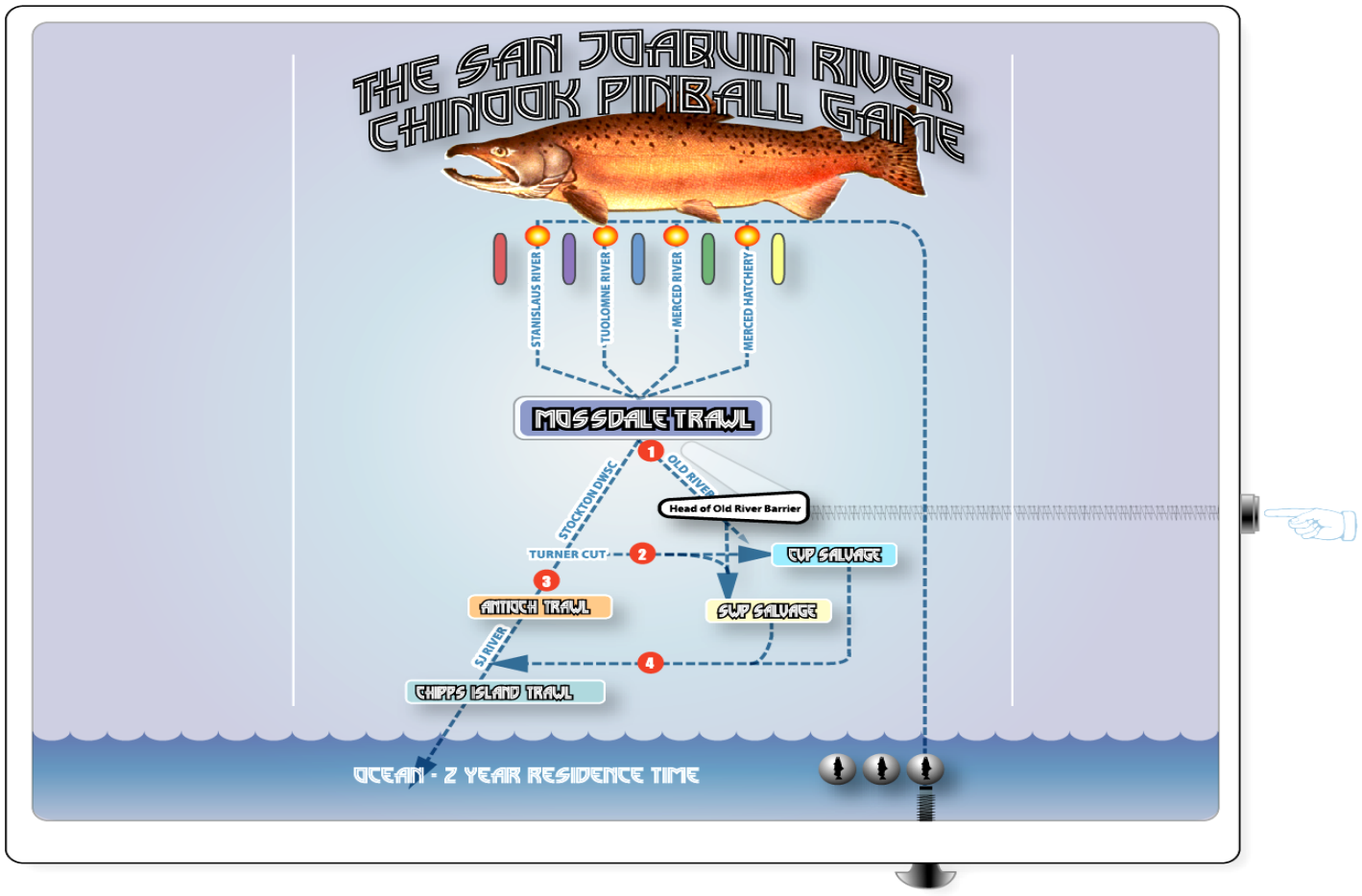

EVALUATION OF FISH PROTECTION FROM THE HEAD OF OLD RIVER BARRIER

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The effectiveness of installing the head of Old River barrier for reducing the entrainment of migrating San Joaquin river (SJR) fall-run Chinook salmon was evaluated. Estimating the fraction of the fish that might be protected by just one of the Vernalis Adaptive Management Plan (VAMP) actions is difficult because single-action conditions seldom have been observed. The goal of this Reclamation study was to develop a simple model that would estimate the fraction of SJR salmon salvaged at CVP and SWP pumps and the overall survival fraction to Chipps Island, as a function of SJR flow, exports, and head of Old River barrier (in or out). This evaluation compared the daily patterns of salmon abundance in the SJR at the Mossdale trawl to the observed daily salvage of salmon at the Central Valley Project (CVP) and State Water Project (SWP) pumping plants. The daily Mossdale fish abundance and the estimated flow diversions and fish preferences were combined to calculate the number of fish expected at the CVP and the SWP salvage. The comparison of the Mossdale abundance and the CVP and SWP salvage for the 1996–2005 period provided a method to estimate the expected salvage fraction for the full range of SJR flows and CVP and SWP exports, with and without the head of Old River barrier. Both the reduced exports (i.e., reduced pumping) and the head of Old River barrier will reduce the fraction of fish salvaged. The overall comparison of survival to Chipps Island for juvenile SJR salmon is more uncertain than the calculation of the fraction of juvenile salmon reaching CVP and SWP salvage.

INTRODUCTION

The goal of this evaluation is to determine the effectiveness of installing the head of Old River barrier for reducing the entrainment of migrating SJR fall-run Chinook salmon. The quantitative goal is to determine the fraction of the SJR Chinook salmon that are protected (i.e., increased survival to Chipps Island trawl) by the head of Old River barrier installation. This is somewhat difficult because the VAMP experimental program includes three simultaneous actions implemented each spring:

1. increased SJR flows at Vernalis (pulse flow),
2. reduced CVP and SWP pumping (export reduction), and
3. head of Old River barrier installation (barrier).

Some fish protection is provided by each of these coordinated actions, and identifying the portion of the protection that is achieved by the barrier installation must include a comprehensive evaluation of fish movement and behavior during VAMP conditions. Estimating the fraction of the fish that might be protected by just one of these actions (without the others) is even more difficult because single-action conditions seldom have been observed. The management goal is to develop a simple model that would estimate the SJR fall-run Chinook salmon survival for a range of possible conditions to compare survival for management alternatives for a range of pulse flows, different target CVP and SWP pumping rates, and with or without barrier installation.

This evaluation includes the comparison of daily patterns of SJR Chinook salmon abundance in the SJR at the Mossdale trawl with the observed daily counts of Chinook salmon at the CVP and SWP pumping plants, referred to as *fish salvage numbers*. The evaluation also investigates the results of coded-wire-tag (CWT) recoveries from experimental release groups on the SJR, as recovered at the CVP and SWP salvage facilities and at the Chipps Island trawl. A daily descriptive model of the movement and survival of SJR Chinook salmon migrating down the major pathways from Mossdale to Chipps Island is developed, and the simulated results for various assumed factors (e.g., migrating fish "splits" at the head of Old River and Turner Cut, predation rates, travel times) are presented. This daily model allows all the available flow measurements and "fish counts" (e.g., hatchery releases, screw-trap records, Mossdale trawl, CVP and SWP salvage, Chipps Island trawl) to be connected and integrated within a comparative evaluation framework.

MOSSDALE KODIAK TRAWL

California Department of Fish and Game (DFG) has operated the Mossdale Kodiak trawl for the April–June period since 1989. The USFWS has cooperatively operated the Mossdale Kodiak trawl from mid-June to April since 1999 as part of its comprehensive Delta juvenile Chinook salmon monitoring program. In 2005 and 2006, DFG also operated a Kodiak trawl in Old River concurrent with the Mossdale trawling to determine the proportion of SJR fish that entered Old River. High flows in the SJR in these years precluded the California Department of Water Resources (DWR) from installing the head of Old River barrier.

The evaluation of the head of Old River fish protection described in this report covers the 10-year period 1996–2005. The daily data used for estimates of the natural (unmarked) fish are the daily catch, the daily trawl volume (of 75–125 acre-feet per day [af/day]), the daily flow volume (af/day), and the size of the fish (minimum, average, and maximum length). Sampling has been conducted each year during the April–June period, so the smolt-sized fish (i.e., longer than 75 millimeters [mm]) can be reliably estimated. A comparison of the larger fish sampled in the April, May, and June period each year may provide the best comparison of migrating smolt abundance. The daily Mossdale fish estimate was the volume-expanded trawl catch. Daily fish = trawl catch x flow volume/trawl volume.

COMPARISON OF MOSSDALE ABUNDANCE AND SALVAGE

Each year will have a unique pattern of daily SJR flows, daily Chinook salmon abundance at Mossdale, CVP and SWP export pumping, and corresponding CVP and SWP salvage. The evaluation of the head of Old River barrier

compares the daily observed Mossdale abundance with the observed CVP and SWP salvage, to determine what fraction of the SJR fish likely were salvaged. The head of Old River barrier is assumed to reduce the number of fish being salvaged and to increase the number of fish migrating down the SJR to Chipps Island trawl. This should be evident in the reduced fraction of the Mossdale fish that are observed at CVP and SWP salvage. The comparison for 1996 is explained as an example.

The evaluation of the benefits of the head of Old River barrier depends on being able to accurately estimate the fraction of the SJR fish that likely would be salvaged at the CVP and SWP pumping plants with and without the barrier. This fraction will depend on the SJR flow, the Old River flow, and the CVP and SWP pumping rates. These flows will control the flow split at the head of Old River and will control the fraction of the SJR flow that is diverted at Turner Cut and flows toward Middle River and the CVP and SWP pumping plants. The two possible pathways for fish moving between Mossdale and the pumping plants were evaluated by considering the water flow splits and then considering the likely movement of fish at these junctions. Fish are assumed to generally follow the water flow, with possible preferences at each flow split (i.e., head of Old River and Turner Cut) as well as at the CVP and SWP export diversions. The fish preference value can be greater than 1 (i.e., preference) or less than 1 (i.e., avoidance). The fish moving with a flow split will be the flow fraction times the preference value. A preference of 1 indicates the fish split will be equal to the water split. A preference of 1.2 would suggest that the fish split would be 20% higher than the flow split. A preference of 0.2 indicates that the fish split would be only 20% of the flow split. The fish preference is specified for the diversion only. The other fish move downstream with the remaining flow. The recent acoustic tag data can be used to more accurately specify these fish preferences. The VAMP 2008 acoustic tag results and the 2009 bio-acoustic fish fence (BAFF) barrier results both indicated that the fish split at the head of Old River was similar to the flow split (preference of 1).

HEAD OF OLD RIVER FLOW AND FISH

The diversion of flow from the SJR into Old River is about 50% of the SJR flow when there is relatively low CVP and SWP pumping. Tidal flow modeling (i.e., DSM2 results) and tidal flow measurements indicate that the Old River flow will increase by about 5% of the combined CVP and SWP pumping. Each pumping flow of 1,000 cfs therefore will increase the Old River diversion by 50 cfs. A pumping flow of 10,000 cfs would increase the Old River flow by 500 cfs and might divert the entire SJR flow during low-flow periods.

Comparative Kodiak trawl sampling was conducted at Mossdale and in Old River in two recent years (2005 and 2006). The fish density in Old River was generally similar to the fish density at Mossdale, although there was considerable variability from day to day. During May 2005, the Mossdale flow was about 8,000 cfs, and the flow split into Old River was about 50%. If the fish preference was 1, the density of fish in Old River would be the same as the fish density at Mossdale, and the number of fish caught in the Old River trawl would be about the same as in the Mossdale trawl (for the same trawl volume). The total unmarked fish caught in Old River was 373, compared to the Mossdale catch of 466. For CWT fish, the catch in Old River was 340 and the catch at Mossdale was 812. However, the trawling volume for Old River was only about 60% of the Mossdale trawl volume, so the adjusted unmarked catch ratio was 1.33 and the adjusted CWT catch ratio was 0.7. These results were generally repeated in 2006. The head of Old River preference was assumed to be 1, so the density of fish in the diverted Old River flow would be the same as at Mossdale.

The culverts and leakage through the rock barrier were assumed to provide a minimum flow of about 500 cfs (leakage and six culverts). The comparison of SJR fish abundance and salvage data suggests that only a few fish were diverted into Old River when the barrier was installed. This is likely because few fish move through the rock barrier with the leakage flow, and few fish move toward the culverts. The fish preference is assumed to be 0.1 (10% of the upstream fish density) when the head of Old River barrier is installed.

EXPORT FLOW AND FISH SALVAGE

The majority of the CVP exports come from Old River. It was assumed that all the Old River flow will be diverted into the CVP pumping intake if the CVP pumping flow is greater than the Old River flow. All the fish diverted into Old River will be diverted into the CVP salvage under these conditions.

However, if the Old River flow is greater than the CVP diversion, the fish preference value was assumed to be equal to this flow ratio. This suggests that fish will avoid the CVP intake if the CVP diversion is less than the Old River flow. For example, if the Old River flow is twice the CVP pumping, the expected CVP fish preference would be 0.5 and the CVP fish density would be about half of the Mossdale fish density. This avoidance of the CVP pumps has been observed during periods when the Old River flow is relatively high compared to the CVP pumping.

Some Old River flow was assumed to be diverted to SWP pumping only if the Old River flow was greater than the CVP pumping. The fish preference for the SWP diversion was assumed to be 1 if the remaining Old River flow was less than the SWP pumping. If the remaining Old River flow was greater than the SWP pumping, the fish preference was assumed to be the ratio of the SWP pumping to the remaining Old River flow. Only during very high SJR flows would the remaining Old River flow be greater than SWP pumping.

TURNER CUT FLOW AND FISH

The Turner Cut diversion from the SJR depends on the excess CVP and SWP pumping (i.e., pumping not supplied by the head of Old River diversion). Based on tidal hydraulic modeling results (DSM2), the Turner Cut diversion flow is about 10% of this excess pumping.

Because there is a very strong tidal flow (of about 15,000 cfs) in the SJR at Turner Cut, the daily evaluation model assumes that the fish preference at the Turner Cut diversion is about 0.25. Therefore, only 25% of the SJR fish that would have been diverted into Turner Cut with the diverted SJR flow will move toward the SWP and CVP exports. Most of the SJR fish migrating to Turner Cut will continue down the SJR toward the Chipps Island trawl. This assumed fish preference is most important when the pumping is greater than the SJR flow. All of the SJR flow would be diverted toward the pumps, but only 25% of the fish reaching Turner Cut would be diverted toward the salvage. Because the April–May period with high fish abundance generally corresponds to the reduced pumping as part of VAMP, periods of high pumping when the Turner Cut diversions would be high enough to evaluate the assumed fish preference (i.e., avoidance) are relatively rare. The recent acoustic tag results can be used to specify this fish split avoidance factor more accurately.

EXAMPLE RESULTS—EVALUATION OF 1996 CONDITIONS

The daily Mossdale fish abundance and the estimated flow diversions and fish preferences can be combined to calculate the number of fish expected at the CVP and the SWP salvage. The daily evaluation model does not include a travel-time delay between Mossdale and the CVP and SWP salvage. The VAMP 2008 results suggest a travel time of about 2–3 days. Daily fish abundance and flow conditions during 1996 will be used to introduce these daily model calculations.

Figure 1 shows the flows and exports during the February–June period of 1996. The SJR flows were generally high (>10,000 cfs) in February and March. The SJR Flows were about 6,000 cfs in April and early May but increased to 10,000 cfs in late May and were less than 4,000 cfs in June. The Old River diversions were about half of the SJR flows. The head of Old River barrier was installed in early May but was removed when the flow increased in late May. Exports were about 6,000 cfs in early April and were reduced to 1,500 cfs in the second half of April and the first half of May. Exports then were raised to about 10,000 cfs in the second half of May and June.

Figure 2 shows the daily Mossdale fish abundance (blue triangles) and the combined daily CVP and SWP historical salvage compared to estimates for water splits only and with the assumed fish preferences. The fish abundance scale is logarithmic to allow the fraction of fish reaching CVP and SWP salvage to be more easily compared to the Mossdale abundance for the full period, which has both low and high daily fish numbers. On the logarithmic scale, a factor of 2 is about 1/3 of the log scale interval.

The Mossdale trawl sampled fish from early April through most of June in 1996. The maximum abundance of SJR fish occurred in mid-April, with a peak of more than 25,000 per day for a few days. Many days in late April and

mid-May had more than 10,000 fish. Most of the early-April through mid-June period had more than 1,000 fish each day. The Mossdale abundance was much lower in early April and late June, with fewer than 100 fish per day.

The combined daily salvage was similar to the SJR fish abundance in early April and late May, when pumping was slightly more than the SJR flow. The estimates of salvage indicate that most of the fish diverted into Old River were observed at salvage, so the combined salvage was about half of the SJR fish. The pumping was greatly reduced during the VAMP period, and the corresponding fraction of the SJR fish observed at salvage declined to less than 10%. The water splits at the export diversions accounted for part of the reduction (purple squares), but the export diversion preferences (i.e., export/Old River flow) provided a better match with the observed salvage during this period of reduced exports.

Figure 3 shows the separate estimates for CVP and SWP salvage, based on water splits and assumed fish avoidance for export diversions and Turner Cut diversions compared to the historical CVP and SWP salvage for 1996. The CVP salvage was almost always greater than SWP salvage. This was accurately predicted by assuming that head of Old River flows move past CVP salvage first, and only the remaining flows move to SWP exports. Only in the early-April and late-May periods when pumping was greater than head of Old River flow was there any simulated diversion at Turner Cut. The estimated and observed SWP salvage was similar to the CVP salvage in late May when the combined exports were higher than the SJR flow. The estimated SWP salvage was higher than observed during the low export period of mid-April to mid-May. There was a general agreement between the measured and estimated CVP and SWP salvage in 1996, based on the Mossdale fish abundance and the SJR flow, head of Old River diversion, and CVP and SWP export diversions.

The fraction of the Mossdale fish expected at the CVP and SWP salvage will be equal to the head of Old River diversion fraction if the CVP and SWP pumping is greater than the head of Old River diversion flow. The number expected at the CVP and SWP salvage will decrease as the pumping flow is reduced to less than the head of Old River flow. This decrease will be greater as the CVP and SWP diversions are reduced because the assumed fish avoidance is the ratio of the CVP or SWP diversion to the Old River flow. Reduced pumping will reduce the expected salvage of fish, even without the head of Old River barrier.

HEAD OF OLD RIVER EFFECTIVENESS

This daily evaluation model of CVP and SWP salvage of juvenile SJR Chinook salmon can be summarized as follows.

1. The head of Old River diversion fraction (water and fish) will be about 50% of the SJR flow plus 5% of the combined exports.

2. The fraction of fish in the flow that is diverted at Turner Cut will be about 25% of the flow fraction because most of the SJR fish are tidally oriented.

3. The maximum fraction of the SJR fish that can be salvaged is the ratio of combined exports to the SJR flow. Reducing the exports to less than the SJR flow will reduce the fraction of the SJR fish that are salvaged.

The additional protection provided by the head of Old River barrier depends on the CVP and SWP pumping. If pumping is equal to or greater than the head of Old River diversion, the barrier will have a relatively large effect (protecting most of the fish in the head of Old River diversion flow from salvage). Because the assumed Turner Cut fish avoidance is 25%, the majority (75%) of the fish that would have been salvaged without the barrier will be protected. The barrier effectiveness for protecting Mossdale fish from salvage is reduced when CVP and SWP pumping is less than the head of Old River diversion.

The difference between the expected CVP and SWP salvage with and without the barrier can be accurately calculated with these basic rules for any specified pattern of SJR flows and exports. For example, if the SJR flow was 3,000 cfs with exports of 1,500 cfs, about 1,575 cfs would be diverted at the head of Old River (50% SJR plus 5% pumping), and about 50% of the fish would be salvaged (1,500/3,000) without the barrier. The other 1,425 cfs of the SJR flow and about half of the SJR fish would move down the SJR past Stockton toward the estuary. Because there would be no Turner Cut diversion toward the pumps, all the fish at Turner Cut would move toward the estuary.

The installation of the barrier would reduce the flow diverted into Old River to about 500 cfs, and would reduce the fish diverted in this 500 cfs flow by 90% to about 2% of the SJR fish (i.e., 50/3,000). About 10% of the remaining exports of 1,000 cfs (with 500 cfs supplied from Old River) would be diverted at Turner Cut (i.e., flow split), but with the assumed fish avoidance of 0.25, only SJR fish in 25 cfs would be diverted at Turner Cut. The fraction of fish salvaged therefore would be about 2.5% (i.e., 75 cfs/3,000 cfs) with the head of Old River barrier installed. Therefore, the head of Old River barrier would protect about 45% of the SJR fish from salvage, if the combined exports are more than 50% of the SJR flow.

INCREASED SURVIVAL OF SAN JOAQUIN RIVER CHINOOK SALMON

Comparison of the fraction of SJR fish that would be salvaged (with and without the barrier) with different SJR flow and export pumping does not provide the complete answer for the SJR survival and VAMP evaluation. The effectiveness of VAMP for improving the survival of the SJR juvenile Chinook salmon migration to Chipps Island also must consider the effectiveness of CVP and SWP salvage operations for juvenile Chinook salmon survival.

The survival of fish migrating the 25 km (15 miles) down Old River to CVP and SWP salvage (with salvage losses) must be compared to the likely survival for juveniles migrating the 100 km (60 miles) from Mossdale to Chipps Island through the Delta channels. As indicated by CWT recoveries, the travel time to Chipps Island (about 15–30 days) is generally longer than the travel time to CVP or SWP salvage (about 5–10 days). The 2008 acoustic tag results show 5–15 days to Chipps Island and 3–10 to salvage. The expected mortality during the additional days of migration to Chipps Island should be compared to the salvage losses to determine the pathway with the highest overall Chinook survival. This overall comparison of survival for juvenile SJR Chinook salmon is more uncertain than the calculation of the fraction of juvenile SJR Chinook salmon reaching CVP and SWP salvage. Because the majority of SJR fish are salvaged at the CVP facility, losses in Clifton Court Forebay may be less important than for fish from the central Delta (e.g., longfin and delta smelt).

Because the survival estimates for CWT fish moving to Chipps Island are generally low (5% to 25%), survival for SJR Chinook salmon might be greater if the salvage fraction were increased. This could be accomplished by not installing the head of Old River barrier and increasing exports to greater than the SJR flow. For additional information about this evaluation method, please contact Russ Brown at 916-621-7035. russbrownriverconsulting@gmail.com.

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Jones and Stokes. 2007. Evaluation of Fish Protection from Installation of the Head of Old River Barrier. September (J&S 06757.06) Sacramento, CA. Prepared for the U.S. Department of Interior, Bureau of Reclamation.

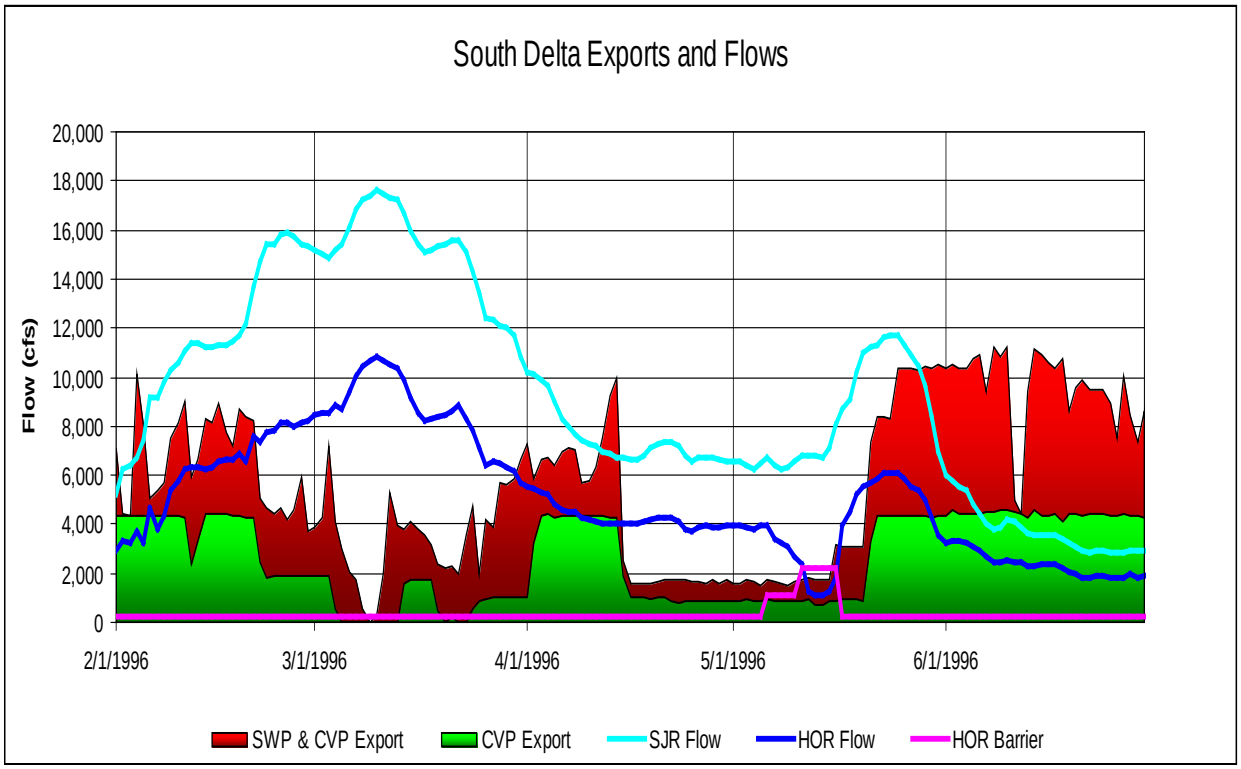

Figure 1. Daily flows (cfs) and exports (cfs) during the February–June period of 1996.

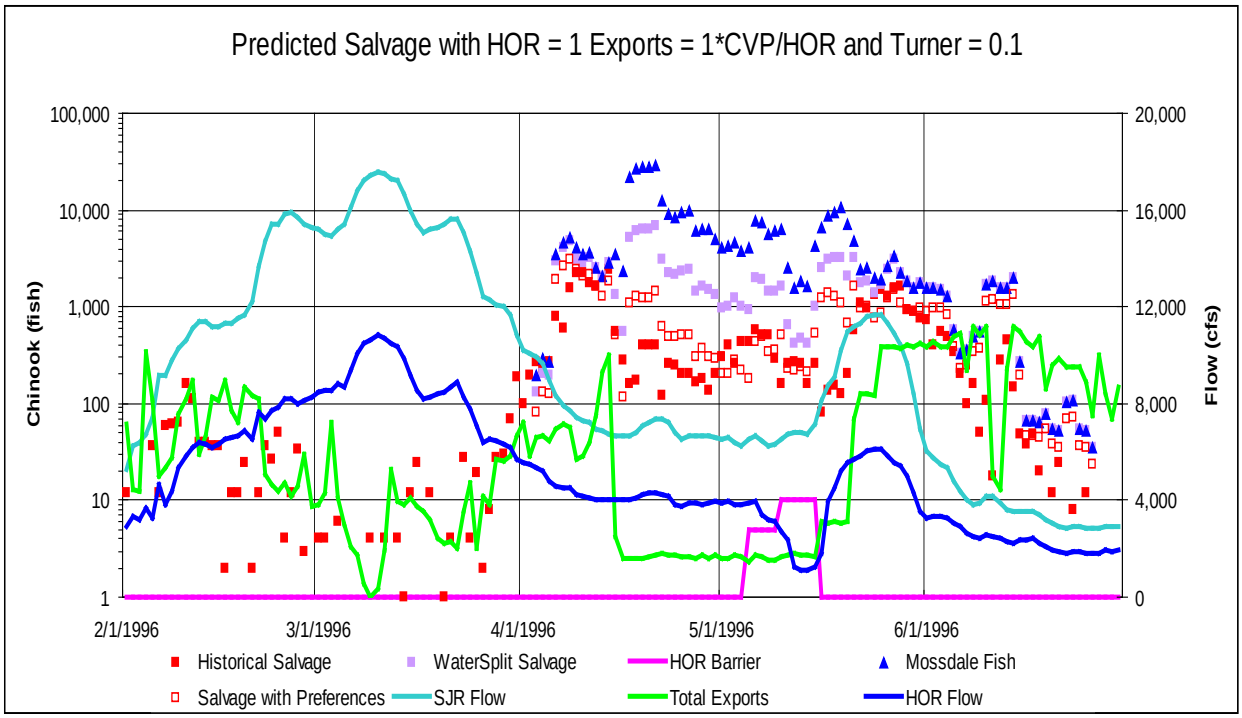

Figure 2. Daily Mossdale fish abundance (blue triangles) and combined daily CVP and SWP historical salvage (red boxes) compared to estimated salvage for water splits only (gray boxes) and with the assumed fish preferences for 1996.

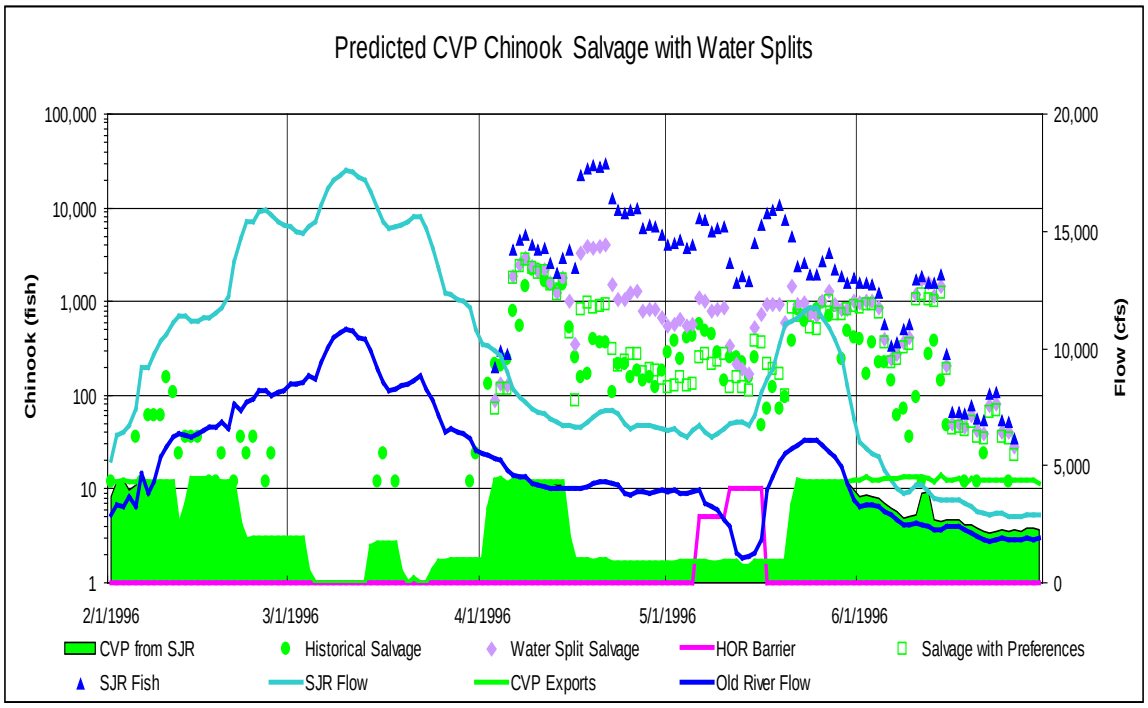

Figure 3a. Daily estimates of CVP salvage, based on water splits (gray diamonds) and assumed fish avoidance at exports and Turner Cut (open boxes) compared to historical CVP salvage for 1996.

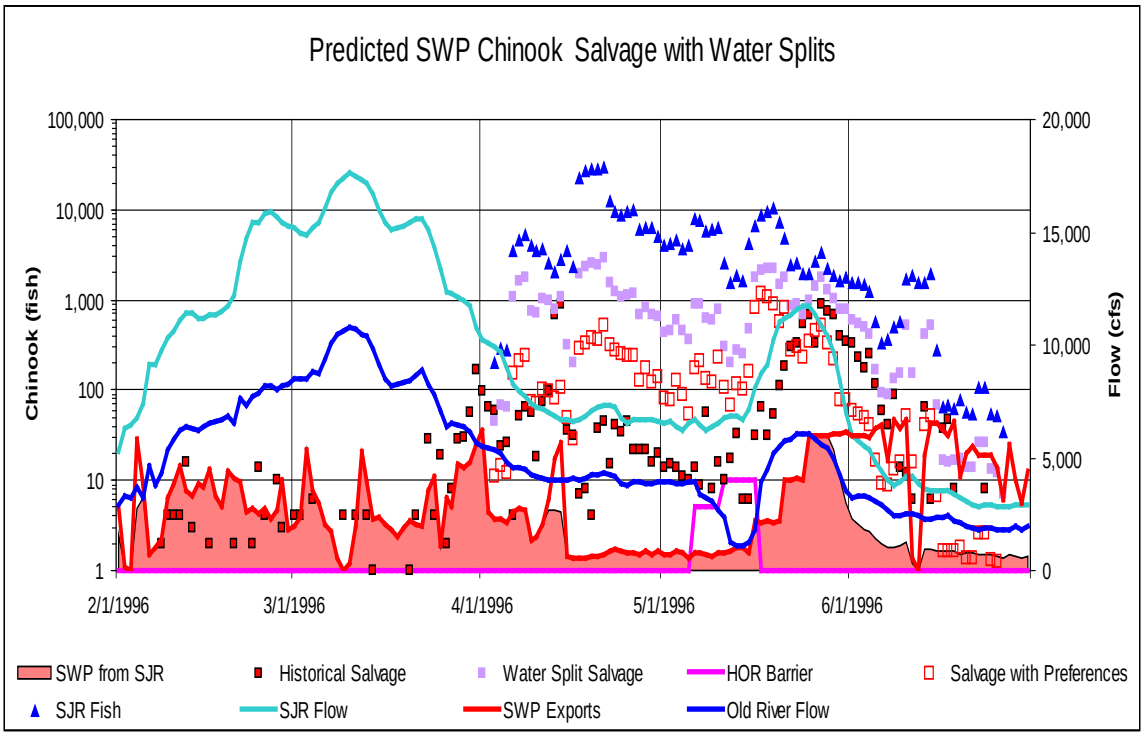

Figure 3b. Daily estimates of SWP salvage based on water splits (gray boxes) and assumed fish avoidance at exports and Turner Cut (open boxes) compared to historical SWP salvage for 1996.