Flow Requirements and other Recommendations to Protect San Joaquin River Fisheries

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Photo of fall Chinook salmon from Yolo Bypass, March 2013. (Photo by Jacob Katz)

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San Joaquin River Flow Recommendations

Introduction

The California Sportfishing Protection Alliance (CSPA) asked me for my opinion and recommendations on flows and standards needed to protect Chinook salmon, steelhead, and other fish populations in the San Joaquin River and its major tributaries. CSPA also asked me to review the State Water Resources Control Board's (Board's) Substitute Environmental Document (SED) for the *Evaluation of San Joaquin River Flow and Southern Delta Water Quality Objectives and Implementation,* released on December 31, 2012. This report responds to CSPA on these matters.

In the SED, the Board finds that higher and more variable flows in the major San Joaquin River tributaries and in the San Joaquin River at Vernalis are needed to support salmon and steelhead populations in these rivers as well as their migratory and rearing habitat in the lower San Joaquin River within the Delta. The target tributaries are the Stanislaus, Tuolumne, and Merced rivers (Figure 1). Neither the Board in the SED nor I in this report address the upper San Joaquin above the Merced River or the three Delta tributaries (Mokelumne, Cosumnes, and Calaveras Rivers).

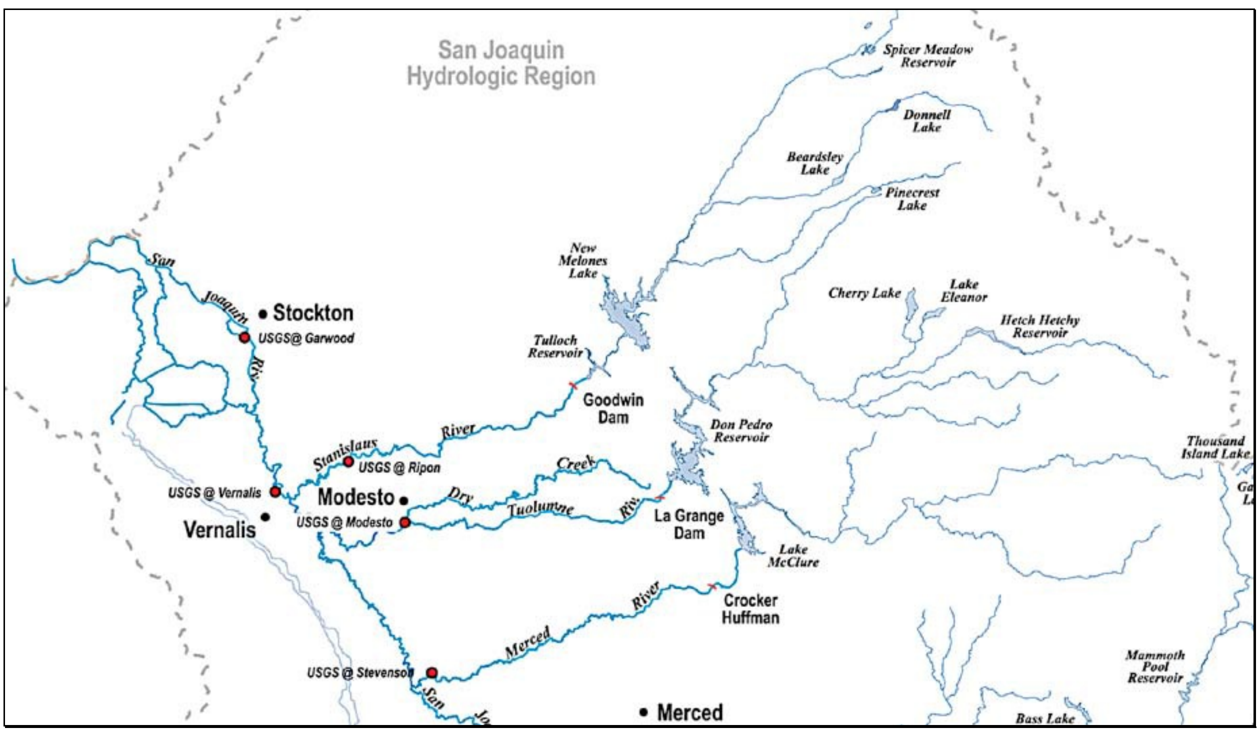

Figure 1. Lower San Joaquin River and its three main tributaries below Merced, California. (Source: Appendix C, SWRCB 2012)

Large mainstem water supply reservoirs on the Stanislaus, Tuolumne, and Merced and associated water supply developments have markedly altered the rivers flow regimes to the point that existing salmon and steelhead populations in these rivers are now threatened with extinction.[1] While the annual salmon runs vary widely, there has been a continuing long-term downward trend in escapement in each of these rivers (see Figure 2 below). Salmonid populations in these tributaries need flows of higher magnitude and greater variability to recover. Higher flows will improve connectivity with the Delta and San Francisco Bay, and will provide better rearing and migration habitat in the three tributaries, the lower mainstem San Joaquin River, and the Delta. Furthermore, an increase in the amount of water from the San Joaquin watershed that reaches San Francisco Bay will increase in the production of anadromous adult salmonids from the entire Central Valley, not just the San Joaquin River.

After a comprehensive review of the case, evidence, science, and issues before the Board, I offer the following recommendations regarding the flow needs of the San Joaquin River specifically for the three mainstem tributaries, the Stanislaus, Tuolumne, and Merced Rivers.

- A replication of the unimpaired flow pattern in each of these rivers must be restored to allow salmon and steelhead populations to respond positively toward recovery. My specific recommendation is to allow 60% of the January through June unimpaired flow of these rivers to reach the Delta at Vernalis in a natural annual and seasonal flow pattern.

- I also recommend pulse flows in the fall to improve the success of adult salmon migrating into the San Joaquin and operational measures to ensure the successful out-migration of young salmon to the sea. The purpose of this report is to recommend conditions that would lead to recovery of the salmon and steelhead populations of the three San Joaquin tributaries, not to balance benefits or effects among beneficial uses.

My recommendations would provide a flow regime that more closely follows the natural seasonal flow conditions to which native migratory salmonid fish are adapted. The flow regimes that I recommend do not represent exact alternatives that are evaluated in the SED. However, they do represent fundamental elements of the flow regimes that the Board analyzes in the SED. The range of San Joaquin River flow and southern Delta salinity patterns proposed in this recommendation are also included in the alternatives analyzed in the SED.

Proposed Actions

Change Tributary Reservoir Operations and Flow Release Patterns

The major storage dams on the Stanislaus, Tuolumne, and Merced rivers should release 60% of daily unimpaired inflows, calculated on a short-term running average, during the months of January through June. The resulting flow-release pattern will thus closely replicate the natural daily unimpaired flow pattern of each river. In addition, there should be a year-round minimum flow of 2000 cfs at Vernalis as a lifeline flow for the lower San Joaquin River and the Delta and to ensure that at least 1000 cfs passes through the Stockton Deep-water Channel to maintain the

[1] *Biological and Conference Opinion on the Long-Term Operations of the Central Valley Project (CVP) and State*

dissolved oxygen standard.[2] Application of this minimum flow would incrementally increase the cumulative January to June flow to somewhat greater than 60% in drier years.

Maximize San Joaquin Delta Inflow to the Bay

There are several actions that would maximize the amount of San Joaquin inflow as measured at Vernalis that passes through the Delta to the Bay. First, the Delta Cross Channel (DCC) on the Sacramento River should be kept open as much as possible to ensure positive net tidal flows at Jersey Point. Second, the Head of Old River Barrier (HORB[3]) should be kept closed as much as possible other than providing flows needed to maintain circulation and water quality in South Delta channels. Third, negative flows in the lower San Joaquin River within the Delta, and in Old River and Middle River should be reduced or eliminated. Fourth, San Joaquin flows should be coordinated with Bay-Delta hydrodynamic factors including Sacramento River Delta inflow levels, DCC and HORB operations, Delta exports, local rainfall, and in-Delta seasonal, monthly, and daily tidal conditions.

Emulate Natural Flow Pulses

Given the 60% of unimpaired January through June criterion for each tributary, flow pulses will occur more or less simultaneously in winter and spring in each of the tributaries. Operators should adjust the releases over a short term (days) to maximize the magnitude of the overall pulse in the San Joaquin River by synchronizing flow releases with the other tributaries, with local rainfall, and with runoff. Such operations would observe flood safety requirements. However, the flow caps for percent of unimpaired flow for each of the tributaries as stated in the SED are extremely conservative, and would eliminate much of the high flow benefit that the percent-of-unimpaired approach is designed to create. Equally, the proposal in the SED to operate tributary reservoirs on a 14-day running average would result in a smoothing of flows, greatly reducing the benefits of high flows and daily variability. The Board should evaluate operations that capture as much as possible the benefits of high flows by eliminating the tributary flow caps, and should also evaluate shorter running averages (such as 3-day or 4-day) for daily reservoir operations.

In addition, fall pulses are needed to stimulate adult salmon upstream migrations from the ocean, Bay, Delta, and San Joaquin River into the spawning grounds of the tributaries. I recommend a modification of the date-certain approach to fall attraction flows that has been historically applied in the San Joaquin basin. When rainfall events occur between October 1 and October 31, fall pulses should be timed to enhance and extend the associated natural flow increases. In the absence of such natural events, the fall pulses should begin on November 1.

To maximize the benefits in the Delta, the Board should be particularly strict in requiring positive flows in the Delta portion of the San Joaquin River at Jersey Point, and in Old River and Middle River during Delta inflow pulses from the San Joaquin. The importance of these positive flows is increased even further when the DCC is closed and when the HORB is open.

[2] http://www.gfredlee.com/SJR-Delta/SJRIssuesEngineerogram.pdf

[3] For more on HORB see: http://baydelta.wordpress.com/2010/06/23/the-head-of-old-river-barrier-and-a-delicate-balance-of-species-and-exports/

Purpose and Need

The proposed flows will provide more natural flow pulses in the fall, winter, and spring. They will also provide higher base flows in the winter and spring. Salmon and steelhead are adapted to each of these natural flow patterns.

Fall rainfall pulses provide the olfactory stimuli to attract spawners to their spawning rivers. Fall pulses stimulate spawning by freshening water, cleaning gravels, and lowering water temperatures. Fall pulses also stimulate the river and Bay-Delta food chains on which young salmon will depend.

Winter flow pulses provide the natural higher-turbidity, higher-velocity highways for newly hatched salmon fry to migrate to the Bay-Delta estuary. It is a well-established fact for Central Valley fall-run and spring-run Chinook salmon that fry rearing in tidal estuaries including the Bay-Delta is an important life history strategy essential to population production and viability (Appendix C, SWRCB 2012[4]). Therefore, it is important to provide winter (and early spring) pulses and manage Delta operations to create maximum opportunity for fry to reach Suisun Bay. Winter pulses also provide the attraction flows for adult steelhead, and in the future will be important for attracting restored spring Chinook salmon to the Upper San Joaquin River.

Spring flow pulses are critical for the growth of juvenile salmon and steelhead rearing in the rivers and Bay-Delta, and for providing enhanced opportunities for juvenile salmon to migrate downstream to and through the Delta to the Bay. Such pulses help all the salmon and steelhead rearing in and passing through the Bay-Delta to get successfully to the ocean. Spring pulses are also important to upstream migrating adult steelhead, and in the future will be important for attracting restored spring Chinook salmon to the Upper San Joaquin River.

Higher overall flows between pulses also provide more and better in-channel and in some cases floodplain rearing habitat for young salmon and steelhead. Higher flows provide more physical space, better water temperatures, protection from predators, and greater food production and availability. Higher flows also sustain conditions for migrating and rearing fishes throughout the system. Spring flow improvements will also enhance spawning, rearing, and migrating conditions for splittail, striped bass, sturgeon, and other fishes, as well as improve water quality of the three tributaries, lower San Joaquin, and the Delta (e.g., salinity and water temperature).

Basic Rationale

The relationship between San Joaquin flows and the salmon populations has been noted for decades as seen in Figure 2 below. This highly significant relationship shows that when average lower San Joaquin River flows fall below the 5,000 cfs level during winter and spring,

[4] See: http://www.waterboards.ca.gov/waterrights/water_issues/programs/bay_delta/bay_delta_plan/water_quality_control_planning/2012_sed/docs/2012ap_c.pdf

subsequent adult escapement falls, often sharply, two years later. The cause is generally believed to be poor survival of young salmon migrating down the rivers through the Delta during the year when flows were lower. The resulting poor escapement further confounds the recovery of the population by limiting subsequent escapement from poor egg production (Figure 3). In other words, it may take several years and generations for recovery to occur after the initial population collapse. This is a likely cause of poor response to two recent years of higher flows (2005-2006).

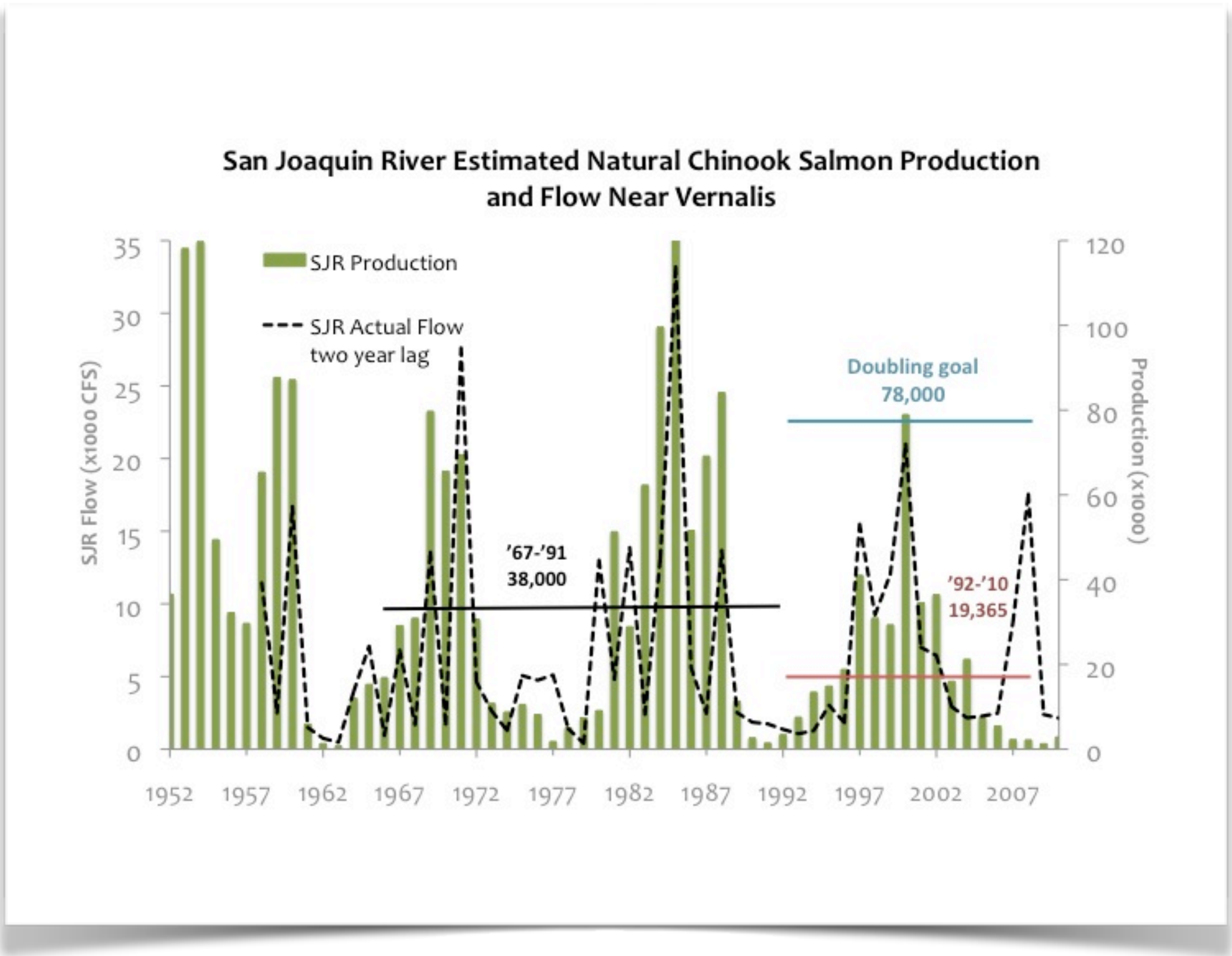

Figure 2. San Joaquin salmon production as related to San Joaquin flow two years earlier. (Source: Appendix C, SWRCB 2012)

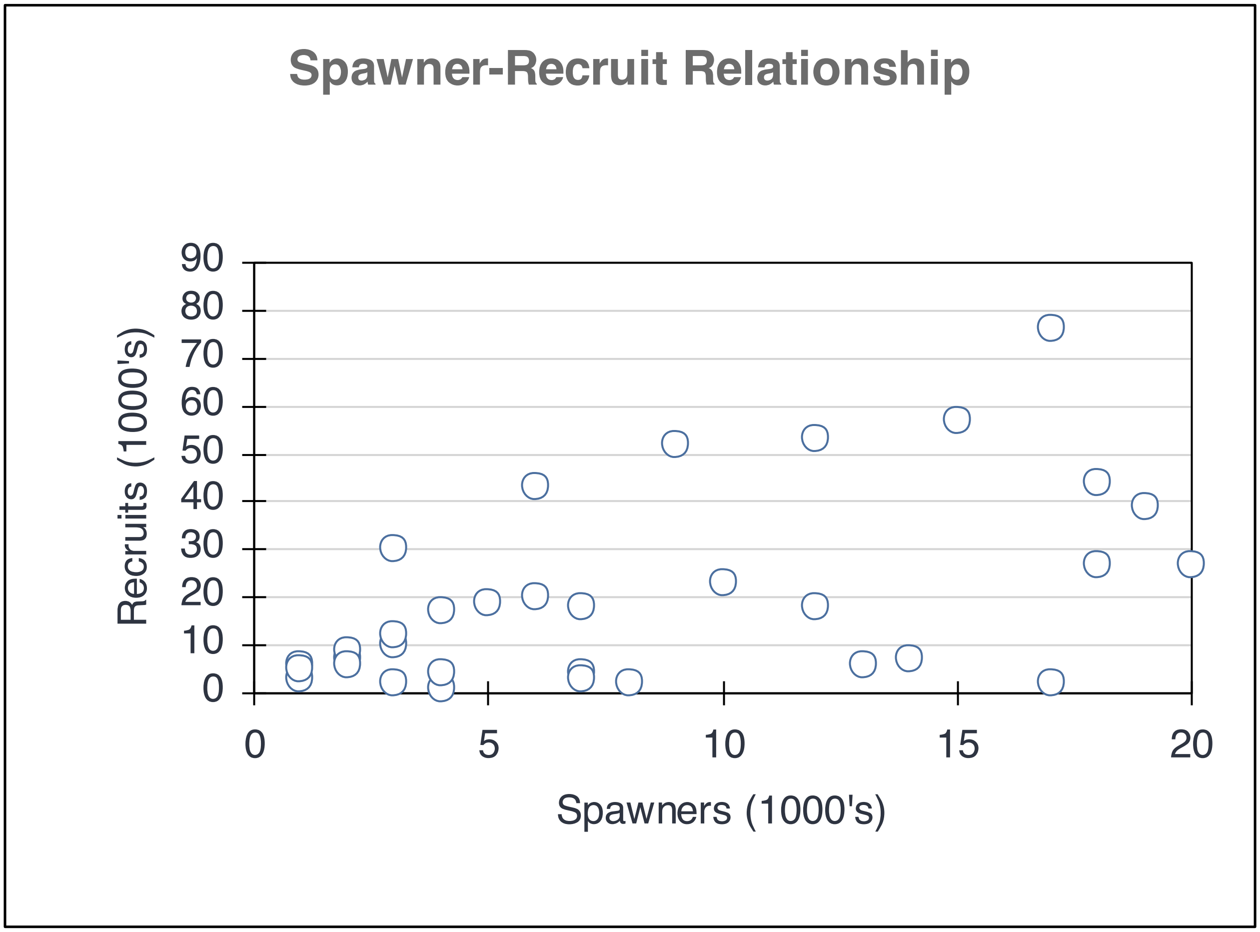

Figure 3. Spawner-recruit analysis for three tributaries combined: X-axis: number of spawners from Figure 2. Y-axis: recruits (spawners three years later). (Source: the author).

The escapement trend took a severe turn for the worse in the last decade. No positive response occurred following the 2005-2006 wet period. There are several explanations, which more likely overlap than conflict. These include unproductive ocean conditions, increased Delta exports (Figure 4), and a low number of spawners as an artifact of previous years with low escapement. While ocean conditions cannot be changed, it is essential to improve on the anthropogenic causal factors as soon as possible.

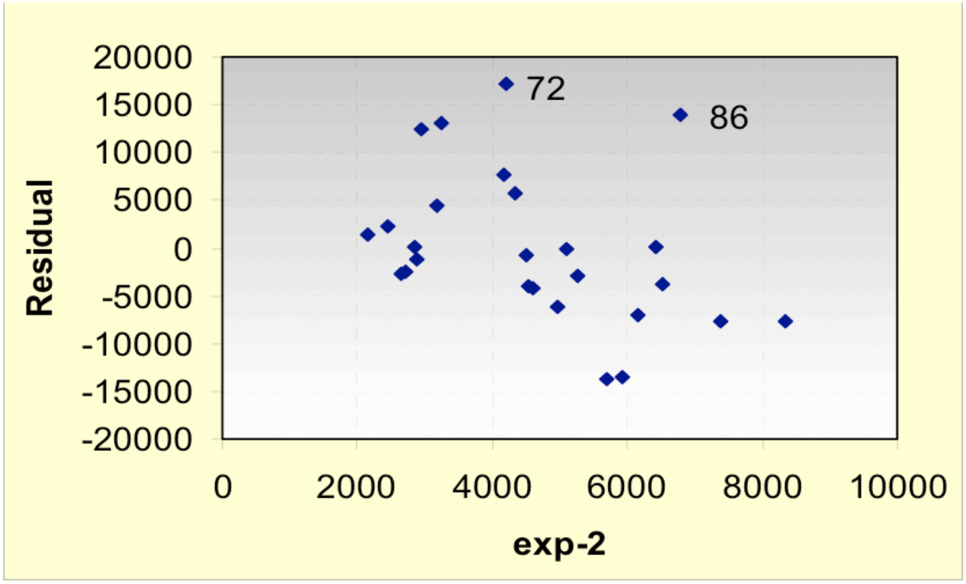

Figure 53. Residuals of regression of escapement, flow, and escapement two years earlier versus export level in April-May two years earlier for only low flow years. The relationship is marginally significant with 1972 and 1986, and highly significant without these years.

*Figure 4. Analysis of residual (unexplained) error in relationship between April-May San Joaquin flow two years earlier and salmon escapement to the San Joaquin not including the past ten years (numbers from Figure 2). Residual error is plotted against South Delta exports in April-May two years earlier (**exp-2**). Simply interpreted, the significant relationship means that lower than expected salmon population levels in the San Joaquin tributaries may be due in part to higher Delta exports.* (Source: the author)

Rationale for Release of 60% of January – June Unimpaired Flows

Sixty percent of the unimpaired flow in the January – June time period is needed for two reasons: (1) to keep winter-spring total flow levels in drier years above the 5000 cfs level as shown in Figure 2, as this by itself would help reduce the dramatic population collapses that occur in dry years; and (2) to emulate the magnitude and frequency of flow pulses and baseline flows in the unimpaired flow patterns of the three tributaries in winter and spring in all water-year types (Figure 5). As can be seen in Figure 5, 60% of the January – June unimpaired daily flow in a dry year barely retains the pulses in the pattern. Retention of 60% of unimpaired flows (including pulses) in wet years ensures that the major factors that influence migration and habitat will continue to provide much of their functional purposes and the large escapement levels of the historical period as seen in Figure 2. There is also a substantial body of evidence that higher Delta inflows and outflows benefits salmon production and migration success in the Delta and

Bay (Section 3, Appendix C, SWRCB 2012). The evidence also suggests that the benefits would extend to other resources including striped bass, sturgeon, splittail, and food chain production.

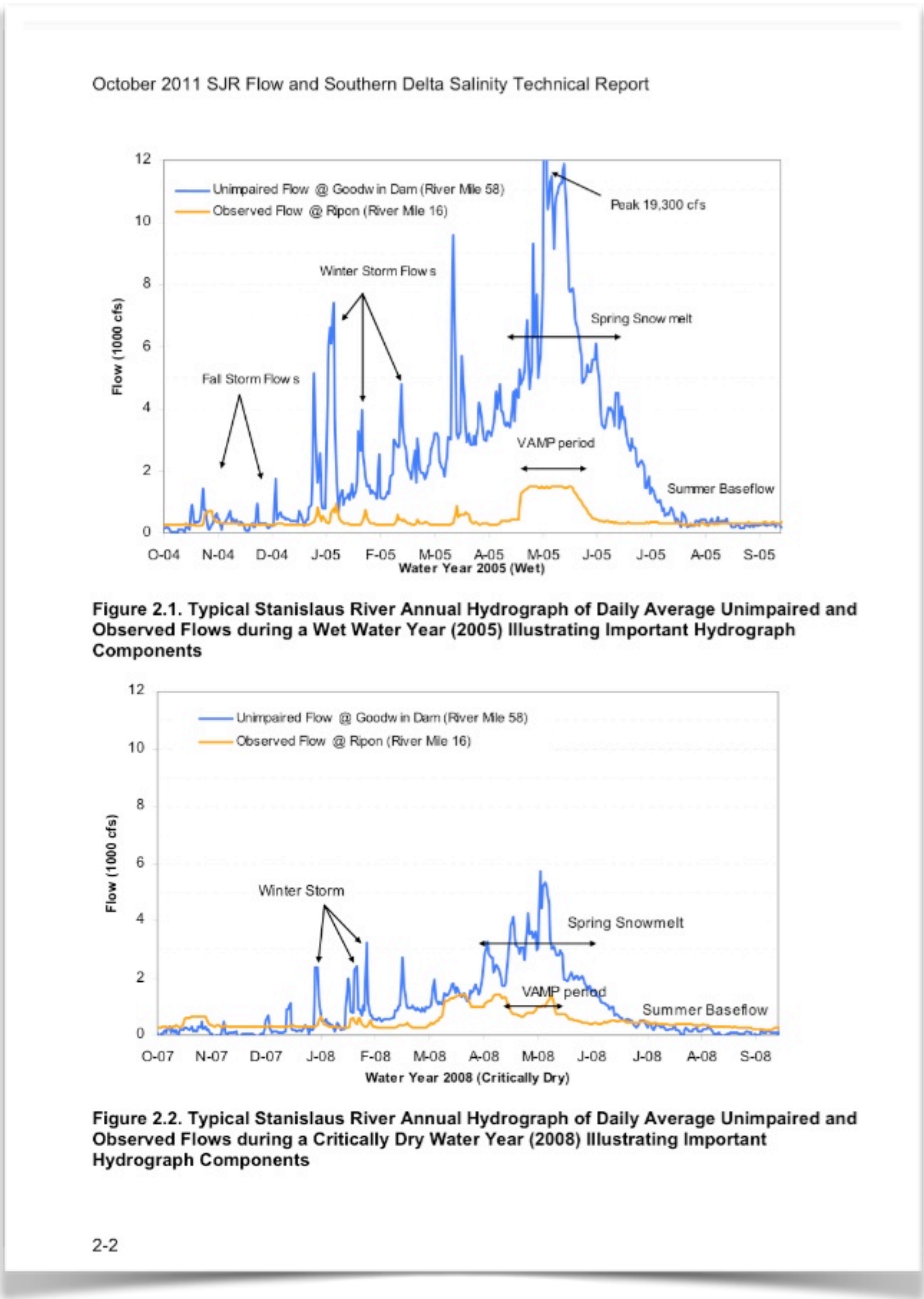
October 2011 SJR Flow and Southern Delta Salinity Technical Report

Figure 2.1. Typical Stanislaus River Annual Hydrograph of Daily Average Unimpaired and Observed Flows during a Wet Water Year (2005) Illustrating Important Hydrograph Components

Figure 2.2. Typical Stanislaus River Annual Hydrograph of Daily Average Unimpaired and Observed Flows during a Critically Dry Water Year (2008) Illustrating Important Hydrograph Components

2-2

Figure 5. Actual and unimpaired flows in a typical recent wet and dry year for the Stanislaus River. (Source: SED, Appendix C, SWRCB 2012)

This report recommends San Joaquin tributary flows as a percent of unimpaired in the months of January through June, rather than the months of February through June recommended in the SED. Flows in the month of January are at least as important as those from February through June for purposes of protecting and improving San Joaquin watershed salmonid populations. The month of January is very important because many Chinook fry emerge and move downriver in this month (Figures 6-8). Many fry also reach the Delta and are salvaged at Delta Pumping Plants (Figure 9). Because the fish facilities are not efficient in collecting fry (25-40 mm), the number salvaged is not representative of the total numbers entering, moving through, and rearing in the Delta. Enhancing fry movement in January (and February) is important because cold waters typical of the month (10ºC or less) minimize the vulnerability of fry to the many warm-water Delta fish predators. Getting young salmon to the Bay and Delta as early as possible shortens their tenure in the rivers, limits their exposure to predators, accelerates their growth, and ensures early entrance to the ocean, a well known positive factor in Chinook salmon production.

Minimum flows for the Merced and the Tuolumne should be prescribed in the new FERC licenses for the Merced River Project and the Don Pedro Project (both currently being relicensed by FERC) to protect and enhance steelhead in July through December; flows prescribed in the OCAP Biological Opinion for salmonids help to protect and enhance steelhead on the Stanislaus. The recommended year-round minimum flow of 2000 cfs at Vernalis may also improve flows for steelhead in one or more individual tributaries.

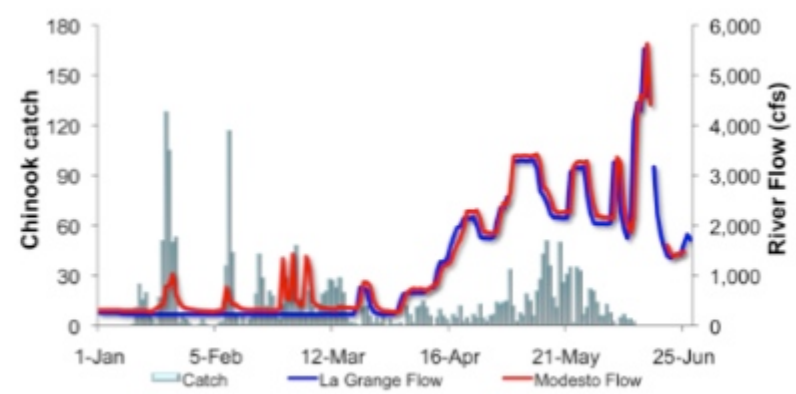

Figure 9. Daily Chinook salmon catch at Waterford and Tuolumne River flow recorded by La Grange (LGN) and Modesto (MOD), 2010.

Figure 6. Chinook catch in screw trap in Tuolumne River at Waterford (Source: Fishbio Newsletter, Vol. 2012, Issue 16)

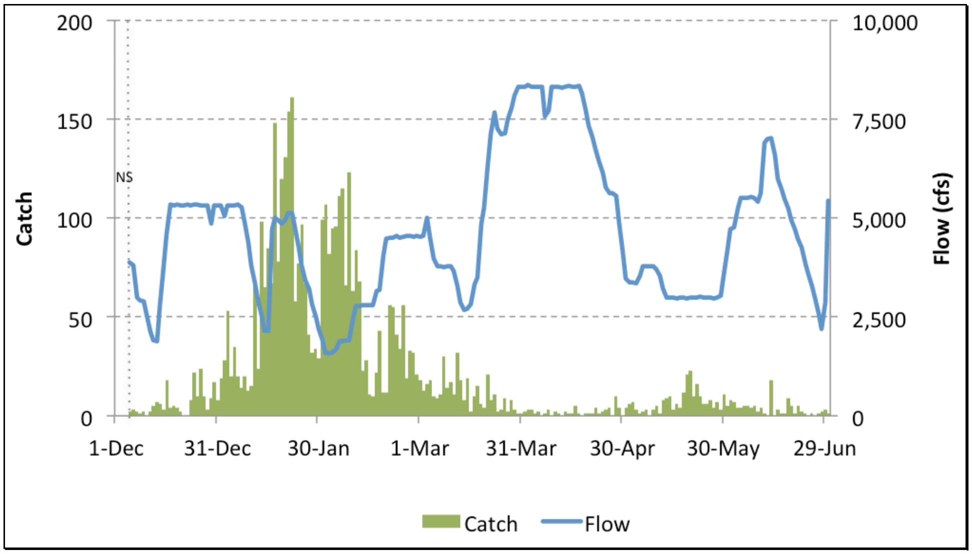

Figure 7. Chinook catch in screw trap in Tuolumne River at Waterford and river flow at La Grange (LGN) during 2011. (Source: Sonke et. al. 2012)

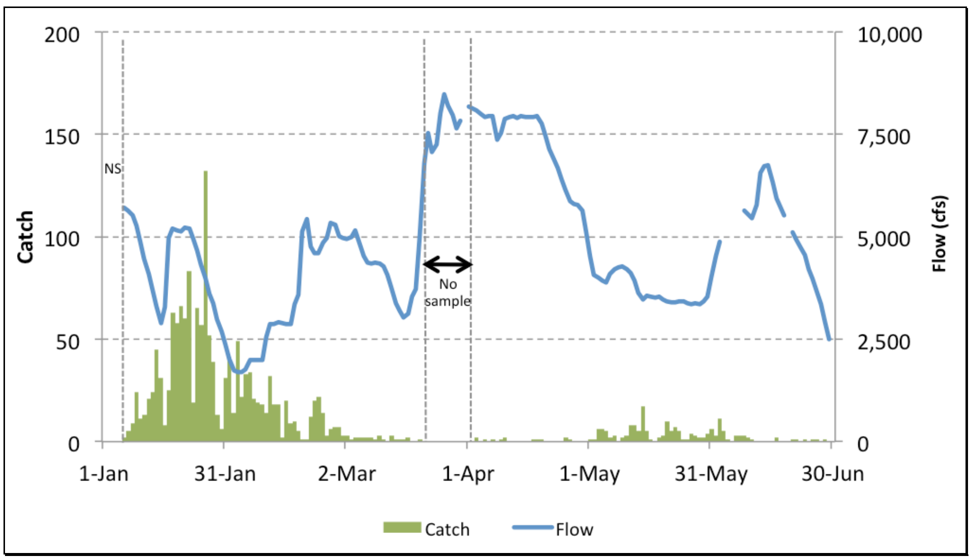

Figure 8. Chinook catch in screw trap in Merced River at Grayson and river flow at Modesto (MOD) during 2011. (Source: Sonke et. al. 2012)

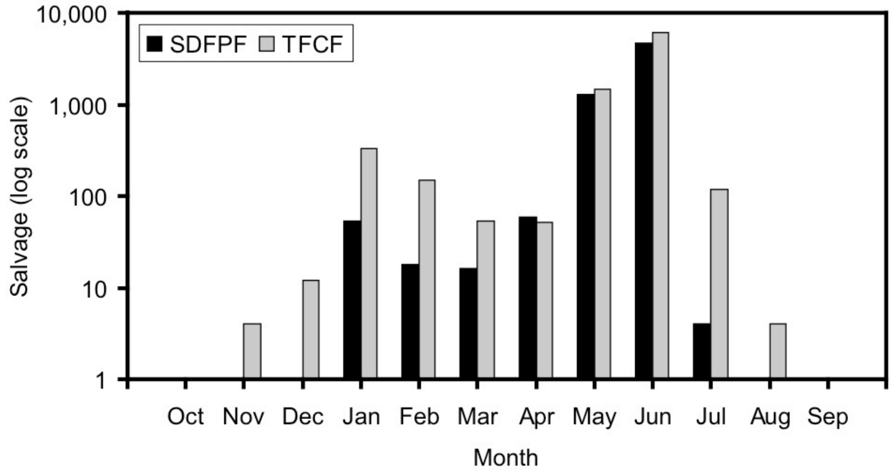

Figure 6 Monthly salvage of wild, fall-run Chinook salmon at the SDFPF and the TFCF, 2011. The logarithmic scale is $\log_{10}$.

Figure 9. Monthly salvage at Byron (SDFPF) and Tracy (TFCF) fish facilities in 2011. (Source: IEP Newsletter, Winter 2012)

Higher flows will greatly improve spawning and rearing habitats from the tributary tailwaters, down through the lower San Joaquin River, and through the Delta to the Bay (EPA 2012; Moyle et. al. 2012).

Salinity Has Important Effects on Fish

The SED addresses the role of salinity in the context of the suitability of water for irrigation, but does not consider salinity in terms of its effects on aquatic biota. This omission erases an entire line of analysis that was an important component of earlier SWRCB proceedings on Delta flow and water quality.

In examining the spawning of striped bass in the San Joaquin River, Farley (1966) concluded: "*No significant amount of spawning occurred in areas where the total dissolved solids content of the water was above 180 parts per million*[5]*; in 1964 TDS values above that level prevented bass from migrating above Stockton in the San Joaquin River*."

Radtke and Turner (1967) found:

> *"The quality of water in the two rivers [Sacramento and San Joaquin] is quite different. In dry years, such as 1966, the flow in the San Joaquin River is greatly reduced and consists largely of irrigation return water having relatively high concentrations of*

[5] A rough approximation conversion: [(TDS)ppm = Conductivity μS/cm x 0.67]. [Example: 180 ppm = 240 X 0.67]

total dissolved solids. In contrast, the Sacramento River is characteristically low in dissolved solids. A dissolved solids gradient is created in the study area by the mixture of water from the two rivers as they are drawn across the central Delta by the U.S. Bureau of Reclamation pumping plant at Tracy, California. The net effect is that water in the San Joaquin River from the study area to its junction with the Sacramento River about 25 miles downstream is primarily Sacramento River water. It is fresher than either the water farther downstream, which is mixed with ocean water, or the San Joaquin River water upstream. Thus, striped bass moving upstream and having made the normal adjustment to fresh water must readjust to more saline water if they continue upstream."

Radtke and Turner concluded that their study demonstrated "*…that 350 ppm is the critical concentration and helps explain the erratic [striped bass] spawning migrations that have occurred in the past in the San Joaquin River above Stockton*." They noted that "*with some proposed water development plans, the entire spawning migration in the San Joaquin River could be threatened.*" (Note: this spawning segment of the striped bass population has been virtually non-existent for decades.)

The Environmental Protection Agency wrote in its preamble to its Final Rule for *Water Quality Standards for Surface Waters of the Sacramento and San Joaquin Rivers, and San Francisco Bay and Delta* (1995):

"In addition to its general finding that the 1991 Bay/Delta Plan did not contain sufficient criteria to protect the designated uses, EPA also disapproved the absence of salinity standards to protect the Estuarine Habitat and other fish and wildlife uses in the Suisun, San Pablo, and San Francisco Bays and Suisun Marsh, the absence of scientifically supportable salinity standards (measured by electrical conductivity) to protect the Fish Spawning uses of the lower San Joaquin River" … .[6]

In the Final Rule, EPA specified salinity levels for the months of April and May much lower than those currently proposed in the SED, to protect fish migration and spawning in the San Joaquin River in the South Delta and upstream:

"The State Board's 1991 Bay/Delta Plan established objectives of 1.5 mmhos/cm EC at Antioch and 0.44 mmhos/cm EC at Prisoners Point in April and May. EPA disapproved these objectives, in part, because they are not adequate to protect spawning habitat in the reach farther upstream between Prisoners Point and Vernalis. EPA also disapproved the 1991 Bay/Delta Plan spawning criteria because they were not based on sound science. The State Board explained that the 1.5 mmhos/cm EC criteria at Antioch was intended to protect spawning habitat upstream of Antioch (near Jersey Point), not at the Antioch location itself. The State Board acknowledged that ``the use of 1.5 [mmhos/cm] EC at Antioch appears not to be generally appropriate, and proposed that a thorough review of this [criterion] be undertaken at the next triennial review'' (1991 Bay/Delta Plan, p. 5±32). EPA found this unproven approach of setting criteria downstream in hopes of attaining different criteria upstream deficient, and disapproved

[6] EPA's Water Quality Standards regulations at 40 CFR part 131; see *Federal Register*, January 24, 1995, p. 4666.

it….. EPA believes there is substantial scientific evidence indicating that increased salinities in the designated reaches of the San Joaquin River do in fact have an adverse effect on fish spawning".[7]

The EPA preamble also notes that striped bass are not the only species that would benefit from spawning standards for salinity:

> *"EPA believes that salinity problems in the lower San Joaquin affect aquatic species other than the striped bass. Recent research findings of USFWS (Meng 1994) suggest that the spawning habitat for the Sacramento splittail (currently proposed for listing as threatened under the ESA) is also being adversely affected by increased salt loadings in the lower San Joaquin. Accordingly, these criteria are consistent with a multiple species approach"*.[8]

Though they have not been enforced, the 1995 EPA salinity standards have never been rescinded.

Higher inflows from the San Joaquin will help protect fish spawning in the lower San Joaquin River and Delta by lowering total dissolved solids and salinity in the lower San Joaquin River. The recommended higher San Joaquin River inflows to the Delta will improve salinity levels in the lower San Joaquin River to more frequently meet the fish spawning objectives adopted by EPA in 1995.

Delta Operations Must Allow Migration to Suisun Bay

The benefits of increasing the flow releases in the San Joaquin River and its tributaries will be greatly diminished if the water released into the San Joaquin does not reach the Bay. Unfortunately, Delta operations today are such that in drier years almost none of the water from the San Joaquin escapes the Delta[9] and reaches Suisun Bay (also noted by SWRCB 2012, NMFS 2009). Present operations of the Delta Cross Channel (DCC) (closed most of December-June period) and Head-of-Old-River Barrier (HORB) (frequently open), in combination with Delta exports, cause most of the San Joaquin inflow at Vernalis to be directed into Old River and Middle River to the south Delta export facilities.

Salmon fry, fingerlings, and smolts moving downstream into the Delta from the San Joaquin tributaries follow the net flows to the screened entrances to the South Delta pumping plants. Those large enough to be salvaged at the fish collection facilities must first avoid many predators in front of the screens and then survive a truck trip to Sherman Island in the West Delta. Those too small to be salvaged (fry) generally do not survive. Smolts migrating down the San Joaquin River to the Delta have a similar problem successfully making it through the Delta (Vogel 2005).

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[7] *Id*, p. 4698.
[8] *Id*.
[9] http://www.water.ca.gov/iep/docs/pod/GrossEtAl_POD3D_Particle_tracking_2010.pdf

The present operation that emphasizes closing the DCC from December to June and keeping the HORB open runs counter to the barriers' original purposes. The DCC was constructed in the 1950s to ensure that more of the higher quality Sacramento water reached the Tracy Pumping Plant in the South Delta. Existing water quality standards and biological opinions require the DCC to be closed much of the December to June period to minimize the movement of Sacramento salmon into the interior Delta, not recognizing (or ignoring) the severe consequences to San Joaquin salmon.

The HORB was installed in 1963 to limit negative flows in the lower San Joaquin River caused by the Tracy Pumping Plant pulling water upstream in the San Joaquin into the head of Old River. The negative flows were detrimental, but low dissolved oxygen in the Stockton Ship Channel also disrupted salmon migrations. The HORB remains open more often than not today[10] to protect delta smelt living in the Central Delta from being drawn to the export pumps in the South Delta, again sacrificing San Joaquin salmon to protect other fish populations from the effects of reverse flows in Old River and Middle River.

The benefits of having a greater proportion of San Joaquin River flows reach Suisun Bay outweigh the potential negative effects on Sacramento salmon and delta smelt that might arise from these recommended changes in DCC and HORB operations. Recommendations in the 80's that the DCC be closed in winter and spring were derived from experiments that showed Sacramento salmon drawn into the interior Delta had a lower survival, based on tag release data for hatchery salmon smolts.[11] The present author's personal review of that data found very poor survival (and high salvage rates at South Delta export fish facilities) for tagged hatchery salmon groups released in the Mokelumne channels below the DCC *when the DCC was closed*. For releases at the same locations when the DCC was open, survival was higher, and similar to survival rates for salmon released in the lower Sacramento River above and below the DCC. Many years have passed and more studies have been conducted since then with similar results.

A more recent approach (Perry et. al. 2010, Perry et. al. 2012) followed survival of pit-tagged hatchery salmon smolts released in the river below Sacramento. The authors compared survival rates of tagged fish that followed different migration routes through the Delta. The approach was new because the tagged fish had the same beginning and end points. The authors determined the migration routes using pit-tag detection arrays positioned strategically throughout the Delta. Results of the study (Figure 10) show that pit-tagged hatchery salmon released in the lower Sacramento with the DCC open (December 5, 2006) had a survival rate that was similar to the combined survival rate of salmon that migrated through the Sacramento River and Steamboat-Sutter sloughs. On the other hand, survival was much lower for fish that passed

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[10] "*The HOR barrier (HORB) has been installed in most years during the fall (roughly between September 30 and November 15) since 1968, and in some years during the spring (roughly between April 15 and May 30) since 1992. In general, the HORB was not installed during the spring in years with higher flows. In addition, the HORB has not been installed in the spring since 2007 due to a court order. A non-physical fish barrier was installed in its place in 2009 and 2010. When the physical barrier at HOR is installed, the flow into Old River is reduced to between 20% and 50% (Jones and Stokes 2001). Data from Jones and Stokes (2001) further suggests that the agricultural barriers alone (when physical barrier at HOR was not installed), reduces flow into Old River for all pumping ranges, and reduced the effects of increased pumping on water levels and circulation*.". (SWRCB 2012)

[11] This work is summarized in in Perry et. al. 2010.

through Georgiana Slough in January 2007 when the DCC was closed. In both papers, the authors point to the overall higher survival of fish that do not pass through the interior Delta. Singer et. al. (2012) also note low survival of tagged Sacramento fish that pass through the East Delta (with the DCC closed).

The authors noted that less Sacramento water entered the interior Delta with the DCC closed[12]; however, this extrapolation from water to fish fails to consider comparable circumstances for fish emigrating from the San Joaquin. The experiment did not have groups of San Joaquin tagged salmon under the two circumstances to compare. Effectively, the tagged fish from the Sacramento that passed through DCC or Georgiana Slough can be considered a surrogate for those San Joaquin salmon juveniles that successfully reach the mouth of the Mokelumne River.

TABLE 1.—Route-specific survival through the Sacramento–San Joaquin River Delta ($\hat{S}_h$) and the probability of migrating through each route ($\hat{\psi}_h$) for acoustically tagged fall-run juvenile Chinook salmon released on 5 December 2006 and 17 January 2007. Also shown is population survival through the delta, which is the average of route-specific survival weighted by the probability of migrating through each route; NA = not applicable.

Migration route	$\hat{S}_h$ (SE)	95% profile likelihood interval	$\hat{\psi}_h$ (SE)	95% profile likelihood interval
5 December 2006				
Sacramento River	0.443 (0.146)	0.222–0.910	0.352 (0.066)	0.231, 0.487
Steamboat and Sutter sloughs	0.263 (0.112)	0.102–0.607	0.296 (0.062)	0.186, 0.426
Delta Cross Channel	0.332 (0.152)	0.116–0.783	0.235 (0.059)	0.133, 0.361
Georgiana Slough	0.332 (0.179)	0.087–0.848	0.117 (0.045)	0.048, 0.223
All routes	0.351 (0.101)	0.200–0.692		
17 January 2007				
Sacramento River	0.564 (0.086)	0.403–0.741	0.498 (0.060)	0.383, 0.614
Steamboat and Sutter sloughs	0.561 (0.092)	0.388–0.747	0.414 (0.059)	0.303, 0.531
Delta Cross Channel	NA		0.000	NA
Georgiana Slough	0.344 (0.200)	0.067–0.753	0.088 (0.034)	0.036, 0.170
All routes	0.543 (0.070)	0.416–0.691		

Figure 10. Summary table from Perry et. al. (2010). Mean survival rate and standard errors are in first column. Confidence intervals are in second column. Proportion of tagged individuals taking each route is in third column, along with the confidence intervals in column 4. Note route-survival rates in second column are from Sacramento River releases upstream of the DCC.

In sum, three elements are needed to protect emigrating San Joaquin River salmon: 1) high flows through the DCC (DCC open); 2) high San Joaquin inflows; and 3) high outflows at Jersey Point ("Q-West") (see Figure 11, location E). This will protect Sacramento salmon and move them to Suisun Bay and at the same time greatly improve successful emigration of San Joaquin salmon to Suisun Bay.

Keeping the HORB closed will help San Joaquin salmon to reach the mouth of the Mokelumne (near location C in Figure 11) and Jersey Point. Negative flows from the Central Delta (moving from location C to location D in the chart) increase, however, with the HORB closed, because the South Delta pumping plants then draw more water from the north ends of

[12] *"Thus, on average, we suspect that the closure of the Delta Cross Channel will reduce the proportion of the fish entrained into the interior Delta by reducing the fraction of the mean discharge entering the interior Delta.*" (Perry et. al. 2012, p. 153)

Old and Middle rivers. The effects of the resulting negative flows in Old and Middle River will be substantially diminished with the DCC open.

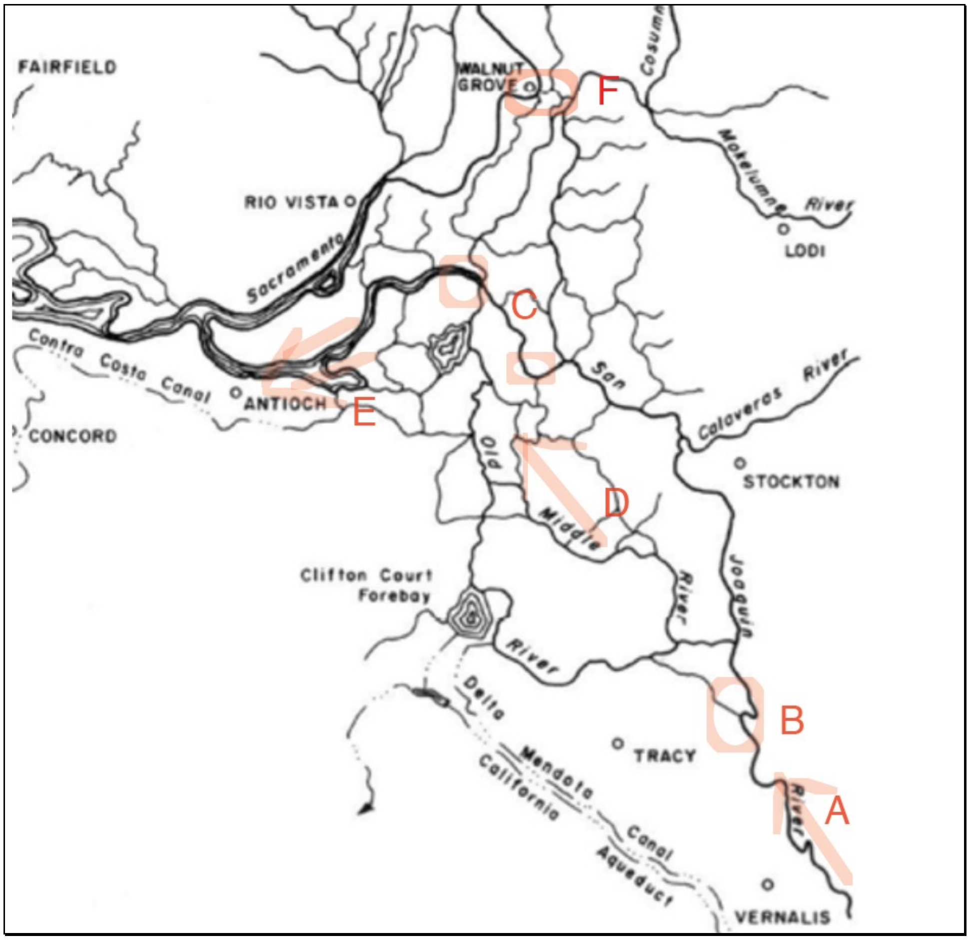


Figure 11. Locations:

A -Vernalis San Joaquin Flow
B -Head-of-Old-River Barrier
C -net flows in outlets of Old and Middle Rivers
D -net flow direction in Old and Middle Rivers between South Delta Pumping Plants and river mouths on Lower San Joaquin River in Central Delta.
E -net flow in Lower San Joaquin River below mouth of Old River as measured at Jersey Point
F -Delta Cross Channel

A screened gate at the HORB could let some San Joaquin River flow into upper Old River to meet some of the export demands and reduce the negative flows in lower Old and Middle rivers, while protecting emigrating San Joaquin juvenile salmon from being drawn into the interior Delta. It might also increase the range of operation: HORB at present is not functional at flows greater than about 8000 cfs. Replacement of the fish screens and other facilities at the entrances to the south Delta pumping plants is also desperately needed to reduce the present losses of Sacramento and San Joaquin salmon and numerous other species.

Higher San Joaquin Delta inflow, if allowed to reach the Central and Western Delta as well as Suisun Bay, will also benefit the Bay-Delta ecological food chain. The Independent Science Panel explained:

> "*While San Joaquin River flows are hydrologically less important, there is an increasing recognition of their disproportionately strong role in Bay-Delta productivity. While phytoplankton resources in the estuary are considered relatively poor (Jassby et al. 2002), the lower San Joaquin River represents a relatively enriched region (Lehman 2007). The contribution of these resources to the downstream food web is strongly regulated by San Joaquin River flow. Food web effects may not be limited to phytoplankton as San Joaquin River inflow is hypothesized to be one of the primary sources of the calanoid copepod Pseudodiaptomus forbesi. P. forbesi is a major food for key fishes such as delta smelt (John Durand UC Davis/San Francisco State University studies reported in Baxter et al. 2010). The bottom line is that San Joaquin River inflow appears to play a relatively strong role as a source of high-quality phytoplankton and fish-prey organisms*."[13]

[13] Available at:
http://www.waterboards.ca.gov/waterrights/water_issues/programs/bay_delta/docs/cmnt091412/randy_baxter.pdf

Future Considerations

These same recommendations (i.e., 60 % of unimpaired flow) and rationale will also be applicable to the upper San Joaquin River above Merced once fall-run and spring-run Chinook salmon are restored to that portion of the river. Fall-run have already been reintroduced to the upper San Joaquin below Friant Dam, and have been observed spawning in that reach. A captive broodstock program is a principal component for producing the quantity of eggs and juveniles needed to achieve the Restoration Program's reintroduction goals for spring-run salmon. Eggs from the captive broodstock should be available to the Program beginning in 2015. The number of eggs available is expected to increase over time, thus allowing the Restoration Program to plan focused releases of spring-run salmon into the San Joaquin River. These initial releases are expected to result in some adult spring-run salmon returning to the system within three to five years.

Conclusion

The flow proposal presented in Appendix K of the SED is inadequate. The SED provides no justification for why the proposed 35% of February through June unimpaired flow is sufficient. Appendix K of the SED defines compliance in such a way that flows can be as low as 25% and no more than 45% of February through June unimpaired. The *Delta Flow Criteria Report* (SWRCB 2010) found that 60% of February through June unimpaired flow was needed as a flow requirement at Vernalis; the Board has provided no science to show why so much less flow will protect San Joaquin and Delta fisheries, or why January should not be included.

Thirty-five percent of February through June unimpaired flow will not provide flow magnitudes for productive juvenile rearing habitat or protective emigration habitat in the tributaries, in the San Joaquin, and in the Delta. It will not provide sufficient baseflow, flow peaks, or variability to create the benefits that that emulating the natural hydrograph is designed to create. The use of a 14-day running average will further reduce the benefits of a percent-of-unimpaired methodology. The flow caps for percent-of-unimpaired diminish the benefits yet again, almost totally limiting floodplain inundation to flood releases.

Appendix K of the SED does not define how flow magnitudes and durations will be determined within the effective 25% to 45% water budget. It requires creation of an Implementation Workgroup and a Coordinated Operations Group. The processes that these groups will conduct are left to be determined by the groups, as are the performance measures and decision points which might lead them to recommend modifications of operations.

The SED separates elements that are fundamentally connected in the context of biological resources in the San Joaquin watershed and the Delta. The SED does not consider San Joaquin tributary flows in combination with different operations of the DCC gates, HORB, and South Delta export facilities, or in combination with reverse flows, or in combination with the need for San Joaquin River water to reach Suisun Bay. The SED does not consider the effects of salinity and salinity requirements on aquatic biota.

Literature Cited and Summaries

Environmental Protection Agency (EPA). 2012. Water Quality Challenges in the San Francisco Bay/Sacramento-San Joaquin Delta Estuary, EPA's Action Plan. Available at: http://www.epa.gov/sfbay-delta/pdfs/EPA-bayareaactionplan.

>>Migratory fish rely on diverse habitats during different life stages and they require appropriate cues and connections to guide them to those habitats. Juvenile salmon use flow as the primary cue to maneuver from their spawning grounds through the rivers to the estuary. Salinity gradients and tidal action can then guide them to the ocean. Adult fish follow the unique chemical signature of their natal stream, although straying is common. Along these migratory paths, contaminants, high temperatures, low dissolved oxygen, physical barriers, and predators may interfere with migratory success. Thus, salmon management requires a watershed approach to ensure a connected and unblocked migratory corridor. (EPA 2012: 26)

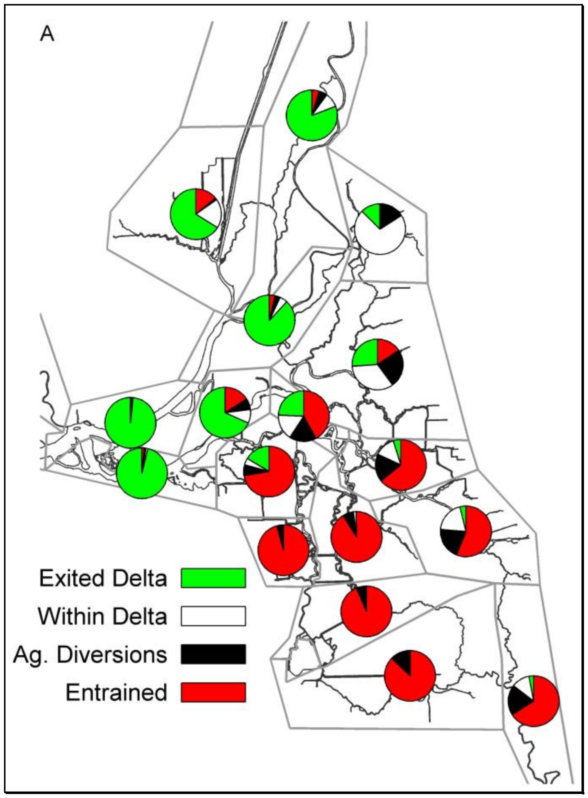
Migratory passage along the San Joaquin River is a beneficial use that may not be adequately protected. Outmigrating juveniles have some protection; adults migrating back to their natal streams have little protection. The absence of migratory cues for returning adult San Joaquin fish has not been comprehensively addressed in a regulatory framework.

Although critical, the remediation of temperature and dissolved oxygen alone is unlikely to restore depleted salmon stocks unless water from the San Joaquin River and its tributaries supports a migratory corridor to and from the Estuary during both the season of adult upmigration and young outmigration.

Environmental Protection Agency (EPA), Federal Register January 24, 1995, *Water Quality Standards for Surface Waters of the Sacramento and San Joaquin Rivers, and San Francisco Bay and Delta, California; Final Rule.*

Gross, E. S. and others. 2010. POD3D particle tracking modeling study. Prepared for Interagency Ecological Program (IEP). www.water.ca.gov/iep/docs/pod/GrossEtAl_POD3D_Particle_tracking_2010.pdf

Author's note: The paper included this figure showing the fate of particles on April 11, 2007 from different points in the Delta after 60 days. Conditions: DCC was closed with 2000 cfs San Joaquin inflow to Delta. Note the very small percentage of particles (green) that are able to exit the Delta to the Bay from the lower San Joaquin River. At 7000 cfs San Joaquin flow, the proportion exiting the Delta is higher at about 20% (with DCC closed). If the DCC were kept open with the HORB in place, (conditions not modeled by the study) the proportion would be significantly higher.



>> *The authors noted*: The estimates of delta smelt distribution and, in particular, hatching distribution, are highly relevant to ongoing policy decisions. Any project that modifies flow pathways and mixing in the Delta is likely to decrease entrainment of fish from some regions and increase entrainment of fish from other regions. Therefore, in order to confidently estimate impacts of such project, it is critical to estimate the distribution of delta smelt and any other relevant fish species. Hydrodynamic and particle tracking modeling tools, particularly if applied in a probabilistic framework, will be useful supplements to ongoing observational programs in estimating the distribution and entrainment of delta smelt and other species for current conditions and different Delta operations scenarios.

Independent Science Panel, submittal to Workshop #2 for Phase II of the Update of the Bay-Delta Water Quality Control Plan, September 14, 2012. Available at: http://www.waterboards.ca.gov/waterrights/water_issues/programs/bay_delta/docs/cmnt091412/randy_baxter.pdf

Moyle, P., W. Bennett, J. Durand, W. Fleenor, B. Gray, E. Hanak, J. Lund, and J. Mount. 2012. Where the Wild Things Aren't: Making the Delta a Better Place for Native Species. Public Policy Institute of California, San Francisco, CA. 55p. Available at: http://www.ppic.org/content/pubs/report/R_612PMR.pdf

>> Furthermore, there is reason to believe that proportionate impacts of salmon entrainment that are expressed as a proportion of juvenile production would also significantly underestimate the population level effect of entrainment on Chinook salmon

populations. DFG and NMFS have not updated the estimated survival to the Delta in the JPE calculation to account for recent acoustic tag data on survival to the Delta. (NMFS 2012b: 7) For instance, recent studies of late fall run Chinook salmon released in 2007 with acoustic tags found that the average survival rate was only 3.9% for the migration from Battle Creek / upper Sacramento River release site to the ocean and that survival from the release site to the Delta was below 40% in all three years and was below 20% in 2007. (Michel 2010: 8 and Fig. 4). Thus current estimates of entrainment at the pumps may substantially underestimate the fraction of the population that is taken, as well as the population level effects of this entrainment.

National Marine Fisheries Service (NMFS). 2009. Biological Opinion on proposed long term operations of the Central valley Project and State Water Project. Available at: http://www.swr.noaa.gov/ocap/NMFS_Biological_and_Conference_Opinion_on_the_Long-Term_Operations_of_the_CVP_and_SWP.pdf]

National Marine Fisheries Service (NMFS). 2012. Delta hearing exhibit. http://www.waterboards.ca.gov/waterrights/water_issues/programs/bay_delta/deltaflow/docs/exhibits/nmfs/nmfs_summary.pdf

>>Entrainment and low survival rates through the Delta remain a concern for steelhead from the San Joaquin River basin, Sacramento River basin, and eastside tributaries. Although there is no population estimates for Central Valley steelhead, the 2009 NMFS biological opinion continues use of an incidental take limit of 3,000 wild steelhead that is not based on a measure of steelhead abundance. (NMFS 2011b at 53-54) Salvage of wild steelhead in 2011 (738) was lower than in 2010 (1,029), with the highest monthly salvage of wild steelhead observed in June 2011. (NMFS 2011b: 54, 68) The seasonal salvage for hatchery steelhead in 2011 was the lowest observed in the past 11 years. (NMFS 2011b: 54).

Moyle et al 2012 attributes harm to native species living in or passing through the Delta as well as the degradation of water quality and habitat to key stressors working singly and in combination. These stressors include alteration of flows, channelization of waterways, discharge of pollutants, introduction of non-native species, and the diversions of water from the system. Their analysis identifies five core premises that have strong scientific support including that the most restrictive physical and biological constraints on the system include limits on the availability of fresh water, and the domination of the ecosystem by invasive species. The report recommends five key components of a strategy for recovery and reoperation of the delta, the first of which is that natural processes place limits on all water and land management goals.

Perry, R. W., J. R. Skalski, P. L. Brandes, P. T. Sandstrom, A.P. Klimley, A. Ammann, and B. MacFarlane. 2010. *Estimating Survival and Migration Route Probabilities of Juvenile Chinook*

Salmon in the Sacramento–San Joaquin River Delta. North American Journal of Fisheries Management 30:142–156. DOI: 10.1577/M08-200.1

>> Juvenile salmon entering the interior delta must traverse longer migration routes and are exposed to entrainment at the water pumping projects, both of which may decrease survival of fish using this migratory pathway…. To date, the proportion of fish migrating through the interior delta has not been estimated, yet such estimates are critical to understand the relative effect of water management actions on the population as a whole (Newman and Brandes 2009)…. Coincident with lower river discharge, fish released in January took substantially longer to migrate through the Delta and exhibited higher variation in travel times relative to fish released in December (*Author's note: DCC was open in December and closed in January*). At 500 m3/s (*18,000 cfs*) 35 % went into interior Delta (*via DCC and Georgianan Slough with DCC open*) compared with 11 % (*via Georgiana Slough with DCC closed*)…. Coincident with lower river discharge, fish released in January took substantially longer to migrate through the delta and exhibited higher variation in travel times relative to fish released in December. In general, similar to our study, these studies found that survival of fish released into the interior delta via Georgiana Slough was lower than survival of fish released into the Sacramento River downstream of Georgiana Slough (*with DCC closed)*… This evidence continues to support the hypothesis that survival for fish migrating through the interior delta is lower than for fish that remain in the Sacramento River (*with DCC closed)*. Closure of the Delta Cross Channel reduces channel capacity of the Sacramento River at the second river junction, which slightly increases the proportion of river flow diverted into Sutter and Steamboat sloughs.

>> *See figure below:*

SACRAMENTO–SAN JOAQUIN SALMON MIGRATION 143

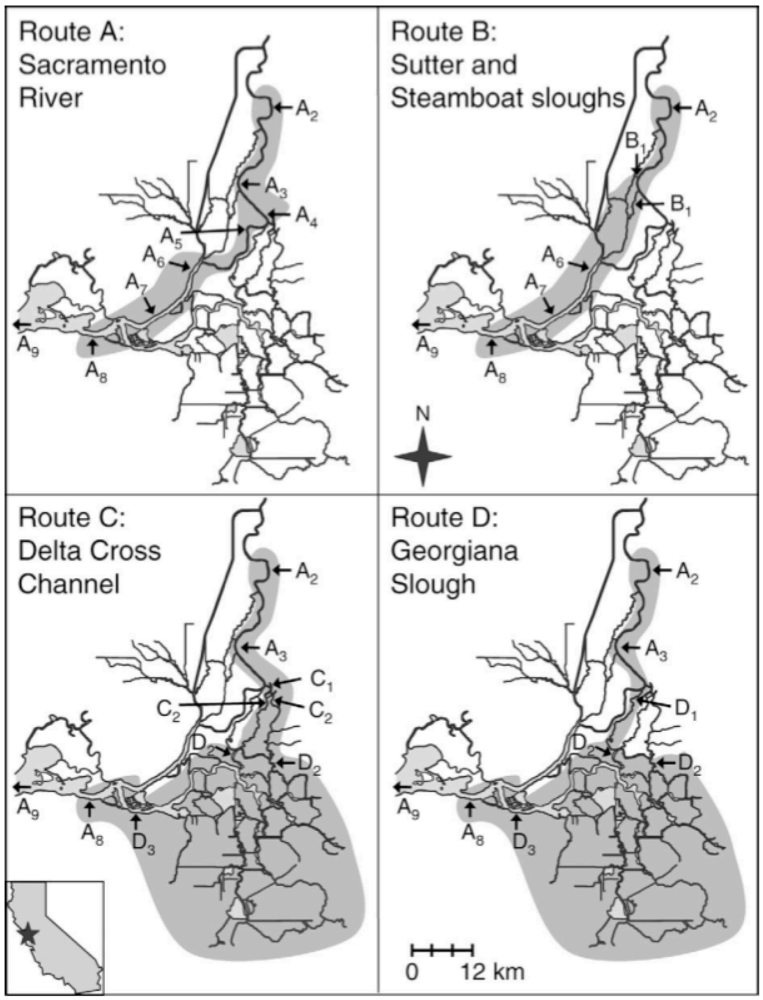


FIGURE 1.—Maps of the Sacramento–San Joaquin River Delta, with shaded regions showing the river reaches that comprise four different migration routes. Arrows show the locations of the telemetry stations specific to each route. The delta extends from station A_2 at Freeport to station A_8 at Chipps Island. The first river junction occurs where Sutter and Steamboat sloughs (B_1) diverge from the Sacramento River at station A_3. The second junction occurs where the Delta Cross Channel (C_1) and Georgiana Slough (D_1) diverge from the Sacramento River at station A_4. For routes C and D, the interior delta is the large shaded region to the south of station D_2. Telemetry stations with the same label (B_1, C_2, and D_2) were pooled as one station in the mark–recapture model. Station A_3 was not operational during the first release in December 2006. Station A_9 pools all of the telemetry stations in San Francisco Bay downstream of A_8. The release site (rkm 92) was 19 rkm upriver of station A_2 (rkm 73).

Perry, R. W., P. L. Brandes, J. R. Burau, A. P. Klimley, B. MacFarlane, C. Michel, and J. R. Skalski. 2012. *Sensitivity of survival to migration routes used by juvenile Chinook salmon to negotiate the Sacramento-San Joaquin River Delta*. Environ. Biol. Fish. DOI 10.1007/s10641-012-9984-6]

Radtke, L and Turner, J, *High Concentrations of Total Dissolved Solids Block Spawning Migration of Striped Bass, Roccus saxatilis, in the San Joaquin River, California***,** Delta Fish and Wilflife Study, California Department of Fish and Game, 1967.

Singer, G., A. R. Hearn, E. D. Chapman, M. L. Peterson, P. E. LaCivita, W. N. Brostoff, A. Bremner, and A. P. Klimley. 2012. Interannual variation of reach specific migratory success for Sacramento River hatchery yearling late-fall run Chinook salmon (Oncorhynchus tshawytscha) and steelhead trout (Oncorhynchus mykiss). Environ Biol Fish DOI 10.1007/s10641-012-0037-y

> >> It has been suggested that fish entrained in the East Delta have lower survival rates than other routes (Perry et al. 2010), although it is important to note that Perry defined "survival" as migration to Chipps Island. This was consistent with our results - throughout the duration of our study, fish migrating through the East Delta had lower overall survival than fish choosing either the West Delta or the mainstem Sacramento River, with the exception of West Delta steelhead in 2009 (Fig. 6). (p. 15) Although their study did not directly examine why survival was lower in the East Delta routes, the authors note that migratory survival is generally inversely related to migratory distance, and note that fish entrained into the East Delta have a longer route to the ocean and potentially encounter the CVP and SWP pumps.
>
> Additionally, the Operations Criteria and Plan (OCAP) Biological Assessment (BA) (USBR 2008) contains regressions of monthly steelhead salvage at the Central Valley Project and State Water Project pumping facilities, which shows a significant relationship between number of steelhead salvaged and the amount of water exported during the months of January through May, the same time that our tagged fish where in the Sacramento River Watershed. Our study suggests that entrainment in the east delta was negatively correlated with success to the ocean."

Sonke, C.L., S. Ainslehy, and A. Fuller. 2012. Outmigrant Trapping of Juvenile Salmon in the Lower Tuolumne River, 2011. FISHBIO report. Oakdale, CA 95361. Available at: http://www.tuolumnerivertac.com/Documents/2011%20Tuolumne%20RST%20Annual%20Report_final.pdf

SWRCB. 2012. SED Technical Report and Appendices. http://www.waterboards.ca.gov/waterrights/water_issues/programs/bay_delta/bay_delta_plan/water_quality_control_planning/2012_sed/docs/2012ap_c.pdf

> > >The SED and supporting appendices have determined that the Preferred LSJR Alternative would generally increase mean annual river flows relative to baseline conditions, with that increase occurring mainly in the spring months. As a result, the quantity of surface water available for diversion in the three tributaries would generally be reduced. This would have a potentially significant impact on agricultural production dependent on these diversions and the associated sectors of the economy, particularly in the Tuolumne and Merced River watersheds where baseline flows on those rivers are lower than on the Stanislaus River. There may also be significant indirect impacts on groundwater and other resources if there is an increase in groundwater pumping in response to reduced surface water diversions.
>
> *Author's note: The Board is proposing that the operators of each major storage dam on the San Joaquin tributaries release 35% of the unimpaired inflow in the months of*

February through June. The SWRCB 2010 Delta Flow Criteria Report recommended that the release from the San Joaquin to the Delta should be 60% of unimpaired in the months of February through June; we were told that this was already a compromise, since for the Sacramento watershed the 2010 Delta Flow Criteria Report recommends release of 75% of unimpaired inflow.

>> Fall-Run Chinook Salmon Flow Needs: Flows in the SJR basin affect various life stages of fall-run Chinook salmon including: adult migration, adult spawning, egg incubation, juvenile rearing, and outmigration to the Pacific Ocean. Analyses indicate that the primary limiting factor for salmon survival and subsequent abundance is reduced flows during the late winter and spring when juveniles are completing the freshwater rearing phase of their life cycle and migrating from the SJR basin to the Delta (February through June; DFG 2005a, Mesick and Marston 2007, Mesick et al. 2007, Mesick 2009). As such, while SJR flows at other times are also important, the focus of the State Water Board's current review is on flows within the salmon-bearing tributaries and the SJR at Vernalis (inflows to the Delta) during the critical salmon rearing and outmigration period of February through June.

>> In late winter and spring, increased flows provide improved transport downstream and improved rearing habitat for salmon migration. These flows may also provide for increased and improved edge habitat (generally inundated areas with vegetation) in addition to increased food production for the remainder of salmon that are rearing in-river. Later in the season, higher inflows function as an environmental cue to trigger migration of smolts, facilitate transport of fish downstream, and improve migration corridor conditions (USDOI 2010). Specifically, higher inflows of various magnitudes in spring support a variety of functions including: maintenance of channel habitat and transport of sediment, biota, and nutrients (Junk et al. 1989). Increased turbidity and more rapid flows, may also reduce predation of juvenile Chinook salmon (Gregory 1993; Gregory and Levings 1996, 1998). Higher inflows also provide better water quality conditions by reducing temperatures, increasing dissolved oxygen levels, and reducing contaminant concentrations. NMFS has determined that each of these functions is significantly impaired by current conditions.

>> Studies that examine the relationship between fall-run Chinook salmon population abundance and flow in the SJR basin generally indicate that: 1) additional flow is needed to significantly improve production (abundance) of fall-run Chinook salmon; and 2) the primary influence on adult abundance is flow 2.5 years earlier during the juvenile rearing and outmigration life phase (AFRP 2005, DFG 2005a, Mesick 2008, DFG 2010a, USDOI 2010). These studies also report that the primary limiting factor for tributary abundances are reduced spring flow, and that populations on the tributaries are highly correlated with tributary, Vernalis, and Delta flows (Kjelson et al. 1981, Kjelson and Brandes 1989, AFRP 1995, Baker and Mohardt 2001, Brandes and McLain 2001, Mesick 2001b, Mesick and Marston 2007, Mesick 2009, Mesick 2010 a-d).

>>Analyses have been conducted for several decades that examine the relationship between SJR fall-run Chinook salmon survival (escapement) or abundance (e.g., adult

Chinook salmon recruitment) and flow. Specifically, analyses have also been conducted to: 1) evaluate escapement (the number of adult fish returning to the basin to spawn) versus flow 2.5 years earlier when those salmon were rearing and outmigrating from the SJR basin; and 2) to estimate juvenile fall-run Chinook salmon survival at various reaches in the SJR basin and the Delta versus flow. For example, flows from March through June have been correlated to the total number of smolt outmigrants within a tributary (Mesick, et al. 2007, SJRRP 2008). Figure 3.8 suggests that prolonged late winter and spring flows in the Tuolumne River are an important factor in determining smolt survival rate (Mesick 2009). Additionally, adult Chinook salmon is thought to be highly correlated with the production of smolt outmigrants, which are highly correlated to spring flows, for each of the major SJR tributaries (Mesick and Marston 2007, Mesick, et al. 2007)...... Kjelson et al. (1981) found that peak catches of salmon fry often follow flow increases associated with storm runoff, suggesting that flow surges influence the number of fry that migrate from spawning grounds into the Delta and increase the rate of migration for fry. Kjelson et al. (1981) also found that flows in the SJR and Sacramento River, during spawning and rearing periods, influence the numbers of juvenile Chinook salmon that survive to migrate to the Delta. In addition, observations made in the SJR basin between 1957 and 1973 indicate that numbers of Chinook spawners are influenced by the amount of river flow during the rearing and outmigration period (February to June) 2.5 years earlier. As a result, Kjelson et al. (1981) found that flow appears to affect juvenile survival, which in turn affects adult abundance. In testimony before the State Water Board in 1987, Kjelson again reported that data indicate that the survival of fall-run salmon smolts migrating from the SJR basin through the Delta increases with flow. Kjelson found that increased flows also appear to increase migration rates, with smolt migration.... Mesick (2009) found that since the 1940s, escapement has been correlated with mean flow at Modesto from February 1 through June 15 (2.5 years earlier), and that flows at Modesto between March 1 and June 15 explain over 90 percent of the escapement variation. This correlation suggests that escapement has been primarily determined by the rate of juvenile survival, which is primarily determined by the magnitude and duration of late winter and spring flows, since the 1940s.

Vogel, D. 2005. The effects of Delta hydrodynamic conditions on San Joaquin River juvenile salmon. May 2005. Natural Resources Scientists, Inc. Red Bluff, CA.

>>"Fish movements into Turner Cut appeared to be a principal route for fish entry into areas south of the San Joaquin River and to a lesser extent, Columbia Cut or Middle River….The second interesting finding from these studies was the fact that most fish, once they left the San Joaquin River, did not get back to the mainstem. This finding was unexpected at the time because it was assumed that fish moving into the south Delta channels for reasons solely attributable to the tidal effects (e.g., during a flood tide) would move back out into the San Joaquin River during the change in tidal phase (e.g., an ebb tide). Empirical data were collected that demonstrated some of those fish kept moving in a southerly direction toward the export facilities. Some of the fish entering channels south of the San Joaquin River were tracked several miles into those channels. It was particularly evident that net southerly movement was rapid. Within a period of just several days, some fish were located far south in Middle River and Old River. It was

also evident that the lowest "entrainment" of fish off the mainstem occurred when the net reverse flows and SWP and CVP exports were lowest.

When radio-tagged smolts were released in Old River nine miles north of Clifton Court (CC) during combined exports in the range of 8,000 – 11,000 cfs, it was estimated that about two-thirds of the fish were entrained into the export facilities during the study period. Generally, the fish exhibited a rapid, southerly migration pattern in concert with the high southerly flow direction caused by medium export levels damping out or eliminating northerly or downstream flows in Old River.

The mechanisms explaining how and why salmon smolts can be diverted off the mainstem San Joaquin River into channels south of the Delta remain unknown. Also, it appears that some smolts, once they move into those south channels, do not re-emerge back into the San Joaquin to continue normal migration toward salt water. This latter phenomenon is also not understood. Because of net reverse flows that fish encounter in specific channels south of the San Joaquin River, outmigrating salmon apparently have difficulty re-emerging back into the mainstem. The magnitude of the net reverse flows increases with closer proximity to the south Delta export facilities. Once salmon enter this region of the Delta, the fish likely experience high mortality rates.

Author's Note: These VAMP studies (experiments) were conducted most often with the DCC closed, thus making longer still the long odds of survival of salmon migrating down the San Joaquin River to the Delta toward the Bay. There was little chance that the VAMP experiments would provide good survival for San Joaquin River salmon , with slightly higher San Joaquin River flows not being high enough, reduced export levels not being low enough, and the DCC being closed.

Thomas Cannon

Statement of Qualifications

I am a fisheries biologist and statistician with degrees in fisheries biology (B.S.) and biostatistics (M.P.H) from the University of Michigan. As an estuarine fisheries ecologist, I began my study of estuary ecosystems on the Hudson River Estuary from 1972-1977. Turner and Kelly's 1966 DFG Bulletin 136 and Turner and Chadwick's 1972 paper on Bay-Delta striped bass versus outflow and exports were the bible for management of striped bass East Coast estuaries. The concept that estuary fish populations were controlled by outflow via survival of larvae and juvenile fish was new to estuarine science. During my years on the Hudson River, I consulted on several occasions with DFG scientists. Pete Chadwick, DFG's lead Delta scientist, was a consultant to the Hudson River program.

I began working on Central Valley fisheries in 1977 and have more than 35 years experience in Delta fishery issues. From 1977-1980, I was project director of Bay-Delta ecological studies for PG&E's Bay-Delta power plants study programs, which evaluated the effects of power plant operations on the Bay-Delta ecosystem. From my experience working on estuaries it was obvious to me that the Bay-Delta was unique in not only having large power plants, but also unprecedented large water diversions that had great effects on outflow during critical spring-summer months.

From 1980-82, I was a consultant to the State Water Contractors focusing on the effects of D-1485 and the development of a new Two Agency Agreement between DWR and DFG. I also was a consultant to the National Marine Fisheries Service where I assessed the importance of the Bay-Delta as a nursery area for Central Valley salmon. I was also a member of the State Water Resources Control Board's Striped Bass Working Group charged with evaluating why the D-1485 Standards were not protecting the Bay-Delta ecosystem and the striped bass population.

From 1986-1987, I was a consultant to the State Water Contractors and US Bureau of Reclamation on developing new water quality standards. From 1994-1995, I was again a consultant to the State Water Contractors and the California Urban Water Agencies, working on the 1995 Bay-Delta Water Quality Standards and how the new standards would affect the Bay-Delta ecosystem.

From 1995-2002, I was a staff consultant to the CALFED program where I worked on various projects including the Anadromous Fish Restoration Program (AFRP), Ecosystem Restoration Program Plan, the Delta Entrainment Effects Team, the Tracy Technical Advisory Team, the Environmental Water Account, CVPIA Environmental Impact Statement, and the Delta Cross Channel Through Delta Facility evaluation team. Between 2000 and 2004, I participated in many AFRP projects involving flow-habitat relationships in the lower American, Cosumnes, Calaveras, and Stanislaus Rivers. I also participated in project planning and environmental assessments of the Delta Wetlands Project, the Montezuma Wetlands Project, and many other Bay-Delta development and restoration projects including PG&E's Delta Power Plants HCP.

In 2002, I participated in a DFG review of the status of the striped bass population. From 2002 to 2005, I was involved in activities related to the Striped Bass Stamp Program including stocking and tagging striped bass and as the California Striped Bass Association's representative on the DFG/DWR Four Pumps Mitigation Committee.

More recently I have advised the California Striped Bass Association on proposed new striped bass fishing regulations, and advised USBR staff on the merits of the proposed new Fall X2 Standards. From 2002 through 2010, I have been involved in developing and evaluating many estuary habitat restoration projects including sites in the Yolo Bypass, the Delta, and Suisun Bay. Over the last decade, I have been a consultant to CSPA member organizations and, since 2012, have advised the California Sportfishing Protection Alliance on flow and other measures needed to protect fisheries in the Delta Estuary and its tributaries.