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November 15, 2011

Kari Kyler
Environmental Scientist
Bay-Delta Unit
State Water Resources Control Board
P.O. Box 2000 Sacramento, CA 95812

Re: External Peer Review of "Technical Report on the Scientific Basis for Alternative San Joaquin River Flow and Southern Delta Salinity Objectives"

Dear Ms. Kyler,

I am pleased to submit my external peer review of the "Technical Report on the Scientific Basis for Alternative San Joaquin River Flow and Southern Delta Salinity Objectives". As instructed, my evaluation focuses on the scientific validity of the topics listed in Attachment 2 of which I have sufficient scientific expertise (notably in the areas of "Aquatic Ecology and Fishery Science" and "Hydrology"). Please let me know if you have any additional questions.

Sincerely,

Julian D. Olden

Scientific Review of "Technical Report on the Scientific Basis for Alternative San Joaquin River Flow and Southern Delta Salinity Objectives"

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Issues pertaining to San Joaquin River Flows for the Protection of Fish and Wildlife Beneficial Uses

1. Adequacy of the Technical Report's hydrologic analysis of the San Joaquin River basin comparing unimpaired flow with actual observed flow in representing changes that have occurred to the hydrograph of the San Joaquin River basin in order to provide background and support for the remaining chapters of the Technical Report.

River discharge data may be sourced from either a streamgage (observed) or from a hydrologic model (estimated from observed data or precipitation), recorded at daily, monthly or annual time steps, spanning short or long time periods, and varying in geographic coverage. The Technical Report's hydrologic analysis (section 2.2.1) "uses the USGS gages located at the most downstream location for each of the major SJR tributaries and at Vernalis to characterize historical observed flows" (p. 2-5). According to the USGS National Streamflow Information Program a streamgage is defined as an active, continuously functioning measuring device in the field for which a mean daily streamflow is computed or estimated (from stage height) and quality assured for at least 355 days of a water year or a complete set of unit values are computed or estimated and quality assured for at least 355 days of a water year. By using observed streamgage data, data uncertainty associated with the Technical Report is limited to that derived from processing of raw stream stage and discharge data measured at the gage versus both this error and model uncertainty associated with modeling discharge from a hydrologic model (i.e., leading to error propagation). Given the high level of quality assurance performed by the USGS, the level of uncertainty in measured discharge at the streamgages is likely negligible, and thus the quality of the discharge data is high.

The length of the discharge record is critical for maximizing precision and minimizing bias in the estimation of important attributes of the hydrograph, including the quantification of annual, inter-annual and seasonal flows (Olden and Poff 2003, Kennard et al. 2010, Olden et al. 2011); the latter being the focus of the Technical Report. Here, precision is defined as the degree of variation in an estimate, and bias is defined as the difference between an estimate and the true value (Wheaton et al. 2008). Ultimately, bias and precision influences the ability to characterize and detect meaningful variation in hydrologic characteristics through space and time. Quantifying the length of discharge record required to accurately characterize temporal variability has long been important in climatology (e.g. reconstructing historical temperature and rainfall regimes and predicting future climate patterns; McMahon et al. 2007) and hydroclimatology (e.g. estimating the effects of input uncertainty on rainfall-runoff models; Kuczera et al. 2006). A recent review study by Kennard et al. (2010) found that the length of the discharge record influences our ability to accurately portray the different components of the hydrograph. This study showed that the least accurately estimated hydrologic attributes for a given record length were those describing variability in annual flows and low flow magnitude, duration and timing. This is perhaps not surprising given that variability estimates would be expected to be highly influenced by individual years with unusually high peak or total annual discharges. Maximizing the length of record used in hydrologic analyses has clear benefits because the probability of capturing extreme discharge events is enhanced with longer periods of record (Shaw 1988). Kennard et al. (2010) recommended that 15 years or more of discharge record is sufficient to estimate hydrologic attributes with comparatively low bias, high precision and high overall accuracy. Characterizing hydrographs from less than 10 years of discharge record, while occasionally recommended under specific circumstances, increases the risk of generating biased, imprecise results, especially in regions of high climatic variability. The Technical Report's hydrologic analysis (section 2.2.2) is based upon 80 years of discharge data across all years, and 11-25 years of discharge data for periods categorized as critical (wet, above normal, below normal, dry) (Table 2.2 and 2.3), therefore, in my opinion the characterization of hydrologic conditions is considered robust with respect to accuracy and precision.

Characterizing the naturally varying flow that existed in a river prior to substantial human influence is necessary to provide insight into the flow regimes to which native species and ecosystems have adapted. Comparisons of the natural flow regime with current or projected conditions can shed light on the degree of departure from natural flow conditions that has already taken place or is expected in the future. A number of approaches exist to quantifying alteration to hydrologic regimes; all of which compare present-day (altered) flows to historical (un-developed) flows (e.g., Richter et al. 1996, Mathews and Richter 2007). The Technical Report's hydrologic analysis (section 2.2.2) follows common scientific guidelines by making comparisons to unimpaired flows, which are defined as those "that would have occurred had the natural flow regime remained unaltered in rivers instead of being stored in reservoirs, imported, exported, or diverted" (p. 2-6). The Technical Report is accurate in recognizing that "unimpaired flow differs from the full natural flow in that the modeled unimpaired flow does not remove the changes that have occurred such as channelization and levees, loss of floodplain and wetlands, deforestation, and urbanization." (p. 2-6). In other words, this assumes that the historical gage data represents unimpaired flow, thus providing a conservative estimate of flow alteration by underestimating unimpaired flows. This approach has been utilized repeatedly in the scientific literature (e.g., Poff et al. 2007, Carlisle et al. 2010) and is considered robust. Furthermore, the Technical Report clearly defines four components of flow that are not addressed in the calculation of unimpaired flow (pp. 2-7 – 2.8), thus recognizing that uncertainties exist that are important to acknowledge, but do not preclude the application of the proposed methodology. I agree with this assessment, and conclude that the comparative methodology is scientifically rigorous.

The primary components of a flow regime are the magnitude, frequency, seasonal timing, predictability, duration and rate of change of flow conditions (Poff et al. 1997); these factors are the most important to the geomorphology, physical habitat, and ultimately the biota of riverine ecosystems (Bunn and Arthington 2002). Accordingly, researchers have developed and applied a number of hydrologic metrics in attempts to characterize different components of the flow regime (see Olden and Poff 2003 for a review of 171 published metrics). The Technical Report's selection of hydrologic metrics was robust for: (1) characterizing ecologically relevant flow attributes for Chinook salmon and steelhead trout in the San Joaquin River basin, (2) describing overall variability in hydrologic regimes, and (3) quantifying flow characteristics that are believed reflect human-induced changes in flow regimes across a broad range of influences including dam operations, water diversions, ground-water pumping, and landscape (catchment) modification. The hydrologic analysis included an investigation of monthly and seasonal magnitudes of flow, and the timing, duration and frequency of peak flows and floods (using summary statistics and flow frequency analysis) following standard hydrologic approaches (Gordon et al. 2004). The degree of hydrologic alteration was calculated as present-day observed flow as a percent of unimpaired flow (Table 2.5 - 2.14). This approach is appropriate, scientifically robust, and has been used repeatedly in the scientific literature (e.g., Richter et al. 1996, 1997, 1998, Poff et al. 2007).

The Technical Report concludes that "water development in the SJR basin has resulted in: reduced annual flows; fewer peak flows; reduced and shifted spring and early summer flows; reduced frequency of peak flows from winter rainfall events; shifted fall and winter flows; and a general decline in hydrologic variability over multiple spatial and temporal scales" (p. 3-2). These major findings are strongly supported by the hydrologic analysis and the previous research cited throughout the Technical Report.

2. Determination that changes in the flow regime of the San Joaquin River basin are impairing fish and wildlife beneficial uses.

The structure and function of riverine ecosystems, and the adaptations of their constituent freshwater and riparian species, are determined by patterns of intra- and inter-annual variation in river flows (Poff et al. 1997, Naiman et al. 2008). A key foundation of the natural flow paradigm (*sensu* Poff et al. 1997) is that the long-term physical characteristics of flow variability have strong ecological consequences at local to regional scales, and at time intervals ranging from days (ecological effects) to millennia (evolutionary effects) (Lytle & Poff 2004). The Technical Report provides a succinct overview of how these attributes of the flow regime interact to influence physical habitat for Chinook salmon and steelhead trout, the availability of refuges, the distribution of food resources, opportunities for movement and migration, and conditions suitable for reproduction and recruitment. The assumption is made that present-day hydrographs that aim to mimic unimpaired hydrographs represent more "natural" conditions that favor the life-histories of Chinook salmon and steelhead trout in the San Joaquin River basin. This assumption is both well defended in the Technical Report and by decades of scientific research conducted in California and elsewhere.

Life-history summaries and population trends are presented for Chinook salmon and steelhead trout in the San Joaquin River using both original analysis and existing scientific literature. Time series for fall-run Chinook salmon escapement exceed 50 years in length, highlighting steady declines since 1952 (Figure 3.5), and evidence is presented that hatchery-produced fish constitute a majority of the natural fall-run spawners in the Central Valley (Figure 3.6). The Technical Report and scientific papers discussed within collectively highlight the decadal long declines in Chinook salmon and steelhead trout (albeit limited data in the latter case) in the San Joaquin River basin. The Technical Report also correctly emphasizes that escapement numbers for the three tributaries are comparable in many years, thus suggesting the importance of coordinating flow management across the tributary systems. Indeed, discrete contributions from different tributaries may provide a portfolio effect by decreasing inter-annual variation in salmon runs across the entire system, thus stabilizing the derived ecosystem services (*sensu* Schindler et al. 2010, but within basins).

3. Appropriateness of the approach used to develop San Joaquin flow objectives for the reasonable protection of fish and wildlife beneficial uses and the associated program of implementation.

Despite notable scientific progress in the last decade for establishing flow-ecology relationships to ensure beneficial uses of fish and wildlife (Poff et al. 2010), there are still scientific uncertainties that must be recognized. The functional relationship between an ecological response and a particular flow alteration can take many forms, as noted by Arthington et al. (2006). Based on current hydroecological understanding, we expect the form of the relationship to vary depending on the selected ecological response variable (i.e., adult abundance, smolt outmigration), the specific flow metric (i.e., magnitude of spring flows, frequency of floods) and the degree of alteration under present-day conditions. These relationships could follow a number of functional forms, from monotonic to unimodal to polynomial, and different ecological response variables may increase or decrease with flow alteration.

Given these uncertainties, a key challenge in determining flow alternatives is to synthesize the knowledge and experience from previous research in a coherent and comprehensive fashion to support future management. I believe that the Technical Report was successful in this regard by collating knowledge across a number of existing scientific studies. Collectively, the Technical Report summarizes the current state of knowledge demonstrating that “additional flow is needed to significantly improve production (abundance) of fall-run Chinook salmon; and the primary limiting factor for tributary abundances are reduced spring flow” (p. 3-26). Analyses over the past several decades have established statistical linkages (supported by ecological mechanisms) between escapement versus flow 2.5 years earlier when those salmon were rearing and outmigrating, and between juvenile salmon survival and flow. These relationships were quantified using standard time series analysis and statistical tests of correlation between the timing and magnitude of discharge and estimates of salmon escapement and smolt outmigration. All time series were of sufficient length for robust statistical analyses involving cross-correlations (time lags), according to the simulation study and guidelines presented by

Olden and Neff (2001). Time lags of 2.5 years are examined (ecological mechanism discussed above), which are well with the range of lag values that ensure a low probability of spurious cross-correlations between time series.

4. Determination that more flow of a more natural spatial and temporal pattern is needed from the three salmon bearing tributaries to the San Joaquin River during the February through June time frame to protect San Joaquin River fish and wildlife beneficial uses.

The Technical Report presents both original analysis and summarized previous studies to support the conclusion that additional flow during the spring period (Feb-June) is need to protect San Joaquin River fish and wildlife beneficial uses. Given the complexity at which hydrologic factors interact at multiple spatial and temporal scales to influence Chinook salmon and steelhead trout in the San Joaquin River, the Technical Report correctly provides multiple lines of evidence in support of this recommendation. Taken together, the scientific evidence presented in the Technical Report suggests that: (1) water development in the SJR basin has resulted in reduced annual flows, fewer peak flows, and reduced and shifted spring and early summer flows (among other things), (2) reduced spring flow has led to reduced production (abundance) of fall-run Chinook salmon, and (3) given (1) and (2), greater flow magnitude during the spring period is predicted to result in greater fish and wildlife beneficial uses in the San Joaquin River basin. This argument is both logical and based on sound scientific knowledge, methods and practices.

Development of robust flow alteration–ecological response relationships will need to take into account the role that other environmental factors play in shaping ecological patterns in streams and rivers. The predicted response of Chinook salmon and steelhead is certainly known to reflect factors other than flow regime, such as water quality and habitat structure; however, a quantitative understanding of how flow interacts with these other factors is not yet well developed. The Technical Report adequately discusses potential co-founding factors that may influence the positive influence of additional flow during the spring period (Feb-June) to protect San Joaquin River fish and wildlife beneficial uses. Factors related (but not limited) to ocean climate conditions, winter flow conditions, and water temperature are discussed. Of particular importance is that human land-use (e.g., riparian habitat degradation, urbanization) and dams/diversions that alter and reduce flows can also have significant effects on riverine thermal regimes (Olden and Naiman 2010). This is discussed only briefly in the Technical Report (p. 3-44), but requires additional examination. For example, dams and diversions can cause either decreases or increases in downstream temperatures depending on their mode of operation and specific mechanism and depth of water release (Olden and Naiman 2010). Below I discuss how stream temperature can influence stream ecosystems and may affect the success of instream flow management aimed to protect fish and wildlife. This topic requires additional exploration in the Technical Report.

Dam-induced modifications to a river's thermal regime (also termed thermal pollution) can have both direct and indirect consequences for freshwater ecosystems, yet it has been relatively unappreciated in discussions of instream flow management (Olden and Naiman 2010), including the Technical Report. For example, many dams release water from above the thermocline of the reservoir (i.e. the epilimnetic layer) resulting in elevated spring–summer water temperatures (e.g. Lessard and Hayes 2003). In addition to the well-recognized ecological effects of temperature stress for salmonids, dam-induced changes in thermal regimes may also have long-term evolutionary consequences by inducing a mismatch between a species' life-history and other critical environmental conditions. For example, Angilletta et al. (2008) hypothesized that warmer temperatures during the autumn and winter below Lost Creek Dam (Rogue River, U.S.A.) may indirectly influence the fitness of Chinook salmon by accelerating the development of embryos, leading to earlier timing of emergence. Shifts to earlier emergence could lead to mortality from high flow events, elevated predation or insufficient resources. Using an age-based population model the authors predicted a decrease in mean fitness of Chinook salmon after dam construction.

The benefits of flow restoration may be enhanced if riverine thermal regimes are also considered. One example supporting this notion is in the lower Mississippi River where research has shown that growth and abundance of juvenile fishes are only linked to floodplain inundation when water temperatures are greater than a particular threshold. Schramm and Eggleton (2006) reported that the growth of catfishes (*Ictaluridae* spp.) was significantly related to the extent of floodplain inundation only when water temperature exceeded 15°C; a threshold temperature for active feeding and growth by catfishes. Under the current hydrographic conditions in the lower Mississippi River, the authors report that the duration of floodplain inundation when water temperature exceeds the threshold is only about 1 month per year) on average. Such a brief period of time is believed to be insufficient for floodplain-foraging catfishes to achieve a detectable energetic benefit (Schramm and Eggleton 2006). These results are consistent with the 'thermal coupling' hypothesis offered by Junk et al. (1989) whereby the concordance of both hydrologic and thermal cycles is required for maximum ecological benefit.

5. Appropriateness of using a percentage of unimpaired flow, ranging from 20 to 60 percent, during the February through June time frame, from the Stanislaus, Tuolumne, and Merced Rivers is an appropriate method for implementing the narrative San Joaquin River flow objective.

A variety of methods have been developed for setting instream flow schedules; each has its strengths and weaknesses and requires varying levels of effort (see review by Tharme 2003). Some of these methods employ scientific expertise from a variety of disciplines and sophisticated computational models and tools (Poff et al. 2003, Richter et al. 2003, 2006). These approaches tend to be time-consuming, but they are the most appropriate for in-depth, river-specific analysis of environmental flow needs. On the other end of the spectrum are ''desktop'' or ''standard-setting'' methods that can be readily applied. Among these are hydrologically based standard-setting approaches, such as the Tennant Method, the Aquatic Base Flow Standard, and flow duration curve methods (Tharme 2003, Annear et al. 2004). Each of these methods uses hydrologic data to establish a flow rate that should be met or exceeded, based upon statistical evaluation of historical flows. The Technical Report undertakes the second of the two approaches, specifically relying heavily on flow duration curves to schedule flow according to a percentage of unimpaired flow.

Three important points must be made in regard to the appropriateness of the proposed approach. Each should be addressed in the Technical Report.

First, methods that are designed to "protect" some portion of the overall flow in a river (e.g., 60% of mean annual flow) are useful for their ease of application, but have been criticized because they do not adequately reflect the full range of variability in flows that is essential for sustaining river-dependent species and ecosystem processes for the long term (Tharme 1996, Arthington and Zalucki 1998, Bragg and Black 1999, Railsback 2001, Annear et al. 2004). The Technical Report discusses previous hydrologic analyses presented in the San Joaquin Basin Ecological Flow Analysis (Cain et al. 2003) and by Brown and Bauer (2009), which calculated percent alteration to a set of metrics evaluating magnitude, timing, and frequency of minimum and maximum flows (see p. 2-5). Although such information can be used to inform instream flow management, this knowledge was not used in Technical Report to inform different flow objectives. Instead, the Technical Report focused solely on flow magnitude during the spring months, thus, not accounting for other critical flow events occurring during different times of the year. For example, recommendations by CSPA/CWIN highlighted the importance of high pulse flows in October to attract adult spawning salmon to the SJR basin (p. 3-49). In summary, although I agree that a fixed monthly prescription is not useful given spatial and temporal variation in runoff (p. 3-52), the Technical Report does not account for the range of ecologically-important flow events that occur over the entire year that are critical for salmon persistence and sustained productivity.

Second, the Technical Report states that "In its 2010 report on Development of Flow Criteria for the Sacramento – San Joaquin Delta Ecosystem, the State Water Board determined that approximately 60 percent of unimpaired flow during the February through June period would be protective of fish and wildlife beneficial uses in the SJR." Further, the Technical Report states "State Water Board analysis indicate that 60 percent of unimpaired SJR flow at Vernalis from March through June would achieve flows of 5,000 cfs in over 85 percent of years and flows of 10,000 cfs in approximately 45 percent of years" (p. 3-47). These results imply that flows of 5,000 cfs would be achieved for all spring months (March through June) based on 60 percent of unimpaired flow. Unfortunately, this is not the case. Table 1 below illustrates percent exceedance for March – June according to 5,000 cfs threshold identified in the 2010 report "Development of Flow Criteria for the Sacramento – San Joaquin Delta Ecosystem" (data extracted from Figure 3.16 - 3.19). This shows that according to 60% of unimpaired flow that 5,000 cfs is achieved > 85% of the years only according to April and May (supporting the statement above), whereas considerably lower percentages are apparent for March and June.

Table 1. Percent exceedance for March – June according to 5,000 cfs threshold identified in the 2010 report "Development of Flow Criteria for the Sacramento – San Joaquin Delta Ecosystem" as a minimum flow threshold for salmon survival on the SJR. Data from Figure 3.16 - 3.19.

	Unimpaired	60% unimpaired	40% unimpaired	20% unimpaired
March	85	53	30	5
April	98	90	63	10
May	99	96	85	48
June	90	75	65	28

Third, although stated for only illustrative purposes in the Technical Report, the decision to illustrate only <60% of unimpaired flows is puzzling because the 2005 report *Recommended Streamflow Schedules to Meet the AFRP Doubling Goal in the San Joaquin River Basin* indicates that "estimates of flows needed on each tributary to double salmon production range from 51 to 97 percent of unimpaired flow" (p. 3-47). Given the choice of scenarios to report (20-60% of unimpaired flow) is based on TBI/NRDC analysis suggesting 5,000 cfs threshold for salmon survival (p. 3-48) and that >50% is estimated to be needed to achieve doubling of salmon production, implies that the Technical Report is only considering potential flow schedules that **may** lead to salmon survival at current low levels and not salmon recovery into the future. Therefore, the rationale for examining 20-60% of unimpaired flow as the only scenarios is questionable, and it needlessly limits a full investigation of the flows required to achieve fish and wildlife beneficial use. Taken together, the use of the word "illustrative" (p. 3-53) is misleading. According to the Merriam-Webster dictionary, illustrative is defined as clarifying by use of examples or serving to demonstrate. Yet, the Technical Report states "In addition to an existing conditions scenario, these illustrative alternatives represent the likely range of alternatives the State Water Board will evaluate in the environmental document supporting any revised SJR flow objectives" (p. 3-53). Therefore, these are not illustrative scenarios, but rather the actual scenarios that will be evaluated.

6. Appropriateness of proposed method for evaluating potential water supply impacts associated with flow objective alternatives on the San Joaquin River at Vernalis, and Stanislaus, Tuolumne, and Merced Rivers.

No response is provided because the topic is outside my realm of expertise.

7. Sufficiency of the statistical approach used by the State Water Board staff in the Technical Report to characterize the degradation of salinity conditions between Vernalis and the interior southern Delta

No response is provided because the topic is outside my realm of expertise.

8. Sufficiency of the mass balance analysis presented by the State Water Board staff in the Technical Report for evaluating the relative effects of National Pollutant Discharge Elimination System (NPDES) permitted point sources discharging in the southern Delta.

No response is provided because the topic is outside my realm of expertise.

9. Determination by State Water Board staff that the methodology and conclusions in the January 2010 report by Dr. Glenn Hoffman, regarding acceptable levels of salinity in irrigation water, are appropriate for reasonable protection of agricultural beneficial uses in the southern Delta.

No response is provided because the topic is outside my realm of expertise.

10. Other issues

In conclusion, it is my opinion that although components of the Technical Report are based on sound scientific knowledge (notably, those discussed in topics 1-4), the appropriateness of using a percentage of unimpaired flow (ranging from 20 to 60 percent) as a methodology for implementing the San Joaquin River flow objective is overly simplistic and only in part accounts for the full suite of flow conditions likely required to provide a reasonable level of protection for fish and wildlife benefit uses.

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