United States Department of the Interior

Comments on the Review of and Potential Modifications to the San Joaquin River Flow and Southern Delta Salinity Objectives Included in the 2006 Water Quality Control Plan for the San Francisco Bay/Sacramento-San Joaquin Delta Estuary

February 8, 2011

The U.S. Department of the Interior (Interior) submits these comments on behalf of the U.S. Bureau of Reclamation (Reclamation) and the U.S. Fish and Wildlife Service (FWS), pursuant to the State Water Resources Control Board (SWRCB or the Board) November 22, 2010, Notice of Opportunity for Public Comment on the review and potential modifications to the San Joaquin River Flow and Southern Delta Salinity Objectives included in the 2006 Water Quality Control Plan for the San Francisco Bay/Sacramento-San Joaquin Delta Estuary (Bay-Delta) (2006 Bay-Delta Plan), and a program of implementation to achieve these objectives. These comments are in addition to comments submitted by Interior on December 6, 2010 on the Board's Draft Technical Report pursuant to the Board October 29, 2010, Notice of Opportunity for Public Comment.

I. SUMMARY

Thank you for this opportunity to provide comments to the State Water Resources Control Board (Board) regarding the review of and potential amendments to the San Joaquin River flow and southern Delta salinity objectives included in the 2006 Bay-Delta Plan, and a program of implementation to achieve these objectives. Consistent with our previous comments to the Board, Interior remains very concerned about the continued decline of the San Joaquin Basin fall-run Chinook salmon and the federally listed steelhead. San Joaquin River flows into the Delta have been reduced significantly from pre-development conditions, and the declines in San Joaquin salmon production are correlated to the reduction in the magnitude and duration of San Joaquin basin flows in the late winter and spring. Currently, the San Joaquin basin flows are inadequate to protect and/or restore healthy populations of salmonids. Consequently, Interior is committed to working with the Board and providing technical information needed to develop and implement San Joaquin River flow objectives.

Interior supports the Board's consideration of flow objectives based on the percent of unimpaired flow. The Board has sufficient information that warrants increasing Vernalis flows to support a healthy San Joaquin Basin ecosystem, and the Board should consider the source water for flow objectives on the mainstem. The Board should be concerned with contributions of the major San Joaquin tributaries (Stanislaus, Tuolumne and Merced rivers) that support salmonid populations, and which are capable of achieving increased flows at Vernalis. Not only will considering tributary sources help to protect salmonid populations, but it will also result in a more equitable and robust implementation plan.

Interior believes that each of the concepts presented in these comments should be further fully developed, with the biological and ecosystem goals described, modeled and otherwise analyzed to evaluate potential trade-offs. The comments that follow are in three sections. Sections 2 and 3, below, discuss the past program of implementation from a water rights and water supply perspective, and Interior's concerns with New Melones Dam and Reservoir analyses and operations in connection with past and future San Joaquin River flow and salinity objectives. Section 4, below, provides additional information for setting and implementing San Joaquin River flow objectives from a biological perspective. This section discusses the importance of setting biological goals, adaptive management principles, and further provides the following: a primer on the relationship between habitat threats and flow; information on experiences from the Trinity River restoration program; a response to the San Joaquin River Group Authority's presentation to the Board during the January, 2011, workshop; and an example of using a lifecycle approach for developing survival goals.

II. BRIEF HISTORY OF PAST PROGRAM OF IMPLEMENTATION – SAN JOAQUIN RIVER FLOW OBJECTIVES

In 2000, the Board adopted Water Rights Decision 1641 (D-1641), to allocate responsibility to water right holders for meeting certain water quality objectives in the 1995 Bay-Delta Plan. With respect to the San Joaquin River flow objectives, which are an element of Delta inflow requirements, Reclamation agreed to negotiate with stakeholders for a plan of implementation. During that process, Reclamation agreed to accept temporary responsibility for the San Joaquin flow objectives to allow the Board additional time to undertake proceedings to assign permanent responsibility to other water right holders that divert water from the Bay-Delta watershed. Reclamation testified during the D-1641 hearings that it would accept temporary responsibility by backstopping certain San Joaquin River objectives, even though Reclamation could control only one facility (New Melones Dam), on one tributary (the Stanislaus River), capable of meaningfully impacting the San Joaquin River objectives at Vernalis. However, given that the responsibility would be temporary, New Melones Dam would not be operated aggressively over the long-term.

The negotiated agreement, the San Joaquin River Agreement (SJRA), is for a term of up to eleven years, and expires at the end of 2011. The SJRA includes provisions for Reclamation to backstop the Board's February – June "baseflow" requirements, while paying other San Joaquin parties to make water available to meet the April – May, spring, and October, fall, "pulse" flow requirements. The SJRA also provided a framework for a Vernalis Adaptive Management Plan (VAMP) experiment, which was designed to determine the biological benefits of the experimental spring and fall pulse flows. While the SJRA has been valuable for the VAMP experiment, under the SJRA, including the 2011 extension, the total cost is expected to be around $90 million. Reclamation will have paid to San Joaquin River Group Authority approximately $78 million from the federal Central Valley Project Improvement Act's Restoration Fund; the State has paid $12 million. In addition, during the SJRA, the demands on New Melones have exceeded its safe yield, and carryover storage has not recovered at the rate of other reservoirs, even in wetter years. The SJRA has been expensive to Reclamation in both money and water.

At the present time, Reclamation has no intention of continuing the SJRA, or similar arrangement, in the future.

III. FUTURE PLAN OF IMPLEMENTATION: WATER RIGHTS AND WATER SUPPLY

A. San Joaquin River Flow Objectives (Vernalis).

Now that the Board is reviewing the San Joaquin River Flow Objectives at Vernalis, the Board needs to consider new paradigms for a plan of implementation. Whatever the future objectives may be, a first step in designing a plan of implementation for those objectives will be assignment of responsibility. For flow-dependent objectives, the Board exercises its authority over water rights. Therefore, the Board will assign responsibility for instream flow objectives among water right holders. The Board will need to decide whether it will deal with all water right holders individually, or by classes.

Interior strongly opposes any assignment of responsibility only on water rights of the Central Vallely Project (CVP). On the San Joaquin, there simply is no basis for singling out federal Reclamation projects as the sole class of water rights to bear the burden for flows on the mainstem of the San Joaquin. Instead, the Board should consider apportioning responsibility for mainstem instream flow among as many water users as possible. Such method, “increases the operational flexibility of the water system, and thereby reduces the total impact of meeting the proposed [objectives].” 1994 EPA Proposed Rule, 59 Fed. Reg. 810, 822. As we have seen, the Interior “backstop” of mainstem instream flows has resulted in a disproportionate burden of mainstem flows being contributed by the Stanislaus River (Draft Technical Report, p. 23, Table 2.9), as well as imprudent New Melones operations. Interior contends that all water users that divert water from the Bay-Delta watershed, that would otherwise reach the Bay-Delta in the system as it exists today, should be assigned a portion of responsibility for meeting mainstem San Joaquin River flow objectives.

Once the Board determines who will be responsible for the objectives, the Board will need to determine how to implement that responsibility among water right holders. At this point, California water law affords the Board a great deal of alternatives from strict adherence to the priority system to outright protection of the public trust, and several in between.

Although there are likely other alternatives, at least four main alternatives should be considered: (1) the Board could enjoin junior diverters (by tributary, discussed below), until the requisite instream flow is reached; (2) the Board could look at individual users or classes of users and determine that certain uses are now considered unreasonable under Article X, Sec. 2 of the California Constitution in light of the deleterious effects of diversions on the Bay-Delta; (3) the Board could require that all water right holders (or at least major water right holders) reduce their diversions by their proportional share of unimpaired flow; or (4) the Board could use its reserved jurisdiction to reduce diversions or increase reservoir releases for those water right holders with reserved jurisdiction clauses in their permits.

a. The Board must include major tributary "source water" in its plan of implementation.

Irrespective of how the Board ultimately implements responsibility among water right holders, the Board must include major tributary sources in its plan of implementation. Water right holders on the Stanislaus, Tuolumne and Merced Rivers should all contribute to instream flow needs of the mainstem San Joaquin River at Vernalis. Not only is this required from a water right perspective, but also to restore the health of the San Joaquin ecosystem, and to achieve a more natural hydrograph for the San Joaquin system. Implementing mainstem flow objectives primarily with water rights on the Stanislaus, is an inequitable and improper administration of the priority system, but also results in deleterious impacts to Bay-Delta fishery above Vernalis.

The Board should consider staging its implementation of the Upper San Joaquin River portion. As we know, the Upper San Joaquin is not currently, or only minimally, hydraulically connected to the mainstem below the Merced River. The San Joaquin River Restoration Program is in the process of restoring flows and salmon in the mainstem San Joaquin River, and the Upper San Joaquin will likely regain connectivity to the balance of the mainstem in the future. Until more is known about how much water from the Upper San Joaquin can reach the mainstem below the Merced River, Interior believes that the Board should defer assigning responsibility to water users of the Upper San Joaquin until the Board can, within a degree of certainty, be assured that water released or bypassed in the Upper San Joaquin can reach the lower mainstem.

b. The Board must implement water right responsibility within each major tributary.

Each major tributary should contribute its proportional share of instream flows to the mainstem. This should be based on the proportional share of unimpaired flow in the respective major tributaries. This is NOT the same thing as requiring a proportional reduction in share of water from water right holders, in contradiction of the priority system. This is simply administering each tributary basin within its own watershed. Even if the Board were to implement responsibility among water right holders according to a strict adherence to the priority sytem, there is no basis to implement the priority system across tributaries.

The purpose of "first in time, first in right" law of prior appropriation is to protect senior appropriators, in times of shortage, against appropriations from an upstream junior. See Waters and Water Rights § 17.02. If a senior water right holder on the Tuolumne had their supply impaired by junior diverters in a water short year, the Board could not enjoin junior water right holders on the Stanislaus from diverting to make seniors on the Tuolumne whole. The priority system would never be administered that way to serve its purpose of protecting seniors from upstream juniors, and there is no basis to administer the priority system across tributaries to achieve an instream flow requirement on the mainstem. The past program of implementation wherein Reclamation has borne the burden has been the result of political compromise, NOT the result of the law of priorities. Administering the tributaries individually does no harm to the priority system, but does result in skewed flows as compared to the natural hydrograph of the San Joaquin and its major tributaries.

c. There is no basis to require depletion of stored water held by a junior water right holder before requiring natural flow water from a senior water right holder under the priority system.

Once the Board begins to implement the San Joaquin instream flow requirements by major individual tributary, Reclamation's interest is on the Stanislaus, and New Melones Dam and Reservoir. We have long heard the argument from Oakdale/South San Joaquin Irrigation Districts that Reclamation's stored water is required, under the law of priorities, to be depleted before natural flow rights from senior water right holders can be required to meet instream flow needs. Again, there is no basis for such an assertion in basic prior appropriation principles. As stated by the Board in WR 2001-22:

> A water right holder's seniority over the Projects does not allow diversions when the Projects are not diverting natural and abandoned flows for additional appropriations. Nor does seniority over the Projects entitle a water right holder to make use of stored water which the Projects diverted to storage when natural flows were sufficient to divert water under the Projects' priorities, either by taking that water from Project reservoirs or by requiring the Projects to release additional stored water to meet water quality objectives.

This principle was recognized by the court in *El Dorado Irrigation District v. SWRCB*, 142 Cal. App. 4th 937; Cal. Rptr. 3d 468 (September 8, 2006), in which the court stated, "Of course, the rule of priority applies only to the use of natural or abandoned flows in a watercourse." *Id*. at 962, and "… no appropriator has a right to take water that was previously stored or imported by another upstream and then released into the watercourse …" either actually or constructively. *Id.* at 968. In other words, water right holders with direct diversion rights and water right holders with rights to divert to storage are both diverters of natural flow. It is the diversion of natural flow which is administered on a priority bases. Junior storage right holders can be made to divert less to storage to satisfy senior water rights, but are not required to deplete previously stored waters (especially water stored from prior years) before the natural flow diversions of senior water rights are decreased. In the case of federal Reclamation projects, this rule helps to ensure that only those who contract to repay the costs of the initial federal outlay for construction, operation and maintenance of those facilities, receive the benefits of water stored by federal facilities.

d. New Melones Dam and Reservoir.

New Melones Dam and Reservoir is unique and experiences overprescribed demands in many water years. The inflow to New Melones and storage yield are required for prior water rights holders, CVP contractors, fish flows, salinity control, temperature control, dissolved oxygen requirements, flood control, power, and recreation purposes, to name a few. In addition, Reclamation operators strive to sustain usable New Melones storage yield in extreme drought conditions. This is no easy task, given that it is never clear how long consecutive drought years will continue.

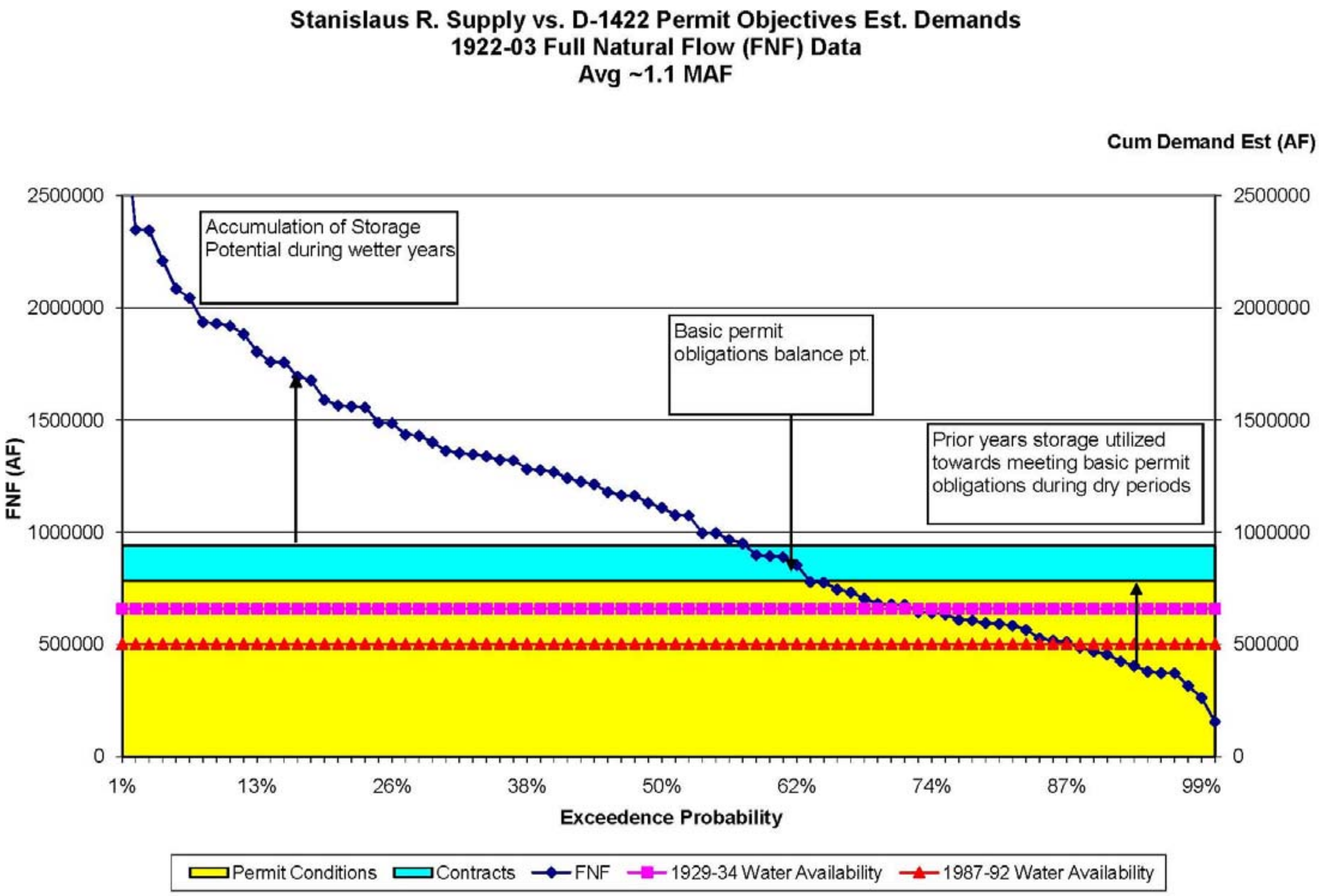
The Board can place valid conditions on Reclamation's water right permits for the control, appropriation, use, or distribution of water from a Reclamation storage facility, provided that such conditions do not conflict with a Congressional directive. *California v. United States*, 438

U.S. 645, 675 (U.S. 1978). Therefore, the Board has authority to allocate New Melones yield under state law, provided again, that such restrictions do not conflict with a Congressional directive. Allocating storage yield of a multi-purpose reservoir is not the same thing as allocating annual natural or unimpaired flow of a stream. However, allocating annual or unimpaired flow influences allocation of reservoir yield. Allocating storage yield necessarily includes multi-year drought protection, carryover storage and refill potential as critical factors. In the case of New Melones, proper allocation of storage yield is not simply to protect consumptive uses, but also the fish flow, salinity dilution, temperature, and other non-consumptive use benefits and obligations of New Melones yield under D-1422.

New Melones was initially permitted by the Board under D-1422 in 1973, and has been amended by Water Right Orders (WRO) 80-20, 82-3, 82-9, 83-3, D-1616, WRO 88-6, and D-1641. Beginning with D-1641, the Board's analysis for allocating storage yield of New Melones changed from more classic yield and water availability analyses to a computer modeling exercise. This modeling supporting D-1641 on the San Joaquin, however, had several flaws which add water to the system, or simply assume compliance with salinity dilution requirements, to illustrate that water quality objectives at Vernalis could be attained. What the analysis did not do is show the impact on New Melones yield from meeting cumulative water quality objectives and other demands from the water resources available at New Melones, over the long-term.

Also in D-1641, the Board adopted a view that it was not requiring Reclamation to meet Vernalis objectives, including salinity requirements, with water releases from New Melones, and that Reclamation could meet the objectives by any other means, including purchase of water. Unfortunately, it is becoming untenable for Reclamation to operate under such vague permit conditions. For flow-dependent objectives, Reclamation's only facility which can meaningfully impact the lower San Joaquin is New Melones. Yet, the Board's D-1641 permit conditions have not been quantified, or even analyzed by the Board in terms of project yield. Reclamation looks forward to working with the Board in the future to return to a more classic yield and water availability analysis to study impacts of future San Joaquin River flow, salinity objectives, and alternative programs of implementation, on the long-term, sustainable yield of New Melones Reservoir.

To illustrate the issues with drought sustainability and yield analysis for New Melones, the graph below shows that even under D-1422 permit conditions, water stored from previous years was needed in approximately 40% of the years to meet those basic conditions.



In addition, this graph illustrates the quantity of stored water needed to meet D-1422 permit conditions assuming a 1929-34 drought water availability and the 1987-92 drought water availability. In order to have enough water to make it through all six years of those droughts, New Melones would have to have available storage approximately six times the amount of water shown between the drought water availability line and the permit conditions. As shown by this graph, it would take significantly more conserved water to protect against a 1987-92 magnitude drought, as opposed to a 1929-34 magnitude drought. Therefore, drought protection levels, in terms of available conserved storage, are extremely important to water availability analysis to meet permitted beneficial uses or classic yield analysis. No such analysis has been done for D-1641 permit conditions.

e. The Board has reserved jurisdiction for fish flows and salinity requirements under D-1422.

In determining a program of implementation, the Board should keep in mind that it has reserved jurisdiction under D-1422, specifically for fish flows and salinity dilution requirements. However, this authority is reserved to prevent waste, unreasonable use, unreasonable method of use, or unreasonable method of diversion of water. Therefore, use of this reserved jurisdiction to increase flow-dependent objectives, and displace other uses, will require a Board finding that such other uses are wasteful or unreasonable. In addition, the 9th Circuit Court of appeals has warned that the Board could not use its reserved jurisdiction under D-1422 inconsistently with Congressional intent for New Melones Dam and Reservoir. *United States v. California*, *State Water Resources Control Bd*., 694 F.2d 1171, 1182 (9th Cir. Cal. 1982).

f. The Board is not required to implement San Joaquin River flow objectives based upon a strict adherence to the water right priority system.

If the Board were to choose a strict adherence to water right priorities in implementing San Joaquin River flow and salinity objectives for the Stanislaus portion, this rule would apply to Reclamation's natural or unimpaired flow diversions for New Melones. If one considers the water availability analysis in D-1422, after prior rights water, the average annual inflow for Reclamation use (based on a 1923-1953 period of study), is 335,000 acre feet, with a range from zero to 1.90 million acre feet. Under this analysis, zero inflow for Reclamation use occurred in nine out of the thirty years. In these years, the entire burden for instream flow requirements, under a strict priority system, will fall solely on the senior right holders on the Stanislaus. Therefore, in order to allocate storage yield to instream flow, above the 98,000 acre feet (155,000 acre feet with Dissolved Oxygen requirements) allocated to fish, and the 70,000 acre feet allocated to salinity under D-1422, the Board will need to take advantage of California law which allows flow requirements to be implemented outside of the strict rule of priority, such as the reasonable use doctrine, or public trust. The Board's authority to implement instream flow requirements on bases other than strict priority was cemented in *El Dorado Irrigation District v. SWRCB*, 142 Cal. App. 4th 937; Cal. Rptr. 3d 468 (September 8, 2006). In that case, the court held, "Thus, like the rule against unreasonable use, when the public trust doctrine clashes with the rule of priority, the rule of priority must yield." *Id*. at 966. In crafting a sustainable and achievable implementation strategy for San Joaquin River flow objectives, Interior encourages the Board to use its full portfolio of authorities over all water rights, and not simply rely on the rule of priorities or limited reserved jurisdiction.

B. Southern Delta Salinity Objectives

Under D-1641, Reclamation was assigned full responsibility for salinity objectives at Vernalis, and partial responsibility for salinity as measured at the three interior South Delta stations. The Board attempted to change the finding of Reclamation's partial responsibility to full responsibility through a cease and desist order (CDO) process, but took no evidence on the issue of responsibility and had no bases in the record on which to alter the original finding in D-1641. For that reason, the United States challenged a Board order for the first time in 25 years. This lawsuit has been tolled pending the Board's review of these objectives.

Under D-1641, only salinity objectives as measured at Vernalis were implemented through dilution flows. The three interior South Delta stations (Brandt Bridge, Old and Union Island) were never intended to be met using dilution flows, as evidenced by the Board's environmental analysis supporting D-1641. Instead, the Board essentially made a State and federal construction project, permanent operable barriers, which raise water levels and increase circulation rates to move salinity out to the Delta, a condition of the water rights of the CVP to partially implement the interior Delta objectives. Construction of the permanent operable barriers, however, appears highly unlikely since the NOAA Fisheries biological opinion finding it to have detrimental impacts to salmon habitat. The Board did not foresee the delays in construction of the permanent operable barriers, and did not have an alternative implementation strategy.

Interior believes the Board should consider implementation strategies for the three interior South Delta stations by mechanisms other than water rights. It does not appear likely that construction of permanent operable barriers is a feasible solution. In addition, Reclamation is working on studies and analysis which show the extreme water costs of attempting to meet the current interior South Delta salinity objectives with dilution flows from the San Joaquin River, and will be providing this information to the Board this Spring. Passing these water costs on to water users of the San Joaquin would be difficult for the Board to justify. Salinity objectives are designed to protect agriculture, not a traditional public trust resource. The Board's ability to extract water from current water right holders of the San Joaquin River, or stored water, to protect Southern Delta agriculture is limited, at best.

Interior has a number of considerations for the Board to consider in setting, evaluating, and implementing changes to the Southern Delta salinity objectives, set forth below.

a. The Board should use the best available science to support objective setting

Interior supports the use of the best available science in defining and setting water quality and flow objectives. The January, 2010 report *Crop Salt Tolerance in the Southern Sacramento-San Joaquin River Delta* by Dr. Glenn J. Hoffman (Salt Tolerance Report), along with public comments, should be forwarded to the peer review process so that neutral technical experts can determine if it represents the best available science.

b. The Board should include additional considerations in setting the objectives.

At present the same numeric objectives are set at all four Southern Delta locations (Vernalis and the three interior South Delta stations). Data presented in the Draft Technical Report clearly shows there is a level of degradation between Vernalis and downstream Delta locations. This is due to beneficial consumptive use and to the geophysical conditions of this area. The Board should consider whether it is appropriate, given these facts, to expect an objective set the same for all four locations to protect conditions downstream (effectively allowing for no consumptive use), or whether it is more appropriate to incorporate a consumptive use allowance in setting objectives between upstream and downstream locations.

The existing water quality objectives for the Southern Delta were established over fifteen years ago to protect salt sensitive crops such as dry beans and alfalfa. The growing season objective from April through August was established to protect agriculture (dry beans) but there is not a clear rationale for the non-growing season objective from September through March for the protection of alfalfa. Assuming the harvesting of alfalfa continues through October, an additional objective could be in place from November to March to create additional assimilative capacity for salinity management. Information provided through the Salt Tolerance Report strongly suggests that current water quality objectives in the southern Delta can be relaxed without impacting crop yield for salt-sensitive produce. The scientific information from the Salt

Tolerance report plus testimonies and comments submitted through the public process will guide the Board in evaluating new water quality objectives that balance basin beneficial uses. Within this evaluation, the Board also needs to determine if non-growing season objectives are needed for all water years.

Salt Tolerance appears to be extremely sensitive to effective rainfall, which is highly variable in the Southern Delta and San Joaquin basin. Effective rainfall is an important variable that can be used to determine irrigation needs and could be more dynamically tied to the new southern Delta objectives. A more dynamic water quality objective could create much needed flexibility in the system from September through March and allow opportunities to implement management actions for short and long term salinity control in the San Joaquin watershed.

Issues of localized degradation in the southern Delta channels, particularly the Old River at Tracy Road station, were brought forth by various parties during the Board workshop and documented in DWR's report, "Sources of Salinity in the South Sacramento-San Joaquin Delta." The Board must acknowledge the role of localized degradation in its analysis of an appropriate water objective and not place an unreasonable burden on parties upstream.

Finally, as the Board considers a program of implementation for salinity it cannot disregard the interconnected influence of the CVP and the SWP on salinity dynamics within the delta channels and their influence on salt movement in the basin.

Finally, as the Board considers a program of implementation for salinity it cannot disregard other factors that alter salinity at the export pumps and its influence to the San Joaquin River Basin and the southern Delta.

c. The Board Should Acknowledge how San Joaquin Flow Objective Modifications at Vernalis Affect the Salinity Profile.

While Reclamation bases its evaluation and comments on the historic salinity profiles in the lower San Joaquin River and Southern Delta, we recognize that changes to the flow regime have the potential to dramatically change the salinity profile in the lower San Joaquin River and southern Delta. The Board should therefore develop its alternative flow scenarios and then analyze the changed salinity profile to address the following:

- Because ecosystem needs and water quality needs are not conjunctive but competing uses, what is the total water cost to meet the ecosystem needs using a percentage of unimpaired flows and meeting water quality needs on an annual and multi-year basis?

- Using a percentage of unimpaired flow to manage ecosystem needs will most likely alter the salinity profile of the basin from historical conditions. How will the intensity, duration, and seasonality of the new salinity profile compare to historical? Will additional flows be needed to meet objectives? How will meeting the objective with the new profile impact storage compared to historical conditions?

- What are the water supply impacts if the water quality objectives were relaxed for both the irrigation and non-irrigation periods?

- Will the new salinity profile create new opportunities or obstacles to long term salinity control of the basin?

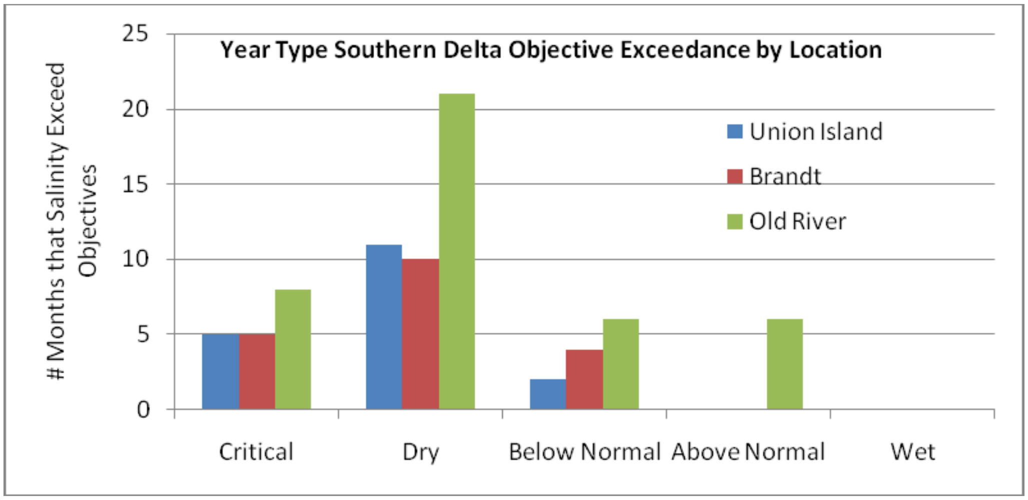
- How will flow changes affect the Regional Board's efforts to control salts through loading allocation programs?

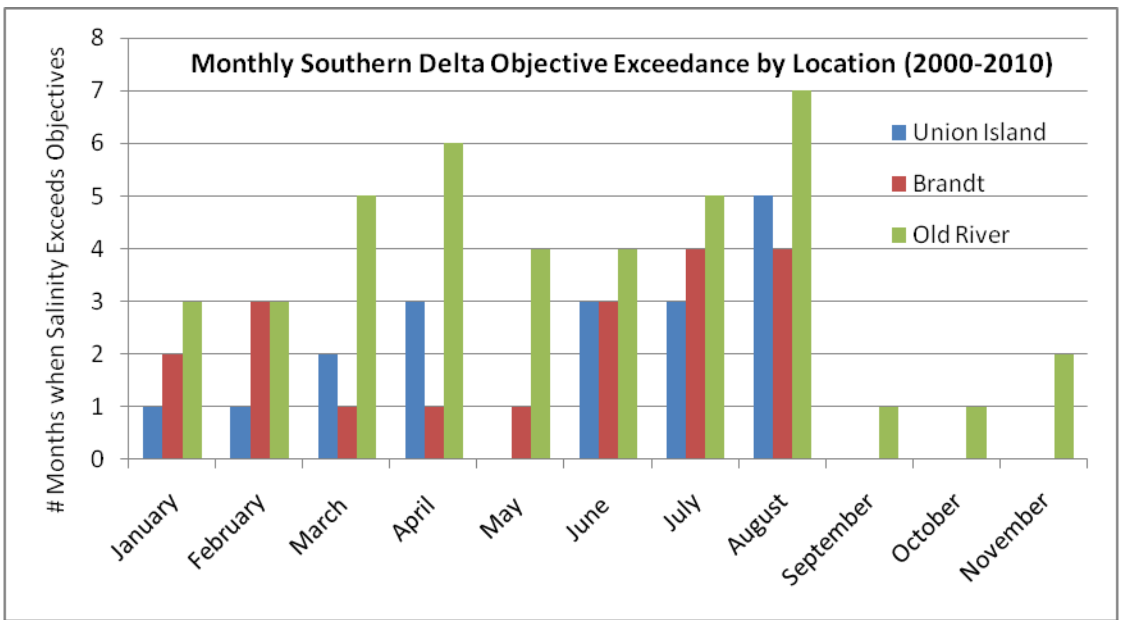
d. The Board should consider additional information in developing implementation alternatives.

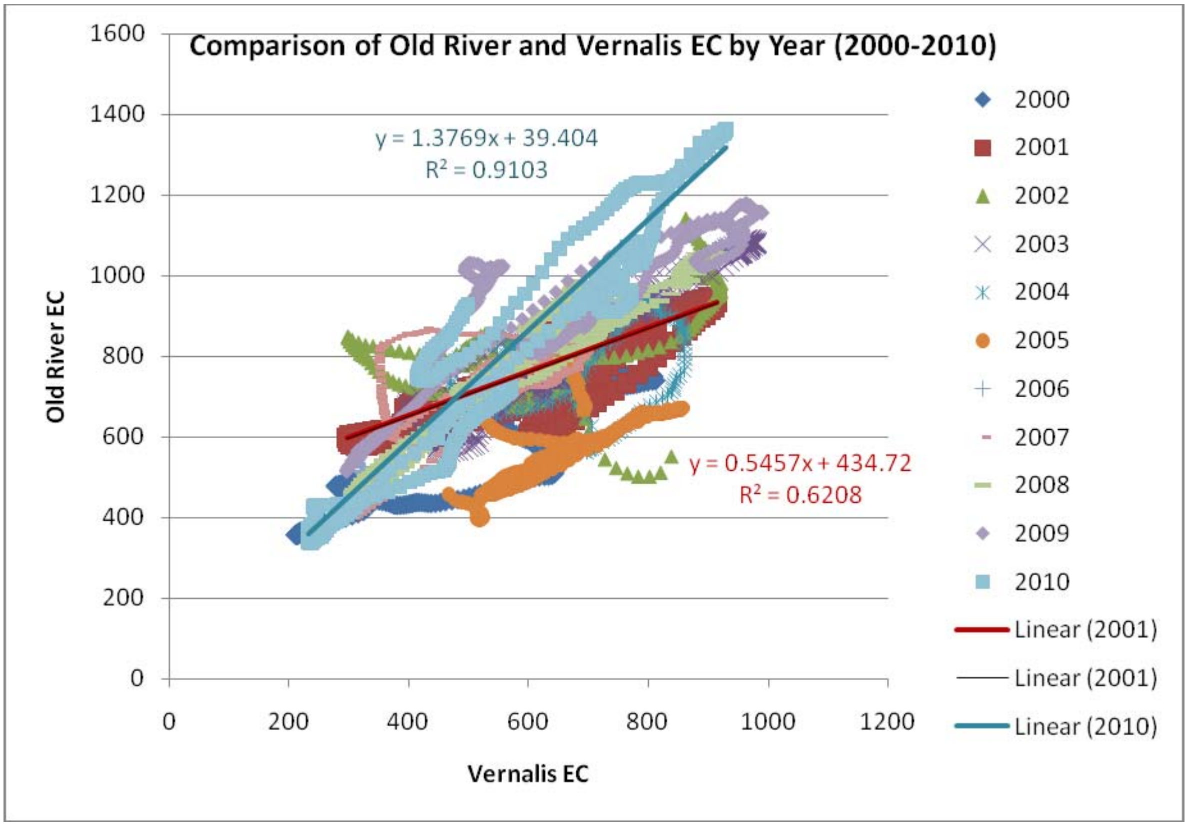
As the board evaluates the water quality objective for the South Delta, Interior believes the approach should be expanded to explore opportunities for salinity management in the basin. CV-SALTS and the Salinity and Boron TMDL specify a long term goal of achieving a salt balance in the San Joaquin basin and the Central Valley Regional Water Quality Control Board is a proponent of real time management for the lower San Joaquin River. The Board must recognize that any long term strategy must include opportunities to export excess of salt out of basin and provide land owners the ability to discharge when conditions exist without jeopardizing beneficial uses. In a highly managed system such as the San Joaquin, artificially created conditions do not always allow sufficient periods of export to achieve a salinity balance.

In addition, Reclamation is working on studies and analysis which explore the extreme water costs of attempting to meet the current interior South Delta salinity objectives with dilution flows from the San Joaquin River (should the Board pursue the simplified relationship identified in the Draft Technical Report), and will be providing this information to the Board this Spring. The Board should therefore continue its analysis of salinity patterns in the Southern Delta to determine an accurate and reasonable approach to implementation that minimizes unnecessary water costs.

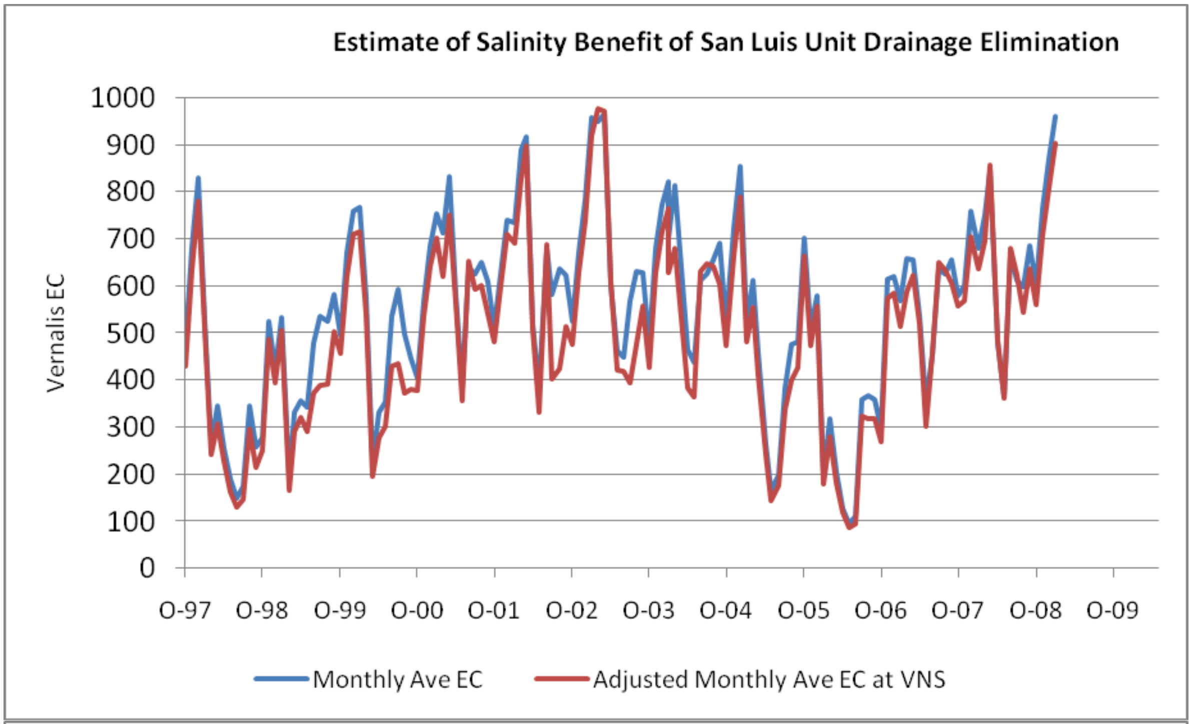
For example, the three interior Delta locations do not historically experience the same patterns of high salinity over the same water year types or annual seasons. When the data points of the Old River salinity versus Vernalis salinity plot are differentiated by year, a number of relationships between the two locations emerge, varying by water year.

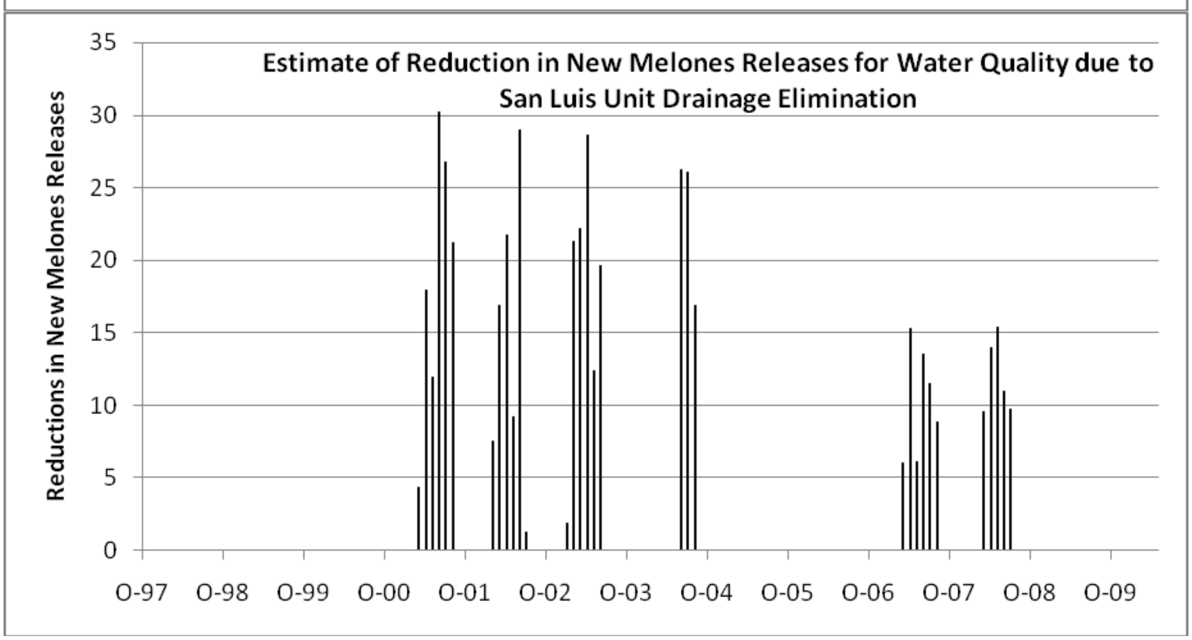

Year Type Southern Delta Objective Exceedance by Location
Months that Salinity Exceed Objectives
25
20
15
10
5
0
Union Island
Brandt
Old River
Critical
Dry
Below Normal
Above Normal
Wet


Monthly Southern Delta Objective Exceedance by Location (2000-2010)
Months when Salinity Exceeds Objectives
8
7
6
5
4
3
2
1
0
Union Island
Brandt
Old River
January
February
March
April
May
June
July
August
September
October
November



Reclamation also did a quick analysis to determine the benefits to the Southern Delta of fulfillment of Reclamation's obligation to provide drainage service to the San Luis Unit of the Central Valley Project. Since the Grassland Bypass Drainage Area includes more than the portion of the San Luis Unit that drains to the San Joaquin River, its historic salinity loads can be subtracted from the historic salt loads at Vernalis to determine the change in Vernalis EC. Of course, since releases are made from New Melones to control Vernalis salinity, some of this benefit would likely become a water supply or ecosystem benefit. Drainage elimination would reduce the number of months of salinity above the water quality objectives by 33% at Union Island and Brandt Bridge locations and by 13% at the Old River location.


Estimate of Salinity Benefit of San Luis Unit Drainage Elimination
Vernalis EC
1000
900
800
700
600
500
400
300
200
100
0
O-97 O-98 O-99 O-00 O-01 O-02 O-03 O-04 O-05 O-06 O-07 O-08 O-09
Monthly Ave EC
Adjusted Monthly Ave EC at VNS


Estimate of Reduction in New Melones Releases for Water Quality due to San Luis Unit Drainage Elimination
Reductions in New Melones Releases
35
30
25
20
15
10
5
0
O-97 O-98 O-99 O-00 O-01 O-02 O-03 O-04 O-05 O-06 O-07 O-08 O-09

IV. ADDITIONAL INFORMATION FOR SETTING AND IMPLEMENTING BIOLOGICAL GOALS FOR SAN JOAQUIN RIVER FLOW OBJECTIVES (VERNALIS)

Key points

- This process should start with well-defined goals, such as the CVPIA and WQCP doubling goal
- Flow on each of the tributaries is important to salmon and steelhead populations
- Increased flows, and increased variability of flows are needed to increase salmonid populations and decrease non-native species
- Implementation alternatives need to be fully developed and modeled to see which best meets biological and ecosystem goals
- A strong science and adaptive management program are needed

A. Goals

a. Development of Goals

Clearly articulating the goals and objectives for protecting and restoring the San Joaquin Basin ecosystem and its salmonid populations should be the starting point in the Board's process of developing San Joaquin River flow objectives. We believe the goal of the flow standards should be to achieve doubling of the natural production of salmon and steelhead compared to the average levels during the 1967-1991 period. This goal is consistent with the doubling goals described in the Central Valley Project Improvement Act (CVPIA), and the Board's narrative salmon doubling goal in the Water Quality Control Plan (WQCP). We recommend the Board consider the following specific goals that would contribute to meeting the overall salmonid doubling goal for the San Joaquin basin:

Biological Objectives for use as biological metrics:

- To achieve a survival rate of 0.50 for emigrating salmonid smolts in the Delta
- To achieve survival of emigrating salmonid smolts in each of the tributaries (Stanislaus, Tuolumne and Merced rivers) that result in an average juvenile production rate of 250 emigrating juveniles (measured near the mouth) per adult spawner in each San Joaquin River tributary.
- No delay or blocking of adult salmonids during their upstream migration to the San Joaquin basin and its tributaries due to the effects of water operations (e.g. Stockton Deepwater Ship Channel dissolved oxygen and temperature issues).

Habitat and Flow conditions required to achieve biological objectives

- Provide adequate flows to connect the San Joaquin River and its tributaries to existing floodplains for three months during the February through June period to realize improved productivity of macro invertebrates, increased growth rates of juvenile salmonids, and provide refuge from predators.
- Provide significantly high enough flows to activate geomorphic processes in the San Joaquin River and its tributaries to: mobilize fine sediments, deposit fines in riparian floodplain habitats, and activate natural creation of floodplain habitat.
- Provide flow volumes that contribute to a suitable water temperature regime necessary to maximize survival and growth of incubating eggs, rearing, and migrating salmonids.

- Provide flows to maximize quality (low siltation presence and low armoring of spawning habitat) and provide an appropriate quantity (with low rates of superimposition) of spawning habitat for adult salmonids.

b. Basis for and development of biological objectives

The Department of Interior has been charged with doubling the natural Chinook salmon production from the average production estimated between 1967 and 1991 through the Central Valley Project Improvement Act (CVPIA). The goal for the salmon production in the San Joaquin basin is approximately 78,000. Between 1992 and 2009, average Chinook salmon production from the San Joaquin basin was only about half that during the baseline period (20,289 between 1992 and 2009 compared to 38,822 between 1967 and 1991) (AFRP website, accessed http://www.fws.gov/stockton/afrp/ 1/26/11). Thus, the Board needs to consider implementing significant improvements in the San Joaquin basin to meet Interior's CVPIA doubling goals.

We considered the CVPIA goals and the lifecycle of Chinook salmon when recommending and developing biological objectives on the San Joaquin River tributaries and in the Delta. Table 1 shows how the objectives in the San Joaquin tributaries and Delta outlined above result in doubling given certain assumptions about survival in other phases of the life-cycle. The rationale behind each of the given survival rates in Table 4.1 is included in the Appendix 3. The first row in the table shows how the objectives of achieving 250 juvenile salmon from each of the tributaries relative to each spawner (column 5) and survival of 0.5 through the Delta (column 6) interact to achieve a cohort replacement rate of 1.77. Subsequent rows display the effect of modifying specific survival rates on the resulting number of adults returning.

The cohort replacement rate is the number of adults returning per spawner. A value of 1.0 indicates a stable population. Values greater than 1.0 indicate an increasing population size while values less than 1.0 reflect a declining population size. A 1.77 cohort replacement rate will double the starting population size in two generations, or six years, assuming a predominantly three-year lifecycle. Figure 1 displays the effect of different cohort replacement rates on the population over time. As we identified above, we actually need to achieve more than doubling of the 1992 – 2009 population level to reach the production goals of 78,000 in the San Joaquin basin.

Table 4.1. Example of a lifecycle approach to developing survival goals for San Joaquin River tributary Chinook salmon runs. The bold first row shows recommended initial survival goals (green shading). The following rows show the effect of modifying survival through specific lifestages (red shading) of returning adults.

(1) Eggs per adult (assume 1:1 sex ratio)	(2) Egg to fry survival	(3) Fry per adult	(4) In-river juvenile survival	**(5) Emigrating juveniles per adult goal**	**(6) SJ through delta survival goal**	(7) Delta exiters	(8)Smolt to adult survival (20-year average)	(9) Adults	(10) Survival to escapement - includes harvest	(11) Returning adults (cohort replacement rate)
2500	**0.333**	**832.5**	**0.3**	**250**	**0.5**	**125**	**0.0283**	**3.53**	**0.5**	**1.77**
2500	0.333	832.5	0.3	250	0.3	75	0.0283	2.12	0.5	1.06
2500	0.333	832.5	0.4	333	0.3	100	0.0283	2.83	0.5	1.41
2500	0.333	832.5	0.3	**250**	0.15	37	0.0283	1.06	0.5	0.53
2500	0.333	832.5	0.3	**250**	0.3	75	0.0283	2.12	0.9	1.91
2500	0.333	832.5	0.3	**250**	0.15	37	0.0283	1.06	0.9	0.95
2500	0.333	832.5	0.3	**250**	0.15	37	0.0566	2.12	0.5	1.06
2500	0.333	832.5	0.15	125	0.15	19	0.0283	0.53	0.5	0.27
2500	0.333	832.5	0.15	125	0.15	19	0.0566	1.06	0.9	0.95

Figure 4.1. Progress towards doubling a population with a range of constant cohort replacement rates and three year lifecycle. Eventually density dependence would reduce the cohort replacement rate to a sustainable level fluctuating around 1.0.

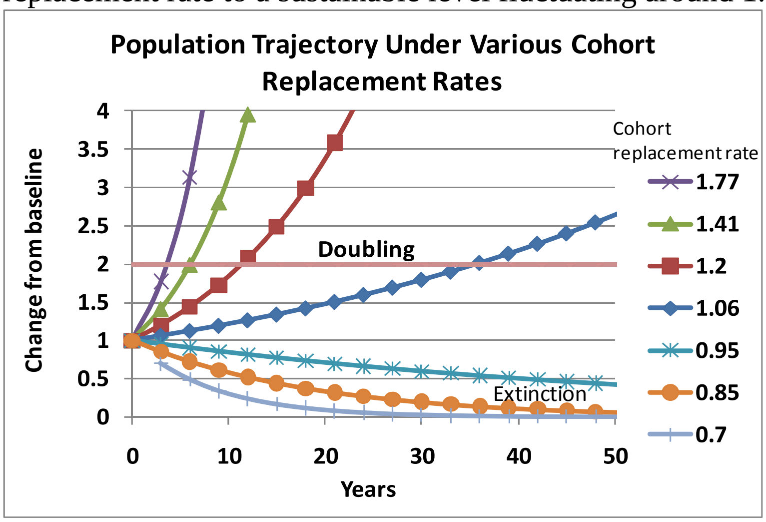


Table 4.2. Juvenile Chinook salmon emigrants at lower river monitoring locations per adult (from escapement estimates) in the San Joaquin River tributaries during years when monitoring occurred. The second listing of tributaries compares emigrants during years with data from all three tributaries, 2007-2009.

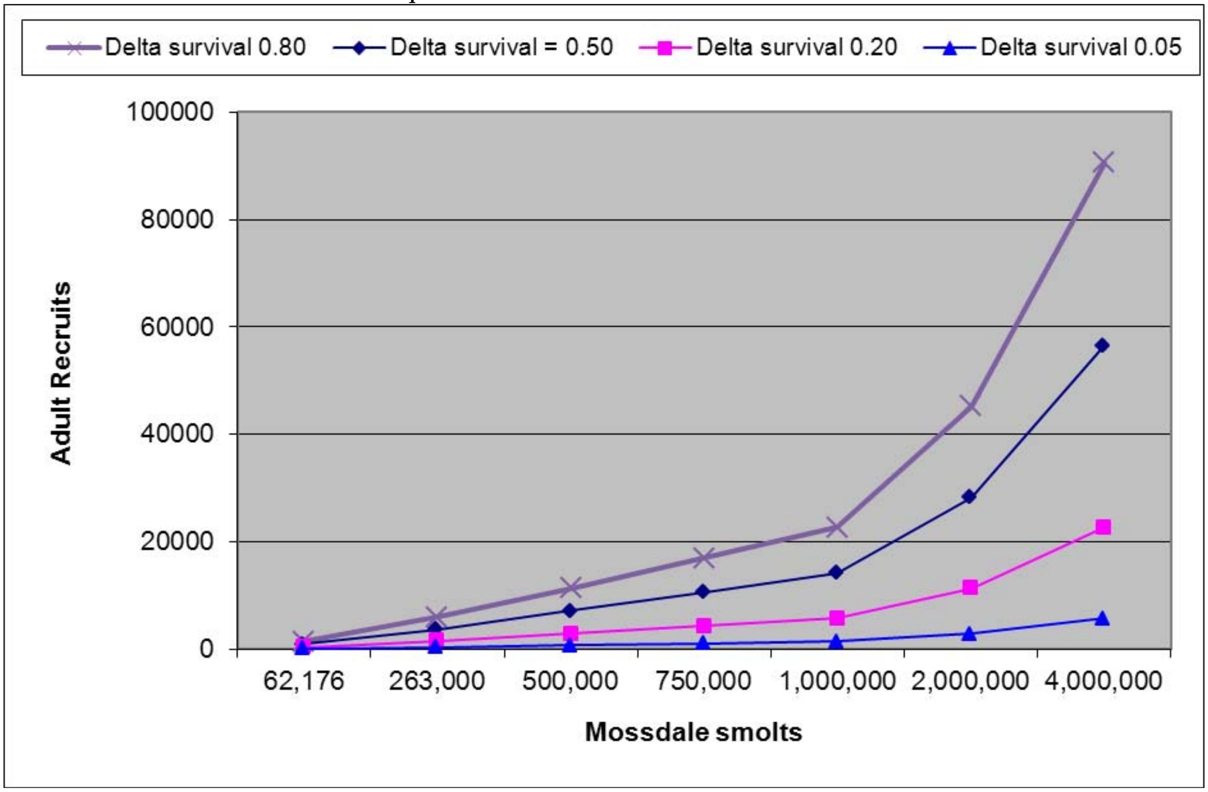
River	**Years sampled**	**Average juvenile emigrants per adult**	**Range during years sampled**
Stanislaus	1996 - 2009	166	8 – 571
Tuolumne	1995 - 2009	46	1 – 226
Merced	2007 - 2009	10	2 – 20
Comparison during years when estimates occurred in all tributaries.			
Stanislaus	2007 - 2009	30	8 – 49
Tuolumne	2007 - 2009	10	1 – 16
Merced	2007 - 2009	10	2 – 20

The goal of 250 emigrants per spawner is achievable based on past estimates of production on the Tuolumne and Stanislaus Rivers (Table 2). Unfortunately estimates for a similar time period are not available on the Merced, however it would be the Service goal to obtain this level of juvenile production on Merced as well. Benefits from increased production in the tributaries will compound even if other components of the life-cycle do not change as more juveniles will result in more adults given there is no density dependency feed-back at these production levels. Any benefit to salmon production in the tributaries that results in increases in the Delta will also compound.

To determine what survival is needed in the Delta, given 250 emigrants per spawner arriving at Mossdale from each of the tributaries, further modeling was conducted to link the number of emigrants at Mossdale and smolt survival through the Delta to adult recruitment (Figure 2). This modeling exercise determined that 3.5 million smolts are needed and smolt survival through the Delta needs to be 0.8 to achieve an adult production of greater than 78,000 (79,240) (Figure 2) in any one year. To obtain 3.5 million smolts at Mossdale, given the survival assumptions in table 1, 14,000 spawners are needed to produce the 250 emigrants per spawner. Figure 2 also shows how variation in production in the tributaries and survival through the Delta result in different levels of annual adult production. However this exercise does not incorporate the starting population and the compounding that occurs as you increase the population each year.

With an estimate of only 62,176 smolts arriving at Mossdale in 2010, even the highest rate of Delta survival (0.8) results in only 1,408 adult recruits (includes both escapement and harvest). In comparison with 4 million smolts entering the Delta, and low Delta survival (0.05) adult recruitment is less than 6,000. Thus the best solution is to increase production in the tributaries and increase survival through the Delta. When flows are high on the tributaries, they are generally also high through the Delta so production into the Delta is high and survival through the Delta is high. The converse is also true, such that when flows in the tributaries are low, production of smolts to Mossdale and survival through the Delta is also low. The correlation between population size and flows is evident in the San Joaquin basin and it illustrates the need for increased tributary and Delta flows to meet our salmon production goals.

Figure 4.2: The relationship between Delta survival, tributary production and adult recruits for Chinook salmon in the San Joaquin Basin.



In 2010, there were 62,176 juveniles estimated to have arrived at Mossdale. With that starting population and survival through the Delta of 0.50 (given that tributary survival equals 0.3, there are 2500 eggs per adult, egg to fry survival is 0.333, and 50% of the adults produced are harvested), it would take 9 generations (27 years assuming adults return in year 3) to reach an adult production level of greater than 78,000 (80,442). With a survival rate through the Delta of 0.20 or 0.05 given the same starting population as the previous example, doubling never occurs and instead populations go extinct in 18 and 4 generations (54 and 12 years) respectively, given that all other parameters remain the same.

Survival through the Delta has not been greater than 0.20 since 2001 of coded wire tagged fish used in the VAMP studies (although survival was not measured in 2007 or 2009 and is not yet available for 2010). This illustrates just how dire present conditions are for juvenile salmon migrating through the Delta. To have viable and increasing populations in the San Joaquin basin, this modeling would indicate that survival through the Delta must be greater than 0.20.

The simple modeling above is the type of modeling that should be done by the Board staff to determine the specific goals and objectives in the Delta for determining the flows needed in the Delta and tributaries to meet the doubling goals for San Joaquin basin salmon and steelhead. We encourage the Board to adopt the CVPIA doubling goals and specifically identify production objectives for each of the tributaries and survival objectives for the Delta and a reasonable timeframe (less than 30 years) for meeting the CVPIA doubling goals.

Recent information (Barnett-Johnson etal 2007, RMIS database) points to hatchery produced fish making up a larger than expected proportion of the returns to the San Joaquin River tributaries; consequently we may be further from meeting these survival goals than expected. Twenty six percent of the Chinook passing the Stanislaus River weir were adipose clipped in 2010 indicating a high hatchery proportion (and lower than expected cohort replacement rate for naturally produced fish). The goals presented in this document, and in CVPIA are to achieve doubling of naturally produced (i.e. non hatchery) salmon in the Central Valley. The effects of hatchery fish present a confounding effect in not only achieving our doubling goals, but also in assessing progress towards meeting the doubling goals. Our understanding of the role of hatchery fish is improving and will affect future hatchery proportion estimates and may enable updating of past hatchery proportion estimates.

B. Relationship of Tributary, Delta Flows and Salmon Production and Survival

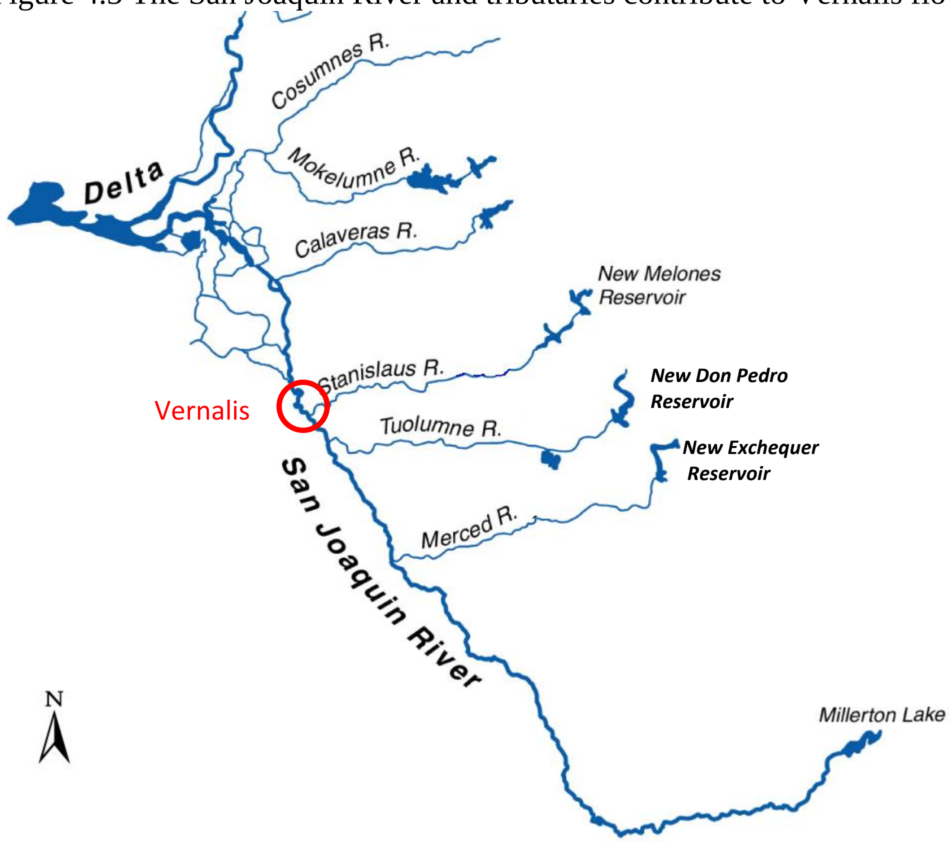
Key Points:

- Flow on each of the major tributaries is important to salmon and steelhead populations
- Increased flows, and increased variability of flows are needed to increase salmonid populations and decrease non-native species
- The Board should develop a comprehensive and integrated plan that addresses San Joaquin's tributary flows and Delta flows (at Vernalis) simultaneously
- When the Board considers flow objectives based upon percent of unimpaired flow, it should also consider a similar percent of unimpaired flow in each of the major tributaries in order to meet the Vernalis flow objective
- Increased flows that mimic the general seasonality, magnitude, and duration of the natural hydrograph (based on percent of unimpaired flow) in each of the tributaries and Vernalis, will benefit salmonids

Flow on each of the major San Joaquin River tributaries is important to salmonids in the San Joaquin Basin. Salmonid populations in the San Joaquin Basin and its three main tributaries (Stanislaus, Tuolumne and Merced rivers) have experienced significant declines since the fall of 2000. Each tributary has salmonid populations that depend on appropriate quality, quantity, and timing of flows to provide habitat for the freshwater part of their lifecycle. It is important that the Board not only consider flows at Vernalis, but also flows within each of the tributaries in the San Joaquin Basin. Relying on flows from just one of the tributaries to meet the Vernalis flow objectives will not protect salmonid populations in the other two tributaries. We support the Board in considering flow objectives based upon percent of unimpaired flow. Increased flows during February through June that mimic the general seasonality, magnitude, and duration of the natural hydrograph in each of the tributaries and Vernalis, will benefit salmonids by increasing seasonal floodplain habitat conducive to juvenile salmonid rearing and growth, and improving survival of emigrating salmonid smolts through tributaries, the Delta and to the ocean.

It is important to note the relationship between San Joaquin River flows and the abundance and survival of migrating Chinook salmon from the San Joaquin basin through the Delta. Although, the Board has indicated that tributary flows will be the focus of future Board proceedings, the Board should develop a comprehensive and integrated plan that addresses San Joaquin's tributary flows and Delta flows (at Vernalis) simultaneously. This process should give consideration to not only the source of the flows, but the balancing of flow needs for aquatic resources in the Delta as well as the flow needs upstream in the rivers. When considering the needs of anadromous fish, for example, the conditions in the Delta are important as are the conditions upstream (such as temperature) and both affect fish populations. The linkages between tributary and Delta flows at Vernalis are obvious (Figure 4.3).

Figure 4.3 The San Joaquin River and tributaries contribute to Vernalis flows



The importance of flow from each of the San Joaquin River tributaries to Chinook salmon (and likely similarly to steelhead) can be illustrated by comparing production of juvenile Chinook measured near the mouth of each tributary to the number of adult spawners that produced the fish. The Stanislaus River, which receives higher flows, on average, produces an average of 166 juvenile emigrants per adult spawner (range = 8 to 571 juveniles per spawner) (Figure 4-2). The Tuolumne River, which receives lower flows on average but experiences high flood control releases more often, averages 46 juveniles per adult (range = 1 to 226). Comparable averages were not available for this range of years for the Merced River. During the dry and critical years of 2007-2009, the average juvenile emigrant per adult is much lower for all three tributaries. The Merced River produced 10 juveniles per adult spawner (range = 2 to 20) similar to that in the Tuolumne in the same years. However, the Stanislaus averaged 30 juveniles/adult, three times more than the Tuolumne and Merced which both averaged 10 juveniles/adult. More comparable in-river survival rates could likely be obtained by providing the same proportion of the natural runoff in each tributary. The Tuolumne and Merced emigrants have a longer route to the delta so may experience lower survival from the mouth to the delta and may actually need higher flows to obtain similar survival rates through the tributaries and mainstem San Joaquin River. DFG also has shown that juvenile production on the Tuolumne River and at Mossdale is related to spring flows (CDFG, 2010a).

Survival of Chinook salmon increases with flow both on the tributaries and in the Delta. Relevant studies are described and the relationship between flow at Vernalis and survival through the Delta with the physical Old River barrier is shown in the Board's Technical Report (SWRCB, 2010a). In addition, California Department of Fish and Game's (CDFG, 2010a) December 6, 2010 comments on the SWRCB's technical report, show an additional relationship between spring flows and survival through the Tuolumne River (CDFG, 2010a). Many of the other studies linking juvenile salmon survival to flow are listed in your report (SWRCB, 2010a) such as the relationship between spring flows and survival through the Delta with the physical head of Old River Barrier in place (SWRCB, 2010a). Additionally, survival appears to increase with increased flows for survival of fish released on the San Joaquin River downstream of Old River (Dos Reis releases) (SJRTC, 2009) CDFG also describes the relationship between the number of fish released at Jersey Point and those that return (CDFG, 2010a). These studies support the link between abundance and survival and flows and the link between juvenile production and survival to adult recruitment.

While the Board has stated the focus of this proceeding will be on the February-June period, salmonids in the San Joaquin Basin and Delta have year round flow and habitat needs. Table 4.4, below, illustrates that salmonids have various temperature, migration, and habitat needs throughout the year that must be met by providing appropriate flows. The migratory nature of salmonids results in dynamic flow and habitat needs that span from the upper tributaries through the Delta and out to the ocean. To reach salmonid doubling goals, the Board must consider the temporal and spatial needs of all life stages of salmonids.

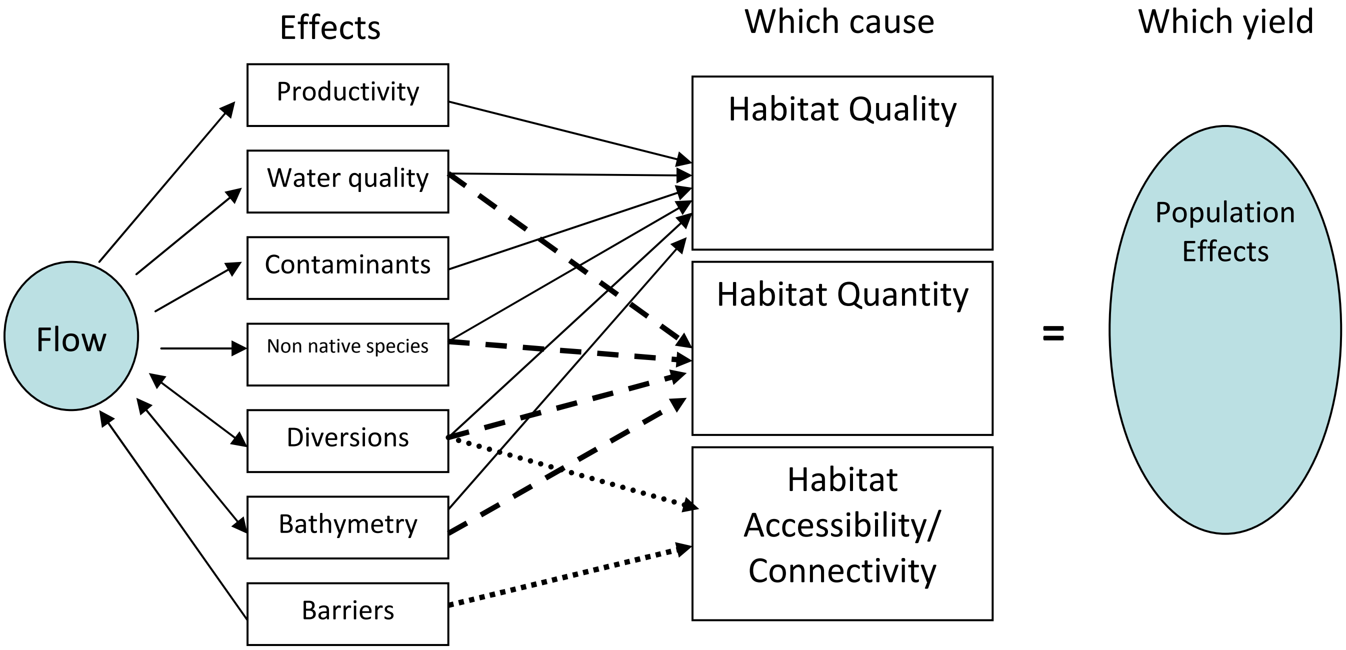
Table 4.4 Example of general fall run salmonid functional objectives. Anadromous fish have year round needs in the tributaries and Delta that affect the size of their populations.

Life stage	**Example functional flow objectives**	**Fall**	**Winter**	**Spring**	**Summer**
Adult (October-February)		Importance of flows for each life stage			
Temperature	Provide flows with suitable water temperatures to reduce or eliminate temperature induced pre-spawn mortality during spawning and migration. Provide sufficient flows to minimize effects of contaminants and/or disease.	High			Medium
Spawning habitat	Provide flows to maximize quality and provide an appropriate quantity of spawning habitat for adult salmonids.	High	High		
Upstream migration	Mimic natural pattern of pulse flows to cue upstream migration of adult salmonids and provide adequate upstream migration conditions.	High	Medium		
Fry/Smolts (January – June)					
Temperature	Provide flows with suitable water temperatures (less than 65 degrees) to maximize survival and growth of rearing salmonids.	Low		High	Medium
Rearing habitat	Provide flows to connect the river to the flood plains for 3 months (February –May) to realize improved productivity of macro invertebrates and increased growth rates of juvenile salmonids, and provide refuge from predators.			High	Medium
Downstream migration	Provide flows from March 15 to June 15 to maximize survival of out migrating juvenile salmon to support viable salmonid populations.			High	Low
Eggs/Alevin (October – March)					
Temperature	Provide flows with suitable water temperatures (less than 56 degrees) to maximize survival of incubating salmonid eggs.	High	High	Low	Medium
Geomorphic process (Jan-June)	Provide significantly high enough flows to activate geomorphic processes to: mobilize fine sediments, deposit fines in riparian floodplain habitats, and maintain spawning/rearing grounds.		High	High	

a. Mechanisms of Increased Flow to Increase Survival and Production of Juvenile Salmonids

During the Board's workshop on January 6 and 7, there were a number of questions concerning the relationship of flow and various aspects of habitat. Figure 4.4, below illustrates the role of flow to various important aspects of habitat which ultimately cause population level affects. Appendix 1, A Primer on the relationship of flow and habitat, attempts to explain the basics of the relationship between flow; contaminants, predators, physical habitat, temperature, turbidity, etc in more detail. Fish need water, water affects all aspects of their habitat, and we believe timing, duration and magnitude more similar to natural flows will make all aspects of their habitat better.

Figure 4.4 Conceptual model of flow to habitat linkages



C. Flows to Achieve Doubling Goal

Presently, the major San Joaquin tributaries on average, release only a small portion of the historical unimpaired spring flows (11% of the historical unimpaired flow on the Tuolumne, 31% on the Stanislaus, and 17% on the Merced)(SWRCB, 2010). Continuation of these levels of flow will likely result in continued decreases in the salmon population in the San Joaquin basin. Estimates of the proportion of unimpaired flow needed to double salmon production range from 51 to 97 percent (as summarized in USFWS, 2005, see table 4.6), with the greater proportion of unimpaired flow needed in the drier years.

When the Board considers flow objectives based on percent of unimpaired flow, it should consider imposing similar flow objectives based on percent of unimpaired flow in each of the three major tributaries to meet the Vernalis flow objective. Managing the San Joaquin basin for flows only at Vernalis has not been effective in improving or restoring salmonid populations on the San Joaquin and its tributaries. Increased flows during February through June that mimic the general seasonality, and magnitude of the natural hydrograph in each of the tributaries and Vernalis, will benefit salmonids by increasing seasonal floodplain habitat conducive to juvenile salmonid rearing and growth, and improving survival of emigrating salmonid smolts through the Delta and to the ocean.

The Service developed estimates (USFWS, 2005) of flow levels needed at Vernalis to achieve doubling (over the CVPIA baseline period of 1967-1991) in predicted Chinook salmon production for the San Joaquin basin and its three major tributaries (see the tables below). In the analysis, if the recommended flows are implemented over the course of one generation (3 - 5 years), it is expected, that generation will double in population size relative to the baseline. While the analysis represents a dramatic growth rate to achieve doubling, the growth rate of the population would be expected to slow over time (even if the flows are maintained) as the population would reach carrying capacity (that the habitat could support). Doubling (or higher) would be maintained as long as the flows are implemented, and would be expected to occur 3-5 years (depending on age distribution of returning adults) after the flows are first implemented. Assessment of population changes would take longer to observe; the National Marine Fisheries Service applies the logarithm of the 10 year average to assess population change, while others recommend at least four generations spanning all water year types to assess population change. Based on the scientific information we reviewed, the Board should consider the Vernalis flows and the major tributary flows needed to meet the Vernalis flows contained in USFWS (2005) as a starting point for establishing flow objectives for the protection of salmon and steelhead migrating from the San Joaquin basin.

Table 4.5 From USFWS 2005: The average flow (cfs) for February, March, April, and May in the Stanislaus, Tuolumne, and Merced rivers that would be expected to double Chinook salmon production for the basin.

	WET	ABOVE NORMAL	BELOW NORMAL	DRY	CRITICAL
			Stanislaus		
February	1,280	787	514	500	500
March	2,560	1,573	1,028	927	785
April	3,117	2,636	1,998	1,811	1,385
May	4,827	3,676	2,738	1,950	1,438
			Tuolumne		
February	2,013	1,212	794	784	744
March	4,027	2,424	1,589	1,568	1,487
April	4,811	3,574	3,225	2,696	2,415
May	8,139	6,850	4,763	4,072	2,895
			Merced		
February	1,140	582	500	500	500
March	2,279	1,165	864	651	559
April	2,559	1,941	1,498	1,375	1,112
May	4,402	3,205	2,410	1,766	1,332
			Total		
February	4,433	2,581	1,809	1,784	1,744
March	8,866	5,162	3,481	3,146	2,832
April	10,487	8,151	6,721	5,883	4,912
May	17,369	13,732	9,912	7,787	5,665

Table 4.6 From USFWS 2005; The total annual volume of water (acre-feet) and percentage of unimpaired flows estimated to increase Chinook production by an average of 53% and 100% in the Stanislaus, Tuolumne, and Merced rivers.

	WET	ABOVE NORMAL	BELOW NORMAL	DRY	CRITICAL
			53% Increase		
Stanislaus	604,286	487,578	422,911	384,882	334,899
	33%	*38%*	*48%*	*60%*	*73%*
Tuolumne	877,247	673,275	549,579	510,996	435,634
	29%	*32%*	*37%*	*44%*	*50%*
Merced	513,068	394,518	340,966	279,861	241,566
	32%	*38%*	*47%*	*52%*	*61%*
			Doubling		
Stanislaus	1,006,557	785,985	614,584	525,231	445,016
	55%	*62%*	*70%*	*82%*	*97%*
Tuolumne	1,530,914	1,169,192	885,659	783,854	653,656
	51%	*55%*	*59%*	*68%*	*76%*
Merced	869,671	624,749	503,572	404,055	343,591
	54%	*59%*	*69%*	*75%*	*86%*

D. Implementation Alternatives

The Board has requested assistance formulating a plan for how the flow objectives should be implemented. Below are several implementation alternatives for the Board to consider. We recommend that each implementation alternative be modeled and analyzed, allowing the Board to make an informed decision on which alternative to implement. Based on the modeling and evaluation, the Board should consider implementing the initial Vernalis and tributary flows as a starting point for establishing long term flow objectives for the protection of salmon and steelhead in the San Joaquin basin.

Key Points:

- Defined goals for the outcome of the flow are needed
- Flows on the major San Joaquin tributaries matter to fish populations on the tributaries
- The water released for fish and ecosystem purposes in each of the tributaries should have some level of protection as it flows downstream through the river, to the Delta and through the Delta
- The natural hydrograph is a useful guide for the timing, magnitude, and duration of flows that will benefit the (native components of the) ecosystem
- Thorough modeling and analysis of each flow alternative is needed to make an informed decision
- When modeling implementation alternatives the needs of anadromous fish and conditions in the Delta as well as the conditions upstream (such as temperature) must be evaluated as both are important and affect fish populations at different life stages.

All of these concepts need to be fully developed with alternative flow objectives modeled to see which best meets the biological and ecosystem goals. These ideas should be implemented in a flexible way to incorporate what has been learned from the monitoring to improve the implementation of the flows (timing and magnitude) in future years. Whichever implementation alternative is adopted needs to be monitored and evaluated as part of a strong science and adaptive management program to see how well it meets defined biological and ecosystem goals.

Alternative implementation strategies to evaluate:

a. Block of water: establish a block of water for environmental purposes. The size of the block will vary based on hydrologic conditions each year, but should be based on the percent of unimpaired. The block could be defined during a look back at hydrologic conditions, with water being delivered for fish later, or the size of the block could be forecast based on what future conditions will be.The block of water should be managed using the natural hydrograph as a guide and to meet specific habitat criteria (eg: time pulses with rain events, time pulses for migration, pulses to maintain goals for sediment cleanliness, etc). This concept should also take into account monitoring results that will inform and improve the timing and magnitude of future flow releases.
    i. Pros: 1) provide certainty of water availability 2) the block could be managed to meet specific habitat goals 3) the block could be flexibly managed to meet specific functional flow objectives
    ii. Cons: 1) methods to establish the size of the block may be difficult 2) would require a high degree of operator coordination 3) the look-back method could cause a disconnect in storage between dry and wet years 4) the forecast method may miss opportunities for flows early in a water year before the size of the block can be known

Example: see Appendix 2 for a more complete summary of the Trinity River Flow Restoration efforts. The Trinity River Restoration Program uses the “block of water” approach and has developed annual flow schedules based on hydrologic year type (critically dry through extremely wet). The annual allocations to River restoration range from 368 TAF to 815 TAF and represent approximately 40% to 69% of the Trinity Reservoir inflows. Year types are established on April 1 each year based on 50% exceedence forecasts. The daily flow schedules within any given annual schedule may be adjusted but the annual flow volumes may not be changed.

b. Unimpaired with 5 - 7 day lag: release water based on percent of unimpaired flow, but with a lag of 5 - 7 days to allow operators some flexibility.Whatever the percent of unimpaired flow the Board adopts could be managed to focus on the most important times/events for fish. Example: if the Board adopts 40% of unimpaired flow, there may be times when more than 40% is needed and there may be times when less than 40% is needed to meet fish/habitat goals and/or functional flow objectives. There should be some flexibility built into scheduling the flow releases to best meet biological and ecological goals.
    i. Pros 1) relatively simple accounting for water ‘costs’ 2) would provide a more natural flow regime 3) provide some flexibility for operators

ii. Cons: 1) by having a lag, the timing of high flows might not be able to take advantage of rain events that trigger migration, turbidity, etc 2) the longer the time lag, the better for operators, but the less variable flows will be for the ecosystem, as more averaging will flatten the variability of the hydrograph 3) lack of certainty of quantity of delivery for water users 4) at time steps other than daily, storm and snowmelt runoff peak flows are not well represented in the unimpaired record.

c. Strict percent of unimpaired flow: percent of what goes in goes out. Monitor results, conduct a 10 year review where effectiveness of flows will be evaluated and modified (if needed) to meet biological and ecological goals.

A. Pros: 1) most similar to natural flows 2) may provide a more appropriate flow regime for fish and wildlife than managers can engineer 3)

B. Cons: 1) without having modeled the changes that the flow may cause, it is hard to know if temperatures will be suitable in this flow regime 2) summer flows may be less than they are now (which are frequently close to unimpaired flow) and may negatively affect steelhead 3)

Example: The "Montana method" developed by Donald Tennant is an example of an unimpaired flow approach that has been used in western states since the 1970's. It is primarily a reconnaissance-level method that was developed after measurements of width, average depth, and average velocity in 11 streams in Montana, Wyoming, and Nebraska. As a result of these measurements, Tennant concluded that 10% of the average annual flow is the minimum instantaneous flow needed to sustain short-term survival. A flow of 30% of the average annual flow was required to maintain fair habitat for aquatic life; at this flow, widths, depths and velocities were generally satisfactory, streambanks provided some cover and larger fishes could pass most riffles. Optimum habitat was provided by flows of 60-100% of the average annual flow and flushing flows were 200% of the average annual flow. Therefore, to recommend a flow to provide habitat described as minimal, optimum, or flushing, a percentatge of the average annual flow is selected (Table 4.7).

Table 4.7 (from Orth, 1981): Montana method for prescribing instream flow regimens for fish, wildlife, recreation and related environmental resources. For Oklahoma streams, the flows recommended (6) for Oct.-Mar. are recommended for July through December and the Apr.-Sept. flows are recommended for January through June.

	Recommended base flow regimens (Percent of average annual flow)	
Description of flows	Oct.-Mar.	Apr.-Sept.
Flushing or maximum	200	200
Optimum range	60-100	60-100
Outstanding	40	60
Excellent	30	50
Good	20	40
Fair or degrading	10	30
Poor or minimum	10	10
Severe degradation	0-10	0-10

E. **Adaptive Management**

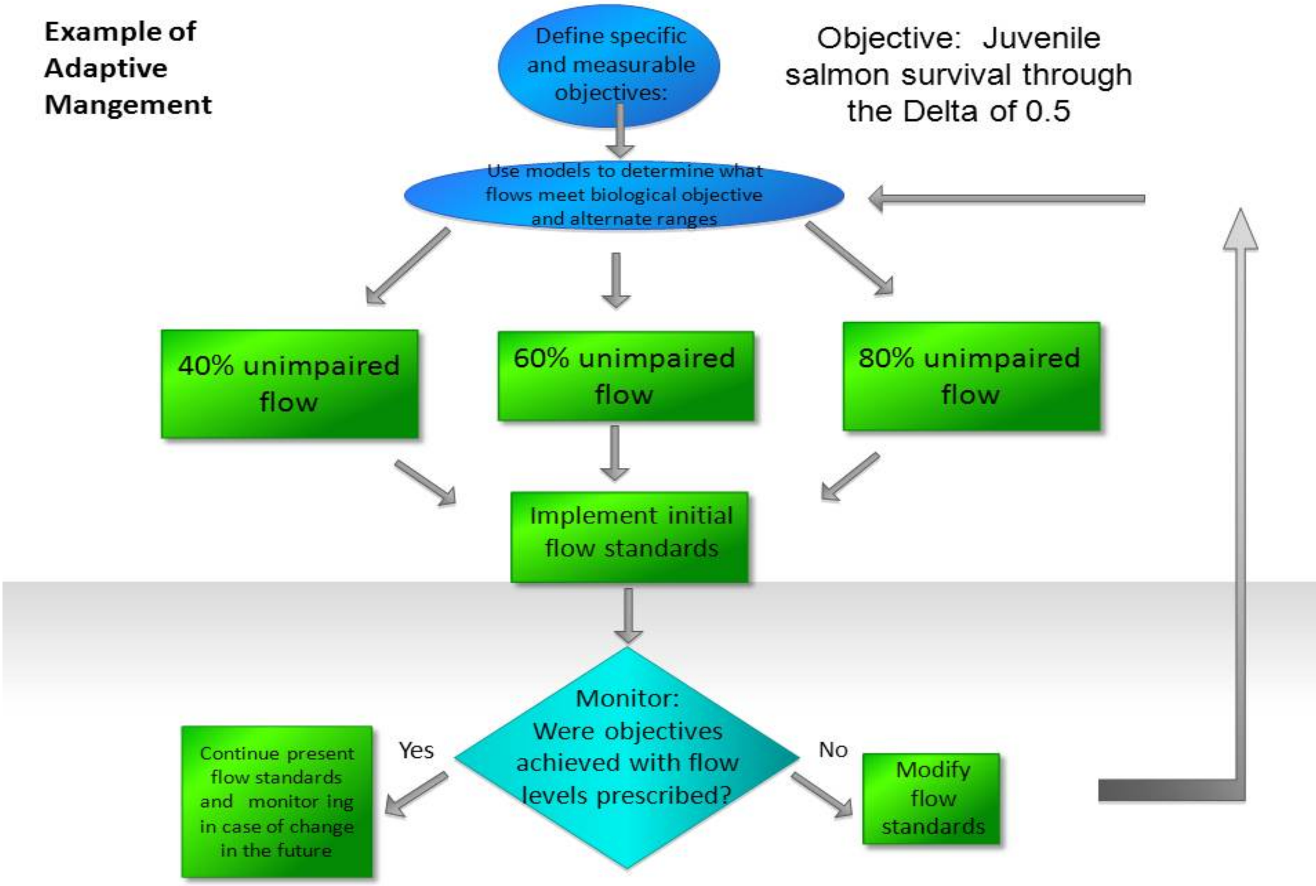
The importance of an adaptive management approach, cannot be overstated. Adaptive Management provides a framework that will allow the Board to make decisions on flow objectives even with the multiple levels of uncertainty inherent in dynamic ecological systems with limited understanding, and in measuring biological responses to changes in flows. Essentially, adaptive management is iterative learning to reduce uncertainty to inform and improve future management. Interior has an extensive technical guide to assist the Board in implementing adaptive management (Williams et al., 2007) and a discussion on legal considerations when applying adaptive management may be particularly useful to the Board. It also includes examples where adaptive management has been successful.

Key points:

- Adaptive Management provides a framework that will allow the Board to make decisions
- This process should start with well-defined biological goals and objectives to determine what flows are needed to meet the objectives.
- A strong science and monitoring program are needed to 1) determine if the objectives are being met and 2) understand why the flows management did or did not achieve the objectives.

The first step in the adaptive management framework, after identifying goals and objectives, is to use models to hypothesize what flows would meet the objective; in this case a survival rate through the Delta of 0.50. For this example (Figure 5), if we assume flows to meet the survival objective are 60% of the unimpaired flows, those flows objectives are initially implemented. Alternative flow objectives, such as a higher flow (80% of unimpaired flows) and lower flow (40% of unimpaired flows) should also be explicitly identified as potential management alternatives at the beginning of the process. Such management alternatives become important if monitoring indicates the initial flows have not met or have exceeded the objective. A range of management alternatives that maximize differences facilitates faster learning than if a range of management alternatives are not specified or very similar. Specific monitoring is implemented to measure smolt survival under the flows that are implemented (60% of unimpaired flows) and to understand the ecological processes (or mechanisms) of how flow is hypothesized to affect salmon survival. If the survival objective is not met (i.e. survival is lower than 0.50), an alternative flow objective is then implemented (in this case 80% of unimpaired flow) the following year and monitored again. As more information is gathered, the models are updated to refine what flows are needed and how flow affects survival. This iterative process leads to structured learning and when the results of the monitoring are used to modify management, it also leads to improved management over time. This is a very simplified example of how adaptive management works. We recommend this adaptive management approach to the Board in setting flow objectives for the San Joaquin River.

Figure 4.5 Example of the adaptive management loop



It is critical that the Board commit to providing the necessary funding for a well-designed and executed monitoring program at the correct scale and the analyses of the results for the life of the adaptive management program. Below are a couple examples from the Interior Technical Guide where adaptive management has worked:

1. Five Rivers Landscape Management Project (Williams et al., 2007).
2. Bully Creek Landscape Area Management Project (Williams et al., 2007).
3. Montana Bison Population example (case study 7, Williams et al., 2007).
4. The Yakima/Klickitat Fisheries Project (YKFP) is an example of an ongoing, large-scale salmon and steelhead supplementation/restoration project sponsored by the Northwest Power Planning Council. It is among the largest and most complex fisheries management projects in the Columbia Basin in terms of data collection and management, physical facilities, habitat enhancement and management, and experimental design and research on fisheries resources. Using principles of adaptive management, the YKFP is attempting to evaluate all stocks historically present in the Yakima subbasin and apply a combination of habitat restoration and hatchery supplementation or reintroduction, to restore the Yakima Subbasin ecosystem with sustainable and harvestable populations of salmon, steelhead and other at-risk species. The project is expected to provide new knowledge about supplementation benefits, constraints, costs, and procedures.

Implementation of the experimental plan is envisioned in 5-year cycles, but review and modifications based on experimental results will occur annually. Scientific work teams coordinate the biological aspects of the YKFP and establish standards for experimental design and data. The experimental design incorporates the philosophy of adaptive management where knowledge gained at each step is used to refine future actions (Lee and Lawrence 1986). Each iteration of the experimental design will involve identification of critical uncertainties, identification of response variables, and modification of previous uncertainties and hypotheses based upon results of the experimental program (Experimental Design Work Group 1988, 1990). To date, the YKFP has been successful in reintroducing Coho salmon, and appears to be increasing the production of steelhead and spring and fall run Chinook salmon in the Yakima Basin.

F. **Economics Related to Salmon Fishery**

While there are many different ways to analyze the effects of changing San Joaquin flows, the impacts from not changing flows, and continued low production of salmon should be one alternative to examine. Below are summaries of a few economic reports, produced by economists, concerning the value from commercial and recreational salmon fishing.

Key points:

- The commercial and recreational salmon fishery affect California's economy
- Increasing the size of salmon populations will likely benefit California's economy

In a recent analysis performed by Jeffery Michael (**Employment Impacts of California Salmon Fishery Closures in 2008 and 2009**), he estimated the financial impacts of closing the salmon fishery to have been roughly $118.4 million and 1,823 jobs to have been lost. His analysis may have been more conservative than other analysis estimating loses from the salmon closure, as he did not take into account losses that could be potentially filled with other revenue sources (eg shipping company's losses from shipping salmon were replaced by shipping other products). Report can be found at: http://forecast.pacific.edu/BFC%20salmon%20jobs.pdf .

Table 4.5 Estimated Economic Impact of Salmon Fishery Closure.

	Income	**Jobs**
Commercial	$47.9 million	961
Recreational	$70.5 million	862
Total	**$118.4 million**	**1,823**

Southwick and Associates conducted an economic analysis "Calculation of the Projected Economics and Jobs Impact of Salmon Recovery in California" in 2009. They analyzed the economic contribution to California's economy of 2004-2005 salmon estimates versus 'historical' numbers of salmon. They estimated an over $4 billion increase to California's economy by restoring salmon to historical numbers. Report can be found at http://www.asafishing.org/newsroom/documents/salmon_recovery_economics.pdf.

Table 4.6 Total Economic Impacts of Salmon Fishery to California's Economy

	Sales Impacts	Jobs Impacts:
Based on 2004-2005 levels:		
Commercial	$ 1.170 billion	21,480
Recreational	$ 205 million	1,345
Total	**$1.375 billion**	**22,825**
If historical salmon harvests could be reached:		
Commercial	$ 4.830 billion	88,672
Recreational	$ 846 million	5,555
Total	**$5.676 billion**	**94,227**

Conclusion

Interior commends the Board for continuing the process of developing and implementing alternative San Joaquin flow objectives using the best available technical information and tools. Interior remains concerned about the continued decline of the San Joaquin Basin fall-run Chinook salmon and the federally listed steelhead. Currently, the San Joaquin basin flows are inadequate to protect and/or restore healthy populations of salmonids pursuant to the CVPIA and WQCP doubling goals. Significant flow improvements are needed soon to protect these populations from extinction. We support the Board considering flow objectives based on the percent of unimpaired flow and developing a comprehensive and integrated plan that addresses San Joaquin's tributary flows (Stanslaus, Tuolumne and Merced rivers) and Delta flows (at Vernalis) simultaneously. The Board has an opportunity to provide adequate resources and flow improvements needed for salmonid protection and restoration in the San Joaquin Basin. Interior is committed to working with the Board and providing technical information needed to develop and implement San Joaquin River flow and southern Delta salinity objectives.

In conclusion we ask the Board to consider:

- Setting well-defined goals
- Increasing flows to double populations of salmonids
- Using the natural hydrograph to guide flow decisions
- The importance of Delta *and* tributary flows to salmonids
- Utilizing appropriate modeling to evaluate flow alternatives
- Developing an adaptive management framework supported by a strong science program

Appendices

Appendix 1: A primer on the relationship of habitat/threats and flow:

During the Board's workshop on January 6 and 7, there were a number of questions concerning the relationship of flow and various aspects of habitat. Below are examples and diagrams explaining the basics of the relationship between flow; contaminates, predators, physical habitat, temperature, and turbidity.

Key Points:

- Fish need water, water affects all aspects of their habitat, and we believe timing and magnitude more similar to natural flows will make all aspects of their habitat better
- The alternative flows should be modeled to determine the effects to all important aspects or variables that affect fish habitat and ultimately affect fish population size
- Changing the flow regime in the San Joaquin Basin will likely effect fish habitat in many ways. Modeling implementation alternatives before implementation, monitoring the results of the flow changes, and adjusting management actions will improve our capacity to meet biological goals.

Contaminants:

There are literally millions of organic and inorganic compounds that have been indexed by the American Chemical Society's Chemical Abstracts Service (CAS) in their Registry. Our understanding of the direct and indirect effects of most of these compounds on organisms is either poor or completely absent. Sources of contaminants range from point sources like effluents from wastewater treatment plants and agricultural drainage, to non-point sources such as atmospheric deposition.

A long history of industrial, agricultural and urban land use in the Delta and its watershed has resulted in extensive environmental impacts from anthropogenic contaminants. Contaminant stressors in the Delta are recognized as one reason why large-scale changes in the ecosystem have been observed. Additionally, their role in the recently observed pelagic organism decline has been identified. Some contaminants have direct impacts on wildlife, such as mortality and decreased reproductive performance, while others exhibit low level chronic effects that can indirectly impact wildlife (e.g., prey base depletion). Moreover, the synergistic effect of combining multiple contaminants has only recently been considered and is still poorly understood. The fact that the Delta is listed as an 'impaired water body' on the State Water Quality Control Board's 303(d) list for 30 individual or groups of contaminants speaks to the level of contamination present (State Water Resources Control Board, 2010 Integrated Report).

The relationship between flow and contaminants is complicated and depends almost entirely on what type of contaminant is examined. Some contaminants (e.g. pyrethroids) have exhibited toxic spikes in Central Valley streams during the early parts of rain storm events. These toxic spikes are largely due to surface run-off that makes its way through small, ephemeral tributaries. These toxic spikes are relatively short lived, but the levels of toxicity are many times the levels considered 'safe' to human exposure and cause dramatic die-off of local invertebrate communities. In this case, more flow actually exhibits negative effects on the ecosystem in the early stages of a storm event. Werner (2008) reports that "in recent years, pyrethroids at toxic concentrations have been detected in the majority of sediment samples collected from water bodies draining agricultural areas in the Central Valley (Weston et al., 2004; California Regional Water Quality Control Board Agricultural Waiver Program, 2007), as well as from urban creeks in the Bay/Delta region (Amweg et al., 2006; Woudneh and Oros, 2006a & b)."

Some forms of contaminants were loaded into the system long ago and their affects are ongoing. Mercury is such an example. The primary source of historic mercury contamination in Central Valley Rivers and streams was gold mining activities in the Sierra Nevada. Today, historically deposited elemental mercury continues to be a concern due to its conversion to methylmercury. This conversion is carried out by sulfate reducing bacteria found in sediments, effectively linking methylmercury production to aquatic ecosystems. Methylmercury, the most toxic form due to its bioavailable nature and bioaccumulative potential, readily enters aquatic food-webs and can reach toxic concentrations in higher trophic level organisms. It is unclear in the long term how to manage mercury contamination. In some instances wetlands have been shown to increase the conversion of mercury into methylmercury (Davis, 2003), and in some cases wetlands are thought to reduce methylmercury (Werner, 2008). Habitats with the highest potential to produce methylmercury are characterized by periodic flooding events that are spaced far enough apart to allow completely drying of the area (Alpers et al., 2008). The wetting-drying cycles in seasonally inundated floodplains resulting from increased flows has the potential to increase methylmercury production and its subsequent export downstream. In the long term, increased flows from the San Joaquin basin (and tributaries) will decrease the amount of accumulated mercury; however, in the short term, increased San Joaquin basin flows may increase exposure to mercury and increase transformation to methylmercury.

Some contaminants, such as selenium, are naturally occurring in Central Valley soils. As crops are irrigated selenium is mobilized and carried out with the drainwater. Loading of selenium to the San Joaquin River through a portion of the San Luis Drain and Mud Slough was authorized in 1995 (Werner, 2008). Selenium concentrations in agricultural drainwater that passed through the San Luis National Wildlife Refuge were elevated enough to cause adverse effects on aquatic and aquatic-dependent wildlife (USFWS 2008). Increasing flows in the San Joaquin and tributaries would likely have a flushing effect of selenium from the area, diluting the concentration of selenium entering the system from agricultural drainwater. However, increasing flows to the San Joaquin River also has potential to increase selenium exposure downstream. Some stretches of the San Joaquin River (Mendota area) are usually dry and have high concentrations of selenium in the soil from historically deposited agricultural drainage. Typically, some of this selenium would be mobilized only during large episodic storm events. Increased flows could mobilize large amounts of selenium from this area. The resulting impacts to wildlife are currently unknown. In the long term, increased flows in the San Joaquin basin will dilute the selenium concentration coming from the upper San Joaquin River, which will have a net positive effect.

While the traditional school of thought was "dilution is the solution," the current thought on reducing contaminant loading is much more complicated. The solution to reducing contaminant loading of some compounds (e.g. pyrethroids), centers on the reduction of the use of the contaminant. There are instances where reducing the effects of other contaminants (e.g. selenium) is best accomplished by diluting the water after the point of loading occurs. In general, increased (high quality) flows in the San Joaquin basin, should reduce the effects of contaminants on fish and wildlife; however, the effectiveness of the dilution depends on the contaminant and the quality of the diluting water. Contaminants are an area where the Board and all agencies must flex their regulatory muscle to collectively and comprehensively reduce contaminant loading into the natural world.

Physical habitat

Defining and implementing objectives to restore physical habitat is imperative in achieving ecosystem goals. The results of restoring appropriate flow patterns for fish cannot be fully realized without restoring the important functions of natural geomorphic processes. Flow is positively linked with improvements in physical habitat. Increased flows can provide additional habitat for juvenile salmonids as floodplains inundate. Flows also mobilize fine sediments and sand, depositing the sediment on floodplains, improving spawning gravel quality and the productivity of the floodplain. Peak flows above a certain threshold will mobilize coarser sediments preventing armoring of riffles and providing a natural dynamic habitat.

From Nobriga 2008:

> Floodplain connectivity is also very important to fish habitat variability (Bowen et al. 2003; Feyrer et al. 2006a) and food web structure (Winemiller 1996). There has been a lot of research on local floodplain ecology in the past ten years. Moyle et al. (2007) recently categorized fishes occurring on the Cosumnes River floodplain based on their use patterns. They noted that fishes could be floodplain spawners (e.g., splittail and carp), river spawners that inadvertently occur on floodplains (e.g.,Sacramento pikeminnow and channel catfish), and floodplain pond fishes, some of which leave ponded areas during flood events to take advantage of foraging opportunities (e.g., largemouth bass and inland silverside). Inundated floodplains provide the primary spawning habitat for *splittail* (Sommer et al. 1997; Moyle et al. 2007) and extended periods of springtime floodplain inundation greatly increase splittail production (Sommeret al. 1997; Feyrer et al. 2006b). Local floodplain inundation also stimulates *Food Webs*
> based on aquatic insects and zooplankton (Sommer et al. 2001; Sommer et al. 2004; Grosholz and Gallo 2006). Thus, inundated floodplain also provides a temporary high quality rearing habitat for splittail, *chinook salmon* (Sommer et al. 2001) and numerous other San Francisco Estuary fishes.
> Riverine fishes that access floodplains may become stranded in ponds and flood control structures as floodwaters recede (Sommer et al. 2005; Moyle et al. 2007); generally however, this risk generally does not appear to outweigh benefits such as expanded spawning habitat, and high food production that stimulates rapid growth. For instance, the survival of Chinook salmon emigrating to the Delta through Yolo Bypass is comparable to that of individuals that stay in the main channel of the Sacramento River (Sommer et al. 2005). Both migration routes have risks – stranding in Yolo Bypass versus low food availability and vulnerability to entrainment into the central Delta for fishes remaining in the river.

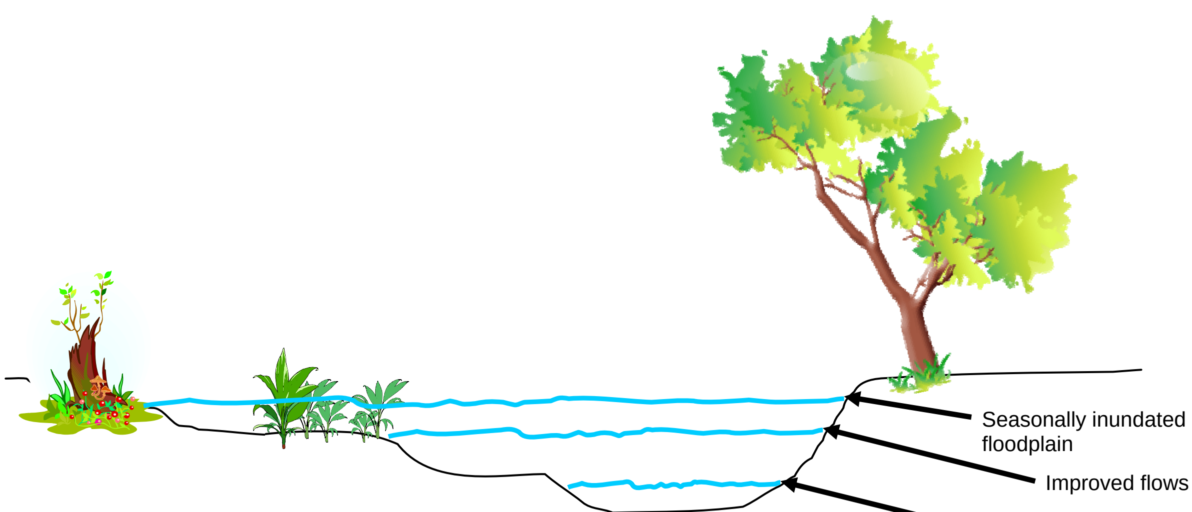
The purpose of seasonally inundating floodplain habitat is to provide off channel areas conducive to juvenile salmonid rearing and growth, which should improve survival through the Delta and to the ocean. Larger outmigrating smolts should also have higher rates of ocean survival (Healey 1982; Parker 1971) and produce more returning adults two to four years later.

However, Sommer et al., (2005) also conclude that areas with engineered water control structures had comparatively high rates of stranding – thus impact of flooding on the survival of juvenile salmon needs to be continually evaluated to assure losses do not overshadow the benefits of increased flooding in the floodplains. Floodplain restoration projects should be designed to drain completely minimizing the formation of ponds and the occurrence of fish stranding (Jones and Stokes, 1999).

Restoring geomorphic processes has a crucial role in creating and maintaining habitat for various fish species. Currently there is a lack of functional floodplain habitat in the major San Joaquin tributaries and the Delta. Changing of flows to mimic more natural flow events will not only make better use of current floodplain habitat available to fish, but will also create more of this habitat. Additional measures to increase the quality and quantity of floodplain habitat include engineering levees in way that they don't impede river meandering, bank erosion, and the eventual creation of natural fish habitat. Thus, increasing flows to activate geomorphic processes is essential to restore and recover a healthy ecosystem.

Physical habitat and flows are also related as the amount of habitat inundated by flow is directly related to the amount of flow released. Lower flows yield fairly homogenous river environments that do not provide an abundance of habitat available to all life stages of native fish species. Figure 4.6 below, is an example of how different flow levels provide access to different habitat types within the river.

Figure 4.6 Example of the relationship between flow and physical habitat variability



Current flows: characterized by low variability, low quality juvenile rearing habitat, Disconnection of the river from the floodplain (which has high food productivity), etc

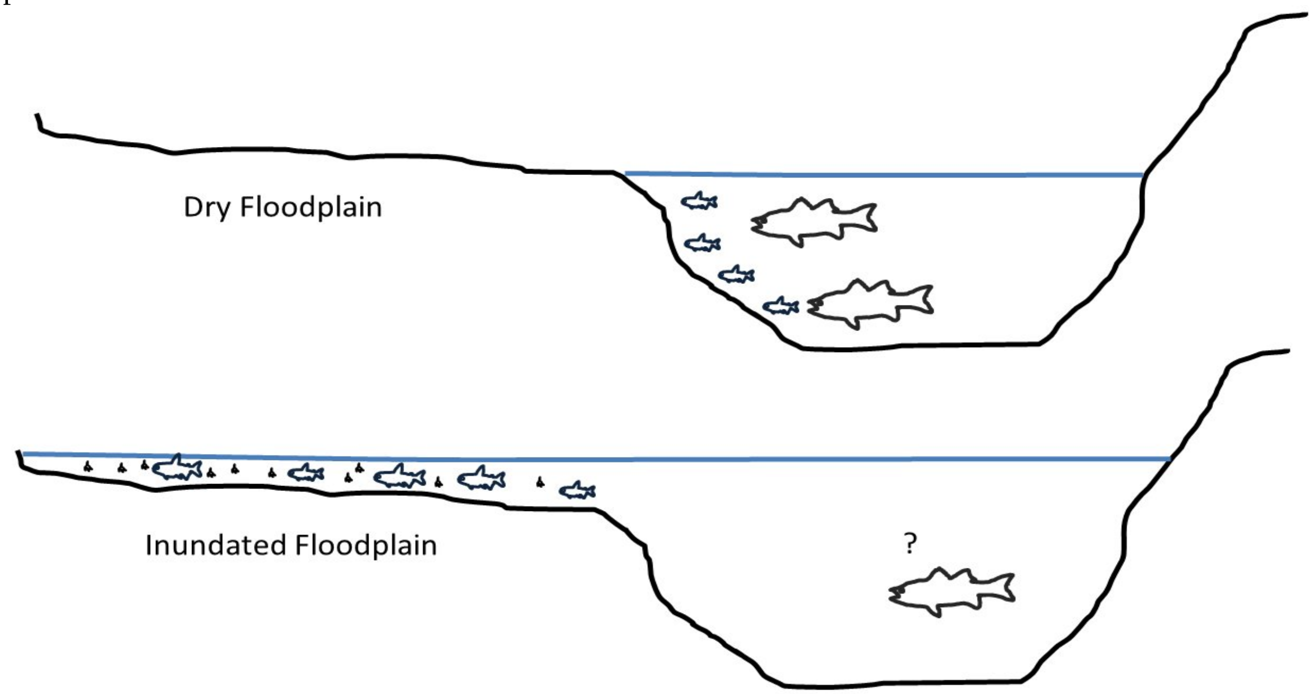
Improved flows: characterized by higher variability, reconnection to the floodplain, presence of deep cool water pools for adult holding, etc

Seasonally inundated floodplain: provide dramatic increase of habitat variability, increase of fish food, increase growth rate of young fish, shelter from predators, etc

Predators:

Flow reduces predation on juvenile salmonids via several mechanisms. Increased flow increases suspended sediments (turbidity) reducing a predator's ability to visually locate prey (Rodríguez and Lewis 1994; Gregory and Levings 1998). Increased flow can speed migration rates of juvenile salmonids (BPNWL, 1995), reducing the time spent in areas with high predation mortality. Higher flows can inundate historical floodplain habitats, providing both a refuge from predators and increased food resources for juvenile salmon (Figure 4.7). Increased food can increase growth and larger juveniles are better able to avoid predators (Jeffres and others 2008). Additionally, increased flows from the tributaries can reduce the available habitat for predatory fish such as striped bass that prefer warmer water, and also reduce their metabolic (and feeding) rates (Kruger and Brocksen 1978).

Figure 4.7 During periods of higher flows, floodplain habitats are connected to the main channel offering juvenile salmonids a refuge from predation and increased food resources. Disconnected floodplains force juvenile salmonids into the main channel where they are more vulnerable to predators.



Temperature:
The hydrology of the San Joaquin River Basin has been significantly altered by impoundments and diversions (McBain and Trush, 2000). There are over 80 dams with a total storage capacity of over 7.7 million acre-feet on the San Joaquin River and its three primary tributaries. Combined, these facilities have the capacity to capture and control the entire average annual yield of the rivers they dam (Cain et al., 2003). Instream flow rates and volumes are some of the primary determinants of the resultant downstream water temperature regime (Anderson and Wright, 2007; Bartholow, 1989; Edinger et al., 1968; TVA, 1972; Jobson and Schoellhamer, 1993; Thomann and Mueller, 1987; Wright et al., 2008). Because the riverine flow conditions of the San Joaquin Basin are largely controlled by reservoir releases, the thermal dynamics of those riverine segments are also largely controlled by reservoir releases and the thermal dynamics associated with specific reservoirs and their outlet structures. As such, the water temperature regime in the San Joaquin Basin has also been significantly altered.

Water temperature is one of the most important physical characteristics of aquatic systems. It affects a number of water quality parameters that are of concern for domestic, environmental, industrial, and agricultural applications (Deas and Lowney, 2000). Gas solubility, chemical and biological reaction rates, contaminant toxicity, and the efficacy of water treatment are all functions of water temperature (Thomann and Mueller, 1987). From an ecological perspective, water temperature is an important indicator of environmental quality and overall species health (Gu and Li, 2002). Further, the evolution, distribution, and ecology of aquatic organisms are fundamentally affected by water temperature. Growth and respiration rates are temperature dependent, and most organisms have distinct temperatures ranges within which they reproduce and compete (Denny, 1993; Cain et al., 2003).

Physically, water temperature and its variation represents the state of a water body as a result of heat inputs, losses, and exchange. This is commonly referred to as the energy (or heat) budget of a specific water body and is used to describe the energy exchange at the air- water and bed-water interfaces (Denny, 1993). Although formulations may differ slightly, the heat budget generally consists of five terms representing short wave (solar) radiation, incoming long wave (atmospheric) radiation, upwelling long wave (water surface) radiation, latent heat flux (condensation / evaporation), and sensible heat flux (conduction)(Jobson and Schoellhamer, 1993; TVA, 1972; Thomann and Mueller, 1987). Another term, ground heat conduction (transfer between the substrate and the water), is often negligible but still important in some instances. A schematic diagram of heat flux at the air and bed interfaces is shown in figure 4.8.

While energy flux determines heat load into a water body, fluid movement (flow) within the water body determines heat distribution (Deas and Lowney, 2000; Thomann and Mueller, 1987). The term advection is used to describe the bulk movement of a constituent (in this case heat), and constituent spreading occurs by three separate processes: molecular diffusion, turbulent diffusion, and dispersion. Molecular diffusion is driven by concentration gradients (differences in temperature). Turbulent diffusion is similar to molecular diffusion but is driven more by small-scale velocity fluctuations. Mixing processes due to differences in channel velocity are termed dispersion. The influence of molecular diffusion is typically much smaller than the other transport mechanisms and is often ignored. A schematic diagram of transport mechanisms is shown in figure 4.9. Although the thermal dynamics of water bodies are described by a complex set of physical processes and governing equations, the phenomena of interest, change in water temperature, can be simplified and represented by the following relationship:

Change in temperature = advective transport + diffusive transport + heat exchange
(bulk flow) (spreading) (atmosphere)

Of particular importance to this proceeding is the recognition of flow as a principal driver of water temperature dynamics. Weather and climate conditions cannot be controlled, and the mixing processes within a water body can only be slightly modified with structural alterations. Flow in the form of reservoir releases and controlled diversions, on the other hand, can be managed and manipulated to effectively influence the water temperature regimes of the San Joaquin River and its primary tributaries. Numerous studies and reports have documented the importance of water temperature to the aquatic species both in and outside of the San Joaquin

River Basin, and most, if not all, of those studies, have attempted to link thermal dynamics with the flow regime and flow prescriptions (e.g. AFRP, 2005; Anderson and Wright, 2007; Cain et al, 2003; CDFG, 2005; CDFG, 2010; McBain and Trush, 2000; Wright et al., 2008).

The U.S. Fish and Wildlife Service Anadromous Fish Restoration Program (USFWS, 2005) provided recommendations for a variety of flow-based measures in the San Joaquin Basin targeting temperature requirements for various life stages of Chinook salmon. These recommendations included flows at least in part to maintain suitable temperature ranges for adult passage through the Delta, fall flows required for spawning and incubation habitat, and summer flows required to increase habitat for yearling steelhead and salmon. Similarly, the California Department of Fish and Game (CDFG, 2010) proposed flow alterations to the State Water Resources Control Board (SWRCB) as partial remedies to the impairment of fishery beneficial uses in the San Joaquin River. Specifically, their analysis showed that one critical factor limiting anadromous salmon and steelhead population abundance is habitat impairment due to high water temperatures that largely result from water operations and management. CDFG (2005) also provided flow recommendations to the SWRCB to assist in meeting the Board's Narrative Salmon Doubling Goal. Amongst other conclusions, the report stated that water temperature trend data suggests that increasing Vernalis flow magnitude and duration would result in decreased water temperature and associated water temperature mortality in east-side tributaries and in the south Delta, given the direct strong correlation between combined east-side tributary flow level and Vernalis flow level.

Although the physical processes controlling reservoir and riverine thermal dynamics are relatively well understood on a conceptual level, it is important to emphasize that the water temperature regimes on the San Joaquin, Stanislaus, Merced and Tuolumne Rivers are all somewhat different. This is primarily a function of the configuration of the hydrologic control structures within each basin. In a naturally flowing river free of structural modifications, higher flow volumes typically result in cooler water temperatures when the ambient air temperature is warmer than instream temperatures and warmer water temperatures when the ambient air temperature is cooler than instream temperatures. However, all of these basins are highly regulated, and reservoir thermal dynamics and outlet structure configuration largely drive reservoir release temperatures and, thus, instream water temperatures. In other words, more flow volume does not always produce the desired temperature effects. For example, it has been shown on the Stanislaus River that mid-summer, instream water temperatures may actually increase when New Melones Reservoir falls below the storage level where Old Melones Dam influences the reservoir withdrawal dynamics and release temperatures. Similarly, the physical configuration at Tulloch Dam, downstream of New Melones Dam, limits low level outlet releases to approximately 1,700 cfs. Releases above 1,700 cfs are taken from the water surface, which are typically warmer.

A key, and often times challenging, component of reservoir management for downstream water temperature considerations is cold water pool management. Since construction of the various dams and diversion structures in the San Joaquin Basin, access to much of the historic spawning and rearing habitat of fall-run Chinook salmon and steelhead has been blocked (NMFS, 2009). To mitigate for these impacts, reservoirs must be managed to preserve cold water resources during critical periods (SWRCB, 2010). Managing reservoir release temperatures for the sole benefit of steelhead in the summer could potentially adversely affect fall-run Chinook. Conversely, conserving cold water through the summer and releasing it in the fall could potentially adversely affect the summer temperature regime for steelhead. Maximizing the benefits to both species by effectively managing the cold water supply is highly dependent on the prevailing hydrologic conditions and the release configuration at each impoundment structure within the basin. Adding to the already complex management environment is the natural pattern of inflow temperatures (SWRI, 1999; Thomann and Mueller, 1987). The coldest inflows into the reservoirs typically come in the spring during the snowmelt period and typically flow through the bottom of the reservoir due to higher densities associated with the colder water. For reservoirs with low-level, hypolimnetic withdrawal structures (e.g. New Melones Reservoir), this results in the potentially coldest waters being released at a time when they may not be needed.

Essentially, the Board should recognize that the flow-temperature relationships for each basin are unique and largely controlled by upstream structural modifications. Flow management for water temperature considerations should be evaluated on a basin-by-basin basis driven by specific biological goals at specific geographic locations. For the San Joaquin River at Vernalis, this includes incorporating the thermal regimes of its tributaries as they are the source waters that heavily influence water temperature dynamics at the Vernalis compliance location.

Figure 4.8 Heat flux sources entering and leaving a flowing stream. Adopted from Bartholow, 1989.

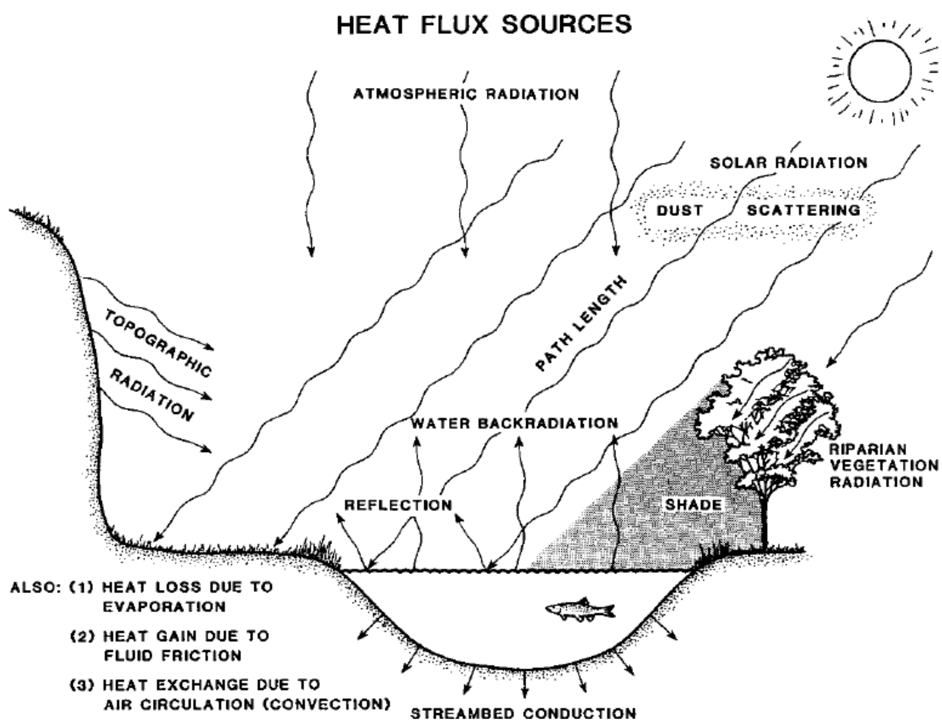
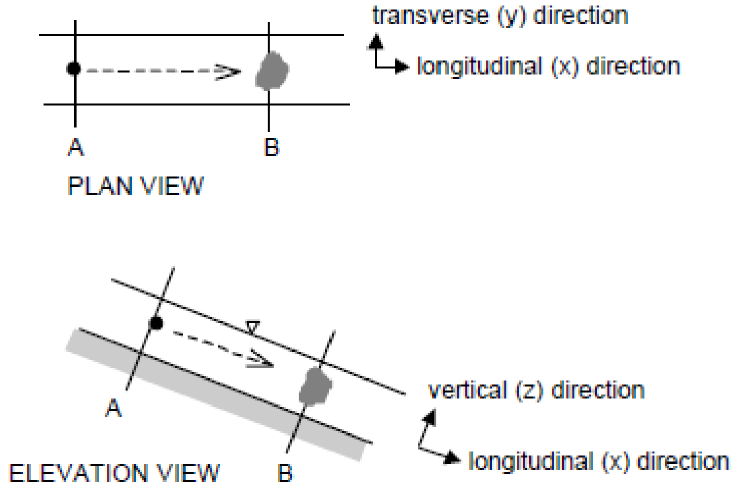


Figure 4.9 Schematic of river mixing by advection (bulk movement) and diffusion (spreading). Adopted from Deas and Lowney, 2000.



Turbidity: much of the following is from Nobriga, 2008
Turbidity refers to the clarity, or lack, of water and is dependent on the amount of suspended particles. Major inputs of turbidity include: suspended sediment (e.g. dirt), and dissolved organic matter (e.g. algae). The level of turbidity in natural ecosystems is heavily dependent on high flows and high wind patterns. In many aquatic systems native species evolved with turbidity spikes and rely on them to cue migration, avoid predators, an increase foraging success. Currently, the main hypothesis to explain the effect of turbidity on fish assemblages is that turbidity strongly influences the success of visual predators; visual predators hunt more successfully in clear water (Rodríguez and Lewis 1994; Gregory and Levings 1998). The turbidity of San Francisco Estuary water is dominated by inorganic particles (i.e., suspended sediments) and is thus affected by river flows; turbidity increases when inflows are high (Kimmerer 2004). Turbidity is also affected by tidal currents, wind events and bathymetry (Ruhl et al. 2001). Turbidity in the Delta has decreased through time (Jassby et al. 2002). The primary hypotheses to explain the turbidity decrease are (1) reduced sediment supply due to dams in the watershed (Wright and Schoellhamer 2004), (2) sediment washout from very high inflows during the 1982-1983 El Nino (Jassby et al. 2005), and (3) trapping by Submerged Aquatic Vegetation (Brown and Michniuk 2007). Turbidity affects large river and estuarine fish assemblages because some fishes survive best in turbid (muddy) water, while other species do best in clear water (Blaber and Blaber 1980; Quist et al. 2004).

The distribution of fish assemblages in the Delta is also influenced by turbidity (Feyrer and Healey 2003; Nobriga et al. 2005; Brown and Michniuk 2007). Turbid habitats have higher proportions of native fishes, while clear water habitats have higher abundance of submerged aquatic vegetation and nonnative centrarchid fishes like largemouth bass. Largemouth bass are efficient predators on small nearshore fishes, including native fishes like prickly sculpin and tule perch that use the vegetated habitats (Nobriga and Feyrer 2007). Delta smelt (Feyrer et al. 2007; Nobriga et al. in press) and age-0 striped bass (Feyrer et al. 2007) are distributed mainly in turbid water (i.e., Secchi disk depths < 0.6 m).

The feeding success of cultured delta smelt larvae is positively influenced by turbidity (Baskerville-Bridges et al. 2004), apparently because the turbidity provides contrast needed for the larvae to see their prey. High water clarity has also been shown to increase predation risk for young chinook salmon in a British Columbia river (Gregory and Levings 1998). The timing of outmigrating juvenile salmon in the San Joaquin Basin is coincident with high spring flow and high turbidity events; the timing may be explained as an evolutionary adaptation to maximize survivorship by seeking the cover of turbidity from predators.

Figure 4.10 The relationship of flow and turbidity

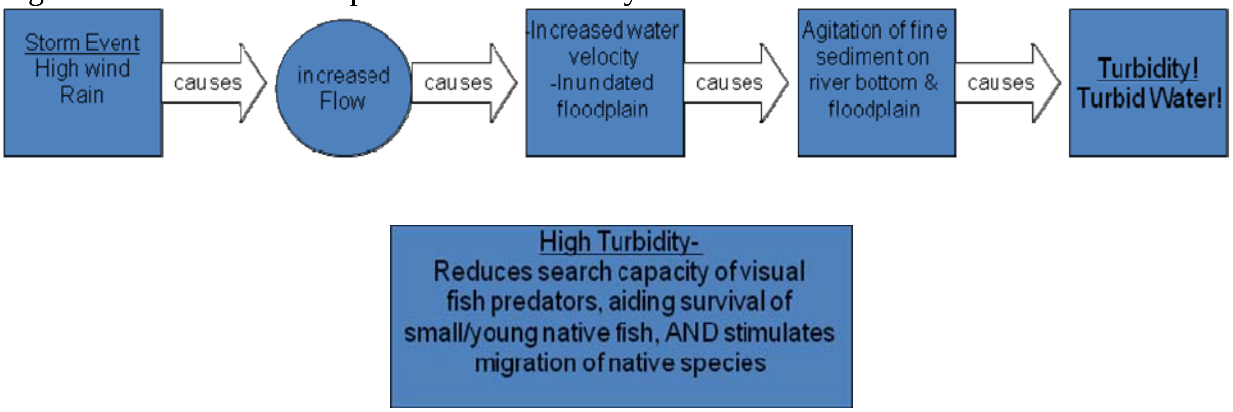
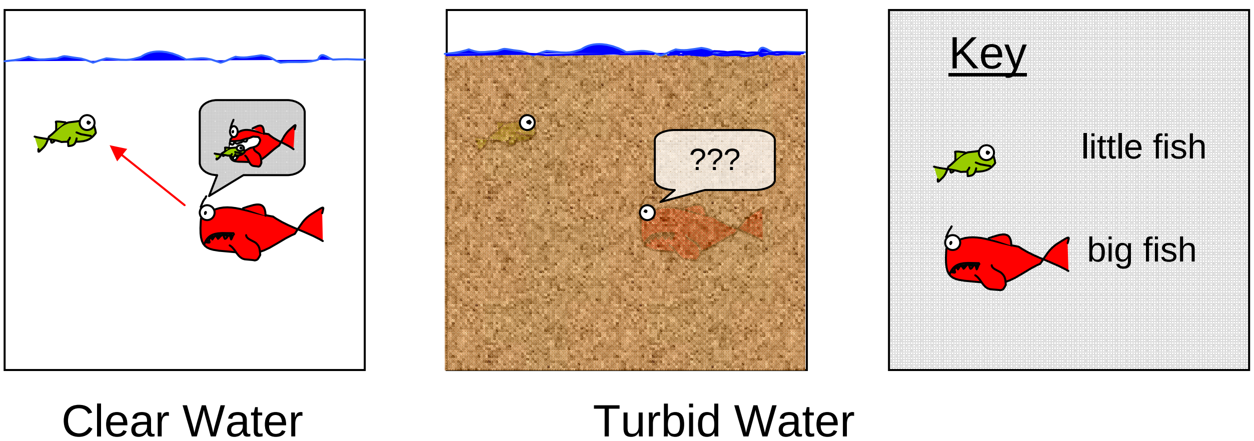


Figure 4.11 A conceptual model of the relationship between fish predators and turbidity



Dissolved Oxygen From: Nobriga 2008

In most of the San Francisco Estuary most of the time, dissolved oxygen is high enough so that it does not impact fish distributions (Kimmerer 2004). However, there are two known problem areas in the estuary for low dissolved oxygen; both in highly altered habitats. There is a decrease in summer-fall dissolved oxygen in 14 km of the San Joaquin Deepwater Ship Channel (Lehman et al. 2004). Several factors contribute to low summer-fall oxygen in the San Joaquin shipping channel, but low flows through this deeply channelized reach are probably the most significant factor (Jassby and Van Nieuwenhuyse 2006). The severe anoxic environment of the San Joaquin Deepwater Ship Channel is thought to act as a barrier to migrating salmon and potentially cause direct mortality of salmon trying to pass through the area.

Appendix 2: Trinity River Restoration Program:

This is a good example of a large-scale salmonid restoration project on a drainage heavily impacted by the Central Valley Project. There is a long history of litigation, directed studies, and legislation that culminated in the 2000 Trinity Record of Decision.

The Trinity River Flow Evaluation Study (1981-1999) was authorized by Congress, acknowledging that the fishery resources were severely impacted by operation of the Trinity River Division of the CVP. In some years 90% of the Trinity River inflows were routed to the Sacramento River (average 1964-1999 approx 74%).

The Trinity River Restoration Program (TRRP) clearly states that restoring river processes is a key objective in the effort to restore the salmon and steelhead populations in the Trinity Basin. Successful fisheries restoration is dependent on re-establishing the natural processes that create variability in habitat and suitable instream conditions for fish. Recommendations include "… reshaping selected channel segments, managing coarse and fine sediment input, prescribing reservoir releases to allow flow-related geomorphic processes to reshape and maintain a new dynamic channel condition, providing suitable spawning and rearing microhabitat, and providing favorable water temperatures for salmonids. This new channel morphology will be smaller in scale than that which existed pre-TRD, but it will exhibit the essential attributes of a dynamic alluvial river."

The collective scientific effort led to:

• the conclusion that a modified flow regime, a reconfigured channel, and strategy for sediment management are necessary to have a **functioning alluvial river** (mixed-size rock, gravel, and sand deposited by river flow) that will provide the diverse habitats required to restore and maintain the fishery resources of the Trinity River (Chapter 7, TRFES 1999);

• instream flow, channel-rehabilitation, and fine and coarse sediment recommendations to address this conclusion (Chapter 8, TRFES 1999); and

• a recommendation to utilize an Adaptive Environmental Assessment and Management (AEAM) approach to guide future management and ensure the restoration and maintenance of the fishery resources of the Trinity River (Chapter 8, TRFES 1999).

The Trinity Flow Evaluation Study evaluated several alternatives (including an annual volume based on 40% of inflow to Trinity Reservoir). However, the TRFES Final Report (1999) chose a different alternative and recommended very specific flow patterns and annual volumes based on hydrologic year type. Each year type pattern was crafted to provide the most habitat restoration/protection goals they thought could be reasonably attained given the year's hydrology. For example, high flows for geomorphic purposes (i.e., coarse sediment movement, scouring alternate bars, floodplain scour, etc) are only attempted in wet or extremely wet years. In drier years the goals are more modest; such as temperature control, moving spawning gravel, and transporting sand.

The TRFES preferred alternative was adopted by the Trinity Record of Decision in 2000. Among it's provisions was the designation of 5 different water year types (Critically Dry to Extremely Wet) and the associated annual volume of water for release into the Trinity River below Lewiston Dam (from 369,000 – 815,000 AF/year).

The water year type designation is based on the 50% exceedence forecast on April 1 of each year. Annual flow schedules for each water year type have been adopted "…which link two essential purposes deemed necessary to restore and maintain the Trinity River's fishery resources: (1) flows to provide physical fish habitat (i.e., appropriate depths and velocities, and suitable temperature regimes for anadromous salmonids), and (2) flows to restore the riverine processes that create and maintain the structural integrity and spatial complexity of the fish habitats.

Based on monitoring and studies guided by the Trinity Management Council, the schedule for releasing water on a daily basis, according to that year's hydrology, may be adjusted, but the annual flow volumes established in the ROD may not be changed.

Overall, the TRRP seems to be working; salmon and steelhead populations are increasing and additional habitat restoration is continuing. The TRRP's uses an adaptive management process and continues to evaluate flow improvements to increase the effectiveness of program implementation. Future flow improvements for fisheries include: the ability to flexibly manage base flows, and overall flow management to avoid catastrophic die-offs during extreme hydrologic conditions.

Appendix 3: Response to the San Joaquin River Group Authority presentation

Interior provides the following wishes to comments on several of the statement in the San Joaquin River Group Authority **(**SJRGA) presentation. Our responses will take the format of providing the quotation in italics and surrounded by quotation marks followed by our comments.

"In absence of floodplain connectivity, the functions attributed to higher 'pulse flows' cannot be achieved as described by the Flood Pulse Concept"

Water to meet Vernalis objectives must come from somewhere. Assuming that this water comes from upstream, floodplain benefits will occur in the upstream reaches where floodplain connectivity is higher. Inundated floodplains provide additional rearing habitat and food resources allowing juvenile salmonids to grow faster and larger (Jeffres and others 2008) as well as providing a special refuge from predators.

"Modeling indicates that increased San Joaquin River flows have little influence over velocities and stage in the South Delta downstream of the Head of Old River.

Instead, tidal influence and exports dominate flows in the South Delta downstream of the Head of Old River.

Effect of Increased Flow in the San Joaquin River on Stage, Velocity, and Water Fate, Water Years 1964 and 1988. Paulsen et al. 2008"

During the Dry and Critically dry water years of 1964 and 1988 flows at Vernalis were low. Data from CDEC for Vernalis flow show a maximum of 2,776 cfs recorded for the entire year of 1988. Using extremely low flows during drought periods is unlikely to produce fish friendly results.

"Water temperature, while easy to measure, is not a simple factor from both a physical and biological perspective. Thus single temperature standards (e,g., 18ºC [64ºF] is often given as maximum permissible temperature for salmon waters) are rarely very meaningful."

Temperature is highly important to smoltifying salmonids from a physiological perspective. A summary of temperature requirements for salmonids has already been provided to the Board and can be found on page 15 of the City and County of San Francisco submission to this proceedings (http://www.waterboards.ca.gov/waterrights/water_issues/programs/bay_delta/bay_delta_plan/water_quality_control_planning/comments120610/dennis_herrera.pdf). If salmonid juveniles are prevented from smolting by high temperatures (>59 F), they will be unable to successfully migrate to the ocean. Increasing the magnitude of spring flows will provide a larger geographic area in which salmonids may undergo smoltification .

"The Delta is Now Dominated by Non-native Species"

Many of the fish species listed in the SJRGA presentation are naturally found in warm water lakes and are not well adapted to river environments. Increasing flows and flow variability will benefit native riverine species at the expense of non-native lake species.

"Invasive species represent one of the most serious obstacles to preservation and restoration of listed native species."

Reduction in invasive species adapted to warm water lake environments can be accomplished through increased flows. Flow pulses are used on the Mokelumne River to reduce the abundance of the invasive aquatic macrophyte *Egeria*. Providing a variable flow environment that mimics the natural hydrograph will encourage diversity in Delta fish populations that are currently dominated warm water centrachids. Allowing periodic pulses of more saline water into the interior Delta can reduce *Egeria* densities (CDBW 2006) and may also reduce other freshwater non-native species.

"Predation on winter-run Chinook salmon is a "major stressor" with very high importance

Restoration for salmonids will require, among other actions, "significantly reducing the nonnative predatory fishes that inhabit the lower river reaches and Delta"

Reducing abundance of striped bass and other non-native predators must be achieved to "prevent extinction or to prevent the species from declining irreversibly"

NMFS draft Recovery Plan for Central Valley salmon and steelhead"

Flow reduces predation on juvenile salmonids via several mechanisms. Increased flow increases suspended sediments (turbidity) reducing a predator's ability to visually locate prey. Increased flow can speed migration rates of juvenile salmonids, reducing the time spent in areas with high predation mortality. Higher flows can inundate historical floodplain habitats, providing both a refuge from predators and increased food resources for juvenile salmon. Increased food can increase growth and larger juveniles are better able to avoid predators. Additionally, increased flows from the tributaries can reduce the available habitat for predatory fish that prefer warmer water, and also reduce their metabolic (and feeding) rates.

"The NMFS has determined that poor ocean conditions are a major factor of the low 2008 SRFC [Sacramento River Fall Chinook] abundance. The NMFS also expects these poor conditions to continue affecting subsequent years' SRFC escapements in the near future."

The NMFS paper blames near-shore ocean conditions as the proximate cause of the recent salmon collapse (Lindley and others 2009). However, it goes on to state that "Mid-term solutions include continued advocacy for more fish-friendly water management".

"The Black Box Approach to Modeling and Management"

The SJRGA presentation implies that since salmon spend most of their life history in the ocean (black box) and that we have little ability to manage ocean conditions that we should also ignore the freshwater habitats that we do have the ability to manage. A few slides later in the presentation, the following quote appears from the 2008 VAMP Summary Report. "…a strong positive relation between estimated survival rates and Vernalis flow was evident." Given this evidence, it seems obvious that flow management can aid in doubling salmonids.

"Boom and near-bust cycles"

The presentation shows a graph depicting the boom and bust cycles of San Joaquin Basin Chinook salmon. It does not display any flow information. Mesick and Marston (2007) show the relationship between Vernalis flow and Chinook salmon recruitment for the Tuolumne, Merced, and Stanislaus rivers in Figures 12-14. The boom-bust cycle is an artifact of instream flow.

"There is no statistically-significant relation between estimated CWT survival rates and Vernalis flow . . . when the HORB has not been in place."

The lack of a significant relationship does indicate that there is no relationship. Additionally, VAMP survival studies are conducted solely within the lower San Joaquin River on hatchery produced juvenile salmon for the express purpose of testing survival through a specific reach of river. The studies do not measure the benefits to naturally produced salmonids which experience increased flows in the tributaries. These benefits have been addressed elsewhere in this document.

"If flow is so important to survival, why isn't the relationship obvious?"

Numerous publications and models have documented the relationship between flow and survival in salmonids. Figures 1- 4 of the DFG submission to these proceedings document the relationship.
(http://www.waterboards.ca.gov/waterrights/water_issues/programs/bay_delta/bay_delta_plan/water_quality_control_planning/comments120610/carl_wilcox.pdf)

"DFG 2005 - Escapement and spring flows at Vernalis - Peer review indicated the analysis and recommendations were FLAWED

AFRP 2005 - Escapement and spring flows at Vernalis - Used simple linear regression to predict fish abundance from average spring flow at Vernalis--the same approach taken by DFG and rejected by peer review

TBI/NRDC 2010 - Escapement and spring flows at Vernalis - Used a logistic model that only considered flow; predicted that flows of 10,000 cfs are "likely" to double salmon production but DID NOT provide any definition of "likely" or quantify uncertainty surrounding this estimate"

The presentation summarily rejects three models (DFG 2005, AFRP 2005, TBI/NRDC 2010). However, these are the best available science and provide flow recommendations that are quite similar to each other. These models offer a starting point from which an adaptive management implementation program can begin to test hypotheses.

"Baker and Morhardt 2001 - Escapement and spring flows at Vernalis - The relationship between flow and survival was "not well quantified," and the lack of relationship between flow and escapement was likely due to other factors"

The actual quote from the citation was "this relationship has not been well quantified yet, especially in the range of flows for which such quantification would be most useful." This suggests that the authors believe that studies should be conducted at the range of flows that are not well represented. The authors provide in Figure 11 a plot of San Joaquin Basin Chinook salmon escapement versus Vernalis flow with a 2.5 year offset. The majority of data points fall in the <5,000 cfs range. Additionally, the figure demonstrates a positive relationship between flow and escapement and includes 95% confidence intervals, further evidence of the relationship between flow and survival.

"The San Joaquin River flow objectives are not changed in the 2006 Plan due to a lack of scientific information on which to base any changes."

Additional information continues to be collected, compiled and analyzed. Newman (2008) concluded that "flow is positively associated with the probability of surviving from Dos Reis to Jersey Point".

The Stanislaus and San Joaquin Basin Temperature Model developed by AD Consultants can be used to predict flows necessary to meet smolting temperature criteria within the basin. The model demonstrates that temperatures in the San Joaquin River near the confluence with the Stanislaus River exceed smolting thresholds of 60 F during baseflows in the spring, and that pulse flows reduce the water temperature in this reach through early May.

An ongoing study by Barnett-Johnson and others has documented that while Chinook salmon fry outmigrants do contribute to adult escapement in wet outmigration years, the relative survival of these fish is much lower than the larger parr and smolt outmigrants. This indicates that steps to increase growth in the tributaries (such as floodplain inundation) should increase smolt production and also returning adults.

To summarize, spring flows are necessary to provide sub 60 F temperatures necessary for smoltification. Smolts contribute most successfully to adult escapement.

Important new information developed since 2006:

Newman, K.B. 2008. An evaluation of four Sacramento-San Joaquin River Delta juvenile salmon survival studies. 181 pages.
http://www.waterboards.ca.gov/waterrights/water_issues/programs/bay_delta/deltaflow/docs/exhibits/cspa/cspa_exh18.pdf

San Joaquin temperature model

Barnet-Johnson juvenile migration studies on the Stanislaus River using otolith microchemistry.

Appendix 4 Example of a Lifecycle Approach to Developing Survival Goals

Table 1. Example of a lifecycle approach to developing survival goals for San Joaquin River tributary Chinook salmon runs. The bold first row shows recommended initial survival goals (green shading). The following rows show the effect of modifying survival through specific lifestages (red shading) on the returning adults.

(1) Eggs per adult (assume 1:1 sex ratio)	(2) Egg to fry survival	(3) Fry per adult	(4) In-river juvenile survival	**(5) Emigrating juveniles per adult goal**	**(6) SJ through delta survival goal**	(7) Delta exiters	(8)Smolt to adult survival (20-year average)	(9) Adults	(10) Survival to escapement - includes harvest	(11) Returning adults (cohort replacement rate)
2500	**0.333**	**832.5**	**0.3**	**250**	**0.5**	**125**	**0.0283**	**3.53**	**0.5**	**1.77**
2500	0.333	832.5	0.3	250	0.3	75	0.0283	2.12	0.5	1.06
2500	0.333	832.5	0.4	333	0.3	100	0.0283	2.83	0.5	1.41
2500	0.333	832.5	0.3	**250**	0.15	37	0.0283	1.06	0.5	0.53
2500	0.333	832.5	0.3	**250**	0.3	75	0.0283	2.12	0.9	1.91
2500	0.333	832.5	0.3	**250**	0.15	37	0.0283	1.06	0.9	0.95
2500	0.333	832.5	0.3	**250**	0.15	37	0.0566	2.12	0.5	1.06
2500	0.333	832.5	0.15	125	0.15	19	0.0283	0.53	0.5	0.27
2500	0.333	832.5	0.15	125	0.15	19	0.0566	1.06	0.9	0.95

Survival rates shown in the table were derived as described below for each column.
1) Eggs per adult. This assumes that females have a fecundity of 5,000 eggs per female on average recognizing that fecundity is related to fish size and there is a range of returning fish sizes with most fish being three year olds. Numbers of females are generally unknown so this term is expressed on a per adult basis assuming a 1:1 sex ratio.

2) Egg to fry survival. An egg to fry survival rate of 0.333 is based on published survival rates suggesting under natural conditions most survival rates are less than 30% and local data suggesting survival can be higher. Mesick has measured higher survival rates in the Stanislaus River. The well monitored Sacramento River winter-run Chinook salmon produces an egg to emigrating fry survival rate of close to 30% on average.

3) Fry per adult = (1) * (2)

4) In-river juvenile survival rate of 0.3 was estimated using the range of production rates (adult spawner to juvnenile emigrants) experienced in years of measured escapement and juvenile production in the tributaries. This rate has been exceeded in wetter years in the Stanislaus River but has not been achieved in years monitoring occurred in the Tuolumne or Merced.

5) Emigrating juveniles per adult goal = (3) * (4). This is a goal that has been shown to be achievable in some, but not most, years on the Stanislaus River. There is no evidence to suggest that the goal is not achievable, through improved conditions favoring increased survival, on the Tuolumne and Merced rivers.

6) San Joaquin River through Delta survival goal of 0.3. This survival goal is higher than has been measured in the years of monitoring for the VAMP program, but may approximate a doubling of the current survival rate through this area. The sum of freshwater survival from egg to exit from the Delta can be summed up by (2) * (4) * (6) = 0.03, or 3%.

7) Delta exiters = (5) * (6) = 75 juveniles per adult spawner.

8) Smolt to adult survival = 0.0283. This is the estimated average smolt to adult survival rate in the ocean for the period 1998 – 2007. It was estimated for the OCAP BO using the 1998 – 2007 average production of fall and late fall-run Chinook from AFRP's Chinookprod and the known hatchery releases with an assumed hatchery proportion of 0.9 in the ocean catch.

9) Adults in ocean (production) = (7) * (8)

10) Survival to escapement. This takes into account harvest and other adult prespawning mortality sources. A 0.5 survival is a general average during years with a traditional ocean fishery. A consequence of mixed stock fisheries is that a commercial fishery supported by abundant hatchery stocks has significant population effects on weaker runs, such as those from the San Joaquin tributaries.

11) Returning adults = (9) * (10) with the given survival assumptions each adult spawner will produce 1.06 adults in the next generation. This is referred to as the cohort replacement rate or recruits per spawner. A value of 1.0 indicates a stable population. Values greater than 1.0 indicate an increasing population size while values less than 1.0 reflect a declining population size. A constant 1.06 cohort replacement rate will double the starting population size in 12 generations, or 36 years, assuming a predominantly three-year lifecycle (Figure 4.1).

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