish, and retrieve the tag. Indicate on data sheet that tag was not heard and that fish was removed. Note on the bucket lid using a grease pencil the number of fish remaining in the bucket. Place the tag back into the vial from which it came.

- Return the datasheet to the tagging crew.

Holding Between Tagging and Transport

- After tags are validated, transfer buckets to the flume. After placing a bucket in the flume cover the tank with a trash can lid to provide shade.

- Check temperature in the flume periodically during each tagging session and adjust as needed to maintain desired water temperature.

Loading

- Begin fish loading/ transport/ release data sheets.

- Fill hauling tank. Do not use water from the chiller – it will not be able to keep up. Allow water to sit in the tank for at least 15 minutes before purging.

- Re-fill tank with water at the same temperature, or 1-2 degrees cooler than the source tank depending on temperature at Durham Ferry. Add non-chlorinated ice if needed to reach/maintain desired temperatures.

- Turn on oxygen.

- 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 must be returned to the tagging area. The tag must be removed and identified by the validation crew. The tag will then 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 on 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 in the tagging area.

- Record water temperature and DO in each tank and record the departure time.

- Secure the tank.
- Send datasheets with transport crew.

Cleanup

- Return tag tray with empty vials and datasheets to coordinator at the 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 must 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.

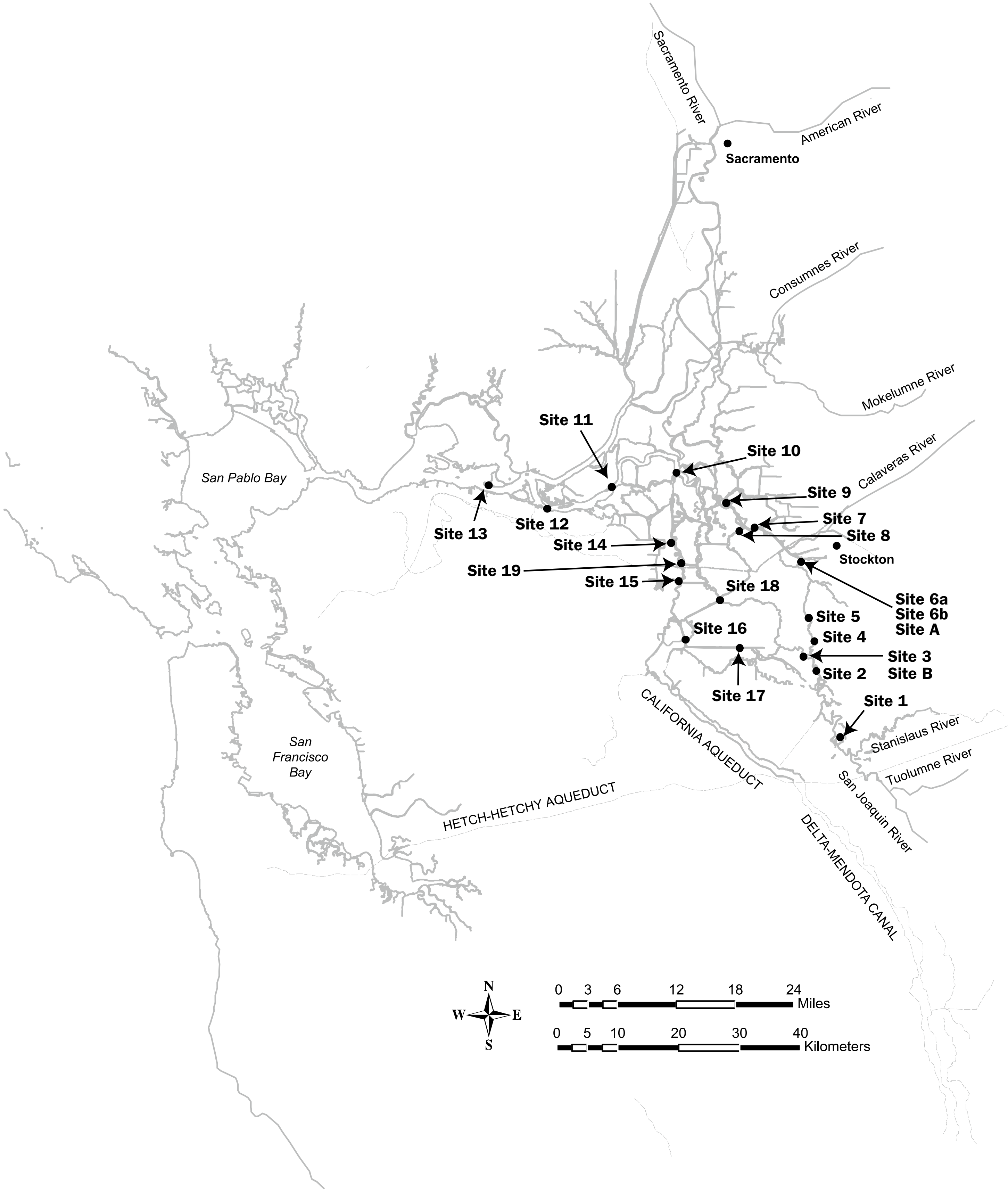
APPENDIX G

Appendix G, Table 1
Site Descriptions for Water Temperature Monitoring Locations in the San Joaquin River and Delta as Part of the 2011 Vernalis Adaptive Management Program (VAMP)

Site #	Logger Number	Temperature Monitoring Location	Latitude	Longitude	Date Deployed	Date Retrieved	Notes
A*	1292417	Merced River Fish Hatchery with acoustic tagged fish			2/18/2011	6/3/11	
B**	1259811	Merced River Fish Hatchery with control group fish			2/18/2011	6/3/11	
1	1284089	Durham Ferry	N 37 41.263	W 121 15.609	5/1/2011	6/30/2011	dewatered at times
2	1293985	Mossdale Landing	N 37 47.142	W 121 18.383	5/1/2011	6/30/2011	
3	1293994	Old River at HORB	N 37 48.633	W 121 19.232	5/1/2011	6/30/2011	dewatered at times
4	1293969	Dos Reis	N 37 49.956	W 121 18.791	5/1/2011	6/30/2011	dewatered at times
5	1284092	DWR Monitoring Station	N 37 51.874	W 121 19.388	5/1/2011	6/30/2011	at water surface
6a	1284085	Confluence – Top	N 37 56.817	W 121 20.293	5/1/2011	Not Retrieved	
6b	1293989	Confluence- Bottom	N 37 56.817	W 121 20.293	5/1/2011	Not Retrieved	
7	1259796	Upstream of Channel Marker 33	N 37 59.682	W 121 24.699	5/1/2011	6/30/2011	
8	1027498	Turner Cut - Channel Marker 21-22	N 38 00.339	W121 27.095	5/1/2011	6/30/2011	
9	1271941	"Q" Piling 1/2 mile upstream of Channel Marker 13	N 38 01.949	W 121 28.770	5/1/2011	Not Retrieved	
10	1293984	All Pro Abandoned Boat	N 38 04.497	W 121 34.399	5/1/2011	6/30/2011	
11	1271943	Jersey Point USGS Gauging Station	N 38 03.177	W121 41.623	5/1/2011	Not Retrieved	
12	1271938	Antioch Marina	N 38 01.370	W121 48.689	5/1/2011	6/30/11	
13	1259803	Chipps Island	N 38 03.011	W 121 55.038	5/1/2011	6/30/11	
14	1284084	Holland Riverside Marina	N 37 58.324	W 121 34.900	5/1/2011	Not Retrieved	
15	2400407	Old River / Indian Slough Confluence	N 37 54.985	W 121 34.038	5/1/2011	6/30/2011	
16	1292418	CCF Radial Gates	N 37 49.898	W 121 33.238	5/1/2011	6/30/2011	
17	1293975	Grant Line Canal at Tracy Blvd Bridge	N 37 49.194	W 121 26.988	5/1/2011	6/30/2011	
18	1027495	Union Pt.	N37 53.427	W121 29.359	5/1/2011	6/30/2011	
19	1284069	Werner Cut: Channel above Woodward Isle	N 37 56.381	W 121 32.467	5/1/2011	6/30/2011	

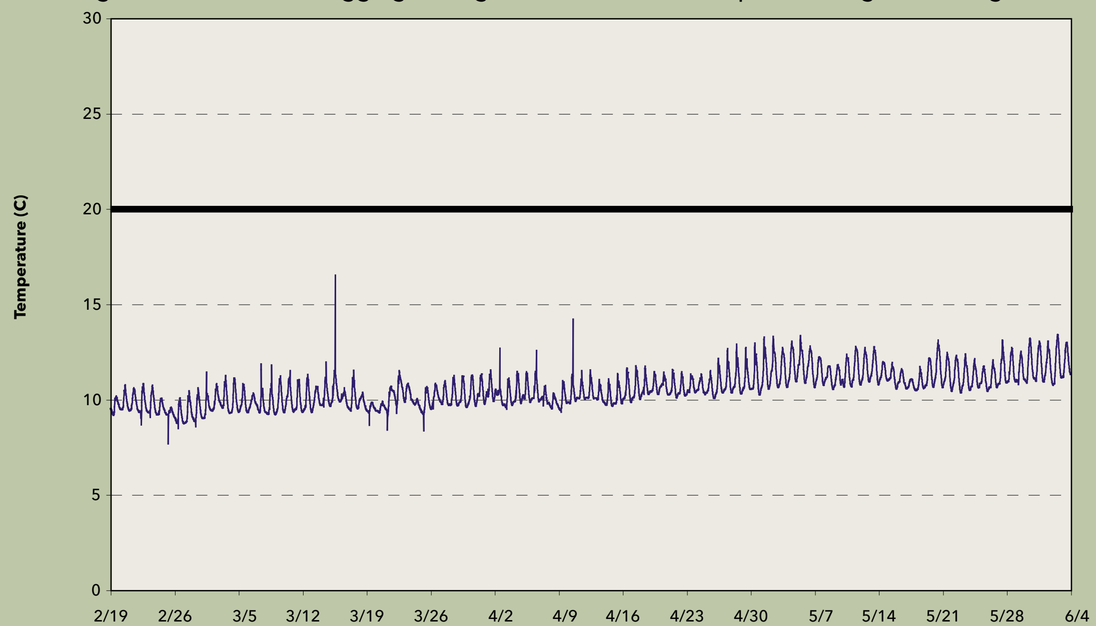
*Logger A was placed with acoustic tagged fish in the hatchery building
**Logger B was placed with control group fish in the outside hatchery nursery tanks

Appendix G, Figure 1
Overview of Water Temperature Monitoring Locations in the Lower San Joaquin River and Delta as Part of the 2011 Vernalis Adaptive Management Program (VAMP)



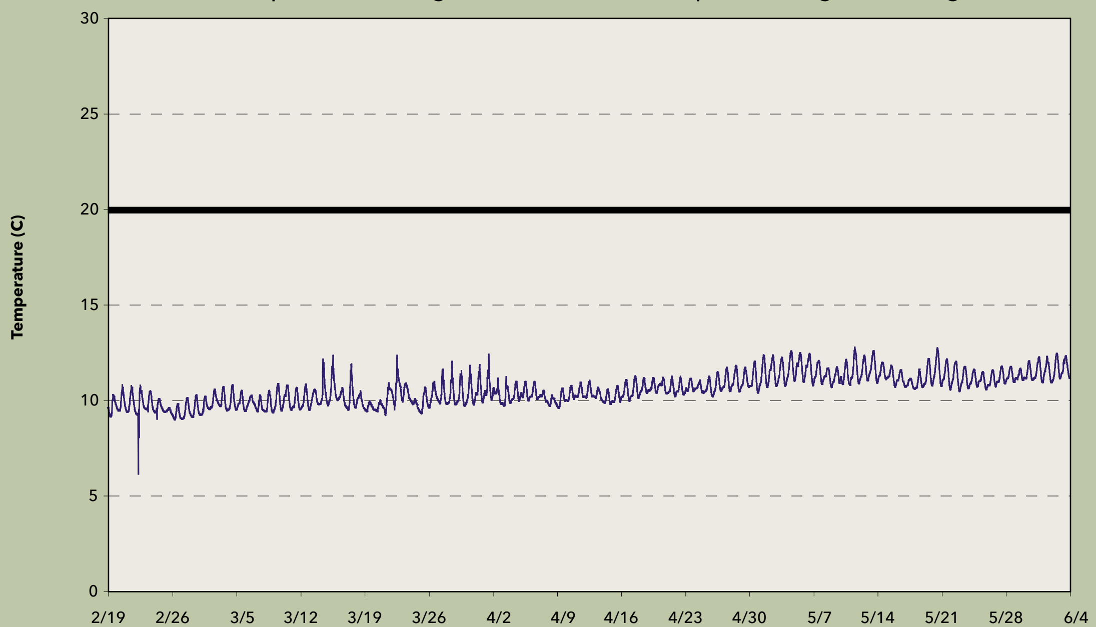
Appendix G, Figure 2

Daily Water Temperature Fluctuations (°C) at the CDFG Merced River Fish Hatchery with the Fish Designated for Acoustic Tagging During the 2011 Vernalis Adaptive Management Program (VAMP)



Appendix G, Figure 3

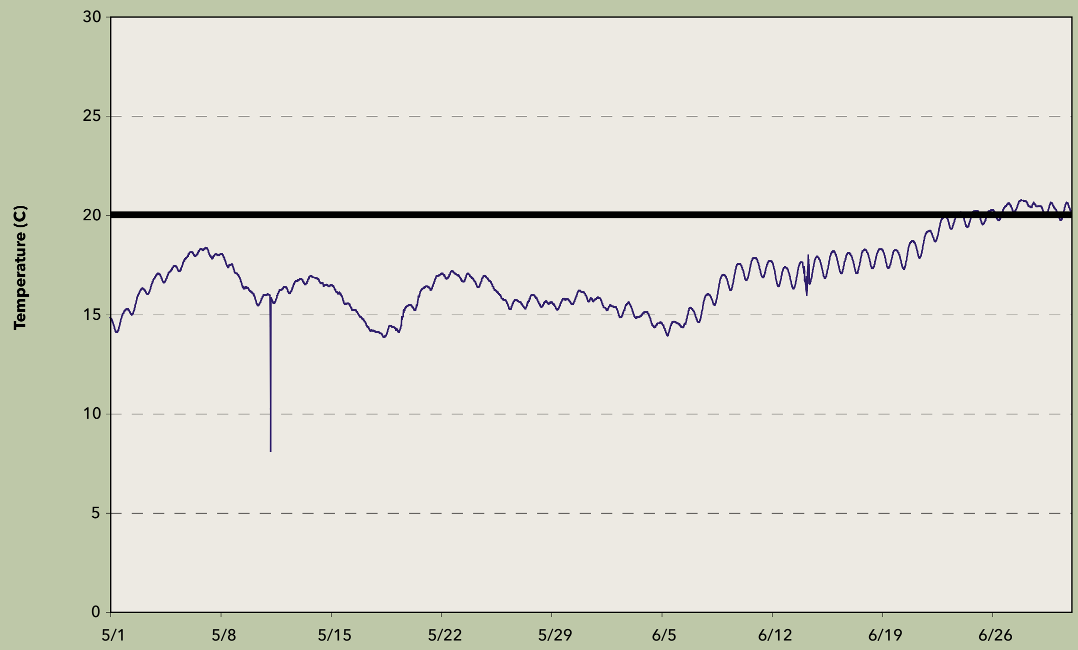
Daily Water Temperature Fluctuations (°C) at the CDFG Merced River Fish Hatchery with the Control Group of Fish During the 2011 Vernalis Adaptive Management Program (VAMP)



Appendix G, Figure 4

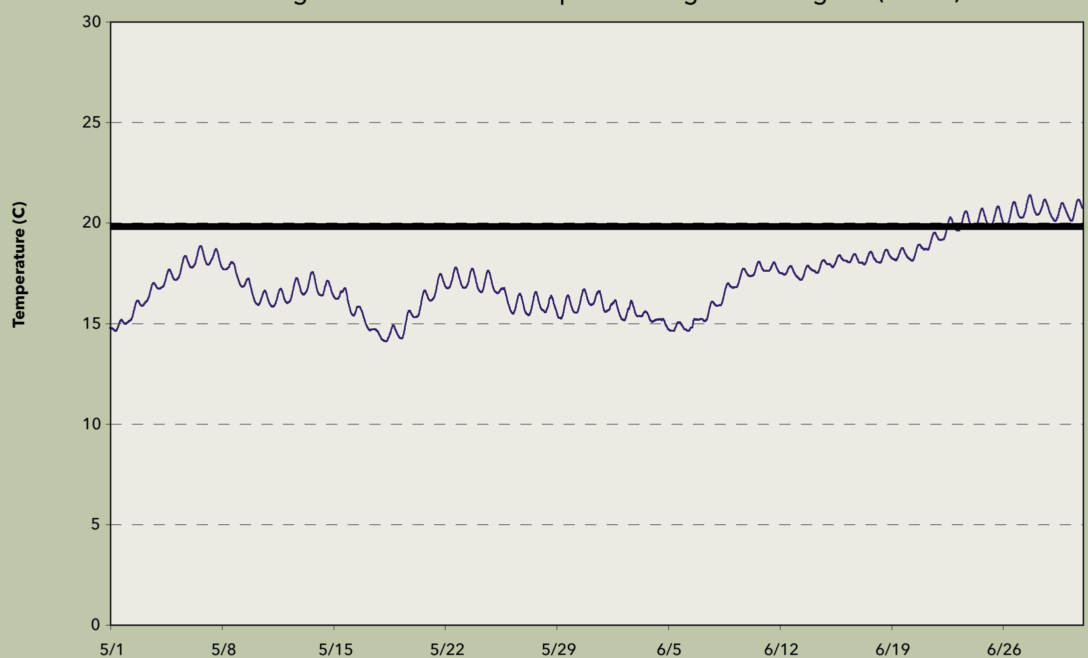
Daily Water Temperature Fluctuations (°C) in the San Joaquin River at Durham Ferry
During the 2011 Vernalis Adaptive Management Program (VAMP)

(Recorder may have been dewatered briefly during a one-hour period on 5/11/2012; also logger was dewatered at the time of retrieval due to lower flow)

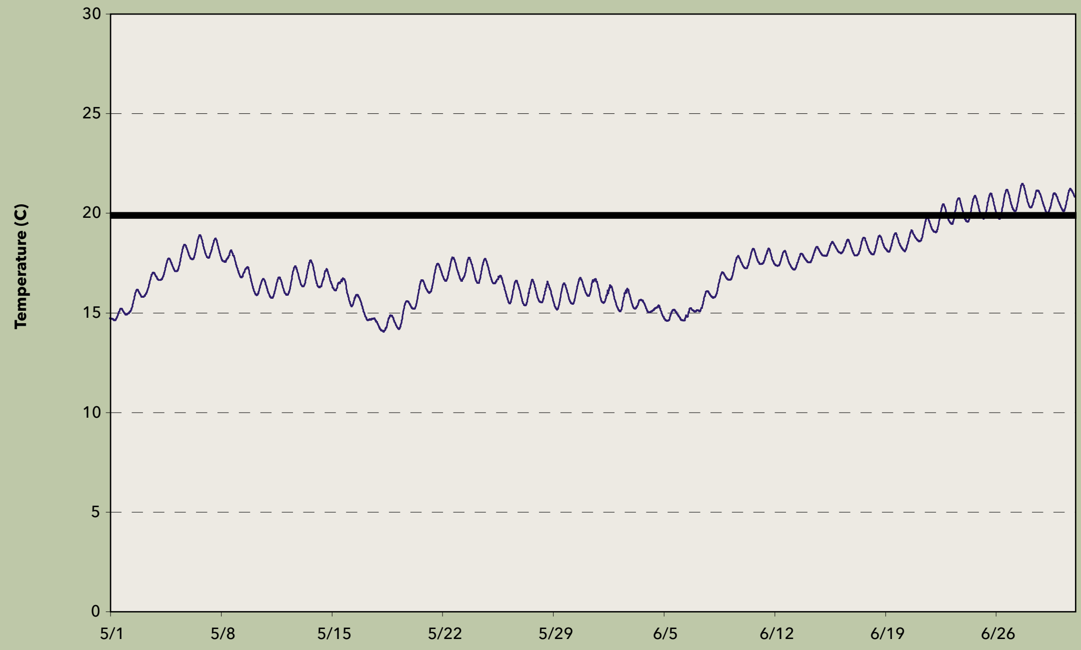


Appendix G, Figure 5

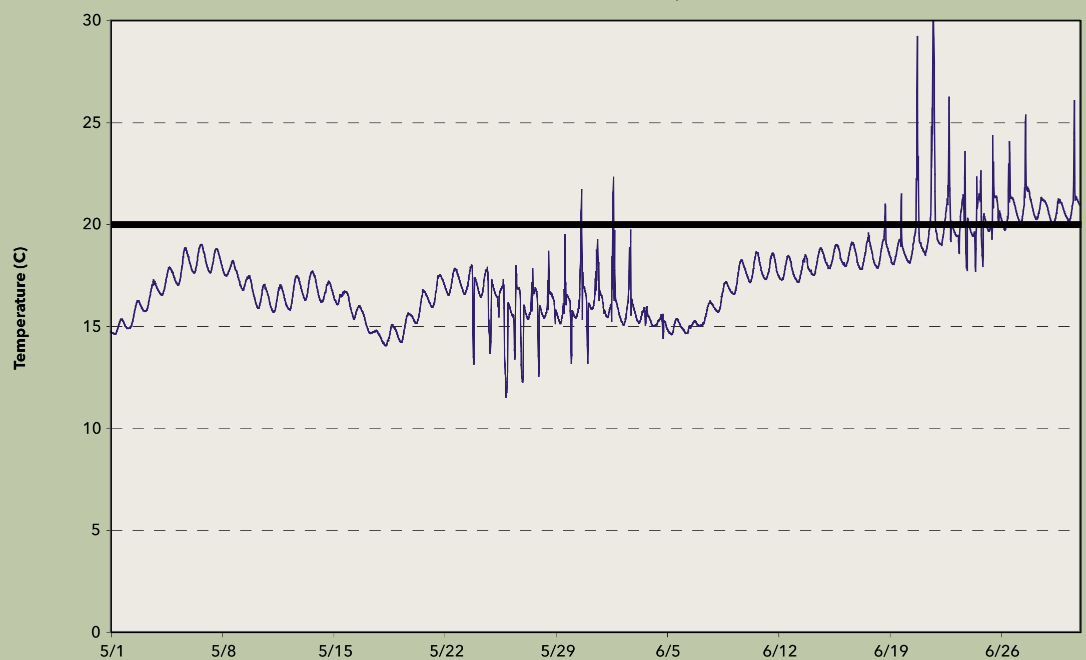
Daily Water Temperature Fluctuations (°C) in the San Joaquin River at Mossdale Bridge
During the 2011 Vernalis Adaptive Management Program (VAMP)



Appendix G, Figure 6
Daily Water Temperature Fluctuations (°C) in Old River at the Head of Old River Barrier During the 2011 Vernalis Adaptive Management Program (VAMP)
(Recorder was dewatered at the time of retrieval)



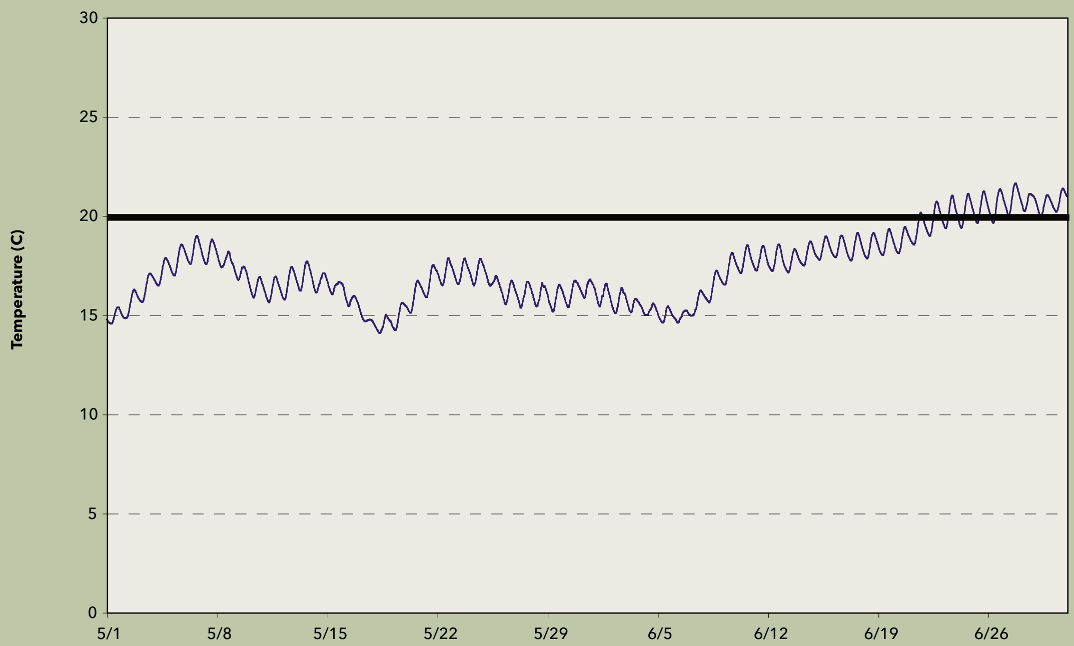
Appendix G, Figure 7
Daily Water Temperature Fluctuations (°C) in the San Joaquin River at Dos Reis County Park During the 2011 Vernalis Adaptive Management Program (VAMP)
(Recorder was dewatered at the time of retrieval and data shows it may have been dewatered on numerous occasions)



Appendix G, Figure 8

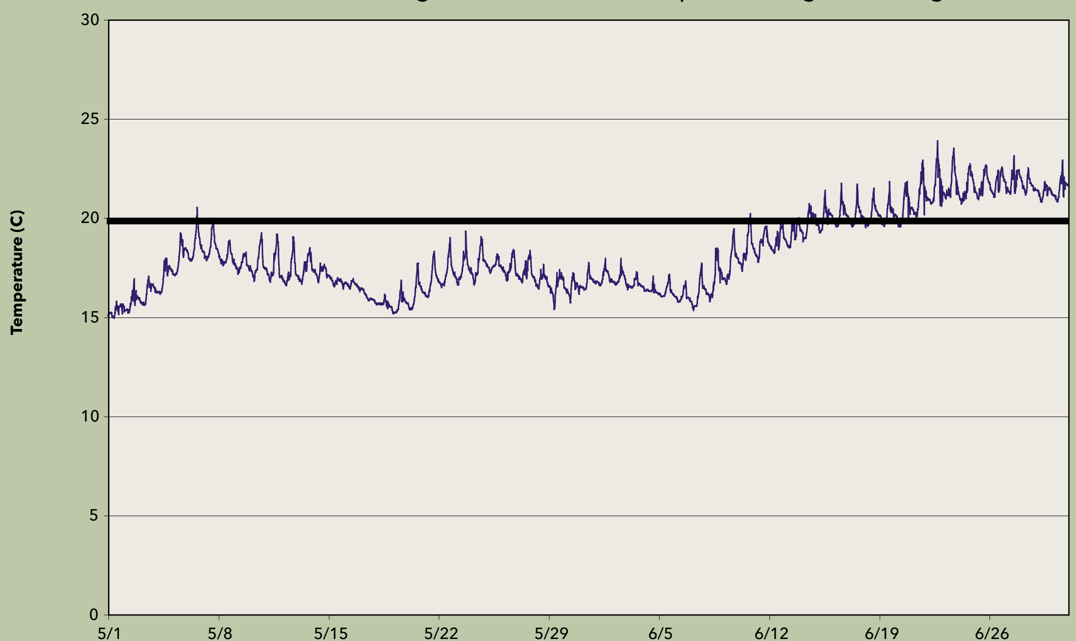
Daily Water Temperature Fluctuations (°C) in the San Joaquin River at the DWR Flow Monitoring Station Near Lathrop During the 2011 Vernalis Adaptive Management Program (VAMP)

(Recorder was found at the water surface on the day of retrieval)

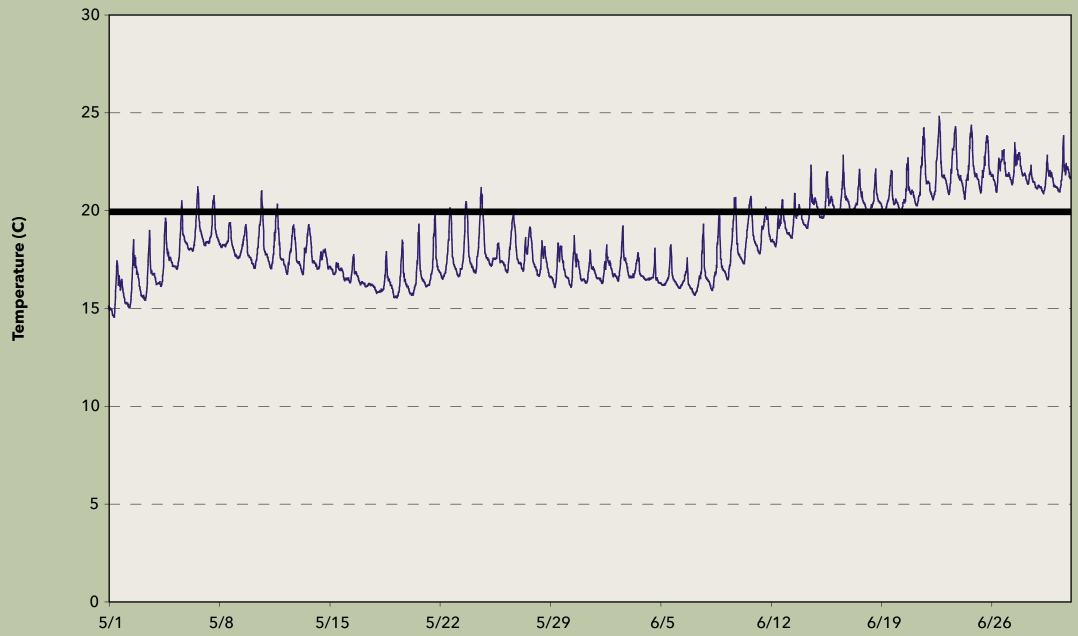


Appendix G, Figure 9

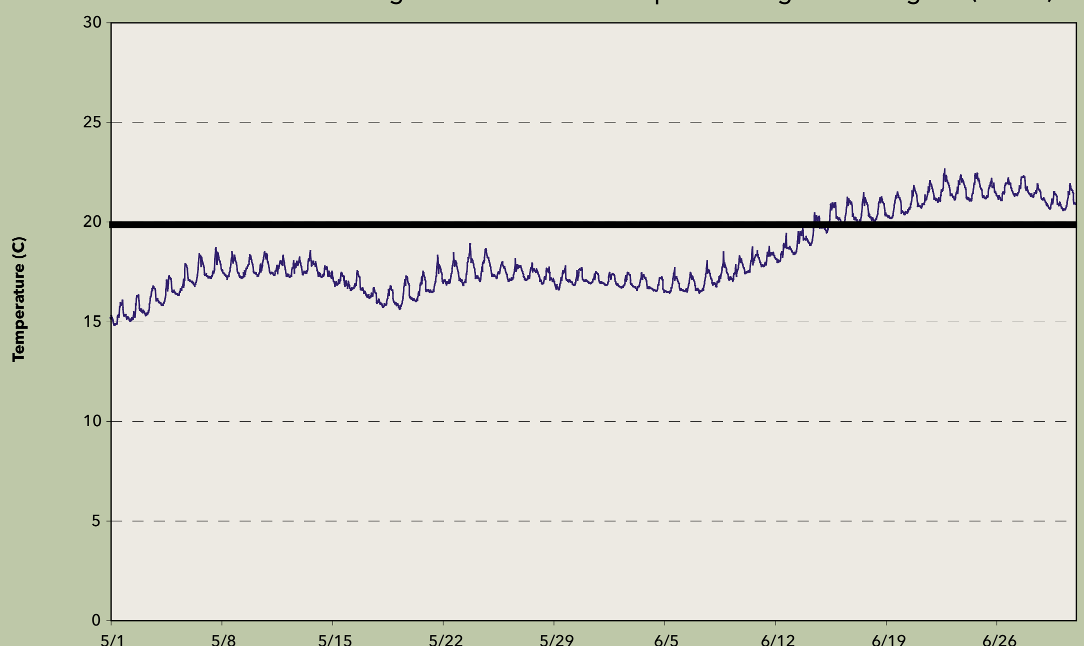
Daily Water Temperature Fluctuations (°C) in the San Joaquin River Upstream of Channel Marker No 33 During the 2011 Vernalis Adaptive Management Program (VAMP)



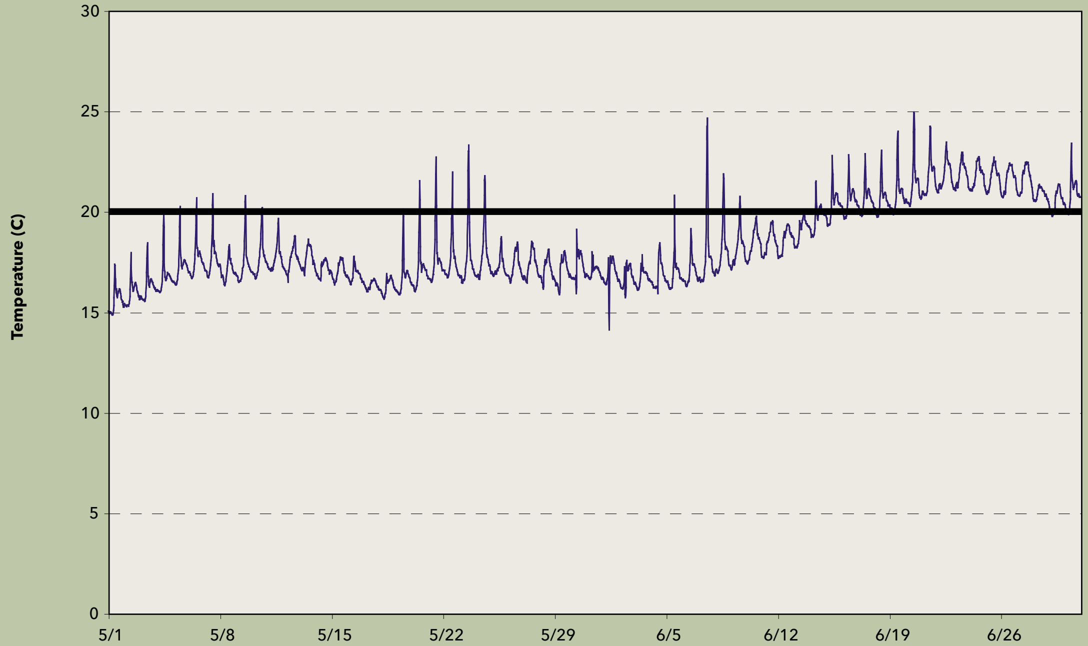
Appendix G, Figure 10
Daily Water Temperature Fluctuations (°C) in the San Joaquin River at Turner Cut (Channel Marker 21-22)
During the 2011 Vernalis Adaptive Management Program (VAMP)



Appendix G, Figure 11
Daily Water Temperature Fluctuations (°C) in the San Joaquin River at the All Pro
Abandoned Boat During the 2011 Vernalis Adaptive Management Program (VAMP)

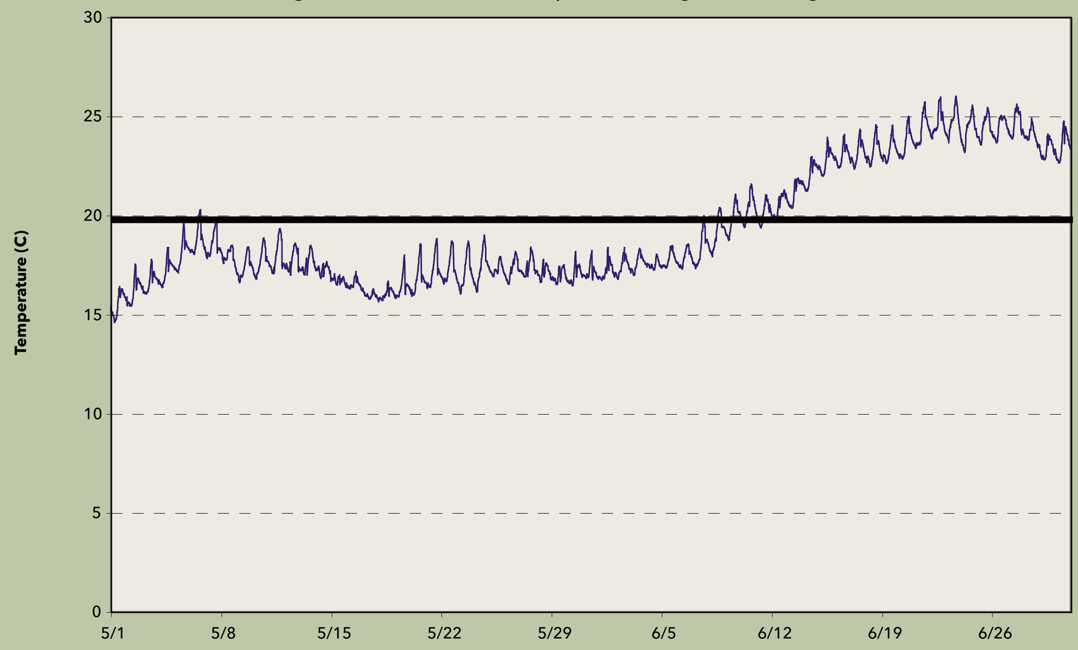


Appendix G, Figure 12
Daily Water Temperature Fluctuations (°C) in the San Joaquin River Near the Antioch Marina During the 2011 Vernalis Adaptive Management Program (VAMP)

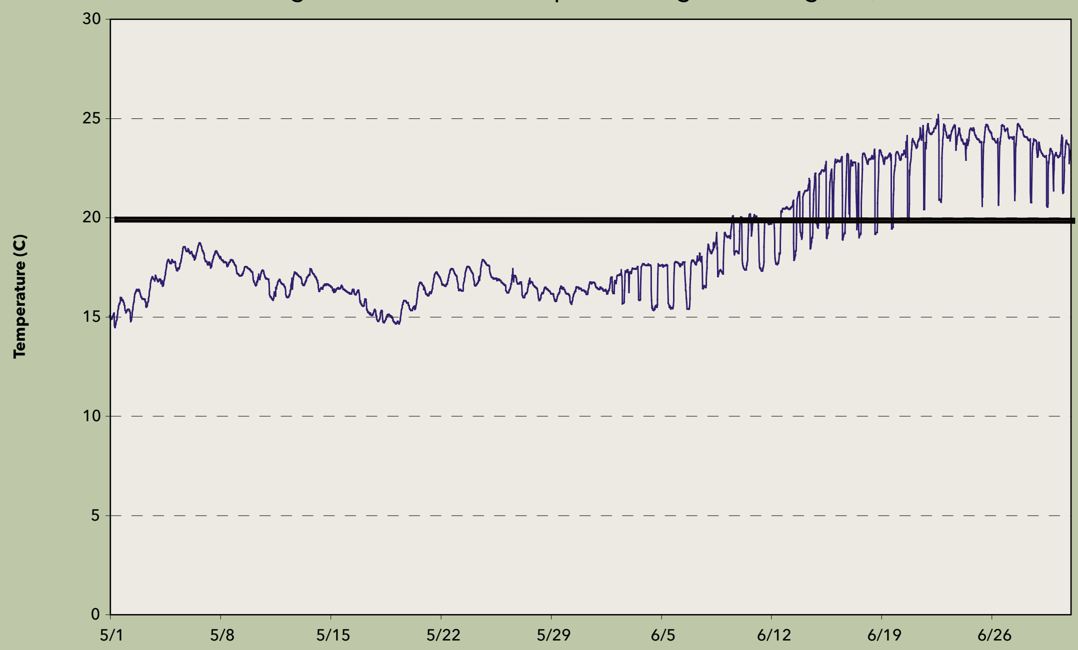


Appendix G, Figure 13
Daily Water Temperature Fluctuations (°C) in the South Delta Near Chipps Island During the 2011 Vernalis Adaptive Management Program (VAMP)

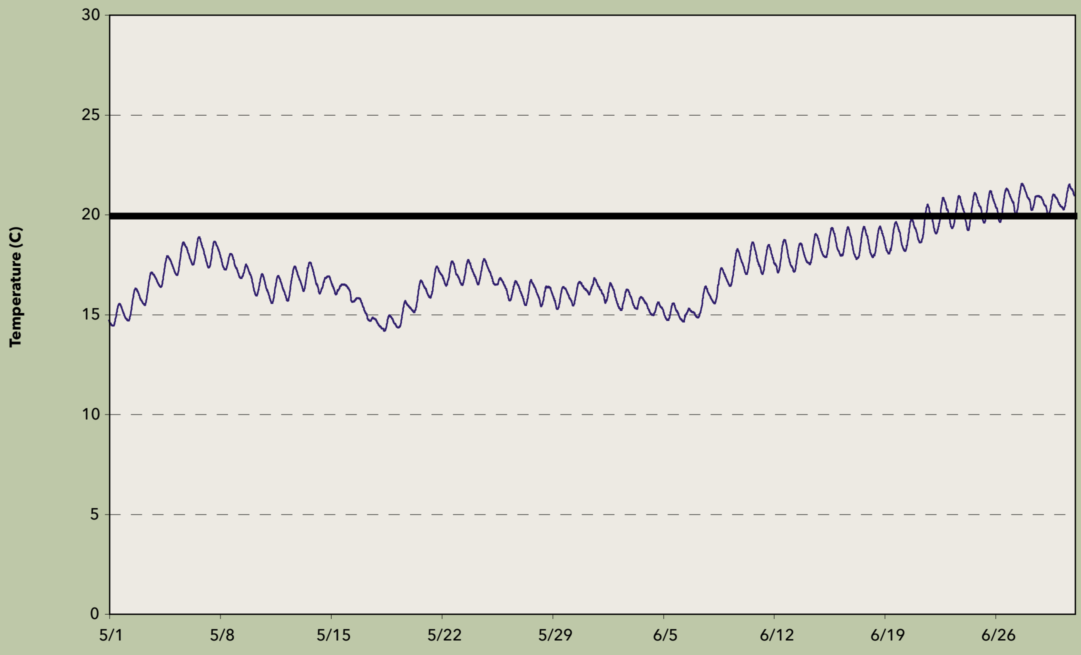
Appendix G, Figure 14
Daily Water Temperature Fluctuations (°C) in the South Delta Near the Old River/Indian Slough Confluence
During the 2011 Vernalis Adaptive Management Program (VAMP)



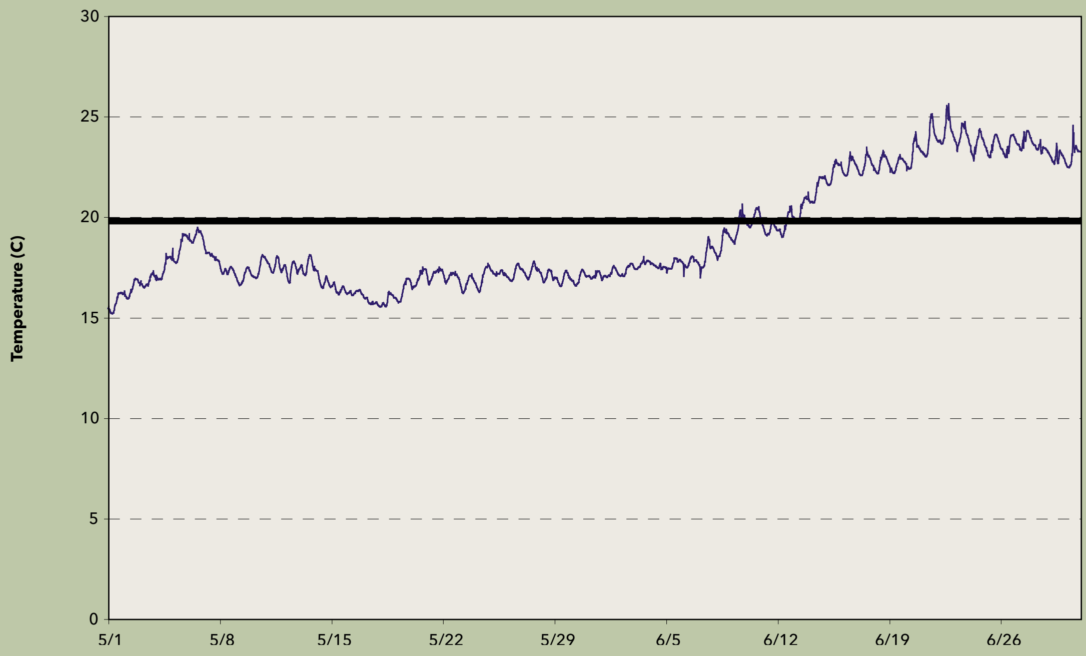
Appendix G, Figure 15
Daily Water Temperature Fluctuations (°C) in the South Delta Near the CCF Radial Gates
During the 2011 Vernalis Adaptive Management Program (VAMP)



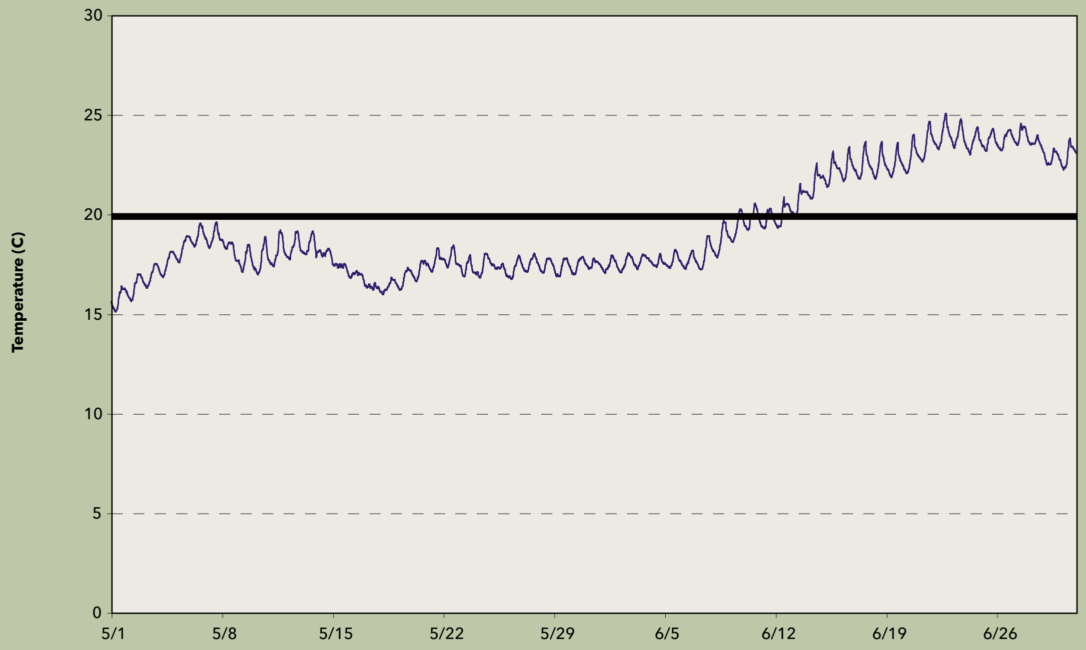
Appendix G, Figure 16
Daily Water Temperature Fluctuations (°C) in the South Delta in the Grant Line Canal at Tracy Blvd Bridge During the 2011 Vernalis Adaptive Management Program (VAMP)



Appendix G, Figure 17
Daily Water Temperature Fluctuations (°C) in the South Delta Near Union Point During the 2011 Vernalis Adaptive Management Program (VAMP)



Appendix G, Figure 18
Daily Water Temperature Fluctuations (°C) in Werner Cut at the Channel Above Woodward Isle During the 2011 Vernalis Adaptive Management Program (VAMP)



APPENDIX H

Appendix H, Table 1
Acronyms and Abbreviations Used in Appendix "H"

Acronym or Abbreviation	Definition
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
DFD	San Joaquin River Downstream of Durham Ferry
FRE	False River East Receiver
FRW	False River West Receiver
JPTE or JPE	Jersey Point East Receiver
JPTW or JPW	Jersey Point West Receiver
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
ORE	Old River East
ORED	Old River Downstream
OREU	Old River East Upstream
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
PCO	Paradise Cut
RGD	Radial Gates at Clifton Court Forebay, Interior (2 Receivers)
RGD1	Radial Gates at Clifton Court Forebay, Interior Receiver 1
RGD2	Radial Gates at Clifton Court Forebay, Interior Receiver 2
RGU	Radial Gates at Clifton Court Forebay, Entrance Channel
RGU1	Radial Gates at Clifton Court Forebay, Entrance Channel, Receiver 1
RGU2	Radial Gates at Clifton Court Forebay, Entrance Channel, Receiver 2
SJ1/SJ2	San Joaquin River at Lathrop (2 Receivers)
SJL	San Joaquin River at Lathrop
SJLD	San Joaquin River at Lathrop Downstream Receiver
SJLU	San Joaquin River at Lathrop Upstream Receiver
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)
TMN/TMS	Threemile Slough (2 Receivers)

Appendix H, Table 2
Definitions of Parameters Used in the Release-Recapture Survival Model Shown in Chapter 5

Parameter	Definition
S_{A2}	Probability of survival from Durham Ferry Downstream (DFD) to Banta Carbona (BCA)
S_{A3}	Probability of survival from Banta Carbona (BCA) to Paradise Cut (PCO)
S_{A4}	Probability of survival from Paradise Cut to Mossdale (MOS)
S_{A5}	Probability of survival from Mossdale (MOS) to Lathrop (SJL) or Old River East (ORE)
S_{A6}	Probability of survival from Lathrop (SJL) to Stockton USGS Gauge (STS)
S_{A7}	Probability of survival from Stockton USGS Gauge (STS) to Stockton Navy Drive Bridge (STN)
S_{A8}	Probability of survival from Stockton Navy Drive Bridge (STN) to Shipping Channel Markers (C18/C16) or Turner Cut (TCN/TCS)
S_{B1}	Probability of survival from Old River East (ORE) to Old River South (ORS)
ψ_{A1}	Probability of remaining in the San Joaquin River at the junction with Paradise Cut; assumed = 1
ψ_{A2}	Probability of remaining in the San Joaquin River at the head of Old River; = 1 - ψ_{B2}
ψ_{A3}	Probability of remaining in the San Joaquin River at the junction with Turner Cut; = 1 - ψ_{F3}
ψ_{B2}	Probability of entering Old River at the head of Old River; = 1 - ψ_{A2}
ψ_{B3}	Probability of remaining in Old River at the head of Middle River; = 1 - ψ_{C3}
ψ_{C3}	Probability of entering Middle River at the head of Middle River; = 1 - ψ_{B3}
ψ_{F3}	Probability of entering Turner Cut at the junction with the San Joaquin River; = 1 - ψ_{A3}
ψ_{G1}	Probability of moving downriver in the San Joaquin River at the Jersey Point/False River junction; = 1 - ψ_{H1}
ψ_{H1}	Probability of entering False River at the Jersey Point/False River junction; = 1 - ψ_{G1}
$\phi_{A1,A2}$	Joint probability of moving from Durham Ferry release site downstream toward DFD, and surviving to DFD
$\phi_{A8,G2}$	Overall survival from MFE/MFW to Chipps Island (CHPE/CHPW)
$\phi_{A9,A10}$	Joint probability of moving from C18/C16 toward MFE/MFW, and surviving from C18/C16 to MFE/MFW
$\phi_{A10,GH}$	Joint probability of moving from MFE/MFW toward Jersey Point (JPTE/JPTW) or False River (FRE/FRW), and surviving to JPTE/JPTW or FRE/FRW
$\phi_{A10,G2}$	Joint probability of moving from MFE/MFW toward Chipps Island (CHPE/CHPW), and surviving from MFE/MFW to CHPE/CHPW
$\phi_{B1,B2}$	Joint probability of moving from ORE toward ORS, and surviving from ORE to ORS
$\phi_{B2,B3}$	Joint probability of moving from ORS toward ORN, and surviving from ORS to ORN
$\phi_{B2,C2}$	Joint probability of moving from ORS toward MRN, and surviving from ORS to MRN
$\phi_{B2,D1}$	Joint probability of moving from ORS toward RGU, and surviving from ORS to RGU
$\phi_{B2,E1}$	Joint probability of moving from ORS toward CVP, and surviving from ORS to CVP
$\phi_{B2,G2}$	Overall survival from ORS to Chipps Island (CHPE/CHPW)
$\phi_{B3,GH}$	Joint probability of moving from ORN toward Jersey Point (JPTE/JPTW) or False River (FRE/FRW), and surviving from ORN to JPTE/JPTW or FRE/FRW
$\phi_{B3,G2}$	Joint probability of moving from ORN toward Chipps Island (CHPE/CHPW), and surviving from ORN to CHPE/CHPW
$\phi_{C1,B3}$	Joint probability of moving from MRS toward ORN, and surviving from MRS to ORN
$\phi_{C1,C2}$	Joint probability of moving from MRS toward MRN, and surviving from MRS to MRN
$\phi_{C1,D1}$	Joint probability of moving from MRS toward RGU, and surviving from MRS to RGU
$\phi_{C1,E1}$	Joint probability of moving from MRS toward CVP, and surviving from MRS to CVP
$\phi_{C1,G2}$	Overall survival from MRS to Chipps Island (CHPE/CHPW)
$\phi_{C2,GH}$	Joint probability of moving from MRN toward Jersey Point (JPTE/JPTW) or False River (FRE/FRW), and surviving from MRN to JPTE/JPTW or FRE/FRW
$\phi_{C2,G2}$	Joint probability of moving from MRN toward Chipps Island (CHPE/CHPW), and surviving from MRN to CHPE/CHPW
$\phi_{D1,D2}$	Joint probability of moving from RGU toward RGD, and surviving from RGU to RGD
$\phi_{D2,G2}$	Joint probability of moving from RGD toward Chipps Island (CHPE/CHPW) and surviving from RGU to CHPE/CHPW
$\phi_{E1,E2}$	Joint probability of moving from CVP toward CVPtank, and surviving from CVP to CVPtank
$\phi_{E2,G2}$	Joint probability of moving from CVPtank toward Chipps Island (CHPE/CHPW) and surviving from CVPtank to CHPE/CHPW

Appendix H, Table 2 (Continued)
Definitions of Parameters Used in the Release-Recapture Survival Model Shown in Chapter 5

Parameter	Definition
$\phi_{F1,GH}$	Joint probability of moving from TCN/TCS toward Jersey Point (JPTE/JPTW) or False River (FRE/FRW), and surviving to JPTE/JPTW or FRE/FRW
$\phi_{F1,G2}$	Joint probability of moving from TCN/TCS toward Chipps Island (CHPE/CHPW), and surviving to CHPE/CHPW
$\phi_{G1,G2}$	Joint probability of moving from JPE/JPW toward Chipps Island (CHPE/CHPW), and surviving to CHPE/CHPW
P_{A2}	Conditional probability of detection at DFD
P_{A3}	Conditional probability of detection at BCA
P_{A4}	Conditional probability of detection at PCO
P_{A5}	Conditional probability of detection at MOS
P_{A6}	Conditional probability of detection at SJL (either SJLU or SJLD)
P_{A7}	Conditional probability of detection at STS
P_{A8}	Conditional probability of detection at STN
P_{A9}	Conditional probability of detection at either C18 or C16
P_{A10a}	Conditional probability of detection at MFE
P_{A10b}	Conditional probability of detection at MFW
P_{B1}	Conditional probability of detection at ORE (either OREU or ORED)
P_{B2a}	Conditional probability of detection at ORSU
P_{B2b}	Conditional probability of detection at ORSD
P_{B3a}	Conditional probability of detection at ORNU
P_{B3b}	Conditional probability of detection at ORND
P_{C1}	Conditional probability of detection at MRS
P_{C2a}	Conditional probability of detection at MRNU
P_{C2b}	Conditional probability of detection at MRND
P_{D1}	Conditional probability of detection at RGU (either RGU1 or RGU2)
P_{D2a}	Conditional probability of detection at RGD1
P_{D2b}	Conditional probability of detection at RGD2
P_{E1}	Conditional probability of detection at CVP
P_{F1a}	Conditional probability of detection at TCN
P_{F1b}	Conditional probability of detection at TCS
P_{G1a}	Conditional probability of detection at JPTE
P_{G1b}	Conditional probability of detection at JPTW
P_{G2a}	Conditional probability of detection at CHPE
P_{G2b}	Conditional probability of detection at CHPW
P_{H1a}	Conditional probability of detection at FRW
P_{H1b}	Conditional probability of detection at FRE

Appendix H, Table 3
Parameter Estimates (Standard Errors in Parentheses) for Tagged Juvenile Chinook Salmon Released in 2011, Excluding Predator-type Detections. Parameters Without Standard Errors Were Estimated at Fixed Values in the Model. Population-level Estimates Were Estimated from the Pooled Release Groups. Some Parameters Were Not Estimable Because of Sparse Data

Parameter	Release Occasion				Population Estimate
	1	2	3	4	
S_{A2}	0.99 (0.01)	0.99 (0.01)	0.94 (0.01)	0.96 (0.01)	0.97 (0.00)
S_{A3}	1.03 (0.02)	0.99 (0.01)	0.95 (0.02)	0.96 (0.02)	0.99 (0.01)
S_{A4}	0.96 (0.02)	0.96 (0.01)	0.92 (0.02)	0.92 (0.02)	0.94 (0.01)
S_{A5}	1.00 (0.00)	0.99 (0.01)	0.97 (0.01)	0.98 (0.01)	0.99 (0.00)
S_{A6}	0.92 (0.02)	0.89 (0.02)	0.85 (0.03)	0.85 (0.03)	0.88 (0.01)
S_{A7}	0.96 (0.01)	0.96 (0.01)	0.90 (0.02)	0.93 (0.02)	0.94 (0.01)
S_{A8}	0.63 (0.03)	0.62 (0.03)		0.55 (0.04)	0.59 (0.02)
S_{B1}		0.97 (0.01)	0.98 (0.02)	0.98 (0.01)	0.98 (0.01)
ψ_{A1}	1.00	1.00	1.00	1.00	1.00
ψ_{A2}	0.59 (0.02)	0.57 (0.02)	0.63 (0.03)	0.55 (0.03)	0.58 (0.01)
ψ_{A3}	0.73 (0.04)	0.81 (0.03)		0.91 (0.03)	0.79 (0.02)
ψ_{B2}	0.41 (0.02)	0.43 (0.02)	0.37 (0.03)	0.45 (0.03)	0.42 (0.01)
ψ_{B3}		0.98 (0.01)	0.98 (0.01)	1.00	0.99 (0.01)
ψ_{C3}		0.02 (0.01)	0.02 (0.01)	0.00	0.01 (0.01)
ψ_{F3}	0.27 (0.04)	0.19 (0.03)		0.09 (0.03)	0.21 (0.02)
ψ_{G1}	0.80 (0.18)			1.00	0.93 (0.07)
ψ_{H1}	0.20 (0.18)			0.00	0.07 (0.07)
$\phi_{A1,A2}$	0.98 (0.01)	0.99 (0.01)	0.97 (0.01)	0.96 (0.01)	0.97 (0.00)
$\phi_{A8,G2}$	0.02 (0.01)	0.005 (0.005)	0.02 (0.01)	0.01 (0.01)	0.01 (0.00)
$\phi_{A9,A10}$	0.58 (0.05)	0.31 (0.05)		0.44 (0.06)	0.40 (0.03)
$\phi_{A10,GH}$	0.06 (0.03)			0.06 (0.04)	0.08 (0.02)
$\phi_{A10,G2}$	0.05 (0.04)	0.03 (0.03)		0.03 (0.03)	0.05 (0.02)
$\phi_{B1,B2}$	0.97 (0.01)	0.96 (0.02)	0.96 (0.02)	0.98 (0.01)	0.97 (0.01)
$\phi_{B2,B3}$	0.32 (0.03)	0.27 (0.03)		0.00	0.16 (0.01)
$\phi_{B2,C2}$	0.00	0.01 (0.01)		0.01 (0.01)	0.003 (0.002)
$\phi_{B2,D1}$	0.21 (0.03)	0.22 (0.03)		0.41 (0.04)	0.29 (0.02)
$\phi_{B2,E1}$	0.17 (0.03)	0.13 (0.03)		0.33 (0.04)	0.23 (0.02)
$\phi_{B2,G2}$	0.004 (0.005)	0.02 (0.01)	0.06 (0.02)	0.07 (0.02)	0.04 (0.01)
$\phi_{B3,GH}$	0.02 (0.02)				0.02 (0.01)
$\phi_{B3,G2}$	0.01 (0.02)	0.00			0.01 (0.01)
$\phi_{C1,B3}$		0.33 (0.27)			0.22 (0.16)
$\phi_{C1,C2}$		0.33 (0.27)			0.11 (0.11)
$\phi_{C1,D1}$		0.33 (0.27)			0.40 (0.18)
$\phi_{C1,E1}$		0.00			0.00
$\phi_{C1,G2}$		0.00 (0.00)	0.50 (0.36)		0.01 (0.00)
$\phi_{C2,GH}$				0.00	0.00
$\phi_{C2,G2}$		0.00		0.00	0.00
$\phi_{D1,D2}$	0.78 (0.07)	0.78 (0.07)	0.87 (0.05)	0.69 (0.06)	0.77 (0.03)
$\phi_{D2,G2}$	0.00	0.00	0.03 (0.03)	0.00	0.02 (0.01)
$\phi_{E1,E2}$	0.00	0.33 (0.10)	0.23 (0.07)	0.31 (0.06)	0.23 (0.03)
$\phi_{E2,G2}$		0.50 (0.18)	0.56 (0.17)	0.71 (0.11)	0.62 (0.08)
$\phi_{F1,GH}$	0.00			0.00	0.00
$\phi_{F1,G2}$	0.00	0.00		0.00	0.00
$\phi_{G1,G2}$	1.00 (0.5)			0.50 (0.35)	0.69 (0.13)

continued

Appendix H, Table 3 (continued)
Parameter Estimates (Standard Errors in Parentheses) for Tagged Juvenile Chinook Salmon Released in 2011, Excluding Predator-type Detections. Parameters Without Standard Errors Were Estimated at Fixed Values in the Model. Population-level Estimates Were Estimated from the Pooled Release Groups. Some Parameters Were Not Estimable Because of Sparse Data

Parameter	Release Occasion				Population Estimate
	1	2	3	4	
P_{A2}	1.00 (0.00)	0.96 (0.01)	0.90 (0.01)	0.98 (0.01)	0.96 (0.00)
P_{A3}	0.93 (0.01)	0.91 (0.01)	0.88 (0.02)	0.91 (0.01)	0.91 (0.01)
P_{A4}	0.15 (0.02)	0.41 (0.02)	0.39 (0.03)	0.43 (0.03)	0.34 (0.01)
P_{A5}	0.92 (0.01)	0.86 (0.02)	0.80 (0.02)	0.90 (0.02)	0.87 (0.01)
P_{A6}	0.96 (0.01)	1.00 (0.00)	0.91 (0.02)	0.98 (0.01)	0.96 (0.01)
P_{A7}	0.96 (0.01)	0.93 (0.02)	0.88 (0.02)	0.96 (0.02)	0.93 (0.01)
P_{A8}	0.99 (0.01)	0.99 (0.01)	1.00	0.98 (0.02)	0.99 (0.01)
P_{A9}	1.00	1.00		1.00	0.99 (0.01)
P_{A10a}	0.93 (0.03)	0.97 (0.03)		0.91 (0.05)	0.93 (0.02)
P_{A10b}	0.98 (0.02)	1.00		0.91 (0.05)	0.96 (0.02)
P_{B1}	0.97 (0.01)	0.96 (0.01)	0.96 (0.02)	0.99 (0.01)	0.97 (0.01)
P_{B2a}	0.88 (0.02)	0.91 (0.02)	0.87 (0.03)	0.93 (0.02)	0.9 (0.01)
P_{B2b}	0.94 (0.02)	0.98 (0.01)	0.95 (0.02)	0.97 (0.01)	0.96 (0.01)
P_{B3a}	1.00	1.00		1.00	0.99 (0.01)
P_{B3b}	0.79 (0.05)	0.86 (0.05)		1.00	0.81 (0.04)
P_{C1}		1.00	1.00	1.00	0.76 (0.23)
P_{C2a}	1.00	1.00		1.00	1.00
P_{C2b}	1.00	1.00		1.00	1.00
P_{D1}	0.97 (0.03)	1.00		0.76 (0.06)	0.85 (0.03)
P_{D2a}	0.96 (0.04)	0.96 (0.04)		0.98 (0.02)	0.98 (0.01)
P_{D2b}	0.96 (0.04)	0.87 (0.06)		1.00	0.97 (0.01)
P_{E1}	1.00	1.00		1.00	1.00
P_{F1a}	1.00	1.00		0.86 (0.13)	0.99 (0.01)
P_{F1b}	0.95 (0.03)	0.96 (0.04)		0.86 (0.13)	0.96 (0.02)
P_{G1a}	1.00			1.00	0.84 (0.11)
P_{G1b}	0.75 (0.22)			1.00	0.76 (0.12)
P_{G2a}	0.5 (0.35)	1.00	1.00	1.00	0.96 (0.04)
P_{G2b}	0.5 (0.35)	1.00	0.67 (0.14)	0.85 (0.1)	0.78 (0.07)
P_{H1a}	1.00			1.00	1.00
P_{H1b}	1.00			1.00	1.00

Appendix H, Table 4
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. Population-level Estimates Were Estimated from the Pooled Release Groups. Some Parameters Were Not Estimable Because of Sparse Data

Parameter	Release Occasion				Population Estimate
	1	2	3	4	
S_{A2}	0.99 (0.00)	0.99 (0.01)	0.94 (0.01)	0.96 (0.01)	0.97 (0.00)
S_{A3}	1.04 (0.03)	1.00 (0.01)	0.94 (0.02)	0.95 (0.02)	0.99 (0.01)
S_{A4}	0.95 (0.03)	0.96 (0.01)	0.93 (0.02)	0.92 (0.02)	0.94 (0.01)
S_{A5}	0.98 (0.01)	0.98 (0.01)	0.96 (0.01)	0.98 (0.01)	0.97 (0.00)
S_{A6}	0.95 (0.01)	0.91 (0.02)	0.88 (0.02)	0.86 (0.03)	0.90 (0.01)
S_{A7}	0.96 (0.01)	0.97 (0.02)	0.9 (0.02)	0.97 (0.03)	0.96 (0.01)
S_{A8}	0.64 (0.03)	0.64 (0.03)		0.54 (0.04)	0.60 (0.02)
S_{B1}	0.99 (0.01)	0.97 (0.01)	0.97 (0.02)	0.98 (0.01)	0.98 (0.01)
ψ_{A1}	1.00	1.00	1.00	1.00	1.00
ψ_{A2}	0.58 (0.02)	0.56 (0.02)	0.62 (0.03)	0.57 (0.03)	0.58 (0.01)
ψ_{A3}	0.73 (0.04)	0.82 (0.03)		0.91 (0.03)	0.79 (0.02)
ψ_{B2}	0.42 (0.02)	0.44 (0.02)	0.38 (0.03)	0.43 (0.03)	0.42 (0.01)
ψ_{B3}	0.99 (0.01)	0.98 (0.01)	0.98 (0.01)	1.00	0.98 (0.01)
ψ_{C3}	0.01 (0.01)	0.02 (0.01)	0.02 (0.01)	0.00	0.02 (0.01)
ψ_{F3}	0.27 (0.04)	0.18 (0.03)		0.09 (0.03)	0.21 (0.02)
ψ_{G1}	0.80 (0.18)			1.00	0.93 (0.06)
ψ_{H1}	0.20 (0.18)			0.00	0.07 (0.06)
$\phi_{A1,A2}$	0.99 (0.01)	0.98 (0.01)	0.97 (0.01)	0.97 (0.01)	0.98 (0.00)
$\phi_{A8,G2}$	0.02 (0.01)	0.01 (0.01)	0.02 (0.01)	0.01 (0.01)	0.01 (0.00)
$\phi_{A9,A10}$	0.55 (0.05)	0.31 (0.04)		0.45 (0.05)	0.39 (0.02)
$\phi_{A10,GH}$	0.06 (0.03)			0.05 (0.03)	0.08 (0.02)
$\phi_{A10,G2}$	0.05 (0.04)	0.04 (0.04)		0.05 (0.03)	0.06 (0.02)
$\phi_{B1,B2}$	0.98 (0.01)	0.95 (0.02)	0.95 (0.02)	0.98 (0.01)	0.96 (0.01)
$\phi_{B2,B3}$	0.31 (0.04)	0.28 (0.04)		0.00	0.17 (0.02)
$\phi_{B2,C2}$	0.00	0.01 (0.01)		0.01 (0.01)	0.003 (0.002)
$\phi_{B2,D1}$	0.24 (0.03)	0.22 (0.03)		0.41 (0.04)	0.29 (0.02)
$\phi_{B2,E1}$	0.22 (0.03)	0.19 (0.03)		0.35 (0.04)	0.27 (0.02)
$\phi_{B2,G2}$	0.004 (0.005)	0.03 (0.01)	0.06 (0.02)	0.07 (0.02)	0.04 (0.01)
$\phi_{B3,GH}$	0.02 (0.02)				0.03 (0.02)
$\phi_{B3,G2}$	0.01 (0.02)	0.00			0.02 (0.01)
$\phi_{C1,B3}$	0.00	0.27 (0.23)			0.30 (0.15)
$\phi_{C1,C2}$	0.00	0.27 (0.23)			0.09 (0.09)
$\phi_{C1,D1}$	0.51 (0.36)	0.47 (0.27)			0.50 (0.17)
$\phi_{C1,E1}$	0.00	0.00			0.00
$\phi_{C1,G2}$	0.00 (0.00)	0.01 (0.01)	0.50 (0.36)		0.02 (0.01)
$\phi_{C2,GH}$				0.00	0.00
$\phi_{C2,G2}$		0.00		0.00	0.00
$\phi_{D1,D2}$	0.91 (0.04)	0.88 (0.05)	0.94 (0.04)	0.70 (0.06)	0.85 (0.03)
$\phi_{D2,G2}$	0.00	0.03 (0.03)	0.03 (0.03)	0.00	0.02 (0.01)
$\phi_{E1,E2}$	0.00	0.23 (0.07)	0.24 (0.06)	0.33 (0.06)	0.21 (0.03)
$\phi_{E2,G2}$		0.50 (0.18)	0.50 (0.16)	0.63 (0.11)	0.58 (0.08)
$\phi_{F1,GH}$	0.00			0.00	0.00
$\phi_{F1,G2}$	0.00	0.00		0.00	0.00
$\phi_{G1,G2}$	1.00 (0.5)			1.00	0.74 (0.13)

continued

Appendix H, Table 4 (continued)
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. Population-level Estimates Were Estimated from the Pooled Release Groups. Some Parameters Were Not Estimable Because of Sparse Data

Parameter	Release Occasion				Population Estimate
	1	2	3	4	
P_{A2}	1.00 (0.00)	0.96 (0.01)	0.90 (0.01)	0.96 (0.01)	0.96 (0.00)
P_{A3}	0.93 (0.01)	0.91 (0.01)	0.88 (0.02)	0.89 (0.02)	0.90 (0.01)
P_{A4}	0.15 (0.02)	0.41 (0.02)	0.39 (0.03)	0.42 (0.03)	0.33 (0.01)
P_{A5}	0.92 (0.01)	0.86 (0.02)	0.80 (0.02)	0.88 (0.02)	0.87 (0.01)
P_{A6}	0.96 (0.01)	1.00 (0.00)	0.91 (0.02)	0.94 (0.02)	0.95 (0.01)
P_{A7}	0.96 (0.01)	0.93 (0.02)	0.89 (0.02)	0.92 (0.02)	0.93 (0.01)
P_{A8}	0.98 (0.01)	0.98 (0.01)	1.00	0.93 (0.03)	0.97 (0.01)
P_{A9}	1.00	1.00		1.00	0.99 (0.01)
P_{A10a}	0.92 (0.03)	0.94 (0.04)		0.95 (0.04)	0.93 (0.02)
P_{A10b}	1.00	1.00		0.95 (0.04)	0.97 (0.01)
P_{B1}	0.97 (0.01)	0.96 (0.01)	0.96 (0.02)	0.99 (0.01)	0.97 (0.01)
P_{B2a}	0.88 (0.02)	0.90 (0.02)	0.87 (0.03)	0.93 (0.02)	0.90 (0.01)
P_{B2b}	0.94 (0.02)	0.97 (0.01)	0.95 (0.02)	0.97 (0.01)	0.96 (0.01)
P_{B3a}	0.85 (0.05)	0.85 (0.06)		1.00	0.84 (0.04)
P_{B3b}	0.76 (0.06)	0.83 (0.06)		1.00	0.79 (0.04)
P_{C1}	1.00	0.80 (0.24)	1.00	1.00	0.62 (0.18)
P_{C2a}	1.00	1.00		1.00	1.00
P_{C2b}	1.00	1.00		1.00	1.00
P_{D1}	0.98 (0.02)	0.97 (0.03)		0.76 (0.06)	0.86 (0.03)
P_{D2a}	0.97 (0.03)	0.97 (0.03)		0.98 (0.02)	0.98 (0.01)
P_{D2b}	0.92 (0.04)	0.85 (0.06)		1.00	0.95 (0.02)
P_{E1}	1.00	1.00		1.00	1.00
P_{F1a}	0.95 (0.04)	1.00		0.87 (0.12)	0.97 (0.02)
P_{F1b}	0.92 (0.04)	0.96 (0.04)		0.87 (0.12)	0.95 (0.02)
P_{G1a}	1.00			1.00	0.85 (0.1)
P_{G1b}	0.75 (0.22)			1.00	0.78 (0.11)
P_{G2a}	0.5 (0.35)	0.83 (0.15)	1.00	1.00	0.93 (0.05)
P_{G2b}	0.5 (0.35)	1.00	0.67 (0.14)	0.79 (0.11)	0.76 (0.07)
P_{H1a}	1.00			1.00	1.00
P_{H1b}	1.00			1.00	1.00

APPENDIX I

Sample Sizes to Estimate Survival through the State Water Project

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Summary

Maximum standard error on all parameters: 0.05
Using fish released only at Durham Ferry and in Old River (site B1, at the head of Old River):

- low survival from B1 to CCFB (0.20), through CCFB (0.11), from release sites to Chipps (0.5):
    - ≥ 800 fish are needed to estimate survival from the radial gates at CCFB to the trashrack
    - ≥5,000 fish are needed to estimate survival from trashrack to holding tank
    - ≥3,500 fish are needed to estimate survival from holding tank to release sites
    - ≥14,000 fish are needed to estimate survival from release sites to Chipps Island
- higher survival from B1 to CCFB (0.35), through CCFB (0.27), from release sites to Chipps (0.7):
    - ≥ 500 fish are needed to estimate survival from the radial gates to the trashrack
    - approximately 600 fish are needed to estimate survival from trashrack to holding tank
    - ≥800 fish are needed to estimate survival from holding tank to release sites
    - ≥4,000 fish are needed to estimate survival from release sites to Chipps Island

With 225 fish released at Durham Ferry, 150 fish released in Old River, and another supplemental release directly into CCFB:

- low survival from B1 to CCFB, through CCFB, and from release site to Chipps:
    - 60 fish should be released at CCFB to estimate survival from the radial gates to the trashrack
    - 970 fish should be released at CCFB to estimate survival from trashrack to holding tank
    - 640 fish should be released at CCFB to estimate survival from holding tank to release sites
    - 2700 fish should be released at CCFB to estimate survival from release site to Chipps
- higher survival from B1 to CCFB, through CCFB, and from release site to Chipps:
    - 50 fish should be released at CCFB to estimate survival the radial gates to the trashrack
    - 100 fish should be released at CCFB to estimate survival from trashrack to holding tank
    - 190 fish should be released at CCFB to estimate survival from holding tank to release sites
    - 1290 fish should be released at CCFB to estimate survival from release sites to Chipps

Relaxing the maximum standard error would require fewer fish, as would higher survival to the CCFB. With only 225 fish released at Durham Ferry and 150 fish released in Old River, the standard errors expected on estimates of transition and survival parameters range from 0.07 to 0.09 on the transition from the radial gates to the trashracks, 0.25 to 0.88 from the trashracks to the holding tanks, 0.24 to 0.49 from the holding tanks to the release sites, and 0.19 to 0.39 from the release sites to Chipps Island.

Methods

The release sizes necessary to estimate survival through different portions of Clifton Court Forebay and the State Water Project were analyzed in order to attain maximum standard errors of 0.05 for each segment survival. The main analysis considered only two releases: the initial release is at Durham Ferry, and a supplemental release is located at the first detection site in Old River (site B1). Parameters estimated are:

- Transition probability (joint probability of movement and survival) from site B1 to the radial gates at CCFB: $\phi_{B1,CCFB}$
- Transition probability from radial gates to trashrack: $\phi_{CCFB,TR}$
- Transition probability from trashrack to holding tanks: $\phi_{TR,HT}$
- Survival probability from holding tanks to release sites: $\sigma_{HT,Rel}$
- Transition probability from release sites to Chipps Island: $\phi_{Rel,Ch}$

Assumed parameter values were based on parameter estimates reported in the VAMP 2008 report (Holbrook et al. 2009), and the DWR 2009 report (Clark et al. 2009) (Table 1). At most two values were considered for each parameter, representing both high and low values based on available estimates from these two reports (Table 2)

University of Washington software SampleSize (http://www.cbr.washington.edu/paramest/samplesize/) was used to determine the release sizes needed at Durham Ferry and site B1 in Old River to estimate the 5 parameters with a maximum standard error of 0.05 on each. The minimum release size considered at Durham Ferry was 95. The minimum supplemental release size considered in Old River was 0. No consideration was given to estimating migration parameters through the San Joaquin downstream of the head of Old River, or through the CVP.

Another supplemental release made directly into Clifton Court Forebay at the radial gates was considered for the case with 225 fish released at Durham Ferry and 150 fish released in Old River at site B1.

Table 1. Parameters used in sample size analysis. At most two values were considered for each parameter, representing low and high values based on point estimates and 95% confidence intervals from the VAMP 2008 report and the DWR 2009 report.

Parameter	Definition	Values	Source
S_{RO}	Survival from Durham Ferry to head of Old River	0.5, 0.75	Preliminary VAMP 2009 results, and higher value
ψ_B	Proportion of fish at head of Old River that enter Old River	0.4, 0.7	VAMP 2008, and lower value if barrier is operating
$\phi_{DF,B1}$	Joint probability of moving from Durham Ferry to first detection site in Old River, and surviving to first site in Old River	0.3, 0.5	$=S_{RO} \cdot \psi_B$ (approximately)
$\phi_{B1,CCFB}$	Joint probability of moving from first site in Old River to CCFB (inside radial gates), and surviving to CCFB	0.2, 0.35	VAMP 2008
$\phi_{CCFB,TR}$	Joint probability of moving from radial gates at CCFB to trashrack at SWP, and surviving to trashrack	0.3, 0.4	VAMP 2008
$\phi_{TR,HT}$	Joint probability of moving from trashrack to holding tank, and surviving to holding tank	0.85	DWR 2009 (adjusted from acoustic-tagged steelhead fish guidance efficiency)
$\sigma_{HT,Rel}$	Probability of surviving from holding tank to salvage release sites	0.45, 0.8	$=\sigma_{B3}/(\phi_{TR,HT}\ \phi_{Rel,Ch})$, where σ_{B3} is from VAMP 2008
$\phi_{Rel,Ch}$	Joint probability of moving from release sites to Chipps, and surviving to Chipps	0.5, 0.7	VAMP 2008 (= $\sigma_{JPT,Chipps}$)
p_{B1}	Detection probability at first site on Old River	0.95	VAMP 2008 report
p_{CCFB}	Detection probability at CCFB (radial gates)	1	Discussions with DWR
p_{TR}	Detection probability at trashracks	0.95	Guess
p_{HT}	Detection probability in holding tanks	1	Assumption that all tanks are monitored
p_{Rel}	Detection probability at salvage release sites	0.95	Guess
p_{Ch}	Detection probability at Chipps Island dual array	0.76	Conservative guess based on VAMP 2008 estimates

Table 2. Parameter scenarios used in sample size analyses.

Scenario	$\phi_{DF,B1}$	$\phi_{B1,CCFB}$	$\phi_{CCFB,TR}$	$\phi_{TR,HT}$	$\sigma_{HT,Rel}$	$\phi_{Rel,Ch}$
1	0.3	0.2	0.3	0.85	0.45	0.5
2	0.5	0.35	0.4	0.85	0.8	0.7

Results

Releases only at Durham Ferry and Old River

The release sizes necessary to estimate the 5 parameters at the desired level of error (SE<=0.05) depend on the parameter to be estimated, and on the assumed parameter values (Table 3). To a lesser extent, the minimum release size required at Durham Ferry depends on the size of the supplemental release in Old River (Table 3), and vice versa (Table 4). However, in most cases the lowest total release size corresponds to releasing only 95 fish at Durham Ferry, with considerably more released in Old River. Recall that this analysis ignores the use of Durham Ferry releases for migration through the San Joaquin route or through the CVP.

Transition from B1 in Old River to CCFB ($\phi_{B1,CCFB}$ = 0.2 or 0.35)

Estimating the probability of getting from the first Old River site to the CCFB requires 270 fish released, with 95 released at Durham Ferry and 175 released in Old River.

Transition from radial gate at CCFB to Trashrack ($\phi_{CCFB,TR}$ = 0.3 or 0.4)

With low survival to and through the State Water Project, estimating the probability of getting from the radial gates at the CCFB to the trashrack requires 793 fish, with 95 released at Durham Ferry and 698 fish released into Old River. With higher survival, 501 fish are required, with 95 fish released at Durham Ferry and 406 fish released in Old River.

Transition from Trashrack to Holding Tank ($\phi_{TR,HT}$ = 0.85)

Estimating the probability of getting from the trashrack to the holding tank depends heavily on the underlying survival probabilities. If survival to the trashrack is low (0.06 from B1), then 5,195 fish are required, with 95 released at Durham Ferry and 5,100 released in Old River. If survival to the trashrack is higher (0.14 from B1), then only 582 fish are required, with 95 released at Durham Ferry and 487 released in Old River.

Survival from Holding Tank to Release Sites ($\sigma_{HT,Rel}$ = 0.45 or 0.8)

Estimating the probability of surviving from the holding tank to the release sites requires at least 3495 fish for the low survival scenario, with 95 fish released at Durham Ferry and 3400 fish released in Old River. If survival is higher throughout the system, then 843 fish are required, with 95 fish released at Durham Ferry and 748 released in Old River.

Transition from Release Sites to Chipps Island ($\phi_{Rel,Ch}$ = 0.5 or 0.7)

In the low survival scenario, estimating the probability of getting from the salvage release sites to Chipps Island requires over 10,000 fish, with 225 released at Durham Ferry and 13,380 fish released in Old River. In the high survival scenario, 3,995 fish are required, with 95 released at Durham Ferry and 3900 released in Old River.

Table 3. Minimum size of release at Durham Ferry needed in order to estimate parameters with SE <=0.05. Results for the previously recommended supplemental release size of 150 are in bold.

Scenario	Release Size in Old River	$\phi_{B1,CCFB}$	$\phi_{CCFB,TR}$	$\phi_{TR,HT}$	$\sigma_{HT,Rel}$	$\phi_{Rel,Ch}$
1	**150**	**165**	**1,920**	**16,270**	**10,848**	**44,140**
1	300	95	1,420	15,770	10,340	43,400
1	750	95	95	14,300	8,900	42,200
1	1000	95	95	14,000	8,100	41,300
1	2000	95	95	10,100	4,700	40,000
1	3000	95	95	6,800	1,400	35,000
2	**150**	**145**	**597**	**768**	**1,300**	**7,600**
2	300	95	296	467	1,000	7,250
2	750	95	95	95	95	6,400
2	1000	95	95	95	95	5,900
2	2000	95	95	95	95	3,900
2	3000	95	95	95	95	1,900

Table 4. Minimum size of supplemental release in Old River needed in order to estimate parameters with SE <=0.05. Results for the previously recommended release size of 225 are in bold. The sampling scheme with the smallest total release size is highlighted for each scenario and each parameter.

Scenario	Release Size at Durham Ferry	$\phi_{B1,CCFB}$	$\phi_{CCFB,TR}$	$\phi_{TR,HT}$	$\sigma_{HT,Rel}$	$\phi_{Rel,Ch}$
1	95	175	698	5,100	3,400	14,000
1	**225**	**135**	**658**	**4,970**	**3,340**	**13,380**
1	475	57	587	7,890	3,300	13,400
1	1000	0	426	4,730	3,200	13,200
1	2000	0	200	4,500	2,900	13,000
1	3000	0	0	4,200	2,600	12,600
2	95	175	406	487	748	3,900
2	**225**	**115**	**336**	**426**	**688**	**3,810**
2	475	0	215	296	567	3,690
2	1000	0	0	33	296	3,420
2	2000	0	0	0	0	3,000
2	3000	0	0	0	0	2,500

Releases at Durham Ferry, Old River, and Clifton Court Forebay

With an additional release made directly into Clifton Court Forebay, the total necessary release sizes generally decrease, ranging from 425 (50 at CCFB) to estimate survival from the radial gates to the trashrack if survival is relatively high, to 3075 (2700 at CCFB) to estimate survival from the release sites to Chipps Island if survival is low (Table 5).

Table 5. Minimum release size needed at Clifton Court Forebay to estimate parameters with maximum standard error of 0.05, with 225 fish released at Durham Ferry and 150 fish released at site B1 in Old River.

Scenario	$\phi_{CCFB,TR}$	$\phi_{TR,HT}$	$\sigma_{HT,Rel}$	$\phi_{Rel,Ch}$
1	60	970	640	2,700
2	50	100	190	1,290

References

Clark, K., M.D. Bowen, R. B. Mayfield, K. P. Zehfuss, J. D. Taplin, and C. H. Hanson. 2009. Quantification of Pre-Screen Loss of Juvenile Steelhead in Clifton Court Forebay. Technical report, CA Department of Water Resources, Sacramento, CA.

Holbrook, C. M., R. W. Perry, and N. S. Adams. 2009. Distribution and joint fish-tag survival of juvenile Chinook salmon migrating through the Sacramento-San Joaquin River Delta, 2008. Submitted to San Joaquin River Group Authority, Modesto, CA.

APPENDIX J

Steelhead and Salmon Tagging Data Files from the 2011 VAMP, 2011 South Delta Temporary Barriers Project and the 2011 OCAP 6-Year Study

[Click to open to Microsoft Excel File]

APPENDIX K

The San Joaquin River Agreement

Appendix A - Conceptual Framework for Protection and Experimental Determination of Juvenile Chinook Salmon Survival Within the Lower San Joaquin River in Response to River Flow and SWP/CVP Exports

Appendix B - Planning and Operation Coordination for the Vernalis Adaptive Management Plan.

1.0 Parties to this Agreement
The parties to this San Joaquin River Agreement are:

1.1 California Resources Agency parties: California Department of Water Resources (CDWR), and California Department of Fish and Game (CDFG).

1.2 United States Department of the Interior (DOI) parties: United States Bureau of Reclamation (USBR), and United States Fish and Wildlife Service (USFWS).

1.3 San Joaquin River Group parties: San Joaquin River Group Authority (SJRGA), and its member agencies Modesto Irrigation District, Turlock Irrigation District, Merced Irrigation District, South San Joaquin Irrigation District, and Oakdale Irrigation District; the San Joaquin River Exchange Contractors Water Authority and its member agencies Central California Irrigation District, San Luis Canal Company, Firebaugh Canal Water District and Columbia Canal Company; the Friant Water Users Authority on behalf of its member agencies; and the City and County of San Francisco (CCSF).

1.4 Central Valley Project/State Water Project (CVP/SWP) Export Interests parties: State Water Contractors, Kern County Water Agency, Tulare Lake Basin Water Storage District, Santa Clara Valley Water District, San Luis and Delta-Mendota Water Authority, Westlands Water District, and Metropolitan Water District of Southern California.

1.5 Environmental Community parties: Natural Heritage Institute and The Bay Institute of San Francisco.

2.0 Introduction

2.1 This San Joaquin River Agreement proposes, among other things, a San Joaquin River flow and SWP/CVP export study during the April-May Pulse Flow Period and a mechanism by which the State Water Resources Control Board (SWRCB) can issue an order to implement the San Joaquin River Portion (as defined herein) of the 1995 Water Quality Control Plan (WQCP) for the San Francisco Bay and Sacramento-San Joaquin River Delta Estuary system. As used in this Agreement, the term "implement" means to provide the flows and establish the pumping regiment called for in this Agreement which the Parties intend will provide environmental benefits in the lower San Joaquin River and Delta at a level of protection equivalent to the San Joaquin River Portion of the 1995 WQCP. The Parties anticipate that the SWRCB will make an independent determination of the protection provided by this Agreement before deciding whether to adopt this Agreement and its Implementation Plan. The implementation package to provide the environmental benefits intended consists of these components:

2.1.1 As set forth in Paragraph 10.1, for the term of this Agreement, the USBR shall assume responsibility for the San Joaquin River Portion of the 1995 WQCP objectives that can be reasonably met through flow measures.

2.1.2 As set forth in Paragraph 10.1.2 for the term of this Agreement, the USBR and, as appropriate, the CDWR shall assume responsibility for the 1995 WQCP objectives for the San Joaquin River basin share of Delta outflow.

2.1.3 Except as provided in Paragraph 12.1, for the term of this Agreement, the USBR and the CDWR agree that the water provided by the SJRGA and its members under this Agreement shall be the entire contribution of the SJRGA, its members, and the agencies comprising any of its members to the implementation of the San Joaquin River Portion of the 1995 WQCP.

2.1.4 For the term of this Agreement, subject to qualifications and limitations set forth herein, the State Water Project/Central Valley Project (CVP/SWP) Export Interests agree to operational constraints and export targets as specified in Paragraph 6.4.

2.1.5 As set forth in paragraph 7.1, a fish barrier at the head of Old River will be installed and operated by the CDWR.

2.2 On December 15, 1994, the federal government, the State of California, and urban, agricultural and environmental interests reached agreement on a comprehensive, coordinated package of actions designed to provide interim protection to the San Francisco Bay and Sacramento-San Joaquin River Delta Estuary. That agreement is referred to as the 1994 Bay-Delta Accord, which was recently extended to December 15, 1998.

2.3 Many of the coordinated package of actions agreed upon in the 1994 Bay-Delta Accord were adopted by the SWRCB in the WQCP adopted as 95-1WR by SWRCB Resolution No. 95-24 on May 22, 1995.

2.4 A San Joaquin River flow and SWP/CVP export study framework was developed by Doctors Bruce Herbold and Chuck Hanson. From that study framework, a collaborative effort of scientists from state and federal agencies and stakeholder groups developed the Vernalis Adaptive Management Plan (VAMP) to gather better scientific fisheries information on the lower San Joaquin River. The VAMP study referred to in this Agreement is attached as Exhibit A to this Agreement. When the VAMP study is joined with the other provisions of this Agreement, they are intended to provide environmental benefits in the lower San Joaquin River and Delta, at a level of protection equivalent to the San Joaquin River Portion of the 1995 WQCP for the duration of this Agreement.

2.5 This San Joaquin River Agreement is intended to achieve three primary objectives:

2.5.1 Implement protective measures for San Joaquin River fall-run chinook salmon within the framework of a carefully designed management and study program which is designed to achieve, in conjunction with other non-VAMP measures, a doubling of natural salmon production by improving smolt survival through the Delta. However, the Parties recognize that future salmon production cannot be guaranteed.

2.5.2 Gather scientific information on the relative effects of flows in the lower San Joaquin River, CVP and SWP export pumping rates, and operation of a fish barrier at the head of Old River on the survival and passage of salmon smolts through the Delta.

2.5.3 Provide environmental benefits in the lower San Joaquin River and Delta at a level of protection equivalent to the San Joaquin River Portion of the 1995 WQCP for the duration of this Agreement.

2.6 The 1994 Bay-Delta Accord and the VAMP study require the construction of an operable fish barrier at the head of Old River. Construction and operation of an operable Old River barrier may also require the construction of additional barriers in the south Delta to mitigate impacts of the Old River fish barrier, CVP/SWP export pumping, and other factors affecting water quality and water elevation concerns raised by in-Delta agencies. Fish barrier installation is being addressed in separate proceedings pursuant to state and federal law.

2.7 The VAMP study includes experimental operating conditions including San Joaquin River flow rates, limitations on pumping rates at the SWP and CVP export pumps located in the southern Delta, and fish barrier operations during a 31-day period during the months of April and May, beginning in 1999.

2.8 The VAMP study does not evaluate, and is not designed to control for, other factors which may be limiting fishery populations. These other factors may be material, and their effects may therefore impact the results of the VAMP study. Additional studies during the course of the VAMP study may be necessary to understand the extent to which other factors may have adverse effects on fishery populations. This Agreement imposes no obligation on the parties hereto to participate in these additional studies.

2.9 During the term of this Agreement, flow and non-flow actions, besides those provided for in the VAMP study, may take place within the San Joaquin basin to improve conditions for fisheries. These actions include but are not limited to programs under the Central Valley Project Improvement Act (CVPIA), the San Joaquin River Management Program, the "Four Pumps Agreement", and the Federal Energy Regulatory Commission (FERC) Settlement Agreement" on the Tuolumne River. It is further anticipated that projects will be undertaken pursuant to the "Category 3" Program, Proposition 204 funding, and the CALFED solution for the Bay-Delta Estuary. These additional programs will not affect the Parties' obligations under this Agreement, and this Agreement will not affect the Parties' participation in any such additional programs.

2.10 In addition to the fall-run Chinook salmon, there are other species of concern which may migrate through or reside in the Delta, some of which may be present in or reside in the San Joaquin River basin. The Agreement is also intended to provide benefits to various aquatic species other than salmon through the actions set forth herein. While the VAMP study is not directed to those other species, many of them may benefit from the flows provided by the VAMP study and other flow and non-flow actions to be taken.

2.11 Various San Joaquin River basin water users, the CVP/SWP export interests and others have already incurred monetary and water costs pursuant to state or federal proceedings or agreements as contributions toward the improvement of fishery populations in the San Joaquin River basin.

2.12 The Parties intend that implementation of the VAMP study not directly cause violations of the Vernalis salinity standard or violate water rights of any downstream water rights holder.

2.13 The Parties recognize that the State Board may be petitioned to review the water quality objectives established in the 1995 WQCP and the Board's order implementing the Plan as part of the triennial review process under the federal Clean Water Act.

3.0 Definitions

3.1 "San Joaquin River Agreement" - this Agreement.

3.2 "Existing Flow" - 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, but not limited to the following:

(a) tributary minimum in stream flows pursuant to Davis-Grunsky, FERC, or other regulatory agency orders existing on the date of this Agreement;

(b) water quality or scheduled fishery releases from New Melones Reservoir, and as provided in Paragraph 5.4;

(c) flood control releases from any non-Federal storage facility required to be made during the Pulse Flow Period pursuant to its operating protocol with the U.S. Army Corps of Engineers in effect when this Agreement is executed;

(d) uncontrolled spills not otherwise recaptured pursuant to water right accretions (less natural depletions) to the system; and/or, (e) local runoff.

3.3 "Pulse Flow Period" - A period of 31 days during the months of April and May as established by the SJRTC.

3.4 "San Joaquin River Portion" - The segments of the 1995 WQCP relating to flow at Vernalis, specifically: (1) River Flows/San Joaquin River at Airport Way Bridge, Vernalis p 19; (2) San Joaquin River Salinity p. 18, (3) Southern Delta/San Joaquin River at Airport Way Bridge, Vernalis; and (4) the San Joaquin River basin share of all Delta outflow objectives.

3.5 "SJRTC" - The San Joaquin River Technical Committee described in Section 11.

3.7 "VAMP Implementation Plan" or "Implementation Plan" - The Planning and Operation Coordination for the Vernalis Operation

3.8 "60-20-20 Indicator" - The numeric adjunct to the SWRCB's San Joaquin Valley Water Year Hydrologic Classification used in this Agreement to establish Target Flows and certain responsibilities of the parties. Unless otherwise agreed, the most current Department of Water Resources forecast of the San Joaquin Valley Water Hydrologic Classification will be used for the then current year. The 60-20-20 indicator for the VAMP is as follows:

SJR Basin 60-20-20 Classification
60-20-20 Indicator:
(Wet-5), (Above Normal-4),(Below Normal-3),
(Dry-2), (Critical-1)

4.0 Term of Agreement

This Agreement shall terminate on December 31, 2009, unless extended pursuant to Paragraph 5.1, or terminated earlier pursuant to Section 13.

5.0 Obligations of SJRGA and its Members

5.1 Water To Be Provided For VAMP By SJRGA's Members. The SJRGA's members shall provide, during each Pulse Flow Period, the amount of water needed to achieve the Target Flow described herein, or 110,000 acre-feet, whichever is less except in years when extraordinary events such as facilities failure or flood make the provision of such water impossible. At the option of the DOI Parties, the term of this Agreement may be extended so that the SJRGA's members shall provide water during the Pulse Flow Period in years beyond the initial term of this Agreement needed to meet Target Flows that were not met due to impossibility. Water provided by the SJRGA's members shall be determined as the sum of waters released, in excess of Existing Flow, to implement this Agreement to achieve Target Flows. Water provided by a SJRGA member shall be measured at that member's last points of control.

5.2 SJRGA Discretion. The SJRGA shall have discretion as to the method by which its members' water will be made available, but the SJRGA shall coordinate its water release planning with the USFWS and the CDFG by way of the SJRTC. The timing and amount of flow made available shall nevertheless be sufficient to meet the Parties' obligations.

5.3 Sequential Dry-Year Relaxation. During years when the sum of the current year's 60-20-20 indicator and the previous two years' 60-20-20 indicator is four (4) or less, the SJRGA's members will not be required to provide water above Existing Flow. The USBR has continuing obligations to meet San Joaquin River flows pursuant to the March 6, 1995 Biological Opinion.

5.4 Contingent Upon New Melones Operations. The risk assumed by the SJRGA's members to provide water for the VAMP is based on the assumption that the Stanislaus River will be operated consistent with USBR's Interim Plan of Operation, dated May 1, 1997. The Stanislaus River is assumed to be operated as simulated by USBR's spreadsheet model "STANMOD" which simulates the Interim Plan of Operation during the 1922-1992 hydrologic period. Critical to the amount of water provided by the SJRGA's members are the annual water allocations of the Interim Plan of Operation and the distribution of the fishery releases during the Pulse Flow Period. The Parties acknowledge, however, that the current operation of New Melones Reservoir will be superseded by the long-term Plan of Operation currently being developed through the New Melones Stakeholders Process, and which may differ from the USBR's Interim Plan of Operation. Until the long-term plan is developed, however, the USBR agrees to operate the New Melones Reservoir consistent with the Interim Plan of Operations. In the event that, under the interim or long-term plan, flows from New Melones during the Target Flow period are less than those assumed, the water provided by the SJRGA's members shall be determined as if such flows occurred. If the New Melones flows are higher, then the Management Committee shall manage the additional flows based on the recommendation of the SJRTC.

5.5 Single-step Target Flow. Unless established otherwise pursuant to Paragraph 5.6, the 31-day out-migration Target Flow equals:

EXISTING FLOW (cfs)	TARGET FLOW (cfs)
0-1,999	2,000
2,000-3,199	3,200
3,200-4,449	4,450
4,450-5,699	5,700
5,700-6,999	7,000
7,000 or greater	Existing flow

When the Target Flow is 2000 cfs, the USBR will act, pursuant to Section 8, to purchase additional water necessary to fulfill the Vernalis flow requirements of existing biological opinions. When Existing Flow exceeds 7,000 cfs, the Parties will exert their best efforts to maintain a stable flow rate during the Pulse Flow Period to the extent reasonably possible. Target Flows shall be provided in accordance with the Implementation Plan.

5.6 Double-step. In any year when the sum of the current year's 60-20-20 Indicator and previous year's 60-20-20 Indicator is seven (7) or greater, an annual 31-day out-migration flow target will be the Target Flow one level higher than that established by the single-step Target Flow described in Section 5.5. If achieving the double-step Target Flows requires more water than the 110,000 acre feet of water provided by the SJRGA's members, the USBR will act, pursuant to Section 8, to acquire additional water required to achieve the double-step Target Flow.

6.0 Obligations of DOI and California Resources Agency Parties

6.1 Payment. An annual payment of four million dollars ($4,000,000) (three million dollars ($3,000,000) from the USBR to be paid from CVPIA Restoration Fund or other sources, as available; and one million dollars ($1,000,000) from CDWR as part of its CVPIA cost share or from other vailable sources, not including funds derived from SWP contractor payments),

escalated annually each January to reflect the CPI-U index, shall be made by USBR to the SJRGA, so long as SJRGA and its members perform under the terms of this Agreement. The USBR will draw first upon funds not designated for environmental purposes to the extent the right to support or oppose the use of the funds for any particular project. The funds paid to the SJRGA are intended to be substantially used to enhance efficient water management within the districts including, but not limited to water reclamation, conservation, conjunctive use, and system improvements. Use of these funds by public agencies will be documented in each agency's annual financial audit report. Payments made under this Agreement shall not be included in water rates charged by USBR or CDWR and shall not become a recoverable cost charged to any USBR or CDWR contractors. Provided, that nothing herein precludes the use of the CVPIA Restoration Fund for implementation of this Agreement. No additional payment will be required if this Agreement is extended pursuant to Paragraph 5.1. The maximum payment to be made to the SJRGA for the purposes of Paragraph 5.1 of this Agreement is $48,000,000 (December 1997 price levels).

6.2 Contingent on Appropriations. The expenditure or advance of any money or the performance of any obligation of the DOI Parties under this Agreement shall be contingent upon appropriation or allotment of funds. No liability shall accrue to the DOI and CDWR Parties in case funds are not appropriated or allotted.

6.3 Consequence of No Payment. Notwithstanding Paragraph 6.2, in any year that the required payment is not made to the SJRGA by April 1 of that year, no contributions to the VAMP Target Flows by the SJRGA will be required.

6.4 Operational Constraints and Export Targets. Except as provided in Paragraph 11.5, the CVP and SWP shall limit their exports during the Pulse Flow Period as follows:

Vernalis Target Flows (cfs)

	2,000	3,2000	4,450	5,700	7,000
Exports					
1500	●	●	●		●
2250				●	
3000					●

The Parties agree that the export limits established in this Agreement are consistent with the existing biological opinions. In circumstances where the limits in this paragraph do not apply, the USBR and CDWR will operate their respective pumping plants in compliance with any applicable provisions of then existing water quality control plans, then existing biological opinions, the 1994 Bay-Delta Accord, and any other requirements then in effect

6.5 Other Flow Conditions. The parties recognize that there will be years during the term of this agreement when the Existing flows will be greater than 7,000 cfs during the Pulse Flow Period and that in such years the Old River Barrier will not be in place or operated and that it may not be possible to maintain a constant flow rate at Vernalis. The DOI Parties believe, however, that there will be value in studying the relationship between flows and export rates on salmon smolt survival during such high flow events. When such a high flow event is forecasted, the SJRTC shall attempt to develop a plan pursuant to which those studies will be conducted under this Agreement and report its recommendation to the Management Committee. In the event the SJRTC is unable to develop a plan or if the plan is rejected by the Management Committee, the DOI Parties will conduct any such studies outside of this Agreement pursuant to applicable authority, if any. If such studies are conducted during the term of this Agreement, whether or not under this Agreement, the monitoring will be carried out and the costs of monitoring will be shared pursuant to Paragraph 9.1 of this Agreement. An inability to develop an operations plan under this Agreement when the flow conditions are greater than 7,000 cfs shall not invoke Paragraph 6.7.

6.6 Operations Plan. By February 15 of each year of this Agreement, the USBR and CDWR shall develop, in cooperation with the SJRTC, an operations plan that will describe how the VAMP will be implemented in that year. If the USBR, CDWR and the SJRTC do not complete an acceptable operations plan by February 15, or if by March 1, any party objects to the

operations plan, then the Parties will be notified and will meet to identify and resolve outstanding issues related to that year's operations plan. If the matter remains unresolved on April 10, the provisions of Paragraph 13.4 will be invoked.

6.7 Export Reductions Caused by the VAMP. If, on April 10, or 5 days before the Pulse Flow Period, the operations plan for that year is unacceptable to any Party, then the export limitations contained in Paragraph 6.4 shall not apply during that calendar year. This Paragraph 6.7, however, shall not limit or constrain the USBR or the CDWR in the operation of their respective project. When any Party objects to the operations plan developed as described in Paragraph 6.6, the Party objecting to the operations plan will be deemed to have invoked the provisions of Paragraph 13.2 as of April 10. All other provisions of this Agreement, particularly related to flows at Vernalis, shall remain in effect.

6.8 Old River Fish Barrier. CDWR shall install and operate a fish barrier at the head of Old River in a manner that will protect San Joaquin River chinook salmon smolts and in conjunction with the flows provided during the Pulse Flow Period. Until such time as a permanent barrier is constructed, a temporary barrier shall be installed each year, except in years when flood flows would prevent installation. Any negative impacts associated with the fish barrier at the head of Old River shall be mitigated consistent with CEQA, NEPA and ESA by the state and federal entities that are responsible for its construction. Design and operation of the barrier will be consistent with existing relevant biological opinions.

6.9 No Recirculation Obligation. Nothing in this Agreement shall obligate the DOI Parties to implement a plan under which water appropriated via the Delta Mendota Canal is released into the San Joaquin River to meet the objectives of the 1995 WQCP.

7.0 Conditions

The Parties' obligations under this Agreement are conditioned upon the entry by the California State Water Resources Control Board (SWRCB) of an order:

(1) finding that the terms

of this Agreement provide environmental protection at a level of protection equivalent to the Vernalis flow objectives of 1995 WQCP during the Pulse Flow Period and implementation of the remaining San Joaquin River Portion of the 1995 WQCP for the duration of this Agreement;

(2) committing to expedited issuance of notice and timely completion of appropriate hearings if objection to the operations plan described in Paragraph 6.6 are unresolved after April 10, or this Agreement should terminate;

(3) enforcing the obligations of the USBR and CDWR under this Agreement; (4) committing to the enforcement of Water Code Section 1707, through Water Code Sections 1725, 1435 or similar protection by prohibiting (a) unauthorized diversions of any portion of the flows provided by the SJRGA's members pursuant to this Agreement until they pass Vernalis; and, (b) unauthorized diversions of any Existing Flow between SJRGA members' last point of control and Vernalis; and, (5) adding appropriate changes to permits held by those SJRGA's members that have an obligation to provide water as needed to permit them to comply with the obligations imposed by this Agreement.

8.0 Purchase of Additional Water

8.1 Willing Sellers. Water for in-stream uses in excess of that required to be provided by the SJRGA's members under this Agreement may be purchased from willing sellers by the USBR.

8.2 Good Faith Efforts. The SJRGA and its members understand the importance of achieving needed data points as a part of the VAMP, and have pledged to work in good faith to make available additional amounts of water which may be purchased by the USBR on a willing seller/willing buyer basis for the limited purpose of increasing flows when necessary to obtain reasonably achievable additional data points; and to reach flows sufficient to reach the "Double-Step" data points described in Paragraph 5.6 and identified in the Implementation Plan. The parties understand that the SJRGA and its members cannot ensure that a market will be available at any specific time for the purchase of additional water because the SJRGA and its members cannot control market forces, hydrologic conditions, or other factors affecting the availability of marketable water.

8.3 Identification of Additional Available Water. Without in any way altering the obligations of SJRGA's members under Paragraphs 8.1 and 8.2, on or before March 1 of each year during the term of this Agreement, the SJRGA's members will meet and confer with the SJRTC for the purpose of identifying water which may be available for purchase by the USBR . The SJRGA and its members will use their best efforts to identify all water that is or will become available for sale to the USBR which could be utilized to meet the purposes of this Agreement and for USBR's compliance with the San Joaquin River Portion of the 1995 WQCP or its successor.

8.4 Additional Water from Merced. Merced Irrigation District shall provide, and the USBR shall purchase 12,500 acre feet of water above the Existing Flow delivered at the last point of control for release to the Merced River during October of all years. Such water releases shall be scheduled by Merced Irrigation District, CDFG and USFWS. The USBR shall pay Merced Irrigation District, within 30 days of invoice, as follows:

8.4.1 If the water is released from storage, the USBR shall pay $60.00 per acre foot ($75 per acre-foot for years in which the provisions of Section 5.3 are in effect);

8.4.2 If the water provided is re-operated flood-control releases the USBR shall pay $15.00 per acre foot;

8.4.3 These payments shall be increased annually by the same factor set forth in Paragraph 6.1;

8.4.4 Water purchased pursuant to this Paragraph 8.4 may be scheduled for months other than October provided Merced, CDFG, and USFWS all agree.

8.5 Additional Water From Oakdale. Oakdale Irrigation District shall sell 15,000 acre-feet of water to the USBR in every year of this Agreement. The price for this water will be $60 per acre-foot ($75 per acre-foot for years in which the provisions of Paragraph 5.3 are in effect). 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. The price for this water will be $60 per acre-foot ($75 per acre-foot for years in which the provisions of Paragraph 5.3 are in effect). It will be made available at New Melones during any month of the year as required by the USBR, and may be used for any authorized purpose of the New Melones project.

8.6 Favored Purchaser. From the date of the meeting specified in Paragraph 8.3 through the end of that year's Pulse Flow Period, a SJRGA member will not sell water, for delivery solely during the Pulse Flow Period, to a party other than the USBR at a price lower than that offered to the USBR for additional water for that year's Pulse Flow Period. This limitation on sale of water during the Pulse Flow Period does not include water needed by SJRGA's members for in-district needs; district obligations and/or operations which exist on the effective date of this Agreement; and water transfer arrangements at any price that post date this Agreement where water is transferred over a period of time that extends beyond the Pulse Flow Period. For Example: Water transferred from an SJRGA member at $45 an acre foot is to be delivered to an adjacent agricultural water agency during the period April 1 to October 31. This will not violate USBR's Favored Purchaser status during the Pulse Flow period even if the price offered by USBR for Favored Purchaser water is $55 per acre foot.

8.7 The USBR's status as Favored Purchaser pursuant to Paragraph 8.6 is intended to assure the USBR that, without in any way altering the obligations of the SJRGA's members under Paragraphs 8.1 and 8.2, they will (1) use their best efforts to identify sources of water to the extent requested by the USBR ; (2) immediately notify the USBR upon becoming aware that water from willing sellers is available for sale to the USBR for use during that year's Pulse Flow Period; and, (3) not sell water that is to be delivered solely during the Pulse Flow Period at a price less than that offered to the USBR for additional water for that year's Pulse Flow Period. The USBR's status as Favored Purchaser pursuant to Paragraph 8.6 is not intended to grant a right of first refusal to the USBR over all water available for sale from SJRGA's members during, or outside the Pulse Flow Period.

9.0 Monitoring

9.1 Costs. Monitoring of fishery responses to the Target Flows is an essential component of the VAMP. The SJRTC will lead the monitoring efforts. The USBR, USFWS, CDWR and CDFG will pay half of the monitoring costs. The SJRGA, CCSF and CVP/SWP Export Interests will pay for the other half of the monitoring costs. Payments made by the DOI and California Resources Agency Parties under this Agreement shall not be included in water rates charged by USBR or CDWR and shall not become a recoverable cost charged to any USBR or CDWR contractors. Provided, that nothing herein precludes the use of the CVPIA Restoration Fund for implementation of this Agreement. The SJRGA, CCSF and CVP/SWP Export Interests will equally share their portion of monitoring costs. The SJRGA and its members, CCSF, CVP/SWP, USBR, USFWS, CDWR and CDFG will be credited for any in-kind expenses incurred in conjunction with this monitoring, and those costs incurred to support the operation of the SJRTC.

9.2 Access to Data. The Parties shall exchange all data acquired through monitoring pursuant to this Agreement. All such data shall be available to the public.

9.3 Review By IEP. The Interagency Ecological Program shall be requested to prepare an annual report on the monitoring programs in the San Joaquin River basin, including the VAMP study and any other studies relating to limiting factors.

10.0 Petition to SWRCB

10.1 Adoption of VAMP by SWRCB. All Parties shall jointly petition, prior to April 1, 1998, the SWRCB to adopt this Agreement and to implement this Agreement through an appropriate SWRCB order. The petition to adopt this Agreement will not seek to change the 1995 WQCP objectives. The petition shall make the following representations to the SWRCB:

10.1.1 In order to achieve the purposes of this Agreement, the USBR shall assume responsibility, for the term of this Agreement, for the San Joaquin River Portion of the 1995 WQCP objectives that can reasonably be met through flow measures. If this Agreement is terminated pursuant to Section 13, the USBR will operate its project in compliance with then applicable provisions of the then existing water quality control plans, then existing biological opinions, the 1994 Bay-Delta Accord and any other requirements then in effect. The requirements of this Paragraph 10.1.1 shall survive the termination of this Agreement for the shorter of two years or until the SWRCB issues a final order implementing the San Joaquin River Portion of the 1995 WQCP.

10.1.2 In order to achieve the purposes of this Agreement, the USBR and, as appropriate, the CDWR shall assume responsibility, for the term of this Agreement, for the San Joaquin River basin share of the "Delta Outflow" objectives of the 1995 WQCP. If this Agreement is terminated pursuant to Section 13, the USBR and the CDWR will operate their respective projects in compliance with applicable provisions of the then existing water quality control plans, then existing biological opinions, the 1994 Bay-Delta Accord and any other requirements then in effect to achieve the San Joaquin River basin share of Delta Outflow. The requirements of this Paragraph 10.1.2 shall survive the termination of this Agreement for the shorter of two years or until the SWRCB issues a final order implementing the San Joaquin River Portion of the 1995 WQCP.

10.1.3 Except as provided in Section 12.1, water required under this Agreement shall be the contribution of the SJRGA, its members', and the agencies comprising any member of the SJRGA to assist the USBR and CDWR in meeting the 1995 WQCP objectives. The contribution by the SJRGA and its members to assist the USBR and CDWR in meeting the Target Flows shall be the entire contribution of the SJRGA, its members and the agencies comprising any of its members, for the implementation of the San Joaquin River Portion of the 1995 WQCP for the duration of this Agreement.

10.1.4 All NEPA and CEQA documentation shall be completed and all documents required by the SWRCB shall be submitted by the Parties by March 1, 1999.

10.2 Water Code section 1707. The petition to SWRCB shall include a Water Code section 1707 petition pursuant to Section 7.0 of this Agreement. The petition may also include requests for other changes to permit the Parties to carry out their obligations under this Agreement. The petition may be accompanied by the appropriate environmental documentation for adoption of the Agreement, or, if the SWRCB elects, it may include this Agreement as an alternative in its draft EIR for the implementation of the 1995 WQCP.

10.3 Implementation Matters. If the SWRCB fails to adopt and implement the VAMP under terms consistent with this Agreement, the Parties will cooperate to petition for a change in the SWRCB adoption or implementation. If the SWRCB does not change its adoption or implementation in a manner consistent with terms acceptable to the Parties to this Agreement, the Parties will work in good faith to negotiate a modification to this Agreement that will allow its continued implementation by the SWRCB. If that negotiation is not successful, any Party to the Agreement may withdraw from the Agreement and the remaining parties will continue to work in good faith to implement the VAMP.

10.4 Vernalis Hearing. The Parties shall ask the SWRCB to continue its hearing on the interim Vernalis flow objective specified in the 1995 WQCP. The hearing was specified in the 1994 Bay-Delta Accord and the 1995 WQCP, and is required under the Settlement For Dismissal of Action filed on September 25, 1996 in SJTA et al vs. SWRCB between the SWRCB and the San Joaquin River Tributaries Association. The Parties shall request that the SWRCB convene the hearing at such time as this Agreement is terminated.

10.5 Termination Requires Notice to SWRCB.In the event that this Agreement is terminated pursuant to Sections 13 or 16, the Parties agree to notify the SWRCB immediately of such termination

11.0 San Joaquin River Technical and Management Committees

11.1 SJRTC. The SJRTC will be an interagency effort to successfully implement the VAMP by undertaking the activities described in Paragraph 11.2 and other technical activities that its members deem appropriate to meet the goals of this Agreement. The SJRTC will report its findings and recommendations to the Management Committee. Each Party shall have the right to place one technical specialist on the SJRTC. The SJRTC may, on a unanimous vote, invite other technical specialists to join including representatives from local conservation organizations. In addition, the Management Committee shall appoint two other technical specialists to the SJRTC in order to provide an independent source of scientific review, and the resulting costs of such specialists shall be paid as provided in Section 9.1. The SJRTC shall make its decisions by consensus, which allows any Party representative to veto any decision or action by the SJRTC, provided that a recommendation by any member or invited technical specialist shall be forwarded to the Management Committee. Meetings of the SJRTC will be open, and materials freely available, to the public.

11.2 SJRTC Duties. The SJRTC will:

a. Annually coordinate flow releases, export and Old River barrier operations, and use of hatchery fish, to implement the VAMP study;b. Determine best management of flow releases during the Pulse Flow Period to achieve Target Flows; c. Plan and oversee monitoring activities, in coordination with the Interagency Ecological Program and existing monitoring programs on the San Joaquin tributaries. d. Develop annually the Existing Flow calculation protocols;The SJRTC shall have no authority to adjust any export limitations imposed pursuant to this Agreement or to adjust Target Flows below those set pursuant to this Agreement, but may recommend such changes to the Management Committee.

11.3 Exchange of Technical Information. The SJRTC members agree to exchange technical information. Representatives to the SJRTC shall be technical specialists in the field of engineering, hydrology or aquatic sciences. Any party may also send other representative(s) to SJRTC meetings.

11.4 Other Support. The SJRGA agrees to provide administrative, clerical, and support facilities for the SJRTC activities.

11.5 Management Committee. A Management Committee shall review the reports and recommendations of the SJRTC and resolve all issues and disputes that the SJRTC cannot resolve. The Management Committee may adjust the Target Flows and export limitations contained herein, and which adjustment shall be reported to interested parties and the SWRCB and implemented unless disapproved by the SWRCB within 10 days. The Management Committee shall include one representative from each signatory to this Agreement. The Management Committee shall make its decisions by unanimous vote, which allows any representative to veto any Management Committee decision or action.

11.6 Management Committee Disputes. If the Management Committee cannot achieve a unanimous vote to resolve an issue presented to it, the Parties agree to try in good faith, on a schedule that is expedited to meet the objectives of this Agreement, to resolve the issue by mediation as described in Section 14.0.

12.0 Additional Assurances

12.1 Flow Requirements. Other than those flow objectives established for the VAMP, neither (1) the members of the SJRGA, (2) any of the agencies comprising a member of the SJRGA, nor (3) the CCSF shall have, during the term of this Agreement, any other requirements for flow at Vernalis or the San Joaquin River Portion of the 1995 WQCP, nor will they have an obligation under the 1995 WQCP to mitigate the impacts on water quality resulting solely from any reduction in flows in the San Joaquin River or its tributaries. This Agreement shall not affect the responsibility of these parties to mitigate impacts on water quality resulting from discharges of waste into the San Joaquin River or its tributaries. Based on its modeling of Vernalis flow requirements, the USBR hereby provides assurance that they will pursue acquisition of additional water to comply with the San Joaquin River Portion of the 1995 WQCP, pursuant to Section 8 of this Agreement.

12.2 Habitat Conservation Plan. The USFWS and/or CDFG will assist the Parties in the development of a Habitat Conservation Plan, NCCP or other appropriate plan, at the request of any Party.

13.0 Termination

13.1 Withdrawal By San Joaquin River Group Parties. Any action which materially impairs, reduces or otherwise adversely affects the water supply used or relied upon by (a) any member of the SJRGA; (b) any of the agencies comprising a member of the SJRGA; or (c) the CCSF will be grounds for that Party's withdrawal from this Agreement, provided the remaining Parties can still satisfy this Agreement's requirements for water.

13.2 Re-negotiation; Termination. It is the intent of all parties that this Agreement is to be re-negotiated and/or terminated, as appropriate, in the event of changes to the basic water supply, water rights, assumptions, facts or circumstances upon which this Agreement is based, including without limitation breach of Section 6.8 or a dispute under Paragraph 6.7.

13.2.1 Initiating Conditions. The re-negotiation/termination provisions of Paragraphs 13.1 and 13.2 will take effect when:

13.2.1.1 there is a material change to the basic water supply, water rights, assumptions, facts or circumstances upon which this Agreement is based.

13.2.1.2 a dispute arises concerning the operations plan as described in Paragraphs 6.6 and 6.7, or a dispute arises concerning the barrier at the head of Old River as described in Paragraph 6.8.

13.2.1.3 a change in condition causes a material adverse impact on any Party's or Party's member agency's (a) water deliveries to its customers; (b) water deliveries for obligations existing when this Agreement is executed; or (c) ability to perform under this Agreement. If the change in condition only requires the release of additional water by the Party currently providing water for in stream use during the Pulse Flow Period, then this Section will not take effect provided the additional water is credited toward and does not exceed the water this Agreement requires from the SJRGA and its members.

13.2.1.4 in any year the Target Flows are not achieved except when the term of this Agreement is extended by an additional year as provided in Paragraph 5.1 with payment limited as provided in Paragraph 6.1.

13.2.1.5 when, in the judgment of the USFWS, CDFG or National Marine Fisheries Service, continuation of the VAMP study is likely to jeopardize the survival or recovery of (a) any species listed, or which is a candidate for listing, under the ESA and/or CESA or (b) any species covered by an HCP or NCCP.

13.2.1.6 in any year that federal appropriations for the CVPIA Restoration Fund intended to provide payment under Paragraph 6.1 fall below $20 million.

13.2.2 Process. A Party may call for mediation in accordance with Section 14.0 to assist in the re-negotiation of this Agreement to solve the problem presented or the change in condition. A meeting of the principals of each Party will occur within 30 days of receipt of written notice to all Parties and to the SWRCB of the particular problem presented, the change in condition and the effect on the Party or the Party's member agency. The Parties will use their best efforts to re-negotiate this Agreement and resolve the problem presented.

13.2.3 Outcome. If mediation is not successful and the Parties cannot agree on how to resolve the problem within 90 days of the notice, then they may agree to terminate this Agreement immediately. If the Parties lack consensus on resolution or termination, then this Agreement terminates as of the following March 1.

13.3 Termination For Breach. If the USBR fails to pay the SJRGA as required by Paragraph 6.1, then, after a 60-day notice to cure default has been given to the USBR, the SJRGA may terminate this Agreement. If the SJRGA and its members fail to perform their obligations under this Agreement, then the USBR or the CDWR may terminate this Agreement and, except where the failure to perform is based on impossibility as described in Paragraph 5.1, require the SJRGA to pay back the money the USBR paid for the year that SJRGA and its members failed to meet their obligations.

13.4 Notice of Termination or Likelihood of Termination to SWRCB. If objection has been made by a Party to the operations plan described in Paragraph 6.6, or there has been termination of this Agreement, or after 90 days of re-negotiation without resolution as provided in Section 13.2, the Parties shall promptly advise the SWRCB.

14.0 Mediation

14.1 Resolution of Disputes. Resolution of disputes, and issues which a Party believes may subject this Agreement to Termination, shall first be submitted to a mediator, mutually selected by the Parties, with experience in water-related disputes. The Parties shall request of the SWRCB, in the order it issues pursuant to Section 10, to appoint the SWRCB Executive Director as mediator, without cost to the Parties, for Management Committee disputes on issues critical to meeting Target Flows during the Pulse Flow Period. The Parties will use their best efforts to resolve the issues within 48 hours.

14.2 Resolution of Non-Critical Issues. Mediation of issues that are not critical to meeting Target Flows during the Pulse Flow Period shall be on the same schedule as the process described in Paragraphs 13.2.2 and 13.2.3.

14.3 Mediation Costs. Mediation costs shall be divided as follows: 50% paid by the Party or Parties asserting a veto and 50% by the remaining Party or Parties. Provided that, the environmental community parties shall not be responsible for mediation costs if a veto is asserted by any other party. Provided, further that the environmental community parties shall not be responsible for mediation costs in excess of $2,000 if a veto is asserted solely by environmental community parties. In this event, mediation costs in excess of $2,000 shall be paid 50% by the DOI and California Resources Agency Parties, and 50% by the SJRGA, CCSF, and CVP/SWP Parties, share and share alike. If mediation is not completed during the specified time schedule, then issues within the existing jurisdiction of any state or federal agency shall be submitted to such agency. This section shall not be construed to expand or limit in any way the jurisdiction of any state or federal agency.

15.0 Effect of this Agreement on Other Matters

15.1 As a Precedent. Nothing in this Agreement, and nothing incorporated by reference into the terms of this Agreement, is intended or shall be construed as a precedent or other basis for any argument that the participants to this Agreement have waived or compromised their rights which may be available under state or federal law except as to the matters addressed in this Agreement.

15.2 As an Admission. Nothing in this Agreement shall be construed as an admission by any Party that such Party has obligations relative to the protection of fishery or other resources and/or the maintenance of water quality standards in the Delta. Similarly, nothing in this Agreement shall be construed or used in an effort to demonstrate that any of the Parties has surplus water or water which is not being beneficially used by such Party.

15.3 As to Jurisdiction of SWRCB. Nothing contained in this Agreement shall constitute the acknowledgment by a Party of any jurisdiction of the SWRCB over the Party outside the terms of this Agreement or SWRCB implementation of the VAMP, nor does participation in this Agreement waive any defenses that a Party may have concerning the SWRCB's jurisdiction. Further, participation in this Agreement shall not, in and of itself, give rise to SWRCB jurisdiction over the Parties for matters not expressly stated in this Agreement.

15.4 As Compromise of Disputed Claims. It is understood and agreed that this Agreement is the result of a good faith compromise settlement of disputed claims regarding the obligations of Parties to provide water required to implement the 1995 WQCP, and that this Agreement shall not be taken or construed to be an admission of any obligation or responsibility to provide that water. Each of the Parties hereto is entering into this Agreement to avoid the expense, disruption and uncertainty of a contested water right proceeding before SWRCB and the courts.

16.0 No Intended Use of Friant Water

16.1 Pursuant to this Agreement, the USBR has contractually undertaken certain obligations relative to the provision of San Joaquin River water and the implementation of the San Joaquin River Portion of the 1995 WQCP, including without limitation the obligations described in Paragraphs 5.3, 10.1.1, 10.1.2. and 12.3. The Parties do not intend that these obligations of the USBR shall be satisfied using water released for that purpose from Friant Dam or which is otherwise intended for use within the Friant Division of the Central Valley Project, other than water acquired from willing sellers.

16.2 In furtherance of that intent, if the USBR satisfies any of its obligations under this Agreement using water released from Friant Dam for that purpose, or which is otherwise intended for use within the Friant Division, other than water acquired from willing sellers, this Agreement shall immediately terminate upon written notice from the Friant Water Users Authority to the other Parties notwithstanding the provisions of Section 13 or any other provisions of this Agreement.

16.3 Upon such termination, for the intended term of this Agreement none of the other Parties shall enter into an agreement intended to accomplish the purposes of this Agreement as set forth in Section 2 without the participation and agreement of the Friant Water Users Authority; Provided, that nothing in this Paragraph 16.3 shall preclude the USBR from acquiring water from willing sellers.

16.4 Nothing in this Agreement is intended to alter the positions of any Party in Natural Resources Defense Council, et al vs. Patterson, et al. or other pending judicial proceedings.

17.0 Specific Performance

So long as the USBR and CDWR have made the payments to the SJRGA required by this Agreement, the refusal by the SJRGA or its members to provide the water required by this Agreement shall entitle a Party to an order of specific performance in a manner which gives effect to the goals of the VAMP and this Agreement.

The Sacramento-San Joaquin Delta

18.0 Representation By Counsel

This Agreement is entered into freely and voluntarily. The parties hereto acknowledge that they have been represented by counsel of their own choice, or that they have had the opportunity to consult with counsel of their own choosing, in the negotiations that preceded the execution of this Agreement and in connection with the preparation and execution of this Agreement. Each of the parties hereto executes this Agreement with full knowledge of its significance and with the express intent of effecting its legal consequences.

19.0 Entire Agreement

This Agreement constitutes the entire Agreement between the parties pertaining to the settlement of disputes and obligations between them with respect to obligations under the 1995 WQCP. This Agreement supersedes all prior and contemporaneous agreements and/or obligations concerning those obligations which are merged into this Agreement. Each party has made its own independent investigation of the matters settled, has been advised concerning the terms of this agreement by counsel of its choice or has had an opportunity to be so advised, and is not relying upon any representation not specified herein.

20.0 Applicable Law

This Agreement shall be construed under and shall be deemed to be governed by the laws of the State of California and of the United States, without giving effect to any principles of conflicts of law if such principles would operate to construe this Agreement under the laws of any other jurisdiction.

21.0 Construction of Agreement

This Agreement is the product of negotiation and preparation by and among each party hereto and its attorneys. Therefore, the parties acknowledge and agree that this Agreement shall not be deemed to have been prepared or drafted by any one party or another. Accordingly, the normal rule of construction to the effect that any ambiguities are to be resolved against the drafting party shall not be employed in the interpretation of this Agreement.

22.0 Modification of Agreement

No supplement, modification, waiver, or amendment with respect to this Agreement shall be binding unless executed in writing by the party against whom enforcement of such supplement, modification, waiver or amendment is sought.

18.0 Representation By Counsel

This Agreement is entered into freely and voluntarily. The parties hereto acknowledge that they have been represented by counsel of their own choice, or that they have had the opportunity to consult with counsel of their own choosing, in the negotiations that preceded the execution of this Agreement and in connection with the preparation and execution of this Agreement. Each of the parties hereto executes this Agreement with full knowledge of its significance and with the express intent of effecting its legal consequences.

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22.0 Modification of Agreement

No supplement, modification, waiver, or amendment with respect to this Agreement shall be binding unless executed in writing by the party against whom enforcement of such supplement, modification, waiver or amendment is sought.

23.0 Counterparts of Agreement

This Agreement may be signed in any number of counterparts by the parties hereto, each of which shall be deemed to be an original, and all of which together shall be deemed one and the same instrument. This Agreement, if executed in counterparts, shall be valid and binding on a party as if fully executed all on one copy.

24.0 Signatories' Authority

The signatories to this Agreement on behalf of all of the parties hereto warrant and represent that they have authority to execute this Agreement and to bind the parties on whose behalf they execute this Agreement.

25.0 Reasonable Cooperation

The parties hereto shall reasonably cooperate with each other, including the execution of all necessary further documents, if any, to carry out the purpose and intent of this Agreement.

26.0 Effective Date

The parties hereto deem this Agreement to be signed and of binding legal effect as of the date on which the last signatory hereto signs the Agreement or March 1, 1999, whichever is earlier.

27.0 Notice to Parties

All notices required under or regarding this Agreement shall be made in writing addressed as provided in the Party address list attached hereto as Exhibit C.

28.0 Federal and State Agency Obligations

Nothing in this Agreement is intended to limit the authority of the DOI Parties or the California Resource Agency Parties to fulfill their responsibilities under federal or state law. Moreover, nothing in this Agreement is intended to limit or diminish the legal obligations and responsibilities of the DOI Parties or the California Resource Agency Parties.

Appendix A - Conceptual Framework for Protection and Experimental Determination of Juvenile Chinook Salmon Survival Within the Lower San Joaquin River in Response to River Flow and SWP/CVP Exports

Appendix B - Planning and Operation Coordination for the Vernalis Adaptive Management Plan.

Dated: 4/6/99 By: ______ Friant Water Users Authority

Dated: By: ______ Metropolitan Water District of Southern California

Dated: April 21, 2000 By: ______ Natural Heritage Institute

Dated: 4-5-99 By: ______ San Joaquin River Group Authority

Dated: 4-5-99 By: ______ Modesto Irrigation District

Dated: 4-5-99 By: ______ Turlock Irrigation District

Dated: 4/5/99 By: ______ Merced Irrigation District

Dated: 4-5-99 By: ______ South San Joaquin Irrigation District

Dated: 4-5-99 By: ______ Oakdale Irrigation District

Dated: 4-8-99 By: ______ San Joaquin River Exchange Contractors Water Authority

Dated: 4-8-99 By: ______ Central California Irrigation District

Dated: 4-9-99 By: ______ Firebaugh Canal Water District

Dated: 4/8/99 By: ______ Columbia Canal Company

Dated: 4-8-99 By: ______ San Luis Canal Company

Dated: April 12, 1999 By: ______ United States Bureau of Reclamation

Dated: 7/30/99 By: ______ United States Fish and Wildlife Service

Dated: 3/28/00 By: ______ California Department of Water Resources

Dated: 3/28/00 By: ______ California Department of Fish and Game

Dated: 10/27/00 By: ______ Public Utilities Commission of the of the City and County of San Francisco

Dated: 4/6/99 By: ______ Friant Water Users Authority

Dated: 11/21/00 By: ______ State Water Contractors

Appendix A

Conceptual Framework for Protection and Experimental Determination of Juvenile Chinook Salmon Survival Within the Lower San Joaquin River in Response to River Flow and SWP/CVP Exports

March 20, 1998

Introduction

San Joaquin River flows and State and Central Valley Water Project (SWP/CVP) exports are commonly believed to affect survival of juvenile fall-run Chinook salmon emigrating from the San Joaquin River Basin. Experimental survival studies have provided valuable information and recent analyses have shown a significant relationship between San Joaquin River flow at Stockton and smolt survival through the delta. However, smolt survival studies have been performed at some, but not at all, intermediate flow and export rates specified in the 1995 WQCP, so the exact nature of the response of smolt survival to both export and flow are a subject of contention. Estimated survival rates for coded-wire tagged (CWT) juvenile Chinook salmon smolts have been low in recent years. Those low survival rates as smolts are generally mirrored in low rates of adult returns 2 1/2 years later so that improving survival through the delta is believed by many to be an essential part of restoring San Joaquin salmon runs. Aside from flow and export rate manipulations, installation of a barrier at the head of Old River has been identified by several parties as likely to improve the survival of downstream migrating salmon. Such a barrier is apt to alter the impacts of flow and export rates on smolt survival.

To restore fall-run Chinook salmon, efforts are being evaluated and implemented within the San Joaquin River tributaries to improve spawning and juvenile rearing habitat. However, achieving the doubling goals of the State's WQCP and the federal CVPIA will likely require improvements in tributary spawning reaches and rearing reaches of the tributaries and mainstem and during passage through the delta. This document proposes an adaptive management strategy to use current knowledge to provide a level of protection for smolt passage through the delta while gathering information to allow more efficient protection in the future.

Objectives

The proposed experimental program has been designed to:

(1) Implement protective measures for San Joaquin River fall-run Chinook salmon within the framework of a carefully designed management and study program which is designed to achieve, in conjunction with other non-VAMP measures, a doubling of natural salmon production by improving smolt survival through the Delta.

(2) Gather scientific information on the relative effects of flows in the lower San Joaquin River, CVP and SWP export pumping rates, and operation of a fish barrier at the head of Old River on the survival and passage of salmon smolts through the Delta. (3) Provide environmental benefits on the lower San Joaquin River during the April- May Pulse Flow Period at a level of protection equivalent to the Vernalis flow objectives of the 1995 WQCP and implement the remaining San Joaquin River Portion of the 1995 WQCP.

The design of this investigation has been based, in large part, on experience gained in earlier fisheries investigations and on expected opportunities for providing increased fisheries protection during the spring. Many parties have offered valuable contributions to the improvement of this document since its initial draft and all comments were considered in developing the present design. This investigation is designed to allow clearer interpretation of sampling results regarding specific questions about the impacts of different flow and export regimes on San Joaquin smolt passage through the delta. Additional sampling regimes are described which will provide more data and enable improved statistical analysis of the data. Because a permit for construction of a temporary barrier at the head of Old River has been approved for the next three years, such a barrier is assumed to be in place. A design for evaluating the value of such a barrier is included in this study design.

If smolt survival through the delta is affected by both flow and export rates, then various combinations of flow and export conditions could provide the same level of protection. However, current data do not allow confident quantification of the contribution of each variable to smolt survival. It is likely that flow and export impacts on salmon passage are different, they are probably non-linear, and they may often interact. For instance, reducing export rates by 1000 cfs may have a different impact on smolt passage than increasing river flow by 1000 cfs, the change in export impact of a reduction of 1000 cfs is probably different at high or low exports and at high or low levels of river flow. This proposal uses as wide a range of flows and exports as possible with the head of Old River in place to allow quantification of flow and export impacts while maintaining protection of outmigrant salmon smolts.

Recent studies by USFWS have used ratios of recapture to estimate absolute survival rates rather than the independent indices of survival. This study design will use such ratios to estimate survival rates. Absolute survival rates will allow quantification of the goals of smolt survival designed to help in doubling natural salmon production in the most efficient manner. With such goals, adaptive management will use early experimental results to alter later experimental targets.

By determining the nature of the response to each variable and how each contributes to salmon survival rates through the delta, this proposal aims to allow improved protection when the plan is revisited during future triennial reviews. This proposal has been developed with close coordination of the USFWS and their efforts to develop an Anadromous Fish Restoration Plan and with interested parties associated with water management on San Joaquin tributaries, with delta export operations, and with salmon restoration.

Test Conditions

Vernalis Adaptive Management Program (VAMP)

The WQCP specifies two different San Joaquin River flow rates within each water year type and holds export rates to no more than the total San Joaquin River flow. Since exports under the WQCP are a function of flow rates it would be impossible to assess their separate impacts on salmon passage. Under the USFWS Biological Opinion for delta smelt, the Bureau of Reclamation has developed an interim operating plan to attempt to meet the specified flow targets at Vernalis through their operations of New Melones reservoir. In its Biological Opinion, USFWS recognizes that there may be years the Vernalis flow targets are unlikely to be achieved through the operations of New Melones alone.

This plan does not use water year type explicitly. Instead, in each year when the existing flow at Vernalis is anticipated to be below 7,000 cfs on April 15, one of the following test conditions is used (Table 1). This matrix of flow and export (when combined with the variety of procedures to estimate smolt survival) is intended to assess impacts of flow at three levels of export and impacts of export at four levels of flow. The intermediate condition (D)permits estimation of the degree of curvature in response.

Choice of maximum flow level of 7000 results from the need to have flow rates in the San Joaquin below 5000 cfs to install and below 7500 cfs to operate the barrier at the head of Old River. A minimum export rate of 1500 cfs is based on the minimum pumping capacity and the likely drawdown rate from the canals during this season. Given the minimum export rate of 1500 cfs the chosen minimum flow rate of 3200 cfs is based on the intent of the USFWS Biological Opinion that exports be less than 50% of the Vernalis flow standard (since the Biological Opinion is based on water year type the numbers in the opinion are not directly comparable). Similarly, the maximum export rate of 3000 cfs is determined by the maximum flow of 7000 cfs and the intent of the BO to limit exports to less than half of the required Vernalis flow standard.

		Vernalis Flow rate			
		7000	5700	4450	3200
Exports	1500	A (4.7:1)		B (3.0:1)	C (2.1:1)
	2250		D (2.5:1)		
	3000	E (2.3:1)			

Table 1. Proposed flow and export rates (in cfs) to achieve the experimental goals.

Under extremely dry conditions, the San Joaquin river flow and associated exports shall be determined per section 6.4 of the San Joaquin River Agreement. USFWS staff in charge of the Anadromous Fish Restoration Program have expressed a desire to use additional water purchases to augment flows in any year when the SJRGA flow contribution is 2000 cfs. In consideration of these factors the 2000 cfs flow target is not considered a required data point within VAMP.

In this design the data for a given combination of flow and exports are assumed to be derived from a single year. However, if impacts of flow and export are overridden by some other factor that particular combination would need to be achieved in a later year. For example, smolts would be held in net containers (live cars) at release sites along the migration route to assess water toxicity; if significant mortality occurred in these enclosures the data in regard to flow and export rates likely would not be comparable with other years. Similarly, parameters of water quality, size of fish at release, or disease rates in hatchery smolts might invalidate the data from any given year. Evaluation of such uncontrolled variables is discussed under 'logistics' below. This approach reduces the need to replicate all conditions and thereby reduces the length of time needed to perform the experiment. By determining the effects of flows and exports separately it will also be possible to determine whether the ratio of flows to exports or some other (perhaps non-linear) relationship best reflects salmon survival. Several parties suggested that the experimental conditions aim at different ratios of flow to export, but such an approach (like the requirements of the WQCP) would not permit separation of the individual impacts.

These juvenile Chinook salmon VAMP survival studies rely on the consistent installation and operation of the Head of Old River Barrier each year.

Installation and Operation and Evaluation of the Head of Old River Barrier

The California Department of Water Resources currently has a permit allowing installation and operation of a temporary rock barrier at the Head of Old River during the spring period of Chinook salmon smolt emigration. DWR is applying for modifications to the barrier design to include multiple culverts with operable gates. The Head of Old River barrier, installed as a temporary structure each year, requires San

Joaquin River flows at Vernalis be less than 5,000 cfs during construction. DWR will be responsible for construction and operation of the barrier. The project team will coordinate with DWR staff regarding anticipated river flows and the installation of the Head of Old River barrier. Consideration is being given to the construction of an operable barrier at the Head of Old River for use during the salmon smolt survival studies. Either an operable or temporary barrier at the Head of Old River is expected, for purposes of development of the experimental design for these smolt survival studies, to be fully functional at San Joaquin River flows less that 7,500 cfs. Salmon smolt survival studies will be conducted as part of VAMP only in those years in which the Head of Old River Barrier is installed and Vernalis flows and exports are in accordance with the experimental design.

A complementary study has been developed as part of the survival investigations to evaluate salmon smolt survival during those years in which San Joaquin River flows are sufficiently high to prohibit either installation or operation of the Head of Old River barrier. These studies will be conducted as part of the Old River barrier evaluation and/or general survival studies on the lower San Joaquin River. Although complementary, salmon survival studies conducted during periods when the Head of Old River Barrier is not installed or not operated in accordance with this study design, will not be included in the survival evaluation outlined under the VAMP experimental design, but will provide useful complementary data on salmon smolt survival.

Evaluation of the effectiveness of the barrier, however, will be enhanced if exports are as similar as possible to conditions in the VAMP. Table 2 describes a set of flow and export conditions similar to Table 1, but with the expectation that flows would be a result of flood control operations rather than water allocations or purchases. To the extent possible, maintenance of steady flow conditions for each release group of fish would lessen variability in the data. Export conditions at these higher flows would likely be influenced by implementation of the WQCP's narrative salmon standard and DOI's Anadromous Fish Restoration Plan.

		Vernalis Flow rate (cfs)		
		up to 10,000	up to 15,000	over 15,000
Exports	1500	F(6.7:1)		
	2250		G(6.7:1)	
	3000	H(3.3:1)		I(>5:1)

Table 2. Suggested flow and export rates (in cfs) to assist evaluation of the head of Old River barrier by keeping exports similar in all cases and to allow a similar statistical approach as with the VAMP. Conditions F and H alone would provide much useful information by comparison with Conditions A and E of Table 1. Condition G was omitted from a similar design released as part of the CVPIA, b-2 actions earlier. Coordination with CVPIA would therefore need to be addressed in the particular year when flows on the San Joaquin are likely to fall between 10,000 cfs and 15,000 cfs.

The primary juvenile Chinook salmon survival studies being conducted as part of VAMP rely on the consistent installation and operation of the Head of Old River Barrier each year. The experimental design assumes that the Head of Old River Barrier will operate with a consistent permeability from one year to the next and that the barrier will be in place throughout the April 15- May 15 (or modified) period of these investigations.

Monitoring will be performed as part of the Old River Barrier evaluation to document juvenile Chinook salmon entrainment through either a temporary barrier with culverts or an operable barrier. In the event that the Head of Old River Barrier is constructed using culverts or other means of diverting flow through the barrier, the experimental design assumes that fisheries monitoring will be performed to document the numbers of coded-wire tagged juvenile Chinook salmon entrained through the barrier throughout the VAMP testing period (100% of the diverted flow monitored) to account for the loss of coded-wire tagged juvenile Chinook salmon as a result of permeable Head of Old River Barrier operations. Operation of the barrier during such monitoring will need to be done in a consistent manner, so that it does not confound the results of the VAMP study. A long term monitoring plan will be prepared to reflect this consistent operation during the VAMP text period.

If the Head of Old River Barrier is removed during the VAMP test period (e.g., April 15-May 15) as a result of such factors as incidental take of Delta smelt at the SWP/CVP diversions, results of the mark-recapture study likely would be compromised as a result of the removal of the Head of Old River Barrier.

Criteria for selecting experimental conditions
In each year the choice of target condition would be determined from the Existing Flow conditions as described in Appendix B.

For purposes of planning, the VAMP period has been assumed in this experimental design and study plan to occur during the period from April 15 through May 15. The VAMP program should include sufficient flexibility, however, to accommodate variation in the seasonal timing of Chinook salmon smolt emigration from the San Joaquin River and its tributaries to allow the VAMP testing period to coincide, to the extent possible, with the seasonal period of peak salmon emigration within the April to May time period. The current Biological Opinion (April 26, 1996) for the Temporary Barriers Program precludes installation of the barrier at the Head of Old river prior to April 15. Any changes in timing or configuration will require amending the 404 permit with the Corps of Engineers and the associated biological opinions. Flexibility in the implementation of VAMP would also require developing predictive indicators of natural smolt emigration timing. The timing VAMP also incorporates size of juvenile salmon available for release as part of the survival tests. Coordination for shifting the period of protection will require close coordination between the Hydrology Group and the VAMP Project Work Team described below.

The 31 day period designated for the VAMP testing may be extended, through the Anadromous Fish Restoration Program (AFRP) or other mechanisms to include a 2 week ramping period at the completion of the VAMP test. During this ramping period lower San Joaquin River flows and SWP/CVP export rates may be adjusted in accordance with biological and environmental conditions. The current biological opinion (April 26, 1996) for the Temporary Barriers Program requires a ramping program if the barrier at the Head of Old River remains in place after the conclusion of the pulse flow.

Experimental Design and Logistic Support

Introduction
The experimental design proposed for evaluating the effects of San Joaquin River flows and SWP/CVP export rates on juvenile Chinook salmon survival during emigration from the lower San Joaquin River represents a long-term commitment to complete these investigations. Implementation of the program will require a substantial commitment of both financial and personnel resources. The proposed salmon survival tests will require hatchery production of juvenile Chinook salmon on the San Joaquin River System, equipment and personnel for coded- wire tagging, holding facilities for tagged fish prior to release, transportation of tagged fish to the release sites, and sampling to recapture marked fish. In addition, logistic coordination is required regarding installation and operation of the barrier at the Head of Old River, and establishing San Joaquin River flow and export levels to be maintained during the period of each year's test. As a result of the long-term nature of the investigation and the importance of developing valid information on juvenile salmon survival each year, the success of the program

depends on establishing stable and consistent test conditions for comparisons among years, and reliable implementation of the investigation. These logistic considerations are briefly discussed below.

Project Work Team Coordination and Scientific Direction
Implementation of the VAMP and the associated investigations to determine juvenile Chinook salmon smolt survival as a function of Vernalis flows and SWP/CVP exports will require a multi- disciplinary and multi-agency approach. To facilitate coordination among participants a project work team (PWT) will be formed as a subcommittee of the San Joaquin River Technical Committee (SJRTC). Participation in the project work team would be limited to individuals having scientific and technical expertise relevant to the lower San Joaquin River salmon smolt survival studies. The project work team would be responsible for reviewing the experimental design for the proposed investigations, coordination of sampling activities and data collection, review of proposed investigations submitted as complementary elements to the VAMP, and scientific review and analysis of data collected during each year's investigations, subject to review and approval by the SJRTC and the Management Committee. An explicit liaison with the Hydrological Group (see Appendix B) will be required.

The PWT would work closely with the existing Interagency Ecological Program (IEP) Central Valley Salmon Project Work Team to assure proper coordination between these programs.

The proposed experimental design measures salmon smolt survival rates under at least five different combinations of flow and export rates. The experimental design assumes at least two series of releases of CWT smolts each year during the outmigration period to provide at least two estimates of salmon smolt survival under each set of conditions. Release strategies will be similar in all years of the study with a minimum of 50,000 to 75,000 CWT smolts per release group dependent on location. Further consideration of these smolt numbers may be required if recoveries are either too high or too low due to specific circumstances.

The primary recapture locations would be at Chipps Island, as in previous studies, and at a new, intensively sampled location in the lower San Joaquin (near Jersey Point) and through the ocean fishery recoveries. Additional recapture of coded-wire tagged salmon would occur at the State and Federal Water Project salvage as part of ongoing fisheries monitoring programs within the San Joaquin River and the IEP real-time monitoring program. Recapture of marked salmon in these monitoring programs could be helpful in improving the confidence in survival rate estimates and therefore the budget and resources allocated to these efforts may need to be augmented over the short period of the mark-recapture tests to ensure adequate sampling effort at all key recapture locations.

The experimental design includes both multiple release locations (at Mossdale, Dos Reis, mouth of the Mokelumne River and Jersey Point), and multiple recapture locations, including Jersey Point and Chipps Island and in the ocean fisheries. The use of data from multiple recapture locations and replicated release series provides a stronger basis for evaluating juvenile Chinook salmon smolt survival as part of the VAMP testing program, than reliance on recapture data from only one sampling location and only one series of releases per year. The proposed release and recapture locations (including Jersey Point recapture site) will be consistent from one year to the next, providing a greater opportunity to assess salmon smolt survival over a range of Vernalis flows, SWP/CVP exports, and with- and without the presence of the Head of Old River Barrier. In addition, releases at the mouth of the Mokelumne River will serve as a control for recaptures at both Chipps Island and Jersey Point, thereby allowing the calculation of survival indices based on the ratio of marked salmon recaptured from upstream (e.g., Mossdale and Dos Reis) and downstream (mouth of the Mokelumne River) release locations. The use of ratio estimates as part of the VAMP study design substantially reduces the bias associated with differential gear collection efficiency within and among years, and substantially strengthens the analytical ability of the experimental design to detect differences in salmon smolt survival as a function of Vernalis flows and SWP/CVP exports.

Coded-Wire Tagged Salmon Allocation and Release Strategy
Releases would be made using juvenile Chinook salmon smolts produced from San Joaquin River origin broodstock when available. Releases would be made twice within the period of VAMP each year with the second release series made about one week after the first. The proposed allocation of juvenile Chinook salmon to the experimental design is summarized below with and without a Head of Old River barrier:

Head of Old River Barrier Operational

Release Location	First Release Series	Second Release Series
Mossdale	75,000[a]	75,000[a]
Dos Reis Mokelumne Mouth Jersey Point	50,000[b]	50,000[b]
	50,000[a]	50,000[a]
	50,000[a]	50,000[a]
Total number of fish[a]	175,000	175,000

[a] First priority

[b] Second priority release to evaluate the Head of Old River Barrier in a more comprehensive manner

Head of Old River Barrier Non Operational

Release Location	First Release Series	Second Release Series
Mossdale	75,000[a]	75,000[a]
Dos Reis Mokelumne Mouth Jersey Point	50,000[a]	50,000[a]
	50,000[a]	50,000[a]
	50,000[a]	50,000[a]
Total number of fish[a]	225,000	225,000

[a] First priority

Analysis and Interpretation of Results

Biological and physical data to be recorded as part of each test will then be critically reviewed to ensure that the proper smolt survival data are appropriate for subsequent use in statistical analyses. Data from each test will be available to all interested parties for independent review and analysis. The VAMP study will need to continue until valid data from each of the five experimental conditions have been gathered. Weather conditions in each year will determine the experimental conditions in each year until all five conditions have been achieved, thus, there may be a series of dry years when the only flow target that can be achieved is 3200 cfs, or there may be a series of years when flows are too high to allow the experiment to proceed. Therefore, it is impossible to say how long it will be necessary to continue this experiment in order to satisfy the experimental requirements.

The goal of the analyses is to determine the respective roles of flow and exports on smolt survival so that the correct management actions can be taken to improve smolt survival through the San Joaquin Delta.

Plans are to analyze the data in a way similar to that done on the Sacramento Delta (Newman and Rice, 1998), where the log of the recoveries would be modeled using a linear combination of covariates. The model would be fitted using weighted least squares as was done for the Sacramento Delta data. The amount of time and ability to reach a reasonable conclusion from the data will depend on the amount of data and the strength of the effect of the covariates. Replicates within a year, even with a different stock of fish will increase the estimated precision of coefficients and may reduce the number of years needed to conduct the experiment. The present design will allow absolute survival to be estimated between Mossdale and the mouth of the Mokelumne and between Mossdale and Jersey Point using recoveries at Jersey

Point and Chipps Island respectively. Recovery data from the ocean fishery will add precision. All the data will be used simultaneously to estimate the model parameters and to determine the respective roles of flows and exports on salmon smolt survival. Attempts also will be made to describe the interaction between flow and export to smolt survival.

It has been recommended that the extremes of conditions within the matrix be tested first and defer testing of the intermediate values until the relationships with the extremes are clear. This may mean repetitious testing of the extremes before the intermediate values are tested. Such a design process would be a sequential adaptive design where conditions tested each year would be determined on which values would provide the most useful information to finding the respective roles of flows and exports on smolts survival.

In addition, past data may be used to estimate the strength of the effects from flows and exports to better determine the amount of time necessary to conduct the experiment. If appropriate, past data may be incorporated in the model fitting process.

Juvenile Chinook Salmon- San Joaquin Basin Origin

Salmon smolt survival studies would be conducted primarily using juvenile fall-run Chinook salmon produced from San Joaquin River brood stock. Factors such as inter-annual variation in the numbers of adult Chinook salmon returning to the San Joaquin River system to spawn, viability of eggs, disease within the hatchery, and other factors may influence the numbers of San Joaquin River-origin salmon smolts available for testing each year. Currently, the only source for juvenile Chinook salmon to be used in these tests are those fish produced in the Merced River Fish Hatchery. Limited facilities for producing and holding juvenile Chinook salmon at the Merced River Fish Hatchery constrains the number of fish available each year for experimental studies. Options for meeting the demand for juvenile Chinook salmon to be used in these tests include re- prioritization of existing fish available each year from the Merced River Hatchery or augmenting the existing facilities and personnel at the Merced River Hatchery. The CWT salmon allocation and release strategy calls for two series of releases each year. Each release series would consist of a minimum of from 175,000 to 225,000 smolts.

As a consequence of competing demands for San Joaquin River origin salmon smolts for use in testing and evaluation programs within the tributaries, in addition to the Delta survival studies, implementation of the long-term survival study program that does not rely on a contingency plan of Feather River CWT hatchery fish will require a commitment of additional resources to ensure salmon smolts of San Joaquin basin origin are available for use in these tests each year. In addition to providing financial support for hatchery production and rearing facilities, there will be costs associated with incremental increases in labor by hatchery personnel for the care and feeding of juvenile salmon during the holding period, fish health inspections, and loading marked fish from the hatchery holding facilities into the transport truck. As part of development of the long-term plan agreements, financial commitments will need to be established for reliably providing the necessary numbers of juvenile salmon to be used in these survival studies.

In developing the design of the proposed VAMP salmon smolt survival studies, considerable discussion focused on the use of San Joaquin River origin juvenile Chinook salmon, and those produced in the Feather River Fish Hatchery for use in these tests. Many of the previous salmon smolt survival studies conducted in the lower San Joaquin River relied on the use of Feather River Hatchery-origin Chinook salmon. Concern has been expressed regarding the potential genetic implications associated with the release of Feather River-origin salmon into the lower San Joaquin River, and the subsequent return and spawning of these fish within the San Joaquin River basin. In addition, future action by the National Marine Fisheries Service (NMFS) relative to the proposed listing of fall-run Chinook in the Central Valley could also influence CWT smolt transfers between river basins. The above also reflects the concern regarding the impact of hatchery fish on the wild stocks. In response to these concerns, the proposed VAMP experimental design outlined above relies on the use of San Joaquin River-origin Chinook salmon smolts.

Coded-Wire Tagging

The experimental design for coded-wire tagging of San Joaquin River origin salmon smolts (six discrete tag groups) includes consideration of logistic constraints imposed by limitations in hatchery holding facilities. Numerous parties have commented on the potential benefits associated with the release of additional coded-wire tag groups. These recommendations have included releasing smaller numbers of marked salmon (e.g., 25,000 fish lots) more frequently throughout the period of the tests, rather than fewer large release groups. Similarly, recommendations have been made for simultaneous release of two or more tag codes to allow for the calculation of independent, replicate survival indices within a release, assuming that a sufficient number of each tag code are recaptured. Given these logistic constraints, multiple tag codes could be applied to groups released at each location (e.g., each 75,000 lot release could be comprised of three discretely tagged groups of 25,000 fish). However, the individual tag groups may not necessarily be held separately within the existing holding facilities prior to release.

Each of the proposed releases of coded wire tagged salmon would be comprised of multiple tag codes of approximately 25,000 fish each. For example, the release of 75,000 coded wire tagged salmon at Mossdale would be comprised of three separate tag codes of 25,000 fish each which would simultaneously be released during each test to provide the opportunity for estimating variance in survival indices within each release group.

Prior to and after coded-wire tagging, juvenile salmon will be inspected for evidence of disease and parasites. Fish health inspections will be performed by a fish pathologist. Any group of marked fish showing unusually high mortality within the hatchery holding facility prior to or after marking, or evidence of disease or other pathogens which cannot be effectively treated, will not be released as part of these tests. Additional observations of fish health conditions after release will be made for a sub-sample of marked fish held in live cars at release locations (see discussion below).

The coded-wire tagging would be subject to a quality control/quality assurance program to ensure that juvenile salmon have been effectively tagged, and to document tag retention. The quality control/quality assurance program would include a standard magnetic detector to separate tagged and untagged salmon as they are released from the tagging machine. A second quality control check would occur prior to release of the marked fish. A statistically valid sub-sample of marked fish from the hatchery holding facility will be processed using a tag detector to document coded- wire tag retention and tags will be processed to verify appropriate tag codes for each release group. Tag codes will be verified for with a sub-sample of 50 fish per 25,000 marks. A decision will be made about the validity of a release group if one or more erroneous tag codes are detected in the composite sub-sample prior to release. The sub-sample of fish from the hatchery holding facility would also be examined to quantify the percentage of marked fish having a recognizable adipose fin clip. The total number of each coded-wire tag group released would then be calculated based on the actual number of fish marked (actual count) adjusted to account for post-marking mortality within the hatchery holding facilities, a correction factor for coded-wire tag retention, a correction factor for adipose fin clipping, and an adjustment for mortality occurring during loading and transport of marked fish to the release site. Data on length and weight for a sub-sample of each marked group (approximately 200 fish) will be made to document both the length-frequency distribution, and length - weight relationship (condition factor) for each test group. These fish will be held in live cars as part of the quality control program for each release group (see discussion below).

Coded-wire tagging equipment will be required, on a dedicated basis, to ensure that juvenile Chinook salmon can be reliably tagged each year for use in this program. It is recommended that four coded-wire tag machines and support equipment be purchased and dedicated to this project. Replacement parts and maintenance will be part of the annual cost of the program.

Tag codes will be coordinated with other salmon evaluation programs and with the statewide tag coordinator. All juvenile Chinook salmon which are coded-wire tagged will also receive an adipose fin clip.

As part of utilizing facilities to support the proposed experimental program, facilities should have adequate capabilities for segregating and holding separate coded-wire tag groups. It is required that juvenile Chinook salmon be held for a period of at least 21 days after tagging when chemical anesthetics are used. Hatchery raceway facilities need to be available which allow for the separation and holding of tagged groups of salmon (tag groups of typically 25,000-75,000 fish each) prior to release. Availability of hatchery facilities for isolating coded-wire tag groups is can be a limiting factor in the types of experimental programs which can be developed for evaluating Chinook salmon survival.

In addition to providing financial support for utilizing holding facilities, there will be costs associated with labor by hatchery personnel for the care and feeding of juvenile salmon during the holding period, fish health inspections, and loading marked fish from the hatchery holding facilities into the transport truck.

Agreements and financial compensation for the increased costs associated with the mark- recapture program will need to be resolved as part of the logistic support and commitment of resources to the long-term plan.

Tagged Fish Transport

Coded-wire tagged salmon used in previous investigations have been transported from the hatchery to the point of release using transport trucks and personnel provided either by the hatchery or from the State Water Project fish salvage operation. The use of this equipment in the past has resulted in a number of constraints regarding scheduling of fish releases, limited availability of equipment and operators, issues of disease transmission, and limitations on the time of day when releases can be made. To eliminate these constraints, it is recommended that a dedicated fish transport trailer be purchased or rented each year specifically for use in this project. The fish transport trailer should have the capacity to transport up to 125,000 juvenile Chinook salmon smolts, segregated into three or four compartments to allow for separate releases. A truck and operator would be hired privately through the project to accomplish the desired releases at the locations, and in accordance to the schedule established by this experimental design.

Juvenile salmon will be transported from the hatchery to the release location in water of comparable temperature to that occurring within the hatchery. Water temperature will be monitored within the hatchery rearing facilities, transport truck, and release site, to identify and document any potential thermal stress occurring as part of the fish release. Transport of fish from the hatchery to the release location at night will help reduce exposure to elevated water temperatures within the transport truck. Juvenile salmon will not be transported or released as part of this investigation if average daily water temperatures at the release location exceed 20 C (68 F). In the event that water temperatures in the lower San Joaquin River exceed the 20 C threshold, the marked fish will be released downstream at the mouth of the Mokelumne River or at Jersey Point. Water temperature, dissolved oxygen concentrations, and mortality of marked fish within the transport truck will all be documented prior to release.

Tagged Fish Release

Releases of coded-wire tagged juvenile salmon will be made at the Mossdale boat ramp (upstream of the Head of Old River), Dos Reis Park, at the mouth of the Mokelumne River, and Jersey Point. Twelve-inch diameter PVC pipe will be used to facilitate transfer of the marked fish from the transport truck into the river at release locations along the levee. Once established, the release locations would not be modified during the period of these tests to allow comparison of survival indices among years.

Coded-wire tagged salmon will be released, when possible, at an average minimum length of 75 mm or greater. Marked salmon would be released during the late evening/night to reduce the potential effects of predation. To the extent possible, releases at Mossdale or Dos Reis will be made on an ebb tide, while releases at the mouth of the and Mokelumne River and Jersey Point will be made on a flood tide.

Live Car Holding

As part of the mark-recapture studies, juvenile Chinook salmon will be held *in situ* in live cars in the vicinity of each of the release locations. Live cars will be constructed using a PVC frame, non- toxic screen mesh, and supporting floatation. A subsample of juvenile Chinook salmon will be removed from the transport truck for holding in the live cars.

Observations during the post-release holding period will include mortality rates, feeding activity, and swimming behavior. These observations are intended to identify the occurrence of major mortality for a release group which may result from factors such as handling stress during transport and release of a marked group that would influence the validity and interpretation of the corresponding group of marked salmon released into the river as part of these survival studies. Additional parameters to be considered as part of the complementary evaluation of the condition of marked salmon include gill ATPase, thyroxin, lipids, and other physiological parameters. Complementary studies of contaminants and other factors may also be performed to assess the potential effects of other factors on smolt survival.

At the completion of the holding period all marked fish held in the live cars will be sacrificed, and the coded-wire tags will be archived as part of the QC program to ensure the integrity of each mark group. A sub-sample of 50 tags will be processed to verify tag codes for each release group. Additional tags may be processed if tag code errors are identified. Based on results of this QC check a decision will be made regarding the validity of the release for inclusion in subsequent analyses. A preliminary criteria of 95% reliability in tag codes for each composite release group has been selected for evaluating the validity of a test.

Recapture Methods and Locations

Sampling locations for recapture of marked juvenile Chinook salmon include Jersey Point, Chipps Island, and the SWP and CVP salvage facilities. For purposes of the VAMP investigation the primary sampling locations are Jersey Point and Chipps Island. Recaptures will also be documented as part of routine monitoring at the SWP/CVP salvage facilities. Additional recapture data will be obtained from ocean commercial and recreational fisheries.

Sampling for juvenile Chinook salmon at Mossdale by the California Department of Fish and Game (DFG) as part of their routine San Joaquin River fisheries sampling program will determine the seasonal timing of smolt emigration for each year. Sampling by DFG and others in the tributaries will supplement the Mossdale data. Sampling at Turner and Columbia cuts will be performed as part of the IEP real-time monitoring program. Sampling at Chipps Island will be performed by the U.S. Fish and Wildlife Service as part of the routine Chinook salmon abundance and survival investigations (DWR, IEP, AFRP or other program funding). Standard U.S. Fish and Wildlife Service sampling protocols, using a mid-water trawl, will be employed at Chipps Island. Sampling effort at Chipps Island is typically 10 20-minute tows per day. Recovery of coded-wire tagged salmon at the State and Federal Water Project salvage operations would be conducted as part of routine monitoring. Sampling regimes for recapture of CWT smolts will need to be modified as necessary to accommodate limits on the take of delta smelt. Ocean adult recoveries would also be performed as part of ongoing State and Federal fishery resource investigations. Sampling effort at Jersey Point will be conducted and financed as a direct element of the VAMP.

Fishery sampling as a direct element of the VAMP survival studies will be conducted from April 15 to May 15. Sampling will continue as part of this investigation (potentially at a lower level of intensity) from May 16 to June 1 to evaluate the ramping period. Data collected during each sampling period will be reviewed by the technical team to determine the most appropriate and valid use for evaluating smolt passage and survival under VAMP. Exact dates of sampling will shift in response to any changes in the dates of fish release as recommended by the VAMP PWT.

The salmon smolt survival study includes intensive fisheries monitoring in the general vicinity of Jersey Point. This intensive sampling location will be directly related to the salmon smolt survival studies, and therefore labor and equipment costs will be a specific component of the proposed project budget. The addition of the Jersey Point sampling site, and the increase in sampling effort proposed for this location, have been designed to increase the recapture of marked salmon released as part of these investigations and provide an opportunity for developing an independent salmon smolt survival estimates between upstream releases (Mossdale and Dos Reis) and Jersey Point (releases at the mouth of the Mokelumne River will serve as a control location for estimating survival using a ratio recapture method). Sampling will be conducted 18 hours per day throughout the recapture period (approximately 2 hours before dawn to 2 hours after sunset).

Sampling at Jersey Point will be conducted using a Kodiak trawl. The Kodiak trawl has a graded stretch mesh, from 2-inch mesh at the mouth to ¼-inch mesh at the cod end. Its overall length is 65 feet, and the mouth opening is 6 feet deep and 25 feet wide. A flow meter will be used to determine the volume of water sampled during each collection, for use in calculating catch-per- unit-of-effort (CPUE). Trawl duration will be 20-minutes, sampling in an up-current direction. Trawling will be performed in a consistent reach of the lower San Joaquin River, which has been selected based on results of the 1997 reconnaissance survey. Trawling within a consistent reach each year will facilitate comparisons in recoveries among years and the development of appropriate expansion factors for calculating survival indices. The identified Jersey Point sampling area is in the general vicinity of a USGS flow monitoring station that will also provide useful data on hydraulics in the sampling area for use in evaluating results within and between years.

The Kodiak trawl will be towed between two skiffs. A third skiff will be available on-site to provide reliability of sampling effort over the intensive monitoring period in the event of boat breakdown or equipment failure. A duplicate Kodiak trawl will also be available on-site to help ensure reliable and consistent sampling throughout the April 15-June 1 period of these collections.

Fisheries Collection and Tag Processing

Data collected during each trawl sample will include species identification, enumeration and forklength measurements of juvenile Chinook salmon and other fish species collected, and water volume sampled. Juvenile Chinook salmon having an adipose fin clip, indicating the presence of a coded-wire tag, will be sacrificed, placed in individual, labeled, plastic bags and held on ice until they can be frozen.

The frozen samples will be provided to the U.S. Fish and Wildlife Service, California Department of Fish and Game, or other qualified organization, for coded-wire tag removal and processing as part of the existing coded-wire tag processing program. A result of the San Joaquin River salmon smolt survival studies, there will be an incremental labor cost associated with coded-wire tag processing. An agreement for financial compensation for the incremental cost of tag processing will need to be established as part of the long-term program to ensure that tags are processed promptly and data made available for use in estimating smolt survival each year.

Operational and Hydrologic Monitoring

USGS, USBR, and DWR will perform hydrologic monitoring within the lower San Joaquin River and Delta during the period of these tests. During 1997 problems in flow monitoring at the Vernalis gauge were encountered as a consequence of changes in rating curves during the period of these tests. As a part of VAMP additional gauging and monitoring will be performed to document flows occurring within the lower San Joaquin River. Hourly information on water surface elevation and flow measurements at established monitoring locations throughout the lower San Joaquin River and Delta will be used to document conditions during each test period. Based on experiences in 1997, recalibration of the gauging stations at Vernalis by USGS near the start of the VAMP flow period would be an important adjunct.

Detailed operational records of SWP and CVP operations (e.g., Clifton Court gate operations, hourly export rate and volume) will also be maintained to document operational conditions during each test. Data on daily exports from other relatively large diversions located on the lower San Joaquin River and Delta emigration route will also be documented. The Hydrology Group would likely carry out all these activities.

Concern has been expressed regarding the effects of the operation of the Clifton Court Forebay on hydraulic conditions occurring within the Delta during the period of VAMP. To minimize daily variation associated with Clifton Court Forebay operation, Clifton Court Forebay should be opened once per day during the VAMP study period with subsequent export rates, as determined by diversions at the Banks Pumping Plant, in accordance with the experimental design.

Water Quality Monitoring

Routine water quality monitoring will be performed from April 1 through June 1 each year. Water quality monitoring will include, but not be limited to, water temperature, dissolved oxygen, and electrical conductivity. Water quality monitoring performed specifically as part of this test will complement routine baseline water quality monitoring performed by the Department of Water Resources.

Water temperature will be monitored using individual computerized temperature recorders (e.g., Onset Stowaway Temperature Monitoring/Data Loggers). Ten temperature monitoring locations will include fish release sites within the San Joaquin River, fisheries sampling locations (Mossdale, Columbia Cut, Chipps Island), and locations downstream along the longitudinal gradient of the San Joaquin River and interior Delta channels used as migratory pathways for juvenile Chinook salmon released as part of these tests. Temperature monitoring will also be performed at the SWP and CVP diversions.

Water temperature will be recorded at 20-minute intervals throughout the period of the investigations. Temperature recorders will be located near the surface and near the bottom at selected stations to determine potential vertical stratification in temperature. Temperature loggers will be retrieved and the data downloaded at approximately two week intervals to reduce the risk of instrument failure and loss of monitoring data.

Dissolved oxygen will be monitored using a portable DO meter (e.g., YSI Instruments) near the surface and near the bottom at each of the fisheries sampling locations twice per day (morning and afternoon). In addition, dissolved oxygen will be measured coincident with the retrieval of temperature monitoring data at the surface and bottom at each of the 10 temperature monitoring locations described above.

Electrical conductivity will be monitored using a portable meter (e.g., YSI Instruments) at the same locations and frequency as described for dissolved oxygen monitoring.

Water quality monitoring data such as electrical conductivity, water temperature, and water surface elevations will also be obtained for use in documenting conditions occurring during each salmon smolt survival test as part of routine monitoring performed by DWR, USBR, USGS, and other agencies.

In addition to routine water quality monitoring, interest has been expressed in complementing these survival investigations with measurement of water quality constituents (contaminants) which may affect the health, condition, or survival of juvenile salmon migrating through the lower San Joaquin River and Delta. Although not a direct element of the VAMP survival studies, the experimental design provides a scientific framework for accommodating complementary investigations.

VAMP Documentation Reports

Results of coded-wire tag processing, documenting the numbers of juvenile salmon from each tag group released, in association with data on the operating and environmental conditions occurring during the period of each study, will be documented and made available as part of annual reports. Draft annual reports will be completed and made available for peer review by December of each year, with a final annual report completed no later than March 1 each year. All data collected will be made available in electronic format for independent review and analysis by any interested party.

Funding

The proposed San Joaquin River Chinook salmon smolt survival studies (VAMP) outlined in this proposal represent an increased level of effort above the survival studies routinely performed as part of IEP investigations. Incremental costs associated with the proposed investigations discussed above will occur as a direct result of conducting the VAMP investigations. These incremental costs would include, but not be limited to, intensive sampling efforts in the vicinity of Jersey Point, increased labor costs associated with tagging, transport and release, coded-wire tag processing, and any additional sampling effort requested at existing agency or IEP-sponsored sampling sites (Chipps Island). Additional capital investment will be required for developing facilities to ensure the adequate production of a sufficient number of San Joaquin origin Chinook salmon for use in these tests and for purchase of the coded-wire tagging machines, coded-wire tags, and the transport trailer.

Scientific Collection Permits

The sampling program, as outlined in this proposal, includes intensive fisheries monitoring during the spring at several locations, including Chipps Island and Jersey Point, where Delta smelt may be collected. Sampling with a Kodiak trawl has been shown in previous investigations to be an effective method of collecting not only juvenile Chinook salmon, but also juvenile and adult Delta smelt. Scientific collection and incidental take (ESA) permits will be required as part of the proposed investigations. Contingency plans will be developed and implemented as part of the proposed sampling in the event that Delta smelt or other protected species (e.g., juvenile winter- run salmon, Sacramento splittail) are collected as an incidental component of fisheries sampling targeting on juvenile fall-run Chinook salmon. Permits have been established for IEP sampling, including conditions of sampling as part of the real-time monitoring program and Chipps Island sampling programs, which would apply to sampling as part of either this proposal or the high flow contingency salon smolt survival investigations. Intensive sampling in the vicinity of Jersey Point will be covered under a separate permit unless an arrangement is made to include it under the IEP permit by regulatory agencies and the IEP.

Products

Results of the proposed experimental investigations will provide detailed scientific information regarding the relationship between San Joaquin River Chinook salmon smolt survival and lower San Joaquin River flows and SWP/CVP exports. The study finding will provide a technical foundation for assessing and refining management recommendations.

Results of each year's sampling will be documented in annual technical reports presenting detailed information regarding the experimental design, results of data collection activities. The final report will present results of statistical analyses and hypothesis testing as established a priori within the framework of these tests.

The proposed experimental design will also provide interim levels of protection for Chinook salmon smolts targeted on the maximum biological benefit coincident with the peak period of smolt outmigration. Interim levels of fisheries protection established in concert with this proposed investigation will directly benefit the San Joaquin River Chinook salmon population.

Complementary Investigations

Various parties have expressed interest in developing complementary monitoring elements to further evaluate the potential factors influencing Chinook salmon mortality within the lower San Joaquin River (river reach) and Delta. Interest has been expressed in evaluating the potential effects of hydraulic conditions, predation, entrainment mortality, and exposure to toxic contaminants. Although these studies would not be a direct element of VAMP, the basic experimental design developed for this program can be complemented by additional studies to evaluate the specific factors contributing to salmon mortality. We encourage the development of these complementary study elements and their integration into the overall San Joaquin River Chinook salmon survival program and a timely report of all results to interested parties. Detailed proposals identifying the objectives and general approach for evaluating Chinook salmon emigration patterns (e.g., radio tracking and hydroacoustic studies), contaminant toxicity, and predation are being developed. Direct entrainment losses of marked salmon under the various experimental conditions proposed as part of this investigation will also be evaluated, using data from SWP/CVP salvage operations. Examples of several of the potential complementary studies are briefly described below.

<u>Hydraulic Measurements and Studies</u>

As a complementary element to VAMP, additional measurements of hydraulic conditions, such as the direction and velocity of flows within various channels and the influence of tidal interactions on Delta hydraulic conditions, should be performed. During the 1997 pilot studies, dye injection studies were conducted coincident with the release of marked juvenile Chinook salmon into the lower San Joaquin River. Additional dye release studies can be performed as a complementary element of VAMP to provide further information on the pattern and distribution of water flows under different conditions of Vernalis flow and exports for use in documenting changes in environmental conditions occurring among years. Results of dye injection studies can also be used to help calibrate particle tracking model studies, in addition to other hydrodynamic modeling of South Delta flows. As a complementary element to VAMP, these studies offer the opportunity to integrate better information on hydraulic conditions and the corresponding biological information developed through the VAMP salmon mark-recapture program.

Furthermore, efforts should be made to improve the flow measurements being used within the lower San Joaquin River to manage upstream releases in accordance with the Vernalis flows established by the experimental design. Additional measurements can also be made to evaluate the influence of Clifton Court gate operations on velocity conditions occurring within the South Delta and other hydrodynamic effects that may be directly or indirectly influencing salmon smolt survival.

<u>Index of Predation Losses</u>

Predation within the lower San Joaquin River, primarily by striped bass and largemouth bass, has been identified as a potentially significant factor reducing the survival of juvenile Chinook salmon during these investigations.

To develop an indicator of the relative abundance of predatory fish within the area each year, the salmon survival studies could be expanded to include a creel survey of recreational anglers. An example of a creel survey program is briefly outlined below.

The creel survey would be conducted within the area from Mossdale downstream on the lower San Joaquin River to Pittsburg (adjacent to Chipps Island). The creel surveys would be performed during the period from April 1 through May 15. The creel survey program would include surveys of angler catch (by species) and effort by boat and by interviews at marinas and boat launching facilities. Based upon the results of the creel survey an index of predator abundance for both largemouth bass and striped bass, in addition to other species, can be developed. The predator abundance index would not be a quantitative estimate of the absolute numbers of predatory fish inhabiting the lower San Joaquin River each year. The relative index would provide a measure of predation for comparison with juvenile Chinook salmon survival indices among years and account, potentially, for variability in smolt survival indices in addition to Vernalis flow, SWP/CVP exports, and SWP/CVP salvage.

Predator surveys could also be designed using other sampling methods, analyses of stomach contents, radio tracking of predators to determine geographic distribution and movement patterns, etc.

Wild Chinook Salmon Live Car Holding

As a complementary investigation, live cars would also be available for holding wild juvenile Chinook salmon collected within the San Joaquin River and tributaries for comparison with survival of hatchery-reared salmon used in these tests. Wild Chinook salmon may be collected from rotary screw traps (or beach seines) located within the San Joaquin River tributaries. Wild salmon would be transported downstream to live car observation sites located in the San Joaquin River at the release location upstream of Mossdale, and at the recapture location in the vicinity of Jersey Point. Approximately 50 wild Chinook salmon would be held in live cars at each of the two locations. Coordination in obtaining wild Chinook salmon for use in these observations would be established between the Delta survival program and upstream tributary monitoring efforts. Capture and observation of wild salmon would coincide, to the extent possible, with the release schedule of San Joaquin River origin hatchery-reared smolts.

Contaminant Toxicity

Considerable interest has been focused on evaluating the potential effects of contaminant toxicity on juvenile Chinook salmon survival within the lower San Joaquin River. Pesticides, herbicides, and other water quality contaminants have been documented within the lower San Joaquin River which may contribute to chronic and sub-lethal stress or acute mortality. Complementary studies to VAMP which could be developed to evaluate the effects of contaminant toxicity on juvenile Chinook salmon survival may include an expansion of the live car holding to observe juvenile Chinook salmon survival over longer periods of time (e.g., 5 - 20 days) at various locations along the longitudinal gradient to the lower San Joaquin River. In addition to live car holding tests, juvenile Chinook salmon collected from the lower San Joaquin River may be sacrificed for pathological examination (e.g., liver necrosis) and/or chemical analyses of body burden concentrations of various chemical constituents.

More sophisticated studies may involve evaluation of juvenile Chinook salmon growth, feeding activity, predator avoidance, or other behavioral and physiological measurements of chronic sub- lethal stress that may result from exposure to chemical constituents and would ultimately affect juvenile Chinook salmon survival.

The design of the contaminant toxicity investigations proposed as a complementary element to VAMP should be coordinated and reviewed by the IEP contaminant project work team.

Entrainment Losses

There are a large number of water diversions located on the lower San Joaquin River and Delta that may contribute to direct entrainment losses of juvenile Chinook salmon. Complementary studies could be developed and implemented to assess the potential significance of entrainment mortality on the overall survival of juvenile Chinook salmon emigrating from the lower San Joaquin River. Additional investigations of salmon losses attributable to direct entrainment at the SWP/CVP diversions can also be developed using data from the mark-recapture tests being performed as part of VAMP.

Juvenile Salmon Behavior and Movement Patterns

It has been hypothesized that changes in Vernalis flow and SWP/CVP export rates will affect Delta hydraulic conditions and the rate of emigration and movement patterns of juvenile Chinook salmon within the lower San Joaquin River and Delta. Crude estimates of the rate of emigration can be developed based upon analyses of the timing of coded-wire tag recaptures performed as part of VAMP. More sophisticated observations of juvenile salmon behavior may be made through such techniques as radio or acoustic tag tracking. Juvenile Chinook salmon could be equipped with radio transmitters and their movement patterns through the lower San Joaquin River and Delta determined under various flow and export conditions implemented through VAMP.

Although radio tracking has proven to be a valuable technique in many investigations, the size of the transmitter at this time prohibits the use of this technique on salmon smolts particularly those emigrating during the spring in the lower San Joaquin River (typically less than 100 mm). Larger juvenile salmon, however, could be used for radio and acoustic tracking as part of these complementary study elements to VAMP.

Seasonal Timing of Salmon Fry and Smolt Outmigration

The VAMP program has been targeted on a 31 day period from April 15 - May 15. Complementary studies on the seasonal timing and abundance of salmon fry and smolt emigration in the lower San Joaquin River will provide valuable input into the design of VAMP and, ultimately, development of management actions designed to improve protection for juvenile Chinook salmon. Studies are currently being conducted using Kodiak trawl collections on the lower San Joaquin River at Mossdale in addition to screw trap collections and seining within San Joaquin River tributaries and/or mainstem San Joaquin River. Results of these complementary studies will provide the necessary information to determine the seasonal period of peak salmon outmigration and potential biological and environmental triggering indicators which will allow flexible implementation of VAMP to coincide with the peak salmon smolt outmigration each year.

Juvenile Salmon Emigration and Survival from the Tributaries

Mark-recapture survival studies are being conducted to evaluate Chinook salmon smolt emigration and survival from the tributaries. Results of such investigations can provide additional complementary information to further assess the relative significance of mortality within the tributaries and river section of the lower San Joaquin River, and be used to compare it to survival estimates developed through VAMP for the Delta reach. Mark-recapture survival studies with San Joaquin origin Chinook salmon smolts will benefit from the increased sampling effort and recapture of marked salmon as part of the VAMP sampling program. The expansion of sampling at Jersey Point as part of VAMP will provide an opportunity to calculate indices of salmon smolt survival from the tributaries for comparison each year with survival indices from Mossdale and Dos Reis releases. Coordination will be required, however, to ensure that the seasonal timing of tributary and Delta releases coincides with the period of intensive sampling and flow and export conditions developed as part of VAMP.

Additional survival estimates can be derived using results of marked juvenile Chinook salmon released at various locations within the upstream tributaries, in combination with downstream recaptures. Additional survival indices can also be developed for marked salmon using recapture data from ocean adult recoveries. These survival indices offer the opportunity for evaluating survival between the river segment of the lower San Joaquin River, and within the Delta. The experimental design and methods used in CWT releases will be reviewed by the technical work group to determine valid comparisons among survival indices from these complementary tests. These data will provide an opportunity to examine trends in Chinook salmon survival within these various reaches, and potential changes in survival in response to variation in San Joaquin River flows and SWP/CVP exports.

Comparison of Wild versus Hatchery Chinook Salmon Smolt Survival

A number of questions have arisen regarding the use of hatchery produced Chinook salmon smolts for assessing survival of wild salmon emigrating from the lower San Joaquin River and tributaries. The combination of increased sampling within the tributaries, opportunities for additional marking of wild Chinook salmon, and the increased level of sampling and recaptures occurring as part of VAMP provide an opportunity to evaluate and compare survival of juvenile Chinook salmon produced in the Feather River Hatchery, Merced River Hatchery, other production facilities, and wild salmon smolts produced in the tributaries. Comparisons can be made of the relative size and abundance of marked and unmarked salmon collected as part of these tests, in addition to other indicators of smolt condition. Provisions have been made within the experimental design for VAMP, for example, for complementary studies of physiological indicators such as ATPase levels, length frequencies, condition indices, and other measurements among stocks used as part of these tests. Further consideration would need to be given to methods in which the experimental design for VAMP can be used as a framework for evaluating the comparative survival of the hatchery produced and in-river produced salmon smolts. Coordination of these investigations should be made with the San Joaquin River project work team.

Jersey Point Trawl Efficiency Calibration

VAMP includes a major expansion of sampling effort at Jersey Point in an effort to increase the numbers of marked juvenile Chinook salmon recaptured and improve the corresponding indices on salmon smolt survival. Fisheries sampling has been found to vary based on instream flows with generally greater sampling efficiency occurring under lower flow conditions. The influence of flow on sampling efficiency of the Kodiak trawl at Jersey Point is unknown. The inclusion of releases of marked salmon at the mouth of the Mokelumne as part of the VAMP experimental design provides the necessary paired control to allow comparison of relative survival indices across a range of flow conditions.

As part of these investigations data from the USGS flow and velocity monitoring station at Jersey Point, and other available data, would be reviewed to determine the magnitude of variation in flow expected at the sampling location as influenced by variation in flow at Vernalis, SWP/CVP export rates, and tidal dynamics. If flow at Jersey Point is found to be relatively stable among years within the range of flow and export conditions being considered as part of VAMP, variation in collection efficiency may be small. If flow is found to vary substantially among years, variation in collection efficiency may contribute to variation of survival indices developed as part of VAMP.

Appendix B

PLANNING AND OPERATION COORDINATION FOR THE VERNALIS ADAPTIVE MANAGEMENT PLAN

Successful implementation of the Vernalis Adaptive Management Plan (VAMP) will require communication and coordination among the several operating agencies that manage flows and facilities in the San Joaquin River Basin and the Bay Delta. Also, significant coordination will be required between project operators and fishery resource managers to provide the conditions that will produce the needed information to be provided by VAMP while at the same time protect the naturally produced salmon of the San Joaquin River Basin.

This document provides the framework, and certain specific detail, of the communications, protocols and procedures to be used to provide operations for the conduct of VAMP. This framework focuses on aspects of basin operations that providee flows to the Bay Delta, and the directly linked operation of the fishery barrier at the head of Old River and exports at the Central Valley Project (CVP) and State Water Project (SWP) delta facilities. The aspects of VAMP that address protocols for the marking, release and recapture of salmon will be described in a separate document. These communications, protocols and procedures are provisional and may be modified by the San Joaquin River Technical Committee (SJRTC) pursuant to Section 11 of the San Joaquin River Agreement.

Hydrology Group of the San Joaquin River Technical Committee

The Hydrology Group of the San Joaquin River Technical Committee (SJRTC) is charged with the responsibility to develop and exchange information concerning forecasted hydrologic conditions, execute the protocols that establish the Test Flow Target and determine San Joaquin River Group (SJRG) Supplemental Water, establish an operations plan for the coordination of flows, and provide a post-analysis and report of operations. The Hydrology Group will also be required to coordinate with other technical groups to develop an efficient operation best fitting the needs of all interests.

The makeup of the Hydrology Group will be determined by the SJRTC. All signatories to the San Joaquin River Agreement will have the right to participate on an equal basis in the Hydrology Group. The SJRTC may also elect to add non-signatory members, pursuant to Section 11.1 of the San Joaquin Agreement. However, in order to function effectively, the Hydrology Group requires participation from at least the water project operators which will be coordinating their respective operations to provide flows and test conditions for VAMP. Those agencies and their initial representatives to the Hydrology Group are as follows:

Agency	Operator Contact
United States Bureau of Reclamation (USBR)	John Burke
California Department of Water Resources	Jim Spence
San Joaquin River Group (SJRG)	Mike Archer
Modesto Irrigation District	Walt Ward
Turlock Irrigation District	Wes Monier
Merced Irrigation District	Ted Selb
Oakdale Irrigation District	Steve Felte
South San Joaquin Irrigation District	Steve Felte
Exchange Contractors	Steve Chedester

John Burke from the USBR and Mike Archer, representing the SJRG, will be Lead Co-coordinators.

The Hydrology Group will meet, confer and report as necessary to carry-out their duties and responsibilities as defined by the procedures described hereafter. The SJRTC will ratify outputs from the Hydrology Group or, at its option, delegate authority to the Hydrology Group to make needed determinations on its own.

Forecasting

No later than February 10, the Hydrology Group will develop a preliminary basin-wide Forecast Report of San Joaquin River operations (without the effects of VAMP) for the February through June period. The format of the Forecast Report will be consistent with Attachment A. Forecasts will be provided for at least 90% and 50% probability of exceedence hydrologic runoff and water demand conditions. DWR runoff forecasts will be used as the basis of unimpaired runoff in the tributaries unless otherwise agreed. Each of the Hydrology Group participants will be responsible for providing the USBR and SJRG Lead Co-coordinators with either reservoir operations plans or the information necessary to develop the appropriate reservoir operations plans for each affected tributary. The Hydrology Group will be responsible for assessing information concerning accretions and depletions for the San Joaquin River and its tributaries, and for acquiring information regarding the planned operations of others affecting San Joaquin River flows to the Bay Delta. The Forecast Report will be provided to the CALFED Operations Group, Biology Group, and local tributary groups.

The USBR and the SJRG Lead Co-coordinators will be responsible for the tracking and periodic updating of forecasted/actual hydrologic conditions, initially on a bi-weekly frequency and later on a weekly basis as the Test Period approaches. Significant changes in hydrologic conditions will trigger the development of revised forecast reports. At a minimum, a revised Forecast Report will be provided the first week of March, mid-March, the first week of April and each week thereafter until the Operations Plan is employed.

After the conclusion of the pulse flows, the Hydrology Group will continue to share and update operations forecast information on a monthly basis so that the best available forecasts of San Joaquin River flows can be included in the CVP/SWP operations plans. The group may decide to suspend this routine coordination during periods when operations plans have become fixed or predictable.

Test Flow Target

The flow target for the 31-day Test Period will be established as the Test Flow Target immediately greater (Single-step Criteria) than the average flow that is forecasted to occur during the Test Period at Vernalis, unless increased by the Double-step Criteria. The Test Flow Target criteria are described below:

Single-step Criteria. Unless increased by the Double-step Criteria, the flow target will be the Test Flow Target immediately greater than the average flow that is forecasted to occur during the Test Period at Vernalis, consistent with the following table:

Forecasted Average Flow at Vernalis (cfs)	Test Flow Target (cfs)
0 – 1,999	2,000
2,000 – 3,199	3,200
3,200 – 4,449	4,450
4,450 – 5,699	5,700
5,700 – 6,999	7,000
7,000 or greater	Existing Flow

When the flow exceeds 7,000 cfs, the SJRG will exert its best efforts to maintain a stable flow rate during the Test Period to the extent reasonably possible. When the flow is 2,000 cfs or less the USBR shall operate pursuant to Sections 5.5 and 6.4 of the San Joaquin River Agreement.

Double-step Criteria. In any year when the sum of the current year's forecasted and previous year's 60-20-20 Indicators is seven (7) or greater, the flow target for the Test Period will equal the Test Flow Target one level higher than that established by the Single-step Criteria. The 60-20-20 Indicator for the VAMP is as follows, and is related to the San Joaquin Valley Water Year Hydrologic Classification as described in 95-1WR (1995 Water Quality Control Plan). The 90% probability of exceedence forecast will be used to calculate the current year's San Joaquin Valley Water Year Hydrologic Classification.

San Joaquin Valley Water Year Hydrologic Classification	60-20-20 Indicator
Wet	5
Above Normal	4
Below Normal	3
Dry	2
Critical	1

Test Period

Although focused on test protocols that measure the survival of tagged hatchery salmon smolt, the VAMP creates an opportunity to provide pulse flow conditions for smolts naturally spawned within the San Joaquin River Basin. The Biology Group will heavily influence the scheduling of the Test Period, initially constructed as a continuous 31-day period elapsing sometime during April and May. It is important for the VAMP to coincide the Test Period with the peak period of time when naturally spawned smolts are migrating out of the San Joaquin River Basin. However, it is recognized that trade-offs in the scheduling of the VAMP will be required to recognize the practicalities of hatchery operations, monitoring activities, barrier operation, and flow and export operational constraints.

The Biology Group will provide its initial estimate of the preferred period of the VAMP beginning in February, coincident with the Hydrology Group's Forecast Report, and provide an updated estimate coincident with each revised Forecast Report. Coincident with the mid-March

Forecast Report, the Hydrology Group and the Biology Group will jointly identify the Tentative Test Period. This Tentative Test Period will be used in subsequent planning efforts, and will be modified only as a result of significant changed circumstances.

SJRG Supplemental Water Determination

Supplemental Water to be provided by the SJRG for the VAMP is the amount of water needed to achieve the Test Flow Target or 110,000 acre-feet, whichever is less. Additionally, during years when the sum of the current year's and the previous two years' 60-20-20 Indicators is four (4) or less, the SJRG will not be required to provide Supplemental Water above the Existing Flow at Vernalis.

The determination of Forecasted Supplemental Water will be performed by the Hydrology Group coincident with each Forecast Report. Prior to the mid-March Forecast Report, it will be assumed that the Test Period will occur mid-April through mid-May. The estimate of Forecasted Supplemental Water will be consistent with Attachment B, and will be based on the average flow that is forecasted to occur during the Test Period at Vernalis and the coinciding Test Flow Target.

Adjustment for Melones Operation. For the determination of Supplemental Water, Existing Flow at Vernalis will be mathematically adjusted to account for any differences between the scheduled [actual] river release below Goodwin and the river release assumed under the Interim Operation Plan. Supplemental Water provided by the SJRG will be determined as if Melones is operated to provide the river release assumed under the Interim Operation Plan. Deviation from the assumed river release during the Test Period will also account for the carry-over affect of varying from the Interim Operation Plan during other periods of the year.

Adjustment for Water Purchase Programs. The determination of the amount of Supplemental Water to be provided by SJRG will take into account the existence of water at Vernalis that occurs as the result of other sales or transfers by the SJRG, or by other flow augmentation programs provided by the USBR. Supplemental Water provided by the SJRG will be determined as if flow at Vernalis is absent of these actions.

Operations Plan

Beginning with the mid-March Forecast Report, the Hydrology Group will develop the Operations Plan to provide the VAMP flows. The Operations Plan will be revised coincident with changes in the Forecast Report. The Operations Plan will provide a daily plan of operation for April and May. The format of the Operations Plan will be consistent with Attachment C.

The SJRG will provide to the Hydrology Group the information necessary to develop the Vernalis flow component of the Operations Plan. Such information will include the locations from which Supplemental Water will be released. The Hydrology Group will integrate the Supplemental Water with the other forecasted hydrology and water management programs of the basin into a forecast of VAMP Vernalis flow conditions.

The Hydrology Group will also coordinate with the CALFED Operations Group and appropriate agencies to identify the plan for barrier installation/operation and VAMP export operations.

Implementation Procedure

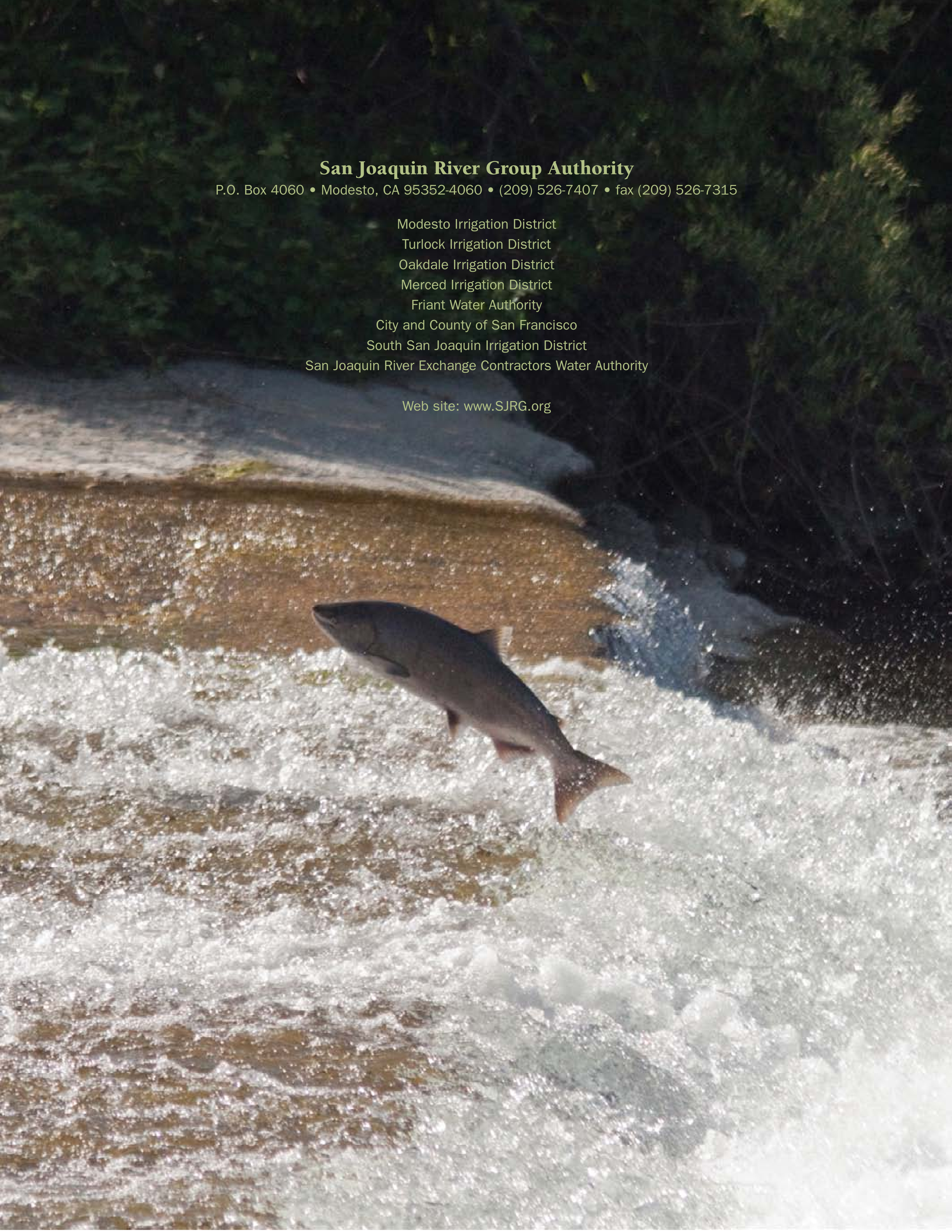
The SJRG members and USBR will carry-out the Operations Plan using best efforts to make Control Point releases match the Operations Plan forecast of releases. The USBR and the SJRG Lead Co-coordinators will track actual operations and hydrologic conditions during the Test Period and disseminate such information along with a projection of conditions anticipated for the remainder of the Test Period. The Hydrology Group will confer weekly, beginning late March, to review schedules. Storms, flood control or other unforeseen circumstances may require more frequent schedule changes. In order to maintain the intent of a stable flow, an effort will be made to keep flows within a specified range above and below the target flows.

Post-Analysis and Report

The Hydrology Group will provide an Operations Report each year following the Test Period. The format of the Operations Report will be consistent with Attachment D. The purpose o f the Operations Report is to provide a summary of the hydrologic conditions that occurred during the Test Period, and to identify issues that occurred during that year concerning the planning and operation of the VAMP. The Operations Report will also provide alternatives to resolve those issues prior to the next year of the VAMP.

Calibration of Flow Measuring Points

The agencies will consult with USGS prior to the pulse flows regarding planned flow measurement of river sections for the purpose of adjustment to rating tables for Vernalis and upstream control points. Ideally, ratings would be checked just before the beginning of the 31-day period.



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San Joaquin River Exchange Contractors Water Authority

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