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March 17, 2017

Chair Felicia Marcus and Board Members
State Water Resources Control Board
1001 I Street, 24th Floor
Sacramento, CA 95814-0100

Jeanine Townsend, Clerk to the Board
State Water Resources Control Board
1001 I Street, 24th Floor
Sacramento, CA 95814-0100

Re: Comment to the Amendment to the Water Quality Control Plan for the San Francisco Bay/Sacramento-San Joaquin Delta Estuary and Supporting Draft Revised Substitute Environmental Document (September 2016)

Dear State Water Resources Control Board:

Enclosed herewith via flashdrive are the joint comments of the Modesto and Turlock Irrigation Districts (Districts) on the Amendment to the Water Quality Control Plan for the San Francisco Bay/Sacramento-San Joaquin Delta Estuary (WQCP) and Supporting Draft Revised Substitute Environmental Document (SED). In addition to these joint comments, the Modesto and Turlock Irrigation Districts will each be filing separate comments. The Districts also incorporate by reference all written and orally submitted comments of the San Joaquin Tributaries Authority (or its predecessor agency, the San Joaquin River Group Authority) to include the materials presented as Technical Comments to the Phase 1 SED (2012) and request that these materials be included in the Administrative Record for this amendment to the WQCP and revised SED. Many of these materials are posted on the SWB's website with the 2012 SED, such materials to be found in the folder entitled "unsolicited comments." The Districts also incorporate by reference all written comments submitted on the amendment to the WQCP and the revised SED by the San Joaquin Tributaries Authority and the separate comments submitted by its member agencies—the South San Joaquin Irrigation District, the Oakdale Irrigation District, the Modesto Irrigation District, the Turlock Irrigation District, and the City and County of San Francisco. Finally, the Districts also incorporate by reference comments submitted by the Merced Irrigation District.

<u>General Comments</u>

The Districts have spent considerable time, money, and effort studying the resources and habitat of the Tuolumne River, most of which was ignored by the SWRCB in their SED. As a result, the Districts and their consultants have developed considerable expertise about the fishery resources of the Tuolumne. Instead of using outdated general information about rivers, the Districts' comments on the SED are based on sound science specific to the Tuolumne River and its resources. Among the major findings included in our comments are the following.

- Finding #1: The SED has failed to demonstrate an understanding of the current physical conditions and resources of the lower Tuolumne River.

- Finding #2: "Unimpaired flows", as defined by the SED, do not "mimic the natural hydrograph" of the Tuolumne River.

- Finding #3: The SED fails to analyze its own proposal.

- Finding #4: The SED largely ignores the vast body of scientific data and technical information that has been compiled on the Tuolumne River and its associated resources over the last 20-plus years.

- Finding #5: Effects to fish and wildlife at the population level are not evaluated in the SED.

- Finding #6: The SED's preferred alternative is projected to result in certain adverse resource effects. The need to mitigate the adverse effects of the SED's preferred alternative eliminates the minimal fish population benefits that were hoped to be achieved through implementation of that alternative.

- Finding #7: The SED's failure to define a specific proposal prevents substantive analysis of the Amended Plan. More specifically, there are at least two distinct "amended plans" in the SED, each of which is based on a mutually exclusive scientific hypothesis.

- Finding #8: The adaptive implementation plan ("AIP") suggested in the SED is critically flawed because it lacks even the most basic elements of an implementable plan.

- Finding #9: According to the SED's own analysis, the SWB's preferred alternative will have an adverse effect on the fry life stage of Tuolumne River fall-run Chinook salmon, while having no measurable beneficial effect on Tuolumne River juvenile fall-run Chinook salmon.

- Finding #10: The economic assessment of the SWB's proposal fails to account for any adverse effects on several of the agricultural sectors that are important to the region's economy thereby vastly underestimating effects economic loss, lacks a rigorous evaluation of the reasonably foreseeable impacts of the state's recent groundwater regulations, and neglects to consider the disproportionate its proposal will have on disadvantaged and minority populations.

The SED suffers from a number of defects including a lack of scientific basis, a lack of clearly-defined goals and objectives, a lack of a plan of implementation that is capable of implementation, false assumptions, unsupported conclusions, and inappropriate use of citations, to name a few. Overall, the plan is a solution looking for a problem. Rather than laying out clear goals and objectives, the SED presumes there is a problem—a lack of flow has caused the decline of SJR salmon—without fully understanding what is causing the decline of salmon, not just in the SJR, but in the entire Central Valley and West Coast. For example, dams are cited as one of the culprits even though Don Pedro Dam has been existence for more than 50 years and dams have been on the Tuolumne River and the other San Joaquin tributaries for more than 100 years. The SWB then adopts a "more is better approach" as the solution. This leads the SWB to conclude that more flow is needed, which in turn leads to the conclusion that "colder is better" for temperature and "more flooded area is better" for floodplains. Unfortunately, when the SWB actually measures the results of its "more is better" approach using SalSIM, the result is 1,100 fish at a cost of more than 300,000 acre-feet of water and billions of dollars in economic costs. The human costs cannot even be calculated.

Many of the defects in the SED were identified by Mark Holderman, the principal engineer with the California Department of Water Resources (DWR) at the January 3, 2017, fifth and final public hearing on the SED. The conclusion of DWR was that the Bay-Delta water plan was written "without evidence, incomplete scientific information, ill-suited for real-time operations, and unverified assumptions." The Districts echo those same concerns.

Among the many defects are the following:

- Assigns responsibility for environmental harms without evidence
- Contains out-of-date and incomplete scientific information
- Uses Unimpaired Flow Standards ill-suited for real-time operations
- Makes inappropriate use of a "Flow-Only" approach
- Makes unverified assumptions about its effects on groundwater sustainability
- Relies on dated groundwater data prior to 2010 and does not include impacts of data collected during the 2012-2017 drought, and
- Passes the buck to the Groundwater Sustainability Agencies for preventing damage to the state's aquifers

The State Water Board's "unimpaired flows" approach for the San Joaquin River and its tributaries is not the path to achieve the desired ecological outcomes. It is inconsistent with established state policies, such as the California Water Action Plan, the coequal goals defined in the Delta Reform Act of 2009, the Sustainable Groundwater Management Act of 2014, and the Human Right to Water Act.

This proposal would undermine investments in storage, adversely impact the drinking water quality of disadvantaged communities, increase groundwater overdraft in a part of the state where groundwater basins are already out of balance, and put large acreages of agricultural land out of production.

Any strategy that would result in vast amounts of agricultural land going out of production and ultimately reduce water supply reliability for the majority of Californians is irreconcilable with the policy of coequal goals and the State Water Board's statutory obligation to protect all beneficial uses of water when establishing water quality objectives.

The State Water Board should set aside the percent of unimpaired flows approach and heed Gov. Jerry Brown's call for negotiated agreements. Such agreements have been demonstrably successful in achieving desired ecological outcomes while maintaining water supply reliability.

The State Water Board should embrace a collaborative process to develop water quality objectives that incorporates the best available science, utilizes comprehensive solutions that address multiple variables, aligns with established state policies, considers economic impacts, and ensures that Bay-Delta Plan decisions enable rather than obstruct implementation of the California Water Action Plan.

Legal Comments

I. The SED's Program of Implementation Will Constitute a Compensable Taking Underthe Fifth Amendment.

The SED provides that the when the LSJR flow objectives are implemented, the SWB "will include minimum reservoir carryover storage targets or other requirements…," (SED, App. K, p. 28), including minimum end of September storage requirements, minimum diversion levels, and maximum allowable draws from storage (SED, App. F, p. F.1-31). While the SED does not establish any specific carryover storage or other requirements for any party or reservoir, it notes that such requirements will be needed because the additional streamflow requirements of the LSJR alternatives "require adjustment of parameters to ensure feasibility for the 82-year simulation so that the reservoirs are not drained entirely in the worst droughts of record." (SED, App. F, p. F.1-31). While the scope and magnitude of such requirements are yet unknown, they are expected to reduce the available water supply from the New Don Pedro reservoir for consumptive use, particularly in dry and critical years. (Jan. 3, 2017 Tr., p. 24, ln. 18-24).

Additionally, the SED provides that in some cases, the volume equivalent to that which would have been released via the unimpaired flow ("UIF") percentage from February through June can be treated as a block of water and a portion released outside of the February through June period, including in the following year. (SED, App. K., p. 30-31).

For such a scheme to work, MID and TID, as owners of the New Don Pedro Dam and reservoir, will be required to divert into storage a quantity of water, maintain such quantity of water in storage, and then release such water from the dam at a later date.

All of these actions – requiring MID and TID to divert water into storage, requiring MID and TID to leave water in storage and refrain from diverting it for consumptive use, and requiring MID and TID to release water from storage for the benefit of fish and wildlife located downstream – constitute compensable takings under the Fifth Amendment to the United States Constitution.[1]

A. MID and TID Have Private Property Rights that Will Be Taken for a Public Purpose Under the SED.

To constitute a compensable taking under the Fifth Amendment, the government must take private property for public use. (Klamath Irr. v. U.S., 129 Fed. Cl. 722 (2016)). The physical facilities necessary to effectuate the SWB's plan – the dams, canals, drains and other facilities MID and TID use to divert, store and deliver water from the Tuolumne River – are all private property facilities owned, operated, built and maintained by MID and TID. Further, the pre-and post-1914 appropriative water rights held by MID and TID are private property which cannot be taken by government action without just compensation. (*See*, *e.g.*, United States v. State Water Res. Control Bd. (1986) 182 Cal.App.3d 82, 101).

The commandeering of MID and TID's storage at New Don Pedro Dam and reservoir and subsequent release of stored water, *water that the Districts would have provided to their customers,* for the benefit of fish and wildlife downstream will be considered a public use for purposes of the Fifth Amendment. (Casitas Mun. Water Dist. v. U.S., 543 F.3d 1276, 1292-1293 (2008) ("Casitas III")).

B. The SED's Program of Implementation Constitutes a Physical Taking.

Regulatory action by a governmental entity is considered a per se, physical taking if it (1) requires the owner to suffer a permanent physical invasion of property, no matter how small (Loretto v. Teleprompter Manhattan CATV Corp., 458 U.S. 419, 434-435 (1982), or (2) completely deprives the owner of all economically beneficial use of the property. (Lucas v.

[1] Compensation will be required even if the appropriation is based upon the SWB's alleged public trust authority. (*See* National Audubon Soc. v. Superior Court (1983) 33 Cal.3d 419, 440, *citing* Illinois Central Railroad Co. v. Illinois, 146 U.S. 387, 455 (1892), for the proposition that use of public trust to order removal of improvements on public trust lands would require compensation).

S.C. Coastal Council, 505 U.S. 1003, 1019 (1992)). The carryover storage and withdrawal limitations of the SED constitute permanent physical invasions of MID's and TID's New Don Pedro reservoir. Instructing MID and TID how much water they must store in New Don Pedro for future release to satisfy non-consumptive uses, and limiting the amount of stored water that they can release from storage for consumptive uses, are clear physical invasions of New Don Pedro Dam and reservoir by the SWB. For all intents and purposes, the SWB will have taken for itself some of the available storage space in New Don Pedro reservoir which currently belongs to MID and TID. The SED thus constitutes a "classic taking" via physical appropriation of available storage space in New Don Pedro Reservoir by the SWB. (*See*, *e.g.*, United States v. Security Industrial Bank, 459 U.S. 70, 78 (1982)).

The requirement to release water stored in New Don Pedro Reservoir for purposes of fish and wildlife enhancement likewise constitutes a *per se*, physical taking of water rights owned by MID and TID. Once the stored water is taken and released for benefit of fish and wildlife, it is forever gone from the Districts, no different than if the SWB piped the water from New Don Pedro reservoir to a different location. (Casitas III, 543 F.3d at 1294). The government-caused storage and release of water away from MID and TID will be analyzed under the physical takings rubric. (Casitas III, 543 F.3d at 1298; *see also* Washoe Cty., Nev. V. U.S., 319 F.3d 1320, 1326 (Fed.Cir.2003) [physical taking where government has "decreased the amount of water accessible by the owner of the water rights."]).

Once the SED is adopted and allocates responsibility for implementing the SED's requirements, MID and TID will seek compensation for both the value of the storage space in New Don Pedro reservoir taken by the SWB, as well as the value of the water rights taken.

II. Fish and Game Code Section 5937 Does Not Require the Release of Stored Water.

The SED provides that in some cases, the volume equivalent to that which would have been released via the unimpaired flow percentage from February through June can be treated as a block of water and a portion released outside of the February through June period, including in the following year. (SED, App. K., p. 30-31). In either case, although the STM Working Group will be consulted, the SWB's Executive Director can approve such a scheme upon the recommendation of a single member of the STM Working Group. (SED, App. K, p. 29-30, items (b) and (c)). Obviously, for such a scheme to work, the dam owner would be required to divert into storage a quantity of water, maintain such quantity of water in storage, and then release such water from the dam at a later date. During the public hearings regarding the SED, several parties raised concerns about the SWB's ability to require the release of stored water for the benefit of fish and wildlife beneficial uses located downstream. In response, Chairwoman Marcus identified Fish and Game Code Section 5937 as a source of the SWB's authority to require the release of stored water. (*See*, *e.g.*, Dec. 16, 2016 Tr., p. 216, ln. 3-11; Dec. 19, 2016 Tr., p. 152-153). Chairwoman Marcus is incorrect, and Fish and Game Code Section 5937 does not authorize the SWB to require the release of stored water. [2]

Fish and Game Code Section 5937 requires dam owners to allow water to pass through a fishway, or in the absence of a fishway, pass over, around or through a dam to keep fish below the dam in good condition. Section 5937 does not mention stored water at all. As explained by the courts that have construed Section 5937, it is a limitation on the amount of water that can be appropriated from a stream.

For example, in Natural Resources Defense Council v. Patterson, 791 F.Supp.1425, 1435 (E.D. Cal. 1992), the court explained that

> "[w]ithout deciding whether section 5937 is a water appropriation statute, vel non, the statute's plain language demonstrates that it was intended to limit the amount of water a dam owner desiring to collect for eventual irrigation may properly impound from an otherwise naturally flowing stream. Thus, it is a prohibition on what water the … owner of the dam, may otherwise appropriate … Put another way, …, 5937 preserves from appropriation … an amount of water necessary for instream uses …"

A similar finding was made in California Trout, Inc. v. State Water Resources Control Bd. (1989) 307 Cal.App.3d 585, 599:

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[2] Fish and Game Code Section 5937 does not authorize the SWB to take any action nor provide a source of authority for any of the actions proposed in the SED. Section 5937 is part of the Fish and Game Code, whose provisions are to be administered and enforced by the Department of Fish and Wildlife. (Fish and Game Code § 702; see also § 37, defining "department."). Further, violations of the Fish and Game Code are specifically designated as misdemeanors (§ 12000(a)), for which there is no remedy via civil action. (Babu v. Petersen (1935) 4 Cal.2d 276, 288 ["No civil right can be predicated upon the violation of a criminal statute."]; compare language of Penal Code § 308, making the seller of tobacco in certain instances subject to prosecution for a misdemeanor or subject to a civil suit, with the language of Fish and Game Code §§ 5937 and 12000(a)). Moreover, the SWB has not made any findings as to what "good condition" means, has no evidence to support a conclusion that fish are or are not in "good condition," has not made any findings as to how far "below the dam" fish must be maintained in "good condition," and has not explained why natural production should trump protection for "any fish that may be planted" below a dam as called for in § 5937.

> "[t]hese provisions straightforwardly limit the amount of water that may be appropriated by diversion from a dam … by requiring that sufficient water first be released to sustain the fish below the dam."

Both of these cases correctly determined that Section 5937 is a limit on the appropriation of the natural flow of water in a stream or river. It does not require the release of stored water from a reservoir.

This interpretation is supported by the SWB's own regulation designed to implement Section 5937, which states:

> "In the case of a reservoir, this provision shall not require the passage or release of water at a greater rate than the unimpaired natural flow into the reservoir." (Cal. Admin. Code, tit. 23, § 782).

The plain language, implementing regulation, and controlling authorities clearly indicate that Section 5937 does not mandate the release of stored water to keep fish below a dam in good condition.

In addition, Fish and Game Code Section 5937 cannot be used by the SWB to require the release of stored water from New Don Pedro reservoir because it is a component of a hydroelectric project licensed by the Federal Energy Regulatory Commission ("FERC"), and the Federal Power Act ("FPA") preempts the independent applicability of Section 5937 to the New Don Pedro Dam and reservoir. (California v. FERC, 495 U.S. 490, 497-5000 (1990) [holding that the FPA preempts regulations under state laws because the federal government occupies the field of hydropower licensing]).

III. The carryover storage provisions contained in the SED are unconstitutional impairments of the contractual obligations of the 4th Agreement between MID, TID and the City and County of San Francisco.

In 1966, MID, TID and the City and County of San Francisco ("CCSF") entered into the 4th Agreement, by which CCSF participated financially in the costs of construction of New Don Pedro Dam and reservoir in exchange for water banking privileges in New Don Pedro reservoir. (SED, App. L, p. L-3). . The water banking privileges enable CCSF to release water to MID and TID (1) in advance of the time when releases are required under the Raker Act, (2) when such releases can be stored in New Don Pedro Reservoir, and (3) to subsequently intercept or divert equivalent amounts of water which it would otherwise be required to pass to MID and TID to satisfy their superior water rights. (4th Agreement, Art. 7, p. 7; SED, App. L, p. L-3). As recognized by the SWB, CCSF does not hold water rights to, nor physically divert from, New Don Pedro reservoir. The rights to all water in New Don Pedro reservoir are owned by MID and TID. (SED, App. L, p. L-3). In addition to dividing the costs of the construction of New Don Pedro Dam and reservoir, the 4th Agreement also provides for the sharing of certain additional future costs and flow obligations, with CCSF agreeing to be responsible for 51.7121% and the Districts 49.2879%. These percentages were derived by comparing the size of CCSF's water banking privileges to the size of the additional storage obtained by MID and TID as a result of the construction of New Don Pedro Dam and reservoir. (4th Agreement, Appendix A, page 4).

The carryover storage requirements established in the SED, including end of September storage targets, maximum allowable withdrawal from storage, and end of drought refill criteria (*see*, *e.g.*, SED, App. F, p. F.1-31-32) will result in storage levels in New Don Pedro reservoir being higher than under current conditions. As a result, there will be fewer times that there is room in New Don Pedro reservoir for MID and TID to store water that is released by CCSF in advance of when it is required to make releases under the Raker Act. In essence, this may result in the change in size of CCSF's water banking privileges and/or the size of MID's and TID's additional storage, and thus affect the negotiated percentages of responsibility for future costs and flow obligations as currently defined in the 4th Agreement. Such changes will frustrate the purpose of the 4th Agreement and potentially lead to its dissolution.

Article I, Section 9 of the California Constitution prohibits legislative or judicial actions which significantly impair the obligations of an existing contract. (Bradley v. Superior Court (1957) 48 Cal.2d 509, 519). Since the SWB's SED is a quasi-legislative act, its significant impairment of the obligations and benefits of the 4th Agreement will violate Article I, Section 9 of the California Constitution.

IV. The SED Cannot Be Made Applicable to MID and TID Via the Section 401 Process.

The SED states in several places that its flow and carryover storage requirements may be implemented against MID and TID via the CWA Section 401 process. (*See*, *e.g.*, App. K, p. K-26). The SWB has the authority and duty to certify that any discharge from MID's and TID's operation of the New Don Pedro Project under a new FERC license will comply with the CWA and any appropriate water quality requirement of State law. (33 U.S.C. 1341 (a), (d)). As explained below, much of the SED does not fall within this authority granted to the SWB by Congress and thus cannot be applied to MID and TID via the Section 401 process.

A. The Alleged Harms to Native Fish Caused By the Existence of the New Don Pedro Dam To Be Rectified by the SED Are Not a Point-Source Issue that Can Be Addressed Via the 401 Process.

The CWA regulates point-source pollution, and "[n]onpoint source pollution is not regulated directly by the [CWA] …" (ONDA v. Dombeck, 172 F.3d 1092, 1096 (9th Cir. 1998)). Section 401 certification thus does not apply to nonpoint source pollution. (ONDA, *supra*, 172 F.3d at 1097-1099). Traditionally, harms to fish allegedly caused by the existence of dams have been considered nonpoint source pollution. (*see* United States *ex rel*. TVA v. Tenn. Water Quality Control Bd., 717 F.2d 992, 999 (6th Cir. 1983); *see also* Nat'l Wildlife Fed'n v. Gorsuch, 693 F.2d 156, 177 (D.C.Cir. 1982)). Significantly, the SWB has relied upon this very distinction to argue that EPA cannot promulgate water quality objectives based upon streamflow under the CWA. According to the SWB,

> "These cases demonstrate … that **changes in water quality caused by dams are the result of nonpoint sources of pollution**…Where the predominant or sole cause of pollution in a water body is operation of water diversions, as is the case with the proposed salmon smolt survival criteria …, adoption of water quality standards under the Clean Water Act is not an appropriate method of regulation." March 11, 1994 letter of the SWB to EPA, p. 28, cited by the SWB in its 2006 WQCP, p. 4, fn. 3; SED, App. K, p. K-5, fn. 4, 5)(emphasis added).

Controlling caselaw and SWB policy[3] both demonstrate that alleged impacts to fish from the existence of dams is considered a nonpoint source of pollution. Since the Section 401 process does not apply to nonpoint source pollution, the flow and carryover storage requirements of the SED which are designed to provide floodplain, temperature and other benefits for native anadromous fish species cannot be applied to MID and TID via the Section 401 process.

[3] The holding of S.D. Warren Co. v. Maine Bd. Of Environmental Prot., 547 U.S. 370 (2006) is not controlling here. In that case, the parties conceded that the pollution at issue was from a point-source. (*see* Oregon Natural Desert Ass'n v. United States Forest Serv., 550 F.3d 778, 783-784 (9th Cir. 2008)). In this case, no such concession has been made, and in fact, the SWB has made the opposite assertion.

B. Section 401 Does Not Apply to Streamflow, Operations or Water Rights.

As noted above, the Section 401 process applies to ensure a federal permittee complies with the CWA and any appropriate water quality requirement of State law. (33 U.S.C. 1341 (a), (d)). In this case, the UIF and carryover storage requirements proposed to be applied against MID and TID are not related to water quality and thus cannot be implemented via the Section 401 process.

For purposes of the CWA, "water quality" does not include impacts associated with reductions in freshwater flows caused by dams and diversions. (33 U.S.C. 1252(b); 33 U.S.C. 1313(c)). Thus, SWB cannot rely on the authority of Section 401(a) for authority to apply the SED against MID and TID.

Nor can the SWB rely upon the authority of Section 401(d), which enables a state to provide water quality certification to assure that the permitted activity complies with "any other appropriate requirement of State law…" This provision is limited in scope, and only authorizes a state to impose conditions "affecting water quality in one manner or another." (American Rivers v. FERC, 129 F.3d 99, 107 (2d Cir 1997); Arnold Irr. Dist. v. Department of Environmental Quality, 717 P.2d 1274, 1279 (1986); Matter of Eastern Niagara Project Power Alliance v. New York State Department of Environmental Conservation, 42 A.D.3d 857, 859-860 (2007)). In this case, it is clear that the flow and carryover storage requirements are not related to water quality, but rather are matters of streamflow, water rights, and operations of dams and diversions.

In 1994, EPA published a proposed rule to protect fish migration and protect cold water habitat pursuant to CWA Section 303(c), 33 USC 1313 (c)). In the proposed rule, EPA suggested that the SWB should implement such criteria by amending water rights permits. These "salmon smolt survival" standards included both export limitations and minimum streamflow requirements. (59 Fed Reg. 810, 825-826 (January 6, 1994))[4]. In comments filed on March 11, 1994, the SWB objected to the proposed rule, arguing strenuously that because the "salmon smolt survival criteria" were flow and export standards, they were not properly considered "water quality" issues for purposes of the CWA. The SWB argued, for example:

- "the salmon smolt survival standards … take direct control of the heart of the State's water rights and water distribution system." (p. 9)

[4] SWB Chairwoman Marcus was the regional administrator for EPA Region IX at the time.

- "Streamflow Matters Are Not To Be Regulated By EPA" (section heading, page 10).
- "For purposes of the Clean Water Act the proposed criteria for … salmon smolt survival are streamflow requirements, not water quality criteria." (p. 10).
- The only means of meeting EPA's … salmon smolt criteria would be for the State to regulate water project operations and allocate water storage and streamflow … for instream flows." (p. 11).
- "It is beyond dispute that outflow and water project operations are not water quality matters." (p. 11-12).
- That the EPA had written that impacts caused by reductions in streamflow were a "stream flow/water allocation issue, not a water quality issue under Section 303." (p. 15).
- "Here, EPA apparently wants the State to 'work back' and cut diversions to attain the water quality standards. This method is inappropriate…" (p. 26).

Each of the above statements apply equally to the UIF and carryover storage requirements of the SED. Although described as being promulgated as part of a water quality control plan amendment, clearly such requirements have nothing to do with "water quality" as described and understood in the CWA. As a result, the SWB will not be able to implement the provisions of the SED against MID and TID using Section 401(d).[5]

Because the UIF and carryover storage requirements are not related to water quality, they exceed the authority delegated by Congress in Section 401 of the CWA. This is significant since Section 401 is the only opportunity for states to include mandatory conditions in federal power licenses; all other authority is vested in FERC. (*See*, *e.g.*, Karuk Tribe of Northern Calif. V. California Regional Water Quality Control Bd. (2010) 183 Cal.App.4th 330, 359-360 [CWA gives the states a significant role in federal hydropower licensing, but this is the only area Congress has allowed]; American Rivers, *supra*, 129 F.3d at 111 [noting the preemptive reach of the Federal Power Act had been diminished by Section 401]; First Iowa Hydro-Elec Coop v. FPC, 328 U.S. 152, 180 (1946) [detailed provisions of federal plan for regulation of power leave no room for conflicting state regulation]). This means that while the SWB can participate in the relicensing process of New Don Pedro, and provide FERC with recommendations and comments as to the

[5] PUD No. 1 v. Wash. Dep't of Ecology, 511 U.S. 700 (1994) will not be of any assistance to the SWB. While the Supreme Court did conclude that Section 401(d) could be used to impose minimum instream flow requirements, in that case such requirements were adopted pursuant to CWA Section 303, 33 U.S.C. 1313. (Id. at 712-713). However, the SWB takes the position that Section 303 "is not intended to regulate pollution caused by reduction of fresh water flow." (March 11, 1994 letter, p. 10; cited as current view at 2006 WQCP, p. 4, fn. 3 and SED, App. K, p. K-5, fn. 4 and fn. 5).

appropriate streamflow downstream of New Don Pedro Dam, FERC retains sole and exclusive jurisdiction to establish minimum streamflow and other conditions of the license in the absence of the 401 conditions. As explained by the U.S. Supreme Court when California made a prior effort to require flow requirements on a FERC-licensed project via conditions in a water rights permit,

> "we conclude that the California requirements for minimum in-stream flows cannot be given effect and allowed to supplement the federal flow requirements. … As Congress directed in FPA 10(a), FERC set the conditions of the license, including the minimum stream flow, after considering which requirements would best protect wildlife and ensure that the project would be economically feasible, and thus further power development. Allowing California to impose significantly higher minimum stream flow requirements would disturb and conflict with the balance embodied in that considered federal agency determination. … we agree that allowing California to impose the challenged requirements would be contrary to Congressional intent regarding [FERC's] licensing authority and would 'constitute a veto of the project that was approved and licensed by the FERC.'" (California, *supra*, 495 U.S. at 506-507)(citations omitted).

Even if adopted, the UIF and carryover storage requirements cannot unilaterally be applied against MID and TID because they are preempted by FERC's determination on appropriate streamflows. Absent agreement by FERC, and inclusion of such requirements by FERC in any new license issued, the UIF and carryover storage requirements set forth in the SED will simply not apply to MID and TID.

C. Section 401 Certification is Likely Unnecessary for New Don Pedro

Generally, an applicant for a FERC license for the operation of a hydroelectric facility that may result in a discharge into navigable waters must obtain certification from the state that the project will comply with state water quality standards. (33 U.S.C. 1341). However, not every circumstance requires a 401 certification from the state, particularly those that will either reduce the amount of discharge, or for which an increase may occur that will not have an adverse impact on the water quality of the discharge. Either of these exceptions will likely apply to New Don Pedro.

1. MID and TID May Apply for a New License that Will Reduce the Amount of Amount of Water Discharged By New Don Pedro Dam and Reservoir, Thus Nullifying the Need for Certification Under Section 401.

As part of their effort to relicense the Don Pedro hydroelectric project, MID and TID may request a new license that results in less water being passed through the turbines than currently passes under the existing license. Such effort would eliminate the existence of a "discharge" as defined under the Clean Water Act. (North Carolina v. FERC, 112 F.3d 1175, 1188 (1997)["A decrease in the volume of water passing through the dam turbines cannot be considered a 'discharge' as that term is defined in the CWA."])(citation omitted). Since a "discharge" is a prerequisite for Section 401 to apply, FERC will be able to issue a new license without MID and TID obtaining a water quality certification from California. (Id., p. 1189; *see also* San Diego Elec. & Gas Co.,105 FERC ¶ 61,226 (2003) ["new certification would be required only if extending the license term would result in a new or greater discharge from the project."]).

2. Even if MID and TID Seek a New License that Would Keep the Flows through the Dam Substantially the Same or Even Result in a Slight Increase, Section 401 Certification May Not Be Needed.

Not all increases in flows from hydroelectric projects will trigger the need for Section 401 certification. For example, a licensee sought permission to replace its turbine generators, which would increase the project's hydraulic capacity and enable water to be discharged more quickly. Parties argued that a new Section 401 certification was necessary, but FERC disagreed. FERC found that while increased discharges could occur, the "nature of the discharge would not change." FERC also found that the environmental analysis accompanying the proposal revealed that the changes would have no adverse impact to the water quality. (Alabama Power Co., 106 FERC ¶ 62,014 (2004)).

For the New Don Pedro hydroelectric project, MID and TID are confident that the studies they have performed at FERC's direction, the proposed new terms and conditions, and the supporting environmental analysis under NEPA and CEQA will demonstrate that the nature of the discharge will not materially change from what it is now. Even if there is a slight increase in certain circumstances in terms of rate or volume, such increase will not result in a material adverse impact. As such, certification under Section 401 will not be required, and thus the SED will not be applied to MID and TID via Section 401.

The State Water Board proposal and its singular focus on unimpaired flows is the wrong choice for the state's future. The Districts urge the State Water Board to set aside the unimpaired flows approach and recognize that the best outcome can be achieved through comprehensive, collaborative approaches that include "functional flows" as well as non-flow solutions that contribute real benefits.

MODESTO IRRIGATION DISTRICT

Greg Salyer
General Manager

TURLOCK IRRIGATION DISTRICT

Casey Hashimoto
General Manager

Enclosure (Flashdrive)

<u>SED Technical Comments</u>

1.0 Summary of Findings Related to SWB's Revised Draft Substitute Environmental Document

2.0 Comments on the SED's Description of the Tuolumne River Basin

3.0 Comments on Hydrology, Unimpaired Flow, and Related Adverse Impacts on Fry and Juvenile Fall-Run Chinook Salmon

4.0 Comments on the SED's Assessment of Temperature Benefits

5.0 Comments on the SED's Assessment of Floodplain Benefits

6.0 Comments of the SED's SalSim Model and Analyses

7.0 Comments of the SED's Adaptive Implementation Plan

8.0 Comments on the SED's Economic Analysis

9.0 The Missing Science and How It Would Change the SED

10.0 Other Material Errors or Misrepresentations Contained within the Draft SED

11.0 References

Attachments

Attachment 1	Table TR-1
Attachment 2	Figures TR-5 through TR-11

Appendices

Appendix A	Evaluation of the SED's Floodplain Benefits and Hatchery Impacts
Appendix B	[INTENTIONALLY OMITTED]
Appendix C	Evaluation of Economic Impacts of the Draft SED
Appendix D	Response to the Resource Agencies' Presentations at the January 3, 2017 Public Hearing
Appendix E	Final Swim Tunnel Study Report
Appendix F	Final Tuolumne River Floodplain Hydraulic and Habitat Assessment Study Report
Appendix G	Final License Application (FLA), Don Pedro Project
Appendix H	Final Otolith Study Report, e-filed with FERC post-FLA filing
Appendix I	Regional Economic Impact Caused by a Reduction in Irrigation Water Supplied to Turlock Irrigation District and Modesto Irrigation District: Methodology Memorandum

COMMENTS ON
STATE WATER CONTROL BOARD'S
REVISED DRAFT SUBSTITUTE
ENVIRONMENTAL DOCUMENT

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Table of Contents

Table of Contents (Cont'd.)

Attachments

Attachment 1	Table TR-1: Review Team Comments on the SED's Citations Related to Natural Flow Regime and "Unimpaired" Flow Regime
Attachment 2	Figures TR-5 through TR-11: Plots comparing modeled Tuolumne River flow variability for the following years at the La Grange and Modesto USGS gages from (1) SWB's WSE model's flat, constant monthly flows and (2) the 7-day running average flow in from the daily flow record in the Tuolumne River Operations Model developed by TID and MID as part of the Don Pedro Project FERC relicensing.

Figure TR-5: Year 1973

Figure TR-6: Year 1979

Figure TR-7: Year 1984

Figure TR-8: Year 1989

Figure TR-9: Year 1996

Figure TR-10: Year 2004

Figure TR-11: Year 2010

Appendices

Appendix A — Evaluation of the SED's Floodplain Benefits and Hatchery Impacts:

- A-1: Technical Review of the SWRCB's SED – Floodplain Analyses
- A-2: Technical Review of the SWRCB's SED – Supplemental Analysis of Hatchery Impacts upon Survival and Escapement of Naturally-Produced Chinook Salmon from the Lower San Joaquin River Tributaries

Appendix B — [INTENTIONALLY OMITTED]

Appendix C — Comments on the SWRCB's SED: Economics, Agriculture, Social and Environmental Justice

Appendix D — Response to the Resource Agencies' Presentations at the January 3, 2017 Sacramento Public Hearing

- D-1: Response to SWB Staff Presentation at the January 3, 2017 Sacramento Public Meeting
- D-2: Review of CDFW SalSim Presentation (Bay-Delta Phase 1 Hearing, January 3, 2017)
- D-3: Review of CDFW Presentation at January 3, 2017 Public Hearing on the SWRCB's Draft Revised SED
- D-4: Review of NMFS-UCD Presentation (Bay Delta Phase 1 Hearing, January 3, 2017)

Appendix E — Final Report: Thermal Performance of Wild Juvenile *Oncorhynchus Mykiss* in the Lower Tuolumne River: A case for local adjustment to high river temperatures

Appendix F — Final Report: Lower Tuolumne River Floodplain Hydraulic Assessment

Appendix G — Final License Application, Don Pedro Project

Appendices (Cont'd.)

Appendix H	Final Report: Chinook Salmon Otolith Study, e-filed with FERC post- FLA filing
Appendix I	Regional Economic Impact Cause By a Reduction in Irrigation Water Supplied to Turlock Irrigation District and Modesto Irrigation District: Methodology Memorandum

1.0 Summary of Findings Related to SWB's Revised Draft Substitute Environmental Document

On September 15, 2016, the State Water Resources Control Board ("SWB") released for public comment the Revised Draft Substitute Environmental Document ("SED"). The SED totals over 3,500 pages of text, tables, graphs, and computer models describing and analyzing proposed Amendments to the Bay-Delta Water Quality Control Plan ("Amended Plan"). The geographic scope of the Amended Plan includes the lower San Joaquin River ("LSJR") and the three east-side tributaries draining into the LSJR – the Stanislaus, Tuolumne, and Merced rivers. The Turlock Irrigation District and the Modesto Irrigation District (collectively the "Districts") requested that HDR conduct a review and provide comments on certain technical areas of the SED, including hydrology, project operations, fisheries and aquatic resources, floodplains, water temperatures, economic impacts, and related analyses and modeling. Assisting HDR in this review were a number of experienced scientists, engineers, and economists from the firms of Stillwater Sciences, FishBio, Cardno Entrix, and LGL, as well as Mr. Daniel Steiner, P.E., one of the developers of the CALSIM II model for the San Joaquin basin.

This team of scientists, engineers, and economists ("Review Team") has been working with the Districts for the past eight years performing studies and preparing operations modeling and engineering, environmental, recreational, cultural, and socioeconomic assessments for the relicensing of the Don Pedro Project with the Federal Energy Regulatory Commission ("FERC"). Members of the Districts' Review Team have also been involved throughout the last 20-plus years in field investigations and analytical studies on not only the Tuolumne River, but also on the Stanislaus and Merced rivers. Specifically related to the Tuolumne River, the Review Team has intensively investigated the river's hydrology, geomorphology, fisheries and aquatic resources, floodplains, riparian and terrestrial resources, macroinvertebrate populations, cultural resources, socioeconomic conditions, and the associated Tuolumne River landscape. Therefore, the majority of the comments and findings provided herein deal with the SED's treatment of the Tuolumne River.

The Review Team was asked to analyze the key benefits and impacts of the Amended Plan as described in the SED. Our assessment, presented herein, discusses the following topics: hydrology, floodplains, water temperatures, fish populations, economic impacts, and related subjects. It is important to acknowledge at the outset that deciphering and understanding the 3,500 pages of text, tables, plots, and complex computer models which were five years in the making at the SWB is a challenging task, and more time would have afforded a more detailed review.

According to the SED, its proposal would decrease flow available to water users for beneficial purposes by approximately 300,000 acre-feet per year on average compared to existing conditions. In turn, by its own analysis, the SED's proposal will increase the Central Valley fall-run Chinook salmon population by 1% and decrease average temperatures as measured at Vernalis by 1°C in May and June. Overall, the Districts' Review Team concludes that the SED has overstated the potential temperature, floodplain, and fishery benefits to be expected to occur in the lower Tuolumne River and understated the adverse impacts of the SWB's Amended Plan.

We provide below ten findings which support our conclusion, all of which are discussed in greater detail in the body of these comments and in the attached appendices.

Finding #1: The SED has failed to demonstrate an understanding of the current physical conditions and resources of the lower Tuolumne River.

> Summary: The Tuolumne River has undergone a tremendous transformation in the past 150 years from being a natural riverscape to being a *highly modified river*.[1] The SED acknowledges the degree of the transformation in Chapter 7, but then neglects to consider how this major transformation of the river environment affects the anadromous fish populations that are at the core of the Amended Plan. Providing a "natural flow regime" to what is otherwise a completely modified, far from natural river-floodplain system is unlikely to lead to improvements to the anadromous fish populations of the Tuolumne River or LSJR.

Finding #2: "Unimpaired flows", as defined by the SED, do not "mimic the natural hydrograph" of the Tuolumne River.

> Summary: At the core of the SED's preferred alternative is the assumption that requiring water supply reservoirs on the eastside tributaries to seasonally release a percent of unimpaired flows will increase the abundance of fall-run Chinook salmon simply because such flows will mimic the natural hydrograph to which these fish are adapted. Unimpaired flows, as defined in the SED, are a human invention, have never actually occurred in the lower Tuolumne River or LSJR, and are not the flow regime which anadromous fish experienced before pre-European development. Sparks (1995) and Walker et al. (1995), two references cited by the SWB, provide precise descriptions of why "unimpaired flows" as defined in the SED are not representative of the natural flow regime of the lower Tuolumne River.

Finding #3: The SED fails to analyze its own proposal.

> Summary: The SED reports that the LSJR fall-run Chinook salmon population, as well as other fish species not specifically analyzed, will increase as a result of greater floodplain access and cooler water temperatures. The proposed Amended Plan as defined in Appendix K of the SED and the alternatives described in Chapter 3 of the SED call for increased instream flows below La Grange Diversion Dam from February through June equal to a percent of the unimpaired flow of the Tuolumne River computed as a ***7-day running average***. That is, the SED's preferred alternative would provide instream flows that fluctuate every day based on a running 7-day average of the unimpaired flow. Without explanation or any demonstration of equivalency, the SED analyzes the potential

[1] Yarnell et al (2015) defines *highly modified rivers* "to be those that (1) have a high proportion of their total length converted to reservoirs, (2) have a high proportion of their total annual stream flow diverted and/or managed for societal uses, (3) have a high proportion of their total annual stream flow stored in reservoirs, and/or (4) have a large proportion of their total length channelized or lined by levees. These four characteristics rarely occur in the same river, but even one of these characteristics can greatly affect the riverscape, particularly in terms of sediment transport, and floodplain extent and constrain e[nvironmental]-flow implementation and ecosystem restoration potential."

for floodplain inundation and river temperature benefits using ***average monthly*** flows, which are flat, constant flows across an entire month, and therefore do not represent the instream flows as proposed in the Amended Plan. It is impossible to draw reasoned, scientific conclusions on potential floodplain and temperature benefits to fall-run Chinook salmon attributable to the SED's preferred alternative based on an analysis of a flow regime that would never occur under that alternative. Therefore, because the SED lacks the scientific analysis of the proposed action, the SED should be withdrawn and re-analyzed using methods appropriate to the resource questions raised.

Finding #4: The SED largely ignores the vast body of scientific data and technical information that has been compiled on the Tuolumne River and its associated resources over the last 20-plus years.

Summary: The Tuolumne River is one of the most studied rivers in California. Over the last 25 years, more than 200 individual scientific investigations of the river's resources have been completed. Neglecting to seriously assess this wealth of empirical data and analysis leaves the SWB to rely on "qualitative" assessments of the potential benefits and impacts of the alternatives considered in the SED. The end result of the lack of evaluation of the extensive site-specific data available, as discussed further in the sections below, is that the various "AQUA" impacts described in Chapter 18 of the SED are largely unsupported, incomplete, or incorrect and lead to erroneous conclusions about the effects of the SED's alternatives on fall-run Chinook salmon and *O. mykiss* on the Tuolumne River.

Finding #5: Effects to fish and wildlife at the population level are not evaluated in the SED.

Summary: As repeated many times in the SED, the goal of the Amended Plan is to "*support and maintain native fish **populations***" (pg ES-18) [emphasis added] and eventually improve "*productivity as measured by **population** growth rate*" (ES-19) [emphasis added]. The SED over and over again properly declares its purpose to be to improve fisheries at the population level. Predicting or measuring the effects of environmental actions at the population level is considered an essential element of environmental restoration actions (Bennett et al. 2016). The only quantitative assessment of the direct impact of the Amended Plan, and its alternatives, to fish and wildlife *populations* is a prediction of the effects to fall-run Chinook salmon abundance using the California Department of Fish and Wildlife ("CDFW") SalSim model. This peer-reviewed model predicts an increase in the adult fall-run Chinook population of roughly 1,000 fish, or 10%, under the SWB's alternative of increasing instream flows in the three eastside tributaries to 40% of the unimpaired flow (UF) for the February through June period.[2] The SED does not report what level of uncertainty is associated with the SalSim

[2] The SED's preferred alternative also includes adaptive implementation, the limits of which are not expressly defined in the SED. The SED includes SalSim model results for two alternative reallocation scenarios, neither of which is specifically identified as part of the preferred alternative. Detailed comments on the SalSim model are provided in these technical comments.

estimates.[3] The SJR fall-run Chinook population makes up approximately 6.7%[4] of the total Central Valley fall-run Chinook population. Therefore, according to the SED, the additional 300,000 acre-feet of water per year that will no longer be available for other beneficial uses of water is predicted to increase the total Central Valley fall-run Chinook population by less than 1% over the long term. Furthermore, according to the SED, increasing the instream flow to 60% UF is predicted to produce fewer fish than the 40% unimpaired flow.[5] There is no other quantitative population assessment of Chinook salmon or other fish and wildlife species provided in the entire 3,500 pages of the SED. The SED does not make a scientifically defensible case that any percent of the unimpaired flow from February through June will materially and measurably increase the population abundance of the selected "indicator species" – fall-run Chinook salmon. Furthermore, the SED lacks an assessment of the preferred alternative's effects on non-native predator species in the LSJR or Bay-Delta. By example, the proposed change in May and June flows is likely to benefit striped bass spawning.[6] It is conceivable that increased flows at certain times of year and in certain reaches would benefit non-native predators to a greater extent than the SED's targeted native species. Analysis of this possibility is a significant omission in the SED.

Finding #6: The SED's 40% UF from February through June alternative is projected to result in certain adverse resource effects. The need to mitigate the adverse effects of the SED's preferred alternative may eliminate the minimal fish population benefits that were hoped to be achieved through implementation of that alternative.

Summary: The SED acknowledges that the Amended Plan as proposed in Appendix K and the preferred alternative identified in Chapter 3 ("LSJR Alt3") is likely to result in certain adverse impacts to water temperatures in the Tuolumne River in the summer and fall periods. The greater instream flows called for in the SED, when combined with historical levels of water use for irrigation and M&I purposes, result in lower Don Pedro Reservoir levels, which in turn are presumed to affect the thermal stratification in the reservoir and result in the release of water from the reservoir that is warmer than historical releases. The SWB proposes to mitigate this adverse impact of its proposal by imposing a limit on reservoir drawdowns, which further limits the amount of water able to be used for water supply purposes. To mitigate the impact of the SED's preferred alternative, SWB shifts a portion of the instream flows to be delivered in the February through June timeframe to other parts of the year. The maximum "flow shifting"

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[3] At the January 3, 2017, Public Hearing the SWB staff declared that SalSim was not relied upon in the development of the SED's preferred alternative, despite the SED containing almost 100 individual references in the SED about the role SalSim played in the SWB's decision-making process.

[4] Based on GrandTab dated April 11, 2016, pages 10-11 using CDFW run estimates from 1975-2015.

[5] The results of the peer-reviewed SalSim fall-run Chinook population model refute the conclusions of the *Development of Flow Criteria for the Sacramento–San Joaquin Delta Ecosystem*" (2010 Flow Criteria Report) which is the basis for the SED's assumption that 60 percent of unimpaired SJR inflow from February–June is the preferred alternative when only considering fishery needs.

[6] Striped bass begin spawning in the spring when the water temperature reaches 60 degrees. Most spawning occurs between 61 and 69 degrees and the spawning period usually extends from April to mid-June. Stripers spawn in open fresh water where the current is moderate to swift. The Delta, especially the San Joaquin River between the Antioch Bridge and the mouth of Middle River, and other channels in this area, is an important spawning ground. https://www.wildlife.ca.gov/fishing/inland/striped-bass#35540374-history. Lac

alternative ("40%MAXFS") reduces the planned February to June flows from 40% to 30% of the unimpaired flow. However, under the 30% unimpaired flow from February through June alternative, the SalSim model indicates there is no benefit to the target species of fall-run Chinook salmon from the February to June flows compared to the baseline (see Table 19-32 of the SED). Under the 40%MAXFS scenario, it appears that the predicted fish population benefit is derived from providing flows in the fall, thereby call into question any need above baseline flows from February through June. The alternative of increased fall flows combined with February through June baseline flows is not reported in the SED.

Finding #7: The SED's failure to define a specific proposal prevents substantive analysis of the Amended Plan. More specifically, there are at least two distinct "amended plans" in the SED, each of which is based on a mutually exclusive scientific hypothesis.

Summary: By the time one finishes reading the SED, it is difficult to discern what "plan" is actually being proposed as the revised Bay-Delta Plan. The SED begins by presenting a case for the essential need of providing a more natural flow regime for the LSJR and the three eastside tributaries during the February through June time period to support critical life stages of salmonids, including spawning, rearing, and outmigration. The specific goal of the SED is to *"support and maintain the natural production of viable native San Joaquin River Watershed fish populations migrating through the Delta"* and the SED provides several citations to support its case for the need for mimicking natural flows during the fry and juvenile fish rearing period. But by Chapter 7, this necessity tends to be abandoned when the goal statement is modified to the following: "*support and maintain the natural production of viable native San Joaquin River Watershed fish populations migrating through the Delta* ***and meet any biological goals****"* [emphasis added]. This represents a fundamental change in goals. One is left to guess what "any biological goals" might entail. Furthermore, establishing the "biological goals" is delayed to a future date to coincide with the development of an "adaptive implementation plan" ("AIP"). One can only interpret that the phrase "*and meet any biological goals"* was added to show support for the notion of treating the unimpaired flow volume as just a "block of water" to be "managed" within the AIP framework. Flows originally presented as being necessary to mimic the natural hydrograph in each month of the February through June period are now considered to be capable of being reallocated as necessary to meet "*any biological goals"*.

In summary, the SED presents not one "Amended Plan", but many, proceeding from the "necessary" 40% percent of unimpaired flow for each month of February through June to having the percent of unimpaired flow in February through June be allowed to be managed as a total volume of water and released on an adaptive schedule *within that period* to allowing flows to be shifted out of the February through June timeframe to other unspecified times of the year and, finally, to allowing flows to be shifted in frequency, timing, magnitude, and duration to "*meet any biological goals*". This last version of the "Amended Plan" leads the SWB to state *"[t]he LSJR alternatives entail a* ***virtually unlimited number*** *of possible functional flow regimes, limited* **only** *by the upper and lower bounds of the analyzed range of flows"* (ES-17) [emphasis added]. While many generalized flow regimes are qualitatively considered, none are ruled out and all appear possible within the scope of the adaptive implementation plan, completely abandoning the original "necessity" of a more natural flow regime. If there is no definitive "biological goal", how can it be determined by the SWB that the preferred alternative will achieve a set of yet-to-be defined "biological goals"?

Finding #8: The adaptive implementation plan suggested in the SED is critically flawed because it lacks the most basic elements of an implementable plan.

Summary: Bennett et al. (2016) identifies key ingredients for an effective adaptive management plan, these being having "[c]learly defined objectives, understanding of the ecological concerns (i.e., what is not working), conceptual models of the system function, testable hypotheses, the development of a sound experimental design, and long-term funding". Having no defined biological goals, or worse, having the goal of meeting "*any biological goals*" and having a "*virtually unlimited number*" of alternatives does not define a proper AIP. Even with a well-formulated AIP, Bennett et al. (2016) cautions that "it will likely take years to decades for such [environmental] responses to unfold". The AIP does not attempt to place a limit on the scope of measures to be tested, nor is there any metrics identified for what constitutes success. All the essential ingredients of an effective AIP are undefined; even the "biological goals" are to be established in the future. Furthermore, it appears the AIP has completely supplanted the Amended Plan, or, in effect, has become the Amended Plan. Endorsing an AIP with a "*virtually unlimited number of possible functional flow regimes*" is a recipe for failure because of the very long timeframes needed for environmental benefits to be confirmed even under a well-defined experimental analysis with carefully defined testable hypothesis and experimental methods. There is no rational basis for concluding that handing a volume of water and a virtually unlimited number of possible trial and error experiments to a Working Group will provide fish and wildlife benefits. To fulfill its regulatory responsibility, the SWB appears to want to rely on an AIP that lacks goals, metrics, decision thresholds, or even a clear statement of what constitutes success or the expected fish and wildlife benefits. The SED's AIP is an example of adopting "adaptive management" in order to avoid making an informed decision on the record because the SWB has not done the necessary serious study to arrive at a well-supported conclusion regarding potential benefits to fish and wildlife resulting from its proposal.

Finding #9: According to the SED's own analysis, the SWB's preferred alternative will have an adverse effect on the fry life stage of Tuolumne River fall-run Chinook salmon, while having no measurable beneficial effect on Tuolumne River juvenile fall-run Chinook salmon.

Summary: The SWB makes it abundantly clear that the primary species of interest and evaluation in the SED is the fall-run Chinook salmon populations of the LSJR and the three eastside tributaries. As discussed in detail in these comments, the SED's preferred alternative would adversely impact the fry life stage of fall-run Chinook salmon on the Tuolumne River when compared to the baseline. The SWB's own analysis demonstrates such adverse effects when one reviews and integrates the information on usable juvenile rearing habitat contained in Tables 7-13b, 7-15b, 7-15d, and total floodplain habitat in Table 19-21 of the SED.

Finding #10: The economic assessment of the SWB's proposal (1) fails to account for any adverse effects on several of the agricultural sectors that are important to the region's economy thereby vastly underestimating economic loss, (2) lacks a rigorous evaluation of the reasonably foreseeable impacts of the state's recent groundwater regulations, and (3) neglects to consider the disproportionate effects of its proposal on disadvantaged and minority populations.

Summary: The SWB fails to include the SED's economic and employment impact on the production of animal commodities, including dairy, cattle and calf operations or impacts to the food and beverage processing industries. During critical water years under the SED's proposal, the Review Team estimates the economic impact would exceed $1 billion, including direct, indirect, and induced impacts. Impacts under sequential critical water years are not evaluated in the SED. The SWB's use of average economic values over multiple water years reveals a fundamental lack of understanding of the nature of the industry it is affecting. This is also depicted by the failure to quantitatively assess the adverse economic impact of the SED's proposal in conjunction with the recently enacted statewide groundwater regulations, even while acknowledging the significance of the state's 2014 Sustainable Groundwater Management Act ("SGMA"). Lastly, the SED's proposal will have a disproportionate impact on the region's disadvantaged and minority populations, an impact the SED neglects to recognize or analyze.

2.0 Comments on the SED's Description of the Tuolumne River Basin

The SED is lacking a thorough description of the current physical characteristics of the areas within the geographic scope of the Amended Plan, especially each of the three eastside tributaries. This would help the public understand the existing environmental conditions of the region, the rivers, and their floodplains. Related specifically to the lower Tuolumne River, this is one of the most studied rivers in California. Well over 200 studies and investigations have been conducted covering virtually every aspect of the lower Tuolumne River. Available data are not limited to studies of fall-run Chinook salmon, but include, for example, investigations of river substrate composition, geomorphology, riparian habitats, floodplain habitat models and assessments, hydrologic studies, predation studies, *O. mykiss* population studies, fall-run Chinook and *O. mykiss* redd surveys, adult fish counting weirs, RST monitoring, instream flow studies, studies of non-native species populations, state-of-the-art thermal capability studies of wild *O. mykiss* juveniles, reservoir temperature profiles, river temperatures based on a network of a dozen in-situ monitors, and multiple computer models depicting the resources of the lower river and the Don Pedro Reservoir, including a state-of-the-art three dimensional ("3-D") reservoir temperature model. While a very small portion of this data is referenced in the SED, there is no evidence that this substantial body of work, representing the best available science for the lower Tuolumne River, was seriously evaluated or considered in any of the various quantitative or qualitative assessments reported to have been performed as part of the development of the SED. This omission has resulted in the SWB reaching misinformed and erroneous conclusions related to factors affecting the fall-run Chinook salmon and *O. mykiss* populations of the Tuolumne River, as discussed further below.

One of the fundamental errors of the SED is the underlying assumption that the three eastside tributaries can be lumped together and treated essentially as a single river presumed to be contributing to the decline of fisheries in the Bay-Delta region. For example, the three tributaries are subjected to the same method of analysis when considering the complex issue of whether greater spring flows will provide "floodplain benefits" for salmon, as if an acre of inundated floodplain in the Tuolumne River would have the same population level effect as an acre of inundated floodplain in the Stanislaus or Merced rivers, or that reducing river temperatures 1°C in each river would produce a "benefit" to that river's fish populations, or that fall-run Chinook salmon population benefits are somehow directly proportional to the size of the river's drainage area. Over the past two decades, a large body of research has consistently demonstrated that every river system is unique. It is only for the sake of convenience that the SWB has treated the three eastside rivers as if they would each deliver their proportionate share of benefits from the same flow prescription. There is little to no evidence presented in the SED that providing 40% of the unimpaired flow from February to June in the Tuolumne River would have similar population-level effects as 40% of the unimpaired flow on either the Merced or the Stanislaus rivers. There is even less evidence for relying on an adaptive implementation plan to produce proportional results. Adopting a one-size-fits-all approach to the analysis of the eastside tributaries runs counter to the current scientific understanding of each river's uniqueness.

Ignoring the large amount of information and data available to the SWB leads, at best, to an incomplete understanding of the Tuolumne River ecosystem, and at worse, to ill-conceived and poorly informed decisions. The SED's analytical approach of relying on general qualitative assessments about the rivers instead of considering and evaluating the hundreds of available site-specific reports can only lead to poorly informed decision making. For example, of the 3,500 pages in the SED, four pages, one plot, and two tables are dedicated to describing the current complex aquatic and associated floodplain environment of the lower Tuolumne River. To compound the problem, much of what is reported in those four pages is either misleading or inaccurate as discussed below.

<u>On page 7-35</u>, the SED reports that the Tuolumne River *"now supports smaller populations of steelhead"*. This is inaccurate and misleading, and needs to be corrected. Although a rearing population of adult-sized *O. mykiss* was quantified during three years of intensive snorkel surveys (2008–2011), other than the occurrence of one steelhead and several resident fish exhibiting maternal anadromy demonstrated in otolith analyses by Zimmerman et al. (2009), there is no indication of a steelhead population on the Tuolumne River. Between 2009 and 2016, a total of five *O. mykiss* presumed to be "steelhead" (that is, greater than 16-inches in size) have been identified in the adult migrant counting weir located at River Mile 24.5. The statement quoted above misleads the public, and perhaps the SWB staff, and can lead to unfounded conclusions related to, for example, temperature requirements for Tuolumne River "steelhead".

<u>On page 7-35,</u> almost immediately after the statement quoted above, the SED goes on to say *"Central Valley steelhead were thought to have been extirpated from the Tuolumne River, but fisheries monitoring for the New Don Pedro Federal Energy Regulatory Commission (FERC) relicensing project have documented the presence of O. mykiss in the Lower Tuolumne River (TID and MID 2012)."* It should be noted that although NMFS considers that resident and

anadromous *O. mykiss* to be Central Valley steelhead under the ESA, there is no evidence of a self-sustaining steelhead population on the Tuolumne River. If every *O. mykiss* were a "steelhead", Central Valley steelhead would not be listed under the ESA because there are many thriving populations of *O. mykiss* in Central Valley streams.

<u>*On page 7-36,*</u> the SED, in describing the fish species found in the Tuolumne River, states *"Nonnative fish species important for sport fisheries include American shad, catfish species, largemouth, smallmouth and striped bass, and sunfish species."* To the best knowledge of the Districts, there are no data available, nor are there any referenced by the SWB, which would support the claim that American shad, catfish, sunfish, or any other non-native fish species are *"important for sport fisheries"* on the Tuolumne River. However, there are data supporting the finding that non-native species are a major cause of mortality to Tuolumne River juvenile fall-run Chinook[7]. It is difficult to understand why the SWB would include an unsupported statement about recreational use of non-native fish in the Tuolumne River but not include a supportable statement about their role in predation, which would seem to be of greater relevance to the purposes of the SED.

<u>*On page 7-36*</u>, it is reported that data collected *"in recent years indicates that returns to the Tuolumne River are dominated by hatchery-origin fish."* In 2011, hatchery-origin fish represented over 70% of the adult fall-run Chinook escapement. The dominance of hatchery-reared fall-run Chinook in the eastside tributaries is a very significant issue. The potential impact on the SED's proposal of such a high percentage of hatchery-origin fish in the Tuolumne River and the other eastside tributaries is never fully explored or evaluated in the SED. Hatchery dominance has the potential to significantly affect the Amended Plan's goal of supporting "natural production" of fall-run Chinook. Appendix A of these comments discusses the potential effects of hatchery-origin salmon on the genetics, ecology, and population viability of naturally-spawning fall-run Chinook salmon in the Tuolumne River and the San Joaquin River basin.

<u>*On page 7-37*</u>, the SED properly discloses that the *"historical distribution of steelhead in the SJR Basin, including the Tuolumne River, is poorly known".* However, this is a bit of an understatement given there is no evidence of a self-sustaining steelhead population on the Tuolumne River, as we have previously commented. Steelhead populations are known to potentially exhibit unique life stage characteristics; therefore, trying to accurately predict the behavior of steelhead on the Tuolumne River is problematic. However, in Chapter 18, the SWB feels sufficiently confident in its knowledge of "steelhead populations" that it asserts that the SED's preferred alternative *"would substantially improve rearing habitat conditions for ... steelhead in the three eastside streams and LSJR. Considering the overall beneficial effects of higher flows on rearing habitat availability, no significant adverse impacts on … steelhead populations would occur."* There is no scientific data or evidence provided in the SED examining variations in current *O. mykiss* population levels nor any site-specific sampling results that could be used to determine variations in resident and anadromous *O. mykiss* life history in response to flow and temperature conditions.

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[7] The TID/MID final Predation Study on the Tuolumne River was filed with FERC as part of the April 2014 Final License Application on the Don Pedro Hydroelectric Project (see Appendix G of these comments).

On page 7-37, the SED finally begins to reveal an accurate assessment of the existing conditions on the Tuolumne River. Here, the SED acknowledges the history of anthropogenic disruption to the lower river and its effects on the current riverscape:

> *"During the early twentieth century, the Tuolumne River channel and floodplain were dredged for gold. The gold dredges excavated channel and floodplain deposits to the depth of bedrock (approximately 25 ft [7.6 m]) and often realigned the river channel. Due to gravel mining activities, the channel has become constrained by dredge tailings, which restricts channel meander and reduces delivery of gravel to the river. Riparian vegetation is also scarce due to dredge tailings. By the end of the gold mining era, the floodplain adjacent to 12.5 miles (20 km) of the river (RM 50.5–38) had been converted to tailings deposits. Tailings remain in the reach from RM 45.4–40.3 (Stillwater Sciences n.d.). Additionally, pits were made in the channel that provide habitat for largemouth bass and other predatory fish species. Land clearing for gold dredging, aggregate mining, and agricultural and urban development has resulted in the loss of 85 percent of the Tuolumne River's historical riparian forest. Vegetation that once extended from bluff to bluff prior to the Gold Rush is now confined to a narrow band along the active channel margins in many areas, or is nonexistent. Nearly all of the areas in the gravel-bedded zone that historically supported riparian forests have been mined, grazed, or farmed (Stillwater Sciences n.d.)."*

Given the vast scale and scope of these significant historical environmental impacts to the lower Tuolumne River, there is no scientific basis to assume that flow alone could be some "master variable" that will solve the legacy and lingering impacts to the river. This description of the condition of the Tuolumne River is reason enough for the SWB to question the assumption that the highly modified and disrupted floodplains along the river would provide suitable habitat for fry or juvenile fall-run Chinook salmon. Yet the SED assumes, without citing a single source of site-specific evidence, that every acre of this highly disrupted floodplain, once inundated, would be suitable fish habitat and would provide an abundant supply of food for these fish. By the same token, there is no scientific evidence provided in the SED which suggests that non-native predators inhabiting the large and deep pools formed by the in-channel mining would be displaced downstream by higher flows. The SED offers general, qualitative assessments of effects of flows to an imagined river environment, not reflective of the real site-specific conditions existing on the river.

On page 7-38, the SED posits that a lack of site-specific data and analysis is no reason to qualify or limit what conclusions can reasonably be drawn on the Tuolumne River:

> *"Although specific food web studies have not been conducted in the Tuolumne River, current research indicates that regulated flows downstream of dams and losses of overbank flooding have likely contributed to historical declines and current limitations on native fish populations through reductions in primary and secondary production (phytoplankton and invertebrate production) associated with seasonal floodplain inundation (Sommer et al. 2004; Ahearn et al. 2006)."*

In this example, the SWB states that, to its knowledge, there are no *"food web studies"* available on the Tuolumne River. So the SWB cites the work of Sommer et al. (2004) conducted on the Yolo Bypass in the northwest Delta to draw its conclusions about food availability on the Tuolumne River floodplains. Further below in these comments, we explain the lack of any similarity between the 60,000 acre Yolo Bypass floodplain and the 600 acre, heavily-disturbed Tuolumne River floodplain. Suffice it to say here, especially given the SED's own description of the Tuolumne floodplain on the immediate prior page, the two floodplains are not comparable in any respect. However, the larger problem here is that the reference to *"current research"* relating to *"historical declines and current limitations on native fish"* is implied to be a finding of Sommer et al. (2004). This is not the case, and misrepresents the Sommer et al. (2004) work. One can find no such direct conclusion in the Sommer et al. (2004) report. The SWB is also incorrect in reporting the findings of Sommer et al. (2004) related to invertebrate production. The published report on the Yolo Bypass actually indicates that "no major differences were observed in zooplankton densities between the river and its floodplain", which were reported by Sommer et al. (2004) to be similar to the findings of Speas (2000). Zooplankton are invertebrates, so the SWB's attribution to Sommer et al. (2004) of a finding related to invertebrate production in general should be appropriately qualified.

More importantly, but not helpful to the SED, the purpose of the Sommer et al. (2004) study "was to examine how variation in hydrology affected several food-web organisms of a large temperate river-floodplain." These food-web organisms are the food source for fish which are needed to promote the growth of juvenile salmon. Instead of using a floodplain's inundated acreage as indicative of suitable habitat, as is done in the SED, Sommer et al. (2004) analyzed a number of factors known to affect the amount of suitable fish habitat on a floodplain, including water depth, velocity, and hydraulic residence time, not simply inundated surface area. Sommer et al. (2004) recognizes that wetted surface area alone is not an acceptable measure of usable habitat. Therefore, the SWB's own citation used to support its case would in fact suggest strongly that such a simplified view of "floodplain habitat" is unfounded.

Another observation based on the work conducted on the Yolo Bypass, as reported in Sommer et al. (2001), again not helpful to the SED, was the link found between higher temperatures and the greater growth of salmon juveniles on the floodplain when compared to the adjacent Sacramento River. As reported in Sommer et al. (2001), temperatures observed on the floodplain were up to 5°C higher than the adjacent river. Sommer et al. (2001) reports "[a]pparent growth differences between the two areas [Sacramento River channel and floodplain] are consistent with water temperatures and stomach-content results. We found that the Yolo Bypass floodplain had significantly higher water temperatures and that young salmon from the floodplain ate significantly more prey than those from the Sacramento River". Further, Sommer et al. (2001) reported the prey availability in Yolo Bypass was sufficient to offset increased metabolic requirements from higher water temperatures. The various studies of the Yolo Bypass suggest that greater growth of juvenile salmon resulting from floodplain access is due to *both* increased temperatures on the floodplain compared to the adjacent river and substantial food availability. Temperature data collected on the Tuolumne River floodplain has shown no difference between river temperatures and floodplain temperatures during rearing periods of fry and juveniles (Stillwater Sciences 2012). Furthermore, the SWB presents no information or data on food availability on the Tuolumne River floodplain, or any other floodplain in the geographic area covered in the SED.

Ahearn et al. (2006) is also unsupportive of the SWB's assumptions about the floodplains of the eastside tributaries. Ahearn et al. (2006) investigated floodplain food sources on the Cosumnes River. One of the key findings reported by Ahearn et al. (2006) was:

> *"The degree of [floodplain] complexity revealed in this analysis makes clear the need for high resolution spatial and temporal studies such as this to begin to understand the functioning of dynamic and heterogeneous floodplain ecosystems."*

The SED's analysis of the Tuolumne River floodplain, or any of the floodplains in the project area, falls far short of the type of scientific analysis the SWB's own citations suggest would be needed in order to conclude that the SED's preferred alternative would benefit fall-run Chinook salmon as a result of floodplain inundation. Instead of supporting the analysis performed by the SWB, both Sommer et al. (2004) and Ahearn et al. (2006) can only be interpreted as indicating the significant shortcomings of the SWB's methods. Section 5.0 below and Appendix A of these comments provide a detailed critique of the SWB's assessment of the Tuolumne River floodplains.

On page 7-39, on the topic of "Disease", the SED states the following:

> *"Fish species on the Tuolumne River are susceptible to similar diseases as those discussed for fish in the Stanislaus River. The causative agent of BKD was detected in naturally produced juveniles caught in rotary screw traps from Tuolumne River (Nichols and Foott 2002)."*

Contrary to what the SED implies related to disease, Nichols and Foott (2002) report that no *"gross clinical signs of Bacterial Kidney Disease (BKD) were seen in any of the fish examined",* including those in the Tuolumne River. Further, but not reported in the SED, of 18 Tuolumne River fish also sampled as part of the referenced study, Nichols and Foott (2002) reported only a single incidence of *T. bryosalmonae*, the causative agent of Proliferative Kidney Disease (PKD) and this one was at the "Early" stage, meaning few parasites and no sign of significant inflammatory response. No incidence of PKD was found. For some reason, the SED did not cite the most recent study of disease on the Tuolumne River reported in December 2013 by the US Fish and Wildlife ("USFWS"). In summary, the 2013 study found no pathogens or infections in any of the Tuolumne River fish.

Overall, the SED fails to provide a thorough description of the actual physical environment and ecology of the lower Tuolumne River using the site-specific data that is readily available. Where such site-specific data is not used, the SED needs to appropriately qualify its conclusions. If the SWB had considered even a portion of the extensive site-specific data available on the Tuolumne River, including studies of invertebrate food supply (e.g., TID/MID 1997, Report 96-4; TID/MID 2003, Report 2002-8) as well as food ration studies (TID/MID 1992, Appendix 16;

TID/MID 1997, Report 96-9), floodplain studies (HDR and Stillwater 2017[8]), annual seine results since 2001 (e.g., TID/MID 2016, Report 2015-3), annual rotary screw trapping results since 2006 (e.g., TID/MID 2016, Report 2015-4), intensive *O. mykiss* population estimate (Stillwater Sciences. 2008, 2009, 2011) and annual snorkeling studies since 2001 (e.g. TID/MID 2016, Report 2015-5), predation studies (TID/MID 1992, Appendix 22; FishBio 2013), as well as spawning gravel availability studies (McBain and Trush 2004; Stillwater Sciences 2013b), to name but a few, the SWB would find that in-channel spawning and rearing habitat, and high quality food resources, are abundant in the Tuolumne River, and that floodplain access is already provided at an annual recurrence interval supportive of viable salmon populations (Matella and Merenlender 2014). In fact, the SED does not present any evidence that the current baseline conditions on the Tuolumne River do not fully support the life stages of fall-run Chinook salmon. The SWB adopts the presumption of conditions needing to be improved without demonstrating with scientific, site-specific data that this is the case.

3.0 Comments on Hydrology, Unimpaired Flow, and Related Adverse Impacts on Fry and Juvenile Fall-Run Chinook Salmon

Chapter 19 of the SED is entitled *Analyses of Benefits to Native Fish Populations from Increased Flow between February 1 and June 30.* On page 19-2, the SWB summarizes its key findings contained in Chapter 19:

> *"The results of the temperature, floodplain, and SalSim analysis presented in this chapter indicate that as the percentage of unimpaired flow is increased during the February through June time period, the flow related benefits to salmon and steelhead also increase. Improving flows that mimic the natural hydrographic conditions including related temperature and floodplain regimes to which native fish species are adapted, are expected to provide many juvenile salmonids with additional space, time, and food resources which are necessary for required growth, development, and survival."*

Chapter 19 is intended to be the technical and scientific core of the SED. Its purpose is to describe the work performed which led the SWB to select the preferred alternative for future instream flows in the eastside tributaries to be 30% to 50% of the unimpaired flow from February through June[9]. In the beginning section, 19.1**,** it is asserted that Chapter 19 will present the "*measurable benefits of providing higher and **more variable** flow during the February 1 through June 30 time period."* [emphasis added]. These "measurable benefits" are said to be quantitatively demonstrated by analysis of "*temperature and floodplain habitat*" and the fish "*population level changes that could be expected under a variety of unimpaired flow scenarios.*" The initial section goes on to state without qualification *"[t]he results of the temperature, floodplain, and SalSim (fish population) analysis presented in this chapter indicate that as the percentage of unimpaired flow is increased during the February through June time period, the flow related benefits to salmon and steelhead also increase."* And, further still, that

[8] A final draft of this report was issued to resource agencies for review and comment in September 2014. Comments were received from USFWS and responded to in the final report (2017). There were no substantive changes to the findings or conclusions of the draft report.
[9] The preferred alternative also includes adaptive implementation, as do all the alternatives considered in the SED, except the baseline alternative.

these "measurable benefits" will be the result of *"improving flows that mimic the natural hydrographic conditions including related temperature and floodplain regimes to which native fish species are adapted"*. To address a serious shortcoming of its earlier 2012 draft of the SED, Chapter 19 is intended to supplement the prior work by *"quantitatively evaluating the benefits of this project in terms of potentially available cold water and floodplain habitats, and* ***associated population implications*** *to native salmonids"* (page 19-2). [emphasis added].

Not a single one of the stated purposes of Chapter 19 is fulfilled in the SED. In fact, the SWB has not only failed to demonstrate any scientifically valid population-level benefits resulting from the preferred alternative, its own analysis can be shown to support the opposite finding. As will be shown throughout the comments provided in this review document, and based on the over 200 site-specific studies performed on the Tuolumne River since the early 1990s, which have been largely ignored in the SED, the SWB's preferred alternative is as likely, if not more likely, to have an adverse effect than a beneficial effect on fall-run Chinook salmon and *O. mykiss* populations in the Tuolumne River.

Section 19.1 of the SED closes with this assertion: *"Analyses of historical abundance (of fall-run Chinook salmon) indicate that late winter and spring flows (February through June) in the tributaries and mainstem SJR have had a strong influence on survival and abundance of SJR Basin salmon since records began in the 1940s or 1950s (Figure 19-2; and CDFG 2005a; Mesick and Marston 2007; Mesick et al. 2007; Mesick 2009; Sturrock et al. 2015)."* SWB's reliance on these figures and citations for its conclusion is misplaced.

On page 19-3, the SWB presents Figure 19-1 which purports to show that the Tuolumne River has had significant "reductions in the *natural production* of adult fall-run Chinook salmon" [emphasis added] when compared to other Central Valley tributaries. As a first matter, the plot should be extended to 2015. But more importantly, the SED is deficient because it lacks any analysis of the past and present adverse effects of hatchery practices and releases on "natural production". The SED should describe the very significant statistical uncertainties associated with estimates of "natural production" dating back to 1967, a time period lacking consistent and reliable data on the large numbers of unmarked hatchery releases to Central Valley rivers (Newman and Hankin 2004). A thorough discussion of the various hatchery practices over the subject time period and the challenges this introduces for interpreting this figure is necessary to properly understand the limited significance of Figure 19-1. To the extent that Figure 19-1 means anything at all due to the large statistical uncertainties, the figure may be more indicative of the displacement of natural production that has occurred on the Tuolumne River due to hatchery fish. In fact, the SED lacks a comprehensive discussion and analysis of the adverse effects hatchery practices and releases have had on the native Tuolumne River fall-run Chinook population, effects which are likely to continue with or without adoption of the SED preferred alternative.[10] The distinct possibility that hatchery practices and influences could negate the assumed benefits to be provided by the SED is never seriously considered or discussed in the SED. There is no analysis provided in the SED to support the SWB's conclusion that additional instream flows will have a positive effect on fall-run Chinook natural production given the current levels of hatchery fish in the three eastside tributaries. To justify the need for 300,000

[10] "Appendix A to these comments provide a thorough discussion of the effects of historical and current hatchery practices and releases and their potential impact on the SWB's proposal."

acre-feet of additional instream flows to the LSJR, the SWB must provide the scientific basis for its supposition that hatchery dominance of the adult escapement would not continue indefinitely.

Appendix C of the SED (page 3-42) acknowledges that "*fall-run Chinook salmon and other salmon hatcheries have unintentionally caused a reduction of genetic variability within the species by altering the genetic makeup of native salmon due to interbreeding with stocked strains of salmon. In addition, the greater quantity of hatchery fish within the river system has caused* ***declines in native salmon****, and further reduced the* ***genetic viability of naturally produced strains*** *due to predation and competition for spawning grounds, food, and space."* [emphasis added]. The adverse effects of hatchery fish on native salmon is also acknowledged in Chapter 7 when the SED states that the "*federal status of fall-run Chinook salmon is due in part to concerns regarding hatchery influence*." In Chapter 7 of the SED, hatcheries are discussed more in the context of how the SED's proposal might affect hatchery reared fish. But this entirely misses the real issue, which is the effects of hatchery practices on the SED's proposal. Hatchery-reared fish are reported in the SED to make up approximately 80%, 75%, and 90% of the fall-run Chinook populations in the Stanislaus, Tuolumne and Merced rivers, respectfully, as measured in the 2011 escapement, the latest figures available. There is not any scientific analysis or evidence in the SED to demonstrate that the SWB's preferred alternative would overcome, eliminate, or even reduce these adverse effects on natural production. The fall-run Chinook salmon adult populations of all three of the eastside tributaries are dominated by hatchery fish. The SED lacks the necessary showing that the preferred alternative would reduce the dominance of hatchery fish in the LSJR. Since the goal of the SED is to improve "natural production", a critical analysis of how the SED would achieve this goal in light of the current dominance of hatchery fish is essential. Failure to provide this critical analysis and thereby ignoring the ongoing and future role of hatchery practices is a serious omission in the SED.

Immediately following Figure 19-1, the SED includes Figure 19-2 which is purported to show for the years 1952 to 2014 a relationship between the historical "adult abundance" of SJR fall-run Chinook salmon and SJR flows during February to June occurring 2.5 years prior when these adult fish were juveniles. While there does appear to be a relationship between historical LSJR tributary escapement estimates and time-lagged spring outflow, this relationship has grown weak in recent years due in part to hatchery releases, predation effects in the Delta, as well as changes in ocean conditions, to name a few. For example, on the Tuolumne River, 48% of the variation in escapement is explained by annual discharge three years earlier on the Tuolumne River from 1971–2013 (see Figure TR-1 below). Interestingly, however, since implementation of increased outmigration flows on the Tuolumne River since 1996 (see Figure TR-2 below), the escapement vs "lagged flow" relationship from 1997-2013 explains only 26% of annual escapement. This suggests that recent increases in spring pulse flows under the FERC process as well as the Vernalis Adaptive Management Program (VAMP) have coincided with a declining and weakening relationship between tributary spring flows and subsequent escapement.

Similar data exploration for the Stanislaus River shows the relationship between lagged discharge since the completion of New Melones Dam (ca 1978) explains only 33% of the long term escapement since 1980 (see Figure TR-3 below). More recently, however, even with the large flow increases coinciding with the implementation of the Vernalis Adaptive Management

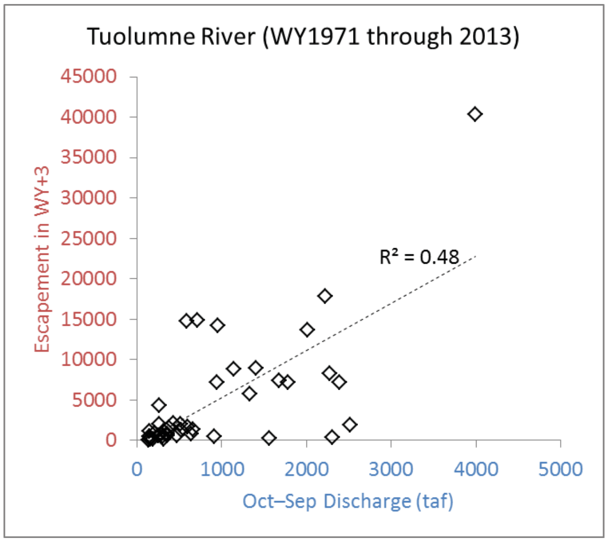

Figure TR-1. Plot of Tuolumne River escapement vs Water Year flow for the Period 1971 to 2013.

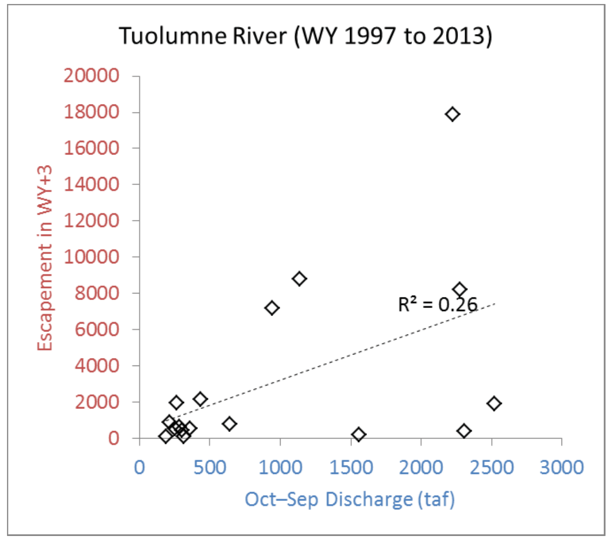

Figure TR-2. Plot of Tuolumne River escapement vs Water Year flow for the Period 1997 to 2013.

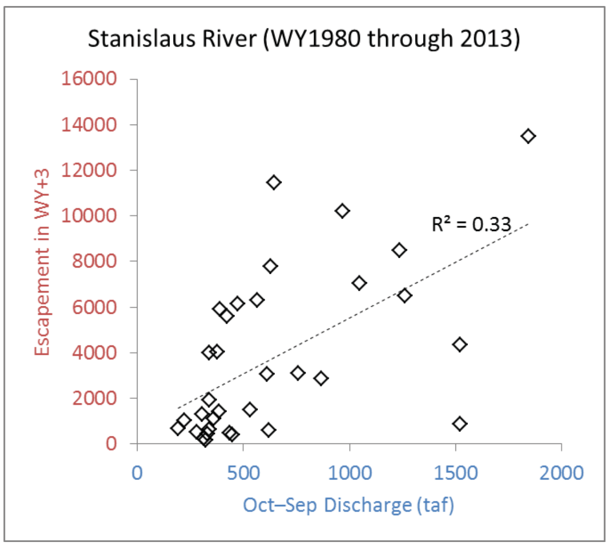

Figure TR-3. Plot of Stanislaus River escapement vs Water Year flow from 1980 to 2013.

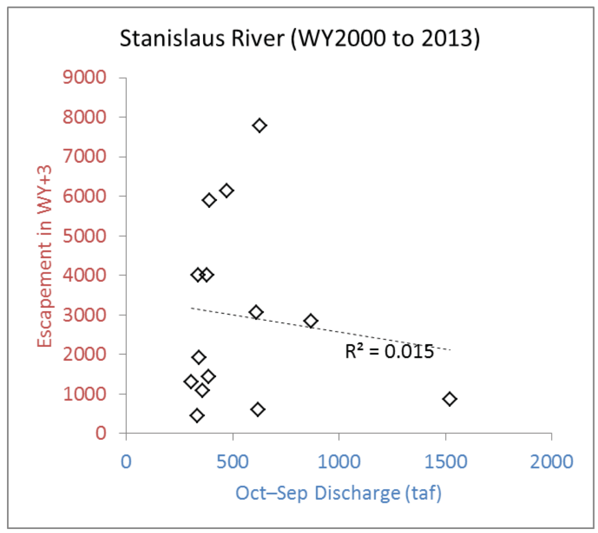

Figure TR-4. Plot of Stanislaus River escapement vs Water Year flow from 2000 to 2013.

Plan (VAMP) in 2000 as well as more recent flow increases as a result of the Central Valley Project/State Water Project Biological Opinions (BiOps) in 2010, lagged discharge now has no relationship ($p=0.68$, $R^2=0.015$) with recent escapement on the Stanislaus River (i.e., does not explain any of the variation).

As seen in Figure TR-4 above, the relationship between Stanislaus River annual discharge and subsequent Chinook salmon escapement (t+3 yrs) is no longer apparent since adoption of increased spring pulse flows under VAMP (2000) and further increases with implementation of the CVP/SWP BiOps (2010).

It must be acknowledged that the effect of high flows is not consistently observed in the LSJR tributaries and that a number of confounding influences other than spring outflow have diminished or even eliminated the purported benefits of the SED flow proposals. As one example, and as briefly mentioned above, the hatchery practices, number of released hatchery fish, and locations of releases varied widely throughout this period. The potential effect of these highly varied hatchery practices on "historical abundance" is not accounted for in Figure 19-2 of the SED. Another example is the effect of changing ocean conditions on adult salmon survival. Only relatively recently has it been recognized that varying ocean conditions can be a major factor affecting adult salmon returns. The SED's Appendix C itself contains numerous references to the potential effects of changing ocean conditions on adult returns, yet these effects are not discussed when the SWB interprets Figure 19-2 as supporting its hypothesis of the relationship between unimpaired flows and adult returns. The expert peer review of the SWB's 2010 draft Technical Report on the Scientific Basis for Alternative San Joaquin River Flow and Southern Delta Salinity Objectives conducted by the University of Washington's Thomas Quinn, properly captures the role of ocean conditions:

> *"This text* [in the SWB's draft Technical Report] *(which would benefit from basic references such as Hilborn et al. 2003 for sockeye salmon, and the more recent papers by Moore and by Carlson on salmon in areas more extensively affected by humans) is fine but the reference to variable ocean conditions and marine survival seems to contradict the earlier statements that only smolt number going to sea really matter. Overall, I think this holistic view is more tenable than one only emphasizing the link between flow and smolt production."* (see page 12 of Quinn's review in the SED).

Therefore, while Figure 19-2 does provide a plot of flows and adult returns to the SJR, it must be acknowledged that a significant and variable portion of the adult returns over time have consisted of hatchery releases. Since hatchery releases are predominantly smolts which are normally released from the hatcheries in mid-to-late April or May, flows that occurred in February through mid-April would have no effect on these fish. Furthermore, the SWB does not appear to account for the number of hatchery strays into the three eastside tributaries which can be significant and likely vary from year to year. For the Tuolumne River where a salmon counting weir has been in place since 2009, as much as 80% of the adult escapement has consisted of hatchery strays from the Merced, Mokelumne, and Coleman hatcheries. These numbers are readily available to the SWB.

Of the five individual papers cited in Section 19-1 of the SED to support the SWB's hypothesis of a relationship between February through June flows and adult abundance (*CDFG 2005a; Mesick and Marston 2007; Mesick et al. 2007; Mesick 2009; Sturrock et al. 2015)*, **not one** of these papers concludes that 40% of the unimpaired flow from February to June would lead to improved salmon populations in the LSJR.

One additional aspect of Figures 19-1 and 19-2 is worthy of note. Later in Chapter 19, on page 19-85, when explaining the apparent limits of the SalSim model to predict the low "adult production" during years 2005 – 2009 (more on this further below), the SWB makes specific mention of "ocean crash" being the cause of low returns in these years. However, there is no similar cautionary mention of this phenomena when describing Figure 19-1, and only adult returns in 2007 are mentioned as being affected in Figure 19-2. It is worth noting NMFS, the agency responsible for monitoring relevant ocean conditions, did not regularly assess ocean productivity until very recently and it is very possible, even likely, that ocean conditions affected "adult production" to an unknown degree in many of the years covered by this plot. The SWB's interpretation of Figures 19-1 and 19-2 is misinformed due to the lack of consideration of the many confounding factors and uncertainties in the underlying data.

Beginning with the SED's basic "Problem Statement" provided in Section 19.1.1, the overall structure of Chapter 19 reveals the thought process used by the SWB in the formulation and development of its preferred alternative. The chapter first asserts as a statement of accepted fact, instead of a scientific hypothesis to be rigorously examined, that *"a more natural flow regime from the salmon bearing tributaries (Stanislaus, Tuolumne, and Merced Rivers) is needed during the February through June time frame"* (see page 19-4). Subsequent sections of Chapter 19 are then intended to describe and display the quantitative analyses that provide the technical support for the prior assertion. This method of resource planning where a hypothesis is accepted as a matter of settled fact, then attempted to be justified by subsequent analysis often fails to achieve the hoped-for benefits when implemented. Having the "solution" precede any rigorous scientific, technical, or biological evaluation often results in the subsequent evaluations being analyzed and presented in a manner that supports the "solution" and, to the extent that data or analyses are not supportive, the non-conforming data or analyses are discarded, discredited, unreported, or rationalized away. As we discuss below, this does seem to be the case with the SED, where only data that provide support for the SWB's "solution" are considered as valid and data not helpful are disregarded, discredited, or not mentioned at all.

3.1 Discussion of Unimpaired Flow and the Natural Flow Regime of the LSJR

The first technical section of Chapter 19 presents the SWB's most basic underlying scientific rationale for the preferred alternative. Section 19.1 is entitled *"Importance of a Natural Flow Regime"*. The SWB's entire supposition as to the need for a percent of unimpaired from February to June and why this flow will deliver significant benefits to fish and wildlife is summed up succinctly when the SED states the following:

> *"Using a river's unaltered hydrographic conditions as a foundation for determining ecosystem flow requirements is well supported by scientific literature (Poff et al. 1997; Tennant 1976; Orth and Maughan 1981; Marchetti and Moyle 2001; Mazvimavi et al. 2007; Moyle et al. 2011). In addition, major regulatory programs in Texas, Florida, Australia and South Africa have developed flow prescriptions based on unimpaired hydrographic conditions in order to enhance or protect aquatic ecosystems (Arthington et al. 1992; Arthington et al. 2004; NRDC 2005; Florida Administrative Code 2010), and the World Bank now uses a framework for ecosystem flows based on the unaltered quality, quantity, and timing of water flows (Hirji and Davis 2009)."*

Returning the LSJR, and the eastside tributaries, to a flow condition that mimics their "natural flow regime" is, in essence, the underlying basis for the Amended Plan's alternatives. As stated herein previously, the "settled fact" of the need for a "natural flow regime" is taken as a given based on reference to various literature sources which speak to the importance of restoring a river's unaltered hydrographic conditions. Subsequent sections of the SED's Chapter 19 attempt to support this assertion. Relying on this list of citations, many of which are either theoretical or involve river systems not remotely like the three eastside tributaries, the SED goes on to conclude that its preferred alternative of requiring each tributary to release 30% to 50% of the unimpaired flow from February 1 to June 30 will benefit fish and wildlife:

> *"The current updates to the Bay-Delta Plan include improving flow conditions during the February through June time period so that they more closely mimic the natural hydrographic conditions to which native fish species are adapted, including the relative magnitude, duration, timing, and spatial extent of flows as they would naturally occur."*

The SED's supposition that the preferred alternative will result in significant improvements to fish and wildlife suffers from a fundamental flaw:

- While the citations do generally refer to the potential value of having flows mimic unaltered "natural hydrographic conditions", "unimpaired flows" as defined in and by the SED do not depict the natural, unaltered flow regime of the eastside tributaries or the LSJR. The "unimpaired flows" developed and relied upon by the SWB in the SED are a human invention and have never actually occurred in the LSJR or its contributing tributaries at their confluence with the LSJR; therefore, migrating salmon and steelhead could never have become "adapted" to the SED's "unimpaired flow regime".
- None of the referenced citations endorse adoption of the "unimpaired flow" regime as defined in the SED and some could as readily be read to argue against it.

Table TR-1[11] (see Attachment 1 of these comments) contains a summary of the citations relied upon by the SWB to support its conclusion that simply providing a percentage of "unimpaired flow" from the three eastside tributaries will result in significant improvements to the fish and wildlife of the Bay-Delta.[12] The primary cited reference is Poff et al. (1997), which is also liberally cited in the other referenced literature. Poff et al. (1997) contends that successful river basin ecological restoration must begin with understanding and mimicking a river's natural flow regime. Poff et al. (1997), as do most of the citations to the extent they discuss a natural flow regime at all (see Table TR-1), defines a natural flow regime as one that is ***"unaltered by human intervention".*** The SWB itself makes it abundantly clear throughout the SED that the "unimpaired" flow regime concept it employs is specifically ***not one*** that is unaltered by human intervention. The SED frequently acknowledges that *unimpaired* flows are not equal to, nor do they represent the natural, unaltered hydrology of the LSJR or its tributaries. On the first page of Chapter 19, the SED states via footnote:

[11] Tables and figures not embedded in the text are provided at the end of these comments. For Table TR-1, see Attachment 1.

[12] The tributaries to the LSJR as referenced in the SED are the Stanislaus, Tuolumne, and Merced rivers (the three eastside tributaries) and the upper San Joaquin River (USJR). According to Table 2-1 of Chapter 2, the drainage area of the USJR is given as 1,675 mi^2, while Table 2-1 of Appendix C lists the drainage area size of the USJR as 5,813 mi^2. The drainage area of the LSJR above the Vernalis gage is listed by the USGS as 13,539 mi^2 (https://pubs.usgs.gov/of/2004/1015). Therefore, the SED's unimpaired flow estimates of the LSJR at Vernalis given in Table 2-24 appear to be missing estimates of unimpaired flow from over 7,000 mi^2, or 50%, of the contributing drainage area to the LSJR at Vernalis.

> "*Unimpaired flow represents the water production of a river basin, unaltered by upstream diversions, storage, or by export or import of water to or from other watersheds.* ***It differs from natural flow because*** *unimpaired flow is the flow that occurs at a specific location under the current configuration of channels, levees, floodplain, wetlands, deforestation and urbanization."* [emphasis added]

On page 4 of the Executive Summary, the SED states with great clarity:

> *"The State Water Board does not propose to revert to natural flows. Though unimpaired flow is not the same as natural flow, it is nevertheless reflective of the frequency, timing, magnitude, and duration of the natural flows to which fish and wildlife have adapted and have become dependent upon."*

The SED acknowledges that the "unimpaired" flows it proposes do not represent the pre-development, unaltered, natural flow regime of the LSJR. It is the unaltered, natural flow regime to which native fish of the LSJR and tributaries over the centuries would have become adapted. Native fish could not possibly be adapted to "unimpaired flows" because the SED's unimpaired flows are a human invention and have never actually occurred, so it is impossible that these species would be somehow "adapted" to a flow regime that never existed in the LSJR or lower reaches of the three eastside tributaries. This basic fact undermines the SED's most fundamental underlying principle. As an indication of the degree of significance of this issue to the scientific underpinnings of the SED, the SWB, recognizing the problem presented by this logical and technical flaw, finds it necessary to declare in Appendix C of the SED the following:

> *"For the purposes of this report, a more natural flow regime is defined as a flow regime that more closely mimics the shape of the unimpaired hydrograph."*

With this single sentence, the SWB now declares that it is no longer the unimpaired flow regime that supposedly mimics the natural flow regime, but it is the natural flow regime, by definition of the SWB, that mimics the unimpaired flow regime. That the SWB has to depend on such distortion only serves to reveal the weakness of the SED's fundamental assertions. The SWB finds this necessary because it is evident that the SED's unimpaired flows are not the natural flow regime to which the native fish are adapted.

Even if we overlook this fundamental flaw (that is, "unimpaired flows" do not represent the natural, unaltered flow regimes to which LSJR fisheries are adapted), the stated goal of the SED is to provide an unimpaired flow regime in the *lower San Joaquin River* to benefit the Bay-Delta fisheries and ecology. One does not need to be an expert in hydrology, biology or engineering to readily understand that if you eliminate from consideration a large portion of the watershed that contributes to the lower San Joaquin River flows, as the SWB has done, river flows from the remaining portion cannot possibly represent either the natural or even the unimpaired flow regime of the LSJR. The SED only requires flows from the three eastside tributaries, but the largest of all the tributaries to the LSJR – the upper San Joaquin River – is not required to contribute essentially any water to the river as measured at the Vernalis USGS gage. The SED's goal is to improve the fish and wildlife of the San Francisco Bay-Delta. The lower San Joaquin River enters the Delta from the south and Vernalis is identified in the SED as the measuring point for flow to the Delta from the LSJR. The total watershed of the San Joaquin River above the USGS gage at Vernalis is approximately 13,500 square miles (mi^2). The three eastside tributaries combined have a watershed of 4,335 mi^2. The three tributaries thereby account for only 32% of the watershed. It is therefore physically impossible for the three tributaries to provide or mimic the "unaltered, natural flow regime" or the "unimpaired flow" of the SJR at Vernalis. Furthermore, for some reason unexplained by the SWB, the SED omits from consideration in this SED two other significant eastside tributaries to the LSJR's inflow to the Delta – the Mokelumne and Calaveras rivers -- with a total combined watershed of 2,200 mi^2, a drainage area only slightly smaller than the combined area of the Merced and Stanislaus watersheds (2,465 mi^2).[13]

The SWB misrepresents the size of the watershed upstream of the confluence of the Merced and San Joaquin rivers. In Chapter 2-1 of the SED, a chapter entitled *"Water Resources"*, the SWB reports that the size of the upper San Joaquin River as 1,675 mi^2. Including the three eastside tributaries which are the subject of the SED, these four "tributaries" to the LSJR at Vernalis only account for 6,010 mi^2 of watershed. It therefore appears that the SED's analysis of the LSJR's unimpaired flows do not include the contribution of 7,490 mi^2 (55%) of the watershed above the LSJR at Vernalis (13,500 mi^2 – 6,010 mi^2). Suffice it to say that omitting 55% of the contributing drainage area to the LSJR may result in significantly underestimating the unimpaired flows as provided in Table 2-24, much less the "natural flows" to which the fish are adapted. This results in the reporting of misleading, and erroneous "unimpaired" flows to the Delta from the LSJR. Other portions of the SED readily cite that the natural hydrology of the lower-lying LSJR drainage areas would contribute significant flow to the San Joaquin River in the December through April periods, periods that are in the core of the February through June flow period underlying the Amended Plan's preferred alternative.

It is evident that the SWB acknowledges its "unimpaired flows" do not represent unaltered, natural flows and, further, the SWB acknowledges that natural flows, not unimpaired flows, are the flows to which native fish species would be adapted. In addition, the unimpaired flow values, as presented in the SED, do not represent the historical, unaltered, natural flow regime of the LSJR because the SWB estimates of unimpaired flow exclude a large portion of the watershed above the Vernalis measuring point. The SWB's unimpaired flow values do not include or account for the effects of alterations to the natural flow regime caused by human modifications to the river's floodplains, agricultural development, filling of wetlands, construction of levees for flood protection, stream channel modification, in-river and floodplain mining of gravels, deforestation, urbanization, or the loss of the native riparian and overbank vegetation. Basic textbooks on hydrology make it clear that each of these development factors may modify the natural flow regime.

None of the many citations that are referenced by the SWB in Chapter 19, Section 19.2 *"Importance of a Natural Flow Regime"* define the natural flow regime in a manner consistent with the "unimpaired flow" regime defined by the SWB. The overwhelming majority of the

[13]The SED reports that these two watershed contributing flows to the LSJR will be considered in a future proceeding. However, the scientific basis for excluding these prominent tributaries to the lower San Joaquin River from the current SED scope is not explained.

citations in Chapter 19 as well as in Appendix C, Section 3.7, including the much cited Poff et al. (1997), define the natural flow regime, the regime native fish are ecologically adapted to, as being that which is "unaltered by human activity". Historically, the lower valley segments of the eastside tributaries, each being some 50-miles long and more than a mile wide at their confluence, significantly affected the flow regime of the tributary as it entered the San Joaquin River and then contributed to Delta inflow. Another of the prominent references cited by the SWB was the Florida everglades restoration. As referenced in the South Florida Water Management District report of 2007 (SFWMD 2007), the Comprehensive Everglades Restoration Plan ("CERP") relied upon developing an understanding of flow regime of the south Florida region which existed *prior to* human development, disturbance, and drainage activities. The SWB's "unimpaired flows" do not exclude the effects of development, disturbance, and floodplain modifications, and therefore, cannot represent the natural flow regime.

The SWB also references Sparks (1995) to support the contention of the need for "unimpaired" flows to aid LSJR fish and wildlife. However, Sparks (1995) specifically notes that *"small, weirs, barrages, causeways, levees, and river training structures may be no less influential than dams, by virtue of their numbers and ubiquity. Their effects (on the natural flow regime) are compounded by offstream storages, selective manipulation of tributary flows, and interbasin transfers, such that the cumulative effects may represent a far more extensive level of regulation than that suggested by dams alone."* The many referenced citations do more to refute than support the SWB's claims that "unimpaired" flows, as defined by the SED, mimic a natural flow regime.

The SWB does not explain why it failed to estimate the natural flow regime of the San Joaquin River after repeatedly citing its importance. Fortunately for the SWB just such a study was completed for the entire Sacramento-San Joaquin basin and published in a well-respected scientific journal in October 2015. The professional international journal Hydrology and Earth Systems Sciences published a study entitled "*Reconstructing the Natural Hydrology of the San Francisco Bay–Delta Watershed"* (Fox et al. 2015). This study evaluated the effects of landscape changes on the inflows to the Bay-Delta region from the Sacramento and San Joaquin rivers. The study estimated tributary flows by reconstructing the natural, undisturbed landscape of the Central Valley and, using the standard hydrologic methodology of computing water balances, estimated the *natural flow regime* of the Bay-Delta watershed which would have occurred for the period 1922 to 2009. These estimates of the natural flow regimes were then compared to "unimpaired flows", using the same definition of unimpaired flows as used in the SED.

The Fox et al. (2015) analysis shows that the amount of water currently used by farms, cities, and other water users is about equal to the amount of water formerly used by native vegetation on the undisturbed Central Valley landscape. According to this published study, the development of water resources in California's Central Valley transferred water formerly used by native vegetation to new beneficial uses without substantially reducing the long-term annual average flows to the San Francisco Bay–Delta estuary. Another key finding of this study is that "unimpaired" flows, as computed by the SWB, significantly overestimate natural flows because unimpaired flows fail to include consumptive use by natural vegetation in the valley floor. This study concludes that *"unimpaired delta outflow calculations should not be used as a surrogate* *measure of natural conditions or to set flow standards to restore ecosystem health"*, and further *"by definition, unimpaired delta outflow calculations provide a high estimate when used as a surrogate for natural delta outflow."* This study demonstrated that unimpaired flows do not reflect, nor should they be used to represent, the natural flow regime to which anadromous fish are adapted. The SWB did not consider this study, which cannot be found in the citations of the SED.

In March 2016, the California Department of Water Resources ("DWR"), issued a report entitled *"Estimates of Natural and Unimpaired Flows for the Central Valley of California: Water Years 1922-2014"*. DWR is the California state agency responsible for the management and regulation of the state's water usage and is widely recognized for its expertise in compiling the quantitative estimates and records of the water resources of the state. DWR's March 2016 report on page 1 of the Executive Summary states unequivocally: *"Unimpaired flow estimates are theoretical in that such conditions have not occurred historically"*, and on the same page 1 provides this conclusion: *"In sum, the findings of this report show that unimpaired flow estimates are poor surrogates for natural flow conditions."*

The DWR (2016) report and the published Fox et al .(2015) study reached the same conclusion that "unimpaired flow" estimates, as those used by the SWB, do not represent the natural flow conditions of the Central Valley's rivers. Both of these studies were available to the SWB in a manner that was timely, and neither were cited or appeared to be used to inform the SED. SWB chose to disregard this available information. This exclusion of relevant, but conflicting, technical information is contrary to accepted practice. As we shall continue to point out below, the SWB appears to have systematically elected to only consider data, information, and reports which do not conflict with its underlying justification for the pre-ordained conclusions about the SED's preferred alternative, an alternative which imposes significant restrictions on the water users of the three eastside tributaries to the LSJR.

In summary, as discussed above, the overwhelming majority of the citations relied upon by the SWB[14] for justifying the need for a "more natural flow regime" in the LSJR define a natural flow regime as the *pre-development hydrologic regime* as referenced in the south Florida CERP, or as a flow regime *unaltered by human intervention* as in Poff et al. (1997). A number of the citations, while not specifically suggesting adoption of an unaltered, natural flow regime to restore natural ecosystems, endorse the use of *functional biological flows (*see Richter et al. 1996, Yarnell et al. 2015, Kiernan et al. 2012 and others in Table TR-1) to promote stream restoration by "manipulating stream flows at key times of the year".[15] Functional biological flows provide more precisely timed flows matched to preferred species' specific biological needs, in lieu of natural, unaltered flows or "unimpaired" flows. The SED has neglected to consider or scientifically evaluate the use of functional biological flows, in lieu of unimpaired flow volume to improve the fish and wildlife of the Bay-Delta and the eastside tributaries.

The SWB use of the concept of "unimpaired flows" as defined in the SED to represent a natural flow regime is unique to the SED. It appears to have been used by the SWB for the reason that estimates of the "unimpaired flow" were readily available, and not as a result of a rigorous

[14] See Table TR-1 in Attachment 1 to these comments.
[15] As concluded in Kiernan et al 2012 study of the Putah Creek fisheries.

scientific assessment to verify that "unimpaired flows" actually mimicked natural flows. The SWB does not appear to have consulted with DWR on the limits of application of "unimpaired" flows. DWR originally developed these estimates for use in large scale water supply assessments, and not to inform fishery or floodplain management which, as in the case of the SED, require more detail than monthly estimates of flows. The DWR has indicated very clearly to the SWB that the "unimpaired flow" would not be suitable for use in the manner being employed by the SWB.

To try to bolster its presumption of the need to require flows that mimic a natural flow regime to improve Bay-Delta fish and wildlife, and not considering that unimpaired flows do not actually mimic natural flows, the SWB tries to rely upon citing three "real-world examples" of the beneficial effects of restoring a "natural flow regime" to a river. The first of these is a discussion of Putah Creek, a tributary to the Sacramento River. As the SED states on page 19-13, the *"effectiveness of restoring the natural flow regime was demonstrated by Kiernan et al. (2012) in lower Putah Creek"*. The SED asserts that the reestablishment of a natural flow regime in Putah Creek below the Putah Diversion Dam ("PDD") resulted in the displacement of the non-native species dominating the reach to locations approximately 20 km downstream, and thereby restoring the upper 20 km to native species. The SED further implies the Putah Creek experiment demonstrates by "real example" that returning to a natural flow regime on the LSJR would control non-native species infestations. Even aside from the fact that Putah Creek has little similarity to any of the three eastside tributaries that are the subject of the SED, the SWB's explanation of the Putah Creek "example", and the lessons one might derive from it, differs substantially from the contents and conclusions of the Kiernan et al. (2012) study.

According to Kiernan et al. (2012), the non-native species originally dominating the entire 35 km reach below PDD were displaced downstream by a series of uncontrolled, high flow events occurring from 1997 to 1999, not from any action on part of the owners of the PDD. The new controlled flow release regime at PDD wasn't initiated until 2001. The original downstream displacement of non-native fish was not the result of the new flow regime, as implied by the SWB. As Kiernan et al. (2012) reports: *"[b]eginning in 1997, a series of water years with high winter and spring flows displaced or suppressed alien species while creating advantageous spawning and rearing conditions for native fishes. By 1999, the proportion of native fish had greatly increased at the four upstream sites, driven by increases in abundance of Sacramento sucker and Sacramento pikeminnow. Marchetti and Moyle (2001) cited these changes as evidence that native fishes in lower Putah Creek could be enhanced by restoring a more natural flow regime."* The change in the flow regime cited in the SED was the result of a settlement agreement reached in 2000 and then initiated following the agreement. The flow regime changes following the settlement agreement consisted of a combination of seasonal pulse and spawning flows (that is, functional biological flows) and summer constant releases to maintain a wetted stream. Contrary to the impression the SED attempts to portray, the new flow regime was not based on a percent of unimpaired flow. Furthermore, the species involved were not anadromous salmonids. Kiernan et al. (2012) concludes with the following statement: *"This favorable outcome was achieved by manipulating stream flows at key times of the year and only required a small increase in the total volume of water delivered downstream (i.e., not diverted) during most water years"*. The ultimate conclusion of the Kiernan et al. (2012) tends to refute the SED's preferred alternative and agrees with ideas previously put forward by the Districts that functional biological flows, consisting of properly timed, seasonal flow pulses, when combined with site-specific non-flow measures, can result in substantial improvements to in-river production of fall-run Chinook on the Tuolumne River without the large adverse impacts to water users that will occur under the SED's preferred alternative. Such a concept provides a better balanced outcome, but was not analyzed or considered by the SWB.

The only other two "real-world examples" cited in the SED to support the contention of flow regime changes leading to measured improvements in fish populations are Butte Creek and Clear Creek, both tributary to the Sacramento River. While citing improvements in salmonid populations, the SED is careful to report that these improvements were the result of *"fish responding substantially well to flow and non-flow restoration actions"*. Here the SWB at least does not contend that the favorable response by salmon populations was the result of a change to a percent of unimpaired flow. Again, the Butte and Clear creek examples do more to support ideas previously put forward by the Districts than the alternatives evaluated by the SWB. In summary, the overwhelming majority of the SED's own citations reference the potential benefit of carefully timed, functional biological flows, and not "unimpaired flows.

For the reasons discussed above, with respect to the need for a percent of "unimpaired" flow from February through June to improve fall-run Chinook or steelhead populations, the information presented by the SWB in the SED does not support adoption of the preferred alternative's flow schedule, and, in fact, tends to refute the SED's proposal of a percent of "unimpaired" flow in the manner that the SED defines such flows.

With respect specifically to the Tuolumne River, the SWB presents unimpaired flow estimates at the confluence of the Tuolumne River and the SJR. Since there are no records of flows entering the SJR from the Tuolumne River, the SWB presented an estimate of unimpaired flow at the USGS Modesto gage located below Dry Creek at river mile ("RM") 16. The flow at the Modesto gage includes an amount of flow entering the river between the USGS gages at La Grange and Modesto (accretion flows). According to the WSE model, described in Appendix F of the SED, accretion flows make up approximately 20% of the 40% unimpaired flow requirement at the river's confluence of the SJR under the SED's 40% UF alternative. An accretion flow of this magnitude significantly overestimates actual accretion flows between the two gages, and in so doing allows the SWB to significantly underestimate the flows that would be required to be released at the Don Pedro Reservoir to meet the 40% unimpaired flow requirement, which in turn significantly underestimates impacts to the Districts' customers and the regional economic impact of the SED's preferred alternative. The SWB provides no analysis or evidence to independently verify these high estimates of accretion flows. The Review Team discusses this further in Section 10 of these comments.

3.2 Comments on the SED's Predicted Impact on Fall-run Chinook Fry and Juvenile Fish

Fall-run Chinook salmon are used as the "indicator species" for the SWB's analysis of the effects of the SED's preferred alternative on the fish and wildlife of the Bay-Delta area and three affected eastside tributaries. By its own analysis, the SED's preferred alternative ("LSJR Alt3" in Chapter 7) will adversely impact the critical life stages of fry and juvenile rearing of fall-run Chinook salmon on the Tuolumne River. As the SED points out, the February through April time periods are important rearing periods for fall-run Chinook in the Tuolumne River. While the SED reports in Table 19-1 that the core rearing period for fall-run Chinook is March 1 through May 31, data obtained from monitoring fall-run Chinook outmigration at rotary screw traps on the Tuolumne River indicate that over 95% of Tuolumne River juvenile fall-run Chinook salmon have left the river by May 6[16]. Outmigrants exiting the river from late April through May are predominantly smolts, so rearing activity has largely ceased by early May[17]. The core rearing time for Tuolumne River fall-run Chinook is February through April, except in wet years, and the occurrence of wet year spills such as those in 2011 or 2017 would be little affected by the SED's proposal.

The SWB neglects to provide a specific section in the SED analyzing the impacts to each fall-run Chinook life stage on each river, but the relevant information can be mined from the document. Fall-run Chinook fry may rear in both the river channel and the floodplain[18]. Table 7-13b of the SED provides estimates of available in-channel fry rearing habitat under baseline conditions and for each of the SED's alternatives given in terms of Weighted Usable Area (WUA)[19]. By comparing the in-channel rearing habitat for the baseline and alternative LSJR Alt3, on average, the SED's alternative reduces the available rearing habitat by 17% in February and 25% in March. However, fry may also rear on the Tuolumne River floodplains. While there are a number of methodological problems with the SWB's assessment of suitable floodplain habitat on the Tuolumne River, as discussed below in Section 5.0, the SWB's assessment of Tuolumne River floodplain inundation in February and March is provided in Table 7-15b. Comparing the baseline and LSJRAlt3 alternative, the table shows that the SED's preferred alternative reduces inundated floodplain by 35% in February and 26% in March. Therefore, by the SWB's own analysis, the SED's preferred alternative has a significant adverse impact on floodplain rearing opportunities for this critical life stage of fall-run Chinook salmon on the Tuolumne River.

While fry have been documented to be displaced downstream from the Tuolumne River to the LSJR in wet years, Table 7-15d also shows the LSJR Alt3 alternative results in a reduction in LSJR floodplain inundation as well[20]. Additionally, Table 19-21 shows that there is very little floodplain available on the LSJR below the confluence with the Tuolumne River, especially at the estimated median February and March flows at Vernalis under LSJT Alt3.

By the SED's own assessment, the SWB is predicting the SED's preferred alternative will adversely affect Tuolumne River fall-run Chinook fry rearing. Juvenile rearing is also adversely impacted. Contrary to Table 19-1 of the SED, there is little juvenile rearing occurring in May on the Tuolumne River according to RST data. By May 1, except during wetter water years, most of the fall-run Chinook juveniles have smolted and are actively emigrating and no longer rearing. Juvenile rearing primarily occurs in March and April. In any event, Table 7-14d shows that in-

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[16] See Figures TR-12 and TR-13 embedded in the text below in Section 4.0.
[17] The failure to consider data obtained at the Districts' two RSTs on the Tuolumne River leads the SED to the erroneous conclusion of May being a core rearing period as it reports in Table 19-1 of the SED.
[18] Floodplain habitat is discussed in detail in Section 5.0 and Appendix A of these comments.
[19] WUA is normally provided in units of ft^2 per 1,000 linear feet of stream, but no specific units are provide in the SED's Table 7-13b.
[20] As discussed below, the SWB provide no estimates of floodplain ***habitat*** in the SED.

channel rearing habitat is reduced by 14% in April (and May) when comparing LSJRAlt3 to the baseline conditions. Again, floodplain inundation is less on average by 26% in April[21].

The SWB's analysis demonstrates that the SED's preferred alternative would have an adverse effect on rearing of the critical fry and juvenile life stage of fall-run Chinook on the Tuolumne River. While the SED acknowledges an impact to fall-run Chinook spawning habitat, the significant reduction in fry and juvenile rearing habitat is not discussed or acknowledged in the SED. In fact, Chapter 7 of the SED describes the effects of LSJRAlt3 on fry and juvenile rearing habitat as "less than significant" justifying this finding with the following (see page 18-37):

> *"Reductions in WUA for Chinook salmon spawning would occur in the three eastside tributaries, but higher flows and lower temperatures are expected to improve attraction and migration and the longitudinal extent of suitable spawning habitat. This alternative would substantially improve rearing habitat conditions for Chinook salmon and steelhead in the three eastside streams and LSJR. Considering the overall beneficial effects of higher flows on rearing habitat availability, no significant adverse impacts on Chinook salmon and steelhead populations would occur. Higher spring flows under this alternative would also benefit other native fish species improve rearing habitat conditions for Chinook salmon and steelhead in the three eastside streams and LSJR. Considering the overall beneficial effects of higher flows on rearing habitat availability, no significant adverse impacts on Chinook salmon and steelhead populations would occur. Higher spring flows under this alternative would also benefit other native fish species."*

There are a number of problems with this description of impacts. First, the explanation indicates that "*higher flows and lower temperatures are expected to improve attraction and migration and the longitudinal extent of suitable spawning habitat."* One can only interpret this to mean that the LSJRAlt3 includes "higher flows" than baseline during the adult upmigration and spawning periods. However, nowhere in the description of LSJR Alt3 is there included a mention that it includes spawning flows different than the baseline spawning flows. At this point, it is not even clear what flow schedule has been included in LSJR Alt3. What does LSJRAlt3 actually consist of? Where do these extra spawning flows come from? This lack of transparency about what alternative is actually being evaluated is troubling and erodes the credibility of the SED. Even more difficult to understand, is how the SWB can conclude that LSJR Alt3 would "s*ubstantially improve rearing habitat conditions for Chinook salmon and steelhead in the three eastside streams and LSJR"*. On the face of it, this appears to contradict the various analyses shown in the tables in Chapter 7 which are discussed above. Without further detailed explanation in the SED, one can only conclude the directly opposite finding related to impacts to Tuolumne River fall-run Chinook salmon; that is, the SED's preferred alternative will have significant adverse effects on fall-run Chinook salmon on the Tuolumne River.

[21] Table 7-15b shows May floodplain inundation increases by 21%, but May is not a core rearing time on the Tuolumne River for fall-run Chinook juveniles.

4.0 Comments on the SED's Assessment of Temperature Benefits

Of the four factors[22] encompassed within the SED's preferred alternative which are intended to show scientific support for the SED's contention that the Amended Plan will benefit the fish and wildlife of the Bay-Delta, the SED states *"[o]f all of the habitat attributes for native fishes, water temperature is likely the most important one...because without adequate water temperature all of the other habitat attributes become unusable."*[23] The SED explains on page 19-8 why the preferred alternative will result in benefits related to water temperature:

> *"The current updates to the Bay-Delta Plan include improving flow conditions during the February through June time period so that they more closely mimic the natural hydrographic conditions to which native fish species are adapted, including the relative magnitude, duration, timing, and spatial extent of flows as they would naturally occur. This document describes the benefits of the project to native salmon and steelhead in terms of improvements to temperature and floodplain habitat in response to the proposed changes in flow conditions which will more closely mimic the natural hydrographic conditions during February through June."*

As we have presented above, the SED preferred alternative, by both SWB's own admission and that of the DWR, will not deliver flows that "mimic the natural hydrographic conditions" of the LSJR or the eastside tributaries. As will be explained below, the SED also fails to demonstrate that its estimated temperature benefits could reasonably be expected to result in measurable increases to salmon or steelhead populations. Beyond the fact that the flow regime of the preferred alternative does not mimic the natural unaltered flow regime of the LSJR, the SWB analysis of temperature benefits falls short for the following reasons:

- The temperature model employed has not been independently verified by the SWB.
- SWB's analysis does not evaluate the flow regime actually proposed by the SED's preferred alternative; therefore, the results of its analysis cannot represent water temperatures expected under the preferred alternative.
- SWB's assessment of the potential beneficial effects of future water temperatures on Tuolumne River fish are overstated because the temperatures under the current baseline conditions are not unfavorable to fall-run Chinook salmon.
- SWB presents no scientific data or analysis that links the small changes in water temperatures under the SED's preferred alternative to increases in salmon or steelhead populations.
- SWB's oversimplified hypothesis related to temperature – that simply "colder is better" – is unsupported in the record and in much of the scientific literature the SED itself cites.

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[22] The four factors intended to improve fish and wildlife are (1) more natural flow regime from February through June, (2) temperature "improvements", (3) greater floodplain inundation, and (4) adaptive implementation.

[23] On page 19-5 at the beginning of the section on the importance of flow, the SED indicates that flow is the "master variable"; and at the conclusions of the section on water temperature on page 19-47, water temperature seems to have become the most critical element, displacing flow as the master variable.

Temperature Model Employed by SWB

There is a fundamental issue related to the SWB's analysis of potential temperature benefits that should be brought to the public's attention. In Section 19.2.2 of Chapter 19, entitled *"Methods of Temperature Evaluation",* the SWB describes the methods and tools used to estimate the temperature changes it expects to occur under the SED's preferred alternative. The SWB is clear that it has relied heavily on a water temperature computer model named "SJR HEC-5Q", a model developed by a *"group of consultants between 2003 and 2008"*. The SWB gives no indication that it independently verified the reliability or accuracy of the model. Placing such high reliance on a computer model developed by others, the code of which is not in the public domain, is a substantial risk assumed by the SWB, especially when the model is used to evaluate what the SED asserts is likely the most important habitat attribute (see page 19-47). The SWB likely considered its confidence in the model to be well-placed because the SED cites in several locations that the SJR HEC-5Q model development "*included peer review and refinement*". As recognized throughout the scientific and engineering community, having a document, analysis, report, or computer model go through an independent peer review process represents a stamp of assurance in the reliability and usefulness of the information contained therein.

Unfortunately, the SWB's confidence is misplaced. The SJR HEC-5Q model relied upon by the SWB has not gone through a peer review process. Falsely claiming that a model has been through a peer review process raises significant concerns. By itself, this mischaracterization of the SJR HEC-5Q model **disqualifies** all subsequent findings based on the model, until such time as the model undergoes the full and formal peer review process it was professed to have gone through, including review of the non-public code. Intentionally misrepresenting that a model has been "peer reviewed" undermines the public trust and the credibility of the SED, and not only related to the temperature analysis and results.

Relatedly, we are also concerned that almost as an aside the SWB reports that the "temperature model" was "updated by the CDFW and released in June of 2013". Having a model "updated" by persons other than the original model developers is fraught with risk, and this alone should have raised questions among SWB staff. Further, in response to an October 31, 2016 email from HDR staff member Robert Sherrick concerning the SWB's model results, SWB staff member William Anderson responded on November 4, 2016 that *"[i]t has come to our attention that some of the HEC-5Q temperature model files that we provided* ***were altered by CDFW****, working as a cooperative agency, in the production of SalSim results for the SED report based on the 'SB40%OPP' scenario only."* Based on this response, it is apparent that CDFW has continued to "modify" the SJR HEC-5Q model within the SED development process, and apparently without the knowledge or oversight of the SWB. This is unacceptable practice and reduces the public's trust in the SED development process.

The false claim of peer review, when added to the disclosure of a third party modifying a key modeling tool without the knowledge of the SWB, is sufficient to discount all subsequent temperature assessment results and "findings".

SWB's Temperature Analysis of the SED's Alternatives

Beyond the core issues of claims of peer review and undocumented model modifications, there are methodological and fact-related errors in the SWB's analysis which deserve discussion.[24] Perhaps the most basic and serious of these methodological shortcomings is the fact that SWB's analysis of the effects on water temperature of the preferred alternative does not evaluate the actual preferred alternative, or for that matter, any of the alternatives indicated to be considered in the SED. For the sake of brevity, we will discuss the SWB's 40% unimpaired flow ("UF") alternative for the Tuolumne River, which is the SED's recommended starting point for its preferred alternative of 30%-50% UF from February through June. Although the SED never clearly states how in actual practice such a flow requirement would be implemented[25], the SWB states in Chapter 3[26] that the SED's preferred alternative requires flow to be released from the three rim reservoirs based on a rolling seven-day average of the unimpaired flow at the rivers' confluence with the LSJR. The SWB repeatedly emphasizes in the SED that it is not only the amount of flow (magnitude) which is critical to improving fish and wildlife, but as critical is that releases to the river reflect the "*duration, timing, and spatial extent of flows as they would naturally occur"*[27]*;* that is, the variability of flows that would occur in a natural flow regime is as important to capture as the magnitude. Unlike the summer months in the Central Valley tributaries when runoff can be relatively unchanging, the natural runoff in the months of February through June would experience high and frequent variability. In Figures 19-3 and 19-4, the SED depicts the significant daily variability that can occur in the February through June period. SWB places considerable importance in this variability and the associated temperature and floodplain benefits to fish and wildlife associated with this variability.

Accurately evaluating the occurrence of this variability under the SED's preferred alternative is therefore a prerequisite to being able to demonstrate the benefits of the preferred alternative to fish and wildlife. The SWB purports to do this in section 19.2. Based on the analysis presented in section 19.2, including innumera
ble tables, even going so far as to show the future expected *"% of maximum compliance achieved"* under the alternative unimpaired flow percentages, the SED goes on to conclude the following:

> *"Significant temperature improvements in the Tuolumne River occur under all alternative unimpaired flows with the least benefit occurring under 20% unimpaired flow and the most benefit occurring under 60% unimpaired flow."*

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[24] We mention here, and discuss later in these comments, that the temperature model employed by the SWB uses a one-dimensional (1-D) reservoir temperature model to estimate the thermal regime of the Don Pedro Reservoir. A 1-D model is ill-suited for the task of accurately modeling the thermal dynamics of a reservoir as complex as Don Pedro.

[25] For example, according to the SED's adaptive implementation plan, discussed later, the UF flow volume expected for the upcoming February through June timeframe would have to be estimated in early January. This seems problematic and unworkable because no reliable information exists in January as to what the volume of the unimpaired flow would be from February through June.

[26] See page 3-9. Also see Appendix 9, page 29.

[27] See pages ES-11, 1-8, 3-8, 4-12, 19-8, 23-4 and others.

An underlying presumption in the SED related to "temperature benefits" for the Tuolumne River is that there is a need for changes to the current temperature regime. Without any analysis of the large body of empirical data on the condition or health of Tuolumne River fall-run Chinook and *O. mykiss* populations, the SWB simply presumes temperature improvements are necessary and would be "beneficial". The basis for this presumption is a comparison to a set of temperature values provided in Table 19-1, the relevancy of which to the Tuolumne River is also presumed.

Even disregarding the lack of a scientific finding of any need for temperature improvements, the SWB's analysis does not support a conclusion of "*significant temperature improvements*" occurring for the simple reason that the analysis performed and presented in the SED does not analyze the instream flows expected to occur under any of the alternatives. For the Tuolumne River, the SWB's analysis of temperature benefits is based on monthly average instream flows below La Grange Diversion Dam converted to daily flows by assuming the same flow occurs every day of the month. This "flat flow" across an entire month is a flow regime that would not occur under the SED's alternatives, and is certainly not one that reflects the "*duration, timing, and spatial extent of flows as they would naturally occur".* Having the same flow occur every day of the month does not mimic the variability of natural flows, especially in the months of February through June. Nor does using a flat monthly flow represent the instream flows the SWB purports to evaluate under each alternative (see Chapter 3, Section 3.3.2). In fact, by assuming a flat flow across each month, the SWB has essentially modeled the one flow regime that ***cannot*** occur. As mentioned above, the SED itself calls for the eastside tributaries to use a seven-day average of the unimpaired flow so as to capture the temperature, floodplain and other benefits the SWB expects to occur through the combination of flow magnitude ***and*** flow variability. The significance of the SWB's inappropriate use of flat monthly flows can be seen in the Districts' Figures TR-5 to TR-11 (see Attachment 2 of these comments), which compare the SWB's flat monthly unimpaired flow to the seven-day rolling average unimpaired flow which would occur in the lower Tuolumne River under the Amended Plan's preferred alternative. By example, in many of the months the flat flow used in the SWB's analysis which is assumed to occur for 30 straight days would only actually occur for one or two days when compared to the required 7-day rolling average flow. It is apparent by inspection that SWB's assessment using its flat flow assumption does not represent the instream flows projected to occur under the SED's preferred alternative; therefore, the analysis is not relevant and must be discarded. The numerous tables presented in section 19.2 of the SED (from Table 19-3 to 19-14) all suffer from the same flawed analysis and cannot be relied upon to draw any conclusions about the effects on water temperature of any of the SED's alternatives.

This error is compounded by then comparing the temperature analysis that uses monthly flat flows to the temperature "criteria" of Table 19-1. The "criteria" adopted by the SWB for its analysis is, reportedly, the EPA's *"recommended temperature criteria for protection of salmonids"* (pg 19-18), which is based on the seven-day average of the **daily maximum** temperature ("7DADM"). Comparing the results of modeled water temperatures derived using a constant daily flow for every day of a month to a criteria that is based on the metric of the seven-day average of the daily **maximum** temperature provides an erroneous view of the expected water temperature improvements for the river. For example, water temperatures in the lower Tuolumne River are a function primarily of river flow and local meteorological conditions, with flow being the dominant variable. A flow of 300 cfs will result in much different water temperature conditions than a flow of 200 cfs or 400 cfs. A daily flow that is constant over a month-long period is not able to capture the changes in daily water temperature (and resulting daily maxima) that occur when flows vary every day, as they would under the SED's various alternatives. By assuming flat flows for every hour of every day and every day of every month, there is no ability to capture the variations in daily maximum temperature that occur under the 7-day rolling average flow, especially under below normal and critical water years.

River temperature data is normally collected at 15-minute intervals for the specific purpose of understanding diurnal temperature fluctuations and daily maximum temperatures. Using average monthly flow values masks potentially significant day-to-day, let alone hour-to-hour, temperature fluctuations. As an example, Myrick and Cech (2001), a reference cited by the SWB, reports *"Central Valley salmon can apparently grow at temperatures approaching 24°C"*, but then acknowledge that the "*chronic upper lethal limit for Central Valley Chinook salmon is approximately 25°C*". Therefore, using a monthly flat flow could mask potentially harmful temperatures, especially when flows may be falling and ambient temperatures rising in the mid-to-end of May period. This is problematic for the SWB's analysis of temperature benefits which applies the temperature thresholds shown in Table 19-1, where, for example, the 7DADM "temperature threshold" is 16°C from March 1 through May 31. Use of monthly flat flows prevents any reasoned opinion to be formed about "temperature benefits" resulting from each of the SED's alternatives. Evaluating the effects of temperature on fish living in a dynamic hour-to-hour temperature environment by using constant flow for every day of a month is unrealistic at best. The SWB's analysis using monthly flat flows does not capture the important fluctuations in daily temperatures maxima; therefore, it should not be used to draw conclusions about potential *"temperature improvements in the Tuolumne River [to] occur under all alternative unimpaired flows"*.

The SWB's assessment of the need for, and potential beneficial effects of, reducing water temperatures on Tuolumne River below the baseline are lacking the necessary scientific support. There is no evidence provided in the SED that the river's temperature regime under the current baseline conditions is unfavorable to fall-run Chinook salmon or O. mykiss populations

Nowhere in the SED is there to be found a sound argument based on scientific data or information that the current temperatures experienced in the Tuolumne River have an adverse impact on the river's fall-run Chinook or *O. mykiss* populations. Lacking a valid scientific analysis, the SWB presumes baseline conditions are unacceptable, without any explanation as to the scientific merit of this assumption. For discussion purposes only, even if we assume the SWB's analysis is appropriate and accurate, we assess below the "temperature improvements" anticipated to occur under the SED's preferred alternative, focused on the 40% UF alternative on the Tuolumne River. Table 19-7 from the SED is reprinted below (the portions applicable for RM 0, RM 13.2, RM 28.1, and RM 38.3).

Table 19-7 from the SED entitled "The average daily 7DADM temperature values for each month on the Tuolumne River under modeled baseline (base) conditions from 1970 to 2003, and the modeled difference in °F for each of the unimpaired flow percentages between 20% to 60%."

TR Average 7DADM	Confluence (RM 0)						¼ River (RM 13.2)						½ River (RM 28.1)						¾ River (RM 38.3)					
	Base	Percent Unimpaired Flow					Base	Percent Unimpaired Flow					Base	Percent Unimpaired Flow					Base	Percent Unimpaired Flow				
	(°F)	20%	30%	40%	50%	60%	(°F)	20%	30%	40%	50%	60%	(°F)	20%	30%	40%	50%	60%	(°F)	20%	30%	40%	50%	60%
Sep	**75.5**	0.0	0.1	-1.1	-1.1	-1.0	**74.9**	0.0	0.1	-1.2	-1.2	-1.1	**70.9**	0.0	0.2	-1.1	-1.0	-1.0	**68.3**	0.0	0.2	-0.8	-0.7	-0.7
Oct	**67.5**	0.0	0.1	-0.5	-0.5	-0.5	**66.5**	0.0	0.2	-0.5	-0.4	-0.4	**63.3**	0.0	0.2	-0.3	-0.2	-0.2	**61.3**	0.0	0.2	-0.1	0.0	0.0
Nov	**57.8**	0.0	0.0	-0.2	-0.1	-0.1	**56.9**	0.0	0.0	-0.1	0.0	0.0	**57.2**	0.0	0.1	0.0	0.1	0.1	**56.7**	0.0	0.1	0.0	0.1	0.1
Dec	**50.2**	0.0	0.0	0.0	0.0	0.0	**49.6**	0.0	-0.1	0.0	0.0	0.0	**52.6**	0.0	0.0	0.1	0.2	0.2	**53.3**	0.0	0.0	0.2	0.2	0.2
Jan	**50.0**	0.0	0.0	0.0	0.0	0.0	**49.4**	0.0	0.0	-0.1	0.0	0.0	**51.9**	0.0	0.1	0.1	0.2	0.2	**52.2**	0.0	0.1	0.2	0.2	0.2
Feb	**54.2**	-0.1	-0.2	-0.3	-0.4	-0.7	**53.3**	-0.1	-0.2	-0.3	-0.5	-0.7	**53.6**	-0.1	-0.4	-0.5	-0.8	-1.0	**53.1**	-0.1	-0.4	-0.5	-0.7	-1.0
Mar	**58.5**	-0.4	-0.7	-1.2	-1.6	-2.2	**57.2**	-0.5	-0.9	-1.3	-1.7	-2.2	**55.7**	-0.8	-1.2	-1.7	-2.0	-2.4	**54.5**	-0.8	-1.2	-1.6	-1.9	-2.2
Apr	**61.7**	-0.7	-1.6	-2.5	-3.2	-3.8	**60.1**	-0.8	-1.7	-2.5	-3.2	-3.8	**57.0**	-0.7	-1.4	-2.0	-2.5	-2.9	**55.2**	-0.6	-1.2	-1.7	-2.1	-2.5
May	**65.9**	-1.7	-3.8	-4.8	-5.6	-5.4	**63.8**	-1.9	-3.9	-5.1	-6.0	-6.6	**59.6**	-1.5	-2.9	-3.7	-4.2	-4.4	**57.2**	-1.3	-2.5	-3.1	-3.4	-3.4
Jun	**72.2**	-2.8	-4.7	-6.0	-7.0	-7.3	**70.7**	-3.4	-5.5	-6.9	-8.1	-9.0	**67.4**	-4.3	-6.1	-7.2	-8.1	-8.6	**65.3**	-4.8	-6.4	-7.4	-8.2	-8.5
Jul	**77.6**	-0.6	-0.4	-2.1	-2.1	-1.9	**76.5**	-0.7	-0.3	-2.2	-2.2	-2.0	**72.6**	-0.9	-0.5	-2.4	-2.4	-2.1	**69.8**	-0.8	-0.4	-2.0	-1.9	-1.7
Aug	**79.1**	0.0	0.2	-0.5	-0.4	-0.3	**78.5**	0.0	0.2	-0.6	-0.5	-0.3	**74.0**	0.0	0.2	-0.6	-0.5	-0.3	**71.1**	0.0	0.2	-0.4	-0.3	-0.2

It is immediately apparent that there is no significant "temperature improvement" in February at any location under any alternative. There is no "temperature improvement" in March for the simple reason that the baseline conditions already meet the SWB's assigned temperature threshold of 60.8°F (16°C) for fall-run Chinook juvenile rearing[28].

This is also the case in April in areas where juvenile fall-run Chinook primarily rear given the SWB's assigned temperature threshold of 60.8°F[29]. Although the SWB threshold is exceeded in April at the mouth of the river, it is exceeded by only 0.9°F (0.5°C), not a significant amount, and as indicated by the years of data collected by the Districts, this is not an in-river core juvenile rearing area. In May, once again, the baseline conditions already meet the SWB's threshold temperatures above RM 28, where the bulk of the juvenile rearing occurs. The 40% UF flow is predicted by SWB's modeling to reduce river temperatures in the most downstream parts of the lower river, a reach used as a migration corridor by Tuolumne River smolts. However, temperatures under baseline conditions are only 1.7°C higher than the SWB's threshold of 16°C. Again, there is no evidence provided by the SWB that the model's estimate of temperature difference is statistically significant for model predictions, or that this temperature is biologically significant to fall-run Chinook outmigrants. June temperatures show significant improvement under the 40% UF, but by the end of May, except in wet water years, 99% of the fall-run Chinook juveniles have left the Tuolumne River (Figures TR-12 and TR-13 below). In wet water years, spill events would be keeping river temperatures lower. Furthermore, June temperatures above RM 38 (65.3°F; 18.5°C) already reasonably meet the SWB threshold temperature of 18°C.

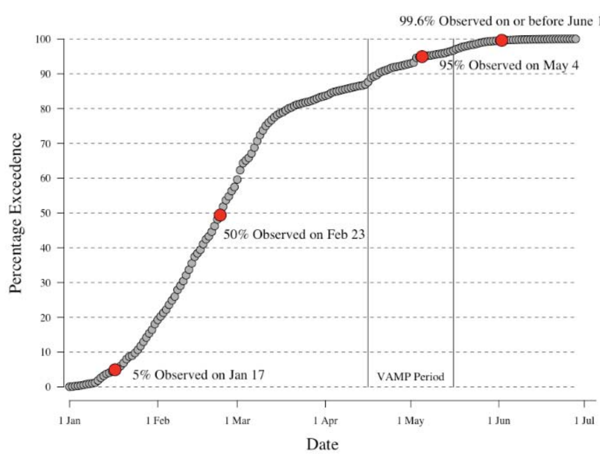

Figure TR-12. Long-term migration pattern of observed juvenile Chinook salmon captured at the Waterford RST (2006-2016).

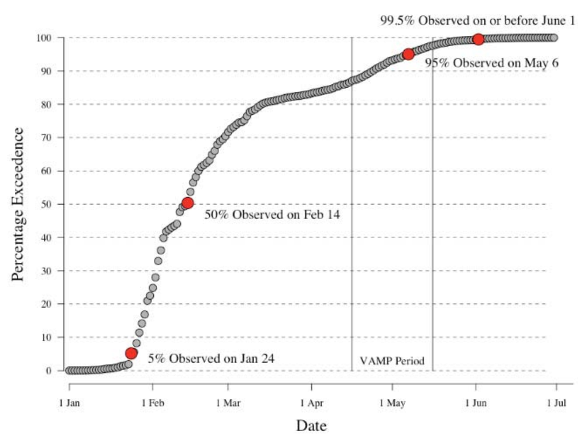

Figure TR-13. Long-term migration pattern of observed juvenile Chinook salmon captured at Grayson RST (1999-2014, 2016).

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[28] The baseline temperature in March also meets the SWB's March threshold of 13°C for the areas used by *O. mykiss* (that is, above RM 38). The 13°C is assumed to be *O. mykiss* spawning and incubation because there is no documented fall-run Chinook spawning or incubation in March.

[29] Smoltification in April can occur, but normally occurs in the mid-to-late April and May timeframe and areas above RM 28 already meet the SWB threshold. It is uncertain as to what basis was used for the SWB's smoltification threshold.

Applying the SED's own temperature thresholds and analysis, the SED's Table 19-7 demonstrates that areas known to be used by fall-run Chinook salmon and *O. mykiss* on the Tuolumne River under baseline conditions already meet the SWB's February, March, and April temperature "thresholds". In general, May temperatures are also adequate above RM 28, which corresponds to the fall-run Chinook core juvenile rearing area.

The SED does not define what the "temperature threshold" values provided in Table 19-1 are intended to represent. The temperature tolerance of Central Valley salmonids is a complex matter. Simply referring to outdated, undefined temperature "benchmarks" intended for salmonid species of the Pacific Northwest is not adequate to support scientific analysis of impacts to Central Valley salmon and *O. mykiss*. The SED lacks a comprehensive discussion on the thermal tolerance of Central Valley salmonids based on the latest studies and scientific literature available on this topic (e.g., Myrick and Cech 2001, Verhille et al. 2016, Poletto et al. 2016). It is unclear if the various temperature thresholds in the table are intended to be temperatures that are "optimal", "upper optimal", "upper tolerable", "suboptimal", "upper incipient lethal", "acute", or some other defined parameter of salmonid's thermal tolerance. Absent a thorough discussion of the biological significance of the temperature "thresholds" provided in Table 19-1, there is no valid, scientific basis for the SWB to evaluate the effects of the existing or proposed flow regimes on the thermal tolerance of fall-run Chinook salmon or *O. mykiss*. If the Table 19-1 values are meant to designate temperatures for "optimal growth", then exceeding these temperatures by 2 to 3°C may have no discernable effect on fish growth or behavior (Jeffres et al. 2008, Sommer et al. 2001). However, if the values in Table 19-1 are intended to represent "upper tolerable" temperatures, then the effect of a 2 to 3°C exceedance may be significant. The SED lacks the necessary comprehensive explanation of the intended significance of the temperature values provided in Table 19-1 and the scientific basis for their selection.

Absent such a discussion and analysis in the SED, there is no scientific basis upon which to decide if a 3°F temperature reduction from say 64°F (18°C) to 61°F (16°C) would have any effect on or make any difference in survival or growth of *O. mykiss* or fall-run Chinook salmon juveniles. In fact, several of the references cited by the SWB demonstrate significant growth by juvenile fall-run salmon at temperatures above 20°C (Jeffres et al. 2008; Myrick and Cech 2001). Related specifically to *O. mykiss* juveniles, researchers from the University of California at Davis and University of British Columbia conducted a state-of-the-art study on Tuolumne River wild *O. mykiss* juveniles in 2013/2014. This study determined that wild Tuolumne River juvenile *O. mykiss* appear to be acclimated to the relatively higher temperature regime of the lower Tuolumne River and have near *optimal* metabolic performance across a wide temperature range from approximately 17°C to 24°C. This study has been published in the journal Conservation Physiology (Verhille et al. 2016). The SWB is well aware of this study and had the study results since 2014 but has chosen not to consider the findings of this well-regarded work. Another similar study was recently performed by UC Davis under contract with EPA Region 9, the federal agency being referenced as providing temperature "criteria" for fall-run Chinook salmon in the SED's Table 19-6. This study examined the thermal performance of hatchery-reared juvenile fall-run Chinook salmon and the findings were recently published in the journal Conservation Physiology (Poletto et al. 2016). UC Davis researchers found that the tested juvenile fall-run Chinook "aerobic capacity was unaffected by test temperatures up to

23°C" and that the tested hatchery fish demonstrated "an impressive aerobic capacity when acutely warmed to temperatures close to their upper thermal tolerance limit, regardless of their acclimation temperature."

SWB presents no scientific data or analysis that relates the changes in water temperatures projected to occur to increased salmon or steelhead populations

For this discussion, we again focus on the Tuolumne River. The relevant results of the SWB's analysis are provided in Table 19-7 which is reported to show the presumed "improvement" in temperature provided by each of the SED's alternatives compared to baseline conditions. This is the most relevant table of any because it at least provides results in terms of changes in temperature (the variable being examined) and provides a comparison to the baseline temperatures. It is unclear what the intended purposes of Tables 19-6 and 19-8 are, as they both present information the scientific significance of which is not explained or substantiated by the SWB[30].

By the SWB's own analyses, there is no difference between the current temperatures (baseline) and any of the SED's unimpaired flow alternatives from essentially August through January, and it is goes unexplained by the SWB how alternatives which do not affect flows in July can result in a reduction in July temperatures compared to the baseline. In any event, we'll focus our discussion on the remaining months of the year (February through June), which are indeed the primary months intended to be dealt with in the SED. However, two additional items deserve further mention.

- Nowhere in the Chapter on temperature modeling and benefits, or anywhere in the SED that we could find, is there a discussion of the degree of accuracy of the temperature model used by the SWB. Without an adequate description of the statistical uncertainty associated with the model results, there is no basis for interpreting whether modeled temperature differences between baseline and the alternatives of 1°, 3°, or 5°F are meaningful.

- Contrary to the SED's statement that the "*temperature thresholds used in this evaluation are based on the U.S. Environmental Protection Agency (USEPA) recommended temperature criteria for protection of salmonids*" (page 19-18), Table 19-1 does not reflect the EPA's benchmark temperatures or relevant river reaches for the Tuolumne River, nor is it appropriate to label EPA's suggested temperatures as "criteria".

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[30] For example, Table 19-6 purports to show "temperature habitat" benefits if higher flows provided by an alternative reduce modeled temperatures to a value lower than the EPA "criteria". As a first matter, there are no "EPA temperature criteria" for the Tuolumne River. More importantly, as discussed in detail in this section, the SWB has not modeled or analyzed the SED's alternatives by virtue of its use of flat monthly flows; therefore, any comparisons are based on an alternative that has not been proposed in the SED. Lastly, the SWB indicates a change of greater than 10% in the table would "*represent significant changes to salmon and steelhead temperature habitat*". The SWB provides no scientific basis or reasoning for arriving at this newly defined parameter of "biological significance". The unsupported selection of 10% is biologically meaningless and arbitrarily chosen.

On November 12, 2010, EPA approved the SWB's 2008-2010 Section 303(d) List of Impaired Waters and disapproved the omission of several water bodies and associated pollutants that were judged to meet federal listing requirements. On October 11, 2011, EPA issued its final decision regarding the waters EPA added to the State's 303(d) list. Included in Enclosure 2 to that decision, EPA determined that the Tuolumne River from Don Pedro Reservoir to the San Joaquin River has "water quality-limited segments" requiring TMDLs for temperature pursuant to the Clean Water Act (CWA), sec. 303(d) and 40 CFR 130.7(b). EPA's Enclosure 2 identified four temperature "benchmarks" for the Tuolumne River. Relevant to EPA's determination, the temperatures and segments identified as being "impaired" were:

- 18°C for salmon adult migration from September 1 to October 31 for the entire lower Tuolumne River,
- 13°C for salmon spawning for RM 26 to 52 from October 1 to December 15,
- 16°C for salmon smoltification and juvenile rearing from March 15 to June 15 for the entire lower Tuolumne River, and
- 18°C for *O. mykiss* rearing from June 15 to September 15 upstream of RM 42.6

The Districts do not agree with the EPA's TMDL temperature "benchmarks"[31]; however, for the purposes of the SED, the temperatures and segments associated with EPA's List of Impaired Waters should be the ones used for comparison. It is unclear how the "temperature evaluation thresholds" and "primary evaluation locations" were selected by the SWB. The SED lacks a discussion of the SWB's rationale for the selected temperatures and locations. We note there are many years of data collection related to habitat use on the Tuolumne River which show the juvenile core rearing for both *O. mykiss* and fall-run Chinook salmon occurs above RM 30 (Final FERC License Application for the Don Pedro Project 2014).

Lacking (1) a robust discussion on the degree of accuracy of the temperature model results, (2) model runs which actually model the SWB's alternatives as proposed in the SED, (3) a thorough discussion of the scientific basis for the temperature thresholds and reaches selected in Table 19-1, and (4) an analysis based on valid scientific studies of the effects on Tuolumne River salmonid populations when river temperatures exceed the SWB's temperature thresholds by 1°, 3°, or 5°F, the information provided in Table 19-7 (or Tables 19-6 and 19-8) are simply numbers without any scientific meaning. The only basis the SWB puts forward for claiming its estimated reductions in river temperature are "beneficial" to the subject salmonids is the unsound, unscientific, and unsupported claim that "colder is better". The SWB provides no basis to conclude that the temperature changes presented in the SED are necessary or would lead to increased fall-run Chinook or *O. mykiss* at the population level.

[31] Table 19-6, 19-7, and 19-8 purport to demonstrate the "temperature benefits" of greater instream flow compared to either the base case or EPA (2003) temperature benchmarks. In many places in the text and tables of Chapter 19, the SWB labels the EPA 2003 temperature benchmarks as "criteria". As the SWB knows, the temperature benchmarks used in EPA (2003) have not been adopted by the SWB as water quality "criteria" and have no regulatory standing until such time they are formally adopted by the SWB. As such, suggesting the EPA (2003) temperatures are "criteria" is misleading. This should be clarified in the SED.

SWB's oversimplified hypothesis related to temperature – that "colder is better" – is unsupported in the record and in the scientific literature cited by the SED

The SED devotes considerable attention to the subject of water temperature suitability in the LSJR and the three eastside tributaries. The formulation of the importance of water temperature in the text, tables, and figures of the SED has the consistent theme of "colder is better". Temperature "benefits" to fall-run Chinook salmon and "steelhead" are presented in the SED in terms of the extent and degree to which the alternatives would produce lower temperatures compared to the baseline, without ever providing a scientific basis or analysis supporting the assertion that baseline temperatures are detrimental to fall-run Chinook or *O. mykiss* populations in the eastside tributaries. It is important to keep in mind that lower temperatures are not a goal in and of themselves. The SED presents no scientific evidence that a reduction in river temperatures in the eastside tributaries are biologically necessary or will increase the target fish populations. The goal of the SED Amended Plan is to improve fish and wildlife *populations* of the Bay-Delta, one of the corollary aspects of which is to improve fry and juvenile survival on the three eastside tributaries and the LSJR. The need for improved survival is, ultimately, the basis of the SWB's hypothesis of the need for increased instream flows in the February through June timeframe. Therefore, the need to reduce water temperatures must be judged on whether such reductions can reasonably be expected to contribute to the goal of increasing the in-river populations of the target fish species of fall-run Chinook and *O. mykiss*.

The SED cites numerous studies which are reported to show a relationship between water temperatures and the health and survival of juvenile salmonids (e.g. Myrick and Cech 2001; Nichols and Foott 2002; Marine and Cech 2004; Boles et al., 1988; Kiernan et al 2012; Mesick 2012). The Mesick 2010 study primarily deals with assessing the influence of hatchery releases on natural production in the Merced River and attempts to relate temperature in the lower Merced River with smoltification. The Boles et al., (1988) work is somewhat outdated as considerable research on fall-run Chinook and *O. mykiss* has been conducted since the publication of that study. The SED's iteration of the events on Putah Creek reported in Kiernan et al. (2012) are misleading and incorrect, as discussed previously in this report. Myrick and Cech (2001) and Marine and Cech (2004) are widely reported in the literature and frequently cited by the SWB in the SED's discussions about temperature. As Myrick and Cech (2001) points out "[g]rowth is perhaps the most powerful and complete integrator of environmental, behavioral, and physiological influences on a fish's fitness". Juvenile fish growth rates are a function of numerous factors, an important one of which is temperature. Another factor, perhaps as important as temperature, is available food quantity and quality. It is the combination of food availability and temperature, not temperature alone, which affects growth rates (Sommer et al. 2001; Jeffres et al. 2008). Based upon field studies of floodplain use by juvenile fall-run Chinook salmon, Jeffres et al. (2008) found the "optimum temperature for growth of juvenile salmon is dependent on food availability." Jeffres et al. (2008) observed that "[t]emperature on the [Cosumnes] floodplain for a 1-week period had a daily average of 21°C and reached a daily maximum of 25°C and fish continued to grow."

Another factor regularly identified in the scientific literature as affecting thermal tolerance of juvenile salmon and *O. mykiss* is acclimation temperature. As referenced in Myrick and Cech (2001), work by Hanson (1991) reported an incipient upper lethal temperature ("IULT") of 25°C for Feather River salmon acclimated to 13°C. Myrick and Cech (2001) reports that "studies of IULT are the most biologically relevant form of thermal tolerance study." Marine and Cech (2004) conducted studies of the effects of temperature regimes typical of the range experienced by Central Valley fall-run Chinook salmon during juvenile rearing and smoltification. Their studies demonstrated that "Chinook salmon can readily survive and grow at temperatures up to 24°C." For the SWB to suggest that the temperatures provided in Table 19-1 can be considered as the single functional parameter used to judge thermal suitability and "temperature improvements" is unsupported and arbitrary. The SWB's own citations would generally instruct against using such a single temperature parameter for each life stage, especially a temperature metric that is not clearly defined. Employing a number of references, Myrick and Cech (2001) states: "Fish growth rates are influenced by a number of factors including temperature (Myrick and Cech 2000b), race (Cheng et al.,1987), ration size (Shelbourn et al., 1995), ration quality (Fynn-Aikins et al. 1992), disease (Jensen, 1988), fish size (Wurtsbaugh and Davis, 1977a), habitat (Ewing et al., 1998), social interactions (McDonald et al., 1998), photoperiod (Clarke et al., 1981), and water quality (Ross et al., 1995)."

Research studies conducted on the thermal tolerance of salmonids[32] have consistently shown chinook salmon and steelhead thermal tolerances can also be a function of acclimation temperature and exposure time, with fish exposed to higher acclimation temperatures generally having greater tolerance, within limits, to warmer river temperatures than those acclimated to cooler temperatures[33]. According to Myrick and Cech (2001)[34], several studies reported maximum growth rates for Central Valley juvenile salmon at 17°C to 20°C, including the Marine (1997) study of juvenile fall-run Chinook from the Coleman National Fish Hatchery. Myrick and Cech (2001) also reported the highest growth rate for Central Valley steelhead occurred at 19°C[35]. Verhille et al. (2016) reported optimum thermal metabolic performance of wild Tuolumne River *O. mykiss* between 21°C to 22°C.

In Chapter 19, Table 19-7, the SED presents the results of the analysis of changes in average water temperature on the Tuolumne River under the SED's alternatives.[36] Inspecting the results of the analysis of the preferred alternative of 40% UF from February through June, the SED predicts that the average monthly water temperatures in April would be reduced from 13.9°C to 12.8°C at RM 28.1 and from 12.9°C to 11.9°C at RM 38.3. In May, at RM 28.1, temperatures are predicted to be reduced from 15.3°C to 13.3°C and at RM 38.3 from 14°C to 12.3°C. The month of April, and to a much lesser extent May, is an important time period for juvenile rearing. Aside from the numerous methodological problems related to the SWB's analyses previously identified in this review, and that nowhere in the SED does the SWB demonstrate with scientific analysis that such temperature reductions materially would affect fish growth, fish size, or fish populations, let's assume for discussion purposes these estimated reductions in temperature

[32] For a thorough reference to relevant scientific literature, see references cited in Poletto et al (2016) "Unusual aerobic performance at high temperatures in juvenile Chinook salmon, *Oncorhynchus tshawytscha*".

[33] For specific reference to temperatures tested, limits of acclimation temperatures, and results, see page 18 of Myrick and Cech (2001).

[34] See Myrick and Cech (2001), Figure G.1, Figure g.3 and pages 28, 29, and 31.

[35] See Figure G.5 in Myrick and Cech (2001).

[36] The Review Team has previously reported that the SWB has not actually analyzed any of the SED's alternatives because it uses flat monthly flows and not 7-day rolling average flows.

would actually occur. Based on the results of a number of the studies cited by the SWB in its SED as referenced just above, it is not only likely that the asserted "temperature benefits" associated with reduced river temperatures would not occur, it is equally plausible the reduced temperatures would slow the growth of juvenile salmonids, which according to the SWB, would make them less able to avoid predation in their outmigration. Under conditions where food rations are plentiful, as in the Tuolumne River (TID/MID 1992, Appendix 16; TID/MID 1997, Report 96-9), the optimum growth rate for fall-run Chinook juveniles may occur at temperatures ranging from 17°C to 20°C, or higher. As shown in Table 19-7, even base case temperatures are slightly below this optimum range in April and May. Studies conducted for the Districts on the Tuolumne River, and in the possession of the SWB, have shown that the availability of drift as well as benthic macroinvertebrates (BMI) in the Tuolumne River are robust (TID/MID 1997, Report 96-4; TID/MID 2003, Report 2002-8), and should be adequate to support the ration needed for optimum growth. By the SED's own analysis and its own citations, the reductions in river temperature resulting from the preferred alternative may actually have the unintended consequence of producing fish with smaller size at outmigration, potentially making Tuolumne River parr and smolts more vulnerable to predation. The SED must consider and analyze the potential for adverse effects to occur due to the potential effects of lower temperatures on the growth of juvenile salmonids. The hypothesis of colder being automatically better is not supported by the best available science and is logically inconsistent with many of the SED's own references.

It is informative to examine Tables 19-12 and 19-13 of the SED in light of the fact that the goal of the Amended Plan is to improve fish and wildlife, specifically those of the Bay-Delta area. The SED uses the USGS gage at Vernalis as a measuring point for informing the effects of the SED's preferred plan on the fisheries of the Bay-Delta. Vernalis is located several miles upstream from the confluence of the LSJR with the Delta. According to the SED's Table 19-13, the Amended Plan's preferred alternative, which will remove an average of almost 300,000 acre-feet of water each year from its current beneficial uses in the Stanislaus, Tuolumne, and Merced river valleys, will have no measurable effect on water temperatures in the LSJR at Vernalis in the months of February, March, or April, and will lower LSJR water temperatures in May and June by a mere **1°C** on average. Based on its own analysis, the SWB must conclude that the Amended Plan's preferred alternative will have no measurable effect on the Bay-Delta ecology due to its projected temperature "improvements". Table 19-12 can be referenced to further bolster this conclusion because it shows that the preferred alternative will have **no positive effect** on meeting the SED's assigned temperature "criteria" in the months of April, May, and June. The SWB should provide an explanation of how this meets its responsibilities to balance impacts to the region's water users with the "benefits" to fish and wildlife when there are no predicted benefits to temperature, the parameter for which the SED claims on page 19-47 "*of all of the habitat attributes for native fishes, water temperature is likely the most important one...because without adequate water temperature all of the other habitat attributes become unusable".*

Additional Misleading and Misrepresented Statements Contained in Section 19.2

There are a number of statements in the Temperature Section of Chapter 19 where the record needs to be corrected and/or clarified. The more prominent of these are discussed below. While much of the discussion in section 19.2 is very general in nature and does not serve to inform the public about conditions on the Tuolumne River, or any of the eastside tributaries for that matter (e.g., citing the importance of water temperature for salmonids in the *Pacific Northwest* on page 19-11), the SED does contain a discussion on "Influence of Temperature On Disease Risk in Salmonids", wherein there is specific reference to the occurrence of *disease* in Chinook salmon juveniles in the eastside tributaries as follows (page 19-12):

> *"Diseased fish are present and have been caught in the Stanislaus, Tuolumne, Merced and San Joaquin Rivers. Naturally produced Chinook salmon juveniles caught in these rivers were infected with the causative agents of bacterial kidney disease (BKD) and proliferative kidney disease (PDK). These diseases and others can rapidly increase in the population as water temperature rises above the optimal temperature range of salmonids (Nichols and Foott 2002)."*

This statement, the only site-specific reference in the SED about Tuolumne River fish and disease, is misinformed at best, and intentionally misleading at worst. It is noteworthy that the sole citation provided to support the statements related to disease is Nichols and Foott (2002). With respect to the Tuolumne River, the Nichols and Foott (2002) study found a single fish (from a sample of 18) with the myxozoan parasite *Tetracapsula bryosalmonae*. This parasite can be a causative agent for Proliferative Kidney Disease (PKD), but is neither a disease itself nor even evidence of the disease. The single Tuolumne River fish inflicted with *Tetracapsula bryosalmonae* was diagnosed with *"relatively few parasites and no associated lesions"* (see Figure 2, page 6 of the report). Of 20 other Tuolumne River fish sampled for the incidence of *Renibacterium salmoninarum* (causative agent for Bacterial Kidney Disease [BKD]), two fish were found to have the parasite present; however, as reported in Nichols and Foott (2002), "*[n]o gross clinical signs of BKD were seen in any of the fish examined*" (see page 7 of Nichols and Foott 2002). The SWB seriously misrepresents its information source when it claims "diseased fish are present" in the Tuolumne River and implies the use of Nicholas and Foott (2002) as the reference. The sentence the SED specifically attributes to Nichols and Foott (2002) that reads "*These diseases and others can rapidly increase in the population as water temperature rises above the optimal temperature range of salmonids (Nichols and Foott 2002)"* is nowhere to be found in the Nichols and Foott report. There is no sentence in the report specifically relating disease levels to "*water temperature rises above the optimal temperature range"*. In summary, there were no "*diseased fish*" found to be present in the Tuolumne River by Nichols and Foott (2002), and such statements must be removed from the SED and the citations to Nichols and Foott (2002) should be corrected.

The SED gives the impression of being highly selective about the information it cites. For example, in the case of concerns the SED raises related to disease, the USFWS also produced a report in 2001 (Nichols and Foott 2001) describing disease presence in fall-run Chinook salmon sampled from the LSJR at Mossdale, the Merced River and the Merced River Hatchery. In summary, the findings of the 2001 report were *"[n]o clinical signs of disease, viral or obligate bacterial pathogens were detected in any of the juvenile fall-run chinook salmon examined."* (see page 1 of the report). One of the other reasons the SWB may have found it inconvenient to cite Nichols and Foott (2001) is that it contains this finding on page 12:

"We expected to see changes in the health and physiology of the juvenile salmon during the decreasing flows and increasing water temperatures typical of late spring. River temperatures reached 23°C, the temperature shown statistically to reduce survival of migrating smolts by 50% (Baker et al 1995). Normal physiological changes associated with smolting and migration were observed, and no decline in health was detected in our sample groups."

This finding by the USFWS in Nichols and Foott (2001) does not fit the picture attempted to be drawn in the SED, and so better to ignore information that does not fit the desired end. The SWB also chooses to ignore a much more recent river-specific study on the incidence of disease. This study was undertaken by the USFWS and was issued in December 2013 (USFWS 2013). In 2013, the USFWS' California-Nevada Fish Health Center "*performed health and physiological condition screening of Chinook salmon smolts in the San Joaquin River basin."* Samples of fall run Chinook smolts (FL> 70mm) were collected from **each of the three eastside tributaries**. A host of lab assays were performed. With regard to all of the smolts collected and assayed, the USFWS reported *"[n]o obligate bacterial or viral fish pathogens were detected in any of the fish sampled"*. And further, the USFWS reported the only *"abnormality observed was minor kidney inflammation in* ***one fish in the March Stanislaus River*** *sample and* ***one fish from the April Merced River sample****."* While some increase in KFL and gill ATPase levels were noted between April and May in fish from the Merced and Stanislaus rivers, no such increase was reported for Tuolumne River fish. The USFWS went on to report that the "*lower KFL and gill ATPase observed in March smolts were not biologically significant or likely to impact outmigration performance."* And finally, the USFWS reported that the "*only significant pathogen detected was Tetracapsuloides bryosalmonae, the causative agent of proliferative kidney disease. This pathogen was detected during April in smolts from the Stanislaus, San Joaquin and Merced Rivers.*" There was no detection of "the causative agents" of BKD or PDK in Tuolumne River fish, as suggested by the SWB in the SED. This recent study which involved fish directly from the Tuolumne River isn't even listed in the "References Cited". The study is widely available, and its lack of reference gives the appearance of "selective science" being used in the SED.

On page 19-13 of the SED in the section entitled *"Influence of Temperature on Predation Risk to Salmonids",* several generalized, non-specific statements are made in an apparent attempt to link "high" water temperatures to increased vulnerability to predation. However, the only citation provided that relates directly to Central Valley juvenile fall-run Chinook salmon is Marine and Cech (2004). In this study, the researchers took fish from the Coleman National Fish Hatchery and reared them in three tanks with the water in each tank being held at a different temperature for a protracted period (2.5 months). The SED reports the study results as follows:

"When water temperatures increase above preferred ranges, juvenile salmonids become stressed and potentially disoriented and erratic, which consequently causes them to become more vulnerable to increased predation rates (CDFG 2010a). ***Marine and Cech (2004)*** *found that juvenile salmon that were reared in 21-24°C (69.8°F-75.2°F) were significantly more vulnerable to predation by striped bass than juvenile salmon reared at lower temperatures."*

The Districts have long maintained that predation by black bass, striped bass, and other non-native species is a major cause of low juvenile survival, and subsequently low escapement, on the Tuolumne River. The Districts have performed several site-specific studies of predator abundance and predation on the Tuolumne River going as far back as 20 years (FishBio 2013; TID/MID 1992, Appendix 22). While all of these studies are publicly available, they all have apparently been ignored in the development of the SED alternatives. It is well-known by resource agencies that predation by non-native species is a major problem affecting fry and juvenile salmon survival, yet the only solution put forward by the SWB and other agencies is more flow will fix the predation problem. One of the prominent studies that SWB cites to bolster its case is the Marine and Cech (2004) study. Yet while the SWB cites this study to support the argument that higher flows will lower temperatures, which in turn should substantially reduce predation, once again the SWB's own information serves to prove it wrong. Marine and Cech (2004) indicates that juvenile salmon *reared* at temperatures exceeding 70°F (21°C) are "significantly more vulnerable" to predation by striped bass. The SWB reports that the core rearing period for juvenile fall-run Chinook on the Tuolumne River is March 1 to May 31 (see Table 19-1). Table 19-7 of the SED reports that **under the current baseline conditions**, depending on the river reach, the average March temperature on the Tuolumne River ranges from 49.7°F to 58.5°F, the average April temperature ranges from 49.7°F to 61.0°F, and the average May temperature ranges from 50°F to 65.9°F. Therefore, by its own analysis, the SWB shows that increasing flows to reduce temperatures is not necessary on the Tuolumne River because Tuolumne River fish already rear at temperatures lower than, and in fact much lower than, 70°F.

The Marine and Cech (2004) study cited by SWB is another example of selectively citing research deemed to be favorable to the SED's preferred alternative. However, the findings of the Marine and Cech study go well beyond the single paraphrase provided in the SED and repeated above. To cite just a few:

- Marine and Cech (2004) found there to be no difference in growth rates between groups of salmon juveniles reared at 17°C to 20°C and 13°C to 16°C.
- Although the juveniles reared as part of the 21-24°C group were smaller, the report concludes that *"no predator size selection was detected within rearing temperature test groups"*.
- The study also notes *"that applicability of our results to fish in the wild is limited by the lack of refugial habitat for prey fish in the open tank experiments."*

The point needs to be emphasized – the sentence contained in the SED that reads *"Marine and Cech (2004) found that juvenile salmon that were reared in 21-24°C (69.8°F-75.2°F) were significantly more vulnerable to predation by striped bass than juvenile salmon reared at lower temperatures"* misapplies the findings of the study. The study must be considered within the limitations of the experiment. For example, the fish reared at 21-24°C were reared at those temperatures for a protracted period of 2.5 months. A comparable juvenile rearing period for Tuolumne River fall-Chinook would be the 2.5 month period from March 1 to mid-May. Even a quick glance at the SWB's own analysis (see Table 19-7) indicates these temperature conditions do not exist on the Tuolumne River. The Review Team is unaware of any studies examining *O.*

mykiss or Chinook vulnerability in relation to temperature conditions in the three eastside tributaries, and the SED does not present any relevant site-specific studies.

And, finally, it is instructive that the Marine and Cech (2004) study states the following:

> "*Most of the prior investigations have focused on more northerly salmon stocks. Applications of these results to southerly distributed salmon stocks is probably not appropriate because differences among anadromous fish stocks in their physiological responses to temperature have been reported (Myrick and Cech 2000, 2002).*"

The temperature "criteria" used by the SWB to conclude that temperature benefits may result from the SED's preferred alternative are based on temperature guidelines developed for salmon stocks in the Pacific Northwest. Marine and Cech (2004) would apparently not support the use of such "criteria", but evidently the SWB does not consider this aspect of the Marine and Cech study useful to the purposes of the SED.

As another example of the "improvements" the SWB expects from "more natural temperature and flow regimes", the SWB cites Kiernan et al. (2012) and lower Putah Creek where the SWB reports a new flow regime was implemented that mimics the natural seasonal streamflow. The SED on page 19-13 states:

> *"Following implementation of the new flow regime, native fish populations expanded and regained dominance across more than 20 km of lower Putah Creek.*"

Once again, this summary statement of the conditions and changes in Putah Creek is misleading. As previously discussed, the original downstream displacement of non-native fish in Putah Creek was not the result of *"the new flow regime"*, as implied in the SED. As Kiernan reports: *"[b]eginning in 1997, a series of water years with high winter and spring flows displaced or suppressed alien species while creating advantageous spawning and rearing conditions for native fishes. By 1999, the proportion of native fish had greatly increased at the four upstream sites, driven by increases in abundance of Sacramento sucker and Sacramento pikeminnow. Marchetti and Moyle (2001) cited these changes as evidence that native fishes in lower Putah Creek could be enhanced by restoring a more natural flow regime."* The initial displacement of non-native species came ***before*** the implementation of the new flow regime. We do not dispute the success experienced in Putah Creek, but as Kiernan reports *"[t]his favorable outcome was achieved by manipulating stream flows at key times of the year and only required a small increase in the total volume of water delivered downstream (i.e., not diverted) during most water years"*. Improvements in Putah Creek are maintained through relatively small amounts of well-timed functional flows, not a percent of unimpaired flow.

In addition to the examples above, the SED provides a lengthy discussion of the potential effects of temperature on salmonids using a number of citations, many of which describe hypothetical scenarios, but not actual conditions on the eastside tributaries. For example, following a discussion of the effects of water temperature on incubating eggs on page 19-14 and 19-15, the SED summarizes the section with:

"Under existing conditions, elevated water temperatures appear to be impairing reproductive life-stages of salmonids in the SJR Basin, including its tributaries (CDFG 2010a). The magnitude in which poor temperatures effect the survival of incubating eggs, and ultimately population abundance, is currently unknown."

This concluding sentence in this section is an example of the relatively frequent occurrence in the SED of two sentences on the same subject matter stating logically conflicting conclusions. If the "*magnitude*" of a problem is unknown, then one cannot reasonably conclude it is a real problem, even if it is heavily qualified with the phrase "appear to be impairing". In this specific case, once again, the SWB chooses to ignore a study performed on this very subject on one of the eastside tributaries – the Merced River. In March 2013, the Merced Irrigation District ("Merced ID") completed an in-river, site-specific fall-run Chinook salmon egg viability study on the Merced River. The study concluded that although river temperatures exceeded EPA guidelines, egg survival was comparable or better when compared to other Central Valley rivers. Also, test group egg survival was higher in the river than the test group at the nearby Merced River Hatchery. This study was provided to the SWB in 2013.

On page 19-43, the SED presents a section entitled *"Summarized Temperature Benefits"*. The SED states:

"When considering temperature results at different river locations and different times of the year, it becomes difficult to provide an overall picture of potential temperature benefits. One way to summarize the temperature benefits of different unimpaired flows is to consider a data output we refer to as ***"mile-days".*** *This result is a measure of* ***temperature criteria compliance*** *in both space and time."* [emphasis added]

Using a compliance "criteria" termed "mile-days" would be a new and novel method of compliance management by the SWB. To the best knowledge of the Review Team, there is no project or river currently monitored or required by the SWB to report temperature compliance in "mile-days". The table providing the results of the SWB's temperature analysis contains a column heading entitled *"% of maximum compliance achieved"*. Since there is no specific numeric temperature standard promulgated for the eastside tributaries, referring to a degree of "compliance" would be premature, at best. Despite the numerous methodological and analytical concerns raised above by the Districts, the table may be instructive. It shows under the SWB's preferred alternative two items worth pointing out:

- Even with the substantial increase in water required to be released to the river, in none of the months analyzed is "compliance" achieved, except when it is already achieved under baseline conditions (December January, February, March).
- In most months, there is little overall change in the percent "compliance", especially when considering, as enumerated above, the SWB does not analyze the actual preferred alternative contained in the SED.

One additional aspect of the temperature model used by SWB is worth noting. On page 19-78, the SED states:

> *"The model simulates the reservoir stratification, release temperatures, and downstream river temperatures as a function of the inflow temperatures, reservoir geometry and outlets, flow, meteorology, and river geometry. Calibration data was used to accurately simulate temperatures for a range of reservoir operations, river flows, and meteorology."*

The HEC-5Q model is a one-dimensional ("1-D") temperature model. By definition, a 1-D model cannot simulate full reservoir or river geometry. By inspection of a map of the Don Pedro Reservoir, one can readily see the unusual shape of the impoundment. The shape is highly dendritic with numerous arms and large changes in configuration in both the longitudinal and transverse directions. To further complicate modeling, the original Don Pedro Dam ("old Don Pedro") built in the 1930s remains in place with its discharge gates in the open position. A 1-D temperature model does not physically capture these elements of this complex reservoir. The Districts, on the other hand, developed a fully three-dimensional ("3-D") temperature model to study and understand the thermal regime and thermal structure of the Don Pedro Reservoir. This fully 3-D model is available for use, but requests for its use have not been forthcoming from the SWB. The 3-D model of the reservoir provides the best available science regarding the thermal structure of the Don Pedro Reservoir as well as a more accurate assessment of release temperatures to the lower Tuolumne River under a range of annual outflow assumptions.

According to the SED, the HEC-5Q model was run on a daily time step using monthly flows from WSE/CalSim, which are then assumed to be the same, constant, flat flow for each day of the month. For purposes of the temperature analysis presented in the SED, the HEC-5Q model was run for the period 1970 to 2003 using the monthly flows converted to daily flows by assuming a constant flow for each day. However, to support SalSim model runs extended to 2010, HEC-5Q was also run for the period 1994 through 2010. There is no discussion in the SED of whether the version of the HEC-5Q model supporting the SalSim runs was put through a model verification procedure. If this was not done, and there is no evidence that it was, then the version of the model extended to 2010 is not a calibrated and verified model, and should not be relied upon. The process by which the model was extended to 2010 by the SWB should be discussed and described in the SED. Furthermore, by email dated November 4, 2016, a SWB staff member alerted the Districts' consultant, HDR, to the fact that CDFW had recently altered HEC-5Q files without the knowledge of the SWB. It would not be a usual or preferred practice for a third-party to make changes to a critical analytical tool without the prior approval of and subsequent verification by the party using that analytical tool.

5.0 <u>Comments on the SED's Assessment of Floodplain Benefits</u>

The SWB predicts that the SED's preferred alternative will provide "*floodplain inundation benefits to juvenile salmonids and other native fishes from increased flows during the February through June time period.*" According to the SWB, increased floodplain inundation would benefit the juvenile life stage of fall-run Chinook salmon by providing access to better sources of food than what is available from in-river rearing, which would result in greater juvenile growth which, in turn, may lead to higher juvenile and smolt survival, which might lead to greater escapement. The SED acknowledges that for juvenile fish to achieve greater growth due to floodplain access, there must be plentiful food sources on the floodplain, at least equal to, if not greater than, in-river food availability. The SED contains no data related to the quantity or quality of food on any of the eastside tributaries' floodplains. Therefore, there is no empirical site-specific data that would lead one to reasonably conclude that floodplain access will provide greater growth than in-channel rearing.

Lacking any river-specific data about food availability on the floodplains of the three eastside tributaries, the SWB provides a number of citations to try to support its presumption of greater food availability. The SED asserts *"prey items can be orders of magnitude greater in floodplains than in adjacent rivers"* which will lead to larger growth because "*floodplain habitats in the Central Valley have been found to have a positive effect on growth"* which in turn, presumably, leads to greater fish survival to adulthood. This bootstrapping of one presumption onto another to arrive at a favorable conclusion is the "scientific" basis of the SED's "floodplain benefits" assessment. The conclusion related to "floodplain benefits" provided by the preferred alternative compared to baseline conditions is arrived at by evaluating the increase in a metric the SWB labels as "floodplain acre-days". This evaluation leads the SWB to conclude on page 19-72:

> *"Implementation of the proposed project will produce substantial increases in floodplain habitat which is available to native fish and wildlife populations, and it is expected that there will be significant positive population responses by native salmonids, and other native fishes."*

There is not a single piece of direct scientific evidence or river-specific data presented in the SED to support this conclusion as it might specifically apply to the three eastside tributaries. As explained below, the SWB's analysis fails to provide any quantitative evidence that the expected increases in floodplain inundation *area* would result in access to greater food sources, larger growth, greater emigration survival through the LSJR, or measurable increases in long-term salmon or steelhead populations. Because there are no data comparing floodplain vs in-channel rearing of fish in the LSJR or tracking emigration of fish substantially using one or the other rearing area, there is most certainly no evidence provided of *"positive population responses by native salmonids"* as claimed in the SED. As detailed in the sections below, the SWB analysis of floodplain benefits suffers from the following problems:

- Most of the citations relied upon by the SWB are either not relevant to the LSJR and the eastside tributaries or conflict with the SWB's assertions related to floodplain benefits.
- SWB fails to analyze the SED's preferred alternative, or any of the SED's alternatives for that matter; therefore, the results of its analysis cannot reasonably be interpreted to conclude any floodplain benefits would occur.
- SWB presents no evidence of *"substantial increases in floodplain* ***habitat****"* as it purports to do [emphasis added].
- SWB provides no quantitative evidence of any benefit to fall-run Chinook or steelhead at the population level due to "floodplain benefits".

<u>*Citations relied upon are either not relevant to the LSJR and the eastside tributaries or directly conflict with the SWB's assertions related to floodplain benefits*</u>

As a first matter, for the floodplain benefits predicted by the SWB to occur, there must be greater food availability on the eastside tributaries' floodplains than what is available in their respective river channels. The SED presents no evidence that this is the case for any of the eastside tributaries or the LSJR. Lacking any river-specific data, the SWB relies heavily on a report by Sommer et al. (2001), a two-year study of juvenile fall-run Chinook use of the Yolo Bypass floodplain. The Yolo Bypass floodplain is located along the lower Sacramento River. The Yolo Bypass is a unique floodplain because of its large size, engineered flow control structures, degree of separation from the adjacent Sacramento River by levees, land uses, surface gradient, and vegetation communities. Flow to the Yolo Bypass area is controlled by the Fremont and Sacramento weirs and other structures. The Yolo Bypass floodplain is large, encompassing approximately 60,000 acres which floods seasonally in about 60% of the years (Sommer et al .2004) and is characterized as uniformly wide, shallow, and with a low gradient that results in weeks or months of inundation following high flow events. Notwithstanding recent extremes in spring runoff such as 2010 and 2016, inundation of the Tuolumne River floodplain over the period of 1971–2012 occurs at a 2- to 4-year recurrence interval on the lower Tuolumne River (HDR and Stillwater Sciences 2017), consistent with the typical return periods of fall-run Chinook suggested to be supportive of salmon by Matella and Merenlender (2014).

According to the SWB, at a river flow of 5,000 cfs, approximately 750 acres of Tuolumne River floodplain would be inundated (see Figure 19-12 of the SED), a tiny fraction of the inundated area of the Yolo Bypass floodplain. Further, because of the relatively higher gradient and higher velocities within Tuolumne River floodplain habitats, water temperatures are generally similar at in-channel and floodplain areas on the Tuolumne River (Stillwater Sciences 2012). The Yolo Bypass floodway bears no similarities to the Tuolumne, Merced or Stanislaus river floodplains, and the SWB does not attempt to make the case that it does.

However, that does not prevent the SED from citing Sommer et al. (2001) as saying *"prey items can be orders of magnitude greater in floodplains than in adjacent rivers*" (page 19-53 of the SED). However, this is not what the Sommer (2001) report actually states. The actual quote is:

> *"…the density of Diptera was much higher in the Yolo Bypass than in the Sacramento River (Fig 4), particularly in 1998, when densities were consistently an order of magnitude higher."*

Diptera is just one of the many "prey items" which juvenile salmonids can feed upon. There are many other "prey items" that serve as food sources for juvenile salmonids. The Sommer et al. (2001) report also examined zooplankton in the Yolo Bypass. In fact, in the same paragraph cited in the SED, the Sommer et al. (2001) report goes on to say:

"There was little difference in zooplankton density in the Yolo Bypass between 1998 and 1999 ***or between Yolo Bypass and the Sacramento River in 1999"*** [emphasis added; note also the study reports that "1998 zooplankton data were not available for the Sacramento River"].

Contrary to what is stated in the SED, there was no finding in Sommer et al. (2001) that supports the SED's statement *"prey items can be orders of magnitude greater in floodplains than in adjacent rivers"*. In the end, the Sommer et al. (2001) report concludes:

> *"The Yolo Bypass floodplain may be seasonally more productive than the Sacramento River for **some** fish and vertebrates, but we have no data regarding its contribution during dry months or years."*

The SED contains no data on the abundance of Diptera, zooplankton, or any other "prey items" on the Tuolumne, Merced, or Stanislaus river floodplains. There is no evidence presented, nor to the Review Team's knowledge does any exist, that one could use to predict or expect greater prey items being available on the eastside tributaries' floodplains compared to the in-river food sources. However, studies have been conducted on in-river invertebrate food sources on the Tuolumne River, and these studies show that these in-river sources are plentiful (TID/MID 1997, Report 96-4; TID/MID 2003, Report 2002-8). No parties in the Don Pedro relicensing process, or at any other time, have claimed that Tuolumne River channel lacks adequate food sources.

Regarding the second of the floodplain benefits the SWB predicts to occur under the preferred alternative -- greater juvenile fall-run Chinook growth rates and "increased survivorship in river" (see page 19-53) -- the SED cites Sommer et al. (2001) and Jeffres et al. (2008), among others. Sommer et al. (2001) does report greater growth rates for juveniles that reared on the Yolo Bypass floodplain. Sommer et al. (2001) attributes the greater growth rate to food availability, but also notes that in both 1998 and 1999 "temperature levels in Yolo Bypass were up to 5°C higher than those in the adjacent Sacramento River during the primary period of inundation, February-March". Figure 2 of the Sommer et al. (2001) report shows that juvenile fish grew to large size at temperatures ***up to and exceeding 20°C,*** well above the SED's temperature criteria presented in Table 19-1 of 16°C. Other sources cited by the SWB in the SED (e.g., Myrick and Cech 2001; Marine and Cech 2004) indicate that juvenile fall-run Chinook with adequate food sources, while not differentiating between floodplain or in-river rearing, grow well at temperatures up to 20°C, and can continue to grow at temperatures approaching 24°C. It should be noted that these temperatures far exceed the "temperature threshold" of 16°C applied in the SED's assessment of temperature benefits. By relying on Sommer et al. (2001), Myrick and Cech (2001), and Marine and Cech (2004), it appears the SED is promoting floodplain rearing at these higher temperatures. Having adequate food sources is consistently reported in references cited by the SWB to be an important determinant of growth, and "positive" fall-run Chinook growth rates are not simply a function of floodplain rearing, but are a function of food availability and river temperature, among other factors. Regarding increased survival, Sommer et al. (2001) reported that although juvenile fall-run Chinook reared on the Yolo Bypass floodplain had greater size and the survival indices were somewhat higher for fish released in the Yolo Bypass than for those released in the Sacramento River for both 1998 and 1999, statistical analysis of the two groups – floodplain vs in-river reared – indicated that the differences in the survival indices were not statistically significant.

It is worth mentioning that flooding of the Yolo Bypass to improve juvenile salmonid growth is an example of the use of engineered structures and controlled pulse flows, and not an example of the implementation of a percent of unimpaired flow. The Yolo Bypass is not comparable to the floodplains of the eastside tributaries and cannot be relied upon by the SWB to draw conclusions on supposed "floodplain benefits" under the SED's preferred alternative, or any other alternative. The Yolo Bypass has been the subject of years of investigation of the structure, geometry, food sources, and food web. No such comparable study, indeed no study at all, has been carried out or referenced by the SWB related to the floodplains of the eastside tributaries or the LSJR. Estimates of floodplain area inundated, or "floodplain acre-days" are not adequate substitutions for the detailed scientific information needed to conclude what the effect might be of a greater frequency of floodplain inundation on the eastside tributaries. In Appendix A to this report, the SED's claims of floodplain rearing of juvenile fish are more thoroughly examined.

Another study carried out on the Yolo Bypass and reported in Sommer et al (2005) received little attention in the SED. The title of this report is *"Habitat Use and Stranding Risk of Juvenile Chinook Salmon on a Seasonal Floodplain"*. Based on Brown (2002), the Sommer et al. (2005) report acknowledges it is "still unknown whether seasonally dewatered habitats are a net 'source' or a 'sink' for salmonid production relative to production in permanent stream channels." Stranding of juvenile fish is cited in Sommer et al. (2005) as a potential concern. There is no assessment of stranding risk on the floodplains of the eastside tributaries undertaken by the SWB, it is simply presumed not to be a factor without further analysis. In contrast, the Sommer et al. (2005) study carefully evaluated data collected over three years, 1998, 1999, and 2000, to draw its conclusions related to stranding risk. The SED, on the other hand, evaluated no site-specific data, in spite of the fact that the USFWS in March 2013[37] when commenting to FERC on the need for a floodplain habitat assessment for the Tuolumne River as part of the Don Pedro Project relicensing stated the following:

> *"Furthermore, a comprehensive evaluation of stranding survey was conducted on the lower Tuolumne River which indicated direct Project effects on juvenile salmonids when flows inundate the floodplain (TID and MID 2005). The tradeoffs between Project-related stranding of salmonid fry and juveniles and their expected increased growth and survival in off-channel habitats have yet to be evaluated."*

One of the studies cited frequently in the SED, as well as in several other cited scientific literature, as supposedly demonstrating the benefits of floodplain rearing compared to in-river rearing is Jeffres et al. (2008). The SED, and others, cites Jeffres et al. (2008) as demonstrating that juvenile fall-run Chinook salmon reared on floodplains grow larger and faster, and have greater access to prey, than juvenile fall-run Chinook reared in the river. According to the SED (page 19-53):

> *"The higher growth rates of juvenile Chinook salmon using Central Valley floodplains, relative to other river habitat types, have largely been attributed to the greater availability of prey within floodplain habitats (Sommer et al. 2001; Jeffres et al. 2008)."*

We have discussed above the lack of applicability of the Sommer et al. (2001) study of the Yolo Bypass to the eastside tributaries of the SJR, and have also pointed out the role of higher floodplain temperatures (up to 5°C higher) in contributing to greater growth for fish on the Yolo Bypass. Jeffres et al. (2008) reared juvenile Chinook for two consecutive flood seasons within various habitats of the Cosumnes River, a tributary to the Mokelumne River which empties into

[37] See USFWS letter to FERC dated March 2013 as part of the Don Pedro Relicensing proceeding.

the LSJR. In the winter/early spring flood seasons of 2004 and 2005, six enclosures containing fall-run Chinook juveniles were placed in each of three different habitat types in the floodplain and two different locations in the river channel. Noteworthy for this discussion, the two river locations were the river channel upstream of the floodplain and the river channel downstream of the floodplain. The upstream river location was a riverine, non-tidal reach with a sandy substrate and the downstream location was in a freshwater tidal area. While there are a number of interesting findings from the Jeffres et al. (2008) study conducted on the Cosumnes River, the conclusion most relevant to the SWB's supposition of higher juvenile growth rates from floodplain is the following:

> *"Our study indicates that off-channel floodplain habitats provide significantly better rearing habitat, supporting higher growth rates, than the* ***intertidal river channel****"* [emphasis added]

There are no intertidal river reaches in any of the LSJR's three eastside tributaries. If anything, a close and accurate reading of the Jeffres study actually disproves the hypothesis of the need for floodplain access to increase juvenile growth. In the 2004 study year, the size of the juvenile fish located in the *non-tidal* river channel location upstream of the floodplain "*increased rapidly"* and by the end of the season *"fish in the river site upstream of the floodplain were statistically grouped with the fish in the ephemeral floodplain sites, with greater lengths than fish placed in both the lower pond and river below the floodplain habitats"*. In study year 2005, after the first 20 days of being in the river, *"fish in the flooded vegetation (site), upper pond, and above the floodplain (in-river site) had increased in length significantly more than fish in the lower pond and below the floodplain (other in-river site)"*. A large flow then occurred during the 2005 study which buried in sand most of the enclosures containing the pens at the upstream in-river site, apparently killing the in-river fish. Jeffres et al. (2008) cannot be used to show greater growth on floodplains compared to a non-tidal riverine channel; that is, the channel-types encountered in the three eastside tributaries. The SWB should more properly cite Jeffres et al. (2008) as showing that food supply is a major determinant of juvenile growth, whether fish are rearing on the floodplain or in the river channel proper. However, doing this would only highlight the fact that the SWB has no data comparing in-river to floodplain food supply for any of the LSJR eastside tributaries, and therefore lacks the scientific basis to conclude that providing floodplain flows would result in greater growth of juvenile anadromous fish.

Furthermore, Jeffres et al. (2008) reports the maximum daily temperatures at the floodplain study site supporting the higher growth was in excess of 22°C for ten consecutive days and the juveniles continued to grow. The SED did not cite or mention this finding in Jeffres et al. (2008). Therefore, both citations relied upon by SWB--Jeffres et al. (2008) and Sommer et al. (2001) -- attribute improved growth of juvenile salmon on floodplains to higher temperatures in combination with adequate food supplies as physically observed on the floodplains investigated. In both cases, the temperatures contributing to higher growth significantly exceeded the "compliance" temperatures used by SWB in Table 19-1, but, once again, the SWB chooses to ignore this part of the studies, possibly because this does not support the SED's "colder-is-better" paradigm.

The SED presents no evidence that large temperature differentials exist between floodplain and in-channel habits (up to 5°C observed on the Yolo Bypass) on any of the eastside tributaries or the LSJR. On the Tuolumne River, temperature data were collected during spring runoff in 2011 in the river and the adjacent floodplain. There were no significant temperature differentials observed (Stillwater Sciences 2012). The SWB has this data in its possession.

Lacking site-specific data on floodplain food supplies or floodplain temperatures, the SWB is forced to try to rely on the scientific literature on Central Valley juvenile salmon growth to make its case. The key citations relied upon by the SWB as evidence of "floodplain benefits" do not support the SWB's conclusions that juvenile fish inhabiting the eastside tributaries would benefit from increased floodplain inundation, and, in fact, only demonstrate the need for site-specific empirical data to draw a reasoned conclusion. The SWB has presented no evidence that either the Yolo Bypass or the Cosumnes River floodplains have any similarity to the floodplains of the eastside tributaries or the LSJR. The citied studies might be useful in demonstrating higher growth potentially associated with higher temperatures than the "criteria" adopted in the SED; unfortunately, these results are not presented or discussed in the SED.

SWB fails to analyze the SED's preferred alternative; therefore, the results of its analysis cannot conclude there would be floodplain inundation benefits

Beyond relying on citations, the SWB states that it has conducted a quantitative study of floodplain inundation evaluating the SED's baseline conditions and alternatives using its WSE computer models. As stated on page 19-56:

> *"The frequency during the 82-year modeling period (1922 to 2003) that different monthly average flows, and the related floodplain acreages, are achieved was compared between baseline and unimpaired flows of 20%, 30%, 40%, 50%, and 60%. A 10% change in the frequency of floodplain flows, in combination with professional judgment, is used to determine a significant benefit or impact. Ten percent was selected because it accounts for a reasonable range of potential error associated with the assumptions used in the various analytical and modeling techniques. In addition, lacking quantitative relationships between a given change in environmental conditions and relevant population metrics (e.g., survival or abundance), a 10% change was considered sufficient to potentially result in beneficial or adverse effects to sensitive species at the population level."*

As stated numerous times in the SED, the core purpose of the SWB's proposed flow objectives is to provide:

> *"Flow conditions that reasonably contribute toward maintaining viable native migratory SJR fish populations include, but may not be limited to, flows that more closely mimic the hydrographic conditions to which native fish species are adapted, including the relative magnitude, duration, timing, and spatial extent of flows as they would naturally occur. Indicators of viability include abundance, spatial extent or distribution, genetic and life history diversity, migratory pathways, and productivity."* [Appendix C, page 3-56]

These two statements, the first describing the floodplain benefits assessment undertaken by the SWB and the second defining the core purpose of the flow objectives, are in direct conflict with one another. The SWB's goal in adopting an unimpaired flow regime as the instream flow requirement is to capture the variability that occurs in natural flows, including the variability in magnitude, duration, timing, and spatial extent of flows "*as they would naturally occur*". However, as the SWB states in the first quotation above, floodplain acreages were determined using "*monthly average flows*". Monthly average flows cannot possibly capture the variability of natural flows or even a percent of unimpaired flows. In fact, the monthly constant flow modeled by the SWB (that were then turned into constant daily flows) is probably the only flow regime that would never occur under any of the unimpaired flow regimes being considered in the SED. What sense would it make to repeatedly site the benefits of natural flow variability, and then model constant monthly flows? The SED indicates the preferred alternative includes using a 7-day running average of the unimpaired flow as the instream flow to capture the benefits of flow variability. Therefore, the SWB cannot claim any floodplain benefits based on the "quantitative analysis" it undertakes because its quantitative analysis never analyzes either the baseline conditions, the SED's preferred alternative, or any other of the SED's alternatives. The analysis only considered an alternative that would never occur.

*Contrary to SWB's conclusions, the SED presents no evidence of "substantial increases in floodplain **habitat**"* [emphasis added]

On page 19-72, the SED claims that the preferred alternative contained in the SED will result in "*substantial increases in floodplain habitat*". Even beside the fact that the SWB cannot make this claim because the SED's preferred alternative was never analyzed, the SWB analysis makes no attempt to actually determine amounts of "*floodplain **habitat***". The SWB analysis evaluates floodplain inundated ***acreage.*** As the SWB well knows, every inundated acre cannot possibly qualify as suitable habitat. Just as every square foot of a wetted river channel does not constitute usable fish habitat, every wetted square foot of inundated floodplain does not constitute suitable fish *habitat*.

In Chapter 7, the SWB goes into substantial detail explaining how wetted channel habitat is evaluated to determine the portion of that habitat that is suitable fish habitat. The SWB appropriately explains that considerations must include such factors as suitable water velocities, water depths, substrate, and cover. This explanation in Chapter 7 is thorough and well done. Directly following the discussion of what constitutes suitable in-river fish habitat versus just wetted in-channel area, the SWB then goes on to explain that for floodplains, none of those factors were considered, only wetted area. While the criteria of what may constitute suitable floodplain ***habitat*** may differ from that for stream channel habitat**,** there are still suitability criteria that apply[38]. The SED provides no analysis of the percent of inundated floodplain area that could qualify as suitable floodplain ***habitat***.

[38] The Districts performed a detailed 2-D floodplain hydraulic and **juvenile fish habitat assessment** for the entire 52 miles of the lower Tuolumne River and released the report to Don Pedro Project relicensing participants for comment, including the SWB, in September 2015. In comments on the Districts' study plan, the USFWS provided lengthy comments about floodplain Habitat Suitability Criteria. The USFWS rejected the use of inundated area as a measure of juvenile habitat. See USFWS comments dated March 11, 2013.

The Districts understand that estimating the amount of suitable habitat, and how it varies with flow, for an area as large as that being considered in the SED is not an easy task. We understand this because the Districts, at the request of the SWB, CDFW, and the USFWS actually undertook and completed just such a study of the lower Tuolumne River floodplain in 2014/2015 from river mile 52 to the confluence with the San Joaquin River (HDR and Stillwater Sciences 2017)[39]. For this study, LiDAR aerial imagery of the entire valley was acquired in 2011. The resource agencies, including SWB, CDFW, and USFWS, were consulted in the development of the study, including criteria for what would constitute suitable floodplain ***habitat,*** recognizing that estimating inundated area is not sufficient as a measure of suitable floodplain habitat[40] . The study's 2-D modeling and related assessment of the entire Tuolumne River floodplain is the best available science on the floodplain habitat of the Tuolumne River. The SED provides no indication that the SWB considered the findings of this state-of-the-art study. Instead, the SWB has chosen to rely on a study issued in 2008 by the USFWS which only considered inundated area and only at certain flows. The USFWS in its March 2013 comments on the Districts' proposed 2-D floodplain modeling of the Tuolumne River floodplains states the following:

> *"The Service (USFWS 2008) conducted an empirical analysis of flow-inundated floodplain area for the reach between La Grange Dam (RM 52.2) and just upstream of the Santa Fe Bridge, at RM 21.5, near the town of Empire……While this study indicated that floodplain inundation began at flows between 1,100 and 3,100 cfs,* ***it could not be used*** *to determine how much floodplain area was inundated at flows between 1,100 and 3,100; 3,100 and 5,300; and from 5,300 to 8,400 cfs;* ***because there were no data*** *between these points……Further study of Project-related effects on fry and juvenile rearing habitat in the lower Tuolumne River, with a focus on off-channel rearing habitat, is warranted for several reasons."*

The USFWS letter went on to say that the "*work of the Service (2008) that did address off-channel habitat focused on only a narrow range of flows; quantification still needs to be done under a wider range of flows to sufficiently evaluate Project-related effects (i.e., at both pre-and post-Project flows.*" While the USFWS letter mentions both the Sommer et al. (2001) and Jeffres et al. (2008) studies, the USFWS goes on to remark "*however, it is unknown if off-channel habitats function similarly in the lower Tuolumne River*".

The importance of applying habitat suitability criteria to inform judgments about the potential benefit of floodplain flows is depicted in Figures TR-14 and TR-15 below. These figures demonstrate the significant difference that exists between inundated floodplain acreage and inundated floodplain habitat.

Serving to only further compound the shortcomings of its floodplain analysis, the SWB adopts a term called "acre-days" for assessing "floodplain benefits", citing a study from the USFWS

[39] Comments on the September 2015 report were provided by the USFWS; these comments have been addressed, and the final report is being submitted to the SWB as part of these comments on the draft SED (see Appendix F). There were no changes to the conclusions and findings of the September 2015 report based on the USFWS comments.

[40] See USFWS March 2013 study plan comments filed with FERC and the Workshop Meeting notes in the September 2013 report and the report filed with these comments on the Draft SED (Appendix F).

(2014) on the Stanislaus River that used this term. The term "acre-days" is the *"number of acres inundated each day summed over an identified time period"*. If simply using the number of inundated acres as a measure of suitable habitat is unjustified, then multiplying the inundated acres by the number of days that the acreage is inundated only compounds the misapplication. An even more important element of this misapplication of "inundated acres" again relates to the methodology the SWB used to estimate the inundated acreage. Using constant monthly flows as discussed above only exacerbates the lack of relevancy of the "floodplain benefits" predicted to occur by the SWB.

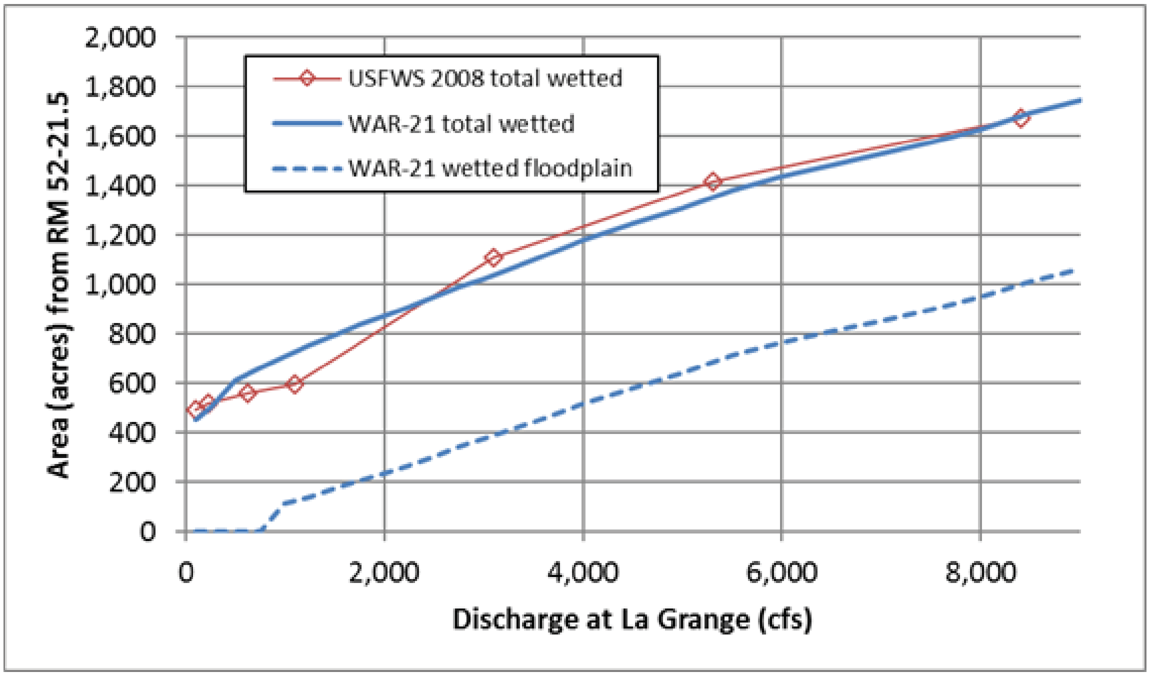

Figure TR-14. Plot of wetted area vs flow on the Tuolumne River. Total wetted area includes the in-river channel area. Wetted floodplain includes only floodplain wetted area. Floodplain inundation begins at a flow of approximately 1,100 cfs.

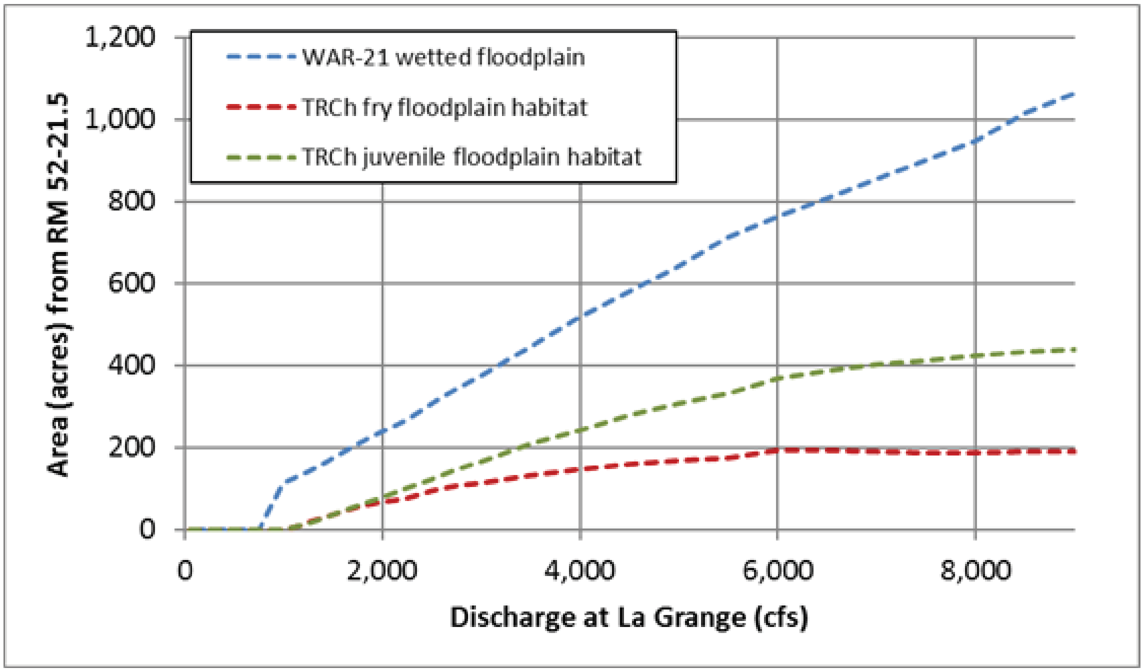

Figure TR-15. Plot of floodplain wetted area and floodplain fall-run Chinook fry and juvenile habitat on the Tuolumne River.

As was pointed out previously in these comments, the SWB did not evaluate the "floodplain benefits" of the preferred alternative because the model it employed used monthly average flows and not the variable flows proposed in the SED alternatives. Figures TR-5 through TR-11 (see Attachment 1 of these comments) illustrate the difference in daily flows between the SWB use of flat flows and using a 7-day rolling average of flow. By example, the degree of error embodied in the SWB's analytical method based on constant daily flows can be understood when one examines the month of April in Figure TR-5, especially in light of Figure 15. Instead of there being a constant daily flow for the month of about 1,500 cfs as modeled by the SWB, which would yield 30 days of about 50 acres of constantly usable habitat (see Figure TR-15), the 7-day rolling average flow provides no usable floodplain habitat for the first 10 days, then about 70 acres for 15 days and roughly 170 acres for 5 days. Also observable by combining Figure TR-5 with the figures shown above is the degree and frequency of changes in the floodplain habitat. This changing physical environment is demanding on the energy reserves of rearing juvenile fish. As the suitability of habitat keeps changing, energy reserves used to continually search for suitable habitat that must be made up by greater food availability.

Use of monthly flat flows introduces another methodological error in the analysis conducted for the SED. There is little discussion in the SED about the importance of the duration of floodplain habitat inundation necessary to yield a growth benefit for rearing juvenile salmonids. When the primary goal of providing access to such floodplain habitat is to promote the growth of fry and juveniles, then the length of time that habitat is available becomes a key variable. Fish growth takes time. Several of the citations referred to in other sections of the SED indicate that the duration of inundation is an important factor (Sommer et al. 2001, Sommer et al. 2005, Jeffres et al. 2008, Matella and Merenlender 2014). While the work of Sommer et al. (2005) on the Yolo Bypass reported a minimum, continuous residence time of 32 days on the floodplain, Matella and

Merenlender (2014) suggest a minimum continuous period for fall-run Chinook juveniles of at least 14 days. Except for the acknowledgement of the importance of the duration of floodplain rearing, there is not general scientific agreement on the number of days needed in order to confer growth or survival advantages. For purposes of discussion, if we assume a minimum duration of 21 continuous days is beneficial for growth, then by inspection of Figures TR-5 to TR-11 the effect of the SED's flat flows on estimates of "floodplain benefits" is apparent. There is hardly any period where flows would be constant for 21 days in the February through June period. Juvenile fish would have to be constantly moving on and off the floodplains in order to find suitable habitat under the SED alternatives. In addition to potential losses due to stranding and avian predation, fry and juvenile fish would have to expend considerable energy to continually move to locate suitable habitat in such a dynamic floodplain environment, the intrinsic dynamics of which are not captured by the assumption of constant daily flows. The SWB's use of constant, or flat, flows over an entire month to represent flows occurring under an unimpaired flow objective is unrealistic, and the use of flat flows gives misleading results when considering the expected duration of inundation.

On page 19-71, the SED provides a narrative overview of the results of the SWB's floodplain inundation study:

> *"A critically important time period for floodplain inundation, and also the time period that achieves the greatest benefit from the flow proposal, is the April through June period. Floodplain inundation does not change much during February and March because flows are relatively high during those months already under baseline."*

This statement is deserving of close inspection, even given the numerous errors and methodological shortcomings of the SWB's floodplain analysis. As can be seen in Figures TR-12 and TR-13 in Section 4.0 of these comments, based on site-specific Tuolumne River data from the Grayson rotary screw trap ("RST"), 99.6% of the outmigrating fall-run Chinook salmon have left the Tuolumne River by the end of May. Therefore, there are few, if any, potential "floodplain benefits" to parr-sized fish potentially rearing on the Tuolumne River in June. In fact, by May 1, over 90% of the fall-run Chinook have left the system. The most significant time periods for fry and juvenile rearing on the Tuolumne River are February and March, and as acknowledged in the SED, flows are "relatively high" under baseline conditions in those months. Just as with the SED's temperature benefits assessment, the results of the SED's own analysis show few to no incremental "floodplain benefits" in February or March, nor would there be significant floodplain benefits in most of May or June because fall-run Chinook have largely left the river. Therefore, the SWB's own analyses show that there are no measurable incremental benefits to be expected from the preferred alternative in February, March, or June. Floodplain benefits, and the lack thereof, are more thoroughly considered in Appendix A of these comments.

SWB provides no quantitative evidence of any benefit to fall-run Chinook or steelhead at the population level

Lastly, in its conclusory statement on page 19-72 related to floodplain benefits, the SWB states "*it is expected that there will be significant positive **population responses** by native salmonids, and other native fishes.*" [emphasis added]. On page 19-56, the SED explains the basis for this expectation when it states "*lacking quantitative relationships between a given change in environmental conditions and relevant population metrics (e.g., survival or abundance), a 10% change was considered sufficient to potentially result in beneficial or adverse effects to sensitive species at the population level.*" This is the sum total of the scientific basis used by the SWB to predict *"significant positive population responses".* It is left unexplained why a 10% change is considered sufficient to represent significance. It's worth noting there is no citation provided for this "judgment". There is no statistical analysis, or sensitivity analysis, to test this opinion. Even a professional opinion by an expert in the field is only an opinion when it is not supported by evidence. Without a reasoned basis for the 10% opinion, it is not a rational basis for requiring 300,000 acre-feet of additional water be dedicated to instream flows. The only tool available to the SWB which provides an estimate of fish population response to the SED's alternative of 40% UF from February to June is SalSim, and SalSim estimates that for an additional instream flow of 300,000 acre-feet of water, the SWB can expect about 1,000 additional fall-run Chinook adults under this alternative, or approximately a 10% increase in the LSJR population, which equates to about a 1% increase in the Central Valley fall-run Chinook population.

6.0 Comments of the SED's SalSim Model and Analyses

At the conclusion of the SalSim section of the SED (Section 19.4), under the heading *"Final SalSim Summary",* the SED states:

> *"With the projected temperature and floodplain benefits during the spring time period (as indicated by modeling results in the previous sections of this chapter), and with adaptive implementation, it is expected that there will be substantial increases in fall-run Chinook salmon abundance on these tributaries from unimpaired flows at or greater than 40%. The SalSim results support this expectation, and because of the apparent conservative nature of SalSim, the results are likely a lower bound of potential salmon production increases that could have occurred during the SalSim evaluation time period. Finally, it is important to consider that many other native fish and wildlife species are expected to benefit from improved flow conditions during the February through June time period including other imperiled Bay-Delta species such as steelhead, sturgeon, and splittail."*

There is no valid scientific evidence presented in the SED that supports any of these several conclusions, and no factual or valid scientific basis for the SWB to expect *"substantial increases in fall-run Chinook salmon abundance on these tributaries".* Claims of temperature and floodplain benefits are addressed in prior sections of these comments. The various contentions of the SED related to SalSim are discussed herein. Contrary to the SED's assertion of increased abundance "*on these tributaries",* nowhere in the SED does the SWB provide any information about changes in salmon abundance in each tributary compared to the baseline. Only the predicted change in the "combined tributaries" is provided. Therefore, the SWB does not present any information about the contribution to *"salmon abundance"* from each tributary.

Relying on an undefined, unexplained adaptive management plan to increase salmon abundance is also not supported by reasoned scientific analysis and is arbitrary. There is no sound scientific basis for such an expectation. By the SWB's own quantitative population analysis, there is no valid basis for concluding that flows released as 40% of the February 1 to June 30 unimpaired flow will deliver substantially increased salmon abundance. By its own analysis, flows from February through June higher than the 40% UF (i.e., 50% or 60%) actually *produce lower* average adult fall-run Chinook salmon production (see SED Figure 19-13 and Table 19-32).[41] Contrary to the SED's stated conclusion, SalSim does not support the SWB's expectation of unimpaired flows at or greater than 40% substantially increasing salmon abundance. The text of the SED is in direct conflict with the results of its analysis.

Of all the computer models employed by the SWB, SalSim is the only one which attempts to provide a quantitative assessment of the ***population-level*** benefits estimated to occur for fall-run Chinook salmon resulting from the proposed revisions contained in the Amended Plan. The SED presents mixed-messages about the usefulness and reliability of the SalSim model. On the one hand, the SWB relies completely on the SalSim model to conclude that taking a portion of the February through June unimpaired flow requirement and applying it to other parts of the year will result in greater salmon production than applying the 40% unimpaired flow to each of the February to June months alone. Indeed, the results of the SalSim model for the SB40%MaxFS and SB40%OPP model runs are the only evidence provided in the entire SED that the SWB could cite to conclude that an "adaptive management" approach would improve results over the direct 40% UF proposal. But then on the other hand, when the SalSim model predicts that the preferred alternative's 300,000 acre-feet of additional water released as 40% of the UF from February through June will only increase the fall-run Chinook population by about 1,000 fish (from 11,373 to 12,436), the SWB indicates the SalSim model has serious scientific limitations and it lacks confidence in the SalSim model's results.

SWB used results from the SalSim model to evaluate the potential benefits of alternative flow shifting scenarios and to support its recommendations regarding "adaptive implementation". SWB's conclusions are largely based on SalSim model results which suggest higher average total adult production when some of the spring flow is reallocated to the fall. However, SWB did not identify what fall life history components were affected, nor the relationship to flow that resulted in this predicted higher level of total adult production.

[41] The SED also presents the results of two SalSim alternative flow scenarios that evaluated reallocating a portion of the February through June flows to other times of the year ("flow shifting"). The potential population benefits depicted in the model results from such flow shifting scenarios provides evidence that the essential concept presented in the SED that greater flows are needed in the February through June period is itself flawed.

Lacking a detailed analysis of the model's accuracy of simulating individual life stages, it is not clear in the SED how the SWB can have confidence in only the SalSim model results which produce greater salmon abundance, while being dismissive of results which produce little to no population benefit. Selectively choosing which model results are useful and which ones are not reveals that, once again, the SWB is using only those results which meet the SWB's ends, versus trying to make an informed decision considering all of the information available to the SWB. The SWB has stated that it has relied significantly in the development of the preferred alternative on input from CDFW, a cooperating state agency and the state agency responsible for managing California's fishery resources. Yet when it comes to SalSim, a model described by CDFW as "state-of-the-art", "best available science", and "no better tool available to perform th[e] task" of predicting the average change in salmon production from river system modifications, the SWB substitutes its own judgment for CDFW's[42] in the following statement:

> *"SalSim appears to underrepresent the benefit of habitat improvements related to floodplain and water temperature conditions during the spring time period that result from different flow scenarios which were evaluated for this project. Specifically, in SalSim, the downstream movement of juvenile salmon is slowed down when they pass inundated floodplains, which results in a later date and larger size of entry into the SJR and Delta, where a larger size improves survival. However, SalSim does not increase the growth rate of these fish when they are "on a floodplain". Recent literature (see Jeffres et al. 2008) indicates that growth rates of juvenile salmon on a floodplain can be significantly greater than juvenile salmon rearing in the adjacent river channel."*

This sentence is very interesting and needs to be read carefully. In this sentence, the SWB, without limitation, indicates that when downstream salmon movement is slowed down; that is, when river flow velocities are lower, juvenile salmon will reach larger size and have improved survival, irrespective of whether the fish have floodplain access. This conclusion by the SWB is consistent with the findings of Chinook salmon in-river habitat studies conducted on the Tuolumne River where PHABSIM modeling shows optimum fry in-channel habitat suitability occurs at flows less than 75 cfs and the optimum juvenile in-channel habitat suitability occurs at 150 cfs (Stillwater Sciences 2013), well below the flows resulting from the 40% unimpaired flow alternative. The SWB then explains that it rejects SalSim because SalSim does not provide the *extra* growth rate which *should* occur if the fish can be *"on a floodplain"* instead of merely in the river channel adjacent to the floodplain. As we have stated above, the SED presents no scientific evidence to support an expectation that Tuolumne River juvenile fish would grow to greater size with floodplain access. To arrive at this expectation of "extra growth", the SWB feels it is able to substitute its judgment over that of CDFW based on the single reference to Jeffres et al. (2008). We have discussed the Jeffres et al. (2008) study in our comments previously, but here it is worth repeating the actual findings of Jeffres et al. (2008) again:

[42] At the January 3, 2017 Public Hearing sponsored by the SWB, both the SWB staff and the staff of CDFW provided explanatory remarks on the SalSim model and its apparent shortcomings. Appendix D of these comments provide a critique of the various resource agency presentations made by SWB staff, CDFW staff, and NMFS-UC Davis at the January 3 Hearing.

> *"However, lengths of fish in the river site above the floodplain increased rapidly and were intermediate between the ephemeral floodplain habitats and the lower pond and river location below the floodplain (Fig. 4). The final time that the fish were sampled, 32 days after deployment, fish in the river site upstream of the floodplain [site] were statistically grouped with the fish in ephemeral floodplain sites, with greater lengths than fish placed in both the lower pond and river below the floodplain habitats."*

Jeffres et al. (2008) also concluded the following:

> *"Our study indicates that off-channel floodplain habitats provide significantly better rearing habitat , supporting higher growth rates, than the* ***intertidal river channel****"* [emphasis added]

And Jeffres et al (2008) provides this cautionary note about juvenile salmon on floodplains:

> *"...fish risk stranding and periods of stagnation, which can also create conditions lethal to juvenile salmon. However, natural floodplains tend to be heterogeneous in terms of water quality (Ahearn et al. 2006) and fish can avoid stressful conditions and seek more favorable habitats (Matthews and Burg 1997). The risk of stranding merits further study in this and other systems.."*

Therefore, not only does Jeffres et al. (2008) not support SWB's basis for rejecting SalSim, Jeffres et al. (2008) can just as readily be cited to suggest that higher flows may have an adverse effect on fall-run Chinook fry and juveniles when it states:

> *"When juvenile salmon are migrating down from upstream spawning grounds during high flow events, migration is more passive than active (Healey 1980; Kjelson et al. 1981) and they are essentially entrained in the water column until they find slower water velocities where active swimming becomes possible. The Cosumnes River is similar to most rivers in the Central Valley in that it is incised and lacks channel complexity. Because other Central Valley rivers also lack access to floodplains – with the notable exception of the Yolo Bypass for the Sacramento River (Sommer et al. 2001) – juvenile salmon in these systems are frequently displaced to the intertidal delta during high flows."*

Jeffres et al. (2008) found slow growth when fish are displaced by high flows, like the flows proposed in the SED, to downstream "intertidal" river reaches on the east side of the Delta. But most significantly, the Jeffres et al. (2008) study argues persuasively for the need for site-specific data when examining the potential benefit and risks to fish on floodplains compared to in-river habitats. For the Tuolumne River, the SWB has presented no site-specific information that serves as evidence that floodplain access has any greater growth advantage than in-river habitats. The SED contains no information on Tuolumne River floodplain food availability, yet a number of studies show the Tuolumne River has ample in-channel food sources for fish (TID/MID 1992, Appendix 16; MID/TID 1997, Report 96-9). RST data collected on the Tuolumne River show that smolts leaving the river are large and in good condition. USFWS studies show Tuolumne River fish have no disease (Nichols and Foott 2002; USFWS 2013). The high flows that will occur under the SWB alternatives in February and March may result in the displacement of fry and smaller juvenile fish to the LSJR where there is little floodplain access, possibly inadequate food supply, and potential relocation of the fish to the intertidal portion of the LSJR, the very river habitat locations where Jeffres et al. (2008) did actually show lower growth on the Cosumnes River. The potential for fish being stranded on the floodplain under the SED's fluctuating unimpaired flows was not adequately considered by the SWB, even though USFWS identified the possibility of stranding on the Tuolumne River based on a site-specific study. Using constant, flat flows as a basis to assess stranding is unacceptable because the constant daily flows would minimize the chance of stranding compared to 7-day rolling average instream flows. Fluctuating flows both exacerbate the risk of fish stranding and require the exertion of energy reserves to continue moving in the search to find suitable habitat under changing flows.

One of the other problems with SalSim cited by the SWB is that it is structured as a "backcasting" model. However, the SWB does not cite this as a problem with the HEC-5Q model which is also a "backcasting" model (pg19-77), another example of selectively choosing what to consider and what not to consider in its evaluations. The Districts would generally agree that SalSim has limitations, and perhaps even serious limitations, but not necessarily the ones identified by the SWB. The Districts have equally serious concerns as raised above with both the SWB's temperature model and floodplain analysis. SalSim was developed by the CDFW as a tool to evaluate different river management options. SWB used it for that express purpose. On page 19-81 of the SED in Section 19.4.1 entitled *"Results of the SalSim Evaluation*", the SWB states:

> *"The SalSim results for the unimpaired flow cases (as used in the SED analysis) and the two 40% flow shifting cases indicate that as percent of unimpaired flow is increased, annual average total adult salmon production would have also increased during the 1994 to 2010 time period (Figure 19-13, Figure 19-14, and Table 19-32)."*

Based on this statement, it appears that the SWB decided to accept the SalSim model results. However, even this final conclusion is either just wrong or intentionally misleading, because the SalSim results portrayed in the referenced table and figures directly conflict with this statement. Both the 50% and 60% unimpaired flow alternatives have lower adult salmon production than the 40% unimpaired flow, indicating that as the percent of unimpaired flow is increased, salmon production is estimated to decline.[43] Adult production actually goes down as unimpaired flows are increased above 40%. This is significant because SalSim itself contradicts statements in the SED that prior studies demonstrated that a 60% unimpaired flow from February through June was necessary to protect fish and wildlife. The SWB stated that it chose the preferred alternative *as a balance* between the needs of fish and the impacts to agriculture, but according to SalSim results, 40% appears to be the optimum unimpaired flow alternative for fish and not one that strikes a balance between benefits to fish and losses to water users.

[43] It is worth noting that the SED only presents "flow shifting" model results for the 40% UF preferred alternative. The SED does not explain the mechanism for the benefit to salmon abundance under either flow shifting scenario.

In fact, a closer inspection of the SED's Table 19-32 undermines the need for a percent of unimpaired flow from February through June altogether. The 30% UF alternative results in essentially the same salmon production as the base case, according to SalSim. By looking closely at the SalSim results of the SB40%MaxFS option, all the benefits to salmon production appear to occur due to reallocating flow from the spring to a window in the fall. Reallocating a small amount of water in the same fashion in the base case might produce nearly the same increase in production, but the SWB evidently did not test this alternative, but should. SalSim simply reallocating a relatively small portion of the baseline flows may produce significantly greater salmon production than the SWB's preferred alternative.

SalSim is the only model which estimates the effects of the SED's Amended Plan at the population level. Without fall flow redistribution, SalSim estimates an increase in fall-run Chinook salmon adult escapement to be approximately 1,000 fish, or 10% of the current estimated run size. If the SWB disregards SalSim, as it appears ready to do based on comments made at the January 3, 2017, Public Hearing, the entire 3,500 page SED has no basis for predicting a positive population response when implementing the preferred alternative of the SED.

7.0 Comments of the SED's Adaptive Implementation Plan

It is apparent that the SED places a substantial reliance on the concept of "adaptive implementation" to deliver the fish and wildlife benefits the SWB expects to occur from the preferred alternative. Related to the goal of the Amended Plan to improve conditions for fish and wildlife, the SED states the following (see page 3-2):

> *"The underlying fundamental purpose and goal of the plan amendments is … [t]o establish flow water quality objectives during the February–June period and a program of implementation for the reasonable protection of fish and wildlife beneficial uses in the LSJR Watershed, including the three eastside, salmon-bearing tributaries."*

This fundamental "program of implementation" is referred throughout the SED as "adaptive implementation". The phrase is used no fewer than 400 times in the first 700 pages of the SED. The importance placed on this aspect of the plan objectives is further emphasized by having it embedded as an objective itself in each alternative considered, except the baseline which is never evaluated as an option with an adaptive implementation plan. On page 3-7, the SED states that each alternative considered in the SED that includes adaptive implementation achieves "goal 4" of the plan objectives, which is:

> *"[Goal] 4. Allow adaptive implementation of flows that will afford maximum flexibility in establishing beneficial habitat conditions for native fishes, addressing scientific uncertainty and changing conditions, developing scientific information that will inform future management of flows, and meeting biological goals, while still reasonably protecting the fish and wildlife beneficial uses."*

Of course, it would be odd for the SWB to establish adaptive implementation as a fundamental goal, but then not to include it as a part of each of the alternatives, so specifically calling out that each alternative meets the goal of adaptive implementation seems a bit unnecessary. In any event, the SWB relies to a very large extent on the benefits to be derived from adaptive implementation to justify its conclusion that the SED's preferred alternative will substantially improve "fish and wildlife beneficial uses" in the LSJR and the three eastside tributaries. A few statements from the SED indicate the level of reliance the SWB is placing on adaptive implementation:

> *"With the projected temperature and floodplain benefits during the spring time period (as indicated by modeling results in the previous sections of this chapter), and with adaptive implementation, it is expected that there will be substantial increases in fall-run Chinook salmon abundance on these tributaries from unimpaired flows at or greater than 40%." (page 19-87)*
>
> *"This adaptive implementation element allows for flows under each alternative to be "shaped" or shifted in time to provide more functionally useful flows and to respond to changing information and conditions. Functionally useful flows achieve a specific function such as increased habitat, more optimal temperatures, or a migration cue." (page 3-10)*
>
> *"Adaptive implementation achieves one of the principal goals for flow objectives." (page 3-10)*
>
> *"Adaptive implementation of the blocks of water represented by the various percentages of unimpaired flow can result in even larger [temperature] benefits". (page 19-47)*

But the anticipated benefits accruing to adaptive implementation go even further to include being able to mitigate the adverse effects on fish caused by the SED's February through June unimpaired flow requirements:

> *"Adaptive implementation allows for flows to be reduced to the low end of the range as long as these reductions do not reduce benefits to fish and wildlife and, thus, could have the effect of lessening the environmental impacts associated with higher flow alternatives." (page 3-10)*
>
> *"As described in the SED, the proposed project allows for adaptive implementation actions that could shift a portion of the required February through June unimpaired flows to other times of the year to prevent adverse effects to fisheries, including temperature." (page* 19-80)

As if that isn't enough, adaptive implementation apparently has the flexibility to completely modify and reallocate the original flow objectives of the revised Plan:

> *"Although framed as February–June flow objectives, the range of alternatives captures the entire feasible quantity of water that could be used to reasonably protect fish and wildlife in the LSJR* ***year round."*** *(page 3-12)* [emphasis added]

So what exactly is the SWB's plan for adaptive implementation? And what is the rational basis for the SWB's confidence in and reliance on adaptive implementation to produce the expected benefits to fish and wildlife *"year round"*? In fact, what exactly are the expected benefits, and how does one know when they have been achieved?

By adopting a highly flexible adaptive implementation plan, in one wave of the baton, the SWB discards the critical importance that it had placed on "mimicking natural flows" in favor of providing flows "*'shaped' or shifted in time to provide more functionally useful flows*." Adaptive implementation now becomes the means to use *"blocks of water"* to "*protect fish and wildlife in the LSJR year round.*" The SWB goes so far as to assert the following in the Executive Summary on page ES-19:

> *"Adaptive implementation allows the frequency, timing, magnitude, and duration of flows to shift in order to enhance the biological benefits. The LSJR alternatives entail a virtually* ***unlimited number*** *of possible functional flow regimes, limited only by the upper and lower bounds of the analyzed range of flows."* [emphasis added]

Although the two words "adaptive implementation" are used with great frequency in the 3,500 pages of the SED, exactly three pages are devoted to describing and defining the content and requirements of what has now become the most essential and critical element of the SWB's revised WQCP -- the adaptive implementation plan ("AIP"). Having proposed to extract on average 300,000 acre-feet of additional surface water from the water supply users of the three eastside tributaries based on the apparent need to provide higher instream flows mimicking the natural hydrograph, the pretense of the need for "natural hydrograph" is now abandoned and in its place is substituted a completely undefined plan for conducting annual experiments with a "block of water" calculated as 30% to 50% of the UF expected to be available from February through June.

Basically, the AIP as defined in the SED consists of the SWB authorizing the establishment of a working group (the "STM Working Group", or "STMWG") operating under the auspices of the SWB which can experiment with a "*virtually unlimited number"* of flow regimes in real time over a region that covers the entire LSJR and the three eastside tributaries. According to the SWB's description of its AIP, the flow regimes can be changed annually as long as the SWB approves of the change. A request for a changed flow regime can be made *"by one or more"* of the members of the STMWG. Apparently, the so-named "Annual Operations Plan" containing a proposed change to an existing flow regime must be submitted to the SWB by January 10 of the year of the proposed change, and while the deadline for the SWB to approve the change is not mentioned, it is presumed to be by January 31 because the flow change would likely affect the required February to June flows.

The SWB indicates it will approve a change so long as *"scientific information supports that such changes would continue to support and maintain the natural production of the viable native fish LSJR fish populations migrating through the Delta"(page 3-10)* and if the change would *"better protect fish and wildlife beneficial uses" (*see also Appendix K). The SED provides no guidance as to what is meant by "natural production" and how it will be measured, "viable native LSJR fish populations", and which of those are considered to be "migrating through the Delta", nor is there any guidance on what type of scientific information would be needed to prove that a proposed flow change would meet these "criteria". Further, there is no guidance for what would constitute "better protection of fish and wildlife beneficial uses" or what metric or metrics the SWB intends to use to make that decision. Indeed, the experimental flow regime would only be required to *"support and maintain"* existing fisheries, instead of being expected to increase fish population abundance, productivity, and spatial extent.

As we have previously stated, the only information, data, or analysis presented in the entire SED that could possibly, and mistakenly, lead the SWB to conclude adaptive implementation might lead to increased fish populations, or any other fish and wildlife benefit, is the results from the two "flow shifting" ideas examined by the SalSim model (SB40%MaxFS and SB40%OPP). Yet, the SWB asserts that the SalSim model is not reliable and, according to statements by the SWB staff at the January 3, 2017 Public Hearing, was not considered in the SWB's decision making. We have previously described in detail why the SWB's analysis of potential "temperature" and "floodplain" benefits is flawed and unreliable, not the least of which is the fact that the SWB has never actually analyzed its own preferred alternative. Therefore, the SWB is forced to make a finding that the AIP, in and of itself, will somehow deliver the expected benefits to fish and wildlife.

There are numerous reasons why the SWB can make no such finding. Most basically, the SED never actually describes exactly what benefits to fish and wildlife the SWB is expecting to achieve by adopting the Amended Plan other than in very general, qualitative terms. Much of the SED is devoted to trying to make the case that the preferred alternative will result in improved abundance of the "indicator species" – fall-run Chinook salmon. But there is no evidence provided that "more flow will equal more fish". It is simply presumed to occur, according to the SWB, because the flow regime will mimic natural flow (which it is no longer required to do), juvenile fish grow larger on floodplains (which there is not a single piece of ***site-specific evidence*** put forward to support this contention for the LSJR or eastside tributaries), and river temperatures will be cooler (there is no evidence presented that juvenile fall-run Chinook for example in the Tuolumne River are adversely effected by the current river temperature regime, and the sum total change in temperatures at Vernalis near the entry to the Delta is 1°C in May and June).

The SED's lack of clarity in defining the needed or expected benefits to the target fish populations greatly diminishes the possibility of the AIP achieving the goals hoped for by the SWB, precisely because there are no well-defined goals. The most basic element of a well-conceived AIP is to describe and establish clear, well defined goals and objectives so testable hypotheses can be put forward to try to achieve these goals (Bennett et al. 2016; Fischman and Ruhl 2015). Further, without a well-defined goal, how do participants know when the goal is achieved, what constitutes success or even progress, or when to stop the flow experiments? The

AIP proposed in the SED leaves the development of the "biological goals" to be achieved by the SED's AIP to a future date, and these goals are to be developed by the STMWG. How can the SWB reasonably conclude that the instream flows of the preferred alternative, or any alternative for that matter, are adequate to meet biological goals which have not yet been established? The SED asserts that "[a]daptive implementation achieves one of the principal goals for flow objectives", that being to "[a]llow adaptive implementation of flows…that will inform future management of flows, and meeting biological goals..." (page 3-10). So, adaptive implementation achieves the goal of adaptive implementation. Adaptive implementation cannot be a goal in and of itself; there has to be a purpose to be fulfilled. This sort of self-fulfilling goal only sets the stage for failure of the AIP.

Adaptive management, the common term for the SED's AIP, is an often-used and often-abused term. More formally, it generally refers to a decision-making process of taking actions and adopting measures through an explicit, structured process the essential ingredients of which start with having clearly stated goals and management objectives, an established baseline from which to compare and measure results, framing hypothesis about cause and effect that can be realistically tested over an appropriate time period, and setting the benchmark for when success is achieved (Bennett et al. 2016, Zimmerman et al. 2012, Delta Independent Science Board 2016).

The geographic scope of the AIP being proposed in the SED is vast covering the entire LSJR and three substantial tributaries each with its own unique characteristics, while also dealing with anadromous fish that spend the great majority their life outside the study area. It must be acknowledged that an AIP of this magnitude and importance is an enormously difficult undertaking with the potential to be hugely expensive with high risk of failure. Most of the AIPs of such scale and dealing with salmon and steelhead have been undertaken in the Pacific Northwest. Adaptively managing resources on the scale and of the type proposed by the SWB have come to be known as "intensively managed watersheds", or IMWs.

According to Bennett et al. (2016), an underlying assumption of much of the river restoration projects in the Pacific Northwest has been that improvements in freshwater habitat will automatically lead to increased population viability and ultimately delisting of threatened or endangered species (National Marine Fisheries Service 2014). However, Bennett et al. (2016) reports there being a lack of evidence that past stream restoration projects have actually benefited salmon and steelhead populations (as cited in Roni et al. 2008). The need for reliable information about whether stream restoration is increasing salmon and steelhead viability led to the establishment of several "intensively monitored watershed" experiments in the Pacific Northwest (Bilby et al. 2005). According to Bennett et al. (2016), the IMW approach is defined as an experiment in one or more catchments with a well-developed, long-term adaptive management program to determine watershed-scale fish and habitat responses to restoration actions (e.g., Zimmerman et al. 2012). The goals of the IMW approach are to determine the effectiveness of restoration actions at increasing salmon and steelhead productivity, determine the causal mechanisms of fish responses to restoration, and possibly extrapolate the results to other watersheds where intensive monitoring is not possible (Bilby et al. 2005; McDonald et al. 2007).

One of the common problems cited in Bennett et al. (2016) is that restoration actions and studies often assess the effects of multiple restoration actions implemented at the same time (e.g., in the Keogh River where road deactivation, nutrient enhancement, wood and boulder additions were undertaken at the same time), which confounds an assessment of the effectiveness of an individual restoration action type. The Keogh River study also demonstrated the difficulty in definitively determining whether restoration has increased freshwater production of salmon and steelhead because changing climatic conditions in both the ocean and freshwater confounds the fish response (Ward 2000). This describes only part of the problem with the AIP as defined in the SED. By the SWB's own acknowledgement, there are a "*virtually unlimited number*" of flow regimes for testing in real time on three separate watersheds. To add to the potential for inconclusive and confounding results, on page 3-19 in Chapter 3, the SED lists another 10 separate non-flow measures which *"are recommended for evaluation and subsequent implementation"* to occur over an undisclosed timeframe.

Simply declaring that an AIP will be established does not constitute evidence that an AIP will be successful or will lead to greater fish populations. The SWB does not demonstrate an understanding of the enormity of the AIP it would unleash under the SED. While providing a degree of flexibility in flow regimes and being open to considering both flow and non-flow measures seems like a good idea, it virtually ensures failure as a prescription for an AIP. The SED is not even clear about the overall goal of the experimental program. Is it to increase the adult fall-run Chinook population? If it is, what specifically in measurable terms constitutes success? Is it to increase steelhead abundance? What is the baseline population of "steelhead" in each tributary? While the SWB considers that these two species will respond in the same way to specific actions, this is not true. Steelhead have a unique life history very different from fall-run Chinook, including different responses to temperatures, flows, and use of floodplains. As just one example, the higher flows proposed by the SED in April and May to increase juvenile fall-run Chinook parr and smolt survival is very likely to have an adverse impact on the ESA-listed *O. mykiss* fry that will be in the river at that time of year by displacing them downstream where predator species are abundant, causing the displaced *O. mykiss* to be more vulnerable to predation or exposed to the higher temperatures that occur in the LSJR. This displacement process is described in the SED's oft cited Jeffres et al. (2008) study:

> *"When juvenile salmon are migrating down from upstream spawning grounds during high flow events, migration is more passive than active (Healey* 1980*; Kjelson et al.* 1981*) and they are essentially entrained in the water column until they find slower water velocities where active swimming becomes possible."*

Jeffres' description applies to both fry and smaller juvenile salmon and *O. mykiss*. Fish on the eastside tributaries at early life stages can be entrained in the water column and non-volitionally transported downriver to what is, or what will become, less suitable physical, food and temperature habitats. Fry and juvenile salmon and *O. mykiss* are unlikely to swim back to upstream areas because of the energy that must be expended to do so. This potential downstream drift and the potential conflicts among species the SED is attempting to benefit are not issues considered by the SWB. These factors add to the complexity and difficulty of developing an effective AIP.

Bennett et al (2016) also cites another problem experienced in some AIPs; that is, identifying the wrong primary ecological concern. Bennett et al. (2016) found this can happen *"when the primary ecological concerns are misidentified (e.g., relying on expert opinion alone)."* This is likely to be a problem encountered in the SWB's proposed AIP because this issue is closely linked to the lack of a well-defined, structured process with clearly defined and measurable goals. It is not at all clear what goals the AIP proposes to achieve. The biological goals are unspecified and evidently come later during the STMWG process. The SED sometimes references temperature goals to be met in the summer and fall (see ES-16) as a goal. The only "metric" put forward in the SED is a general reference to the idea that the SWB will require the *later* development of *"biological goals for abundance, productivity, and population spatial extent, distribution and structure."* (ES-72) None of these terms are quantitatively defined. The other "metrics" to be employed by the SWB for assessing whether specific measures would meet AIP goals are that such measures must *"support and maintain the natural production of the viable native fish LSJR fish populations migrating through the Delta" (Chapter 3)* and/or must *"reasonably protect fish and wildlife beneficial uses"* (page 3-11). How this would be determined in left unsaid.

Zimmerman et al. (2012) explains the fundamental elements necessary to be established from the outset for an AIP which is intended to improve ecosystem function and produce more fish. The fundamental elements to be considered are (1) the study approach, which should be designed to demonstrate cause and effect, (2) the baseline fish population, which any improvement would be measured against, (3) the magnitude of change required to detect an actual effect, and (4) the expected magnitude of the effect, which needs to be shown to be reasonably feasible. Zimmerman et al. (2012) provides an example of the application of these elements which involved the identification of statistical parameters, including natural variability, measurement error, and predicted increases. In the case described in Zimmerman et al. (2012), eight years of baseline fish populations were available prior to the implementation of improvements. As a minimum, the SWB's AIP should establish these most basic elements. For example, is the baseline fall-run Chinook adult escapement abundance to be 11,300 fish over the three tributaries? Since even the historical abundance from Mills and Fisher (1994) used to establish the AFRP doubling goal (USFWS 1995) have unaccounted biases from unmarked hatchery releases that cannot be estimated from available data (Newman and Hankin 2004), how is the baseline to be established for implementation of an AIP? What is the expected magnitude of effect to be tested? Is that magnitude reasonably able to be achieved? For the three LSJR tributaries, what is the baseline "steelhead" population? What is the expected magnitude of the change based on the preferred alternative? None of these most basic elements are provided in the AIP as proposed in the SED.

But where the AIP proposed in the SED displays a complete lack of realism, and therein lays the groundwork for it being unsuccessful, is in the absence of any realistic sense of the experimental time scales necessary to conduct studies for the species being "restored". SWB's lack of appreciation for the undertaking proposed to be accomplished by the AIP can be demonstrated by considering even the simplest of experimental designs for the plan area covered by the SED.

Let's assume for discussion purposes that the SWB would want statistically valid results. Let's consider the time required to just explore the 30% to 50% range in unimpaired flows contained in the preferred alternative by employing a "smolts per spawner at the confluence" metric. Assuming 5% increments in the unimpaired flow were to be evaluated (30%, 35%, 40%, etc.), this would be a 5-year experiment ***if each*** of the five years happened to end up being the same water year type. Assuming that different water year types are to be evaluated and that at least one replicate would be required to improve the precision of the metric, by applying the historical frequency of occurrence of water year types, it would take 50 years to examine this ***one*** question. If other flow scenarios (i.e., "flow shifting") were to be examined, it would be quite easy to identify at least five alternative flow regimes under the flow shifting paradigm. This would require another 50-year experiment. This simplistic approach also assumes there is no error in RST data and extrapolations, and the metric of "smolts per spawner" is not itself dependent on number of spawners (density dependencies). However, conducting an experiment over this long a period of time introduces other factors to be considered, like those already mentioned in the SED, including natural variability (boom and bust periods occurring on the order of 14 years, see SED Appendix C; varying ocean conditions). Considering these factor, it would take at least two and probably three cycles to be able to discern biological changes above natural variability of the system. We would now be looking at **150 years** to obtain statistically reliable results to determine the *best* flow regime, even if the climate remained relatively stable over this timeframe. This timeframe also assumes system stability with respect to other major factors, such as ocean conditions as well as the changing influences of hatcheries and predation.

This simplified experimental design shows the importance, at a bare minimum, of precisely defining the goal of the AIP, the metric or metrics to be used, and when success is achieved. Having as the metric *"protection of fish and wildlife beneficial uses"* or, even worse, *"better protection of fish and wildlife beneficial uses*" or *"support and maintain the natural production of the viable native fish LSJR fish populations migrating through the Delta"* are not sufficient direction from the overarching regulatory authority. Further, endorsing flexibility through having a *"virtually unlimited number"* of flow options is leading the STWWG in the wrong direction. Bennett et al. (2016) points out this challenge when it cautions that when dealing with salmon or steelhead, the "populations being studied have variable life histories that require monitoring for 2–5 or more years to ***assess a single cohort***." Bennett et al. (2016) provides guidelines for designing IMWs, giving high priority to "explicit adaptive management plans"; "explicit criteria to minimize confounding response", including ensuring a minimum influence from hatcheries and exotic species; identifying "ecological concerns derived from prior data"; and having a "clearly defined experimental design". To have a reasonable chance at success, the party that established the overall goal must establish the bounds of the parameters for the AIP. Just providing a "block of water" to experiment with resembles, at best, a "trial-and-error" approach, which is the least preferred type of adaptive management. But the AIP approach is one step worse than trial-and-error because there is not a success metric established in advance.

In the Executive Summary, section 11.6, the SED indicates that the SWB's prior 2012 draft Plan was criticized for not containing adequate "bounds and rigor" and having "no goals" in the then-proposed adaptive implementation plan. The SWB's response to this criticism in the current Amended Plan is to modify the 2012 Plan such that "[t]he *program of implementation now includes a* ***requirement to develop*** *tributary-specific numeric biological goals for abundance,* *productivity, and population spatial extent, distribution, and structure."* In four years' time, the SED has gone from having no goal to requiring that a goal be developed later. It is difficult to discern any meaningful difference between these two positions.

For the simple reason that the SWB's expectation is that the additional 300,000 acre-feet (or more) of water it is removing from a known and acknowledged beneficial use will produce significant incremental benefits to fish and wildlife populations, the SWB needs to take the time necessary to work with interested parties to develop a real AIP ***before*** it adopts the revised WQCP. If the goals are quantitatively defined, it may be possible to meet them with much less water and through other measures and actions. On the other hand, if the goals are set at a level where they are unlikely to be achieved, substantial beneficial uses of food production and M&I water supply would be sacrificed. Just as providing flows on the Tuolumne River floodplain cannot be a goal in and of itself, having a block of water to ostensibly benefit fish does not assure increased fish production. The SED provides no valid scientific evidence that the block of water the SED is acquiring for fish and wildlife will actually benefit fish and wildlife populations, especially when this water is allowed to be used without reasonable bounds, rigor, metrics, or quantitative indicators of success.

8.0 Comments on the SED's Economic Analysis

A detailed technical review of the SED's economic assessment is provided as Appendix C to these comments. Only a brief overview of this thorough technical review is provided here.

The SED estimates the economic impact to the water users of the Stanislaus, Tuolumne and Merced rivers from the SED's proposed Amended Plan to be $64 million per year on average. This grossly underestimates the economic loss to the region that would occur under the Amended Plan. The depth of the mischaracterization of the economic loss points to a fundamental misunderstanding on the part of the SWB of the nature of the local economies and the overriding importance of water to the irrigation, industrial, municipal, and commercial water users of the areas served by the three eastside tributaries.

This fundamental lack of understanding portrayed in the SED is exemplified by five methodological errors in the analysis:

- Use of and reference to an average economic impact.
- Exclusion of major components of the economic base from the economic analysis.
- Lack of quantitative analysis of the reasonably foreseeable restrictions on the future use of groundwater sources.
- Failure to consider the social and community impacts that result from loss of key portions of the tax base.
- Failure to evaluate and understand the disproportionate impact the SED's proposal will have on disadvantaged and minority populations of the affected region.

Use of and reference to an ***average*** *economic impact*

The most basic tenet of water supply planning is to maintain a sufficient available supply to withstand drought conditions. No entity in the water supply business plans for average water conditions. All water planners and the associated regulatory bodies understand that drought conditions, especially consecutive years of drought, pose the greatest threat and will have the greatest economic impact. This is especially applicable to the Tuolumne River study area affected by this SED because of the prominence of fruit and nut trees and dairy, cattle and calf operations in the agricultural economy of the TID and MID service territories. In contrast to annual crops, large initial capital outlays are required for tree crops and dairy and cattle operations and a reliable water supply is needed in all years to protect that investment. By evaluating and reporting the economic impact based on average conditions, the SWB reveals a fundamental misunderstanding of the nature of the local economies its actions are affecting and the true water supply impacts. The SED's use of averages masks the real economic effects of the SED's proposal.

An effective way to understand the lack of relevancy of estimating average economic impact is to consider it on a personal level. Let's say over a twenty-year period, a person is required to shoulder the burden of a reduction in salary. That reduction will now result in the employee receiving on average 87% of their former salary. That sounds palatable, until it is further described as receiving the full salary for 17 years and 10% of their salary for three of those years, and the three years of 10% will be consecutive. Of course, no average person, and their family, would survive economically with 10% of their salary for three consecutive years. By using average water supply numbers over a longer time frame, the SED is seriously mischaracterizing the economic impact of the SED's proposal. By not considering the economic impact during the drought years, the SED underestimates the economic loss just for the TID and MID service areas by over **$1.5 billion** during critical water years, including direct, indirect, and induced economic losses.

Exclusion of major components of the economic base from economic analysis

The Districts conducted a detailed assessment of baseline economic conditions as part of the Don Pedro Project Final License Application filed with FERC in April 2014, and this baseline assessment was made available to the SWB at that time. The SWB did not use or rely upon this extensive study of the Districts' service area. If the SWB had considered this work, it would have been aware that animal commodities comprise over half the annual commodity revenues resulting from the Districts' water supply (TID/MID FLA 2014). Food and beverage processing is also a substantial economic driver in the area and provides between one-quarter and one-third of the jobs in the study area analyzed in the Districts' study area (TID/MID FLA 2014). The SED fails to include in its assessment the economic impacts of the SED's preferred alternative on either the dairy, cattle and calf industries, or the food and beverage processing industries that benefit from the Districts' water supply. The lack of consideration of the full economic base of the region misleads the public about the degree of economic impact.

Lack of quantitative analysis of the reasonably foreseeable restrictions on the future use of groundwater sources

In 2014, the state legislature passed the Sustainable Groundwater Management Act (SGMA). Under SGMA, groundwater districts will be established and regulatory controls will be established that will place limits on groundwater extraction. Groundwater is a significant component of the Districts' and their customers' water supplies, especially during drought years. Comments provided on the SWB's 2012 draft SED directed the SWB to improve its assessment of groundwater/surface water interactions in order to develop a quantitative evaluation of the effects of future restrictions on groundwater supplies and the resulting increased reliance this will place on surface water supplies. On page ES-24 of this 2016 draft SED, the SWB acknowledges the issue when it states that the *"sustainability of increased reliance on groundwater pumping is an important issue"* and the *"reduced availability of surface water diversions in the plan area could also affect groundwater recharge"*. Reduced groundwater recharge is likely to affect the SED's current assumptions about accretion flows to the Tuolumne River (this is discussed further below in Section 10 of these comments). The importance of accounting for the interaction of surface water and groundwater was emphasized in the peer review comments on the Review Panel Report for the San Joaquin River Valley CalSim II Model[44]:

> *Groundwater is the most important process not included in the newer [CalSim] model, and was absent from previous models. It is clear from the documentation and the oral presentations that adding groundwater to the model was not part of the scope of work for this project. Thus our comments on groundwater are not intended as a criticism of the work done to improve the model. They are intended to point out an important* ***missing element in modeling water management in the San Joaquin valley****. Groundwater interaction with various components of the model is critical for several reasons:*
>
> > *• Groundwater is an important basin water supply, especially during droughts.*
> >
> > *• Groundwater is an important source of tributary inflows, mainstem inflows, and is a potentially important source of salinity from the Westside.*
> >
> > *• Groundwater is an important subject of management within the basin, with important interactions with the surface water demands and processes involved in the CalSim model of this region.*
>
> *…**Without explicit groundwater representation, the [CalSim] model's applicability to planning, policy, and operational problems under future water management and hydrologic conditions could be severely limited.** This problem will become increasingly limiting for planning applications involving activities that affect the availability of groundwater (including any ongoing overdraft), groundwater return flows, and*

[44] http://science.calwater.ca.gov/pdf/calsim/calsim_II_final_report_011206.pdf

> *groundwater management. Given the difficulties and expense of groundwater modeling and data for such a large region, it is understandable why this was not included in the effort being reviewed. However, explicit groundwater representation is likely to be important for future applications.* [emphasis added]

The SWB's modeling has not accounted for this critical interaction, and the peer review comments on the SWB's base model flows from CalSim still apply. Without addressing the peer review comments regarding the specific inclusion of groundwater, the SWB is unable to address the economic impact of reductions in surface water supplies resulting from the SED's preferred alternative.

Failure to consider the social and community impacts that result from loss of key portions of the tax base.

Economic impacts during drought periods are vastly underestimated in the SED. These impacts are projected to be severe under the SED (see Appendix C of these comments), especially when the effects of SGMA are considered. The economic impact to the communities' business interests will directly affect the tax revenues of the local communities, revenues which support schools, law enforcement, social services, public health and community programs.[45] Quantifying these impacts must be undertaken by the SWB and shown in the SED. The potential impacts of the reduced tax base must also be discussed. Without a substantial assessment of these impacts, the SED fails to demonstrate a recognition of the effects of its proposed action. Lack of acknowledgement of the impact provides the SWB with the ability to avoid the need to mitigate for the impact of its actions.

Failure to evaluate the disproportionate impact the SED's proposal will have on disadvantaged and minority populations of the affected region.

The communities affected by the SED's proposal are already some of the most disadvantaged in the state, having significantly higher unemployment and lower incomes than the state average. Nowhere in the SED is the issue of environmental justice discussed or addressed. Environmental justice refers to considering the potential impact on the environmental and public health issues and challenges confronting the nation's minority, low income, and disadvantaged communities. Environmental justice also refers to the "fair treatment of people of all races and cultures".[46] It is apparent that the SWB has not considered its proposed action within the context of environmental justice because the term cannot be found in the SED.[47]

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[45]See, e.g. comments provided by the San Joaquin County District Attorney Tori Verber Salazar (December 16, 2016 Tr., page 89-93), Merced County Supervisor Deidre Kelsey (November 29, 2016 Tr., page 84, In 15-21), Merced County Assessor Barbara Levey (December 19, 2016 Tr., page 72-74), Stanislaus County Supervisor Terry Withrow (December 20, 2016 Tr., page 97), and MID Board Member Jack Wenger (December 20, 2016 Tr., page 400).

[46]California Government Code §65040.12.12

[47]This issue was raised in the public hearings. *See, e.g.*, the comments of Kathy Miller, member of the San Joaquin County Board of Supervisors, who noted that the SED will create "an environmental justice nightmare for our region." (December 16, 2016 Tr., p. 88, ln. 8-11).

9.0 The Missing Science and How It Would Change the SED

Certainly in terms of quantity, at 3,500 pages the SED is a tremendous accomplishment. However, within these 3,500 pages, there is a lack of any evidence that the SWB seriously considered the resource studies that have been carried out by Turlock Irrigation District (TID), Modesto Irrigation District (MID), and the City and County of San Francisco (CCSF) on the Tuolumne River since 1995. Over the last 20-plus years, the Districts and CCSF have undertaken well over 200 separate investigations of the aquatic and terrestrial resources of the 52 mile reach of the lower Tuolumne River, the river reach which the SED asserts is in need of substantial modification, such modification to be accomplished by establishing a new, though yet undefined, flow regime. It is important to note that all of these 200-plus studies are publicly available, and the overwhelming majority have been filed with the SWB previously. Many of the studies involved SWB in the scoping and reviewing process. But even with the studies cited with some frequency in the SED, Stillwater Sciences (2006) and Stillwater Sciences (2013), the study results were evidently not considered by the SWB because they would have dissuaded the SWB from recommending an instream flow of 40% of the unimpaired flow in February and March, at a minimum because of the potential adverse impacts to fall-run Chinook fry and juveniles.

The Tuolumne River has been referred to as one of the most studied rivers in California. Nearly every aspect of the lower 52 miles of river have been investigated over the last 25 years. Most recently, as part of the FERC relicensing of the Don Pedro Project, a process in which the SWB was actively involved, an additional 20-plus studies of the water resources and aquatic resources were conducted and submitted to all interested parties, including the SWB. Each of these studies underwent detailed public scrutiny as required by FERC from the study planning phase to collaboration with relicensing participants during study execution and public review of draft reports and issuance of the final reports. These 200-plus studies constitute the most recent and best available science on the resources of the lower Tuolumne River.

The SWB appears to have systematically ignored this entire body of work. Provided below is only a brief overview of some of the information available to the SWB that would have better informed the SED.

Don Pedro Reservoir Inflow Hydrology Extends Through 2012: The SWB's WSE model is based on monthly data for the period 1922 to 2003. For the purpose of evaluating "temperature benefits", the SWB used the period 1970 to 2003. Aside from the numerous and serious concerns raised previously in these comments about the SWB's temperature assessment, our understanding is the SJR HEC-5Q temperature model was originally calibrated to **daily flow and temperature data**. There is no evidence the SWB recalibrated the model before using just monthly data; if not, then the SWB's "temperature benefits" were estimated by the SWB using an uncalibrated model. As part of the relicensing of the Don Pedro Project, the Districts, at the urging of the SWB and CDFW, developed a daily flow hydrology record for the inflow to the Don Pedro Project for the period 1971 to 2012. This daily flow record was calibrated to meet mass balance criteria over the monthly time steps for that entire period. This full data set was provided to, reviewed, and accepted by the SWB and CDFW in March 2013 (Final License

Application [FLA], Don Pedro Project, 2014). The Districts' hydrology database represents the best available science on the Tuolumne River. The SWB's WSE model and subsequent temperature and floodplain assessments should have relied upon this daily hydrology developed as part of the Don Pedro Project relicensing for the 1971 to 2012 period.

Don Pedro Reservoir Inflow Hydrology: Another and more significant aspect of the Don Pedro Reservoir inflow hydrology is that since it is a daily record, the SWB could have employed this data set to properly investigate the alternatives actually proposed in the SED. According to the SED (see Appendix K), the February through June releases to instream flows on all three eastside tributaries would be the 7-day rolling average of the unimpaired inflow. Since the WSE model only had monthly inflow data, the SWB analysis was only able to examine monthly variations in flow (that is, constant or flat flows) in the lower Tuolumne River. Monthly average flows do not adequately represent the daily variations in flow that occur in the river, which are especially variable in the February through June time period. In fact, since monthly flat flows are not the preferred alternative, the SWB never actually evaluated the preferred alternative, and therefore, is not able to draw any reasoned conclusions about floodplain inundation or river temperature benefits under the preferred alternative since these were not properly evaluated. The SWB neglected to use the best available hydrologic record in its possession for developing the 7-day rolling average flow record and the associated percents of unimpaired flow which would have represented the instream flow variability of the preferred alternative.

The Tuolumne River Operations Model: As part of the Don Pedro Project's FERC relicensing process, the Districts developed a daily operations model for the entire Tuolumne River system, consisting of both the Districts' Don Pedro project and water operations of the upstream Hetch Hetchy Project owned and operated by CCSF, including the protocols for CCSF's use of the "water bank" privileges it has in Don Pedro Reservoir. The WSE model does not consider the Hetch Hetchy operations and its potential effects on Don Pedro inflows. Omitting the role of CCSF's Hetch Hetchy System in the flow regime of the Tuolumne River is a shortcoming of the WSE model when representing Tuolumne River flows and effects of the SED alternatives. The Tuolumne River Operations Model is fully available to the SWB; and SWB staff were trained in its use in 2013 (FLA, Don Pedro Project 2014).

Don Pedro Reservoir 3-D Temperature Model: On page 5-60 of the SED in a section discussing the HEC-5Q temperature model employed by the SWB, the SWB states:

> *"The model simulates the reservoir stratification, release temperatures, and downstream river temperatures as a function of the inflow temperatures, reservoir geometry, and outlets, flow, meteorology, and river geometry."*

Here the SWB misrepresents the capability of a model it used in the development of the SED, in this case, the SJR HEC-5Q model. HEC-5Q is a one-dimensional model, meaning that each of the three dimensional locations along the length of the reservoir is represented in one dimension only, therefore, reservoir geometry is not simulated as the SWB represents. This is important for several reasons. First, the shape and physical structure of the Don Pedro Reservoir is highly dendritic with complex plan and profile divergences and convergences. Its geometry can't possibly be accurately represented by a one-dimensional model. The complex three-dimensional configuration has implications for reservoir temperature stratification. A 1-D model is not adequate to accurately depict the thermal regimes of this complex reservoir. This is particularly true when it is recognized that the old Don Pedro Dam still remains in the reservoir and introduces even greater complexity to the reservoir thermal regime. In addition, a 1-D reservoir model cannot depict the 2-D dimensions of outlets, and, therefore, cannot reliably predict reservoir release temperatures. Recognizing these complexities, and the importance of reliably depicting the full reservoir thermal regime, old Don Pedro Dam, and reservoir outlets, the Districts developed a state-of-the-art 3-D reservoir temperature model. The Districts' 3-D reservoir temperature model is the best available science, the SWB is aware of this model, and it is available for use.

Fall-run Chinook Population Model: As part of relicensing, the Districts developed, in consultation with the relicensing participants, a detailed fall-run Chinook population model that simulates the in-river life stages of that species in the Tuolumne River. This model incorporates data collected over the past 20-plus years on fall-run Chinook in the Tuolumne River, including data on adult spawning, redd location and superimposition, egg incubation, emergence, fry dispersal and development, parr growth, and smolt outmigration. The model includes and considered data on habitat availability by life stage and how it varies with flow, food availability, temperature response, size-at-age, size-at-river-exit, and survival by life stage. The SWB staff participated in the collaborative model development process, all of which is documented in the Don Pedro Project Final License Application filed with FERC in April 2014, and which is appended to these comments on the SED (see Appendix G). This model predicts changes in-river survival under different Don Pedro Project operation scenarios and can be used to evaluate alternative flow and non-flow measures and their effects on Tuolumne River fall-run Chinook in-river survival. This is the best available science and should have been used by the SWB when considering changes to the Tuolumne River.

O. mykiss Population Model: A population model for in-river life cycle stages of *O. mykiss* was also developed as part of the Don Pedro Project relicensing based on in-river data collected on *O. mykiss* in the Tuolumne River. Since the SED did not even attempt to undertake a valid scientific investigation to assess the effects of the SED alternatives on in-river *O. mykiss* populations in any of the eastside tributaries, this population model would have been especially beneficial to the SWB. Instead, the SWB simply presumes that flows that benefit fall-run Chinook will also benefit *O. mykiss* because both are salmonids. This oversimplification is not reasonable on the face of it, for it is recognized that *O. mykiss* life-stage periodicities in the Tuolumne River, determined using river-specific data, are substantially different than that of fall-run Chinook, and even more broadly, *O. mykiss* are acknowledged throughout the literature to have one of the most complex life histories of any fish species. The SWB's presumptions about the effects of the SED's alternatives on *O. mykiss* lack the careful scrutiny that could have been achieved by using this model.

Fall-run Chinook and O. mykiss Spawning and Population Studies: The Districts have collected accurate river counts of adult escapement in the Tuolumne River since 2009. The Districts have also undertook spawning and redds assessments over many years. The Districts have also conducted *O. mykiss* population relative abundance studies. These studies would have informed the SWB's decision-making process through the use of the best available science on Tuolumne River anadromous species.

Predation Studies: The SED barely acknowledges the large populations of non-native predator species in the eastside tributaries and the LSJR, and the significant role they play in the high mortality rates of fall-run Chinook fry and juveniles. In fact, the SED seems to ignore this important, and potentially limiting, factor to fall-run Chinook populations. The Districts conducted a Predation Study on the Tuolumne River in 2012, and reported the results in 2013. The findings were highly informative. Virtually all of the mortality measured by the two Tuolumne River RSTs could be accounted for by predation by just three species: largemouth bass, smallmouth bass, and striped bass. Considering this study would have greatly informed the SWB's decision-making process. The Districts' analyses using the best available science concerning predation in the Tuolumne River demonstrate that a small change in the current flows, discharged at biologically functional times, combined with specific predator reduction and control measures improves fall-run Chinook smolt survival to a much greater extent than the 40%, 50%, or 60% unimpaired flow. Instead, the SWB has chosen to rely on inferences that high flow by itself will substantially reduce the current high mortality rates on fry and juvenile salmon. While RST data do show higher survival of smolts on the Tuolumne River under certain flows, this is only in the high flow years ("wet years") and this increase is not observed in all high flow years. Furthermore, studies of predation on the LSJR have shown high predation rates during all water year types. The SWB chose to ignore this important information about the role of predation related to fall-run Chinook in-river survival on the Tuolumne River.

Otolith Study:[48] The Districts, with the cooperation of the CDFW and UC Santa Cruz, conducted a study of fall-run Chinook otoliths from five different year classes representing a range of year types. This study consisted of deconstructing the otoliths of fall-run Chinook adults from the Tuolumne River to determine, among other things, rearing location and growth rates. There are a number of interesting findings from this study. One of the findings of the study is that fall-run Chinook adult escapement in the Tuolumne River is chiefly made up of fish that leave the Tuolumne as parr or smolts. In the years represented in the study, it was shown that fish which leave the Tuolumne River as fry are poorly represented (less than 5%) in subsequent escapements (FLA, Don Pedro Project 2014). This points to the possibility of high predation losses in the San Joaquin River and Delta or overall poor rearing conditions in the LSJR. Considering this study would be of significant value to the SWB because as cited in Jeffres et al. (2008), high early flows can displace fry and young juvenile fish well downriver where rearing conditions appear to be poorer. The SWB chose to ignore the findings of this study.

Thermal Capability of Wild Juvenile O. mykiss: The Districts supported a study planned and conducted by fishery researchers at UC Davis and University of British Columbia (UBC) to investigate the thermal performance of wild juvenile *O. mykiss* that inhabit the Tuolumne River. This state-of–the-art study employed the use of swim tunnels and highly accurate measuring devices to evaluate the thermal tolerance of wild fish. Over the last ten or more years, a large amount of research and studies have consistently shown that fish in general, and *O. mykiss* in particular, express population-specific performance in many traits – growth, swimming

[48] See Appendix H of these comments for the Otolith Final Study Report, e-filed with FERC post-FLA filing.

performance, lethal thermal limits-each of which can be shaped by the temperature characteristics of their environment. The Districts' funded study evaluated the absolute aerobic scope (AAS) of wild Tuolumne River juvenile fish and how AAS changed with changes in temperature. While the SED does not present any direct relationships between reductions in temperature from current conditions and improvements in fish growth, health, or survival, the SED generally assumes a "colder-is-better" paradigm for all salmonid species in the eastside tributaries, including the Tuolumne River. However, the study performed by the UC Davis and UBC researchers found this not to be the case. Wild juvenile *O. mykiss* on the Tuolumne River performed optimally at approximately 21°C to 22°C, and within 5% of the maximum performance from 18°C to 24°C. Summer flows recommended by the SWB are intended to reduce temperatures below 18°C to benefit *O. mykiss*. However, this study, representing the best available science on Tuolumne River *O. mykiss,* was arbitrarily ignored by the SWB. This study was recently published in the respected journal Conservation Physiology and is now part of the peer-reviewed scientific literature on *O. mykiss* thermal tolerance (Verhille et al. 2016). The Districts are submitting this study in full with these comments on the Draft SED (see Appendix E).

Tuolumne River Floodplain Hydraulics Study: The Districts, at the request of the CDFW, USFWS, and SWB conducted an assessment of the relationship between flow and floodplain habitat for the entire 52-mile lower Tuolumne River. This is the most recent, best scientific information available on the floodplain system of the Tuolumne River. Unlike the USFWS (2008) study used by the SWB to estimate floodplain area-flow relationship for the Tuolumne River, the Districts study, developed in consultation with the resource agencies, recognized that not all wetted floodplain area is suitable fish habitat, The Districts study, evaluated using 2-D hydraulic modeling, developed floodplain ***habitat*** versus flow relationships. This recent study used LiDAR imagery from 2011 (versus early 1990s imagery used in the USFWS 2008 study) and supplemented existing river cross-section data with dozens of additional river transects to capture all potential hydraulic controls in order to accurately evaluate when floodplain inundation occurs. This study was released to the SWB in 2015. It is being filed with these comments in its final form which incorporate the Districts' response to comments provides by the USFWS (see Appendix F).

These studies are just a sample of the science that is missing from the SED. Consideration of this body of work would have materially changed the results of the analyses, and should have changed the conclusions, presented in the SED. The SWB's failure to use the best available science on the resources of the Tuolumne River has led to erroneous conclusions about the effects of the SED's preferred alternative.

10.0 Other Material Errors or Misrepresentations Contained within the Draft SED

The above comments specifically identify numerous errors, omissions, and unsupported conclusions of the draft SED. There remain other and still important material misrepresentations in the SED needing further explanation and discussion. We identify these below.

Presentation of Results: The SWB's representation of "floodplain benefits" as "acre-days" gives the reader the impression that the SWB's analysis was conducted using daily flows (when, in fact, the flows were average monthly flows assumed to be the same for each day of the month). This implies a level of detail to the analysis of the relationship between flow and floodplain inundation for each day of the period of record of 1922 to 2003 which did not occur. This is misleading and gives a false impression to the public. Only by examining the computer model itself does it become apparent that the SWB's floodplain benefits analysis was conducted using monthly average flows, not daily average flows, and that the "acre-days" was simply computed by multiplying by the number of days in the month. These values should be properly presented as "acre-months" and avoid giving the reader the impression that the SWB used "acre-days" to simply make the numbers larger.

Inundation Duration: On the same subject, the SED does not adequately discuss the importance of inundation duration when assessing use of floodplains by juvenile salmon. The importance of this parameter is brought up in several of the citations referenced in the floodplain benefits assessment section of the SED. It is a matter of debate in the scientific literature regarding the amount of time, in consecutive days, suitable floodplain ***habitat*** needs to be inundated to have a measurable benefit on juvenile salmon growth (even assuming the floodplain has more plentiful food than the river channel). There are trade-offs for fish selecting floodplain habitats over in-river habitats, including energy use, food supply, overall habitat suitability, stranding risk, and other factors. Certainly providing say one day or two consecutive days of floodplain access would not be sufficient to produce some measurable benefit in growth. The SED cited two studies (Sommer et al. 2001; Jeffres et al. 2008) related to the growth of juveniles residing on floodplains. Both of these studies measured juvenile salmon growth of fish residing continuously on the floodplain over relatively long periods. On page 19-53 of the SED, SWB cites Jeffres et al. (2008) as saying *"[t]he benefits of floodplain inundation generally increase with increasing duration, with even relatively short periods of 2 weeks providing potential benefits to salmon (Jeffres et al. 2008)."* While there does appear to be some general scientific consensus that a period of *at least* two weeks of continuous residence time may be needed for juvenile salmon to derive a growth benefit (Matella and Merenlender 2014),the reference to two weeks cannot be found in Jeffres et al. (2008). In fact, we cannot find the statement the SWB attributes to Jeffres et al. (2008) anywhere in the *Jeffres* report.

What Jeffres et al. (2008) actually states is quite informative, but is seemingly ignored by the SWB. Contrary to the temperature of 16°C the SED puts forward as necessary for juvenile core rearing in Table 19-1, Jeffres et al. (2008) found "[h]*igher water temperature is one of the factors that distinguished floodplain habitat from the river habitat. Temperatures on the floodplain for a 1-week period had a daily average of 21°C and reached a daily maximum of 25°C and fish continued to grow rapidly."* Jeffres et al. (2008) also specifically states *"[r]earing on a floodplain is a balance of risk and reward for juvenile salmon. Growth rates can be very high on the floodplain, but fish risk stranding and periods of stagnation, which can also create conditions lethal to juvenile salmon."* These two findings by Jeffres et al. (2008) may have been ignored because they do not support the SWB's temperature "criteria" provided in Table 19-1.

The fact that the SWB has no data on food availability on any of the floodplains of the eastside tributaries, and therefore could not make any reasoned about the value of providing flows sufficient to provide access to the floodplains, is a serious shortcoming and should be acknowledged and discussed in the SED. For discussion purposes, and by example, the Tuolumne River floodplain has undergone substantial modification since the late 1800s. Modifications by urban development, gravel mining, agricultural development, and levee construction have restructured and disrupted the natural floodplain ecosystems. Furthermore, non-native vegetative species are prominent in the limited amount of remaining vegetated floodplains. To simply presume that the Tuolumne River floodplain has greater food availability than the river channel is unsupportable, especially when site-specific data exist that show the in-river food sources to be plentiful.

The Role of Hatcheries:[49] It has long been recognized that anadromous fish hatcheries play an important, often critical, role in sustaining and protecting salmon populations. It is also widely recognized that hatchery bred and reared salmon can have adverse effects on natural salmon production. The SED acknowledges this and lists hatcheries (see Chapter 7) as one of the anthropogenic factors affecting salmon populations on the three eastside tributaries. The SED also makes it clear that the goal of the revised Plan is more than just increasing fall-run Chinook populations, the flow objective is to *"support and maintain the **natural production** of viable native SJR Watershed fish populations migrating through the Delta*" (emphasis added), although this goal seems to abruptly change in Chapter 13 and further on in the SED when the phrase *"and meet any biological goals"* appears.

Fall-run Chinook salmon is considered a "species of concern" by NMFS under ESA, indicating its sensitive status. On page 7-13, the SED duly notes *"[t]he federal status of fall-run Chinook salmon is due in part to concerns regarding hatchery influence".* Although the potential adverse effects of hatchery operations on natural production are acknowledged, there is no discussion of how, or if, increased instream flows in the three eastside tributaries would reduce hatchery influences or benefit naturally produced salmon over hatchery salmon. The SWB is obligated to show through scientific analysis that the increased flows proposed by the Amended Plan would increase natural production of fall-run Chinook salmon in light of the dominance of hatchery fish in the adult escapement. The mechanism by which the SED's proposed flow increases would decrease the hatchery influence and increase natural production is not discussed or addressed in the SED. On page ES-20, the SWB calls for *"[i]mprove(d) management and operation of fish hatcheries*" as a recommendation of the revised Plan. However, the SED also reports CDFW's response to this comment in Appendix M when it states "*CDFW also takes issue with the assertion that it should "develop and implement improvements to its anadromous fish hatcheries."* In Chapter 7, the SWB provides brief descriptions of each of the three eastside tributaries. Specifically related to the influence of hatcheries, the SED indicates that fall-run Chinook salmon populations on each of the three tributaries are *"maintained by natural production and hatchery strays"*. This description seriously misrepresents the influence of hatchery fish on natural production in the eastside tributaries. On the Stanislaus River, recent escapements have been essentially 100% hatchery fish. The Tuolumne River hatchery influence is reported to be nearly 80%, as is the Merced fall-run Chinook run. How increased flows will reduce hatchery influence and its attendant adverse effects and benefit natural production is never explained in the SED. There is no evidence provided in the SED that could lead the SWB

[49] The potential effects of hatcheries on the SED's Amended Plan is discussed extensively in Appendix A attached to these comments.

to conclude that simply increasing instream flows will somehow reduce the influence of hatchery releases.

However, the opposite is true, at least on the Tuolumne River. The Otolith Study undertaken on the Tuolumne River show that fish leaving the Tuolumne River as fry make up a very small percent (<5%) of the later adult escapement. On the other hand, hatchery fish are released as smolts, and these fish, comparatively, may be aided in their outmigration through the Delta by higher spring flows, continuing the trend to less natural production and greater influence of hatchery fish. The SED does not consider or discuss this possibility, nor provide a rationale for why it is unlikely to occur. The SED states in Chapter 19 that the "*Stanislaus, Tuolumne, and Merced Rivers (individually or combined) have had larger reductions in the natural production and returns from the ocean of adult fall-run Chinook salmon than any of the other tributaries (or combination of tributaries) to the Sacramento River".* The SED appears to then immediately jump to the conclusion that the cause is too little flow. The SED would benefit from a more complete discussion of the many potential causes of this reduction. The first issue to discuss would be the lack of data on hatchery operations before 2007 when CDFW initiated a program of constant fractional marking of hatchery releases. The impact of hatchery fish on the native Tuolumne River fall-fun Chinook population deserves additional discussion. Reliable estimates of natural production are highly uncertain, and this uncertainty should be acknowledged in the SED. The SWB suggests the distinct possibility the adverse effects of hatchery releases on the Tuolumne River native Chinook run in Chapter 7 (page 7-39):

> *"In recent years, up to 200,000 hatchery-origin salmon from the Merced River Hatchery have been released annually in the Tuolumne River. As a result, a significant number of hatchery-origin Merced River salmon return to the Tuolumne River each year. Fish produced by the hatcheries have the potential to negatively affect natural fall-run Chinook salmon by displacing wild salmonid juveniles through competition and predation, competing with natural adults for limited resources, and hybridizing Central Valley Chinook salmon with fish from outside the SJR Basin (CDFG 2011a)."*[50]

<u>*Stranding:*</u> The SED acknowledges the potential for floodplain inundation to result in adverse effects on juvenile salmon if stranding of juvenile fish occurs when water levels drop or due to exposure to avian predation in shallow areas. In Chapter 19, page 55, the SED states *"[i]n addition, areas with engineered and managed water control structures can have comparatively higher rates of stranding fish (Sommer et al. 2005). Further, floodplains that are too shallow or that lack vegetative cover may also make salmon more susceptible to avian predation (Gawlik 2002)."* The amended Plan in Appendix K goes so far as to recommend that interested parties should take steps to *"reduce salmon stranding events in ponds, pits, and other unnatural features by physically modifying problem areas within river corridors."* As mentioned above, virtually the entire Tuolumne River floodplain could be considered to have "unnatural features". The SWB received a number of comments on its 2012 draft Plan related to the potential for stranding

[50]This quote from Chapter 7 identifies the potential adverse effects of hatchery releases on natural production of fall-run Chinook salmon. The number of releases to the Tuolumne provided in the quote is far larger than the annual CWT releases prior to 2005, which were on the order of 100,000. Since 2008, there have been only three releases of hatchery salmon to the Tuolumne, none of which totaled more than about 7,000 fish.

of juvenile fall-run Chinook on floodplains emphasizing that *"evaluating the effects of redd dewatering and fish stranding losses base on average monthly flow does not accurately capture the effects on aquatic species."* (see Appendix M, pg 24 of the SED). The SWB has made no attempt to examine this potential adverse effect in the current draft Plan on any one of the three rivers' floodplains. This is especially the case on the Tuolumne River floodplain where, as pointed out above, the USFWS acknowledged this possibility. This would not have been difficult to do given that the Tuolumne River Floodplain Hydraulics Study, undertaken as part of the relicensing of the Don Pedro Project, contained information enabling the performance of such an investigation, and was in the possession of the SWB since September 2015.

<u>*Accretion Flows:*</u> According to SWB's analysis, accretion flows in the lower Tuolumne River make up a significant portion of the preferred alternative's February through June 40% unimpaired flow requirement. Each alternative in the SED is defined such that the flow requirement applies at the confluence of the tributary with the San Joaquin River (see pg 3-14). However, since there are no streamflow gages at these locations, the "compliance" point was moved to the streamflow gage that is closest to the confluence. It's worth mentioning that this location for computing unimpaired flow is problematic, given for example, the 24 hour travel time on the Tuolumne River between the point of release to the downstream gage under normal flows.

But there's a larger problem related to water accounting in the SED's analysis when is using the Modesto USGS gage as the location for estimating unimpaired flow. This problem involves the method used to estimate accretion flows between the La Grange and Modesto gages.

The accretion flow estimates, which play a large role in meeting the flow targets, were pulled directly from CalSim II into the WSE model. As shown in Table TR-2 below, the assumed accretions account for about 20% of the 40% unimpaired flow requirement in the Tuolumne River. The accretion/depletion assumptions from CalSim II are calculated using the difference in monthly volume between the downstream and upstream gages, as well as some assumptions about return flows and riparian diversions as reported in USBR (2005).

Table TR-2. Portion of 40% unimpaired flow met by SWB's assumed accretions (1923-2015)

Tributary	Feb	Mar	Apr	May	Jun	Total
Stanislaus	25%	22%	14%	9%	25%	17%
Tuolumne	34%	29%	19%	11%	16%	21%
Merced	46%	38%	20%	7%	19%	21%

A significant problem with assuming such a high percent of the SED's required flows are made up of accretion flows is that it requires perfect foresight for this method of counting accretion flows to be part of the 40% UF. This is impossible in real time, and lacks practical application. However, the most significant problem with assuming such high accretion flows lies with their lack of reliability in the future. Even now, the values in CalSim II are outdated and overestimate the accretion flows. Figure TR-16 below shows recent data on accretion flows in the Tuolumne River and depicts the systematic overestimation of accretion flows built into the SWB's WSE model. The SED fails to recognize this significant change in accretion flows.

The result of the erroneous assumptions regarding the volume of accretion flows is that it leads the SWB to underestimate the flow contribution required to be released from Don Pedro Reservoir to meet the 40%UF at the Modesto gage, which in turn leads the SED to underestimate the economic impact to the Districts of the SED's alternatives.

More importantly, as groundwater levels drop as predicted by the SWB due to reduced recharge as a result of the Amended Plan's flow prescription, accretion flows will be further reduced, even to the extend where the Tuolumne River between La Grange and Modesto may become a depleting reach and not an accreting reach. Furthermore, the SED has not accurately accounted for the riparian diversions that occur in the Tuolumne River between La Grange and the confluence.

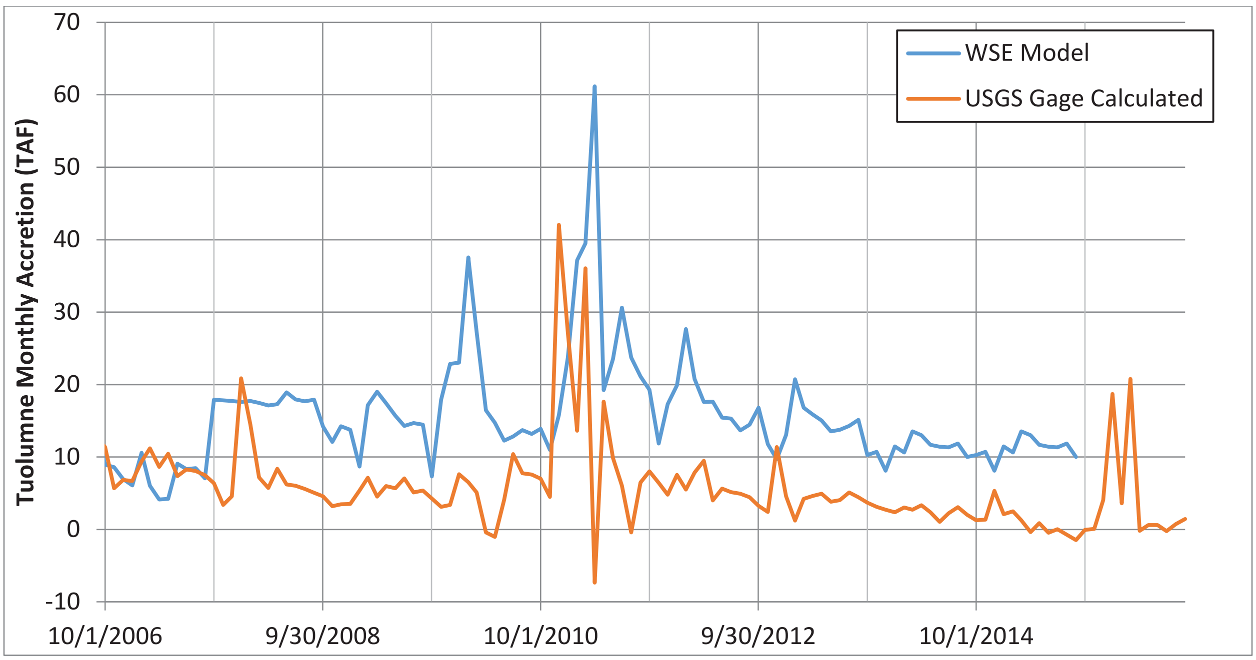

Figure TR-16. Plot of actual accretion flows between the Tuolumne River La Grange and Modesto USGS gages since WY 2007 and assumed values in the SWB's analyses.

Predation: The SED acknowledges the detrimental effect of predation of fry and juvenile salmon by non-native species. In Appendix C, *Technical Report on the Scientific Basis for Alternatives San Joaquin River Flow and Southern Delta Salinity Objectives*, predation is identified as not only a limiting factor, but a significant limiting factor, for fall-run Chinook salmon outmigrant survival in the SJR Basin and southern Delta and a major impediment to Central Valley salmon recovery efforts. On page 16-188, the SED reports that "*[j]uvenile salmon are clearly consumed by fish predators and several studies indicate that the population of predators is large enough to effectively consume all juvenile salmon production.*"

As for the Tuolumne River specifically, in the most recent study of predation (FishBio 2013) it was shown that predation by just three species – striped bass, largemouth bass, and smallmouth bass – was sufficient to account for all the losses of juveniles estimated to occur between the two RSTs. Large juvenile mortalities occur in the Tuolumne River at all river flows except the very wettest years. It's not possible to have every year be a wet year, therefore, without addressing the effects of predation, none of the alternatives evaluated in the SED should be expected to materially increase outmigrant survival. This result is essentially predicted by the SalSim model, which may be a reason why the SWB is now discrediting the SalSim model results. The SWB makes no effort to quantitatively evaluate the effect of predation in the three eastside tributaries, nor quantitatively assess what benefits would occur with even a small-to-modest reduction in predation rates. The SWB is in possession of, and has been trained to use, a model that can be used to perform such an assessment, at least for the Tuolumne River. The SWB has chosen not to perform this assessment.

Instead of using site-specific information of the Tuolumne River, the SWB relies on Marine and Cech (2004) where, according to the SED, it was found that juvenile salmon that were reared in 21-24°C (69.8°F-75.2°F) were significantly more vulnerable to predation by striped bass than juvenile salmon reared at lower temperatures. To be clear, the results of the experiment reported in Marine and Cech (2004) were that *"[j]uvenile Chinook salmon reared at 21–24°C* ***for 2.5 months*** *exhibited an increased vulnerability to predation compared with fish reared at 13–16°C or 17–20°C"* [emphasis added]. Since juvenile fish on the Tuolumne River do not rear at anywhere near these experimental temperatures for the period tested (21°C -- 24°C for 2.5 months), that part of the findings of Marine and Cech (2004) would not be applicable. On the other hand, Marine and Cech (2004) did find that *"growth performance of juvenile Sacramento River Chinook salmon remained similar among the temperature regimes that included daily maximum temperatures up to 20°C, ,when fed rations similar to those reported for wild fish"* and further that that their *"laboratory experiments demonstrated that Chinook salmon can readily survive and grow at temperatures up to 24°C" and "we did not observe significant reductions in growth rates for juvenile salmon reared with adequate food to promote growth until daily temperatures (daily means or daily maxima) exceeded 20°C."*

O. mykiss Impacts: In several sections of the SED, the SWB refers to "steelhead" and "steelhead populations" on the eastside tributary rivers or the LSJR. The first reference appears at ES-78 where the SED reports LSJR Alternative 3 "*would substantially improve rearing habitat conditions for Chinook salmon and steelhead in the three eastside streams and LSJR."* Aside from there being no empirical data provided in the SED to support "steelhead" rearing on floodplains[51] in any of the three eastside tributaries, the SED is implying there exist steelhead populations on the three eastside tributaries. Although NMFS considers that resident and anadromous *O. mykiss* to be Central Valley steelhead under the ESA, there is little to no evidence of self-sustaining steelhead populations on any of the LSJR tributaries south of the Stanislaus River and the influence of strays from Mokelumne River hatchery releases on any natural origin steelhead on the Stanislaus River have not been evaluated.

While an occasional large *O. mykiss* (presumed to be a "steelhead") has been captured in the Tuolumne River adult fish counting weir, there have been a total of ***five*** *O. mykiss* larger than 16-inches that ascended the counting weir between 2009 and 2014, inclusive. Therefore, there are

[51] In fact, a number of sources can be cited to show that steelhead/rainbow trout do not use floodplains for rearing. See Bustard and Narver (1975), Feyrer et al. (2006), Swales and Levings (1989), Keeley et al. (1996), Moyle et al. (2007).

no data to support "steelhead use" of habitats or predict increase use by steelhead. This is arbitrary speculation on the part of the SWB.

In Chapter 7, and other places in the SED, the SWB refers to its use of WUA habitat curves, and for the Tuolumne River cites IFIM studies by Stillwater Sciences (2013). Contrary to recommending higher flows for the fry and juvenile rearing life stages of *O. mykiss*, this study demonstrates that ***lower flows*** produce greater habitat for these two life stages. In fact, maximum fry rearing WUA occurs at flows of 50 cfs to 75 cfs, and maximum juvenile rearing WUA occurs at flows of about 175 cfs. Based upon generalized life history timing from NMFS (2009) and corroborated by seine and snorkel data collected by the Districts' timing of *O. mykiss* fry rearing in the Tuolumne River occurs from about April through June and juvenile rearing occurs from July through September. There is little to no data to suggest that *O. mykiss* use floodplain habitat, but instead prefer to use in-channel physical structure and stream margins during early life stages. In fact, a strong case can be made that high flows in the spring months could adversely affect young-of-the-year *O. mykiss* fry by displacing them into downstream habitats where they will encounter unsuitable and lethal water temperatures even under the UF flow scenarios proposed in the SED. The SED has not recognized or discussed this potential adverse impact on this ESA-listed species, and this is a significant omission in the SED.

11.0 References

Ahearn, D.S., J.H. Viers, J.F. Mount, and R.A. Dahlgren 2006. Priming the productivity pump: flood pulse driven trends in suspended algal biomass distribution across a restored floodplain. Freshwater Biology. 51,1417-1433.

Bennett, S., G. Pess, N. Bouwes, P. Roni, R.E. Bilby, S. Gallagher, J. Ruzycki, T. Buehrens, K. Krueger, W.J. Ehinger, J. Anderson, C. Jordan, B. Bowersox, and C. Greene 2016. Progress and challenges of testing the effectiveness of stream restoration in the Pacific Northwest using intensively monitored watersheds. Fisheries. Vol 41. No 2. February 2016.

Bilby, R.E, W.J. Ehinger, C. Jordan, K. Krueger, M. McHenry, T. Quinn, G. Pess, D. Poon, D. Seiler, and G. Volkhardt 2005. Evaluating watershed response to land management and restoration actions: intensively monitored watersheds (IMW) progress report. Prepared by the IMW Scientific Oversight Committee. Submitted to the Washington Salmon Recovery Funding Board.

Boles, G.L., S.M. Turek, C.D. Maxwell, and D.M. McGill 1988. Water temperature effects on Chinook salmon (*Oncorhynchus tshawytscha*) with emphasis on the Sacramento River: a literature review. Report to the California Department of Water Resources, Northern District. 43 pp.

Brown, T.G. 2002. Floodplains, flooding, and salmon rearing habitats in British Columbia: a review. Canadian Science Advisory Secretariat, Research Document 2002/007.

Bustard, D.R. and D.W. Narver 1975. Aspects of the winter ecology of juvenile coho salmon (Oncoryhnchus kisutch) and steelhead trout (Salmo gairdneri). Journal of the Fisheries Research Board of Canada 32:667-680.

California Department of Water Resources 2016. Estimates of natural and unimpaired flows for the Central Valley of California: Water Years 1922-2014.

Delta Independent Science Board (2016). Improving Adaptive Management in the Sacramento-San Joaquin Delta.

Farrell, A.P., N.A. Fangue, C.E. Verhille, D.E. Cocherell, K.K. English 2015. Thermal performance of wild juvenile *Oncorhynchus mykiss* in the lower Tuolumne River: a case for local adjustment to high river Temperature. Prepared for Turlock Irrigation District and Modesto Irrigation District for the Don Pedro Hydroelectric Project, FERC No. 2299.

Fischman, R.L. and J.B. Ruhl 2015. Judging adaptive management practices of U.S. agencies. DOI: 10.1111/cobi.12616.

FishBio 2013. Predation study report (W&AR-07). Attachment to Don Pedro Hydroelectric Project Initial Study Report. Prepared by FishBio, LLC, Oakdale, California for the Turlock Irrigation District and Modesto Irrigation District.

Florida Administrative Code. 2010. *Rule 40D-8.041*.

Fox, P, P.H. Hutton, D.J. Howes, A.J. Draper, L. Sears 2015. Reconstructing the natural hydrology of the San Francisco Bay-Delta watershed. Hydrology and Earth System Sciences. 19, 425-4274.

Feyrer, F, T.R. Sommer, W. Harrell 2006. Importance of flood dynamics versus intrinsic physical habitat in structuring fish communities: evidence from two adjacent engineered floodplains on the Sacramento River, California. North American Journal of Fisheries Management 26: 408-417.

Hanson, C.R. 1991. Acute temperature tolerance of juvenile chinook salmon from the Mokelumne River, Walnut Creek, CA. Prepared by Hanson Environmental, Inc., 1991. 15.

HDR and Stillwater Sciences 2017. Lower Tuolumne River floodplain hydraulic assessment study report (W&AR-21). Final report. Prepared by HDR, Sacramento, California and Stillwater Sciences, Berkeley, California for the Turlock Irrigation District and Modesto Irrigation District.

Jeffres, C.A., J.J. Opperman, and P.B. Moyle 2008. Ephemeral floodplain habitats provide best growth conditions for juvenile Chinook salmon in a California river. Environmental Biology of Fishes 83:449-458. DOI 10.1007/s10641-008-9367-1.

Keeley, E.R., P.A. Slaney and D. Zaldokas 1996. Estimates of production benefits for salmonid fishes from stream restoration initiatives. Watershed Restoration Management Report No. 4. Watershed Restoration Program, Ministry of Environment, Lands and Parks and Ministry of Forests, British Columbia. 20 pp.

Kiernan, J.D., P.B. Moyle, and P.K. Crain 2012. Restoring native fish assemblages to a regulated California stream using the natural flow regime concept. Ecological Applications. 22(5):1472-1482.

Kormos BM, M. Palmer-Zwahlen, A. Low. 2012. Recovery of coded-wire tags from Chinook salmon in California's Central Valley escapement and ocean harvest in 2010. Santa Rosa (CA): California Department of Fish and Game, Fisheries Branch Administrative Report 2012-02.

MacDonald, L.L., R. Bilby, P.A. Bisson, C.C. Coutant, J.M. Epifanio, D. Goodman, S. Hanna, N. Hundy, E. Merrill, B. Riddell, W Liss, E.J. Loudenslager, D.P. Philipp, W. Smoker, R.R. Whitney, and R.N. Williams 2007. Research, monitoring, and evaluation of fish and wildlife restoration projects in the Columbia River Basin: lessons learned and suggestions for large-scale monitoring programs. Fisheries. 32(12):582-590.

Marine, K.R. 1997. Effects of elevated water temperatures on some aspects of the physiological and ecological performance of juvenile chinook salmon (*Oncorhynchus Tshawytscha*): implications for management of California's Central Valley salmon stocks. Master Thesis. University of California, Davis.

Marine, K.R. and J.J. Cech. 2004. Effects of high water temperature on growth, smoltification, and predator avoidance in juvenile Sacramento River Chinook salmon. North American Journal of Fisheries Management. 24:198–210, 2004.

Matella, M. and A. Merenlender 2014. Scenarios for restoring floodplain ecology given changes to river flows under climate change: case from the San Joaquin River, California River Research and Applications. 31(3): 280-290.

McBain and Trush 2004. Coarse sediment management plan for the lower Tuolumne River. Revised Final Report. Prepared by McBain and Trush, Arcata, California for Tuolumne River Technical Advisory Committee, Turlock and Modesto Irrigation Districts, USFWS Anadromous Fish Restoration Program, and California Bay-Delta Authority.

Merced Irrigation District 2013. Chinook salmon egg viability study. Technical Memorandum 3-6. Merced River Hydroelectric Project, FERC No. 2179. March 2013.

Mesick, C. 2010. The high risk of extinction for the natural fall-run chinook salmon population in the lower Merced River due to insufficient instream flow releases. November.

Mills, T.J., and F. Fisher 1994. Central Valley anadromous sport fish annual run size, harvest estimates, and population trends, 1967 through 1991. Revised August 1994 (Inland Fisheries Technical Report) California Department of Fish and Game. Sacramento, CA.

Moyle, P.B., P.K. Crain, and K. Whitener. 2007. Patterns in the Use of a Restored California Floodplain by Native and Alien fishes. San Francisco Estuary and Watershed Science 5:1–27. http://repositories.cdlib.org/jmie/sfews/vol5/iss3/art1

Myrick, C.A. and J.J. Cech 2001. Temperature effects on Chinook salmon and steelhead: a review focusing on California's Central Valley populations. Bay-Delta Modeling Forum Technical Publication 01-1. 57 pp.

National Marine Fisheries Service (NMFS). 2009. Biological Opinion and Conference Opinion on the long-term operations of the Central Valley Project and State Water Project. National Marine Fisheries Service, Southwest Region, Long Beach, California. June 4, 2009. 844 pp.

National Marine Fisheries Service 2014. Endangered Species Protection Act Section 7(a)(2) supplemental biological opinion. Consultation on remand for operation of the federal Columbia River Power System. NOAA Fisheries Log Number NWR-2013-9562.

Newman, K.B., and D.G. Hankin. 2004. Statistical procedures for defining and detecting the CVPIA natural Chinook salmon production doubling goal. Unpublished report prepared for the U.S. Fish and Wildlife Service, Comprehensive Assessment and Monitoring Program, Sacramento, California. June. 36 pp.

Nichols, K. and J.S. Foott 2001. FY2000 Investigational report: health monitoring of hatchery and natural fall-run Chinook salmon juveniles in the San Joaquin River and Delta, April-June 2000. U.S. Fish and Wildlife Service. California-Nevada Fish Health Center.

Nichols, K. and J.S. Foott 2002. FY2001 Investigative report: health monitoring and natural fall-run Chinook salmon juveniles in the San Joaquin River and tributaries, April-June 2001. U.S. Fish and Wildlife Service. California-Nevada Fish Health Center.

Palmer-Zwahlen, M. and M. Kormos 2013. Recovery of coded-wire tags from Chinook salmon in California's Central Valley escapement and ocean harvest in 2011. Santa Rosa (CA): California Department of Fish and Game, Fisheries Branch Administrative Report 2013-02.

Palmer-Zwahlen, M. and M. Kormos 2015. Recovery of coded-wire tags from Chinook salmon in California's Central Valley Escapement, inland harvest, and ocean harvest in 2012. Santa Rosa (CA): California Department of Fish and Wildlife, Fisheries Branch Administrative Report 2015-4.

Poff, N.L., J. David Allan, M.B. Bain, J.R. Karr, K.L. Prestegaard, B.D. Richter, R.E. Sparks, and J.C. Stromberg 1997. The natural flow regime: A paradigm for river conservation and restoration. BioScience. 47:11.

Poletto,J.B., D.E. Cocherell, S.E. Baird, T.X. Nguyen, V. Cabrera-Stagno, A.P. Farrell, N.A. Fangue 2016. Unusual aerobic performance at high temperatures in juvenile Chinook salmon, *Oncorhynchus tshawytscha.* Conservation Physiology, doi: 10.1093/conphys/cow067.

Regional Mark Processing Center RMIS database accessible at http://www.rmpc.org.

Richter, B.D., J.V. Baumgartner, J. Powell, and D.P. Braun 1996. A method of assessing hydrologic alteration within ecosystems. Conservation Biology. 10:1163-1174.

Richter, B.D., R. Matthews, D.L. Harrison, and R. Wigington 2003. Ecologically sustainable water management: managing river flows for ecological integrity. Ecological Applications 13:206-224.

Roni, P., K. Hanson, and T. Beechie 2008. Global review of the physical and biological effectiveness of stream habitat rehabilitation techniques. North American Journal of Fisheries Management 28-856-890. American Fisheries Society.

Sommer, T.R., M.L. Nobriga, W.C. Harrell, W. Batham, and W.J. Kimmerer 2001. Floodplain rearing of juvenile Chinook salmon: evidence of enhanced growth and survival. Canadian Journal of Fisheries & Aquatic Sciences. 58: 325-333.

Sommer, T.R., W.C. Harrell, A.M. Solger, B. Tom, and W. Kimmerer 2004. Effects of flow variation on channel and floodplain biota and habitats of the Sacramento River, California, USA. Aquatic Conservation: Marine and Freshwater Ecosystems 14: 247-261.

Sommer T.R., W.C. Harrell, and M. Nobriga 2005. Habitat use and stranding risk of juvenile Chinook salmon on a seasonal floodplain. North American Journal of Fisheries Management. 25:1493-1504, 2005.

South Florida Water Management District Report of 2007.

Sparks, R.E. 1995. Need for ecosystem management of large rivers and their floodplains. BioScience. 45: 168-182.

Speas, D.W. 2000. Zooplankton density and community composition following an experimental flood in the Colorado River, Grand Canyon, Arizona. Regulated rivers: research and management 16:73-81.

State Water Resources Control Board 2016. Recirculated draft substitute environmental document in support of potential changes to the Water quality Control Plan for the San Joaquin Delta Estuary: San Joaquin River flows and southern Delta water quality. State Clearinghouse No. 2012122071.

Stillwater Sciences 2008. July 2008 population size estimate of *Oncorhynchus* mykiss in the lower Tuolumne River study plan. Prepared by Stillwater Sciences, Berkeley, California for Turlock Irrigation District and Modesto Irrigation District.

Stillwater Sciences 2009. March and July 2009 population size estimates of *Oncorhynchus* mykiss in the lower Tuolumne River. Prepared by Stillwater Sciences, Berkeley, California for Turlock Irrigation District and Modesto Irrigation District.

Stillwater Sciences 2011. March and August 2010 population size estimates of *Oncorhynchus* mykiss in the Lower Tuolumne River. Prepared for the Turlock Irrigation District and the Modesto Irrigation District by Stillwater Sciences, Berkeley, CA. March.

Stillwater Sciences 2012. Lower Tuolumne River instream flow studies: pulse flow study report. Final. Prepared by Stillwater Sciences, Berkeley, California for Turlock Irrigation District and Modesto Irrigation District, California.

Stillwater Sciences 2013a. Lower Tuolumne River instream flow study, final report. Prepared by Stillwater Sciences, Davis CA for Turlock Irrigation District and Modesto Irrigation District, Turlock CA and Modesto CA.

Stillwater Sciences 2013b. Spawning gravel in the lower Tuolumne River study report (W&AR-04). Attachment to Don Pedro Hydroelectric Project Initial Study Report. Prepared by Stillwater Sciences, Berkeley, California for the Turlock Irrigation District and Modesto Irrigation District.

Swales, S. and C.D. Levings 1989. Role of off-channel ponds in the life-cycle of coho salmon (Oncorhynchus kisutch) and other juvenile salmonids in the Coldwater River, British Columbia. Canadian Journal of Fisheries & Aquatic Sciences 46: 232-242.

TID/MID (Turlock Irrigation District and Modesto Irrigation District) 1992. Report of Turlock Irrigation District and Modesto Irrigation District Pursuant to Article 39 of the License for the Don Pedro Project, No. 2299. Vol. III.

TID/MID 1997. Report of Turlock Irrigation District and Modesto Irrigation District Pursuant to Article 39 of the License for the Don Pedro Project, No. 2299.

TID/MID 2003. 2002 Report of Turlock Irrigation District and Modesto Irrigation District Pursuant to Article 58 of the License for the Don Pedro Project, No. 2299. 2 Volumes. March.

TID/MID FLA 2014. Final License Application for the Don Pedro Project, No. 2299. E-filed April 2014. www.ferc.gov.

TID/MID 2016. 2015 Report of Turlock Irrigation District and Modesto Irrigation District Pursuant to Article 58 of the License for the Don Pedro Project, No. 2299. March.

United States Environmental Protection Agency (EPA) 2003. EPA Region 10 guidance for Pacific Northwest State and Tribal Temperature Water Quality Standards. EPA 910-B-03-002. 49 pp. Region 10 Office of Water, Seattle, Washington.

United States Fish and Wildlife Service 1995. Working paper on restoration needs: habitat restoration actions to double natural production of anadromous fish in the Central Valley of California. Prepared for the U.S. Fish and Wildlife Service under the direction of the Anadromous Fish Restoration Program Core Group

United States Fish and Wildlife Service 2008. Flow-overbank inundation relationship for potential fall-run chinook salmon and steelhead/rainbow trout juvenile outmigration habitat in the Tuolumne River. Sacramento, CA.

United States Fish and Wildlife Service 2013. Identification of the instream flow requirements for anadromous fish in the streams within the Central Valley of California and Fisheries investigations. Annual progress report fiscal year 2013.

United States Fish and Wildlife Service 2014. Identification of the instream flow requirements for anadromous fish in the streams within the Central Valley of California and Fisheries investigations. Annual progress report fiscal year 2014.

United States Fish and Wildlife Service 2013. Comment Letter on the Districts' Proposed 2-D Floodplain Study of the Tuolumne River.

Walker, K.F., F. Sheldon, and J.T. Puckridge 1995. A Perspective on Dryland River Ecosystems. *Regulated Rivers* 11:85–104.

Ward, B. 2000. Declivity in steelhead (*Oncorhynchus mykiss*) recruitment at the Keogh River over the past decade. Canadian Journal of Fisheries and Aquatic Sciences 57:298-306.

Verhille C.E., K.K. English, D.E. Cocherell, A.P. Farrell, N.A. Fangue 2016. High thermal tolerance of a rainbow trout population near its southern range limit suggests local thermal adjustment. Conservation Physiology 4(1): cow057; doi:10.1093/conphys/cow057.

Yarnell, S.M., G.E. Petts, J.C. Schmidt, A.A. Whipple, E.E. Beller, C.N. Dahm, P. Goodwin, J. H. Viers 2015. Functional flows in modified riverscapes: hydrographs, habitats and opportunities. BioScience. XX: 1-10. Doi: 10.1093/biosci/biv102.

Zimmerman, C. E, G. W. Edwards, and K. Perry. 2009. Maternal origin and migratory history of steelhead and rainbow trout captured in rivers of the Central Valley, California. Transactions of the American Fisheries Society 138: 280–291.

Zimmerman, M., K. Krueger, B. Ehinger, P. Roni, B. Bilby, J. Walters, T. Quinn 2012. Intensively managed watersheds program: an updated plan to monitor fish and habitat responses to restoration actions in the lower Columbia watersheds. Prepared for the Washington Department of Fish and Wildlife.

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March 17, 2017

Chair Felicia Marcus and Board Members
State Water Resources Control Board
1001 I Street, 24th Floor
Sacramento, CA 95814-0100

Jeanine Townsend, Clerk to the Board
State Water Resources Control Board
1001 I Street, 24th Floor
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Re: Comment to the Amendment to the Water Quality Control Plan for the San Francisco Bay/Sacramento-San Joaquin Delta Estuary and Supporting Draft Revised Substitute Environmental Document (September 2016)

Dear State Water Resources Control Board:

Enclosed herewith via flashdrive are the joint comments of the Modesto and Turlock Irrigation Districts (Districts) on the Amendment to the Water Quality Control Plan for the San Francisco Bay/Sacramento-San Joaquin Delta Estuary (WQCP) and Supporting Draft Revised Substitute Environmental Document (SED). In addition to these joint comments, the Modesto and Turlock Irrigation Districts will each be filing separate comments. The Districts also incorporate by reference all written and orally submitted comments of the San Joaquin Tributaries Authority (or its predecessor agency, the San Joaquin River Group Authority) to include the materials presented as Technical Comments to the Phase 1 SED (2012) and request that these materials be included in the Administrative Record for this amendment to the WQCP and revised SED. Many of these materials are posted on the SWB's website with the 2012 SED, such materials to be found in the folder entitled "unsolicited comments." The Districts also incorporate by reference all written comments submitted on the amendment to the WQCP and the revised SED by the San Joaquin Tributaries Authority and the separate comments submitted by its member agencies—the South San Joaquin Irrigation District, the Oakdale Irrigation District, the Modesto Irrigation District, the Turlock Irrigation District, and the City and County of San Francisco. Finally, the Districts also incorporate by reference comments submitted by the Merced Irrigation District.

General Comments

The Districts have spent considerable time, money, and effort studying the resources and habitat of the Tuolumne River, most of which was ignored by the SWRCB in their SED. As a result, the Districts and their consultants have developed considerable expertise about the fishery resources of the Tuolumne. Instead of using outdated general information about rivers, the Districts' comments on the SED are based on sound science specific to the Tuolumne River and its resources. Among the major findings included in our comments are the following.

- Finding #1: The SED has failed to demonstrate an understanding of the current physical conditions and resources of the lower Tuolumne River.

- Finding #2: "Unimpaired flows", as defined by the SED, do not "mimic the natural hydrograph" of the Tuolumne River.

- Finding #3: The SED fails to analyze its own proposal.

- Finding #4: The SED largely ignores the vast body of scientific data and technical information that has been compiled on the Tuolumne River and its associated resources over the last 20-plus years.

- Finding #5: Effects to fish and wildlife at the population level are not evaluated in the SED.

- Finding #6: The SED's preferred alternative is projected to result in certain adverse resource effects. The need to mitigate the adverse effects of the SED's preferred alternative eliminates the minimal fish population benefits that were hoped to be achieved through implementation of that alternative.

- Finding #7: The SED's failure to define a specific proposal prevents substantive analysis of the Amended Plan. More specifically, there are at least two distinct "amended plans" in the SED, each of which is based on a mutually exclusive scientific hypothesis.

- Finding #8: The adaptive implementation plan ("AIP") suggested in the SED is critically flawed because it lacks even the most basic elements of an implementable plan.

- Finding #9: According to the SED's own analysis, the SWB's preferred alternative will have an adverse effect on the fry life stage of Tuolumne River fall-run Chinook salmon, while having no measurable beneficial effect on Tuolumne River juvenile fall-run Chinook salmon.

- Finding #10: The economic assessment of the SWB's proposal fails to account for any adverse effects on several of the agricultural sectors that are important to the region's economy thereby vastly underestimating effects economic loss, lacks a rigorous evaluation of the reasonably foreseeable impacts of the state's recent groundwater regulations, and neglects to consider the disproportionate its proposal will have on disadvantaged and minority populations.

The SED suffers from a number of defects including a lack of scientific basis, a lack of clearly-defined goals and objectives, a lack of a plan of implementation that is capable of implementation, false assumptions, unsupported conclusions, and inappropriate use of citations, to name a few. Overall, the plan is a solution looking for a problem. Rather than laying out clear goals and objectives, the SED presumes there is a problem—a lack of flow has caused the decline of SJR salmon—without fully understanding what is causing the decline of salmon, not just in the SJR, but in the entire Central Valley and West Coast. For example, dams are cited as one of the culprits even though Don Pedro Dam has been existence for more than 50 years and dams have been on the Tuolumne River and the other San Joaquin tributaries for more than 100 years. The SWB then adopts a "more is better approach" as the solution. This leads the SWB to conclude that more flow is needed, which in turn leads to the conclusion that "colder is better" for temperature and "more flooded area is better" for floodplains. Unfortunately, when the SWB actually measures the results of its "more is better" approach using SalSIM, the result is 1,100 fish at a cost of more than 300,000 acre-feet of water and billions of dollars in economic costs. The human costs cannot even be calculated.

Many of the defects in the SED were identified by Mark Holderman, the principal engineer with the California Department of Water Resources (DWR) at the January 3, 2017, fifth and final public hearing on the SED. The conclusion of DWR was that the Bay-Delta water plan was written "without evidence, incomplete scientific information, ill-suited for real-time operations, and unverified assumptions." The Districts echo those same concerns.

Among the many defects are the following:

- Assigns responsibility for environmental harms without evidence
- Contains out-of-date and incomplete scientific information
- Uses Unimpaired Flow Standards ill-suited for real-time operations
- Makes inappropriate use of a "Flow-Only" approach
- Makes unverified assumptions about its effects on groundwater sustainability
- Relies on dated groundwater data prior to 2010 and does not include impacts of data collected during the 2012-2017 drought, and
- Passes the buck to the Groundwater Sustainability Agencies for preventing damage to the state's aquifers

The State Water Board's "unimpaired flows" approach for the San Joaquin River and its tributaries is not the path to achieve the desired ecological outcomes. It is inconsistent with established state policies, such as the California Water Action Plan, the coequal goals defined in the Delta Reform Act of 2009, the Sustainable Groundwater Management Act of 2014, and the Human Right to Water Act.

This proposal would undermine investments in storage, adversely impact the drinking water quality of disadvantaged communities, increase groundwater overdraft in a part of the state where groundwater basins are already out of balance, and put large acreages of agricultural land out of production.

Any strategy that would result in vast amounts of agricultural land going out of production and ultimately reduce water supply reliability for the majority of Californians is irreconcilable with the policy of coequal goals and the State Water Board's statutory obligation to protect all beneficial uses of water when establishing water quality objectives.

The State Water Board should set aside the percent of unimpaired flows approach and heed Gov. Jerry Brown's call for negotiated agreements. Such agreements have been demonstrably successful in achieving desired ecological outcomes while maintaining water supply reliability.

The State Water Board should embrace a collaborative process to develop water quality objectives that incorporates the best available science, utilizes comprehensive solutions that address multiple variables, aligns with established state policies, considers economic impacts, and ensures that Bay-Delta Plan decisions enable rather than obstruct implementation of the California Water Action Plan.

Legal Comments

I. The SED's Program of Implementation Will Constitute a Compensable Taking Underthe Fifth Amendment.

The SED provides that the when the LSJR flow objectives are implemented, the SWB "will include minimum reservoir carryover storage targets or other requirements…," (SED, App. K, p. 28), including minimum end of September storage requirements, minimum diversion levels, and maximum allowable draws from storage (SED, App. F, p. F.1-31). While the SED does not establish any specific carryover storage or other requirements for any party or reservoir, it notes that such requirements will be needed because the additional streamflow requirements of the LSJR alternatives "require adjustment of parameters to ensure feasibility for the 82-year simulation so that the reservoirs are not drained entirely in the worst droughts of record." (SED, App. F, p. F.1-31). While the scope and magnitude of such requirements are yet unknown, they are expected to reduce the available water supply from the New Don Pedro reservoir for consumptive use, particularly in dry and critical years. (Jan. 3, 2017 Tr., p. 24, ln. 18-24).

Additionally, the SED provides that in some cases, the volume equivalent to that which would have been released via the unimpaired flow ("UIF") percentage from February through June can be treated as a block of water and a portion released outside of the February through June period, including in the following year. (SED, App. K., p. 30-31).

For such a scheme to work, MID and TID, as owners of the New Don Pedro Dam and reservoir, will be required to divert into storage a quantity of water, maintain such quantity of water in storage, and then release such water from the dam at a later date.

All of these actions – requiring MID and TID to divert water into storage, requiring MID and TID to leave water in storage and refrain from diverting it for consumptive use, and requiring MID and TID to release water from storage for the benefit of fish and wildlife located downstream – constitute compensable takings under the Fifth Amendment to the United States Constitution.[1]

A. MID and TID Have Private Property Rights that Will Be Taken for a Public Purpose Under the SED.

To constitute a compensable taking under the Fifth Amendment, the government must take private property for public use. (Klamath Irr. v. U.S., 129 Fed. Cl. 722 (2016)). The physical facilities necessary to effectuate the SWB's plan – the dams, canals, drains and other facilities MID and TID use to divert, store and deliver water from the Tuolumne River – are all private property facilities owned, operated, built and maintained by MID and TID. Further, the pre-and post-1914 appropriative water rights held by MID and TID are private property which cannot be taken by government action without just compensation. (*See*, *e.g.*, United States v. State Water Res. Control Bd. (1986) 182 Cal.App.3d 82, 101).

The commandeering of MID and TID's storage at New Don Pedro Dam and reservoir and subsequent release of stored water, *water that the Districts would have provided to their customers,* for the benefit of fish and wildlife downstream will be considered a public use for purposes of the Fifth Amendment. (Casitas Mun. Water Dist. v. U.S., 543 F.3d 1276, 1292-1293 (2008) ("Casitas III")).

B. The SED's Program of Implementation Constitutes a Physical Taking.

Regulatory action by a governmental entity is considered a per se, physical taking if it (1) requires the owner to suffer a permanent physical invasion of property, no matter how small (Loretto v. Teleprompter Manhattan CATV Corp., 458 U.S. 419, 434-435 (1982), or (2) completely deprives the owner of all economically beneficial use of the property. (Lucas v.

[1] Compensation will be required even if the appropriation is based upon the SWB's alleged public trust authority. (*See* National Audubon Soc. v. Superior Court (1983) 33 Cal.3d 419, 440, *citing* Illinois Central Railroad Co. v. Illinois, 146 U.S. 387, 455 (1892), for the proposition that use of public trust to order removal of improvements on public trust lands would require compensation).

S.C. Coastal Council, 505 U.S. 1003, 1019 (1992)). The carryover storage and withdrawal limitations of the SED constitute permanent physical invasions of MID's and TID's New Don Pedro reservoir. Instructing MID and TID how much water they must store in New Don Pedro for future release to satisfy non-consumptive uses, and limiting the amount of stored water that they can release from storage for consumptive uses, are clear physical invasions of New Don Pedro Dam and reservoir by the SWB. For all intents and purposes, the SWB will have taken for itself some of the available storage space in New Don Pedro reservoir which currently belongs to MID and TID. The SED thus constitutes a "classic taking" via physical appropriation of available storage space in New Don Pedro Reservoir by the SWB. (*See*, *e.g.*, United States v. Security Industrial Bank, 459 U.S. 70, 78 (1982)).

The requirement to release water stored in New Don Pedro Reservoir for purposes of fish and wildlife enhancement likewise constitutes a *per se*, physical taking of water rights owned by MID and TID. Once the stored water is taken and released for benefit of fish and wildlife, it is forever gone from the Districts, no different than if the SWB piped the water from New Don Pedro reservoir to a different location. (Casitas III, 543 F.3d at 1294). The government-caused storage and release of water away from MID and TID will be analyzed under the physical takings rubric. (Casitas III, 543 F.3d at 1298; *see also* Washoe Cty., Nev. V. U.S., 319 F.3d 1320, 1326 (Fed.Cir.2003) [physical taking where government has "decreased the amount of water accessible by the owner of the water rights."]).

Once the SED is adopted and allocates responsibility for implementing the SED's requirements, MID and TID will seek compensation for both the value of the storage space in New Don Pedro reservoir taken by the SWB, as well as the value of the water rights taken.

II. Fish and Game Code Section 5937 Does Not Require the Release of Stored Water.

The SED provides that in some cases, the volume equivalent to that which would have been released via the unimpaired flow percentage from February through June can be treated as a block of water and a portion released outside of the February through June period, including in the following year. (SED, App. K., p. 30-31). In either case, although the STM Working Group will be consulted, the SWB's Executive Director can approve such a scheme upon the recommendation of a single member of the STM Working Group. (SED, App. K, p. 29-30, items (b) and (c)). Obviously, for such a scheme to work, the dam owner would be required to divert into storage a quantity of water, maintain such quantity of water in storage, and then release such water from the dam at a later date. During the public hearings regarding the SED, several parties raised concerns about the SWB's ability to require the release of stored water for the benefit of fish and wildlife beneficial uses located downstream. In response, Chairwoman Marcus identified Fish and Game Code Section 5937 as a source of the SWB's authority to require the release of stored water. (*See*, *e.g.*, Dec. 16, 2016 Tr., p. 216, ln. 3-11; Dec. 19, 2016 Tr., p. 152-153). Chairwoman Marcus is incorrect, and Fish and Game Code Section 5937 does not authorize the SWB to require the release of stored water. [2]

Fish and Game Code Section 5937 requires dam owners to allow water to pass through a fishway, or in the absence of a fishway, pass over, around or through a dam to keep fish below the dam in good condition. Section 5937 does not mention stored water at all. As explained by the courts that have construed Section 5937, it is a limitation on the amount of water that can be appropriated from a stream.

For example, in Natural Resources Defense Council v. Patterson, 791 F.Supp.1425, 1435 (E.D. Cal. 1992), the court explained that

> "[w]ithout deciding whether section 5937 is a water appropriation statute, vel non, the statute's plain language demonstrates that it was intended to limit the amount of water a dam owner desiring to collect for eventual irrigation may properly impound from an otherwise naturally flowing stream. Thus, it is a prohibition on what water the … owner of the dam, may otherwise appropriate … Put another way, …, 5937 preserves from appropriation … an amount of water necessary for instream uses …"

A similar finding was made in California Trout, Inc. v. State Water Resources Control Bd. (1989) 307 Cal.App.3d 585, 599:

[2] Fish and Game Code Section 5937 does not authorize the SWB to take any action nor provide a source of authority for any of the actions proposed in the SED. Section 5937 is part of the Fish and Game Code, whose provisions are to be administered and enforced by the Department of Fish and Wildlife. (Fish and Game Code § 702; see also § 37, defining "department."). Further, violations of the Fish and Game Code are specifically designated as misdemeanors (§ 12000(a)), for which there is no remedy via civil action. (Babu v. Petersen (1935) 4 Cal.2d 276, 288 ["No civil right can be predicated upon the violation of a criminal statute."]; compare language of Penal Code § 308, making the seller of tobacco in certain instances subject to prosecution for a misdemeanor or subject to a civil suit, with the language of Fish and Game Code §§ 5937 and 12000(a)). Moreover, the SWB has not made any findings as to what "good condition" means, has no evidence to support a conclusion that fish are or are not in "good condition," has not made any findings as to how far "below the dam" fish must be maintained in "good condition," and has not explained why natural production should trump protection for "any fish that may be planted" below a dam as called for in § 5937.

> "[t]hese provisions straightforwardly limit the amount of water that may be appropriated by diversion from a dam … by requiring that sufficient water first be released to sustain the fish below the dam."

Both of these cases correctly determined that Section 5937 is a limit on the appropriation of the natural flow of water in a stream or river. It does not require the release of stored water from a reservoir.

This interpretation is supported by the SWB's own regulation designed to implement Section 5937, which states:

> "In the case of a reservoir, this provision shall not require the passage or release of water at a greater rate than the unimpaired natural flow into the reservoir." (Cal. Admin. Code, tit. 23, § 782).

The plain language, implementing regulation, and controlling authorities clearly indicate that Section 5937 does not mandate the release of stored water to keep fish below a dam in good condition.

In addition, Fish and Game Code Section 5937 cannot be used by the SWB to require the release of stored water from New Don Pedro reservoir because it is a component of a hydroelectric project licensed by the Federal Energy Regulatory Commission ("FERC"), and the Federal Power Act ("FPA") preempts the independent applicability of Section 5937 to the New Don Pedro Dam and reservoir. (California v. FERC, 495 U.S. 490, 497-5000 (1990) [holding that the FPA preempts regulations under state laws because the federal government occupies the field of hydropower licensing]).

III. The carryover storage provisions contained in the SED are unconstitutional impairments of the contractual obligations of the 4th Agreement between MID, TID and the City and County of San Francisco.

In 1966, MID, TID and the City and County of San Francisco ("CCSF") entered into the 4th Agreement, by which CCSF participated financially in the costs of construction of New Don Pedro Dam and reservoir in exchange for water banking privileges in New Don Pedro reservoir. (SED, App. L, p. L-3). . The water banking privileges enable CCSF to release water to MID and TID (1) in advance of the time when releases are required under the Raker Act, (2) when such releases can be stored in New Don Pedro Reservoir, and (3) to subsequently intercept or divert equivalent amounts of water which it would otherwise be required to pass to MID and TID to satisfy their superior water rights. (4th Agreement, Art. 7, p. 7; SED, App. L, p. L-3). As recognized by the SWB, CCSF does not hold water rights to, nor physically divert from, New Don Pedro reservoir. The rights to all water in New Don Pedro reservoir are owned by MID and TID. (SED, App. L, p. L-3). In addition to dividing the costs of the construction of New Don Pedro Dam and reservoir, the 4th Agreement also provides for the sharing of certain additional future costs and flow obligations, with CCSF agreeing to be responsible for 51.7121% and the Districts 49.2879%. These percentages were derived by comparing the size of CCSF's water banking privileges to the size of the additional storage obtained by MID and TID as a result of the construction of New Don Pedro Dam and reservoir. (4th Agreement, Appendix A, page 4).

The carryover storage requirements established in the SED, including end of September storage targets, maximum allowable withdrawal from storage, and end of drought refill criteria (*see*, *e.g.*, SED, App. F, p. F.1-31-32) will result in storage levels in New Don Pedro reservoir being higher than under current conditions. As a result, there will be fewer times that there is room in New Don Pedro reservoir for MID and TID to store water that is released by CCSF in advance of when it is required to make releases under the Raker Act. In essence, this may result in the change in size of CCSF's water banking privileges and/or the size of MID's and TID's additional storage, and thus affect the negotiated percentages of responsibility for future costs and flow obligations as currently defined in the 4th Agreement. Such changes will frustrate the purpose of the 4th Agreement and potentially lead to its dissolution.

Article I, Section 9 of the California Constitution prohibits legislative or judicial actions which significantly impair the obligations of an existing contract. (Bradley v. Superior Court (1957) 48 Cal.2d 509, 519). Since the SWB's SED is a quasi-legislative act, its significant impairment of the obligations and benefits of the 4th Agreement will violate Article I, Section 9 of the California Constitution.

IV. The SED Cannot Be Made Applicable to MID and TID Via the Section 401 Process.

The SED states in several places that its flow and carryover storage requirements may be implemented against MID and TID via the CWA Section 401 process. (*See*, *e.g.*, App. K, p. K-26). The SWB has the authority and duty to certify that any discharge from MID's and TID's operation of the New Don Pedro Project under a new FERC license will comply with the CWA and any appropriate water quality requirement of State law. (33 U.S.C. 1341 (a), (d)). As explained below, much of the SED does not fall within this authority granted to the SWB by Congress and thus cannot be applied to MID and TID via the Section 401 process.

A. The Alleged Harms to Native Fish Caused By the Existence of the New Don Pedro Dam To Be Rectified by the SED Are Not a Point-Source Issue that Can Be Addressed Via the 401 Process.

The CWA regulates point-source pollution, and "[n]onpoint source pollution is not regulated directly by the [CWA] …" (ONDA v. Dombeck, 172 F.3d 1092, 1096 (9th Cir. 1998)). Section 401 certification thus does not apply to nonpoint source pollution. (ONDA, *supra*, 172 F.3d at 1097-1099). Traditionally, harms to fish allegedly caused by the existence of dams have been considered nonpoint source pollution. (*see* United States *ex rel*. TVA v. Tenn. Water Quality Control Bd., 717 F.2d 992, 999 (6th Cir. 1983); *see also* Nat'l Wildlife Fed'n v. Gorsuch, 693 F.2d 156, 177 (D.C.Cir. 1982)). Significantly, the SWB has relied upon this very distinction to argue that EPA cannot promulgate water quality objectives based upon streamflow under the CWA. According to the SWB,

> "These cases demonstrate … that **changes in water quality caused by dams are the result of nonpoint sources of pollution**…Where the predominant or sole cause of pollution in a water body is operation of water diversions, as is the case with the proposed salmon smolt survival criteria …, adoption of water quality standards under the Clean Water Act is not an appropriate method of regulation." March 11, 1994 letter of the SWB to EPA, p. 28, cited by the SWB in its 2006 WQCP, p. 4, fn. 3; SED, App. K, p. K-5, fn. 4, 5)(emphasis added).

Controlling caselaw and SWB policy[3] both demonstrate that alleged impacts to fish from the existence of dams is considered a nonpoint source of pollution. Since the Section 401 process does not apply to nonpoint source pollution, the flow and carryover storage requirements of the SED which are designed to provide floodplain, temperature and other benefits for native anadromous fish species cannot be applied to MID and TID via the Section 401 process.

[3] The holding of S.D. Warren Co. v. Maine Bd. Of Environmental Prot., 547 U.S. 370 (2006) is not controlling here. In that case, the parties conceded that the pollution at issue was from a point-source. (*see* Oregon Natural Desert Ass'n v. United States Forest Serv., 550 F.3d 778, 783-784 (9th Cir. 2008)). In this case, no such concession has been made, and in fact, the SWB has made the opposite assertion.

B. Section 401 Does Not Apply to Streamflow, Operations or Water Rights.

As noted above, the Section 401 process applies to ensure a federal permittee complies with the CWA and any appropriate water quality requirement of State law. (33 U.S.C. 1341 (a), (d)). In this case, the UIF and carryover storage requirements proposed to be applied against MID and TID are not related to water quality and thus cannot be implemented via the Section 401 process.

For purposes of the CWA, "water quality" does not include impacts associated with reductions in freshwater flows caused by dams and diversions. (33 U.S.C. 1252(b); 33 U.S.C. 1313(c)). Thus, SWB cannot rely on the authority of Section 401(a) for authority to apply the SED against MID and TID.

Nor can the SWB rely upon the authority of Section 401(d), which enables a state to provide water quality certification to assure that the permitted activity complies with "any other appropriate requirement of State law…" This provision is limited in scope, and only authorizes a state to impose conditions "affecting water quality in one manner or another." (American Rivers v. FERC, 129 F.3d 99, 107 (2d Cir 1997); Arnold Irr. Dist. v. Department of Environmental Quality, 717 P.2d 1274, 1279 (1986); Matter of Eastern Niagara Project Power Alliance v. New York State Department of Environmental Conservation, 42 A.D.3d 857, 859-860 (2007)). In this case, it is clear that the flow and carryover storage requirements are not related to water quality, but rather are matters of streamflow, water rights, and operations of dams and diversions.

In 1994, EPA published a proposed rule to protect fish migration and protect cold water habitat pursuant to CWA Section 303(c), 33 USC 1313 (c)). In the proposed rule, EPA suggested that the SWB should implement such criteria by amending water rights permits. These "salmon smolt survival" standards included both export limitations and minimum streamflow requirements. (59 Fed Reg. 810, 825-826 (January 6, 1994))[4]. In comments filed on March 11, 1994, the SWB objected to the proposed rule, arguing strenuously that because the "salmon smolt survival criteria" were flow and export standards, they were not properly considered "water quality" issues for purposes of the CWA. The SWB argued, for example:

- "the salmon smolt survival standards … take direct control of the heart of the State's water rights and water distribution system." (p. 9)

[4] SWB Chairwoman Marcus was the regional administrator for EPA Region IX at the time.

- "Streamflow Matters Are Not To Be Regulated By EPA" (section heading, page 10).
- "For purposes of the Clean Water Act the proposed criteria for … salmon smolt survival are streamflow requirements, not water quality criteria." (p. 10).
- The only means of meeting EPA's … salmon smolt criteria would be for the State to regulate water project operations and allocate water storage and streamflow … for instream flows." (p. 11).
- "It is beyond dispute that outflow and water project operations are not water quality matters." (p. 11-12).
- That the EPA had written that impacts caused by reductions in streamflow were a "stream flow/water allocation issue, not a water quality issue under Section 303." (p. 15).
- "Here, EPA apparently wants the State to 'work back' and cut diversions to attain the water quality standards. This method is inappropriate…" (p. 26).

Each of the above statements apply equally to the UIF and carryover storage requirements of the SED. Although described as being promulgated as part of a water quality control plan amendment, clearly such requirements have nothing to do with "water quality" as described and understood in the CWA. As a result, the SWB will not be able to implement the provisions of the SED against MID and TID using Section 401(d).[5]

Because the UIF and carryover storage requirements are not related to water quality, they exceed the authority delegated by Congress in Section 401 of the CWA. This is significant since Section 401 is the only opportunity for states to include mandatory conditions in federal power licenses; all other authority is vested in FERC. (*See*, *e.g.*, Karuk Tribe of Northern Calif. V. California Regional Water Quality Control Bd. (2010) 183 Cal.App.4th 330, 359-360 [CWA gives the states a significant role in federal hydropower licensing, but this is the only area Congress has allowed]; American Rivers, *supra*, 129 F.3d at 111 [noting the preemptive reach of the Federal Power Act had been diminished by Section 401]; First Iowa Hydro-Elec Coop v. FPC, 328 U.S. 152, 180 (1946) [detailed provisions of federal plan for regulation of power leave no room for conflicting state regulation]). This means that while the SWB can participate in the relicensing process of New Don Pedro, and provide FERC with recommendations and comments as to the

[5] PUD No. 1 v. Wash. Dep't of Ecology, 511 U.S. 700 (1994) will not be of any assistance to the SWB. While the Supreme Court did conclude that Section 401(d) could be used to impose minimum instream flow requirements, in that case such requirements were adopted pursuant to CWA Section 303, 33 U.S.C. 1313. (Id. at 712-713). However, the SWB takes the position that Section 303 "is not intended to regulate pollution caused by reduction of fresh water flow." (March 11, 1994 letter, p. 10; cited as current view at 2006 WQCP, p. 4, fn. 3 and SED, App. K, p. K-5, fn. 4 and fn. 5).

appropriate streamflow downstream of New Don Pedro Dam, FERC retains sole and exclusive jurisdiction to establish minimum streamflow and other conditions of the license in the absence of the 401 conditions. As explained by the U.S. Supreme Court when California made a prior effort to require flow requirements on a FERC-licensed project via conditions in a water rights permit,

> "we conclude that the California requirements for minimum in-stream flows cannot be given effect and allowed to supplement the federal flow requirements. … As Congress directed in FPA 10(a), FERC set the conditions of the license, including the minimum stream flow, after considering which requirements would best protect wildlife and ensure that the project would be economically feasible, and thus further power development. Allowing California to impose significantly higher minimum stream flow requirements would disturb and conflict with the balance embodied in that considered federal agency determination. … we agree that allowing California to impose the challenged requirements would be contrary to Congressional intent regarding [FERC's] licensing authority and would 'constitute a veto of the project that was approved and licensed by the FERC.'" (California, *supra*, 495 U.S. at 506-507)(citations omitted).

Even if adopted, the UIF and carryover storage requirements cannot unilaterally be applied against MID and TID because they are preempted by FERC's determination on appropriate streamflows. Absent agreement by FERC, and inclusion of such requirements by FERC in any new license issued, the UIF and carryover storage requirements set forth in the SED will simply not apply to MID and TID.

C. Section 401 Certification is Likely Unnecessary for New Don Pedro

Generally, an applicant for a FERC license for the operation of a hydroelectric facility that may result in a discharge into navigable waters must obtain certification from the state that the project will comply with state water quality standards. (33 U.S.C. 1341). However, not every circumstance requires a 401 certification from the state, particularly those that will either reduce the amount of discharge, or for which an increase may occur that will not have an adverse impact on the water quality of the discharge. Either of these exceptions will likely apply to New Don Pedro.

1. MID and TID May Apply for a New License that Will Reduce the Amount of Amount of Water Discharged By New Don Pedro Dam and Reservoir, Thus Nullifying the Need for Certification Under Section 401.

As part of their effort to relicense the Don Pedro hydroelectric project, MID and TID may request a new license that results in less water being passed through the turbines than currently passes under the existing license. Such effort would eliminate the existence of a "discharge" as defined under the Clean Water Act. (North Carolina v. FERC, 112 F.3d 1175, 1188 (1997)["A decrease in the volume of water passing through the dam turbines cannot be considered a 'discharge' as that term is defined in the CWA."])(citation omitted). Since a "discharge" is a prerequisite for Section 401 to apply, FERC will be able to issue a new license without MID and TID obtaining a water quality certification from California. (Id., p. 1189; *see also* San Diego Elec. & Gas Co.,105 FERC ¶ 61,226 (2003) ["new certification would be required only if extending the license term would result in a new or greater discharge from the project."]).

2. Even if MID and TID Seek a New License that Would Keep the Flows through the Dam Substantially the Same or Even Result in a Slight Increase, Section 401 Certification May Not Be Needed.

Not all increases in flows from hydroelectric projects will trigger the need for Section 401 certification. For example, a licensee sought permission to replace its turbine generators, which would increase the project's hydraulic capacity and enable water to be discharged more quickly. Parties argued that a new Section 401 certification was necessary, but FERC disagreed. FERC found that while increased discharges could occur, the "nature of the discharge would not change." FERC also found that the environmental analysis accompanying the proposal revealed that the changes would have no adverse impact to the water quality. (Alabama Power Co., 106 FERC ¶ 62,014 (2004)).

For the New Don Pedro hydroelectric project, MID and TID are confident that the studies they have performed at FERC's direction, the proposed new terms and conditions, and the supporting environmental analysis under NEPA and CEQA will demonstrate that the nature of the discharge will not materially change from what it is now. Even if there is a slight increase in certain circumstances in terms of rate or volume, such increase will not result in a material adverse impact. As such, certification under Section 401 will not be required, and thus the SED will not be applied to MID and TID via Section 401.

The State Water Board proposal and its singular focus on unimpaired flows is the wrong choice for the state's future. The Districts urge the State Water Board to set aside the unimpaired flows approach and recognize that the best outcome can be achieved through comprehensive, collaborative approaches that include "functional flows" as well as non-flow solutions that contribute real benefits.

MODESTO IRRIGATION DISTRICT

Greg Salyer
General Manager

TURLOCK IRRIGATION DISTRICT

Casey Hashimoto
General Manager

Enclosure (Flashdrive)

SED Technical Comments

1.0 Summary of Findings Related to SWB's Revised Draft Substitute Environmental Document

2.0 Comments on the SED's Description of the Tuolumne River Basin

3.0 Comments on Hydrology, Unimpaired Flow, and Related Adverse Impacts on Fry and Juvenile Fall-Run Chinook Salmon

4.0 Comments on the SED's Assessment of Temperature Benefits

5.0 Comments on the SED's Assessment of Floodplain Benefits

6.0 Comments of the SED's SalSim Model and Analyses

7.0 Comments of the SED's Adaptive Implementation Plan

8.0 Comments on the SED's Economic Analysis

9.0 The Missing Science and How It Would Change the SED

10.0 Other Material Errors or Misrepresentations Contained within the Draft SED

11.0 References

Attachments

Attachment 1	Table TR-1
Attachment 2	Figures TR-5 through TR-11

Appendices

Appendix A	Evaluation of the SED's Floodplain Benefits and Hatchery Impacts
Appendix B	[INTENTIONALLY OMITTED]
Appendix C	Evaluation of Economic Impacts of the Draft SED
Appendix D	Response to the Resource Agencies' Presentations at the January 3, 2017 Public Hearing
Appendix E	Final Swim Tunnel Study Report
Appendix F	Final Tuolumne River Floodplain Hydraulic and Habitat Assessment Study Report
Appendix G	Final License Application (FLA), Don Pedro Project
Appendix H	Final Otolith Study Report, e-filed with FERC post-FLA filing
Appendix I	Regional Economic Impact Caused by a Reduction in Irrigation Water Supplied to Turlock Irrigation District and Modesto Irrigation District: Methodology Memorandum

APPENDIX A

Evaluation of the SED's Floodplain Benefits and Hatchery Impacts

A-1:

Technical Review of the SWRCB's SED – Floodplain Analyses

A-2:

Technical Review of the SWRCB's SED – Supplemental Analysis of Hatchery Impacts upon Survival and Escapement of Naturally-Produced Chinook Salmon from the Lower San Joaquin River Tributaries

Technical Review of the SWRCB's (SED) – Floodplain Analyses

Stillwater Sciences
March 6, 2017

The proposed updates to the Bay-Delta Plan analyzed in the SED include improving flow conditions during the February through June time period so that they more closely mimic the natural hydrographic conditions to which native fish species are adapted, including the relative magnitude, duration, timing, and spatial extent of flows as they would naturally occur. For aquatic resources, the SED primarily analyzes impacts and benefits of baseline and alternative flow regimes upon aquatic resources primarily based upon flow needs of Fall-run Chinook salmon using a supporting rationale that includes hydrologic analyses, life history reviews and population trends, water temperature modeling evaluations, salmon vs flow relationships, as well as salmon population modeling. At the Districts' request we have reviewed floodplain analyses primarily focusing on materials presented in Chapter 19, Analyses of Benefits to Native Fish Populations from Increased Flow Between February 1 and June 30.

1 SUMMARY OF SED FLOODPLAIN ANALYSES

After discussing changes in the historical extent and inundation of lands within California's Central Valley, the SED advances an "indicator species" approach to assess potential benefits of increased floodplain inundation, using Fall-run Chinook salmon fry and juveniles as indicators. The ecological importance of floodplain inundation was based upon the following literature sources:

- General literature references comparing present day with historical estimates of riparian forests and floodplain extent in the Central Valley (Katibah 1984) as well as other parts of North America (Barbour and Billings 1988).
- Literature references to generalized conceptual models of ecosystem services supported by floodplain inundation in the greater U.S. as well as large world rivers (Junk et al 1989; Bayley 1991).
- Recent conceptual models of ecosystem functioning in the Delta using examples from areas north of the LSJR study area boundary at Vernalis (Opperman 2012).
- References to other studies outside of the LSJR tributaries that examined floodplain habitat use by native fish species, including:
    - Studies of the Yolo bypass floodway and northwest Delta in reference to Sacramento Splittail (Sommer et al 1997; Moyle et al 2004) and Chinook salmon (Sommer et al 2001; Sommer et al 2005);
    - food and growth studies of juvenile Chinook and other fish using off-channel habitats within the lower Cosumnes River (Ahearn et al 2006; Jeffres et al 2008; Moyle et al 2007) in the eastern Delta; as well as growth studies of juvenile salmonids in off-channel habitats in Washington State rivers (Bellmore et al 2013).

- Other floodplain associated species discussed in the SED include Sacramento Splittail (*Pogonichthys macrolepidotus*), which are recognized to have historically made use of the broad Tulare Lake basin upstream of the LSJR study area as well as being found during flooding of the low gradient floodplain habitats near the LSJR tributary confluences (Moyle et al 2004).

The general method of analysis presented in the SED compares the relative amounts and periods of floodplain inundation using Baseline and potential alternative monthly UIF time series, numerically transformed into frequency relationships using area vs flow relationships developed for the LSJR and each tributary. Monthly floodplain inundation frequency, expressed as acre-days, was assessed using:

- Time series of average *monthly* flows for each tributary were developed from the WSE model (Appendix F.1) over the period 1922–2003 (n=82 years) under Baseline (i.e., historical) conditions as well as a range of scenarios representing fractions of monthly unimpaired flows (i.e., 20%, 30%, 40%, 50%, and 60%).
- Floodplain inundation area vs. flow relationships were developed for portions of the LSJR and its tributaries based upon a combination of modeling and GIS analyses.
    - Merced River – 1-D modeling of existing HEC-5Q model cross sections were used to estimate wetted width at flows from 1,000 cfs to 5,000 cfs for the river from RM 52.2 to RM 27.
    - Tuolumne River – USFWS (2008) performed GIS analysis of digitized air photos from the 1990s to estimate inundated area at four flows from 1,100 cfs to 8,400 cfs for the river from RM 52.2 to RM 21.5).
    - Stanislaus River – USFWS (2013) developed a 2-D model to assess inundation over a flow range from 1,000 to 5,000 cfs for the river from RM 54.5 to the confluence.
    - Lower San Joaquin River – cbec (2010) recalibrated a 1-D HEC-RAS model to assess inundation over a flow range from 1,000 to 15,000 cfs extending in three reaches from the Merced River confluence at RM 118 downstream to the Tuolumne River at RM 84 (modeling Reaches 1 and 2), to the Stanislaus River confluence at RM 72.5 (modeling Reach 3), and Mossdale at RM 57.5 (modeling Reach 4).

From the information above, average monthly unimpaired flows are transformed using area vs. flow estimates to calculate inundation areas for each month of the 82-year analysis. Annual recurrence frequency was then calculated as the percentage of years meeting or exceeding a given average monthly flow or inundation area threshold. To provide a simpler level of comparison between baseline flows and various UIF proposals, these results are also summarized on an annual basis as average total acre-days of inundation across the 82-year analysis period.

2 ERRORS OF FACT OR ASSUMPTION

The SED uses the generally accepted ecological importance of floodplain access as a justification that some “improvement” in the current floodplain inundation amounts and frequency in the

LSJR and its tributaries are needed. However, almost none of the references presented related to current or historical use of LSJR floodplain habitats by Chinook salmon or other floodplain adapted species use of the LSJR. Other than anecdotal accounts of historical floodplain inundation in the lowland portions of the greater San Joaquin River, the SED contains no evidence of, or a basic statement of, a specific floodplain related problem in the LSJR to be solved associated with baseline conditions. The broadest assumption of the SED floodplain analysis which was not stated is that the present-day floodplain inundation amounts and frequency do not support existing aquatic and wildlife beneficial uses. However, no information is provided that demonstrates that aquatic or wildlife beneficial uses are not supported by existing amounts, frequency and timing of floodplain inundation within the San Joaquin Flood Control Project levees.

The potential benefits of the UIF alternatives rely upon a more specific assumption that increasing the percentage of time that existing floodplains are inundated will result in increased growth, survival, and production for Chinook salmon and other species. However, rather than relying on any direct assessment of biological resources use of existing floodplain habitats within the in the LSJR, or attempting to examine the strength of the relationship among various biological metrics above with floodplain inundation or other explanatory variables, the presumption of a problem is used to establish a general equivalency between incremental changes in inundation area or frequency and the abundance of the selected floodplain indicator species, Chinook salmon and Sacramento splittail. One would presume that use of indicator species is warranted when information exists for these species use of floodplain habitats. However, because no such information from the LSJR is presented and purported ecological linkages are not documented to any level of local detail there is no way to confidently assess whether current floodplain inundation amounts and frequencies are not protective of beneficial uses or that specific increases and decreases relative to existing conditions are demonstrably more or less protective of these beneficial uses.

The “plan area” for analysis of impacts on aquatic biological resources consists of the three eastside tributaries and the lower San Joaquin River between the Merced River confluence and Vernalis. Rather than analyzing each river individually, SED floodplain effects determinations are reached for the plan area as a whole. This serious logical flaw fails to account for the variable conditions and differences in effects among the three tributaries, many of which are discussed in the impact analysis but not given proper consideration for each individual river in the overall determination of significance.

Lastly, as the SED itself describes in Chapter 19, there is no generally accepted, or standard relationship between wetted floodplain area and usable floodplain habitat. The use of “wetted area” to express an “improvement” for specific fish populations is unsupported in the SED and unsupportable in general. References cited by the SED speak to the need for detailed site-and river-specific data on these factors. Without any information on these and other factors from within the areas analyzed, any expectation of “improvement” over current conditions is speculative at best. These issues are described more fully below with specific reference to the Tuolumne River.

3 DETAILED COMMENTS

3.1 Inappropriate use of citations

There are many examples of the SED citing a document that is not appropriate or even contrary to the SED findings. For example, in discussing the importance and ecological functions of natural flow regimes, most of the references cited were not based on information developed in the LSJR basin or other Central Valley Rivers (e.g., Bunn and Arthington 2002; Junk et al 1989; Poff and Ward 1989; Poff et al. 1997; Poff et al. 2006; Poff et al. 2007; Richter et al. 1996; Richter et al. 2003; Sparks 1995; Tharme and King 1998; Tharme 2003; Walker et al. 1995). The lack of information on ecological functioning at any specific fraction of UIF suggests that the alternatives presented are arbitrary and the expected benefits are largely hypothetical with no basis in actual data from the LSJR basin. As previously stated, the SED (pages 19-52 through 19-55) makes inappropriate reference to fish growth in studies of seasonal flooding on lowland bypass areas (Sommer et al. 2004; Ahearn et al. 2006) which have no counterpart in the higher gradient foothill settings of the LJSR tributaries to the east of the San Joaquin valley floor, and the SED makes no effort to draw the necessary comparison of similarity between the floodplains referenced in the literature and the floodplains of the three east side tributaries. Use of Sommer et al. 2004 and Ahearn et al. 2006 to support conclusions regarding food web limitations within floodplains or in-channel habitats of the LSJR and tributaries (SED Page 7-43) is inappropriate. No information is presented regarding current levels of food resources within the LSJR tributaries. Use of Matella and Merenlender (2014) to support statements regarding food limitation for Chinook salmon related to floodplain access within the LSJR and tributaries (SED page 7-45) is also inappropriate. The reference analyzes floodplain inundation frequency and no information is presented regarding current levels of food resources within the LSJR tributaries.

3.2 No evidence of food availability or Chinook salmon rearing within floodplain or in-channel habitats of the LSJR and tributaries is presented

In Section 19.3, no information is presented regarding floodplain ecology within the modeled LSJR tributaries, such as data on current levels of food resources, Chinook salmon growth rates or survival rates related to floodplain access or the frequency and duration of inundation events. For example, page 7-38 states: “Although specific food web studies have not been conducted in the Tuolumne River, current research indicates that regulated flows downstream of dams and losses of overbank flooding have likely contributed to historical declines and current limitations on native fish populations through reductions in primary and secondary production (phytoplankton and invertebrate production) associated with seasonal floodplain inundation (Sommer et al. 2004; Ahearn et al. 2006).” This statement does not take into account the many years of benthic macroinvertebrate and drift sampling (e.g., TID/MID 1997, Report 96-4; TID/MID 2003, Report 2002-8), food ration studies from direct stomach sampling (TID/MID 1992, Appendix 16; TID/MID 1997, Report 96-9), as well as recent evidence showing high lipid content found in Chinook salmon smolts sampled from the Tuolumne River and other LSJR tributaries in 2001 by Nichols and Foott (2002), all of which demonstrate that food resources are not currently limiting based upon current levels of floodplain access. Lastly, because no evidence is presented showing in-channel food resources are limiting Chinook salmon rearing and emigration success from the LSJR and its tributaries to the point that increases in floodplain inundation is needed to relieve this limitation, future monitoring will be unable to statistically discriminate the relative benefits of specific UIF recommendations on the basis of floodplain inundation.

3.3 Study reach extent and characteristics

In Section 19.3.2, the study reach in the SED for the LSJR includes only limited floodplain extent due to the confining levees of the San Joaquin River Flood Control levees authorized by the Flood Control Act of 1944 and constructed between 1956 and 1972. Leaving aside concerns over the timing of floodplain inundation for the moment, the areas being characterized as floodplain habitats in the SED are generally limited to toe berms of the project levees in the reach downstream of the Tuolumne River with the total inundated area shown in Table 19-21 (2,773 acres in reaches 3 and 4 at a flow of 15,000 cfs) is less than 5% of the 59,000-acre Yolo bypass considered in floodplain rearing studies in the SED (Sommer et al 2001). For the Tuolumne River, the modeled study reach extent is from RM 52 to RM 21.5 (page 19-58), which omits the lower 20 miles of the river that was modeled by HDR and Stillwater Sciences (2016). The SED provides no explanation for this. While much of that lower river is urban area within the City of Modesto, there is also some agricultural land use. Based on the Districts' own study of the entire floodplain habitat on the Tuolumne River the varying topography in these confluence areas presents different inundation thresholds, flow vs inundation area relationships, and habitat suitability considerations (HDR and Stillwater Sciences 2016).

3.4 Selected assessment metrics

The most common approaches used in species recovery planning include (1) development of ecological or other performance standards based on descriptive statistics of habitat metrics, and (2) assessment of the relative importance of limiting factors that potentially constrain the production of a species of interest (ISAB 2003). For the floodplain topic addressed by the SED, the quantity of available floodplain habitat for the indicator species is evaluated using only the area of inundation and total number of days of inundation (p. 19-56), without consideration of the duration of continuous inundation as well as habitat suitability of the inundated habitat based on common criteria such as depth, velocity, cover, or water temperature on the floodplains. Similarly, in advancing a functional floodplain approach the proposed floodplain inundation frequency metric used to analyze rearing benefits for indicator species does not consider the annual recurrence period of inundation events of particular durations. Matella and Merenlender (2014), which was reviewed in the preparation of the SED, presents suggested durations and recurrence periods to benefit Chinook salmon, splittail, and other native species.

While the SED recognizes there is little data available to assess specific inundation goals (SED page 19-56) or to separate the effects of floodplain inundation from other factors affecting inland and ocean life stages of Chinook salmon, the SED claims as useful and then adopts the floodplain inundation area and frequency metrics above and then adopts a 10 percent change from baseline in combination with "professional judgment" to determine a significant benefit or impact. This arbitrary assignment of significance is unsupported and will simply lead to self-fulfilling conclusions that UIF scenarios producing greater than 10 percent increases are necessary for species recovery. Courts have previously rejected the assertion that an agency conclusion is a "finding" where it was merely a prediction based on opinions. (See Bangor Hydro-Elec. Co. v. FERC, 78 F.3d 659, 663 [D.C. Cir. 1996]). Basing such "professional judgment" opinions upon limited studies from areas outside of the LJSR study area is unwarranted. Because the information presented which has been available for well over a decade, one would expect it would be used to inform monitoring studies during the multiple years of floodplain inundation that have occurred since the earliest floodplain rearing studies of Sommer et al (2001). Any conclusions on ecological functioning of in-channel and floodplain habitats should be based upon a well-designed study program that examines physical and biological monitoring data to develop a local understanding regarding inter-annual variations in life history outcomes at a range of flow magnitudes, floodplain inundation frequency and event duration within the LSJR.

3.5 Assessment Results

We fundamentally disagree with the premise of comparing floodplain inundation for baseline hydrology and various UIF proposals based on annual exceedance frequency of total acre-days of inundation across the 82-year analysis period. Because no minimum inundation amounts, minimum duration, or minimum annual recurrence frequency for floodplain is established in the SED or compared to other factors affecting the target Fall-run Chinook salmon population or other aquatic beneficial uses, there is no basis to conclude that the current inundation amounts and frequency do not adequately support existing beneficial uses or that the apparent “improvements” in the selected metrics will support future species recovery. Nevertheless, examining the LSJR and tributary-specific results shown in Tables 7-15(a-d) shows that baseline inundation areas are generally present at frequencies equal to, or in excess of those under the proposed UIF scenarios presented during the February and March periods when fry and juvenile Chinook salmon would be expected to benefit from floodplain inundation. Although some UIF scenarios show small increases in floodplain inundation frequency during April and greater amounts in May which could potentially support Splittail spawning no information is presented analyzing the timing or duration of flows necessary for Splittail spawning. For Chinook salmon, the vast majority of rearing juveniles would be expected to reach smolt size and emigrate by this time and not benefit from floodplain growth opportunities. Further, the April and May periods generally coincide with rapidly rising air temperatures and it is unlikely that temperatures suitable for survival let alone smoltification (USEPA 2003) occur within inundated floodplain habitats during this timeframe.

Not assessed here is that the rearing habitat impact analyses do not account for total usable rearing habitat variations with flow. In Sections 19.3.2 and 19.3.3, the floodplain versus flow relationships presented for the LSJR and its tributaries (SED pages 19-58 through 19-62) do not consider habitat suitability of inundated overbank habitat for juvenile Chinook salmon or other species based on depth, velocity, or other attributes such as water temperature on floodplains. Because this method will over-represent usable habitat amounts at different flows, the reported inundation frequency results for the specific UIF scenarios evaluated (Tables 7-15, 19-24, 19-25, and 19-28) must lead to differing conclusions than if usable habitat had been considered. For example, information available from the Districts’ more recent and more detailed floodplain hydraulic study of Tuolumne River floodplains (HDR and Stillwater Sciences 2016) shows that the fraction of usable to total habitat is sometimes as low as 30 percent, varying both by river sub-reach as well as with discharge. The Tuolumne River study shows that potential gains in habitat that come with increased floodplain inundation are accompanied by losses in habitat associated with increased in-channel velocities and depths, and these gains/losses are not assessed. Because there is a non-linear relationship between flow and usable habitat and because channel and floodplain morphology contributes to large spatial variations between usable habitat and flow, any conclusions regarding annual exceedance frequencies of floodplain inundation will differ if expressed based on total inundation area rather than usable habitat.

3.6 Inappropriate attribution of Chinook smolt survival to floodplain inundation

In Section 19.3.1 (page 19-53), reference is made to a USFWS (2014) study purporting to show a positive relationship between juvenile survival as a function of floodplain inundation expressed in acre-days. This analysis is flawed in several ways. First, the referenced study did not specifically analyze the difference in fish survival within floodplain vs in-channel habitats, which is normally accomplished using PIT-tagging or other mark-recapture techniques. Instead, the USFWS (2014) study re-analyzed in-channel rotary screw trap (RST) data from 1996–2009 based on a flow data transform to arrive at a floodplain inundation metric. No comparisons of other flow data transformations (e.g., log-flow, power law fits, flows within particular months) are presented to determine if the hypothesized linkage between floodplain inundation and in-channel RST passage is suggested. Since the RSTs are deployed at in-channel locations, floodplain benefits cannot possibly be separated from the effects of in channel flow variations on predator habitat suitability and encounter rates between predators and emigrating juvenile salmon. Because the study does not attempt to assess spatial variations in Chinook salmon mortality within either floodplain or in-channel locations, use of inundation area as an explanatory variable is inappropriate and only a traditional survival vs. flow relationship is supportable. Lastly, whether using the flow-area data transform presented or simply flow as an explanatory variable, the resulting regression presented in USFWS (2014) to explain relative RST passage as a survival index appears to be based on just three groups of clustered points. Statistically, the resulting relationship can only be considered suggestive and should only be used as the basis of data collection efforts to validate the hypothesized linkages. Such studies would include controlled mark-recapture or tracking studies to assess differential growth and mortality of fish within adjacent in-channel and floodplain habitats of the LSJR and tributaries.

3.7 Other publicly available information not considered

As an example of publicly available information that was not reviewed for the SED includes studies of invertebrate food supply (e.g., TID/MID 1997, Report 96-4; TID/MID 2003, Report 2002-8), direct stomach content sampling of Chinook salmon (TID/MID 1992, Appendix 16; TID/MID 1997, Report 96-9) as well as physiological assessments by USFWS (Nichols and Foott 2001), data representing current levels and frequency of floodplain inundation, data that suggests existing food resources are more than adequate for rearing and smoltification of Chinook salmon. Further, because seasonal air temperatures in the lower portions of the LSJR tributaries may reach 80–90°F during late May and through June (TID/MID 2013), water temperatures within inundated floodplain habitats in the lower reaches of the Tuolumne River would be well above EPA (2003) temperature recommendations being used in other sections of the SED and there is no reason to believe that increased floodplain inundation metrics in this time period (Tables 19-22 through 19-27) would benefit the targeted Fall-run Chinook salmon population.

4 ALTERNATIVE FINDINGS AND CONCLUSION

Because many of California's native species have evolved and adapted to take advantage of seasonal floodplain inundation (See Moyle 2002), several studies suggest that increasing the inter-annual inundation frequency (Matella and Merenlender 2014) and duration of floodplain habitats (Matella and Jagt 2014) may provide access to significant food resources for rearing salmonids (Sommer et al. 2001, Sommer et al. 2004, Grosholz and Gallo 2006). In addition to direct biological data collection within in-channel and floodplain habitats of the LSJR study area, modeling that predicts area, depth, frequency, and duration of floodplain inundation would be a much more appropriate and valuable tool than the modeling used in the SED. Such models are available such as the expected annual habitat (EAH) method of Matella and Jagt (2014).

As an example of an alternative modeling approach, floodplain inundation for the WY 1971–2012 hydrology on the lower Tuolumne River was considered by the Don Pedro Project relicensing floodplain study (HDR and Stillwater Sciences 2016). Area-duration-frequency analyses for the period above were conducted based on 2-D modeling floodplain habitat vs flow relationships. The results show that floodplain inundation (e.g., 14 to 21 days) analyzed during the rearing period of Chinook salmon (February through May) currently occurs at a 2- to 4-year recurrence interval on the lower Tuolumne River consistent with the typical return periods of fall-run Chinook salmon and Sacramento River suggested to be supportive of salmon by Matella and Merenlender (2014). Only considering inundated area, for comparability to the SED, Figure 1 shows the frequency of occurrence of inundated area over several event durations under current hydrology conditions on the Tuolumne River. This analysis does not consider habitat suitability and any direct assessment of actual habitat use, but is intended to illustrate the functional flow concepts advanced by several references included in the SED.

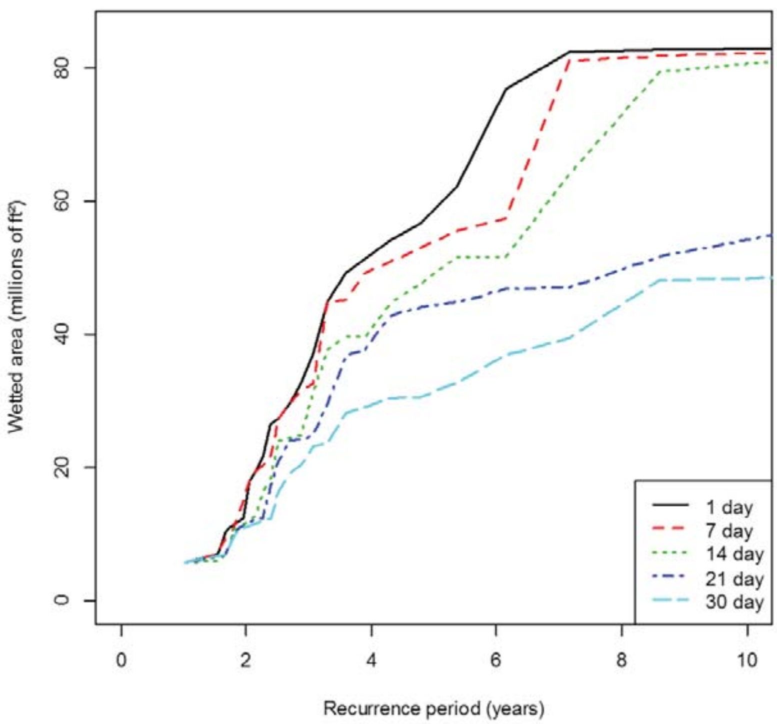


Figure 1. Total area-duration-frequency (ADF) plot showing recurrence of events exceeding various total inundation area and duration thresholds in the lower Tuolumne River (RM 52-0) from February through May under Base Case (1971–2012) hydrology (HDR and Stillwater Sciences 2016).

5 REFERENCES

Ahearn, D. S., J. H. Viers, J. F. Mount, and R. A. Dahlgren. 2006. Priming the productivity pump: flood pulse driven trends in suspended algal biomass distribution across a restored floodplain. Freshwater Biology 51:1417–1433.

Barbour M. G., W. B. Billings. 1988. North American Terrestrial Vegetation. Cambridge, NY: University Press. As cited in J. J. Opperman, 2012. A Conceptual Model for Floodplains in the Sacramento-San Joaquin Delta. San Francisco Estuary and Watershed Science 10(3).

Bayley, P. B. 1991. The flood pulse advantage and the restoration of river-floodplain systems. Regulated Rivers: Research and Management 6: 75–86

Bellmore, J. R., C. V. Baxter, K. Martens, and P. J. Connolly. 2013. The Floodplain Food Web Mosaic: A Study of its Importance to Salmon and Steelhead with Implications for their Recovery. Ecological Applications 23(1):189–207.

Bunn, S. E., and A. H. Arthington. 2002. Basic Principles and Ecological Consequences of Altered Flow Regimes for Aquatic Biodiversity. Environmental Management 30(4):492–507.

cbec. 2010. San Joaquin Floodplain inundation mapping. Memorandum. Cbec, Inc, Sacramento, CA. Page 24 in Appendix 4 of Comments pertaining to the "Scientific Basis for Developing Alternate San Joaquin River Delta Inflow Objectives" described in the State Water Resources Control Board's October 29, 2010, Draft Technical Report on the Scientific Basis for Alternative San Joaquin River Flow and Southern Delta Salinity Objectives. Prepared for the San Joaquin River Group Authority. December 6.

Grosholz, E. & E. Gallo, 2006. The influence of flood cycle and fish predation on invertebrate production on a restored California floodplain. Hydrobiologia 568: 91–109.

ISAB 2003. A Review of Strategies for Recovering Tributary Habitat. ISAB Report 2003 prepared by the Independent Scientific Advisory Board for the Northwest Power Council, Portland, OR.

Junk, W. J., P. B., Bayley, and R. E. Sparks. 1989. The Flood Pulse Concept in River-Floodplain Systems. Special publication. Canadian Journal of Fisheries and Aquatic Sciences 106:110–127.

HDR and Stillwater (HDR Engineering and Stillwater Sciences). 2016. Lower Tuolumne River Floodplain Hydraulic Assessment Study Report (W&AR-21). Final Report. Prepared by HDR Engineering, Inc., Sacramento, California and Stillwater Sciences, Berkeley, California for the Turlock Irrigation District and Modesto Irrigation District.

Jeffres, C. A., J. J. Opperman, and P. B. Moyle. 2008. Ephemeral Floodplain Habitats Provide Best Growth Conditions for Juvenile Chinook Salmon in a California River. Environmental Biology of Fishes 83: 449–458.

Katibah, E.F. 1984. A brief history of riparian forests in the Central Valley of California. In R. E. Warner, and K. M. Hendrix (editors). 1984. California riparian system: ecology, conservation, and productive management. Berkeley, CA: University of California Press. 23–28 pp.

Matella, M. and Jagt, K. 2014. Integrative Method for Quantifying Floodplain Habitat. Journal of Water Resource Planning and Management, 140(8), 06014003.

Matella, M. and A. Merenlender. 2014 Scenarios for restoring floodplain ecology given changes to river flows under climate change: Case from the San Joaquin River, California River Research and Applications 31(3): 280-290

Moyle, P. B. 2002. Inland Fishes of California, Revised and Expanded. University of California Press. 502 pp.

Moyle, P. B., R. D. Baxter, T. Sommer, T. C. Foin, and S. A. Matern. 2004. Biology and population dynamics of the Sacramento splittail (Pogonichthys macrolepidotus) in the San Francisco Estuary: a review. San Francisco Estuary and Watershed Science 2(2):1-47.

Moyle, P. B., P. K. Crain, and K. Whitener. 2007. Patterns in the Use of a Restored California Floodplain by Native and Alien fishes. San Francisco Estuary and Watershed Science 5:1–27. Available: http://repositories.cdlib.org/jmie/sfews/vol5/iss3/art1

Nichols, K., and J. S. Foott. 2002. FY2001 Investigation Report: Health Monitoring and Natural Fall-run Chinook Salmon Juveniles in the San Joaquin River and Tributaries, April-June 2001. U.S. Fish and Wildlife Service. California-Nevada Fish Health Center.

Opperman, J. J. 2012. A Conceptual Model for Floodplains in the Sacramento-San Joaquin Delta. San Francisco Estuary and Watershed Science 10(3).

Poff, N. L., and J. V. Ward. 1989. Implications of streamflow variability and predictability for lotic community structure: a regional analysis of streamflow patterns. Canadian Journal of Fisheries and Aquatic Sciences 46:1805–1818.

Poff, N. L., J. K. Allan, M. B. Bain, J. R. Karr, K. L Prestegaard, B. D. Richter, R. E. Sparks, and J. C. Stromberg. 1997. The Natural Flow Regime. Bioscience 47:769–784.

Poff, N. L., J. D. Olden, D. M. Pepin, and B. P. Bledsoe. 2006. Placing Global Stream Variability in Geographic and Geomorphic Contexts. River Research and Applications 22:149–166.

Poff, N. L., J. D. Olden, D. M. Merritt, and D. M. Pepin. 2007. Homogenization of Regional River Dynamics by Dams and Global Biodiversity Implications. National Academy of Sciences 104:5732–5737.

Richter, B. D., J. V. Baumgartner, J. Powell, and D. P. Braun. 1996. A Method for Assessing Hydrologic Alteration within Ecosystems. Conservation Biology 10:1163–1174.

Richter, B. D., R. Matthews, D. L. Harrison, and R. Wigington. 2003. Ecologically Sustainable Water Management: Managing River Flows for Ecological Integrity. Ecological Applications 13:206–224.

Sommer, T., M. L. Nobriga, W.C. Harrell, W. Batham, and W. Kimmerer. 2001. Floodplain rearing of juvenile Chinook salmon: evidence of enhanced growth and survival. Canadian Journal of Fisheries and Aquatic Sciences 58:325–333.

Sommer, T., W. C. Harrell, A. M. Solger, B. Tom, and W. Kimmerer. 2004. Effects of flow variation on channel and floodplain biota and habitats of the Sacramento River, California, USA. Aquatic Conservation–Marine and Freshwater Ecosystems 14(3):247–261.

Sommer, T., W.C. Harrel, and M. L. Nobriga. 2005. Habitat Use and Stranding Risk of Juvenile Chinook Salmon on a Seasonal Floodplain. North American Journal of Fisheries Management 25:1493–1504.

Sparks, R. E. 1995. Need for Ecosystem Management of Large Rivers and Their Floodplains. Bioscience 45:168–182.

Tharme, R. E., and J.M. King. 1998. Development of the Building Block Methodology for Instream Flow Assessments, and Supporting Research on the Effects of Different Magnitude Flows on Riverine Ecosystems. Water Research Commission Report No. 576/1/98. 452 pp.

Tharme. R. E. 2003. A Global Perspective on Environmental Flow Assessment: Emerging Trends in the Development and Application of Environmental Flow Methodologies for Rivers. River Research and Applications 19:397–441.

TID/MID (Turlock Irrigation District and Modesto Irrigation District). 1992. Report of Turlock Irrigation District and Modesto Irrigation District Pursuant to Article 39 of the License for the Don Pedro Project, No. 2299. Vol. III.

TID/MID. 1997. Report of Turlock Irrigation District and Modesto Irrigation District Pursuant to Article 39 of the License for the Don Pedro Project, No. 2299.

TID/MID. 2003. 2002 Report of Turlock Irrigation District and Modesto Irrigation District Pursuant to Article 58 of the License for the Don Pedro Project, No. 2299. 2 Volumes. March.

USFWS. 2008. Flow-Overbank Inundation Relationship for Potential Fall-Run Chinook Salmon and Steelhead/Rainbow Trout Juvenile Outmigration Habitat in the Tuolumne River. Sacramento, CA.

USFWS. 2013. Identification of the Instream Flow Requirements for Anadromous Fish in the Streams Within the Central Valley of California and Fisheries Investigations. Annual Progress Report Fiscal Year 2013. Sacramento, CA.

USFWS. 2014. Identification of the Instream Flow Requirements for Anadromous Fish in the Streams Within the Central Valley of California and Fisheries Investigations. Annual Progress Report Fiscal Year 2014. Sacramento, CA.

Walker, K. F., F. Sheldon, and J. T. Puckridge. 1995. A Perspective on Dryland River Ecosystems. Regulated Rivers 11:85–104.

Technical Review of the SWRCB's SED – Supplemental Analysis of Hatchery Impacts upon Survival and Escapement of Naturally-Produced Chinook Salmon from the Lower San Joaquin River and Tributaries

Stillwater Sciences
March 6, 2017

As noted in the SED Chapter 7, Central Valley fall-run Chinook salmon evolutionarily significant unit (ESU) is listed as a federal species of concern due in part to concerns over hatchery impacts upon this species. To address the lack of detailed historical information on unmarked hatchery fish presented by Mills and Fisher (1994) as the basis of CVPIA salmon doubling goals, a program of constant fractional marking (CFM) was recommended by Newman and Hankin (2004), since the implementation of CFM at the state and federal hatcheries in 2007, increasing evidence of hatchery dominance of annual salmon escapements has accumulated suggesting that there is little relationship between tributary conditions during rearing of naturally reproducing Chinook salmon and subsequent escapement. Because the SED contains relatively little information regarding the impacts of hatchery salmon, Stillwater Sciences conducted a review to determine whether flow increases proposed in the SED improve survival and escapement of naturally-produced Chinook salmon. The following key points are summarized based upon the review in the sections below:

- Recent evidence shows that hatchery-origin fall-run Chinook salmon are replacing and now far outnumber natural fall-run Chinook in the Central Valley, with adult returns to all SJR tributaries dominated by hatchery fish in most years.
- An observed lack of genetic distinction between hatchery and naturally spawning fall-run Chinook salmon throughout the Central Valley and the loss of early life history diversity, due to the long history of interbasin hatchery transfers and stocking, as well as the increasing practice of out-of-basin release of hatchery-reared juveniles, are reducing the population's ability to adapt and maintain stability in the face of fluctuating environmental conditions. Increasing evidence indicates that these and other hatchery influences are likely reducing reproductive fitness of Central Valley Chinook salmon on a large scale.
- The high proportions of hatchery-origin Chinook salmon represented in recent Tuolumne River spawning runs suggest that the influence of Project-related effects (e.g., flow) on salmon production as well as the ability to discriminate the effectiveness of potential measures intended to benefit naturally-reproducing salmon and steelhead populations may be obscured by uncertainties related to the production, survival, recruitment, and reproductive fitness of hatchery fish from the Mokelumne River hatchery, Merced River hatchery and other Central Valley hatcheries.
- If the proposed flow measures primarily benefit hatchery salmon and steelhead, substantial adverse impacts may result and should be specifically analyzed in the EIR. Johnson et al. (2012) found that the clear majority of adult Chinook salmon spawning in the Stanislaus

River were hatchery-produced fish only 1 to 2 generations removed from the hatchery, and concluded that hatchery-related genetic and ecological impacts could be contributing significantly to the large-scale population decline observed for Chinook salmon throughout the Central Valley.

- The SED includes little acknowledgment of the current and increasing prevalence of hatchery-origin Chinook salmon in SJR populations, and provides no information on the relative effects of flows on hatchery fish vs. naturally-produced fish or whether the proposed measures can be reasonably expected to improve natural production. Because the WRCB goal is "natural production," the SED needs to analyze the benefits and impacts of the proposed measures in a manner that specifically addresses whether the proposed alternatives would have any beneficial effect on natural production of Chinook salmon and steelhead or would mainly benefit hatchery fish, as well as the long-term implications of the alternatives on population viability in consideration of increasing hatchery influence.
- The observation that estuary releases of advanced smolts compose most of the fishery catch and hatchery escapement yet exhibit high rates of straying from their natal hatcheries indicates that hatchery practices are increasingly producing salmon that survive at relatively high rates but have low rates of fidelity to their natal streams and little need or opportunity to express a diversity of life history traits. Because these fish are largely disconnected from the selective pressures present in the natural riverine environment, the effects of management actions that target freshwater habitat without also addressing hatchery practices and other influences on survival and fitness (e.g., predation and habitat quality in the estuary) may be increasingly futile for conservation and recovery of Central Valley salmon and steelhead. This position is supported by the results of Johnson et al. (2012), who found that wild-origin Chinook salmon in the Mokelumne River were 3 times as likely as hatchery-origin salmon to spawn in the river. The authors note that if wild-origin salmon preferentially spawn with other wild-origin fish, then advantageous genetic traits remaining within the natural population could become re-established if the abundance of hatchery-origin salmon is reduced and mortality (e.g., from predation in the river and estuary) is decreased.
- While abundance is one of the essential measures of salmonid population viability (McElhany et al. 2000), management measures aimed at increasing abundance without also understanding how abundance is associated with demographic processes such as survival and immigration (Johnson et al. 2012), and how these processes are affected by hatchery influence, are unlikely to improve the viability of anadromous salmonid populations. As demonstrated by Johnson et al. (2012), substantial subsidies of hatchery-origin Chinook salmon into a local population can decouple abundance from viability and obscure the dynamics of the naturally-produced population.

In the sections below, we provide a more detailed review of hatchery and natural production assessments as well as whether proposed flow increases envisioned by the SED would improve survival and escapement of naturally produced Chinook salmon from the LSJR and its three tributaries (Merced, Tuolumne, and Stanislaus rivers).

1 RELATIVE AMOUNTS OF HATCHERY- AND NATURALLY-PRODUCED CHINOOK SALMON AND CHANGES OVER TIME

Populations of fall-run Chinook salmon in the Central Valley, including runs in the Sacramento and San Joaquin basins, are heavily supplemented by hatchery production (Huber and Carlson 2015). Recent evidence shows that hatchery-origin fall-run Chinook salmon are replacing and now far outnumber natural fall-run Chinook in the Central Valley (Kormos et al. 2012, Palmer-Zwahlen and Kormos 2013, 2015), and Barnett-Johnson et al. (2007) determined that 90% of Chinook salmon captured in the California ocean harvest originated from Central Valley hatcheries. The proportion of hatchery fall-run Chinook salmon is particularly high in San Joaquin River tributaries and streams with hatcheries (e.g., Battle Creek, Feather River, Mokelumne River) (Kormos et al. 2012, Palmer-Zwahlen and Kormos 2013, 2015). In the Mokelumne River, Johnson et al. (2012) found that 91–99% of spawning adults in 2004 were of hatchery origin, and that without hatchery-origin salmon the Mokelumne River Chinook salmon population would not be viable (i.e., would have a negative population growth rate). Although total releases of Chinook salmon from the two dominant Central Valley hatcheries (Coleman and Nimbus) have declined over time since inception of the hatchery programs, releases from the Feather, Mokelumne, and Merced hatcheries have generally increased (Huber and Carlson 2015).

Estimates based on mathematical expansions of coded-wire tag recoveries from Tuolumne River Chinook salmon in 2010, 2011, and 2012 revealed that hatchery-origin salmon composed an estimated 49%, 73% and 36% of the runs in these years, respectively (Kormos et al. 2012; Palmer-Zwahlen and Kormos 2013, 2015). Relative contributions from various hatcheries to the Tuolumne River fall-run Chinook spawning runs varied from 2010–2012. In 2010, the hatchery component of the spawning run was dominated by fish from the Merced River hatchery, the Coleman National Fish Hatchery, and the Feather River hatchery, with smaller contributions from the Mokelumne and Nimbus hatcheries (Kormos et al. 2012). In 2011, Tuolumne River spawners of hatchery origin were composed mainly of fish from the Mokelumne River, Merced River, and Feather River hatcheries, with smaller numbers of fish from the Coleman and Nimbus hatcheries (Palmer-Zwahlen and Kormos 2013). In 2012, hatchery-origin spawners in the Tuolumne River were overwhelmingly from the Mokelumne hatchery, with small proportions from the Merced River, Coleman, and Feather River hatcheries (Palmer-Zwahlen and Kormos 2015). Tuolumne River spawners from out-of-basin hatcheries are overwhelmingly strays, as the relative proportion of salmon from those hatcheries released in the San Joaquin River basin has been very low in the last 20 years and there have been no out-of-basin hatchery salmon released in the basin since 2008 (Figure 1). With few exceptions (e.g., 2007 and 2008), almost all hatchery Chinook salmon from the Merced River and Mokelumne River hatcheries are released at locations in the San Joaquin River basin (Figure 2).

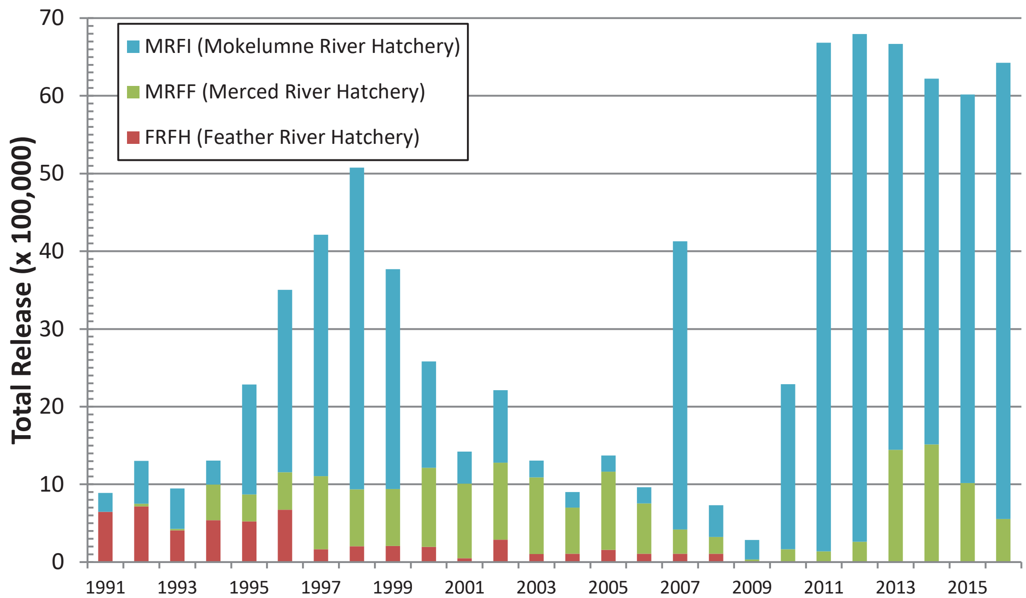


Figure 1. Hatchery releases of fall-run Chinook salmon into the San Joaquin River basin since 1991 (source: RMIS 2017).

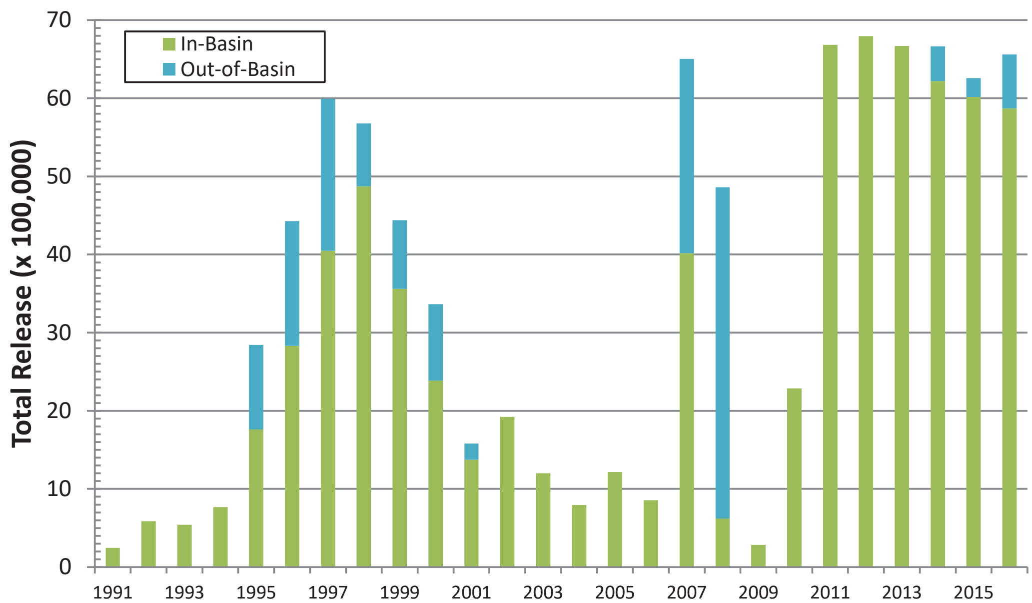


Figure 2. In-basin and out-of-basin releases of Chinook salmon from the Merced River and Mokelumne River hatcheries combined (source: RMIS 2017).

Otolith analysis from eight generations of Chinook salmon spawning in the Tuolumne River indicates that hatchery contributions make up a somewhat larger proportion of the annual spawning runs than indicated by the coded-wire tag analyses, and the proportions of hatchery fish have been increasing in recent years (Stillwater Sciences 2015). Using recovery data only from 3-year olds, which are expected to make up the bulk of the annual escapement, the mean proportion of Tuolumne River spawners of hatchery origin in five spawner years (2000–2002, 2005, and 2011) was 58% (range: 36–90%). Whereas Palmer-Zwahlen and Kormos (2015) estimated a 73% hatchery contribution to the 2011 Tuolumne River spawning run, the otolith study results indicate that 90% of the spawning run was of hatchery origin in the same year (Stillwater Sciences 2015). The apparent underestimate of the hatchery contribution is consistent with the findings of Mohr and Satterthwaite (2013), which revealed that misclassification of adipose fin presence/absence in Chinook salmon carcass counts can result in significant estimation bias. If these findings apply to the Tuolumne River, the actual proportion of hatchery-origin spawners in the Tuolumne River is likely higher than reported from recent coded-wire tag expansions (e.g., Kormos et al. 2012; Palmer-Zwahlen and Kormos 2013, 2015).

In fall 2015, the most recent year for which data are available, 23% of adult Chinook salmon observed at the Tuolumne River counting weir were adipose-clipped, indicating hatchery origin (Becker et al. 2016). Because the constant fractional marking (CFM) program implemented at the Merced River hatchery in 2012 and elsewhere in 2007 marks only 25% (on average) of all hatchery-produced Chinook salmon, this represents a theoretical minimum, and the actual proportion of hatchery-origin fish was undoubtedly higher. Becker et al. (2016) postulate that most and perhaps all the adult salmon observed at the Tuolumne River weir in 2015 were of hatchery origin, since about 75% of hatchery salmon are not adipose-clipped and the assumption that adipose fin-clipping has no influence on the high hatchery straying rate.

While the large proportion of hatchery-origin Chinook salmon spawning in the Tuolumne River in recent years may be correlated with the increasing releases from the two San Joaquin River basin hatcheries, data that would allow investigation of such longer-term trends are lacking. Because the numbers of unmarked hatchery releases have been very high and variable in the several decades prior to initiation of the CFM program in California, the accuracy of reported long term averages and directions of long term trends in natural production cannot be determined using analytical procedures (Newman and Hankin 2004).

2 HATCHERY INFLUENCE ON CENTRAL VALLEY CHINOOK SALMON

Most research has focused on genetic effects and, to a lesser degree, ecological effects of hatchery-reared salmonids. A study of the population genetic structure and diversity in Central Valley Chinook salmon by Williamson and May (2005) suggests that fall-run Chinook salmon occupying rivers and streams throughout the Central Valley belong to a genetically homogeneous population, with lower genetic diversity than other fall-run Chinook salmon populations examined at similar geographic scales and little to no differentiation between salmon reared in hatcheries and their wild counterparts. The lack of genetic distinction between hatchery and naturally spawning fall-run Chinook salmon indicates that considerable gene flow occurs between fall-run Chinook salmon throughout the Central Valley, almost certainly due to the long history of interbasin hatchery transfers and stocking throughout the Central Valley and the increasing practice of off-site release of hatchery-reared juveniles (Huber and Carlson 2015, Garza et al. 2008, Williamson and May 2005). Since the early 1980s, a substantial and increasing proportion of Chinook salmon from Central Valley hatcheries has been released in the San Francisco estuary downstream of Chipps Island. From 1981–2012, estuary releases averaged 13 million fish annually (Huber and Carlson 2015). Of the Chinook salmon that survive to adulthood, those reared in Central Valley hatcheries and released off-site (outside their basin of natal origin, including the estuary) stray into non-natal basins at a frequency about eight times greater than hatchery salmon released on-site (Huber and Carlson 2015, Cramer 1991). Straying is problematic for anadromous salmonid conservation and recovery because it can reduce the ability of salmon to adapt to local environmental conditions (McElhany et al. 2000, Lindley et al. 2009) and mask the decline of wild populations (Johnson et al. 2012).

The loss of genetic diversity and differentiation between Chinook salmon subpopulations in the Central Valley is a major concern because genetic diversity and its phenotypic expression in life history and behavioral traits is a crucial factor in maintaining the adaptability and resilience of the population to variable environmental conditions (Sturrock et al. 2015). Using a multi-component index to describe life history diversity, Huber and Carlson (2015) found that early life history diversity of Chinook salmon released from Central Valley hatcheries has declined by approximately 50% since the 1980s. The loss of diversity among populations of Central Valley Chinook salmon is an outbreeding effect that can be caused by unnatural changes in gene flow from high rates of straying and reproduction by out-of-basin hatchery fish (NMFS 2011). These findings suggest that hatchery practices, such as off-site release of hatchery-reared juveniles and interbasin hatchery transfers and stocking, are reducing the prevalence of diverse early life history traits that provide population stability in the face of fluctuating environmental conditions (Hilborn et al. 2003, Schindler et al. 2010, Carlson and Satterthwaite 2011) including climate change and flow regulation.

In addition to outbreeding effects such as loss of within-population diversity, other genetic effects of hatchery production can include domestication selection that results in reduced fitness and survival of salmon and steelhead in the wild compared with natural-origin fish (NMFS 2011). Araki et al. (2007) demonstrated that the fitness (reproductive success) of hatchery-reared steelhead reproducing in the wild declined by 37.5% per generation due to rapid domestication effects. Chilcote et al. (2011) found that hatchery salmon had a recruitment performance (offspring per parent) that was only 13% that of naturally-produced salmon.

Ecological effects of hatchery production can include reduced survival of hatchery and natural fish, increased predation risk of hatchery fish, and changes in the timing of outmigration and spawning by hatchery fish (Kostow 2009, NMFS 2011). Hatchery-reared salmonids grow faster than those rearing in the wild, and many hatcheries now produce and release larger fish than in previous decades to accelerate smolting and improve ocean survival (Kostow 2009, Huber and Carlson 2015). While it is well documented that larger size at ocean entry generally confers greater early marine survival in anadromous salmonids (Bilton et al. 1982, Ward and Slaney 1988, Ward et al. 1989, Sogard 1997, Osterback et al. 2014), hatchery salmonids may not have greater marine survival or overall reproductive success than those of wild origin. Ocean conditions appear to have a major influence on survival of juvenile salmonids regardless of natal origin. Woodson et al. (2013) found that Central Valley Chinook salmon of hatchery origin had marine survival like natural-origin Chinook during a period of low ocean productivity, even though the hatchery salmon were larger and had higher growth rates upon ocean entry. Under similar conditions of low ocean productivity, Beamish (2012) found that hatchery-origin Chinook salmon in the Strait of Georgia (B.C., Canada) survived at rates six to 24 times lower than wild-origin salmon. Fritts et al. (2007) found that hatchery-reared wild-origin Chinook salmon fry were significantly more vulnerable to predators than wild Chinook salmon fry of the same stock.

Kostow (2009) cites evidence that altered spawn timing by hatchery-origin salmonids, which is due largely to intentional hatchery practices, can have ecological implications for survival and fitness of both hatchery and wild populations. Earlier spawning results in earlier emergence, and while this may confer a territorial and feeding advantage over later-spawning (and later-emerging) wild juveniles (Berejikian et al. 1996), Brannas (1995) found that early emergence may be associated with increased predation mortality. Nickleson et al. (1986) and Kostow et al. (2003) found that the offspring of early-spawning hatchery salmonids in Oregon had very poor survival to adulthood. Hatcheries frequently select for early run timing by spawning a disproportionately higher percentage of earlier returning fish (Flagg et al. 2000). Although there is currently no evidence of altered run timing in the Tuolumne River resulting from hatchery influences, the high degree of hatchery influence in the Central Valley Chinook salmon population may nonetheless be causing reduced reproductive fitness on a large scale.

In their examination of historical releases of Chinook salmon from Central Valley Chinook hatcheries, Huber and Carlson (2015) revealed several trends with implications for stability and viability of the population, including a recent shift toward releases of smolts and advanced smolts and away from fry releases, more downstream releases (i.e., in the Delta or Estuary), and increased size-at release for each release month over time. Observations by Woodson et al. (2013), who found that Central Valley hatchery Chinook salmon were an average of 20 days older than wild-origin salmon collected at the Golden Gate as they exited the estuary, are indicative of the trend toward releases of hatchery salmon that are more developmentally advanced than wild salmon at the same date and location in their outmigration pathway. As noted by Huber and Carlson (2015), the trend toward spring releases of advanced smolts has created a new Chinook salmon phenotype that exhibits reduced life history diversity and extremely high rates of straying into non-natal basins, yet contributes the most to hatchery escapement throughout the Central Valley. Despite the high likelihood that these hatchery-origin fish exhibit reduced fitness due to domestication selection, this maladaptive phenotype is being propagated by hatcheries at an increasing rate.

3 EFFECTS OF FLOW ON CHINOOK SALMON SURVIVAL AND RECRUITMENT

Despite the prevalence of hatchery Chinook salmon throughout California's Central Valley, little is known about the effects of river flow on the survival and ecology of hatchery salmon and whether hatchery and wild salmon respond differently to flow and its influence on survival and population response. Michel et al. (2015) found that survival of hatchery-origin Chinook salmon outmigrating from the Sacramento River was 2–5 times higher in an above-normal flow year than in four below-normal flow years. The increased survival observed during the above-normal flow year (2011) primarily occurred in the riverine portions of the migration route, whereas survival was lowest in the estuary and similar there during all study years (Michel et al. 2015). In the Stanislaus River, Sturrock et al. (2015) found that Chinook salmon fry contributed more to the spawning population during a year of higher river flow, while smolts contributed more spawners during a low-flow year. However, because hatchery-origin salmon were specifically excluded from the Sturrock et al. (2015) study it is not possible to determine whether survival of the various juvenile life stages or if relationships between survival and river flow were different for wild- and hatchery-origin Chinook salmon. This information would seem particularly important to inform flow management decisions on the Stanislaus River and elsewhere, as hatchery-origin Chinook salmon have composed a large proportion of the Stanislaus River spawning population in recent years (≥ 50% in 2010 [Kormos et al. 2012] and ≥ 83% in 2011 and 2012 [Palmer-Zwahlen and Kormos 2013, 2015]).

Although Sturrock et al. (2015) postulate that a regulated flow regime may reduce the prevalence of the fry life history type in Central Valley Chinook salmon by truncating migratory windows for early fry outmigration and suppressing winter pulse flows during which fry survival can be high, recent evidence from the Tuolumne River indicates that fry survive at very low rates and contribute very little to the spawning escapement (Stillwater Sciences 2016). Of the five outmigration years examined in otolith studies of Chinook salmon from the Tuolumne River (1998 [Wet], 1999 [AN], 2000 [AN], 2003 [BN], and 2009 [BN]), there were zero fry contributions to subsequent escapement in three out of the five outmigration years analyzed and a maximum fry contribution of 5% for fish emigrating in the above-normal water year (WY 2000) (Stillwater Sciences 2016). Survival through the south Delta appears to be consistently low regardless of flow. For this reason, flow management that encourages early emigration of naturally-produced fry through increased flow releases may not result in measurable increases in subsequent returns. Instead, measures to improve in-river rearing success of wild-origin Chinook salmon and reduce hatchery influence and straying will be more likely to increase river, Delta, and ocean survival and lead to increased population viability.

Whereas previous investigations (e.g., Mesick et al. 2008) indicated that Chinook salmon smolt production from the Tuolumne River may have been highly correlated with winter-spring flow magnitude and duration, and that spawner recruitment was likely correlated with the number of emigrating smolts (and thus related to the Delta and ocean survival of those smolts), newer evidence of substantial contributions of hatchery strays to the annual Tuolumne River spawning population (see Section 1) indicates that these relationships are likely no longer valid. Furthermore, the recent finding that the contribution of smolts to the population of returning Chinook salmon spawners in the Stanislaus River was highest in a low-flow year (Sturrock et al. 2015) suggests that correlations between river flow and salmon recruitment and population viability are equivocal at best and are likely intertwined with the influence of hatcheries on Chinook salmon population dynamics acting across multiple life stages (fry, parr, smolt, adult) and geographical scales (river, estuary, ocean). Although Baker and Morhardt (2001) demonstrated a positive relationship between Chinook salmon escapement and flow in the San Joaquin River 2.5 years prior to escapement, as discussed in SED comments by Noah Hume for the Districts in Modesto on December 20, 2016, more recent investigations show that such lagged flow relationships in the Tuolumne River are becoming weaker over time, suggesting that factors other than flow need to be more thoroughly analyzed.

Large releases of hatchery salmon into the estuary in recent decades appear to be increasing ocean survival but are further decoupling survival from river outflow. Hatchery production and estuary releases also eliminate many environmental influences that would otherwise select for traits such as predator avoidance and life history variability that maximize fitness in the riverine environment and adaptability to changing environmental conditions. Thus, even if we assume that increased flows from SJR tributaries will improve juvenile salmon production and river survival, benefits to the naturally-produced populations would be unlikely. This is because, as described previously, returns of adult Chinook salmon to SJR tributaries are dominated by hatchery fish, most of which are strays from out-of-basin hatcheries that were released outside their basin of natal origin (e.g., in the estuary) and thus not subject to the influence of river flows. Any flow-related benefits to juvenile salmon from SJR tributaries would overwhelmingly be conferred to the progeny of hatchery-origin individuals that would not contribute to the recruitment or viability of the natural population.

The relationship between river flows and salmonid production and survival during outmigration is especially complex because flow has a direct effect on other factors that influence survival; notably water temperature, turbidity, predation, and availability of highly productive off-channel rearing habitat (i.e., floodplains). Flow-related effects, particularly water temperature, also affect the timing and reproductive success of spawning adult salmonids. Although the SED estimates the potential effects of increased SJR tributary flows on water temperature and floodplain availability, it does not address the extent to which these relationships may affect hatchery-origin and wild-origin salmonids differently. With the current and increasing prevalence of hatchery-origin Chinook salmon in the Central Valley and SJR populations, it is critically important that management decisions include consideration of effects on hatchery-origin salmonids, and whether such decisions truly benefit naturally-produced populations.

4 REFERENCES

Araki, H., B. Cooper, and M.S. Blouin. 2007. Genetic effects of captive breeding cause a rapid, cumulative fitness decline in the wild. Science 318(5847):100–103. doi: *http://dx.doi.org/10.1126/science.1145621*

Baker P. F. and J. E. Morhardt. 2001. Survival of Chinook Salmon Smolts in the Sacramento-San Joaquin Delta and Pacific Ocean. In: Brown RL, editor. Fish Bulletin 179: Contributions to the biology of Central Valley salmonids. Volume 2. Sacramento (CA): California Department of Fish and Game. www.stillwatersci.com/resources/2001BakerMorhardt.pdf

Barnett-Johnson R, Grimes CB, Royer CF, Donohoe CJ. 2007. Identifying the contribution of wild and hatchery Chinook salmon (*Oncorhynchus tshawytscha*) to the ocean fishery using otolith microstructure as natural tags. Can J Fish Aquat Sci 64:1683–1692. doi: *http://dx.doi.org/10.1139/F07-1*

Beamish, R.J., Sweeting, R.M., Neville, C.M., Lange, K.L., Beacham, T.D., and Preikshot, D. 2012. Wild chinook salmon survive better than hatchery salmon in a period of poor production. Environ. Biol. Fishes, 94:135–148. doi:10.1007/s10641-011-9783-5

Becker, C., J. Guignard, and A. Fuller. 2016. Fall Migration Monitoring at the Tuolumne River Weir: 2015 Annual Report. Report 2015-6 in 2015 Lower Tuolumne River Annual Report. FISHBIO Environmental, LLC, Oakdale, California.

Berejikian, B.A., S.B. Mathews, and T.P. Quinn. 1996. Effects of hatchery and wild ancestry and rearing environments on the development of agonistic behavior in steelhead trout (*Oncorhynchus mykiss*) fry. Can J Fish Aquat Sci 53:2004–2014.

Brannas, E. 1995. First access to territorial space and exposure to strong predation pressure: a conflict in early emerging Atlantic salmon (*Salmo salar* L.) fry. Evol Ecol 9:411–420.

Bilton, H.T., D.F. Alderdice, and J.T. Schnute. 1982. Influence of time and size at release of juvenile coho salmon (*Oncorhynchus kisutch*) on returns at maturity. Can J Fish Aquat Sci 39:426–447.

Carlson, S. M. and W. H. Satterthwaite. 2011. Weakened portfolio effect in a collapsed salmon population complex. Can J Fish Aquat Sci 68:1579–1589. doi: *http://dx.doi.org/10.1139/F2011-084*

Chilcote, M.W., K.W. Goodson, and M.R. Falcy. 2011. Reduced recruitment performance in natural populations of anadromous salmonids associated with hatchery-reared fish. Canadian Journal of Fisheries and Aquatic Science 68:511–522.

Cramer, S.P. 1991. Contribution of Sacramento basin hatcheries to ocean catch and river escapement of fall Chinook salmon. Sacramento (CA): S.P. Cramer & Associates. Report prepared for the California Department of Water Resources.

Flagg, T., B. Berejikian, J. Colt, W. Dickhoff, L.W. Harrell, D.J. Maynard, C.E. Nash, M.S. Strom, R.N. Iwamoto, C.V.W. Mahnken. 2000. Ecological and behavioral impacts of artificial production strategies on the abundance of wild salmon populations. National Marine Fisheries Service. NOAA Technical Memorandum NMFS-NWFSC-41.

Fritts, A.L., J.L. Scott, and T.N. Pearsons. 2007. The effects of domestication on the relative vulnerability of hatchery and wild origin spring Chinook salmon (*Oncorhynchus tshawytscha*) to predation. Can J Fish Aquat Sci 64:813−818.

Garza, J.C., S.M. Blankenship, C. Lemaire, and G. Charrier. 2008. Genetic population structure of Chinook salmon (*Oncorhynchus tshawytscha*) in California's Central Valley. Santa Cruz (CA): Report prepared for the CalFed Research Project "Comprehensive Evaluation of Population Structure and Diversity for Central Valley Chinook Salmon." Available from *https://swfsc.noaa.gov/publications/FED/01110.pdf*Hilborn et al. 2003

Huber, E.R. and Carlson, S.M. 2015. Temporal trends in hatchery releases of fall-run Chinook salmon in California's Central Valley. San Francisco Estuary and Watershed Science 13(2): article 3. http://escholarship.org/uc/item/7237t9xn

Johnson, R., P.K. Weber, J.D. Wikert, M.L. Workman, R.B. MacFarlane, M.J. Grove and A.K. Schmitt. 2012. Managed Metapopulations: Do Salmon Hatchery 'Sources' Lead to In-River 'Sinks' in Conservation? PLoS ONE 7(2): e28880. doi:10.1371/journal.pone.0028880

Kormos, B.M., M. Palmer-Zwahlen, and A. Low. 2012. Recovery of coded-wire tags from Chinook salmon in California's Central Valley escapement and ocean harvest in 2010. Fisheries Branch Administrative Report 2012-02. California Department of Fish and Game, Santa Rosa, California.

Kostow, K. E., Marshall, A. R. and Phelps, S. R. 2003. Naturally spawning hatchery steelhead contribute to smolt production but experience low reproductive success. Trans. Am. Fish. Soc. 132:780–790.

Kostow, K.E. 2009. Factors that contribute to the ecological risks of salmon and steelhead hatchery programs and some mitigating strategies. Rev Fish Biol Fish Sci 19:9–31.

Lindley, S.T., C.B. Grimes, M.S. Mohr, W. Peterson, J. Stein, J.T. Anderson, L.W. Botsford, D.L. Bottom, C.A. Busack, T.K. Collier, J. Ferguson, J.C. Garza, A.M. Grover, D.G. Hankin, R.G. Kope P.W. Lawson, A. Low, R.B. MacFarlane, K. Moore, M. Palmer-Zwahlen, F.B. Schwing, J. Smith, C. Tracy, R. Webb, B.K. Wells, and T.H. Williams. 2009. What caused the Sacramento River fall Chinook stock collapse? NOAA Technical Memorandum NMFS, NOAA-TM-NMFS-SWFSC-447. NOAA National Marine Fisheries Service, Southwest Fisheries Science Center, Fisheries Ecology Division, Santa Cruz, California.

McElhany, P., M.H. Ruckelshaus, M.J. Ford, T.C. Wainwright, and E.P. Bjorkstedt. 2000. Viable salmonid populations and the recovery of evolutionarily significant units. U.S. Dept. of Commerce, NOAA Tech. Memo. NMFS-NWFSC-42.

Mesick, C., J. McLain, D. Marston, and T. Heyne. 2008. Limiting factor analyses and recommended studies for fall-run Chinook salmon and rainbow trout in the Tuolumne River. Draft Report. Joint Report of the U.S. Fish and Wildlife Service (Anadromous Fish Restoration Program), National Marine Fisheries Service, Sacramento Office, and California Department of Fish and Game, Fresno Office. August 13, 2008.

Michel, Cyril J., Arnold J. Ammann, Steven T. Lindley, Philip T. Sandstrom, Eric D. Chapman, Michael J. Thomas, Gabriel P. Singer, A. Peter Klimley, and R. Bruce MacFarlane. 2015. Chinook salmon outmigration survival in wet and dry years in California's Sacramento River. Can. J. Fish. Aquat. Sci. 72:1749–1759. dx.doi.org/10.1139/cjfas-2014-0528

Mills, T. J., and F. Fisher. 1994. Central Valley anadromous sport fish annual run-size, harvest, and population estimates, 1967 through 1991. 8/94 draft. Inland Fisheries Technical Report. California Dept. of Fish and Game. 62 p.

Mohr, M.S. and W.H. Satterthwaite. 2013. Coded-Wire Tag Expansion Factors for Chinook Salmon Carcass Surveys in California: Estimating the Numbers and Proportions of Hatchery-Origin Fish. San Francisco Estuary and Watershed Science 11(4). http://escholarship.org/uc/item/3471w9mv

Newman, K.B. and D.G. Hankin. 2004. Statistical procedures for detecting the CVPIA natural Chinook salmon production doubling goal and determining sustainability of production increases. Unpublished report completed under CH2M Hill purchase order/subcontract 73603.

Nickelson, T.E., M.F. Solazzi, and S.L. Johnson. 1986. Use of hatchery coho salmon (*Oncorhynchus kisutch*) presmolts to rebuild wild populations in Oregon coastal streams. Can J Fish Aquat Sci 43:2443–2449.

NMFS (National Marine Fisheries Service). 2011. Effects of Hatchery Programs on Salmon and Steelhead Populations: Reference Document for NMFS ESA Hatchery Consultations. NMFS Northwest Regional Office, Salmon Management Division.

Osterback, A-M. K., D. M. Frechette, S. A. Hayes, M. H. Bond, S. A. Shaffer, and J. W. Moore. 2014. Linking individual size and wild and hatchery ancestry to survival and predation risk of threatened steelhead (*Oncorhynchus mykiss*). Canadian Journal of Fisheries and Aquatic Sciences 71:1877–1887.

Palmer-Zwahlen, M. and M. Kormos. 2013. Recovery of coded-wire tags from Chinook salmon in California's Central Valley escapement and ocean harvest in 2011. Fisheries Branch Administrative Report 2013-02. California Department of Fish and Wildlife, Santa Rosa, California.

Palmer-Zwahlen, M. and M. Kormos. 2015. Recovery of coded-wire tags from Chinook salmon in California's Central Valley Escapement, Inland Harvest, and Ocean Harvest in 2012. Fisheries Branch Administrative Report 2015-4. California Department of Fish and Wildlife, Santa Rosa, California.

RMIS (Regional Mark Information System). 2017. RMIS Standard Reporting query results obtained from the CWT database maintained by the Pacific States Marine Fisheries Commission's Regional Mark Processing Center. Available online at http://www.rmpc.org/. Accessed February 2017.

Schindler, D.E., R. Hilborn, B. Chasco, C.P. Boatright, T.P. Quinn, L.A. Rogers, and M.S. Webster. 2010. Population diversity and the portfolio effect in an exploited species. Nature 465:609–612. doi: http://dx.doi.org/10.1038/nature09060

Sogard, S. 1997. Size-selective mortality in the juvenile stage of teleost fishes: a review. Bull. Mar. Sci. 60:1129–1157.

Stillwater Sciences. 2016. Chinook salmon otolith study, W&AR-11. Final Report. Prepared for Turlock Irrigation District and Modesto Irrigation District. Don Pedro Hydroelectric Project, FERC No. 2299.

Sturrock, A., J.D. Wikert, T. Heyne, C. Mesick, A.E. Hubbard, T.M. Hinkelman, P.K. Weber, G.E. Whitman, J.J. Glessner, and R.C. Johnson. 2015. Reconstructing the migratory behavior and long-term survivorship of juvenile Chinook salmon under contrasting hydrologic regimes. PLOS ONE. DOI:10.1371.

Ward, B.R. and P.A. Slaney. 1988. Life history and smolt-to-adult survival of Keogh River steelhead (*Salmo gairdneri*) and the relationship to smolt size. Can J Fish Aquat Sci 45:1110–1122.

Ward, B.R., P.A. Slaney, A.R. Facchin, and R.W. Land. 1989. Size-based survival in steelhead trout: back-calculated lengths from adults' scales compared to migrated smolts at the Keogh River, British Columbia. Can J Fish Aquat Sci 46:1953–1858.

Williamson, K.S. and B. May. 2005. Homogenization of fall-run Chinook salmon gene pools in the Central Valley of California, USA. North American Journal of Fisheries Management 25:993–1009.

Woodson, L.E., B.K. Wells, P.K. Weber, R.B. MacFarlane, G.E. Whitman, and R.C. Johnson. 2013. Size, growth, and origin-dependent mortality of juvenile Chinook salmon *Oncorhynchus tshawytscha* during early ocean residence. Mar Ecol Prog Ser 487:163–175 https://doi.org/10.3354/meps10353

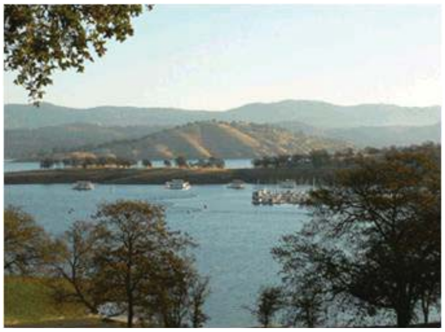
APPENDIX B

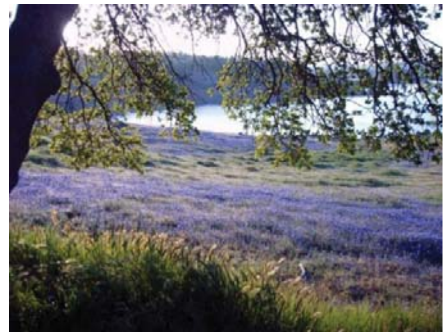
[INTENTIONALLY OMITTED]

APPENDIX C

Comments on the SWRCB's SED: Economics, Agriculture, Social and Environmental Justice

COMMENTS ON THE SWRCB'S SED: ECONOMICS, AGRICULTURE, SOCIAL AND ENVIRONMENTAL JUSTICE





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Prepared for:
Turlock Irrigation District – Turlock, California
Modesto Irrigation District – Modesto, California

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March 2017

1 Comments on the Underlying Technical Concepts of the Agricultural Economic Impact of the SED

Based on review of: *Chapter 11 Agricultural Resources*; *Chapter 20, Economic Analysis*, Appendix *G, Agricultural Economic Effects of the LSJR Flow Alternatives: Methodology and Modeling Results*; and the Modeling Tools Information and Files, specifically the *Agricultural Economic Analysis* and the *Ground Water and Surface Water Use Analysis*, we have the following comments. The comments are specific to the analysis of impacts of reducing canal deliveries to TID and MID (the Districts).

In summary, the SWRCB's estimate of the economic impact of the preferred alternative is significantly lower than the Districts' estimate of the economic impact.[1] In critical water year types the SWRCB estimates that the economic impact of reducing canal deliveries to the Districts under Alternative 3, the 40 percent unimpaired flow (UF), is an annual loss of $141.7 million. Whereas the Districts' estimate the economic loss for the same alternative as just under $1.6 billion, that's billion, with a "b", a difference of $1.4 billion. A bridge, describing the between the SWRCB's estimated annual impacts on agricultural output in critical water year types, which occur 20 percent of the time, and the Districts' estimate are:

SWRCB's critical year impact estimate ($ millions):	**$141.7**
Additions to the SED's annual impact estimate for critical water-year types:	
SED's incorrect modeling assumptions	**$167.5**
Re-allocating water to "highest value" crop is incorrect; 1) TID does not accommodate intra-district water transfers, 2) SWRCB's analysis did not consider the valued-added by animal feed crop into the production of animal commodities (milk and beef)	*$85.6*
Additional groundwater cannot be pumped due to SGMA and chronic overdraft	*$10.7*
"Ripple effect", e.g. indirect and induced impacts on above ($96.2).	*$71.1*
Omissions from SED's model	**$1,285.6**
Animal commodities (e.g. milk and beef)	*$266.2*
Food and beverage processing of crop and animal commodities	*$590.6*
"Ripple effect", e.g. indirect and induced impacts on above ($96.2)	*$428.7*
Restate SWRCB's impact estimate to 2012 dollars	-9.3
Total estimated critical year impact	**$1,585.3**

[1] Regional Economic Impact to the Agricultural Economy caused by Reductions in Service Water Supplies to Turlock Irrigation District and Modesto Irrigation District, 2017, included in Appendix I of the Districts' comments.

2 Detailed Technical Comments on Chapter 20, Economics and Appendix G

Table 1 lists the technical comments in order of importance and the section number of this document where a detailed description of the comment can be found. The technical comments are grouped as follow:

- Errors of Fact or Assumptions
- Comments on Method of Analysis
- Comments on Analysis
- Improper Use of Citations
- Missing Data/Science

The comments conclude with a presentation of the Districts' estimate of the impact of the SED on the agricultural economy and a comparison of that estimate to the SED's impact estimate.

2.1 Errors of Fact or of Assumption

2.1.1 Factual Errors

2.1.1.1 Number of Acres of Crop Land and Crop Distribution are not Correct

Issue: The SED does not use the most recent estimates of irrigated acres of crop land for each TID and MID and does not use the correct crop distribution for the acres that it did use.

Impact: The SED is using incorrect acres of all crops however the most egregious error is the fact that the SED assumes nut tree acres are only 55 percent of their actual value.

Discussion: The SED did not utilize the best available data about irrigated crop acres for TID or MID (the Districts). Neither the total number of irrigated acres by district nor the crop distribution of those acres within each district is correct. Each district publishes an Agricultural Water Management Plan (AWMP), most recently in 2015, however the SED used the 2012 AWMP version to estimate the total acres irrigated in the Districts. For no understandable reason the SED used DWR DAU data for the crop distribution, even though crop distribution is available in the AWMP (both 2012 and 2015). In addition to using old data it appears an error was made interpreting the 2012 AWMP data.

Table 1. Technical Comments in Priority Order

Priority	Technical Comment	Summary of Impact	Estimated Annual Critical Water-Year Impact	Document Section
1	The SED fails to include any mention of or impact of the project to the production of animal commodities, e.g. milk and cattle and calves, to the agricultural economy.	Animal commodities comprise over half the annual commodity revenue produced in the study area. Not only does the SED omit any mention of dairies and cattle & calf operations, the SED assumes that reducing the production of feed crops will help maintain irrigation supplies for tree and vegetable crops. The impact of the reduction in feed crops on animal operations is inadequate.	$420 million; $266 million direct impact on milk and beef commodity revenue (roughly 40 percent of baseline) plus $154 million of indirect and induced impacts, representing a loss of ~ 1,200 jobs.	2.2.1.1
2	The SED fails to include any mention of or impact of the SED's preferred alternative to the food and beverage processing sector of the agricultural economy	The food and beverage processing sector is estimated to support between one quarter and one third of all jobs in the study area. The sector is dependent on raw input of crop and animal commodities.	$865 million; $590 of direct impact and $275 million in indirect and induced impacts, representing a loss of approximately 2,500 jobs	2.2.1.2
3	In summarizing results, the SED averages the annual impacts, obfuscating the true impact of a change in long-term water supply reliability	The SED estimates that annual average surface water deliveries to TID and MID under Alternative 3 will be 67% of baseline. However, in critical water year-types, which occur one in five years, and are known to occur sequentially, the surface water supplies are estimated to be only 31 percent of baseline.	Minimum impact of $1.6 billion in economic activity and upwards of 4,000 jobs	2.3.2 and 3

Priority	Technical Comment	Summary of Impact	Estimated Annual Critical Water-Year Impact	Document Section
4	In summarizing results the SED neglects to discuss the impact of an increase in sequential years of irrigation shortages on agricultural operations, particularly animal operations and permanent crops	The SED estimates that not only will the magnitude of irrigation shortages increase but the number of sequential years of shortages will also increase. Sequential years of drought are particularly hard on the permanent crops and animal operations that characterize the project area's agricultural economy. Having not just a short-term effect but also a lag effect. Under the SED's preferred alternative of 40% unimpaired flow (Feb-Jun, Inc) shortages occur with greater frequency and are more likely to occur in sequential years. The SED fails to analyze this economic impact.	Irrigation stress on trees reduce yields in subsequent years. Herds take years to rebuild. These impacts have not been discussed, let alone quantitatively examined.	2.2.3
5	Not all irrigation Districts facilitate intra-district transfers of water	A fundamental assumption in the SED is that irrigation water will be transferred within each of the Districts (TID and MID), supporting tree, fruit and vegetable crops and sacrificing animal feed crops and all other field crops. However, TID does not facilitate intra-district transfers of water.	The SED understates the impact of the preferred alternative on crop commodity revenue. The economic cost of the SWB's unfounded assumption is not known, but should be evaluated in the final SED.	2.1.2.2
6	The economic analysis does not consistently consider the geographic scope of impacts	The SED presents what it refers to as summary of costs and benefit of its proposal over the entire affected area by category, however not all benefits or costs are considered in all geographic plan areas	Vastly understates the cost to the state-wide agricultural economy as well as the water supply benefits to the South of Delta water users	2.2.2

Priority	Technical Comment	Summary of Impact	Estimated Annual Critical Water-Year Impact	Document Section
7	Number of acres of crop land and crop distribution is incorrect	In the SED, crop acres are too low for MID and too high for TID. More importantly the crop distribution is significantly wrong. The estimate of the number of acres of trees is 40,000 acres too low.	The SED understates the impact of its proposal on crop commodities.	2.1.1.1
8	The impact of stress irrigation on the acres of trees is not explained.	It appears that the SWAP model estimates that tree acres come in and out of production with the availability of irrigation supplies. This is an erroneous assumptions and is unrealistic.	Not quantified	2.3.3
9	The SED assumes additional groundwater can be pumped to offset reductions in surface water supply	The SED ignores the fact that there is already overdraft throughout the region and does not quantitatively evaluate the implementation of SGMA, the effects of which are reasonably foreseeable, when assuming additional groundwater can be used to offset surface water.	$10.7 million annually, as a minimum.	2.1.2.1
10	Missing Existing Condition section in the Economic Chapter	There is no description of the demographics or economics of the project area, an area characterized by relatively higher population growth, higher unemployment and more people living in poverty compared to the state. This is a serious flaw as it enables the SWB to ignore the disproportionate impacts of its proposal on low income and minorities.	NA	2.5.1

Priority	Technical Comment	Summary of Impact	Estimated Annual Critical Water-Year Impact	Document Section
11	Missing an Environmental Justice section/chapter	There is no description of the relative high density of minority populations or poverty that characterize the affected area.	NA	2.5.2
12	Impacts to Williamson Act enrollment not accurately described	The reduction in long-term water supply reliability may cause growers to have to un-enroll land that is current enrolled in the Williamson Act. The SED argues that land can be dryland, however given the capital investment made in permanent and animal operations most growers could not afford to continue to farm without irrigation water	The expense to the growers has not been quantified in the SED.	2.3.1
13	Impact of the project's reduction in canal deliveries on the Districts' irrigation rate structure.	Both TID and MID utilize a tiered rate structure tied to volume of water delivered. When there is less water to deliver, rates may need to increase and/or there is less operational revenue for the Districts.	Not quantified	2.5.4
14	Consideration of dairies' Waste Management Programs (WMP) is missing	The SED assumes that animal feed crops will be the first to be removed from production. Animal operations rely on those acres not only for animal feed but also as a critical component of WMP. The SED lacks an analysis of this relationship and the cost of alternative means, if any, for growers to manage waste without those crops	No quantified	2.5.5
15	Impact on future housing needs not addressed	14 Cal. Code Regs. § 15131(c) requires that water quality plans must consider "Economic, social, and particularly housing factors".	Not quantified	2.5.6

Priority	Technical Comment	Summary of Impact	Estimated Annual Critical Water-Year Impact	Document Section
16	Aggregation of the results obfuscates the impact on individual water resources management agencies.	Burdensome and time consuming effort to analyze the estimated impacts of the project at a geographic scale that is consistent with water management and water rights. While most of the data is available in supporting spreadsheets, this demonstrate a lack of understanding of how water management decisions are made.	Not applicable	2.2.2
17	SED model input data not provided	Most of the data used as input to the SED model including prices, yields, costs, water rates, crop aggregation details is not provided thereby limiting the affected public's ability to understand the full set of assumptions and analytical approach. This lack of transparency is contrary to full disclosure requirements.	Not applicable	2.5.3
18	SED states all values in 2008 dollars	This unnecessarily complicates the decision makers' review of the impact estimates. Resource managers and other readers of the document may naturally assume the impacts are in current dollars	$9.3 million	2.3.1

2.2 Errors of Fact or of Assumption

2.2.1 Factual Errors

2.2.1.1 Number of Acres of Crop Land and Crop Distribution are not Correct

Issue: The SED does not use the most recent estimates of irrigated acres of crop land for each TID and MID and does not use the correct crop distribution for the acres that it did use.

Impact: The SED is using incorrect acres of all crops however the most egregious error is the fact that the SED assumes nut tree acres are only 55 percent of their actual value.

Discussion: The SED did not utilize the best available data about irrigated crop acres for TID or MID (the Districts). Neither the total number of irrigated acres by district nor the crop distribution of those acres within each district is correct. Each district publishes an Agricultural Water Management Plan (AWMP), most recently in 2015, however the SED used the 2012 AWMP version to estimate the total acres irrigated in the Districts. For no understandable reason the SED used DWR DAU data for the crop distribution, even though crop distribution is available in the AWMP (both 2012 and 2015). In addition to using old data it appears an error was made interpreting the 2012 AWMP data.

The SED used TID's **accessed** acres as input in the SED model instead of the **irrigated** acres. TID's 2012 AWMP reports (page 56) "between 2007 and 2011 an average of 143,160 assessed acres received surface water from TID. This translates to an average of 134,751 irrigated acres when an estimate of field roads and other small non-irrigated acres are account for." The SED reports using 143,783 irrigated acres for TID which is essentially the assessed acres. TID's 2015 AWMP reports 135,836 total irrigated acres, which is what should be used in the SED model instead of the 143,783 used. The difference, 6,947 acres (6 percent) acres, is the number of acres overstated in the SED (Table 2).

The SED also used the incorrect number of acres for MID, but instead of overstating acres, the number of irrigated acres was understated. The SED assumed irrigated acres in MID were 57,354. The 2012 AWMP reports irrigated acres of 59,153 PLUS double cropped acres of 8,855. So the total number of acres in production in MID is the sum of the cropped and double cropped acres (see Table 23 in MID's 2012 AWMP). Using the most recent data from the 2015 AWMP the total acres under production in MID is estimated to be 62,778 (Table 2). So the SED understated productive acres in MID by 5,424 (9 percent).

In addition to using an incorrect number of total acres in the SED model the SED also uses an incorrect crop distribution, e.g. the specific number of acres of each crop grown in the Districts. The SED reports on this error, but does not fix it. Rather than use information presented in the AWMP about the types of crops grown in the Districts the SED chooses to use, without explanation, DWR's DUA data. The SED states (Page G-44):

> *For all irrigation districts except SEWD and CSJWCD, the crop distribution and applied water rates based on DWR DAU data were used.*

Attachment 1 of Appendix G compares the differences, by crop acres, between the DWR DAU data and the Districts' AWMP. For example, the SED states (page 6 of Attachment 1 to Appendix G):

> *The total applied water demand resulting from the DAU distribution is about 50,000 AF lower than the AWMP distribution estimate.*

A difference of 50,000 AF is 20 percent of the total applied water demand, and yet our review could not find a correction to this data in the SED model. In addition to the difference in the applied water demand the crop distributions used in the SED are significantly different than those reported in either the 2012 or the 2015 AWMP. And the difference in crop distribution would change the SED's estimated impact of the project on crop commodities. Table 2 compares the data used in the SED to the data available from the Districts' 2015 AWMP. The SED data shown in Table 2 is summarized from information found in the spreadsheet available on the SWRCB's SED web page under Modeling Tools Information and Files entitled Agricultural Economic Analysis_09142016. In that spreadsheet the crops are aggregated into the five categories shown, namely Fruit, Grain, Other, Tree Nut, Vegetables.

Table 2. Crop Distribution Comparison, Districts' AWMP to the SED

SED Aggregate Crop *Districts' Crop*	**TID**				**MID**			
	AWMP	**SED**	**Diff**	**% Diff**	**AWMP**	**SED**	**Diff**	**% Diff**
Fruit	**5,806**	**10,297**	**4,491**	**77%**	**3,995**	**9,284**	**5,289**	**132%**
Apples	*434*				*54*			
Apricots	*2*				*0*			
Berries	*25*				*0*			
Cherries	*431*				*0*			
Citrus	*8*				*0*			
Kiwi	*16*				*0*			
Peaches, stone fruit	*3,305*				*2,526*			
Pears	*7*				*0*			
Plums	*3*				*0*			
Vineyard	*1,575*				*1,415*			
Grain	**56,678**	**44,808**	**-11,870**	**-21%**	**11,063**	**11,613**	**550**	**5%**
Corn	*11,866*				*10,204*			
Double	*7,322*				*0*			
Grain	*106*				*859*			
Oats	*3,358*				*0*			
Oats/Corn	*18,232*				*0*			
Dry-forage/ Irr. Corn	*15,794*				*0*			
Other	**19,114**	**46,070**	**26,956**	**141%**	**12,930**	**19,643**	**6,713**	**52%**
Alfalfa	*9,839*				*3,034*			
Beans	*258*				*0*			
Christmas	*0*				*183*			
Clover	*79*				*0*			
Gypsophilia	*0*				*0*			
Lawn	*1,389*				*0*			
Other Crops	*352*				*340*			
Pasture	*6,433*				*9,373*			
Sudan	*764*				*0*			
Tree Nut	**52,253**	**33,741**	**-18,512**	**-35%**	**33,686**	**13,139**	**-20,547**	**-61%**
Almonds	*46,513*				*23,758*			
Olive	*108*							
Other Trees	*368*				*1,334*			
Walnuts	*5,264*				*8,594*			
Vegetables	**1,985**	**8,867**	**6,882**	**347%**	**1,104**	**3,675**	**2,571**	**233%**
Beets	*0*				*0*			
Carrots	*0*				*0*			
Eggplant	*9*				*0*			
Garden	*70*				*0*			
Melons	*118*				*0*			
Onions	*17*							
Peas	*8*				*0*			
Pumpkins	*76*				*0*			
Squash	*30*				*3*			
Sunflowers	*8*				*0*			
Sweet potatoes	*1,638*				*1,101*			

Tomatoes	*11*				*0*			
Grand Total	**135,836**	**143,783**	**7,947**	**6%**	**62,778**	**57,354**	**-5,424**	**-9%**

Sources: SED data from the SWRCB's SED web page under Modeling Tools Information and Files, spreadsheet entitled Agricultural Economic Analysis_09142016. TID data from Turlock Irrigation District Agricultural Water Management Plan, 2015. MID data from Modesto Irrigation District Agricultural Water Management Plan, 2015.

The SED over reports TID's fruit acres (primarily peaches, other stone fruit and apples) by 4,491 acres and MID's by 5,289 acres. The SED under reports grain acres for TID by 11,870 acres and slightly over reports for MID by 550 acres. The SED over reports "other" acres by 26,956 for MID and 19,643 acres for MID. Nut tree acres are under reported by 18,512 acres for TID and 20,547 acres for MID. Lastly vegetable acres (primarily sweet potatoes) are over reported by 6,882 acres for TID and 2,571 acres for MID.[2]

The impact of this crop-distribution error on the SED model's estimates of a change in crop commodities acres could be significant. The assumption in the SED model is that water would be allocated to the "highest value" crop commodity. And because the SED does not account for the additional value that "grain" (primarily silage) and "other" (primarily alfalfa and pasture) contribute as feed for animals, the acres of those two crops are first to be removed from production as water supplies are reduced. By understating the number of acres of the permanent crops (e.g. fruit and nut trees) the SED model is under estimating the proposed project's impact to grain and other crops. In other words, if the SED model was re-run with the correct, and higher, acres for fruit and nut trees, there would be even less water for grain and other crops, such that the reduction in the acres of animal feed would be even larger than the current SED estimate. As it is the SED represents much more grower flexibility to adapt to a reduction in long-term supply reliability than actually exists.

2.2.1.2 Estimates of the Volume of Existing Groundwater Pumping

Issue: The SED assumes that groundwater will continue to be used in the same volume as is currently pumped. Given the impending implementation of SGMA this is an erroneous assumption.

Impact: The SED's estimate of the economic impact to agriculture is understated.

Discussion: It is not reasonable to assume that the current volume of pumping could continue under SGMA, because the current volume of groundwater pumping is supported by recharge from surface

[2] Analyzing the crop distribution is made more difficult by the fact that the SED does not provide the aggregation of district crops to the SED model's crop categories. However, something is wrong with the aggregation which is easiest to see when comparing MID's 2012 OR 2015 AWMP to SED's Table 5 on page 6 of Attachment 1 to Appendix G. The table shows MID's crops by the SED model's crop category. The table does not include a category for walnuts, despite the fact that there are over 8,000 acres of walnuts reportedly grown in MID in both the 2012 and 2015 AWMPs. Presumably the SED includes the walnuts in the category "other deciduous" crops, which it reports as 11,624 acres. However, the SED also reports on Table F.5-1. Comparison of the SED model's Crop Categories to IMPLAN Crop Groups that "other deciduous" acres are aggregated into IMPLAN category for Fruit. So the SED is analyzing walnuts as if they were a fruit. The impact of this may not have ramifications on the analysis, it is not possible to know without re-running the model. However, it is worrisome that the crop categorizations do not accurately reflect the area being impacted.

water supplies.[3] Under the SED, surface water supplies significantly reduce the amount of surface water that will be available to recharge the groundwater system. As a result, there will likely be a corresponding reduction in groundwater pumping that will be viable. That is, unless there can be recharge projects installed to make use of the surface water supplies that might be available in the wettest of years to help bolster groundwater supplies. The SED impacts are on top of any impacts or changes to groundwater availability that might be available as a result of SGMA. There has been no determination of "sustainability" as it pertains to the subbasin, which makes it difficult to predict what the future will look like when SGMA is fully implemented.

2.2.2 Errors of Assumptions

2.2.2.1 Estimates of Ability to Pump Additional Groundwater is Incorrect

Issue: The SED recommends lost surface water supplies be replaced by increasing the volume of groundwater pumped in nearly every year.

Impact: Including this additional groundwater in the SED impact estimates understates the economic impact of the SED to the agriculture.

Discussion: Given the current overdraft of the basin and the impending implementation of the SGMA it is incorrect to assume groundwater can be used to replace lost surface supplies.

2.2.2.2 Not All Irrigation Districts Support Intra-District Water Transfers between Growers.

Issue: The SED model (page G-43) "selects those crops, water supplies, and irrigation technology that **maximize profit** subject to …. constraints." An underlying assumption in the selection of those crops is that intra-district water transfers are utilized to maintain irrigation supplies to high valued crops, such as trees, and reduce irrigation supplies to lower valued crops, such as alfalfa and irrigated pasture. However TID's by-laws do not allow for intra-district transfers of water between landowners.[4]

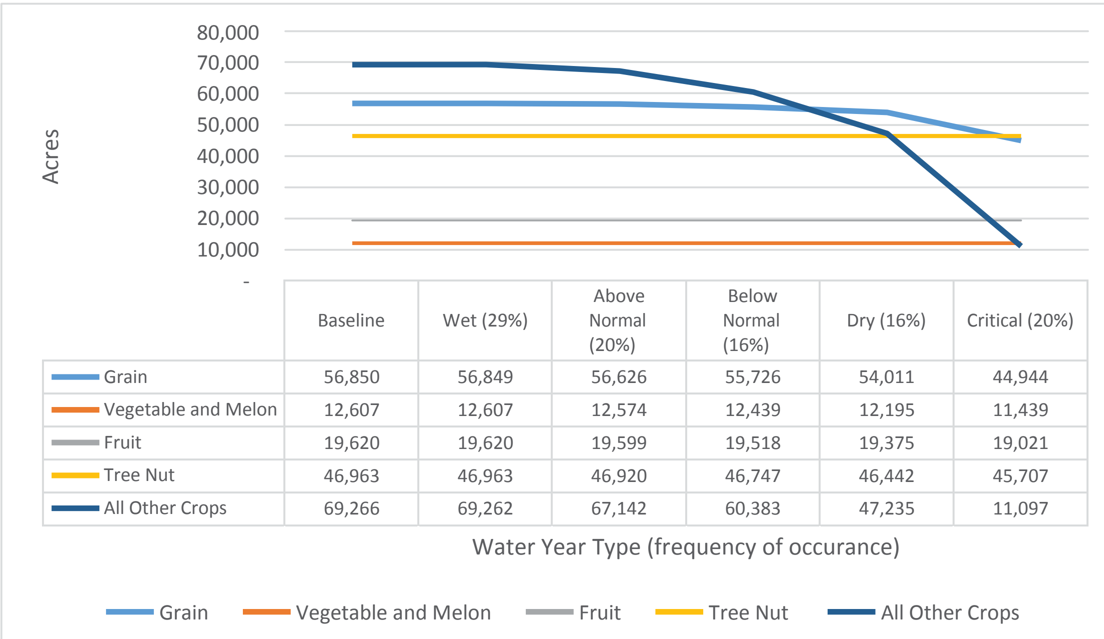
Impact: As modeled in the SED, the estimated reduction of acres of "high valued" crops is too low and the estimated reduction of acres of "low valued" crops is too high.

Discussion: The SED model assumes that water is allocated to maximize the revenue at a district level. This assumption infers that water can be transferred from one grower/landowner to another. Under this assumption the SED model's estimates of acres to "high valued" crops (e.g. trees, fruit and vegetables) would be last to be impacted. Instead acres of "lower valued" crops (e.g. grains, other) would decline (Figure 1). For example, tree nut acres are just over 46,000 acres in every year, with a slight decline below 46,000 in critical dry water year types. However, acres of "all other crops" (primarily alfalfa and irrigated pasture) declines from over 69,000 acres in wet years to approximately

[3] San Joaquin River Flows and South Delta Water Quality Substitute Environmental Document – Comments of Groundwater Impact Analysis for the Turlock Subbasin, Memorandum from Gus Yates, Senior Hydrologist Todd Groundwater, 2017.
[4] See section 6.8 of TID's AWMP, 2015.

67,000 acres in above normal and continues to decline in each water-year type until there are just over 11,000 acres in critical water-year types.

Given that TID does not support the transfer of water from one grower to another this is an extremely unlikely outcome. In addition, as will be mentioned in Section 2.2, animal feed crops, represented in "grain" and "all other crops", are not "low value" as the SED purports.



	Baseline	Wet (29%)	Above Normal (20%)	Below Normal (16%)	Dry (16%)	Critical (20%)
Grain	56,850	56,849	56,626	55,726	54,011	44,944
Vegetable and Melon	12,607	12,607	12,574	12,439	12,195	11,439
Fruit	19,620	19,620	19,599	19,518	19,375	19,021
Tree Nut	46,963	46,963	46,920	46,747	46,442	45,707
All Other Crops	69,266	69,262	67,142	60,383	47,235	11,097

Source: SED data from the SWRCB's SED web page under Modeling Tools Information and Files, spreadsheet entitled Agricultural Economic Analysis_09142016.

Figure 1. Acres by Crop Category Under SED Alternative Three for TID and MID.

2.3 Comments on Method of Analysis

The method of analysis uses industry standard models however the **scope of the study is too narrow in places and ill-defined** in other. Three concerns about the scope are: 1) the SED does not account for all **agricultural sectors** impacted, 2) the SED does not describe a **temporal scope** and is missing an analysis of the long-term impacts on all agricultural sectors and 3) the SED's **geographic scope** is inconsistent across impact categories. Each of these concerns is discussed below

2.3.1 Agricultural Sectors

The SED excluded impacts on animal commodities and the food and beverage manufacturing sectors.

2.3.1.1 Animal commodities are not included in the modeling

Issue: The scope of the SED's agricultural economic impact analysis does not include potential impacts to animal commodities, e.g. milk and beef, despite the SED's projection of an average annual reduction in the number of acres of animal feed crops in production.

Impact: The SED's estimate of the average annual reduction in agricultural output supported by irrigation supplies from TID and MID is significantly understated. Implementing the SED will impact the dairy and cattle & calf industry. The economic impact is estimated to be an annual reduction of between $140.9 million dollars upwards to $289.7 million in more than half of all years. With a corresponding reduction of full and part-time jobs of between 620 and 1,480.

Discussion: this issue was discussed at all of the public hearings and SWRCB member Dorene D'Adamo requested clarification multiple times. For example, the transcript of the November 29, 2016 meeting (page 241):

> *Ms. D'Adamo: I just think that this is a really important issue. And not to take up time now, but just to get whether its staff and then also your industry to give us a sense of what a dairy will do with their forage crops if there's an assumption that they will sell the water to the highest bidder, when they're going to end up with a loss of feed for their dairy. So some way to make that real in terms of what's the acreage out there that is owned or under control by these dairies as opposed to purchasing it from other growers that are in the area.*

California leads the nation in milk and cream production, with a 19 percent share of U.S. production in 2015.[5] Stanislaus and Merced Counties ranked **second and fourth in the nation, respectively,** in terms of the value of milk produced.[6] In 2015, a year in which milk prices were down, the combined value of those two commodities was $2.2 billion, one third of the total value of agricultural commodities produced in those two counties. [7] In 2014, when milk prices were higher, the total production value of milk was $3.1 billion. Historically, between 20 percent and 25 percent of California's total production value of milk and cattle & calves, $9.6 billion in 2015 and $13.1 billion in 2014, is produced in these two counties, ranking **second and third in animal commodity production counties in the state**.[8]

TID and MID supply water to farmers and ranchers to irrigate approximately 20 percent to 30 percent of the animal feed crops (e.g. corn silage, hay and pasture) necessary to support approximately 20 percent to 30 percent of the two-counties' dairy and beef herds. These feed crops support annual animal commodity production valued between $930 million and $440 million. Since the SED did not include animal commodities in its analysis the baseline estimate of the value of irrigation water supplied by TID

[5] California Agricultural Statistics Review, 2014-2015, California Department of Food and Agriculture.
[6] Dairy Cattle and Milk Production, October 2014, USDA Census of Agriculture, National Agricultural Statistics Service.
2015 Report on Agriculture, Merced County Department of Agriculture *and Stanislaus County Agricultural Report, 2015*, Stanislaus County Agricultural Commissioner.
[8] California Agricultural Statistics Review, 2014-2015, California Department of Food and Agriculture.

and MID is understated. On average, **the estimated baseline value of animal commodities, excluded from the SED analysis, supported by water delivered from the Don Pedro Project, is $665 million annually** (2012 dollars).[9] The SED baseline also excludes the jobs created by production of these animal commodities, estimated to be **2,890 full and part time jobs**, annually paying workers over **$30.8 million in labor income**.[10]

The full **economic impact** of a reduced water supply reliability on the dairy and cattle & calf industries is not estimated in the SED. The reduction in the acres of feed crop produced **is** estimated. The SED treats these animal feed crops as "lower net-revenue crops" relative to nuts and fruits without regard to the contribution these crops make to supporting animal commodities. For example (page G-48)

> *The lower net-revenue crops cover large portions of the study area; consequently, these crop groups are substantially reduced for the LSJR alternatives with higher unimpaired flow requirements, particularly for LSJR Alternative 4.*

Furthermore, because the SED states that these "lower net-revenue crops **cover large portions of the study area**", without explaining the value added at dairies and cattle & calf operations, it could appear to water resource managers reading this document that the region grows lower value agriculture. Nothing could be further from the reality, it's just that the SED ignored the value added and the impact of **the reduction in feed crop on animal commodities**.

Unlike annual crops, e.g. rice, tomatoes, truck crops, etc., where a grower's operational response to a reduction in irrigation supplies ends with the decision not to plant - diary and cattle & calf operators have to go one step further and either find replacement feed for acres not planted or choose to cull their herds. Both of these types of responses were seen in the recent drought. In *Economic Analysis of the 2015 Drought For California Agriculture*[11], (Howitt et.al., 2015) the authors (one of whom is the lead author for the SED's Appendix G) describe both types of operators' responses (Page 8, emphasis added):

> ***Losses to California's dairy and cattle and calf** industries derive primarily **from higher costs and lower availability of California-produced forage,** including hay, silage and pasture…. The drought has **accelerated milk cow culling rates and reduced milk output** on top of depressed milk prices**. Milk production in California has dropped from 2014, whereas national production outside California has remained high.***

The SED estimates an **average** annual 5 percent reduction in corn silage acres (e.g. 95 percent of baseline) under Alternative 3 (**Figure 2-a**). **Average annual** alfalfa and irrigated pasture would fall by 20 percent (e.g. 80 percent of baseline) under Alternative 3 (**Figure 2-b**).[12] However, when it comes to animals the **average annual impact to feed crops does not accurately represent the potential impact** to animal commodities. Animals eat every day **in every year**. What matters in this analysis is the change in the **reliability of feed supplies over all water year types.**

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[9] Socioeconomics Study Report, Don Pedro Project FERC No. 2299, 2014, Turlock Irrigation District and Modesto irrigation Distri ct.
[10] Ibid
[11] Economic Analysis of the 2015 Drought for California Agriculture, 2015. R.E. Howitt, D. MacEwan, J. Medellin-Azuara, J. Lund, D. Sumner, UC Davis Center for Watershed Sciences, ERA Economics and UC Agricultural Issues Center.
[12] Agricultural Economic Analysis 09142016.xls spreadsheet found on the SWRCB's SED website under the heading Modeling Tools and Information Files.

For example, under the Baseline corn silage acres are 100 percent of the acres under full demand in all but critical water-year types (which occur 20 percent of the time), when acres fall by approximately 5 percent (e.g. 95 percent of full demand). Under Alternative 3, in critical water-year types **corn silage is nearly 20 percent below full demand** (an addition 15 percent reduction from full) and **alfalfa and irrigated pasture are estimated to be 80 percent below full demand** (an additional 65 percent reduction from full).

It is highly unlikely that the dairy and cattle & calf industries could manage a 20 percent reduction in corn silage and an 80 percent reduction in alfalfa and irrigated pasture in one out of five years (e.g. frequency of critical water-year types) without at least an impact to the volume of milk and beef produced or more likely a structural change to the industry (e.g. a contraction in the two-county herd size representing a reduction in animal operators' income and/or the closing of operations). For example, after a two-year drought in Texas in 2012 and 2013 a beef processing plant shut down. "The drought dried up pastures and increased the costs of hay and feed, forcing some ranchers to sell off their herds to reduce expenses." As a result, a beef processing plant that employed 2,300 people was shut down. "…executives said they were idling the plant and not permanently closing it, and it could reopen if the drought breaks and the cattle herd rebounds, **a process that would take years**."[13]

As Figure 2-a and Figure 2-b show, under the SED estimated shortages of both silage and irrigated pasture and alfalfa are not only greater than under full demand and baseline but shortages of irrigated pasture and alfalfa occur **with greater frequency**.

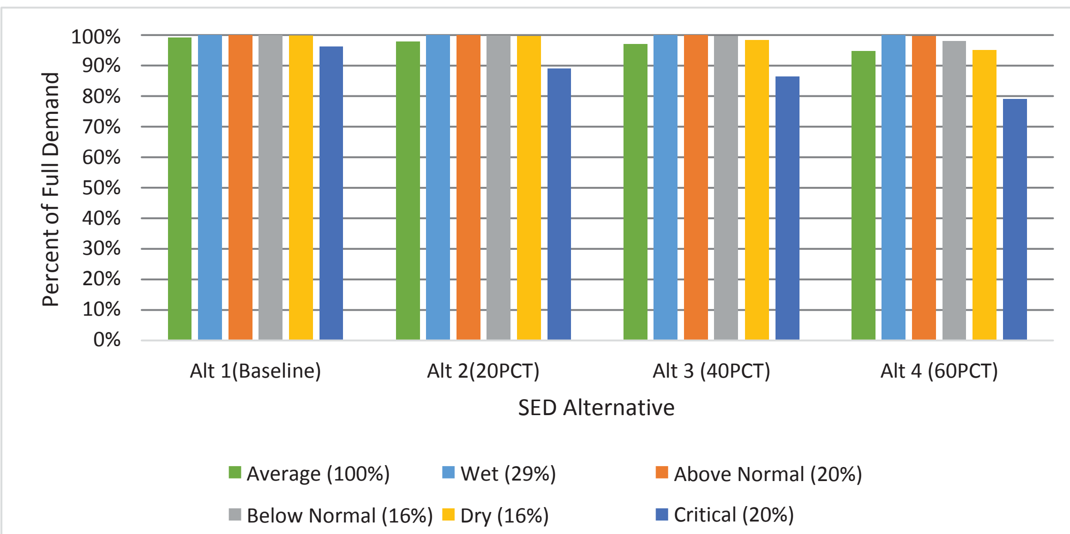


Figure 2-a. Corn Silage Acres as a Percent of Baseline by Water-Year Type, all Alternatives.

Irrigated pasture and alfalfa shortages occur under Alternative 3 and Alternative 4 in all but wet and above normal years. Under Alternative 3 shortages occur in 50 percent of all water year types (below normal, dry and critical). And the magnitude of the shortage is 20 percent to 64 percent larger than baseline, up to 80 percent of full demand under Alternative 4.

[13] F Fernandez, M. Drought Fells a Texas Town's Biggest Employer, February 27, 2013. NY Times.

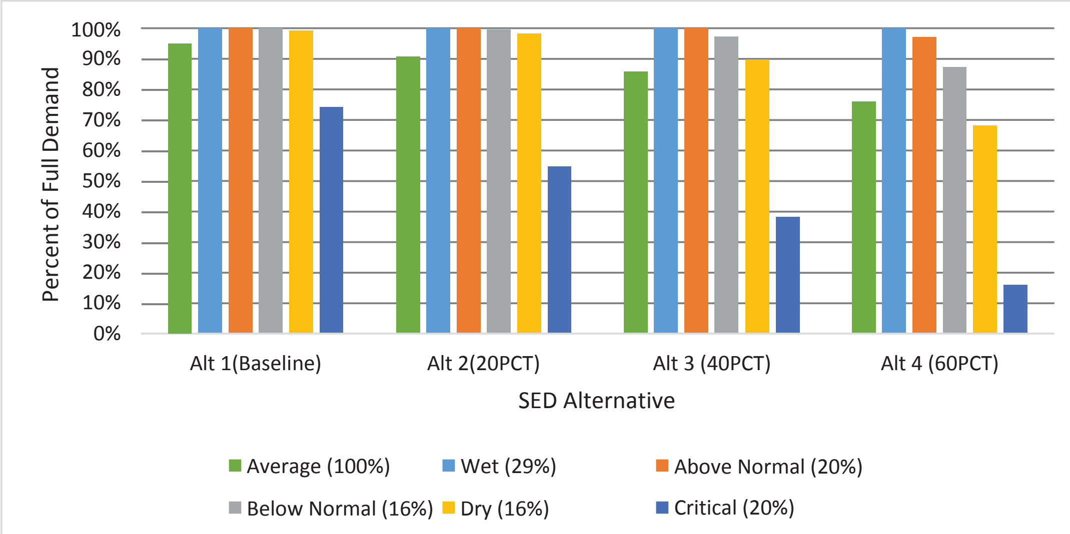


Figure 2-b. Alfalfa and Irrigated Pasture Acres as a Percent of Baseline by Water-Year Type, all Alternatives.

The only comment in the SED about the impact of a reduction in feed crops on dairies and cattle & calf operations is found on page G-55, reproduced below in its entirety.

> *Livestock (beef cattle) and dairies, the two main animal operations in California, require both irrigated and non-irrigated crops as production inputs. Evaluating the effects of the LSJR alternatives on these two sectors requires a forward-linkage assessment that typically is beyond the capabilities of traditional input-output analysis, including IMPLAN. Nevertheless, it is possible to draw some inferences using economic information about the affected dairy and livestock sectors and the built-in information about the relationships in IMPLAN for the study area.*
>
> *Beef cattle require pasture (including non-irrigated winter pasture) and other fodder crops, whereas dairy cattle rely heavily on alfalfa, locally grown silage corn, and a concentrate that is usually imported from out of state. Implementation of some of the LSJR alternatives may limit the economic feasibility of growing feed crops near affected water districts. Thus, these districts would experience some cost increase for inputs during water-short years.*[14] *Dry forms of feed crops, such as alfalfa hay, can be imported to replace the limited supply of locally grown feed crops when regional markets for these crops are operating. However, silage corn, which has higher water content, is more costly to transport and is often not sold in the market. Because of the higher transport cost, this product is more often produced by farm operators. The ability to substitute various crops in the milk cow and the beef cattle diet with imported feed crop or concentrate is considered the determining factor for potential economic impacts of the LSJR*

[14] The SED's statement that the "districts experience some cost increase for inputs" is not correct. The cost increase in inputs **would be borne by the dairy and cattle & calf operators**, not the irrigation districts. Likely this error is an oversight, however it is worrisome in that it misleads the reader into thinking that the irrigation districts, rather than the individual operators, would be the affected party.

alternatives on livestock and dairy net returns. In addition, the ability to substitute corn for fodder crops is limited by dairy dietary restrictions.

The SED is correct that IMPLAN does not estimate the impact of a change in feed supplies on animal commodity production. However, that is not to say that an analysis cannot be done. TID and MID have undertaken an analysis of the impact of implementing the SED on animal commodities.[15] The analysis used two different assumptions to estimate responses to an increase in uncertainty about feed supplies.

- No structural change to the existing dairies and cattle & calf operations. Operators attempt to maintain baseline herd size, butdo have to respond to annual variability in feed crops either by culling their herds or paying higher feed costs.
- There is a structural change to the existing dairies and cattle & calf operations. The industry down-sizes commensurate with the reduction in feed supplies.

Under the first assumption the analysis bookended a range of impacts. The maximum impact occurs when animal commodity values fall in proportion to the reduction in animal feed. Under SED Alternative 3 the maximum annual impact to direct animal commodity revenue in critical water-year types is estimated to be a $186.4 million dollars plus another $103.36 million in backward linkages for a total of $289.73 million dollars and a reduction in approximately 1,480 jobs (both direct and indirect). The minimum impact assumes that all of the feed can be replaced, albeit at a higher cost, so there is no reduction in animal commodity revenue or jobs however operator's income falls by an average 3 percent to 7 percent. Given the magnitude of annual changes in feed supplies, the cost of re-building a herd and the potential reduction in operator income it is unlikely that operators would choose to maintain baseline herd size if the SED is implemented.

A more reasonable approach to estimating the long-term impact of the SED on dairy and cattle & calf operators assumes that operators choose to permanently down-size herds, or relocate out of the area, to maintain the same level of certainty in feed-supply reliability as currently exists under the baseline. Currently under baseline conditions the only reduction in feed crops occurs in critical water-year types when corn silage is reduced by 4 percent and alfalfa and irrigated pasture are reduced by 25 percent (compared to the 20 percent reduction in corn silage and the 80 percent reduction in alfalfa and irrigated pasture under the SED for the same year type). Under this assumption herd size would be permanently reduced, e.g. the dairy and cattle & calf industry would contract, by approximately 15 percent to 30 percent.

A contraction in the dairy and cattle & calf sector, in addition to reducing revenue and eliminating jobs, would also strand a significant amount of capital. Diary and cattle & calf operations require a significant capital investment. In the dairy industry the cash costs of operations are estimated to be between 78 percent and 98 percent of total costs depending on factors including debt structure, age of infrastructure, type of infrastructure, etc. Depreciation and interest costs for the investments in items including the milking barn, free stall, manure pit, bulk tank, hay barn, silage pit, maternity pens, etc.,

[15] Agricultural Economic Impacts of a Reduction in Water Supply to Turlock Irrigation District and Modesto Irrigation District, 2017.

represent between 22 percent and 2 percent of total costs.[16] [17] In 2015 an estimated $7.3 million to $10.9 million of depreciate expense was taken by dairies and cattle & calf operations that feed their cows crops that are grown with water from TID and MID.[18] Depreciation expense of that magnitude suggests capital investments between $36.5 million to $305.2 million.[19] Investments of this magnitude were made because growers depended on the historically high water supply reliability created by TID's and MID's Don Pedro Project. These capital investments would be at risk if the dairy and cattle & calf sectors contracted.

Another way the dairy and cattle & calf sector can contract is through relocation of operations to area that are not threatened with a reduction in irrigation supplies. Kansas, Nebraska and other Midwest states are pitching themselves as a dairy heaven, hoping to attract dairy owners and looking for a windfall of jobs and money in rural economies.[20] "Each new dairy represents millions to the local economy. It takes an investment of $14 million to $15 million to build a 2,000-cow dairy, according to Jeff Keown, a retired dairy specialist with the University of Nebraska-Lincoln."[21] At the World Ag Expo in Tulare, in 2015, more than a half dozen states—Nebraska, Iowa, Kansas, North Dakota, South Dakota, Texas, and Nevada—had booths to recruit milk producers with "promise of water, stable feed supply and abundant land".[22] In Iowa the executive director of the Iowa State Dairy Association has been quoted as getting "a lot of inquiries from people" interested in relocating from California to Iowa, following one dairy that already relocated.[23] The region has already seen a reduction in the number of dairy operations, and some operations have moved. Implementation of the SED, creating uncertainty about the reliability of water and feed crops, may encourage more dairies to leave California.

2.3.1.1 Processing Sector and Forward Economic Linkages

Issue: The scope of the SED's agricultural economic impact analysis does not include potential impacts to the agricultural food and beverage processing/manufacturing sector.

Impact: The SED's estimate of the economic impact to output and jobs in the region is understated.

Discussion: In Citizens Association for Sensible Development of Bishop Area v. Inyo (1985) 172 Cal. App. 3d 151, the court held that "…., economic and social effects of a physical change may be used to determine that the physical change is a significant effect on the environment." In this case, the Court

[16] Market Milk Production in San Joaquin County, Cost analysis Work Sheet, 1986. University of California Cooperative Extension.
[17] California Cost of Milk Production 2015 Annual, California Department of Food and Agriculture. https://www.cdfa.ca.gov/dairy/pdf/Annual/2015/COP_Annual2015.pdf.
[18] CDFA reports that 2015 depreciation expense for the North Coast was $6.31 per cow per month and the herd size in Stanislaus and Merced County was 480,000 head. Of which approximately 20 percent to 30 percent were assumed to be fed on feed crops grown with water from Don Pedro water supplies.
[19] Assuming straight-line depreciation of most assets assuming a useful life of 5 to 28 years and no salvage value.
[20] Midwest lures California dairies with lower costs, wide open spaces, The Kansas City Star, January 12, 2015. http://www.kansascity.com/news/business/article6172863.html.
[21] Ibid.
[22] Outside states to California dairy farmers: We have water. CNBC, February 12, 2015. http://www.cnbc.com/2015/02/10/california-drought-states-tempt-california-dairy-farms--we-have-water.html.
[23] Dairy industry could see slight shift amid drought in California, Illinois Farmer Today, August 17, 2015. http://www.illinoisfarmertoday.com/news/dairy-industry-could-see-slight-shift-amid-drought-in-california/article_a0eedd80-4059-11e5-84a9-871a19198e6c.html.

held that an EIR for a proposed shopping center located away from the downtown shopping area must discuss the potential economic and social consequences of the project, if the proposed center would take business away from the downtown and thereby cause business closures and eventual physical deterioration of the downtown. (14 Cal. Code Regs. § 15131).

The SED incorrectly states [notes added for emphasis]: "For this application, direct agricultural-related revenues generated by the SED model [note: which is only estimating the crop commodity and ignores the animal commodity], and indirect and induced economic effects estimated using the IMPLAN multipliers together provide an estimate of the total economic effects on economic output and jobs."

The "indirect and induced economic effects" included in the SED account for the inputs to agricultural production, e.g. the labor for pruning and harvesting, fertilizer, pesticides, etc. However, the SED does not qualify or quantify the impact that a reduction in the production of crop and animal commodities – used as inputs to food and beverage processing – would have on the processing sector. Food and beverage processing plants transform raw agricultural materials into products for intermediate or final consumption by applying labor, machinery, energy, and scientific knowledge. Given the volume of the crops grown in the two-county area processors have chosen to locate processing facilities, including warehousing and refrigeration, in the two-county area also.

The California Employee Development Department (EDD) reports the top 25 major employers in California counties (measured in terms of number of employees). In Stanislaus and Merced County 25 of the two-county total of 50 major employers are directly or indirectly involved in agriculture, either growing or processing agricultural output (Table 3). Together, these top 25 agricultural employers alone provide between 16,150 and 71,476 jobs to Stanislaus and Merced County.

Table 3. Top 50 Employers in Stanislaus and Merced Counties by Industry

No	Employer	Industry	Sector	Location	County	Employment Range
1	Live Oak Farms	Agriculture	Fruits & Vegetables-Growers & Shippers	Le Grand	Merced	250-499
2	Nor Cal Nursery	Agriculture	Fruits & Vegetables-Wholesale	Turlock	Merced	250-499
3	J Marchini & Son	Agriculture	Farms	Le Grand	Merced	500-999
4	Andre Champagne Cellars	Ag. Processing	Wineries (mfrs)	Modesto	Stanislaus	1,000-4,999
5	Carlo Rossi Winery	Ag. Processing	Wineries (mfrs)	Modesto	Stanislaus	1,000-4,999
6	Con Agra Foods Inc	Ag. Processing	Canning (mfrs)	Oakdale	Stanislaus	1,000-4,999
7	Copperidge Winery	Ag. Processing	Beverages (whls)	Modesto	Stanislaus	1,000-4,999
8	Del Monte Foods Inc	Ag. Processing	Food Products & Manufacturers	Modesto	Stanislaus	1,000-4,999
9	E & J Gallo Winery	Ag. Processing	Wineries (mfrs)	Modesto	Stanislaus	1,000-4,999
10	Ecco Domani Winery	Ag. Processing	Wineries (mfrs)	Modesto	Stanislaus	1,000-4,999
11	Fairbanks Cellars	Ag. Processing	Wineries (mfrs)	Modesto	Stanislaus	1,000-4,999
12	Foster Farms	Ag. Processing	Poultry Processing Plants (mfrs)	Livingston	Stanislaus	1,000-4,999
13	Foster Farms	Ag. Processing	Poultry Processing Plants (mfrs)	Turlock	Merced	1,000-4,999
14	Hornsby's Pub Draft Cider Ltd	Ag. Processing	Beverages (whls)	Modesto	Stanislaus	1,000-4,999
15	Peter Vella Winery	Ag. Processing	Wineries (mfrs)	Modesto	Stanislaus	1,000-4,999
16	Zabaco Winery	Ag. Processing	Wineries (mfrs)	Modesto	Stanislaus	1,000-4,999
17	E & J Gallo Winery	Ag. Processing	Wineries (mfrs)	Livingston	Merced	100-249
18	Yosemite Wholesale Warehouse	Ag. Processing	Warehouses	Merced	Merced	100-249
19	Gallo Cattle Co	Ag. Processing	Cheese Processors (mfrs)	Atwater	Merced	250-499
20	Liberty Packing Co	Ag. Processing	Packing & Crating Service	Los Banos	Merced	250-499

No	Employer	Industry	Sector	Location	County	Employment Range
21	Sensient Natural Ingredients	Ag. Processing	Flavoring Extracts (whls)	Livingston	Merced	250-499
22	Frito-Lay Inc	Ag. Processing	Potato Chips (whls)	Modesto	Stanislaus	500-999
23	Hilmar Cheese Co	Ag. Processing	Cheese Processors (mfrs)	Hilmar	Merced	500-999
24	Western Marketing & Sales	Ag. Processing	Farms	Atwater	Merced	500-999
25	Amazon Fulfillment Ctr	Durable Goods	Distribution Centers (whls)	Patterson	Stanislaus	500-999
26	Atwater Elementary Teachers	Education	Professional Organizations	Atwater	Merced	100-249
27	Merced College	Education	Schools-Universities & Colleges Academic	Merced	Merced	100-249
28	Weaver Union School District	Education	School Districts	Merced	Merced	100-249
29	Livingston Union School District	Education	School Districts	Livingston	Merced	250-499
30	University of California, Merced	Education	Schools-Universities & Colleges Academic	Merced	Merced	500-999
31	Community Services Agency	Government	Government Offices-County	Modesto	Stanislaus	1,000-4,999
32	Merced County Human Services	Government	Government Offices-County	Merced	Merced	500-999
33	Stanislaus County Community	Government	Government Offices-County	Modesto	Stanislaus	500-999
34	Stanislaus County Welfare Dept	Government	County Government-Social/Human Resources	Modesto	Stanislaus	500-999
35	Women Infants Child Prgm	Government	Health Services	Modesto	Stanislaus	500-999
36	Doctors Medical Ctr	Health Services	Hospitals	Modesto	Stanislaus	1,000-4,999
37	Memorial Medical Ctr	Health Services	Hospitals	Modesto	Stanislaus	1,000-4,999
38	Mercy Medical Center Merced	Health Services	Hospitals	Merced	Merced	1,000-4,999
39	Memoiral Hospital Los Banos	Health Services	Hospitals	Merced	Merced	250-499
40	Emanuel Medical Ctr	Health Services	Hospitals	Turlock	Stanislaus	500-999
41	Golden Valley Health Center	Health Services	Clinics	Merced	Merced	500-999
42	Oak Valley Hospital District	Health Services	Hospitals	Oakdale	Stanislaus	500-999
43	Werner Co	Manufacturing	Ladders-Manufacturers	Merced	Merced	250-499
44	Quad/Graphics Inc.	Manufacturing	Printers (mfrs)	Merced	Merced	500-999
45	Atwater Signal	Newspapers	Newspapers (publishers/Mfrs)	Merced	Merced	100-249
46	Modesto Bee	Newspapers	Newspapers (publishers/Mfrs)	Modesto	Stanislaus	500-999
47	Walmart	Retail	Department Stores	Merced	Merced	250-499
48	Walmart Supercenter	Retail	Department Stores	Atwater	Merced	250-499
49	Macdonald Group	Service Producing	Real Estate	Modesto	Stanislaus	500-999
50	Turlock Irrigation District	Utility	Electric Companies	Turlock	Stanislaus	250-499

Source: California Employment Development Department (EDD) 2015. Note: Shaded rows are directly or indirectly involved in agriculture.

The SED's lead author for the agricultural impact analysis contributed to a report entitled *The Economic Impact of Food and Beverage Processing in California and Its Cities and Counties* in which the authors estimate that food and beverage processing is responsible for 20 percent or more of all jobs in Merced and Stanislaus Counties.[24] The report states (page 5):

> *Here we see vividly the importance of food and beverage processing to the economies of many California counties, particularly those that are most rural and which were hit hardest by the prolonged economic downturn and have also been impacted most by California's drought.*

Relative to the state, the two-county area depends more on agriculture and agricultural processing (e.g. manufacturing) for employment. The agriculture and manufacturing industries in the two counties comprise a larger relative share of employment compared to the state (Table 4). Total farm employment in the two counties was between 10 percent and 11 percent of total employment between

[24] Sexton, R.J., J. Medellin-Azuara and R.L. Saitone, *The Economic Impact of Food and Beverage Processing in California and Its Cities and Counties, January 2015*. Prepared for the California League of Food Processors.

2010 and 2015 compared to 3 percent of state employment for the same time period. In absolute numbers, the agricultural industry in the two counties supported 29,000 jobs in 2015. Manufacturing, much of which is the processing of crops (e.g., food snacks, canned food, wine, cheese), supported another 31,000 jobs—combined these jobs account for approximately one quarter (23 percent) of the employment in the two counties.

Table 4. Employment by Industry, Two-County Total and Statewide, 2010-2015

Industry	Two-County Total						California					
	2010	2011	2012	2013	2014	2015	2010	2011	2012	2013	2014	2015
Total, All Industries[1]	**233**	**233**	**238**	**245**	**252**	**258**	**14,665**	**14,823**	**15,161**	**15,567**	**16,002**	**16,475**
Total farm[1]	24	24	26	28	28	29	383	390	400	412	416	423
Percent of total	*10%*	*10%*	*11%*	*11%*	*11%*	*11%*	*3%*	*3%*	*3%*	*3%*	*3%*	*3%*
Total nonfarm[1]	209	209	212	217	224	229	14,283	14,434	14,761	15,154	15,586	16,052
Percent of total	*90%*	*90%*	*89%*	*89%*	*89%*	*89%*	*97%*	*97%*	*97%*	*97%*	*97%*	*97%*
Manufacturing[1]	29	29	29	30	31	31	1,244	1,250	1,255	1,256	1,274	1,292
Percent of total	*12%*	*12%*	*12%*	*12%*	*12%*	*12%*	*8%*	*8%*	*8%*	*8%*	*8%*	*8%*
All other[1,2]	181	180	182	188	193	198	13,039	13,185	13,507	13,898	14,313	14,760
Percent of total	*78%*	*77%*	*76%*	*77%*	*77%*	*77%*	*89%*	*89%*	*89%*	*89%*	*89%*	*89%*

1 Number of jobs (thousands)

2 Industry categories include: Mining, logging and construction; Trade, transportation and utilities, Information, financial activities, Professional & business services; Educational & health services, Leisure & hospitality, Other services and Government.

Source: California Employment Development Department (EDD) 2010-2015.

The SED does not assess how a reduction in crop commodities would impact the food processing sector. Despite evidence that the most recent drought has impacted output and jobs in the food processing sector. In a 2015 Fortune article entitled *6 industries hurt by the California drought* the author quotes a senior economist describing the drought's impact on both agriculture and agricultural processing[25]:

> *California not only grows food but processes it. In 2015, the state had 11% of the country's food-processing jobs. "That segment is directly tied to agriculture," Walters said. "It's in the same boat. It's less input for them and reduced payroll as well." The news will be bad for lower-income communities that depend on the jobs. "You'll see significant reductions in household incomes in areas already severely hurting." Higher prices for processed goods could also hurt sales.*

The only way that the reduction in raw inputs (e.g. crop and animal commodities) would NOT have an impact on the processing sector would be if food processors replaced raw inputs from outside the region without an increase in cost. This is an erroneous assumption. If the reduction in the availability of raw inputs, caused by a reduction in irrigation supplies, COULD be imported from outside the region at least two things would happen. First, the transportation costs would increase. Second the increased transportation costs would result in either or both a decrease in processors' profits and an increase in food costs. More likely the processors would be forced to scale back production relative to baseline, resulting in a loss of jobs.

[25] Sherman, E. 6 industries hurt by the California drought, April 9, 2015. Fortune Magazine.

TID and MID undertook an analysis to estimate the economic impact of a reduction in irrigation water on the food and beverage processing sector. This analysis is called a "forward linkages" analysis. The Districts used IMPLAN to estimate the impacts. While IMPLAN is not specifically designed to estimate forward linkages it has been used by others (Cai and Leung[26]; Guerrero B. et.al.[27]), including the USDA in its recently published article entitled *A Practitioner's Guide to Conducting an Economic Impact Assessment of Regional Food Hubs using IMPLAN: a step-by-step approach*.[28] The Districts estimated that the impact to the food and beverage processing sector from a change in irrigation supplies could be as high as $865.5 million in critical years and on average could be a $231.5 million dollar annual reduction in output, with a reduction of jobs ranging between 3,000 and 4,000. All related to a contraction in the food and beverage sector.

2.3.2 Geographic Scope

Issue: The economic analysis does not analyze impacts consistently within the geographic scope.

Impact: The full impacts of the SED are not quantified and the results are presented in a misleading manner.

Discussion: The geographic scope for the SED is described in section ES3.2 and 1.2 referred to as the Plan Area. Three areas are described:

- The Plan Area (page ES-5): "salmon-bearing tributaries of the LSJR below the rim dams5 on the Stanislaus, Tuolumne, and Merced Rivers, and the mainstem of the LSJR between its confluence with the Merced River and downstream to Vernalis to protect fish and wildlife beneficial uses in those reaches."
- The Extended Plan Area (page ES-6): "…the Stanislaus, Tuolumne, and Merced Watersheds above the rim dams."
- Areas not included or contiguous with either the Plan Area or the Extended Plan Area but were plan amendments have the potential to create impacts. "These areas are included in the areas of potential effects for some of the resources evaluated throughout this SED and are listed below.
    - City and County of San Francisco (CCSF)
    - Any other area served by water delivered from the plan area or extended plan area not otherwise listed above."

The economic impact analysis is not consistent with regard to geography scope described above. This inconsistency does not help water resource managers consider and balance all costs and benefits from the proposed project. Specifically, the data presented in the SED summary tables (Table 20.2.-1 through Table 20.2-5) is misleading. The tables, are entitled **Summary of Average Annual Cost and Beneficial**

[26] Cai J. and P.Leung, The Linkages of Agriculture to Hawaii's Economy, Cooperative Extension Service, College of Tropical Agriculture and Human Resources University of Hawaii at Manoa, Economic Issues, Aug 2002.

[27] Guerrero, B. D. Hudson, S. Amosson, R. Dudensing, D. McCorkle and D. Hanselka, Direct and Indirect Economic Contributions of Farm Level Production to Agribusiness Supply Chains and Local Communities, Texas A&M, AfriLife Extension Service, October 2012.

[28] T.M. Schmit, B.B.R. Jablonski, and D. Kay. *A Practitioner's Guide to Conducting an Economic Impact Assessment of Regional Food Hubs using IMPLAN: a step-bystep approach,* September 2013.

Effects of the LSJR Alternatives 2, 3, and 4, Relative to Baseline Conditions for the various water use category, e.g. Agricultural Production and Related Economics (Table 20.2-1), Municipal and Industrial Water Supply and Related Economics (Table 20.2-1), Hydropower Generation and Related Economics (Table 20.2-3), Fisheries and Related Economics (Table 20.2-4 and Recreation Activity-Related Economics (Table 20.2-5). Organizing the result in this manner leads the reader to assume that the summaries are a comprehensive list of all benefits and costs for the various water use category. However, that is not the case.

The geographic scope of the economic analysis adheres to the definition above, except where it does not, the SED states (Page 20-2, emphasis added):

> *The geographic locations or study areas discussed in this chapter **vary by topic**, depending on the resource being evaluated, the temporal and geographic distribution of that resource, and **the geographic extent of potential effects on local and regional economies**. As such, evaluations may **extend beyond the defined plan area described in Chapter 1**, Introduction. For example, the evaluation of recreation and commercial fisheries includes the Pacific Ocean marine waters and corresponding coastal areas. …. Given the spatial variability among topics discussed in the analyses, each subsection in this chapter describes the geography in which the analysis focuses*.

This fractured view of the geographic scope and impact analysis does not consider all beneficial uses of water consistently across all areas. A request that was made by SWRCB Chairwoman Marcus at the December 16, 2016 hearing (page 16 emphasis added) when she stated:

> *20 …The Bay-Delta Plan lays out*
>
> *21 water quality protections to ensure that various water*
>
> *22 uses including agriculture, municipal use, fisheries,*
>
> *23 hydropower, recreation and more are protected.*
>
> *24 In establishing these objectives, the State*
>
> *25 Water Board must consider and balance **all** beneficial uses*
>
> *(Page 17)*
>
> *1 of water, **not just pick one and discard the others**. So*
>
> *2 please help us do that.*

Chairwoman Marcus's request to "not just pick one and discard the others" echoes guidelines written by the Council on Environmental Quality (CEQ) to identify major actions significantly affecting the quality of the environment (emphasis added)[29]:

> *In many cases, broad program statements will be required in order to assess the environmental effects of a number of individual actions **on a given geographical area**.*

[29] 40 C.F.R. § 1500.6(d)(1) (1974).

For example, the geographic scope for the discussion about use-benefits to fisheries is the entire California economy. Specifically, (page 20-69):

> *As discussed above under Recent Salmon Fishery Closures in California, the closures of the ocean commercial and sport fisheries in 2008 and 2009* ***cost the California economy an estimated $255–$275 million in industrial output*** *(sales), $118 million in personal income, and 1,800–2,700 jobs during each year of the closure.*

Additionally, the geographic scope of the non-use valuation studies (see Table 20.3.5-3) uses examples in the SED with a range of geographic scope from local areas to the nation.

If the California economy and beyond is the geographic scope for a discussion about fish benefits then the California economy should also be the geographic scope for other benefits, including agriculture and municipal and industrial water supply. If not, then the *statewide* agricultural and municipal and industrial water supply benefits are being "discarded". The statewide agricultural benefits would include food and beverage processing of food grown within the three-county area but processed outside the three-county area. For example, the large volume of the almonds grown in the three-county area are processed at the Blue Diamond plant in Sacramento County. The statewide benefits to municipal and industrial water use would accrue from increase delta exports.

Or, if the geographic scope of the economic analysis is not consistent across all water use types, then at a minimum the names of Tables 20.1-1 through 20.1-5 should be changed to (additions in **bold**): Summary of **Some** of the Average Annual Cost and Beneficial Effects of the LSJR Alternatives 2,3, and 4, Relative to Baseline Conditions, or: Summary of the Average Annual Cost and Beneficial Effects **that the SWRCB analyzed** of the LSJR Alternatives 2,3, and 4, Relative to Baseline Conditions

2.3.3 Temporal Scope

Issue: The SED does not state the temporal scope for the analysis despite the fact that the long-term water supply reliability of the Districts will be significantly impacted under the SED.

Impact: The long-term structural change to the agricultural economy in the area caused by the SED's long-term impact to water supply reliability is not addressed.

Discussion: CEQA Guideline 15126(a), states:

> *An EIR shall identify and focus on the significant environmental effects of a proposed project. Direct and indirect significant effects of the project on the environment shall be clearly identified and described, giving due consideration to short term and* ***long term effects***.

The long-term effects of the SED on agriculture are not considered. The SED assumes that permanent crops will continue at their current level of production. And by omitting any estimate about an impact to animal commodities the SED is implicitly estimating no change to animal commodities. Despite a decrease in water supply reliability, with larger and more frequent reductions in irrigation water supplies, the SED estimates that acres of trees will only decline in below normal, dry and critical water-year types and "bounce back" to current levels again in the wet and above normal water year types.

This assumption is incorrect. The SED fails to take into account how an increase in the number of sequentially dry years would impact the agricultural sector.[30]

The SED model's foundational economic assumption is that growers and ranchers optimize their **annual use** of resources in order to maximize returns. Given that foundational economic assumption it is reasonable to assume that growers and ranchers have optimized **their investment** in permanent crops, and capital equipment for animal operations (e.g. milking barns, etc.) based on the current water supply reliability afforded by the Don Pedro Project. Any long-term change in water supply reliability and growers and ranchers would re-optimize their investments and consequently change either/or both cropping patterns and herd size.

Historically, the top eight commodities in the two-county region, measured in terms of commodity value, have been almonds, milk, cattle & calves, chickens, silage/hay/pasture, walnuts and sweet potatoes (**Table 5**).[31] Those top eight commodities account for between 75 percent to 85 percent of the total commodity value for the two counties and are either animal-based commodities (e.g. milk, cattle & calves and chickens), animal feed crops (e.g. silage/hay/pasture) or permanent nut trees (e.g. almonds and walnuts). Only one of the top eight commodities is an annual crop, sweet potatoes, comprising only 3 percent of the 2015 total commodity value. And many of the commodities that are not in the top eight are also animal-based (sheep, bees, etc.) and/or permanent trees and vines (pistachios, peaches, citrus, etc.).

Table 5. Top Eight Commodities by Value, Stanislaus and Merced Counties, 2015.

Commodity	Commodity Category	County		Total	Percent of Total
		Stanislaus	Merced	($)	(%)
Almonds	Crop Commodity, permanent	$1,297,052	$552,042	$1,849,094	26%
Milk	Animal commodity	$647,812	$895,150	$1,542,962	22%
Cattle & Calves	Animal commodity	$350,209	$357,426	$707,635	10%
Chickens	Animal commodity	$304,226	$364,085	$668,311	9%
Silage, Hay, Pasture	Crop Commodity, animal feed	$226,736	$345,287	$572,023	8%
Walnuts	Crop Commodity, permanent	$171,741	$23,819	$195,560	3%
Sweet Potatoes	Crop Commodity, annual	$19,870	$194,317	$214,187	3%
Top 8		$3,017,646	$2,732,126	$5,749,772	81%

[30] The importance of considering sequentially dry years was not lost to the SWRCB's member, Ms. D'Adamo, who stated at the November 29, 2016 SWRCB workshop when discussing impacts to fisheries (page 286 of the hearing transcript):

24 And then another area is sequential dry years….

(Page 287):

2 … But I think it's really important for
3 us to just overlay the last four years on this SED and
4 see what it looks like.

[31] Production of chickens does not rely heavily on regional irrigation water supplies. Chickens feed is primarily imported from the mid-west. Therefore, the value of chicken-based commodities is not included in subsequent impact estimates. This is consistent with the way the SED handled chicken-based commodities.

Commodity	Commodity Category	County		Total	Percent of Total
		Stanislaus	Merced	($)	(%)
Grand total		$3,879,332	$3,215,800	$7,095,132	100%

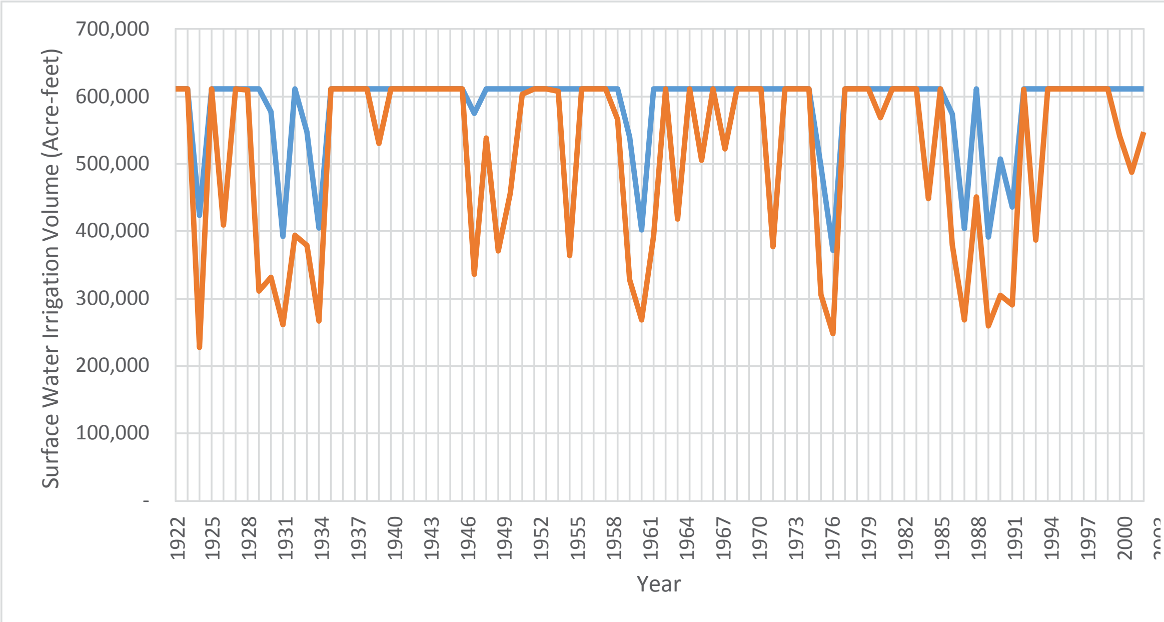
Sources: Stanislaus County Agricultural Report, 2015, Agricultural Commissioner's Office. 2015 Report on Agriculture, Merced County Department of Agriculture.

These commodities are high value and require significant capital investments making them relatively fixed in the short run (approximately 25 years). The capital investment required to establish an almond orchard is over $5,000 per acre. The establishment cost is the sum of the costs for land, planting, trees, etc., as well as the production expenses for growing the trees until almonds are harvested and revenue is generated--approximately 3 years (UCCE 2011). For a 40-acre orchard, that equates to over a $200,000 investment before revenue is generated. These establishment costs are recovered over the remaining 22 of the 25 years the orchard is in production.

In the dairy industry the cash costs of dairy operations only represent between 98 percent and 78 percent of the total annual costs (see discussion below). Depreciation and interest costs for the investments in items including the milking barn, free stall, manure pit, bulk tank, hay barn, silage pit, maternity pens, etc., represent 2 percent to 22 percent of total costs (UCCE 1986). Capital investment in these high-valued crops was made possible because of the relatively high degree of water supply reliability provided by TID and MID.

Utilizing data reported in the SED's supporting models and spreadsheets the baseline water deliveries from TID and MID show the high degree of water supply reliability the Districts have afforded their growers thereby justifying the investment in permanent crops and animal operations (**Figure 3**). The estimated applied water for the period 1922 through 2003 for the SED baseline shows surface water deliveries have been just over 600 TAF in most years. Shortages of any magnitude (between 100TAF and 200TAF) occurred in only nine of the 82 years (1924, 1931, 1935, 1961, 1978, 1988, 1990, 1991, 1993). Those water-short years occur sporadically, only two were sequential, 1990 and 1991.

Under SED Alternative 3 not only does the magnitude of the water shortages increase but the frequency and the pattern of water-short years changes too. Under Alternative 3 the number of water short years increases to 31 from nine. Also the water shortages are greater than the baseline and occur in sequential years much more frequently. For example, six sequential years, between 1929 and 1934, see water shortages between 200 TAF and 300 TAF below baseline. The period from 1949 to 1986 is characterized by two to three-year water shortages followed by a five-year period, from 1988 to 1992, of water shortages ranging between just under 200 TAF and approximately 300TAF. Given the relatively fixed nature of the crops grown in the region the pattern of water shortages is as important if not more important to growers' operations than the magnitude of the shortage and would cause a re-thinking or re-optimization of investment in permanent crops and capital.



Sources: Water: Agricultural Economic Analysis 09142015.xls spreadsheet available on the SWRCB SED website, tab entitled "Water". Frequency of water year types: Table 2.3 in SED Appendix C, Technical Report on the Scientific Basis for Alternative San Joaquin River Flow and Southern Delta Salinity Objectives.

Figure 3. TID and MID, Estimated Applied Water by Year, Baseline and SED Alternative 3 (40% UF).

This re-optimization by growers and ranchers is not addressed in the SED model. The SED model is an annual model, e.g. it estimates growers' responses to a reduction in irrigation supplies without consideration for the prior year's irrigation supplies or projections of next year's irrigation supplies. This model can work well if 1) modeling short-term impacts of droughts, as it has been used to estimated annual impacts from the most recent drought and/or 2) the crops grown are primarily annual crops (e.g. tomatoes, sweet potatoes, rice, etc.) and there is no significant demand for animal feed crops.

However, in the TID and MID service area, given the fixed nature of the agricultural crops a decrease in water supply reliability as proposed under the SED, there would be a permanent contraction in the agriculture sector. Either/or the acreage planted to permanent crops would be reduced over the long-term, or the diary and cattle & calf operations would downsize, reducing the herd size. However neither of these responses are discussed in the SED.

At best, using the SED model in a situation when, long-term water supply reliability is declining and the area is characterized by permanent crops and animal operations, the estimated impacts should be considered a **minimum impact to agriculture**. Permanent crops need water in every year and animals need feed in every year. The likely outcome is the cropping patterns will change as a consequence of this long-term change in water supply reliability and the agricultural sector will permanently contract.

2.4 Comments on Analysis

Issue: The SED aggregates the estimated impacts over time and geography.

Impact: The estimate of the SED's impact to growers dependent on water from TID and MID is both obscured by this aggregation and significantly understated. In addition to understating the impacts of the proposed project, because animal commodities and the food processing sector are omitted, the impacts that are estimated, crop commodities, are reported as **average annual impacts** to the **total project area** both of which obscure the impact of implementing the SED to the entities that are impacted. The focus of the SED write-up should be on the impact of a reduction in irrigation supplies **to each irrigation district** and **by water-year type**. This disaggregated information is provided in the SED but only in the *Modeling Tools Information and Files* and requires significant re-formatting and review to comprehend. Disaggregated district-level data should be front and center so that water resource managers and water-rights holders can make informed decisions about implementation and potential settlements. The fact that this crucial decision-making data is not in the text of the SED and is obscured in the supporting models and tools is highly unusual for a public document and calls into question the State's understanding of the perspective of the local water resource managers, the agricultural sector and a commitment to transparency.

Discussion:

2.4.1 Geographic Aggregation Obfuscates Impacts and Does Not Conform with Water Resource Governance

The SED reports that the average annual project-wide loss of implementing Alternative 3 is $64 million from crop commodities and related "ripple effects".[32] This loss in crop commodity revenue is caused by an 11 percent average annual project-wide reduction in irrigation supplies. Close examination of data reported in the SED's supporting models and spreadsheets reveals that TID and MID bear a larger share of both the loss in crop commodity revenue and irrigation water. The economic loss to the growers in TID and MID is $42 million, or 65 percent of the total estimated project-wide loss, despite the fact TID and MID comprise 40 percent of the irrigated acreage of the study area.[33] And the average annual reduction in irrigation supplies to TID and MID is 17 percent, 55 percent higher than the project-wide average of 11 percent. We recommend that not only should the state revise its damage estimate to include animal commodities and the processing sector, the revised damage estimate should be reported at the district level, which is the level of governance and water resource management.

2.4.2 Aggregating Over Time

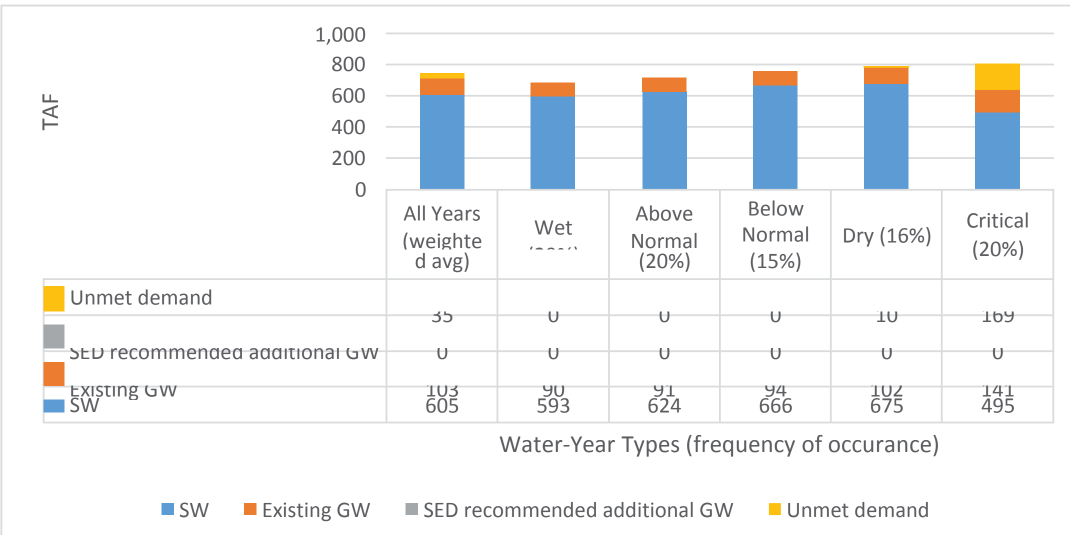
Equally as important as disaggregating the impacts to the district level is to disaggregate the impacts over time, at least by water year type. **Average annual** changes in water supply mean very little in terms of how a change in irrigation supply will impact agriculture and should NOT be used to make informed decisions about water resource management. Under Alternative 3, the SED reports that the annual average reduction in surface water for the entire study area would only be 240 TAF (15 percent of baseline) and that 105 TAF (seven percent) of that shortage would be made-up by pumping additional

[32] Table ES-9. Average Annual Total Economic Output Related to Agricultural Production in the irrigation Districts under Baseline Conditions and the Change for LSJR Alternatives 2, 3, and 4. Evaluation of San Joaquin River Flow and Southern Delta Water Quality Objectives and implementation, September 2016.

[33] Agricultural Economic Analysis (zip file) located on the SWRCB website under Modeling Tools Information and Files.

ground water. So that the annual average increase in unmet demand would only be 140 TAF (seven percent of baseline).

However, when disaggregated for just TID and MID and over time, the estimated shortages are not only larger than for those of the entire study area, the significant difference in reporting annual averages become apparent. Under the baseline all but critical water year types TID and MID have provided growers with upwards of 600 TAF of surface water (**Figure 4**). The SED reports that an additional 110 TAF of groundwater has been pumped in each water-year type from District wells and by individuals, to meet the total irrigation demand of approximately 710 TAF to 800 TAF, depending on water-year type. In critical water-year types, which occur 20 percent of the time, unmet demand under the baseline is estimated to be 169 TAF (24 percent of full demand). Full deliveries in 80 percent of all years provides a high degree of water supply reliability and is the reason growers have invested millions of dollars of permanent crops and capital infrastructure needed for dairies and cattle & calf operations.

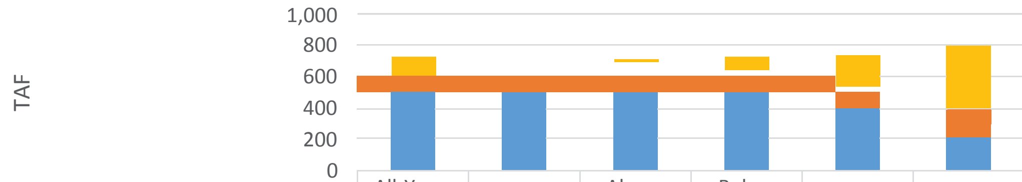


Sources: Water: GW and SW use analysis 09142016.xls spreadsheet available on SWRCB website. Frequency of water year types: Table 2.3 in SED Appendix C, Technical Report on the Scientific Basis for Alternative San Joaquin River Flow and Southern Delta Salinity Objectives.

Figure 4. TID and MID Baseline Irrigation Water Supply by Source and Water-Year Type

The frequency of shortages and the pattern of those shortages under Alternative 3 tell a different story than the annual average story (**Figure 5**). Most notable is that unmet demand now occurs in all but wet years (70 percent of the time). In dry and critical water-year types (38 percent of the time) unmet demand ranges from 201 TAF (28 percent of full demand) to 403 TAF (56 percent of full demand and 32 percent higher than the critical dry year baseline shortage of 24 percent). And these shortages are somewhat offset by the SED's assumption that additional groundwater can and will be pumped to make up for lost surface water supplies. The SED assumes that additional groundwater will be pumped in every water year type, ranging between 2 TAF (wet years) to 50 TAF (dry years), water that will not be available in a post-SGMA world, increasing dry-year shortages by an additional 7 percent.

In summary, compared to baseline, water supplies would be 30 percent less than baseline in dry and critical years, or more than one in three years. That is a far cry from reporting the project-wide average annual water shortages is 11 percent of baseline.



	All Years (weighted avg)	Wet (29%)	Above Normal (20%)	Below Normal (15%)	Dry (16%)	Critical (20%)
Unmet demand	127	0	17	83	201	403
SED recommended additional GW	0	0	0	0	0	0
Existing GW	103	90	91	94	102	141
SW	494	591	599	545	435	249

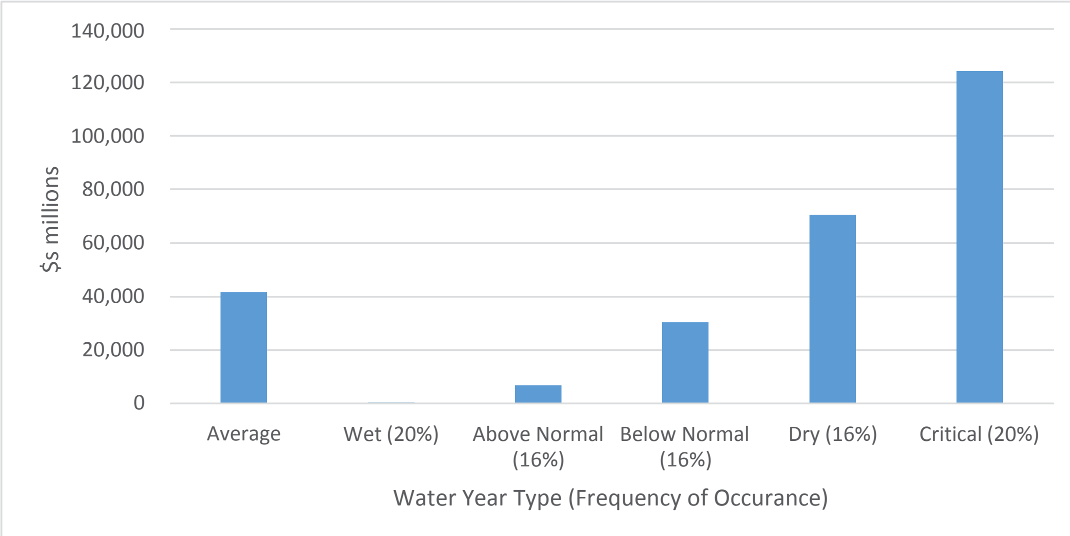
Water-Year Types (frequency of occurance)

SW Existing GW SED recommended additional GW Unmet demand

Sources: Water: GW and SW use analysis 09142016.xls spreadsheet available on SWRCB website. Frequency of water year types: Table 2.3 in SED Appendix C, Technical Report on the Scientific Basis for Alternative San Joaquin River Flow and Southern Delta Salinity Objectives.

Figure 5. Irrigation Water by Source and Water-Year Type Provided by TID and MID under SED Alternative 3 (40% UF).

The average economic impact of this reduction in surface water supplies is estimated to be $40 million by the SWRCB (Figure 6). However, when disaggregated by water year type the true impact is much more clear. In critical water-year types, 20 percent of all years, the SWRCB’s estimated impact is over $120 million. In dry water year types, 16 percent of all years, the impact is over $70 million. And in below normal years, 16 percent of the time, the impact is estimated to be $35 million. Even in above normal years, 16 percent of the time, there is an estimated $5 million impact. This variation in income would have a long-term impact on the agricultural sector, a fact that is obfuscated by reporting annual average impacts.



Sources: Water: GW and SW use analysis 09142016.xls spreadsheet available on SWRCB website. Frequency of water year types: Table 2.3 in SED Appendix C, Technical Report on the Scientific Basis for Alternative San Joaquin River Flow and Southern Delta Salinity Objectives.

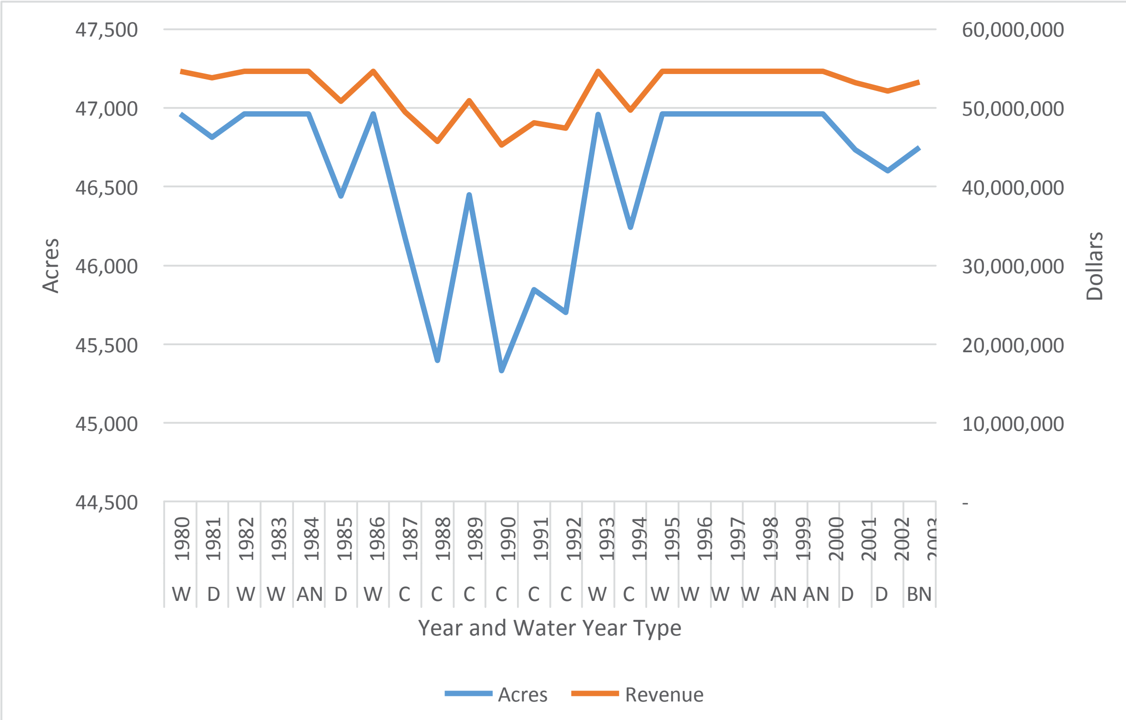
Figure 6. SWRCB's Estimate of Agricultural Economic Impact by Water Year Type

2.4.3 Estimates of a Reduction in the Acres of Tree Crops is not Explained

Issue: The SED states that the acres of trees changes from year to year due to a change in irrigation supplies.

Impact: Misrepresents the management of permanent crops during periods of reduced irrigation supply and understates or ignores the lag impact that stress irrigation has on the yield of tree nuts and fruits.

Discussion: The acres of nut trees estimated by the SED model varies by year, depending on irrigation water supplies (**Figure 7**). It is unclear how to interpret this result. It could mean that trees are removed from the fields in drier years and replanted when irrigation supplies are available – which would not be consistent with orchard management best management practice. Or rather, the reduction in acres is a proxy for a reduction in the yield of almond orchards, but not an actual removal of trees from the field. However, it is difficult to understand why the results report a reduction in tree-nut acres. Also, water stress can negatively affect both the primary yield components in almond: kernel size (Girona et al. 1993) and fruit load (Goldhamer and Smith 1995, Goldhamer and Viveros 2000, Esparza et al. 2001). And this effect persists a year or two, even if irrigation returns to yield maximizing volume. It does not appear that the SED has accounted for this lag effect, based on the pattern of nut- crop land and revenue shown in **Figure 7**. Note that in wet and above normal water-year types nut-tree acres are approximately 47,250 acres (left-hand vertical axis) and nut-tree revenue is approximately $55 million (right-hand vertical axis). In critical water-year types both acres and revenue fall. Acres of nut-tree crops fall up to 3,000 acres (1988, 1990 and 1992). However immediately following the critical dry water-year types land and revenue immediately return to pre-drought levels. For example, in 1993, a wet year sandwiched between two critical years, revenue and acres return to levels seen during consecutive wet and above normal years (e.g. 1996 through 2000) when there would be a lag effect due to water stress that occurs in 1988 through 1991.



Sources: Land and Revenue: Agricultural Economic Analysis 09142016.xls spreadsheet available on SWRCB website. Frequency of water year types: Table 2.3 in SED Appendix C, Technical Report on the Scientific Basis for Alternative San Joaquin River Flow and Southern Delta Salinity Objectives.

Figure 7. Estimated Acres and Revenue of Tree Crops, SED Alternative 3 (40% UF).

2.4.1 Using 2008 as the baseline year for data

Issue: The SED states all of the impacts in 2008 dollars.

Impact: Stating the value of agricultural production in 2008 dollars gives the appearance that the impacts are less than they are.

Discussion: Most readers assume a report is estimating value in dollars that are relatively current. It is understandable that a report may estimate value using dollars that are a few years old, simply due to the time it takes to produce a report of this magnitude, but it is hard to understand why the SWRCB uses dollars that are 8 years old? The U.S. Department of Labor CPI inflation calculator suggests that a 2008 dollar should be inflated by 12 percent to reflect a current 2016 dollar. Just based on the SED's estimate of impacts to TID and MID, restating the impacts in 2016 dollars would increase annual impacts between $200 thousand and $9.3 million depending on water-year types.

2.4.1 Chapter 11, Williamson Act contracts

Issue: The SED says there will be minimal impact to Williamson Act contracts because agricultural land currently enrolled in the Williamson Act can still be dryland farmed. The assumption that it is financially viable to dryland farm in the project area is an overstatement.

Impact: Williamson Act subscriptions may fall and the impact of un-enrolling land that is no longer profitable to farm is understated in the SED.

Discussion: Growers who originally enrolled land in the Williamson Act did so with an expectation that irrigation supplies would continue to be available. That expectation changes under the SED and could change whether growers will or can remain enrolled.

The Williamson Act Program enables local governments to enter into contracts with private landowners for the purpose of restricting specific parcels of land to agricultural or related open space use. Private land within locally-designated agricultural preserve areas is eligible for enrollment under contract. The minimum term for contracts is ten years. However, since the contract term automatically renews on each anniversary date of the contract, the actual term is essentially indefinite.

Landowners receive substantially reduced property tax assessments in return for enrollment under Williamson Act contract. Property tax assessments of Williamson Act contracted land are based upon generated income as opposed to potential market value of the property. Local governments receive a partial subvention of forgone property tax revenues from the state via the Open Space Subvention Act of 1971.

Contracts may be exited at the option of the landowner or local government by initiating the process of term nonrenewal. Under this process, the remaining contract term (nine years in the case of an original term of ten years) is allowed to lapse, with the contract null and void at the end of the term. During the nonrenewal process, **the annual tax assessment continually increases each year until it is equivalent to current tax rates at the end of the nonrenewal period.** Under a set of specifically defined circumstances, a contract may be cancelled without completing the process of term nonrenewal. Contract cancellation, however, involves a comprehensive review and approval process, and **the payment of a fee by the landowner equal to 12.5 percent of the full market value of the property in question**. Local activities such as eminent domain, or, in some rare cases city annexation, also result in the termination of Williamson Act contracts.

The impact to landowners whose best interest may be served by exiting the program have not been considered in the SED. Because a decision to exit the program would be predicated on the SED's reduction in long-term irrigation water supply, the estimated cost of the 12.5 percent fee should be included in the SED.

2.4.2 Errors in the SED Model

Issue: It appears that there are errors in the SED model's production function, calibration or input substitutability.

Impact: The SED's impact on crop commodities is understated.

Discussion: The model used in the SED incorporates a production function which allows substitution between inputs in agricultural production. For example, when water supplies are reduced the SED model's production function might substitute technology and/or labor in the form of an increase in irrigation efficiency, to maintain the baseline per acre yield. Clearly, a reduction in irrigation supplies must be replaced by some other input (e.g. irrigation technology) or the per acre yield of the crop would decline, modeling deficit irrigation.

However, in reviewing data from the SWRCB's spreadsheet entitled, Agricultural Economic Analysis 09142016.xls with additional data provided by SWRCB staff we compared the estimates of per acre water use in almond trees to the estimates of per acre almond yield (Table 6).[34] In critical water-year types per acre water use declined 12 percent compared to baseline, however per acre yield did not change relative to baseline. The only way this is possible is if some other factor of production, for example irrigation technology, increased significantly. The SED does not include all of the SED model output, so it is not possible to check. However, the model output is highly suspect, suggesting that either the calibration or input substitutability is not correct in the model.

Table 6. Per Acre Applied Water and Yield, Critical Year Average of TID and MID

Crop	Applied Water /Acre			Yield/Acre		
	Baseline	Alternative 3 (40% UF)	% Baseline	Baseline	Alternative 3 (40% UF)	% Baseline
Almonds (ALPIS)	3.05	2.67	-12%	1.0	1.0	0%

Sources: Applied Water/Acre calculate using data from the SWRCB's spreadsheet entitled, Agricultural Economic Analysis 09142016.xls. Yield/Acre calculated using data from personal e-mail communication from Rich Satkowski, SWRCB to Susan Burke, Cardno, dated 12/15/2016.

2.5 Improper use of Citations

No improper use of citations was noted.

2.6 Missing Data/Science

2.6.1 Existing Condition Section Missing from the Economics Chapter

Issue: SED does not describe the existing condition in the project area.

Impact: Impossible for a reader to fully understand the impact of the proposed plan without an understanding of the demographics and current economic conditions of the region.

Discussion: Stanislaus and Merced Counties' demographic and economic data show an area characterized by higher projected population growth, lower household income, higher unemployment, and a higher percentage of people living in poverty than within the state. The agricultural industry supports nearly one quarter to one third of the counties' jobs. Approximately 18 percent of counties' agricultural jobs are on-farm jobs, compared to 3 percent for the state. Farms in the area tend to be family owned and smaller when compared to farms throughout the state. The data supporting these summary statements follows.

[34] Personal e-mail communication from Rich Satkowski, SWRCB to Susan Burke, Cardno, dated 12/15/2016.

The population in the two-county area has grown and is projected to continue to grow faster than the population in the rest of the state. Between 1970 and 2010, the population in two counties grew at an annual average 2.4 percent, 52 percent faster than the state's annual average growth rate of 1.6 percent (Table 7). Population projections between 2020 and 2060 show that growth rates in the two counties is expected to continue to outpace the state by 84.7% percent. County population is projected to grow at an annual average rate of 1.6 percent from 2020 to 2060, compared to the state's 0.6 percent average annual growth rate for the same period of time.

Table 7. Population Growth in Stanislaus and Merced County compared to California 1970-2060

Year	Total Two-County Region		California		County Growth Rate Higher than State's Rate
	(population)	(average annual percent change)	(population)	(average annual percent change)	(percent)
	U.S. Census Estimates				
1970	299,135		19,953,134	NA	
1980	400,458	3.0%	23,667,902	1.7%	71.90%
1990	548,925	3.2%	29,758,213	2.3%	38.32%
2000	657,551	1.8%	33,873,086	1.3%	39.77%
2010	770,246	1.6%	37,254,503	1.0%	66.77%
1970 to 2010	NA	2.4%	NA	1.6%	52.09%
	California Department of Finance Projections				
2020	862,785		40,619,346	0.90%	
2030	985,874	1.3%	44,085,600	0.80%	67.82%
2040	1,104,844	1.1%	47,233,240	0.70%	63.69%
2050	1,222,080	1.0%	49,779,362	0.50%	102.72%
2060	1,342,429	0.9%	51,663,711	0.40%	135.92%
2020-2060	NA	1.1%	NA	0.6%	84.27%

Source: U.S. Census Bureau; California Department of Finance, multiple years

For the last 12 years (2005 through 2016) the two-county area's unemployment rate has been significantly (between 48 percent and 92 percent) higher than the state's unemployment rate (Table 8). In all but two years (2006 and 2016) the two-county unemployment rate has been in double digits, ranging between 9.1 percent (in 2016) and 18.0 percent (in 2010). For example, in 2014 there were an estimated 242,000 people in the labor force of the two counties, of which 27,000 were unemployed, a 9.1 percent unemployment rate–-over 69 percent higher than the state's unemployment rate of 5.4 percent for the same period.

Table 8. Labor Force, Employment and Unemployment in Merced County and California, 2005-2014

	Two-Counties				California				County Unemploy-ment Rate Higher than State's Rate
	Labor Force (a)	Employ-ment	Unem-ployment	Unem-ployment Rate	Labor Force (a)	Employ-ment	Unem-ployment	Unem-ployment rate	
Year	(000s)	(000s)	(000s)	(%)	(000s)	(000s)	(000s)	(%)	(%)
2016	361	328	33	9.1%	19,200	18,159	1,041	5.4%	69%
2015	358	322	36	10.1%	18,955	1,771	1,184	6.2%	62%
2014	242	215	27	12.8%	18,802	17,400	1,402	7.5%	72%
2013	242	210	31	14.5%	18,651	17,006	1,646	8.8%	64%
2012	242	206	36	16.3%	18,510	16,609	1,901	10.3%	59%
2011	242	202	40	17.6%	18,372	16,243	2,128	11.6%	52%
2010	244	202	41	18.0%	18,305	16,083	2,221	12.1%	48%
2009	235	198	36	16.6%	18,221	16,172	2,049	11.2%	48%
2008	232	206	26	12.6%	18,203	16,845	1,358	7.5%	69%
2007	227	207	20	10.1%	17,899	16,931	968	5.4%	87%
2006	224	206	18	9.4%	17,649	16,784	865	4.9%	92%
2005	227	208	19	10.0%	17,525	16,586	939	5.4%	87%

(a) Civilian labor force

Source: U.S. Census Bureau, American Fact Finder, 2015

Total median household income and benefits in the two counties (Table 9) in 2015 ($47,714) was approximately 30 percent lower than in the state ($61,818). More than half of the households in the two counties (52 percent) received less than $50,000 in 2015 in income and benefits. Compared to more than half the households in California (58 percent) that received less than $75,000 in 2014 in income and benefits.

Table 9. Total Household Income and Benefits, 2015

	Two-County Total			California		
Income and Benefits	Number	Percent	Cumulative Percent	Number	Percent	Cumulative Percent
Less than $10,000	16,265	7%	7%	742,545	6%	6%
$10,000 to $14,999	17,179	7%	14%	646,023	5%	11%
$15,000 to $24,999	29,376	12%	25%	1,206,056	9%	20%
$25,000 to $34,999	29,342	12%	37%	1,134,601	9%	29%

Income and Benefits	Two-County Total			California		
	Number	Percent	Cumulative Percent	Number	Percent	Cumulative Percent
$35,000 to $49,999	36,107	15%	52%	1,528,711	12%	41%
$50,000 to $74,999	45,987	19%	71%	2,118,346	17%	58%
$75,000 to $99,999	28,119	11%	82%	1,542,550	12%	70%
$100,000 to $149,999	28,372	11%	93%	1,902,528	15%	85%
$150,000 to $199,999	8,950	4%	97%	886,811	7%	92%
$200,000 or more	7,191	3%	100%	1,009,630	8%	100%
Median household income (dollars)	47,714	NA	NA	61,818	NA	NA
Mean household income (dollars)	63,571	NA	NA	87,877	NA	NA

Source: U.S. Census Bureau, American Fact Finder, 2015

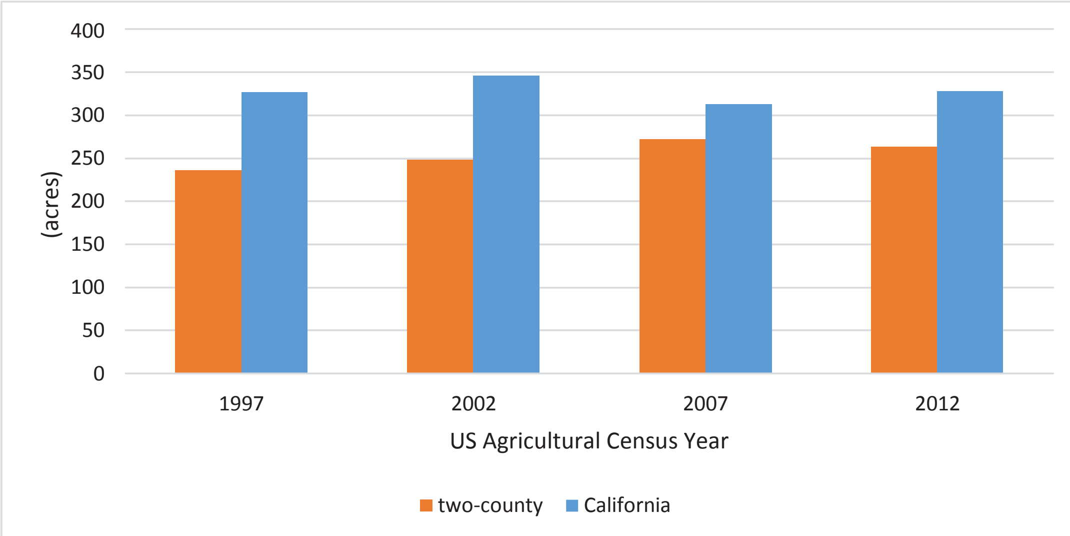
It follows that with a lower median household income there are also more people in poverty in the two-county area than in California. In 2015, 16 percent of Californians were below the poverty level compared to 22 percent of all people in the two-county area (Table 10). Or 36 percent higher than the state.

Table 10. Percentage of Families and People Whose Income is Below the Poverty Level, Merced County and California, 2014

Families and Individuals	Merced	California	Difference
	Percent	Percent	Percent
All families	18%	12%	47%
Married couple families	11%	7%	48%
Families with female householder, no husband present	38%	28%	38%
All people	22%	16%	36%

Source: U.S. Census Bureau, American Fact Finder, 2015

As previously discussed, agriculture accounts for between 1 in 4 to 1 in 3 jobs in the two-county area. Farms in the two-county area are characterized as smaller family owned operations compared to the state (Figure 8). Farms in the two county area average between 236 acres (1997) to 272 acres (2002). Compared to farms in the state which average between 313 (2007) and 346 (2002). Farm size in the two-county area has been increasing since 1997, meaning individual farms are getting larger. This represents a consolidation of farms in the area. That average farm size in the state has remained steady over the same timeframe.



Source: U.S. Agricultural Census, multiple years.

Figure 8. Average Size of Farms in the Two-County Area and the State

In summary, the two-county area is heavily dependent on family-owned farms for jobs and household income. The farms are heavily invested in permanent crops and animal operations with little flexibility to absorb a long-term reduction in water supply reliability. This story of character of the community is not told in the SED because the Existing Condition is not included in the Economic Chapter.

2.6.2 Environmental Justice

Issue: SED does not address the environmental justice impacts of the proposed plan.

Impact: The proposed plan's long-term impact to agriculture will have an impact on disadvantaged communities.

Discussion: Environmental Justice considers the potential impact of the project on the environmental and public health issues and challenges confronting the nation's minority, low-income, tribal and indigenous populations (e.g. disadvantaged communities). The SED partially defines disadvantaged communities as "those communities with an annual median household income (MHI) that is less than 80 percent of the statewide annual MHI" (page 22-1). The reviewer could find no mention of the fact that environmental justice also means the "fair treatment of people of all races and cultures".[35] However, the SED does not consider how the proposed project would impact the disadvantaged communities in Stanislaus and Merced Counties with respect to an impact in the agricultural sector.

The median household income in California in 2015 was $61,818 (Table 9). Eighty percent of that MHI is $49,454. Fifty-two percent of the households in the two-counties made less than $50,000 in income in

[35] California Government Code § 65040.12.12.

2015, passing the threshold for a disadvantaged community. Additionally, 46 percent of the population reports itself as Hispanic or Latino in the two-counties compared to 38 percent in the state. [36]

A recent study conducted by UCDavis Center for Regional Change entitled California's San Joaquin Valley: A Region and its Children Under Stress describes the demographics and poverty challenges facing the area (Page 8):

> *The agriculture/food processing industry is expected to be the primary employer in the San Joaquin Valley for years to come,… these industries rely heavily on low-wage and seasonal laborers, including undocumented immigrants, who often face poor working conditions and workplace violations such as wage theft.*
>
> *As a result, poverty remains an acute problem in the region, where 1 in 3 families with children under 18 have incomes below the FPL [Federal Poverty Level]. Poverty rates are even higher for children of color and children with immigrant parents, while children of undocumented immigrant parents have still higher poverty rates. It is estimated that 1 in 5 children in the San Joaquin Valley has at least one undocumented parent, and that nearly 3 in 4 children with an undocumented parent have family incomes that are below 150% of the FPL*.
>
> *In the words of a social justice advocate who works in the southern San Joaquin Valley, "The root of many of the Valley's problems is poverty and the lack of economic diversity in the region. It is a cycle that limits options in employment to low-wage, low-skill work. That affects educational attainment, and impacts the environmental quality."*

2.6.3 Social Impacts are not Considered

Issue: SED does not address social impacts caused by the uncertainty of the long-term feasibility of the agriculture economy and community.

Impact: The proposed plan's potential long-term impact to the communities and social fiber of the region is not considered, vastly understating the total impact of the proposed project.

Discussion: The long-term change in agricultural output caused by the proposed project only begins to tell the story of the impact the proposed project would have on the region. Because of a lack of economic diversity in the region a reduction in the size of the agricultural economy, with a commensurate reduction in jobs, will further stress people living within the study area. These stresses have not been addressed in the SED. While it can be difficult to quantify social impacts, the SED should at least acknowledge the potential types of impacts that have been seen in other regions undergoing similar shifts in water allocations.

Impacts to communities that face water re-allocation decisions include loss of social capital, increases in community services ranging from mental health treatments to increases in crime fighting forces.[37] In a 2004 study of the social impact of a reduction of irrigation water supplies to the Klamath Project

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[36] US Census, American Fact Finder, 2015.

[37] Water Allocation in the Klamath Reclamation Project, 2001: An Assessment of Natural Resource, Economic, Social and Institutional Issues with a Focus on the Upper Klamath Basin, Oregon State University and UCDavis, April 2004.

researchers interviewed a variety of community members – beyond farmers –including business owners, social service providers, police, etc. The interviews describe increased stress due to increased uncertainty and a threat to a change in lifestyle. Topic areas that should be addressed to thoroughly analyze the proposed project on the community include:

- Sense of division in the community causing a loss in social capital. Tension can be created for many residents who might support the farmers as members of the community but hold other perspectives as well. Members from these groups told the Klamath researchers that people who became especially vocal in their support of the farmers and ranchers had silenced others' voices and concerns. Exemplified in this quote from the Klamath report (page 192):

  > *People are just not as friendly. You know this is a small town, everyone knows each other. Everyone talks to everyone else; now people just don't talk, they don't go out and socialize, don't go to festivals like the Potato Festival. It's been an annual event for 60+ years. I didn't even go this year.*
  >
  > *Every other weekend someone would be having a party or barbecue. You'd go over and have a few beers and cook a steak. I don't know that I went to one barbecue all this summer. Nobody wants to socialize, there's nothing to celebrate.*

- Uncertainty about the future and long-term planning. Farming is inherently filled with uncertainty from such sources as weather, prices and disease. The proposed project adds considerably to the uncertainty and threatens the long-term viability of farming and ranching. This uncertainty impacts individuals by adding uncertainty about their future. For example, one farmer interviewed in the Klamath report states (page 197):

  > *Where am I going to be 10 years from now? I don't even know where I'm going to be next year. You can't make any longterm plans right now. When I got out of college I had a plan with goals, knew what I was going to do. This is where I wanted to make my career."*
  >
  > *One business owner wondered (page 198) "How easy will it be to attract new industry here if you don't know if you can keep an educated workforce?"*

- Impacts on social service providers in the region should be considered. The Klamath researchers saw how the uncertainty about the future had affected those parts of the community that had little voice in the conflict – farm workers, the unemployed and other traditional clients of social service agencies such as head Start, County Health, Mental Health, etc. One service provider from a small community reports:

  > Suicide calls have increased, …. They feel like they have no choice—'I can't do this anymore.' We bring it around to what they can't do anymore and it is the fear of living in the unknown. Not knowing what to expect. What's going to happen? What's going to happen to my family? What's going to happen to my kids? I can't take care of myself anymore and no one understands.

The SED should at least acknowledge these potential impacts, particularly to forward potential settlements. The SWRCB should consider reaching out to groups that stand to be significantly impacts however do not currently have a voice in the process.

2.6.4 The SED model Input Data is not Provided in the SED

Issue: The SED does not present most of the data that is used as input to the SED model.

Impact: Not possible to complete as thorough a review as would be possible if the data were available.

Discussion: Missing data include crop prices, yields and costs; irrigation water rates used in the SED model's cost function, the aggregation of district crops to the SED model crops and the representative crop used for each of the SED model crops.

2.6.5 Impact on Irrigation Districts' Rate Structure

Issue: The Districts' irrigation rate structure is dependent in part on the delivery of water. A long-term reduction in canal diversions which reduces the Districts' ability to delivery water would necessitate a change in irrigation rates.

Impact: The SED does not address the magnitude of the change in irrigation rates or the ability of the growers to continue to pay for water given the increase in the long-term uncertainty of supply.

Discussion: Chapter 20 of the SED includes a section entitled Potential Rate Payer Effects (page 20-32, emphasis added) which states:

> *Ratepayers in districts that substantially rely on surface water diversions from the eastside tributaries, and where current rates do not account for unexpected capital costs, would likely be the service providers most affected by the additional costs of replacing lost surface water supplies. Over the long term, most districts would be expected to recover most,* ***if not all, capital costs through rate adjustments****. Certain water service provider may consider temporarily halting construction for new treatment facilities, as a project could become less economically viable as a result of reduced surface water diversions; however, over time, districts would be expected* ***to re-spread the fixed costs of its projects, whether completed or not, among their ratepayers to achieve the revenue needed to remain economically viable****.*

That discussion seems to be aimed more at residential and M&I providers than agricultural districts. However, the same argument holds. The difference is that the proposed project would increase both the growers' cost of surface water and directly reduce the grower's income. The SED takes account of an increase in water costs from additional pumping, but does not take into account an increase in irrigation rates. This inconsistency in the application of the SED's method should be addressed by considering how irrigation rate could be impacted and that impact on growers' profit.

TID and MID both have tiered irrigation rate schedules based on the volume of water delivered (Table 10 and Table 12). TID has both a normal year and a dry year water rate schedule (Table 11.) MID has a provision to maintain revenue in the event that there are no water deliveries via a facilities maintenance charge, however TID does not have the same provision in their rate structure. The proposed project would reduce the long-term average annual irrigation supplies delivered from TID by 18 percent. Which in turn would reduce the revenue generated by water charges by the same percentage.

Table 11. TID's 2015 Irrigation Rate Schedule

Category	Normal Year Water Charge	Dry Year Water Charge
	$/Acre (AC) or $/Acre Foot (AF)	$/Acre (AC) or $/Acre Foot (AF)
Fixed Charge	$60.00/AC	$68.00/AC
Volumetric - Tier 1 (up to 2 AF)	$2.00/AF	$2.00/AF
Volumetric - Tier 2 (up to 2 AF)	$3.00/AF	$3.00/AF
Volumetric - Tier 3 (up to 1 AF)	$15.00/AF	$15.00/AF
Volumetric - Tier 4 (per AF, additional available)	$20.00/AF	$20.00/AF

Source: TID website, http://www.tid.org/water/water-rates, accessed on 1/15/2017.

Table 12. MID's 2016 Irrigation Rate Schedule

Category	Cost
	$/Acre (AC) or $/Acre Foot (AF)
Fixed Charge	$44.00/AC
Volumetric - Tier 1 (up to 24")	$2.00/AF
Volumetric - Tier 2 (24" up to 36")	$5.00/AF
Volumetric - Tier 3 (36" up to 42")	$11.25/AF
Volumetric - Tier 4 (42" and up)	$40.00/AF

NOTE: The facilities maintenance charge is $22.00 per acre. Please note, a landowner only pays a facilities maintenance charge when they aren't taking any surface water. Each landowner pays either an irrigated charge or a facilities maintenance charge, but not both.

Source: MID website, http://www.mid.org/water/irrigation/allocation.html, accessed on 1/15/2017.

2.6.6 Manure management

Issue: SED does not mention how manure management plans would be impacted by a change in cropping patterns.

Impact: The estimated reduction in field and forage crops would limit dairies opportunities to manage manure, potentially increasing costs or necessitation a reduction in herd size.

Discussion: California dairy farmers have had to adapt to regulations implemented by the Central Valley Regional Water Quality Control Board (CVRWQB) aimed at protecting water quality by managing impacts from waste generated at dairies. Many Central Valley dairies have systems to store and distribute manure, and research has shown that more than 50 percent of excreted nutrients collected in these systems are applied to crops (Pettygrove, et al. 2003).[38] To do so, a dairy is required to develop a nutrient management plan (NMP) and waste management plan (WMP), and to follow a monitoring and

[38] Pettygrove, G. Stuart, et al. 2003.Integrating Forage Production with Dairy Manure Management in the San Joaquin Valley. University of California, Davis.

reporting program (MRP), which includes annual reporting. The NMP requires that any land to which dairy waste is applied must be planted to crops. Consequently, continuous disposal of dairy waste from a herd of given size requires cultivation of a minimum number of acres of proximate crops and, therefore, supplies of fresh water adequate to dilute dairy waste for application to those crops. If supplies of irrigation water are reduced, dairy farmers must change their operations, e.g., by transporting waste to other locations for ground application or reducing the size of their herds.

2.6.7 Housing

Issue: SED does not include an analysis of the impact of the proposed project on housing in the region as required by California Code (Regs § 15131(c)).

Impact: The SED's recommendation that groundwater be pumped to replace the loss in canal diversions does not analyze the impact the increased pumping will have on the ability of urban and rural water purveyors to meet increasing demand for water supply, nor does it address impacts to domestic wells.

Discussion: "Economic, social, and **particularly housing factors** shall be considered by public agencies together with technological and environmental factors in deciding whether changes in a project are feasible to reduce or avoid the significant effects on the environment identified in the EIR. If information on these factors is not contained in the EIR, the information must be added to the record in some other manner to allow the agency to consider the factors in reaching a decision on the project." (14 Cal. Code Regs. § 15131(c)).

Given the estimated increase in population estimated by the California Department of Finance (Table 6) the pressure on groundwater aquifer will only increase. The SED recommends that groundwater pumping increase to offset limits to surface water diversions.

3 Alternative Findings and Conclusions

Issue: Because of the shortcomings of the SED described above the Districts have undertaken and independent impact estimate in order to fully inform water resource decision makers.

Impact: Whereas the SED finds that the annual average impact to ALL OF THE IRRIGATION DISTRICTS is $64 Million per year. The Districts have concluded that the impact in THEIR TWO DISTRICTS ALONE could be as high as $1.6 billion in critical dry year types (20 percent of the time) (Table 13).

Discussion: Table 12. Compares the SED's impact estimate to the Districts' impact estimate, both for a critical water-year type and the annual average. While we do not agree that considering the long-term annual average is the correct way to present the economic impact of a long-term change in water supply reliability on the two county area it is useful in comparing the methodological differences of the two impact estimates.

SED's estimated impacts of reducing irrigation supplies to TID's and MID's growers, compared to the Districts' estimates of the same, are summarized below.

The differences in the SED's estimate of surface water supplies are not vastly different either on average or for a critical water year types than the Districts estimated (Table 13). However, the SED does estimate that additional ground water would be available to offset a portion of the reduction in surface supplies, 11.0 TAF in critical water year types and 18.0 TAF on average.

The difference in the reduction in acres in production are also not that great for either an average year or a critical dry water-year type. The SED estimates that 65 thousand acres would come out of production in a critical water-year type, only 5.4 thousand acres less than the Districts' estimate of a reduction in 70.4 thousand acres. The average annual estimates of the reduction in acres in production are nearly the same, 27.4 thousand for the SED and 25.5 thousand for the Districts.

The SED's estimated decline in crop commodity revenue of $81.3 million in a critical water-year type, is much lower than the Districts' estimate of a $166.9 million decline. The difference reflects the SED's assumption that growers will transfer water to keep "high valued" tree, fruit and vegetable crops in production and let the acres of "lower valued" animal feed decline (Table 12). As discussed above this assumption is incorrect for two reasons 1) TID does not accommodate grower-to-grower water transfers and 2) dairy and cattle operations are dependent on those crops to feed their animals and to as an integral part of their manure management programs. The Districts' estimate of a decline in crop commodity assumes that all crops would decline at close to the same rate.

The SED also estimated that additional ground water would be available to pump in critical water-year types, offsetting the decline in crop commodities by approximately $10.7 million. The Districts do not assume that additional groundwater can be pumped due to the existing chronic overdraft of the basin and the pending implementation of SGMA.

The SED's estimate of the decline in indirect and induced economic activity on crop commodities is $61.8 million dollars, $71.1 million dollars lower than the Districts' estimated impact. This difference is due almost entirely to the difference in the estimate of crop commodity revenue.

The majority of the remainder of the difference in impact estimates are due to the SED's omission of impacts to animal commodities (from a reduction in optimal feed) and the food and beverage processing sector impacts (from a reduction in raw inputs). Those impacts total $1,285.5 million dollars annually.

The only other difference between the Districts' impact estimate and the SED's is the base-year used for the valuation. The Districts' analysis is expressed in 2012 dollars where the SED's analysis is expressed in 2008 dollars. A difference of $9.3 million annually.

In summary the primary differences between the two analyses are the SED's omission of animal commodities and the food and beverage processing sector. The Districts' estimate is the MINIMUM impact because it does not account for a structural change to the agricultural sector from the long-term reduction in water supply reliability of the proposed project.

Table 13. Comparison of SED Impact Estimate for TID and MID to the Districts' Impact Estimates

Water-Year Type	2015/2016			Average		
Source of Estimate	**SED**	**TID & MID**	**Difference**	**SED**	**TID & MID**	**Difference**
SW deliveries (TAF)	-246.0	-200.5	45.5	-111.0	-85.0	26.0
Existing groundwater (TAF)	0.0	0.0	0.0	0.0	0.0	0.0
Adtl GW recommended by SWRCB (TAF)	11.0	0.0	-11.0	18.0	0.0	-18.0
Total irrigation supplies	-235.0	-200.5	34.5	-93.0	-85.0	8.0
Impact Categories:	**($ millions)**			**($ millions)**		
Crop commodities	-$81.3	-$166.9	-85.6	-$37.2	-$39.8	-2.6
Crops irrigated with additional groundwater (est.)	$10.7	NA	-10.7	$13.6	NA	-13.6
Indirect and Induced on crop commodities	-$61.8	-$132.9	-71.1	-$28.3	-$23.5	4.8
Animal commodities (dairy, cattle)	$0.0	-$266.2	-266.2	$0.0	-$69.0	-69.0
Indirect and induced on animal commodities	$0.0	-$153.7	-153.7	$0.0	-$37.7	-37.7
Processing of crops, milk, animals	$0.0	-$590.6	-590.6	$0.0	-$157.7	-157.7
Indirect and Induced on processing	$0.0	-$275.0	-275.0	$0.0	-$73.8	-73.8
2008 dollars adjusted to 2015 dollars	-$9.3	$0.0	9.3	-$3.6	$0.0	3.6
Total Impact	-$141.7	**-$1,585.3**	-$1,443.6	-$55.5	-$401.5	-$346.0
Per Acre Values:	**($)**			**($)**		
Crop commodities	1,251.4	2,370.7	1,119.3	1,358.3	1,562.3	204.0
backward linkages on crop commodities	0.76	0.80	0.04	0.76	0.59	-0.17
backward linkages on animal commodities	NA	0.58	0.58	NA	0.55	0.55
processing / total commodities	NA	1.36	1.68	NA	1.45	2.20
backward linkages on commodities	NA	0.47	0.47	NA	0.47	0.47

APPENDIX D

Response to the Resource Agencies' Presentations At the January 3, 2017 Sacramento Public Hearing

D-1: Response to SWB Staff Presentation at the January 3, 2017 Sacramento Public Hearing

D-2: Review of CDFW SalSim Presentation (Bay-Delta Phase 1 Hearing, January 3, 2017)

D-3: Review of CDFW Presentation at January 3, 2017 Public Hearing on the SWRCB's Draft Revised SED

D-4: Review of NMFS-UCD Presentation (Bay Delta Phase 1 Hearing, January 3, 2017)

RESPONSE TO SWB STAFF PRESENTATION AT THE JANUARY 3, 2017 SACRAMENTO PUBLIC HEARING

Prepared for:
Turlock Irrigation District – Turlock, California
Modesto Irrigation District – Modesto, California

Prepared by:
HDR

March 2017

Ms. Frances Spivy-Weber, Member of the State Water Board, started the hearing in Sacramento with an introductory statement, much of which relayed that there had been many instances during the previous hearings on the SED where she thought the SWB's Amended Plan had been "misrepresented" and that there was considerable misinformation being shared about "what is actually being proposed" in the SED. Ms. Spivy-Weber indicated the staff would go through a presentation to clarify many of these misrepresentations. Ms. Spivy-Weber emphasized that while criticisms were welcome, what would most help was constructive feedback on how to improve the current proposals to "meet all needs". She ended with a statement that the Board can "accept alternative proposals". She then turned it over to staff member Mr. Les Grober.

Slide 3: Carryover Storage

Mr. Grober said one of the main areas of misunderstanding seemed to be whether the "project" included carryover storage requirements. He referred to Appendix K, wherein it is explicitly indicated that the "LSJR flow objectives" will include "minimum reservoir carryover storage targets or other requirements…" So, Mr. Grober said, these targets "are very much a part of the project".

Comments: It is asserted in the SED that regulation of carryover storage in Don Pedro is necessary to mitigate the potential adverse effects on downstream water temperatures resulting from the SED's preferred alternative (40%UF F-J). The SED acknowledges that the reservoir carryover storage targets affect the water supply that would be available for irrigation and M&I purposes. To then mitigate the adverse effects on agriculture potentially resulting from the carryover storage requirements, the SWB's analysis uses a modeling rule that establishes a "minimum diversion" for water supply of 363 TAF for the Districts (TID/MID) under all alternatives and a maximum draw from storage which is different for each SED alternative. Mr. Grober affirmed that carryover storage is part of the proposed Amended Plan. However, Slide 3 only serves to magnify and confirm the very issue that Mr. Grober said is being misrepresented – that it is unclear what is actually being proposed. From the Districts' perspective, the SED remains unclear. Will there be carryover storage restrictions – yes. What are they – not specified. In Appendix K, what are the possible "or other requirements"? How will they be established? Will there be a minimum water supply established by the SWB as well? What is it? So the actual SED proposal still remains unclear. How can the SED evaluate alternatives if the alternatives are yet to be defined?

Slides 4, 5, and 6: Carryover Storage Analysis

To demonstrate the rationale underlying the need to have carryover storage restrictions, Mr. Grober went through a series of slides. Slide 4 is a table of September carryover storage "guidelines" showing both the carryover storage restriction evaluated by the SWB as part of the LSJR baseline and alternatives (Don Pedro Reservoir = 800 TAF) and a new alternative being shared at the Hearing by Mr. Grober (Don Pedro Reservoir = 400 TAF). A footnote on Slide 4 states the 40% flow objective with the lower carryover storage was "not analyzed in the SED *because not included within the project alternatives"* (emphasis added). Slide 5 then shows the results of the WSE modeling for the three alternatives presented (base case, SED's 40%UF and the new 40%UF with the lower carryover storage). Mr. Grober explained the graph on Slide 5 showed that the lower carryover storage would just "allow the reservoirs to run dry", that there would "simply be no water left". Slide 6 shows the difference in water supply under the three alternatives for each of the five WY types.

Comments: There are a number of problems with the SWB's analysis. First, for the Tuolumne River, it incorrectly shows the baseline restriction ("minimum September carryover storage guideline) on storage to be 800 TAF. The "base case" in the SED is supposed to represent the FERC conditions. If there is a "restriction" on Don Pedro storage, it would be "dead pool" at 309 TAF, not 800 TAF. The tables on Slide 4 clearly display the severe restrictions on reservoir storage contained in the SED's 40% Flow Objective alternative. By asserting a baseline Don Pedro carryover storage of 800 TAF, it suggests the SED's preferred alternative of 800 TAF for Don Pedro as being no change from current conditions, yet in actuality it is a very significant change going from 309 TAF to 800 TAF. But more prominent in these slides is this – what Mr. Grober ***said*** at this point in the presentation about the reservoirs being "allowed to just run dry" is not shown in the plot because the plot provided in Slide 5 only shows the increased level of annual diversions and nothing about the reservoirs' storage levels. So we are left to having to trust Mr. Grober's words that each of the three reservoirs (New Melones, Don Pedro, Exchequer) would "simply run dry". Slide 6 presents the effect of the lower carryover storage restrictions, and it is readily observed the only significant differences in annual diversion are in the "dry" and "critically dry" years.

Slides 7, 8 and 9: Effects of Lower Carryover Storage

To demonstrate the effects of the lower carryover storage, Mr. Grober presents three slides. These slides all deal with modeled conditions at New Melones. It's worth pointing out that New Melones is the reservoir with the most significant proposed change in carryover storage under the SED's preferred alternative (carryover storage of 700 TAF) when compared to the lower carryover storage (new) alternative (85 TAF). At this point, Mr. Grober tells the Board that Slide 7 shows a plot of the end of September storage level in New Melones for the period 1922 to 2003 for the "Modified (new) 40% Alternative" and explains the reservoir would be 'drained in 10 of the years'. But when you look at the plot closely, which no one had time to do during the presentation, a question arises – is the alternative modeled and plotted actually the alternative with the lower carryover storage of 85 TAF? More on this below. Taking the results from that modeled alternative, Mr. Grober then presents two slides of modeled temperatures. Slide 8 purports to compare New Melones release temperatures for the SED's 40%UF preferred alternative with the modified (new) alternative with carryover storage. The time period of the plot is from Oct. '89 to Apr '94. The modified alternative results in generally higher release temperatures, with the maximum release temperature being about 54°F under the SED's preferred alternative and between 65°F and 70°F for the alternative with the modified (new) carryover storage. Slide 9 is a river profile of water temperature for those same two alternatives, and the base case alternative, for "October 1991". While showing these two slides, Mr. Grober said that the new alternative with the modified storage "doesn't achieve the goals of the proposal" and results in "lethal temperatures" because the modified temperature alternative "loses temperature control".

Comments: It's hard to know where to begin. First and foremost, only the results of the SWB's modeling of the Stanislaus River is provided and "analyzed". No comparison for Don Pedro is shown or described. New Melones has the greatest change in carryover storage between the two alternatives (700 TAF vs. 85 TAF). One would expect New Melones to show a significant difference in the temperature of reservoir releases under this comparison. But let's go back to the question raised above – what "modified alternative" did the SWB staff actually model? It's not clear. A close look at the plot reveals that the SWB apparently didn't actually model the end of September lower carryover storage of 85 TAF that was supposed to be the alternative carryover storage. Mr. Grober stated that for the lower carryover storage option using 85 TAF, the reservoir is "drained in 10 of the years". It was never clear in the presentation if Mr. Grober intended to mean drained to the minimum 85 TAF, or fully drained? By inspection of the slide, but left unsaid in Mr. Grober's presentation, there's a footnote on slides 7, 8 and 9 that states the assessment of the new "modified alternative" was done assuming "no carryover storage". That's why slide 7 shows that in 10 of the years modeled, the reservoir went ***below*** the 85 TAF carryover storage restriction at the end of September.

So, in fact, it appears the SWB's "analysis" of the "modified alternative" of 85 TAF was actually an analysis of a *modified*, "modified alternative" with zero carryover storage (the footnote also states "no refill criteria", which likely means the WSE model would try to provide maximum water supply diversion each year, so the reservoir would keep "draining" in successive dry years). Then, on slide 8 to *"prove"* his case about higher river temperatures resulting from the *modified* "modified alternative", the slide shows the dry period of '89 to '94. So, to depict the effects of the lower carryover storage alternative on water temperatures in the Stanislaus River, Mr. Grober selects the drought of record (and uses the *modified*, "modified alternative" where 85 TAF carryover storage wasn't what was actually modeled). A look at the plot on Slide 7 shows that the water years '89 to '94 are the only period of the 81-year period of record where there are five years in a row where the end of September storage was below 85 TAF ('90 through '94). Slide 9 even goes further. Slide 9 then takes a single slice of the '90 to '94 drought period (October '91) to depict the temperature effects as the flow goes down the river comparing the preferred alternative to the *modified*, "modified storage" alternative. In the '90 to '94 period, October '91 is the month with the greatest modeled temperature effect. At this point, the comparison seems a bit "rigged", but to complete the lopsided nature of the comparison, the *modified*, modified alternative also has "no flow shifting" (another note in the slide's footnote), while it is likely the preferred alternative does. Even after all of that manipulation, the total difference in temperature at the ***Stan confluence*** (never mind the LSJR), is 21°C vs. 18°C.

There are seemingly a number of problems with this analysis, but this analysis of the two alternatives is tilted to favor the SED's preferred alternative. In essence, this "temperature analysis" of the two "alternative storage" levels is meaningless about the two alternatives effects on fish populations. The only conclusion that one can draw is that based on the assumptions the SWB input to the model (which are not explicitly provided) here is what the model output was. Whether that actually reflects anything but playing with the computer model is doubtful.

Here's a few other items worth noting from examining Slides 7, 8 and 9:

- Would this analysis hold for the Tuolumne? Would the results be similar in terms of temperature effects? It's doubtful, and likely a "no", but the SWB staff should be asked to perform a similar analysis for the Tuolumne and provide it to the Districts for review and comment.

- More than anything, these slides leads one to question the purpose and effectiveness of the Amended Plan? If the Amended Plan is trying to increase survival of fry and juvenile outmigrants by providing flows from February through June, what does an analysis of October temperatures have to do with that? The analysis only exemplifies the potentially disastrous effects of the SED's preferred alternative on October temperatures, effects that then have to be mitigated by further restricting water supplies.
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- Even under the SED's preferred alternative, where the SWB's adult upstream migration temperature "criteria" (Table 19-1) is 18°C (64.4°F) for both the Stan/LSJR confluence and at Vernalis, the SED's temperature criteria are still not met.
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- Slide 9 is instructive though, just not for the purpose Mr. Grober tries to use it. Under the *modified*, "modified storage" alternative, the reservoir is essentially empty in October 1991, the period selected by Mr. Grober to make his case. So, the "modified storage" alternative is essentially showing the model's estimated value of the natural, unaltered temperature in the Stanislaus River at River Mile 60 (New Melones), and that temperature is 69°F (21°C), already well above the SWB "criteria" of 18°C. But if this is the temperature associated with unimpaired or natural flow, shouldn't this be the natural temperature the fish are adapted to, by the hypothesis put forward in the SED? It is apparent from the slide that the temperature of 69°F is the natural temperature of the river because as shown on the slide the water temperature is virtually unchanged all the way down the river, meaning it has reached equilibrium with the meteorological conditions. The only way the "preferred alternative" maintains a lower temperature to the confluence is by discharging a higher flow (via "flow shifting") than the natural, unimpaired flow. Unfortunately, the SWB presentation provided no details of the model run input which resulted in this output.

Slides 10 through 18: Importance of June Flows

Mr. Grober spends 9 slides trying to show why June flows are important. What's never made clear is whether the flows are important for the outmigrating fall-run Chinook salmon (the "indicator species") or just important to add volume to the "block of water" concept. Each slide is discussed below.

Slide 10: Slide 10 lists five reasons why June flows are "important" biologically. Two of them are just wrong; the other three might be half-right at best, but do not tell the whole story. The quotations below are from the slide.

- "*Salmon and steelhead growth and migration period":* Except in very wet years, the first week or two of June is neither a growth nor an outmigration period for fall-run Chinook (more on this below) in the eastside tributaries, and only to a very small degree in the LSJR. Also, there is no evidence of a viable steelhead population in the Tuolumne River or Merced River, and nothing in this SED will change that. Steelhead in the Stanislaus

River normally outmigrate earlier – like January through April, maybe May. This is actually shown on Mr. Grober's Slide 13 (more on this below).

- *"Spawning period for sturgeon and splittail":* This may be true in the LSJR, but not in the Tuolumne. There is only anecdotal evidence of green sturgeon in the LSJR and no evidence at all in the Tuolumne. Fully 80% of the of the available floodplain area that *might* support splittail spawning on the LSJR is above the Tuolumne (see Table 19-21 of the SED), and under the SED's preferred option, the flow is generally not sufficient (except for Wet Years) to provide access to floodplain habitat because of the lack of contribution of flow from the Upper SJR.
.
- "*Higher flows can disrupt and displace non-native species, including predatory fish and water hyacinth":* This contention is repeated with great frequency in the SED without there ever being any scientific evidence put forward to support it. Except in very wet years (e.g., 2011), the June flows under the SED will not displace non-native predators or disrupt their spawning. Water velocities through the Special-run Pools of the Tuolumne River remain well within non-native predator preferences, and the deep pools are likely to provide ideal refugia from temporary higher flows. June is also a time for striped bass spawning. The increased flows in June under the SED's preferred alternative may even improve spawning success for striped bass, thereby increasing the populations of this voracious non-native predator. It is a major flaw of the draft SED that the effects of increased May and June flows on a host of non-native predators is not seriously analyzed, but simply whisked away by unsupported statements like the one on this slide. Providing increased flows in June may have the unintended (and unanalyzed) consequence of aiding predator species more that native species. And regarding water hyacinth: where does it go when it is "washed out" of the eastside tributaries. If the flows are adequate to move the infestations out of the tributaries, the mats don't just disappear; they move downstream and reestablish in the LSJR.

- *"June extends the window of opportunity available to native fish, and allows for additional life history diversity":* This statement is just plain wrong. Without some sort of biological explanation and evidence, using a phrase like *"window of opportunity available to native fish"* doesn't mean anything unless particular species with flow dependent life history events in June are identified (like spawning of non-native Striped bass). But wrong to the extent of being disturbing is the reference to "life history diversity" as used in the slide. "Life history diversity refers to the ***potential*** benefit to the fall-run Chinook population of having fish leave the eastside tributaries at different ***life stages,*** not which day of the month the fish exit. Fall-run Chinook can exit the tributaries as fry, parr, or smolts. Fry and juvenile fish may benefit from floodplain inundation, but not smolts (or parr) which quickly migrate. There are no fry or juveniles left in the tributaries in June and except possibly in the wettest of years, very few parr. If there are fall-run Chinook in the tributaries in late May or June, they would overwhelmingly be smolt-sized, and for this reason flows reaching levels of floodplain inundation in May or June do not benefit the growth of fry, parr, or smolts. There is no contribution to or "*additional"* life history diversity from a smolt exiting the system on May 31 versus June 1. Smolts leave the system as smolts, there is no life stage distinction of "late May smolts" versus "early June smolts".

A smolt leaving the system on May 31 is the same as a smolt leaving on June 1; this is not adding to "life history diversity". This slide is either very misinformed or very misleading, actually both.

- *<u>Flows are important for migration through the San Joaquin River and Delta</u>:* That's true as far as the LSJR is concerned, just not beyond mid-May and possibly early June in Wet Years. The SED's preferred alternative will have little effect on wet years' flows. More importantly, the SED fails to show any analysis of "flows through the Delta and their importance for any fish species. This is just one more presumption the SWB makes without any valid, scientific assessment to support it.

<u>Slides 11 and 12:</u> Slide 11 is purported to be a plot of historical "maximum daily temperatures" versus "average daily flow near Vernalis". A horizontal line is drawn through the plot at about 77.5°F (25°C), and labeled "Lethal Water Temperature". There is no citation for source of information on lethality. Mr. Grober just explained that it is an "important metric". There is also a vertical line drawn from the lethal temperature line to the flow axis at a point where no maximum daily temperatures occur above the lethal line. This flow is 3,100 cfs. Slide 12 is provided next to show that under the SED's preferred alternative, the SJR flow at Vernalis will exceed 3,100 cfs 71% of the time instead of 41% of the time under the base case.

<u>Comments:</u> This plot is meaningless for a number of reasons, just some of which are discussed below.

Where did the "lethal temperature" of 25°C come from? How is it defined? Is it meant to be "upper incipient lethal", "acute lethal", "chronic lethal", or some other "criteria"? In the plot, because the temperature axis (y-axis) is "maximum ***daily*** temperature", it would then be reasonable, and proper, to assume that SWB is referring to "acute" temperature effects on salmon. In Myrick and Cech (2001) *Temperature Effects on Chinook Salmon and Steelhead: A Review Focusing On California's Central Valley Populations,* in the section on "Juvenile Thermal Tolerance"[1], it is reported that *"Chinook salmon subjected to acute temperature changes can tolerate temperatures as high as 28.8°C (84°F) when acclimated to 19°C".*

Why does SWB staff show the "lethal" temperature instead of the SED's "criteria" temperatures in Table 19-1 of the SED which are 16°C (61°F) for rearing and 14°C (57°F) for smoltification? It is readily apparent why these temperatures are not "evaluated" in Mr. Grober's slide by looking at the SWB's own data on slide 11. To meet the SED's "criteria" temperature of 61°F, it would take a flow exceeding 10,000 cfs which occurs 13% of the time under base case conditions with no change in that flow condition to occur under the SED's preferred alternative. Amazingly, what the plot and table of Slides 11 and 12 actually show very clearly is that the LSJR is ***highly unsuitable*** in June under the SED's preferred alternative for fry or juvenile rearing or smoltification. *By the SWB's own presentation, the only logical conclusion is that the LSJR is not suitable for any life stage of fall-run Chinook salmon in June now or under the SED's preferred alternative.*

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[1] Myrick, C.A. and J.J. Cech 2001. Temperature effects on Chinook salmon and steelhead: a review focusing on California's Central Valley populations. Bay-Delta Modeling Forum Technical Publication 01-1. 57 pp

Slide 13: This slide purports to show juvenile "steelhead" captured in the Stanislaus River Oakdale trap in all months from 1995 to 2009. The point Mr. Grober attempts to make is that there are significant outmigrating juvenile steelhead after June 1.

Comments: All of the fish on the plot are captured in the ***Oakdale*** rotary screw trap (RST), the ***upper*** RST located at RM 39. The juveniles captured in June at sizes ranging from 50 to 100 mm are not migrating, they are behaving as normal *O. mykiss* fry and juveniles by dispersing. The fish on the plot larger than 150 mm may be "steelhead" smolts and may be migrating downstream, but for Mr. Grober to make the case about outmigrants in June, he would have had to also show the results of the corresponding passage at the RST at Caswell at RM 8 (the downstream trap), where these same fish, if migrating, would have shown up later, but he didn't do this. FishBio, the operator of the RSTs, reports that *"in 20 years of monitoring Oakdale from 1995-2015 (no monitoring in 1997) there have only been 3 [steelhead] smolts captured in June and all of these were captured in 2000"*. Another logical question would be why show "juvenile steelhead" when there are 20 years of fall-run Chinook RST data available? That would be because the records show 99% of them have left the Stan before June 1.

Slide 14: The next slide then tries to show "significant" fall-run Chinook juvenile outmigration in June on the Tuolumne River. The slide shows 2006 as an "example" year.

Comments: Why 2006, one might ask? It's the 5th wettest year on record since 1922 and the wettest year when there were RST records in the years considered in the SED (through, apparently, 2010). The Districts have consistently maintained that in Wet Years, like 2006, there are some juvenile Chinook outmigrating through mid-June. But even in 2006, only a small percent of the total fish passing Grayson did so in June (it was 8% in 2006); therefore, this slide only supports the Districts' prior statements that when you include all years, about 99% of the fall-run Chinook are out of the Tuolumne by June 1; in Wet Years, some fish will exit the system in early-to-mid-June. This will continue to happen in the future under base case conditions in Wet Years just as it does now.

Slide 15: This slide should be amended to show only the period of historical record since the implementation of the 1995 settlement agreement between the Districts and other parties which was fully implemented starting in 1997, therefore 1997 to 2015.

Slides 16, 17 and 18: Slide 16 shows the significance of June flow volumes to the five month Feb-Jun period. For the Tuolumne, 23% of the UF occurs in June on average.

Comments: It is noteworthy that the June volume is about the same as the combined February/March volume. June flows are important for water supply purposes, and much less important for anadromous fish purposes, as we have shown above. In fact, June flows as proposed in the SED's preferred alternative of 40% UF Feb-Jun may benefit non-native predators more than fall-run Chinook. The increased velocities in the LSJR associated with the higher June flows may improve spawning success of striped bass and the reduction in temperature on the LSJR from 70°F to 68°F (see Table 19-3) is favorable for largemouth bass spawning (USFWS 1982). Slide 18 tells the story. This slide compares the diversions for water supply under a 40% UF Feb-May option compared to the 40% UF Feb-Jun preferred alternative. The impression meant to be portrayed by this slide entitled "June Effect On Diversions" is that there is little difference in water supply diversions in Critical Water Years between the two options. The reasonable question then is -- where does the June runoff go? Slide 17 shows that in Critical Years on the Tuolumne fully 17% of the 40% UF Feb-Jun block of water is contributed in the month of June. The apparent reason very little of that water is going to water supply is that it is going into storage because the WSE model has perfect foresight and this water is needed to maintain the required water level restrictions embodied in the WSE model's rules.

Slide 19 and 20: Multiple Dry Years

Slide 20 is intended to show the effect of the SED's preferred alternative in successive dry years. It doesn't do that; it shows the ***average annual*** surface water diversion through the '87 to '92 period. Having run both the WSE model with its rules, including the rule of a minimum water supply diversion of 363 TAF for the TR, and the Districts' Tuolumne River Operations Model (TROps) with SED restrictions, we present the results below.

	Annual Tuolumne Surface Water Diversion			
Calendar Year	**SED_Base – WSE (TAF)**	**SED_40% - WSE (TAF)**	**SED_Base – TROps (TAF)**	**SED_40% - TROps (TAF)**
1987	796.4	533.3	887.7	822.9
1988	559.5	372.0	587.5	370.0
1989	879.7	601.8	550.8	362.7
1990	566.1	376.9	705.1	362.8
1991	678.6	408.5	612.1	366.5
1992	558.7	370.5	616.8	360.8
Average - 1987-1992	**673.2**	**443.8**	**660.0**	**441.0**

We were able to confirm within a reasonable degree the SWB's numbers presented in slide 20. However, the major, and significant, difference is the annual allocations of water for water supply. In the WSE rules which depend on perfect foresight, water supply in 1989 (middle of the drought) is significantly higher. In the Districts' model, the first year of the drought is close to normal diversion because there is no way of knowing in the first year of a drought that you're in for a five year drought. Cutbacks, as one would expect, begin in Year 2 of the drought. So, in years 2 through 6 of the drought, under the SED's preferred alternative, the Districts would only get the minimum supply (≈ 363 TAF) for five years in a row. This is basically less than 40% of full supply for five straight years. But some of the real-time and real-life problems associated with the model results are discussed below.

The basic problem is that these **are** modeled results. In real time decision-making, the Districts and the farmers/growers do not know that a year will be a minimum diversion year at the beginning of the irrigation season (February). It is quite possible that most of a 363 TAF allotment could be used very early in the season because the Districts do not have perfect foresight like the WSE model and initial soil moisture levels would be very low following a dry winter.

As the total diversions are reduced, the percent of those diversions that are made up of the fixed amount of water needed to operate the irrigation system goes up. For example, the entire irrigation system must be primed, meaning the canals and laterals filled and flowing at the beginning of the irrigation season. This takes a significant amount of water and once filled, must be kept flowing. Therefore the percent of water dedicated to maintaining the system in operation goes up in critical years relative to the total water consumptively used by crops. So while the ***Districts*** might be allotted 40% of full supply, the farmers would receive less than 40% supply because of the significantly larger percentage of the supply needed to maintain the irrigation system primed and running.

Beyond this, it is also absolutely critical to understand the errors and assumptions built into the WSE model. One of the assumptions that especially affects the drought years is that the WSE model has greatly overestimated the amount of accretion water entering the Tuolumne River downstream of the La Grange gage. Under the WSE model, about 25% of the 40% UF block of water comes from assumed accretion flows. This is especially incorrect in drought years, when the river may not be a "gaining" stream at all, but may actually be losing flow to the groundwater system. The WSE model should be adjusted to reflect the 40% UF as being required at the La Grange gage to permit a more realistic evaluation of the effects of the SED's preferred alternative on the Districts and its farmers.

Slides 21 through 26: SED Has More Than Averages

Mr. Grober attempts to make a case in these slides that the SED is not skewed or biased by mainly presenting "average values".

Comments: Using average values for water supply allows the wet years to skew the average water supply diversions over the long-term because in virtually all the wet and above normal flow years, the Districts customers are able to obtain most of their needed full supply of water. But estimates of *long-term average* diversions do not provide any assurance that the TID and MID service areas will continue to be viable agricultural areas over the long-term under the SED's preferred alternative. Using averages is akin to locking you in a room for a day and saying your average oxygen supply will be 90% of maximum (which sounds pretty good), but the 90% will be doled at 100% for 22 hours and zero for the other two hours. Of course, it is apparent how that will come out. Proper water supply planning is not focused on the average conditions. Prudent and proper water supply planning evaluates what happens under reasonable worse case periods ("design drought" periods).

It is worth pointing out that all the slides presented by Mr. Grober are still just different ways of reporting ***average annual*** results over the 81 year period of analysis.

Slide 25 is especially meaningless from a water supply planning perspective. This slide is meant to ***visually*** portray that the 40% UF preferred alternative in the SED strikes a "reasonable balance" because visually it is halfway between base case and the 60% UF alternative. This is unsupported, and has nothing to do with the ability of irrigators to survive an extended drought. A more appropriate and informed perspective would treat the water supply analysis as a "tipping point" assessment. Given the range of adverse of the SED's UF flows proposal in the SED alternatives, a rational, scientific method of determining the effects of flow proposals is needed, not a visual comparison.

<u>Slides 27 through 31: Economics</u>

The Districts will reply to economic issues in their March 17 comments.

<u>Slides 32: Groundwater</u>

There are numerous issues with the SED's treatment of groundwater in the SED which will be discussed in the Districts' upcoming March 17 comments. Two things worth mentioning here are:
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- The slide asserts and Mr. Grober states that the SWB reached out to the Districts for groundwater information. The only "outreach" conducted by the SWB to TID and MID was a request to provide some information. This does not qualify as "outreach to affected parties" in any sense of the current uses of the term to indicate a conversation or collaboration. If the SWB is aware of other "outreach", it would be valuable to have the SWB reference it.

- It is worth noting that the 2006 *Review Panel Report: San Joaquin River Valley CalSim II Model Review* (the CalSim II Peer Review) had this to say about CalSim II (the WSE primary flow database) and groundwater. By the way, Mr. Grober was a member of the Peer Review Panel.

    - *"Groundwater is the most important process not included in the newer [CalSim II] model, and was absent from previous models. It is clear from the documentation and the oral presentations that adding groundwater to the model was not part of the scope of work for this project. Thus our comments on groundwater are not intended as a criticism of the work done to improve the model. They are intended to point out an important missing element in modeling water management in the San Joaquin valley. Groundwater interaction with various components of the model is critical for several reasons:*

        - *Groundwater is an important basin water supply, especially during droughts.*
        - *Groundwater is an important source of tributary inflows, mainstem inflows, and is a potentially important source of salinity from the Westside.*
        - *Groundwater is an important subject of management within the basin, with important interactions with the surface water demands and processes involved in the CalSim model of this region.*

    - *…Without explicit groundwater representation, the model's applicability to planning, policy, and operational problems under future water management and* *hydrologic conditions could be severely limited. This problem will become increasingly limiting for planning applications involving activities that affect the availability of groundwater (including any ongoing overdraft), groundwater return flows, and groundwater management. Given the difficulties and expense of groundwater modeling and data for such a large region, it is understandable why this was not included in the effort being reviewed. However, explicit groundwater representation is likely to be important for future applications."*

Slides 33, 34 and 35: Salinity

The Districts will reply to salinity issues in their March 17 comments.

Slides 36 through 40: SalSim

These slides are intended to present the SWB staff's position on SalSim. Consistent with how SalSim is treated in the draft SED, the presentation provided by Mr. Grober both condemns, but later then uses, the SalSim model. Slide 36 states that the SWB did not "rely on" the SalSim model in its "analysis of fish benefits" because its representation of "water temperature and floodplain inundation" is not "consistent with current scientific information" and because the model "appears to underrepresent the benefit of habitat improvements related to floodplain and water temperature" expected to occur under the SED's preferred alternative.

Comments: Consistent with what was the theme of this entire presentation, neither Mr. Grober, nor the slides, provided much of any technical explanation to support the statements made. In this case, there was no reference to exactly what "current scientific information" was being referenced. Also, the statement "appears to underrepresent the benefit…" gives the impression that the model didn't provide SWB the results it was hoping to see because there was no explanation provided of the rational basis for SWB's expectation of the greater benefits to occur under the SED. Perhaps the model is not underrepresenting the benefits; there just aren't any significant benefits from the SED's proposal. What evidence does the SWB possess that would provide a reasonable expectation of greater fish production or benefits at the population level? Absent SalSim, there is not a single quantitative estimate of benefits to fish at the population level in the entire SED. Then after dismissing any use of SalSim in Slide 36, the SWB spends the next three slides resurrecting SalSim to show on Slide 39 greater fish production numbers. Why go through this exercise if the model wasn't relied upon by the SWB? Is this the first time the SWB went through the exercise shown on slides 37, 38 and 39? What purpose does it serve if SalSim is not useful because of fundamental flaws to continue showing analytical results from the model? Chopping out certain years would not address the "fundamental flaws" associated with how SalSim treats water temperature and floodplains.

It is imperative that CDFW not be allowed to submit a "new and improved" version of SalSim without giving the public a chance to review the new model and comment on it. If the SWB has indeed not relied in any way on SalSim, then all references to the use of SalSim should be removed from the final SED.

Currently in the SED, there are over 100 individual references to how the SWB used and relied on the SalSim model, and roughly 10 references about the SWB's concerns with SalSim. On January 3, the SWB tries to step-back from its often-stated reliance upon SalSim, more probably because the increase in fish production it predicts is minimal for all the water being taken from beneficial water supply purposes.

The Districts will provide detailed comments on SalSim in their March 17 comments.

<u>Slides 44 and 45: Tuolumne River Fish Studies</u>

These slides highlight three studies performed jointly by TID and MID as part of the Don Pedro relicensing. The three studies are what we refer to as the Swim Tunnel study, the Predation Study, and the Fall-run Chinook Population Model. The Districts have performed over 200 individual investigations and studies on the resources of the lower Tuolumne River. The SED uses just ***one*** of them in the SED – an instream flow study performed by Stillwater Sciences – but then fails to apply the results in a prudent fashion that would benefit fall-run Chinook at lower water cost to the Districts. The Districts will comment on this particular study in their March 17 filing.

Each of the three studies identified in the SWB slides are discussed below.

<u>Temperature Study Comments:</u> Mr. Grober's comments reflect a significant lack of familiarity with the cited study, to say the least. He criticizes this study of the thermal tolerance and capability of wild juvenile *O. mykiss* (rainbow trout/steelhead) because the study, according to Mr. Grober, did not evaluate growth, disease vulnerability, predation vulnerability, or behavioral responses. This is a partially true, but completely irrelevant, statement. Like every other of the 200 studies performed by the Districts over the years, the Swim Tunnel study was planned and designed to address a specific question or set of questions. No ***single*** study could ever examine all the items raised by the SWB staff, and of course the SWB understand that. In fact, although generalized growth relationships with temperature have been shown based on laboratory studies, we are not aware of any specific studies from the Central Valley addressing disease vulnerability, predation vulnerability, or behavioral responses of *O. mykiss* over a range of temperatures. The Districts' Swim Tunnel study was specifically designed and executed to investigate the degree to which wild *O. mykiss* in the lower Tuolumne River are, or have become, acclimated to the relatively higher temperatures of the Tuolumne River when compared to rivers in the Northwestern US, which have been suggested by EPA to apply to the rivers of Central Valley. This study was planned and executed by leading experts in the field of fish physiology, including Dr. Nann Fanque, Associate Professor & Master Adviser, Department of Wildlife, Fish & Conservation Biology, UC Davis and Dr. Tony Farrell, University of British Columbia. The results of this ***site-specific*** study carried out on actual, wild Tuolumne River fish are highly instructive and the study concludes that the wild *O. mykiss* juveniles of the Tuolumne River have a high thermal tolerance and are acclimated to the local conditions experienced in the lower Tuolumne River, including observations of active feeding and near optimal swimming performance at temperatures well above SWB criteria. This study and its findings were recently published in the journal of Conservation Physiology, and is now a part of the published scientific literature on this subject. The SWB's comments are misguided and misinformed. The results of the study conflict with CDFW and SWB opinions that the current temperatures of the lower Tuolumne River are unsuitable for *O. mykiss*, and need "improvement". Rejecting a well-done, scientific study because its results do not comport with the goals of the SWB is the opposite of informed decision-making.

Indeed, if the SWB staff had taken the time to examine data collected and analyses performed by the Districts' scientists over the past 20-plus years, it would have noticed that (1) Farrell et al. (2015) did identify active feeding at elevated temperatures, (2) the Districts' *O. Mykiss* Scale Collection and Age Determination Study did report fish size at age, and (3) the USGS' prior Otolith studies done for CDFW and NMFS (Zimmerman et al. 2009) also reported fish size at age. All of these studies, and others with which the SWB is familiar, have all indicated that compared to other CV rivers, there is no statistical difference in size at age for Tuolumne River *O. mykiss*. In this way, the SWB staff could have made informed statements about the Districts' studies.

Predation Study: The Predation Study is another site-specific study undertaken by the Districts as part of relicensing. The study was performed in accordance with a study plan approved by FERC and reviewed by the SWB. The study concludes that predation may account for a large part of the high mortality loss of juvenile fall-run Chinook observed in the river. A range of flows and habitat types were examined in the study, in stark contrast to the misinformed statements provided on the SWB's slide. If SWB had actually read the study, they would have seen that fourteen habitat units were sampled between RM 3.7 and RM 41.3, and that when combined with prior predation studies dating back to 1990, over 90% of the river's habitats have been investigated. That the one year of study did not consider all "water year types" should not be a surprise because, of course, it would be impossible since there are five water year types. It is fairly safe to say that a study conducted in one water year did not evaluate all five water year types. The SWB slide also claims that because the Predation Study selected specific habitat types to investigate, the study should not be used for river-wide estimates. Abundance of predators was sampled in run-pool and SRP habitat units downstream of RM 39.4, the preferred habitat of these fish. Riffles, which would be expected to have low predator densities, were not sampled and these areas were also excluded from the calculations to estimate total predator abundance in the 39.4 mile study reach. If predators are using riffle habitats, then the estimates generated by the 2012/2013 study underestimated total predator abundance. This study is another example of the best scientific information available on the Tuolumne River being ignored in the SED because of its inconvenient results.

Salmon Population Model: The SWB reports that the Districts' salmon population model did not account for mortality due to high water temperatures, increased productivity on floodplains, and predator effects. In this case, the SWB is simply wrong on all three counts. Specific thermal temperature limits from the scientific literature are included in the model, as are floodplain habitat, specific parameters for floodplain food availability, as well as addressing predation risk. Although the model is provided with higher food ration estimates at floodplain than in-channel habitats, the SWB is correct when it points out that the Chinook Population Model does not predict "increased" juvenile productivity due to floodplain access. The reason for this is that food availability and growth rates in the Tuolumne River are already high and water temperatures within floodplain habitats are generally similar to in channel locations during critical fry rearing periods. During the development of the Population Model, the Districts held a series of Workshops with all interested parties, including SWB, CDFW, USFWS, and NMFS in which the Districts requested any and all evidence that the parties might have on floodplain food availability for the Tuolumne River. None was forthcoming. This points out a fundamental problem with the SED's prediction of higher growth on the Tuolumne River floodplain – there is no evidence or information of food sources on the Tuolumne floodplains. Therefore, there is no rational basis for the SWB to “expect” benefits from floodplain flows.

Slides 46, 47 and 48: The Districts have no comments on these slides at this time.

Slides 49, 50, and 51: Predation

The SWB offers three slides on the topic of Predation.

Comments: The Districts’ studies, data, and modeling demonstrate that, at least for the Tuolumne River, predation by non-native species on fry and juvenile fall-run Chinook salmon is a major cause of the very poor outmigration survival on the Tuolumne River. Studies by other parties show that fry and juvenile survival is low on the lower San Joaquin River as well. A host of non-native predators were introduced primarily by CDFW many years ago for recreational fishing purposes. Now the Districts are being asked to fix the problem. The Districts agree that physical conditions on the Tuolumne River and the LSJR are currently favorable for these non-native predators. The primary cause of these favorable conditions are the legacy of in-channel and floodplain gold and gravel mining of the river, agricultural development, levee construction, and urban development. The Tuolumne River is now largely a mixture of stream channel and in-channel ponds, in many places confined within levees. Flows will not “fix” these problems, and will not result in improving fish survival unless and until the role of these other physical conditions are understood. Temperatures on the Tuolumne River are suitable for fall-run Chinook salmon for the periods and locations they occupy in the river. However, temperatures on the LSJR are less than suitable, and the SED’s own analyses show that the preferred alternative will not materially improve these conditions.

On *Slide 51*, the SWB picks out a single table from the Districts Predation Study report, a large study with a tremendous amount of data, to claim that there is “very little survival” of fall-run Chinook at “low flows”. But at the hearing, it was apparent that the SWB’s purpose was much more than that. At the hearing, Mr. Grober admonished the Districts’ consultant that prepared the report of being selective related to displaying certain data in the report, asserting that the report’s author should “look at the full data set” and “show all the data”. For the SWB to pick out a single table of a large report and then accuse someone else of “cherry-picking” data seems a bit ironic. In any event, the table Mr. Grober shows as being the “corrected” version prepared by the SWB is in fact itself incorrect. The flows at the Modesto gage include the inflows from Dry Creek, while the study reach referred to in the table is predominantly upstream of Dry Creek. It would be incorrect to claim, as the SWB does, that the revised table is “showing flows through the actual study reach”. It is more accurate for this table to use the La Grange gage flow just as the Districts’ consultant did. But even further, the purpose of the study was not to investigate flow vs survival at different flows, contrary to what the SWB was trying to use the table to show. If the SWB wanted to make a point about flow and survival, why didn’t the SWB consider the results of thirteen years of TAC-reviewed CWT studies that were actually designed to evaluate the flow vs survival relationship?

It was unfortunate that the presentation was done quickly and provided no opportunity for questions from the public at the Public Hearing. Going through the slides quickly did little to shed light on the “misinformation” Ms. Spivy-Weber hoped to clarify.

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Review of CDFW SalSim Presentation

(Bay-Delta Phase 1 Hearing, Jan. 3, 2017)

By Wendell Challenger (LGL Limited)
January 11, 2017

Executive Summary

The of SalSim portion of the presentation by Dean Marston (CDFW) focused primarily on some of the factors that could have impacted the SWRBC SalSim analysis, resulting in lower fall-run Chinook returns than expected. The CDFW highlighted three potential problems that could have resulted in lower adult returns than expected, these include errors in the SalSim model and errors in the HEC-5Q hydrology scenarios used by the SWRBC. The CDFW also made assertions about the importance of flow on fall-run Chinook abundances which will also be reviewed as these can be considered relevant to some of the design consideration behind SalSim.

SalSim errors highlighted by the CDFW include excessive egg mortality and insufficient juvenile mortality, which were suggested could have been part of the reason for lower than expected adult returns in the SWRBC analysis. The CDFW also suggested that they have corrected these errors and have recalibrated SalSim, details of which will be released in March, 2017.

Investigations into these errors revealed merits to both claims, however the investigation also reveals the difficult in directly testing such claims as SalSim reports population abundances, which are the combined result of birth, death and movements. As such, mortality rates can only ever be indirectly tested. The claim of insufficient juvenile mortality is also quite vague as it could occur in multiple SalSim modules (i.e., SJR tributaries and SJR main stem, or river Delta), each of which model survival differently. More importantly the two highlighted are antagonistic, that is fixes employed to reduce egg mortality will be offset in part by downstream fixes to juvenile mortality. It is unclear how much the final SalSim output will change after the recent CDFW error correction and recalibration effort. Furthermore, there were no mentions of the other errors uncovered by LGL investigations (e.g., apparent pre-spawn mortality), so it is unlikely that a full audit of SalSim was conducted.

The CDFW also highlighted an issue in the SWRBC HEC-5Q hydrology scenarios and emphasized that the reliability of SalSim output depends on the quality of inputted hydrology scenarios. While at first glance this claim seems reasonable, further investigation revealed that the highlighted problem in the SWRBC HEC-5Q hydrology file (i.e., Mossdale flow/temp anomalies in December) should not have affected SalSim output as SalSim only selectively uses portions of the inputted HEC-5Q hydrology. While the CDFW's claim is possible, they did not provide the appropriate supporting evidence to back up their claim. As such, the final claim by the CDFW that Mossdale flow and temperature problems resulted in lower than expected Chinook production in the SWRBC analysis is currently unsubstantiated.

Finally, the CDFW concluded by highlighting the importance of flow, and by extension flow actions, on fall-run Chinook abundances. However, the evidence presented was largely anecdotal, had inconsistencies (e.g., declines of abundances in wet years) and was generally insufficient to validate the claims made. Furthermore, the highlighted claim of the importance of June flows on fall-run Chinook production (assisting outmigration of smolts) is at odds with the CDFW's SalSim model which outmigrates most juveniles well before June.

Table of Contents

Slide11: SWRCB's use of SalSim

Overall CDFW states that the SWRCB's use of SalSim highlighted issues in SalSim that resulted in less fish being produced than expected given empirical data. The CDFW then goes on to claim that this was the result of errors in egg mortality (excessive mortality) and juvenile mortality (insufficient mortality). While the surface this claims seems reasonable, further investigation reveals that some claims are either difficult to verify based on SalSim output or too vague to verify directly.

It is also not clear whether "fixing" these errors will result in desired corrections to adult production. SalSim is a full life-cycle model, "correcting" one component can have unintended downstream effects especially if other components are also incorrect. The two changes that CDFW claims have implemented (improved egg survival and higher juvenile mortality) in many sense are competing. For increase adult production to occur the reduction in egg mortality will have to exceed the increase in juvenile mortality. It will be interesting to see if any notable changes to production occur after "recalibrating" SalSim.

Egg mortality

Proximate Measure of Survival

In general, the impacts of mortality in SalSim are difficult to assess because only final population numbers (either daily or annualized) are provided. The most granular result are daily population numbers which are outcome of eggs production and egg mortality combined. As such, we can never get a direct estimate of mortality without either assumptions or re-implement parts of the SalSim model based on the SalSim documentation (which has already been shown to be in error in parts). That said, as a first order approximation of mortality can be obtained by looking at the daily population numbers change, with large mortality events showing up as rapid decreases in the population numbers.

CLAIM: High egg mortality occurred in the fall period during spawning, which occurred over a few days what should have occurred over a longer period-of-time (2 weeks - month)

It is not clear what constitutes "excessive" mortality, but there are clear instances of rapid declines in the daily number of eggs in both wet and dry years in all tributaries for at least some of the years (Figure 1 and Figure 2 respectively). Rapid mortality can be seen when the daily population numbers suddenly drop. These rapid declines also occur earlier in the season (September to December) which appears to support the CDFW's claim of this error occurring during spawning.

That said, the magnitude and frequency appear to vary by tributary and year under both wet years (Figure 1) and dry years (Figure 2). Daily egg population numbers also show good survivorship (e.g., Tuolumne in most years). We will need to review the CDFW SED comments to get a better understanding whether the CDFW intends to change egg mortality in some tributaries or all tributaries.

Juvenile Survival

The CDFW also made clams in the audio is that there were instances insufficient juvenile survival due to "flow levels were overriding effects of temperature". This claim is rather vague and it is not clear whether CDFW was referring to juvenile survival within the tributaries and SJR main stem or the river Delta, as SalSim models survival in these scenarios differently.

Investigations into both possibilities reveal that the CDFW was likely referring to survival in the SJR tributaries and SJR main stem.

Tributary and SJR Main Stem Survival

Daily density independent survival (there are also fry density dependent survival effects) in the tributaries and SJR main stem is determined by the following equation:

$$P(Survival) = Expit(a + b \times T + c \times Q + d \times Q \times L + e \times L^2)$$

with parameter estimates based on the following table:

Table 14: Parameters and variables for juvenile density-independent survival

Parameter	Variable	Stan.	Tuol.	Merc.
a	N/A – Constant	0	0.02	0.01
b	Temperature (C)	-0.23	-0.23	-0.23
c	Flow (cfs)	0.018	0.02	0.02
d	Flow-Length interaction (cfs*mm)	0.0001	0.0001	0.0001
e	Length-squared (mm^2)	-0.00001	0	0

The CDFW's statement implies that parameter value for flow and potentially flow-length interaction may be too large relative to temperature. If the CDFW is referring to tributary survival, the best way to assess this claim would be to input a variety of spring flow/temp conditions and compare the survivorship.

We can gain some insight into juvenile tributary mortality by looking at the daily juvenile population numbers (Figure 3 and Figure 4 for CDFW designated wet and dry years respectively). Caution needs to be taken when assessing these figures as population numbers as decreases can be caused by mortality our outmigration. When there are long periods without outmigration events (e.g., Feb-Apr, 1997 in the Tuolumne; Figure 3) we can see that the population numbers are largely stable, so there may be some merit to the CDFW statement.

Delta Survival

Survival in the Delta is computed as a single time step based on the following equation:

$$\Pr(Survival) = baseSurvivalProb \times overallFactor \times fryFactor \times MRHFactor$$

with the *baseSurvivalProb* is based a number of predictors including flow at Stockton Ship:

Channel (*Q*) and the temperature at Mossdale (*T*)

$$baseSurvivalPr = Min(Exp(a_0 + a_1 \times Q + a_2 \times stripers + a_3 \times T + a_4 \times releaseCode)^m, 0.99)$$

Parameter values used in the *baseSurvivalPr* equation are based on the following table:

Table 19: Parameters and variables for juvenile Delta mortality

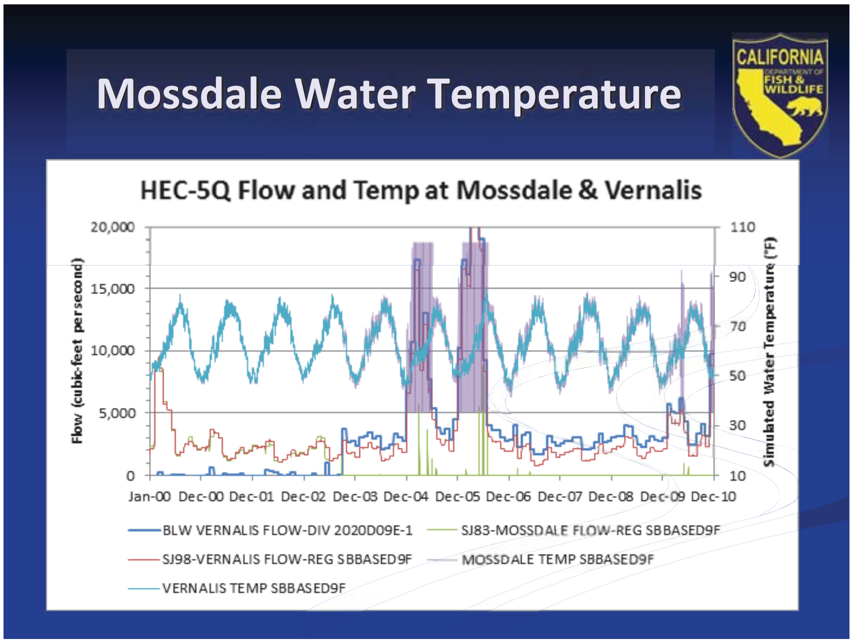
Parameter	Variable	Description	Value
a_0	N/A	Constant	3.493422
a_1	Q	Flow at the Stockton Ship Channel (cfs) on the day the cohort enters the Delta.	.1296343
a_2	stripers	Striper abundance.	-.0297244
a_3	T	Weekly average of daily maximum temperature at Mossdale beginning the day the cohort enters the Delta. Scaled by 0.1.	-.7977701
a_4	releaseCode	Release code from statistical fit that included fish released into the Delta at multiple locations. SalSim always uses releaseCode = 1, corresponding to fish entering the Delta at Mossdale.	-0.38105
m	N/A	Distance ratio (Mile entering Delta)/(Delta length), applied to hatchery plants only.	Var.

If the CDFW's assertion about flow and temperature was referring to Delta survival, then the parameter value flow at Stockton Ship Channel could too high relative to the Mossdale temperature parameter.

It is also unclear if the CDFW is referring to survival of some juvenile stages versus others as SalSim tends to have fry dominant juvenile compositions entering the Delta (Figure 5). While the SalSim manual suggests that fry have higher mortality in the Delta, the overall mortality rates of juveniles in the Delta do not appear to be affected by the proportion of fry making up incoming juveniles into the Delta (Figure 6) and if anything SalSim appears to associate higher production with fry dominant juvenile compositions entering the Delta (Figure 7). However, differences in fry survival, relative to other stages, will not be impacted by flow and temperature, as the Delta survival is formulation treates all juveniles the same in this regards. The only place where juvenile stage is used is in the *fryFactor*, which a constant factor based on juvenile origin.

Taken together, it is unlikely CDFW was referring to the issues of higher than expected fry survival in the Delta survival uncovered by LGL investigations when referring to insufficient juvenile survival.

Slide 12: Mossdale Water Temperature

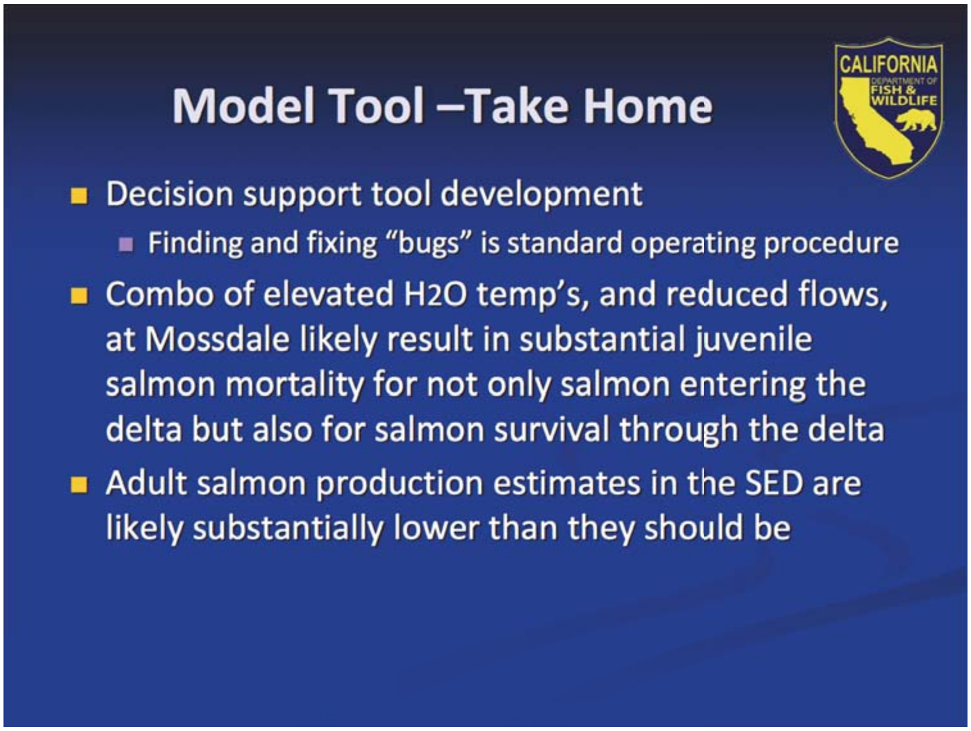


In this slide the CDFW asserts that inaccuracies in the HEC-5Q will impact the accuracy of SalSim estimates. While overall the message has merit, I find it odd that the highlighted Mossdale flows inaccuracies (December) are in a period that, to my best knowledge, is unused by SalSim. Mossdale flows and temperatures are used when determining spawning date, egg viability and juvenile survivorship in the Delta.

The dates shown are outside the spawning date flows used by SalSim (according to the SalSIm manual) and the no juveniles should be entering the Delta this late in the season, so their survival should not be impacted either. Egg viability is the only remaining possibility and it is determined in part by the Mossdale temperature 24 days before nest creation and egg deposition. As such, exposure to Mossdale temperature in December could affect January egg depositions. However, no eggs appear to be deposited in January in any years (i.e., a lack of daily population increases in Figure 1 and Figure 2) and the HEC-5Q anomaly highlighted in the slide should not have affected egg viability either.

Taken together, while it is generally true that errors in the HEC-5Q can affect SalSim accuracy, the highlighted anomaly used as evidence by the CDFW should not have impacted SalSim output and therefore does not sufficiently back their claim.

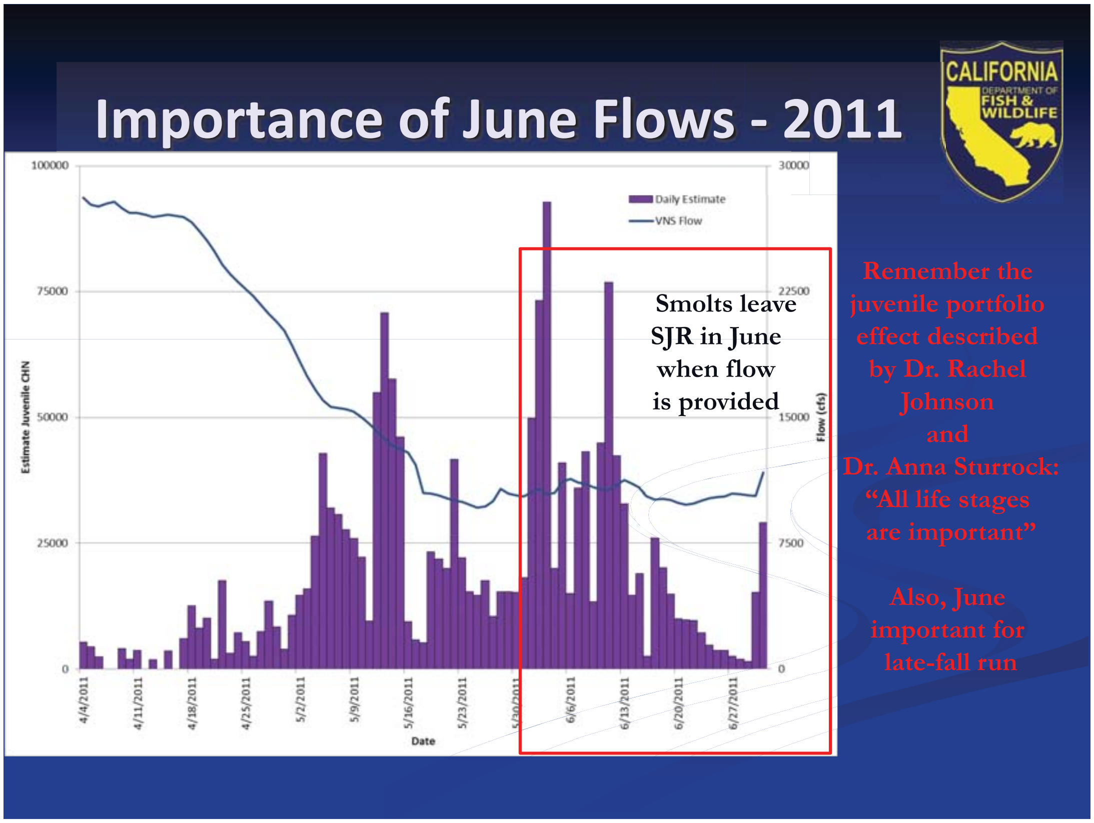
Slide 13: Model Tool – Take Home



This slide was used to make the claim that HEC-5Qanomalies at Mossdale have resulted in higher juvenile mortality and therefore lower adult production. However, the CDFW has not provided any real evidence for Mossdales temperature and flows being a problem during juvenile outmigration. The Mossdale example presented occurred in December, a period when SalSim does not appear to be using Mossdale flows for any of its computations.

As such, the CDFW claim is plausible, but not supported by the evidence shown in the slides.

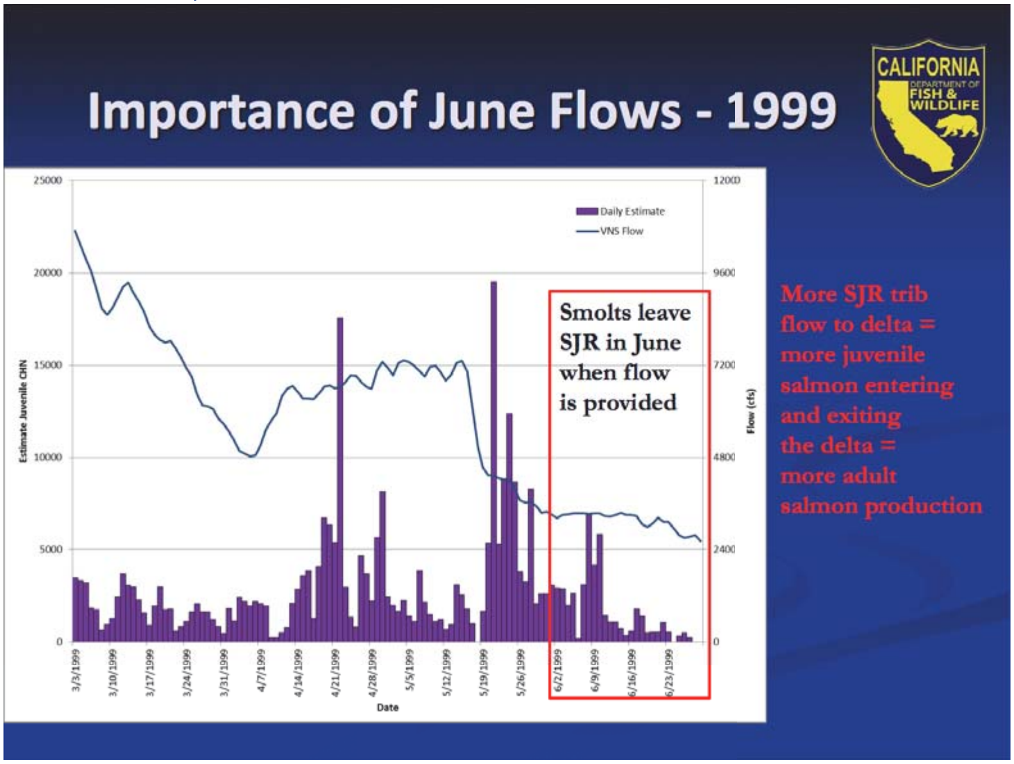
Slide 14: Importance of June Flows – 2011



June flows very well may be important in the natural system, but in its current configuration there is little way for this to be assessed or quantified with SalSim. as most juveniles in most tributaries have outmigrated from their respective tributaries before June under both wet and dry years (Figure 3 and Figure 4 respectively). (The exception to this appears to be Merced which consistently has smolts in June, which few of any appear to outmigrate). Thus, most of the juvenile population has left the SJR and entered the delta prior to June (Figure 8 and Figure 9, wet and dry years respectively).

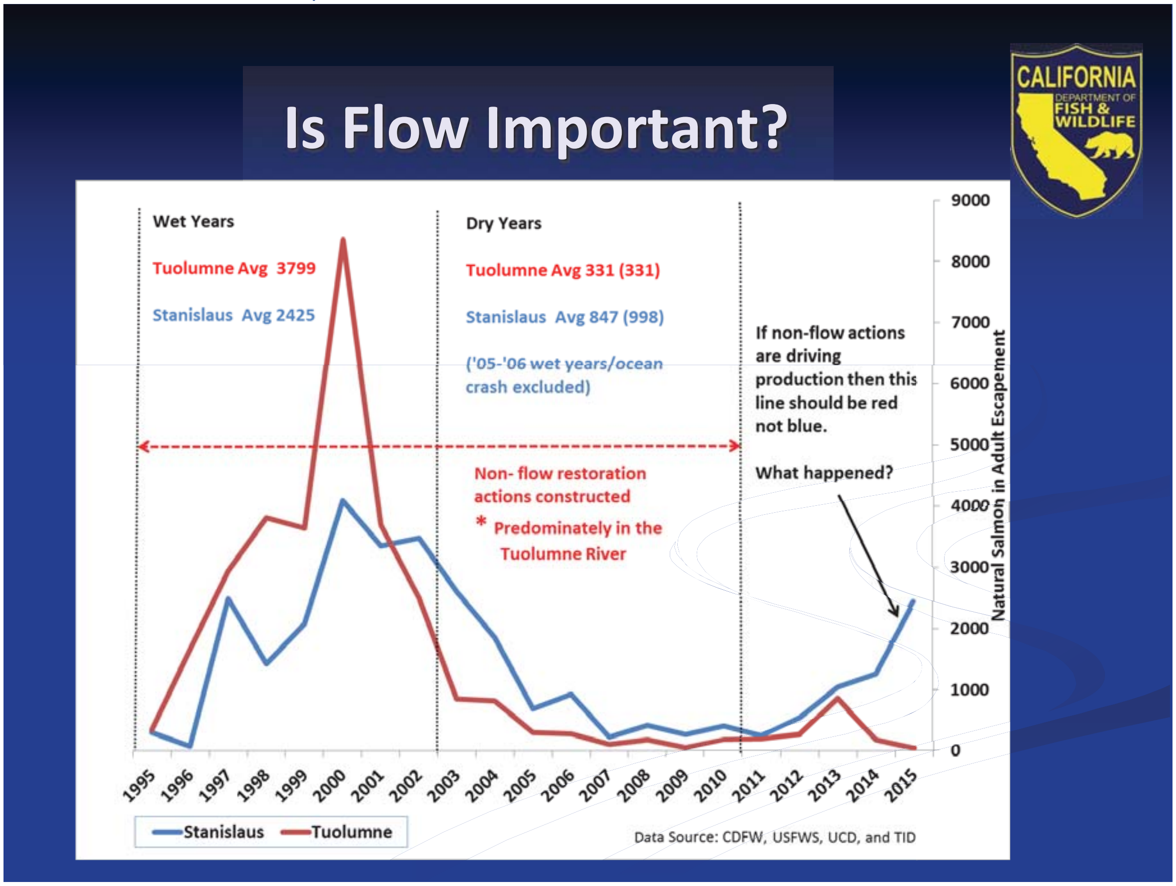
Therefore, the statement by the CDFW about the importance of June flows is contradicted by the programmed behaviour of SalSim,

Slide 15: Importance of June Flows - 1999



Similar to slide 14, SalSim itself does not support this view. Furthermore, this is presented as evidence without any indication of the numbers of juveniles in the tributaries in June. If few juveniles exist in the tributaries or SJR in June in 1999, there would be limited benefit to additional flow during this period.

Slide 16: Is Flow Important?

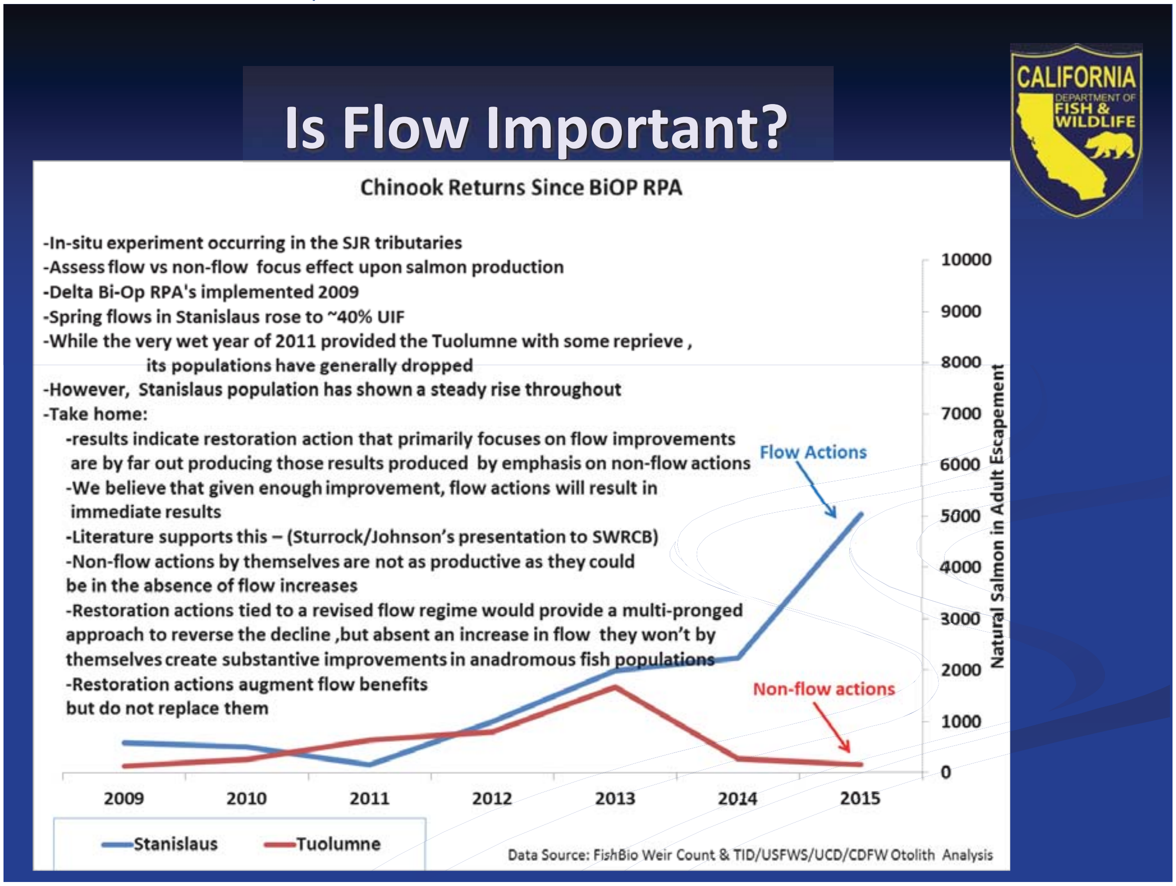


In this slide the CDFW makes an assertion the importance of higher flows on fall run Chinook production by highlighting wet and dry year production in Tuolumne and the Stanislaus tributaries.

There are a few problems with the comparison. Both Tuolumne and Stanislaus start to show the declines well into the “Wet Years” period. Furthermore, the comparison ignores the lag between juvenile rearing conditions and adult returns 2-4 years later. This implies that the decline that appears start in 2001 could relate to juvenile conditions from 1997-1999, a period of high spawning activity. One could also argue that density dependent effects may be a driver in the recent decline.

Either way the comparison and evidence presented for the importance of flow is overly simplistic, which is odd given the complexity undertaken by the CDFW in developing SalSim.

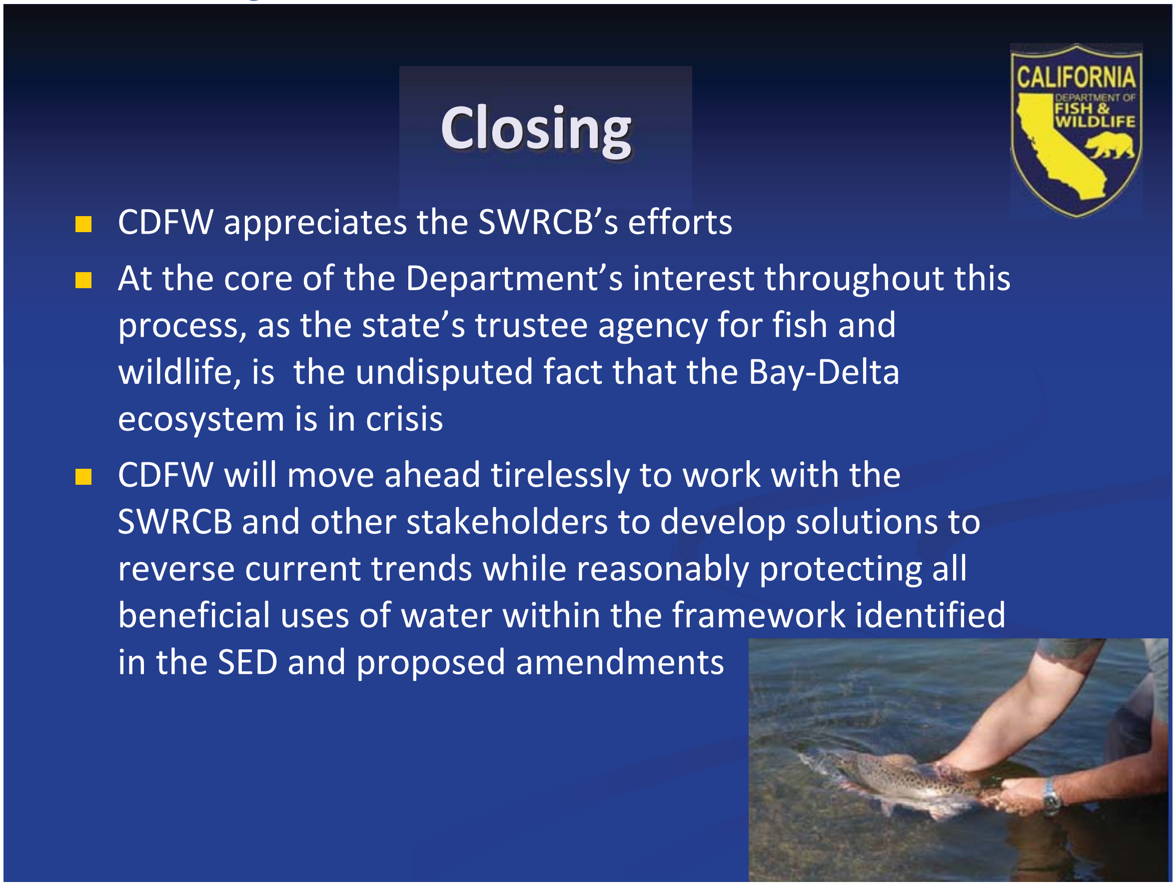
Slide 17: Is Flow Important?



In this slide the CDFW asserts that the recent divergence in adult returns between the Stanislaus and Tuolumne is the result of flow actions that occurred in the Stanislaus, but not in the Tuolumne.

As was adeptly pointed out in the question and answer period the end of the presentation, it is not an "apples-to-apples" comparison. Namely, non-flow actions occurred in both the Tuolumne and the Stanislaus and during this period and that these non-flow actions differed in both tributaries. As such, the impact of flow actions and non-flow actions on adult returns are confounded and cannot be separated. Differences in either flow action or non-flow actions may have been responsible for the differences in observed adult escapement. For example, creation of special run pools in the Tuolumne could have facilitated Bass predator populations which could have also have impacted Chinook populations or the non-flow projects implemented on the Stanislaus could have had more successful.

Slide 18: Closing



No comment.

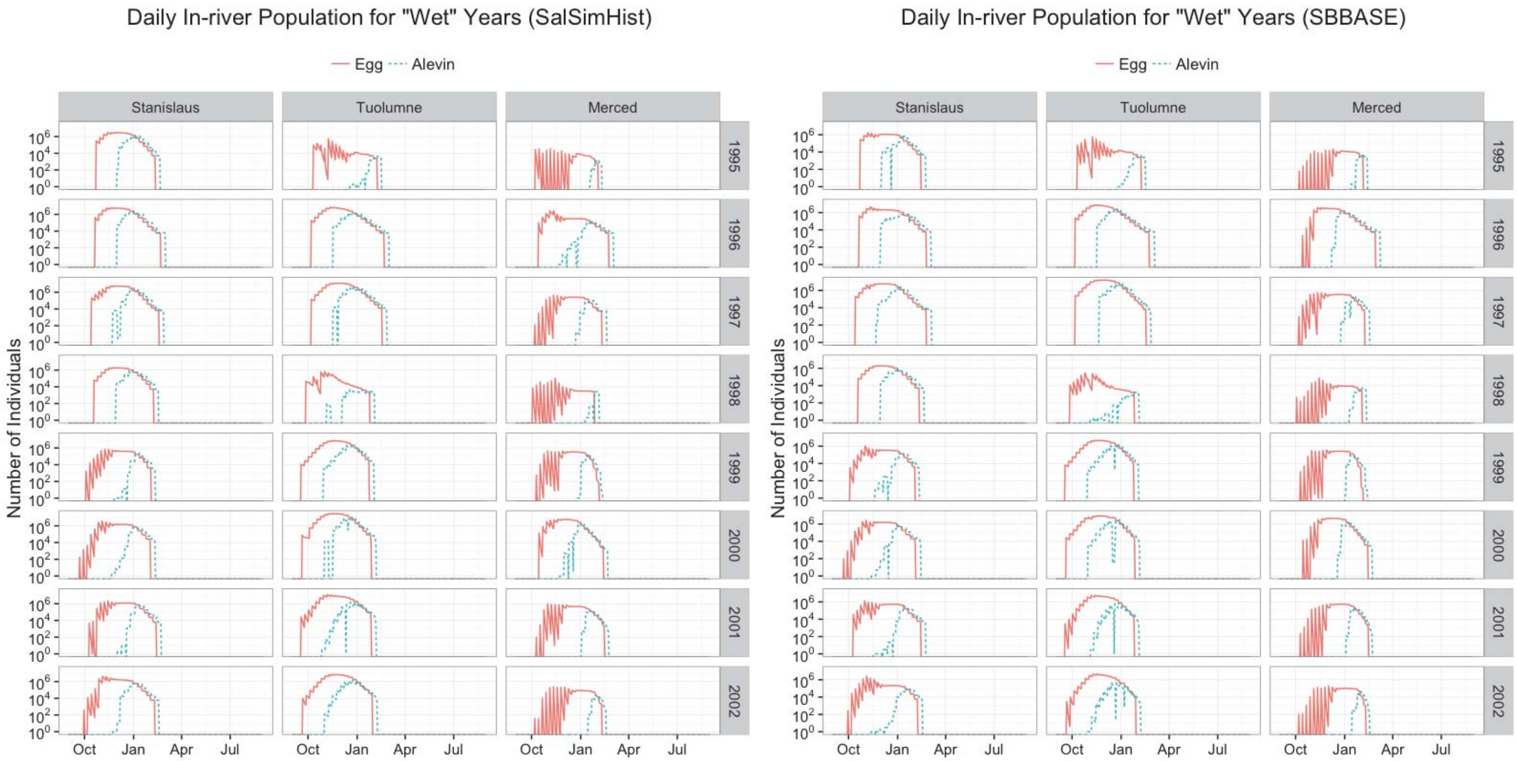


Figure 1. Daily in-river egg and alevin populations under the SalSim calibration hyrology (SalSimHist) and the SWRBC Base Case (SBBASE) during wet years.

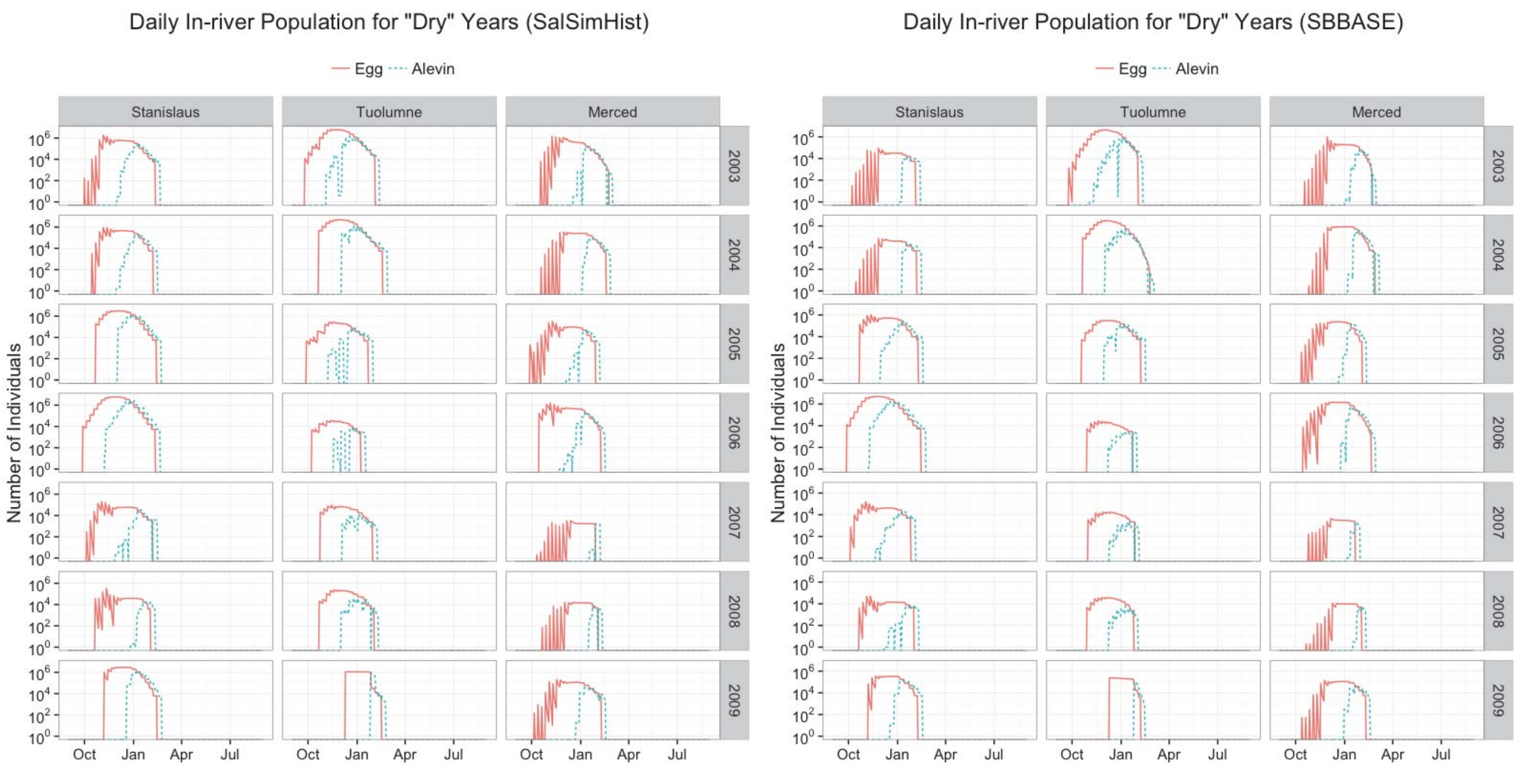
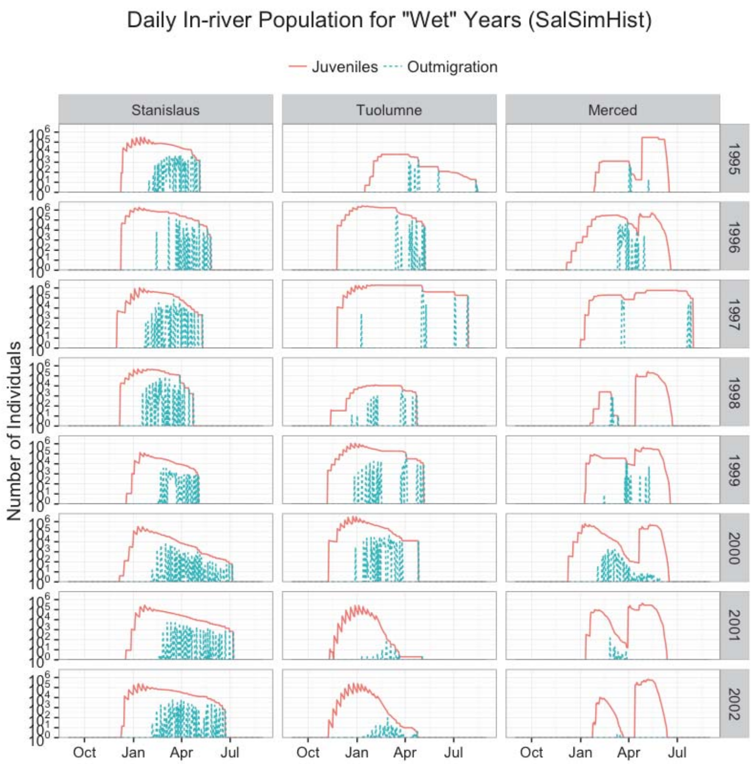


Figure 2. Daily in-river egg and alevin populations under the SalSim calibration hydrology (SalSimHist) and the SWRBC Base Case (SBBASE) during dry years.



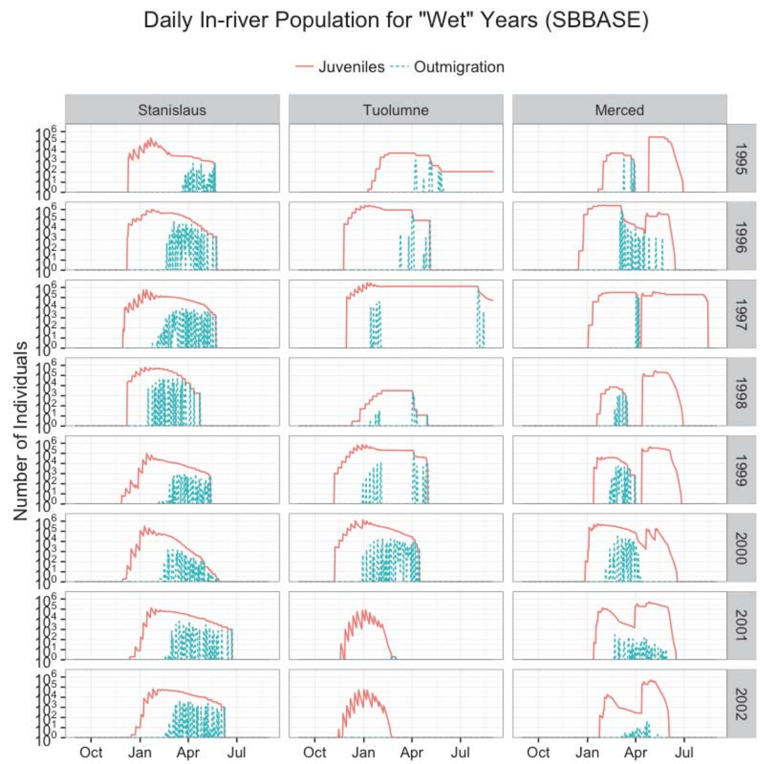


Figure 3. Daily in-river juvenile populations (fry, parr and smolts) under the SalSim calibration hydrology (SalSimHist) and the SWRBC Base Case (SBBASE) during wet years.

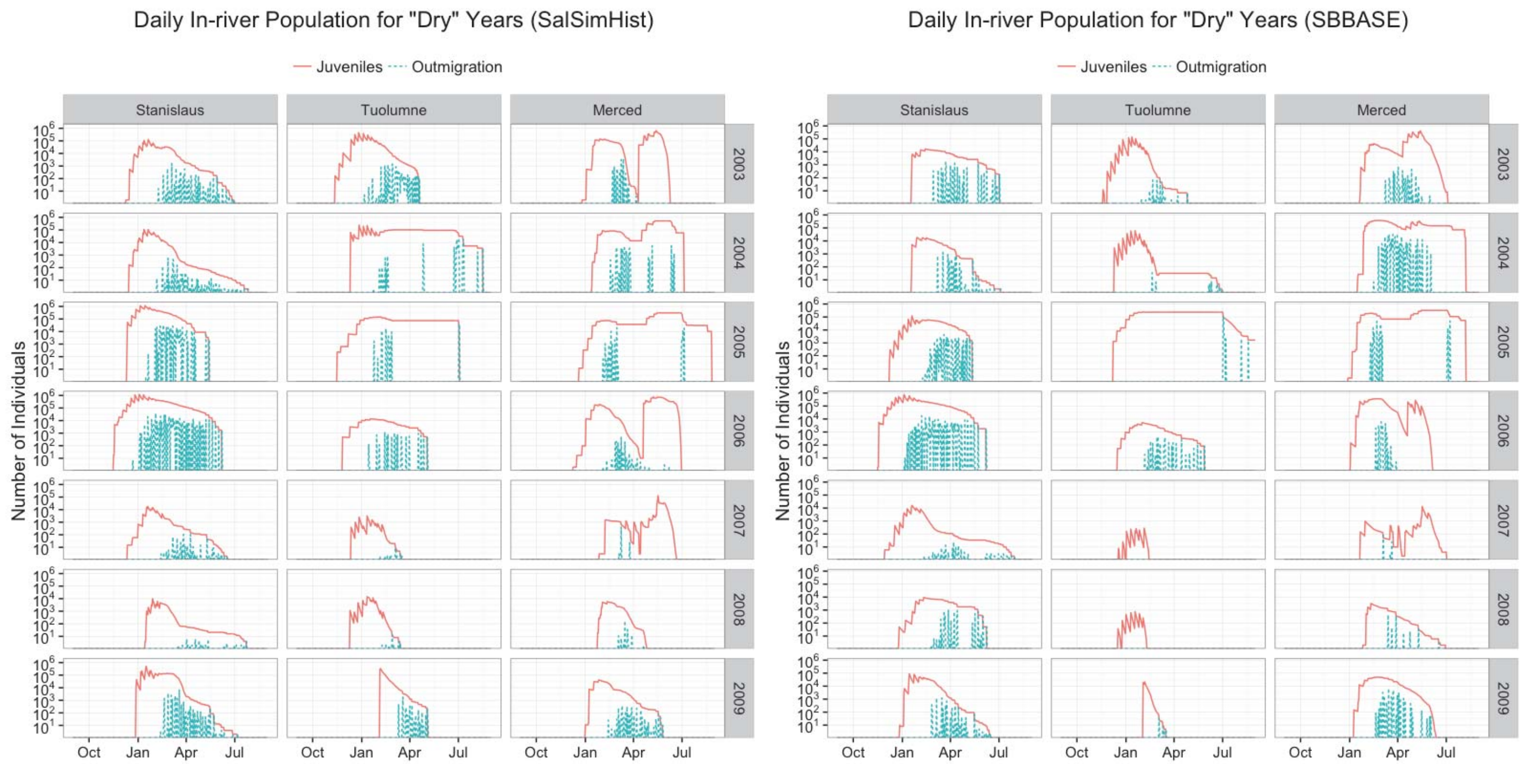


Figure 4. Daily in-river juvenile populations (fry, parr, and smolt) under the SalSim calibration hydrology (SalSimHist) and the SWRBC Base Case (SBBASE) during dry years.

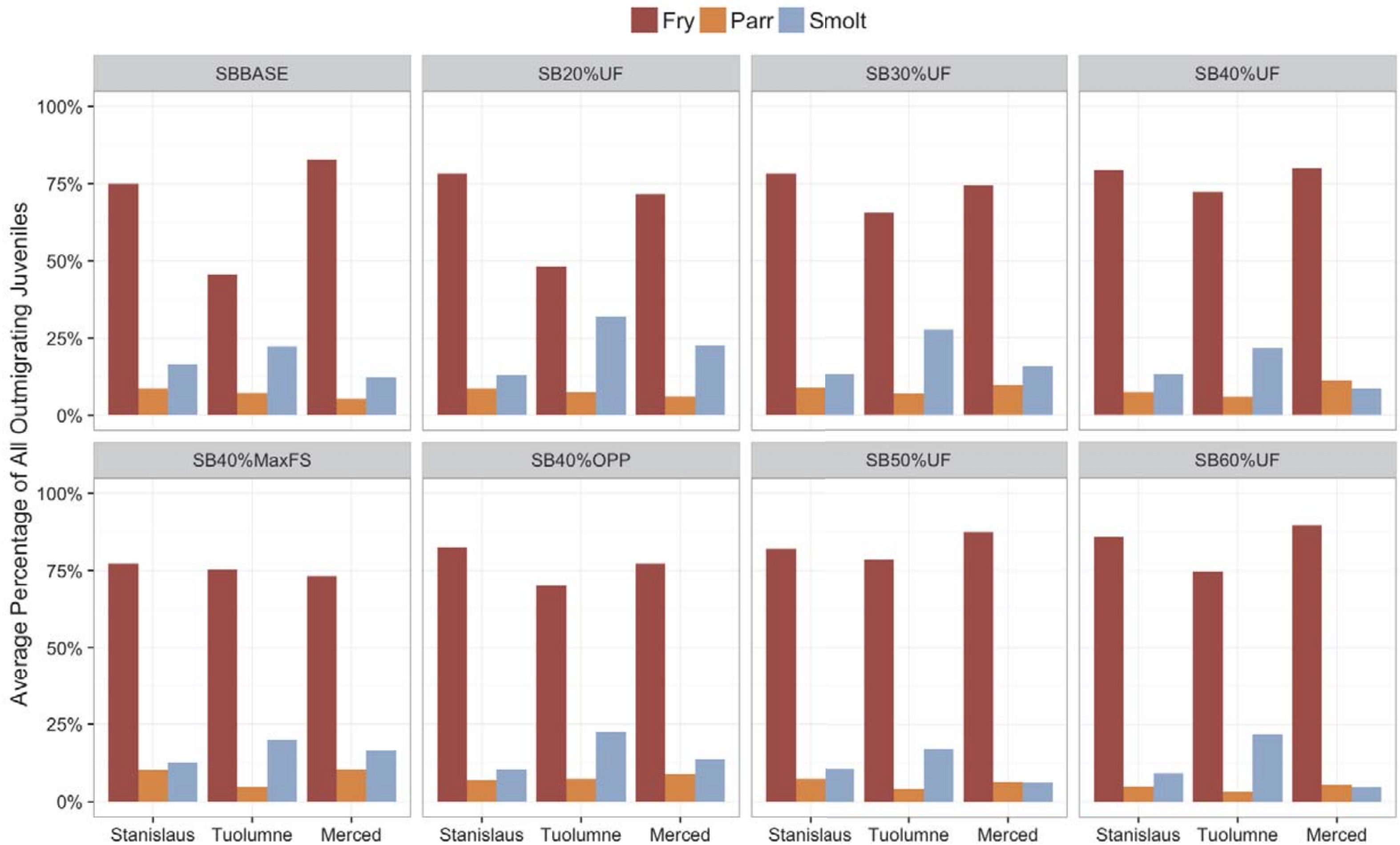


Figure 5. Average composition of outmigrating juveniles at each tributary (Stanislaus, Tuolumne, and Merced) over all study years.

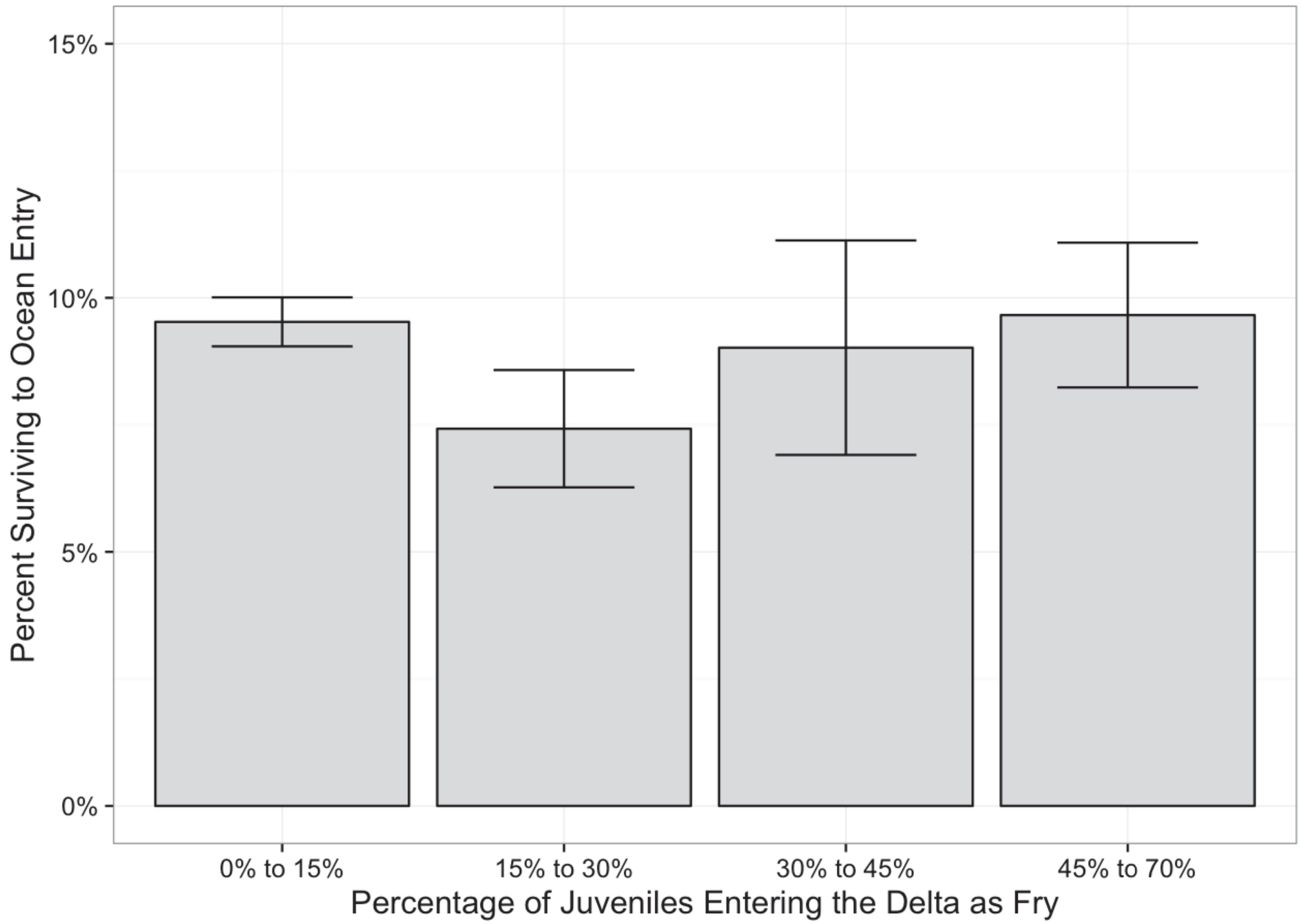


Figure 6. Percentage of juveniles entering the Delta that survived to ocean entry for differing smolt/fry mixtures. Error bars indicate standard error.

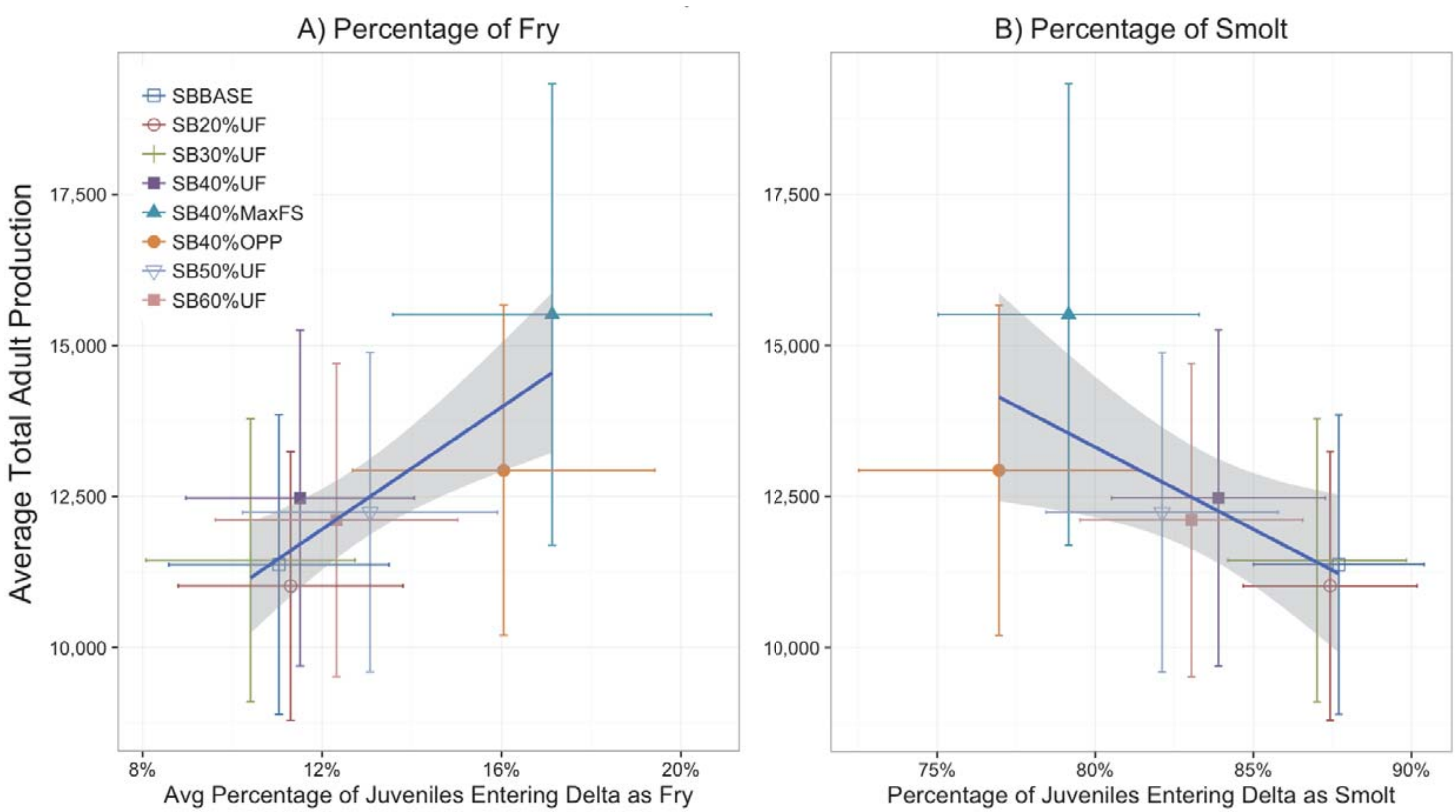


Figure 7. Relationship between the percentage of juveniles entering the Delta as A) fry and B) smolts and the average total adult production. Bars indicate standard error. Blue line indicates a simple linear regression fit and gray shading indicates the 95% confidence band for the regression.

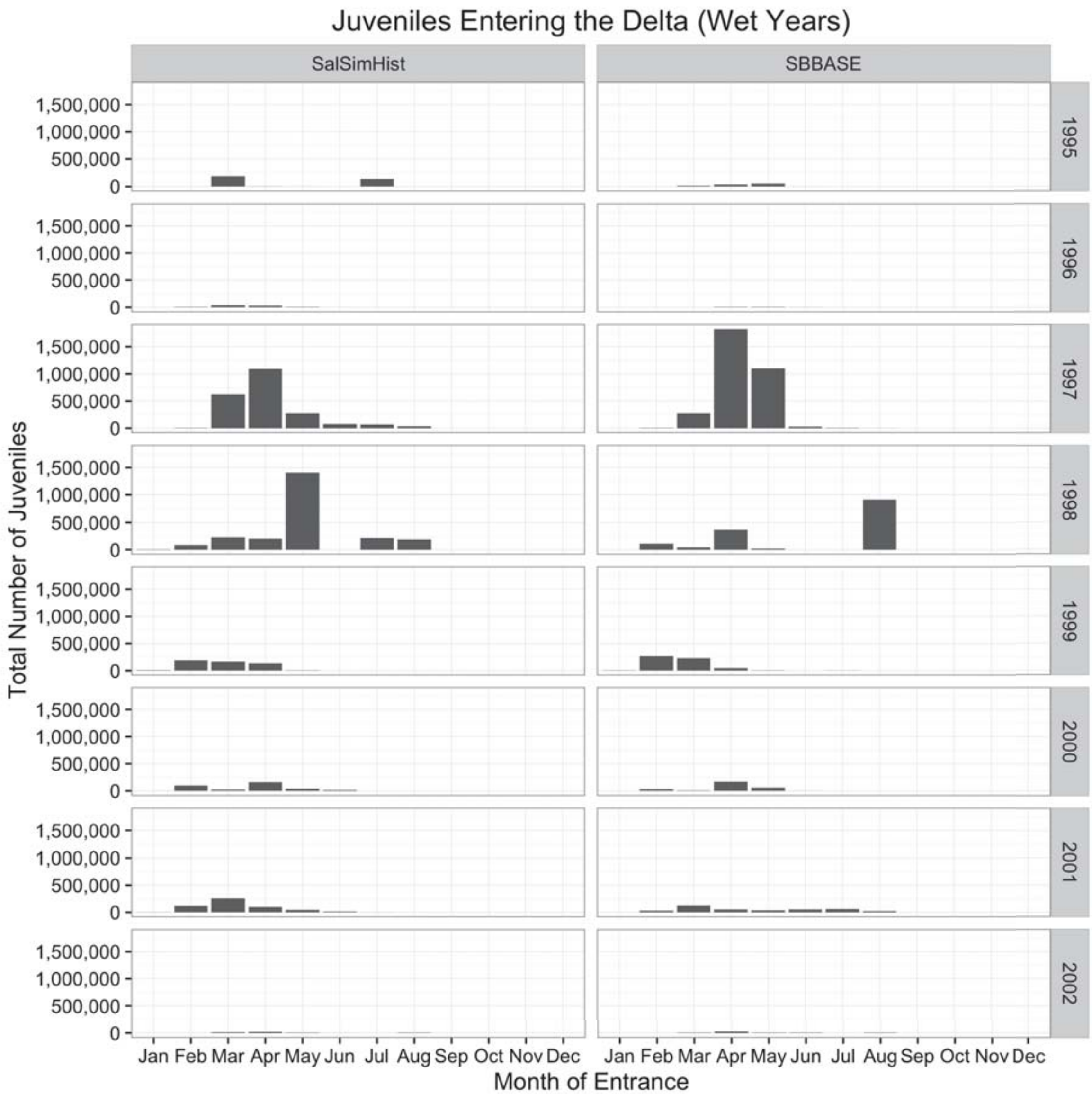


Figure 8. Total numbers of juveniles, excluding hatchery releases into the Delta, entering the Delta by month under the SalSim calibration hydrology (SalSimHist) and the SWRBC Base Case (SBBASE) during wet years.

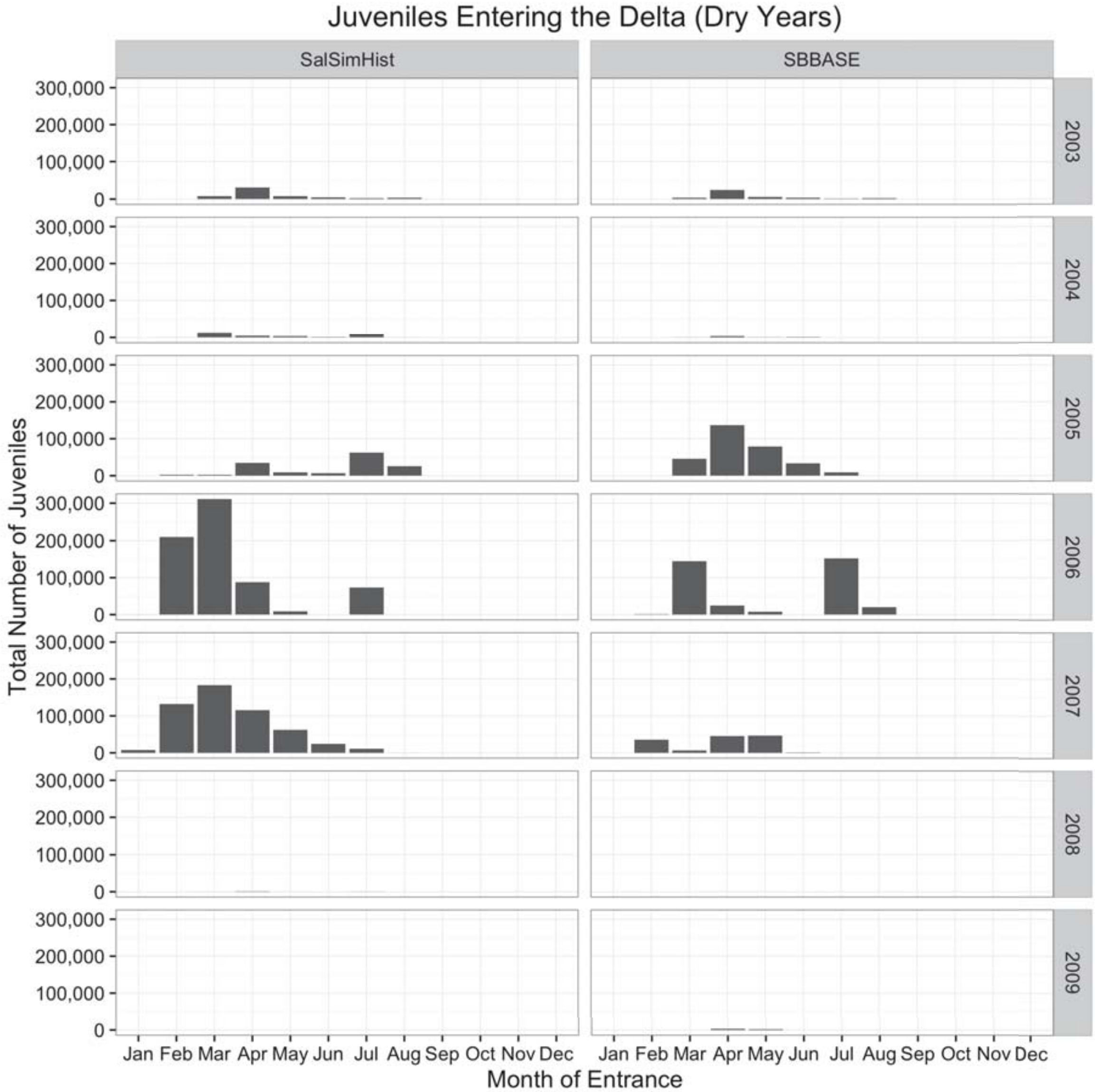


Figure 9. Total numbers of juveniles, excluding hatchery releases into the Delta, entering the Delta by month under the SalSim calibration hydrology (SalSimHist) and the SWRBC Base Case (SBBASE) during dry years.

TO: John Devine
FROM: FISHBIO
DATE: January 26, 2017
SUBJECT: Review of CDFW presentation at January 3, 2017 Public Hearing on the State Water Resources Control Board's Draft Revised Substitute Environmental Document

This memorandum provides comments from our review of the California Department of Fish and Wildlife's (CDFW) presentation at the January 3, 2017 Public Hearing on the Amendment to the Water Quality Control Plan for the San Francisco Bay/Sacramento-San Joaquin Delta Estuary and Supporting Draft Revised Substitute Environmental Document. The presentation discussed five general topics: hydrology, implementation, the SalSim model, June flows, and an assessment intended to demonstrate the importance of spring flow. Our review is organized into sections responsive to claims made by CDFW in each of these portions of the presentation.

Hydrology (Slides 2-4)

Flattening of the hydrograph is a combined result of reduced flows at times for storage and flood control, and higher than natural flows during other times to meet regulatory requirements (i.e., October flows). A more natural flow regime would also include lower flows in the fall which CDFW and the State Water Resources Control Board (SWRCB) continue to ignore. CDFW also fails to acknowledge the significance of other alterations to the aquatic environments of the San Joaquin Basin such as in channel mining, levees, and introduced species, which have had profound effects on native fish populations. Changes in the hydrograph were not made in isolation of these other significant factors, and management decisions also should be made within the context of other ecosystem alterations.

For instance, while we agree that the proliferation of non-native species (i.e., predation) is a significant problem as slide 3 of the CDFW presentation indicates, the claim that the altered hydrograph has favored the proliferation of non-native species, is not supported. We are not aware of any studies in the San Joaquin Basin that have linked trends in predator abundance with flows. Just as we monitor salmon and steelhead abundance, there is a need to monitor and understand the responses of non-native fish populations to flow and non-flow measures. Estimates of the abundance of non-native fishes are required to document population trends, but CDFW has repeatedly denied permit requests for studies such as the Tuolumne Predation Study, required by FERC. One key element of that study was to estimate predator abundance.

Similarly, CDFW claims that a more natural flow regime would boost natural production and reverse the decline in anadromous fish population abundance. CDFW fails to substantiate this claim with citation to scientific studies or with the information presented, and this issue is further discussed in our comments in subsequent sections.

Another claim made by CDFW is that the altered hydrograph has made fish sick/injured and unhealthy. Again there is no reference to scientific data to support this claim. In the Stanislaus and Tuolumne, health studies conducted by the U.S. Fish and Wildlife Service have found low to no disease in their samples, and fish were generally found to be in good health. There have been high rates of BKD infection on the Merced River and the degree to which this affects outmigrant success is unknown (Nichols 2013).

CDFW and others continue to cite the "portfolio effect" as justification for flows allowing for all lifestages to be expressed, with particular emphasis on June flow. All lifehistory strategies are currently expressed as is clear from the observation of fry, parr, and smolts in the upper rotary screw traps on the Stanislaus and Tuolumne rivers each year. However, in years with no natural run-off events or pulses during the fry outmigration period, fry do not make it out of the tributaries. So the expression of the fry lifehistory persists, but the strategy may not be successful in all years. This is not a new finding, and was occurring well before the current rim dams were in operation, as the absence of fry in the San Joaquin River in dry years was documented by CDFW using the Mossdale trawl during 1939-1941 (Hatton and Clark 1942). Recent otolith studies suggest that fry contribution to adult escapement may be improved during dry years with brief pulse flows (Sturrock et al 2015, Demko 2003)

Implementation (Slides 5-9)

CDFW claims a need to focus on achieving connectivity between tributaries and the Bay-Delta. Since the Stanislaus, Tuolumne, and Merced rivers maintain year-round connection to the San Joaquin, and the San Joaquin remains connected to the Delta downstream of the respective tributary confluences, it is not clear what CDFW is referring too. We suspect that this may be a reference to temperature conditions potentially presenting a barrier to migration as has been claimed by CDFW in the past. However, if this is the case, why not be more direct in identifying the concern?

Similarly, CDFW notes that "decisions on implementation of flow and non-flow measures should be tied to achieving clearly defined fish and wildlife narrative objectives." If CDFW believes that the SWRCB's proposed narrative objectives are "clearly defined", perhaps we should start by revisiting those vague objectives which are far from SMART (Specific-Measurable-Achievable-Realistic-Time Bound). If the objectives are not clearly defined, how can one evaluate progress or the potential merit of conservation measures?

This brings us to the issue of effective monitoring. We agree with CDFW that monitoring is necessary to understand progress. The Districts' have invested significant effort in ongoing monitoring activities to inform management decisions. It is unfortunate that management actions are often implemented with insufficient data to describe the baseline or to document response to the action. It is also unfortunate that CDFW provided no examples of what needs to be monitored, where, and how, nor what existing monitoring programs describe the baseline against which progress will be measured. How do they propose to evaluate how non-flow measures such as predator management contribute to meeting the objectives? Over what timeframe will success be measured? By adaptive, does the Department really mean that they want the authority to demand more water when their management of the prescribed block fails?

SalSim (Slides 10-12)

For more than a decade now there has been a consistent pattern of CDFW insisting that SalSim is the best available science then taking years to revise the model when substantial flaws are identified by those reviewing the model. These have been major issues with the statistical validity of the model, not "bugs". It is astonishing that CDFW attempts to dismiss the problems with the SalSim modeling as "bugs" in the model and a common occurrence in the modeling process. The problems identified with the flow and temperature inputs demonstrate a blatant lack of quality control. Clearly there was no consideration of the quality of the outputs from the HEC 5Q model before the data was used as the key inputs to the SalSim model. The problems with the egg and juvenile mortality aspects highlight that CDFW failed to reconcile these functions in the SalSim model with empirical data or logic.

CDFW claims that the issues identified with the model have been fixed and that it *believes* the output will show greater benefit from the proposed spring flows. If the model has been fixed, why can't CDFW make more firm statements about the impact of the correction on modeled juvenile mortality or difference between the SED estimates and estimates generated by the re-calibrated model? Sounds like more of the same – you caught a huge flaw in our work, and although we now have no scientific basis for our claims, stay tuned for the release of our next version. We're bound to find the right combination of numbers to support our claim at same time. Waiting to provide new numbers in their official comments in March suggests that CDFW is delaying further review of the model or its outputs by the scientific community, which could be reflected in comments to SWRCB. This does not demonstrate a commitment to collaboration or policy based on science.

June flows (Slides 13-14)

In discussing Chinook salmon migration during June, CDFW references the work of Dr. Sturrock and Dr. Johnson as justification for June flows. It is important to note that this work looked at the relative contributions to escapement of fry, parr, and smolt outmigrants. A smolt migrating on May 31 is not a different lifestage than a smolt migrating on June 1 or June 15 – they are all smolts. The work referenced by CDFW did not evaluate the relative success or contributions of smolts migrating in May vs. smolts migrating in June.

Further, CDFW fails to recognize that late-fall run, if present in the San Joaquin Basin, migrate primarily as yearlings, not later in the spring (Moyle 2002, Fisher 1994). There have been few instances of fry captured in May or yearlings during the spring that would be consistent with the timing of a late-fall run, suggesting that some late-fall run may stray from the Sacramento Basin. There is not a distinct run of late-fall run Chinook salmon in the San Joaquin Basin as evidenced by weir and rotary screw trap monitoring on the Stanislaus and Tuolumne rivers. It should be further noted that, while CDFW recognizes late-fall run as a unique lifehistory strategy, Central Valley fall and late-fall run Chinook salmon are a single ESU.

CDFW chose the very wet year of 2011 as an example of smolts leaving in June when flow is provided. This was a year when flows at Vernalis were greater than 20,000 cfs from January through April, straining levees and jeopardizing public safety. Flows decreased to approximately 10,000 cfs during June. Under the SED base case this flow occurred 13% of the time and the SWRCB's modeling shows *no increase* in the frequency of occurrence of this flow under the 40% unimpaired flow scenario (Table 19-27). Thus, the example is not representative of conditions that may be expected as a result of implementation of the SWRCB's plan.

The second example of June outmigration provided by CDFW is 1999 when June flows at Vernalis were approximately 3,000 cfs. During this year 17.4% of smolts passed Mossdale during June. In contrast, at a similar flow of approximately 2,800 cfs at Vernalis during June 2000, only 2.9% of smolts migrated past Mossdale during June. Also, at a higher June flow of approximately 3,700 cfs at Vernalis during 1996, only 5.7% of smolts passed Mossdale during June.

In the text of the slide showing June flows and estimated daily abundance of juvenile salmon at Mossdale during 1999, CDFW also claims that more flow equals more juvenile salmon entering and exiting the Delta and more adult salmon production. That is not what this slide shows. This slide only shows the number of salmon that entered the Delta during a single year. It provides no information on the number of salmon from the San Joaquin River that exited the Delta or the number of adult salmon produced, nor does it provide any information from other years to put this single year in context.

Is flow important (slides 15-16)?

The argument is not whether flow is important – it is. The question is how do fish respond to the volume of water and shaping of that volume, and to non-flow measures. Fortunately, ongoing, long-term monitoring efforts in the San Joaquin Basin provide information to assess fish response to past, current, and future management actions. Unfortunately, this wealth of knowledge was underutilized or ignored in the SED, and CDFW often ignores or interprets the data without the appropriate context.

On slide 6 of the presentation, Mr. Marston cites to the importance of monitoring, but the presentation failed to give any examples of what that means, how existing monitoring programs may be used as a baseline against which to measure progress, or examples of what new monitoring may be needed. This is of particular concern given the approach used by CDFW to support its claim that the increase in recent escapement to the

Stanislaus River is due to increased flows required by the 2009 Biological Opinion. Escapement reflects factors influencing survival throughout the entire lifecycle. Chinook salmon spend about 4-7 months in freshwater from the time eggs are deposited until juveniles migrate to the ocean (Fisher 1994). A salmon returning at a typical 3 years of age has spent roughly 80% of its life in the ocean.

One factor that CDFW fails to acknowledge in its assessment of the importance of flow is the impact of excessive growth of water hyacinth in the San Joaquin and Tuolumne rivers on adult upstream migration in 2014 and 2015. Analyses of aerial images indicated that 11.7% of the migration corridor between Vernalis and the Tuolumne River weir was blocked by rafts of water hyacinth in 2014, and this increased to 12.5% in 2015 (TID/MID 2016). There was a clear path to the Stanislaus River, and the growth of water hyacinth likely detoured fish from migrating to the Tuolumne and Merced Rivers. On that note, it is also not clear why CDFW did not consider the Merced River in its assessment.

The claim made by CDFW implies that spring flows resulted in increased juvenile production from the Stanislaus. Rotary screw trap monitoring has been conducted in the Stanislaus River to estimate juvenile production, including before and after implementation of flow measures. Rotary screw trap monitoring at Caswell State Park (RM 8.6) provides a direct measure of trends in the number of juvenile salmon exiting the Stanislaus River annually since 1998 (CFS 2016). It is clear from this data that the number of juveniles exiting the Stanislaus after implementation of the flows required by the Biological Opinion have not increased (Figure 1). If anything, abundance decreased.

CDFW presents estimates of natural production based on otoliths and carcass survey estimates (slide 15) or weir counts (slide 16). It is unclear what data were used as the Stanislaus River otolith study looked at samples escapement years 2001-2006 (Sturrock et al 2015), and the Tuolumne study (Sturrock and Johnson 2014) included otoliths from escapement years 2000-2006 and 2010-2012, yet estimates of natural production are provided for each stream from 1995-2015. Using the available otolith data we attempted to reproduce CDFW's estimates and found notable inconsistencies. For example, otoliths examined in the Tuolumne study from the 2011 escapement indicated that 85.7% of unmarked salmon were of hatchery origin (Sturrock and Johnson 2014). Using this with the weir counts of 1,442 marked and 1,375 unmarked salmon (Cuthbert et al 2012) yields an estimated natural production of 197 salmon on the Tuolumne River in 2011 (Table 1). This differs greatly from what appears to be about 750 in slide 16 of CDFW's presentation.

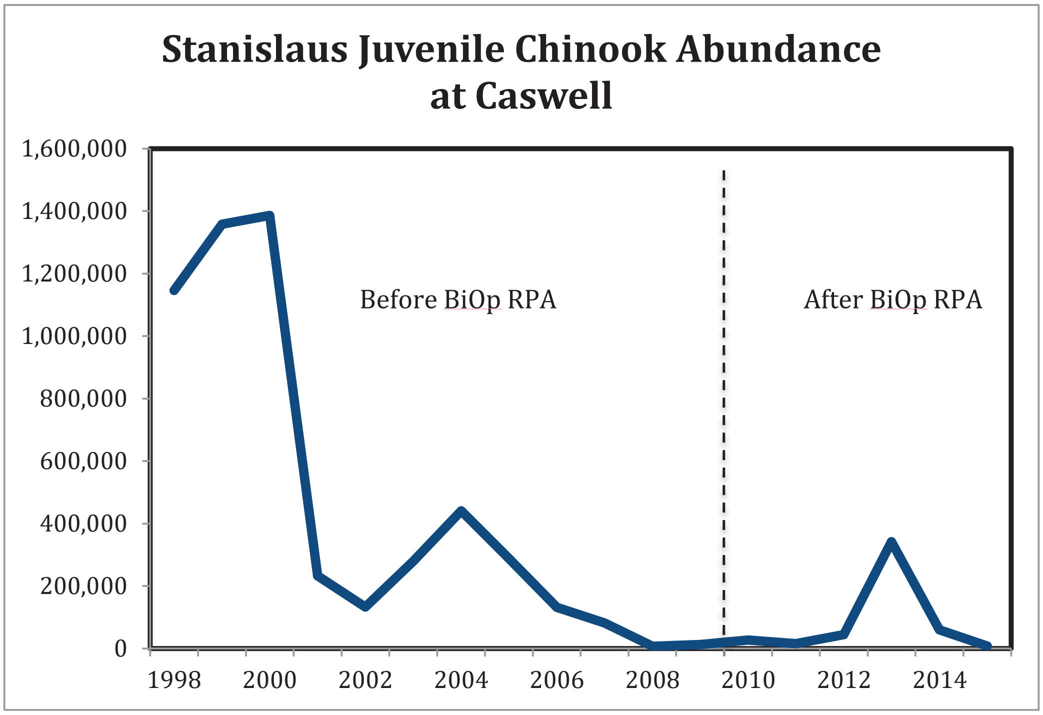


Figure 1. Annual abundance of juvenile Chinook salmon in the Stanislaus River at Caswell, 1998-2015. (Source: CFS 2016)

Table 1. Estimated numbers of hatchery and natural produced salmon in the 2011 Tuolumne River escapement based on weir counts and otoliths. Sources: Cuthbert et al 2012 and Sturrock and Johnson 2014)

	2011 Weir Count (Total = 2,817)	
	Hatchery	Natural
Ad-clipped	1,442	
Unmarked (85.7% hatchery)	1,178	197
Total	2,620 (93%)	197 (7%)

Another method to estimate natural production uses coded wire tags recovered on the spawning grounds. Recent improvements to this method include the Constant Fractional Marking Program which was initiated in 2007 to provide more reliable estimates of natural production of Central Valley salmon. Only two reports containing estimates of hatchery and natural production have been released by the CFM for the 2010 and 2011 escapement years. With 2010 representing partial implementation as 4 year old fish were not subject to CFM, it was estimated that 50% of the escapement to the Stanislaus and 49% of the escapement to the Tuolumne were of hatchery origin (Kormos et al 2012). During 2011, the first year in which all returns would have been subject to CFM, the estimates increased to 83% on the Stanislaus and 73% on the Tuolumne (Palmer-Zwahlen and Kormos 2013). During 2012, the estimates were 83% on the Stanislaus and 36% on the Tuolumne (Palmer-Zwahlen and Kormos 2015). Using these numbers in conjunction with the weir counts and carcass surveys, we were able to roughly reproduce the results presented by CDFW in slides 15 and 16 for 2010 and 2011, but not for 2012. It is possible that CDFW used a mix of CWT recovery and otolith data to arrive at the estimates presented. The data used to generate the estimates should be provided by CDFW to support the analysis.

Some increase in naturally produced individuals might be expected in 2015 and 2016 resulting from an unusually high number of outmigrants from the Stanislaus River during 2013. However, available data on recent hatchery release practices and the proportion of the escapement to the Stanislaus that was ad-clipped (indicating hatchery origin) in 2015 and 2016 suggest otherwise.

During 2015 and 2016, 26% of Chinook salmon passing the Stanislaus River weir were ad-clipped indicating hatchery origin. This means that 26% were known hatchery fish. Since only a fraction of hatchery production is marked, one must look at the proportions of hatchery production released without marks, and either otoliths or coded wire tags recovered on the spawning grounds to quantify the proportion of the unmarked fish that are of hatchery or natural origin. Coded wire tag recovery data is not yet available in the RMIS database for the 2015 or 2016 spawning runs, and we have not seen any results of otolith read. However, it is notable that during brood years (BY) 2012 and 2013, 23% and 26% of the juvenile salmon released from the Merced River Hatchery (MRH) were ad-clipped (Table 2). As most fish return at 2-4 years of age (Fisher 1994), the large escapement to the Stanislaus River during 2015 corresponds to production from BY 2011 - BY 2013.

Production from MRH was low in BY 2011 (262,108) relative to the 1.4 million in BY 2012. In addition, the relatively small number of fish released from BY 2011 were released in the Merced River whereas the much greater production from BY 2012 were trucked to the western edge of the Delta (mostly Jersey Point) and presumably had much better survival (and a higher rate of straying). For the purpose of example, consider the comparison in Table 3 which begins with the number of juveniles released from MRH and hypothetical survival rates to the Delta. The small number produced in BY 2011 were primarily released on site and had to migrate through the Merced River and San Joaquin rivers, and the Delta. The example assumes 10% survival during each of these three segments. In contrast, the 1.4 million juveniles produced at MRH in BY 2012, more than 6 times the BY 2011 production, were trucked to a point 160 miles downstream, bypassing the Merced River, San Joaquin River, and Delta segments. This results in only a few hundred MRH salmon exiting the Delta from BY 2011 compared to the 1.4 million in BY 2012. This, combined with the proportions of hatchery production tagged at release, and the proportion of tagged fish observed in the weir counts, suggests a high likelihood that most of the 2015 Stanislaus River escapement was comprised of hatchery fish.

During BY 2012-2014 approximately 1 million to 1.5 million juvenile salmon were produced at MRH and released far downstream in the Delta, increasing the odds of straying into other basins such as the Stanislaus River. All returns in 2016 would have been from these years. The proportion of ad-clipped fish in the Stanislaus River in 2016 was 26%, quite similar to the 23%-27% released from MRH, suggesting that the majority of the escapement to the Stanislaus River was also of hatchery origin in 2016.

Table 2. Summary of releases from Merced River Hatchery during brood years 2010-2014. (Source: Regional Mark Processing Center online RMIS database.)

Brood Year	#Ad-clipped	Total Released	% Ad-clipped	% off-site
2010	129,642	135,137	96%	15%
2011	262,108	262,108	100%	6%
2012	325,953	1,443,543	23%	98%
2013	393,182	1,515,354	26%	100%
2014	275472	1,016,581	27%	100%

Table 3. Example comparison of differing release strategies and level of production from MRH during BY 2011 and BY 2012.

	2011 (Released on Site)	2012 (Trucked to Delta)
MRH Production	262,000	1,400,000
10% to SJR	26,200	-
10% to Delta	2,620	-
10% thru Delta	262	1,400,000

References

Cuthbert, R., Becker C. and Fuller, A. 2012. Fall/Winter Migration Monitoring at the Tuolumne River Weir, 2011 Annual Report. Submitted to Turlock Irrigation District and Modesto Irrigation District. March 2012. Available at http://tuolumnerivertac.com/Documents/2011%20Tuolumne%20Weir%20Report_final.pdf

Demko. 2004. Evaluation of Chinook Salmon Fry Survival in the Stanislaus River: Biological Response to Supplementa Winter Flow Pulse *in* 2003 Annual Technical Report on Implementation and Monitoring of the San Joaquin River Agreement and the Vernalis Adaptive Management Plan (VAMP). Prepared by San Joaquin River Group Authority. Prepared for the California Water Resources Control Board in compliance with D-1641.

Fisher, F.W. 1994. Past and Present Status of Central Valley Fall-run Chinook Salmon. Conservation Biology 8 (3:870-873).

Hatton, R.S., and G.H. Clark. 1942. A Second Progress Report on the Central valley Fishery Investigations. California Department of Fish and Game 28(2):116-123.

Kormos, B., Palmer-Zwahlen, M., Low, A. 2012. Recovery of Coded-Wire Tags from Chinook Salmon in California's Central Valley Escapement and Ocean Harvest in 2010. Fisheries Branch Administrative Report 2012-02.

Melgo, J., Colombano, P., Sellheim, K., Hinkelman, T., Anderson, J., and Merz, J. 2015. Juvenile Salmonid Outmigration Monitoring at Caswell Memorial State Park in the Stanislaus River, California. 2014-2015 Annual Report. Prepared for the U.S. Fish and Wildlife Service Comprehensive Assessment and Monitoring Program.

Nichols, Ken. 2013. FY 2012 Technical Report: San Joquin, Stanislaus, Tuolumne, and Merced River Chinook Smolt Quality Assessment. U.S. Fish and Wildlife Service California-Nevada Fish Health Center.

Palmer-Zwahlen, M. and Kormos, B. 2013. Recovery of Coded-Wire Tags from Chinook Salmon in California's Central Valley Escapement and Ocean Harvest in 2011. Fisheries Branch Administrative Report 2013-02.

Palmer-Zwahlen, M. and Kormos, B. 2015. Recovery of Coded-Wire Tags from Chinook Salmon in California's Central Valley Escapement and Ocean Harvest in 2012. Fisheries Branch Administrative Report 2015-04.

Sturrock AM, Wikert JD, Heyne T, Mesick C, Hubbard AE, Hinkelman TM, et al. 2015. Reconstructing the Migratory Behavior and Long-Term Survivorship of Juvenile Chinook Salmon under Contrasting Hydrologic Regimes. PLoS ONE 10(5): e0122380. doi:10.1371/journal.pone.0122380

Sturrock, A. and Johnson, R. 2014. Tuolumne River Chinook Salmon Otolith Study – Analysis of Archival Otoliths Using Stable Isotope Microchemistry.

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MEMORANDUM

DATE:	Monday, February 27, 2017
TO:	John Devine (HDR)
FROM:	Noah Hume and Peter Baker
SUBJECT:	Review of NMFS-UCD Presentation – Salmon life history portfolios in a regulated river (Bay Delta Phase 1 Hearing, January 3, 2017)

At the Districts' request we took the opportunity to review "*Salmon life history portfolios in a regulated river*" a joint presentation by researchers from the National Marine Fisheries Service (NMFS) and U.C. Davis (UCD) to the State Water Resource Control Board (SWRCB) hearing on proposed updates to the Water Quality Control Plan for the San Francisco Bay/Sacramento-San Joaquin Delta Estuary (Bay-Delta Plan). Overall, the presentation offered new and important information regarding the viability of various juvenile rearing and emigration strategies on the Stanislaus River. While we generally agree with the conclusions that all life history strategies are viable in some settings, we found this not to be the case in comparisons with a comparable otolith study conducted on the neighboring Tuolumne River. In addition, we have differing interpretation of information presented on several supporting slides and present more detailed exploration of underlying juvenile and adult monitoring data from both the Stanislaus and Tuolumne River. In the paragraphs below, we provide brief comments in the order of the original presentation.

1 PRESENTATION REVIEW

Slides 2-3. What do we already know. While we generally agree with the life history diversity argument and that early fry dispersal is evident in the LJSR, it should be noted that the generalization attributed to Williams (2006) is not based on information from LSJR tributaries. As discussed below using similar results on the Tuolumne River, however, early fry dispersal does not consistently result in successful Delta emigration or adult returns.

Slide 4. life history diversity. On the Stanislaus River, RST monitoring at the Oakdale location (RM 31) shows large fry passage from spawning locations farther upstream, regardless of flow magnitude or variability. This is also seen on the Tuolumne River, where RST passage at Waterford (RM 29.8) between 2006-2014 also shows large numbers of fry dispersing in all Water Year (WY)[1] types. However, survival in the lower portions of both rivers is sensitive to both flow and turbidity which affect predation rates. Interestingly, although higher fry survival under high flows is shown in the Tuolumne River by increased RST passage at Grayson (RM 5.2), comparable otolith data from the lower Tuolumne (Stillwater Sciences 2016) shows that very few if any fry-sized emigrants are represented in subsequent escapements, regardless of WY type or discharge level.

[1] CDWR Bulletin 120 estimates unimpaired runoff as TAF for the San Joaquin River and tributaries. The San Joaquin Basin 60-20-20 Index classifies water years (October 1 through September 30) into five basic types (C=Critical, D=Dry, BN=Below Normal, AN=Above Normal, W=Wet)

Slide 6: Flow vs Survival. As shown in historical RST data from the Stanislaus as well as Tuolumne River, flow magnitude during emigration results in higher relative passage between the upstream and downstream RSTs, allowing for the development of flow vs survival regressions similar to the one shown on Slide 6. It should be noted however, that although the two plots showing discharge magnitude and discharge variance explaining survival, since discharge variance generally increases with increasing discharge, only the discharge magnitude vs survival plot is necessary to make the case for the importance of flow.

Slides 7-8. **Flow vs Escapement.** Regressions of GrandTab (CDFW 2016) escapement vs lagged flow shows little if any relationship in Sacramento River tributaries but does partially explains variations in escapement in the LSJR tributaries. For example, 48% of the variation in escapement is explained by annual discharge 3 years earlier on the Tuolumne River from 1971-2013. Interestingly, however, since implementation of increased outmigration flows on the Tuolumne River since 1996, the escapement vs this "lagged flow" relationship from 1997-2013 explains only 26% of annual escapement. This suggests that recent increases in spring pulse flows under the FERC process as well as the Vernalis Adaptive Management Program (VAMP) have coincided with a declining and weakening relationship between tributary flow and subsequent escapement.

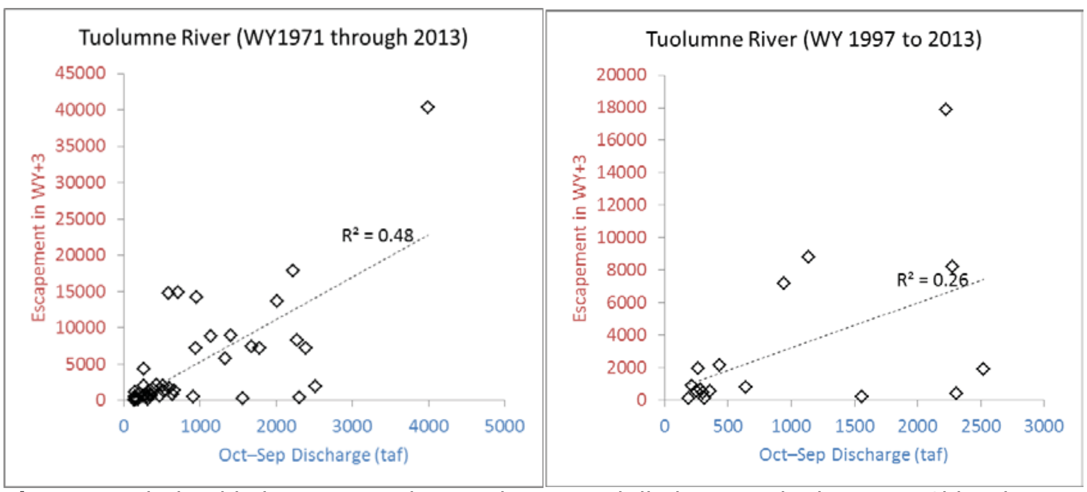

Figure 1. Relationship between Tuolumne River annual discharge and subsequent Chinook salmon escapement (t+3 yrs) is growing weaker since implementation of increased pulse flows in 1996

Similar data exploration for the Stanislaus River shows the relationship between lagged discharge since the completion of New Melones Dam (ca 1978) explains only 33% of the long term escapement since 1980. More recently, however, even with the large flow increases coinciding with the implementation of the Vernalis Adaptive Management Plan (VAMP)[2] in 2000 as well as more recent flow increases as a result of the Central Valley Project/State Water Project Biological Opinions (BiOps) in 2010, lagged discharge now has no relationship (p=0.68,

[2] Adopted in 2000 as part of SWRCB Decision 1641, the Vernalis Adaptive Management Plan (VAMP) provided a steady 31-day pulse flow at the Vernalis (VNS) gage on the San Joaquin River during the months of April and May, along with a corresponding reduction in Delta exports from the SWP and CVP.

R^2=0.015) with recent escapement on the Stanislaus River (i.e., does not explain any of the variation)

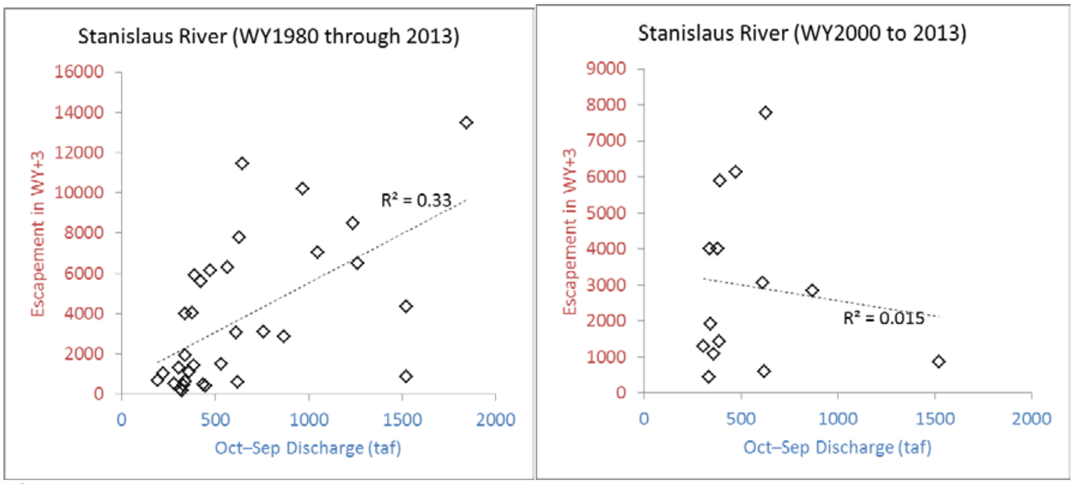

Figure 2. Relationship between Stanislaus River annual discharge and subsequent Chinook salmon escapement (t+3 yrs) is no longer apparent since adoption of increased spring pulse flows under VAMP (2000) and further increases with implementation of the CVP/SWP BiOps (2010)

Slides 9-15. *No Comment*

Slides 16-17. Size Composition. As with the Stanislaus RST data, Tuolumne River RST data show relatively higher proportions of fry emigrating in Wetter WY types, presumably related to reduced predation rates under these conditions. However, otolith data from the lower Tuolumne (Stillwater Sciences 2016) shows that few if any fry-sized emigrants are represented in subsequent escapements, regardless of WY type or discharge level.

Slides 18-19. Juvenile Productivity (Fry/Parr/Smolt per spawner). For the Stanislaus River, we would expect that increased survival with flow would increase juvenile productivity metrics as a result of increased survival between the Oakdale and Caswell RSTs. On the Tuolumne River, historical seining indices (e.g., fry/spawner indices from seine and spawner data)(TID/MID 2005), more recent analyses of RST data, as well as Tuolumne River Chinook (TRCh) population modeling results suggest similar increases in juvenile productivity metrics (Stillwater Sciences 2013).

We would require additional information to examine the inferences regarding carrying capacity and density dependence. On a technical level, the authors seem to assume that density dependence is important by selecting non-linear curves fit to the data shown. While the fry curve is superficially plausible, it is unclear whether conventional statistical criteria (e.g., AIC) would justify the non-linear model. Since juvenile rearing densities, growth rates, or other indications of density dependent factors on the Stanislaus River appear to be unexamined by Sturrock et al (in prep), the inference regarding carrying capacity should be compared to other explanations such as predation losses which would also be proportional to flow.

Slides 20-28. Rearing location and time to ocean entry. We have no comment on the Methods shown or Stanislaus River results. However, in examining timing and estimated sizes at emigration from otolith studies on the Tuolumne River, it was determined that early fry emigrants in Wet years (particularly in WY 2000) typically spent longer rearing in the Delta than for parr- and smolt-sized fish, but that the total time of development from formation of otolith core to ocean entry for juvenile salmonids was relatively constant (Stillwater Sciences 2016). Size-standardized estimated growth rates from this study were generally greater for fish that reared in the Tuolumne River as compared with fish that reared in the Delta, but the pattern was not consistently statistically distinguishable between the two rearing locations.

Slides 29-31. Who Survives. Of the five outmigration years examined in otolith studies of the Tuolumne River (1998 [Wet], 1999 [AN], 2000 [AN], 2003 [BN], and 2009 [BN]), there were zero fry contributions to subsequent escapement in three out of five outmigration years analyzed and a maximum fry contribution of 5% for fish emigrating in WY 2000 (Stillwater Sciences 2016). While salmon do express multiple emigration life history strategies, findings on the Tuolumne suggest that fry emigrant contributions are low under a range of Wet to Dry year conditions and apparently not as important a contribution as found in the 7-yr Stanislaus River dataset.

Slides 32-33. Flow Magnitude and Variability since New Melones. It is accepted that dams primary function in reducing flooding magnitude has consequences upon long-term geomorphic processes as well as flow variability affecting salmonids on shorter biological time scales. However, as discussed above under the flow vs escapement discussion (Slides 7-8), the explanatory power of flow during emigration upon the variations in future escapements appears to be falling in the past 15 years. On the Stanislaus River the statistical relationship since 2000 is negative indicating that antecedent flow has no relationship with the recent escapement increases on the Stanislaus River. This suggests that the other factors not explored by Sturrock et al (in prep.) such as Delta and ocean conditions may have a much larger effect on salmon escapement than tributary flow prescriptions.

Slide 34. Flow Magnitude and Variability effects. This summary slide makes several broad statements not readily tied to the data presented. We offer the following discussion of the environmental considerations discussed:

- <u>Carrying Capacity</u>. Separate from discussions of floodplain activation flows and their duration, flow magnitude affects instream habitat availability for salmonid juveniles in that increased flows will generally result in greater depths and velocities within main channel habitats. Detailed comparison of longitudinal fish distribution from bi weekly seining data from the nearby Tuolumne River generally shows a pattern of downstream displacement in wetter WY types which was attributed as passive displacement of emergent fry (Stillwater Sciences 2013). Interpreting the higher fry RST passage at higher flows on the Stanislaus River as carrying capacity limitation would suggest that overall habitat is somehow limiting at high flows. Conversely, the relatively lower seasonal fry passage at low flows could also be interpreted as higher carrying capacity at lower flows than higher flows. For example, typical survey data used to develop habitat suitability criteria for IFIM studies generally show higher fish densities at low discharges than for higher discharges. Although these are simplified arguments and do not take predation effects into account but it is clear that additional spatially explicit information is needed on the Stanislaus River to properly attribute the underlying mechanisms between increasing flow and juvenile production.
- <u>Reduced life history diversity</u>. With regard to early fry emigration opportunities and downstream rearing locations, the otolith study on the Tuolumne River (Stillwater

Sciences 2016) showed a large predominance of adult spawners that had originally emigrated as smolts and almost no representation of emigrant fry in the subsequent spawner population. Given the high rates of predation (Grossman 2016) and near total absence of tidally influenced wetland habitats in the Delta (Whipple et al 2012) recommendations for increased flows and variability to encourage multiple rearing and emigration pathways does not appear to be an effective strategy.

- Migration Cues. With regard to flow as a migration cues, population modeling on the Tuolumne River including RST passage analyses shows that, smolt emigration appears to be related to size and developmental thresholds rather than flow related emigration cues (Stillwater Sciences 2013). For this reason, other than passive fry displacement with flow, flow variability has little effect upon overall emigration timing for fish that are not at the necessary size thresholds for smoltification. Although emigration timing varies from year to year primarily due to changes in spawner timing, the predominant April-May peak in smolt emigration from Tuolumne is largely a reflection of the developmental timing following the November peak in spawning activity (Stillwater Sciences 2013). For the Tuolumne River Chinook salmon, as well as other LSJR tributary populations, fall-run timing occurs later in the year than for Sacramento River tributary populations (Williams 2006) and it is unlikely that this peak will change substantially under a variable flow regime without changes in spawning timing. As discussed previously, encouraging downstream rearing of early emigrating fry may result in heavy predation losses and lower subsequent escapement. While flow increases in late May and early June might possibly benefit the few remaining smolts emigrating at that time, since the vast majority have emigrated by this time the production benefits will likely not be represented in subsequent escapement.

Slide 35. Habitat Restoration. Although we generally concur that habitat restoration will benefit rearing conditions for salmonids in the LSJR tributaries, such efforts should be undertaken only after careful consideration of factors limiting individual life stages.

Slide 36. Key Messages. Comments by Summary points below:

- Life History Diversity. While contributions vary among years, they also appear to vary among tributaries and it appears that fry emigration strategies may not be viable for the Tuolumne River and likely (not examined here) in the Merced River. Improving the viability of all life history strategies should include a range of measures to improve emigration survival, particularly in the Delta. Missing from the life history diversity discussion is an analysis of the influence of hatchery origin spawners upon life history diversity of naturally produced fish. More simply, because 75-100% of returning fish to the Stanislaus and other LSJR tributaries appear to be of hatchery origin in recent years, the validity and strength of apparent rearing or emigration flow relationships should be carefully re-examined considering only progeny of natural origin fish.
- Early Fry Dispersal and Carrying Capacity. As shown by the RST data presented, flow increases have been shown to improve tributary outmigrant survival of all juvenile life stages. We generally concur that improvements in LSJR and Delta conditions through predator control, wetland and other habitat improvements may improve the viability of an early fry emigration strategy.
- Flow and Survival. Although not examined by the presentation, survival through the south Delta appears to be consistently low regardless of flow. For this reason, encouraging early fry dispersal may not result in measurable increases in subsequent

returns and it is likely that measures to improve rearing success to smolt sizes that have greater swimming performance relative to predators will lead to increased population viability.

2 REFERENCES

California Dept of Fish and Wildlife (CDFW). 2016. GrandTab Chinook salmon escapement data. California Central Valley, Sacramento and San Joaquin river systems, Chinook salmon escapement, hatcheries and natural areas. Anadromous Resources Assessment. CDFG, Fisheries Branch, Sacramento, California. April. Available for download at: http://www.calfish.org/ProgramsData/Species/CDFWAnadromousResourceAssessment.aspx

Grossman, G.D., 2016. Predation on fishes in the Sacramento – San Joaquin Delta: current knowledge and future directions. San Francisco Estuary and Watershed Science, 14(2)

Stillwater Sciences. 2013. Tuolumne River Chinook salmon Population Model Study. Prepared by Stillwater Sciences, Berkeley, California for the Turlock Irrigation District and Modesto Irrigation District. December.

Stillwater Sciences. 2016. Chinook Salmon Otolith Study Report (W&AR-11). Final Report. Prepared by Stillwater Sciences, Berkeley, California for the Turlock Irrigation District and Modesto Irrigation District.

Sturrock, A., J.D. Wikert, T. Heyne, C. Mesick, A.E. Hubbard, T.M. Hinkelman, P.K. Weber, G.E. Whitman, J.J. Glessner, and R.C. Johnson. 2015. Reconstructing the migratory behavior and long-term survivorship of juvenile Chinook salmon under contrasting hydrologic regimes. PLOS ONE. DOI:10.1371.

Turlock Irrigation District and Modesto Irrigation District (TID/MID). 2005. 2005 Ten Year Summary Report. Pursuant to Paragraph (G) of the 1996 FERC Order issued July 31, 1996. Don Pedro Project, No. 2299. April.

Whipple A, R. Grossinger, D. Rankin, B. Stanford, and R. Askevold. 2012. Sacramento–San Joaquin Delta historical ecology investigation: exploring pattern and process. Richmond (CA): San Francisco Estuary Institute. 225 p.

Williams, J.G. 2006. Central Valley salmon: a perspective on Chinook and steelhead in the Central Valley of California. San Francisco Estuary and Watershed Science 4(3).

APPENDIX E

Final Report

Thermal Performance of Wild Juvenile *Oncorhynchus Mykiss* in the Lower Tuolumne River: A Case for Local Adjustment to High River Temperatures

THERMAL PERFORMANCE OF WILD JUVENILE *ONCORHYNCHUS MYKISS* IN THE LOWER TUOLUMNE RIVER: A CASE FOR LOCAL ADJUSTMENT TO HIGH RIVER TEMPERATURE

FINAL REPORT
DON PEDRO PROJECT

Prepared for:

Turlock Irrigation District – Turlock, California

Modesto Irrigation District – Modesto, California

February 2017

Thermal Performance of Wild Juvenile *Oncorhynchus mykiss* in the Lower Tuolumne River: A Case for Local Adjustment to High River Temperature[1]

February 2017

Prepared for:

Turlock Irrigation District – Turlock, California
Modesto Irrigation District – Modesto, California

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[1] This work has been published in the peer reviewed literature as: Verhille CE, English KK, Cocherell DE, Farrell AP, Fangue NA (2016) High thermal tolerance of a rainbow trout population near its southern range limit suggests local thermal adjustment. *Conserv Physiol* 4(1): cow057; doi:10.1093/conphys/cow057.

FOREWORD

In July 2011, as part of the Don Pedro Hydroelectric Project (No. 2299) Federal Energy Regulatory Commission (FERC) relicensing proceeding, Turlock Irrigation Districts (TID) and Modesto Irrigation District (MID) (collectively, the Districts) proposed to study the influence of temperature on juvenile Tuolumne River *Oncorhynchus mykiss*, as part of a suite of investigations described in the Temperature Criteria Assessment (Chinook and *Oncorhynchus mykiss*) (W&AR-14) Study Plan, as provided in the Districts' Proposed Study Plan. In its December 2011 Study Plan Determination, FERC determined that the Districts were not required to complete the Temperature Criteria Assessment (Chinook and *Oncorhynchus mykiss*), but indicated that empirical data collected on the thermal capability of Tuolumne River fish would be considered in the Don Pedro Project relicensing proceeding.

The Districts elected to complete an investigation of the thermal performance of juvenile *O. mykiss* in the lower Tuolumne River, given the importance that empirical evidence on this subject would have in the relicensing proceeding. In June 2014, the Districts finalized the Local Adaptation of Temperature Tolerance of *O. mykiss* Juveniles in the Lower Tuolumne River Study Plan and posted the document to the Don Pedro Project relicensing website. On June 30, 2014, the Districts invited relicensing participants to attend, prior to the start of fieldwork, a site visit to observe the onsite laboratory set-up and a demonstration of the study approach and the equipment to be used. The demonstration, held on July 10, 2014, was attended by a representative from the California Department of Fish and Wildlife and members of the public. Fieldwork for the study began later that month and was completed in August. In January 2015, the Districts sent a draft study report to relicensing participants for 30-day review and comment. Comments on the draft study report were received from the Tuolumne River Trust, the California Sportfishing Protection Alliance, the State Water Resources Control Board, and the California Department of Fish and Wildlife (Appendix 5). The Districts provide responses to these comments in Appendix 6 of this report.

In November 2016, this study was published in the peer reviewed journal *Conservation Physiology*. The journal article is appended to this report as Appendix 7.

EXECUTIVE SUMMARY

The purpose of this study was to investigate the thermal performance of juvenile *Oncorhynchus mykiss* that populate the lower Tuolumne River in the Central Valley region of California with respect to the seasonal maximal water temperatures they experience during the summer months.

The study tested the hypothesis that the Tuolumne River *O. mykiss* population below La Grange Diversion Dam is locally adjusted to the relatively warm thermal conditions that exist in the river during the summer. The basis for this hypothesis is peer-reviewed scientific literature that indicates that salmonid species, including *O. mykiss*, can adjust to local thermal conditions. In the current study, *O. mykiss* were locally caught and tested, and then returned safely within ~ 1 day of capture to the Tuolumne River.

The experimental approach acknowledged the oxygen- and capacity-limited thermal tolerance (OCLTT) hypothesis, which proposes that the extremes of thermal tolerance are set by a fish's inability to supply oxygen to its tissues above and beyond a basic routine need. The experimental approach also acknowledged that every activity of a fish in a river (swimming, catching prey and feeding, digesting a meal, avoiding predators, defending territory, etc.) requires oxygen above and beyond a basic routine need and that salmonids have evolved to maximize their oxygen supply when they fuel muscles during exhaustive swimming. Consequently, the tests performed here directly measured how much oxygen can be maximally extracted from the water by a fish (its maximum metabolic rate; MMR) and how much oxygen is routinely needed by that fish to exist (its routine metabolic rate; RMR). These measurements were performed in a swim tunnel respirometer (the equivalent of an aquatic treadmill) at different test temperatures ranging from 13°C to 25°C. Then, by subtracting RMR from MMR, we determined over this temperature range the capacity of *O. mykiss* to supply oxygen to tissues above and beyond a basic routine need, which is termed the absolute aerobic scope (AAS = MMR - RMR) and defines the fish's capacity to perform the activities essential to complete its life history. Factorial aerobic scope (FAS = MMR/RMR) was also calculated as another way of expressing a fish's aerobic capacity. These measurements were performed over a wide range of test temperatures (13°C to 25°C), which allowed us to determine the dependence of aerobic capacity on water temperature. These short-term direct measurements of temperature effects on fish metabolism did not assess the potentially beneficial physiological and biochemical changes that would be associated with thermal acclimation during longer-term growth studies (i.e., weeks).

As expected, the routine need for oxygen of these fish (RMR) increased exponentially with test temperature from 13°C to 25°C (36 different fish each tested at a single temperature). For these same fish, MMR also increased over the same range of test temperatures, but to a lesser degree. As a result, the absolute capacity to supply oxygen to tissues above routine needs (AAS) reached a peak at 21.2°C (as modeled for all fish by a mathematical equation). Moreover, there was a wide temperature range around this optimum where AAS changed very little. For example, the statistical 95% confidence limit for peak AAS extended between 16.4°C and 25°C. Likewise, 95% of the numerical peak for AAS (i.e., 5.84 mg O_2 $kg^{-0.95}$ min^{-1}) could be maintained between 17.8°C and 24.6°C. By being able to maintain peak AAS across a range of test temperatures that clearly spans the 7-Day Average of the Daily Maximum (7DADM) criterion of 18°C set out by

EPA (2003) for Pacific Northwest *O. mykiss*, Tuolumne River *O. mykiss* population has a broader range of thermal performance than previously thought.

Thus, the physiological measurements presented in this report supports the hypothesis that the *O. mykiss* population found in the Tuolumne River downstream of La Grange Diversion Dam is locally adjusted to the relatively warm thermal conditions that typify the summer months. Indeed, all fish that were tested from 13°C to 24°C recovered quickly from an exhaustive swim test and then were successfully returned to the river. Some of these test fish were inadvertently recaptured up to 11 days later in their original river habitat and appeared to be in excellent condition when visually inspected. Also, three of the four fish tested at 25°C were successfully returned to the river after their arduous experimental tests. The upper thermal performance limit (i.e., the temperature where AAS is zero) for Tuolumne River *O. mykiss* could not be determined with the present experiments due to conditions set forth by the National Marine Fisheries Service (NMFS), but the present data suggest that it must lie above 25°C.

The conclusion of the study is that the thermal range over which the Tuolumne River *O. mykiss* population can maintain 95% of their peak aerobic capacity is 17.8°C to 24.6°C. Moreover, up to a temperature of 23°C, all test fish could at least double their routine oxygen uptake (a FAS value >2.0), which we suggest is sufficient aerobic capacity for the fish to properly digest a meal. Finally, based on a video analysis of the swimming activity of *O. mykiss* in the Tuolumne River, fish at ambient water temperatures were predicted to have an excess aerobic capacity well beyond that needed to swim and maintain station against the river current in their usual habitat.

These results support the hypothesis that the thermal performance of wild *O. mykiss* from the Tuolumne River represents an exception to that expected based on the 7DADM criterion set out by EPA (2003) for Pacific Northwest *O. mykiss*. Moreover, given that the average AAS remained within 5% of peak performance up to a temperature of 24.6°C and that all Tuolumne River *O. mykiss* maintained a FAS value >2.0 up to 23°C, we recommend that a conservative upper aerobic performance limit of 22°C, instead of 18°C, be considered in re-determining a 7DADM for this population.

This wide range of thermal performance for *O. mykiss* from the Tuolumne River is consistent with that found for *O. mykiss* populations already known to be high-temperature tolerant, such as the redband strain of rainbow trout (*O. mykiss gairdneri*) in the high deserts of Eastern Oregon and Idaho, steelhead trout from the south coast of California, and selected and hatchery-maintained strains of *O. mykiss* in Western Australia and Japan. Whether the high thermal performance that was demonstrated for the *O. mykiss* of the Tuolumne River downstream of La Grange Diversion Dam arose through genetic selection or physiological acclimatization was beyond the purpose and scope of the present study.

TABLE OF CONTENTS

Section No.	Description	Page No.

LIST OF FIGURES

LIST OF TABLES

LIST OF APPENDICES

LIST OF ABBREVIATIONS

7DADM	7-Day Average of the Daily Maximum
95% CI	95% Confidence Limits
AAS	Absolute Aerobic Scope (MMR-RMR)
AS	Aerobic Scope
BP	Barometric pressure
CTmax	Critical Thermal maximum
EPA	U.S. Environmental Protection Agency
ESA	Endangered Species Act
FAS	Factorial Aerobic Scope (MMR/RMR)
FL	Fork Length of the fish
ILT	Incipient Lethal Temperature
M	Mass of fish
MMR	Maximum Metabolic Rate
MR	Metabolic Rate
O_2	Oxygen
$O_2(A)$	Tunnel water oxygen concentration at beginning of seal
$O_2(B)$	Tunnel water oxygen concentration at end of seal
OCLTT	Oxygen- and Capacity-Limited Thermal Tolerance
PIT	Passive Integrated Transponder
RM	River Mile
RMR	Routine Metabolic Rate
T	Time
TBF	Tail Beat Frequency
T_{crit}	Critical Temperature when performance (e.g., aerobic scope) reaches zero
T_{opt}	Optimal Temperature when performance (e.g., aerobic scope) reaches a peak
T_p	Pejus Temperature when performance (e.g., aerobic scope) decreases from its peak. In the present study, T_p is set when absolute aerobic scope decreases to 95% of the peak capacity at T_{opt}
V	Tunnel volume
$\alpha(O_2)$	Solubility of oxygen in water
% O_2Sat	Percent saturation of oxygen in water

INTRODUCTION

The Tuolumne River has been significantly affected by human activity since the mid-1800s, including in-channel and overbank mining of gold and gravel, urban and agricultural encroachment, and water resource development. Summertime water diversions from the Tuolumne River near La Grange, CA have been occurring for over 120 years. These changes have contributed to a unique river habitat for the *O. mykiss* population that lives in the Tuolumne River downstream of the La Grange Diversion Dam located at River Mile 52 (RM 52). Year round, the Don Pedro Dam located near RM 54 releases cool water to the river (10-13°C) even during the hottest periods in summer. As this water flows downstream it can gain or lose thermal energy depending on its surrounding environment. In summer months, the average river temperature increases appreciably with distance downstream of the dam (see Appendix 1). At RM 49, for example, river temperature peaked at 20.2°C in July 2014. However, cooler river temperatures are associated with cloud cover and over night, and deeper ponds in the river do show some thermal stratification. In 2013, a detailed study of summertime temperatures in the Tuolumne River was performed between ca. RMs 3-37 (HDR 2014).

Based on observations from monitoring surveys conducted since 1997 (Ford and Kirihara 2010; Stillwater Sciences 2012), *O. mykiss* rearing habitat extends from RM 52 to ca. RM 30, with spawning habitat in 2013 documented from RM 50 to about RM 39 (FISHBIO 2013). Review of this information suggests that primary rearing habitat for *O. mykiss* since 1997 has been concentrated upstream of RM 39.6, where peak water temperatures have occasionally exceeded 27°C during the summer months. Therefore, the realized habitat of *O. mykiss* during summer presently covers a distance of ca. 12.4 river miles, where water temperature varies within the range of 11°C to 28°C. Any difference between where a fish actually lives (the realized habitat) and its fundamental habitat is determined by behavior (Matthews and Berg 1997).

Thermal Tolerance and Thermal Performance

Fundamental habitat of any animal is determined in part by its thermal tolerance limits to warm and cold. Even humans, who normally regulate body temperature at 37°C (98.4°F), quickly succumb if body temperature cannot be maintained below 45°C in extreme heat. However, the body temperature of a fish such as *O. mykiss* in the Tuolumne River is not regulated in the same way as that of humans. Instead, it is always the same as the surrounding river temperature, except for brief (seconds to minutes), non-steady states whenever a fish moves rapidly between regions of thermal stratification. Nevertheless, a fish warmed or cooled beyond its thermal limits will rapidly succumb, just like a human.

Scientists commonly measure the thermal tolerance limit of a fish using either incipient lethal temperature (ILT) or critical thermal maximum (CTmax) tests. An upper ILT test acutely exposes fish to a suite of elevated temperatures and reports the temperature at which 50% of the test fish succumb. In contrast, an upper CTmax test warms (ca. 0.3°C per min) a fish until it can no longer maintain its upright orientation and reports the temperature when 50% of the fish roll over. Fish can rarely live for more than a few minutes at its CTmax.

While CTmax values have been widely used to distinguish thermal tolerance differences among fish species, CTmax does not always discriminate more subtle physiological adjustments in thermal tolerance expected within a fish species in response to season and/or genetic differences. For example, a CTmax value of 29°C is reported for trout acclimated to temperatures ranging from 12 to 20°C (Table 1). While CTmax values for *O. mykiss* can certainly be similar over a wide range of thermal acclimation temperatures and populations, there are exceptions because CTmax can increase in some studies of thermal acclimation of *O. mykiss* (Table 1), as it does when killifish are thermally acclimated (Fangue et al. 2006). The sub-species redband trout has the highest CTmax for the genus *O. mykiss* and red-band trout live in dessert environment. Any insensitivity of the CTmax measurement likely stems from relatively short test exposure times (min) and the rapid but sometimes variable warming rates that are employed when measuring CTmax. Regardless, CTmax is always higher than the temperature that a fish can tolerate for hours to days and certainly higher than the temperature at which a fish can no longer swim aerobically.

Consequently, despite its relative ease of measurement, CTmax, which is a measure of thermal tolerance, is increasingly being replacing by fish biologists with metrics that measure thermal performance. Metrics such as growth are preferred because they have some ecological relevance but have the disadvantage of requiring 30 or more days for a fish to achieve sufficient growth to determine its optimal temperature (or range of temperatures) for growth. Also, growth studies indirectly assess the effects of temperature on fish energetics and usually require rearing fish in controlled conditions that do not account for the full range of bioenergetic functions necessary for survival in nature (e.g. foraging, migration, competition, predation avoidance).

An alternative metric for performance acknowledges that all activities of a fish ultimately require oxygen (O_2). Therefore, it is possible to directly assess a fish's need for and capacity to deliver oxygen and use these measures as an ecologically relevant metric of fish performance. Furthermore, by making such measurements over a range of temperature, as first done some 60 years ago (e.g., Fry 1947), it is possible to accurately characterize the thermal effects on a fish's ability to deliver oxygen to its tissues, which is a direct measurement of energetic capacity to support the bioenergetic functions necessary for survival in nature. Unlike growth studies that require wild fish to be removed from their natural environment into a controlled artificial environment for months, studies of oxygen uptake can be performed in days. While methods to characterize fish thermal performance using oxygen uptake have an extremely long history, watershed managers have only started to embrace these thermal performance metrics over the past decade. As a result, existing regulatory criteria tend not to have considered these metrics, which can be measured at a local scale.

7-day Average of the Daily Maxima (7DADM)

One of the thermal criteria used by EPA to protect fish is the 7-day average of the daily water temperature maximum (7DADM). The explicit recommendation in EPA (2003) for juvenile *O. mykiss* in summer rearing habitats is a 7DADM <18°C. A key study that influenced the current 7DADM criterion for *O. mykiss* from the Pacific Northwest is the growth study of Hokanson et al. (1977), which was reviewed in Issue Paper 5 (EPA 2001). Growth is considered as a very powerful integrator of environmental, behavioral and physiological influences of a fish's fitness.

Hokanson et al. (1977) measured growth of juvenile *O. mykiss* from the Great Lakes in Minnesota using constant and fluctuating (a daily temperature oscillation of ± 3.8°C) thermal regimes. *O. mykiss* grew maximally at 16-18°C, termed the optimum temperature (T_{opt}) for growth. However, there are a number of concerns with applying these results to *O. mykiss* from the Tuolumne River. Foremost, *O. mykiss* are not native to Minnesota; they are an introduced species. Second, the thermal and other environmental conditions in Minnesota are far from similar to those encountered by *O. mykiss* in the Tuolumne River (below we show clear scientific support for local thermal adaptation of fishes, including *O. mykiss*). Moreover, the work of Hokanson et al. (1977) pre-dated the routine statistical packages that can place a statistical 95% confidence interval (CI) around data such as growth and oxygen uptake. This is an important data gap because EPA (2003) states that: "*Each salmonid life stage has an optimal* ***temperature range*** *(our emphasis). Physiological optimum temperatures are those where physiological functions (e.g., growth, swimming, heart performance) are optimized. These temperatures are generally determined in laboratory experiments.*" Therefore, this key study established a temperature optimum for growth rather than a thermal range for peak growth performance. EPA (2003) recommends 20°C as the 7DADM criterion for salmon and trout migration. Curiously, this criterion acknowledges that Pacific Northwest *O. mykiss* have sufficient aerobic scope for the energetic demands of river migration at a temperature that is 2°C higher than the 7DADM for growth in juveniles (18°C). River migration can be the most energetically challenging activity a salmonid can undertake and certainly requires more energy allocation than is used for feeding and growth. A juvenile salmonid in a river or stream will hold station and use darting behavior to opportunistically capture food drifting downstream. Thus they need energy for periodic sprint and burst activities, plus the cost of digesting and assimilating the captured food (specific dynamic action or heat increment of digestion). Furthermore, Hokanson et al. (1977) discovered that "*At temperatures in excess of the growth optimum, mortality rates were significantly higher during the first 20 days of this experiment than the last 30 days.*" The implication of this observation is that a proportion of the test fish were either initially better suited for high temperature or became better suited after living for 20 days at a supra-optimal temperature when compared to the fish that died during the initial 20-day period.

In view of this uncertainty surrounding the applicability of the 7DADM for *O. mykiss* to *O. mykiss* in the Tuolumne River, we now review some of the literature that supports the possibility for local physiological acclimation or genetic adaptation to warm temperature within the *O. mykiss* genus.

Current Evidence for Local Physiological Acclimatization and Genetic Selection

Thermal acclimation is a physiological process whereby an ectothermic animal, such as a fish, can potentially perform better after being placed in a new environment. Thermal acclimation involves a suite of physiological and biochemical changes that occur over a period of several weeks. Thus, if a fish living in say 14ºC water is transferred to 20ºC, its performance would progressively improve as it acclimates to the new temperature. This processes is referred to as thermal plasticity within a species. The extensive knowledge on thermal acclimation among fish species dates back well into the 1940s. Thermal plasticity, however, has limits that vary from species to species, which is a result of thermal adaptation within a species.

As early as the late 1960s, Bidgood and Berst (1969) used upper ILT data to conclusively demonstrate that juvenile *O. mykiss* from four anadromous Great Lakes populations could thermally acclimate, i.e., warm acclimation increased their upper ILT. Likewise in California (CA) there is wide variation in the thermal performance curves for hatching success among different strains of *O. mykiss* (Myrick and Cech 2001). While this variability includes the Eagle Lake and Mt. Shasta strains, these two strains had been shown earlier to have a similar CTmax (Myrick and Cech 2000). Thus, in the early 2000s, evidence for thermal acclimation was extensive within the species *O. mykiss*.

Evidence for thermal adaptation within the species *O. mykiss* was limited at the time of Issue Paper 5 (EPA 2001). Nevertheless, the work did acknowledge the possibility of genetic adaptation by asking is there enough evidence for genetic variation within a species to warrant geographically-specific or stock-specific water temperature standards. The conclusion was *"The literature on genetic variation in thermal effects indicates occasionally significant but very small differences among stocks and increasing differences among subspecies, species, and families of fishes. Many differences that had been attributed in the literature to stock differences are now considered to be statistical problems in analysis, fish behavioral responses under test conditions, or allowing insufficient time for fish to shift from field conditions to test conditions"*. In fact, Issue Paper 5 (EPA 2001) cited (see its Table 1) Sonski (1983), who identified the T_{opt} for growth of redband trout (*O. mykiss gairdineri*) as 20°C, which is the highest value for the genus *O. mykiss*. Therefore, evidence did exist in the literature prior to 2001 that the genus *O. mykiss* can perhaps be genetically adapted to local environmental conditions.

Since 2001, the peer-reviewed scientific literature has provided ample and convincing support for thermal adaptation at the population level and among a wide variety of fish species (e.g., killifish populations on the Atlantic coast, Fangue et al., 2006; stickleback populations in the Pacific Northwest, Barrett et al., 2011). Importantly, included are salmon and trout species belonging to the *Oncorhynchus* genus. For example, Eliason et al. (2011) showed that populations of adult sockeye salmon (*O. nerka*) in British Columbia's Fraser River watershed are adjusted to perform best at the local temperature conditions that they experience during their spawning river migration. Indeed, their maximum aerobic swimming capacity is also well matched with the range of hydraulic challenges that the different populations face migrating upstream to their spawning area (Eliason et al. 2013).

In addition, wild populations of redband trout, a sub-species of *O. mykiss*, inhabit natural desert environments in Oregon and Idaho where summer stream water temperatures can exceed 30°C. New thermal performance studies provide evidence for local thermal adaptation of redband trout (Rodnick et al. 2004) and the redband trout's ability to genetically adapt when acclimated to a common set of experimental conditions has found support (Narum et al. 2010, 2013, Narum and Campbell 2015).

O. mykiss is an introduced fish species on every continent except Antarctica. Moreover, selective breeding of *O. mykiss* has been effective in selecting for high temperature tolerance. For example, Hartman and Porto (2014) found evidence for temperature-dependent growth and differences in feeding performance among three *O. mykiss* strains. Also, severe thermal exposures in a hatchery program in Western Australia have produced in just over 20 generations a line of *O. mykiss* that is thermally tolerant (Morrissy 1973; Molony 2001; Molony et al. 2004; Chen et al. 2015). During summer extremes, the juvenile *O. mykiss* continue to swim and feed even when water temperature reaches 26°C (Michael Snow, Department of Fisheries, Government of Western Australia, pers. comm.). The founder *O. mykiss* population for this thermally tolerant line was transplanted during the last century from CA with the intention of setting up a recreational fishery for *O. mykiss* in Western Australia. Japanese researchers have similarly selected a strain of rainbow trout that show high thermal tolerance (Ineno et al., 2005).

Therefore, clear and compelling scientific knowledge exists for local adjustments and genetic selection of high thermal performance of *O. mykiss*. This new knowledge has been largely added to the scientific literature subsequent to the 18°C 7DADM being identified for *O. mykiss* in the Pacific Northwest by the EPA (2003). EPA (2003) did acknowledge that local adjustment was possible and that well-designed studies could be used to identify site-specific thermal adjustments. The present study aims to provide such evidence for the *O. mykiss* population inhabiting the lower Tuolumne River.

Justification and Purpose of the Study

The primary purpose of this study is to determine the thermal performance of the sub-adult (100-200 mm fork length; FL) *O. mykiss* population that inhabits the lower Tuolumne River (LTR) to assess any local adjustment in thermal performance. Thermal performance was assessed as the range of temperatures over which juvenile *O. mykiss* can increase aerobic metabolic rate (MR) beyond basic needs. This aerobic capacity could be used for any of the normal daily activities of *O. mykiss* in the Tuolumne River during its normal life history (swimming, catching prey and feeding, digesting a meal, growing, avoiding predators, defending territory, etc.). Thus, MR measurements were used to determine the optimal temperature range for Tuolumne River *O. mykiss.*

This experimental approach is consistent with the oxygen- and capacity-limited thermal tolerance (OCLTT) hypothesis that has emerged as a conceptual model to assess thermal performance of aquatic animals and determine the fundamental thermal range for their distributions (Pörtner and Knust 2007; Pörtner and Farrell 2008). The OCLTT hypothesis proposes that the extremes of thermal tolerance will be set by a fish's inability to supply oxygen to its tissues above a basic routine need. The ecological relevance of the OCLTT hypothesis is exemplified through performance measurements in eelpout (*Zoarcidae viviparous*) and spawning Pacific salmon. The temperature at which oxygen supply to the tissues of eelpout becomes limiting closely corresponds with the temperatures where growth performance and abundance of eelpout decrease in the German Wadden Sea (Pörtner and Knust 2007). In spawning Pacific salmon, temperature ranges for upstream migration success correspond with the temperature range across which absolute aerobic scope is maximal (Eliason et al. 2011). More recently, Chen et al. (2015) demonstrated a broad thermal range for absolute aerobic scope in the thermally tolerant *O. mykiss* strain from Western Australia.

Salmonids are examples of fish that have evolved to maximize oxygen supply to exhaustive swimming muscles. Therefore, our experimental approach directly measured MR under two states: routine metabolic rate (RMR), representing how much oxygen is needed by an individual *O. mykiss* to exist in the Tuolumne River and maximum metabolic rate (MMR), representing how much oxygen can be maximally extracted from the water for its tissues, typically when swimming. The capacity of the fish to supply oxygen to tissues above and beyond a basic routine need is then calculated by subtracting RMR from MMR, which is termed the absolute aerobic scope (AAS = MMR - RMR). Therefore, AAS defines a fish's capacity to perform the activities essential to carry out its life functions.

Factorial aerobic scope (FAS = MMR/RMR) is another way of expressing aerobic capacity by characterizing how much a fish can increase oxygen uptake beyond routine needs (RMR). A key activity for survival in nature, namely feeding and digestion, is expected to require up to a doubling of a fish's RMR for a large meal (Jobling 1981; Alsop and Wood 1997; Fu et al. 2005; Luo and Xie 2008), i.e., an FAS value of 2 allows for proper digestion of a large meal.

Measurements of fish MR were obtained using the equivalent of an aquatic treadmill (a swimming tunnel respirometer) and at different test temperatures (from 13°C to 25°C). By mathematically modeling these data, the optimal temperature (T_{opt}) for the peak AAS could be established for juvenile *O. mykiss*. The T_{opt} window (or thermal range) is defined by Parsons (2011) as *"the range in temperatures where maximum aerobic scope is maintained*". In the present study, we use 95% of the peak AAS value to set the optimal thermal range (Figure 1; the two temperatures that bracket T_{opt} are termed a Pejus temperature, T_p). If, as predicted by the OCTTL hypothesis, a cardiorespiratory limitation exists for exercising salmonids during warming, AAS will decrease below 95% of peak AAS beyond the upper T_p, and often rapidly over just a few degrees before lethal temperatures are reached (Farrell 2009). The critical temperature (T_{crit}) is the temperature when there is no aerobic scope and therefore aerobic activities beyond basic needs, including swimming, are impossible. Thus, whenever a fish is warmed beyond its T_p, maximum oxygen delivery progressively fails to quantitatively keep up with the need for increased oxygen delivery just to maintain the resting state (Farrell 2009). As a result, the factorial aerobic scope (AMR/RMR) decreases with temperature. Thus, an important index when considering FAS is the temperature when FAS decreases below a value of 2 because it would not be possible to double RMR for the digestion of a large meal (Jobling 1981; Alsop and Wood 1997; Fu et al. 2005; Luo and Xie 2008).

Thus, the primary study goal is to determine if there is evidence for local temperature 'adjustment' in Tuolumne River *O. mykiss* by establishing the temperatures that set the thermal range for T_{opt} (at 95% of peak) and determining how rapidly AAS declines between the upper T_p and T_{crit} for Tuolumne River *O. mykiss*. This information should help define more accurate criteria for thermal performance of juvenile *O. mykiss* rearing in the lower Tuolumne River. Specifically, the temperature indices and the shape of the aerobic scope curve derived in the present study can also be compared with those of other *O. mykiss* populations and with the EPA (2003) recommendations.

While the curve relating AAS with temperature has been coined a Fry aerobic scope curve (Fry 1947), curves that describe the effect of temperature on a measure of organismal performance (e.g., RMR, MMR, AAS, growth) are more generally called thermal reaction norms (Huey and Kingsolver 1979; Schulte et al. 2011). Reaction norms typically have a shape in which the performance index increases with increasing temperature, reaches a peak at some intermediate temperature, and declines with a further temperature increase. Importantly, the specific shape and position of these performance curves can vary among species and in response to thermal variation in a fish's environment. The magnitude and timescale of environmental temperature exposure are both critical and persistent differences in local thermal conditions over evolutionary time scales may result in compensatory adaptive changes in local populations (Hochachka and Somero 2002). On a shorter time scale, and if temperature varies on a daily or seasonal basis at a given locality, fish may compensate for the temperature difference over weeks to months - termed thermal acclimatization for natural settings or simply thermal acclimation when only temperature is manipulated under controlled laboratory conditions. Fish can also respond immediately (seconds to hours) to acute thermal challenges using either behavioral (e.g., attraction and avoidance), or physiological and biochemical responses (e.g., changes in heart rate and heat shock proteins).

Although the theoretical basis for how patterns of thermal performance can be shaped by local thermal regimes is now well understood and this theory provides the framework for the present study, our study was not designed to distinguish between the mechanisms of local thermal adaptation (which implies a proven genetic change) and acclimatization. Consequently, rather than using the term 'adaptive', we say that the fish are acclimatized to the local conditions and will use the general term that fish are 'well adjusted' to local environmental conditions, if we find that to be the case. However, fish were sampled from the coldest section of their habitat and their response to acute warming was examined. Therefore, our short-term, direct measurements of temperature effects on fish oxygen uptake could not assess the likely beneficial effects of thermal acclimation due to conditions for fish removal set forth by the National Marine Fisheries Service (NMFS).

EPA (2003) also states that: "*Ecological optimum temperatures are those where fish do best in the natural environment considering food availability, competition, predation, and fluctuating temperatures. Both (sic lab-based and field based measurements) are important considerations when establishing numeric criteria.*" Importantly, Issue Paper 5 (EPA 2001) comments that "*Field testing of fish survival under high temperatures is not usually done. If such methods were feasible, the improved realism would be helpful.*" Therefore, the present experiments established a field laboratory beside the Tuolumne River so that the thermal performance of wild *O. mykiss* acclimatized to field conditions could be tested without prolonged transport and holding of fish.

Predictions and Alternate Predictions

Given the EPA (2003) 7DADM and the current scientific literature, it is possible to make two types of contrasting predictions for the upper thermal performance of wild *O. mykiss* captured from the Tuolumne River: a) predictions based on the EPA (2003) 7DADM criterion, and b) alternative predictions based on contemporary literature for local thermal adjustment.

Predictions Derived From EPA (2003)

Based on the EPA (2003) 7DADM criteria alone, one would predict that wild *O. mykiss* captured from the Tuolumne River for the present tests would show the following:

1. Routine metabolic rate (RMR) will increase exponentially until the test temperature approaches the upper thermal limit for *O. mykiss* (i.e., CTmax), which depending on the *O. mykiss* strain and acclimation temperature, is 26°C to 32°C (see Table 1).
2. Maximum metabolic rate (MMR) will increase with test temperature and reach a peak around 18°C according to the EPA criterion.
3. Absolute aerobic scope (AAS) has a T_{opt} around 18°C according to the EPA criteria.
4. AAS will rapidly decline at a temperature just above 18°C.
5. Factorial aerobic scope (FAS) will decline with increasing temperature, reaching a value < 2 (i.e., MMR is less than twice RMR) at a temperature just above 18°C.

Alternative Predictions for a Thermally Adjusted Population

Based on recent peer-reviewed studies, the present study tested the hypothesis that the Tuolumne River *O. mykiss* population below La Grange Diversion Dam is locally adjusted to the relatively warm thermal conditions that exist in the river during the summer. One would then predict that the results of the present study would show the following:

1. RMR will increase exponentially until the test temperature approaches the upper thermal limit for *O. mykiss* (i.e., CTmax), which is ca. 26°C to 32°C depending on the study.
2. MMR will increase with test temperature and reach a peak that is above 18°C.
3. AAS will have a T_{opt} that is above 18°C.
4. AAS will decline at a temperature above 18°C.
5. FAS will decline with increasing temperature, but maintain a value > 2 at temperatures above 18°C.

METHODS

Permitting Restrictions that Influenced the Experimental Design

Wild Tuolumne River *O. mykiss* were collected under National Marine Fisheries Service Section 10 permit # 17913 and California Fish and Wildlife Scientific Collecting Permit Amendments. No distinction was made between resident (rainbow trout) and anadromous (steelhead) life history forms, and both are referred to as *O. mykiss* throughout this document. For permitting purposes, these fish are considered as "ESA-listed California Central Valley steelhead, *O. mykiss*".

Fish collection (to a maximum of 50 fish) was allowed between RM 52.2 and RM 39.5, and between June 1 and September 30, 2014. Fish collections were not allowed at river water temperatures that exceeded 70°F (21.1°C). Incidental fish recaptures were authorized in addition to the initial take limit (n=50), with these reported as 'additional take' under the NMFS permit reporting conditions. Because indirect fish mortality was limited to 3 fish, no more than 2 fish were captured per day as a precautionary measure to limit indirect mortalities. Also, temperatures were not tested randomly and most of the highest temperatures were tested last to preclude premature termination of the work should there be high-temperature related mortality.

Preliminary experiments were performed with hatchery reared *O. mykiss* to ensure that all the equipment was fully functional and properly calibrated prior to testing wild fish. All experimental procedures were approved by the University of California Davis' Institutional Animal Care and Use Committee (Protocol # 18196). All fish capture and handling activities were conducted by experienced FISHBIO personnel.

Fish Collection, Transport, and Holding

Fish capture was conducted via seine net (0.32 cm nylon mesh, 1.8 m high, 9 m long). Several precautions were used during capture activities in order to minimize handling of non-target fish. These included 1-2 snorkelers in the water identifying *O. mykiss* of the target size range (100-200 mm) prior to seine sweeps, as well as the use of a mesh size allowing fish smaller than the target fork length to avoid capture. Captured fish within the target range were transferred to a partially submerged transport tank via a large scoop net to minimize handling and avoid air exposure during transfer. Each captured fish was scanned for presence of a PIT tag to ensure that the fish had not been tested previously. Upon capture, a water temperature logger (Onset Computer Corporation) was placed in the transport tank with the fish recording temperature at 15-min intervals through the duration of the fish holding/testing period. These loggers remained in the water with the fish throughout all transport, experimental protocols and handling until fish were returned to the river.

In total, 48 *O. mykiss* were captured between July 11 and August 13, 2014 (Appendix 2). Each fish was given a unique identification ('W' for wild, followed by a number between 01 and 48). Two fish were captured and tested daily using four capture locations (Figure 2). The fish ID, capture location (River Mile, RM), and any recaptures are shown in Figure 3 and summarized in Appendix 3. Most of the test fish (36) were captured from a single site (RM 50.7), 8 fish were captured at RM 51.6, 2 at RM 50.4 and 2 at RM 49.1 (Figure 3). Instantaneous water temperature and dissolved oxygen (DO) levels were recorded at the time of capture, and varied between 12.7 and 17.1°C. Temperature loggers were placed at RM 40, 42, 44, 46, and 48-50 from early June to late September, 2014. From the logged temperature data, 7DADM at each RM location was calculated and plotted in Appendix 1. Additional information about release locations, water temperatures, time of day, and general comments are summarized in (Appendix 2).

Fish were placed individually into 13-l plastic transport tanks, modified with numerous 0.8 cm diameter holes drilled at least 2.0 cm from the bottom to ensure sufficient water movement through the transport container. The fish, inside its transport tank, was placed into an individual insulated Yeti cooler filled with 25 l fresh river water and driven to the experimental field site (< 20-min journey). Water temperature and DO were re-measured in the transport tanks on arrival and fish were transferred from the coolers to outdoor holding tanks (300 l) filled with flow-through Tuolumne River water between 12.5 and 13.6°C. This water-to-water fish transfer minimized handling stress and eliminated air exposure.

The holding tanks received river water passed through a coarse foam filter then a 18-l gas equilibration column for aeration. This water was split between the holding tanks and the sump tank supplying the swim tunnels. Oxygen content in all vessels remained above 80% air saturation at all times. Time from fish capture in the river to placement into holding tanks ranged from 60 to 120 min. Fish remained in holding tanks for 60 to 180 min before being transfer to a swim tunnel respirometer.

Swim Tunnel Respirometry

Individual fish were tested in one of two, 5-l automated swim tunnel respirometers (Loligo, Denmark). As with the holding tanks, swim tunnels were supplied with Tuolumne River water but via a fine pressurized 20-µm pleated filter; then a 180-l temperature-controlled sump, which operated as a partial recirculating system; and an 18-l gas equilibration column. The sump was continuously refreshed with air-equilibrated river water, turning over the entire system every 80-90 min. Additionally, an aquarium grade air pump supplied air stones in each tunnel bath for aeration. For temperature control, water from the sump was circulated through a 9500 BTU Heat Pump (Aqua Logic Delta Star. Model DSHP-7), and returned to the sump through a high volume pump (model SHE1.7, Sweetwater®, USA), where two proportional temperature controllers (model 72, YSI, Ohio) were mated to one 800 W titanium heater each (model TH-0800, Finnex, USA), resulting in temperature control precision of ± 0.5°C across a temperature range of 12 to 26°C. To prevent buildup of ammonia waste in the water, ammonia-absorbing zeolite was kept in the system's sump and replaced weekly. Swim tunnel water baths were refreshed with the aerated sump water approximately every 20 min.

Water oxygen saturation was monitored using dipping probe mini oxygen sensors, one per tunnel, connected to AutoResp software through a 4-channel Witrox oxygen meter (Loligo). Water temperature in the swim tunnel was monitored with a temperature probe connected through the Witrox system and temperature loggers (see Fish collection, transport, and holding).

To limit disturbance of fish, swim tunnels were enclosed with black shade cloth. Above each tunnel, video cameras with infrared lighting (Q-See, QSC1352W, China) were mounted to continuously monitor and record (Panasonic HDMI DVD-R, DMR-EA18K, Japan) fish during swims and overnight routine metabolism measurements.

Measuring Metabolic Rates

All routine and swimming metabolic rates were measured using intermittent respirometry, a well-established technique that is the gold standard in fish biology (reviewed in Steffensen 1989; Cech 1990). A flush pump connected each tunnel chamber with an aerated external bath to allow control of tunnel sealing (during oxygen measurements) and flushing with fresh, aerated water. The pump was controlled automatically through AutoResp software and a DAQ-PAC-WF4 automated respirometry system (Loligo).

When the flush pump for the swim tunnel was off, no gas or water exchange occurred within the tunnel and so the oxygen level in the tunnel water declined due to fish respiration. Therefore, the rate at which oxygen declined in the tunnel was an estimate of aerobic metabolism. Oxygen drop (in mg O_2) was calculated for a minimum 2-min period when the tunnel was sealed. To restore oxygen levels in the swim tunnel, a flush pump connected to the external water bath refreshed tunnel water for periods of 2 to 5 min. Oxygen levels were never allowed to fall below 80% saturation. Swim tunnels were bleached and rinsed weekly to prevent accumulation of bacteria. At the beginning and end of the 2-month experiment, background oxygen consumption measures of both tunnels without fish were performed. No oxygen consumption for these controls was detected, even at the highest test temperature (25°C).

Two-point temperature-paired calibrations at 100% and 0% oxygen saturation were performed weekly on the oxygen probes. The 100% calibration was performed in aerated distilled water. The 0% calibration was performed in 150 ml distilled water with 3 g of sodium sulfite (Na_2SO) dissolved. Percent oxygen saturation was converted to oxygen concentration ($[O_2]$, mg O_2 l^{-1}) using the formula:

$$[O_2] = \%\ O_2Sat/100 \times \alpha(O_2) \times BP.$$

Where $\%O_2Sat$ is the percent oxygen saturation of the water read by the oxygen probes; $\alpha(O_2)$ is the solubility coefficient of oxygen in water at the water temperature (mg O_2 l^{-1} $mmHg^{-1}$); BP is barometric pressure in mmHg.

Metabolic rate (MR in mg O_2 $kg^{-0.95}$ min^{-1}) for resting and swimming fish was calculated according to the formula:

$$MR = \{[(O_2(A) - O_2(B)) \times V] \times M^{-0.95}\} \times T^{-1}$$

Where $O_2(A)$ is the oxygen concentration in the tunnel at the beginning of the seal (mg O_2 l^{-1}); $O_2(B)$ is the oxygen concentration in the tunnel at the end of the seal (mg O_2 l^{-1}); V is the volume of the tunnel (l); M is the mass of the fish (kg); T is the duration of the seal (min).

To account for individual variation in body mass, MR was allometrically corrected for fish mass using the exponent 0.95. This value is halfway between the life-stage-independent exponent determined for resting (0.97) and active (0.93) zebrafish (Lucas et al. 2014).

Experimental Protocol

Fish were placed individually into the swim tunnels between 1300 h and 1600 h on the day of capture. Water temperature in the swim tunnels was set to 13 ± 0.3°C (i.e., close to the habitat water temperature) and fish were given a 60-min adjustment period to this temperature prior to a 60-min training swim. Each tunnel was equipped with a variable frequency drive motor designed to generate a laminar water flow through the swimming section of the tunnel (calibrated to water velocity using a digital anemometer with a 30-mm vane wheel flow probe; Hönzsch, Germany). During the training swim, water flow velocity was gradually increased until the fish moved off of the tunnel floor and began to swim (usually at ca. 30 cm s^{-1}). Once the fish began swimming, water velocity was further increased to 5-10 cm s^{-1} above the initial swimming speed and held for 50 min. To complete the training swim, water velocity was increased to a maximum of 50 cm s^{-1} for the last 10 min, which was the expected maximum swimming velocity of 150 mm fish at 13°C (Alsop and Wood 1997). Previous studies have shown that training swim protocols result in better swimming performance in critical swimming velocity tests performed the next day (Jain et al. 1997).

Fish then recovered for 60 min at 13±0.3°C before water temperature was increased to the test temperature for each pair of fish (ranging from 13 to 25°C). Water temperature was increased in increments of 1°C 30 min^{-1} and the time that the test temperature was reached was noted, which for the highest test temperature (25°C) took ca. 24 h. Thus, all fish in the study reached their test temperature at least 8 h before swimming tests began the following morning. Measurements of MR began 30 min after the fish reached the test temperature and continued until 0700 h. The lowest four MR measurements collected during this overnight period were averaged to estimate RMR.

Critical swimming velocity tests at the test temperature began between 0800 h and 0900 h for each fish. MMR was measured in two phases: a critical swimming velocity test followed by a burst swimming test. For the critical swimming velocity test, water velocity was again gradually increased until the fish moved off of the chamber floor and began to swim. Once a fish was swimming consistently, water velocity was gradually increased to 30 cm s^{-1} over a 10-min period and then held at 30 cm s^{-1} for 20 min. If a higher initial swimming velocity was required to elicit continual swimming, the fish was held at this initial velocity for 20 min as its first test velocity. Water velocity was then increased in increments of 3 to 6 cm s^{-1} every 20 min until the fish failed to swim continuously. The velocity increment was set to ~10% of the previous test velocity, i.e., if the previous test velocity was between 20 to 39 cm s^{-1}, the velocity increment was 3 cm s^{-1}; when the previous test velocity was between 40 to 49 cm s^{-1}, the velocity increment was 4 cm s^{-1}. Active metabolic rate was monitored at each test velocity by closing the tunnel for either two 7-min or one 17-min measurement periods after the first 3 min of being flushed with fresh water. Water in the tunnel never dropped below 80% air saturation, which is an oxygen level expected to be considered normoxic. At the end of a measurement period, the next test velocity began with a 3-min flush period. Whenever a fish fell back in the swimming chamber and made full body contact with the downstream screen in the tunnel, water velocity was lowered to 13 to 17 cm s^{-1} for 1 min, and the 20-min timer stopped. After a 1-min recovery, the test velocity was gradually restored over a 2-min period and then the 20-min timer was restarted. Failure velocity was defined when the fish fell back to the downstream screen a second time during the same test velocity. The time of this failure velocity was noted.

For each test velocity, video recordings were observed for quantification of tail beat frequency (TBF measured in Hz). Three 10-s sections of video, where the fish was continuously holding station without contact with the downstream screen, bottom or side of the tunnel were identified. If three replicates were not possible throughout the entire 20-min interval, two replicates were used. If only one replicate was possible, that interval was not quantified. For each of the three (or two) sections, video was slowed to 1/4 to 1/8 of real time speed, and the number of tail beats were counted over 10 s of real time. The 2 or 3 replicates were then averaged. The same methodology was applied to video recordings taken of fish swimming in the river at temperatures of 14°C and 20°C during the study period.

Approximately 50% of the wild fish did not respond as expected to the critical swimming velocity protocol, but instead used their caudal fin to prop themselves on the downstream screen to avoid swimming. This behavior was regularly observed at test velocities well above the measured maximum swimming velocity for other fish. Consequently, to estimate MMR for these fish, swimming activity was evoked by rapidly increasing water velocity to a transient velocity stimulus of 70 to 100 cm s^{-1} (increase over 10 s and hold for 30 s or less), then decreasing the velocity back to the test velocity. Fish tended to briefly burst swim off of the downstream screen when velocities exceeded 70 cm s^{-1}. After the transient velocity increase, the fish was allowed to swim without interference (at the test velocity) as long as it continued to swim. For some fish, it was necessary to apply the transient velocity stimulus several times to keep the fish swimming. These fish were otherwise swum identically to fish that swam continuously; i.e., with 20-min test velocity periods and with metabolic rate measurements taken during each test velocity period. Failure for these fish was considered to occur when the fish did not swim upstream to prevent contact with the downstream screen, despite the water velocity being increased to 100 cm s^{-1} and returning to test velocity three times. After a critical swimming velocity trial was terminated, all fish were allowed to recover at velocities of 13-17 cm s^{-1} for 20 min.

The subsequent burst swimming test entailed a series of metabolic rate measurements taken at higher, short-duration (30-s) water velocities. To begin the burst swimming test, the water velocity was reset to the initial critical swimming velocity test increment specific to the individual fish—i.e., the first velocity increment at which the fish swam continuously for 20 min. The burst swimming protocol involved swimming a fish at its initial critical swimming velocity test increment for up to 10 min before the water velocity was rapidly increased over ca. 10 s to the maximum speed the fish could swim without contacting the downstream screen and held for ca. 30 s (or less if the fish fell back on to the downstream screen). After the 30-s burst, the velocity was decreased back to the initial critical test velocity for ca. 30 s. This protocol was repeated multiple times for at least 5 min and up to 10 min. Metabolic rate was measured for these fish by flushing the tunnel for the first 3 min of the 10-min continuous swim, then sealing the tunnel for the remaining time. Similarly, the tunnel was flushed for no more than the first

3 min of the 10-min burst swim, and sealed for the remaining time. After completion of the burst swim protocol, fish were allowed at least 60 min of recovery at the test temperature.

Following the 1-h recovery period after the swim tests, water temperature in the tunnels was lowered to ca. 13-15°C over a 30-min period. Fish were then transferred into the individual transport tanks and placed in the flow through holding tanks before measurement and tagging procedures. Fish were anaesthetized for < 5 min with CO_2 (produced by dissolving 2 Alka-Seltzer tablets in 3 l river water) and without losing gill ventilatory movements. The fork length (FL, mm) and mass (g) for each fish was measured, and half duplex PIT (Oregon RFID) tags were placed into the abdominal cavity of the fish through a 1-mm incision through the body wall, just off center of the linea alba. All equipment was sterilized with NOLVASAN S prior to tagging, and wounds were sealed with 3M VetBond. Fish were returned to the transport coolers filled with 13-15°C river water to revive (observed to swim and maintain equilibrium) before being transported to the river capture site for release. At the release site, river water was gradually added to the transport cooler to equilibrate the fish to river water temperature at a rate of 1-2°C h^{-1} before release. Once the acclimated to the river temperature, fish were allowed to swim away volitionally.

To summarize, prior to release back to the river, all fish were subjected to:

- a 1-h adjustment period in the swim tunnel at 13°C;
- a 1-h training swim at 13°C that began at ca. 1600 h;
- a 1-h recovery period at 13°C before the water temperature was warmed to the test temperatures;
- holding at the test temperature for at least 8 h before testing for MMR;
- swimming at various activity levels for minimally 2 h and maximally 6 h until they reached exhaustion;
- a 1-h recovery period at test temperature;
- decrease from test temperature to 13-15°C over 30 min; and
- morphometric measurement and tagging.

Data Quality Control, Model Selection and Analyses

Routine metabolic rate quality control (QC) was performed by visually inspecting over night video recordings for fish activity. Data from any fish showing consistent activity over night was discarded. Data from three fish (W7, W8, and W17) were discarded based on this criterion. RMR was calculated by averaging the lowest 4 metabolic rate measurements from 30 min after the fish reached the test temperature to 0700 the next morning.

There were two methods of establishing MMR: 1) Swimming (critical swimming velocity and burst performance), and 2) Agitated behavior (i.e., random movements and struggling) in the tunnel. QC criteria for MMR involved assessment of fish behavior in the tunnel via the video, and MR response to incremental increases in tunnel speed. MMR was reported as the single highest MR measurement. The highest MRs observed in this study were concurrent with fish exhibiting intense agitation. For fish not exhibiting intense agitation, the swimming MMR was used as overall MMR. Four of these 'non-agitated' fish (W2, W13, W14, and W15) were discarded due to failure of MR to increase incrementally despite continuous station-holding swimming with tunnel velocity increases of more than 15 cm s^{-1}.

Four different relationships were examined: 1) RMR versus test temperature, 2) MMR versus test temperature, 3) AAS versus test temperature, and 4) FAS versus test temperature. Model fitting was performed in R (http://cran.r-project.org) using the 'lm' function. Four different models were tested: linear, quadratic, antilog base 2, and log base 2 model. To select the model that best described each data set, the r^2 and residuals of each model type were compared. The model with the highest r^2 was chosen, except, when the r^2 of different models were identical, the model with the lowest residual SE was chosen. Confidence intervals and predicted values based on the best-fit model were calculated using the 'predict' function, also in R.

RESULTS

The experimental data table, including raw RMR, MMR, AAS, and FAS data for individual fish are presented in Appendix 4.

1. Routine metabolic rate (RMR) increased exponentially over the range of test temperatures from 13°C to 25°C. This thermal response was fitted with a statistically significant ($P=5.83x10^{-13}$) relationship (Figure 4A), where:

   RMR (mg O_2 $kg^{-0.95}$ min^{-1}) = $5.9513 - 0.5787x + 0.02x^2$

   x = temperature (°C).

   Thus, RMR at 13°C averaged 2.18 ± 0.45 (95% CI) mg O_2 $kg^{-0.95}$ min^{-1} and reached 5.37 ± 0.41 (95% CI) mg O_2 $kg^{-0.95}$ min^{-1} at 25°C. Consequently, the fish's oxygen demand (cost of basic living) increased by 2.5-fold over the 12°C range for test temperature.

   These results for RMR are consistent with our prediction #1 derived from EPA (2003) criteria and the identical alternative prediction #1. They state that RMR should increase exponentially until the test temperature approaches the upper thermal tolerance limit for *O. mykiss*, which according to published CTmax values is 26°C to 32°C (see Table 1). This prediction could not be fully tested because permitting restrictions prevented test temperatures higher than 25°C, a temperature that is clearly lower than the CTmax because fish survived and even swam for several hours at 25°C.

2. Maximum metabolic rate (MMR) increased linearly with test temperature up to the maximum test temperature of 25°C. This thermal response was fitted with a statistically significant ($P=8.94x10^{-7}$) relationship (Figure 4B), where:

   MMR (mg O_2 $kg^{-0.95}$ min^{-1}) = $1.6359 + 0.3835x$

   x = temperature (°C)

   Thus, MMR at 13°C averaged 6.62 ± 1.03 (95% CI) mg O_2 $kg^{-0.95}$ min^{-1} and increased up to 11.22 ± 0.86 (95% CI) mg O_2 $kg^{-0.95}$ min^{-1} at the highest test temperature (25°C). Consequently, the maximum oxygen delivery at 25°C was 1.7-times greater than that at 13°C.

   These results for MMR are inconsistent with our prediction #2 derived from EPA (2003) criteria where MMR was expected to peak near to 18°C. Instead, these MMR results are consistent with our alternative prediction #2 that the Tuolumne River population of *O. mykiss* is locally adjusted to warmer temperature, as demonstrated by peak MMR occurring at least 7°C higher than 18°C.

3. Absolute aerobic scope (AAS) was largely independent of test temperature over the range 13-25°C. Indeed, it was only at the two extremes of test temperature that any change in

AAS was statistically discernable. Because of the weak dependence of AAS on test temperature, the best statistical model for these AAS data only approached statistical significance (P=0.06; Figure 4C) where:

AAS (mg O_2 $kg^{-0.95}$ min^{-1}) = $-5.7993+1.1263x -0.0265x^2$

x = temperature (°C).

This mathematical relationship generated a T_{opt} at 21.2°C with a peak AAS of 6.15 ± 0.71(95% CI) mg O_2 $kg^{-0.95}$ min^{-1}.

These results for AAS are inconsistent with our prediction #3 based on EPA (2003) criteria, but are consistent with our alternative prediction #3 that the Tuolumne River population of *O. mykiss* is locally adjusted by having T_{opt} for AAS that is greater than 18°C, i.e., 21.2°C.

4. Contrary to our prediction #4 and our alternative prediction #4, AAS did not significantly decline above the optimal temperature. In fact, the numerical change in average AAS was surprisingly small over the entire test temperature range. Thus, rather than having a well-defined peak to the AAS curve, as expected for fish with a narrow thermal range and as schematically depicted in Figure 1, the results revealed a rather flat curve more similar to one typical of a temperature generalist. Simply, *O. mykiss* in the lower Tuolumne River were able to maintain peak AAS over a wide range of test temperatures well above 18°C. This fact can be best illustrated by two metrics, the thermal range for the statistical 95% CI of AAS and the T_{opt} window for 95% of the peak AAS (i.e., 5.84 mg O_2 $kg^{-0.95}$ min^{-1}).

   The statistical 95% confidence limits for peak AAS extend from 16.4°C to 25°C. Consequently, the numerical decrease in average AAS from 6.15 ± 0.71(95% CI) mg O_2 $kg^{-0.95}$ min^{-1} at T_{opt} to 5.78 ± 1.09(95% CI) mg O_2 $kg^{-0.95}$ min^{-1} at 25°C was only 6% and did not reach statistical significance. Indeed, the AAS measured at 24.5°C (5.89 ± 1.05 (95% CI) mg O_2 $kg^{-0.95}$ min^{-1}) was numerically identical to that measured at 18°C (5.89 ± 0.80 (95% CI) mg O_2 $kg^{-0.95}$ min^{-1}). But when measured at 13°C, AAS was 4.36 ± 1.21(95% CI), which was below the 95% CI for the peak AAS value. The numerical 95% peak AAS could be maintained from 17.8°C to 24.6°C, which is a more conservative thermal range for T_{opt}.

5. Although individual variability in FAS was considerable, on average the Tuolumne River population of *O. mykiss* could at least double their RMR across the entire test temperature range from 13 to 25°C. On an individual fish basis, a FAS value exceeding 3.5 was achieved in individual fish tested at 13, 16, and 22°C. Factorial aerobic scope (FAS) declined with temperature. This thermal response was fitted with a statistically significant ($P=2.92x10^{-4}$) relationship (Figure 4D) where

   FAS = $2.1438 + 0.1744x -0.0070x^2$

x = temperature (°C).

Consequently, the average FAS at 13°C was 3.32 ± 0.41 (95% CI) and decreased to 2.13 ± 0.33 (95% CI) at 25°C. This result is inconsistent with our prediction #5 derived from EPA (2003) criteria, but consistent with our alternative prediction #5 that FAS will remain above a value of 2 at temperatures well above 18°C. Indeed, all individual fish tested up to 23°C had a FAS value >2, with only 4 out of 14 fish tested at 23°C, 24°C and 25°C having a FAS value <2.

6. During swim tests at test temperatures of 14°C and 20°C, a statistically significant linear relationship ($P=2.05 \times 10^{-5}$ for 14°C and 0.009 for 20°C) was determined between MR and Tail Beat Frequency (TBF) (Figure 5).

   For fish tested at 14°C, this relationship was:
   $$MR\ (mg\ O_2\ kg^{-0.95}\ min^{-1}) = 0.75\ (TBF) + 1.05$$

   For fish tested at 20°C, this relationship was:
   $$MR\ (mg\ O_2\ kg^{-0.95}\ min^{-1}) = 1.04\ (TBF) + 1.89$$

   Video analysis of fish in the lower Tuolumne River at 14°C and 20°C revealed that a fish holding station against a river current required a TBF of 2.94 and 3.40 Hz, respectively. From these TBF values, it was possible using Figure 5 to interpolate a MR associated with *O. mykiss* holding station in normal habitat against the Tuolumne River current. These values were 3.26 mg O_2 $kg^{-0.95}$ min^{-1} at 14°C and 5.43 mg O_2 $kg^{-0.95}$ min^{-1} and 20ºC. These estimates indicate that the cost of holding station increased MR by 1.50- and 2.04-fold, respectively, and used up about half of the available FAS (67% and 49%, respectively) at these two temperatures. This meant that the remaining FAS was 2.0 at 14°C and 1.7 at 20°C.

7. After exhaustive exercise, fish quickly recovered their RMR without any visible consequences when they were inspected before being returned to the river. After a 60-min recovery period, MR either had returned to RMR, or was no more than 20% higher than RMR. There were only two exceptions to this generality. Two fish tested at 25°C regurgitated rather large meals of aquatic invertebrates during the recovery from the swim test, and one of these fish died abruptly during the recovery period. No other fish mortality occurred as a result of testing the fish.

   Further evidence of post-release recovery was provided by the six fish that were inadvertently recaptured 1 to 11 days after they had been tested and returned to the river (Figure 3, Appendix 3). All these fish were recaptured in their same habitat unit and within 20 m of the original capture location. All recaptured fish were visually in good condition. Three of these recaptured fish had been tested at one of the highest test temperatures, 23°C.

DISCUSSION

Data Quality

This report contains the first metabolic rate data for the Tuolumne River *O. mykiss* population, which were used to characterize their capacity for aerobic performance over a wide test temperature range, one that extended above 18°C. The absolute values for RMR and MMR can be compared with the scientific literature even though caution is needed whenever differences exist in body mass, acclimation temperature, populations and species among the studies.

As a generality, a doubling or tripling of RMR is considered a normal biological response for an acute 10°C temperature change (Schmidt-Nielsen 1994). For the Tuolumne River *O. mykiss* population, RMR increased by 2.5-times for a 12°C change, from 2.18 mg O_2 $kg^{-0.95}$ min^{-1} at 13°C to 5.37 mg O_2 $kg^{-0.95}$ min^{-1} at 25°C. By comparison, a study of thermally acclimated and smaller sized (5-7 g) Mount Shasta and Eagle Lake *O. mykiss* found that RMR was similar (2.3-2.8 mg O_2 $kg^{-0.95}$ min^{-1}) at 14°C, but lower (2.9-3.1 mg O_2 $kg^{-0.95}$ min^{-1}) at 25°C (Myrick and Cech 2000, Table 2). Similar RMR values are reported in a wide range of studies for juvenile salmonids (Table 2). Also, when compared with other field-based measurements, but on wild adult salmon (coho, pink and sockeye) at temperatures of 10-16°C (2.9 – 4.3 mg O_2 kg min^{-1}; Farrell et al. 2003), the RMR measured in this study for *O. mykiss* was again lower at these temperatures.

The main methodological challenge with accurately measuring RMR in fish is eliminating spontaneous locomotory activity, which can potentially elevate MR in salmonids more so than any other activity. (Note: An overestimate of RMR reduces the AAS estimate). Therefore, considerable effort was used to select the minimum MR rate measurements to estimate RMR and to use video analysis to confirm that the fish were inactive during the MR measurement, an additional quality control measure that was introduced by Cech (1990). As a result, the variance for RMR of Tuolumne River *O. mykiss* was small despite the fact that the measurements were field-based. The variance was much less than that reported for a field study with adult sockeye salmon (individual RMR values varied by about 2-times) where the experimental protocol was limited to only one RMR measurement (Lee et al. 2003). As a result of this low variance, the statistical model explained 80% of the variance in RMR. Therefore, we are confident in the RMR measurements generated for this report.

Normally, RMR is measured in a post-absorptive state (i.e., following a period of starvation for usually 24 h) because the digestive process is an activity that requires an increase in RMR (Jobling 1981). In the present study, however, the digestive state of the wild fish could not be controlled because the fish would take a day or longer to fully digest a meal and return to a post-absorptive state (Jobling 1981). In fact, feces were regularly found in the swim tunnels after the overnight acclimation period, which indicated that fish in the river were feeding and that the digestive process had continued for at least part of the overnight period. Therefore, although the present measurement of RMR could have been elevated by a variable contribution for digestion, our RMR values still agree with, or fall below, comparable literature values, suggesting that digestion was not a major contributor to the RMR values measured here. Nevertheless, we cannot be certain that we measured standard metabolic rate (SMR), which is more typically used in traditional laboratory experiments to assess AAS. SMR would be lower than RMR, which would result in an underestimate of AAS and FAS when compared with literature that used SMR for these estimates.

The methodological challenge with accurately measuring MMR in wild fish is that fish vary in their willingness to participate in forced activity because they are naive to the holding conditions and to the actual swim challenge. Thus, while it is impossible to overestimate MMR and AAS, MMR and AAS can be underestimated if a fish chooses not to swim maximally. While it is possible that MMR, and therefore AAS, were underestimated in this field study, we gave the wild fish a training swim and then used four different testing protocols to generate a MMR measurement to minimize this complication. Indeed, because some of the wild Tuolumne River *O. mykiss* were reluctant to perform a U_{crit} protocol, a burst swimming protocol was used to generate MMR. The four protocols were:

1. continuous swimming with incremental increases in velocity;
2. a combination of continuous swimming and short velocity bursts to push fish off of the downstream screen;
3. a 10-min burst protocol of alternating 30 s of a very high velocity burst with 30 s of low velocity burst (aimed at maintaining moderate swimming); and
4. spontaneous intense activity during RMR measurements (rarely used, but sometimes MR was greater than the for other 3 protocols).

For Tuolumne River *O. mykiss*, the linear regression of MMR versus temperature estimated that MMR at 13°C was 6.62 mg O_2 $kg^{-0.95}$ min^{-1} and increased to 11.22 mg O_2 $kg^{-0.95}$ min^{-1} at 25°C. The statistical model for MMR explained 50% of the individual variance for the *O. mykiss* tested. We are unaware of any data in the literature assessing the response of MMR to warming in juvenile *O. mykiss*, other than the recent study on thermally tolerant *O. mykiss* (~30 g) tested in Western Australia. These fish had a peak AAS of ~10 mg O_2 kg^{-1} min^{-1} that was similar when tested at both 18ºC and 20ºC, but decreased when measured at 25ºC, the only other test temperature examined above 20ºC (Chen et al. 2015). These authors report that 90% of peak AAS was maintained between 13ºC and 20ºC. Also, the average MMR value 7.4 mg O_2 $kg^{-0.95}$ min^{-1} here at 15°C is at the high end of the range (2.9 to 8.3 mg O_2 $kg^{-0.95}$ min^{-1}) reported in the literature for smaller (2-13 g) *O. mykiss* (Table 2). Also at 15°C, we found an average AAS of 5.1 mg O_2 $kg^{-0.95}$ min^{-1} and FAS of 3.2, both of which were on the high end of the range of reported values in the literature (1.8-5.8 mg O_2 $kg^{-0.95}$ min^{-1} and 2.2-5.8, respectively, Table 2). When compared with similar field measurements on wild adult salmon (coho, pink and sockeye) at temperatures of 10-16°C (8.6-12.6 mg O_2 kg min^{-1}; Farrell et al. 2003), the MMRs measured here overlap with the lower end of this range. The individual variation for MMR was greater than that for RMR in Tuolumne River *O. mykiss*, but less than the individual variation reported for MMR values in a field study of adult sockeye salmon (Lee et al. 2003). It is interesting that the variation in MMR correlated with behavior, such that the fish that displayed frequent spontaneous activity during RMR and U_{crit} tests had the highest MMR within a temperature group. Fish that swam continuously throughout a U_{crit} test without many extra stimuli to encourage swimming invariably had the next highest MMR. The lowest MMR was for fish that propped themselves with their caudal fin to avoid swimming despite repeated stimuli with short velocity bursts and this behavior may have resulted in an underestimate of MMR.

Reaction norms, defined by the shape of the response curves in Figure 4, allow for proper mathematical and statistical consideration of the thermal range of performance, a concept that is fully endorsed by EPA (i.e., the 7DADM designation "*recognizes the fact that salmon and trout juveniles will use waters that have a higher temperature than their optimal thermal range.*"). Indeed, given the rather flat reaction norm centered around a T_{opt} of 21.2°C shown here for the Tuolumne River *O. mykiss,* it is certainly more appropriate to talk about a thermal range of performance. Thus, given the good agreement with existing literature for MR measurements combined with the fact that the shape of the response curves will be independent of the methodological concerns noted above, we are confident in using these response curves to test the predictions based on EPA (2003) and our alternative predictions.

Evidence for Local Thermal Adjustment

Our predictions based on EPA (2003), as listed above, assumed that the Tuolumne River *O. mykiss* population would perform similarly to Pacific Northwest *O. mykiss* populations used to set the 7DADM by EPA (2003). Our alternative predictions, however, allow for the possibility of local thermal adjustment to a warmer river habitat. Collectively, the results show clear deviations from our predictions based on EPA (2003), and consistency with the alternative predictions, which suggests the likelihood that the Tuolumne River *O. mykiss* population is locally adjusted to warm thermal conditions. In particular, the T_{opt} for AAS was 21.2°C, markedly higher than 18°C. Furthermore, AAS at 18°C was numerically the same as that at 24.5°C. Therefore, we discovered that the Tuolumne River *O. mykiss* population has a wide thermal range for optimal performance. Indeed, one fish was inadvertently recaptured in good visual condition from its original habitat location in the Tuolumne River 11 days after being tested at 23°C for 14 h and performing demanding swim tests. All the same, given that the CTmax could not be determined in the present work and that MMR increased up to the highest test temperature (25°C), it was impossible to determine the upper thermal limit when MMR collapses, which means that alternate metrics must be used to set the upper thermal limit for the Tuolumne River *O. mykiss* population.

The present work provides three useful metrics of the optimal temperature range for the Tuolumne River *O. mykiss* population. Using the T_{opt} of 21.2°C for the mathematical peak of AAS, the least conservative metric is the thermal range that is encompassed by the 95% CI for peak AAS, which set the thermal optimum range between 16.4°C and 25°C. The next metric, which was nearly as conservative as the first, is the thermal range where AAS remained numerically within 5% of the peak AAS at 21.2°C, which set the thermal optimum range between 17.8°C and 24.6°C. The small difference between these two temperature ranges is more a result of the individual variation in the data. The third and most conservative metric defines the temperature range where the FAS value for every fish tested was >2, which would set the thermal optimum range between 13 and 22°C, although the average FAS value was 2.13 at 25°C. Thus, the performance of the Tuolumne River *O. mykiss* population remained sufficiently elevated well beyond 18°C, which is compelling evidence of local adjustment to warm conditions.

Yet, there were important indications that the thermal testing and intensive swim imposed on them outside of their normal habitat over a 24-h period taxed a small percentage of individuals at temperatures of 23-25°C. In the present study, the telltale signs were that 4 out of 13 individuals tested at 23-25°C had a FAS < 2. Similar to the present study, Chen et al. (2015) report that FAS was 1.4-1.8 at 25ºC for the thermally tolerant *O. mykiss* in Western Australia. In the next section, we suggest that fish need a FAS value of about 2 for proper digestion of a meal. Interestingly, two fish regurgitated their stomach contents at 25°C, a symptom common during extreme athletic exertion in humans when metabolic rate over-taxes oxygen supply. Such individual variability in upper thermal performance is not unexpected. Indeed, Hokanson et al. (1977) reported heightened mortality only during the initial 20 days of a growth trial for *O. mykiss* at supra-optimal temperatures. Lastly, the only fish mortality occurred in the recovery period (a phenomenon known as 'delayed mortality') after one fish was tested at 25°C.

Ecological Relevance of the Present Findings

Establishing ecological relevance of physiological data, such as those collected for the present report, has always been a challenge because of the multiple factors that influence fish distributions, behaviors and performance in the wild. Here, we measured the aerobic capacity of the Tuolumne River *O. mykiss* population in a field setting to improve the ecological relevance by minimizing fish transport and handling. After a rapid recovery from our exhaustive swim and thermal tests (as seen the 60-min recovery of MR after the swimming test), test fish appeared to reestablish their original habitat in the Tuolumne River because a portion of them were inadvertently recaptured in the river within 20 m of their original capture site. This excellent recovery behavior from intense testing seemed to be independent of the test temperature because fish were recaptured after a wide range of test temperatures (16-23°C; see Appendix 3)

To provide ecological relevance to physiological findings some 60 years ago, Fry (1947) introduced the concepts of a fish being metabolically loaded and metabolically limited to explain environmental effects on fishes. Simply put, a metabolic load from an environmental factor increases the oxygen cost of living (e.g., it costs energy to detoxify a poison, or, as in the present study case, a thermal increase in RMR). Conversely, a metabolic limit from an environmental factor decreases the MMR, leaving less oxygen available for activities. More broadly, the allocation of energy and tradeoffs is now a fundamental tenant of ecological physiology, especially in fishes (see review by Sokolova et al. 2012). Like all other temperature studies with fish, we found that RMR increased between 13 and 25°C, but there was nothing untoward in the magnitude of this thermal response (a 2.5-times increase in RMR over this temperature range).

MMR increased with temperature from 13 to 25°C, which would mean that as fish encounter higher temperatures, they have the capacity to perform an activity at a higher absolute rate, i.e., swim faster to capture food or avoid predators, digest meals faster, detoxify chemicals faster, etc. They certainly swam harder with temperature in the present study. Thus, the Tuolumne River *O. mykiss* population can perform to a higher capacity level at 25°C compared with either 13°C or 18°C. The temperature that the Tuolumne River *O. mykiss* population is predicted to have its highest absolute capacity for aerobic activity, the T_{opt} for AAS, was 21.2°C.

FAS, which measures the capacity for a proportional increase in RMR, typically decreases with temperature in fishes (Clark et al. 2011), as was the case here. Thus, the present finding for FAS was not unexpected. Moreover, being able to maintain FAS above 2 (i.e., being able to at least double its RMR; FAS = 2) may relevance for two important ecological activities for fish: digesting a full stomach and maintaining station in a flowing river.

Many laboratory studies with fish have examined the metabolic cost of digesting a full stomach (i.e., ad libitum feeding in a laboratory). The peak oxygen cost of digesting a meal increases with temperature and meal size, but peak MR does not increase by more than 2-fold at the temperatures used here and with a typical meal size (2% of body mass per feeding) for a salmonid in culture (e.g., Jobling 1981; Alsop and Wood 1997; Fu et al. 2005; Luo and Xie 2008). Therefore, a FAS value of 2 can be used as an index that a fish has the aerobic capacity to digest a full meal, and all individual fish achieved this performance up to 23°C. As a result of high temperature, a fish would digest the same meal with a similar overall oxygen cost but at a faster rate. This means that the fish could eat more frequently and potentially grow faster at a higher temperature with a FAS >2. Thus, the important ecological consideration is whether or not there is sufficient food in the Tuolumne River to support the highest MR associated with high temperature. All available studies suggest that the Tuolumne River population is not food limited, including direct studies of Tuolumne River Chinook salmon diet (TID/MID 1992, Appendix 16), long-term benthic macro-invertebrate sampling data collected from 1988–2008 (e.g., TID/MID 1997, Report 1996-4; TID/MID 2009, Report 2008-7), as well as the relatively high length-at-age for *O. mykiss* sampled in 2012 (Stillwater Sciences 2013). Indeed, the *O. mykiss* sampled for the current study were apparently feeding well in the river during summer months given the high condition factors (see Appendix 2), feces being regularly found in the swim tunnel and two test fish regurgitating rather large meals post-exhaustion. We do not know, however, whether a wild fish would eat meals as large as 2% of body mass, as in laboratory studies.

Here, we took advantage of the video analysis of the swimming behaviors of individual *O. mykiss* in the Tuolumne River habitat to provide a second evaluation of the ecological relevance of MR data. This analysis revealed a common set of swimming behaviors that *O. mykiss* used to maintain station in the water current, as well as darting behaviors used either to protect their territory or to grab food floating down the river. Because maintaining station against a water current requires a sustained swimming activity that is functionally analogous to steady swimming at one of the velocity increments in the swim tunnel, it was possible to estimate the tail beat frequency (TBF) while performing this normal river activity. Then, using Figure 5, the TBF for station holding was compared with the TBF used while swimming in the swim tunnel to determine a MR. Thus, the estimated oxygen cost of maintaining station in the Tuolumne River by *O. mykiss* at 14°C was found to increase metabolism to 1.5-times RMR, leaving fish with a FAS of 2, and therefore plenty of aerobic scope for additional activities besides maintaining station. Similarly at 20°C, maintaining station increased metabolic rate to twice RMR, and the remaining FAS was 1.7. Therefore, by combining laboratory and field observations, we can conclude that the Tuolumne River *O. mykiss* population at 20°C have an aerobic capacity to easily maintain station in their normal river habitat and additionally nearly double their RMR for other activities, or relocating to a lower water flow area to perform other activities.

According to Issue Paper 5 (EPA 2001) "*Acclimation is different from adaptation. Adaptation is the evolutionary process leading to genetic changes that produce modifications in morphology,* *physiology, and so on. Acclimation is a short-term change in physiological readiness to confront daily shifts in environmental conditions. The extent of the ability to tolerate environmental conditions (e.g., water temperature extremes) is limited by evolutionary adaptations, and within these constraints is further modified by acclimation*." Here we could not evaluate the possibility that the Tuolumne River *O. mykiss* population can thermally acclimate to warmer river temperatures as the summer progresses, due to the restrictions on the number of fish removed from the river (a maximum of 50 individuals) and their habitat temperature. Since the instantaneous temperature in the habitat where the test fish were captured was between 12.7 and 17.1°C (see Appendix 1), the upper thermal performance determined here may have underestimated thermal performance if the Tuolumne River *O. mykiss* can acclimate to temperatures higher than the river temperature they were captured in. In this regard, the thermal acclimation study of Mount Shasta and Eagle Lake *O. mykiss* (Myrick and Cech 2000) is particularly informative. Growth rate of the Mount Shasta strain was fastest at acclimation temperatures of 19 and 22°C, temperatures that bracket the T_{opt} for AAS determined here for Tuolumne River *O. mykiss.* However, growth of the Mount Shasta strain stopped at 25°C, which is consistent with our result that FAS approached a value of 2 at 25°C. In contrast, growth rate for the Eagle Lake strain was fastest at 19°C and decreased at 22°C. The Eagle Lake strain actually lost weight at 25°C, which indicated that food intake was not keeping pace with the energy requirements to sustain the RMR at this temperature, perhaps because of a limitation on AAS. Thus, the Mount Shasta strain of *O. mykiss* was better able to thermally acclimate to temperatures above 20°C than the Eagle Lake strain.

With clear evidence that California strains of *O. mykiss* grow optimally at acclimation temperatures >18°C and that local differences among strains amount to as much as a 3°C shift in the optimum temperature for growth, there already existed a precedent that the thermal range for optimal performance can reach 22°C for local populations of *O. mykiss*. Indeed, the new data presented here adds to this evidence of local adjustments of *O. mykiss* to warm river habitats, because while T_{opt} for AAS was 21.2°C, AAS remained within 5% of the peak AAS up to 24.6°C and all fish maintained a FAS value >2 up to 23°C.

CONCLUSION

High quality field data were generated on the physiological performance of Tuolumne River *O. mykiss* acutely exposed to a temperature range of 13 to 25°C. These data on the RMR, MMR, AAS, and FAS were consistent with higher thermal performance in Tuolumne River *O. mykiss* compared to those data used to generate the 7DADM value of 18°C using Pacific Northwest *O. mykiss* (EPA 2003). These new data are consistent with recent peer-reviewed literature that points to local thermal adjustments among salmonid populations. Therefore, these new data provide sound evidence to establish alternative numeric criteria that would apply to the Tuolumne River *O. mykiss* population below La Grange Diversion Dam. Given a measured T_{opt} for AAS of 21.2°C, and that the average AAS remained within 5% of this peak performance up to 24.6°C, and all fish maintained a FAS value >2 up to 23°C, we recommend that a conservative upper performance limit of 22°C, instead of 18°C, be used to re-determine a 7DADM value for this population.

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BIBLIOGRAPHY

Alsop, D. and Wood, C. (1997). The interactive effects of feeding and exercise on oxygen consumption, swimming performance and protein usage in juvenile rainbow trout (*Oncorhynchus mykiss*). J. Exp. Biol. 100, 2337–2346.

Barrett, R. D. H., Paccard, A., Healy, T. M., Bergek, S., Schulte, P. M., Schluter, D., and Rogers, S. M. (2011). Rapid evolution of cold tolerance in stickleback. Proceedings. Biol. Sci. / R. Soc. 278, 233–238.

Becker, C. D. and Wolford, M. G. (1980). Thermal resistance of juvenile salmonids sublethally exposed to nickel, determined by the critical thermal maximum method. Environ. Pollut. 21, 181–189.

Bidgood, B. F. and Berst, A. H. (1969). Lethal temperatures for Great Lakes rainbow trout. J. Fish. Res. Bd. Can. 26, 456–459.

Brett, J. R. (1964). The respiratory metabolism and swimming performance of young sockeye salmon. J. Fish. Res. Bd. Can., 21(5), 1183–1226.

Brett, J. R. and Glass, N. R. (1973). Metabolic rates and critical swimming speeds of sockeye salmon (*Oncorhynchus nerka*) in relation to size and temperature. J. Fish. Res. Bd. Can., 30, 379–387.

Carline, R. F. and Machung, J. F. (2001). Critical thermal maxima of wild and domestic strains of trout. Trans. Am. Fish. Soc. 130, 1211–1216.

Cech, J. J. Jr. (1990). Respirometry. In: Schreck, C.B., Moyle, P.B. (eds). Methods of fish biology. American Fisheries Society, Bethesda, Maryland. pp. 335–362.

Chen, J. Q., Snow, M., Lawrence, C. S., Church, A. R., Narum, S. R., Devlin, R. H. and Farrell, A.P.(2015). Selection for upper thermal tolerance in rainbow trout (*Oncorhynchus mykiss* Walbaum). J. Exp. Biol. 218, 803-812.

Clark, T. D., Jeffries, K. M., Hinch, S. G., & Farrell, A. P. (2011). Exceptional aerobic scope and cardiovascular performance of pink salmon (Oncorhynchus gorbuscha) may underlie resilience in a warming climate. The Journal of Experimental Biology, 214(Pt 18), 3074–81. doi:10.1242/jeb.060517

Currie, R. J., Bennett, W. A., and Beitinger, T. L. (1998). Critical thermal minima and maxima of three freshwater game-fish species acclimated to constant temperatures. Environ. Biol. Fishes. 51, 187–200.

Eliason, E. J., Clark, T. D., Hague, M. J., Hanson, L. M., Gallagher, Z. S., Jeffries, K. M., Gale, M. K., Patterson, D. A., Hinch, S. G., and Farrell, A. P. (2011). Differences in thermal tolerance among sockeye salmon populations. Science. 332, 109–112.

Eliason, E. J., Clark, T. D., Hinch, S. G., and Farrell, A. P. (2013). 521 Cardiorespiratory collapse at high temperature in swimming adult sockeye salmon. Conserv. Physiol. 1, 1−19.

Fangue, N. A., Hofmeister, M., and Schulte, P. M. (2006). Intraspecific variation in thermal tolerance and heat shock protein gene expression in common killifish, *Fundulus heteroclitus*. J. Exp. Biol. 209, 2859–2872.

Farrell, A. P. (2009). Environment, antecedents and climate change: lessons from the study of temperature physiology and river migration of salmonids. J. Exp. Biol. 212, 3771–80.

Farrell, A.P., Lee, C.G., Tierney, K., Hodaly, A., Clutterham, S., Healey, M., Hinch, S. & Lotto, A. (2003). Field-based measurements of oxygen uptake and swimming performance with adult Pacific salmon using a mobile respirometer swim tunnel. Journal of Fish Biology. 62, 64-84. doi:10.1046/j.0022-1112.2003.00010.x

FISHBIO (2013). Salmonid Redd Mapping Study Report. Prepared for the Turlock Irrigation District and the Modesto Irrigation District by FISHBIO, Oakdale, CA

Ford, T. and Kirihara, S. (2010). Tuolumne River *Oncorhynchus mykiss* monitoring report. Prepared by Turlock Irrigation District/Modesto Irrigation District, California and Stillwater Sciences, Berkeley, California for Federal Energy Regulatory Commission, Washington, D.C. January.

Fry, F. E. J. (1947). Effects of the environment on animal activity. Publ. Ontario Fish. Res. Lab. 55, 1–62.

Fu, S. J., Xie, X. J., and Cao, Z. D. (2005). Effect of meal size on postprandial metabolic response in southern catfish (*Silurus meridionalis*). Comp. Biochem. Physiol., A. 140, 445–451.

Galbreath, P. F., Adams, N. D., Sherrill, L. W., and Martin, T. H. (2006). Thermal tolerance of diploid versus triploid rainbow trout and brook trout assessed by time to chronic lethal maximum. Environ. Biol. Fishes. 75, 183–193.

Gamperl, A. K., Rodnick, K. J., Faust, H. A., Venn, E. C., Bennett, M. T., Crawshaw, L. I., … and Li, H. W. (2002). Metabolism, swimming performance , and tissue biochemistry of high desert redband trout (*Oncorhynchus mykiss* ssp.): Evidence for phenotypic differences in physiological function. Physiol. Biochem. Zoo. 75(5), 413–431.

Hartman, K. J. and Porto, M. A. (2014). Thermal performance of three rainbow trout strains at above-optimal temperatures. Trans. Am. Fish. Soc. 143(6), 1445-1454.

HDR Engineering, Inc. (2014). In-River Diurnal Temperature Variation. 81 pp.

Hochachka, P. W. and Somero, G. N. (2002). Biochemical adaptation: Mechanism and process in physiological evolution. Oxford University Press. 480 pp.

Hokanson, K. E. F., Kleiner, C. F., and Thorslund, T. W. (1977). Effects of constant temperatures and diel temperature fluctuations on specific growth and mortality rates and yield of juvenile rainbow trout, *Salmo gairdneri*. J. Fish. Res. Bd. Can. 34, 639–648.

Huey, R. B. and Kingsolver, J. G. (1979). Integrating thermal physiology and ecology of ectotherms: A discussion of approaches. Am. Zool. 19, 357–366.

Ineno, T., Tsuchida, S., Kanda, M., and Watabe, S. (2005). Thermal tolerance of a rainbow trout *Oncorhynchus mykiss* strain selected by high-temperature breeding. Fish. Sci. 71, 767−775.

Jain, K. E., Hamilton, J. C., and Farrell, A. P. (1997). Use of a ramp velocity test to measure critical swimming speed in rainbow trout (*Oncorhynchus mykiss*). Comp. Biochem. Physiol. 117A, 441–444.

Jobling, M. (1981). The influences of feeding on the metabolic rate of fishes: a short review. J. Fish Biol. 18, 385–400.

LeBlanc, S., Middleton, S., Gilmour, K. M., and Currie, S. (2011). Chronic social stress impairs thermal tolerance in the rainbow trout (*Oncorhynchus mykiss*). J. Exp. Biol. 214, 1721−31.

Lee, R. M. and Rinne, J. N. (1980). Critical thermal maxima of five trout species in the southwestern United States. Trans. Am. Fish. Soc. 109, 632–635.

Lee, C. G., Farrell, A. P., Lotto, A., Hinch, S. G., Healey, M. C., & MacNutt, M. J. (2003). Excess post-exercise oxygen consumption in adult sockeye (Oncorhynchus nerka) and coho (O. kisutch) salmon following critical speed swimming. The Journal of Experimental Biology, 206(18), 3239–3251.

Lucas, J., Schouman, A., Plyphout, L., Cousin, X., and LeFrancois, C. (2014). Allometric relationship between body mass and aerobic metabolism in zebrafish *Danio rerio*. J. Fish Bio. 84, 1171–1178. April 2014. doi:10.1111/jfb.12306

Luo, Y. P. and Xie, X. J. (2008) Effects of temperature on the specific dynamic action of the southern catfish, *Silurus meridionalis*. Comp. Biochem. Physiol. A. 149, 150–156

Matthews, K. R. and Berg, N. H. (1997). Rainbow trout responses to water temperature and dissolved oxygen stress in two southern California stream pools. J. Fish Biol. 50, 50–67.

McGeer, J. C., Szebedinsky, C., McDonald, D. G., and Wood, C. M. (2000). Effects of chronic sublethal exposure to waterborne Cu, Cd or Zn in rainbow trout. I: Iono-regulatory disturbance and metabolic costs. Aquatic Tox. 50(3), 231–243. doi:10.1016/S0166-445X(99)00105-8

Molony, B. (2001). Environmental requirements and tolerances of rainbow trout (*Oncorhynchus mykiss*) and brown trout (*Salmo trutta*) with special reference to Western Australia: A review. Fisheries Research Reports No. 130. Western Australia. 28 pp.

Molony, B. W., Church, A. R., and Maguire, G. B. (2004). A comparison of the heat tolerance and growth of a selected and non-selected line of rainbow trout, *Oncorhynchus mykiss*, in Western Australia. Aquaculture 241, 655–665.

Morrissy, N. (1973). Comparison of strains of *Salmo gairdneri* Richardson from New South Wales, Victoria and Western Australia. Aust. Soc. Limnol. Bull. 5, 11–20.

Myrick, C. A. and Cech, J. J. Jr. (2000). Temperature influences on California rainbow trout physiological performance. Fish Physiol. Biochem. 22, 245–254.

Myrick, C. A. and Cech, J. J. Jr. (2001). Temperature Effects on Chinook Salmon and Steelhead: a Review Focusing on California's Central Valley Populations. Bay-Delta Modeling Forum, Technical Publication 01-1.

Myrick, C. A. and Cech, J. J. Jr. (2005). Effects of temperature on the growth, food consumption, and thermal tolerance of age-0 Nimbus-strain steelhead. North Am. J. Aquaculture 67, 324–330.

Narum, S. R., Campbell, N. R., Kozfkay, C. C., and Meyer, K. A. (2010). Adaptation of redband trout in desert and montane environments. Mol. Ecol. 19, 4622–4637.

Narum, S. R., Campbell, N. R., Meyer, K. A., Miller, M. R., and Hardy, R. W. (2013). Thermal adaptation and acclimation of ectotherms from differing aquatic climates. Mol. Ecol. 22, 3090–3097.

Narum, S. R. and Campbell, N. R. (2015). Transcriptomic response to heat stress among ecologically divergent populations of redband trout. BMC Genomics. 16(103). DOI 10.1186/s12864-015-1246-5

Parsons, E. 2011. Cardiorespiratory physiology and temperature tolerance among populations of sockeye salmon (Oncorhynchus nerka). PhD Thesis. University of British Columbia, Canada.

Pörtner, H. O. and Knust, R. (2007). Climate change affects marine fishes through the oxygen limitation of thermal tolerance. Science 315, 95–97.

Pörtner, H. O. and Farrell, A. P. (2008). Physiology and climate change. Science 322, 690–692.

Rasmussen, J. B., Robinson, M. D., Hontela, A., and Heath, D. D. (2012). Metabolic traits of westslope cutthroat trout, introduced rainbow trout and their hybrids in an ecotonal hybrid zone along an elevation gradient. Biol. J. Linn. Soc., 105, 56–72. doi:10.5061/dryad.rr388.functional

Recsetar, M. S., Zeigler, M. P., Ward, D. L., Bonar, S. A., and Caldwell, C. A. (2012). Relationship between fish size and upper thermal tolerance. Trans. Am. Fish. Soc. 141, 1433–1438.

Rodnick, K. J., Gamperl, A. K., Lizars, K. R., Bennett, M. T., Rausch, R. N., and Keeley, E. R. (2004). Thermal tolerance and metabolic physiology among redband trout populations in south-eastern Oregon. J. Fish Biol. 64, 310–335.

Scarabello, M., Heigenhauser, G. J. F., & Wood, C. M. (1991). The oxygen debt hypothesis in juvenile rainbow trout after exhaustive exercise. Respiration Physiology, 84(2), 245–259.

Scarabello, M., Heigenhauser, G. J. F., and Wood, C. M. (1992). Gas exchange, metabolite status and excess postexercise oxygen consumption after repetitive bouts of exhaustive exercise in juvenile rainbow trout. J. Exp. Biol. 167, 155–169.

Scott, M. A. (2012). Performance of wild and domestic strains of diploid and triploid rainbow trout (*Oncorhynchus mykiss*) in response to environmental challenges. Master thesis. University of British Columbia. 69 pp.

Schulte, P.M., Healy, T.M., and N.A. Fangue (2011). Thermal performance curves, phenotypic plasticity, and the time scales of temperature exposure. Integ. Comp. Bio. 51, 691−702.

Schmidt-Nielsen, K. (1994). Animal physiology: adaptation and environment. 4th ed. Cambridge University Press.

Sloat, M. R. and Reeves, G. H. (2014). Individual condition, standard metabolic rate, and rearing temperature influence steelhead and rainbow trout (*Oncorhynchus mykiss*) life histories. Can. J. Fish. Aqu. Sci., 71, 491–501.

Sokolova, I. M., Frederich, M., Bagwe, R., Lannig, G., and Sukhotin, A. A. (2012). Energy homeostatsis as an integrative tool for assessing limits of environmental stress tolerance in aquatic invertebrates. Mar. Env. Res. 79, 1–15.

Sonski, A.J. 1983. Heat tolerance of redband trout. Annu. Proc. Tex . Chap. Am. Fish. Soc. 5, 66−76.

Steffensen, J. 1989. Some errors in respirometry of aquatic breathers: How to avoid and correct for them. Fish. Physiol. Biochem. 6, 49-59.

Stillwater Sciences (2012). Tuolumne River 2011 *Oncorhynchus mykiss* monitoring summary report. Prepared by Stillwater Sciences, Berkeley, California for the Turlock Irrigation District and Modesto Irrigation District. January.

Stillwater Sciences (2013). *Oncorhynchus mykiss* Scale Collection and Age Determination Study Report. Prepared by Stillwater Sciences, Berkeley, California for the Turlock Irrigation District and Modesto Irrigation District. January.

Strange, R. J., Petrie, R. B., and Cech, J. J. Jr. (1993). Slight stress does not lower critical thermal maximums in hatchery-reared rainbow-trout. FOLIA Zool. 42, 251–256.

Turlock Irrigation District and Modesto Irrigation District (TID/MID). (1992). Report of Turlock Irrigation District and Modesto Irrigation District Pursuant to Article 39 of the License for the Don Pedro Project. Turlock, California. 8 Volumes. April.

TID/MID. (1997). 1996 Report of Turlock Irrigation District and Modesto Irrigation District Pursuant to Article 58 of the License for the Don Pedro Project, No. 2299. Turlock, California. 6 Volumes. March.

TID/MID. (2009). 2008 Report of Turlock Irrigation District and Modesto Irrigation District Pursuant to Article 58 of the License for the Don Pedro Project, No. 2299. Turlock, California. March.

U.S. Environmental Protection Agency (EPA). 2001. Issue Paper 5, Summary of Technical Literature Examining the Physiological Effects of Temperature on Salmonids. Available online at: http://yosemite.epa.gov/R10/WATER.NSF/6cb1a1df2c49e4968825688200712cb7/5eb9e547ee9e111f88256a03005bd665/$FILE/Paper%205-Literature%20Temp.pdf

U.S. Environmental Protection Agency (EPA). 2003. EPA Region 10 Guidance for Pacific Northwest State and Tribal Temperature Water Quality Standards. Available online at: http://www.epa.gov/region10/pdf/water/final_temperature_guidance_2003.pdf

Van Leeuwen, T. E., Rosenfeld, J. S., and Richards, J. G. (2011). Adaptive trade-offs in juvenile salmonid metabolism associated with habitat partitioning between coho salmon and steelhead trout in coastal streams. J. Anim. Ecol. 80(5), 1012–23. doi:10.1111/j.1365-2656.2011.01841.x

Van Leeuwen, T. E., Rosenfeld, J. S., and Richards, J. G. (2012). Effects of food ration on SMR: influence of food consumption on individual variation in metabolic rate in juvenile coho salmon (*Onchorhynchus kisutch*). J. Anim. Ecol. 81(2), 395–402. doi:10.1111/j.1365-2656.2011.01924.x

FIGURES

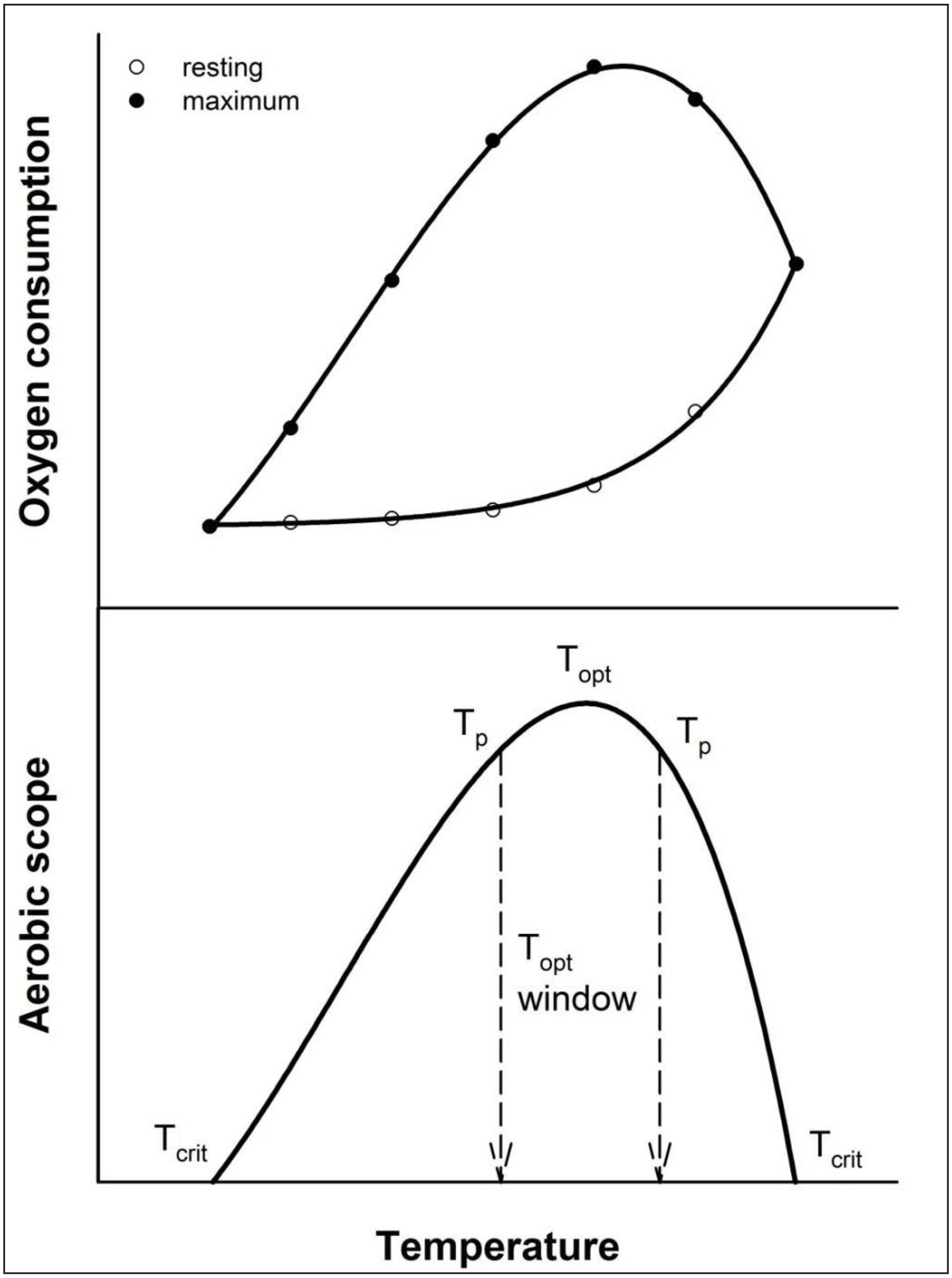
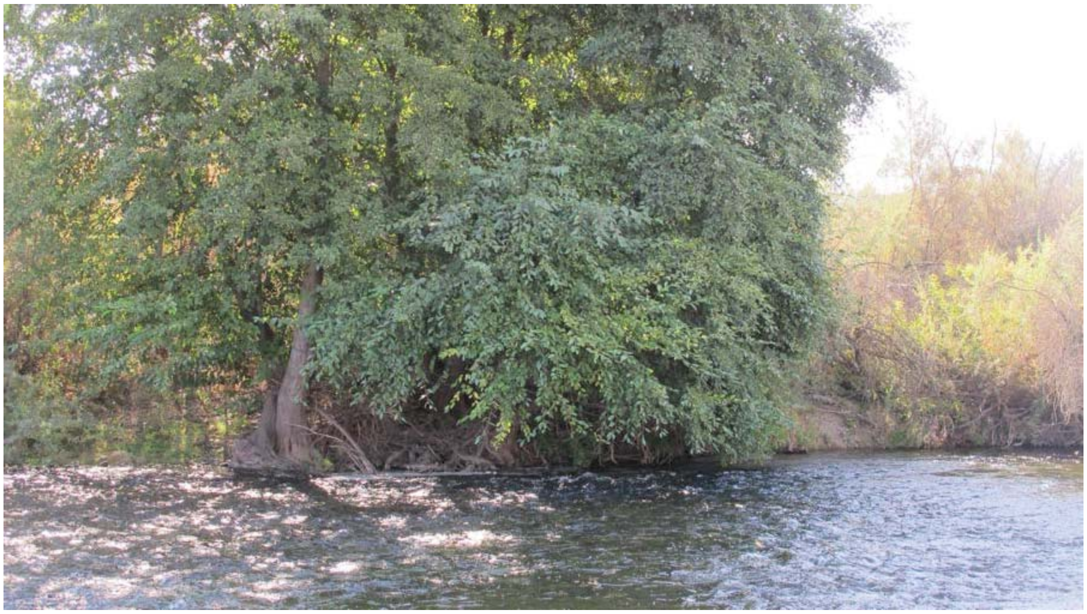


Figure 1. Schematic representation of the resting metabolic rate (= routine; RMR) and maximum metabolic rate (MMR) and aerobic scope (AS = MMR-RMR) for a temperature specialist. See text for details. T_{opt} = optimum temperature, T_p = pejus temperatures which set the thermal window or range in which 95% of the peak value for AS can be maintained; T_{crit} = critical temperatures where there is no aerobic scope. (Parsons 2011).

(a) RM 51.6

(b) RM 50.7

(c) RM 50.4



(d) RM 49.1

Figure 2. Representative photographic images (a-d) of the four capture locations for Tuolumne River *O. mykiss*, by river mile.

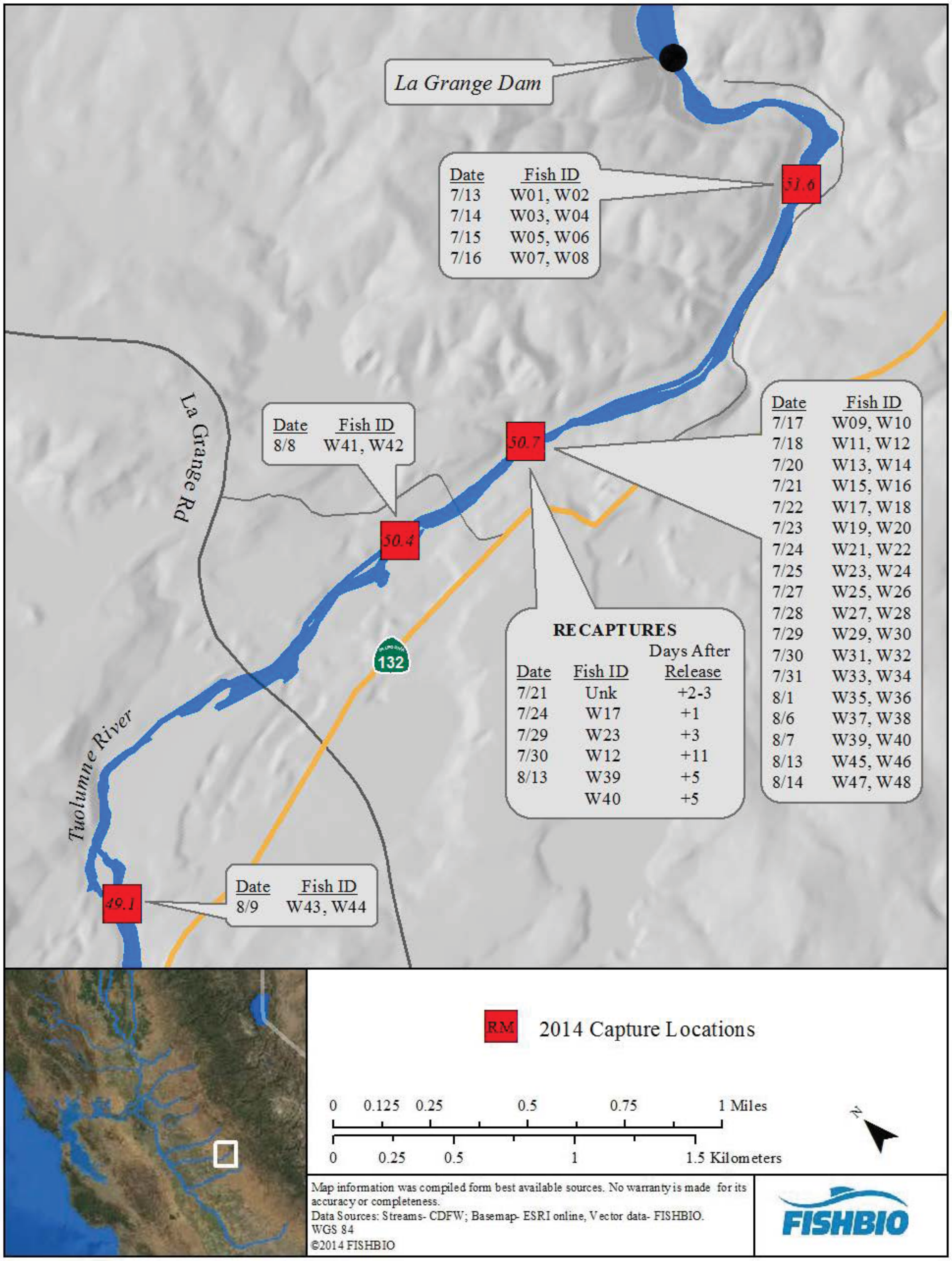


Figure 3. Map of capture and recapture locations of all Tuolumne River *O. mykiss* test fish.

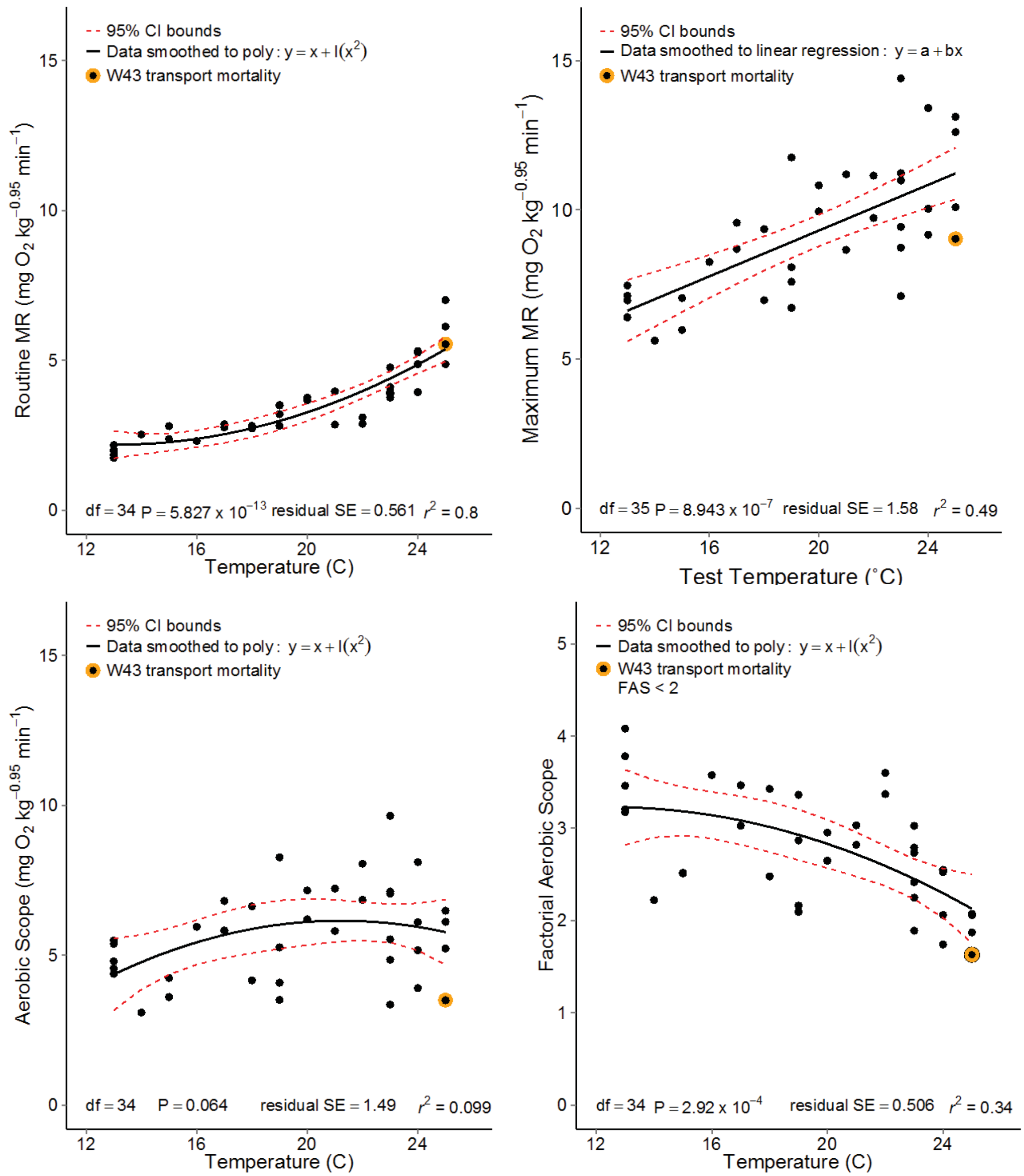


Figure 4. The relationships between test temperature and the routine (RMR) and maximum metabolic rate (MMR) of Tuolumne River *O. mykiss*. Absolute aerobic scope (AAS) and factorial aerobic scope (FAS) were derived from the MR measurements. Each data point represents an individual fish tested at one temperature. These data were given a best-fit mathematical model (solid line or curve) and the 95% confidence intervals for this line are indicated by the broken lines.

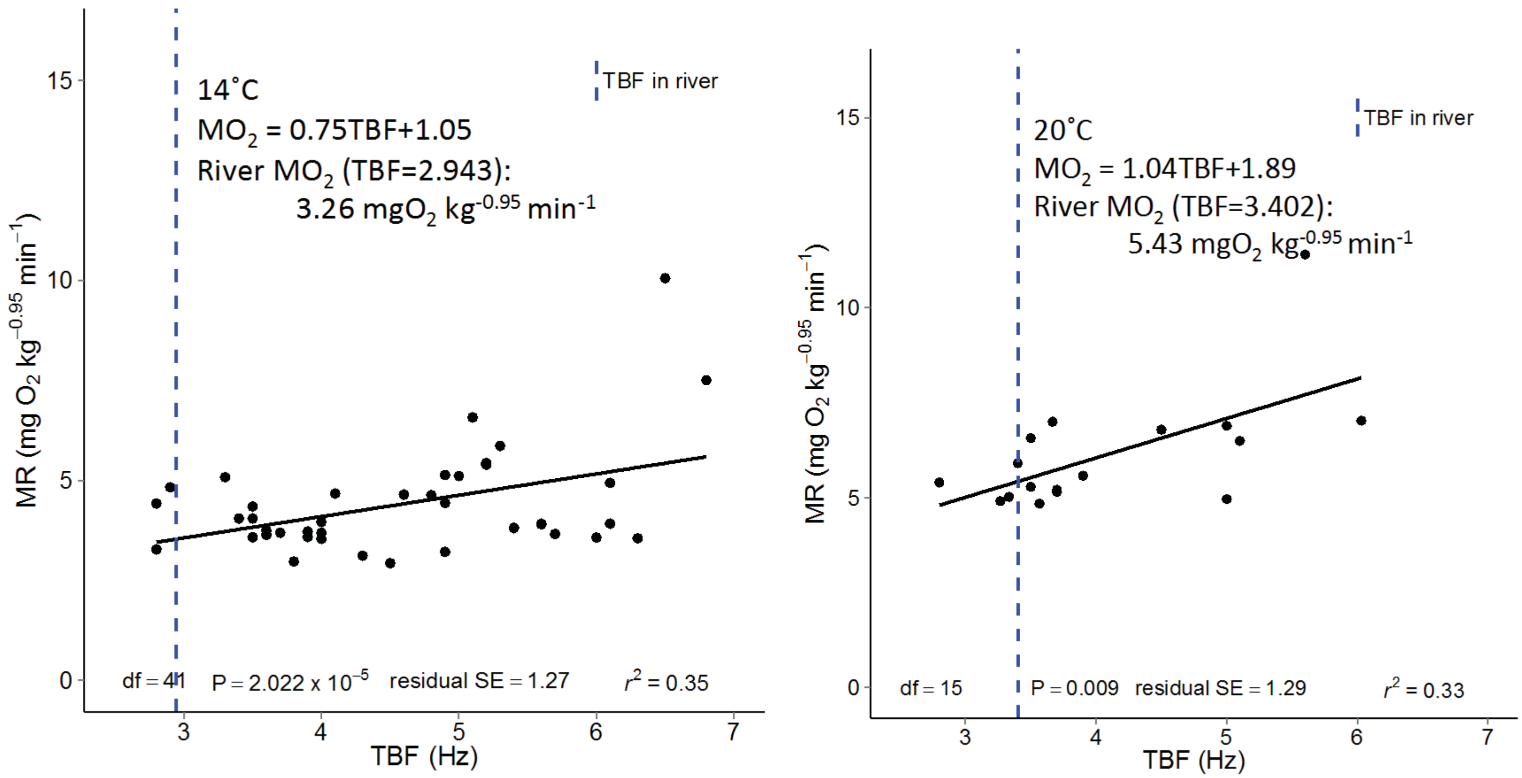


Figure 5. **The relationship between tail beat frequency (TBF; Hz) and metabolic rate (MR; mg O_2 $kg^{-0.95}$ min^{-1}) measured when Tuolumne River *O. mykiss* were swimming continuously in a swim tunnel at 14 °C or 20°C. The solid black line represents the linear regression based on the data for N=7 fish at 14°C and N=5 fish at 20oC). The blue dashed lines represent the estimated TBF (2.94 Hz at 14°C and 3.40 Hz at 20°C (bottom graph) taken from videos of *O. mykiss* maintaining station in a water current in their normal Tuolumne River habitat.**

TABLES

Table 1. Literature values of critical thermal maximum (CTmax) for *O. mykiss* populations.

Acclimation Temperature (°C)	CTmax (°C)	Heating rate (°C min-1)	Mass (g)	Length (cm)	Strain Source	Reference
8	26.9 ± 0.12	0.1		11 – 18	Washington	Becker and Wolford 1980
9.8	27.9 ± 0.05	0.3		15,3 ± 0.25	Pennsylvania	Carline and Machung 2001
10	28.5 ± 0.28	0.02				Lee and Rinne 1980
10	28.0 ± 0.12	0.3	~15	~10	Missouri	Currie et al. 1998
10	27.7 ±0.08	0.3	12.9 ± 0.6		California	Myrick and Cech 2000
11	27.5	0.3	8.0 ± 1.6		California	Myrick and Cech 2005
11 *	29.0 ± 0.05	0.3	2.4 ± 0.5		British Columbia	Scott 2012
13	27.9 ±0.14	0.33		21.8±0.4	Ontario	Leblanc et al. 2011
14	28.5±0.11	0.3	13.8 ± 0.8		California	Myrick and Cech 2000
14	29.4 ±0.1	0.03%	41 - 140		Oregon	Rodnick et al. 2004
15	29.4 ± 0.08	0.3				Strange et al. 1993
15	29.1 ± 0.09	0.3	~15	~10	Missouri	Currie et al. 1998
15	27.7 ±0.03	0.0014 #	89.9 ± 5.4	11.9 – 0.3	North Carolina	Galbreath et al. 2006
15	28.4	0.3	9.3 ± 2.0		California	Myrick and Cech 2005
15	~29.65	0.083 &			Miyazaki, Japan	Ineno et al. 2005
15	29.0 ± 0.02	0.3/0.1	30.2 ± 0.3	13.0 ± 0.4	Western Australia	Present study
18	31.2	0.3		4.1 – 20	Arizona	Recsetar et al. 2012
19	29.6	0.3	14.3 ± 2.9		California	Myrick and Cech 2005
19	29.9 ± 0.17	0.3	11.8 ± 0.7		California	Myrick and Cech 2000
20	29.35 ± 0.19	0.02				Lee and Rinne 1980
20	29.8 ±0.12	0.3	~2	~4	Missouri	Currie et al. 1998
20	~30.4	0.083 &			Miyazaki, Japan	Ineno et al. 2005
20	31.14±0.03	0.3		10.8±0.1	Hatchery (British Columbia)	Hartman and Porto 2014
20	31.20±0.03	0.3		11.9±0.1	Hatchery (Virginia)	Hartman and Porto 2014
20	31.29±0.02	0.3		9.5±0.1	Hatchery (Maryland)	Hartman and Porto 2014
22	30.9 ± 0.13	0.3	9.29 - 0.99		California	Myrick and Cech 2000
25	31.75 ± 0.1	0.3	6.1 - 0.63		California	Myrick and Cech 2000

*fish held at 10 ~12°C.

& temperature was increased at 5°C h^{-1}.

% temperature was increased at 2°C h^{-1}.

temperature was increased at 2°C day^{-1}.

Table 2. Literature values for routine metabolic rate (RMcR), maximum metabolic rate (MMR), absolute aerobic scope (AAS) and factorial aerobic scope (FAS) of juvenile salmonid fishes.

Species	Source[1] (test location)	Mass (g)	Temperature (°C)		Metabolic rates (mg O_2 $kg^{-0.95}$ min^{-1})			FAS	Reference
			Acclimate	Test	RMR	MMR	AAS		
Rainbow trout	Hatchery (L)	13	15	15	0.5	2.9	2.4	5.8	Alsop and Wood 1997
	Hatchery (L)	6	15	15	1	2.8	1.8	2.8	Alsop and Wood 1997
	Hatchery (L)	2-3	15	15	3.9	8.7	4.8	2.2	Scarabello et al. 1991
	Hatchery (L)	6	15	15	2.5	8.3	5.8	3.3	Scarabello et al. 1992
	Hatchery (L)	18	17	17	3.9	7	3.1	1.8	McGeer et al. 2000
	Eagle Lake Wild[2] (L)	6.9	10	10	2.6				Myrick and Cech 2000
	Eagle Lake Wild[2] (L)	7.2	14	14	2.8				Myrick and Cech 2000
	Eagle Lake Wild[2] (L)	14.1	19	19	2.6				Myrick and Cech 2000
	Eagle Lake Wild[2] (L)	13.4	22	22	2.9				Myrick and Cech 2000
	Eagle Lake Wild[2] (L)	5	25	25	3.1				Myrick and Cech 2000
	Mt. Shasta Wild[2] (L)	10	10	10	2				Myrick and Cech 2000
	Mt. Shasta Wild[2] (L)	7.5	14	14	2.3				Myrick and Cech 2000
	Mt. Shasta Wild[2] (L)	24.5	19	19	2.2				Myrick and Cech 2000
	Mt. Shasta Wild[2] (L)	15	22	22	2.4				Myrick and Cech 2000
	Mt. Shasta Wild[2] (L)	5.4	25	25	2.9				Myrick and Cech 2000
Steelhead trout	Wild (H/F)	1.7	8.3	8.3	1.8-3.4	5.7-9.1			Van Leeuwen et al. 2011
	Hatchery (H/F)	3.3	12.3	12.3	1.9-3.6	5.5-9.7			Van Leeuwen et al. 2011
Rainbow trout	Wild[2] (L) (territorial)	60-80		13	0.6-1.9				Sloat and Reeves 2014
	Wild[2] (L) (dispersing)	60-80		13	0.6-1.5				Sloat and Reeves 2014
Rainbow cutthroat hybrid	Hatchery (F)	20-70	9.5-11	9.5-11	2.3				Rasmussen et al. 2012
Cutthroat trout	West slope Wild (F)	20-100	9.5-11	9.5-11	2.6				Rasmussen et al. 2012
Redband trout	Wild Bridge Creek (F)	92 (150-200 mm)	12-24*	13	1.8	8.5	6.7	4.7	Gamperl et al. 2002
	Wild Bridge Creek (F)	108 (150-200 mm)	12-24*	24	4.5	14	9.5	3.1	Gamperl et al. 2002
	Wild Little Blitzen River (F)	58	12-18*	13	2.4	12	9.6	5.0	Gamperl et al. 2002
	Wild Little Blitzen River (F)	71	12-18*	24	5.6	14	8.4	2.5	Gamperl et al. 2002

Species	Source[1] (test location)	Mass (g)	Temperature (°C)		Metabolic rates (mg O_2 $kg^{-0.95}$ min^{-1})			FAS	Reference
			Acclimate	Test	RMR	MMR	AAS		
	Wild 12 Mile Creek (F)	56	19-30 (23.4)*	24	4.7	18.3	13.6	3.9	Rodnick et al. 2004
	Wild Rock Creek (F)	50	12-27 (18.7)*	24	4.7	18	13.3	3.8	Rodnick et al. 2004
	Wild Bridge Creek (F)	63	13-21 (17)*	24	4.6	15.6	11	3.4	Rodnick et al. 2004
Sockeye salmon	Wild (L)	37 (170 mm)	5	5	0.9	7.6	6.7	8.4	Brett 1964
	Wild (L)	33(160 mm)	10	10	1.4	8.7	7.3	6.2	Brett 1964
	Wild (L)	55 (190 mm)	15	15	1.7	14.2	12.5	8.4	Brett 1964
	Wild (L)	63 (190 mm)	20	20	2.1	13.1	11	6.2	Brett 1964
	Wild (L)	52 (180 mm)	24	24	0.8	12.7	11.9	15.9	Brett 1964
	Wild (L)	20-60	5.3	5.3	0.5	6.9	6.4	13.8	Brett and Glass 1973
	Wild (L)	19-60	15	15	0.9	9.9	9	11.0	Brett and Glass 1973
	Wild (L)	20-50	20	20	1.7	12.5	10.8	7.4	Brett and Glass 1973
Coho salmon	Wild (H/F)	3.9	8.3	8.3	1.5-3.1	3.6-6.2			Van Leeuwen et al. 2011
	Hatchery (H/F)	5.4	12.3	12.3	1.1-2.3	3.8-6.5			Van Leeuwen et al. 2011
	Wild[2] (F)	40-100	9.5-11	9.5-11	3.2				Rasmussen et al. 2012
	Wild (L)	4.3	14	14	1.6				Van Leeuwen et al. 2012
Redband trout	Wild 12 Mile Creek (F)	94	19-30 (23)*	14	1.6				Rodnick et al. 2004
	Wild 12 Mile Creek (F)	94	19-30 (23)*	24	2.3				Rodnick et al. 2004
	Wild 12 Mile Creek (F)	94	19-30 (23)*	26	4.8				Rodnick et al. 2004
	Wild 12 Mile Creek (F)	94	19-30 (23)*	28	5.6				Rodnick et al. 2004
	Wild Rock Creek (F)	54	12-27 (19)*	14	1.8				Rodnick et al. 2004
	Wild Rock Creek (F)	54	12-27 (19)*	24	3.7				Rodnick et al. 2004
	Wild Rock Creek (F)	54	12-27 (19)*	26	5.7				Rodnick et al. 2004
	Wild Rock Creek (F)	54	12-27 (19)*	28	6.1				Rodnick et al. 2004
	Wild Bridge Creek (F)	79	13-21 (17)*	14	2.3				Rodnick et al. 2004
	Wild Bridge Creek (F)	79	13-21 (17)*	24	4.2				Rodnick et al. 2004
	Wild Bridge Creek (F)	79	13-21 (17)*	26	5.6				Rodnick et al. 2004
	Wild Bridge Creek (F)	79	13-21 (17)*	28	6.7				Rodnick et al. 2004

[1] L = laboratory; H = hatchery; F=Field.
[2] Spawned in a hatchery.
*Acclimations to cycled temperature regime of range indicated, and average in brackets if reported.

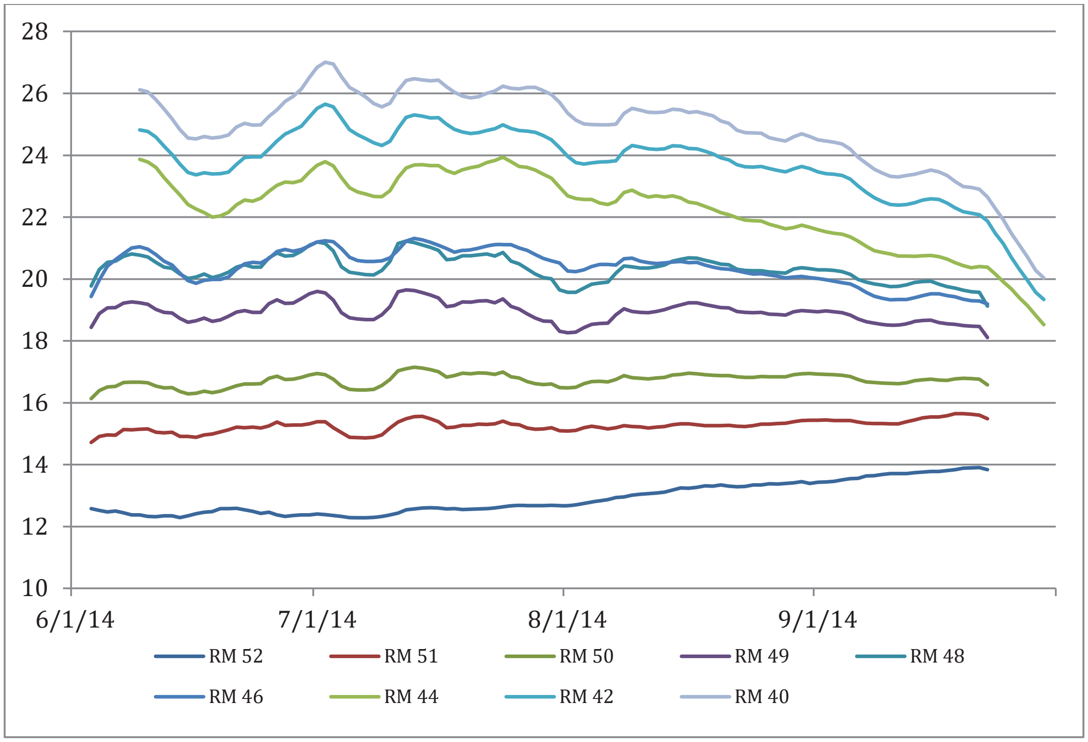
APPENDICES

THERMAL PERFORMANCE OF WILD JUVENILE *ONCORHYNCHUS MYKISS* IN THE LOWER TUOLUMNE RIVER: A CASE FOR LOCAL ADJUSTMENT TO HIGH RIVER TEMPERATURE

APPENDIX 1

TUOLUMNE RIVER 7-DAY AVERAGE OF MAXIMUM DAILY TEMPERATURES

Appendix 1. Tuolumne River 7-day average of maximum daily temperatures (7DADM) from June 1 to September 30, 2014. Thermograph data provided by TID (Patrick Maloney).



THERMAL PERFORMANCE OF WILD JUVENILE *ONCORHYNCHUS MYKISS* IN THE LOWER TUOLUMNE RIVER: A CASE FOR LOCAL ADJUSTMENT TO HIGH RIVER TEMPERATURE

APPENDIX 2

CAPTURE RELEASE TABLE

Appendix 2. Capture release table. Fish capture and release locations and physical conditions.

Fish ID	Capture				Release				Habitat Unit ID (Stillwater 2010)	Est. RM	Comments
	Coordinates	Date	Time	Temp (°C)	Coordinates	Date	Time	Temp (°C)			
W01	N - 37.66574 W - 120.44421	7/13	9:45	12.9	N - 37.66574 W - 120.44421	7/14	15:35	14.4	4 FW Riffle (side channel #3)	51.5	
W02	N - 37.66574 W - 120.44421	7/13	11:24	13.2	N - 37.66574 W - 120.44421	7/14	15:36	14.4	4 FW Riffle (side channel #3)	51.5	
W03	N - 37.66532 W - 120.44482	7/14	11:04	13.5	N - 37.66518 W - 120.44509	7/15	17:25	14.1	4 FW Riffle (side channel #3)	51.5	
W04	N - 37.66538 W - 120.44470	7/14	11:08	13.5	N - 37.66518 W - 120.44509	7/15	17:25	14.1	4 FW Riffle (side channel #3)	51.5	
W05	N - 37.66524 W - 120.44424	7/15	9:50	12.8	N - 37.66544 W - 120.44449	7/16	13:07	14.6	4 FW Riffle (side channel #3)	51.5	
W06	N - 37.66536 W - 120.44474	7/15	10:53	12.9	N - 37.66544 W - 120.44449	7/16	12:00	13.4	4 FW Riffle (side channel #3)	51.5	Fish not measured or PIT tagged to limit handling
W07	N - 37.66544 W - 120.44449	7/16	9:52	12.9	N - 37.66510 W - 120.44515	7/17	13:16	14	4 FW Riffle (side channel #3)	51.5	
W08	N - 37.66544 W - 120.44449	7/16	10:10	12.7	N - 37.66510 W - 120.44515	7/17	13:16	14	4 FW Riffle (side channel #3)	51.5	
W09	N - 37.66586 W - 120.45826	7/17	9:10	13.5	N - 37.66581 W - 120.45829	7/18	14:36	16	11 FW Riffle	50.7	
W10	N - 37.66586 W - 120.45826	7/17	9:24	13.5	N - 37.66581 W - 120.45829	7/18	14:36	16	11 FW Riffle	50.7	
W11	N - 37.66581 W - 120.45829	7/18	8:40	13.7	N - 37.66581 W - 120.45829	7/19	14:49	15.5	11 FW Riffle	50.7	
W12	N - 37.66581 W - 120.45829	7/18	8:40	13.7	N - 37.66581 W - 120.45829	7/19	14:49	15.5	11 FW Riffle	50.7	
W13	N - 37.66579 W - 120.45832	7/20	8:48	13.4	N - 37.66585 W - 120.45823	7/21	13:59	15.3	11 FW Riffle	50.7	
W14	N - 37.66579 W - 120.45832	7/20	8:48	13.4	N - 37.66585 W - 120.45823	7/21	13:59	15.3	11 FW Riffle	50.7	
W15	N - 37.66585 W - 120.45823	7/21	8:35	13.3	N - 37.66579 W - 120.45834	7/22	13:47	15.0	11 FW Riffle	50.7	7/21- recaptured a PIT tagged fish #114779, 114769, or 114734

Fish ID	Capture				Release				Habitat Unit ID (Stillwater 2010)	Est. RM	Comments
	Coordinates	Date	Time	Temp (°C)	Coordinates	Date	Time	Temp (°C)			
W16	N - 37.66585 W - 120.45823	7/21	8:35	13.3	N - 37.66579 W - 120.45834	7/22	13:47	15.0	11 FW Riffle	50.7	
W17	N - 37.66579 W - 120.45834	7/22	10:23	13.6	N - 37.66579 W - 120.45839	7/23	14:13	15.4	11 FW Riffle	50.7	
W18	N - 37.66579 W - 120.45834	7/22	10:28	13.6	N - 37.66579 W - 120.45839	7/23	14:13	15.4	11 FW Riffle	50.7	
W19	N - 37.66579 W - 120.45834	7/23	10:10	13.5	N - 37.66574 W - 120.45786	7/24	14:29	15.3	11 FW Riffle	50.7	
W20	N - 37.66579 W - 120.45834	7/23	10:27	13.5	N - 37.66574 W - 120.45786	7/24	14:29	15.3	11 FW Riffle	50.7	
W21	N - 37.66579 W - 120.45828	7/24	9:00	13.5	N - 37.66571 W - 120.45794	7/25	14:00	15.4	11 FW Riffle	50.7	7/24- recaptured PIT tag #114752
W22	N - 37.66579 W - 120.45828	7/24	9:00	13.5	N - 37.66571 W - 120.45794	7/25	14:00	15.4	11 FW Riffle	50.7	
W23	N - 37.66582 W - 120.45830	7/25	9:05	13.5	N - 37.66582 W - 120.45830	7/26	13:33	15.1	11 FW Riffle	50.7	
W24	N - 37.66582 W - 120.45830	7/25	9:05	13.6	N - 37.66582 W - 120.45830	7/26	13:33	15.1	11 FW Riffle	50.7	
W25	N - 37.66565 W - 120.45826	7/27	8:15	13.6	N - 37.66565 W - 120.45826	7/28	14:15	14.5	11 FW Riffle	50.7	
W26	N - 37.66565 W - 120.45826	7/27	8:15	13.6	N - 37.66565 W - 120.45826	7/28	14:15	14.5	11 FW Riffle	50.7	
W27	N - 37.66565 W - 120.45826	7/28	9:15	13	N - 37.66565 W - 120.45826	7/29	14:15	14.9	11 FW Riffle	50.7	
W28	N - 37.66565 W - 120.45826	7/28	9:15	13	N - 37.66565 W - 120.45826	7/29	14:15	14.9	11 FW Riffle	50.7	
W29	N - 37.66565 W - 120.45826	7/29	9:30	13.3	N - 37.66574 W - 120.45788	7/30	16:30	14.7	11 FW Riffle	50.7	7/29- recaptured PIT tag #114809
W30	N - 37.66565 W - 120.45826	7/29	9:18	13.3	N - 37.66574 W - 120.45788	7/30	16:30	14.7	11 FW Riffle	50.7	
W31	N - 37.66565 W - 120.45826	7/30	9:00	13.3	N - 37.66565 W - 120.45826	7/31	13:38	15.1	11 FW Riffle	50.7	7/30- recaptured PIT tag #114734
W32	N - 37.66565 W - 120.45826	7/30	9:07	13.3	N - 37.66565 W - 120.45826	7/31	13:38	15.1	11 FW Riffle	50.7	

Fish ID	Capture				Release				Habitat Unit ID (Stillwater 2010)	Est. RM	Comments
	Coordinates	Date	Time	Temp (°C)	Coordinates	Date	Time	Temp (°C)			
W33	N - 37.66565 W - 120.45826	7/31	9:05	13.1	N - 37.66565 W - 120.45826	8/1	13:42	15.0	11 FW Riffle	50.7	
W34	N - 37.66565 W - 120.45826	7/31	9:05	13.1	N - 37.66565 W - 120.45826	8/1	13:42	15.0	11 FW Riffle	50.7	
W35	N - 37.66565 W - 120.45826	8/1	9:02	13.2	N - 37.66565 W - 120.45826	8/2	15:40	15.8	11 FW Riffle	50.7	
W36	N - 37.66565 W - 120.45826	8/1	9:30	13.2	N - 37.66565 W - 120.45826	8/2	15:40	15.8	11 FW Riffle	50.7	
W37	N - 37.66565 W - 120.45826	8/6	9:18	13.4	--	--	--	--	11 FW Riffle	50.7	Mortality- due to chloride residue in tunnel
W38	N - 37.66565 W - 120.45826	8/6	9:28	13.4	--	--	--	--	11 FW Riffle	50.7	Mortality- due to chloride residue in tunnel
W39	N - 37.66565 W - 120.45826	8/7	9:08	13.5	N - 37.66668 W - 120.46420	8/8	17:31	15.8	11 FW Riffle	50.7	
W40	N - 37.66565 W - 120.45826	8/7	9:30	13.5	N - 37.66668 W - 120.46420	8/8	17:31	15.8	11 FW Riffle	50.7	
W41	N - 37.66643 W - 120.46432	8/8	11:18	15.5	N - 37.66643 W - 120.46432	8/9	16:00	16.7	14 BC Riffle	50.4	
W42	N - 37.66643 W - 120.46432	8/8	11:35	14.6	N - 37.66643 W - 120.46432	8/9	16:00	16.7	14 BC Riffle	50.4	
W43	N - 37.66426 W - 120.48132	8/9	11:40	17.1	N - 37.66308 W - 120.48160	8/10	15:13	18.0	25 BC Riffle	49.1	Mortality- post- swim test transport
W44	N - 37.66426 W - 120.48132	8/9	11:40	17.1	N - 37.66308 W - 120.48160	8/10	15:13	18.0	25 BC Riffle	49.1	
W45	N - 37.66565 W - 120.45826	8/13	10:25	14.4	N - 37.66565 W - 120.45826	8/14	14:10	15.2	11 FW Riffle	50.7	Fish not PIT tagged to limit handling after study termination per NMFS Section 10 permit conditions
W46	N - 37.66565 W - 120.45826	8/13	10:59	13.9	N - 37.66565 W - 120.45826	8/14	14:10	15.2	11 FW Riffle	50.7	Fish not PIT tagged to limit handling after study termination per NMFS Section 10 permit conditions
W47	N - 37.66565 W - 120.45826	8/14	9:08	13.6	N - 37.66565 W - 120.45826	8/14	14:10	15.2	11 FW Riffle	50.7	Fish released w/o testing per NMFS Section 10 permit conditions
W48	N - 37.66565 W - 120.45826	8/14	9:15	13.6	N - 37.66565 W - 120.45826	8/14	14:10	15.2	11 FW Riffle	50.7	Fish released w/o testing per NMFS Section 10 permit conditions

THERMAL PERFORMANCE OF WILD JUVENILE *ONCORHYNCHUS MYKISS* IN THE LOWER TUOLUMNE RIVER: A CASE FOR LOCAL ADJUSTMENT TO HIGH RIVER TEMPERATURE

APPENDIX 3

PIT CODE AND RECAPTURE TABLE

Appendix 3. PIT code and recapture table. Only five out of seven recapture fish are included in this table because PIT IDs were not recorded for two of the recaptured fish. See Figure 3 for details on the two unidentified recaptured fish, and recapture location for all recaptured fish. Days post-release is the number of days after release the PIT was recaptured.

Fish ID	PIT	Test Temp (˚C)	PIT recap freq	Days post release
W01	114756	13		
W02	114745	13		
W03	114743	13		
W04	114720	13		
W05	114764	15		
W06	--	15		
W07	114755	19		
W08	114807	19		
W09	114779	21		
W10	114773	21		
W11	114769	23		
W12	114734	23	1	11
W13	114750	17		
W14	114759	17		
W15	114741	14		
W16	114766	14		

Fish ID	PIT	Test Temp (˚C)	PIT recap freq	Days post release
W17	114752	16	1	1
W18	114808	16		
W19	114803	20		
W20	114723	20		
W21	114786	22		
W22	114730	22		
W23	114809	18	1	3
W24	114714	18		
W25	114787	23		
W26	114725	23		
W27	526260	17		
W28	526292	17		
W29	526299	24		
W30	526275	24		
W31	526297	19		
W32	526212	19		

Fish ID	PIT	Test Temp (˚C)	PIT recap freq	Days post release
W33	526226	13		
W34	526211	13		
W35	526285	25		
W36	526263	25		
W37	--	--		
W38	--	--		
W39	526255	23	1	5
W40	526298	23	1	5
W41	526227	24		
W42	526235	24		
W43	526284	25		
W44	526252	25		
W45	--	19		
W46	--	19		
W47	--	--		
W48	--	--		

THERMAL PERFORMANCE OF WILD JUVENILE *ONCORHYNCHUS MYKISS* IN THE LOWER TUOLUMNE RIVER: A CASE FOR LOCAL ADJUSTMENT TO HIGH RIVER TEMPERATURE

APPENDIX 4

EXPERIMENTAL DATA TABLE

Appendix 4. Experimental data table. RMR: routine metabolic rate; MMR: maximum metabolic rate; AAS: absolute aerobic scope; FAS: factorial aerobic scope; K: condition factor (mass x 10^5 / FL^3).

Fish ID	Test Temp (°C)	RMR (mg O_2 $kg^{-0.95}min^{-1}$)	MMR (mg O_2 $kg^{-0.95}min^{-1}$)	AAS (mg O_2 $kg^{-0.95}min^{-1}$)	FAS	FL (mm)	Mass (g)	K	Body Depth (mm)	Body Width (mm)	Quality Control
W01	13	1.97	7.46	5.49	3.78	112	15.7	1.12	21	9	
W02	13	2.25				110	13.3	1.00	19	9	DISCARD; tunnel leak confirmed
W03	13	1.85	6.40	4.55	3.46	102	10.9	1.03	19.5	11	
W04	13	1.75	7.12	5.37	4.08	102	10.6	1.00	19.5	14	
W05	15	2.80	7.05	4.24	2.51	113	13.4	0.93	22.0	11	
W06	15	2.37	5.98	3.61	2.52	~160	~29.2	0.87			
W07	19		9.79			126	21.4	1.05	22.5	12	DISCARD; activity during RMR
W08	19		6.41			100	10.5	1.07	18.0	9	DISCARD; activity during RMR
W09	21	3.96	11.19	7.23	2.82	125	20.2	1.03	24.0	12	
W10	21	2.86	8.66	5.80	3.03	197	79.6	1.04	36.0	20	
W11	23	3.94	10.99	7.05	2.79	132	24.3	1.06	21.0	12	
W12	23	3.88	8.73	4.85	2.25	131	25.1	1.12	24.0	13	
W13	17	1.89				141	29.4	1.05	26.0	14	DISCARD; no MR increase with velocity 33 to 53 cms^{-1}
W14	17	2.47				142	29.9	1.04	23.0	10	DISCARD; no MR increase with velocity 30 to 46 cms^{-1}
W15	14	2.14				129	22.2	1.03	26.0	11	DISCARD; no MR increase with velocity 32 to 46 cms^{-1}
W16	14	2.53	5.61	3.08	2.22	137	28.4	1.10	24.0	12	
W17	16		8.13			135	27.6	1.12	26.0	13	DISCARD; activity during RMR
W18	16	2.31	8.26	5.95	3.58	133	25.9	1.10	25.0	10	
W19	20	3.75	9.95	6.19	2.65	147	38.4	1.21	28.0	11	
W20	20	3.66	10.83	7.16	2.96	134	28.1	1.17	25.0	11	
W21	22	3.09	11.15	8.06	3.61	124	21.7	1.14	21.0	10	

Fish ID	Test Temp (°C)	RMR (mg O_2 $kg^{-0.95}min^{-1}$)	MMR (mg O_2 $kg^{-0.95}min^{-1}$)	AAS (mg O_2 $kg^{-0.95}min^{-1}$)	FAS	FL (mm)	Mass (g)	K	Body Depth (mm)	Body Width (mm)	Quality Control
W22	22	2.89	9.73	6.84	3.37	115	15.8	1.04	19.0	8	
W23	18	2.73	9.35	6.62	3.42	164	47.1	1.07	30.0	18	
W24	18	2.81	6.97	4.16	2.48	133	22.6	0.96	21.0	13	
W25	23	4.11	11.23	7.12	2.73	121	18.7	1.06	20.0	11	
W26	23	3.90	9.43	5.53	2.42	129	23.4	1.09	23.0	12	
W27	17	2.76	9.57	6.81	3.47	134	24.9	1.03	21.0	13	
W28	17	2.87	8.69	5.81	3.02	122	19.9	1.10	24.0	12	
W29	24	5.31	13.41	8.10	2.52	104	13.0	1.16	18.0	10	
W30	24	5.26	9.17	3.91	1.74	115	16.5	1.08	19.0	12	
W31	19	2.81	8.07	5.26	2.87	138	29.0	1.10	24.0	10	
W32	19	3.21	6.71	3.51	2.09	140	27.2	0.99	28.0	11	
W33	13	2.17	6.97	4.80	3.21	117	16.4	1.02	19.0	8	
W34	13	2.02	6.40	4.38	3.17	105	12.2	1.05	19.0	7	
W35	25	4.87	10.09	5.21	2.07	130	27.4	1.25	26.0	10	
W36	25	7.01	13.12	6.11	1.87	111	12.4	0.91	17.0	7	
W37	Mortality- due to chloride residue in tunnel										
W38	Mortality- due to chloride residue in tunnel										
W39	23	3.76	7.11	3.36	1.89	101	12	1.02	17.0	6	
W40	23	4.76	14.41	9.65	3.03	122	18.5	1.16	20.0	10	
W41	24	4.87	10.04	5.17	2.06	131	23.1	1.03	22.0	12	
W42	24	3.94	10.04	6.10	2.55	138	25.5	0.97	22.0	12	
W43	25	5.54	9.03	3.49	1.63	107	14.5	1.18	19.0	8	
W44	25	6.13	12.61	6.48	2.06	113	14.9	1.03	19.0	8	
W45	19	3.49	11.76	8.27	3.37	~101	~11.5	1.12	~16	~10	
W46	19	3.51	7.59	4.08	2.16	~108	~13.1	1.04	~17	~10	

Fish ID	Test Temp (°C)	RMR (mg O_2 $kg^{-0.95}min^{-1}$)	MMR (mg O_2 $kg^{-0.95}min^{-1}$)	AAS (mg O_2 $kg^{-0.95}min^{-1}$)	FAS	FL (mm)	Mass (g)	K	Body Depth (mm)	Body Width (mm)	Quality Control
W47	Fish released w/o testing per NMFS Section 10 permit conditions										
W48	Fish released w/o testing per NMFS Section 10 permit conditions										

THERMAL PERFORMANCE OF WILD JUVENILE *ONCORHYNCHUS MYKISS* IN THE LOWER TUOLUMNE RIVER: A CASE FOR LOCAL ADJUSTMENT TO HIGH RIVER TEMPERATURE

APPENDIX 5

COMMENTS RECEIVED ON THE DRAFT STUDY REPORT

Tuolumne River Trust

CALIFORNIA SPORTFISHING PROTECTION ALLIANCE * Since 1983 * CSPA

March 2, 2015

Ms. Rose Staples
HDR, Inc.
rose.staples@hdrinc.com

Re: Comments on January 31, 2015 draft of *Thermal Performance of Wild Juvenile Oncorhynchus Mykiss in the Lower Tuolumne River: A Case for Local Adjustment to High River Temperature.*

Dear Ms. Staples,

The California Sportfishing Protection Alliance (CSPA) and the Tuolumne River Trust (TRT) submit the following comments on the January 31, 2015 draft of *Thermal Performance of Wild Juvenile Oncorhynchus Mykiss in the Lower Tuolumne River: A Case for Local Adjustment to High River Temperature* ("Study").

Overview

Based on our review of the Study and some of the background material cited in the Study, including the EPA (2003) *Region 10 Guidance For Pacific Northwest State and Tribal Temperature Water Quality Standard* that the Study in significant part seeks to address, it appears to us that the Study proposes to recommend to regulators a change in the established EPA (2003) temperature benchmark for a 7DADM value for the population of *O. mykiss* in the lower Tuolumne River based on site-specific evidence.

The EPA (2003) guidelines recognize that site-specific thermal criteria for salmonids may be developed that are more appropriate for specific locations and populations than are the general criteria promulgated in the guidelines. Evaluation of physiological response in a target population is an appropriate approach to development of site-specific conditions. We accept the premise of the Study that site-specific physiological study of the response of fish to water temperature may demonstrate that such response in a specific population is different than broader, more general and geographically unspecific studies of the response of fish to water temperature have shown.

Neither CSPA nor the Tuolumne River Trust has fisheries physiologists on staff, and neither has the resources to hire a consulting fisheries physiologist at this time. We therefore have no comment at this time on the experimental approach adopted within the Study, the value of the metrics adopted, or the execution of the Study. We may bring in an outside consultant at a later point in the ILP process to evaluate these and other technical aspects of the Study.

Instead, we confine our comments to the implicit and explicit argument that Study results can "be used to determine a 7DADM value for this population." (Study Conclusion, p. 24).

The Study does not evaluate the physiological response of the population of *O. mykiss* in the lower Tuolumne River over time.

There are limitations to the Study that the Study does not acknowledge. Chief among these limitations is that the Study does not evaluate physiological response of the population of *O. mykiss* in the lower Tuolumne River over time. On the contrary, 75% of the test fish were sourced from a location one mile downstream of La Grange Powerhouse, where temperatures at capture ranged from 12.7° C to 17.1° C. While the Study is critical of Hokanson (1977) for an issue concerning confidence intervals, the Study does not address Hokanson's use of a 40-day period to evaluate physiological response. Other studies (e.g. Brett 1956; Bidgood 1969) similarly address long-term exposure to less-than-optimal thermal conditions. The Study does not acknowledge this limitation. It is akin to trying to determine the best overall athletic performance in a decathlon based on performance in the sprint alone.

Thermal conditions in the summer in most of the lower Tuolumne River are much more comparable to a marathon than a sprint. In the absence of adequate flow, grinding ambient temperatures with daily highs greater than 90° F for four months, and greater than 100° F on multiple days, create long-term water temperatures that are stressful to juvenile and adult *O. mykiss*. A City of San Francisco biologist has acknowledged on the record in this proceeding that *O. mykiss* populations in the lower Tuolumne River are substantially smaller than populations downstream of rim dams in the Sacramento River drainage, where water temperatures are generally much lower than temperatures in the lower Tuolumne River.[1] A change in the 7DADM value for the population of *O. mykiss* in the lower Tuolumne River is not warranted based on the evidence presented. The document should therefore be re-cast as a study, rather than walking what appears to us to be a gray line between a study and a position paper that advocates a departure from established guidance.

Before any adjustment to the established (EPA 2003) temperature benchmark for a 7DADM value for the population of *O. mykiss* in the lower Tuolumne River is considered based on site-specific conditions and response, further investigation and evaluation would be required. The Study should explicitly state this, and should describe additional evidence needed before any change in the 7DADM value for the population *O. mykiss* in the lower Tuolumne River might appropriately be evaluated.

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[1] *See* Dr. Ronald Yoshiyama, "*Commentary on Evaluating the Temperature-Related Flow Requirements of Steelhead-Rainbow Trout (Oncorhynchus Mykiss) in the Lower Tuolumne River: A Literature Review and Synthesis*," eLibrary no. 20120807-5082 (July 5, 2012), p. 2: "The actual numbers of adult and juvenile trout in the lower Tuolumne River were not accurately known until recently. Routine fish monitoring by the Districts indicates relatively low numbers of trout have been present over the past 1-2 decades--i.e., far below the numbers occurring in the Sacramento River mainstem and tributaries."

We discuss additional limitations of the Study and additional evidentiary needs below.

The Study results alone do not warrant site-specific summer water temperature criteria for *O. mykiss* in the lower Tuolumne River.

The Study is careful in its language not to state outright that its results *alone* can be used to develop alternative summer temperature criteria for the lower Tuolumne River. The Executive Summary states:

> Moreover, given that the average AAS remained within 5% of peak performance up to a temperature of 24.6°C and that all Tuolumne River *O. mykiss* maintained a FAS value >2.0 up to 23°C, we recommend that a conservative upper performance limit of 22°C, instead of 18°C, *be used to determine* a 7-Day Average of the Daily Maximum (7DADM) value. (Study, p. ii, emphasis added).

The Conclusion states in greater context:

> High quality field data were generated on the physiological performance of Tuolumne River *O. mykiss* acutely exposed to a temperature range of 13 to 25°C. These data on the RMR, MMR, AAS, and FAS were consistent with higher thermal performance in Tuolumne River *O. mykiss* compared to that used to generate the 7DADM value of 18°C using Pacific northwest *O. mykiss* (EPA 2003). These new data are consistent with recent peer-reviewed literature that points to local thermal adjustments among salmonid populations. Therefore, these data provide sound evidence to establish alternative numeric criteria that would apply to the Tuolumne River *O. mykiss* population below La Grange Diversion Dam. Given a measured Topt for AAS of 21.2°C, and that the average AAS remained within 5% of this peak performance up to 24.6°C, and all fish maintained a FAS value >2 up to 23°C, we recommend that a conservative upper performance limit of 22°C, instead of 18°C, *be used to determine* a 7DADM value for this population. (Study, p. 24, emphasis added)

The use of the passive voice ("be used to determine") is at once imprecise as to the nature and context of such use and imprecise as to who will or should use it. In our view, the appropriate use of the Study results would be to 1) evaluate their limitations; 2) develop additional investigations that might be necessary to scientifically justify consideration of adjusting thermal criteria for the population of *O. mykiss* in the lower Tuolumne River, 3) enumerate and evaluate regulatory and policy issues that might be involved in adjusting these criteria; and 4) assemble these necessary components and, based on this ensemble, develop a process for considering and evaluating site-specific water temperature criteria.

However, the Study provides no such context and proposes no such process. While the Study does not explicitly say that its results alone can be used to develop alternative summer temperature criteria for the lower Tuolumne River, the Districts have already used the results of the Study to advocate that temperatures greater than those of the EPA (2003) criteria be considered appropriate to determine amount of usable habitat in the lower Tuolumne. The draft

Lower Tuolumne River Instream Flow Study—Evaluation of effective usable habitat area for over-summering O. mykiss distributed by the Districts' consultants to relicensing participants on February 27, 2015 adopts a higher range of suitable temperatures for over-summering O. mykiss *based on the present Thermal Performance Study*:

> Although the majority of historical (1996–2009) snorkel survey observations of *O. mykiss* in the lower Tuolumne River have occurred at temperatures of 20°C (68°F) or below (Ford and Kirihara 2010), *O. mykiss* have been routinely observed occupying Tuolumne River habitats at temperatures ranging from 11–25°C (52–77°C). Using wild juvenile *O. mykiss* collected from the Tuolumne River in the summer of 2014, a recently completed thermal performance study (Farrell et al. 2014) found a peak in the absolute aerobic scope (AAS) vs. temperature curve at 21.2°C (70°F), higher than the 19°C (66°F) growth rate optimum identified by Myrick and Cech (2001). Because Farrell et al. (2014) also found that the AAS of the wild *O. mykiss* test fish remained within 5% of the peak AAS between 17.8°C (64°F) to 24.6°C (76°F), these site-specific empirical data with broader temperature thresholds were selected for evaluation of thermal suitability for *O. mykiss.* In the current study, the temperatures of 18°C (66.4°F), 20°C (68°F), 22°C (71.6°F), and 24°C (75.2°F) were evaluated over each of the summer months (June through September) when these temperatures can be exceeded in the lower Tuolumne River.[2]

In skipping from study to study, any caveats and limitations that might be present or implied disappear. In order to avoid such misuse, the authors of the current Study should be more explicit in its caveats and should describe the limitations of its conclusions.

The Study may be limited because it analyzes a single lifestage.

The Study examines only the juvenile lifestage of *O. mykiss* in the lower Tuolumne River. The Clean Water Act requires that the most sensitive resources be protected. It is not clear whether the adult lifestage, which is also present during the summer time period, is more, equally or less sensitive to high water temperatures. Before adjustments of summer temperature criteria for *O. mykiss* in the lower Tuolumne River could be considered, an evaluation of the physiological response of adult *O. mykiss* in the lower Tuolumne River would need to conducted, in addition to completing the evaluation of the physiological response of juveniles.

The Study makes comparisons between *O. mykiss* in the lower Tuolumne River and populations that are more permanent and defined and that have more common characteristics.

The Study draws comparisons with other populations of rainbow trout that have demonstrated higher temperature tolerances than the figures given for juvenile rearing in the EPA (2003) Criteria. Several of these are cited in the EPA document, including redband trout in Eastern Oregon, southern California coastal steelhead, and trout introduced in Australia.

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[2] Stillwater Sciences, 2015, *Lower Tuolumne River Instream Flow Study—Evaluation of effective usable habitat area for over-summering O. mykiss*. Draft Report. Prepared by Stillwater Sciences, Davis, California for Turlock Irrigation District, Turlock California and Modesto Irrigation District, Modesto, California. Distributed to relicensing participants via e-mail by Ms. Rose Staples on February 27, 2015, pp. 2-3.

Certainly at least the redband and southern California steelhead are more likely to share common ancestry and even genetics than the fish in the lower Tuolumne River, where the population was extremely small due to low project flows until 1995. The current Tuolumne population is likely a combination of residual lower river fish, wild or hatchery fish washed down from La Grange (themselves possibly the result of production in La Grange Reservoir or originating in Don Pedro Reservoir), and some number of anadromous individuals of unknown origin and their progeny. It is further likely that the population is being replenished from these sources on an ongoing basis, and that some portion of the fish that are there in several years will have little directly in common with the current population. This is particularly likely under dry or drought conditions, when a greater proportion of the existing population may be expected to perish. Managing a changing population based on ascribed thermal tolerances of an existing population is questionable both scientifically and as policy.

It is likely that the present population in the lower Tuolumne is temperature tolerant because it has had to be in order to survive, and that improved thermal conditions would create a larger population. Improved thermal conditions would certainly increase the volume of suitable habitat by pushing thermal limitations further downstream. It is a policy as well as a scientific question whether to manage to the highest suitable temperature (whatever that may be) or to manage to what is likely to produce a stronger population. On a policy and recreational basis, it is hard to justify a small population managed for small fish. If the population were more robust, the argument for managing to a higher temperature would be more credible.

There is no bioenergetics study of O. mykiss in the lower Tuolumne River that would support management for water temperatures higher than those recommended in EPA (2003) guidance.

The Districts declined in 2011 to conduct a bioenergetics study of O. mykiss in the lower Tuolumne River as recommended by the Department of Fish and Wildlife.[3] The Commission did not order this study. The current Study recognizes: "the important ecological consideration is whether or not there is sufficient food in the Tuolumne River to support the highest MR associated with high temperature." (Study, p. 22). The Study supports the hypothesis that sufficient food is present only with anecdotal data:

> All available studies suggest that the Tuolumne River population is not food limited, including direct studies of Tuolumne River Chinook salmon diet (TID/MID 1992, Appendix 16), long-term benthic macro-invertebrate sampling data collected from 1988–2008 (e.g., TID/MID 1997, Report 1996-4; TID/MID 2009, Report 2008-7), as well as the relatively high length-at-age for *O. mykiss* sampled in 2012 (Stillwater Sciences 2013). Indeed, the *O. mykiss* sampled for the current study were apparently feeding well in the river during summer months given the high condition factors (see Appendix 2), feces being regularly found in the swim tunnel and two test fish regurgitating rather large meals post-exhaustion. (*ibid*).

[3] *See* California Department of Fish and Wildlife, *Comments on Proposed Study Plan*, eLibrary 20111024-5118, p. 55 ff., proposed Bioenergetics Study.

It is one thing to say that there is apparently sufficient food in the lower Tuolumne for the small population of *O. mykiss* located in a relatively small section of the river. It is quite another to argue in the absence of a targeted study that food production is great enough to support a larger population at the highest metabolic rate associated with high water temperatures. There is no evidence to support such a finding. If food is indeed unusually abundant, why is the *O. mykiss* population in the lower Tuolumne River neither greatly abundant nor characterized by large numbers of large fish?

Conclusion and recommendations

The summer water temperature criteria that are apparently recommended in the Study, and that are more definitively recommended based on the present Study in the just-released draft study entitled *Lower Tuolumne River Instream Flow Study—Evaluation of effective usable habitat area for over-summering O. mykiss,* are not warranted by the evidence the Study has collected. If the Districts wish to persist in seeking to define site-specific summer water temperature criteria for the lower Tuolumne River, they should affirmatively address the scientific and policy issues we have described above. In brief, these are

1. Follow-up site specific physiological studies must address elevated water temperatures over an extended period of time, ideally over an entire summer.
2. Follow-up site specific physiological studies must be conducted on adult as well as juvenile *O. mykiss*.
3. Follow-up site specific physiological studies must address the likely multiple sources and ongoing replenishment of the *O. mykiss* population of the lower Tuolumne River.
4. The Districts should perform a bioenergetics study for juvenile and adult *O. mykiss* in the lower Tuolumne River.

In addition, the Study should be edited so that the Executive Summary and the Conclusion place the value of the findings in the appropriate context of how they might inform a comprehensive review of site-specific summer thermal conditions in the lower Tuolumne River.

Please contact Chris Shutes if you have any questions. Thank you for the opportunity to comment on the draft of the Study entitled *Thermal Performance of Wild Juvenile Oncorhynchus Mykiss in the Lower Tuolumne River: A Case for Local Adjustment to High River Temperature*.

Respectfully submitted,

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Chris Shutes
FERC Projects Director
California Sportfishing Protection Alliance
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State Water Resources Control Board

MAR 1 8 2015

Ms. Rose Staples
HDR, Inc.
970 Baxter Boulevard, Suite 301
Portland, ME 04103
Via email: Rose.Staples@hdrinc.com

Dear Ms. Staples:

COMMENTS ON THE THERMAL PERFORMANCE OF WILD JUVENILE ONCORHYNCHUS MYKISS IN THE LOWER TUOLUMNE RIVER: A CASE FOR LOCAL ADJUSTMENT TO HIGH RIVER TEMPERATURE REPORT; NEW DON PEDRO HYDROELECTRIC PROJECT; FEDERAL ENERGY REGULATORY COMMISSION PROJECT NO. 2299

On January 30, 2015 the State Water Resources Control Board (State Water Board) received the *Thermal Performance of Wild Juvenile Oncorhynchus Mykiss in the Lower Tuolumne River: A Case for Local Adjustment to High River Temperature Report* (Report). This Report was developed by Turlock Irrigation District and Modesto Irrigation District (collectively referred to as Districts[1]) as part of the Federal Energy Regulatory Commission (FERC) relicensing of the Don Pedro Hydroelectric Project (Project). The Project is also referred to as FERC Project No. 2299. The Report is a result of Water and Aquatic Resource (W&AR) Study Plan 14: Temperature Criteria Assessment (Study Plan 14) developed by the Districts. Study Plan 14 was not required by FERC in its Final Study Plan Determination and is not supported by the State Water Board, California Department of Fish and Wildlife (CDFW), United States Fish and Wildlife Service (USFWS), or the National Marine Fisheries Services (NMFS).

Throughout the relicensing process, State Water Board staff maintained that the relicensing studies and environmental impact analyses should use the temperature criteria for salmonids outlined in the 2003 United States Environmental Protection Agency (USEPA) *Region 10 Guidance for Pacific Northwest State and Tribal Temperature Water Quality Standards* (USEPA Guidance) (USEPA 2003). The Tuolumne River from Don Pedro Reservoir to the San Joaquin River was listed as impaired for temperature under Section 303(d) of the Clean Water Act (CWA) in 2008. The 2003 USEPA Guidance for salmonids was used as the evaluation guideline for five of the six lines of evidence used to support the Section 303(d) listing of the Tuolumne River for temperature. As such, State Water Board staff has consistently provided comments requesting that any salmonid related protection, mitigation and enhancement measures developed through the relicensing process follow the 2003 USEPA Guidance.

State Water Board staff reviewed the Report and provides the following comments. State Water Board staff relies upon the specialized expertise of CDFW, USFWS, and NMFS when dealing with aquatic and terrestrial species. Therefore, it is essential that these agencies continue to be actively involved in the development of any *Oncrohynchus mykiss* (*O. mykiss)* temperature criteria specific to the Tuolumne River.

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[1] Districts also refers to the consultants that represent them.

The Report often compares its results to the 2003 USEPA Guidance. The Report does not clearly and accurately introduce the 2003 USEPA Guidance, its goals, and development. The 2003 USEPA Guidance was developed as part of a collaborative process between states, tribes, and federal agencies. One of the stated goals of the 2003 USEPA Guidance is to provide temperature guidance that

> "meets the biological requirements of native salmonid species for survival and recovery pursuant to the Endangered Species Act (ESA), provides for the restoration and maintenance of surface water temperature to support and protect native salmonids pursuant to the CWA, and meets the salmon rebuilding needs of federal trust responsibilities with treaty tribes."

It is important to understand that the 2003 UESPA Guidance was developed using numerous peer-reviewed studies and published papers. Properly understanding the 2003 USEPA Guidance and its goals is essential when comparing information contained in the USEPA Guidance and the Report. Knowledge of the 2003 USEPA Guidance goals assists in the understanding of the Report's limitations, and provides an example regarding how one may approach collaborative development of similar studies in the future.

The Report does not explicitly state that its results alone demand a change in the 7-Day Average of the Daily Maximum (7DADM) temperature outlined in the 2003 USEPA Guidance. Rather, the Report states that this information should be used to determine a 7DADM value specific to Tuolumne River *O. mykiss*. However, the Report does not outline a process to be used to determine a scientifically acceptable and defensible 7DADM specific to the Tuolumne River *O. mykiss*.

As previously stated in this comment letter, the 7DADM developed in the 2003 USEPA Guidance was developed as part of a collaborative effort and relied upon numerous peer-reviewed studies and published reports. State Water Board staff recommends that any process to develop temperature criteria specific to the Tuolumne River follow a similar process as the EPA Guidance. Two additional examples of the recommended process include: *The Final Staff Report for the Klamath River Total Maximum Daily Loads (TMDLs) Addressing Temperature, Dissolved Oxygen, Nutrient, and Microcystin Impairments in California* (NCRWQCB 2010), and *The Effects of Temperature on Steelhead Trout, Coho Salmon, and Chinook Salmon Biology and Function by Life Stage; Implications for Klamath Basin TMDLs* (NCRWQCB 2005).

It is important to point out that the Report focuses on increased water temperature effects on only one parameter (oxygen consumption) and one life stage (juvenile) for *O. mykiss*. Study Plan 14 and the Report do not evaluate long term effects of increased water temperature as well as the other lifestages of *O. mykiss*. Questions that might be evaluated as part of a more comprehensive study include, but are not limited to:

- What is/are the effect(s) of increased temperature conditions on other life stages of *O. mykiss* or the long-term effects of this short-term exposure on *O. mykiss?*
- How does temperature influence other factors which may affect salmonids, such as food availability and disease?

These are a couple of questions that need to be answered prior to considering changes to temperature criteria. Additionally, Study Plan 14 and the Report only consider increased temperature effects on fish persisting in the Tuolumne River under current conditions. Study Plan 14 and the Report fail to examine the effects of increased river temperatures on the recovery of *O. mykiss* populations in the Tuolumne River. In 2006, NMFS listed California Central Valley Steelhead as threatened under the federal ESA. With a listed species, it is important than any subsequent studies also address the ability of the species, *O. mykiss* in this instance, to increase in population size under the proposed temperature(s).

As public agencies with responsibility over the Project, the Districts will act as the lead agency in the development of the California Environmental Quality Act (CEQA) document for relicensing of the Project. As a responsible agency, the State Water Board will rely upon the Districts CEQA document when issuing its CWA Section 401 water quality certification for the Project. State Water Board staff understands the desire to review temperature related information for Tuolumne River salmonids, but is concerned that the Districts will use this limited information in the development of the CEQA document. Further research and consultation is necessary before this Report can be used to advocate for higher water temperature criteria in the Tuolumne River. Study Plan 14 and its associated Report do not justify abandonment of the 2003 USEPA Guidance and shall not be substituted for the 2003 USEPA Guidance.

If you have questions regarding this letter, please contact me at (916) 445-9989 or by email at Peter.Barnes@waterboards.ca.gov. Written correspondence should be directed to:

State Water Resources Control Board
Division of Water Rights
Water Quality Certification Program
Attn: Peter Barnes
P.O. Box 2000
Sacramento, CA 95812

Sincerely,

Peter Barnes
Engineering Geologist
Water Quality Certification Program

References

USEPA. 2003. EPA Region 10 Guidance for Pacific Northwest State and Tribal Temperature Water Quality Standards. April 2003

North Coast Regional Water Quality Control Board (NCRWQCB). 2005. The Effects of Temperature on Steelhead Trout, Coho Salmon, and Chinook Salmon Biology and Function by Life Stage; Implications for Klamath Basin TMDLs. August 2005.

North Coast Regional Water Quality Control Board (NCRWQCB). 2010. Final Staff Report for the Klamath River Total Maximum Daily Loads (TMDLs) Addressing Temperature, Dissolved Oxygen, Nutrient, and Microcystin Impairments in California. March 2010.

cc: Ms. Kimberly D. Bose, Secretary
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Received 9-6-2016
R Staples

August 31, 2016

Rose Staples, Executive Assistant
HDR, Inc.
970 Baxter Boulevard, Suite 301
Portland, Maine 04103

Subject: **Comments to *Thermal performance of wild juvenile Oncorhynchus mykiss in the lower Tuolumne River: A case for local adjustment to high river temperature report Don Pedro Project January 2015* (Study)**

Dear Ms. Staples:

The California Department of Fish and Wildlife (Department) has reviewed the above study report. It is noteworthy that the Department has been informed by Dr. Nann Fangue that a revised study report was completed in May 2015; however, the Department has not received this new version for review. Therefore, we recognize that the new version may have already addressed one or more of our comments as presented below.

The authors conducted an aerobic scope laboratory swim tunnel test for juvenile wild rainbow trout (*O. mykiss*) at temperatures ranging from 13°C to 25°C. Juvenile trout were captured from the Tuolumne River, acclimated to the test facilities and then swim tunnel tested at various water temperatures overnight pending study design. Metabolic oxygen consumption was measured at rest and during swimming by increasing water flows in a swim tunnel. The Department provides the following comments regarding the above mentioned study report.

General Comments:

Survival stress tests (i.e. thermal tolerance tests) are tests that are conducted using a few individuals from a population and exposing them to water temperature regimes that, can vary in degree, time of exposure, and pre-test acclimation water temperature test starting point so that the survival rate(s) for these individual fish can be identified. If a sufficient number of individuals within a distinct population segment have been tested, survival rates obtained from individually tested fish can be inferred to represent the survival rates for the entire population. Survival stress tests for individuals are common, while population thermal tests are rare due to the need to test many fish. The aerobic study that the authors conducted is basically an acute water temperature stress test that attempts to produce individual fish water temperature survival rates using oxygen consumption as the survival metric.

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An aerobic study is basically an acute water temperature survival stress test that requires pushing fish to complete exhaustion, then using oxygen consumption as the measurement metric to document when exhaustion occurs. The study design identifies acute exposure to stressful warmer water temperatures at the individual level; therefore, the study cannot inform development and/or revision of population level chronic water temperature criteria. In their report, the authors compare their acute water temperature results to the United States Environmental Protection Agency's chronic population criteria (USEPA 2003)[1] which is inappropriate.

Anadromous salmonids populations throughout the Pacific Northwest (including California) are declining primarily because of poor reproductive success and recruitment back into the population (Yoshiyama et al 2001)[2] . The intent of the USEPA (2003) analysis was to reverse that trend by presenting chronic population water temperature criteria. Chronic criteria and population criteria are always lower than acute and individual criteria. The authors presented higher acute/individual water temperature criteria based on a single study, but failed to extrapolate the results to a lower chronic population criteria that would be protective for reproductive success and recruitment to maintain a sustainable (i.e. viable) population. Survival rates are based on amount of time exposed, as well as temperature exposure, and are extremely well described in the scientific literature.

The USEPA, in their document entitled "Summary of Technical Literature Examining the Physiological Effects of Temperature on Salmon" (EPA 2001)[3,] further emphasizes the importance of short and long term exposure to temperatures:

> *What are lethal temperature effects?*
> *National Academy of Sciences (NAS) (1972) recommendations for water temperature exposure for protection of aquatic life specify maximum acceptable temperatures for prolonged exposures (≥ 1 week), winter maximum temperatures, short-term exposure to extreme temperature, and*

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[1] U.S. Environmental Protection Agency 2003. *USEPA Region 10 Guidance for Pacific Northwest State and Tribal Temperature Water Quality Standards.* EPA 910-B-03-002. Region 10 Office of Water, Seattle, WA.

[2] Yoshiyama, R.M., E.R. Gerstung, F.W. Fisher, and P.B. Moyle. 2001. *Historical and Present Distribution of Chinook Salmon in the Central Valley Drainage of California.* California Department of Fish and Game. Fish Bulletin 179 (1): 71-176

[3] U.S. Environmental Protection Agency. 2001. Issue Paper 5, Summary of Technical Literature Examining the Physiological Effects of Temperature on Salmonids (page 12).

suitable reproduction and development temperatures. Lethal effects are thermal effects that cause direct mortality within an exposure period of less than 1 wk. Prolonged exposure temperatures and temperatures that interfere with normal reproduction and development can result in mortality or reduction in population fitness or production, but the effects may be delayed or indirect, or result from impairment of function or reduction in suitable habitat or food quantity and quality available.

Specific Comments:

Executive Summary

Page i, second paragraph. The authors stated, "The study tested the hypothesis that the Tuolumne River *O. mykiss* population below La Grange Diversion Dam is locally adjusted to the relatively warm thermal conditions that exist in the river during the summer". What is the authors' definition of "locally adjusted"?

Page i, third paragraph, last sentence. The authors state, "Therefore, the experimental approach also acknowledges that every activity of a fish in a river (swimming, catching prey and feeding, digesting a meal, avoiding predators, defending territory, etc.) requires oxygen consumption above a basic routine need and that salmonids have evolved to maximize their oxygen supply when they fuel muscles during exhaustive swimming". This statement leads to three questions; 1) This test appears to study basic survival, but does the study address reproductive success and recruitment? 2) Does this experimental design measure activities related to spawning, immune function and general overall stress? and 3) Isn't this the case for all vertebrates, that an animal's physiological function evolved to fuel their muscle under non-resting (exercise) or stress conditions?

Page i, fourth paragraph. The authors state "As expected for a fish, RMR [Routine Metabolic Rate] increased exponentially with increasing test temperature from 13°C to 25°C (36 different fish, each at a single test temperature)". Basically the RMR is a fish in a resting state, thus if their RMR increased with temperature in a resting state, this indicates the fish are becoming stressed in the warmer temperatures without exertion. They analyzed their results using a mathematical model. What would the results look like if the results were analyzed using standard statistical analysis for each temperature group? Further they presented temperature ranges from 16.4°C to 25°C and 17.8°C to 24.6°C, suggesting the higher temperatures are protective for basic survival. This leads to the question, do the authors agree that the 16.4°C and 17.8°C temperature levels (i.e. lower end of range) to be a more protective temperature at a chronic population exposure level to provide optimal reproductive success and recruitment rather than the higher temperature's the author are advocating? It's vitally important to remember that just because a fish or a fish population **survives** at a certain temperature; it does not automatically mean that the fish or the fish population **thrives** at the same temperature range. The ability to "thrive", carries with it the ability to successfully grow and reproduce at sufficient levels that keep the both the individual fish, and the fish population, in good condition (i.e. adequate reproductive viability).

The authors further state, "Thus, the maintenance of AAS [Absolute Aerobic Scope] across nearly the entire test temperature range clearly shows that the Tuolumne River *O. mykiss* population has a broad range of thermal performance". Isn't this case for all vertebrates? The authors further state, "Indeed, the AAS of the Tuolumne River *O. mykiss* population was atypical when compared with cold-adjusted, *O mykiss* from the Pacific Northwest, whose thermal performance optimum is reported as 18°C" (USEPA 2003). What exactly is meant by "atypical"? What is meant by "cold-adjusted" fish from the Pacific Northwest when all salmonids are cold water fish that evolved in cold waters that originated from snow melt and ground water seepage into the river systems? The reference to the USEPA (2003) 18°C as a thermal performance optimum is incorrect. The USEPA (2003) report did not discuss thermal performance, but rather concentrated developing sub-lethal chronic population criteria to improve reproductive success and recruitment to reverse a declining population trend. It is inappropriate, and therefore not scientifically valid, to compare acute individual results to chronic population criteria. The last sentence suggesting the upper thermal performance is above 25°C is pure speculation on part of the authors and should be deleted.

Page ii, first paragraph. What do the authors mean when indicating that the fish are locally adjusted? The fish are blocked by a series of dams, preventing them to migrate upstream to cooling temperatures, so they have no choice but to live in a warmer environmental regime. The authors also stated they lost 1 of 4 fish acutely exposed to 25°C. Do the authors agree that 25% fish exposed to 25°C would die, especially if they are chronically exposed to this and higher temperatures?

Page ii, second paragraph. The authors state, "The conclusion of the study is that the thermal range over which the Tuolumne River *O. mykiss population* can maintain a 95% of peak aerobic activity from 17.8°C to 26.6°C". How long can these fish withstand this activity? In the last sentence they state that "Finally, based on a video analysis of the swimming activity of *O. mykiss* in the Tuolumne River, fish at ambient water temperatures were predicted to have excess aerobic capacity well beyond that needed to swim and maintain station against the river current in their usual habitat". However, don't all vertebrates have excess aerobic capacity to survive and meet the basic needs of survival; how are these trout any different from any other living creature? Just because a fish can survive a short duration elevated temperature exposure event (i.e. minutes) does not mean that it can withstand the same elevated temperature for a long exposure event (i.e. days, weeks, and/or months).

A human analogy helps us understand key physiological concepts and keep them separate. For example, an Olympic marathon runner can run 26.2 miles in approximately two hours; however, this same runner cannot maintain the same pace for days, weeks, and months. The point here is that the Olympic runner is training for an acute event but in so doing he/she is not enabling him/herself to maintain an acute pace over a chronic period of time (days, weeks, and months). The ability of fish to survive an acute event is not indicative of a fish's ability to survive a chronic event. As was stated above, acute tolerance is always higher than chronic tolerance. USEPA set chronic criteria while the authors of this report conducted an acute study. At best, this study's results may be used to inform development of acute level criteria (i.e. temperature tolerance over short duration) but is does not translate to predicting a chronic level criterion (i.e. temperature tolerance over long durations).

Page ii, last paragraph. The USEPA (2003) criterion is not an upper performance level for fish. The authors are comparing acute results to a chronic value, an individual result to a population criteria, and survival to reproductive success and recruitment, which are all inappropriate comparisons. The authors need to conduct the same test in other rainbow trout stocks throughout the Pacific Northwest to make a similar comparison to this study <u>before</u> rendering a conclusion that the Tuolumne River rainbow trout have evolved higher population acute water temperature tolerance. The authors recommend "...we recommend that a conservative upper performance limit of 22°C, instead of 18°C, be used to determine a 7-Day Average of the Daily Maximum (7DADM) value". However, for cold water fish, such as trout, it would be more appropriate, conservatively speaking, to use the lower water temperatures values (17.8°C) the authors presented in their study. Their comparison to the redband trout is also inappropriate because the redband trout evolved under a totally different set of environmental conditions compared to coastal rainbow trout/steelhead. Coastal rainbow trout evolved across thousands of years in river systems that originate in high mountain elevations and connect to the Pacific Ocean. Today's rainbow trout have been exposed to river systems, blocked by dams for less than 100 years, which is insufficient on the evolutionary scale to adapt to today's river water conditions.

Introduction

Page 1, first paragraph. The authors' state, "However, cooler river temperatures are associated with cloud cover and over night [sic], and deeper ponds in the river do show some thermal stratification". Did the authors document the daily temperature difference during the hot summers, and identify and document any cool refugia or deep pools locations and measure water temperatures?

Page 1, second paragraph. The location in river miles was discussed as to where rainbow trout are commonly found with temperatures ranging from 11°C to 28°C. This is true; however, these fish have no other choice but to live under these environmental conditions because their natural migratory route to cooler high elevation waters is blocked by dams. If a fish can survive under a set of environmental (i.e. acute and chronic) conditions, including "thriving" (i.e. reproductive success over many generations etc.), then this fish has demonstrated that it has the capacity to withstand higher temperatures. However, not knowing the environmental conditions which other fish populations are actually exposed to and not knowing their population viability, the justification for changing temperature criteria based upon other fish stocks is scientifically invalid.

Thermal Tolerance and Thermal Performance

The entire section discusses acute thermal tolerance in relation to survival, but does not present any information about chronic exposures in relation to reproductive success and recruitment to maintain a sustainable population. On page 2, paragraph 1, last sentence, the authors state "Regardless, CT_{max} is always higher than the temperature that a fish can tolerate for hours to days and certainly higher that the temperature at which a fish can no longer swim aerobically". The CT_{max} is a lethal temperature, at which point a fish can no longer swim aerobically. The tunnel test conducted by the authors accomplished the same end point where the fish were pushed to exhaustion and could no longer swim aerobically. So how does the tunnel test as presented by the authors differ from CT_{max} as stated in this paragraph?

7-day Average of the Daily Maxima (7DADM)

The USEPA (2003) criterion is discussed in this section.

Page 2, second paragraph, last sentence. The authors state, "Interestingly, by setting the 7DADM criterion for salmon and trout migration as 20°C, rather than 18°C, USEPA (2003) acknowledged that juvenile Pacific Northwest *O. mykiss* have sufficient aerobic scope for the energetic demands of river migration even at a temperature 2°C above the 7DADM for juvenile growth". However, the authors failed to mention the 20°C migration criteria is conditioned with a provision to restore or provide the natural thermal regime; or to provide or restore cold water refugia. Examples of cold water refugia or natural cool regime would include the confluence of cold tributaries at the main stem river or where groundwater exchanges with the river flow (hyporheic flow) that would provide cold water refugia for fish to escape maximum temperatures. Waters in tributaries for large rivers in the Central Valley have been diverted, eliminating cold water refugia at the confluence of these tributaries and groundwater pumping in the valley has lowered groundwater levels, thus removing natural cool ground water seeps into the valley's rivers. [4]

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[4] Corbett, F., T. Harter, and M. Sneed. 2011. *Subsidence due to excessive groundwater withdrawal in the San Joaquin Valley, California*. American Geophysical Union. Fall Meeting Abstract #H23H-1397.

Justification and Purpose of the Study

Page 4, first paragraph, last sentence. The authors state, "Thus, MR [Metabolic Rate] measurements were used to determine the optimal temperature range for Tuolumne River *O. mykiss*". Can the authors provide a definition for what they consider "optimal temperature range" and differentiate an acute and chronic optima range? Do the authors consider the hottest temperature as optimal or would a cold water fish be in excellent condition at a lower temperature from a chronic exposure perspective?

Page 5, the first paragraph describes the "aquatic treadmill" similar to Parsons (2011) and Figure 1 that is presented on page 33 in this Study report. The peak T_{opt} in Figure 1 appears to be the maximum acute temperature (T_{max}) at the peak of maximum oxygen consumption and not necessarily an optimal temperature. From the peak temperature to higher temperatures, oxygen consumption decreases, suggesting the fish is exhausted and no longer capable of absorbing oxygen similar to what occurs in hyperventilation with humans. It is vitally important to remember that water at higher temperatures have lower oxygen concentrations, which is noteworthy because oxygen crosses the cellular membrane via a concentration gradient. Thus, lower oxygen concentrations in the water decrease the concentration gradient forcing the fish to use more energy to pull oxygen across their gill membrane, similar to hyperventilation of a human at the 8,000-foot elevation where the oxygen concentration is lower than that which occurs at lower elevations. Clark et al. (2013)[5] Figure 1 B (page 2772) demonstrates that T_{opt} is midway up the aerobic scope and not at the peak of the slope. They further state "*T_{optAS} provides little insight into the preferred temperature or performance of aquatic ectotherms, but rather aerobic scope continues to increase until temperatures approaches lethal levels, beyond which aerobic scope declines rapidly as death ensues.*" We agree with Clark et al. (2013) [5] that the curves peak should be considered a T_{max}, not a $T_{opt.}$

Page 5, second paragraph, last sentence. The authors state, "Specifically, the temperature indices and the shape of the aerobic scope curve derived in the present study can also be compared with those of other *O. mykiss* populations and with the EPA (2003) recommendations". It is inappropriate to compare results from an acute stress test conducted for basic survival needs and then make inferences to a population needing protection at the chronic criterion level. Again, acute level <u>does not</u> equate to chronic level when it comes to conducting tests and/or developing protective criteria. The USEPA criteria are chronic not acute; therefore, any reference to USEPA criteria in

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[5] Clark et al. 2013. *Aerobic scope measurements of fishes in an era of climate change: respirometry, relevance and recommendations.* The Journal of Experimental Biology 216:2771-2782.

this report for purposes of changing chronic criteria is unfounded and is therefore not scientifically valid.

Page 5, last paragraph. This paragraph summarizes Fry (1947)[6] as presented in Parsons 2011.

> Parsons (2011) states:
> *Temperature has profound effects on the distribution and physiology of animals. Temperature effects occur over three distinct time scales: acute (direct effects occurring in minutes to hours), acclimation (physiological, morphological and biochemical adjustments occurring over days to weeks) and adaptation (spans generations, due to natural selection acting on Individuals).*

The "tunnel" experiment is an acute test that measures acclimation rather than adaptation. Central Valley salmonids evolved across thousands of generations to adapt to their living environment before the construction of dams. Fish that exist today have **not** evolved under today's environmental conditions because the time period has been too short for adaptation. Yes, *O. mykiss* can acclimate on an acute basis, but cannot adapt on a chronic basis in the less than 140 years since the construction of dams which blocked their historic spawning grounds.

Similar to Parson (2011) description, resistance or adaptation is a result of the evolutionary process that takes generations to develop and cause a genetic change across those generations in a population[7]. Tolerance or acclimation is a result of an individual, or a group of individuals, repeated exposure across the life of the individual that causes a physiological change. Individual based temperature exposure tolerance does not expand to all individuals in the population, but population based exposure adaptation transfers to all individuals within the population. Population thresholds are designed to protect a population; whereas, an individual threshold is designed to protect an individual or small group of individuals. A population threshold will have minimal health effects for all the individuals, including the most weak, in that population.[8,9]

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[6] Fry, F. E. J. 1947. *Effects of the environment on animal activity*. Publ. Ontario Fish. Res. Lab. 55, 1-62.

[7] Guthrie, F. E. 1980. *Resistance and tolerance to toxicants*. Pages 357-375 in E. Hodgson and F. E. Guthrie, editors. Introduction to Biochemical Toxicology. Elsevier, NY. 437pp.

[8] U. S. Environmental Protection Agency (USEPA). 1989. *Glossary of terms related to health, exposure, and risk assessment.*

[9] Air Risk Information Support Center. Research Triangle Park, N.C: Air RISC. Air Risk Information Support Center. Research Triangle Park, N.C: Air RISC.

Therefore, the population exposure threshold tends to be lower in value (i.e. more restrictive) than the individual exposure threshold. In summary, population thresholds are always less than an individual threshold and chronic thresholds are always less than acute thresholds. Thus, the reported fish water temperature experiment address individual level, but have limited usefulness as a basis for a full understanding of resistance or adaptation at the population level. As such, the tunnel stress test provides great information about tolerance and acclimation at the individual level, but is inappropriate to extrapolate the results to adaptation for chronic population exposure criteria.

Predictions Derived From EPA (2003)

Page 6. The authors proposed predictions based the USEPA (2003) criteria are irrelevant because the USEPA (2003) criteria were not based on an acute stress test. Is data presented in Table 1 based on acute or chronic tests? The USEPA (2003) 18°C criterion is not based on maximum metabolic rate (MMR) acute test as presented in Figure 1, but is a chronic criterion which is lower than acute criterion. The USEPA (2003) never stated an AAS T_{opt} metric, nor discussed this study design, to develop a chronic population criterion.

Alternative Predictions of Thermal Adjustment

Page 6. On what are the predictions based? Again, this study design is an acute stress test. It is well known that *O. mykiss* can survive in temperature above 18°C, but the study design does not answer the questions as to what is the chronic population threshold for reproductive success and recruitment to maintain sustainable populations across many future generations. The study design also does not address how well the *O. mykiss* immune system functions to ward off disease or how well a cold water fish can escape a warm water predator, especially when the water temperature are in the optimal range for the warm water predator. This study design can measure individual cold water fish short sprint energy to avoid a predator, but does not indicate how long a cold water fish can escape in a predatory warm water fish optimal temperature zone.

Fish Collection, Transport, and Handling

Pages 8 to 9. Most of the study fish were caught in the upper coolest reaches of the river. However, if these fish are adjusted to warm temperatures, why were they present in the coolest waters of the river? The fact that most of the fish were found and captured in the coolest waters of the river is indicative that, at the population level, *O. mykiss* in the lower Tuolumne River are seeking cooler water to reside in even though warmer water is available to them.

Experimental Protocols

Page 11, last paragraph. The authors state, "Water velocity was then increased in increments of 3 to 6 cm s^{-1} every 20 min until the fish failed to swim continuously". Is this an acceptable fisheries technique to allow an animal to work to the point of complete exhaustion? Would it be better to do a timed test by stopping the test before the fish is completely exhausted?

Page 12, third paragraph. The authors state, "Approximately 50% of the wild fish did not respond to the critical swimming velocity protocol but instead used their caudal fin to prop themselves on the downstream screen to avoid swimming". Is this a sign the fish were already stressed before the experimentation started and possibly a result of too warm temperatures to begin with?

Data Quality Control, Model Selection and Analyses

Page 13, last paragraph. The authors state, "Routine metabolic rate quality control (QC) was performed by visually inspecting over night [sic] video recordings for fish activity" and that "data from any fish showing consistent activity over night [sic] was disguarded". Why were the data discarded? Was the fish activity a sign of stress before the experiments started? In addition the authors state, "For fish exhibiting intense agitation, the swimming MMR was used as overall MMR." Four of these 'non-agitated' fish (W2, W13, W14, and W15) were disgarded due to failure of MR to increase incrementally; despite continuous station-holding swimming with tunnel velocity increases of more than 15 cm s^{-1}". Were these fish already stressed? How does inclusion of these data influence study results? It is important that data not be "selected" in order to bias study results. Scientific integrity requires that data not be thrown out for invalid reasons, including if the results cannot be explained or if they are different than expected.

Results

Page 15, Number 1, third paragraph, second sentence. The authors state, "They state that Routine Metabolic Rate (RMR) should increase exponentially until the test temperature approaches the upper thermal tolerance limit for *O. mykiss,* which according to published CT_{mas} values is 26°C to 32°C (see Table 1)". Who is "they"? If "they" is the USEPA, this is an incorrect statement because the USEPA did not include RMR studies in their review.

Myrick and Cech's Table 1[10] had significant less food consumption and decreased growth rates and increased mortality in their 25°C test fish compared to their 10°C, 14°C, and 19°C exposed fish. In their Table 2 results, fish consumed significantly less oxygen at 25°C compared to fish exposed to 10°C, 14°C, and 19°C. In their discussion they conclude:

> *Because thermal resistance in fish is closely correlated with exposure time (Elliott and Elliott 1995), fish with higher critical thermal maxima can tolerate longer exposures to sub-lethal temperatures, giving them a better chance of escaping to thermal refuges (Matthews et al. 1994) or surviving diel extremes.*
>
> *We observed no differences between Eagle Lake and Mt. Shasta trouts' thermal tolerances. Critical thermal maxima for both strains appeared to be lower than those reported for other rainbow trout acclimated to low (10–11 ◦C), or medium (14–15 ◦C) temperatures, but were similar to those reported for other salmonids acclimated to higher (19–20 ◦C) temperatures (Table 5). With the possible exception of lake trout (Salvelinus namaycush) (Grande and Andersen 1991), Arctic charr (S. alpinus) (Lyytikäinen et al. 1997) and other salmonids restricted to high latitudes, salmonids appear to have very similar thermal tolerances, irrespective of origin (Table 5).*

O. mykiss can survive in acute warm temperatures as demonstrated by the authors, but cold water fish still need cold water refugia sometime during the day. According to Myrick and Cech (2000) there is very little thermal difference between fish stocks per their comparison of other research studies (see Table 5) under similar experimental conditions.

Page 15, Number 2. The authors state, "These results for MMR are inconsistent with our prediction #2 derived from EPA (2003) criteria where MMR was expected to peak near to 18°C". This statement is irrelevant because the authors are comparing chronic population criteria to acute individual results. Again, chronic and population thresholds are always less than acute and individual thresholds.

Page 16, Number 3, third paragraph. The authors state, "These results for AAS are inconsistent with our prediction #3 based on EPA (2003) criteria, but are consistent with our alternative prediction #3 that the Tuolumne River population of *O. mykiss* is locally adjusted by having T_{opt} for AAS that is greater than 18°C i.e., 21.2°C." This statement is

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10 Myrick, C. A., and J. J. Cech Jr. 2000. Temperature influences on California rainbow trout physiological performance. Fish Physiol. Biochem 22:245-254

irrelevant because the authors are comparing a chronic population criterion to acute individual results. Again, chronic and population thresholds are always less than acute and individual thresholds.

Page 16, Number 4, last sentence. The authors state, "The numerical 95% peak AAS could be maintained from 17.8°C to 24.6°C, which is a more conservative thermal range for T_{opt}". However, based on the authors results, and because rainbow trout are a cold water fish, a true conservative thermal range would be from 16.4°C to 17.8°C.

Pages 16 to 17, Number 5. Same comment as for comparing an acute stress test results to a chronic population criterion. The author state, "Indeed, all individual fish tested up to 23°C has a FAS [Factorial Aerobic Scope] value >2, with only 4 out of 14 fish tested at 23°C, 24°C, and 25°C having a FAS value <2." A chronic population threshold is formulated to protect the weakest individuals in a population, so by using a lower criterion these 4 weaker fish should have better physiological function and survival.

Page 17, Number 7. The authors state, "Two fish tested at 25°C regurgitated rather large meals of aquatic invertebrates during the recovery from the swim test, and one of these fish died abruptly during the recovery period". Since, fish were exposed to an exhaustive state, this causes us to question whether or not this an appropriate testing technique where the test has to force an animal to complete exhaustion, especially for a group of fish that may be already stressed due to having to live in environmental conditions of altered flows and habitats that they did not evolve with.

Discussion

Data Quality

Page 18, first paragraph. This provides a brief summary of the results and comparison to other aerobic studies. The Department completed an analysis of variance as presented in the following Table 1 using the Study's data presented in Appendix 4.

Table 1. Mean RMR, MMR, AAS and FAS for rainbow trout from the Tuolumne River, summer 2014. Means with the same letters within each column are not significantly difference (P<0.05) using analysis of variance.

Temperature (°C)	N	RMR (mgO_2 $kg^{-0.95}$ min^{-1})	MMR mgO_2 $kg^{-0.95}$ min^{-1})	AAS mgO_2 $kg^{-0.95}$ min^{-1})	FAS
≤18	13	2.38	7.37	4.99[a]	3.15[a]
19-20	8	3.41	9.35[a]	5.94[a]	2.74[a,b]
22-25	16	4.58	10.64[a]	6.06[a]	2.41[b]

RMR = Routine Metabolic Rate; MMR = Maximum Metabolic Rate; AAS = Absolute Aerobic Scope; FAS = Factorial Aerobic Scope.

Temperatures at and below 18°C were significantly different for RMR, MMR, and FAS compared to the highest temperatures at and above 22°C. For RMR, which is a fish at rest, is this an indication the fish at the warmer temperatures were already stressed before the experiment started?

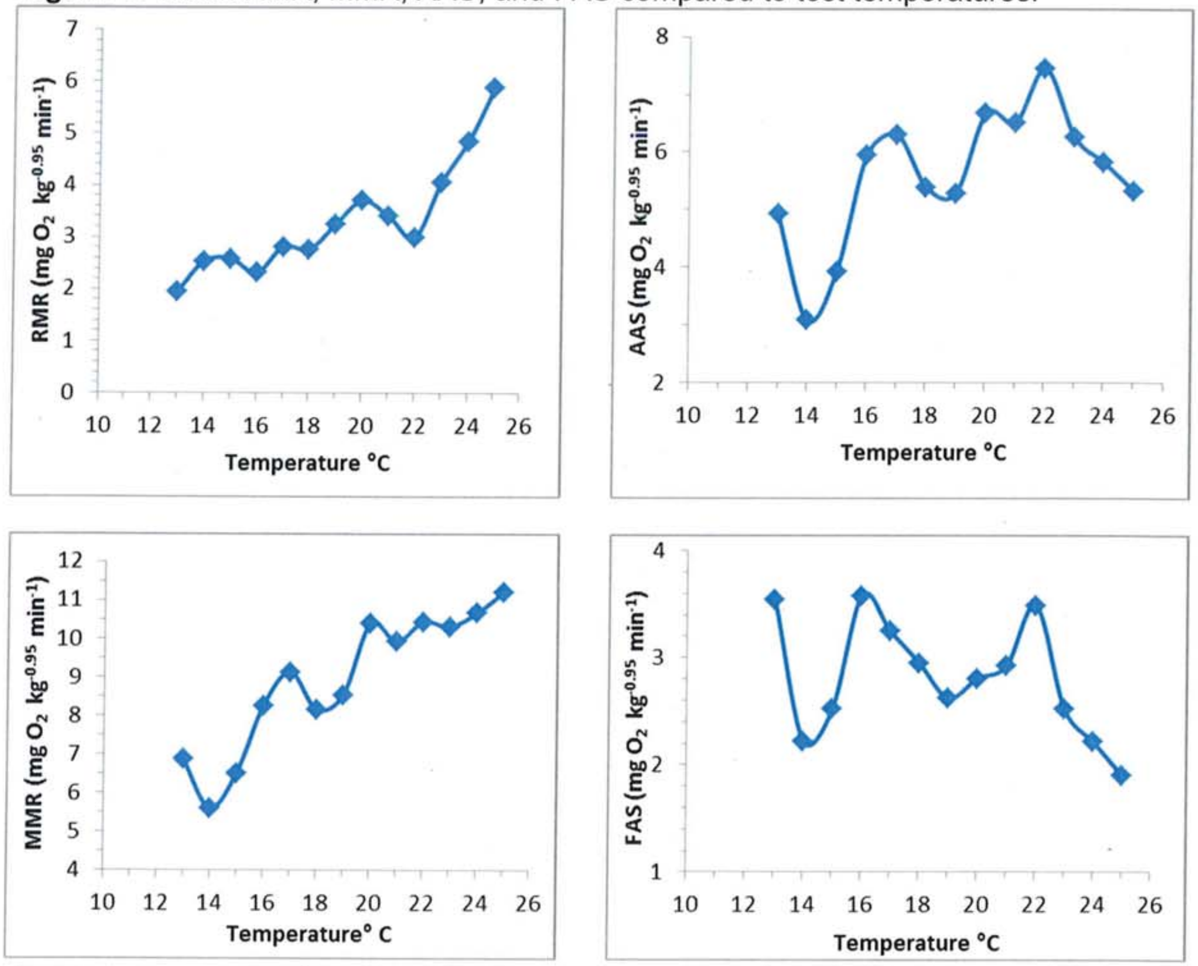
As stated in USEPA (2001) Issue Paper 4, Page 8, *a*s metabolic demands and oxygen consumption increase, gill ventilation must also rise proportionately (Heath and Hughes 1973). Further USEPA (2001) Issue Paper 4, Page 5 states:

> *There is an important relationship between temperature and the dissolved oxygen (DO) needs of fish. As temperature increases, metabolic rates increase, increasing the demand for oxygen by an organism. At the same time, the DO available to the organism decreases. Therefore, at times of the year when fish may experience temperature stress they also may experience stress from low DO levels.*

There is an inverse relationship between water temperature and oxygen concentration. As temperature increases, oxygen decreases. As such, at the warmer temperature with less oxygen, are the fish stressed to the point they are hyperventilating, thus increasing their metabolism trying to pull in as much oxygen as possible from a low oxygen environment.

The Department also graphed the mean results for each temperature as presented in Appendix 4.

Figure 1. Mean RMR, MMR, AAS, and FAS compared to test temperatures.



Note at 22°C for RMR, AAS, and FAS and at 21°C for MMR there is a sudden change in the slope of the graph. Does this change in slope indicate there is a sudden change in the physiological function of the fish and a clinical sign that the fish are highly stressed? A highly stressed animal is considered to be in poor condition.

Page 19, Protocol Number 2. The authors state, "2 a combination of continuous swimming and short velocity bursts to push fish off of the downstream screen". Was this an indication the fish was already tired and stressed at the beginning of the experiment?

Evidence for Local Thermal Adjustment

Page 20, first paragraph. The authors state, "Our predictions based on EPA (2003), as listed above, assumed that the Tuolumne River *O. mykiss* population would perform similarly to Pacific Northwest *O. mykiss* populations used to set the 7DADM by USEPA (2003)". The predictions based on USEPA are irrelevant because the USEPA did not perform tunnel stress techniques or use such data to develop their chronic population criteria recommendations. The authors recommend using 21.2°C rather than 18°C, but they are comparing an acute/individual result to a chronic/population recommendation. Have the authors considered other techniques to determine what cold water fish, such as *O. mykiss* can chronically sustain normal/optimal physiological function, including immune function, reproductive success and recruitment, at their recommended temperature of 21.2°C? It is well understood that cold water fish can simply survive at warmer temperatures to a point, but what about their entire life cycle needs at the individual and population levels? The authors mention these test fish have a wide optimal thermal performance range, but this is true for all living organisms; what do the authors consider "optimal"?

In the same paragraph, last sentence, the authors also state, "However, given that the CT_{max} could not be determined in the present work and that MMR increased up to the highest test temperature (25°C), it was impossible to determine the upper thermal limit when MMR collapses, which means that alternate metrics must be used to set the upper thermal limit for the Tuolumne River *O. mykiss* population". Since the "upper thermal limit" is survival based, can the author's present reproductive success and recruitment base criteria with this type of testing?

Page 20, second paragraph. The authors state, "The present work provides three useful metrics of the optimal temperature range". What is meant by "optimal temperature range"? T_{opt} appears to be more of a temperature maximum (T_{max}) than a T_{opt}. A temperature maximum does not necessarily mean it is an optimal temperature. Fry (1947) page 56, Figure 27, does not state the peak of activity as optimal, but refers to the "potential range of activity" and the "scope for activity". Fry further reduces the area of the activity curve by discussing "controlling factors". The USEPA (2001) as presented below provides a number of "controlling factors". Did the authors for this study consider controlling factors as described by Fry to adjust their activity curve?

In USEPA (2001) Issue Paper 4, Page 2 states:

> *A wide range of biological, chemical, and physical factors can challenge the physiological systems of fish. Various stressors such as handling, fright, forced swimming, anesthesia, rapid temperature changes, and scale loss all elicit a stress response characterized by physiological changes, which tend to be similar for all stressors (Wedemeyer and McLeay 1981). The stress response proceeds as follows: the central nervous system triggers the release of stress hormones (i.e., corticosteroids), changes*

occur in blood chemistry and hematology (i.e., reduced blood clotting time), and metabolism may be altered, which in turn can result in tissue changes (nitrogen balance and oxygen debt) followed by loss of electrolytes (Wedemeyer and McLeay 1981). These responses are expressed through changes in predator avoidance, growth, parr-smolt transformation, spawning success, migratory behavior, and incidence of disease. There also is a reduction in tolerance to subsequent stressors (Wedemeyer and McLeay 1981). At the population level, stress response may reduce recruitment and species abundance and diversity.

In USEPA (2001) Issue paper 5, Page 57 states:

Thermal stress is any temperature change that significantly alters biological functions of an organism and lowers probability of survival (Elliott 1981). Stress was categorized by Fry (1947 as cited by Elliott 1981) and Brett (1958) as lethal (leading to death within the resistance time), limiting (restricting essential metabolites or interfering with energy metabolism or respiration), inhibiting (interfering with normal functions such as reproduction, endocrine and ionic balance, and feeding functions), and loading (increased burden on metabolism that controls growth and activity). The latter three stresses can be lethal when continued over a long period (Elliott 1981).

Page 20, last paragraph, first sentence. The authors state, "Yet, there were important indications that a small percentage of individuals were taxed at 23-25°C by the thermal testing and intensive swim imposed on them outside of their normal habitat over a 24-h period." In the fourth sentence they further state, "In the present study, the telltale signs were that 4 of 13 individuals [31%] tested at 23-25°C had a FAS <2." This supports the concept that a chronic population base threshold is to protect the weakest individuals in a population and <u>cannot</u> be formulated by using just one simple acute stress test.

Pages 21 to 22, top line. In the same paragraph, the authors state, "Lastly the only fish mortality occurred in the recovery period (a phenomenon known as 'delayed mortality') after one fish was tested at 25°C". What is the point of mentioning 'delayed mortality'? The end result is one of four fish (25%) died at the highest temperature when forced to swim until completely exhausted.

Ecological relevance of the Present Findings

Page 21, third paragraph. The authors state, "MMR increased with temperature from 13 to 25°C, which would mean that as fish encounter higher temperatures, they have the capacity to perform an activity at a higher absolute rate, i.e., swim faster to capture food or avoid predators, digest meals faster, detoxify chemicals faster, etc.". Are the authors saying rainbow trout are better off at 25°C instead of <19°C? Their interpretation does not make any sense. We agree a fish will have burst of energy no matter what the temperature, however, the question remains how long can they maintain this energy consumption under chronic warm temperatures at 21.2°C? It takes energy to reproduce, how does exposure to chronic warm temperature impact reproduction success and recruitment into the population? Clark et al. (2013), page 2779, stated that there is a range of optimal temperatures for different processes and life histories and these optimal temperatures are different from T_{optAS}. They used an example for adult pink salmon where a T_{optAS} is at 21°C, but if reproduction occurred at 21°C would fail because the optimal temperature for spawning is <14°C. They further stated on page 2780, that fish have different physiological functions at different optimal temperatures as presented in their Figure 7B.

Page 22, first paragraph, third sentence. The authors state "As a result of high temperature, a fish would digest the same meal with a similar overall oxygen cost but at a faster rate". This study did not measure how fast fish can digest their food at increasing water temperatures, therefore this statement stating that a fish would digest their food at a faster rate at higher temperatures is an assumption based on speculation. As the authors discussed, this study design measured oxygen demand to demonstrate fish have extra burst energy from a resting state to seek and catch food, but does not include measuring the rate of digestion. All animals digest their food during the resting state, otherwise their digestive tract would cramp-up during high activity.

Page 22, last paragraph. The authors state "Here we did not evaluate the possibility that the Tuolumne River *O. mykiss* population can thermally acclimate to warmer river temperatures as the summer progresses, due to the available sample of a maximum of 50 individuals and their habitat temperature." Actually the authors did evaluate if Tuolumne River trout can acclimate, because this was an acute stress test designed for that purpose. Up to a limit, animals can acclimate to an acute environmental change, but how do these animals reproduce successfully under chronic environmental changes such as migratory routes being blocked and under different water flow regimes that they did not evolve with?

Conclusions

Page 24. As previously stated, the USEPA did not use acute tunnel stress test to evaluate a chronic population criterion. They included a number of factors as part of their evaluation. It is inappropriate to compare results from an acute individual test to a chronic population threshold. Since *O. mykiss* are a cold water fish, it would be more appropriate and conservative to use their lower range results (16.4 and 17.8°C) to protect this fish, particularly where reproduction success appears to be low because the population has been declining for decades since the dams were constructed[11].

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[11] Yoshiyama et al, 2001

Figures

Page 33, Figure 1. The T_{opt} appears to be an acute maximum temperature at the peak of maximum oxygen consumption and not necessarily an optimal temperature. From the peak temperature and higher, oxygen consumption decreases, suggesting the fish is exhausted and no longer capable of absorbing oxygen similarly to hyperventilation. See comment above for Page 20, second paragraph.

Page 37, Figure 4. See comment above for Page 20 second paragraph. Per Fry (1947) page 56, Figure 27, did the authors for this study consider controlling factors to adjust their activity curve? For the Factorial Aerobic Scope curve, the peak is approximately 13°C and decreases as temperatures increases. Clark et al. (2013) Figure 6, page 2778, presents a similar Factorial Aerobic Scope curve where the T_{optAS} is at the peak of the curve representing the lowest temperature at 11°C. Using Clark et al. (2013) concept, the authors Figure 4 peak at 13°C should be considered the T_{opt} for Tuolumne River rainbow trout, not the maximum temperatures.

Page 44, Appendix 1. Were *O. mykiss* observed, or attempts made to capture fish, between River Mile 39.5 (permit limit location) and River Mile 49? River water temperatures were above 18°C, so it would be worthwhile information to know if a healthy number of rainbow trout occupied this area. River Mile 48 appears to be below the 21.1°C permit requirement.

Page 47, Appendix 2. Fish W43 died. Did this fish die from delayed Capture Myopathy as a result of handling and exposure to high temperatures? Capture Myopathy results in the death of a captured wild animal during or after the animal has been captured and released.

Page 49, Appendix 4. All the data should be included for peer review, particularly for the fish that were discarded. What would the analysis look like if the discarded fish data was included? According to the Quality Control column the discarded fish were removed because of activity during RMR or no MR increase. Does this indicate the fish were already stressed? Which fish died?

Page 50. Four of 14 fish tested at 23°C, 24°C and 25°C had a FAS < 2. These results of less than 2 at the highest test temperatures indicate these fish were highly stressed at these temperatures.

We appreciate the opportunity to review and comment on the report. If you have any questions regarding these comments please contact Dr. Andrew Gordus, Staff Toxicologist, at the address or telephone number provided on this letterhead.

Sincerely,

for Julie A. Vance
Regional Manager

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THERMAL PERFORMANCE OF WILD JUVENILE *ONCORHYNCHUS MYKISS* IN THE LOWER TUOLUMNE RIVER: A CASE FOR LOCAL ADJUSTMENT TO HIGH RIVER TEMPERATURE

APPENDIX 6

RESPONSE TO COMMENTS ON THE DRAFT STUDY REPORT

Overarching Reply Comments
To CDFW's Review of the Current Study

On August 31, 2016, California Fish & Wildlife (CDFW) provided comments on the draft report entitled "Thermal Performance of Wild Juvenile *O. mykiss* of the Lower Tuolumne River" issued in January 2015. It is evident from the comments received from the reviewers that the study team has not been clear enough in describing:

a) the quality of the experimental work and the scientific rigor that was applied;

b) the applicability of the data generated relative to the larger question regarding the conservation of *O. mykiss* in the Tuolumne River; and

c) what types of data could provide further insight into the thermal ecology of Tuolumne River *O. mykiss*

Therefore, in addition to our detailed reply comments provided in this Appendix 6, we offer the following discussion to deal with certain issues that were raised in the CDFW review comments, issues that lie both within and outside of the primary purpose of our report. Hopefully, along with our detailed response document to the comments, this will better explain why we took the particular study approach that we did, namely using a temperature-dependent metabolic performance measure (i.e. aerobic scope), the ecological value of which is supported by a large volume of scientific literature. Further, the researchers conducting the study applied state-of-the-art methods and measurement techniques. Therefore, the information generated is applicable to the management of Tuolumne River *O. mykiss*.

1) What does absolute aerobic scope (AAS) tell us? AAS is a capacity measure or index that has comparative value. We measure this 'capacity' or 'potential', if you like. It is clear that the present experiments were not intended to directly address how such capacity would or could be used by the fish. Indeed, very few fish studies have even attempted to study capacity allocation given the inherent difficulties of such an effort. Nevertheless, the most important guiding principle is that if a fish has no aerobic capacity, no activities can be performed other than those dealing with basic survival (basal metabolism in human terms). Conversely, if aerobic capacity is evident, as we discovered across a wide range of test temperatures for Tuolumne River *O. mykiss*, then that capacity is available for use for activity across the temperature range.

   AAS is a well-grounded scientific measurement that has only improved with time since its first inception by Fred Fry 60 years ago. We now have better measurement equipment available, as was used in this study, that gives us more reliable, more accurate and more frequent recordings, plus we have video to monitor the fish. Furthermore, we have a much greater appreciation of where errors can be introduced, how large they might be and how they can be avoided. Indeed, an entire special issue of an International journal (Journal of Fish Biology) was devoted to this topic in 2016, which attests to the rigor of the experimental approach we adopted. In the conduct of this study, we followed published principles and guidelines, i.e., our study was state-of-the-art. Few studies, including those used by EPA 2003, have tested wild fish. We tested wild Tuolumne River *O. mykiss* to ensure direct relevance of the data. AAS simply characterizes what capacity is available; further experiments would be informative to characterize how Tuolumne River *O. mykiss* allocate this capacity, including the potentially interactive effects of thermal acclimation, growth or reproduction. Thus, while comments and criticisms along these lines may potentially be relevant to the broader management of Tuolumne River *O. mykiss,* they indicate a misunderstanding of the purpose and use of our study. The present study demonstrates the fact that Tuolumne River *O. mykiss* have the capacity for the performance of ecologically relevant traits across the wide range of relatively higher temperatures experienced in the lower Tuolumne River.

2) One thing that is clear from our work and of critical importance is that the study populations included in the EPA criteria documents are 'northerly' populations. This should not be in dispute. The only work on southern populations comes from Dr. Joseph Cech's lab and post-dates the EPA document which was used to set the 7DADM. Also clear is that the *O. mykiss* benchmark temperatures were established over a dozen years ago and considerable new science has amassed on thermal effects on fishes. Indeed, it may be the most intensely studied topic within fish biology over the past 10 years.

3) Since the early 2000's or so, population-specific thermal sensitivity research, especially for fishes, has expanded greatly, including further methodological and interpretive advancements. It is now widely accepted that local populations of fish of the same species can differ in thermal sensitivity, and it has been consistently demonstrated that their sensitivity is usually matched to their native or local thermal regimes whenever this has been properly tested. These observations are consistent with what is termed local thermal adaptation. Therefore, a logical link should be that thermal regulatory criteria should acknowledge the local population's thermal sensitivity. The main point here is that any regulatory guideline should properly reflect the fish species and location to which they are intended to apply. Indeed, the EPA 2003 supporting document directly acknowledges this, but also notes there was insufficient data *at that time* to provide an informed opinion. The database on local adaptation within a species has now changed enormously. Thus, whenever evidence for local adaptation of a particular population of fish emerges, it is entirely reasonable to challenge the applicability of a more general guideline. This study tested wild Tuolumne River *O. mykiss* to ensure direct relevance of the data.

   Population-specific performance is seen in many traits: growth, lethal limits, swimming performance, metabolic performance and aerobic scope, and each of these traits can be shaped by temperature at a variety of interacting timescales [i.e. acute (seconds to minutes), acclimatory (days to weeks; perhaps 'chronic' using the CDFW reviewer's terminology), and adaptive]. Indeed, these are complex traits, and ecologists agree that these traits have implications at the level of the population. We acknowledge that there is debate about specific 'implications', but we try to be clear and precise, as well as conservative, as to what our data on Tuolumne River *O. mykiss* have revealed for the first time.

As a general rule and an example, positive growth rates occur under conditions that are conducive to survival. Exactly how growth and survival translates to population dynamics requires considerably more detailed study beyond measuring growth rate, and perhaps modeling, which is never perfect without reliable input variables. Natural selection directly operates at the level of the individual, and effects become manifest at the population level. Therefore, understanding effects on individuals and knowing the physiological mechanisms that operate within individuals are key pieces of knowledge to obtain before attempts to extrapolate to the population level can be made with confidence.

Consequently, we performed experiments that targeted individual, wild juvenile fish and probed mechanisms of the thermal tolerance that are well established in the mainstream fish literature. To reiterate, we performed our experiments on wild Tuolumne River fish (not hatchery fish as used for EPA 2003), captured from their native habitat and tested streamside. This experimental design is particularly powerful in estimating innate, real-time AAS capacity for this specific population.

4) AAS allows us to make comparisons. For example, we can safely conclude that the lower Tuolumne *O. mykiss* population does comparatively better at warmer temperatures than northern *O. mykiss* populations because we have shown aerobic performance across a temperature range that includes temperatures higher than those tolerated in northern populations. Consequently, our data only addresses the ‘blanket’ 7DADM guideline for all *O. mykiss* populations across the US, in one specific manner: we no longer have confidence in the growth studies used by EPA in 2003 to set guidelines for lower Tuolumne River *O. mykiss* because our AAS data for lower Tuolumne rainbow trout clearly show that this population is unlike and definitively different from more northern populations. Consequently, it is a confidence issue. Of course, any new guidelines should only be considered in close consultation with the EPA, and using the best available science and its modern interpretation. We did not suggest otherwise in the report and continue to hold this viewpoint. This is what the data are telling us, nothing more and certainly nothing less.

5) What our data should NOT be used for is to pick a new thermal criterion based solely on our aerobic scope curve. In fact, we do not suggest revising the 7DADM based solely on our AAS curve. We simply state that we believe our data are suggestive of local thermal adaptation in Central Valley fish and inconsistent with a blanket criterion for the population under consideration. Because the Tuolumne River *O. mykiss* fish outperform northerly populations at warm temperatures, the inference is that the current guidelines are overly conservative.

6) We also assume, perhaps incorrectly, that all of the scientists working on thermal requirements of fishes would appreciate, without repeated statement, the fact that this study addresses physiological mechanisms related to temperature and temperature alone, and to juvenile fish alone. Nowhere did we extrapolate our findings to other life stages because we are aware of, and therefore sensitive to, some species of fish showing stage-specific thermal sensitivity. We also know that multiple stressors can interact (e.g. temperature sensitive metabolism x food) in additive or synergistic ways, so nowhere do we suggest

that our data are the sole requirement to determine a 7DADM. However, the value of population-specific, site-specific data should not be underestimated.

7) Additional data that may be helpful to managing Tuolumne River *O. mykiss* might include: comparative thermal sensitivity literature from other studies and other populations; knowledge of food resources available to the fish in question; and life-stage sensitivities that could reveal a 'weak link' in life history. Of course, this is not exhaustive, but it does acknowledge possible additional information that would be useful. We understand that at least some of this data is already available.

8) While we never suggest that a new 7DADM value be extracted solely from our data, we do suggest that the current value is conservative for Tuolumne River juvenile *O. mykiss*. Also, we know as a fact that a higher thermal tolerance than that reflected by the EPA 2003 7DADM exists within the *O. mykiss* genome because publications on local thermal selection (e.g. Australian and Japanese rainbow trout) conclusively illustrate that these populations feed and grow at temperatures well in excess of 20°C.

   It is true that we do not know the growth capabilities of Tuolumne River *O. mykiss* but given our new understanding of FAS values, the Tuolumne River *O. mykiss* have sufficient aerobic capacity to eat a large meal, they had food in their stomachs when captured, have an abundance of food in the Tuolumne River, and have been videoed swimming to capture food passing by at temperature well above the EPA recommended 7DADM. This all provides additional evidence that juvenile *O. mykiss* captured from the lower Tuolumne River are feeding and growing in the current thermal regime. Growth studies would be useful to confirm rates of growth, but the present study supports the Tuolumne River *O. mykiss'* significant capacity for growth. If there is any doubt that a higher thermal tolerance than that reflected by the 7DADM exists within the *O. mykiss* genome, we simply have to turn to the established physiological literature on a variety of *O. mykiss* that through natural selection live in the deserts of Idaho and Oregon, namely the redband trout, *Oncorhynchus mykiss gairdneri*. This variety deals with, as well as swims and feeds in, summer temperatures that can reach 26ºC.

It is our hope that these remarks clarify some of the apparent misunderstanding of the design and purpose of the study. Below we respond to individual comments received on the draft report.

A Note about ‘Acute’ and ‘Chronic’ Temperature Response

There is often much discussion and debate about ‘acute’ and ‘chronic’ temperature response in fish. For the purposes of this discussion, we view ‘acute’ as relevant over the timescale of seconds to hours to days. Over longer timescales, weeks to months, temperature is considered ‘chronic’. However, some scientists reserve the term chronic to a certain portion of the lifecycle of a test animal, e.g., mammalian toxicology.

Binning the effects of temperature on fishes into categories like ‘acute’ and ‘chronic’ is not a straightforward task and to attempt to do so is a dramatic oversimplification of both experimental methodologies and organismal biological, physiological and behavioral responses. This is in part because fish can acclimate to a new temperature and this acclimation can follow different time courses depending on the process being studied, and because a fish is rarely exposed to a single, static temperature for many weeks. Thus, while there are very good experimental reasons to control the acclimation temperature for groups of fishes before testing (as you would do in laboratory acclimation studies of thermal tolerance or growth), these tests are artificial and eliminate naturally-occurring thermal oscillations as well as fish behavioral selection of particular thermal habitat.

We argue that it is much more insightful to understand the biologically-relevant oscillations in environmental temperatures of a particular system, which likely include daily fluctuations, fluctuations occurring over seasons, and/or variation in spatial temperature distributions. It is also critical to understand how these temperature profiles interact with the response variable that you are measuring (e.g. molecular responses as compared to organismal growth – each of which will have a distinct response pattern and response time). For example: heat shock proteins show an acclimation response in a matter of hours, whereas whole animal physiology can take weeks to acclimate. Lastly, one of the more challenging tasks for scientists is to understand how fish behaviorally utilize their thermal habitat as a reflection of their physiological capacities and limits.

Consequently, how fish respond, physiologically and behaviorally, to environmental temperature change is a function of previous thermal history (e.g. seasonal acclimation), the magnitude and timescale of the thermal change (e.g. how high did the temperature rise, how quickly), and the duration of the exposure (e.g. how long was the new thermal exposure). Regulations should incorporate data that speak to each of these aspects. We point out that the 7DADM is neither an “acute” or “chronic” regulation, but it is in fact designed to incorporate temperature oscillations. Incorporating thermal heterogeneity into fish habitat, when done properly, is certainly more appropriate than managing to a static (chronic) thermal target (which we all should be able to agree is completely artificial to fishes that evolved in habitats with thermal variability).

Importantly, no single study exists, or can be designed, that completely incorporates the complexities of thermal exposures and measured endpoints to ‘spit out’ the perfect thermal regulatory criteria for a particular species. Thus, regulations are based on a collection of data/experiments spanning so called ‘chronic’ and ‘acute’, biologically relevant thermal exposures and incorporating a variety of well-studied and understood endpoints. Or, in some cases, when data are not available for strong support, regulations should be reasonably protective.

With specific respect to the study conducted on the Lower Tuolumne River, the fish were seasonally acclimated to the prevailing summer river conditions. We knew the temperature at which they were captured, but not the temperatures that they had experienced or for how long they had experienced them. We minimized the potential effects of thermal acclimation of processes that take many hours or weeks (fish were tested immediately, i.e. within hours, following capture from the river). Lastly, metabolic performance capacity was measured as a function of an incremental warming protocol that lasted no longer than 6 hours of exposure to a test temperature between 13 and 25°C, depending on the individual.

Comment # (page #)	Comment	Districts' Response
TRT/CSPA-1 (p. 2)	The Study does not evaluate the physiological response of the population of *O. mykiss* in the lower Tuolumne River over time. There are limitations to the Study that the Study does not acknowledge. Chief among these limitations is that the Study does not evaluate physiological response of the population of *O. mykiss* in the lower Tuolumne River over time. On the contrary, 75% of the test fish were sourced from a location one mile downstream of La Grange Powerhouse, where temperatures at capture ranged from 12.7°C to 17.1°C. While the Study is critical of Hokanson (1977) for an issue concerning confidence intervals, the Study does not address Hokanson's use of a 40-day period to evaluate physiological response. Other studies (e.g. Brett 1956; Bidgood 1969) similarly address long-term exposure to less-than-optimal thermal conditions. The Study does not acknowledge this limitation.	We could have been clearer about stating the design and intent of the study. The Report has been amended accordingly. However, the study plan prepared for the study and reviewed previously by the commenter spelled out the specific design and purpose of the study. This never changed. We do not understand the commenters' concern regarding lack of evaluating responses over time. This was not the objective of the Report as clearly explained in the original study plan. Indeed, the permits issued by the resource agencies for fish removal would NOT permit more than 2 fish to be studied at a time and over time – this was the maximum number of fish that could be removed from the river. To reliably measure growth rate, at least 40 days would be needed to detect responses and rates because the fish have to change their mass by a reliably detectable amount. This was never intended, as explained in the study plan. Nor could we have done this within the limitations of the permits issued. Instead, we measured oxygen uptake, which uses a different time scale, and it can be reliably measured over periods of minutes. Also, we went to great lengths to follow and analyze oxygen uptake over a nearly 24-hour period to examine its variability and ensure our estimates of RMR were as accurate as possible for a field study. Also, we carefully measured maximum oxygen uptake in the manner used by both Fry and Brett (who was Fry's student), but using modern technology with greater accuracy and precision. Therefore, we can state with confidence what the fish's

Comment # (page #)	Comment	Districts' Response
		capacity was in terms of delivering oxygen to tissues over a broad temperature range. If, however, the comment concerning "over time" is that it might be beneficial to study fish that were acclimated to different temperatures (14°C was the coolest temperatures found in the lower Tuolumne River during 2014 study period), this is a valid comment. Nevertheless, it is well known that thermal acclimation is used by fishes to "improve performance" at the new acclimation temperature. Therefore, if the lower Tuolumne River *O. mykiss* used in the present study can be shown to acclimate to water temperatures warmer than they were experiencing at the time of the experiments, we have then provided a conservative estimate of temperature effects on the fish performance by looking only at the effect of a rapid rise in water temperature from river temperature to which they were acclimated. The concern raised does not change the outcome of our results, but does introduce the possibility that this fish population could do even better at warmer temperature if they were allowed to first acclimate. The comment of the reviewer goes on to be critical of our critique of the general application of Hokanson's data on rainbow trout that were studied in the American midwest to a population of rainbow trout in the Central Valley, CA. The fact is, as proven by the study, Tuolumne *O. mykiss* juveniles displayed a physiology and thermal tolerance quite different from more northern populations of rainbow trout. In fact, we point out that they are more similar to *O. mykiss* populations that have adapted to desert streams!

Comment # (page #)	Comment	Districts' Response
		We agree that the experimental approach used in this study differs fundamentally from the approach used by EPA to formulate its temperature recommendations for the Pacific Northwest. Three points of clarification are below. 1. Our criticism of Hokanson (1977) is two-fold. Foremost, today's knowledge of local adaptation of a wide range of species from sticklebacks, through killifish to salmonids tells us that it may be inappropriate to apply studies that are geographically separated by large distances and differing climates. For example, use of data from studies of trout from central USA to the same species locally adapted to California river systems may be inappropriate. Indeed, this was the primary driver for the present study. Our commentary on the work of Hokanson (1977) is valid, as it does not criticize the quality of the data per se, rather the application of the results. Our concern about confidence limits in Hokanson (1977) is a minor one, driven in part because against our a priori predictions of fish performance, we found that the Tuolumne River fish were unexpectedly tolerant of acute changes in temperature and performed similarly over a wide range of temperatures. This introduces the statistical issue of when does warm temperature create an unfavorable fish performance. We think confidence limits are needed. Without confidence limits for a study such as Hokanson (1977), which is nearly 40 years old and did not have access to the statistical tools now

Comment # (page #)	Comment	Districts' Response
		commonly available, we cannot retrospectively interrogate these older data. 2. Lastly, how these fish exploit the local thermal gradients in the lower Tuolumne River was not part of the objectives of the current study. Nevertheless, it is possible to speculate. Perhaps they behave similar to the sockeye salmon that Brett studied in the 1970's, by diurnally moving to warm reaches to feed and returning to cooler reaches to digest their food. This type of behavior would take advantage of warm habitats. In any event, whether such behavior occurs or does not occur has no effect on the conclusions of the present study.
TRT/CSPA-2 (p. 2)	A City of San Francisco biologist has acknowledged on the record in this proceeding that *O. mykiss* populations in the lower Tuolumne River are substantially smaller than populations downstream of rim dams in the Sacramento river drainage, where water temperatures are generally much lower than temperatures in the lower Tuolumne River.	Comparisons of differing *O. mykiss* population sizes from spatially distinct river systems citing a statement by a "City of San Francisco biologist" lacks scientific rigor and should be disregarded. Just as one example, the two rivers under comparison would have substantially different geomorphological histories and structures which may be a more important factor affecting population sizes. Other factors may also play key roles in abundance such as total spawning area, differing food sources, predation pressures, fishing activities, etc. These issues have nothing to do with temperature in this system.
TRT/CSPA-3 (p. 2)	Before any adjustment to the established (EPA 2003) temperature benchmark for a 7DADM value for the population of *O. mykiss* in the lower Tuolumne River is considered based on site-specific conditions and response, further investigation and evaluation would be required. The Study should explicitly state this, and	It should be noted that EPA (2003) does not provide specific temperature recommendations to the lower Tuolumne River or any California river system. It is a general recommendation that applies to all populations of rainbow trout. The report's discussion is not intended as the basis for changing the EPA (2003) 7DADM recommendations.

Comment # (page #)	Comment	Districts' Response
	should describe additional evidence needed before any change in the 7DADM value for the population *O. mykiss* in the lower Tuolumne River might appropriately be evaluated.	Instead, our work simply suggests that the current value of 18°C lacks merit for the current *O. mykiss* population found in the lower Tuolumne River. Minimally, 18°C as the 7DADM value is a very conservative upper thermal limit based on the results of the current study. This report is not intended to preempt consultation with EPA. We strongly believe that the new data collected here are a firm basis for opening such a dialogue about site-specific temperature criteria in general as well as for the Tuolumne River *O. mykiss*. We suspect that EPA would welcome this dialogue being opened as their 2003 report acknowledged the possibility of local adaptation. EPA 2003 simply cited that the scientific evidence at that time was weak. The scientific evidence is now much stronger.
TRT/CSPA-4 (p. 3)	The Study results alone do not warrant site-specific summer water temperature criteria for *O. mykiss* in the lower Tuolumne River.	The Districts assert that the site-specific empirical evidence that exists for Tuolumne River *O. mykiss* warrants considerable weight when compared to data from completely different regions of the country. Also, see response to TRT/CSPA-3
TRT/CSPA-5 (p. 3)	In our view, the appropriate use of the Study results would be to 1) evaluate their limitations; 2) develop additional investigations that might be necessary to scientifically justify consideration of adjusting thermal criteria for the population of *O. mykiss* in the lower Tuolumne River, 3) enumerate and evaluate regulatory and policy issues that might be involved in adjusting these criteria; and 4) assemble these necessary components and, based on this ensemble, develop a process for considering and evaluating site-specific water temperature criteria.	While evaluating natural background provisions and use attainability exceptions to the EPA (2003) 18°C 7DADM recommendations are beyond the scope of the current study, the Districts (TID/MID 2014, Attachment A) previously demonstrated that potential re-operation of the Don Pedro Project to meet EPA (2003) temperature recommendations was infeasible under a range of potential scenarios evaluated, including "without dams" scenarios. Given the infeasibility of meeting the EPA 18°C 7DADM benchmark and that the results of the current study

Comment # (page #)	Comment	Districts' Response
		demonstrated near-optimum physiological performance and active feeding at temperatures well above 18°C, consideration of site-specific exceptions to this recommendations are warranted. We are pleased to read that the reviewer appears to agree with us that further steps are warranted. Therefore, the real issue is not what is contained in the report, but rather what should follow from it.
TRT/CSPA-6 (p. 4)	The authors of the current Study should be more explicit in its caveats and should describe the limitations of its conclusions.	As noted above in the response to TRT/CSPA-1 the data generated here would in our opinion represent the most conservative estimate of temperature effects by only looking at the effect of a rapid change from acclimation temperatures. To speculate on how well *O. mykiss* from the lower Tuolumne River might perform if they were allowed to acclimate to even higher water temperatures is beyond the scope of the present study. We agree that we could have been clearer about stating the limitations of the study, but it is clear that these limitations are more pertinent to the future actions and not the conclusions that are based on our data.
TRT/CSPA-7 (p. 4)	The Study examines only the juvenile lifestage of *O. mykiss* in the lower Tuolumne River. The Clean Water Act requires that the most sensitive resources be protected. It is not clear whether the adult lifestage, which is also present during the summer time period, is more, equally or less sensitive to high water temperatures. Before adjustments of summer temperature criteria for *O. mykiss* in the lower Tuolumne River could be considered, an evaluation of the physiological response of adult *O. mykiss* in the lower Tuolumne River would need to conducted, in addition to completing the evaluation of the physiological response of juveniles.	At no time in the report do we state that our results for juvenile fish are directly applicable to other life stages of this species. Although some studies have examined the relative thermal tolerance of juvenile and adult salmonid life stages, evaluation of the thermal performance of adult *O. mykiss* was outside the scope of the study plan. The decision to use juvenile vs adult-sized fish was made on the basis of higher relative abundance and the ability to capture them with beach seines vs angling that may result in reduced swimming performance and necessitate longer recovery times for adult fish that were captured by that method.

Comment # (page #)	Comment	Districts' Response
		Again, future steps might be to study other life stages, but this possibility does not challenge the present results. We would also like to note that in order to advance to the adult life stage, fish must survive the juvenile life stage. And juveniles are evidence of a successful life stage in this river system. It would be an odd, and unsustainable, biological adjustment to have juvenile fish be well acclimated to local conditions only to prove fatal when it reaches the adult life stage.
TRT/CSPA-8 (p. 4)	The Study makes comparisons between *O. mykiss* in the lower Tuolumne River and populations that are more permanent and defined and that have more common characteristics. The current Tuolumne population is likely a combination of residual lower river fish, wild or hatchery fish washed down from La Grange (themselves possibly the result of production in La Grange Reservoir or originating in Don Pedro Reservoir), and some number of anadromous individuals of unknown origin and their progeny. It is further likely that the population is being replenished from these sources on an ongoing basis, and that some portion of the fish that are there in several years will have little directly in common with the current population. This is particularly likely under dry or drought conditions, when a greater proportion of the existing population may be expected to perish. Managing a changing population based on ascribed thermal tolerances of an existing population is questionable both scientifically and as policy.	This comment is highly speculative. Moreover, we do not fully understand what the reviewer means by "populations that are more permanent and defined and that have more common characteristics". The population that we have studied and that is protected is a resident of the river system, one that has a barrier upstream in the form of a dam and a potential thermal barrier downstream. How they arrived there and how they adapted is not a concern of this Report. This Report focuses on the thermal capacity of the fish that currently reside in the river and are protected by current regulations.

Comment # (page #)	Comment	Districts' Response
		Thus, while the supposition that future lower Tuolumne River *O. mykiss* populations may have little directly in common with the current population is interesting, it does not affect the conclusions of our study since we are limited to testing the current population. Furthermore, if the intent is to do future stocking of this river system with fish from either a hatchery or another wild source, then similar experiments could be performed on those populations. The use of 'wild' or 'local' fish for the Tuolumne River would then have to be redefined.
TRT/CSPA-9 (p. 5)	There is no bioenergetics study of *O. mykiss* in the lower Tuolumne river that would support management for water temperatures higher than those recommended in EPA guidance. The Districts declined in 2011 to conduct a bioenergetics study of *O. mykiss* in the lower Tuolumne River as recommended by the Department of Fish and Wildlife. The Commission did not order this study.	The EPA guidance was not based on any bioenergetics studies. While the Districts were not required to undertake a direct bioenergetics study in FERC's May 21, 2013 study determination, it should be understood that all bioenergetics (activities) require oxygen. **The current study characterized the maximal capacity to deliver oxygen for any and all activities**. Indeed, for any energetic model the currency can be oxygen or Joules. Regardless, the sum of all the bioenergetics inputs cannot in the long term exceed feeding input (the fish would be starving) or the maximum aerobic capacity (which is exactly what we measured). In addition, the multitude of factors that go into a bioenergetics study would require a large number of individuals to be removed from the river, well in excess of the authorized fish take, and many of these fish would have to be sacrificed for such a study. The current study design allowed direct examination of physiological performance without the need for either high levels of fish take or sacrificing fish. Indeed, we successfully returned all but three of the study fish to the river. Further, the *O. mykiss*

Comment # (page #)	Comment	Districts' Response
		population studies and resulting in-river population model does include a bioenergetics component. To be clear, the study was implicitly designed to minimize the impact of fish removal from the river for experimentation.
TRT/CSPA-10 (p. 6)	Follow-up site specific physiological studies must address elevated water temperatures over an extended period of time, ideally over an entire summer.	We do not understand the commenters' concern regarding lack of evaluating responses over time. This was not the objective of the Report, as clearly pointed out in the study plan. Indeed, the permits issued for fish removal would NOT permit more than 2 fish to be studied at a time and over time – this was the maximum number of fish that could be removed from the river. Perhaps the following clarifies matters. To reliably measure growth rate, at least 40 days would be needed to detect a response because the fish have to change their mass by a reliably detectable amount. We clearly could not do this with the permits issued, nor did the study plan (previously reviewed by CDFW) ever suggest this was the intent of the study. Instead, as detailed in the study plan, we measured oxygen uptake, which uses a different time scale, and it can be reliably measured over periods of minutes. Also, we went to great lengths to follow and analyze oxygen uptake over a nearly 24-hour period to examine its variability and ensure our estimates of RMR were as accurate as possible for a field study. Also, we carefully measured maximum oxygen uptake in the manner used by both Fry and Brett, but using modern technology with greater accuracy and precision. Therefore, we can state with confidence what the fish's capacity was in terms of delivering oxygen to tissues over a broad temperature range.

Comment # (page #)	Comment	Districts' Response
		If, however, the comment concerning "over time" is that we need to study fish that were acclimated to different temperatures (14°C was the coolest temperatures found in the lower Tuolumne River during the 2014 study), this is a valid comment. Nevertheless, it is well known that thermal acclimation is used by fishes to "improve performance" at the new acclimation temperature. Therefore, if the lower Tuolumne River *O. mykiss* used in the present study can be shown to acclimate to water temperatures warmer than they were experiencing at the time of the experiments, we have then provided a conservative estimate of temperature effects on the fish performance by looking only at the effect of a rapid change in water temperature from river temperature to which they were acclimated. This concern does not change the outcome of our results, but does introduce the possibility that this fish population could do even better at warmer temperature if they were allowed to first acclimate.
TRT/CSPA-11 (p. 6)	Follow-up site specific physiological studies must be conducted on adult as well as juvenile *O. mykiss*.	The decision to use juvenile vs adult-sized fish was made on the basis of higher relative abundance and the ability to capture them with beach seines vs angling that may result in reduced swimming performance and necessitate longer recovery times for adult fish that were captured by that method. However, we would note that in order to advance to the adult life stage, fish must survive the juvenile life stage. And juveniles are evidence of a successful life stage in this river system. It would be an odd, and unsustainable, biological adjustment to have juvenile fish be well acclimated to local conditions only to prove fatal when it reaches the adult life stage.

Comment # (page #)	Comment	Districts' Response
		The suggestion to study Tuolumne River adult *O. mykiss* would seem to indicate agreement with the Districts' assertion that the EPA 2003 recommended temperatures are invalid because the EPA research involved no site-specific studies nor even results of research on CA *O. mykiss*, neither juvenile nor adult. Note also that Hokanson (1977) on which EPA 2003 recommendation is based, did not consider multiple life stages.
TRT/CSPA-12 (p. 6)	Follow-up site specific physiological studies must address the likely multiple sources and ongoing replenishment of the *O. mykiss* population of the lower Tuolumne River.	See response to TRT/CSPA-8 above. However, the commenter is suggesting that *O. mykiss* from different locations in the lower Tuolumne (even within a mile of each other) would have differing thermal capacities, while the EPA 2003 paper proposes that all *O. mykiss* populations in the entire Pacific NW and CA should be considered to have the same thermal capability. We agree with the commenter that site-specific empirical information is a much better measure of performance. Nonetheless, our Report concerns one specific population.
TRT/CSPA-13 (p. 6)	The Districts should perform a bioenergetics study for juvenile and adult *O. mykiss* in the lower Tuolumne River.	See response to TRT/CSPA-9 and -12.
TRT/CSPA-14 (p. 6)	The Study should be edited so that the Executive Summary and the Conclusion place the value of the findings in the appropriate context of how they might inform a comprehensive review of site-specific summer thermal conditions in the lower Tuolumne River.	The Executive Summary has been amended to address this comment. Also, see response to TRT/CSPA-3. Again, the present study suggests that applying the EPA 2003 recommendation to the Tuolumne River *O. mykiss* population is overly conservative.
SWRCB-1 (p. 1)	Study Plan 14 was not required by FERC in its Final Study Plan Determination and is not supported by the State Water Board, California Department of Fish and	In its December 2011 SPD, FERC stated that it would consider additional empirical evidence from the Tuolumne River. The development, evaluation and application of

Comment # (page #)	Comment	Districts' Response
	Wildlife (CDFW), United States Fish and Wildlife Service (USFWS), or the National Marine Fisheries Service (NMFS)."	empirical evidence that would reduce uncertainties regarding temperature-related effects on Tuolumne River salmonids is the primary purpose of this study. FERC's emphasis on empirical evidence has further encouraged the Districts to identify and consider new evaluations that could contribute to more focused understanding of potential influences of temperature on LTR salmonids, which led to the development of this study approach and report.
SWRCB-2 (p. 2)	The report does not explicitly state that its results alone demand a change in the 7DADM temperature outlined in the 2003 USEPA Guidance. Rather the report states that this information should be used to determine a 7DADM value specific to Tuolumne River *O. mykiss*. However, the report does not outline a process to be used to determine a scientifically acceptable and defensible 7DADM specific to the Tuolumne River *O. mykiss*.	The recommendation lies well beyond the objective of the present report. See response to TRT/CSPA- 3 and -4.
SWRCB-3 (p. 2)	"State Water Board staff recommends that any process to develop temperature criteria specific to the Tuolumne River follow a similar process as the EPA Guidance. Two additional examples of the recommended process include: The Final Staff Report for the Klamath River Total Maximum Daily Loads (TMDLs) Addressing Temperature, Dissolved Oxygen, Nutrient, and Microcystin Impairments in California (NCRWQCB 2010), and The Effects of Temperature on Steelhead Trout, Coho Salmon, and Chinook Salmon Biology and Function by Life Stage; Implications for Klamath Basin TMDLs (NCRWQCB 2005)."	The references provided by the SWRCB deal with TMDL development, a different process than that required for amending the present temperature guidance. In any event, the Districts look forward to working with the SWRCB on temperature issues on the lower Tuolumne River.

Comment # (page #)	Comment	Districts' Response
SWRCB-4 (p. 2)	"It is important to point out that the Report focuses on increased water temperature effects on only one parameter (oxygen consumption) and one life stage (juvenile) for *O. mykiss*. Study Plan 14 and the Report do not evaluate long term effects of increased water temperature as well as the other life stages of *O. mykiss*. Questions that might be evaluated as part of a more comprehensive study include, but are not limited to: 1. What is/are the effect(s) of increased temperature conditions on other life stages of *O. mykiss* or the long-term effects of this short-term exposure on *O. mykiss?* 2. How does temperature influence other factors which may affect salmonids, such as food availability and disease?	We thank the commenter for explicitly stating what our Report achieved. It would seem from this that the reviewer has no difficulty with accepting our data. Again it seems that the reviewer is making suggestions for future steps, which we have commented on above: See response to TRT/CSPA-1 & TRT/CSPA-9. Regardless, it is important to remember that the present study significantly expands the knowledge base regarding *O. mykiss* on the lower Tuolumne River. There were no studies for this population prior to the present study, which was a rigorous and comprehensive examination of thermal performance on juvenile wild fish. Indeed, the reviewer does not challenge the quality of the data in hand. We would argue that empirical data are a better indicator of thermal performance than largely unrelated information the applicability of which is difficult to measure. Related to temperature's influence on other factors, prior studies of food sources on the Tuolumne under the existing temperature and flow regime have indicated healthy BMI populations and that prior studies have not found any significant disease issues with Tuolumne River salmonids.
SWRCB-5 (p. 2)	Study Plan 14 and the Report only consider increased temperature effects on fish persisting in the Tuolumne River under current conditions. Study Plan 14 and the report fail to examine the effects of increased river temperatures on the recovery of *O. mykiss* populations in the Tuolumne River.	The current study was able to examine the effect of increased temperature on juvenile *O. mykiss* persisting in the Tuolumne River under current conditions. While examination of questions related to conditions affecting future *O. mykiss* populations in the lower Tuolumne River are beyond the scope of the current study, the present study indicates an ability of the local population to adjust to local conditions.

Comment # (page #)	Comment	Districts' Response
		The Districts are uncertain as to what is meant by "recovery of *O. mykiss*" under "increased river temperatures".
CDFW-1 (p. 2)	The study design identifies acute exposure to stressful warmer water temperatures at the individual level; therefore, the study cannot inform development and/or revision of population level chronic water temperature criteria. In their report, the authors compare their acute water temperature results to the United States Environmental Protection Agency's chronic population criteria (USEPA 2003) which is inappropriate.	The reviewer has a fundamental misunderstanding of the study design and purpose. The reviewer thinks we were conducting an acute survival study not testing metabolic capacity (through eliciting maximum metabolic rates using swim tests) at chronic water temperatures. We ask that the reviewer please read the overarching statement where we clearly explain what AAS measures tell us, and how these data relate to the 7DADM. Also, see our response to TRT/CSPA-3: The report discussion is not intended as the basis for changing the EPA (2003) 7DADM recommendations. Instead, our work simply suggests that the current value of 18°C lacks merit for the current *O. mykiss* population found in the lower Tuolumne River. Minimally, 18°C as the 7DADM value is a very conservative upper thermal limit based on the results of the current study. Please note that the casual use of 'stress' and 'stressful' should be avoided. Defining 'stress' in fish requires rigorous experiments at a population-specific level, careful endpoint selection and interpretation, and well-described exposure conditions. Assuming that our test conditions were 'stressful' and assuming that warm temperatures are necessarily 'stressful' to Tuolumne River *O. mykiss* is an unsupported statement. Our data, in fact, suggest that at temperatures much higher than 18C, the tested fish maintain maximum AS. We do not see how a fish that is "stressed"

Comment # (page #)	Comment	Districts' Response
		would be able to maintain its AAS given that "stress" is a metabolic load (see Fry, Beamish and Brett reviews of this in the last century) that necessarily limits aerobic performance.
CDFW-2 (p. 2)	Anadromous salmonids populations throughout the Pacific Northwest (including California) are declining primarily because of poor reproductive success and recruitment back into the population (Yoshiyama et al 2001).	It must be noted that this is not what the referenced paper said or concluded.
CDFW-3 (p. 2)	The intent of the USEPA (2003) analysis was to reverse that trend by presenting chronic population water temperature criteria.	This is the reviewer's interpretation of the intent of EPA (2003) but this was not the stated rationale for the document. In fact, the EPA (2003) report did acknowledge that "local adjustment was possible and that well-designed studies could be used to identify site-specific thermal adjustments". This was one of the reasons for conducting the present study, which we believe was well-designed and well-executed. It produced definitive and reliable data. Importantly, the 7DADM criteria incorporates information to estimate thermal optima and performance breadth using a diversity of thermal performance metrics (e.g. lethal limits, longer term thermal experiments related to growth, and many others) that operate several timescales of thermal exposure. The focus by the reviewer in casting the EPA 7DADM criteria as exclusively chronic is misleading and incorrect. Please see our response to TRT/CSPA-3, as well as the overarching response document at the front of this response to comments.

Comment # (page #)	Comment	Districts' Response
CDFW-4 (p. 2)	Chronic criteria and population criteria are always lower than acute and individual criteria. The authors presented higher acute/individual water temperature criteria based on a single study, but failed to extrapolate the results to a lower chronic population criteria that would be protective for reproductive success and recruitment to maintain a sustainable (i.e. viable) population. Survival rates are based on amount of time exposed, as well as temperature exposure, and are extremely well described in the scientific literature.	As stated above, the reviewer's fundamental misunderstanding appears to be that we were conducting a survival study not a test of metabolic capacity. There is no need to extrapolate our study results to a lower chronic temperature criteria since we were making direct measurements of the optimal temperature range for Tuolumne River *O. mykiss* based on their metabolic capacity. Indeed, we would argue that there is no reliable methodology to extrapolate from acute to chronic studies. However, if a fish cannot perform after an acute temperature change, it is unlikely to perform well with a chronic change unless it can thermally acclimate. We show that the fish do well with an acute thermal change, and these data do not appear to be in dispute. Please see the overarching response document at the front of these responses to comments where we explain what should and should not be gleaned from our data as well as specific remarks on how our data 'scale' up to population level functions. Also see our response to CDFW-3 regarding chronic criteria.
CDFW-5 (p. 3)	Executive Summary, page i, second paragraph. The authors stated, "The study tested the hypothesis that the Tuolumne River *O. mykiss* population below La Grange Diversion Dam is locally adjusted to the relatively warm thermal conditions that exist in the river during the summer". What is the authors' definition of "locally adjusted"?	"Locally adjusted" was defined on page 6 as a hypothesis that can be tested by confirming or refuting by evaluating the predictions on page 7 of our report. In short, the hypothesis is: Tuolumne River *O. mykiss* are "locally adjusted" if they have higher metabolic capacity (absolute aerobic scope) at temperatures above 18º C. A finding like this would be in contrast to the earlier data based solely on northern fish data. Locally adjusted is a term that includes, and does not distinguish between, local adaptation and local

Comment # (page #)	Comment	Districts' Response
		acclimation/acclimatization. The assignment of 'adaptive' happens at the level of the population, not for individuals. This is in contrast to acclimation/acclimatization, which are traits/responses that change at the individual level, over the course of a particular individual's lifetime. A simple example would be how season influences fur thickness in bears. This is a trait that varies by individual, by season. Please see the last sentence of the executive summary where we explicitly state that our study does not distinguish between these two explanations as this was not our objective. Also, please see the entire section in the Introduction (Current Evidence for Local Physiological Acclimatization and Genetic Selection) articulating how acclimation/acclimatization/adaptation is defined. Thus, we used a term that encompassed both mechanistic explanations.
CDFW-6 (p. 3)	Executive summary, page i, third paragraph, last sentence. The authors state, "Therefore, the experimental approach also acknowledges that every activity of a fish in a river (swimming, catching prey and feeding, digesting a meal, avoiding predators, defending territory, etc.) requires oxygen consumption above a basic routine need and that salmonids have evolved to maximize their oxygen supply when they fuel muscles during exhaustive swimming". This statement leads to three questions; 1) This test appears to study basic survival, but does the study address reproductive success and recruitment? 2) Does this experimental design measure activities related to spawning, immune function and general overall stress? and 3) Isn't this the case for all vertebrates, that an animal's physiological function evolved to fuel their	As described in the study plan prepared for this study and submitted for review prior to conducting the study, we did not aim to study basic survival. Therefore the reviewer misunderstands the study objectives. We measure aerobic capacity. Survival would require a minimum of SMR, but this study shows that these fish had the capacity to more than double their metabolic rate at specific temperatures. This information can be used to assess whether there is the capacity for activities well beyond survival, such as growth, immune function, reproduction, predator avoidance, etc. We cannot comment on how the fish use this capacity. These are behavioral decisions made by this fish not by us. However, it we know that the energetic cost of an activity is maximally a doubling of metabolic rate, and this fish has this capacity, it is reasonable to then conclude that the fish has the capacity to undertake this activity.

Comment # (page #)	Comment	Districts' Response
	muscle under non-resting (exercise) or stress conditions?	Regarding question (3), the issue is not whether an animal's physiological function has evolved to fuel their muscles during exercise, the issue is their capacity to fuel their muscles at different temperatures.
CDFW-7 (pp. 3 and 4)	Executive Summary, page i, fourth paragraph. The authors state "As expected for a fish, RMR [Routine Metabolic Rate] increased exponentially with increasing test temperature from 13°C to 25°C (36 different fish, each at a single test temperature)". Basically the RMR is a fish in a resting state, thus if their RMR increased with temperature in a resting state, this indicates the fish are becoming stressed in the warmer temperatures without exertion. They analyzed their results using a mathematical model. What would the results look like if the results were analyzed using standard statistical analysis for each temperature group? Further they presented temperature ranges from 16.4 °C to 25°C and 17.8°C to 24.6°C, suggesting the higher temperatures are protective for basic survival. This leads to the question, do the authors agree that the 16.4°C and 17.8°C temperature levels (i.e. lower end of range) to be a more protective temperature at a chronic population exposure level to provide optimal reproductive success and recruitment rather than the higher temperature's the author are advocating? It's vitally important to remember that just because a fish or a fish population survives at a certain temperature; it does not automatically mean that the fish or the fish population thrives at the same temperature range. The ability to "thrive", carries with it the ability to	The commenter's statement *"thus if their RMR increased with temperature in a resting state, this indicates the fish are becoming stressed in the warmer temperatures without exertion"* is simply and fundamentally incorrect. We know of no theoretical reasoning or literature to support such a claim. Arrhenius in the 1920's showed that all rate functions, including many biological ones, increase with an exponent of 2-3. To suggest otherwise reveals a fundamental lack of understanding about how temperature affects ectotherms. Why does RMR go up with increasing temperature? It has to do with simple laws of thermodynamics – fish are ectotherms, their body reflects water temperature. As fish/molecules warm up, they collide more frequently. Biochemical rates, such as ATP turnover, increase. Thus RMR increases. The 'amount' or how temperature sensitive this process is varies across species and reflects variation in biochemistry (I could go on a long tangent here about protein evolution etc.) and we express this temperature sensitivity with calculated temperature quotients, or Q10s. This is an expression for how much a rate (like a metabolic rate) changes with every 10C change in temperature. Ecologically relevant Q10s are usually between 1.5 and 3 in fishes. The lower the Q10, the less temperature sensitive a species is and the less MR changes as temperature changes.

Comment # (page #)	Comment	Districts' Response
	successfully grow and reproduce at sufficient levels that keep the both the individual fish, and the fish population, in good condition (i.e. adequate reproductive viability). The authors further state, "Thus, the maintenance of AAS [Absolute Aerobic Scope] across nearly the entire test temperature range clearly shows that the Tuolumne River *O. mykiss* population has a broad range of thermal performance". Isn't this case for all vertebrates? The authors further state, "Indeed, the AAS of the Tuolumne River *O. mykiss* population was atypical when compared with cold-adjusted, *O. mykiss* from the Pacific Northwest, whose thermal performance optimum is reported as 18°C" (USEPA 2003). What exactly is meant by "atypical"? What is meant by "cold-adjusted" fish from the Pacific Northwest when all salmonids are cold water fish that evolved in cold waters that originated from snow melt and ground water seepage into the river systems? The reference to the USEPA (2003) 18°C as a thermal performance optimum is incorrect. The USEPA (2003) report did not discuss thermal performance, but rather concentrated developing sub-lethal chronic population criteria to improve reproductive success and recruitment to reverse a declining population trend. It is inappropriate, and therefore not scientifically valid, to compare acute individual results to chronic population criteria. The last sentence suggesting the upper thermal performance is above 25°C is pure speculation on part of the authors and should be deleted.	Another incorrect interpretation of increasing RMR with increasing temperature is that when you see an increase in MR, it indicates stress. If a fish were stressed with acute warming the increase in oxygen uptake would have an even higher exponent. However, because MMR does not similarly increase with stress, AAS must then decrease with acute warming due to the following equation; AAS = [MMR – (RMR +stress)]. Therefore the fact that AAS was maintained across temperature despite an increase in RMR with temperature argues AGAINST the very claim the reviewer is making. Interestingly, fish in a variety of situations can behaviorally and deliberately seek out warm temperatures in order to avoid the 'dampening' effects of cool temperatures on activities such as growth. Thus seeking warm water is not 'stressful'. For example, if you want to get big, and if you have access to lots of food, you might select warm temperatures to process food at a faster rate, smoltify sooner etc. The perspective that cold is always 'less stressful' than warm is pervasive throughout the CDFW comments, and is not ecologically relevant and has no biological basis. Fish have evolved with a physiology suited to historic thermal conditions - not the ones imposed by CDFW, EPA, and other regulators. This is called Natural Selection. While Darwin and others advanced this idea centuries ago, biologist are only now beginning to appreciate natural selection at a mechanistic level. To suggest otherwise does not

Comment # (page #)	Comment	Districts' Response
		acknowledge the seasonal/temporal fluctuations in temperature that are part of a fish's life history! Issues regarding the casual use of 'stress', the 7DADM as a chronic criteria, and misunderstandings about what is meant by local adjustment have been dealt with in the clarifier statement at the beginning of this attachment and in responses above. The question put forward after "18°C" (USEPA 2003)" is a rhetorical question since the reviewer provided the results of his "standard statistical analysis" later in his review. The statistical questions are dealt with below in the methods/results. Related to this comment, it is incorrect and purposely misleading to suggest we are advocating for higher temperatures, we are reporting on the results of our study which show that these fish have the capacity to conduct various energetically demanding tasks at temperatures above 18°C. The report discussion is not intended as the basis for changing the EPA (2003) 7DADM recommendations. Instead, our work simply suggests that the current value of 18°C lacks merit for the current *O. mykiss* population found in the lower Tuolumne River. As a minimum, 18°C as the 7DADM value is a very conservative upper thermal limit based on the results of the current study. Related to the question about thermal response of "all vertebrates" the short answer is "no". Some vertebrates can have a much narrower range of temperatures where thermal performance, as indexed by AAS, is much narrower (e.g.

Comment # (page #)	Comment	Districts' Response
		Fraser River sockeye salmon). This is another point where fundamental misunderstanding of the thermal performance literature for fishes has apparently led this reviewer down a confused path. What the study and the data demonstrate is a relatively flat curve, which is consistent with capacity being temperature INSENSITIVE and acclimation/adaptation to a rather wide thermal range. Our use of "atypical" means different from the *O. mykiss* which are the basis for EPA's 18°C criteria. The reviewer clearly believes that all salmonids are genetically programmed for cold water and that there has not been sufficient time for any to become locally adjusted (warm or cold). Scientific evidence indicates that salmonids from different locations within the Pacific Northwest and Canada have different optimal temperatures for day to day existence, migration and feeding in freshwater environments (Parsons 2011; plus other references).
CDFW-8 (p. 4)	Executive Summary, page ii, first paragraph. What do the authors mean when indicating that the fish are locally adjusted? The fish are blocked by a series of dams, preventing them to migrate upstream to cooling temperatures, so they have no choice but to live in a warmer environmental regime. The authors also stated they lost 1 of 4 fish acutely exposed to 25°C. Do the authors agree that 25% fish exposed to 25°C would die, especially if they are chronically exposed to this and higher temperatures?	The explanation of what was meant by "locally adjusted" is provided above. No, the authors do not agree that "that 25% of fish exposed to 25°C would die, especially if they are chronically exposed to this and higher temperatures". Our research did not attempt to answer this question, and it would be inappropriate to try to do so. A different type of study with more fish tested at higher temperatures and more sensitive mortality endpoints would be required to answer this question. What we did show instead was that if fish were at 25°C and swum to exhaustion, 25% died. This observation is very different from the assertion regarding survival, which was not

Comment # (page #)	Comment	Districts' Response
		measured. Of course, "survival" is time-dependent. A CTmax measurement is used by some to measure "survival, but this is a matter of a few minutes. Even the fish that died in our experiments at 25°C lasted longer than a few minutes! Thus, the debate around "survival" and temperature has a long and unresolved history, and thermal resistance and tolerance are better terms at a mechanistic level. This is part of the reason why modern day physiologists measure AAS to assess thermal performance. The study was never intended to define specific chronic thermal exposure limits. We remind the reviewer that our work simply suggests that the current value of 18°C lacks merit for the current *O. mykiss* population found in the lower Tuolumne River. At a minimum, 18°C as the 7DADM value is a very conservative upper thermal limit based on the results of the current study. It is unclear to us what is unclear about this very specific articulation of the study goal and main finding.
CDFW-9 (pp. 4 and 5)	Executive Summary, page ii, second paragraph. The authors state, "The conclusion of the study is that the thermal range over which the Tuolumne River *O. mykiss* population can maintain a 95% of peak aerobic activity from 17.8°C to 26.6°C". How long can these fish withstand this activity? In the last sentence they state that "Finally, based on a video analysis of the swimming activity of *O. mykiss* in the Tuolumne River, fish at ambient water temperatures were predicted to have excess aerobic capacity well beyond that needed to swim and maintain station against the river current in their usual habitat". However, don't all vertebrates have	Some of the fish could maintain this level of activity for hours in the swim tunnel but in the wild most of their lives occur at much lower activity levels and peak activity only occurs for a few seconds to feed or avoid predators. Also, please see clarifying document at the beginning of this attachment where the issue of energy allocation is explained and the value of understanding AAS capacity as a comparative metric is restated. However, no animal ever lives for prolonged periods near its maximum AAS. Therefore, we agree with the contention. Jared Diamond for example suggested that maximum

Comment # (page #)	Comment	Districts' Response
	excess aerobic capacity to survive and meet the basic needs of survival; how are these trout any different from any other living creature? Just because a fish can survive a short duration elevated temperature exposure event (i.e. minutes) does not mean that it can withstand the same elevated temperature for a long exposure event (i.e. days, weeks, and/or months). A human analogy helps us understand key physiological concepts and keep them separate. For example, an Olympic marathon runner can run 26.2 miles in approximately two hours; however, this same runner cannot maintain the same pace for days, weeks, and months. The point here is that the Olympic runner is training for an acute event but in so doing he/she is not enabling him/herself to maintain an acute pace over a chronic period of time (days, weeks, and months). The ability of fish to survive an acute event is not indicative of a fish's ability to survive a chronic event. As was stated above, acute tolerance is always higher than chronic tolerance. USEPA set chronic criteria while the authors of this report conducted an acute study. At best, this study's results may be used to inform development of acute level criteria (i.e. temperature tolerance over short duration) but is does not translate to predicting a chronic level criterion (i.e. temperature tolerance over long durations).	sustained performance in lactating mammals was limited by food movement across the gut; high endurance athletes and lumberjacks appear to have similar problems. Biologists who more broadly measure daily energy expenditures in wild animals rarely find that metabolic rate is on average 2X basal rates. Thus, the finding that Tuolumne River *O. mykiss* have a FAS of >2 for much of the thermal range we studied must have impressed this reviewer. Yes, each vertebrate species will have excess aerobic capacity to perform and survive at some range of temperatures. The issue we specifically address in this Report is "what is this range of temperatures". There are obviously lots of differences between Tuolumne River trout and other living creatures, but the only difference relevant in this study is the optimum temperature range for Tuolumne River *O. mykiss* compared to that for other populations of *O. mykiss*. Tuolumne River *O. mykiss* have been observed living and feeding in a river which has higher water temperatures than most other *O. mykiss* populations. See our discussion of comparative context for help in understanding this point. With regard to the human analogy paragraph: This comment confuses several important concepts that we have explained above and in the clarifying document at the beginning of the attachment. The first part is about how metabolic energy is allocated and we've responded to this already. The next bit introduces acute and chronic exposures, which we've addressed above as well.

Comment # (page #)	Comment	Districts' Response
CDFW-10 (p. 5)	Executive Summary, page ii, last paragraph. The USEPA (2003) criterion is not an upper performance level for fish. The authors are comparing acute results to a chronic value, an individual result to a population criteria, and survival to reproductive success and recruitment, which are all inappropriate comparisons. The authors need to conduct the same test in other rainbow trout stocks throughout the Pacific Northwest to make a similar comparison to this study before rendering a conclusion that the Tuolumne River rainbow trout have evolved higher population acute water temperature tolerance. The authors recommend " ... we recommend that a conservative upper performance limit of 22°C, instead of 18°C, be used to determine a 7-Day Average of the Daily Maximum (7DADM) value". However, for cold water fish, such as trout, it would be more appropriate, conservatively speaking, to use the lower water temperatures values (17.8°C) the authors presented in their study. Their comparison to the redband trout is also inappropriate because the redband trout evolved under a totally different set of environmental conditions compared to coastal rainbow trout/steelhead. Coastal rainbow trout evolved across thousands of years in river systems that originate in high mountain elevations and connect to the Pacific Ocean. Today's rainbow trout have been exposed to river systems, blocked by dams for less than 100 years, which is insufficient on the evolutionary scale to adapt to today's river water conditions.	We agree that USEPA 2003 criterion was not the upper performance level, but it was the optimal temperature for peak growth. See explanation above, regarding that fact that our experiment was measuring the optimal temperature range for Tuolumne River *O. mykiss*, not acute CTmax temperatures for these fish. If there is no peak for ASS we must then talk about a thermal range for peak AAS, which is what we do. The reviewer repeatedly returns to the idea that trout are a cold-water species that cannot adapt to warm conditions. We agree that most trout populations are post-glacial invaders, but there is a groundswell of evidence that indicates exceptions to the rule. Red band trout are a documented exception. So are the hatchery-selected rainbow trout in Western Australia and Japan. We believe Tuolumne River *O. mykiss* are another exception based on the data presented in our Report. Please see previous response to acute/chronic criteria. The reviewer appears to be very certain that 100 years of exposure to higher water temperatures in not sufficient for rainbow trout to become locally adjusted to higher temperatures than other rainbow trout populations. In the report, we thoroughly review the published literature that addresses thermal adaptation among rainbow trout populations and that demonstrates supports for local thermal adaptation. The reviewer cannot be correct with their assertion, as it has taken far shorter for this to occur. Moreover, geneticists are increasingly of the belief that Gene

Comment # (page #)	Comment	Districts' Response
		X Environment effects can take over in about 7 generations and be evident in as little as 2 generations. It is also not clear why the reviewer is focused on potential adaptation happening only over the last 100 years in California in response to dams. There are many natural systems in California (pre-dam) where fish would have encountered warm temperatures that would be comparatively warmer than northern latitudes. In drought years, trout can be trapped in shrinking ponds that get quite warm. Some survive and the survivors add resilience to the population. Please look into some of the portfolio effect literature. The opinion presented here by the reviewer is only one perspective. To think that we have been imposing artificial high temperature selection on California fish over the last 100 years is incomplete and quite likely incorrect. An argument could be made that constant, year-round cold-water access for fish immediately below dam is 'unnatural' selection and could contribute to the loss of high temperature resilience by dampening selective high temperature signals that would have, historically, occurred naturally.
CDFW-11 (p. 5)	Introduction, page 1, first paragraph. The authors' state, "However, cooler river temperatures are associated with cloud cover and over night [sic], and deeper ponds in the river do show some thermal stratification". Did the authors document the daily temperature difference during the hot summers, and identify and document any cool refugia or deep pools locations and measure water temperatures?	It is well known from the literature, human behavior and animal behavior that air temperature cools with cloud cover or at night. Groundwater seeps into rivers also provide cool refugia. To argue otherwise is folly. Indeed, the whole idea behind a 7DADM is that temperature fluctuates overnight and from day to day!!! Extensive studies were performed of water temperatures of the lower Tuolumne River and the reviewer is referred to

Comment # (page #)	Comment	Districts' Response
		these studies that have been previously provided to CDFW as part of the relicensing process.
CDFW-12 (pp. 5 and 6)	Introduction, Page 1, second paragraph. The location in river miles was discussed as to where rainbow trout are commonly found with temperatures ranging from 11°C to 28°C. This is true; however, these fish have no other choice but to live under these environmental conditions because their natural migratory route to cooler high elevation waters is blocked by dams. If a fish can survive under a set of environmental (i.e. acute and chronic) conditions, including "thriving" (i.e. reproductive success over many generations etc.), then this fish has demonstrated that it has the capacity to withstand higher temperatures. However, not knowing the environmental conditions which other fish populations are actually exposed to and not knowing their population viability, the justification for changing temperature criteria based upon other fish stocks is scientifically invalid.	From these comments it seems that the reviewer agrees with our contention that this fish population has a limited and constrained habitat. Also they must be surviving, growing and reproducing in this environment. Therefore, they are likely adapted to the local conditions through natural selection. We are simply showing that this population has an excess aerobic capacity to perform over much of this thermal range. This is an important advance of knowledge, especially since it is not widely shared among other more cold-adapted rainbow trout populations, including those introduced to the midwest of the USA and were used by Hokanson (1977). Please also note: The report discussion is not intended as the basis for changing the EPA (2003) 7DADM recommendations. Instead, our work simply suggests that the current value of 18°C lacks merit for the current *O. mykiss* population found in the lower Tuolumne River. Minimally, 18°C as the 7DADM value is a very conservative upper thermal limit based on the results of the current study.
CDFW-13 (p. 6)	The entire [Thermal Tolerance and Thermal Performance] section discusses acute thermal tolerance in relation to survival, but does not present any information about chronic exposures in relation to reproductive success and recruitment to maintain a sustainable population. On page 2, paragraph 1, last sentence, the authors state "Regardless, CT max is always higher than the temperature that a fish can	See explanation above, regarding that fact that our experiment was measuring the optimal temperature range for Tuolumne River *O. mykiss*, not acute CTmax temperatures or survival for these fish. CTmax measures thermal tolerance; AAS measures capacity. The fact that when a fish is about to die at CTmax can be

Comment # (page #)	Comment	Districts' Response
	tolerate for hours to days and certainly higher that the temperature at which a fish can no longer swim aerobically". The CT_{max} is a lethal temperature, at which point a fish can no longer swim aerobically. The tunnel test conducted by the authors accomplished the same end point where the fish were pushed to exhaustion and could no longer swim aerobically. So how does the tunnel test as presented by the authors differ from CT_{max} as stated in this paragraph?	higher than when FAS is 2 seems to be a reasonable statement. Please also see previous comments regarding acute and chronic metrics, and how our study relates to population metrics like reproduction and survival.
CDFW-14 (p. 6)	7-day Average of the Daily Maxima (7DADM), page 2, second paragraph, last sentence. The authors state, "Interestingly, by setting the 7DADM criterion for salmon and trout migration as 20°C, rather than 18°C, USEPA (2003) acknowledged that juvenile Pacific Northwest *O. mykiss* have sufficient aerobic scope for the energetic demands of river migration even at a temperature 2°C above the 7DADM for juvenile growth". However, the authors failed to mention the 20°C migration criteria is conditioned with a provision to restore or provide the natural thermal regime; or to provide or restore cold water refugia. Examples of cold water refugia or natural cool regime would include the confluence of cold tributaries at the main stem river or where groundwater exchanges with the river flow (hyporheic flow) that would provide cold water refugia for fish to escape maximum temperatures. Waters in tributaries for large rivers in the Central Valley have been diverted, eliminating cold water refugia at the confluence of these tributaries and groundwater pumping in the valley has lowered groundwater levels, thus removing natural cool ground water seeps into the	We have removed this statement from the Report to avoid potentially misleading any reader. This is not an important issue to us, but was meant to illustrate that even the blanket 7DADM had exceptions. We note that the reference to the Corbett report is misleading as it did not draw this conclusion.

Comment # (page #)	Comment	Districts' Response
	valley's rivers. (Corbett, F., T. Harter, and M. Sneed. 2011. Subsidence due to excessive groundwater withdrawal in the San Joaquin Valley, California. American Geophysical Union. Fall Meeting Abstract #H23H-1397.)	
CDFW-15 (p. 7)	Justification and Purpose of the Study, page 4, first paragraph, last sentence. The authors state, "Thus, MR [Metabolic Rate] measurements were used to determine the optimal temperature range for Tuolumne River *O. mykiss*". Can the authors provide a definition for what they consider "optimal temperature range" and differentiate an acute and chronic optima range? Do the authors consider the hottest temperature as optimal or would a cold water fish be in excellent condition at a lower temperature from a chronic exposure perspective?	Please carefully review Figure 1, including the legend. The requested information is stated clearly there. We clearly do not measure chronic temperatures so the distinction is meaningless for this Report. We clearly do not consider the hottest test temperature as optimal and that is also clear from Figure 1.
CDFW-16 (p. 7)	Justification and Purpose of the Study, page 5, the first paragraph describes the "aquatic treadmill" similar to Parsons (2011) and Figure 1 that is presented on page 33 in this Study report. The peak T_{opt} in Figure 1 appears to be the maximum acute temperature (T_{max}) at the peak of maximum oxygen consumption and not necessarily an optimal temperature. From the peak temperature to higher temperatures, oxygen consumption decreases, suggesting the fish is exhausted and no longer capable of absorbing oxygen similar to what occurs in hyperventilation with humans. It is vitally important to remember that water at higher temperatures have lower oxygen concentrations, which is noteworthy because oxygen crosses the cellular membrane via a concentration gradient. Thus, lower oxygen	This appears to be one of the key sources of the reviewer's confusion on the purpose of our study. The maximum acute temperature (Tcrit in Figure 1) is not at the peak of maximum oxygen consumption. To be clear on the definitions that we have used, the temperature at which peak ASS occurs is DEFINED as Topt. This is the accepted definition. Tcrit would be when ASS fell to 0, but we never saw this with the present experiments. Furthermore, the statistics argue that there is no specific peak AAS as such, only a large thermal range over which there is no statistically significant change in AAS. Thus, there is not

Comment # (page #)	Comment	Districts' Response
	concentrations in the water decrease the concentration gradient forcing the fish to use more energy to pull oxygen across their gill membrane, similar to hyperventilation of a human at the 8,000-foot elevation where the oxygen concentration is lower than that which occurs at lower elevations. Clark et al. (2013) Figure 1 B (page 2772) demonstrates that T_{opt} is midway up the aerobic scope and not at the peak of the slope. They further state "T_{optAS} provides little insight into the preferred temperature or performance of aquatic ectotherms, but rather aerobic scope continues to increase until temperatures approaches lethal levels, beyond which aerobic scope declines rapidly as death ensues." We agree with Clark et al. (2013) that the curves peak should be considered a T_{max}, not a T_{opt}.	a Topt as such, only a range over which a peak AAS is maintained. We are not therefore dealing with a mountain peak, but instead a prairie plateau! In this regard, the broad thermal performance of AAS more closely resembles the eurythermal killifish and goldfish. As a former postdoctoral supervisor of Tim Clark and co-author, Dr. Farrell is very familiar with his research and publications. We agree that AAS only tells us what capacity exists. Thermal preference, as pointed out by Clark et al. 2013, is a completely separate issue and should not be confused with Topt. However, if a fish wants to maximize the capacity to perform activities then it should choose Topt. The fish may or may not choose or prefer this temperature, but then there can be situations when they cannot – e.g. overwinter in the Tuolumne River, when the fish are likely to acclimate to cooler seasonal temperatures. Clearly a steelhead trout in the Pacific Ocean could not prefer a Topt of say 18°C for growth (as dictated by the 7DADM simply because such conditions do not exist within their known habitat range at sea. They are found at much lower temperature.
CDFW-17 (pp. 7 and 8)	Justification and Purpose of the Study, page 5, second paragraph, last sentence. The authors state, "Specifically, the temperature indices and the shape of the aerobic scope curve derived in the present study can also be compared with those of other *O. mykiss* populations and with the EPA (2003) recommendations". It is inappropriate to compare results from an acute stress test conducted for basic	See explanation above, regarding that fact that our experiment was measuring the optimal temperature range for Tuolumne River *O. mykiss*, not acute CTmax temperatures for these fish. We fundamentally disagree with the reviewer on this point and again refer to how we are interpreting our work and how it relates to the EPA criteria. The report is not intended as

Comment # (page #)	Comment	Districts' Response
	survival needs and then make inferences to a population needing protection at the chronic criterion level. Again, acute level does not equate to chronic level when it comes to conducting tests and/or developing protective criteria. The USEPA criteria are chronic not acute; therefore, any reference to USEPA criteria in this report for purposes of changing chronic criteria is unfounded and is therefore not scientifically valid.	the basis for changing the EPA (2003) 7DADM recommendations. Instead, our work simply suggests that the current value of 18°C lacks merit for the current *O. mykiss* population found in the lower Tuolumne River. Minimally, 18°C as the 7DADM value is a very conservative upper thermal limit based on the results of the current study. Given the wealth of published literature on the ecological relevance of AAS measures, we think it rather inappropriate for a comment like 'not scientifically valid' to appear in this forum.
CDFW-18 (pp. 8 and 9)	Justification and Purpose of the Study, page 5, last paragraph. This paragraph summarizes Fry (1947) as presented in Parsons 2011. The "tunnel" experiment is an acute test that measures acclimation rather than adaptation. Central Valley salmonids evolved across thousands of generations to adapt to their living environment before the construction of dams. Fish that exist today have not evolved under today's environmental conditions because the time period has been too short for adaptation. Yes, *O. mykiss* can acclimate on an acute basis, but cannot adapt on a chronic basis in the less than 140 years since the construction of dams which blocked their historic spawning grounds. Similar to Parson (2011) description, resistance or adaptation is a result of the evolutionary process that takes generations to develop and cause a genetic change across those generations in a population (Guthrie 1980). Tolerance or acclimation is a result of an individual, or	We never make any claim that this fish population is adapted. We simply say that the evidence is in support of local adaption. We do not want to sound like a broken record, as almost all of these issues are variously and repeatedly dealt with in the responses above and in the clarifying document. There are a couple of points we must emphasize. Our experiment was measuring the optimal temperature range for Tuolumne River *O. mykiss*, not acute CTmax temperatures for these fish. If *O. mykiss* can't acclimate on a chronic basis to warmer water, we should not find them living and feeding in these warm water locations where they are observed in the Tuolumne River. Lastly, populations are made up of individuals. If the individual does not have the AAS to perform, the population

Comment # (page #)	Comment	Districts' Response
	a group of individuals, repeated exposure across the life of the individual that causes a physiological change. Individual based temperature exposure tolerance does not expand to all individuals in the population, but population based exposure adaptation transfers to all individuals within the population. Population thresholds are designed to protect a population; whereas, an individual threshold is designed to protect an individual or small group of individuals. A population threshold will have minimal health effects for all the individuals, including the most weak, in that population (USEPA 2989; Air RISK). Therefore, the population exposure threshold tends to be lower in value (i.e. more restrictive) than the individual exposure threshold. In summary, population thresholds are always less than an individual threshold and chronic thresholds are always less than acute thresholds. Thus, the reported fish water temperature experiment address individual level, but have limited usefulness as a basis for a full understanding of resistance or adaptation at the population level. As such, the tunnel stress test provides great information about tolerance and acclimation at the individual level, but is inappropriate to extrapolate the results to adaptation for chronic population exposure criteria.	will cease to exist. Furthermore, natural selection acts on individuals and the results are reflected in populations. Therefore, if we do not understand the effects of temperature at the level of individuals, we have no hope of properly understanding the population effects.
CDFW-19 (p. 9)	Predictions Derived from EPA (2003), page 6. The authors proposed predictions based the USEPA (2003) criteria are irrelevant because the USEPA (2003) criteria were not based on an acute stress test. Is data presented in Table 1 based on acute or chronic tests?	We agree with the reviewer on what the USEPA 2003 report does and does not contain. This does not mean that we cannot make predictions, which is all we do. The report discussion is not intended as the basis for

Comment # (page #)	Comment	Districts' Response
	The USEPA (2003) 18°C criterion is not based on maximum metabolic rate (MMR) acute test as presented in Figure 1, but is a chronic criterion which is lower than acute criterion. The USEPA (2003) never stated an AAS T_{opt} metric, nor discussed this study design, to develop a chronic population criterion.	changing the EPA (2003) 7DADM recommendations. Instead, our work simply suggests that the current value of 18°C lacks merit for the current *O. mykiss* population found in the lower Tuolumne River. Minimally, 18°C as the 7DADM value is a very conservative upper thermal limit based on the results of the current study. This report is not intended to preempt consultation with EPA. We strongly believe that the new data collected here are a firm basis for opening such a dialogue about site-specific temperature criteria in general as well as for the Tuolumne River *O. mykiss*.
CDFW-20 (p. 9)	Alternative Predictions of Thermal Adjustment, page 6. On what are the predictions based? Again, this study design is an acute stress test. It is well known that *O. mykiss* can survive in temperature above 18°C, but the study design does not answer the questions as to what is the chronic population threshold for reproductive success and recruitment to maintain sustainable populations across many future generations. The study design also does not address how well the *O. mykiss* immune system functions to ward off disease or how well a cold water fish can escape a warm water predator, especially when the water temperature are in the optimal range for the warm water predator. This study design can measure individual cold water fish short sprint energy to avoid a predator, but does not indicate how long a cold water fish can escape in a predatory warm water fish optimal temperature zone.	We agree with the reviewer on what the USEPA 2003 report does and does not contain. This does not mean that we cannot make alternative predictions, which is all we do. The reviewer continues to blindly refer to this population of rainbow trout as a cold-water species, when they clearly live in river temperatures reaching 24°C. The report discussion is not intended as the basis for changing the EPA (2003) 7DADM recommendations. Instead, our work simply suggests that the current value of 18°C lacks merit for the current *O. mykiss* population found in the lower Tuolumne River. Minimally, 18°C as the 7DADM value is a very conservative upper thermal limit based on the results of the current study.
CDFW-21 (p. 9)	Fish Collection, Transport, and Handling, pages 8 to 9. Most of the study fish were caught in the upper coolest	The choice to collect fish from cool reaches had nothing to do with the distribution of fish in the river with respect to

Comment # (page #)	Comment	Districts' Response
	reaches of the river. However, if these fish are adjusted to warm temperatures, why were they present in the coolest waters of the river? The fact that most of the fish were found and captured in the coolest waters of the river is indicative that, at the population level, *O. mykiss* in the lower Tuolumne River are seeking cooler water to reside in even though warmer water is available to them.	temperature. Jumping to this conclusion is incorrect, unsupported, and misleading. The distribution of *O. mykiss* within the Tuolumne River is affected by many factors, only one of which is temperature, e.g there may be more predators downstream. Prior studies on the Tuolumne River have documented *O. mykiss* in warmer water. All of these studies have been provided to CDFW and we refer the reviewer to the many submittals on this subject. The decision to collect fish from relatively cold reaches was twofold. First, by collecting fish from cooler reaches, they were more likely to have a relatively cool thermal history (acclimatization) as compared to fish from warmer reaches. Because thermal history has a positive relationship with performance (i.e. if fish are acclimated to warmer temperatures, performance at warmer temperatures improves), testing cold-acclimatized fish should lead us to the most conservative AAS curve, with respect to temperature, that we could obtain. Certainly, when data are to be used for thermal criterion discussion, conservatism is desired for fish protection. Also it makes for easier comparison with existing data on rainbow trout. Secondly, collecting fish from cooler areas minimized our chances of capture-related mortalities (due to rapid temperature change during capture, release, or transport) during the peak of summer. This was an unnecessary risk that we thought best to avoid so that our study would not be shut down early. Our experiment showed that there is a wide range of temperatures where Tuolumne River *O. mykiss* have the

Comment # (page #)	Comment	Districts' Response
		aerobic scope to live and thrive. *O. mykiss* are found in the Tuolumne River at the range of water temperatures tested in our experiment. The distribution of *O. mykiss* within the Tuolumne River is affected by numerous factors only one of which is temperature.
CDFW-22 (p. 10)	Experimental Protocols, page 11, last paragraph. The authors state, "Water velocity was then increased in increments of 3 to 6 cm s^{-1} every 20 min until the fish failed to swim continuously". Is this an acceptable fisheries technique to allow an animal to work to the point of complete exhaustion? Would it be better to do a timed test by stopping the test before the fish is completely exhausted?	This experimental design has been used in numerous studies and approved by university research protocols. Please refer to the clarifying document and the cited special issue on methodology. Importantly, this comment reveals a fundamental misunderstanding related to why we are using swimming tests and exhaustion. To properly measure AAS, we need a method to estimate MMR and swimming to exhaustion happens to be one way to do this. Swimming fish for an extended period of time and a submaximal swimming velocity would not elicit maximum metabolic rates. A human example might help. Would a jogger out for a 20 min casual, timed run reach MMR? No. Would a runner chased to exhaustion exhibit MMR near the endpoint, yes. Even the cited and supported work by Clark et al. 2013 uses this methodology and Clark and Norin, 2016 used the approach used by us. It seems that the reviewer is adopting double standards.
CDFW-23 (p. 10)	Experimental Protocols, page 12, third paragraph. The authors state, "Approximately 50% of the wild fish did not respond to the critical swimming velocity protocol but instead used their caudal fin to prop themselves on the downstream screen to avoid swimming". Is this a sign the fish were already stressed before the	It is unclear what the reviewer considers stress. See previous comments regarding the pitfalls of using this term casually. This was not a sign of 'stress' and there was no discernable pattern between tail propping with test temperature. Making the speculation that this behavior had something to do with

Comment # (page #)	Comment	Districts' Response
	experimentation started and possibly a result of too warm temperatures to begin with?	elevated test temperatures is incorrect. It is common for some fish to be 'non participants' in tests like these. We see this in all species that I'm familiar with and the literature provides many examples. These fish are wild and a swim tunnel setting is novel. Some individuals require different motivations (stepwise velocity increases, bursting velocities etc.) to help to orient them to the current and elicit sustained swimming. In salmonids, tail propping is often seen at low velocities to save energy rather than swimming, but as velocities continue to increase, salmon will then begin to swim. Once they start swimming, they almost always perform to exhaustion. This fish are built for continuous swimming.
CDFW-24 (p. 10)	Data Quality Control, Model Selection and Analyses, page 13, last paragraph. The authors state, "Routine metabolic rate quality control (QC) was performed by visually inspecting over night [sic] video recordings for fish activity" and that "data from any fish showing consistent activity over night [sic] was discarded". Why were the data discarded? Was the fish activity a sign of stress before the experiments started? In addition the authors state, "For fish exhibiting intense agitation, the swimming MMR was used as overall MMR." Four of these 'non-agitated' fish (W2, W13, W14, and W15) were disgarded due to failure of MR to increase incrementally; despite continuous station-holding swimming with tunnel velocity increases of more than 15 cm s^{-1}". Were these fish already stressed? How does inclusion of these data influence study results? It is important that data not be "selected" in order to bias study results. Scientific integrity requires that data not	It is unclear what the reviewer considers stress. See previous comments regarding the pitfalls of using this term casually. Please review our definition of RMR and reread comments on the effect of stress on RMR and AAS in the previous comments. It is clear that metabolic measure of active fish is NOT the physiological state representative of RMR. Active fish have metabolic rates somewhere between RMR and MMR and are not we were measuring in order to calculate AAS. We are keenly aware of the fact that rigorous science includes all valid data points and rigorous scientists do not 'throw out' valid data. All of our methods are consistent with published methods, see the previously referenced special issue of Journal of Fish Biology. Our rationale is clear and justified and supported by the scientific (published) literature, which we've cited. The insinuation that there is even a hint of a

Comment # (page #)	Comment	Districts' Response
	be thrown out for invalid reasons, including if the results cannot be explained or if they are different than expected.	scientific integrity issue of the co-authors of this study is completely out of line, inappropriate, and disappointing. Certainly, there is a less combative way to query the inclusion or exclusion of specific data points.
CDFW-25 (pp. 10 and 11)	Results, Page 15, Number 1, third paragraph, second sentence. The authors state, "They state that Routine Metabolic Rate (RMR) should increase exponentially until the test temperature approaches the upper thermal tolerance limit for *O. mykiss*, which according to published CT_{mas} values is 26°C to 32°C (see Table 1)". Who is "they"? If "they" is the USEPA, this is an incorrect statement because the USEPA did not include RMR studies in their review. Myrick and Cech's Table 1 had significant less food consumption and decreased growth rates and increased mortality in their 25°C test fish compared to their 10°C, 14°C, and 19°C exposed fish. In their Table 2 results, fish consumed significantly less oxygen at 25°C compared to fish exposed to 10°C, 14 °C, and 19°C. *O. mykiss* can survive in acute warm temperatures as demonstrated by the authors, but cold water fish still need cold water refugia sometime during the day. According to Myrick and Cech (2000) there is very little thermal difference between fish stocks per their comparison of other research studies (see Table 5) under similar experimental conditions.	"They" is referring to the predictions not to any group or report. The sentence should have started with "These predictions" not "They".
CDFW-26 (p. 11)	Results, page 15, Number 2. The authors state, "These results for MMR are inconsistent with our prediction #2 derived from EPA (2003) criteria where MMR was	Chronic/acute criteria are dealt with in CDFW-1 and in the clarifying document.

Comment # (page #)	Comment	Districts' Response
	expected to peak near to 18°C". This statement is irrelevant because the authors are comparing chronic population criteria to acute individual results. Again, chronic and population thresholds are always less than acute and individual thresholds.	
CDFW-27 (pp. 11 and 12)	Results, page 16, Number 3, third paragraph. The authors state, "These results for AAS are inconsistent with our prediction #3 based on EPA (2003) criteria, but are consistent with our alternative prediction #3 that the Tuolumne River population of *O. mykiss* is locally adjusted by having T_{opt} for AAS that is greater than 18°C i.e., 21.2°C." This statement is irrelevant because the authors are comparing a chronic population criterion to acute individual results. Again, chronic and population thresholds are always less than acute and individual thresholds.	Chronic/acute criteria are dealt with in CDFW-1 and in the clarifying document.
CDFW-28 (p. 12)	Results, page 16, Number 4, last sentence. The authors state, "The numerical 95% peak AAS could be maintained from 17.8°C to 24.6°C, which is a more conservative thermal range for T_{opt}". However, based on the authors results, and because rainbow trout are a cold water fish, a true conservative thermal range would be from 16.4°C to 17.8°C.	How does this reviewer know what is "true" for Tuolumne River *O. mykiss*? The 16.4-17.8 °C range is more conservative but not necessarily the "true conservative thermal range". Why not pick, 17.8 to 17.9 to be more conservative still. Such selection is arbitrary and has no statistical basis. Statistically AAS does not change over the range of temperatures stated. Therefore we adopt a scientific rigor that the reviewer does not appear to appreciate. Furthermore, the reviewer has repeatedly ignored the results of our tests of Tuolumne River *O. mykiss* and based his whole review on the assumption that our study fish are no different from other *O. mykiss* populations.

Comment # (page #)	Comment	Districts' Response
		Again the reviewer ignores the data by calling this population a cold-water species when data show that they perform equally well at temperatures in excess of 20°C. It's also important to mention that 'coldwater fish' is not at all a precise term. What is cold, what is warm? Modern thermal ecology literature suggests that some Om populations are simply not as 'cold water' as previously thought.
CDFW-29 (p. 12)	Results, pages 16 to 17, Number 5. Same comment as for comparing an acute stress test results to a chronic population criterion. The author state, "Indeed, all individual fish tested up to 23°C has a FAS [Factorial Aerobic Scope] value >2, with only 4 out of 14 fish tested at 23°C, 24°C, and 25°C having a FAS value <2." A chronic population threshold is formulated to protect the weakest individuals in a population, so by using a lower criterion these 4 weaker fish should have better physiological function and survival.	Chronic/acute criteria are dealt with in CDFW-1 and in the clarifying document.
CDFW-30 (p. 12)	Results, page 17, Number 7. The authors state, "Two fish tested at 25°C regurgitated rather large meals of aquatic invertebrates during the recovery from the swim test, and one of these fish died abruptly during the recovery period". Since, fish were exposed to an exhaustive state, this causes us to question whether or not this an appropriate testing technique where the test has to force an animal to complete exhaustion, especially for a group of fish that may be already stressed due to having to live in environmental conditions of altered flows and habitats that they did not evolve with.	Same comment on casual use of 'stress' and 'stressed out'. What, scientifically, do these qualitative judgment statements mean? They have no value. We have already explained above why we use exhaustion to elicit MMR. We either measure it or we do not. We are dealing with wild fish and cannot hold them outside of the river to ensure a full post-prandial state. We simply cannot believe that the reviewer holds the following premise "a group of fish that may be already stressed due to having to live in environmental conditions of altered flows and habitats that they did not evolve with." How on earth would the reviewer reach such a speculative

Comment # (page #)	Comment	Districts' Response
		conclusion without data to back it up? The amount of supposition and lack of scientific data to back such assertions is a total shock.
CDFW-31 (p. 12)	Discussion, Data Quality, page 18, first paragraph. This section provides a brief summary of the results and comparison to other aerobic studies. The Department completed an analysis of variance as presented in the following Table 1 using the Study's data presented in Appendix 4. Temperatures at and below 18°C were significantly different for RMR, MMR, and FAS compared to the highest temperatures at and above 22°C. For RMR, which is a fish at rest, is this an indication the fish at the warmer temperatures were already stressed before the experiment started?	It is simply not possible to respond to a comment about a re-analysis of the data when no statistical details are given. The statistical test, how the treatment groups were defined, n values, degrees of freedom, alpha level, and p-values are all missing. Note: imprecise use of stress and lack of understanding of the simple effects of temperature on biological rates are repeated once more.
CDFW-32 (p. 13)	There is an inverse relationship between water temperature and oxygen concentration. As temperature increases, oxygen decreases. As such, at the warmer temperature with less oxygen, are the fish stressed to the point they are hyperventilating, thus increasing their metabolism trying to pull in as much oxygen as possible from a low oxygen environment.	The movement of oxygen from water into the blood of a fish is governed by the partial pressure of oxygen in the water and not by oxygen concentration. Therefore the reviewer does not understand the basic principles of oxygen movement into fish by suggesting that the decrease in oxygen concentration with temperature triggers hyperventilation. Fish ventilation responds to oxygen partial pressure not concentration in the water. If the reviewer thinks otherwise they have been misled. Furthermore, oxygen concentration decreased by only 10% per 10°C. Therefore the decrease is around 15% for the entire range of test temperatures. Despite this minor change, the fish increase MMR and maintain AAS, so this is a non-issue. The idea that these fish are stressed has been repeatedly dealt with above.

Comment # (page #)	Comment	Districts' Response
CDFW-33 (pp. 13 and 14)	The Department also graphed the mean results for each temperature as presented in Appendix 4. Note at 22°C for RMR, AAS, and FAS and at 21°C for MMR there is a sudden change in the slope of the graph. Does this change in slope indicate there is a sudden change in the physiological function of the fish and a clinical sign that the fish are highly stressed? A highly stressed animal is considered to be in poor condition.	Our response to CDFW-31 applies here too. It is simply not possible to respond to a graph that we do not have. The equation, the R2 and p value are needed. We are not sure of what clinical sign that the reviewer refers to.
CDFW-34 (p. 14)	Discussion, Data Quality, page 19, Protocol Number 2. The authors state, "2 a combination of continuous swimming and short velocity bursts to push fish off of the downstream screen". Was this an indication the fish was already tired and stressed at the beginning of the experiment?	Of course a fish is tired when it is exhausted. That is why it has reach MMR and we stop the experiment. The fish nevertheless were observed to recover quickly.
CDFW-35 (p. 15)	Evidence for Local Thermal Adjustment, page 20, first paragraph. The authors state, "Our predictions based on EPA (2003), as listed above, assumed that the Tuolumne River *O. mykiss* population would perform similarly to Pacific Northwest *O. mykiss* populations used to set the 7DADM by USEPA (2003)". The predictions based on USEPA are irrelevant because the USEPA did not perform tunnel stress techniques or use such data to develop their chronic population criteria recommendations. The authors recommend using 21.2°C rather than 18°C, but they are comparing an acute/individual result to a chronic/population recommendation. Have the authors considered other techniques to determine what cold water fish, such as *O. mykiss* can chronically sustain normal/optimal physiological function, including immune function, reproductive success and recruitment, at their	Please see the clarifying document at the beginning of this attachment where we reiterate what our study results reveal and should be used for. That the reviewer suggests "The authors mention these test fish have a wide optimal thermal performance range, but this is true for all living organisms;" suggest a complete lack of understanding of thermal biology. Some Antarctic ice fish die at about 4°C.

Comment # (page #)	Comment	Districts' Response
	recommended temperature of 21.2°C? It is well understood that cold water fish can simply survive at warmer temperatures to a point, but what about their entire life cycle needs at the individual and population levels? The authors mention these test fish have a wide optimal thermal performance range, but this is true for all living organisms; what do the authors consider "optimal"?	
CDFW-36 (p. 15)	Evidence for Local Thermal Adjustment, page 20, first paragraph, last sentence. The authors also state, "However, given that the CT_{max} could not be determined in the present work and that MMR increased up to the highest test temperature (25°C), it was impossible to determine the upper thermal limit when MMR collapses, which means that alternate metrics must be used to set the upper thermal limit for the Tuolumne River *O. mykiss* population". Since the "upper thermal limit" is survival based, can the author's present reproductive success and recruitment base criteria with this type of testing?	Reproductive success and recruitment were not part of this study's purpose.
CDFW-37 (p. 15)	Evidence for Local Thermal Adjustment, page 20, second paragraph. The authors state, "The present work provides three useful metrics of the optimal temperature range". What is meant by "optimal temperature range"? T_{opt} appears to be more of a temperature maximum (T_{max}) than a T_{opt}. A temperature maximum does not necessarily mean it is an optimal temperature. Fry (1947) page 56, Figure 27, does not state the peak of activity as optimal, but refers to the "potential range of activity" and the "scope for activity". Fry further reduces the area of the activity curve by discussing	Please see response to CDFW-15. The thermal performance literature has evolved from the fundamental work of Fry to appreciate that there are many forms of thermal performance curves (not a static performance curve, incorporating all metrics for a particular species) like CDFW reviewer is presenting. These curves are shaped by many factors, including the 5 (or 6 depending on the citation) classifications of factors that Fry delineated in his work. They are also shaped by timescale (acute, acclimatory, adaptive), the fish's life history, the fish's

Comment # (page #)	Comment	Districts' Response
	"controlling factors". The USEPA (2001) as presented below provides a number of "controlling factors". Did the authors for this study consider controlling factors as described by Fry to adjust their activity curve?	evolutionary thermal history, etc. We do not disagree with the reviewer on the importance of these aspects and nowhere do we discount any of these details. It is interesting that Fry 1947, while an absolutely critical piece of early work, is also not augmented by the reviewer with more recent literature on thermal performance curves, their utility, and their interpretations. We cite several. Please revisit the clarifying document where we clearly articulate how our results articulate with the 7DADM.
CDFW-38 (p. 16)	Evidence for Local Thermal Adjustment, page 20, last paragraph, first sentence. The authors state, "Yet, there were important indications that a small percentage of individuals were taxed at 23-25°C by the thermal testing and intensive swim imposed on them outside of their normal habitat over a 24-h period." In the fourth sentence they further state, "In the present study, the telltale signs were that 4 of 13 individuals [31 %] tested at 23-25°C had a FAS <2." This supports the concept that a chronic population base threshold is to protect the weakest individuals in a population and cannot be formulated by using just one simple acute stress test.	See explanation above, regarding that fact that our experiment was measuring the optimal temperature range for Tuolumne River *O. mykiss*, not acute CTmax temperatures for these fish. It is incorrect for the reviewer to repeatedly call our test an 'acute stress test' for many reasons. As stated above, the optimal temperature range for Tuolumne River *O. mykiss* suggested by our swim tunnel tests is lower than the temperatures at which 4 fish had FAS values less than 2.
CDFW-39 (p. 16)	Evidence for Local Thermal Adjustment, pages 21 to 22, top line. In the same paragraph, the authors state, "Lastly the only fish mortality occurred in the recovery period (a phenomenon known as 'delayed mortality') after one fish was tested at 25°C". What is the point of mentioning 'delayed mortality'? The end result is one of four fish (25%) died at the highest temperature when forced to swim until completely exhausted.	"Delayed mortality" is just a term used to describe this category of mortality. Certainly, given the repeated interest in the duration of thermal exposure by the reviewer, the importance of expressing whether the death was immediate in response to an acute 25°C exposure or if the response was the result of a more prolonged high temperature exposure can be appreciated.

Comment # (page #)	Comment	Districts' Response
CDFW-40 (pp. 16 and 17)	Ecological Relevance of the Present Findings, page 21, third paragraph. The authors state, "MMR increased with temperature from 13 to 25°C, which would mean that as fish encounter higher temperatures, they have the capacity to perform an activity at a higher absolute rate, i.e., swim faster to capture food or avoid predators, digest meals faster, detoxify chemicals faster, etc.". Are the authors saying rainbow trout are better off at 25°C instead of <19°C? Their interpretation does not make any sense. We agree a fish will have burst of energy no matter what the temperature, however, the question remains how long can they maintain this energy consumption under chronic warm temperatures at 21.2°C? It takes energy to reproduce, how does exposure to chronic warm temperature impact reproduction success and recruitment into the population? Clark et al. (2013), page 2779, stated that there is a range of optimal temperatures for different processes and life histories and these optimal temperatures are different from T_{optAS}. They used an example for adult pink salmon where a T_{optAS} is at 21°C, but if reproduction occurred at 21°C would fail because the optimal temperature for spawning is <14°C. They further stated on page 2780, that fish have different physiological functions at different optimal temperatures as presented in their Figure 7B.	No, we are saying that *O. mykiss* have greater aerobic scope at 21.2°C than at the other temperatures tested. Therefore, they would be better off from a physiological energy perspective at temperatures near 21.2°C than the other temperatures tested. Some of the fish swam for multiple hours at a high rate at 21.2°C and higher temperatures. Please review the clarifying document for our perspectives about how our data do and do not address the 7DADM EPA criteria and how our data relate to energy allocation. Please also note: The report discussion is not intended as the basis for changing the EPA (2003) 7DADM recommendations. Instead, our work simply suggests that the current value of 18°C lacks merit for the current *O. mykiss* population found in the lower Tuolumne River. Minimally, 18°C as the 7DADM value is a very conservative upper thermal limit based on the results of the current study. The reviewer indicates that he does not think our interpretation makes sense. However, it is equally possible that our interpretations do make sense and we have either not communicated them simply and clearly enough or the reviewer is not understanding the study goals and interpretations. We have tried very hard to restate how are data are or are not relevant to the comments from CDFW.
CDFW-41 (p. 17)	Ecological Relevance of the Present Findings, page 22, first paragraph, third sentence. The authors state "As a result of high temperature, a fish would digest the same	The commenter's statement regarding the relationship between digestion rate and temperature is based on basic physiology of fishes and reveals a fundamental lack of

Comment # (page #)	Comment	Districts' Response
	meal with a similar overall oxygen cost but at a faster rate". This study did not measure how fast fish can digest their food at increasing water temperatures, therefore this statement stating that a fish would digest their food at a faster rate at higher temperatures is an assumption based on speculation. As the authors discussed, this study design measured oxygen demand to demonstrate fish have extra burst energy from a resting state to seek and catch food, but does not include measuring the rate of digestion. All animals digest their food during the resting state, otherwise their digestive tract would cramp-up during high activity.	understanding of the effects of temperature on another physiological rate process in fishes – digestion. (Please read the works of Jobling in the 1980-90's and Fu in 2000's. Indeed ecologists have postulated that some fishes actively feed in very warm areas so they can digest more!) We did not study nor use the terminology 'extra burst energy' as suggested by the reviewer. These are the reviewer's words and should not be mistaken for ours. We also note that the last sentence is a bit misapplied in using anthropomorphic words like 'cramp up' in an attempt to describe some sort of physiological relationship or process. Regarding the comment that "[a]ll animals digest their food during the resting state", we assume the reviewer is familiar with the behaviors of pelagic fish. Many swim continuously and eat and swim at the same time. Indeed, filter feeders must swim to feed. We note that the reviewer did not have any comment on the middle paragraph on page 22 of our report, where we provided clear evidence of *O. mykiss* maintaining their station in the Tuolumne River at 20°C where their metabolic rate (derived from tail beat frequency) was twice their RMR but substantially below their MMR at that temperature. The commenter is disregarding data that we provide while preferring to offer spurious speculation.
CDFW-42 (p. 17)	Ecological Relevance of the Present Findings, page 22, last paragraph. The authors state "Here we did not evaluate the possibility that the Tuolumne River *O. mykiss* population can thermally acclimate to warmer river temperatures as the summer progresses, due to the	This comment reveals fundamentally incorrect ideas and misunderstandings about what acute versus acclimatory processes are and what time scales are relevant. We kindly ask the reviewer to review the various report documents noting the definitions of these terms. Please also review the

Comment # (page #)	Comment	Districts' Response
	available sample of a maximum of 50 individuals and their habitat temperature." Actually the authors did evaluate if Tuolumne River trout can acclimate, because this was an acute stress test designed for that purpose. Up to a limit, animals can acclimate to an acute environmental change, but how do these animals reproduce successfully under chronic environmental changes such as migratory routes being blocked and under different water flow regimes that they did not evolve with?	study design. To evaluate thermal acclimation experimentally, you must control and/or measure the fish's thermal acclimation history so that it is known. With those data in hand you can then attribute results to the effect of acclimation. Our fish were wild-caught and acclimatized to the river where thermal history was not measured. Thus, we did not test acclimation. The reviewer comments here regarding 'acute' are not relevant and the later part of the last sentence regarding migration routes and flows are also not relevant. If permitting had allowed us to keep each fish out of the river for 4 weeks, we would have measured acclimation. So the experiments could be performed with our mobile physiology lab, but was not tested because of the available permit.
CDFW-43 (p. 17)	Conclusions, page 24. As previously stated, the USEPA did not use acute tunnel stress test to evaluate a chronic population criterion. They included a number of factors as part of their evaluation. It is inappropriate to compare results from an acute individual test to a chronic population threshold. Since *O. mykiss* are a cold water fish, it would be more appropriate and conservative to use their lower range results (16.4 and 17.8°C) to protect this fish, particularly where reproduction success appears to be low because the population has been declining for decades since the dams were constructed (Yoshiyama et al., 2001).	See explanation above, regarding that fact that our experiment was measuring the optimal temperature range for Tuolumne River *O. mykiss*, not acute CTmax temperatures for these fish. See response to CDFW-1 specific to the repetitive comment regarding chronic/acute criteria. It is nice to see the reviewer finally acknowledge here that the 7DADM incorporates several types of thermal performance data in setting the criteria. One of the strengths of our study is that we have used a state-of-the-art approach (i.e. AAS) to contribute to this understanding. We have clarified how our data relate to the 7DADM in the clarifying document.

Comment # (page #)	Comment	Districts' Response
		Note that we do not think it to be appropriate to casually call *O. mykiss* cold water fish without using more precise and descriptive terminology. The literature has expanded over the last 10-20 years to show that at least some populations of *O. mykiss*, including those in this study, may not all be equally 'cold-water' as previously grouped.
CDFW-44 (p. 18)	Figures, page 33, Figure 1. The T_{opt} appears to be an acute maximum temperature at the peak of maximum oxygen consumption and not necessarily an optimal temperature. From the peak temperature and higher, oxygen consumption decreases, suggesting the fish is exhausted and no longer capable of absorbing oxygen similarly to hyperventilation. See comment above for Page 20, second paragraph.	Addressed above.
CDFW-45 (p. 18)	Figures, page 37, Figure 4. See comment above for Page 20 second paragraph. Per Fry (1947) page 56, Figure 27, did the authors for this study consider controlling factors to adjust their activity curve? For the Factorial Aerobic Scope curve, the peak is approximately 13°C and decreases as temperatures increases. Clark et al. (2013) Figure 6, page 2778, presents a similar Factorial Aerobic Scope curve where the T_{optAS} is at the peak of the curve representing the lowest temperature at 11°C. Using Clark et al. (2013) concept, the authors Figure 4 peak at 13°C should be considered the T_{opt} for Tuolumne River rainbow trout, not the maximum temperatures.	Addressed above.
CDFW-46 (p. 18)	Figures, page 44, Appendix 1. Were *O. mykiss* observed, or attempts made to capture fish, between River Mile 39.5 (permit limit location) and River Mile 49? River water temperatures were above 18°C, so it	Not during the 2014 study but *O. mykiss* were observed in the Tuolumne River below river mile 49 in 2015 and in other years.

Comment # (page #)	Comment	Districts' Response
	would be worthwhile information to know if a healthy number of rainbow trout occupied this area. River Mile 48 appears to be below the 21.1°C permit requirement.	
CDFW-47 (p. 18)	Figures, page 47, Appendix 2. Fish W43 died. Did this fish die from delayed Capture Myopathy as a result of handling and exposure to high temperatures? Capture Myopathy results in the death of a captured wild animal during or after the animal has been captured and released.	The fish that died after the swim tunnel test was one of two fish that regurgitated their stomach contents after being tested at 25°C. We don't know the reason for this mortality but it was likely associated with the excess metabolic demand resulting from digesting a full stomach of food combined with the test used to determine MMR using the swim tunnel. The other fish that regurgitated their stomach contents after the swim tunnel test did not die.
CDFW-48 (p. 18)	Figures, page 49, Appendix 4. All the data should be included for peer review, particularly for the fish that were discarded. What would the analysis look like if the discarded fish data was included? According to the Quality Control column the discarded fish were removed because of activity during RMR or no MR increase. Does this indicate the fish were already stressed? Which fish died?	Addressed above. We followed state-of-the-art peer reviewed methods, and will not comment further on the reviewer's arbitrary assignment of the descriptor 'stressed' to any of our study animals without any supporting data.
CDFW-49 (p. 18)	Figures, page 50. Four of 14 fish tested at 23°C, 24°C and 25°C had a FAS< 2. These results of less than 2 at the highest test temperatures indicate these fish were highly stressed at these temperatures.	Addressed above.

THERMAL PERFORMANCE OF WILD JUVENILE *ONCORHYNCHUS MYKISS* IN THE LOWER TUOLUMNE RIVER: A CASE FOR LOCAL ADJUSTMENT TO HIGH RIVER TEMPERATURE

APPENDIX 7

HIGH THERMAL TOLERANCE OF A RAINBOW TROUT POPULATION NEAR ITS SOUTHERN RANGE LIMIT SUGGESTS LOCAL THERMAL ADJUSTMENT

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Research article

High thermal tolerance of a rainbow trout population near its southern range limit suggests local thermal adjustment

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Transformation of earth's ecosystems by anthropogenic climate change is predicted for the 21st century. In many regions, the associated increase in environmental temperatures and reduced precipitation will have direct effects on the physiological performance of terrestrial and aquatic ectotherms and have already threatened fish biodiversity and important fisheries. The threat of elevated environmental temperatures is particularly salient for members of the *Oncorhynchus* genus living in California, which is the southern limit of their range. Here, we report the first assessments of the aerobic capacity of a Californian population of wild *Oncorhynchus mykiss* Walbaum in relationship to water temperature. Our field measurements revealed that wild *O. mykiss* from the lower Tuolumne River, California maintained 95% of their peak aerobic scope across an impressive temperature range (17.8–24.6°C). The thermal range for peak performance corresponds to local high river temperatures, but represents an unusually high temperature tolerance compared with conspecifics and congeneric species from northern latitudes. This high thermal tolerance suggests that *O. mykiss* at the southern limit of their indigenous distribution may be locally adjusted relative to more northern populations. From fisheries management and conservation perspectives, these findings challenge the use of a single thermal criterion to regulate the habitat of the *O. mykiss* species along the entirety of its distribution range.

Key words: aerobic scope, fish, metabolic rate, *Oncorhynchus mykiss*, swimming, temperature

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Introduction

Rainbow trout (*Oncorhynchus mykiss* Walbaum 1792) is regarded as a cold-water fish species with an indigenous range stretching across an immense temperature gradient, from the subarctic climate region of the Bering Sea to the Mediterranean climate region of Northern Baja California (Reyes, 2008). Despite this large temperature gradient and distribution range, the optimal temperature range for wild *O. mykiss* aerobic performance capacity has been determined only for indigenous populations inhabiting temperate climates. Local adaptation of thermal performance exists within the teleosts (Angilletta, 2009), but has never been shown for wild *O. mykiss* populations across their native range. Without knowledge of the variation in thermal performance among populations of *O. mykiss*, fish conservation managers apply regulatory water temperature criteria derived for higher latitude populations of *O. mykiss* for protection of lower latitude populations.

The present study considered the thermal performance of a population of *O. mykiss* located in a river near the southern limits of its native range and was prompted by a number of recent events. Foremost, global indicators show that 2014 and 2015 were the warmest years on record for the earth's climate (Blunden and Arndt, 2015; NOAA National Centers for Environmental Information, 2016). Animal populations, such as Californian *O. mykiss*, which exist at the latitudinal extremes of their biogeographical range, are expected to experience the most profound negative effects of such climate changes (Lassalle and Rochard, 2009). Second, for a fish that tends to favour pristine, cold water in most of its native habitat, native *O. mykiss* populations inhabiting the extremely warm summer temperatures of Californian rivers are evidence of considerable phenotypic plasticity (or genetic variability) within the species, allowing acclimation (or adaptation) to much warmer environmental temperature regimes. Indeed, severe thermal exposures in southern Western Australia have produced a line of introduced, hatchery-reared *O. mykiss* (Morrissy, 1973; Molony, 2001; Molony *et al.*, 2004) that swim and feed at 26°C (Michael Snow, Department of Fisheries, Government of Western Australia, personal communication) and retain 50% of their peak aerobic capacity at 25°C (Chen *et al.*, 2015). Interestingly, the founder population for this thermally tolerant hatchery strain was transplanted from California during the last century for recreational fisheries. Thus, with climate change continuing to shift baseline river water quality and availability (Sousa *et al.*, 2011; Swain *et al.*, 2014), especially in central California, where the intensification of weather extremes is triggering water crises and extreme droughts (Dettinger and Cayan, 2014), knowledge of the local thermal requirements of vulnerable key fish species becomes ever more pressing (Moyle *et al.*, 2011).

Fish can adjust to warmer habitat temperatures by relocating to a cooler refuge (if available), thermally acclimating or thermally adapting (Farrell and Franklin, 2016); responses that all operate at different time scales. Indeed, the suggestion that fish might tailor their metabolic rate to habitat temperature has a long and strong history across a wide range of aquatic habitats and species (Fry, 1947, 1971; Brett and Groves, 1979; Elliott, 1982; Jobling, 1994; Hochachka and Somero, 2002; Donelson *et al.*, 2012). In fact, local thermal adaptation has been thoroughly characterized for other fish species, such as stickleback populations (Barrett *et al.*, 2011), temperate killifish (Fangue *et al.*, 2006) and tropical killifish (McKenzie *et al.*, 2013). Even within the genus *Oncorhynchus*, Fraser River watershed populations of sockeye salmon (*O. nerka* Walbaum 1792) have apparently tuned their thermal performance to meet the energetic needs of their once-in-a-lifetime upstream migration (Farrell *et al.*, 2008; Eliason *et al.*, 2011, 2013). The ability of *O. mykiss* to acclimate thermally is well documented (Myrick and Cech, 2000), and there appears to be the genetic potential for thermal adaptation given the successful selective breeding of *O. mykiss* lines that perform well at high temperatures (Australian lines, Molony *et al.*, 2004; Japanese lines, Ineno *et al.*, 2005). Nevertheless, assessments of the aerobic capacity in relation to water temperature of wild *O. mykiss* at the southern extent of their range in California are lacking. What is known for two Californian strains of *O. mykiss* (Eagle Lake and Mount Shasta; Myrick and Cech, 2000) is that the thermal performance curves for hatching success differ (Myrick and Cech, 2001) despite similar upper thermal tolerance values (CTmax). In addition, the Eagle Lake and Mount Shasta strains of *O. mykiss* grew fastest at different acclimation temperatures (19 and 22°C, respectively), but growth ceased at 25°C in both strains (Myrick and Cech, 2000).

The accumulating evidence for variation in thermal performance within and among Pacific salmon and rainbow trout populations seems incongruous with the criteria used by the US Environmental Protection Agency (EPA) to regulate water temperatures. The EPA uses a regulatory 7 day average of the daily water temperature maximum (7DADM) of 18°C for all juvenile *O. mykiss* over their entire native US range from southern California into Alaska (US Environmental Protection Agency, 2003). One way to bring greater insight into population-specific thermal tolerance and to take local adaptation and acclimation into consideration for regulatory purposes is to use a well-established non-lethal approach to study the thermal physiology of *O. mykiss* populations inhabiting unusually warm habitats. Therefore, we examined *O. mykiss* that inhabit the Tuolumne River below La Grange Diversion Dam, which is the most downstream habitat for *O. mykiss* in a watershed that drains ~2500 km^2 of the Western Sierra Nevada mountain range. This river reach is characterized by a longitudinal thermal gradient, which increases from 12°C to occasionally as high as 26°C during summer warming over a ~25 km stretch of river. By measuring metabolic scope for activity (Fry, 1947), we tested the hypothesis that *O. mykiss* residing below the La Grange Diversion Dam on the Tuolumne River may be locally adapted to the summer habitat temperatures that can reach 26°C. Mechanistically, our experimental approach builds on a fish's ultimate requirement to have the capacity to supply oxygen for all activities (e.g. for foraging, digestion, growth, migration, predator avoidance and reproduction). The capacity to provide oxygen beyond basic needs is termed absolute aerobic scope (AAS), which, in field situations (e.g. Pörtner and Knust, 2007; Nilsson *et al.*, 2009; Gardiner *et al.*, 2010; Eliason *et al.*, 2011; Rummer *et al.*, 2014), can be estimated from the difference between routine metabolic rate (RMR) and maximal metabolic rate (MMR). Thus, by measuring RMR and MMR over a wide range of water temperatures, the portion of the temperature range where AAS (i.e. the capacity for aerobic activity) is maximized can be defined. Such information is lacking for wild *O. mykiss* in central California. For the present study, a temporary respirometry laboratory was built beside the Tuolumne River. This laboratory allowed wild juvenile

O. mykiss to be tested at temperatures between 13 and 25°C before they were returned to their original habitat within 24 h, as required by the experimental permits.

This study has implications beyond the thermal needs for resident aquatic species because this segment of the Tuolumne River is part of a watershed that provides municipal water to >2.4 million residents of the San Francisco Bay Area and agricultural irrigation water to the Central Valley (Turlock Irrigation District and Modesto Irrigation District, 2011). The recent drought in central California has left reservoirs at historic lows (California Department of Water Resources, 2015) and has challenged the capacity to balance the environmental water flow needs of aquatic biota with the human requirements from this watershed for domestic, agricultural and recreational use. Juvenile *O. mykiss* living below the La Grange Diversion Dam have been observed exploiting summer Tuolumne River temperatures from 12 to 26°C over 25 river km (HDR Engineering, Inc., 2014). There are no additional cool-water inputs (except for rare summer rains), resulting in progressive warming of the water released from the Dam as it flows downstream. Establishing the optimal temperature range for aerobic performance of wild Californian *O. mykiss* will provide fish conservation managers with scientific support for temperature criteria that allow for optimization of this balance between human and fish requirements.

Materials and methods

Permitting restrictions that influenced the experimental design

Wild Tuolumne River *O. mykiss* were collected under National Marine Fisheries Service Section 10 permit no. 17913 and California Fish and Wildlife Scientific Collecting Permit Amendments. No distinction was made between resident (rainbow trout) and anadromous (steelhead) life-history forms. For permitting purposes, these fish are considered as ESA-listed California Central Valley steelhead, *O. mykiss*. Fish collection (up to a maximum of 50 individuals) was allowed only between river kilometer (RK) 84.0 and RK 63.6, and capture temperatures could not exceed 21.1°C. This permit allowed only two fish to be captured and tested each day, and all fish had to be returned to their original river habitat. Given that indirect fish mortality was limited to three fish, a precautionary measure included testing fish at the highest temperatures last (i.e. not randomly assigning test temperature). Additionally, the permit restricted test temperatures to ≤25°C. All experimental procedures were approved by the Institutional Animal Care and Use Committee (protocol no. 18196; the University of California Davis).

Fish collection, transport and holding

Two wild *O. mykiss* were collected daily [a total of 44 fish; 22.4 g (SEM = 1.78, range 10.5–79.6 g) and 125.7 mm (SEM = 2.88)] from four primary locations on the Tuolumne River (Supplementary material, Fig. S1). The two fish were immediately scanned for a passive integrated transponder (PIT) tag to preclude re-testing a fish. The fish were transferred directly to a 13 litre container partly submerged in the river before being driven to the streamside field laboratory (<20 min) in insulated coolers filled with 25 litres of fresh river water. A water temperature logger (recording every 15 min; Onset Computer Corporation, USA) remained with the fish until testing was completed and the fish was returned to the river. At the field laboratory, located immediately downstream from the La Grange Diversion Dam, fish were transferred to holding tanks (300 litres) filled with flow-through Tuolumne River water (directly from the dam) that had passed through a coarse foam filter and then an 18 litre gas-equilibration column for aeration (12.5–13.6°C, >80% air saturation). Thus, field-acclimatized fish were placed into the holding tanks within 60–120 min of capture and remained there for 60–180 min before being transferred to one of two 5 litre automated swim tunnel respirometers (Loligo, Denmark). Routine and maximal metabolic rates were then measured at temperatures between 13 and 25°C (1°C increments).

Swim tunnel respirometers

The swim tunnel respirometers received aerated Tuolumne River water from an 80 litre temperature-controlled sump that was refreshed every 80–90 min. Water temperature was regulated within ±0.5°C of the test temperature by passing sump water through a 9500 BTU Heat Pump (Model DSHP-7, Aqua Logic Delta Star, USA) with a high-volume pump (model SHE1.7, Sweetwater®, USA). Additionally, two proportional temperature controllers (model 72, YSI, USA) each ran an 800 W titanium heater (model TH-0800, Finnex, USA) located in the sump. The water temperature in the swim tunnels was monitored with a temperature probe connected through a four-channel Witrox oxygen meter (Loligo). All temperature-measuring devices were calibrated bi-weekly to ±0.1°C of a National Institute of Standards and Technology certified glass thermometer. Ammonia build-up was prevented by zeolite in the sump, which was replaced weekly. Water oxygen saturation in each swim tunnel was monitored continuously using a dipping probe mini oxygen sensor connected to AutoResp software (Loligo) through the Witrox system (Loligo). Video cameras with infrared lighting (Q-See, QSC1352W, China) continuously recorded (Panasonic HDMI DVD-R, DMR-EA18K, Japan) fish behaviour in the swim tunnels, which were shaded by black cloth to limit fish disturbance. A variable frequency drive motor generated laminar water flow through the swimming section (calibrated using a digital anemometer with a 30 mm vane wheel flow probe; Hönzsch, Germany) in each swim tunnel.

Metabolic rate measurement

Routine and active metabolic rates of fish in the swim tunnel respirometers were measured using intermittent respirometry

(Steffensen, 1989; Cech, 1990; Chabot *et al.*, 2016; Svendsen *et al.*, 2016). The swim tunnel was automatically sealed during measurements and flushed with fresh, aerated sump water between measurements (AutoResp software and a DAQ-PAC-WF4 automated respirometry system, Loligo). Oxygen removal from the water by the fish (in milligrams of oxygen) was measured for a minimal period of 2 min when the swim tunnel was sealed, without oxygen levels falling below 80% air saturation. No background oxygen consumption was detected without fish (performed at the end of each day with both swim tunnels; Rodgers *et al.*, 2016) even at the highest test temperature (25°C). Each oxygen probe was calibrated weekly at the test temperatures using 100% (aerated distilled water) and 0% (150 ml distilled water with 3 g dissolved Na_2SO_3) air-saturated water.

Oxygen uptake was calculated according to the following formula:

$$\text{Oxygen uptake}\left(\text{in mg } O_2\text{kg}^{-0.95}\text{ min}^{-1}\right) = \left\{\left[\left(O_2(t_1) - O_2(t_2)\right) \times V\right] \times M^{-0.95}\right\} \times T^{-1},$$

where $O_2(t_1)$ is the oxygen concentration in the swim tunnel at the beginning of the seal (in milligrams of oxygen per litre); $O_2(t_2)$ is the oxygen concentration in the tunnel at the end of the seal (in milligrams of oxygen per litre); V is the volume of the swim tunnel (in litres); M is the mass of the fish (in kilograms); and T is the duration of the measurement (in minutes). Allometric correction for variable body mass used the exponent 0.95, which is halfway between the life-stage-independent exponent determined for resting (0.97) and active (0.93) zebrafish (Lucas *et al.*, 2014).

Experimental protocol

Fish were introduced between 13.00 and 16.00 h each day into a swim tunnel at 13 ± 0.3°C, which was close to the river temperature at which most fish were caught, and left for 60 min before a 60 min training swim (Jain *et al.*, 1997), during which water flow velocity was gradually increased to 5–10 cm s^{-1} higher than when swimming started (typically at 30 cm s^{-1}) and held for 50 min before a 10 min swim at 50 cm s^{-1} (the anticipated maximal prolonged swimming velocity for a 150 mm fish at 13°C; Alsop and Wood, 1997). Recovery for 60 min preceded the incremental increases in water temperature (1°C per 30 min) up to the test temperature. Oxygen uptake (10–30 min, depending on the test temperature, and followed by a 5–10 min flush period) was continuously measured throughout the night until 07.00 h. Estimates of RMR for each of the 44 tested fish were calculated by averaging the lowest four oxygen uptake measurements at the test temperature for the minimum 8 h overnight period (Chabot *et al.*, 2016). Visual inspection of the video recordings confirmed that fish were quiescent during these measurements with the exception of three fish that were discarded owing to consistent activity throughout the night (Crocker and Cech, 1997), which reduced the RMR measurements to 41 fish.

Critical swimming velocity and burst swimming protocols (Reidy *et al.*, 1995; Killen *et al.*, 2007; Clark *et al.*, 2013; Norin and Clark, 2016) were used to determine MMR. They began between 08.00 and 09.00 h and lasted 2–6 h. For the critical swimming velocity test, water velocity was gradually increased until the fish continuously swam at 30 cm s^{-1} for 20 min. Water velocity was incrementally increased every 20 min by 10% of the previous test velocity (3–6 cm s^{-1}) until the fish was no longer able to swim continuously and fell back to make full body contact with the downstream screen of the swimming chamber. The fish recovered for 1 min at 13–17 cm s^{-1}, the lowest velocity setting of the swim tunnel, before restoring the final water velocity over a 2 min period and restarting the 20 min timer. Fatigue was defined as when the fish made full body contact with the downstream screen of the swim tunnel a second time at the same test velocity or failed to resume swimming. Active metabolic rate was measured at each test velocity using a 3 min flush period and a 7–17 min measurement period. All fish swam for 20 min at one water velocity, but almost 50% of the wild fish used their caudal fin to prop themselves on the downstream screen of the swim tunnel to avoid swimming faster, which required a secondary measurement of maximal metabolic rate using a burst swimming protocol. For the burst swimming protocol, tunnel velocity was set to and held for 10 min at the highest critical swimming velocity test increment where that fish had continuously swum. Afterwards, water velocity was rapidly (over 10 s) increased to 70–100 cm s^{-1}, which invariably elicited burst swimming activity for 30 s or less, when water velocity exceeded 70 cm s^{-1}. This protocol was repeated multiple times for 5–10 min, while oxygen uptake was measured continuously. The MMR was assigned to the highest active metabolic rate measured with the active respirometry methods. Occasionally, fish exhibited intense struggling behaviours with an even higher oxygen uptake, which was assigned MMR. The MMR was not estimated for four fish, which failed to swim and raise their metabolic rate appreciably with any of the methods, resulting in a total of 37 fish with RMR and MMR measurements. Absolute aerobic scope (AAS = MMR − RMR) and factorial aerobic scope (FAS = MMR/RMR) were calculated.

All fish recovered in the swim tunnel at a water velocity of 13–17 cm s^{-1} and at the test temperature for 1 h while measuring oxygen uptake. Water temperature was then decreased to ~13°C over a 30 min period before the fish was removed, measured, PIT tagged and put into a holding tank before release at the capture site. Fish were individually anaesthetized for <5 min with CO_2 (2 Alka-Seltzer tablets dissolved in 3 litres of river water) for morphometric measurements [fork length (FL), in millimetres; and body mass, in grams], condition factor calculation (CF = body mass × 10^5/FL^3), and PIT tagging. Half duplex PIT (Oregon RFID) tags were placed into the abdominal cavity via a

1 mm incision through the body wall, just off-centre of the linea alba. All equipment was sterilized with NOLVASAN S prior to tagging, and incisions were sealed with 3M VetBond. Revived fish were immediately transported to the coolers filled with 13–15°C river water. At the release site, river water was gradually added to the cooler to equilibrate the fish to river water temperature at a rate of 1–2°C h^{-1} before fish were allowed to swim away voluntarily.

Measurements of tail beat frequency

The tail beat frequency (TBF; number of tail beats per 10 s, reported in Hz) of fish swimming continuously and holding station without contacting the downstream screen of the respirometer was measured using the average of two or three 10 s sections of video recordings played back at either one-quarter or one-eighth of real time. The TBF was then related to swimming speed and temperature. Tail beat frequencies of undisturbed fish holding station in the Tuolumne River were measured from footage from underwater video cameras anchored within 1 m of *O. mykiss* schools and left to record for up to 4 h (GoPro Hero 4). The TBFs were determined using the same methodology applied to respirometer video recordings ($n = 15$ at 14°C and $n = 1$ at 20°C).

Data analysis

A statistical model was fitted to individual data [performed in R (R Core Development Team, 2013) using the 'lm' function] to determine the best relationships between the test temperature and RMR, MMR, AAS and FAS. The statistical model (linear, quadratic, antilogarithic base 2 and logarithmic base 2 were tested) with the highest r^2 and lowest residual SE being reported. Confidence intervals and predicted values based on the best-fit model were calculated in R using the 'predict' function. Variances around metabolic rate measurements are reported as 95% confidence intervals (CIs).

Results

As anticipated, basic oxygen needs (RMR) increased exponentially by 2.5-fold from 13 to 25°C (from 2.18 ± 0.45 (95% CI) to 5.37 ± 0.41 mg O_2 $kg^{-0.95}$ min^{-1}). This thermal response was modelled by: RMR (in mg O_2 $kg^{-0.95}$ min^{-1}) = 5.9513 − 0.5787 (temperature, in °C) + 0.0200 (temperature, in °C)^2 ($P < 0.001$, $r^2 = 0.798$; Fig. 1A). The MMR increased linearly by 1.7 times (from 6.62 ± 1.03 to 11.22 ± 0.86 mg O_2 $kg^{-0.95}$ min^{-1}) from 13 to 25°C. This thermal response was modelled by: MMR (in mg O_2 $kg^{-0.95}$ min^{-1}) = 1.6359 + 0.3835 (temperature, in °C) ($P < 0.001$, $r^2 = 0.489$; Fig. 1B). Given that MMR almost kept pace with the thermal effect on RMR, AAS had a rather flat reaction norm that was largely independent of the test temperature range. This thermal response was modelled by: AAS (in mg O_2 $kg^{-0.95}$ min^{-1}) = −5.7993 + 1.1263 (temperature, in °C) − 0.0265 (temperature, in °C)^2 ($P = 0.060$, $r^2 = 0.098$; Fig. 1C). Using this model, peak AAS (6.15 ± 0.71 mg O_2 $kg^{-0.95}$ min^{-1}) was centred at 21.2°C. Nevertheless, the unexpected flat reaction norm meant that 95% of peak AAS was maintained from 17.8 to 24.6°C, which is a broad thermal window for peak AAS that extends well beyond the 7DADM value of 18°C for *O. mykiss*.

Factorial aerobic scope is a useful metric of whether or not a fish might have the required aerobic capacity to perform a specific activity, e.g. a doubling of RMR (i.e. FAS = 2) might be needed to digest a full meal properly (Jobling, 1981; Alsop and Wood, 1997; Fu *et al.*, 2005; Luo and Xie, 2008). As expected, FAS decreased with temperature (Clark *et al.*, 2013), a thermal response modelled by: FAS = 2.1438 + 0.1744 (temperature, in °C) − 0.0070 (temperature, in °C)^2 ($P < 0.001$, $r^2 = 0.344$; Fig. 1D).

In addition, given the need to integrate AAS or FAS within an ecological framework (see Overgaard *et al.*, 2012; Clark *et al.*, 2013; Farrell, 2013, 2016; Pörtner and Giomi, 2013; Ern *et al.*, 2014; Norin *et al.*, 2014), we used measurements of TBF to estimate the oxygen cost required by a wild *O. mykiss* to maintain station in the river currents of typical habitats in the Tuolumne River. A steady TBF used for this activity at ambient temperatures of 14 and 20°C was 2.94 and 3.40 Hz, respectively (see supplemental video, available online). Using respirometer swimming data to relate TBF to oxygen uptake at 14 and 20°C ($P < 0.001$, $r^2 = 0.35$; and $P = 0.009$, $r^2 = 0.33$, respectively; Fig. 2), in-river TBF values of 2.94 and 3.40 Hz corresponded to 3.26 and 5.43 mg O_2 $kg^{-0.95}$ min^{-1}, respectively. Therefore, we suggest that wild fish observed holding station in the Tuolumne River increased RMR by 1.5 times at 14°C and by 2.0 times at 20°C, an activity that would use 49 and 67%, respectively, of the available FAS measured at these two temperatures.

Fish recovery after exhaustive swimming tests was quick and without any visible consequences. The RMR at the end of the 60 min recovery period was either elevated by no more than 20% or fully restored; an observation consistent with previous laboratory studies of *O. mykiss* recovery (Jain *et al.*, 1997; Jain and Farrell, 2003). Two fish tested at 25°C were the only exceptions. These two fish regurgitated their gut contents during recovery and one then died abruptly. Inadvertent fish recapture provided some information on fish survival after being returned to the river. Six PIT-tagged fish were recaptured at 1–11 days post-testing within 20 m of their original capture location; all were visually in good condition, and three of these fish had been tested at 23°C.

Discussion

The present study is the first to consider the thermal response for an *O. mykiss* population so close to the southerly boundary of the natural distribution range for indigenous *O. mykiss*. We clearly show that 95% of peak AAS was maintained over an unexpectedly broad thermal window (17.8–24.6°C) and that all fish tested could maintain an

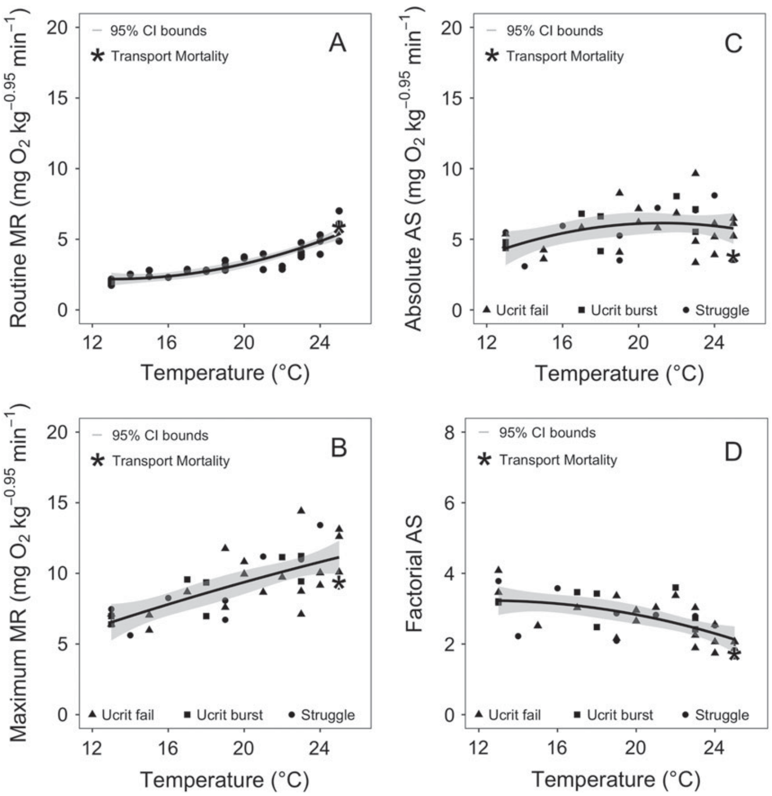

Figure 1: The relationships between test temperature and the routine (RMR; **A**) and maximal metabolic rate (MMR; **B**) of Tuolumne River *Oncorhynchus mykiss*. The three methods used to measure MMR (see Materials and methods section) are distinguished by different symbols. Absolute aerobic scope (AAS; **C**) and factorial aerobic scope (FAS; **D**) were derived from the metabolic rate measurements. Each data point represents an individual fish tested at one temperature. These data were given a best-fit mathematical model (continuous line or curve), and the 95% confidence intervals for each line are indicated by the shaded area. The RMR and FAS were smoothed to a polynomial fit of the form $y = x + I(x^2)$, where y is RMR or FAS, x is temperature, and I is a constant. The MMR and AAS were smoothed to a linear fit of the form $y = x + c$, where c is a constant. For RMR, degrees of freedom (d.f.) = 34, $P < 0.001$, residual standard error (RSE) = 0.561 and $r^2 = 0.798$. For MMR, d.f. = 35, $P < 0.001$, RSE = 1.580 and $r^2 = 0.489$. For AAS, d.f. = 35, $P = 0.060$, RSE = 1.490 and $r^2 = 0.098$. For FAS, d.f. = 34, $P < 0.001$, RSE = 0.506 and $r^2 = 0.344$. The asterisk indicates the one fish that died abruptly after the swimming test.

FAS >2.0 up to 23°C. Moreover, we place these findings into an ecological context by suggesting that the level of FAS at temperatures at least as high as 20°C may be more than adequate to maintain station in the local water current of the Tuolumne River and probably to digest a meal properly and optimize growth, which is a very powerful integrator of environmental, behavioural and physiological influences on a fish's fitness. Moreover, fish were tested on site and returned afterwards to the river, making the work locally relevant for the *O. mykiss* population, sensitive to conservation needs and globally relevant by addressing the following broad question: are fish at the extreme edges of their biogeographical range more physiologically tolerant because of the thermal extremes they experienced there?

The present results show good quantitative agreement with various previous studies with *O. mykiss* that have measured some of the variables measured in the present study. For example, the 2.5-fold exponential increase in RMR from 13 to 25°C (from 2.18 ± 0.45 (95% CI) to 5.37 ± 0.41 mg O_2 $kg^{-0.95}$ min^{-1}) compares well with laboratory studies of RMR reported at 14°C (2.3–2.8 mg O_2 $kg^{-0.95}$ min^{-1}; Myrick and Cech, 2000) for 7 g Mount Shasta and Eagle Lake *O. mykiss*, and at 25°C (~6.5 mg O_2 per $kg^{-0.95}$ min^{-1}; Chen *et al.*, 2015) for 30 g Western Australian *O. mykiss*. Therefore, concerns about handling stress and specific dynamic action were minimal. Likewise, MMR increased linearly by 1.7 times (from 6.62 ± 1.03 to 11.22 ± 0.86 mg O_2 $kg^{-0.95}$ min^{-1}) from 13 to 25°C, comparing well with previous laboratory measurements of MMR reported at 15°C (2.8–8.7 mg O_2 $kg^{-0.95}$ min^{-1}) for 2–13 g *O. mykiss* (Scarabello *et al.*, 1992, Alsop and Wood, 1997) and with the peak MMR at 20°C (~11.13 mg O_2 per $kg^{-0.95}$ min^{-1}) for Australian *O. mykiss* (Chen *et al.*, 2015). As a consequence of MMR nearly keeping pace with the thermal

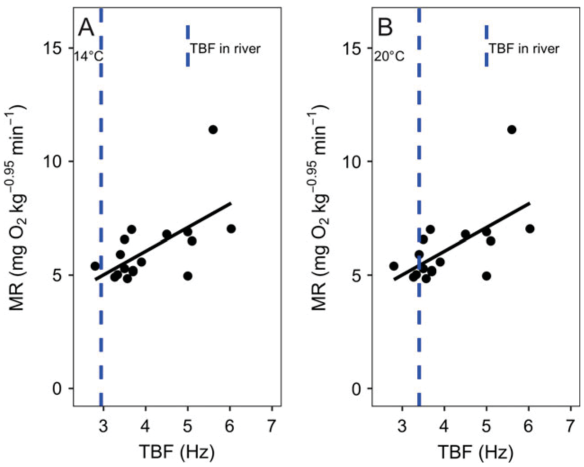

Figure 2: The relationship between tail beat frequency (TBF; in hertz) and metabolic rate (MR; in mg O_2 $kg^{-0.95}$ min^{-1}) measured when Tuolumne River *Oncorhynchus mykiss* were swimming continuously in a swim tunnel at 14 (**A**) or 20°C (**B**). The continuous black line represents the linear regression based on the data for $n = 7$ fish at 14°C and $n = 5$ fish at 20°C. The vertical dashed lines represent the estimated TBF (2.94 Hz at 14°C and 3.40 Hz at 20°C) taken from videos of *O. mykiss* maintaining station in a water current in their normal Tuolumne River habitat. At 14°C, the relationship between TBF and MR followed the equation MR = 0.75TBF + 1.05, with degrees of freedom (d.f.) = 41, $P < 0.001$, residual standard error (RSE) = 1.27 and $r^2 = 0.35$. According to this formula, the MR for the TBF measured in the river (2.943 Hz) at 14°C was estimated to be 3.26 mg O_2 $kg^{-0.95}$ min^{-1}. At 20°C, the relationship between TBF and MR followed the equation MR = 1.04TBF + 1.89, with d.f. = 15, $P = 0.009$, RSE = 1.29 and $r^2 = 0.33$. According to this formula, the MR for the TBF measured in the river at 20°C (3.402 Hz) was estimated to be 5.43 mg O_2 $kg^{-0.95}$ min^{-1}.

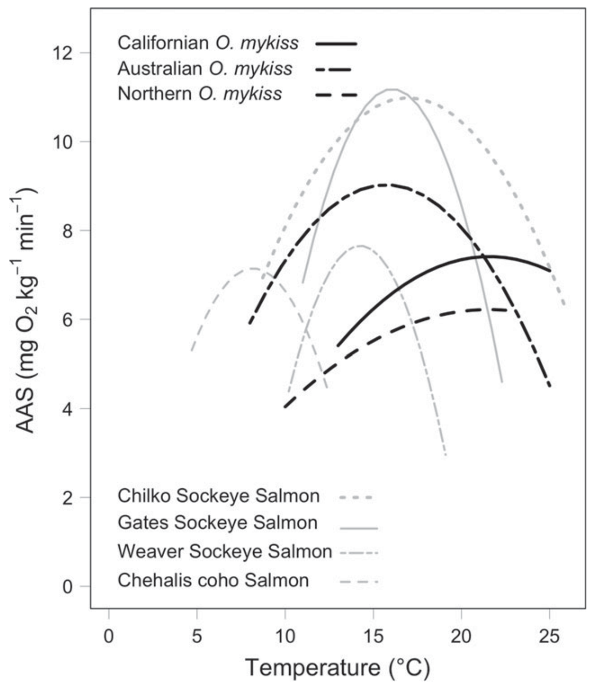

Figure 3: Absolute aerobic scope (AAS) for three strains of *Oncorhynchus mykiss*, i.e. a northern strain (Fry, 1948), an Australian strain (Chen *et al.*, 2015) and the California strain reported in this manuscript, compared with AAS measurements of Chehalis Coho salmon (*Oncorhynchus kisutch* Walbaum 1792) and Gates Creek, Weaver Creek (*Oncorhynchus nerka* Walbaum 1792; Lee *et al.*, 2003a) and Chilko Creek sockeye salmon (Eliason *et al.*, 2011). The best-fit line of the relationship between AAS and temperature of the species and populations from other publications was predicted using a second-order polynomial linear regression performed on the raw data (Lee *et al.*, 2003a; Chen *et al.*, 2015) or data extracted from plots (Fry, 1948; Eliason *et al.*, 2011) from the original publications. Coefficient estimates from the linear regression analysis were then used to determine the peak aerobic scope and the temperatures corresponding to the peak and 95% of peak AAS.

effect on RMR, AAS was largely independent of test temperature. Directly comparing our AAS values with other studies revealed that our result for AAS at 15°C (5.10 mg O_2 $kg^{-0.95}$ min^{-1}) was at the high end of previous laboratory measurements of AAS (1.8–5.8 mg O_2 $kg^{-0.95}$ min^{-1}) for *O. mykiss* at 15°C (Scarabello *et al.*, 1992, Alsop and Wood, 1997; McGeer *et al.*, 2000), but lower than peak AAS (~7.3 mg O_2 per $kg^{-0.95}$ min^{-1}) at 20°C in Australian *O. mykiss* (Chen *et al.*, 2015). Likewise, our FAS values were bracketed by values obtained in previous laboratory studies. At 24°C, FAS (2.13 ± 0.33) was greater than that reported at 25°C (1.8) for Western Australian *O. mykiss* (Chen *et al.*, 2015), but compared with FAS values for juvenile rainbow trout (1.8–5.8) at 13°C (Scarabello *et al.*, 1992, Alsop and Wood, 1997, McGeer *et al.*, 2000), our FAS at 13°C (3.32 ± 0.41) was in the middle of the range.

To place the present data for Californian *O. mykiss* into perspective, we have compared (Fig. 3) their reaction norm with those published for juveniles of northern *O. mykiss* (data from Fry, 1948) and Australian hatchery-selected *O. mykiss* (data from Chen *et al.*, 2015), as well as adult northern populations of selected Pacific salmon populations (data from Lee *et al.*, 2003a and Eliason *et al.*, 2011). Among the native *O. mykiss* populations, the Lower Tuolumne River juvenile Californian *O. mykiss* are likely to experience the highest temperatures during summer (up to 26°C), although the introduced Australian *O. mykiss* population had experienced selection temperatures ≥25°C (Chen *et al.*, 2015). Notably, AAS at 24°C for Tuolumne River *O. mykiss* is greater than other *O. mykiss* populations and only bettered by the Chilko sockeye salmon population, one of several sockeye salmon populations that are known to have a peak AAS at the modal temperature for their upstream spawning migration (Eliason *et al.*, 2011, 2013). Thus, the present data are in line with evidence of intraspecific matching of metabolic rate to local water temperatures within the *Oncorhynchus* genus. Although the peak AAS of the Australian *O. mykiss* population was 50% greater than for the other two *O. mykiss* populations, Tuolumne River *O. mykiss* had the broadest and highest thermal window (17.8–24.6°C) among the *O. mykiss* populations (20.5–22.4°C from Fry, 1948; and 12.8– 18.6°C from Chen *et al.* 2015).

Whether the matching of Tuolumne River *O. mykiss* metabolic performance to local habitat temperatures is a result of thermal acclimation or local adaption, as in the Western Australian *O. mykiss*, will need study well beyond the present work. Thermal acclimation usually results in fish performing better at the new temperature. For example, thermal acclimation offsets the effect of acute warming on RMR in 5–7 g Mount Shasta and Eagle Lake *O. mykiss* (2.3–2.8 mg O_2 $kg^{-0.95}$ min^{-1} at 14°C and 2.9–3.1 mg O_2 $kg^{-0.95}$ min^{-1} at 25°C; Myrick and Cech, 2000), which would normally double RMR over this temperature range, as observed here. Warm acclimation can also increase upper thermal tolerance limits, as it did for four anadromous Great Lakes populations of juvenile *O. mykiss* (Bidgood and Berst, 1969). Given that our fish were captured at and, presumably, thermally acclimatized to between 14 and 17°C, it would be of interest to test wild fish with a warmer thermal acclimation history. But even without thermal acclimation, the present data suggest that Tuolumne River *O. mykiss* and those for northern *O. mykiss* (Fry, 1948; see Fig. 3) have the aerobic capacity temporarily, if not regularly, to exploit temperatures well above 18°C, which is the upper thermal limit suggested by EPA guidance documents (US Environmental Protection Agency, 2003).

Nevertheless, we caution that such local tailoring may not be evident in all salmonid species. For example, the thermal physiology of Atlantic salmon (*Salmo salar* Linnaeus 1758) from northern and southern extremes of their European range did not show any major difference (Anttila *et al.*, 2014). All the same, a sub-species of redband trout (*O. mykiss gairdneri*), which are apparently adapted to high summer temperatures of North American desert streams (Narum *et al.*, 2010; Narum and Campbell, 2015), are likewise capable of high levels of swimming performance up to 24°C (Rodnick *et al.*, 2004) and higher swimming performance for a warm vs. a cool creek population (Gamperl *et al.*, 2002). Redband trout have been observed actively feeding at 27–28°C (Sonski, 1984; Behnke, 2010), but thermal selection of wild redband trout is centred between 13 (Gamperl *et al.*, 2002) and 17°C (Dauwalter *et al.*, 2015). How *O. mykiss* behaviourally exploit the steep summer thermal gradient in the Tuolumne River below the La Grange Diversion Dam (from 12 to 26°C over 25 km; HDR Engineering, Inc., 2014) is another unknown. Even without these important details, Tuolumne River *O. mykiss* appear physiologically to be tolerant of the thermal extremes they experience.

The capacity of a fish to deliver oxygen to support activities in water of varying quality is a concept originally introduced for fishes >60 years ago (Fry, 1947). The oxygen- and capacity-limited thermal tolerance hypothesis broadens this concept and provides a mechanistic explanation (Pörtner, 2001; Pörtner and Farrell, 2008; Deutsch *et al.*, 2015), but is currently under debate (Overgaard *et al.*, 2012; Clark *et al.*, 2013; Farrell, 2013; Pörtner and Giomi, 2013; Ern *et al.*, 2014; Norin *et al.*, 2014). An accepted fact is that a metabolic load from an environmental factor (e.g. temperature) can increase the oxygen cost for living (i.e. RMR). Consequently, like all other temperature studies with fish, the magnitude of the 2.5-fold increase in RMR observed here over a 12°C temperature range (between 13 and 25°C) was expected. However, temperature did not limit MMR, which increased linearly with acute warming, and the peak MMR was not resolved. The statistical models, which were based on individual responses and 1°C temperature increments from 13 to 25°C, predicted a peak AAS at 21.2°C for Tuolumne River *O. mykiss* and a FAS >2.0 up to 23°C. As the allocation of energy and trade-offs are recognized and fundamental tenants of ecological physiology, especially in fishes (Sokolova *et al.*, 2012), we suggest that being able to at least double RMR has ecological relevance for two behaviours that are likely to influence survival of *O. mykiss*, maintaining station in a flowing river and processing a large meal.

Snorkeling in the Tuolumne River provided visual observations of *O. mykiss* maintaining station in the river current for prolonged periods that were punctuated by hiding under the river bank and by darting behaviours to capture prey and to protect their position. Maintaining station required a steady TBF similar to the situation in the swim tunnel respirometer, which allowed us to estimate a metabolic cost of maintaining station in typical Tuolumne River habitats at 14 and 20°C (a 1.5- to 2-fold increase in RMR) and the aerobic scope available for additional activities (1.7–2 times RMR). Although darting behaviours are likely to be fuelled anaerobically, *O. mykiss* must (and were clearly able to) repay the post-exercise excess oxygen debt (Lee *et al.*, 2003b) while maintaining station in the river current. The rapid recovery of RMR after exhaustive exercise in the swim tunnel suggests that *O. mykiss* had the capacity to repay post-exercise excess oxygen debt rapidly at temperatures as high as 24°C. Although digestion of a meal at high temperatures proceeds more rapidly and with a higher peak metabolic rate, the total oxygen cost of the meal remains similar. Thus, fish can theoretically eat more frequently and potentially grow faster at a higher temperature provided there is a sufficient FAS for digestion within the overall AAS. Given that peak metabolic rate during digestion of a typical meal for a salmonid does not necessarily double RMR at the temperatures used here (e.g. Jobling, 1981; Alsop and Wood, 1997; Fu *et al.*, 2005; Luo and Xie, 2008), an FAS value of 2 should be a reasonable index, and all *O. mykiss* tested had this capacity up to 23°C. Indeed, the fish were apparently feeding well in the river, given a high condition factor (1.1 SEM = 0.01), the faecal deposits found in the swim tunnel and two fish regurgitating meals when tested at 25°C. Meal regurgitation would be consistent with an oxygen limitation, given that aquatic hypoxia impairs digestion in *O. mykiss* (Eliason and Farrell, 2014). Indeed, feeding and growth are suppressed at supraoptimal temperatures (Hokanson *et al*., 1977; Brett and Groves, 1979; Elliott, 1982; Myrick and Cech, 2000, 2001). Taken together, these data suggest that Tuolumne River *O. mykiss* were doing well in their habitat and had the aerobic capacity to do so.

Our metabolic measurements, which show good quantitative agreement with controlled laboratory *O. mykiss* studies, represent a major challenge to the use of a single thermal criterion to regulate *O. mykiss* habitat when determining conservation criteria along the entire Pacific coast and perhaps elsewhere. The 7DADM of 18°C for *O. mykiss* draws heavily on a growth study performed in Minnesota (Hokanson *et al*., 1977). Therefore, it will be important to examine whether the peak AAS at 21.2°C for Tuolumne River *O. mykiss* is associated with a peak growth rate. In this regard, the peak growth rate of another Californian *O. mykiss* population (the Mount Shasta strain) occurred at acclimation temperatures (19–22°C; Myrick and Cech, 2000) above the 7DADM and within the thermal window for 95% peak AAS for Tuolumne River *O. mykiss*. The Mount Shasta *O. mykiss* strain also stopped growing at 25°C, the same temperature at which FAS for Tuolumne River *O. mykiss* approached 2. In contrast, the Californian Eagle Lake *O. mykiss* strain grew fastest at 19°C and lost weight at 25°C (Myrick and Cech, 2000). Thus, the Mount Shasta and Tuolumne River *O. mykiss* populations are better able to acclimate thermally to temperatures >20°C than the Eagle Lake strain. With clear evidence that a California strain of *O. mykiss* can grow faster at acclimation temperatures >18°C and that strains may differ in their the optimal temperature for growth by as much as 3°C, there is a precedent that local populations of *O. mykiss* can perform well above 18°C. Our findings also highlight the need for future experiments that consider replicate populations from throughout the species range to assess how widespread intraspecific variation in aerobic scope in *O. mykiss* might be. Continual development and refinement of the metrics used to best inform regulatory criteria should be an ongoing pursuit, particularly if regional standards are to be implemented and if the criteria move away from what may now be considered conservative. Probabilistic modelling approaches associated with a diversity of water temperature standards should be developed in order for managers to understand the balance between standards that are conservative compared with those that are more risky.

The capacity to balance the essential environmental requirements of aquatic biota with human requirements is becoming increasingly challenging across the globe because of recent increases in severe drought and record high temperature occurrences, a trend that climate change models project will continue. We suggest that broadly applying regulatory criteria, such as the 18°C 7DADM criterion for Pacific Northwest *O. mykiss* populations, to all North American *O. mykiss* is no longer realistic and, in the present case, overly conservative. The high degree of thermal plasticity discovered here for the Tuolumne River *O. mykiss* population, which corresponds to local thermal conditions, adds to the accumulating evidence of the capacity for local adaptation among populations within the *Oncorhynchus* genus, including *O. mykiss*. Importantly, this work clearly illustrates that, owing to thermal plasticity, broad application of a single temperature criterion for fish protection and conservation is not scientifically supported, especially for fish populations at the extreme limits of the species' indigenous range.

Supplementary material

Supplementary material is available at *Conservation Physiology* online.

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References

Alsop D, Wood C (1997) The interactive effects of feeding and exercise on oxygen consumption, swimming performance and protein usage in juvenile rainbow trout (*Oncorhynchus mykiss*). *J Exp Biol* 10: 2337–2346.

Angilletta MJ (2009) *Thermal Adaptation: a Theoretical and Empirical Synthesis*. Oxford University Press, Oxford, UK.

Anttila K, Couturier CS, Overli O, Johnsen A, Marthinsen G, Nilsson GE, Farrell AP (2014) Atlantic salmon show capability for cardiac acclimation to warm temperatures. *Nat Commun* 5: 4252.

Barrett RDH, Paccard A, Healy TM, Bergek S, Schulte PM, Schluter D, Rogers SW (2011) Rapid evolution of cold tolerance in stickleback. *Proc Biol Sci* 278: 233–238.

Behnke R (2010) *Trout and Salmon of North America*. The Free Press, New York, NY.

Bidgood BF, Berst AH (1969) Lethal temperatures for Great Lakes rainbow trout. *J Fish Res Board Can* 26: 456–459.

Blunden J, Arndt DS (2015) State of the climate in 2014. *Bul Am Meteor Soc* 96: S1–S267.

Brett JR, Groves TDD (1979) Physiological Energetics. In Hoar WS, Randall DJ, Brett JR, eds, *Fish Physiology Volume VIII Bioenergetics and Growth*, Academic Press, New York, NY, pp 279–352.

California Department of Water Resources (2015) *Reservoir water storage*. http://cdec.water.ca.gov/cgi-progs/reservoirs/STORAGEW

Cech JJ Jr (1990) Respirometry. In CB Schreck, PB Moyle, eds. *Methods for Fish Biology*. American Fisheries Society, Bethesda, MD, pp 335–362.

Chabot D, Steffensen JF, Farrell AP (2016) The determination of standard metabolic rate in fishes. *J Fish Biol* 88: 81–12.

Chen JQ, Snow M, Lawrence CS, Church AR, Narum SR, Devlin RH, Farrell AP (2015) Selection for upper thermal tolerance in rainbow trout (*Oncorhynchus mykiss* Walbaum). *J Exp Biol* 218: 803–812.

Clark TD, Sandblom E, Jutfelt F (2013) Aerobic scope measurements of fishes in an era of climate change: respirometry, relevance and recommendations. *J Exp Biol* 216: 2771–2782.

Crocker CE, Cech JJ Jr (1997) Effects of environmental hypoxia on oxygen consumption rate and swimming activity in juvenile white sturgeon, *Acipenser transmontanus*, in relation to temperature and life intervals. *Environ Biol Fish* 50: 759–769.

Dauwalter DC, Fesenmyer KA, Bjork R (2015) Using aerial imagery to characterize redband trout habitat in a remote desert landscape. *Trans Am Fish Soc* 8487: 1322–1339.

Dettinger M, Cayan DR (2014) Drought and the California Delta—a matter of extremes. *San Francisco Estuary and Watershed Sci* 12: 1–6.

Deutsch C, Ferrel A, Seibel B, Pörtner HO, Huey RB (2015) Ecophysiology. Climate change tightens a metabolic constraint on marine habitats. *Science* 348: 1132–1135.

Donelson JM, Munday PL, McCormick MI, Pitcher CR (2012) Rapid transgenerational acclimation of a tropical reef fish to climate change. *Nat Clim Change* 2: 30–32.

Eliason E, Farrell AP (2014) Effect of hypoxia on specific dynamic action and postprandial cardiovascular physiology in rainbow trout (*Oncorhynchus mykiss*). *Comp Biochem Physiol A Mol Integr Physiol* 171: 44–50.

Eliason EJ, Clark TD, Hague MJ, Hanson LM, Gallagher ZS, Jeffries KM, Gale MK, Patterson DA, Hinch SG, Farell AP (2011) Differences in thermal tolerance among sockeye salmon populations. *Science* 332: 109–112.

Eliason EJ, Wilson SM, Farrell AP, Cooke SJ, Hinch SG (2013) Low cardiac and aerobic scope in a costal population of sockeye salmon, *Oncorhynchus nerka*, with a short upriver migration. *J Fish Biol* 82: 2104–2112.

Elliott JM (1982) The effects of temperature and ration size on the growth and energetics of salmonids in captivity. *Comp Biochem Physiol B Comp Biochem* 73: 81–91.

Ern R, Huong DTT, Phuong NT, Wang T, Bayley M (2014) Oxygen delivery does not limit thermal tolerance in a tropical eurythermal crustacean. *J Exp Biol* 217: 809–814.

Fangue NA, Hofmeister M, Schulte PM (2006) Intraspecific variation in thermal tolerance and heat shock protein gene expression in common killifish, *Fundulus heteroclitus*. *J Exp Biol* 209: 2859–2872.

Farrell AP (2013) Aerobic scope and its optimum temperature: clarifying their usefulness and limitations – correspondence on *J. Exp. Biol*. 216, 2771–2772. *J Exp Biol* 216: 4493–4494.

Farrell AP (2016) Pragmatic perspective on aerobic scope: peaking, plummeting, pejus and apportioning. *J Fish Biol* 88: 322–343.

Farrell AP, Franklin CE (2016) Recognizing thermal plasticity in fish. *Science* 351: 132–133.

Farrell AP, Hinch SG, Cooke SJ, Patterson DA, Crossin GT, Lapointe M, Mathes MT (2008) Pacific salmon in hot water: applying aerobic scope models and biotelemetry to predict the success of spawning migrations. *Physiol Biochem Zool* 81: 697–708.

Fry FEJ (1947) Effects of the environment on animal activity. *Publications of the Ontario Fisheries Research Laboratory* 55: 1–62.

Fry FEJ (1948) Temperature relations of salmonids. *Proc Can Comm Freshwater Fish Res 1st Meeting*. App. D. 1–6.

Fry FEJ (1971) The effect of environment factors on the physiology of fish. *Fish Physiol* 6: 1–98.

Fu SJ, Xie XJ, Cao ZD (2005) Effect of meal size on postprandial metabolic response in southern catfish (*Silurus meridionalis*). *Comp Biochem Physiol A Mol Integr Physiol* 140: 445–451.

Gamperl AK, Rodnick KJ, Faust HA, Venn EC, Bennett MT, Crawshaw LI, Keeley ER, Powell MS, Li HW (2002) Metabolism, swimming performance, and tissue biochemistry of high desert redband trout (*Oncorhynchus mykiss* ssp.): evidence for phenotypic differences in physiological function. *Physiol Biochem Zool* 75: 413–431.

Gardiner NM, Munday PL, Nilsson GE (2010) Counter-gradient variation in respiratory performance of coral reef fishes at elevated temperatures. *PLoS One* 5: e13299.

HDR Engineering, Inc. (2014) In-river diurnal temperature variation. Don Pedro Project FERC No. 2299.

Hochachka PW, Somero GN (2002) *Biochemical Adaptation*. Oxford University Press, Oxford, UK.

Hokanson KEF, Kleiner CF, Thorslund TW (1977) Effects of constant temperatures and diel temperature fluctuations on specific growth and mortality rates and yield of juvenile rainbow trout, *Salmo gairdneri*. *J Fish Res Board Can* 34: 639–648.

Ineno T, Tsuchida S, Kanda M, Watabe S (2005) Thermal tolerance of a rainbow trout *Oncorhynchus mykiss* strain selected by high-temperature breeding. *Fish Sci* 71: 767–775.

Jain KE, Farrell AP (2003) Influence of seasonal temperature on the repeat swimming performance of rainbow trout *Oncorhynchus mykiss*. *J Exp Biol* 206: 3569–3579.

Jain KE, Hamilton JC, Farrell AP (1997) Use of a ramp velocity test to measure critical swimming speed in rainbow trout (*Oncorhynchus mykiss*). *Comp Biochem Physiol A Mol Integr Physiol* 117: 441–444.

Jobling M (1981) The influences of feeding on the metabolic rate of fishes: a short review. *J Fish Biol* 18: 385–400.

Jobling M, Baardvik BM (1994) The influence of environmental manipulations on inter–and intra–individual variation in food acquisition and growth performance of Arctic charr, Salvelinus alpinus. *J Fish Biol* 44: 1069–1087.

Killen SS, Costa I, Brown JA, Gamperl AK (2007) Little left in the tank: metabolic scaling in marine teleosts and its implications for aerobic scope. *Proc Biol Sci* 274: 431–438.

Lassalle G, Rochard E (2009) Impact of twenty-first century climate change on diadromous fish spread over Europe, North Africa and the Middle East. *Glob Change Biol* 15: 1072–1089.

Lee CG, Farrell AP, Lotto A, MacNutt MJ, Hinch SG, Healey MC (2003a) The effect of temperature on swimming performance and oxygen consumption in adult sockeye (*Oncorhynchus nerka*) and coho (*O. kisutch*) salmon stocks. *J Exp Biol* 206: 3239–3251.

Lee CG, Farrell AP, Lotto A, Hinch SG, Healey MC (2003b) Excess post-exercise oxygen consumption in adult sockeye (*Oncorhynchus nerka*) and coho (*O. kisutch*) salmon following critical speed swimming. *J Exp Biol* 206: 3253–3260.

Lucas J, Schouman A, Plyphout L, Cousin X, LeFrancois C (2014) Allometric relationship between body mass and aerobic metabolism in zebrafish *Danio rerio*. *J Fish Biol* 84: 1171–1178.

Luo XP, Xie XJ (2008) Effects of temperature on the specific dynamic action of the southern catfish, *Silurus meridionalis*. *Comp Biochem Physiol A Mol Integr Physiol* 149: 150–156.

McGeer JC, Szebedinsky C, McDonald DG, Wood CM (2000) Effects of chronic sublethal exposure to waterborne Cu, Cd or Zn in rainbow trout. I: Iono-regulatory disturbance and metabolic costs. *Aquat Toxicol* 50: 231–243.

McKenzie DJ, Estivales G, Svendsen JC, Steffensen JF, Agnèse JF (2013) Local adaptation to altitude underlies divergent thermal physiology in tropical killifishes of the genus *Aphyosemion*. *PLoS One* 8: e54345.

Molony BW (2001). Environmental requirements and tolerances of rainbow trout (*Oncorhynchus mykiss*) and brown trout (*Salmo trutta*) with special reference to Western Australia: a review. Fisheries Research Reports No. 130. Western Australia, p 28.

Molony BW, Church AR, Maguire GB (2004) A comparison of the heat tolerance and growth of a selected and non-selected line of rainbow trout, *Oncorhynchus mykiss*, in Western Australia. *Aquaculture* 241: 655–665.

Morrissy NM (1973) Comparison of strains of *Salmo gairdneri* Richardson from New South Wales, Victoria and Western Australia. *Aust Soc Limn Bull* 5: 11–20.

Moyle PB, Katz JVE, Quinones RM (2011) Rapid decline of California's native inland fishes: a status assessment. *Biol Conserv* 144: 2414–2423.

Myrick CA, Cech JJ Jr (2000) Temperature influences on California rainbow trout physiological performance. *Fish Physiol Biochem* 22: 245–254.

Myrick CA, Cech JJ Jr (2001) Temperature Effects on Chinook Salmon and Steelhead: a Review Focusing on California's Central Valley Populations. Bay-Delta Modeling Forum, Technical Publication 01-1.

Narum SR, Campbell NR (2015) Transcriptomic response to heat stress among ecologically divergent populations of redband trout. *BMC Genomics* 16: 103.

Narum SR, Campbell NR, Kozfkay CC, Meyer KA (2010) Adaptation of redband trout in desert and montane environments. *Mol Ecol* 19: 4622–4637.

Nilsson GE, Crawley N, Lunde IG, Munday PI (2009) Elevated temperature reduces the respiratory scope of coral reef fishes. *Glob Change Biol* 15: 1405–1412.

NOAA National Centers for Environmental Information (2016) State of the Climate: Global Analysis for December 2015. http://www.ncdc.noaa.gov/sotc/global/201512.

Norin T, Clark TD (2016) Measurement and relevance of maximum metabolic rate in fishes. *J Fish Biol* 88: 122–151.

Norin T, Malte H, Clark TD (2014) Aerobic scope does not predict the performance of a tropical eurythermal fish at elevated temperatures. *J Exp Biol* 217: 244–251.

Overgaard J, Andersen JL, Findsen A, Pedersen PBM, Hansen K, Ozolina K, Wang T (2012) Aerobic scope and cardiovascular oxygen transport is not compromised at high temperatures in the toad *Rhinella marina*. *J Exp Biol* 215: 3519–3526.

Pörtner HO (2001) Climate change and temperature-dependent biogeography: oxygen limitation of thermal tolerance in animals. *Naturwissenschaften* 88: 137–146.

Pörtner HO, Farrell AP (2008) Physiology and climate change. *Science* 322: 690–692.

Pörtner HO, Giomi F (2013) Nothing in experimental biology makes sense except in the light of ecology and evolution – correspondence on *J Exp Biol* 216: 2771–2782. *J Exp Biol* 216: 4494–4495.

Pörtner HO, Knust R (2007) Climate change affects marine fishes through the oxygen limitation of thermal tolerance. *Science* 315: 95–97.

R Core Development Team (2013) *R: a Language and Environment for Statistical Computing*. R Foundation for Statistical Computing, Vienna. http://www.R-project.org

Reidy SP, Nelson JA, Tang Y, Kerr SR (1995) Post-exercise metabolic rate in Atlantic cod and its dependence upon the method of exhaustion. *J Fish Biol* 47: 377–386.

Reyes KK (2008) Reviewed distribution maps for *Oncorhynchus mykiss* (Rainbow trout), with modelled year 2100 native range map based on IPCC A2 emissions scenario. www.aquamaps.org, version of August 2013.

Rodgers GG, Tenzing P, Clark TD (2016) Experimental methods in aquatic respirometry: the importance of mixing devices and accounting for background respirometry. *J Fish Biol* 88: 65–80.

Rodnick KJ, Gamperl AK, Lizars KR, Bennett MT, Rausch RN, Keeley ER (2004) Thermal tolerance and metabolic physiology among redband trout populations in south-eastern Oregon. *J Fish Biol* 64: 310–335.

Rummer JL, Couturier CS, Stecyk JAW, Gardiner NM, Kinch JP, Nilsson GE, Munday PI (2014) Life on the edge: thermal optima for aerobic scope of equatorial reef fishes are close to current day temperatures. *Glob Change Biol* 20: 1055–1066.

Scarabello M, Heigenhauser GJF, Wood CM (1992) Gas exchange, metabolite status and excess postexercise oxygen consumption after repetitive bouts of exhaustive exercise in juvenile rainbow trout. *J Exp Biol* 167: 155–169.

Sokolova IM, Frederich M, Bagwe R, Lannig G, Sukhotin AA (2012) Energy homeostasis as an integrative tool for assessing limits of environmental stress tolerance in aquatic invertebrates. *Mar Environ Res* 79: 1–15.

Sonski AJ (1984) Comparison of heat tolerances of redband trout, Firehole River rainbow trout and Wytheville rainbow trout. Texas Parks and Wildlife Department, Fisheries Research Station.

Sousa PM, Trigo RM, Aizpurua P, Nieto R, Gimeno L, Garcia-Herrera R (2011) Trends and extremes of drought indices throughout the 20th century in the Mediterranean. *Nat Hazard Earth Sys Sci* 11: 33–51.

Steffensen J (1989) Some errors in respirometry of aquatic breathers: how to avoid and correct for them. *Fish Physiol Biochem* 6: 49–59.

Svendsen MBS, Bushnell PG, Steffensen JF (2016) Design and setup of intermittent-flow respirometry system for aquatic organisms *J Fish Biol* 88: 26–50.

Swain DL, Tsiang M, Haugen M, Singh D, Charland A, Rajaratnam B, Diffenbaugh NS (2014) The extraordinary California drought of 2013/2014: character, context, and the role of climate change. *Bull Am Meteorol Soc* 95: S3.

Turlock Irrigation District and Modesto Irrigation District (2011) Pre-application document, No. 2299. Turlock, CA.

US Environmental Protection Agency (2003) EPA Region 10 Guidance for Pacific Northwest State and Tribal Temperature Water Quality Standards. http://www.epa.gov/region10/pdf/water/final_temperature_guidance_2003.pdf

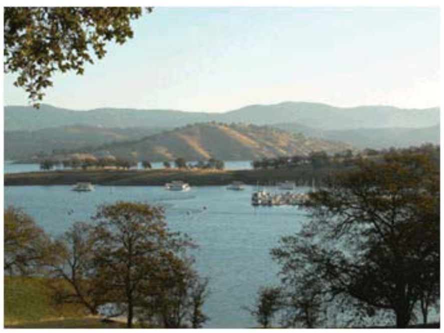
APPENDIX F

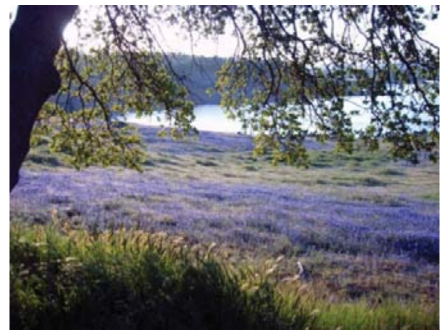
Final Report

Lower Tuolumne River Floodplain Hydraulic Assessment

LOWER TUOLUMNE RIVER FLOODPLAIN HYDRAULIC ASSESSMENT
STUDY REPORT
DON PEDRO PROJECT

FERC NO. 2299





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February 2017

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Lower Tuolumne River Floodplain Hydraulic Assessment
Study Report

TABLE OF CONTENTS

List of Figures

List of Tables

List of Attachments

List of Acronyms

ac ....acres
ACEC.........................Area of Critical Environmental Concern
AF ....acre-feet
ADF...........................Area-Duration-Frequency
ACOE.........................U.S. Army Corps of Engineers
AFY...........................acre-feet per year
ADA...........................Americans with Disabilities Act
ALJ............................Administrative Law Judge
APE...........................Area of Potential Effect
ARMR........................Archaeological Resource Management Report
BA ....Biological Assessment
BAWSCA ....Bay Area Water Supply Conservation Agency
BDCP.........................Bay-Delta Conservation Plan
BEA...........................Bureau of Economic Analysis
BLM..........................U.S. Department of the Interior, Bureau of Land Management
BLM-S ....Bureau of Land Management – Sensitive Species
BMI...........................Benthic macroinvertebrates
BMP..........................Best Management Practices
BO.............................Biological Opinion
CAISO.......................California Independent System Operators
CalEPPC ....California Exotic Pest Plant Council
CalSPA......................California Sports Fisherman Association
CALVIN ....California Value Integrated Network
CAS...........................California Academy of Sciences
CASFMRA ....California Chapter of the American Society of Farm Managers and Rural Appraisers
CCC...........................Criterion Continuous Concentrations
CCIC ....Central California Information Center
CCSF.........................City and County of San Francisco
CCVHJV...................California Central Valley Habitat Joint Venture
CD.............................Compact Disc

CDBW........................California Department of Boating and Waterways

CDEC.........................California Data Exchange Center

CDFA.........................California Department of Food and Agriculture

CDFG.........................California Department of Fish and Game (as of January 2013, Department of Fish and Wildlife)

CDMG........................California Division of Mines and Geology

CDOF.........................California Department of Finance

CDP............................Census Designated Place

CDPH.........................California Department of Public Health

CDPR.........................California Department of Parks and Recreation

CDSOD......................California Division of Safety of Dams

CDWR........................California Department of Water Resources

CE ....California Endangered Species

CEII............................Critical Energy Infrastructure Information

CEQA.........................California Environmental Quality Act

CESA ....California Endangered Species Act

CFR............................Code of Federal Regulations

cfs...............................cubic feet per second

CGS............................California Geological Survey

CMAP ....California Monitoring and Assessment Program

CMC...........................Criterion Maximum Concentrations

CNDDB......................California Natural Diversity Database

CNPS..........................California Native Plant Society

CORP.........................California Outdoor Recreation Plan

CPI ....Consumer Price Index

CPUE ....Catch Per Unit Effort

CRAM........................California Rapid Assessment Method

CRLF..........................California Red-Legged Frog

CRRF ....California Rivers Restoration Fund

CSAS..........................Central Sierra Audubon Society

CSBP..........................California Stream Bioassessment Procedure

CT ....Census Tract

CT ....California Threatened Species

CTR............................California Toxics Rule
CTS ....California Tiger Salamander
CUWA ....California Urban Water Agency
CV ....Contingent Valuation
CVP............................Central Valley Project
CVPIA........................Central Valley Project Improvement Act
CVRWQCB ....Central Valley Regional Water Quality Control Board
CWA ....Clean Water Act
CWD ....Chowchilla Water District
CWHR........................California Wildlife Habitat Relationship
CWT...........................hundredweight
Districts ....Turlock Irrigation District and Modesto Irrigation District
DLA ....Draft License Application
DPRA.........................Don Pedro Recreation Agency
DO..............................Dissolved Oxygen
DPS ....Distinct Population Segment
EA ....Environmental Assessment
EC ....Electrical Conductivity
EDD ....Employment Development Department
EFH............................Essential Fish Habitat
EIR ....Environmental Impact Report
EIS..............................Environmental Impact Statement
ENSO ....El Nino – Southern Oscillation
EO ....Executive Order
EPA............................U.S. Environmental Protection Agency
ERS ....Economic Research Service (USDA)
ESA............................Federal Endangered Species Act
ESRCD.......................East Stanislaus Resource Conservation District
ESU ....Evolutionary Significant Unit
ET...............................Evapotranspiration
EVC............................Existing Visual Condition
EWUA........................Effective Weighted Useable Area
FEMA ....Federal Emergency Management Agency

FERC..........................Federal Energy Regulatory Commission
FFS............................Foothills Fault System
FL..............................Fork length
FMU...........................Fire Management Unit
FMV...........................Fair Market Value
FOT...........................Friends of the Tuolumne
FPC...........................Federal Power Commission
FPPA..........................Federal Plant Protection Act
FPC...........................Federal Power Commission
ft................................feet
ft/mi...........................feet per mile
FWCA........................Fish and Wildlife Coordination Act
g.................................grams
GAMS........................General Algebraic Modeling System
GIS............................Geographic Information System
GLO...........................General Land Office
GPM...........................Gallons per Minute
GPS...........................Global Positioning System
HCP...........................Habitat Conservation Plan
HHWP........................Hetch Hetchy Water and Power
HORB........................Head of Old River Barrier
HPMP........................Historic Properties Management Plan
ILP.............................Integrated Licensing Process
IMPLAN....................Impact analysis for planning
I-O.............................Input-Output
ISR............................Initial Study Report
ITA............................Indian Trust Assets
kV..............................kilovolt
LTAM........................Long-Term Acoustic Monitoring
LTR...........................Lower Tuolumne River
m...............................meters
M&I...........................Municipal and Industrial
MCL...........................Maximum Contaminant Level

mg/kg ....milligrams/kilogram
mg/L..........................milligrams per liter
mgd ....million gallons per day
mi ....miles
mi^2 ....square miles
MID...........................Modesto Irrigation District
MOU ....Memorandum of Understanding
MRP ....Monitoring and Reporting Program
MRWTP....................Modesto Regional Water Treatment Plant
MSCS.........................Multi-Species Conservation Strategy
msl.............................mean sea level
MVA ....Megavolt Ampere
MW ....megawatt
MWh ....megawatt hour
mya............................million years ago
NAE ....National Academy of Engineering
NAHC ....Native American Heritage Commission
NAICS........................North America Industrial Classification System
NAS...........................National Academy of Sciences
NASS ....National Agricultural Statistics Service (USDA)
NAVD 88..................North American Vertical Datum of 1988
NAWQA ....National Water Quality Assessment
NCCP.........................Natural Community Conservation Plan
NEPA.........................National Environmental Policy Act
ng/g ....nanograms per gram
NGOs ....Non-Governmental Organizations
NHI ....Natural Heritage Institute
NHPA.........................National Historic Preservation Act
NISC ....National Invasive Species Council
NMFS.........................National Marine Fisheries Service
NMP...........................Nutrient Management Plan
NOAA ....National Oceanic and Atmospheric Administration
NOI ....Notice of Intent

NPS ............................U.S. Department of the Interior, National Park Service
NRCS ....National Resource Conservation Service
NRHP.........................National Register of Historic Places
NRI.............................Nationwide Rivers Inventory
NTU ....Nephelometric Turbidity Unit
NWI............................National Wetland Inventory
NWIS ....National Water Information System
NWR ....National Wildlife Refuge
NGVD 29 ....National Geodetic Vertical Datum of 1929
O&M ....operation and maintenance
OEHHA......................Office of Environmental Health Hazard Assessment
OID ....Oakdale Irrigation District
ORV ....Outstanding Remarkable Value
PAD............................Pre-Application Document
PDO............................Pacific Decadal Oscillation
PEIR ....Program Environmental Impact Report
PGA............................Peak Ground Acceleration
PHG............................Public Health Goal
PM&E ....Protection, Mitigation and Enhancement
PMF............................Probable Maximum Flood
PMP............................Positive Mathematical Programming
POAOR ....Public Opinions and Attitudes in Outdoor Recreation
ppb.............................parts per billion
ppm ....parts per million
PSP ....Proposed Study Plan
QA ....Quality Assurance
QC ....Quality Control
RA ....Recreation Area
RBP ....Rapid Bioassessment Protocol
Reclamation ...............U.S. Department of the Interior, Bureau of Reclamation
RM ....River Mile
RP...............................Relicensing Participant
RSP ....Revised Study Plan

RST ....Rotary Screw Trap
RWQCB.....................Regional Water Quality Control Board
SD1 ....Scoping Document 1
SD2 ....Scoping Document 2
SE...............................State Endangered Species under the CESA
SFP.............................State Fully Protected Species under CESA
SFPUC ....San Francisco Public Utilities Commission
SHPO ....State Historic Preservation Office
SIC ....Standard Industry Classification
SJR.............................San Joaquin River
SJRA ....San Joaquin River Agreement
SJRGA ....San Joaquin River Group Authority
SJTA ....San Joaquin River Tributaries Authority
SPD ....Study Plan Determination
SRA............................State Recreation Area
SRMA ....Special Recreation Management Area or Sierra Resource Management Area (as per use)
SRMP.........................Sierra Resource Management Plan
SRP ....Special Run Pools
SSC ....State species of special concern
ST...............................California Threatened Species under the CESA
STORET ....Storage and Retrieval
SWAMP.....................Surface Water Ambient Monitoring Program
SWAP ....Statewide Agricultural Model
SWE...........................Snow-Water Equivalent
SWP ....State Water Project
SWRCB......................State Water Resources Control Board
TAC............................Technical Advisory Committee
TAF ....thousand acre-feet
TC ....Travel Cost
TCP ....Traditional Cultural Properties
TDS............................Total Dissolved Solids
TID.............................Turlock Irrigation District

TIN............................ Triangular Irregular Network
TMDL........................Total Maximum Daily Load
TOC...........................Total Organic Carbon
TPH...........................Total Petroleum hydrocarbon
TRT...........................Tuolumne River Trust
TRTAC.....................Tuolumne River Technical Advisory Committee
UC.............................University of California
UCCE........................University of California Cooperative Extension
USDA........................U.S. Department of Agriculture
USDOC.....................U.S. Department of Commerce
USDOI......................U.S. Department of the Interior
USFS.........................U.S. Department of Agriculture, Forest Service
USFWS.....................U.S. Department of the Interior, Fish and Wildlife Service
USGS........................U.S. Department of the Interior, Geological Survey
USR...........................Updated Study Report
UTM..........................Universal Transverse Mercator
VAMP.......................Vernalis Adaptive Management Plan
VELB........................Valley Elderberry Longhorn Beetle
VES...........................Visual Encounter Surveys
VRM.........................Visual Resource Management
W&AR......................Water & Aquatic Resources
WMP.........................Waste Management Plan
WPT..........................Western Pond Turtle
WSA..........................Wilderness Study Area
WSIP.........................Water System Improvement Program
WTP..........................Willingness to Pay
WWTP......................Wastewater Treatment Plant
WY............................water year
µS/cm........................micro-Siemens per centimeter

1.0 INTRODUCTION

1.1 Background

Turlock Irrigation District (TID) and Modesto Irrigation District (MID) (collectively, the Districts) are the co-licensees of the 168-megawatt (MW) Don Pedro Project (Project) located on the Tuolumne River in western Tuolumne County in the Central Valley region of California. The Don Pedro Dam is located at river mile (RM) 54.8 and the Don Pedro Reservoir has a normal maximum water surface elevation of 830 ft above mean sea level (msl; NGVD 29). At elevation 830 ft, the reservoir stores over 2,000,000 acre-feet (AF) of water and has a surface area slightly less than 13,000 acres (ac). The watershed above Don Pedro Dam is approximately 1,533 square miles (mi^2). The Project is designated by the Federal Energy Regulatory Commission (FERC) as project no. 2299.

Both TID and MID are local public agencies authorized under the laws of the State of California to provide water supply for irrigation and municipal and industrial (M&I) uses and to provide retail electric service. The Don Pedro Project serves many purposes including providing water storage for the beneficial use of irrigation of over 200,000 ac of prime Central Valley farmland and for the use of M&I customers in the City of Modesto (population 210,000). Consistent with agreements between the Districts and City and County of San Francisco (CCSF), the Don Pedro Reservoir also includes a “water bank” of up to 570,000 AF of storage which CCSF uses to more efficiently manage the water supply from its Hetch Hetchy water system while meeting the senior water rights of the Districts. The “water bank” within Don Pedro Reservoir provides significant benefits for CCSF’s 2.6 million customers in the San Francisco Bay Area.

The Don Pedro Project also provides storage for flood management purposes in the Tuolumne and San Joaquin rivers in coordination with the U.S. Army Corps of Engineers (ACOE). Other important uses supported by the Don Pedro Project are recreation, protection of aquatic resources in the lower Tuolumne River, and hydropower generation.

The Project Boundary extends from RM 53.2, which is one mile below the Don Pedro powerhouse, upstream to RM 80.8 at a water surface elevation of 845 ft (31 FPC ¶ 510 [1964]). The Project Boundary encompasses approximately 18,370 ac with 74 percent of the lands owned jointly by the Districts and the remaining 26 percent (approximately 4,802 ac) owned by the United States and managed as a part of the U.S. Bureau of Land Management (BLM) Sierra Resource Management Area.

The primary Don Pedro Project facilities include the 580-foot-high Don Pedro Dam and Reservoir completed in 1971; a four-unit powerhouse situated at the base of the dam; related facilities including the Project spillway, outlet works, and switchyard; four dikes (Gasburg Creek Dike and Dikes A, B, and C); and three developed recreational facilities (Fleming Meadows, Blue Oaks, and Moccasin Point Recreation Areas). The location of the Don Pedro Project and its primary facilities is shown in Figure 1.1-1.

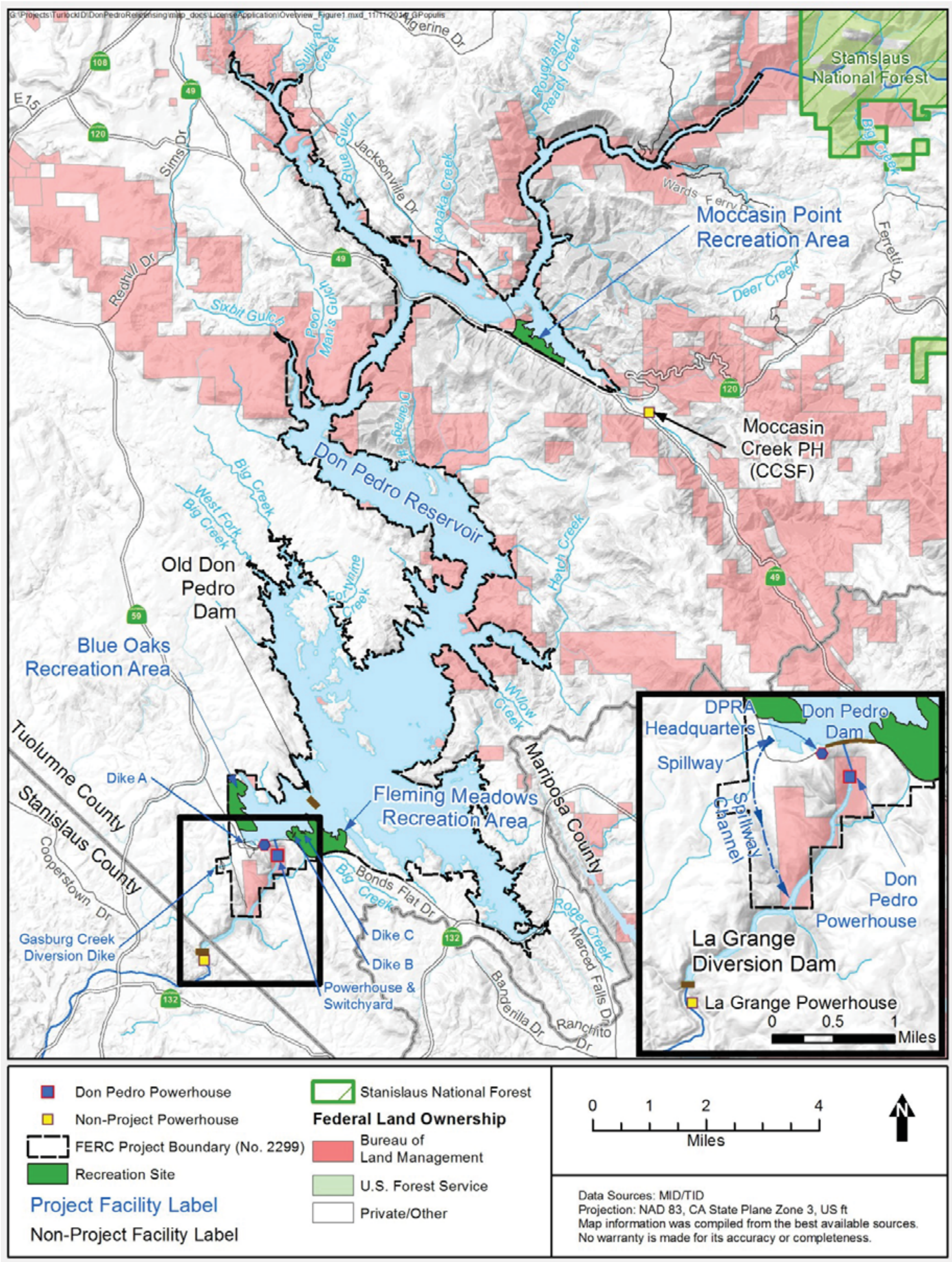


Figure 1.1-1. Don Pedro Project site location map.

1.2 Relicensing Process

The current FERC license for the Project expires on April 30, 2016, and the Districts applied for a new license on April 28, 2014. At that time, and consistent with study schedules approved by FERC through the ILP's study plan determinations, five important studies involving the resources of the lower Tuolumne River were still in-progress. These studies are scheduled to be completed in 2016. Once these studies are completed, the Districts will evaluate all data, reports, and models then available for the purpose of identifying appropriate protection, mitigation, and enhancement (PM&E) alternatives to address the direct, indirect, and cumulative effects of Project operations and maintenance. Upon completion of this evaluation, the Districts will prepare any needed amendments to the license application.

The Districts began the relicensing process by filing a Notice of Intent and Pre-Application Document (PAD) with FERC on February 10, 2011, following the regulations governing the Integrated Licensing Process (ILP). The Districts' PAD included descriptions of the Project facilities, operations, license requirements, and Project lands as well as a summary of the extensive existing information available on Project area resources. The PAD also included ten draft study plans describing a subset of the Districts' proposed relicensing studies. The Districts then convened a series of Resource Work Group meetings, engaging agencies and other relicensing participants in a collaborative study plan development process culminating in the Districts' Proposed Study Plan (PSP) and Revised Study Plan (RSP) filings to FERC on July 25, 2011 and November 22, 2011, respectively.

On December 22, 2011, FERC issued its Study Plan Determination (SPD) for the Project, approving, or approving with modifications, 34 studies proposed in the RSP that addressed Cultural and Historical Resources, Recreational Resources, Terrestrial Resources, and Water and Aquatic Resources. In addition, as required by the SPD, the Districts filed three new study plans (W&AR-18, W&AR-19, and W&AR-20) on February 28, 2012 and one modified study plan (W&AR-12) on April 6, 2012. Prior to filing these plans with FERC, the Districts consulted with relicensing participants on drafts of the plans. FERC approved or approved with modifications these four studies on July 25, 2012.

Following the SPD, a total of seven studies (and associated study elements) that were either not adopted in the SPD, or were adopted with modifications, formed the basis of Study Dispute proceedings. In accordance with the ILP, FERC convened a Dispute Resolution Panel on April 17, 2012 and the Panel issued its findings on May 4, 2012. On May 24, 2012, the Director of FERC issued his Formal Study Dispute Determination, with additional clarifications related to the Formal Study Dispute Determination issued on August 17, 2012. The dispute did not involve the study plan for the *Lower Tuolumne River Floodplain Hydraulic Assessment* (W&AR-21).

On January 17, 2013, the Districts issued the Initial Study Report (ISR) and held an ISR meeting on January 30 and 31, 2013. The Districts filed a summary of the ISR meeting with FERC on February 8, 2013. Comments on the meeting summary and requests for new studies and study modifications were filed by relicensing participants on or before March 11, 2013 and the Districts filed reply comments on April 9, 2013. FERC issued the Determination on Requests for Study Modifications and New Studies on May 21, 2013. As part of that Determination, FERC staff recommended that the Districts undertake an analysis of floodplain inundation and frequency for portions of the lower Tuolumne River to supplement and update information from previous studies conducted by the Districts and the U.S. Fish and Wildlife Service (USFWS). In response, the Districts filed a new study plan with FERC for the *Lower Tuolumne River Floodplain Hydraulic Assessment* (W&AR-21) on September 16, 2013. The Districts addressed all relicensing participant recommended changes to the original draft and FERC approved the study plan without modification on October 18, 2013.

The Districts filed the Updated Study Report (USR) on January 6, 2014; held a USR meeting on January 16, 2014; and filed a summary of the meeting on January 27, 2014. Relicensing participant comments on the meeting summary and requests for new studies and study modifications were due by February 26, 2014. The Districts filed reply comments on March 28, 2014. FERC issued the Determination on Requests for Study Modifications on April 29, 2014.

This study report describes the objectives, methods, and results of the *Lower Tuolumne River Floodplain Hydraulic Assessment* as implemented by the Districts in accordance with FERC's October 18, 2013 Order. Documents relating to the Project relicensing are publicly available on the Districts' relicensing website at http://www.donpedro-relicensing.com/.

1.3 Study Plan and Consultation

The Districts' operation and maintenance (O&M) of the Project may contribute to cumulative effects on habitat availability and production of Central Valley fall-run Chinook salmon (*Oncorhynchus tshawytscha*) and *O. mykiss* in the lower Tuolumne River. In the Determination on Requests for Study Modifications and New Studies issued on May 21, 2013, FERC staff recommended that the Districts undertake an analysis of floodplain inundation and frequency for the lower Tuolumne River between RM 52.5 and RM 21.5 to supplement and update information from previous IFIM studies conducted by the Districts and the USFWS. In response, the Districts issued a draft study plan to relicensing participants on August 9, 2013 for a 30-day review period. Timely comments were provided by CDFW and USFWS. Comments from CDFW and USFWS were either incorporated into the final study plan or, if not adopted, responded to in the study plan attachment. Several agency comments resulted in substantive changes to the study plan. In response to a comment from CDFW, the Districts revised the plan to assess the extent of suitable juvenile salmonid rearing habitat. Based on requests from both CDFW and USFWS, the Districts agreed to extend the study area to the confluence of the Tuolumne River and the San Joaquin River. At the request of USFWS, the area-duration-frequency curves produced under Step 5 of the study plan include the determination of the continuous wetted area for periods of 7, 14, 21, and 30 day durations.

On February 13, 2014, the Districts' study team held a consultation Workshop with relicensing participants. The first of two workshops, Workshop No. 1 was held to (1) update relicensing participants on study progress; (2) present modeling approaches and describe the TUFLOW model (BMT Group Ltd. 2013); and (3) solicit input on delineating the boundary between overbank and in-channel areas to be analyzed using two dimensional (2D) and one dimensional (1D) modeling, respectively, downstream of La Grange Diversion Dam (RM 52.2) to the San Joaquin River (RM 0.0). Comments on materials presented at Workshop No. 1 were received from the Tuolumne River Conservancy, Inc. (TRC) on February 20, 2014. On March 4, 2014, draft meeting notes for Workshop No. 1 were provided to relicensing participants (RPs) for review and comment. No additional comments were received during the 30-day review period. TRC's comments did not result in any changes to the draft meeting notes. On July 17, 2014, the Districts filed final meeting notes for Workshop No.1 (Attachment A).

On July 15, 2014, the Districts provided the draft TUFLOW 1D/2D model domain boundary to relicensing participants for review and comment. The Districts requested that all comments be provided by August 29, 2014. No comments were received.

On December 18, 2014, the study team held consultation Workshop No. 2 with relicensing participants. Workshop No. 2 was held to (1) review the TUFLOW hydraulic model development, (2) present calibration and validation results, (3) present preliminary results of the habitat analysis for the completed modeling subreaches, and (4) present the remaining study and reporting schedule. On January 9, 2015, draft meeting notes for Workshop No. 2 were provided to RPs for review and comment. No comments were received during the 30-day review period. Final meeting notes for Workshop No. 2 are included in Attachment A.

On September 3, 2015, the Districts filed the draft study report and requested that relicensing participants provide comments no later than October 6, 2015. Comments on the draft study report were provided by the USFWS on October 1, 2015. In response to those comments, the report has been revised to remove perennially flooded areas within isolated portions of the floodplain from the estimates of usable floodplain area. The Districts provide a response to each USFWS comment in Attachment A.

2.0 STUDY GOALS AND OBJECTIVES

The goal of this study is to develop a hydraulic model for the lower Tuolumne River that simulates the interaction between flow within the main channel and the floodplain downstream of the La Grange Diversion Dam at RM 52.2 to the confluence with the San Joaquin River (RM 0) and to apply the model results to estimate floodplain juvenile salmonid rearing habitat. The TUFLOW model analysis conducted for this study expands the flow range and number of flow regimes evaluated in the 2012 Pulse Flow Study (Stillwater Sciences 2012) and uses recent data on floodplain topography and in-channel hydraulic controls that were not included in either the 2012 Pulse Flow Study or floodplain GIS analysis conducted by the USFWS (2008). The following objectives apply to this study:

- reproduce observed water surface elevations, within reasonable calibration standards, over the sampled range of hydrologic conditions;
- determine floodplain inundation extents for flows at 250 cfs intervals between 1,000 and 3,000 cfs and 500 cfs intervals between 3,000 cfs and 9,000 cfs;
- estimate the area, frequency and duration of inundation over a range of flows for the base case (WY 1971–2012) hydrology; and
- apply modeled water depths and velocities to quantify the amount of suitable salmonid rearing habitat for juvenile Chinook salmon (*Oncorhynchus tshawytscha*) and *O. mykiss* at the designated flow increments.

The TUFLOW model is available for use in future evaluations of inundation and frequency duration under alternative scenarios.

3.0 STUDY AREA

The study area consists of the lower Tuolumne River from below the La Grange powerhouse tailrace at an elevation of approximately 165 ft to the Tuolumne River's confluence with the San Joaquin River (RM 0.0) at approximately elevation 35 ft. For modeling purposes, the Tuolumne River was divided into three reaches, each simulated with a stand-alone model for computational efficiency. The model reach boundaries are based on changes in geomorphic regime and continuity of terrain data sources. A map depicting the study area and the individual model extents is shown in Figure 3.1-1.

3.1 Landform and Land Use

From upstream to downstream, the lower Tuolumne River leaves a steep and confined bedrock valley at the La Grange Diversion Dam (RM 52.2) and enters the eastern Central Valley near the La Grange Regional Park (at Basso Bridge, RM 47.5), where hillslope gradients in the vicinity of the river corridor are typically less than 5 percent. From this point to the confluence with the San Joaquin River the Tuolumne River corridor lies in a broad alluvial valley. The alluvial valley may be delineated into two geomorphic reaches based on channel slope and bed composition: a predominantly gravel-bedded reach that extends from La Grange Diversion Dam to RM 24 near the City of Hughson and a predominantly sand-bedded reach that extends from RM 24 to the San Joaquin River confluence (McBain & Trush 2000).

As summarized in the Tuolumne River Restoration Plan (McBain & Trush 2000), a number of large-scale anthropogenic changes have occurred in the lower Tuolumne River corridor since the California Gold Rush in 1848. Gold mining, gravel mining, grazing, and agriculture had encroached on the lower Tuolumne River channel even before the first aerial photographs were taken by the Soil Conservation Service in 1937. Dredge mine tailings along the river are primarily the legacy of gold mining abandoned in the early 20th century, however, gravel and aggregate mining still continue alongside the river for a number of miles, particularly upstream of the Town of Waterford (RM 34). Excavation of riverbed material for gold and aggregate to depths well below the river thalweg has formed large in-channel pits ("special run-pools" [SRPs]) as well as off-channel ponds. During the construction of the Don Pedro Dam, aggregate was reclaimed from floodplain areas formerly occupied by dredger tailings between RM 51.5 and RM 40.3 (McBain & Trush 2000). These floodplain areas are characterized by floodplains two to three times wider than floodplains in other portions of the lower Tuolumne River corridor. Although some overbank habitat is available over the length of the lower Tuolumne River, most of the river corridor is confined by either natural bluffs or man-made levees, often built to protect active floodplain gravel mining areas (McBain & Trush 2000).

Along the lower Tuolumne River, agricultural and urban encroachment in combination with in-channel excavation has resulted in a river channel contained within a narrow floodway confined by dikes and agricultural fields. Levees and bank revetment extend along portions of the river bank from near Modesto (RM 16) downstream to the San Joaquin River, limiting potential floodplain access for rearing juvenile salmonids. The remnant SRPs, floodplain mining pits and multiple connected backwaters along the lower Tuolumne River have been noted for juvenile Chinook stranding concerns (TID/MID 2001).

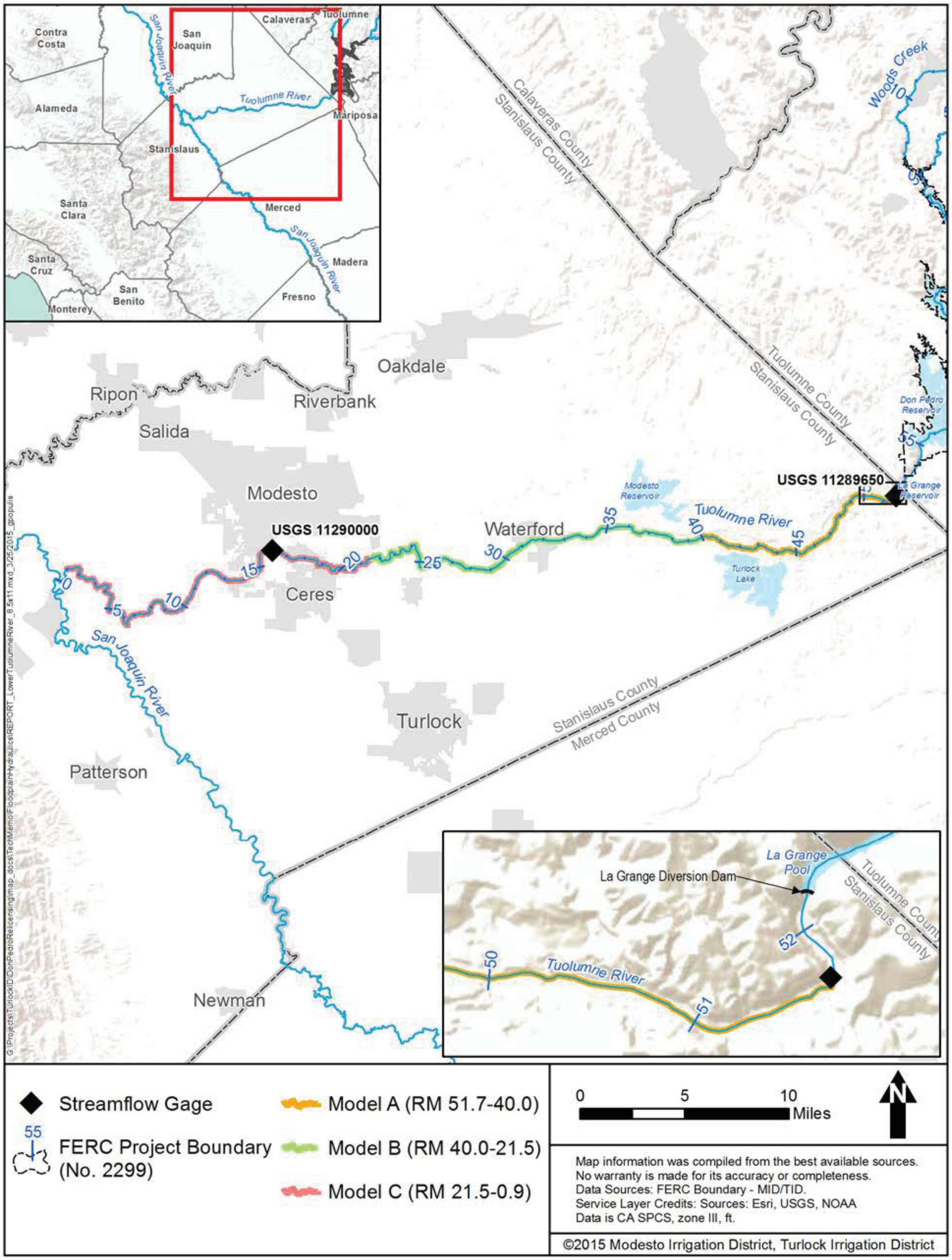


Figure 3.1-1. Lower Tuolumne River study area and model reaches.

3.2 Hydrology

Flow statistics of the mean daily flow for the study period (WY 1971 to 2012) using flows recorded at USGS Gages 11289650 (Tuolumne River below La Grange Diversion Dam) and 11290000 (Tuolumne River at Modesto) are shown in Table 3.2-1. Previous studies estimate that flows as low as 1,000 cfs may reach bankfull within portions of the lower Tuolumne River (USFWS 2008, Stillwater Sciences 2012). The flow frequency curve for the lower Tuolumne River at Modesto for the study period (Figure 3.2-1) indicates that mean daily flows exceed 1,000 cfs approximately 28 percent of the time throughout the year. The highest study flow of 9,000 cfs is exceeded less than 1 percent of the time annually.

Table 3.2-1. Lower Tuolumne River mean monthly flows (cfs) WY 1971-2012.

Month	Mean Daily Flow (cfs)					
	USGS 11289650 - Tuolumne River Below La Grange Dam Near La Grange, CA			USGS 11290000 - Tuolumne River at Modesto, CA		
	Mean	Highest	Lowest	Mean	Highest	Lowest
January	1,440	13,070	10	1,780	15,500	154
February	1,720	8,116	22	2,050	8,782	166
March	1,810	6,636	94	2,150	7,658	239
April	1,790	8,900	41	2,030	9,268	169
May	1,620	9,744	9	1,830	10,420	138
June	940	5,161	8	1,120	5,683	95
July	490	3,808	7	670	4,244	79
August	301	2,498	6	474	2,415	68
September	454	3,491	4	654	4,041	73
October	595	4,187	1	824	4,760	78
November	348	905	8	641	2,089	93
December	864	4,625	10	1,120	5,431	110

Some of the base flow in the reach between the two USGS gages appears to be derived from groundwater inflow and the lower Tuolumne River is generally considered to be a gaining stream[1] (CDWR 2004). A portion of the river flow is also derived from tributary inflows. In addition to Dry Creek (RM 16.4), which joins the lower Tuolumne River upstream of the USGS Modesto gage, minor and unmeasured natural surface inflows come from Gasburg Creek (RM 50.3), Dominici Creek (RM 47.8) and Peaslee Creek (RM 45.2). About 75 percent of the time these tributary inflows occur between December and March, in response to winter rain storm events. Urban and agricultural runoff as well as operational spills from irrigation canals flowing into the river and riparian pumping from the river also contributes to changes in river flow between the two USGS gages.

[1] A gaining stream is a stream whose flow rate increases in the downstream direction, often as a result of groundwater inflows.

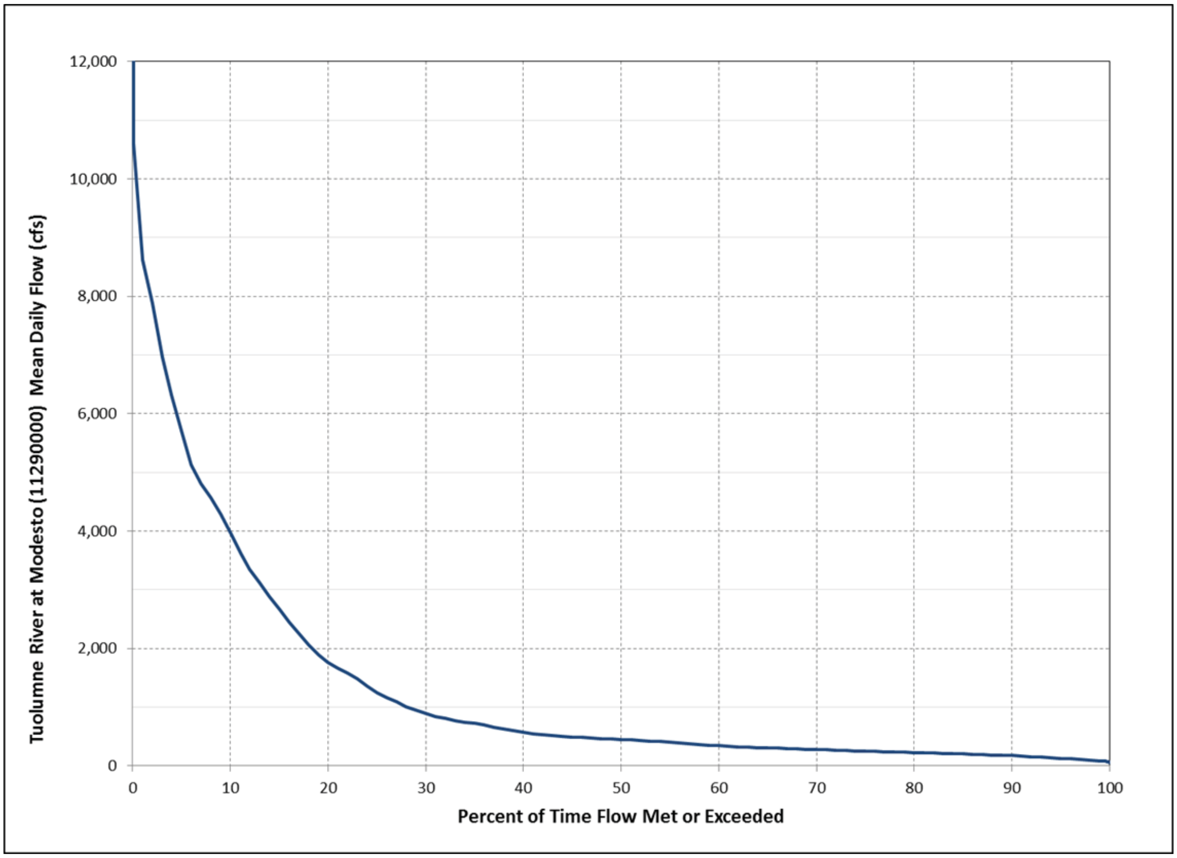


Figure 3.2-1. **Flow exceedance at USGS Gage 11290000 Tuolumne River at Modesto CA, WY 1971 to 2012.**

4.0 METHODOLOGY

4.1 Hydraulic Model Development

A detailed hydraulic model for 52 miles of in-channel and floodplain areas along the lower Tuolumne River was developed using the best available topographic and bathymetric data. A model platform was chosen that allowed for river-wide modeling while at the same time facilitating detailed modeling for complex features and local riverine hydraulics present in the study area such as ponds, pools, narrow flow paths connecting river and overbanks, flow paths connecting overbank ponds, and hydraulic structures like culverts and weirs. Given the study objectives, the TUFLOW modeling platform was chosen to provide accuracy while also providing efficient model run time.

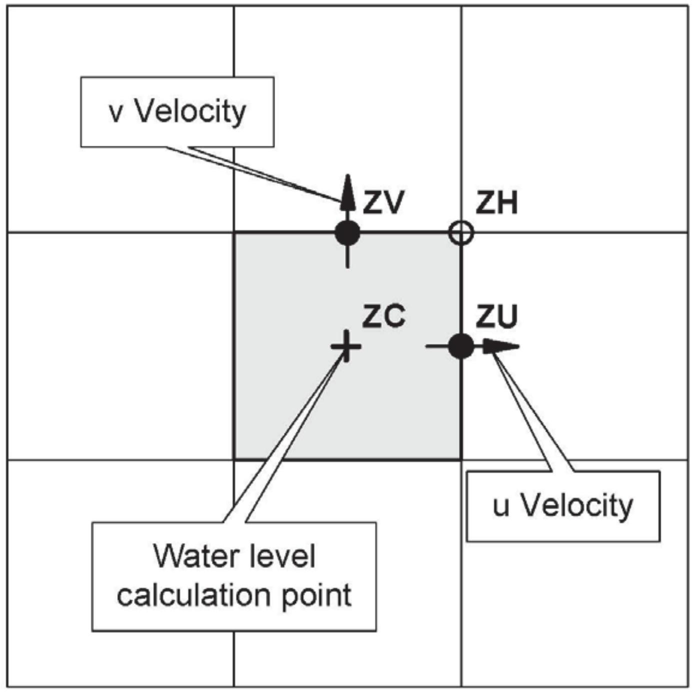
4.1.1 Hydraulic Model Software

TUFLOW Classic (TUFLOW), a propriety model developed by BMT WBM (BMT Group Ltd. 2013), was chosen to model the channel and overbank hydrodynamics along the lower Tuolumne River. TUFLOW simulates the complex hydrodynamics of channel and overbank through dynamic linking of the solutions of the full one-dimensional (1D) St. Venant equations for in-channel flow and full two-dimensional (2D) free-surface shallow water equations in the overbank regions. TUFLOW uses square computational cells (cells) to represent computational domain. Figure 4.1-1 shows the grid, computational points and a typical 1D-2D model divide used in the TUFLOW model.

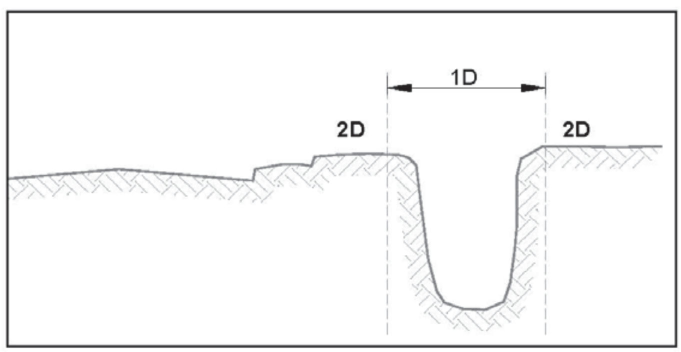
The TUFLOW version used for the study was the 64 bit, double precision version TUFLOW.2013-12-AC-w64. Surface-water Modeling System (SMS) software developed by Aquaveo, LLC was used for visualizing TUFLOW output. SMS version 11.1.10 (Build date: November 06, 2013) was used for the study.

4.1.2 Topographic and Bathymetric Data

A Digital Terrain Model (DTM) was created using the LP360 extension (QCoherent 2014) for ArcGIS to process LiDAR data collected March 30, 2012. Flows in the lower Tuolumne River were approximately 320 cfs at the time the LiDAR data were collected, as measured at USGS Gage 11289650 (Tuolumne River Below La Grange Dam Near La Grange, CA) (TID/MID 2013b). The DTM was created with a cell size of 3.125 ft based on a point density of 5.2 returns per square meter and a vertical root mean square error (RMSEz) of 0.15 ft as defined in the associated LiDAR accuracy assessment report (Photo Science 2012). The LiDAR data define overbank land surface geometry and channel geometry to the water surface elevation at the time of data collection. The remaining bathymetric channel data were collected from additional sources (see Table 4.1-1 below).



Location of Zpts and Computation Points



Modelling a Channel in 1D and the Floodplain in 2D

Figure 4.1-1. TUFLOW grid and 1D-2D boundary (TUFLOW Manual 2010).

4.1.3 Model Spatial and Temporal Resolution

TUFLOW computational cell size can be changed to meet specific requirements posed by the hydraulics of the study site and intended application. The size of the cell directly affects computational accuracy and computational effort. For a given model extent, a smaller cell size results in more accurate hydraulic computations but may be computationally expensive (model would require much longer run times). Conversely, a bigger cell size would result in faster model run times but less accurate results. A cell size sensitivity analysis was completed to determine optimal cell size for the study and its intended applications.

At the early stages of the study, the sensitivity of flow hydraulics and habitat analysis to cell size was evaluated using a test reach spanning RM 50 to RM 47 (Attachment B). This reach, which contains complex overbank features such as ponds, pools, narrow flow paths connecting river and overbanks, and flow paths connecting overbank ponds, represents the complexity of the study area well. Water level data for this reach were available for a steady flow of 3,000 cfs from the Pulse Flow Study (Stillwater Science 2012). Sensitivity test model runs were made for cell sizes of 10, 20, 30, 40 and 50 feet square. Hydraulic and habitat results were evaluated and compared for all five cell sizes (Tables 1, 2, and 3 in Attachment B).

The results indicated that a cell size of 30 x 30 ft would be optimal for the study area. Model development and calibration confirmed that the 30 x 30 ft cell size was optimal for producing accurate results and efficient model development and calibration.

TUFLOW model robustness and performance is measured by three key parameters: a time step that produces stable model runs, the absence of excessive negative depths at cells during calculations, and mass errors less than 1 percent of total volume. Regarding the first parameter, the time step for TUFLOW model hydraulic calculations (both 1D and 2D components) was selected before computations began. Time step directly affects model stability, model run time and the accuracy of results. The Courant stability criterion determines the limiting time step value. The computation time was set in accordance with this criterion as given in the TUFLOW Manual (2010). Given a cell size of 30 ft, the required time step for this project was between 2 and 5 seconds. All three models were progressively debugged to run at a 4 second time step for the 2D scheme and a 2 second time step for the 1D scheme. Regarding the second and third parameters, all model runs were stable with no negative depths at cells during calculations and mass errors were well below 1 percent of total volume.

4.1.4 Hydraulic Model Reaches

The lower Tuolumne River study area was divided into three reaches for modeling efficiency and accuracy of results (Figure 3.1-1):

- Model A – RM 51.7 to RM 40.0
- Model B – RM 40.0 to RM 21.5
- Model C – RM 21.5 to RM 0.9 (confluence with the San Joaquin River)

These reach extents define the applicability of each model's results to particular locations. To minimize boundary condition effects, the downstream limit of Model A was extended to RM 37.4 and the downstream limit for Model B was RM 20.5.

Model A falls within the gravel-bedded geomorphic reach regime (McBain & Trush 2000) and covers the area formerly occupied by dredger tailings reclaimed for use in the construction of Don Pedro Dam. This area includes two broad floodplain sites that were modeled in previous floodplain hydraulic assessments (Stillwater Sciences 2012): (1) downstream of New La Grange Bridge (RM 49–50) and (2) at Bobcat Flat (RM 43). River bathymetric data, available from RM 51.7 to RM 40.0, define the channel morphology for Model A.

Model B covers the remaining gravel-bedded regime upstream of Model C, extending from RM 40.0 to RM 21.5. Most of the channel geometry for Model B is based on cross sections surveyed by TID in 2014. These survey data were supplemented with existing data previously collected for IFIM modeling (Stillwater Sciences 2013).

The upstream extent of Model C is defined by the approximate start of the sand-bedded portion of the reach.

4.1.5 1D Channel – 2D Overbank Demarcation (1D-2D Boundary)

The delineation of the 1D/2D domain boundary between overbank and in-channel areas was an important component of the model development process as it defines what is considered to be overbank habitat for the rearing habitat analysis. The 1D/2D boundary was delineated with the objective of maximizing the area considered to be overbank and distinguishing between in-channel sections where 1D flow predominates and regions that provide additional seasonal habitat. This objective was based on the habitat analysis approach which incorporates the 2D velocity and depth results. The 1D/2D line defines the hydraulic control for TUFLOW. The 1D/2D domain boundary is shown in Attachment C. During Workshop No. 1, the criteria for delineating the 1D/2D boundary was presented to relicensing participants (Attachment A). On July 15, 2014, the Districts provided the draft TUFLOW 1D/2D model domain boundary to relicensing participants for review and comment. The Districts requested that all comments be provided by August 29, 2014. No comments were received.

4.1.6 Hydraulic Model Components

The TUFLOW model for this study has several components. A 1D channel was developed using cross sections from multiple sources, and validated using LiDAR flown during low flows. Overbank roughness coefficients were applied to the TUFLOW 2D scheme and refined during model calibration. Backwater pools connected to the river, large overbank ponds, levees, gullies, and hydraulic structures such as culverts and weirs are also represented in the model.

All the features were developed in a GIS format using ArcGIS 10.2 software (ESRI 2013). Automated tools were developed in Python 2.7 to perform labor intensive GIS tasks. The U.S. Army Corps of Engineers (ACOE) HEC-RAS model (Version 4.1) was used to develop cross-sectional input for the 1D components of each TUFLOW model. Separate 1D/2D TUFLOW and associated 1D HEC-RAS models were developed for each reach.

4.1.7 1D Channel Development

The 1D TUFLOW model components were developed using HEC-RAS, which simplified the geometry development processes and model calibration. HEC-GeoRAS, an ArcGIS extension tool, was used to develop model cross sections and facilitate combining multiple data sources into a single geometry. The HEC-RAS model output was evaluated, reviewed, and revised, if needed, based on 2014 survey data. Automated tools were then used to import the 1D geometry into the TUFLOW model.

4.1.7.1 Cross Section Development

Representative model cross sections were cut from the DTM developed from the March 2012 LiDAR data collected during flows of approximately 320 cfs. The cross section end points were bounded by the 1D/2D domain boundary. Bathymetric data were required to supplement the LiDAR surface below the 320 cfs water surface elevation (Table 4.1-1). A map of model cross sections identified by data source is provided in Attachment C.

Table 4.1-1. Hydraulic model 1D channel data sources.

River Mile	Data Source	Basis for Collection
51.7 to 29.0	Stillwater Sciences (2012 and 2013)	Cross section data at select sites collected for IFIM modeling (Stillwater Sciences 2012 and 2013).
51.2 to 45.5	TID/MID (2013b).	2012 Bathymetric Data. Bathymetry created using ADCP at flows ranging from 650 to 2,100 cfs May, 2012 for the Spawning Gravel Study (W&AR-04).
48.0 to 24.0	TID Field Survey 2014	Supplemental in-channel cross sections surveyed by TID in 2014 using Real Time Kinematic (RTK) GPS. Locations chosen to supplement other cross section data sources for purposes of this study.
45.5 to 37.9	McBain & Trush (2004a)	2005 Bathymetric Data. Bathymetric data originally collected for an update of the lower Tuolumne River Coarse Sediment Management Plan. A vertical shift was applied to the bathymetry data to match geoids with the 2012 bathymetry data (TID/MID 2013b) for this study.
39.9 to 33.6	HDR Field Surveys 2003-2006	Developed from the Ruddy Segment (RS 177300-21074) data developed by HDR Engineering between 2003 and 2006 for the Tuolumne River Floodway Restoration; survey files included stitched TIN surfaces originating from LiDAR and ground truthed bathymetric soundings. More than 100 transects were measured, anywhere from 50 to 100 ft apart. (AD Consultants et al. 2009).
31.5 to 14.0	HDR Field Survey 2012	Field Survey collected every half mile in support of the W&AR-16 Lower Tuolumne River Temperature Model (TID/MID 2013d).
25.9 to 24.4	McBain & Trush (2004b)	Data collected for the lower Tuolumne River Floodway Restoration.
16.1 to 16.4	USGS (2014a, 2014b)	Geometry of three cross sections used to develop rating curves for USGS Gage 11290000. Cross section data are from 2009 to 2014.
13.8 to 6.7	FEMA (2013)	Developed for FEMA HEC-RAS modeling of the lower Tuolumne River and Dry Creek.
6.3 to 0.9	CDWR (2014)	Developed for the HEC-RAS models developed for the CDWR Central Valley Flood Evaluation and Delineation (CVFED) program.

1D model cross sections were placed at locations to capture the pools, constrictions or expansions in river width, islands, riffles and other identifiable changes in gradient within the river that have potential to have significant hydraulic impact. Cross sections were placed at a higher density in high gradient sections.

4.1.7.2 Channel Roughness Coefficients - Manning's 'n'

1D in-channel roughness was estimated based on channel substrate, channel irregularity, cross-section variation, obstructions, aquatic vegetation, and sinuosity (Cowan 1956). Substrate measurements were taken during spawning gravel surveys (TID/MID 2013b) and the coarse sediment study (McBain & Trush 2004a). A reach average D_{84} of 58 mm, based on the set of measurement locations, was used to estimate the base 'n' value of 0.0198 based on USGS Water-supply Paper 1898-B (Limerinos 1970). Modifiers for irregularity, cross sectional changes, and vegetation resulted in a final channel Manning's 'n' value of 0.04 for the reaches upstream of RM 23. Dense riparian vegetation within the 1D boundary was assigned a roughness value of 0.08 based on comparison to reference photos in USGS Water-supply Paper 2339 (Arcement and Schneider 1989).

4.1.7.3 Cross Section Processing

Using the HEC-GeoRAS extension, cross sections were cut from the DTM and then supplemented with the in-channel bathymetric geometry. Output from HEC-RAS model runs at 320 cfs (steady state) was compared to the water surface profile developed from the 2012 LiDAR water return points along the river centerline. Locations requiring additional survey data were identified based on discrepancies between measured and modeled water surface elevations. This iterative process of data collection and cross section revision was used to develop the 1D geometry such that model channel hydraulics adequately matched the 320 cfs profile.

4.1.8 2D Overbank Component Development

The TUFLOW model consists of dynamically linked 1D and 2D components which solve separate hydraulic equations on each side of the 1D/2D domain boundary and provide continuous results across the boundary. The cross sections developed in HEC-RAS provided the required data for the 1D TUFLOW model component. Some additional inputs required for the TUFLOW 2D solution include the gridded model elevation data developed from the DTM, the overbank Manning's 'n' roughness coefficients, boundary conditions, and model run-time parameters.

4.1.8.1 Model Geometry Development

The lateral boundary of the input geometry extends to approximately the 100-yr floodplain to provide adequate coverage for all study flows. The DTM was created using only the bare-earth ground return points from LiDAR surveys conducted in 2012 and did not contain bathymetric data for off-channel ponds, backwaters, and side channels. These features were identified, processed and added to the TUFLOW model as described in the following sections.

4.1.8.2 Ponds and Pools

Ponds, backwater areas, and side channels considered to have little impact on model hydraulics because of limited or no hydraulic connection with the main channel were assigned an elevation 0.2 ft below the water surface elevation at the time the LiDAR was flown to ensure behavior as a sink, an area surrounded by higher elevation that acts to collect water.

To supplement the DTM, bathymetric surfaces were developed for backwater areas and side channels within the 2D domain with considerable interconnectivity to the 1D main channel. The supplemental bathymetric surfaces were developed using several data sources (Table 4.1-2). Side channels were created by connecting bathymetric points into a Triangular Irregular Network (TIN) with breaklines added to increase the triangle density of the surface where necessary for topographic accuracy. The final TIN was then exported with the model grid size of 3.125 ft and incorporated into the DTM.

Table 4.1-2. Hydraulic model bathymetric data sources.

River Mile	Feature Type	Data Source
50.0	Backwater	2012 Bathymetric Data (TID/MID 2013b)
45.3	Backwater	2005 Bathymetric Data (McBain & Trush 2004a)
44.4	Backwater	2005 Bathymetric Data (McBain & Trush 2004a)
43.3	Backwater	2005 Bathymetric Data (McBain & Trush 2004a)
40.4	Backwater	2005 Bathymetric Data (McBain & Trush 2004a)
45.2 to 44.3	Side Channel	2005 Bathymetric Data (McBain & Trush 2004a), Stillwater IFIM Studies (Stillwater Sciences 2012 and 2013), TID Field Survey 2014
43.4 to 42.8	Side Channel	2005 Bathymetric Data (McBain & Trush 2004a), TID Field Survey 2014
42.5 to 42.3	Side Channel	2012 LiDAR (Photo Science 2012)
40.4 to 40.3	Side Channel	2005 Bathymetric Data (McBain & Trush 2004a)
36.7	Side Channel	TID Field Survey 2014
30.8 to 31	Side Channel	TID Field Survey 2014
30.6	Backwater	TID Field Survey 2014
16.2	Dry Creek	FEMA Study 2014

4.1.8.3 Overbank Roughness Coefficients – Manning’s ‘n’

Roughness coefficients, or Manning’s ‘n’ values, represent flow energy friction losses and were defined using a geospatial dataset. Manning’s ‘n’ values were derived from land cover and land use data for the entire study area. The riparian vegetation shape file developed as part of the Lower Tuolumne River Riparian Information and Synthesis Study (TID/MID 2013a) provided cover information for most of the natural areas adjacent to the main channel and much of the natural floodplain. Delineation of urban, rural residential and agricultural areas was obtained from CALVEG land use data (USDA 2014) to supplement the riparian cover.

A geospatial layer combining the Riparian Vegetation and CALVEG land use layers was updated through visual comparison against 2012 aerial imagery (USDA 2014). Vegetation and land use designations irrelevant to roughness determination were revised, removed, or merged into more appropriate categories. The final classifications of vegetation type or land use were associated with representative Manning’s roughness values estimated through interpretation of aerial photos, field photos, and river helicopter videography. The geospatial layer was used to assign Manning's 'n' values at all 2D model locations. In accordance with the recommendations of TUFLOW authors, the Manning's 'n' values were assigned based on Table 10-1 in report "Australian Rainfall & Runoff, Project 15" (Engineers Australia 2012). Land cover/ land use categories and associated Manning's 'n' values used for the overbank areas are provided in Table 4.1-3. Representative photos of cover and land use and associated Manning's 'n' values are provided in Attachment D.

Table 4.1-3. 2D overbank Manning's 'n' designations.

Roughness Value	Description
0.03	Smooth and flat – pavement
0.04	Bare earth with gravel or finer substrate
0.05	Some herbaceous vegetation, grass, or large cobbles
0.06	Backwater areas choked with Water Hyacinth, agriculture, or irregular bedrock
0.07	Sparse permanent vegetation or low lying shrubs
0.08	Oak woodland, cottonwood, or aspen with some canopy spacing
0.09	Dense young riparian vegetation
0.10	Permanent dense forest (riparian or upland)
0.15	Low density residential
0.20	Industrial/Commercial
0.35	High density residential or Industrial/Commercial

4.1.8.4 Levees, Embankments and Narrow Channels

Additional model layers were created to represent features such as levees, embankments, and gullies that would otherwise be poorly represented by 30 ft cells. The gully input feature of TUFLOW was used to define the elevation and width of narrow channels, natural low spots along ridges, narrow flow paths connecting river and overbanks, flow paths connecting overbank ponds and side channels bypassing the river. The ridge input feature was used to define levees, roadways and natural ridges.

4.1.8.5 Hydraulic Structures

Only hydraulic structures that severely constrict flows were modeled. Bridges were not explicitly modeled because river stages at the modeled study flows do not reach bridge chord elevations and increases in stage due to frictional effects of piers were considered negligible.

Model A

No structure was found to be significant enough to include in the model.

Model B

The 12 barrel culvert on the left overbank of the river near RM 38 was included in the model (Figures 4.1-2 and 4.1-3). The dimensions of the culverts were surveyed by TID in August 2014.

Figure 4.1-2. Culverts near RM 38 (Google 2013).

Figure 4.1-3. Culverts near RM 38 - Field survey by TID/HDR in 2014.

Model C

Dennett Dam, located near the City of Modesto (RM 16), was included in the model (Figures 4.1-4 and 4.1-5). This structure is a remnant metal sheet pile that acts to control water levels at low flows. Dennett Dam was surveyed in 2014 (FEMA 2014).

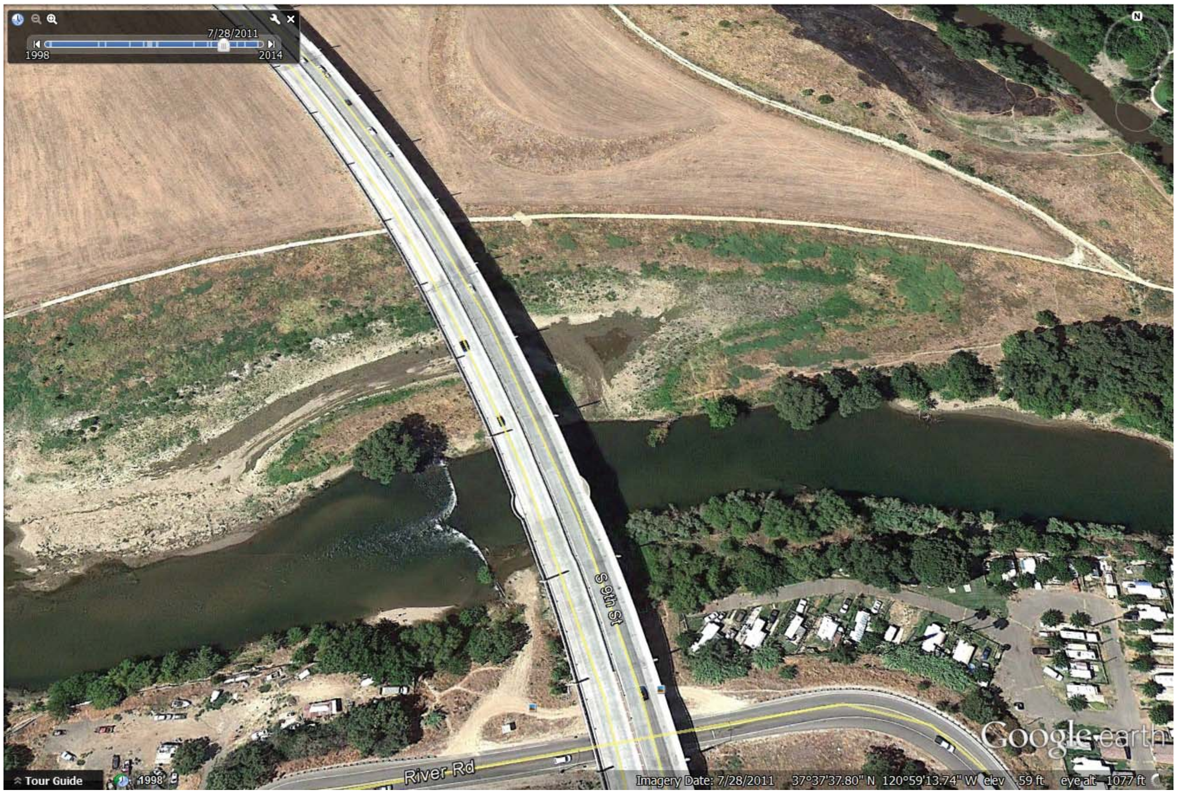


Figure 4.1-4. Dennett Dam near 9th Street Bridge in the City of Modesto (Google 2013).

Figure 4.1-5. Photo showing downstream face of Dennett Dam (FEMA 2014).

4.2 Hydraulic Model Boundary Conditions

The study plan called for 21 steady-state model runs: eight flows at 250 cfs intervals from 1,000 cfs up to 3,000 cfs, and 13 flows at 500 cfs intervals from 3,000 cfs to 9,000 cfs. The upstream boundary condition for all three models consists of a constant flow hydrograph for each of the study runs.

The downstream boundary condition for each model was different due to differences in bed slope. The bed slope of the Tuolumne River is relatively steep until approximately RM 31 and less steep from that point downstream to the confluence (Figure 4.2-1). This necessitated different approaches for Model A and Model B.

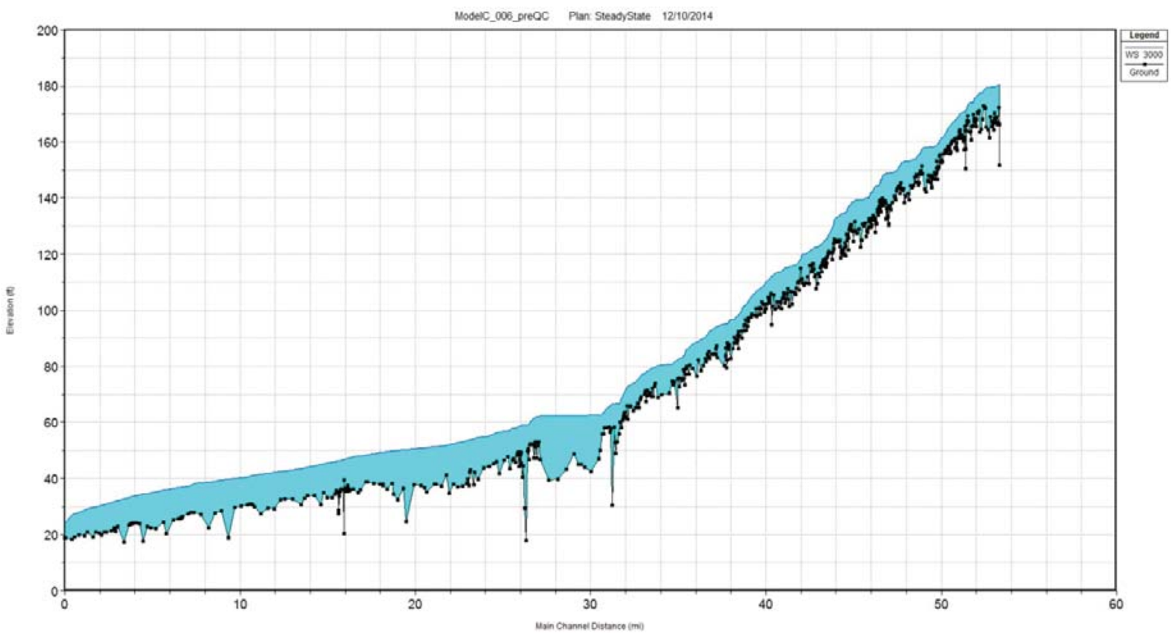


Figure 4.2-1. Bed slope of lower Tuolumne River.

4.2.1 Model A

The relatively steep bed slope in this reach allowed the use of a normal depth boundary condition by extending the model boundary downstream of RM 40 (the applicable downstream model extent) to RM 37.4, such that conditions at the boundary did not affect results at RM 40.

The boundary set-up included a 1D elevation-discharge rating curve developed from the associated HEC-RAS model and a normal depth rating curve for the 2D boundary computed by TUFLOW for a specified steep slope. A sensitivity analysis of the downstream boundary condition was performed for flows of 2,000 and 10,000 cfs (Figures 4.2-2 and 4.2-3). The analysis indicated that varying the 1D rating curve by as much as 5 ft has no impact on results at RM 40.0.

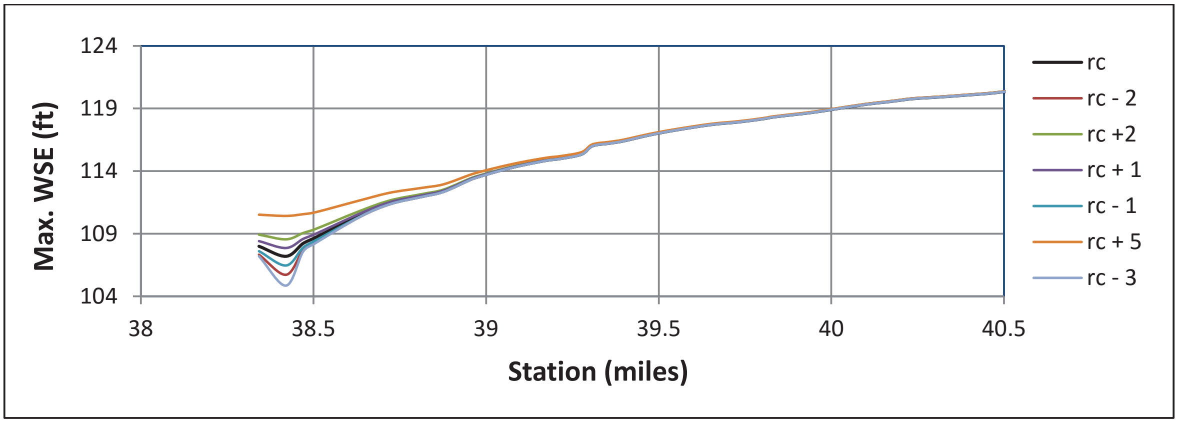


Figure 4.2-2. **Model A - Sensitivity analysis for the boundary condition rating curve at a steady flow of 10,000 cfs. In the legend, "rc" means boundary rating curve elevation and "-" or "+" means minus or plus feet of elevation. For example, "rc-2" means boundary rating curve elevation minus two feet.**

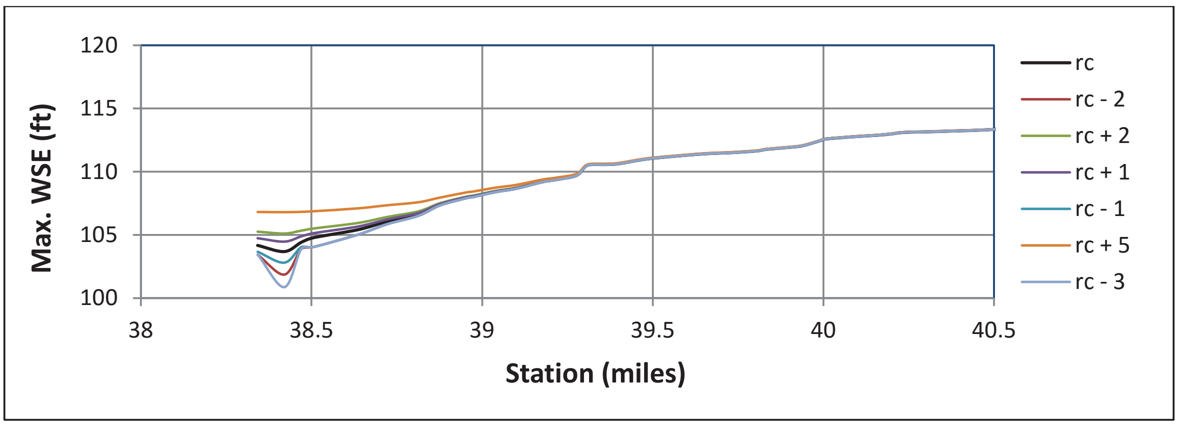


Figure 4.2-3. **Model A - Sensitivity analysis for the boundary condition rating curve at a steady flow of 2,000 cfs. In the legend, "rc" means boundary rating curve elevation and "-" or "+" means minus or plus feet of elevation. For example, "rc-2" means boundary rating curve elevation minus two feet.**

4.2.2 Model B

A normal depth boundary condition was not used for Model B due to the bed slope of this reach of the river. A sensitivity test indicated that boundary effects travel nearly 10 miles upstream, close to RM 31. Because of this, Models B and C were developed simultaneously. Model C was then used to develop an elevation-discharge rating curve for use in Model B. By following this process, differences in results at the model boundaries of B and C were avoided. Figure 4.2-4 shows the rating curve developed for Model B.

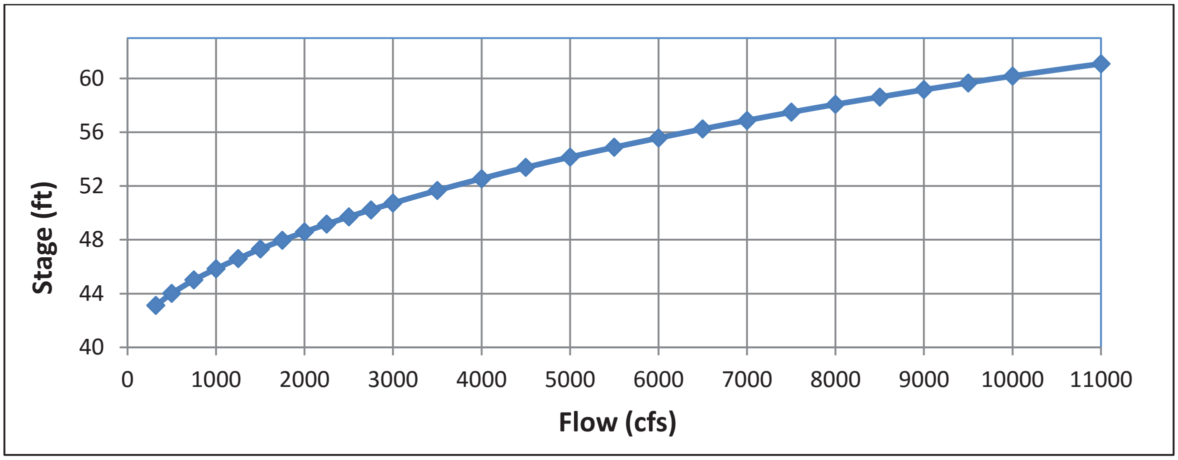


Figure 4.2-4. Model B - Boundary condition rating curve.

4.2.3 Model C

Model C captures the confluence of the lower Tuolumne River with the San Joaquin River. The water surface elevation at the confluence (the boundary condition for Model C) is heavily influenced by the combination of flows in the two rivers.

Backwater effects from the San Joaquin River were determined by an extensive hydrologic and hydraulic analysis (Attachment E). The analysis showed that the potential backwater effects from the San Joaquin River could extend up to approximately RM 13 for the range of flows used in this study. The backwater analysis yielded an elevation-discharge rating curve for the Model C downstream boundary condition (Figure 4.2-5).

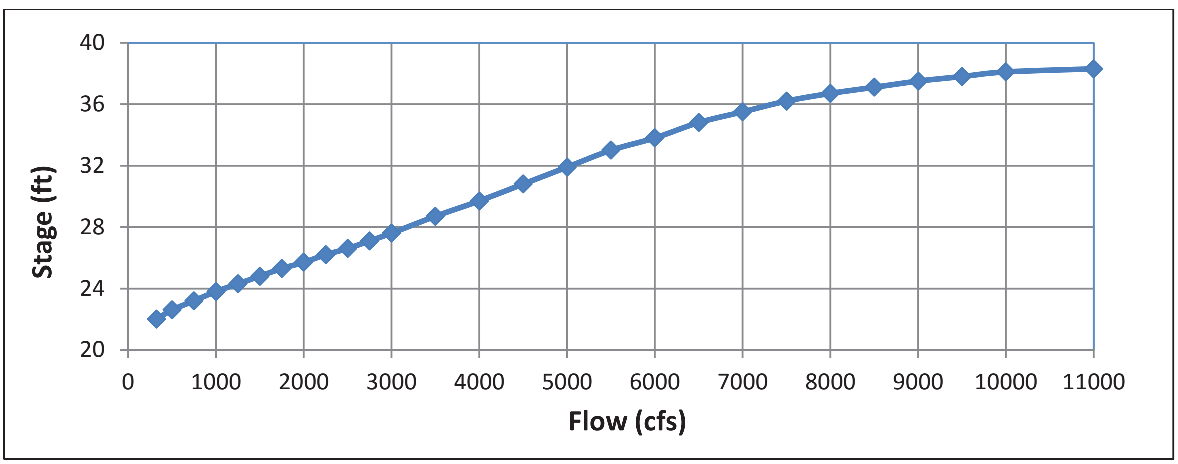


Figure 4.2-5. Model C - Boundary condition rating curve.

4.3 Hydraulic Model Calibration and Validation

The hydraulic model was calibrated and validated to observed physical data such as historical flood inundation extents, high water marks, stage and flow measurements at gaging stations, and other observed stage and flow measurements (Table 4.3-1).

Table 4.3-1. Calibration and validation data.

No.	Data Source
1	USGS Gage 11289650 in the lower Tuolumne River below La Grange Dam near the upstream limit of Model A at RM 51.5
2	Measured water levels for a constant 3000 cfs flow between RM 50 and RM 43 from Pulse Flow Study (Stillwater Sciences 2012)
3	USGS Gage 11290000 in the lower Tuolumne River near City of Modesto in Model C near RM 16
4	Aerial imagery of inundation extents for multiple near-steady flows from Google Earth Pro, Version 7.1.2.2041 (Google 2013)
5	Historic aerial imagery (TID/MID 1997) of inundation extents for multiple near-steady flows collected in 1993 and 1995

4.3.1 Calibration Methodology

The calibration process followed these general steps:

(1) All available calibration data were thoroughly evaluated for quality and applicability.

(2) Significant morphological changes in the river and floodplain between 1993 and 2012 were noted. Identifying and understanding these changes was crucial to establishing calibration data. Locations of morphological changes are identified in Attachment F.

(3) Reaches were calibrated at multiple calibration flows such that each model was calibrated for the entire range of study flows (1,000 – 9,000 cfs).

(4) Flows less than 1,000 cfs were used to calibrate the 1D low flow channel.

(5) To adequately calibrate the 1D channel capacity, calibration flows were selected that exited the channel and entered the floodplain.

(6) Flow travel time was taken into account when interpreting flows associated with aerial images.

(7) The contribution of Dry Creek just upstream of the Modesto gage was taken into account when interpreting flows and associated aerial images.

(8) Model components and parameters were refined without affecting their consistency and reasonableness. This typically included:

- adding cross sections at hydraulic controls that were not obvious;
- obtaining additional field data on split-flow locations and other troublesome areas identified during model runs;
- capturing small islands located in the river that are hydraulically significant using additional cross sections;
- adjusting Manning's 'n' of the 1D channels and 2D overbanks;

- adjusting the 1D-2D line;
- adding and/or adjusting narrow channels and levees to improve flow paths and connections; and
- adjusting the weir coefficient of Dennett Dam.

(9) Models were calibrated by sub-reaches when necessary.

(10) Model reaches were validated using events that were not used for calibration to ensure acceptable performance across the range of study flows.

(11) The lower reach of Model B (below RM 30) and upper reach of Model C (from RM 21.5 to RM 13) were calibrated simultaneously.

4.3.2 Model A Calibration Methodology

Model A was divided into five sub-reaches for calibration and validation. The divisions were based on characteristics of channel-floodplain interaction and local hydraulics. Table 4.3-2 describes the sub-reach extents, areas of interest related to important habitat included in each sub-reach, and the flow events used for calibration or validation at each location. Areas of interest occupying smaller portions of the sub-reaches are designated by the sub-reach number and a letter. Table 4.3-3 lists the historical aerials considered for calibration and validation, associated dates, approximate flows, and whether the data were used for calibration, validation, or limited validation only for each sub-reach location. Aerial imageries from 1993 and 1995 were used only for limited validation.

Measured water levels for a constant 3,000 cfs flow for a small reach between RM 50 and RM 43 from the Pulse Flow Study (Stillwater Sciences 2012) were used in conjunction with aerial images for validating the reach.

Calibration was required for three of the five sub-reaches as the other two reaches provided suitable hydraulic results without model revision. All five sub-reaches were validated.

Table 4.3-2. Model A - Calibration sub-reaches.

Calibration/Validation Sub-reach No.	USGS River Mile	Areas of Interest	Calibration Event No.[1]	Validation Event No.[1]
1	RM 51.6 to RM 48.5	Riffle 4A/4B	2, 6	3, 9
1A	RM 50	Side Channel	--	4
2	RM 48.5 to RM 46	Riffle 5A (Basso Bridge)	1	3, 6, 9
3	RM 46 to RM 44	Zanker Property	6	1, 3, 9
4	RM 44 to RM 42	Bobcat Flat	--	1, 3, 6, 9
4A	RM 43	Bobcat Flat Restoration	--	7, 8
5	RM 42 to RM 40	--	--	3, 6
5A	RM 42 to RM 38	--	--	1, 5

[1] See Table 4.4-3 for calibration and validation event descriptions associated with each number.

Table 4.3-3. Model A - Calibration and validation data.

Event No.	Date	Flow (cfs)	Calibration Sub-reach Number[1]	Validation Sub-reach Number[1]	Limited Validation
1	June 11, 2005[2]	4,030	2	3, 4, 5A	--
2	June 29, 2005[2]	2,680	1	--	--
3	February 23, 2006[2]	1,590	--	1, 2, 3, 4, 5	--
4	May 24, 2009[2]	490	--	1A	--
5	April 24, 2010[2]	1,960	--	5A	--
6	May 30, 2010[2]	2,040	1, 3	2, 4, 5	--
7	June 13, 2010[2]	5,400 to 6,000	--	4A	--
8	June 16, 2011[2]	5,900 to 5,000	--	4A	--
9	July 24, 2011[2]	1,020	--	1, 2, 3, 4	--
10	October 7, 1993[3]	3,100	--	--	All sub-reaches
11	February 16, 1995[3]	5,300	--	--	All sub-reaches
12	April 22, 1995[3]	8,400	--	--	All sub-reaches

[1] See Table 4.4-2 for sub-reach descriptions.
[2] Google Earth Images.
[3] Aerial images from Report 96-14 in TID/MID 1997.

4.3.3 Model B Calibration Methodology

The 1D component of Model B was calibrated along with Model C using USGS Modesto gage information. Model B did not require any model revision based on aerial images referenced during the calibration process. Tables 4.3-4 and 4.3-5 provide the calibration and validation data used for Model B.

Table 4.3-4. Model B - Calibration and validation data – Google Earth Images.

S. No.	USGS River Mile	Approximate Steady Flow* / Image Date			
		654 cfs	2,130 cfs	2,620 cfs	4,050 cfs
1	RM 20 to RM 40	28-Jul-11[2]	24-Apr-10[2]	-	11-Jun-05[2]
2	RM 20 to RM 25			10-Feb-06[2]	

[2] Validation data.
* Previous day average flow to account for travel time from USGS La Grange gage.

Table 4.3-5. Model B - Validation data – TID/MID Images.

S. No.	USGS River Mile	Approximate Steady Flow* / Image Year		
		3,100 cfs	5,300 cfs	8,400 cfs
2	RM 20 to RM 40	1993[3]	1995[3]	1995[3]

[3] Limited validation.
* USGS La Grange gage.

4.3.4 Model C Calibration Methodology

Model C was calibrated in two stages; the reach above RM 13 (which is free of any backwater effects from the San Joaquin River) was calibrated separately from the reach below RM 13. Tables 4.3-6 and 4.3-7 provide the calibration and validation data used for Model C.

Table 4.3-6. Model C - Calibration and validation data – Google Earth Images.

S. No.	USGS River Mile	Approximate Steady Flow* / Image Date		
		900 cfs	3320 cfs	4130 cfs
1	RM 0.88 to RM 16	28-Jul-11[1]	-	11-Jun-05[2]
2	RM 12 to RM 16		10-Feb-06[2]	

[1] Calibration data.
[2] Validation data.
* USGS Modesto Gage (near RM 16).

Table 4.3-7. Model C - Validation data – TID/MID Images.

S. No.	USGS River Mile	Approximate Steady Flow* / Image Year
		8322 cfs
1	RM 0.88 to RM 21.5	22-Apr-95[3]

[3] Limited validation.
* USGS Modesto Gage (near RM 16).

The reach of Model C between the USGS gage near Modesto (upstream of the confluence with Dry Creek) and RM 21.5 was validated using the data in Tables 4.3-4 and 4.3-5 of Model B, due to the possibility that this reach may be affected by inflows from Dry Creek.

Figure 4.3-1 shows the comparison of TUFLOW model results with the USGS Modesto gage rating curve and the USGS flow measurements at the gage.

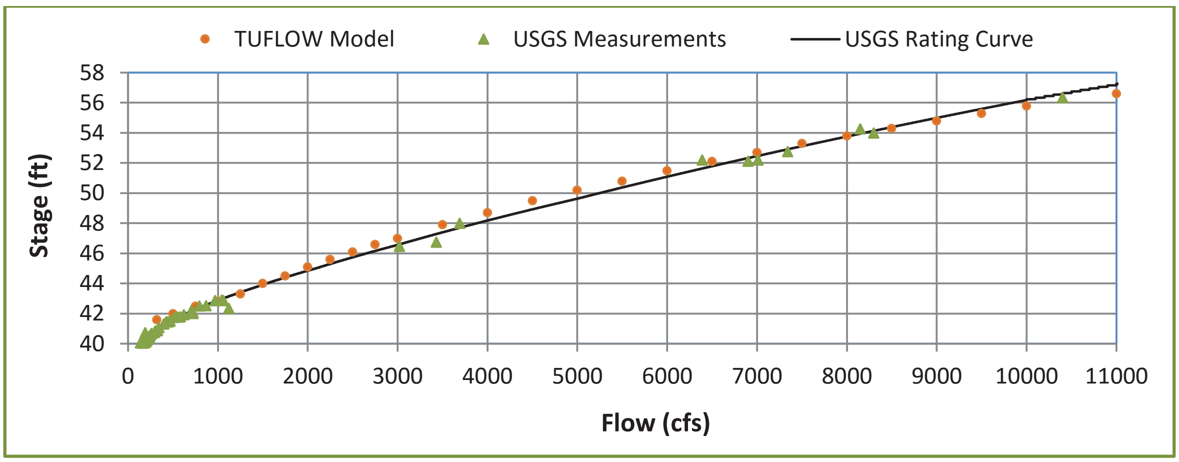


Figure 4.3-1. Model C - Calibration comparison at USGS Gage near Modesto.

4.4 Fish Habitat Suitability Analyses

Habitat Suitability Criteria (HSC) for juvenile life stages of Chinook salmon and *O. mykiss* were selected as part of the completed Instream Flow Incremental Method (IFIM) study (Stillwater Sciences 2013) during workshops held on September 20, 2010, October 20, 2010, and February 3, 2011. So called "Envelope" HSC curves, representing a range of suitable depths and velocities on the lower Tuolumne River, were developed for Chinook salmon fry (Aceituno 1990; USFWS 1988, 2010a), Chinook salmon juveniles (Aceituno 1990), *O. mykiss* fry (Hampton 1997; Moyle and Baltz 1985, TRPA 2004, and USFWS 2010b) and juvenile (TRPA 2000, USFWS 2004) life stages from selected references. The HSC workshop summaries and documentation for selected curves were filed electronically with FERC in the IFIM study progress reports on December 8, 2010 and July 29, 2011.

4.4.1 In-channel habitat suitability

To provide a comparison of the relative amounts of in-channel and floodplain habitat over a range of flows, TUFLOW modeling within the 1D model domain was conducted for flows from 500 cfs up to 9,000 cfs, with additional HEC-RAS model runs at flows of 100 cfs and 250 cfs. Model predictions of depth and velocity within each TUFLOW model grid cell were used to provide a cell-specific prediction of usable habitat area calculated as the product of cell area and a composite suitability index (CSI) for each species/life stage combination at the corresponding depth and velocity estimates. Total usable habitat area within the 1D model domain was calculated for each discharge as the sum of cell-by-cell usable habitat areas throughout the model domain. From the accumulated estimates of usable habitat area for each species/life stage combination, reach specific or river-wide relationships of in-channel usable habitat area vs. discharge are summarized.

4.4.2 Floodplain habitat suitability

The availability of suitable floodplain habitat for juvenile life stages of Chinook salmon and *O. mykiss* was based upon TUFLOW model predictions of depth and velocity as a function of discharge. Inundation area, velocity and depth predictions were made at 250 cfs intervals between 1,000 and 3,000 cfs and 500 cfs intervals between 3,000 cfs and 9,000 cfs, resulting in a total of 21 model runs. Computation of usable area estimates commonly used in PHABSIM analyses was completed in GIS using the following methodology:

(1) At each discharge, total inundated area was calculated by the sum of all modeled grid cells within the 2D domain that have a non-zero depth. Depth and velocity data were accumulated at every point within the 2D model domain.

(2) Usable habitat area for each cell was computed as the product of cell area and the CSI for each species/life stage combination at the corresponding depth and velocity estimates.

(3) CSI range from zero (unsuitable) to 1.0 (suitable) was calculated by the joint product of the appropriate fish HSC curve (depth or velocity) for an individual fish species/life stage combination.

(4) Total usable habitat area was the sum of cell-by-cell usable habitat areas throughout the model domain.

From the accumulated estimates of inundated area as well as usable habitat area for each species/life stage combination, reach specific or river-wide relationships of inundated area vs. discharge or usable habitat area vs. discharge are summarized. Areas within isolated portions of the floodplain created by topographic depressions, backwater areas and ponds, and that were inundated at the lowest flows modeled, were subtracted from the total and usable floodplain area estimates.

4.5 Area-Duration-Frequency Analysis for Base Case (WY 1971–2012) Hydrology

Using the estimates of fish habitat suitability vs. flow in combination with discharge records in the lower Tuolumne River, the quantity of seasonally inundated floodplain habitat may be estimated as a function of duration and frequency. Traditionally, flood frequency analyses are conducted from a record of annual maximum flows or other measures of floods using ranking methods or fitted to particular distributions to estimate probabilities of occurrence or annual return periods (Dunne and Leopold 1978). To determine the maximum continuous wetted area for periods of 1, 7, 14, 21, and 30 day durations, an area-duration-frequency (ADF) analysis was conducted as follows:

(1) Define flow "events" as a combination of discharge as well as duration. For a given flow 'q' and duration 'D', an "event of magnitude (q,D)" is defined as an interval of 'D' consecutive days (within a season of interest) during which mean daily flow is at least 'q'.

(2) Hydrology may be examined on an annual water-year basis, as well as periods representative of rearing periods of Chinook salmon (February through May) and *O. mykiss* juveniles (March through September).

(3) The "recurrence interval (in years) for an event of magnitude (q, D)" is defined as 'N/M', where 'M' is the number of years in which such an event occurred, out of the 'N' (=41) years of record (1971–2012).

(4) For each duration 'D' of interest, 'q' is plotted against the recurrence interval for events of magnitude (q, D).

To allow for examination of alternative scenarios in the current study, a synthetic hydrologic record was previously developed for "base case" conditions contained in the *Project Operations/Water Balance Model Study* (W&AR-02). The Base Case (1971–2012) depicts the operation of the Project in accordance with the current FERC license, ACOE flood management guidelines, and the Districts' irrigation and M&I water management practices since completion of Don Pedro Dam in 1971. Flow frequency and ADF relationships for the current study are based upon the Base Case hydrology.

5.0 RESULTS

5.1 Hydraulic Model Results

TUFLOW model simulations were carried out for 21 flows identified in the Study Plan, from 1,000 cfs to 9,000 cfs. Appropriate downstream boundary conditions were applied and the models were run at a time step of 2 seconds for the 1D component and 4 seconds for the 2D component for a sufficiently long period of time for the models to reach steady-state condition. Model results were thoroughly reviewed for consistency and reasonableness.

Hydraulic outputs were generated at a 15 ft cell size (half the cell size). TUFLOW computes water surface elevations at a model cell size of 30 ft and computes depth and velocity at the center of the cell. This enables TUFLOW to generate results at half the cell size. Outputs were generated in binary grid (flt extension) format which can be viewed and processed in ArcGIS and similar software. These results were used for habitat analysis.

Flood inundation extents for 21 steady flows for the study area are presented in the form of 20 animations (*.avi files) (Attachment G). Using SMS software, animations were developed for the entire study area except where flows were completely contained within the river and significant floodplain inundation was absent.

5.2 Fish Habitat Suitability Analyses

The TUFLOW model results were used to estimate total wetted area as well as usable habitat area within in-channel and floodplain habitats for juvenile life stages of Chinook salmon and *O. mykiss* as a function of flow. Attachment H provides plots comparing total wetted areas and usable habitat in both in-channel and overbank areas for each species/life stage combination as a function of flow within each of the three model reaches and as a river-wide estimate of usable habitat area variation with discharge. Attachment I provides color plots showing overall floodplain inundation at representative sites within each model reach as well as spatial variations in relative habitat suitability (0.0 to 1.0) for the identified species at several intermediate flows.

5.2.1 Floodplain Area vs. Discharge Relationships

Inundated floodplain areas for each of the three TUFLOW model reaches are shown in Figure 5.2-1 as a function of discharge. At the lowest flows modeled, substantial amounts of inundated area within isolated portions of the floodplain were created by topographic depressions and backwater areas (Attachment I). As mentioned in Section 3.1, these off channel ponds and topographic depressions have also been associated with increased incidence of stranding and entrapment of juvenile Chinook salmon (TID/MID 2001). As flows increase, habitat connectivity between ponded habitats and the main channel occurs. Model A (RM 51.7 – 40) shows the largest increase of inundated area with discharge, consistent with the presence of areas that were graded following reclamation of tailings piles during the construction of Don Pedro Dam. However, not all sub-reaches are inundated at the same flows. Although some overbank habitat is available over the length of the lower Tuolumne River, diked areas adjacent to off-channel mining operations within Model B (RM 40–21.5) limit the potential increase in floodplain inundation with increasing discharge. In contrast, and depending on the flow of the San Joaquin River, agricultural areas near the San Joaquin River confluence are subject to broad floodplain inundation at flows in excess of 6,000 cfs and Model C (RM 21.5–0.9) exhibits the highest modeled increase in inundation area with discharge at flows in excess of 8,000 cfs) (Figure 5.2-1).

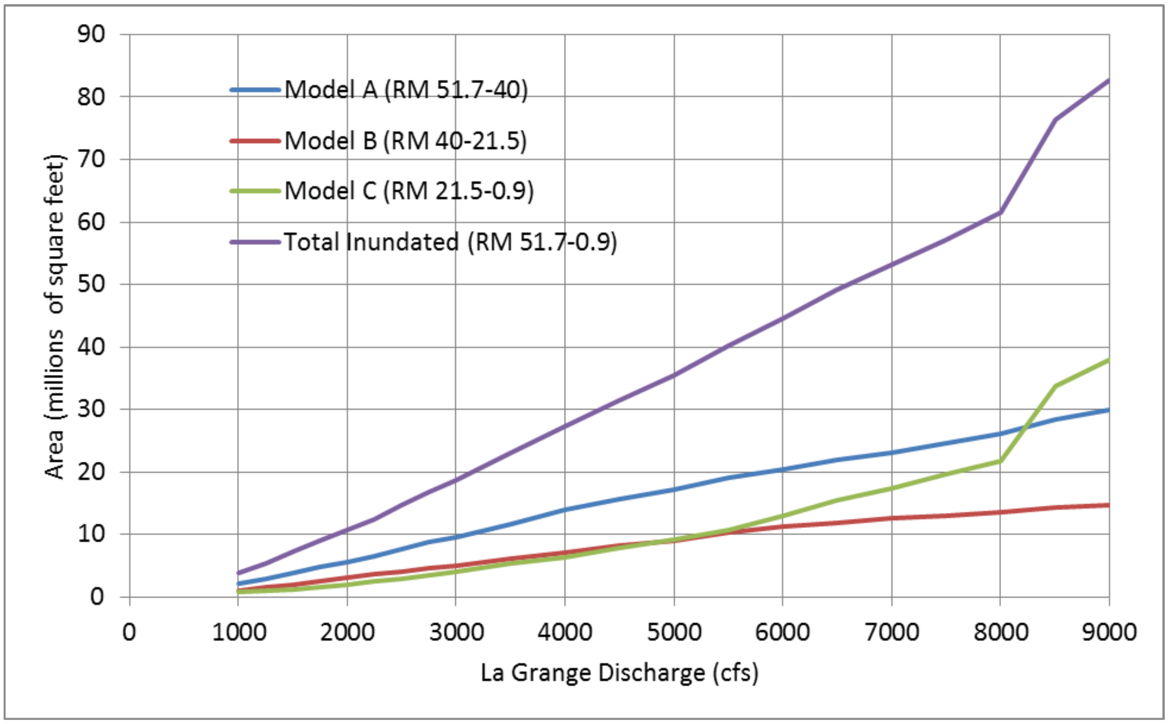


Figure 5.2-1. Total inundated floodplain area as a function of discharge within three modeled reaches of the lower Tuolumne River.

5.2.2 Usable floodplain habitat for juvenile Chinook salmon and *O. mykiss* rearing

Using GIS analysis of inundation areas developed from aerial photography conducted by the Districts (TID/MID 1997), the USFWS (2008) previously developed a report on flow-overbank inundation relationships for fall-run Chinook salmon and steelhead/rainbow trout (*O. mykiss*) juvenile habitat in the lower Tuolumne River. Although GIS analysis used for the development of the USFWS (2008) report excluded areas within isolated portions of the floodplain created by off-channel ponds, topographic depressions, and backwater areas, since habitat suitability for juvenile salmonid rearing was not estimated, flow vs. area relationships developed by the USFWS (2008) study over-estimated the amounts of potential habitat for salmonid rearing as a function of flow. As described below, habitat suitability criteria (HSC) for juvenile salmonids developed for the 2013 IFIM Study (Stillwater Sciences 2013) were used in combination with depth and velocity predictions to estimate total usable habitat as a function of flow.

Table 5.2-1 provides the results of habitat suitability modeling within floodplain areas of the lower Tuolumne River outside of the low flow (1D) channel boundary, with estimates of total available rearing habitat combining both in-channel and over-bank areas found in Attachment H.

At 1,000 cfs, inundated areas outside of the low flow channel boundary provide approximately 1.2 million ft^2 of usable habitat for Chinook salmon fry in Model A (RM 51.7–40.0), with lower amounts of 0.6 million ft^2 and 0.4 million ft^2 within Model B (RM 40–21.5) and Model C (RM 21.5–0.9), respectively. Estimates of usable overbank habitat expand rapidly at higher flows above bankfull discharge, with corresponding increases in habitat carrying capacity for rearing Chinook salmon. On a usable habitat area basis, over half of the usable habitat for Chinook salmon fry is located in the uppermost 12 miles of the lower Tuolumne River (Model A) at flows below 5,000 cfs. Usable habitat expands rapidly between 7,000 cfs and 9,000 cfs in the lowermost reach (Model C) due to backwater influences of the San Joaquin River, assuming simultaneous occurrence of high flows in both rivers.

Table 5.2-1. Hydraulic modeling results of total inundated and usable floodplain habitat for salmonid juveniles at selected flows in the lower Tuolumne River.

Modeled Flow (cfs)	1,000	2,000	3,000	5,000	7,000	9,000
Model A (RM 51.7-40) estimates of total inundated and usable rearing habitat areas (ft^2)						
Inundated Area	2,088,000	5,633,775	9,604,125	17,265,375	23,146,875	29,926,125
Chinook salmon fry	1,222,916	3,193,092	4,756,145	6,419,680	7,108,983	7,618,930
O. mykiss fry	1,741,791	4,318,501	6,639,330	9,167,501	10,124,053	11,863,551
Chinook salmon juvenile	703,341	2,961,988	5,562,806	9,963,276	12,904,300	14,726,723
O. mykiss juvenile	784,686	3,155,993	5,888,722	10,533,523	13,671,567	15,922,373
Model B (RM 40-21.5) estimates of total inundated and usable rearing habitat areas (ft^2)						
Inundated Area	1,059,525	3,055,725	5,024,700	9,061,875	12,527,100	14,743,125
Chinook salmon fry	617,099	1,609,146	2,089,023	2,789,931	2,971,408	2,392,190
O. mykiss fry	885,640	2,222,935	2,994,996	4,007,929	4,393,046	3,668,032
Chinook salmon juvenile	355,594	1,595,783	2,846,802	4,509,524	5,631,474	5,397,445
O. mykiss juvenile	372,266	1,693,502	3,044,601	4,906,282	6,394,684	6,497,518
Model C (RM 21.5-0.9) estimates of total inundated and usable rearing habitat areas (ft^2)						
Inundated Area	724,725	2,015,550	4,044,600	9,141,300	17,406,675	37,903,950
Chinook salmon fry	438,614	1,068,951	1,993,904	3,566,876	6,423,204	14,080,302
O. mykiss fry	616,325	1,506,680	2,757,012	4,971,681	8,765,927	19,833,137
Chinook salmon juvenile	333,783	1,082,079	2,174,819	4,469,145	7,945,966	19,178,555
O. mykiss juvenile	346,295	1,074,538	2,210,151	4,828,970	8,844,476	19,448,788
River-wide (RM 51.7–0.9) estimates of total inundated and usable rearing habitat areas (ft^2)						
Inundated Area	3,872,250	10,705,050	18,673,425	35,468,550	53,080,650	82,573,200
Chinook salmon fry	2,278,630	5,871,189	8,839,073	12,776,487	16,503,594	24,091,422
O. mykiss fry	3,243,756	8,048,116	12,391,338	18,147,111	23,283,027	35,364,719
Chinook salmon juvenile	1,392,718	5,639,850	10,584,427	18,941,945	26,481,740	39,302,723
O. mykiss juvenile	1,503,247	5,924,034	11,143,474	20,268,776	28,910,727	41,868,679

Recognizing that fry and juvenile rearing on floodplains is generally restricted to areas nearest the high flow channel margin, we can contextualize the usable habitat area estimates in terms of a maximum habitat carrying capacity using literature values for rearing density. For example, assuming a maximum density of 1.44 fry/ft^2 found in analyses by Grant and Kramer (1990) would correspond to a river-wide carrying capacity of 3.3 million Chinook fry at 1,000 cfs (i.e, (1.44 fry/ft^2 x 2.28 million ft^2 = 3.3 million fry). At 2,000 cfs, this would correspond to a carrying capacity of 8.5 million fry, with carrying capacity estimates of 12.7 million and 18.4 million at 3,000 cfs and 5,000 cfs, respectively.

Usable habitat for Chinook juveniles at 1,000 cfs, 3,000 cfs and 5,000 cfs is estimated to be 1.4 million ft^2, 10.6 million ft^2, and 18.9 million ft^2, respectively river-wide (Table 5.2-1), which would correspond to a carrying capacity of 0.6 million, 4.9 million, and 8.8 million juveniles using the same calculations as for fry at the maximum density of 0.465 juveniles/ft^2 found by USFWS (1991). Although corresponding estimates of usable habitat for juvenile *O. mykiss* are shown in Table 5.2-1 as a basis of comparison we do not provide a carrying capacity estimate. Floodplain habitat use by juvenile *O. mykiss* has not been observed on the lower Tuolumne River and regional observations of *O. mykiss* rearing on floodplains is limited to incidental observations from the Yolo bypass studies (Sommer et al 2001, USBR 2008) as well as more recent (2011) observations of Age 0 habitat use along higher elevation channel margin habitats created following gravel augmentation along the Lower American River (Sellheim et al 2015).

In addition to the results summary above, variations in total inundation areas as well as total usable area with flow for each of the salmonid life stages within each of the model reaches are depicted in Figure 5.2-2 through Figure 5.2-4, respectively, with spatial distribution of suitable habitat at representative sites shown in Attachment I. At the lowest flows modeled within Model A (RM 51.7–40), approximately 60 to 80 percent of total inundated area is usable by Chinook and *O. mykiss* fry, respectively (Figure 5.2-2). As flows increase, increased depths and velocities in the floodplain areas reduce suitability for fry life stages such that usable habitat falls to 25 to 40 percent of total inundated habitat at 9,000 cfs. Because of the greater swimming performance of juvenile salmonids as compared to fry life stages for a given depth or velocity, usable habitat area for juvenile rearing is approximately 50 to 60 percent of total inundated area at 2,000 cfs and above (Figure 5.2-2).

For Model B (RM 40–21.5), usable habitat area for fry life stages varies from 60 to 80 percent of total inundated habitat at 1,000 cfs, with a lower range of 15 to 25 percent of total inundated habitat at flows of 9,000 cfs (Figure 5.2-3). For juvenile life stages, usable habitat varies from a high estimate of 50 to 55 percent usable area out of total inundated habitat at 1,000 cfs and only 35 to 45 percent usable at flows of 9,000 cfs.

For Model C (RM 21.5–0.9), usable rearing habitat area at flows of 1,000 cfs varies from 60 to 80 percent of total inundated habitat for fry and 50 to 55 percent of total inundated habitat for juveniles (Figure 5.2-4). Although the inundated area increases rapidly at the highest flows modeled due to presence of low gradient agricultural areas and backwater effects of the San Joaquin River confluence, the fraction of usable habitat for rearing at 9,000 cfs decreases to 35 to 50 percent of total inundated habitat for fry and 45 to 50 percent of total inundated habitat for juveniles. It should be noted that floodplain inundation in the areas nearest the San Joaquin River is strongly influenced by San Joaquin River discharge and backwater effects (Section 4.2.3).

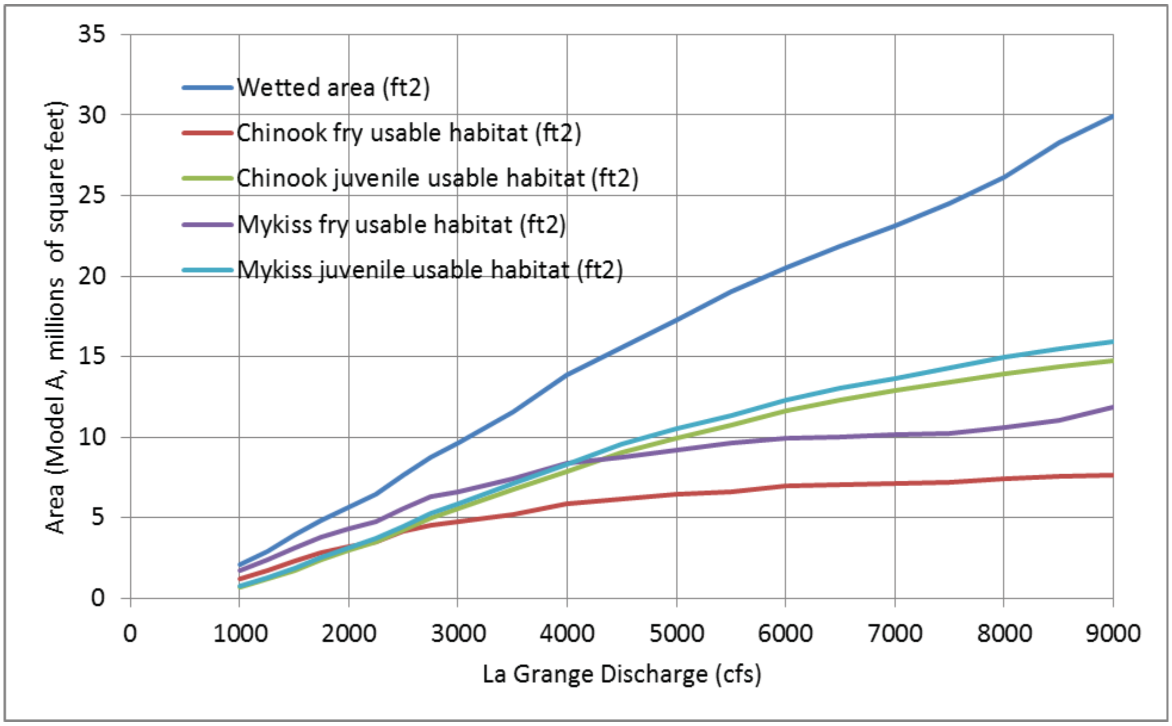


Figure 5.2-2. Model A results showing total wetted and usable habitat areas for juvenile salmonid life stages in the lower Tuolumne River (RM 51.7–40).

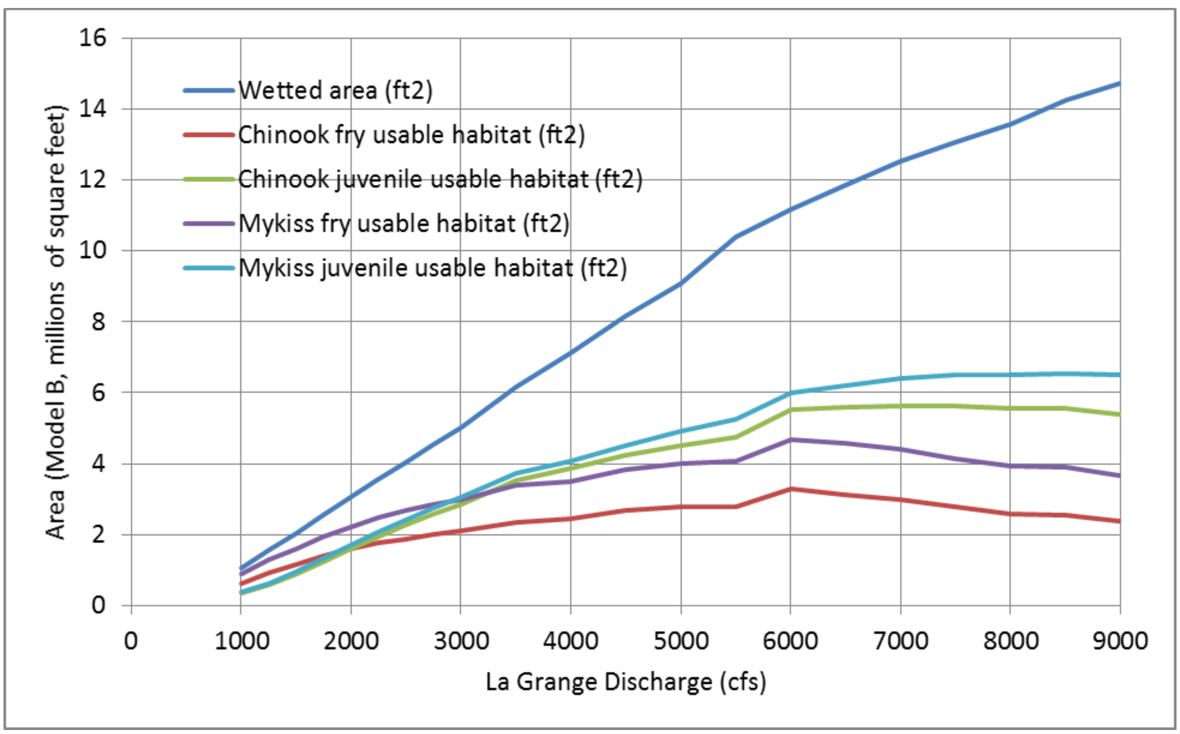


Figure 5.2-3. Model B results showing total wetted and usable habitat areas for juvenile salmonid life stages in the lower Tuolumne River (RM 40–21.5.)

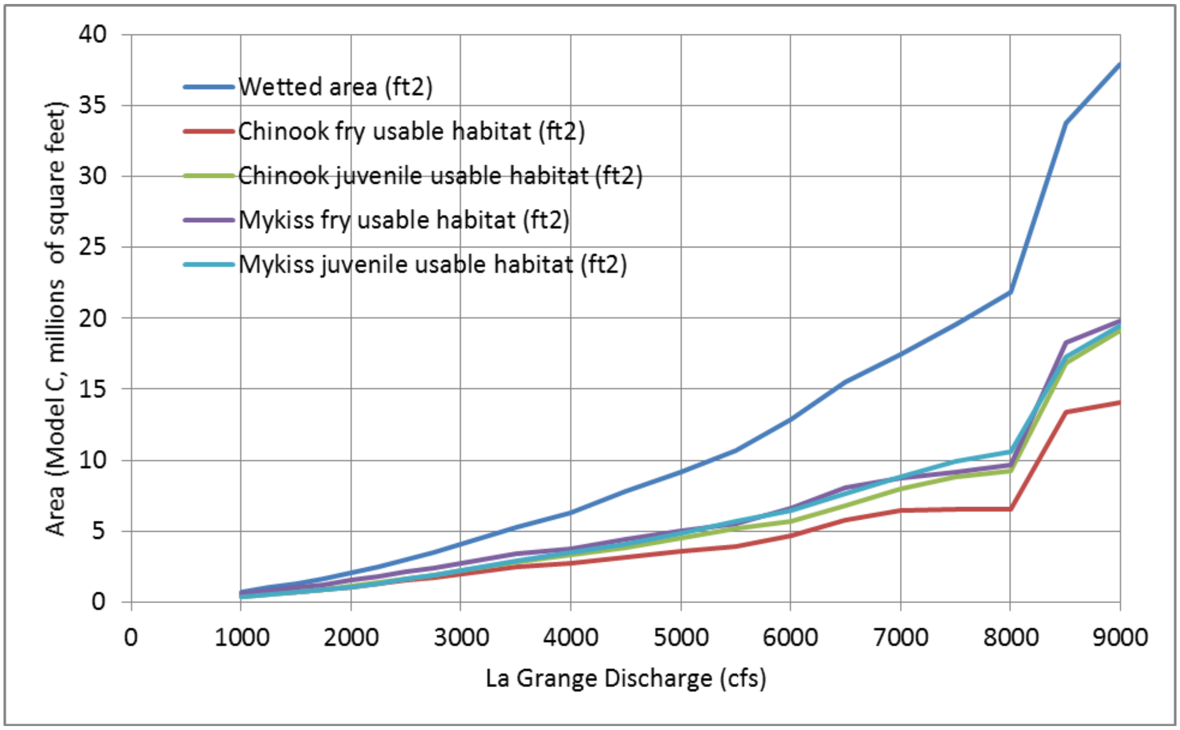


Figure 5.2-4. Model C results showing total wetted and usable habitat areas for juvenile salmonid life stages in the lower Tuolumne River (RM 21.5–0.9).

5.3 Area-Duration-Frequency Analysis for Base Case (WY 1971–2012) Hydrology

5.3.1 Flow Frequency Analysis

Using the Base Case (WY 1971–2012) hydrology from the *Project Operations/Water Balance Model Study* (W&AR-02), an annual exceedance frequency analysis of flow events combining discharge magnitude and duration was conducted. Although flow frequency analyses traditionally use annual hydrology records, we have analyzed the discharge duration-frequency from February through May, months relevant to juvenile Chinook salmon rearing (TID/MID 2013e). Figure 5.3-1 shows the annual recurrence period for these events capturing various flows and durations occurring during the spring time juvenile rearing period for Central Valley Fall-run Chinook salmon. To examine conditions for any rearing Central Valley Steelhead as well as resident *O. mykiss* in the lower Tuolumne River, Figure 5.3-2 shows the annual recurrence period for discharge-duration events occurring between March and September.

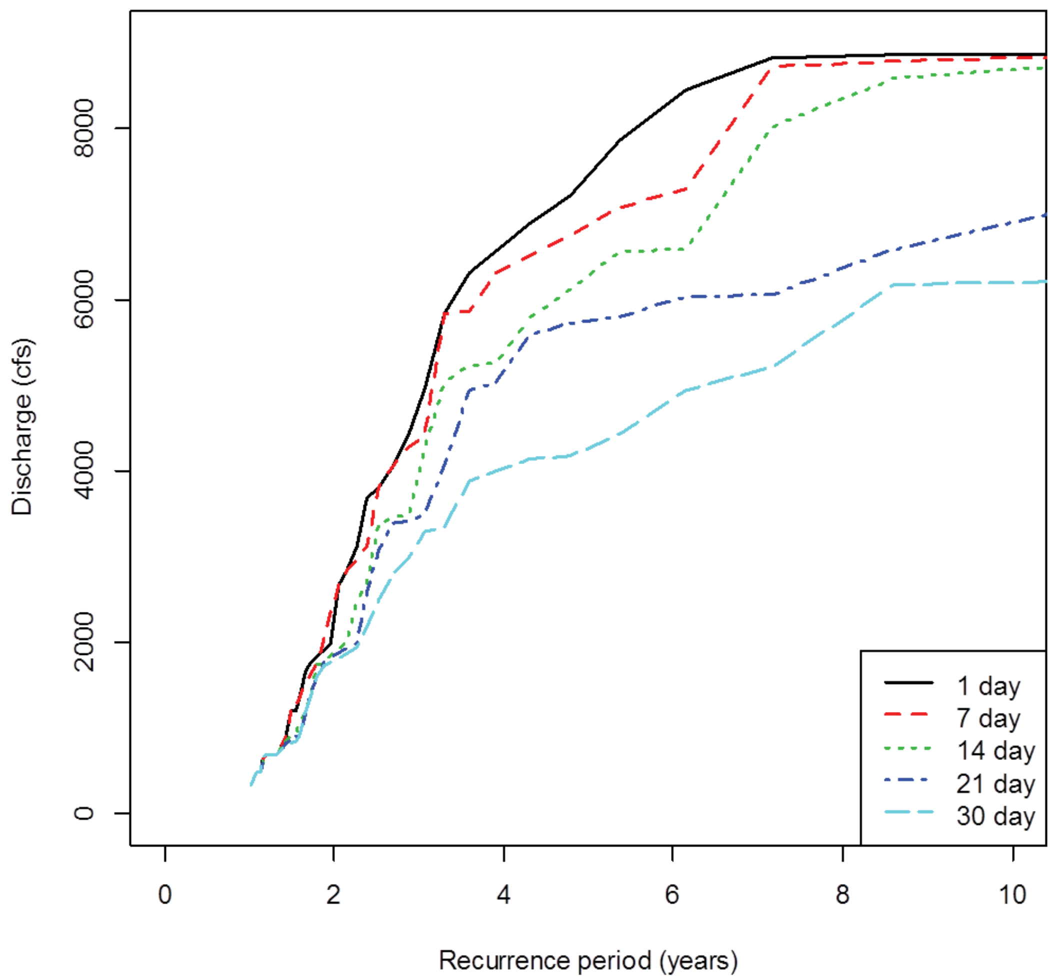


Figure 5.3-1. **Annual frequency with which "events", exceeding given flow magnitude and duration thresholds, occur in the lower Tuolumne River from February through May under Base Case (1971–2012) hydrology.**

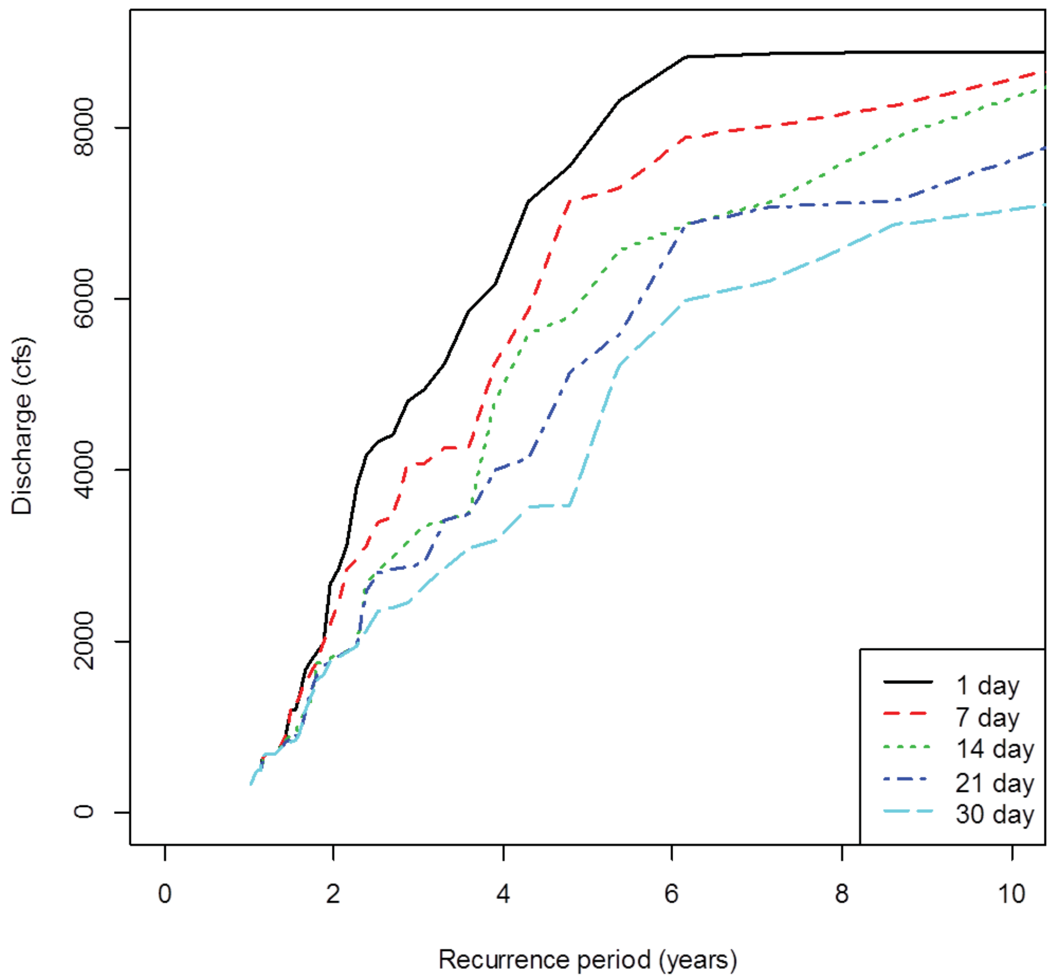


Figure 5.3-2. Annual frequency with which "events", exceeding given flow magnitude and duration thresholds, occur in the lower Tuolumne River from March through September under Base Case (1971–2012) hydrology.

5.3.2 Juvenile Chinook salmon floodplain rearing habitat

The potential benefits of general floodplain rearing for juvenile Chinook salmon have been highlighted in recent reports from the Yolo Bypass (Sommer et al. 2001, 2005) and the lower Cosumnes River floodplain (Jeffres et al. 2008). By comparison to the 60,000 acre Yolo Bypass, potentially inundated floodplain areas on the lower Tuolumne are small and would amount to less than 2,000 acres even at the highest flows (i.e., 9,000 cfs) modeled (Table 5.2-1). Nevertheless, to examine potential floodplain habitat availability for the lower Tuolumne River under Base Case (1971–2012) hydrology, the recurrence of floodplain inundation events for Chinook salmon rearing was assessed by combining the flow frequency and habitat suitability analyses discussed in Sections 5.3.1 and 5.2.2 above. Proceeding from the annual discharge frequency analysis (Figure 5.3-1), Figure 5.3-3 shows the annual recurrence period of events exceeding various total inundation area and duration thresholds in the lower Tuolumne River from February through May. For example, consistent with exceedance metrics defining bankfull discharge on the order of 1.5–2 years (Dunne and Leopold 1978), the lowest flows modeled (1,000 cfs) provide approximately 5.7 million ft^2 of inundated area outside of the low flow (1D) channel boundary (Table 5.2-1). Recurrence periods at larger amounts of continuously inundated area are shown in Figure 5.3-3 for the durations analyzed.

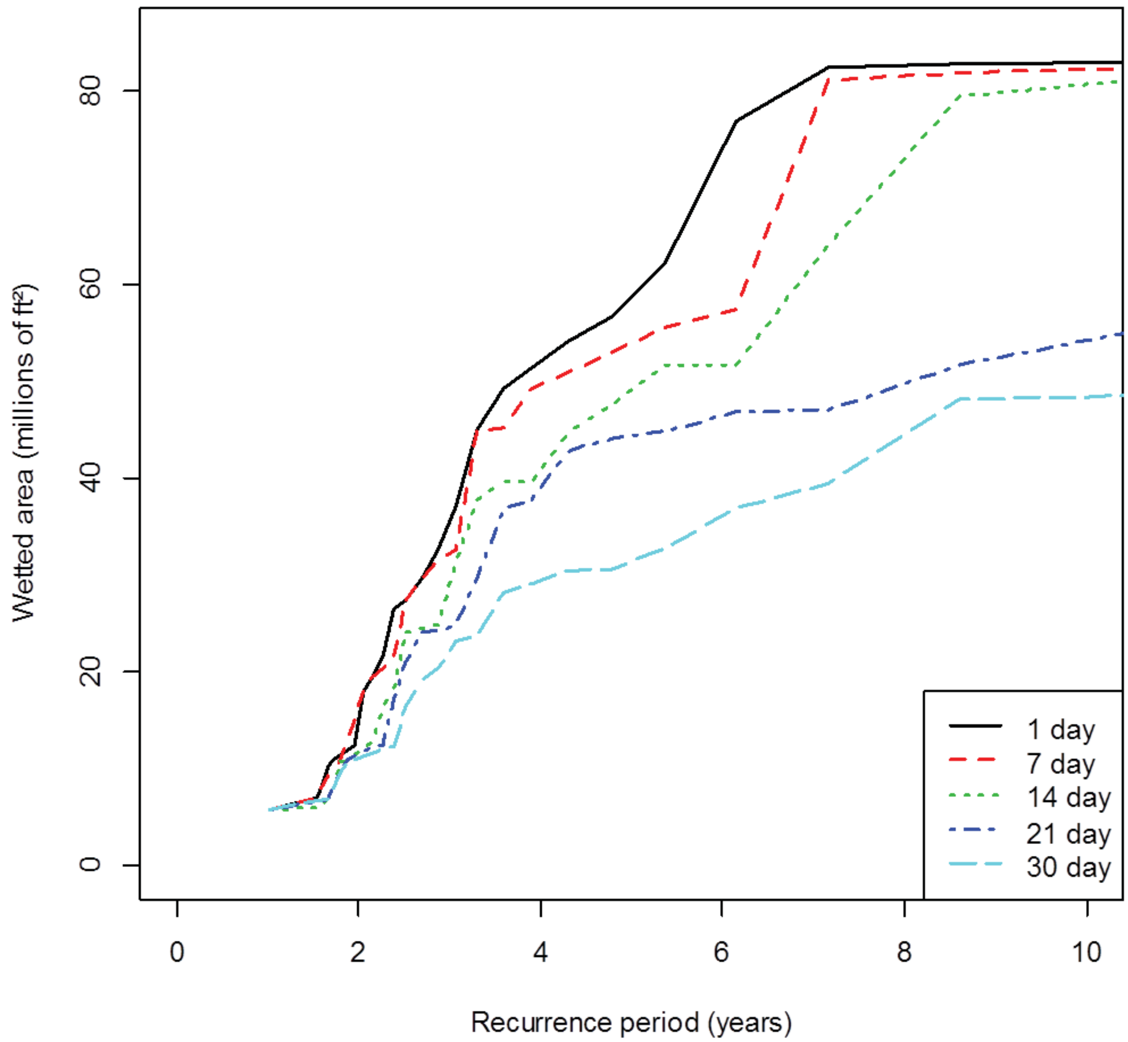


Figure 5.3-3. Total area-duration-frequency (ADF) plot showing recurrence of events exceeding various total inundation area and duration thresholds in the lower Tuolumne River from February through May under Base Case (1971–2012) hydrology.

Examining the recurrence of various inundation area relationships of usable habitat for Chinook salmon fry and juvenile rearing, Figures 5.3-4 and 5.3-5 show usable habitat area-duration-frequency (ADF) plots for Chinook salmon fry and juveniles, respectively. These plots analyze the recurrence of events exceeding various usable habitat area (i.e., determined from velocity and depth predictions at a given flow) and duration thresholds (i.e., events lasting 1, 7, 14, 21, and 30 days).

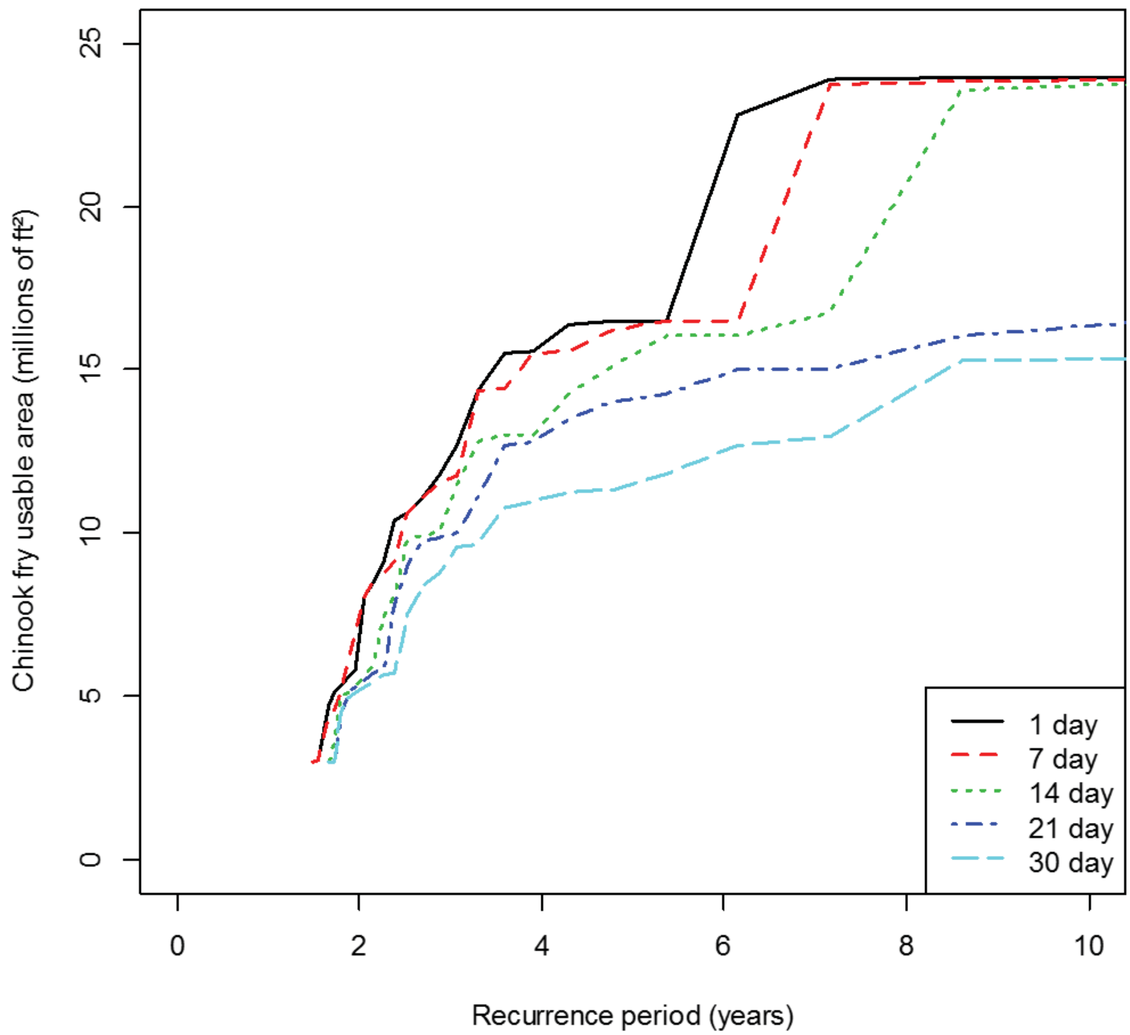


Figure 5.3-4. Chinook salmon fry habitat area-duration-frequency (ADF) plot showing recurrence of events exceeding various usable habitat area and duration thresholds in the lower Tuolumne River from February through May under Base Case (1971–2012) hydrology.

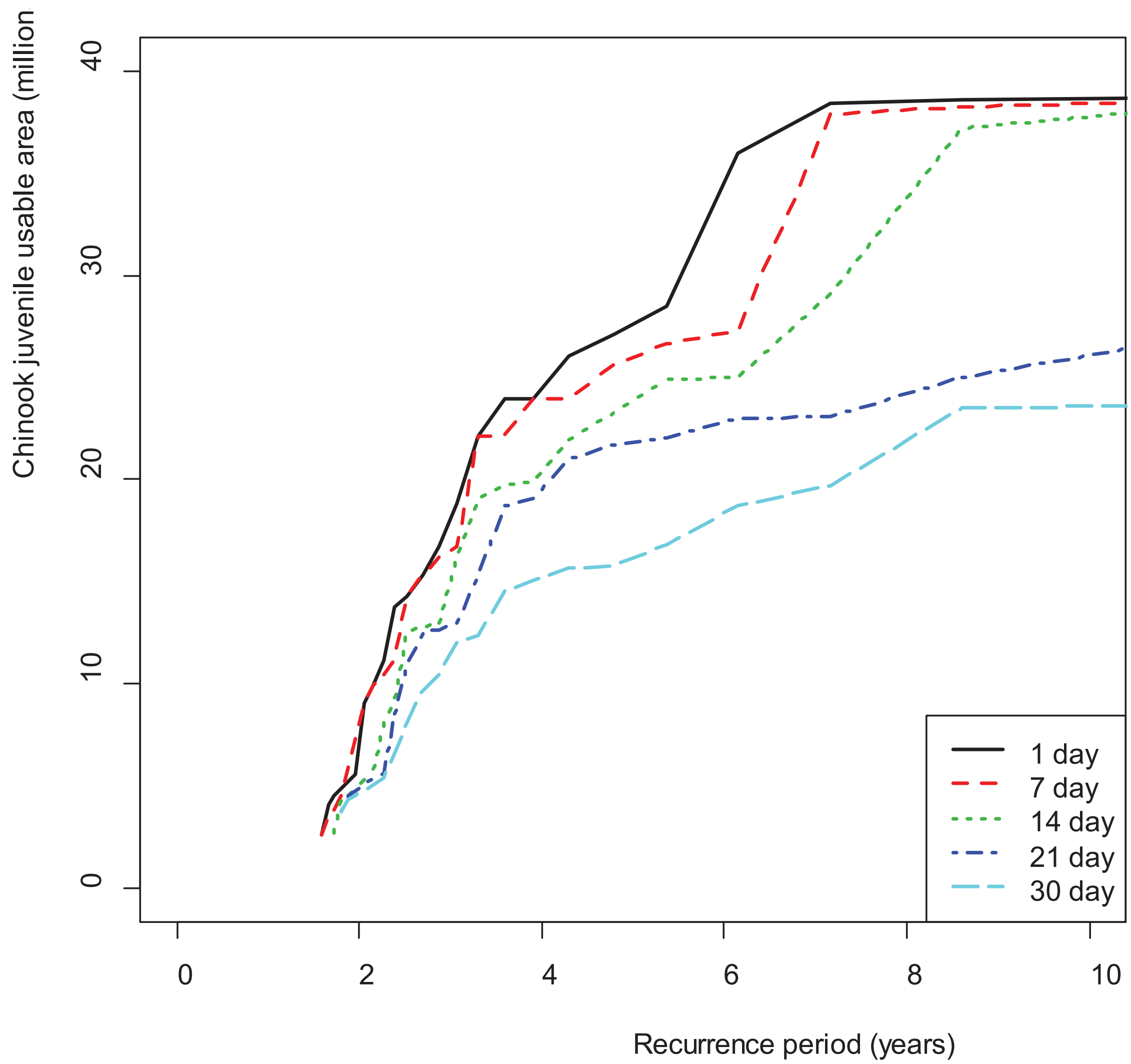


Figure 5.3-5. Chinook salmon juvenile habitat area-duration-frequency (ADF) plot showing recurrence of events exceeding various usable habitat area and duration thresholds in the lower Tuolumne River from February through May under Base Case (1971–2012) hydrology.

5.3.3 Juvenile *O. mykiss* floodplain rearing habitat

In accordance the with approved Study Plan, the final report includes analysis of potential floodplain habitat use by fry and parr sized *O. mykiss* on the lower Tuolumne River using the same ADF analysis applied to Chinook salmon rearing (Section 5.3.2). Figure 5.3-6 shows the annual recurrence period of events exceeding various total inundation area and duration thresholds in the lower Tuolumne River from March through September. Because of the period of analyses extends into the summer months for *O. mykiss* rearing with less frequent flood control releases, comparable floodplain inundation area and durations to those examined for

Chinook salmon also occur less frequently. To examine the recurrence of various inundation area relationships of usable rearing habitat for *O. mykiss* juveniles, Figure 5.3-7 and Figure 5.3-8 show habitat ADF plots for fry and juvenile life stages, respectively. In comparison to the corresponding plots for Chinook salmon juvenile rearing period (i.e., February through March), shorter duration events (e.g., 1 and 7 day duration) occur at a similar return period but extended duration events (e.g., 4, 12, and 30 day durations) occur at a greater return period (i.e., floodplain inundation occurs less frequently in spring and summer).

Although this report analyzes potential usable floodplain habitat for juvenile *O. mykiss*, there are no known data that suggest floodplains are an important habitat for the species. Numerous studies of floodplain use by California native and non-native fishes including Chinook salmon have been conducted (e.g., Sommer et al. 2001, 2005). However, other than limited observations of rearing steelhead smolts along the Yolo Bypass (Sommer 2001, USBR 2008) as well as more recent observations of smaller (Age 0) *O. mykiss* rearing at higher elevation channel margin habitats created following gravel augmentation along the Lower American River (Sellheim et al 2015), juvenile steelhead are not known to rear in floodplain habitats to any great degree at any time of year (Bustard and Narver 1975, Swales and Levings 1989, Feyrer et al. 2006, Moyle et al. 2007).

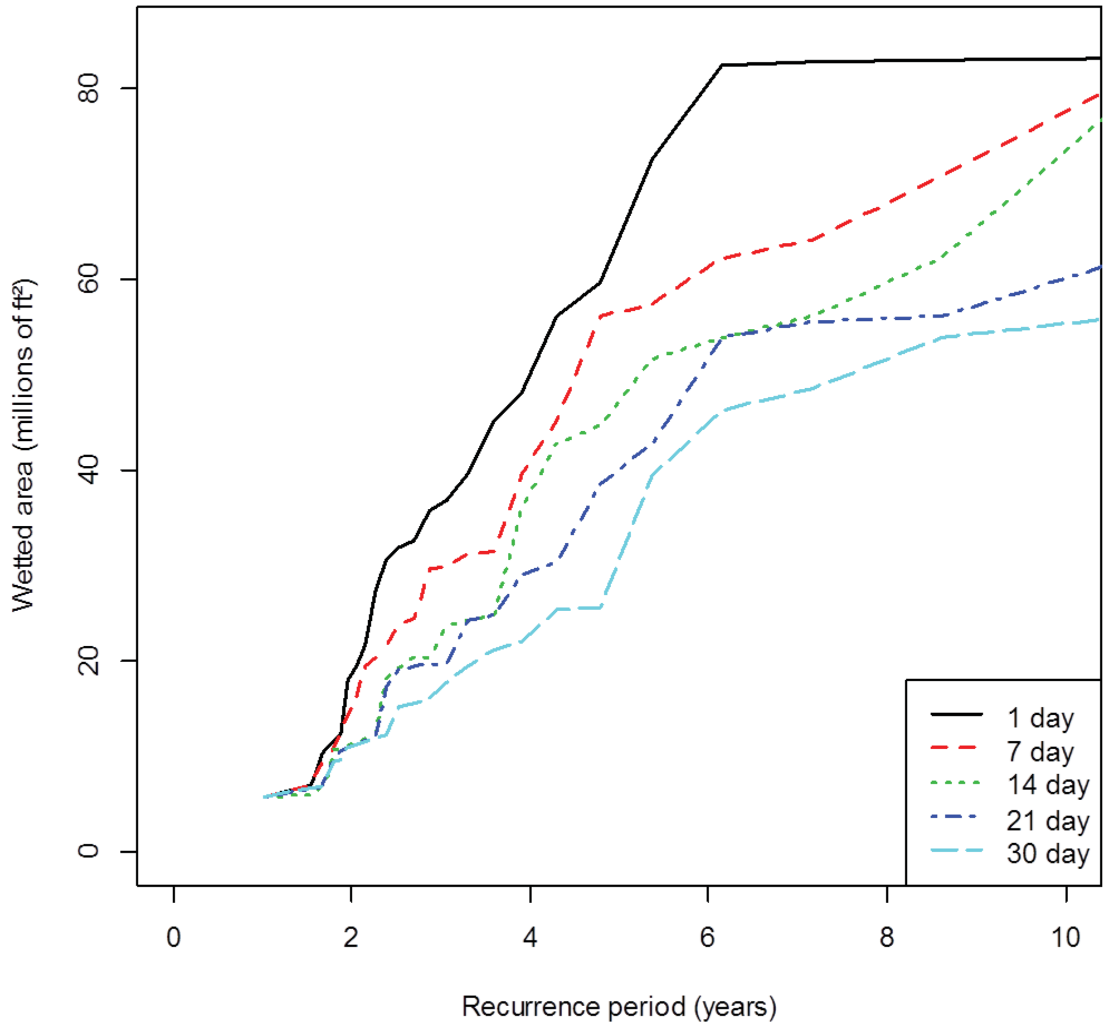


Figure 5.3-6. **Total area-duration-frequency (ADF) plot showing recurrence of events exceeding various total inundation area and duration thresholds in the lower Tuolumne River from March through September under Base Case (1971–2012) hydrology.**

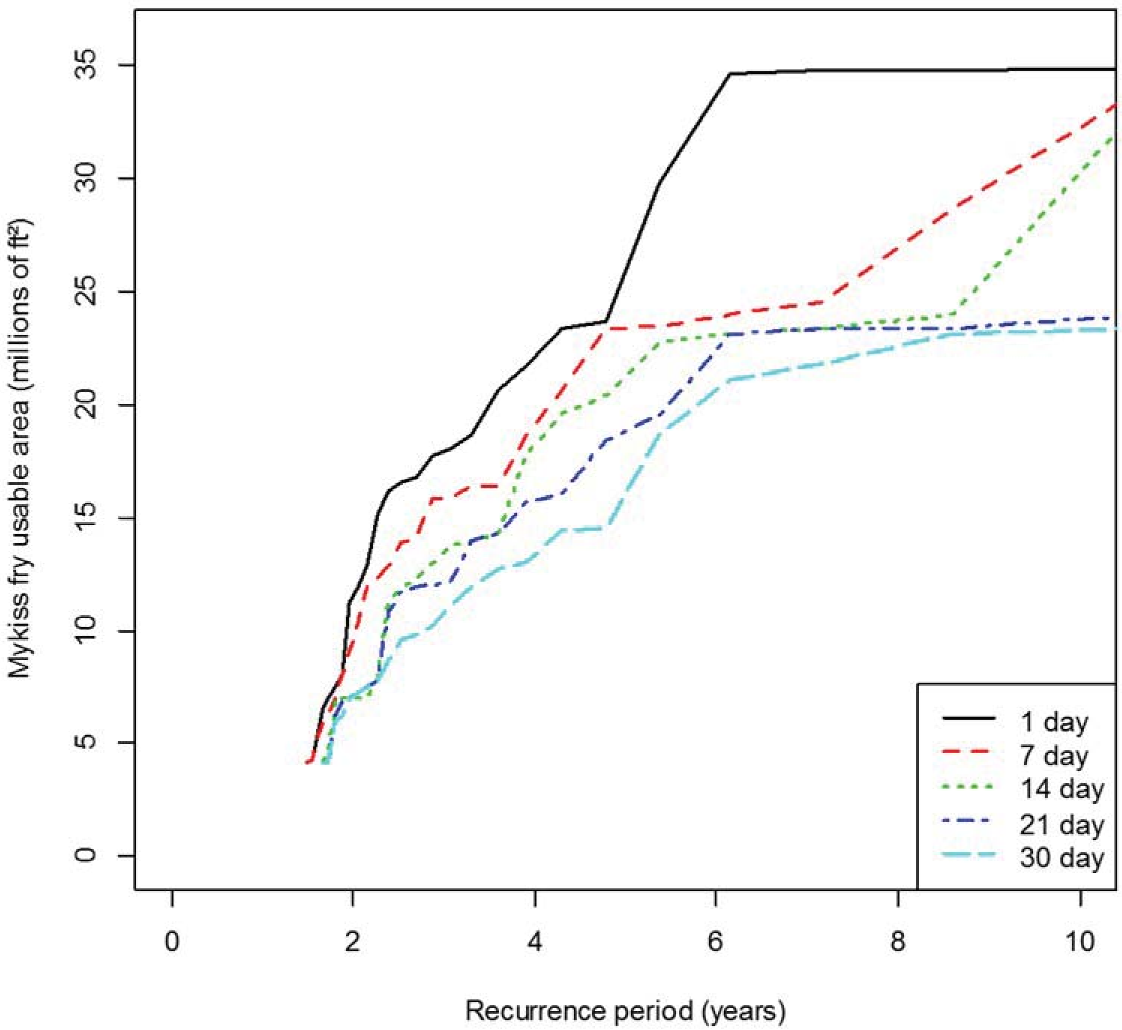


Figure 5.3-7. O. mykiss fry habitat area-duration-frequency (ADF) plot showing recurrence of events exceeding various usable habitat area and duration thresholds in the lower Tuolumne River from March through September under Base Case (1971–2012) hydrology.

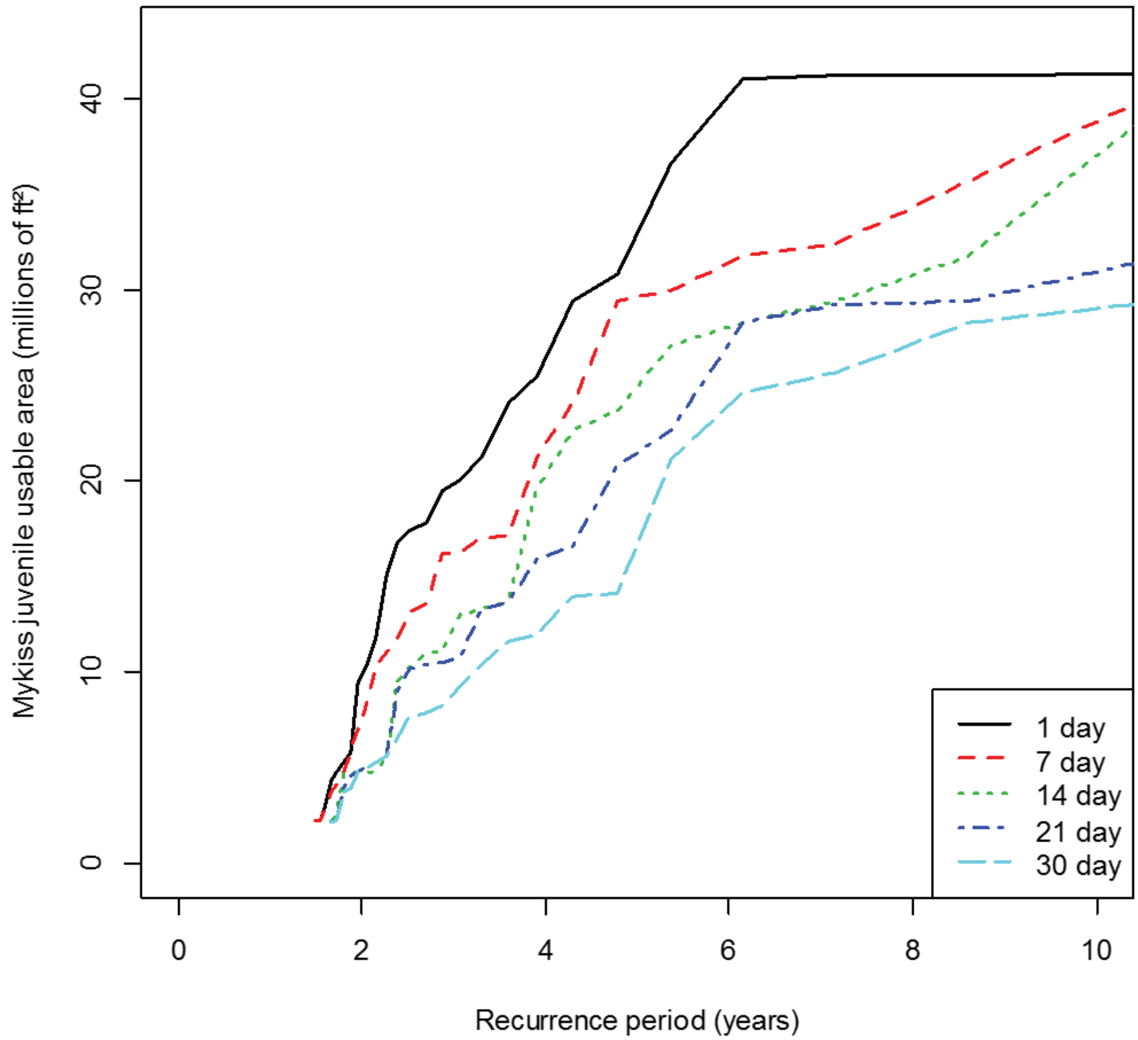


Figure 5.3-8. **O. mykiss juvenile habitat area-duration-frequency (ADF) plot showing recurrence of events exceeding various usable habitat area and duration thresholds in the lower Tuolumne River from March through September under Base Case (1971–2012) hydrology.**

6.0 DISCUSSION AND FINDINGS

6.1 Hydraulic Model

The study required developing a detailed hydraulic model for 52 miles of river and overbank using the best available topographic and bathymetric data and without creating extensive additional data requirements. The TUFLOW modeling platform was used in the study due to the platform's ability to model complex local hydraulics and features present in the study area including ponds, pools, narrow flow paths connecting river and overbanks, flow paths connecting overbank ponds, and hydraulic structures.

Cross sectional and bathymetric data from multiple sources were obtained, evaluated and supplemented to develop model components. To ensure modeling efficiency and accuracy of results, the study area was split into three models. An appropriate boundary condition for each model was determined. Backwater effects from the San Joaquin River were determined by an extensive hydrologic and hydraulic analysis. This analysis showed that the potential backwater effects from San Joaquin River could extend up to approximately RM 13 in the lower Tuolumne River for the range of flows used in this study.

Models were developed with sufficient topographic resolution and identification of the significant hydraulic features and were calibrated and validated for the range of study flows. Calibrated models were used to obtain depth and velocity information for all 21 study flows for habitat analysis and the extent of flood inundation was calculated.

TUFLOW modeling platform proved to be both accurate and efficient for modeling the lower Tuolumne River to achieve the study objectives. Developed models can be readily applied for evaluating potential alternative flow scenarios.

6.2 Fish Habitat Suitability Analyses

Overall, the results of the study show flows above bankfull discharge are associated with increases in habitat area for juvenile life stages of lower Tuolumne River salmonids. Although some floodplain areas are present over the length of the lower Tuolumne River, because of the history of anthropogenic changes to in-channel and floodplain areas not all portions of the river are inundated at the same flows (Section 3.1). Model A (RM 52.2–40.0) results exhibit the largest increase in inundated floodplain area at low to moderate discharge (Figure 5.2-1). However, the majority of available floodplain habitat in this reach is limited to several disturbed areas formerly overlain by dredger tailings (McBain & Trush 2000). These areas were also associated with the highest frequency of stranding and entrapment of juvenile Chinook salmon in historical stranding surveys (1990–1992, 1994–1996, 1999–2000) at flows between 1,100–3,100 cfs (TID/MID 2001). In the Model B reach (RM 40.0–21.5), the lower Tuolumne River exhibits relatively low amounts of floodplain and little increases in inundated area with discharge. As the valley slope of the lower Tuolumne River corridor decreases between Modesto and the San Joaquin River, Model C (RM 21.5–0.9) results exhibit low floodplain availability at flows less than 6,000 cfs, but also large increases in inundated area as discharge increases above 7,000 cfs (Figure 5.2-1). This large increase is primarily due to the presence of large, low gradient agricultural areas near the San Joaquin River confluence. The lower Tuolumne River is also subject to backwater effects from the San Joaquin River up to RM 13 and this backwater effect also influences the amount of floodplain habitat available at a given discharge in the lower Tuolumne River due to variations in San Joaquin River discharge.

Estimates of usable floodplain habitat area for rearing fry and juvenile life stages of Chinook salmon and *O. mykiss* were conducted using joint habitat suitability indices (i.e., 0–100%) from the Stillwater Sciences (2013) IFIM study along with TUFLOW model predictions of depth and velocity within floodplain areas. Overall, usable habitat for fry life stages suitability ranged from near 60 to 80 percent of total inundated floodplain habitat at 1,000 cfs to as low as 15 to 40 percent of inundated habitat at 9,000 cfs. For juvenile life stages, usable habitat ranged from approximately 50 percent of total inundated floodplain habitat at 1,000 cfs to less than 40 percent at flows of 9,000 cfs. Usable in-channel habitat for rearing salmonid juveniles generally decreases with increased depths and velocities as discharge approaches bankfull within Model A (RM 52.2–40) (Attachment H). Decreases in in-channel habitat suitability are offset by large increases in overbank habitat in Model A (RM 52.2–40) and total usable habitat including both in-channel and floodplain areas steadily increases with increasing discharge. Farther downstream, total usable habitat for Chinook salmon and *O. mykiss* fry and juvenile life stages within Model B (RM 40.0–21.5) and Model C (RM 21.5–0.9) is lower at flows from 1,000–2,000 cfs than for either lower (e.g., 100–500 cfs) or higher (e.g., >3,000 cfs) discharges (Attachment H). These patterns are consistent with observations of floodplain encroachment and channel incision within the gravel mining and sand bedded reaches of the lower Tuolumne River (McBain & Trush 2000) which may limit access to overbank habitat at intermediate flows.

Increased spring river flow is associated with increased amounts of floodplain inundation and it is apparent that inundated floodplains on the Tuolumne River below La Grange Diversion Dam have the carrying capacity to support several million rearing Chinook salmon fry and juveniles, depending upon flow and site specific conditions. The results of the current study, however, are not intended to predict actual fish habitat use on inundated floodplains or whether in-channel rearing habitat is currently limiting salmonid populations. Access to floodplain habitats may provide other benefits than increasing available rearing areas, such as reducing the potential encounter frequency between juvenile salmonids and predatory fish species such as black bass (*Centrarchidae: Micropterus*) and other species, thereby reducing overall predation. However, population modeling sensitivity analyses indicate that increased duration of floodplain access for juvenile salmonids may not necessarily result in large increases in subsequent smolt productivity since in-channel rearing habitat is not likely limiting juvenile salmon production. For example, parameter sensitivity analyses conducted as part of the *Tuolumne River Chinook Salmon Population Model Study* (W&AR-06) showed that large decreases in assumed maximum rearing densities in either in-channel or floodplain habitats were not accompanied by corresponding reductions in modeled smolt productivity.

6.3 Area-Duration-Frequency Analysis for Base Case (WY 1971–2012) Hydrology

Using the Base Case (WY 1971–2012) hydrology from the *Project Operations/Water Balance Model Study* (W&AR-02), an annual exceedance frequency analysis of flow events combining discharge magnitude and duration was conducted. Examining the recurrence of various inundation area relationships of usable habitat for Chinook salmon fry and juvenile rearing, floodplain inundation events lasting 7-days or more occur at return periods of 1.5 to 3 years on the lower Tuolumne River.

It should be noted that many of California's native species have evolved and adapted to take advantage of seasonal floodplain inundation (Moyle 2002). Studies of juvenile Chinook salmon rearing within floodplain habitats of lowland rivers of California's Central Valley (e.g., Sommer et al. 2001, 2005 [Yolo Bypass]; Jeffres et al. 2008 [Cosumnes River]) have suggested that increasing the inter-annual inundation frequency of floodplain habitats may promote the production of food resources for rearing salmonids. Although the lower Tuolumne River floodplain areas are relatively small when compared to large flood bypasses of the mainstem Sacramento and San Joaquin Rivers, the results of this study show that extended periods of springtime floodplain inundation (e.g., 14 to 21 days) regularly occurs at a 2- to 4-year recurrence interval on the lower Tuolumne River under the Base Case (WY 1971–2012) hydrology; this floodplain inundation frequency is consistent with typical return periods of fall-run Chinook salmon. Despite resource agency recommendations to increase floodplain inundation to benefit *O. mykiss*, there are no known data that suggest floodplains are an important habitat for the species. Nevertheless, recognizing the potential for floodplain habitat use by fry and parr sized *O. mykiss* on the lower Tuolumne River, shorter duration events (e.g., 1 and 7 day duration) occur at a similar return period than the corresponding analysis for Chinook salmon rearing but extended duration events (e.g., 4, 12, and 30 day durations) occur at a greater return period (i.e., floodplain inundation occurs less frequently in spring and summer than during winter months).

7.0 STUDY VARIANCES AND MODIFICATIONS

The study was conducted in conformance to the FERC-approved *Lower Tuolumne River Floodplain Hydraulic Assessment Study Plan* (W&AR-21) approved in FERC's October 18, 2013 Determination. There are no variances.

8.0 REFERENCES

Aceituno, M. E. 1990. Habitat preference criteria for Chinook salmon of the Stanislaus River, California. USDI Fish & Wildlife Service, Sacramento, California.

AD Consultants, Resources Management Associates Inc., Watercourse Engineering, Inc. 2009. San Joaquin River Basin Water Temperature Modeling and Analysis. Prepared for: CALFED ERP-06D-S20. Moraga, CA.

Arcement, G.J., Jr. and V.R. Schneider. 1989. Guide for Selecting Manning's Roughness Coefficients for Natural Channels and Flood Plains. U.S. Geological Survey Water Supply Paper 2339.

BMT Group Ltd. 2013. TUFLOW software. Available online at: <http://www.tuflow.com>.

Bustard, D.R. and D.W. Narver. 1975. Aspects of the winter ecology of juvenile coho salmon (*Oncoryhnchus kisutch*) and steelhead trout (Salmo gairdneri). Journal of the Fisheries Research Board of Canada 32:667-680.

California Department of Water Resources (CDWR). 2004. California's Groundwater Bulletin 118: San Joaquin Valley Groundwater Basin, Modesto Subbasin. Sacramento, CA.

_____. 2014. Central Valley Floodplain Evaluation and Delineation (CVFED) hydraulic models.

Cowan, W.L. 1956. Estimating hydraulic roughness coefficients: Agricultural Engineering. v. 37, no. 7, p. 473-475.

Dunne, T. and L.B. Leopold. 1978. Water in Environmental Planning. W.H. Freeman and Company, New York

Engineers Australia, 2012 Australian Rainfall & Runoff, Project 15, Two Dimensional Modeling in Urban and Rural Floodplains, Stage 1 & 2 Report.

Environmental Systems Research Institute (ESRI). 2013. ArcGIS Desktop: Release 10.2. Redlands, CA: Environmental Systems Research Institute.

Federal Emergency Management Agency (FEMA). 2014. HEC-RAS modeling of the Tuolumne River and Dry Creek, Stanislaus County, CA. Prepared by HDR Engineering for FEMA in conjunction with the California Department of Water resources (CDWR) as part of the Cooperating Technical Partners Program.

Feyrer, F, T.R. Sommer, W. Harrell. 2006. Importance of flood dynamics versus intrinsic physical habitat in structuring fish communities: evidence from two adjacent engineered floodplains on the Sacramento River, California. North American Journal of Fisheries Management 26: 408-417.

Google. 2013. Google Earth Pro, Version 7.1.2.2041, Google Inc., 2013.

Grant, J.W.A., and D.L. Kramer. 1990. Territory size as a predictor of the upper limit to population density of juvenile salmonids in streams. Canadian Journal of Fisheries Aquatic Sciences 47:1724–1737.

Hampton, M. 1997. Microhabitat suitability criteria for anadromous salmonids of the Trinity River. T.R. Payne and J.A. Thomas, contributing editors. U.S. Fish and Wildlife Service, Coastal California Fish and Wildlife Office, Arcata, CA, December 15, 1997. 10pp + figs and apps.

Jeffres, C., J. Opperman, and P. B. Moyle. 2008. Ephemeral floodplain habitats provide best growth conditions for juvenile Chinook salmon in a California river. Environmental Biology of Fishes 83: 449-458.

Limerinos, J.T. 1970. Determination of the Manning Coefficient From Measured Bed Roughness in Natural Channels. U.S. Geological Survey Water Supply Paper 1898-b.

McBain & Trush, Inc. 2000. Habitat Restoration Plan for the Lower Tuolumne River Corridor. Arcata, California. Prepared for The Tuolumne River Technical Advisory Committee. March 2000.

_____. 2004a. Coarse Sediment Management Plan for the Lower Tuolumne River. Revised Final. Prepared for Tuolumne River Technical Advisory Committee, Turlock and Modesto Irrigation Districts, USFWS Anadromous Fish Restoration Program and the CALFED Bay Delta Authority. Arcata, CA.

_____. 2004b. Tuolumne River Floodway Restoration – Project Design approach and Rationale. Prepared for Tuolumne River Technical Advisory Committee. February 2004.

Moyle P.B. 2002. Inland Fishes of California, Revised and Expanded. University of California Press: Berkeley, CA.

Moyle, P. B., and D. M. Baltz. 1985. Microhabitat use by an assemblage of California stream fishes: Developing criteria for instream flow determinations. Transactions American Fisheries Society 114:695-704.

Moyle, P.B., P.K. Crain, and K. Whitener. 2007. Patterns in the Use of a Restored California Floodplain by Native and Alien fishes. San Francisco Estuary and Watershed Science 5:1–27. Available online at: <http://repositories.cdlib.org/jmie/sfews/vol5/iss3/art1>

Photo Science. 2012. Airborne LiDAR Survey Report. Prepared by Photo Science, Emeryville, California for Turlock Irrigation District and Modesto Irrigation District, California.

QCoherent. 2014. LP360 extension version 2013.2.49.1 for ArcMAP. Information available online at: <http://www.qcoherent.com/products/index.html>

Sellheim, K.L.; C.B. Watry, B. Rook, S.C. Zeug, J. Hannon, J. Zimmerman, K. Dove, and J.E. Merz. 2015. Juvenile Salmonid Utilization of Floodplain Rearing Habitat after Gravel Augmentation in a Regulated River. River Research and Applications. 32:1 DOI: 10.1002/rra.2876.

Sommer, T. R., M. L. Nobriga, W. C. Harrell, W. Batham, and W. J. Kimmerer. 2001. Floodplain rearing of juvenile Chinook salmon: evidence of enhanced growth survival. Canadian Journal of Fisheries and Aquatic Sciences 58: 325–333.

Sommer, T. R, W.C. Harrell and M. L. Nobriga. 2005. Habitat use and stranding risk of juvenile Chinook salmon on a seasonal floodplain. North America Journal of Fisheries Management 25:1,493–1,504.

Stanislaus County. 2006. Stanislaus County General Plan. Stanislaus County Board of Supervisors, Modesto, California.

Stillwater Sciences. 2012. Lower Tuolumne River Instream Flow Studies: Pulse Flow Study Report. Final. Prepared by Stillwater Sciences, Berkeley, California for Turlock Irrigation District and Modesto Irrigation District, California. June.

_____. 2013. Lower Tuolumne River Instream Flow Study. Final Report. Prepared by Stillwater Sciences, Davis, California for Turlock and Irrigation District and Modesto Irrigation District, California. April.

Swales, S. and C.D. Levings. 1989. Role of off-channel ponds in the life-cycle of coho salmon (*Oncorhynchus kisutch)* and other juvenile salmonids in the Coldwater River, British Columbia. *Canadian Journal of Fisheries & Aquatic Sciences* 46:232-242.

Thomas R. Payne & Associates (TRPA). 2000. Determining appropriate HSC for use in the South Fork American River Basin. Testing the transferability of generic and California-specific HSC. Report submitted to El Dorado Irrigation District, Placerville, California.

_____. 2004. Assessment of steelhead habitat quality in the Matilija Creek Basin. Stage two: quantitative stream survey. Report prepared for Public Works Agency and Ventura County Flood Control District, Ventura, California.

TUFLOW Manual 2010, BMT WBM, WBM Pty Ltd.

Turlock Irrigation District and Modesto Irrigation District (TID/MID). 1997. Imageries from Tuolumne River GIS Database Report and Map. Report 96-14 *In* 1996 Report of Turlock Irrigation District and Modesto Irrigation District Pursuant to Article 39 of the License for the Don Pedro Project, No. 2299. Prepared by EA Engineering, Science, and Technology, Lafayette, California.

_____. 2001. Tuolumne River Chinook salmon fry and juvenile stranding report. Report 2000-6 *In* 2000 Report of Turlock Irrigation District and Modesto Irrigation District Pursuant to Article 39 of the License for the Don Pedro Project, No. 2299. Prepared by Noah Hume and Jennifer Vick of Stillwater Ecosystem, Watershed & Riverine Sciences, Berkeley, California.

_____. 2005. Ten year summary report pursuant to Paragraph (G) of the 1996 FERC Order issued July 31, 1996. Report to Federal Energy Regulatory Commission for FERC Project No. 2299-024.

_____. 2011. Tuolumne River water temperature modeling study. Final Report. Prepared by Stillwater Sciences, Berkeley, California for Turlock Irrigation District and Modesto Irrigation District, California. March 2011.

_____. 2013a. Lower Tuolumne River Riparian Information and Synthesis Study Report (W&AR-19). Attachment to Don Pedro Hydroelectric Project Draft License Application. December 2013.

_____. 2013b. Spawning Gravel in the Lower Tuolumne River Study Report (W&AR-04). Attachment to Don Pedro Hydroelectric Project Updated Study Report. December 2013.

_____. 2013c. Project Operations/Water Balance Model Study Report (W&AR-02). Attachment to Don Pedro Hydroelectric Project Updated Study Report. December 2013.

_____. 2013d. Lower Tuolumne River Temperature Model Study Report (W&AR-16). Attachment to Don Pedro Hydroelectric Project Updated Study Report. December 2013.

_____. 2013e. Salmonid Population Information Integration and Synthesis Study Report (W&AR-05). Attachment to Don Pedro Hydroelectric Project Updated Study Report. December 2013.

U.S. Bureau of Reclamation (USBR). 2008. Biological assessment on the continued long-term operations of the Central Valley Project and the State Water Project. U.S. Department of the Interior Bureau of Reclamation Mid-Pacific Region Sacramento, California. August.

U.S. Department of Agriculture (USDA). 2014. Classification and Assessment with LANDSAT of Visible Ecological Groupings (CALVEG) data developed by the USDA Forest Service Pacific Southwest Region Remote Sensing Lab, McLellan, Ca. Available online at: <http://www.fs.usda.gov/detail/r5/landmanagement/resourcemanagement/?cid=stelprdb5347192>

U.S. Fish and Wildlife Service (USFWS). 1988. Tuolumne River Instream Flow Study progress report—fiscal year 1988. The relationship between instream flow and physical habitat availability for Chinook salmon in the lower Tuolumne River, California. Prepared by USFWS, Ecological Services Division, Sacramento, California for Turlock Irrigation District and Modesto Irrigation District, California.

_____. 1991. Trinity River Flow Evaluation-Annual Report. U.S. Fish and Wildlife Service, Division of Ecological Services. Sacramento, CA. 57 pp.

_____. 2004. Flow-habitat relationships for adult and juvenile rainbow trout in the Big Creek Project. USFWS Energy Planning and Instream Flow Branch.

_____. 2005. Recommended Streamflow Schedules to Meet the AFRP Doubling Goal in the San Joaquin River Basin. Prepared by the Anadromous Fish Restoration Program, U.S. Fish and Wildlife Services, Stockton, CA. September 27

_____. 2008. Flow-overbank inundation relationship for potential fall-run Chinook salmon and steelhead/rainbow trout juvenile outmigration habitat in the Tuolumne River. U.S. Fish and Wildlife Service, Sacramento, CA. August, 2008.

_____. 2010a. Flow-habitat relationships for juvenile fall/spring-run Chinook salmon and steelhead/rainbow trout rearing in the Yuba River. Sacramento Fish and Wildlife Office, Planning and Instream Flow Branch.

_____. 2010b. Flow-habitat relationships for juvenile fall/spring-run Chinook salmon and steelhead/rainbow trout rearing in the Yuba River. Sacramento Fish and Wildlife Office, Planning and Instream Flow Branch.

U.S. Geological Survey (USGS). 2014a. Email correspondence with Patricia Orlando, Public Information Officer at the USGS Sacramento Field office, Sacramento CA. November 4, 2014.

_____. 2014b. Email correspondence with Susan Brockner, Hydrologic Technician at the USGS Sacramento Field office, Sacramento CA. October 30, 2014.

STUDY REPORT W&AR-21
THE LOWER TUOLUMNE RIVER FLOODPLAIN HYDRAULIC ASSESSMENT

ATTACHMENT A

STUDY CONSULTATION

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APPENDIX A

WORKSHOP NO. 1 MEETING NOTES

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Don Pedro Project Relicensing
W&AR-21 Workshop No. 1
Meeting Notes

Thursday, February 13, 2014

Attendees

Nolan Adams – HDR	Matt Moses – SFPUC
Peter Barnes – SWRCB	Bill Paris – MID, *by phone*
Jenna Borovansky – HDR	Pani Ramalingam – HDR
Allison and Dave Bouchet – Tuolumne River Conservancy	Bill Sears – CCSF, *by phone*
Steve Boyd – TID	Maia Singer – Stillwater
Jesse Fernandes – HDR, *by phone*	Ron Yoshiyama – CCSF
Noah Hume – Stillwater	
Rob Sherrick – HDR	
Anna Brathwaite – MID, *by phone*	

Background

- Following introductions, Jenna provided background on the study process to date:
  - This is the first workshop for the W&AR-21 modeling effort, in accordance with the Consultation Process.
  - In January 2013, the Districts received comments on ISR, including a request for additional information. Districts agreed to conduct a floodplain study. Spring - Summer 2013 study plan development.
- The W&AR-21 study goals build on past information (Slide 2).
- The purpose of the first workshop is to present the 2D hydraulic and habitat modeling approach (Slide 3). Actual model results are forthcoming.

Previous Studies

- Noah reviewed previous floodplain studies on the lower Tuolumne River (Slide 4).
- Noah noted that the 2012 2D Pulse Flow Study focused on in-channel predictions of habitat availability.
- Noah presented the study objectives (Slide 5)

Modeling Approach

- Pani is the study hydraulic modeling lead, with Nolan responsible for most of the hydraulic model construction.
- Pani reviewed existing topographic data (Slides 7-11). There are no breaks in the LiDAR data, but there are breaks in the floodplain ponds. The team is currently working to fill these data gaps. Available calibration data is shown on Slide 12.
- Why use the TUFLOW model (Slides 13-14)?
  - TUFLOW was developed in Australia and has been used in numerous river hydraulic modeling studies in Europe and Australia. TUFLOW is being used in studies in the US more often, including multiple USACE and DWR studies.

- We are interested in modeling low to moderate flows in the Tuolumne River study, rather than high flows.
- We also want to link hydraulic conditions to fish habitat availability – so the hydraulic model needs to be able to realistically represent a flow path from main channel to the floodplain. This means that a flexible grid size is important.
- TUFLOW is scalable and can be run using different scenarios as the study develops. In other words, you can make changes in local topography if needed, without re-doing all of the topography.
- TUFLOW has a good 1D modeling component, distinguishing it from most other 2D models, which don't also possess a good 1D component.

- The computational efficiency of TUFLOW decreases with smaller grid size. In other words, the model takes a longer time to run at a smaller grid size.
- We ran TUFLOW for the Pilot Reach (RM 40-52) to determine WSEL sensitivity to grid size. TUFLOW results indicate that there is no benefit to running the model at a grid size lower than 30 ft^2 (Slide 21).
- Habitat Sensitivity to Grid Size – results for Riffle 4A/4B indicate that the smaller the grid size, the higher the estimated area of suitable rearing habitat (Slides 22-23). This is particularly evident for fry. Balancing this with the decreasing computational efficiency as grid size gets smaller, the sensitivity analysis indicates that 30 ft^2 also represents an appropriate grid size for habitat predictions. We can decrease the grid size in particular areas, as needed.
- Question (Allison): does the model distinguish between inundated areas that do have active flow/velocity and areas that do not have flow/velocity? For example, when Legion Park floods, there is no flow. Water sits on the grass, but this does not appear to be good habitat.
- Answer (Noah): The model considers both velocity and depth. Based on the habitat suitability criteria (HSC), areas with no flow would not be considered suitable habitat by the model.
- Reminder that the existing IFIM Study (2012) was a 1D study, covering in-channel habitat at flows up to 1,200 cfs.
- The TUFLOW 1D-2D domain boundary is set in locations that will maximize 2D habitat analysis potential (Slides 24-28). Pani provided example images of the 1D-2D domain boundary location within the Pilot Reach.
- Pani presented the TUFLOW modeling plan (Slides 29-30).
- Noah presented the conceptual steps in the habitat analysis, whereby TUFLOW provides cell-specific velocity and depth predictions. These are run through the habitat suitability criteria (HSC) developed in the 2012 IFIM study and combined with discharge recurrence probabilities to generate area-duration-frequency curves (Slides 31-33).
- Question (Allison): Will the results include consideration of suitable habitat in different sections of the river (i.e., reach-by-reach)?
- Answer (Noah): Yes, the model can do that.

Schedule/Next Steps

- We will distribute electronic links to an updated map book of the Lower Tuolumne River shortly; the map book will show the location of the TUFLOW 1D-2D domain boundary. The agencies should please provide feedback on the model domain delineation approach and we can follow up with a conference call to discuss feedback, if needed.
- As previously noted, this workshop represents the first study consultation, with a second consultation forthcoming following full model calibration.

Questions

Question (Allison): Will the report produce information for four different fish lifestages (i.e., fry and juvenile salmon; fry and juvenile *O. mykiss*)? These species require different habitat types, how does the modeling approach consider the differences?

Answer (Noah): Life history timing for each species is specific, which is an inherent screening tool (i.e., fry and juveniles for each species use the habitats at slightly different times in the year).

Question (Allison): Landowners may like to know what is happening on their property in particular. Will that be that possible?

Answer (Jenna): Potentially with respect to habitat, but reminder that the purpose of the study is not to predict when or exactly how properties will flood. We are running the model out to steady state to obtain habitat suitability information.

Question (Allison): How do you know what the velocity is for a particular floodplain location?

Answer (Pani): TUFLOW models velocity on a cell-by-cell basis.

Question (Allison): How does the model deal with velocity in off-channel areas like flooded roads, bends, etc.? Example is on property downstream of new La Grange Bridge. We have observed large eddies during high flows in this area.

Answer (Pani): Pani showed example model results at 3,000 cfs after running the model for 12 hours. You can see the velocity and depth vectors shift with each time step, and the flow eddies are in fact represented.

Question (Allison): How is roughness associated with different vegetation types, like willow?

Answer (Pani/Nolan): We are still working on this, but we're using the best available information (i.e., survey data, aerial flows) to make the distinctions between vegetation types.

Question (Allison): What is the study output? Can the model be run under different scenarios?

Answer (Noah): The report will include plots and tabulations of inundated area. The model will exist and agencies can run it for different scenarios. If the agencies don't choose to obtain and re-run the model, then they can use the report output to extrapolate to a range of flows, or request that the model be re-run.

At the end of the meeting, workshop participants looked at a recently restored site to see how the restored floodplain surface might respond to flows of 8,400 cfs based on TUFLOW predictions. Dave/Allison: The expected flow re-routing looks like it may occur based on model results, good news! The TUFLOW model is a neat tool. It should really help the decision-making process within the agencies.

Attachments

Attachment 1: Modeling Workshop No. 1 Slides

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Attachment 1

Modeling Workshop No. 1 Slides

Don Pedro Relicensing

Floodplain Hydraulic Assessment Workshop

February 13, 2014

Study Plan Goals

- Analyze the amount of floodplain inundated between RM 52.2 and RM 0 of the Tuolumne River at flows between approximately 1,000 cfs and 9,000 cfs
- Assess the suitability of inundated floodplain habitat for juvenile salmon rearing
- Evaluate the frequency and period of inundation over a range of Project operations representing baseline conditions and alternative operating scenarios

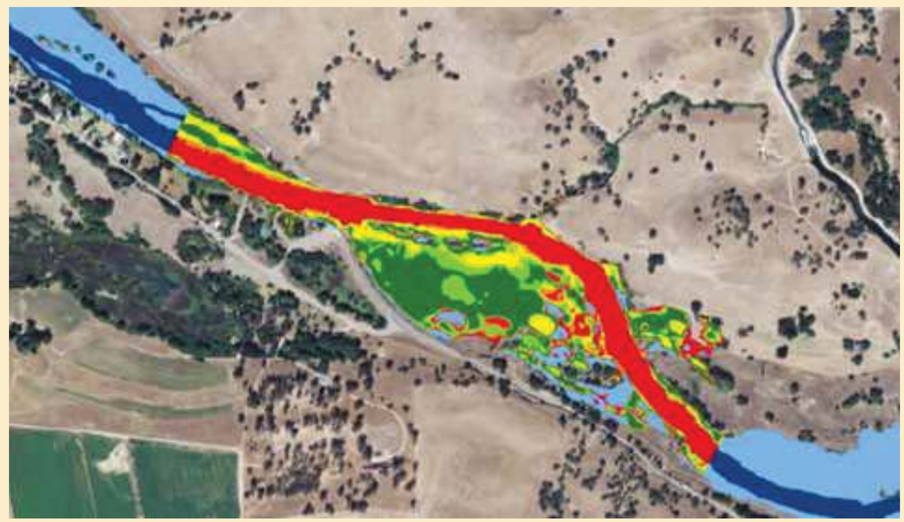
Purpose of Meeting

- Hydraulic Modeling Approach
  - Data Sources
  - TUFLOW Model
  - Overbank vs. In Channel Areas
- Habitat Analysis Approach

Photo Credit: Stillwater Sciences

Previous Studies

- TID (1992, 1997, 2010) Inundation Mapping and GIS (100-8,400 cfs)
- USFWS (2008) floodplain analysis of TID GIS data
- Stillwater Sciences (2012) 2D Pulse Flow Study (1,000-5,000 cfs)



Study Objectives

1. Use hydraulic modeling to simulate the interaction between flow within the main channel and within the inundated floodplain at:
   - 250 cfs intervals from 1,000–3,000 cfs
   - 500 cfs intervals from 3,000–9,000 cfs
2. Determine the maximum continuous wetted area for 7, 14, 21, and 30 day durations
3. Evaluate the Base Case scenario (W&AR-02)
4. Estimate depths and velocities in overbank areas from RM 52 to the San Joaquin River and use existing habitat suitability criteria for depth and velocity for juvenile salmonids to quantify the amount of suitable juvenile rearing habitat as a function of flow

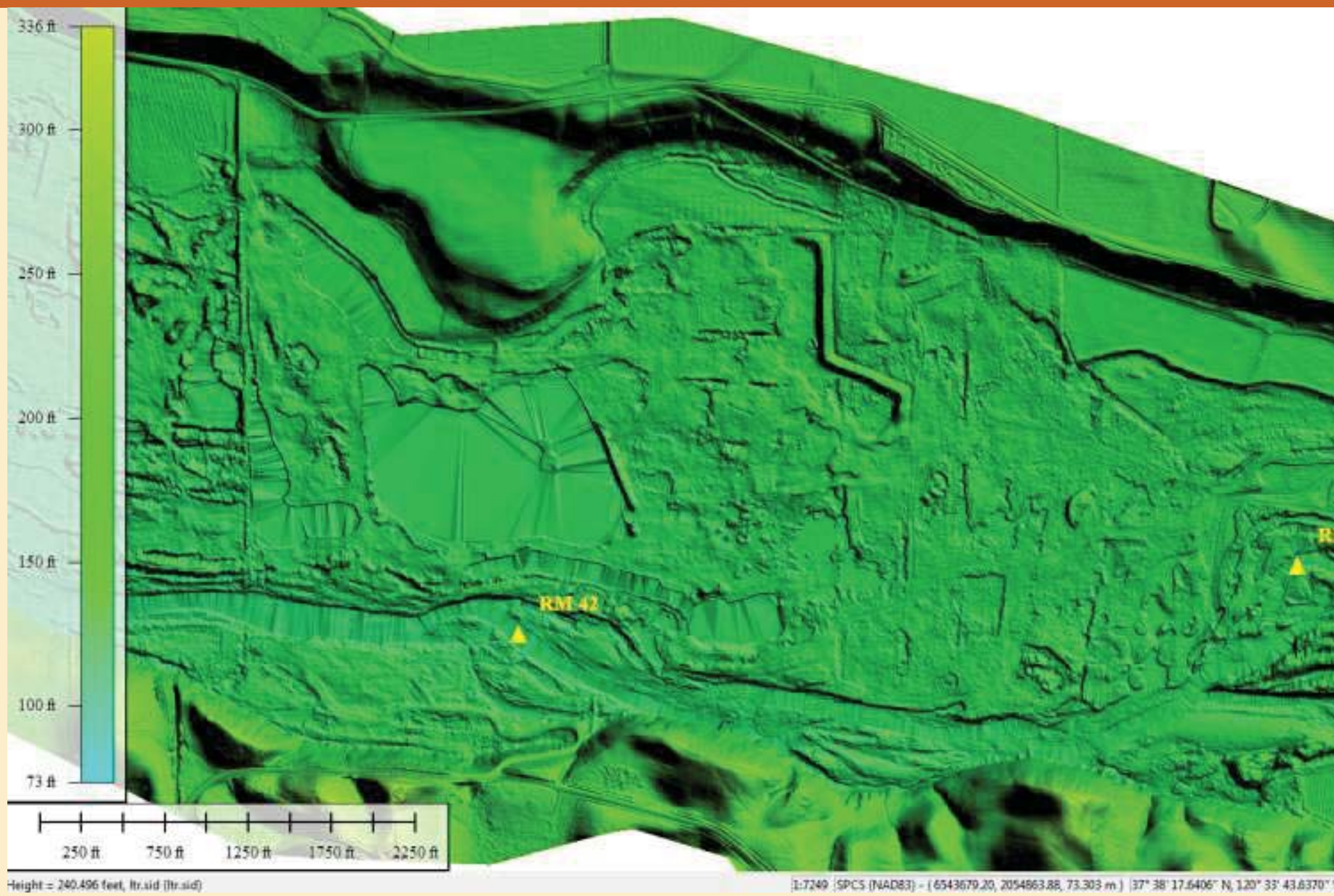
Hydraulic Modeling Approach

- Topographic Data
- Calibration Data
- TUFLOW Model
- Pilot Model/Sensitivity Analysis

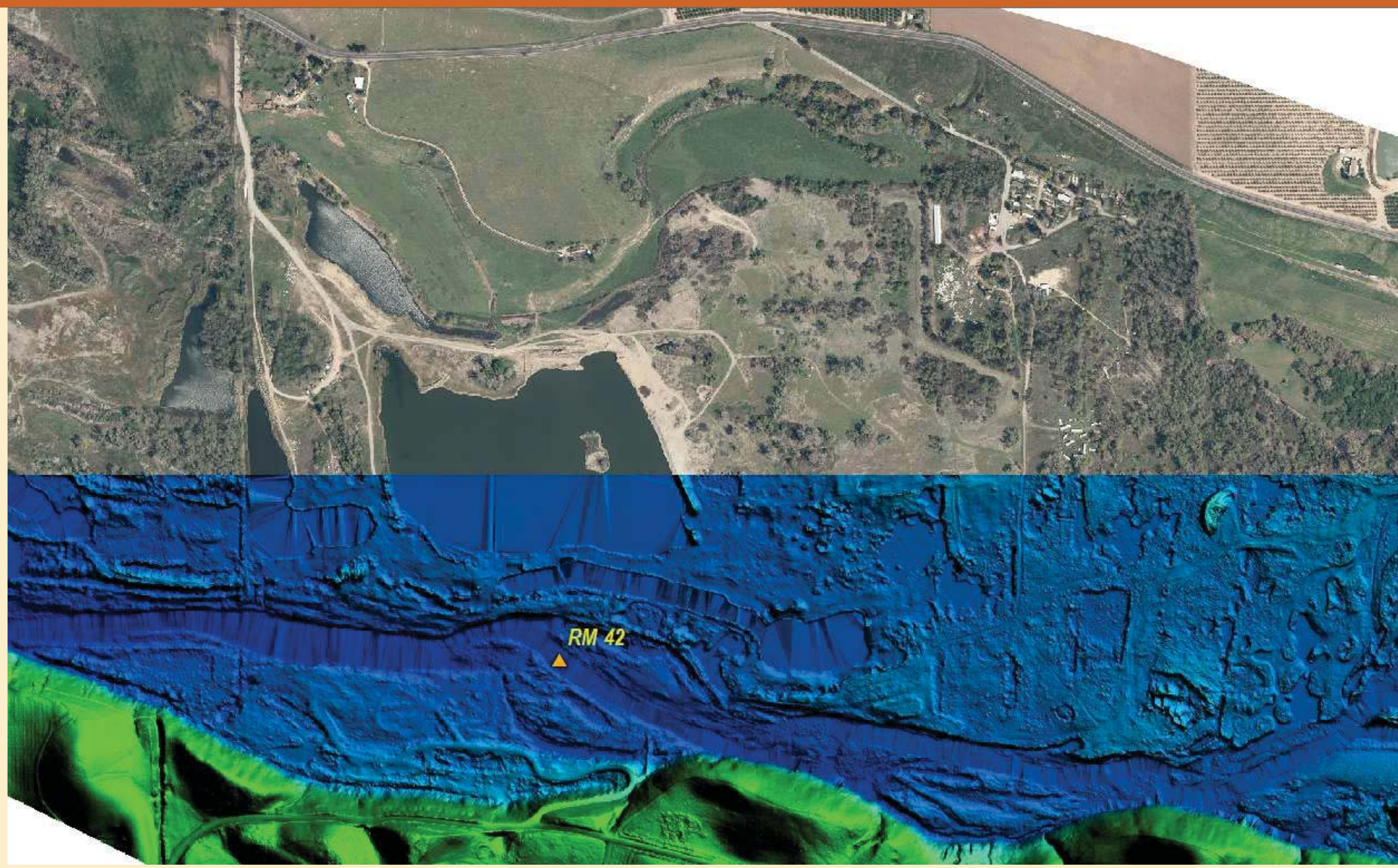
Topographic Data

- 2012 LiDAR Data
  - RM 54.5 to RM 0.
  - Flown on March 30, 2012
  - Flow in River - Approximately 321 cfs
  - No breaklines
- 1D Channel Bathymetry
  - Multiple Data Sources

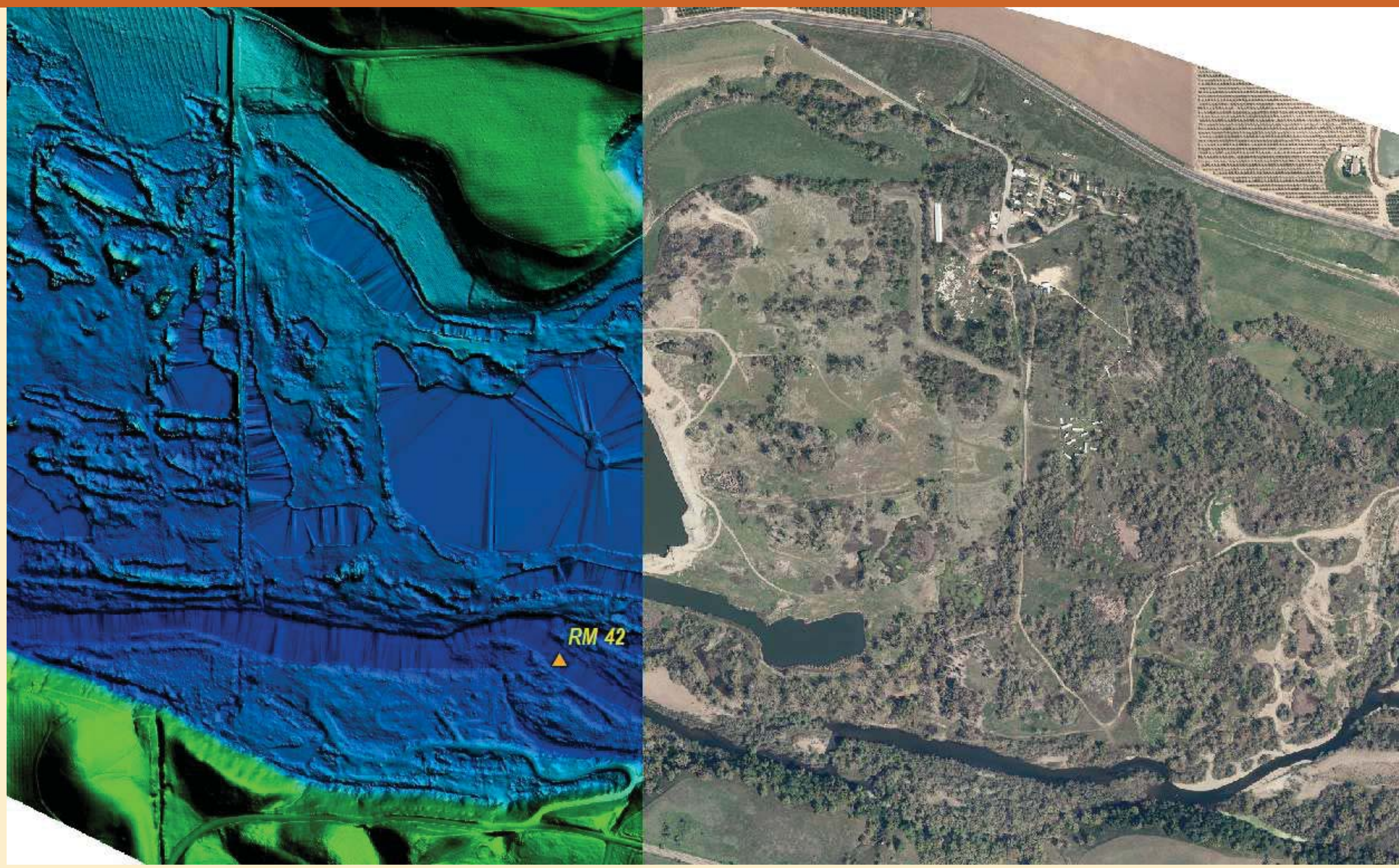
Topographic ASCII Grids



Water Body Details



Water Body Details



1D Low Flow Channel

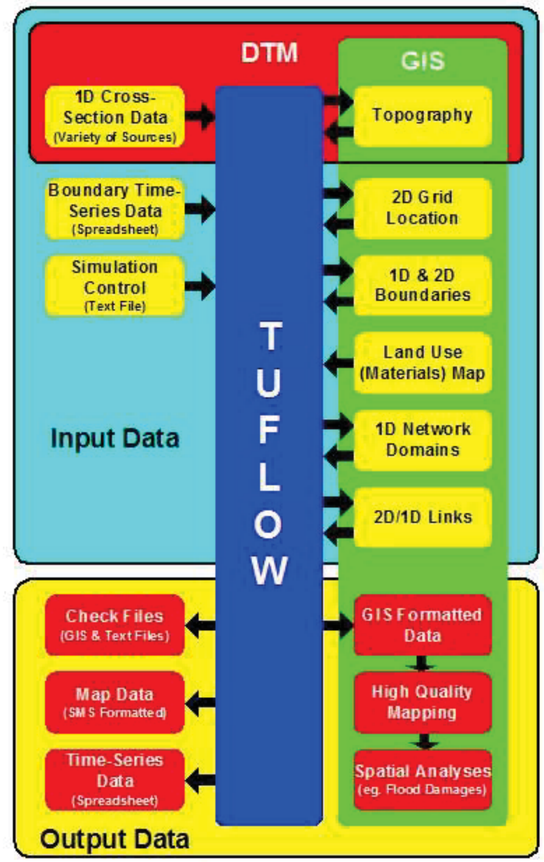
RM	Source	Original Reason for Collection
0-6.7	DWR (2009)	CVFED HEC-RAS, FLO-2D Models
6.7-24	DWR/FEMA (2012)	FEMA Study, HEC-RAS Model
24-38	HDR (2013), Stillwater (2013)	Temperature HEC-RAS Model, IFIM Study
38-51.5	McBain & Trush (2005)	Coarse Sediment Management
45.5-51.8	Stillwater (2013)	W&AR4 – Spawning Gravel in the Lower Tuolumne River

Calibration Data

- **Historic Inundation Extent (e.g., 1,070, 3,100, 5,300, 8,400 cfs)**
- **Water Surface Elevations**
  - **2012 Pulse Flow Study**
  - **2013 IFIM Study**
  - **2012 LiDAR**

TUFLOW Model

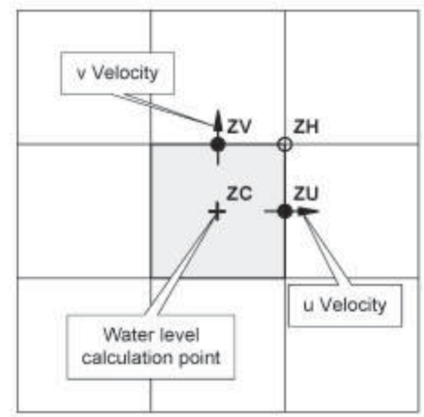
- Unsteady 2D model
- Implicit finite difference scheme – FAST!
- 2D overbank areas with 1-D low flow channel
- River-wide modeling



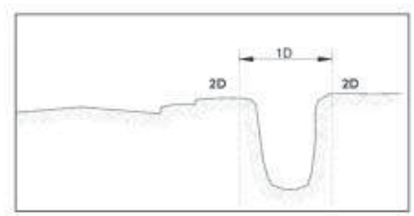
TUFLOW Data Input and Output Structure

Advantages of TUFLOW Model

- Powerful GIS-centric architecture
- Layered data approach
- Flexible grid size
- 1-D low flow channel



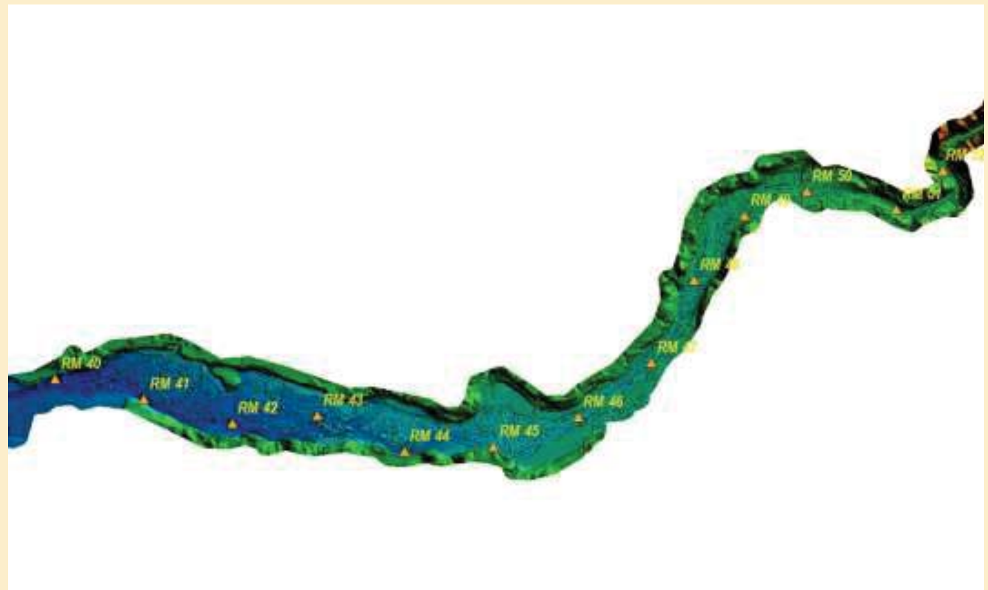
Location of Zpts and Computation Points



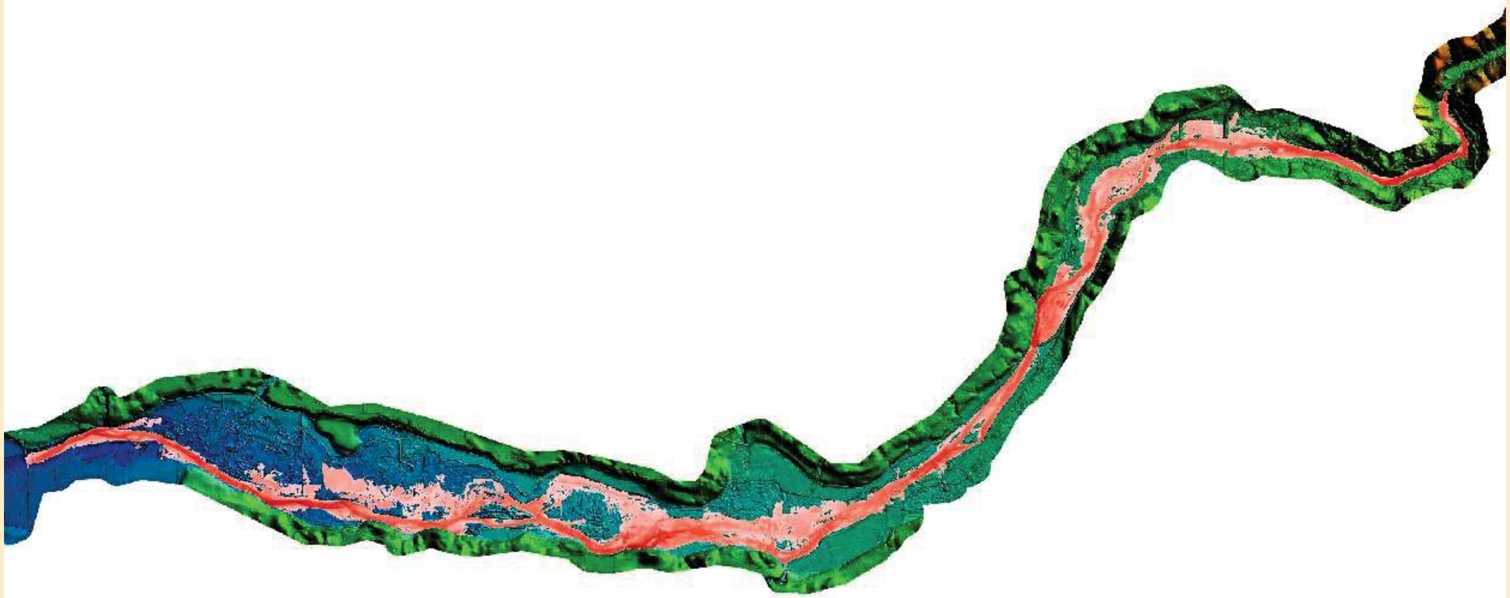
Modelling a Channel in 1D and the Floodplain in 2D

Pilot Model – RM 52 to RM 40

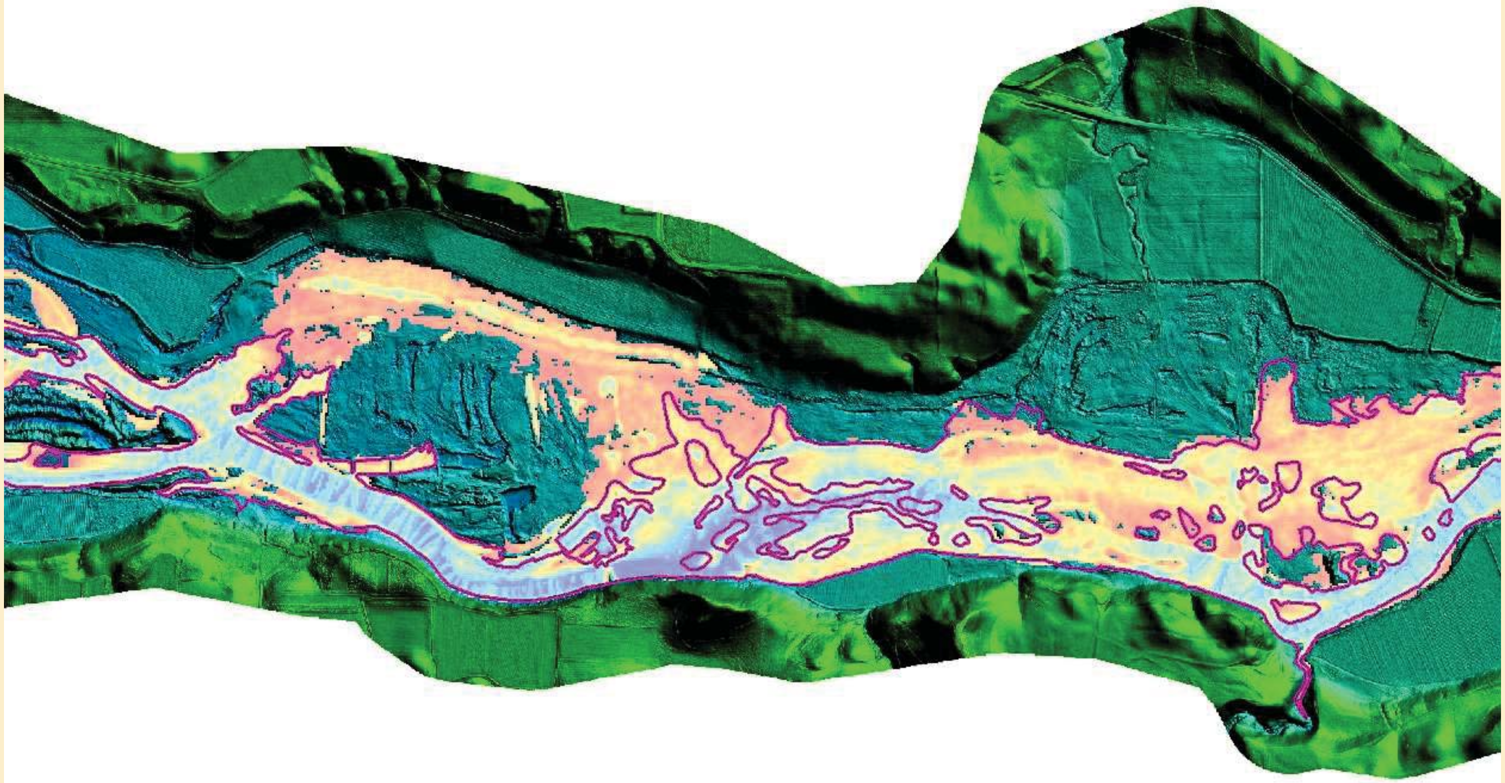
- 2012 Pulse Flow Study
- Continuous river bathymetry data
- Test Runs
- 50, 30 & 20 ft cells



Inundation Extent – 8,400 cfs



Historical Inundation Extent



Habitat Sensitivity Analysis

- Small model from RM 50 to RM 47
- Cell sizes – 10, 20, 30, 40 & 50 ft
- 3,000 cfs
- Pulse Flow Study WSE calibration data

Modeled Inundation Extent

Historical Inundation Extent

WSEL Sensitivity to Grid Size

Sensitivity Analysis of Pilot TUFLOW Model* - Basso Reach (RM 50 - RM 47) Results

S No.	Observed WSE (ft) 3000 cfs	Difference in WSE for Various Grid Size					Remarks
		10 ft	20 ft	30 ft	40 ft	50 ft	
1	169.7	0.2	0.2	0.1	0.1	0.0	
2	168.9	0.5	0.4	0.4	0.3	0.2	
3	166.9	-0.3	-0.3	-0.4	-0.4	-0.6	Overbank
4	166.8	0.5	0.4	0.3	0.2	0.1	
5	165.9	0.3	0.3	0.2	0.0	-0.2	
6	165.2	-0.2	-0.3	-0.3	-0.5	-0.8	
7	163.0	0.0	-0.3	-0.6	-0.5	-0.8	Overbank
8	162.7	0.3	0.2	0.2	0.1	0.0	
9	162.5	0.1	0.1	0.0	-0.1	-0.1	
10	162.3	0.1	0.1	0.0	-0.1	-0.1	
11	161.8	-0.1	-0.1	-0.3	-0.3	-0.4	
12	161.6	0.0	0.0	-0.3	-0.3	-0.5	
13	161.5	0.0	-0.1	-0.1	-0.2	-0.2	
14	161.5	0.1	0.0	0.0	-0.1	-0.1	
15	161.3	0.0	0.0	-0.1	-0.2	-0.2	
16	161.1	-0.1	-0.1	-0.2	-0.3	-0.3	
17	161.0	-0.2	-0.2	-0.3	-0.4	-0.4	
18	160.6	0.2	0.1	0.1	0.0	-0.1	
19	158.2	-0.9	-1.0	-1.1	-1.1	-1.0	Downstream area - Observed WSE drops rapidly over a relatively short distance.
20	157.0	-0.9	-0.9	-0.9	-1.0	-1.0	
21	156.9	-0.6	-0.6	-0.6	-0.7	-0.7	
22	156.5	-2.1	DRY	DRY	-1.9	-2.1	
RMSE (ft) (Lines 1 - 21)		0.4	0.4	0.4	0.5	0.5	
RMSE (ft) (Lines 1 - 18)		0.2	0.2	0.3	0.3	0.4	

* - Model has only overbank geometry and does not include 1D low flow channel, Manning's n and other necessary components for calibration

Habitat Sensitivity to Grid Size

Salmonid fry usable habitat estimates

Grid size (ft)	Fraction of wetted area (%)					
	Chinook Fry			*O. mykiss* Fry		
	Product	Geo. mean	Limiting	Product	Geo. mean	Limiting
10 by 10	29	40	32	40	48	42
20 by 20	27	39	31	39	47	40
30 by 30	27	38	30	38	46	39
40 by 40	28	39	31	38	47	40
50 by 50	26	38	30	37	46	39

Habitat Sensitivity to Grid Size

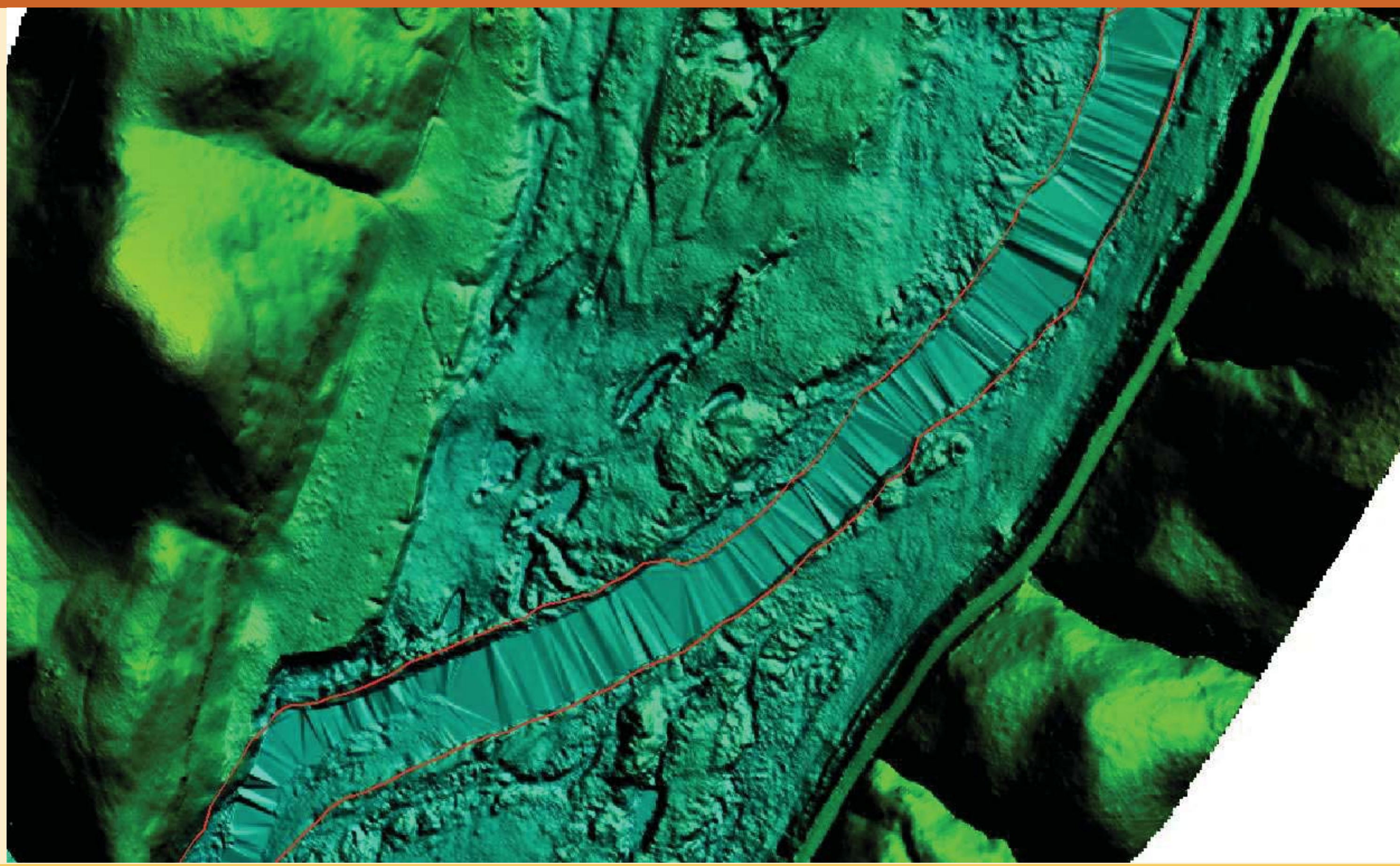
Salmonid juvenile usable habitat estimates

Grid size (ft)	Fraction of wetted area (%)					
	Juvenile Chinook			Juvenile O. mykiss		
	Product	Geo. mean	Limiting	Product	Geo. mean	Limiting
10 by 10	32	42	34	35	43	37
20 by 20	32	42	34	35	43	37
30 by 30	32	41	34	34	42	37
40 by 40	33	42	35	35	43	38
50 by 50	32	41	34	35	43	37

Overbank vs. In-Channel Areas

- **2D domain maximized for habitat analysis**
- **1D-2D line defines hydraulic control for TUFLOW**
- **Approximately historic 1,070 cfs inundation extent**
- **Overbank area transitions to riverine area at higher flows**

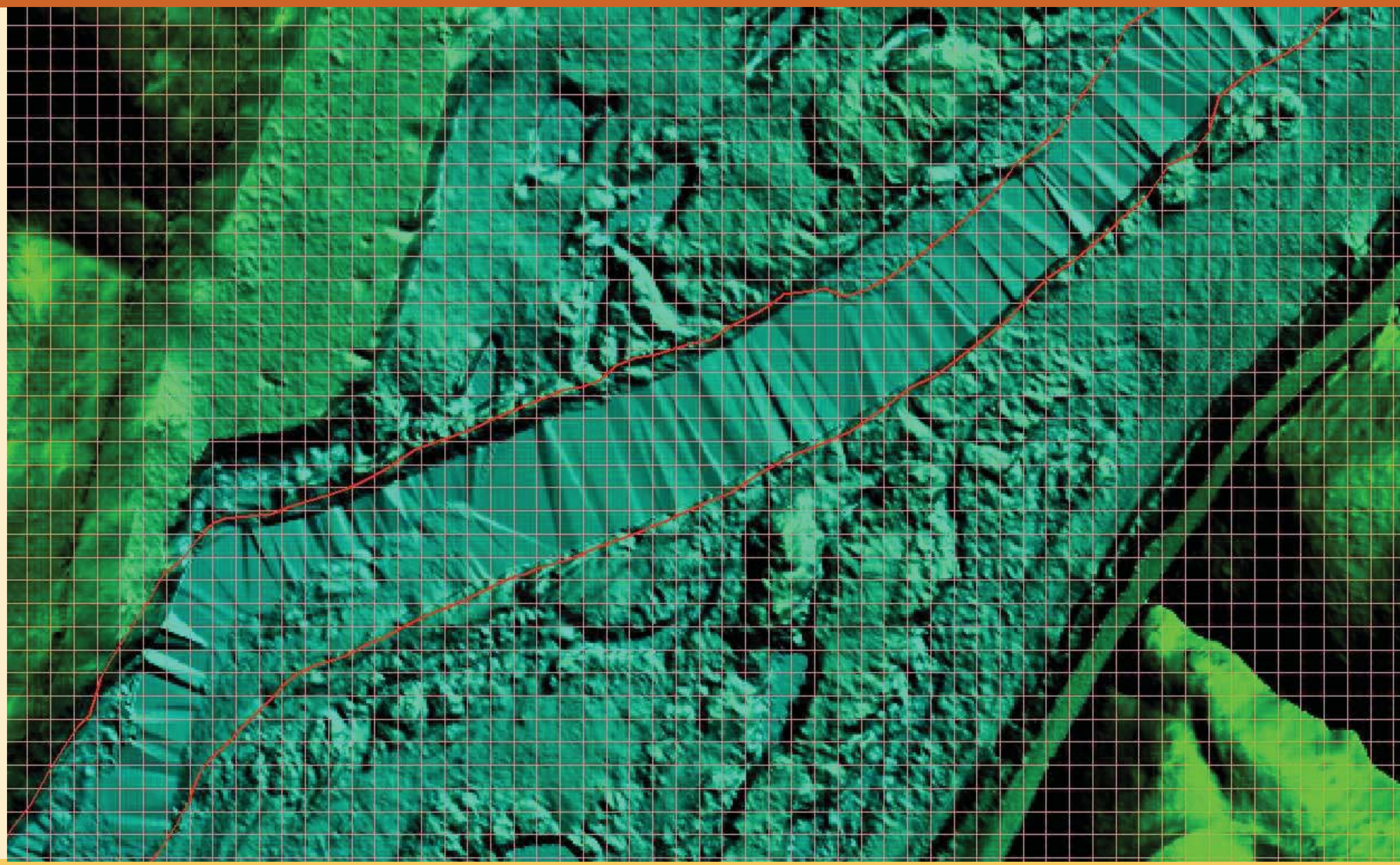
1D-2D Domain Boundary



1D-2D Domain Boundary

1,070 cfs Inundation Extent

1D-2D Boundary for 30ft cells



TUFLOW Modeling Plan

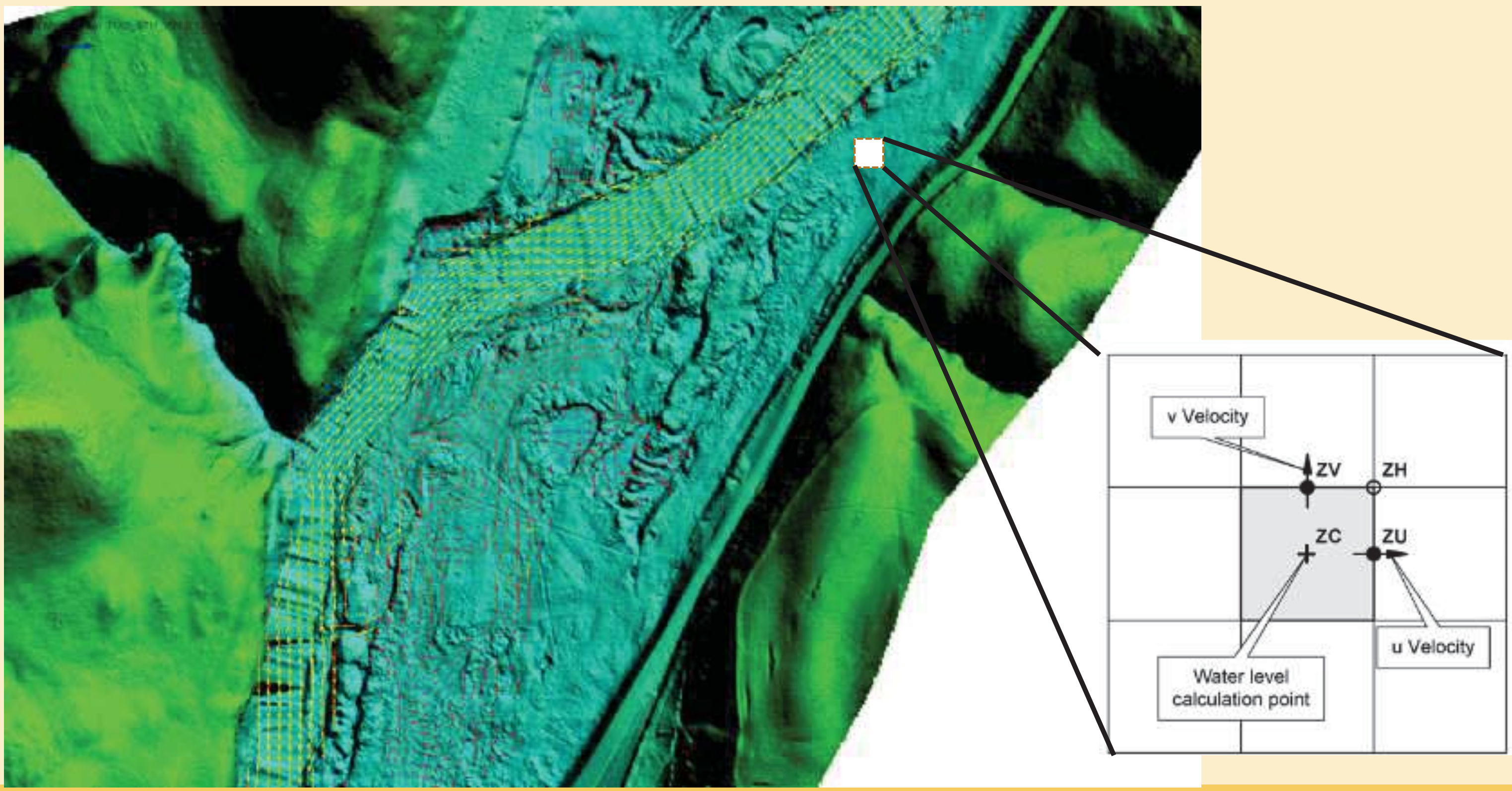
- Units: Foot-Pound-Second (FPS)
- Projection : NAD83 California State Plane, Zone III, US Foot
- 3 or more sub-models
  - RM 52 – RM 40
  - RM 40 – RM 24
  - RM 24 – RM 0
- Cell Size – 30ft or less

Pilot Model - Next Steps

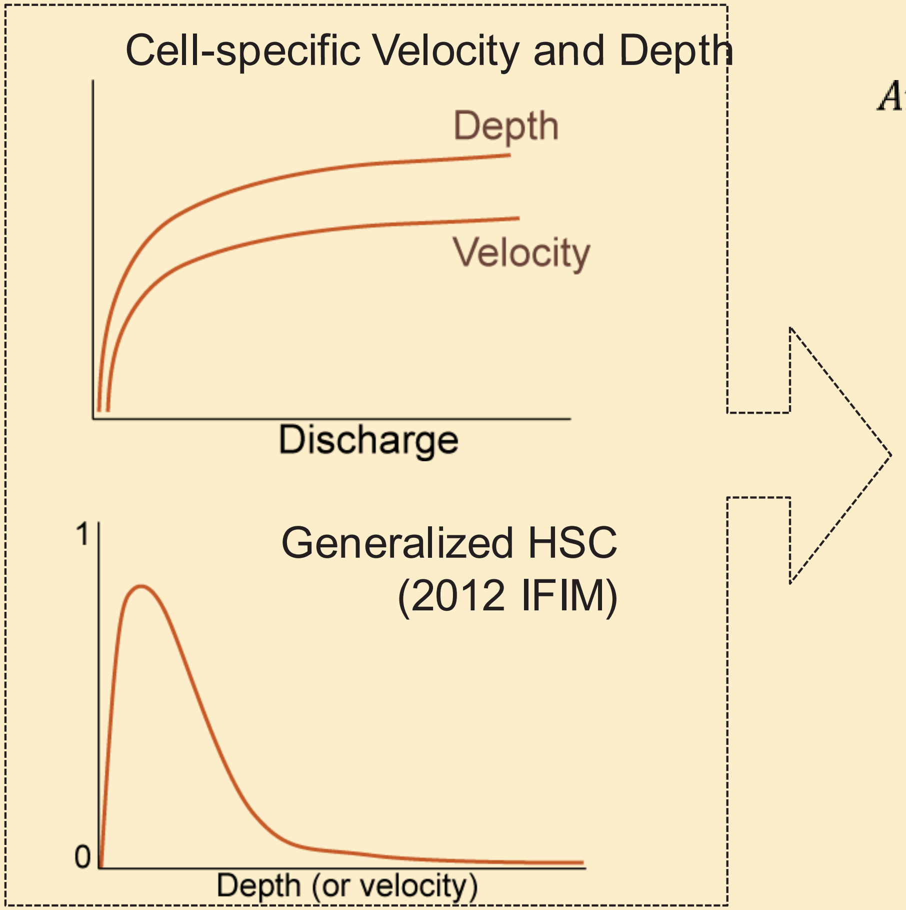
- Add Manning's "n" to overbank areas
- Add embankments using breaklines
- Add elevation of ponds & pools using breaklines
- Add 1D low flow channel geometry
- Calibrate

Habitat Analysis

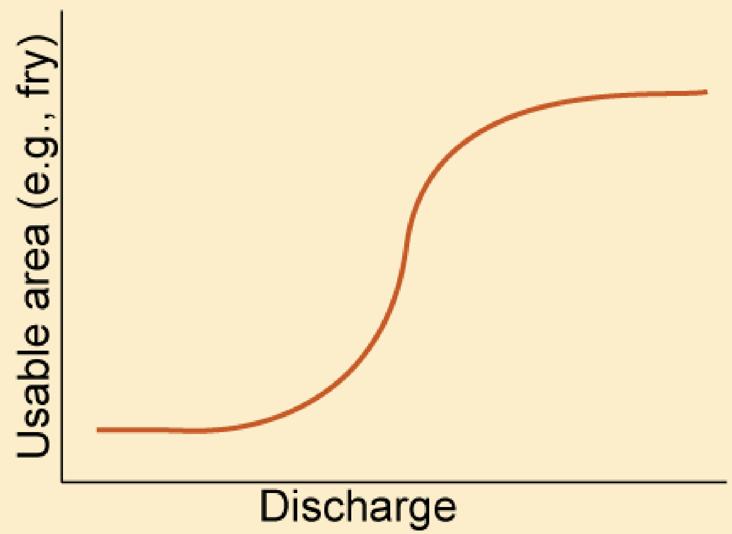
- **Cell-specific Velocity and Depth Predictions**



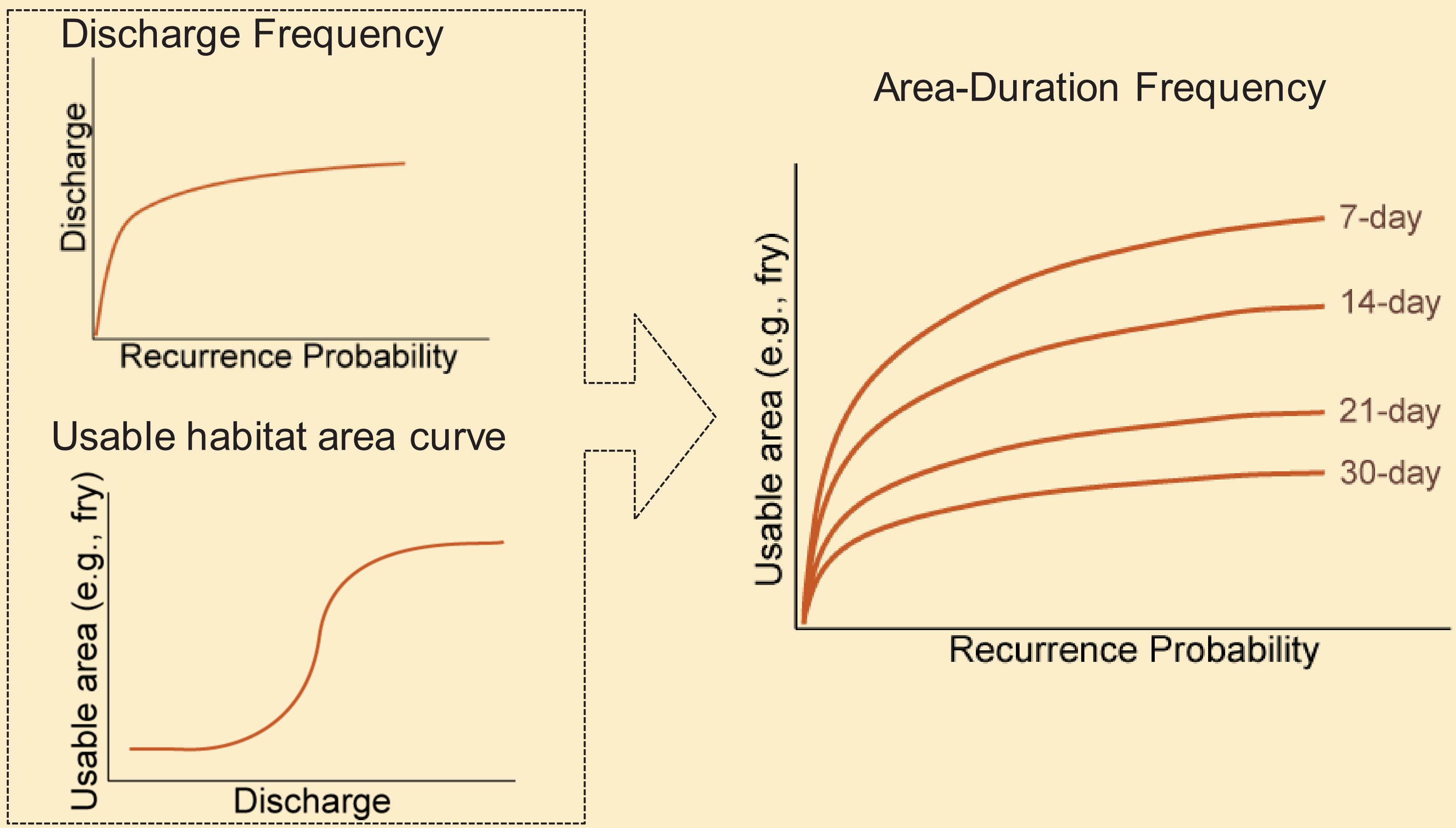
Habitat Analysis



$$Area = \sum_{i=1}^{n} A_i \times HSC(depth, velocity)$$



Habitat Analysis



Questions?

Photo Credit: Stillwater Sciences

Photo Credit: Tuolumne River TAC

Floodplain Hydraulic Assessment Schedule

• Model Input Development	October 2013–February 2014
• Model Hydraulic Development	January–March 2014
• Model Calibration/Validation/RP Consultation	February–March 2014
• Map Inundation Extents	March-April 2014
• Evaluate Inundation Frequency, Period, Duration and Juvenile Rearing	April-June 2014
• Draft Report Preparation	July–August 2014
• Draft Report Review by Relicensing Participants	August 2014
• Final Report Filing with FERC	November 2014

Attachment B
Tuolumne River Conservancy, Inc.
Comments on Floodplain Hydraulic Analysis Workshop No. 1

From: Allison Boucher <aboucher@bendbroadband.com>
Sent: Thursday, February 20, 2014 8:09 PM
To: 'Staples, Rose'; 'Alves, Jim'; 'Amerine, Bill'; 'Asay, Lynette'; 'Barnes, James'; 'Barnes, Peter'; 'Barrera, Linda'; 'Beeco, Adam'; 'Blake, Martin'; 'Bond, Jack'; 'Borovansky, Jenna'; 'Bowes, Stephen'; 'Bowman, Art'; 'Brenneman, Beth'; 'Buckley, John'; 'Buckley, Mark'; 'Burke, Steve'; 'Burt, Charles'; 'Byrd, Tim'; 'Cadagan, Jerry'; 'Carlin, Michael'; 'Charles, Cindy'; 'Cooke, Michael'; 'Cowan, Jeffrey'; 'Cox, Stanley Rob'; 'Cranston, Peggy'; 'Cremeen, Rebecca'; 'Damin Nicole'; 'Day, Kevin'; 'Day, P'; 'Denean'; 'Derwin, Maryann Moise'; 'Devine, John'; 'Dowd, Maggie'; 'Drake, Emerson'; 'Drekmeier, Peter'; 'Edmondson, Steve'; 'Eicher, James'; 'Fargo, James'; 'Fernandes, Jesse'; 'Ferranti, Annee'; 'Ferrari, Chandra'; 'Findley, Timothy'; 'Fleming, Mike'; 'Fuller, Reba'; 'Furman, Donn W'; 'Ganteinbein, Julie'; 'Giglio, Deborah'; 'Gorman, Elaine'; 'Grader, Zeke'; 'Gutierrez, Monica'; 'Hackamack, Robert'; 'Hastreiter, James'; 'Hatch, Jenny'; 'Hayden, Ann'; 'Hellam, Anita'; 'Heyne, Tim'; 'Holley, Thomas'; 'Holm, Lisa'; 'Horn, Jeff'; 'Horn, Timi'; 'Hudelson, Bill'; 'Hughes, Noah'; 'Hughes, Robert'; Noah Hume; 'Hurley, Michael'; 'Jackson, Zac'; 'Jauregui, Julia'; 'Jennings, William'; 'Jensen, Laura'; 'Johannis, Mary'; 'Johnson, Brian'; 'Jones, Christy'; 'Jsansley'; 'Justin'; 'Keating, Janice'; 'Kempton, Kathryn'; 'Kinney, Teresa'; 'Koepele, Patrick'; 'Kordella, Lesley'; 'Le, Bao'; 'Levin, Ellen'; 'Linkard, David'; 'Loy, Carin'; 'Lwenya, Roselynn'; 'Lyons, Bill'; 'Madden, Dan'; 'Manji, Annie'; 'Marko, Paul'; 'Martin, Michael'; 'Mathiesen, Lloyd'; 'McDaniel, Dan'; 'McDevitt, Ray'; 'McDonnell, Marty'; 'Mein Janis'; 'Mills John'; 'Morningstar Pope, Rhonda'; 'Motola, Mary'; 'Murphey, Gretchen'; 'Murray, Shana'; 'O'Brien, Jennifer'; 'Orvis, Tom'; 'Ott, Bob'; 'Ott, Chris'; 'Pavich, Steve'; 'Pool, Richard'; 'Porter, Ruth'; 'Powell, Melissa'; 'Puccini, Stephen'; 'Raeder, Jessie'; 'Ramirez, Tim'; 'Rea, Maria'; 'Reed, Rhonda'; 'Reynolds, Garner'; 'Richardson, Daniel'; 'Richardson, Kevin'; 'Ridenour, Jim'; 'Riggs T'; 'Robbins, Royal'; 'Romano, David O'; 'Roos-Collins, Richard'; 'Rosekrans, Spreck'; 'Roseman, Jesse'; 'Rothert, Steve'; 'Sandkulla, Nicole'; 'Saunders, Jenan'; 'Schutte, Allison'; 'Sears, William'; 'Shakal, Sarah'; 'Shipley, Robert'; 'Shumway, Vern'; 'Shutes, Chris'; 'Sill, Todd'; 'Simsiman, Theresa'; 'Slay, Ron'; 'Smith, Jim'; 'Stapley, Garth'; 'Steindorf, Dave'; 'Steiner, Dan'; 'Stender, John'; 'Stone, Vicki'; 'Stork, Ron'; 'Stratton, Susan'; 'Taylor, Mary Jane'; 'Terpstra, Thomas'; 'TeVelde, George'; 'Thompson, Larry'; 'Tmberliner'; 'Ulibarri, Nicola'; 'Verkuil, Colette'; 'Vierra, Chris'; 'Villalobos, Amber'; 'Wantuck, Richard'; 'Ward, Walt'; 'Welch, Steve'; 'Wenger, Jack'; 'Wesselman, Eric'; 'Wetzel, Jeff'; 'Wheeler, Dan'; 'Wheeler, Dave'; 'Wheeler, Douglas'; Scott Wilcox; 'Williamson, Harry'; 'Willy, Allison'; 'Wilson, Bryan'; 'Winchell, Frank'; 'Wooster, John'; 'Workman, Michelle'; 'Yoshiyama, Ron'; 'Zipser, Wayne'
Cc: Dave Boucher
Subject: Floodplain Hydraulic Assessment

Floodplain Hydraulic Assessment Study:

Although historic recurrence probability might be interesting, the more important analysis would be unimpaired flows recurrence probability. Please add unimpaired flows recurrence probability to the study and compare it to flows since the 1995 Settlement Agreement excluding the flood of 1997. If the flood of 1997 is included, the graph will be misleading.

Allison and Dave Boucher
Tuolumne River Conservancy, Inc.

APPENDIX B

WORKSHOP NO. 2 MEETING NOTES

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Don Pedro Project Relicensing
W&AR-21 Workshop No. 2
Draft Meeting Notes

Thursday, December 18, 2014

Attendees

Jenna Borovansky – HDR	Ron Yoshiyama – CCSF
Jesse Deason – HDR	Jim Hastreiter – FERC, *by phone*
John Devine – HDR	Robert Hughes – CDFW
Pani Ramalingam – HDR	Dean Marston – CDFW
Rob Sherrick – HDR	Dale Stanton – CDFW
Anna Brathwaite – MID	John Wooster – NMFS, *by phone*
Greg Dias – MID	Mark Gard – USFWS
Bill Johnston – MID, *by phone*	Peter Barnes – SWRCB, *by phone*
Noah Hume – Stillwater Sciences	Chris Shutes – CSPA, *by phone*
Maia Singer – Stillwater Sciences	Peter Drekmeier - Tuolumne River Trust, *by phone*
Jonathan Knapp – CCSF	Patrick Koepele – Tuolumne River Trust, *by phone*
Ellen Levin – CCSF	Nicola Ulibarri – Stanford
Bill Sears – CCSF	

Agenda and Purpose

Following introductions, Jenna Borovansky provided an overview of the meeting agenda. The purpose of the Lower Tuolumne River Hydraulic Floodplain Assessment (W&AR-21) modeling Workshop No. 2 is to review the hydraulic model development, present calibration and validation results, present preliminary results of the habitat analysis, and the study schedule (slide 2).

Background

Jenna provided study background (slide 3).

Study Objectives

Jenna presented the study objectives, namely to analyze floodplain inundation at specified flow intervals and estimate associated floodplain habitat availability for rearing juvenile salmon in the lower Tuolumne River (slide 4). Base case hydrology (1970-2012) from the Operations Model report is used for this study. The completed 2-D floodplain model can serve as a tool for modeling future hydrology scenarios.

Study Methodology

Jenna provided an overview of study methodology (slide 5).

Summary of Workshop No. 1

Jenna presented a summary of material covered at Workshop No. 1, held in February 2014, including recommendations that came out of workshop discussions (slides 6 & 7). The primary recommendations were the following:

- Develop three reaches for TUFLOW model
  - Model A (RM 51.4 – 40)
  - Model B (RM 40 – 21.5)
  - Model C (RM 21.5 – 0.9)
- Based on results of the sensitivity analysis, use a 2-D model cell size of 30 ft or less

Question (Patrick Koepele): What geomorphic characteristics were used to define the three study reaches?

Answer (Pani Ramalingam): Three study reaches were adopted primarily based on run-time considerations for TUFLOW. At a 30-ft cell size, the model run time for the entire lower river would be unreasonably long. Breaking the model into three separate reaches allowed us to optimize model construction, calibration, and run time. Each of the three model segments requires approximately 1-2 hours to run, allowing us to work on them simultaneously.

Answer (Noah Hume): The Tuolumne River has a major slope break from gravel bedded to sand bedded at approximately RM 29. As Pani noted, the river was divided into sub-reaches for computational efficiency.

Hydraulic Modeling Status

Pani Ramalingam presented the model reach extents (slide 8). Rob Sherrick presented a summary of the various cross section data sources used to develop model cross-sections for the 1-D (in-channel) portion of the TUFLOW model (slides 9 &10). While existing data were used where available, a considerable amount of additional cross-section data were collected by TID as necessary. Some of the survey locations of the data sources overlapped in various reaches of the river, allowing for improved spatial accuracy and model validation.

Model Components

Pani presented the TUFLOW hydrologic model components (slides 11-12).

- Ponds and pools – manually digitized and were assigned depths from bathymetry if available or assigned water level from 2012 LiDAR
- Levee like features – derived from LiDAR and captured in the model
- Narrow thin channels – derived from LiDAR and captured in the model
- Mannings ‘n’ (roughness or friction factor used in modeling) was derived from prior vegetation mapping studies and existing aerial photos, 2012 helicopter video and field visit photos.
- Model B – includes culverts near RM 38
- Model C – includes Dennett Dam (~RM 16)

Model Boundary Conditions

Pani described the order of model segment development. Boundary conditions were set from downstream to upstream in order to appropriately include backwater effects from the Tuolumne River-San Joaquin River confluence.

1. Model C – An analysis of backwater effects of San Joaquin River was performed. A range of USGS gage data sources were used to estimate statistical relationships of San Joaquin and Tuolumne River stages and flows (slides 13-16). This analysis revealed that backwater effects can extend up to RM 13. A discharge - water surface elevation curve (rating curve) was developed for use as boundary condition.

2. Model B - Model C was built simultaneously along with Model B and the section upstream of Modesto gage (near RM 16) was calibrated. Results from this model were then used to develop a rating curve for use as a boundary condition. It should be noted that extents of Model B and C overlap.

3. Model A – Normal depth boundary condition was used by extending the model downstream to RM 37.5 so that boundary effects are insignificant at RM 40. It should be noted that extents of Model A and B overlap.

Model Calibration and Validation

Pani described the calibration and validation steps for TUFLOW (slides 17-21). Calibration was accomplished by using a combination of model results, gage flows, and historical images. The 1-D in-channel portion of the model was calibrated first, followed by the 2-D floodplain portion of the model.

Question (Bob Hughes): How did you use Google Earth to calibrate the model?

Answer (Pani Ramalingam): We used existing images of historical flow events across a range of flows to visualize the channel wetted width. This included digitizing a series of air photos from four high flow events in the 1990s that were used in the USFWS (2008) and Stillwater Sciences (2012) floodplain studies. Google Earth also provides historical aerial imagery which allowed the observed inundation extent to be validated against the gaged flows on the date of the photo.

Question (Bob Hughes): Was there any calibration to water surface elevations?

Answer (Pani Ramalingam): Yes, in Model Segment A for RM 49 – 43, the stage data records for 3,000 cfs collected at two sites in the 2011 Pulse Flow Study was used. Water surface elevations were also used to calibrate Model Segment C using the existing USGS rating curve information at the Modesto gage.

Hydraulic Modeling Results

Pani showed inundation examples (slide 22) for Model Segment A, B, and C stepping through model results in 250/500 cfs increments (not shown in slides).

Question (Noah Hume): Are the flows entering from Dry Creek calculated using the rating curve approach for Model C or are the observed inundation areas simply due to backwater effects?

Answer (Pani Ramalingam): Backwater effects.

Question (Bob Hughes): I don't understand the interaction between the 1-D and 2-D components of the hydraulic model. Is the calibration accomplished primarily on the 1-D portion? How does TUFLOW work in general terms?

Answer (Pani Ramalingam): Calibration is undertaken for both the 1-D and 2-D portions [Pani showed a visual of the break line between the 1-D and 2-D models]. The model first undertakes calculations for the 1-D portion. Every 2 seconds the two models communicate with one another to determine if water should be crossing the break line into the 2-D portion of the model. We must begin with accurate flow predictions for the 1-D model; that is why we spent so much time collecting additional cross-section data for the 1-D model.

Habitat Analysis

Noah Hume discussed the habitat analysis approach (slides 23-24). Once the hydraulic model results were ready, we modeled habitat availability using suitability criteria for depth and velocity from the completed IFIM Study (Stillwater Sciences 2013). Cell-specific depth and velocity predictions from TUFLOW were summed across the 2-D model domain to estimate usable habitat area for juvenile and fry life stages of Chinook and *O. mykiss*. Results for Model Segment A are complete. Results are in development for model segments B and C.

Noah provided example results for Model Segment A at Riffle 4A/4B (slides 25-29):

- Habitat suitability is shown in 2,000 cfs increments
- In-channel habitat was excluded from the analysis (addressed by earlier Stillwater (2013) IFIM Study)
- Although there is a lot of inundated floodplain area, most of the suitable habitat is limited to backwater habitats and margins of flooded areas

Noah provided example results for Model Segment A at Bobcat Flat (slides 30-34):

- Hydraulic modeling is challenging in this reach due to the intact mining tailings piles and numerous deep ponds
- Given that, TUFLOW did a good job of representing flows in this reach
- Model results indicate inundation into captured gravel ponds at 7,000 and 9,000 cfs

Next we summed cell-specific habitat suitability for Model Segment A to produce the usable habitat vs discharge curve shown in slide 35.

- Note that usability of floodplain habitat for juveniles averages about 50% of total inundated area and does not fall off very quickly because they possess stronger swimming performance at increased depths and velocities
- In contrast, fry habitat usability drops off relatively quickly to less than 30% at the highest modeled flows
- The character of the usable habitat vs discharge relationships changes as we move from Model A which has some floodplain habitat; to Model B which has comparatively less floodplain habitat; to Model C nearest the San Joaquin River which has some floodplain habitat that becomes inundated at the highest flows.

O. mykiss fry life stages may be found in floodplain habitats, but generally these fish find flow refuge in gravels in main channel. Nevertheless we have included *O. mykiss* in the habitat analysis.

Area-Duration-Frequency Analysis

Noah discussed the aim of the ADF analysis – to determine the periods of maximum inundation occurring over a certain duration and at a certain frequency in the flow record (slides 36-45). This used base case (WY1971–2012) hydrology from the Operations Model (W&AR-02)

- Note that as in the example animations, even at 1,000 cfs there is a fair amount of floodplain habitat due to the presence of backwaters and pond features (e.g., 2 million ft^2).

- On a fairly regular basis (2-4 yr recurrence interval) floodplain habitat is inundated and usable for juveniles/fry.
- Flows above bankfull discharge are associated with increases in habitat.
- As with the usable habitat curves, each model reach will exhibit a slightly different character for the curves.
- For the final report, we may present habitat curves by reach, or we may combine into one lower river set of curves.
- In general, these results are consistent with prior floodplain modeling efforts.

Questions

Question: (Dale Stanton): Why limit yourself to the base case hydrology?

Answer (Jenna Borovansky): Base case hydrology is specified in the study plan, but conceivably other hydrologic scenarios could be run in the model.

Question: (Mark Gard): Would you compare results of the habitat assessment at unimpaired flows to results for base case flows? USFWS had recommended a set of flows in their comments on the study plan – what about those?

Answer (John Devine): The study plan suggests other flow scenarios, but in the FERC licensing process we are only considering the base case. The unimpaired flows represent a pre-project condition. If after FERC review there is still interest in modeling other flows, the model will be available as a tool.

Question (Bob Hughes): How much of the modeling tool will be publically available?

Answer (Jenna Borovansky): HDR has committed to having the TUFLOW model available for interested parties to run on their own. The Districts will work with agencies on the most efficient method for making the model available for use.

Answer (Noah Hume): The habitat suitability analysis is a little more involved but we could potentially provide the 'R' code used.

Answer (Rob Sherrick): The post-processing of the hydrology model results would be different for a new flow series, but TUFLOW results would be the same.

Question: Will the inundation animations be posted on the web?

Answer (Jenna Borovansky): Yes. We have some example animations for Model A that we can post – not all of the animations from today will be available since Pani ran them directly from the model for the workshop presentation.

Action Items

- The Districts will post the PowerPoint and sample animations on the relicensing website, www.donpedro-relicensing.com.
- The Districts will work with agencies to provide the model and habitat analysis files available by request, once the report is finalized.

- Following the meeting, Mark Gard (USFWS) contacted Noah Hume and requested summaries of the inundation area vs. discharge results to be provided in MS Excel format. In addition, when they are available, Mark requested velocity and depth predictions in either spreadsheet or csv format. The Districts will provide this information when the draft report is released for relicensing participant review.

Attachments

Attachment 1: Modeling Workshop Agenda

Attachment 2: Modeling Workshop No. 2 Slides

Attachment 1

Modeling Workshop No. 2 Agenda

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Don Pedro Hydroelectric Project
Floodplain Hydraulic Assessment (W&AR-21)
Workshop No. 2 Agenda

Thursday, December 18
1:00 pm – 4:30 pm
MID Offices, 1231 11th Street, Modesto, CA

Phone number: 866-994-6437
Conference code: 542-469-7994
Link to online meeting: Join Lync Meeting (Lync Meeting Help)

- Review agenda and purpose of the meeting
- Study plan goals and objectives
- Overview of study methodology
  - Study flows
- Summary of Workshop No. 1
- River hydraulic model background
  - 2D TUFLOW model
  - 1D HEC-RAS model
- Model reaches
  - Model A: RM 52.2 to RM 40
  - Model B: RM 40 to RM 21.5
  - Model C: RM 21.5 to the confluence
- Data sources
- River hydraulic model calibration process (RM 52.2 – RM 21.5)
- Habitat analysis status
  - Analysis approach
  - Model A – preliminary results
    - Bobcat Flat example
    - Reach estimated usable area
    - Area-duration frequency analysis
- Next steps and schedule

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Attachment 2

Modeling Workshop No. 2 Slides

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MODESTO IRRIGATION DISTRICT | TURLOCK IRRIGATION DISTRICT

Don Pedro Hydroelectric Project Relicensing

Lower Tuolumne River Floodplain Hydraulic Assessment (W&AR-21)

December 18, 2014

Agenda and Purpose

- Study Background
- Hydraulic Modeling Status
- Habitat Analysis Status
- Study Schedule

Background

- FERC ordered a hydraulic analysis of the amount of floodplain inundated in its May 21, 2013 Determination
- Draft study plan provided to relicensing participants for comment, and final study plan modified based on relicensing participant comments submitted in September 2013
  - Revised plan based on relicensing participant comment, including expanded study area and added habitat analysis
- FERC approved study plan October 18, 2013

Study Objectives

- Analyze the amount of floodplain inundated between RM 52.2 and RM 0 of the Tuolumne River at flows between approximately 1,000 cfs and 9,000 cfs
- Assess the suitability of inundated floodplain habitat for juvenile salmon rearing
- Evaluate the frequency and period of inundation over a range of flows for the base case (WY 1971-2012) hydrology

Study Methodology

1. TUFLOW model to determine floodplain extents at:
   - 250 cfs intervals from 1,000 - 3,000 cfs
   - 500 cfs intervals from 3,000 - 9,000 cfs
2. Determine the maximum continuous wetted area for 7, 14, 21, and 30 day durations
3. Evaluate the Base Case scenario (WR 1971-2012)
4. Estimate depths and velocities in overbank areas from RM 52 to the San Joaquin River and use existing habitat suitability criteria for depth and velocity for juvenile salmonids to quantify the amount of suitable juvenile rearing habitat as a function of flow

February 13, 2014: Workshop No. 1

- Hydraulic Modeling Approach
  - Data Sources
  - TUFLOW Model
  - Overbank vs. In Channel Areas
- Habitat Analysis Approach
  - Sensitivity to grid size

Feb.13 Meeting - Recommendations

- **TUFLOW Modeling Plan**
  - **Model A - RM 52 to 40**
  - **Model B - RM 40 to 23**
  - **Model C - RM 23 to 0**

- **2D cell Size – 30ft or less**

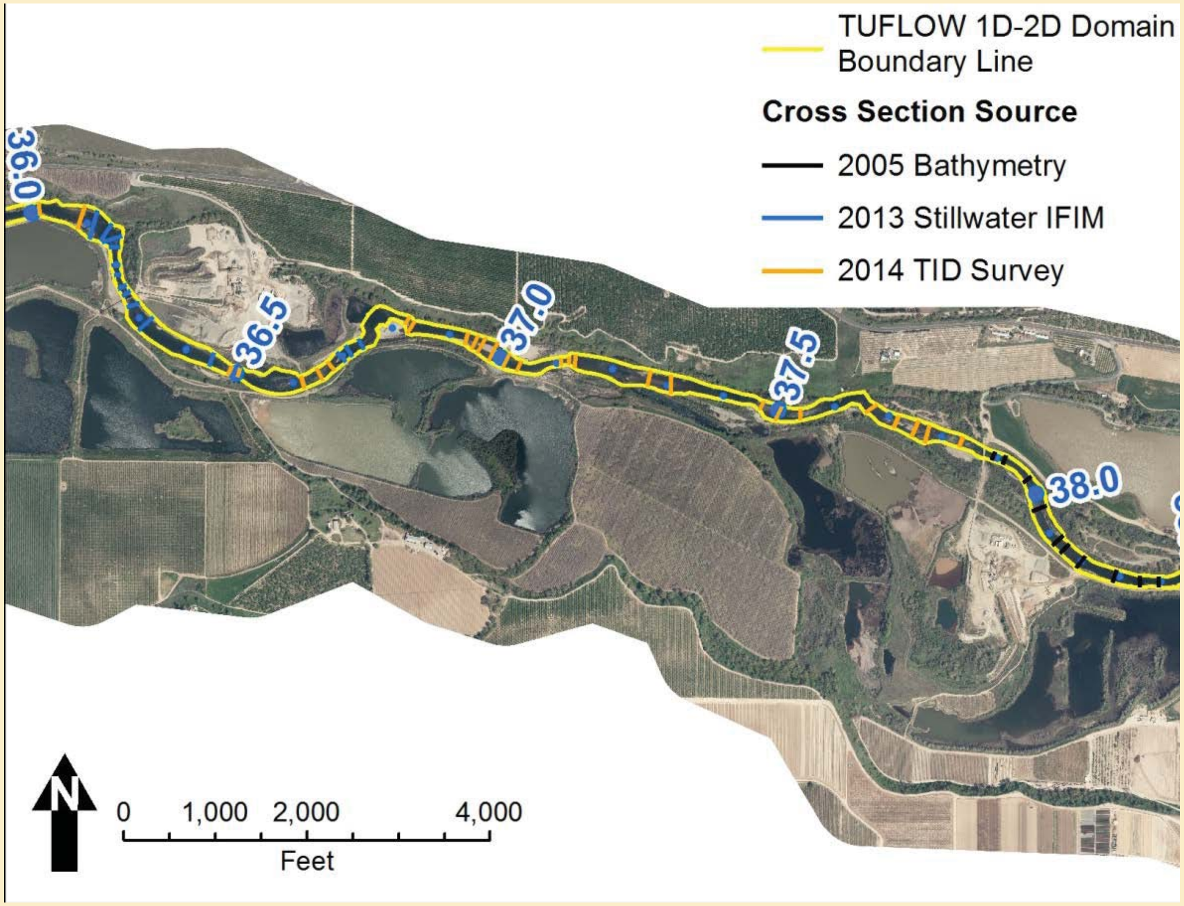
Hydraulic Modeling Status

- **TUFLOW models constructed, calibrated and QCed**
- **Model A – RM 52.2 to RM 40**
- **Model B – RM 40 to RM 21.5**
- **Model C – RM 21.5 to the confluence (RM 0.88)**
  - **San Joaquin River backwater effects analyzed**

1D Cross Section Data Sources

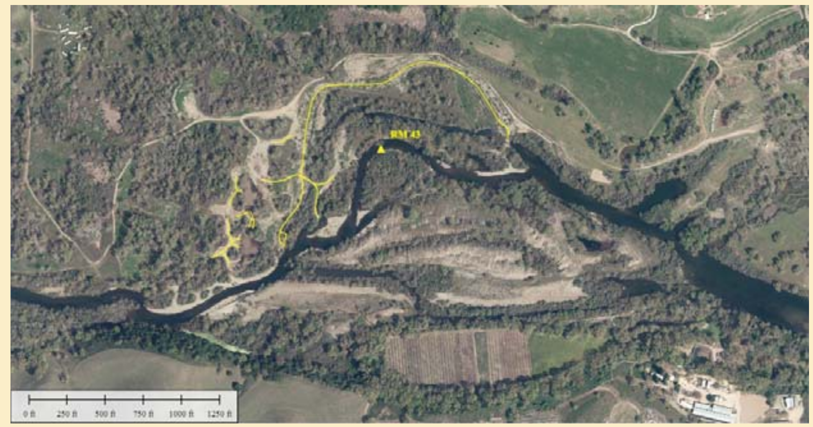
RM (USGS)	RAS Station	Source	Count
0.88-6.31	0.8252-6.3035	2014 DWR-CVFED HEC-RAS Model	28
6.71-22.78	6.715-23.0683	FEMA-CVFED HEC-RAS Model	51
13.99-31.48	13.847-31.9232	2012 HDR Survey	34
4.43-29.54	4.3978-29.98	Interpolated	37
16.13-16.41	15.9601-16.2138	USGS Gage Cross Sections	3
22.59-46.98	22.8536-47.4583	2014 TID Survey	134
24.41-25.86	24.948-26.5125	McBain&Trush SRP 9/10 Restoration	16
30.34-36.74	30.739-37.5818	2013 Stillwater IFIM	19
37.9-45.77	38.9536-46.27	2005 Bathymetry	167
45.78-51.66	46.2985-51.6734	2012 Bathymetry	133
		TOTAL:	622

Sample Cross Section Source Integration



Model Components

- 1D Low flow channel
- Ponds & pools
- Levee like features
- Narrow thin channels
  - connecting river and overbanks
  - connecting overbank ponds

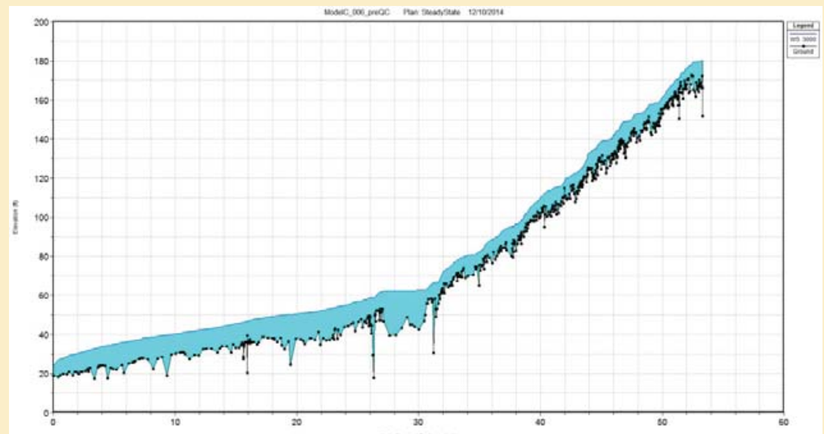


Model Components

- 2D Manning's "n" for overbank areas
- Culverts near RM 38
- Dennett Dam

Model Boundary Conditions

- Model A – Normal depth

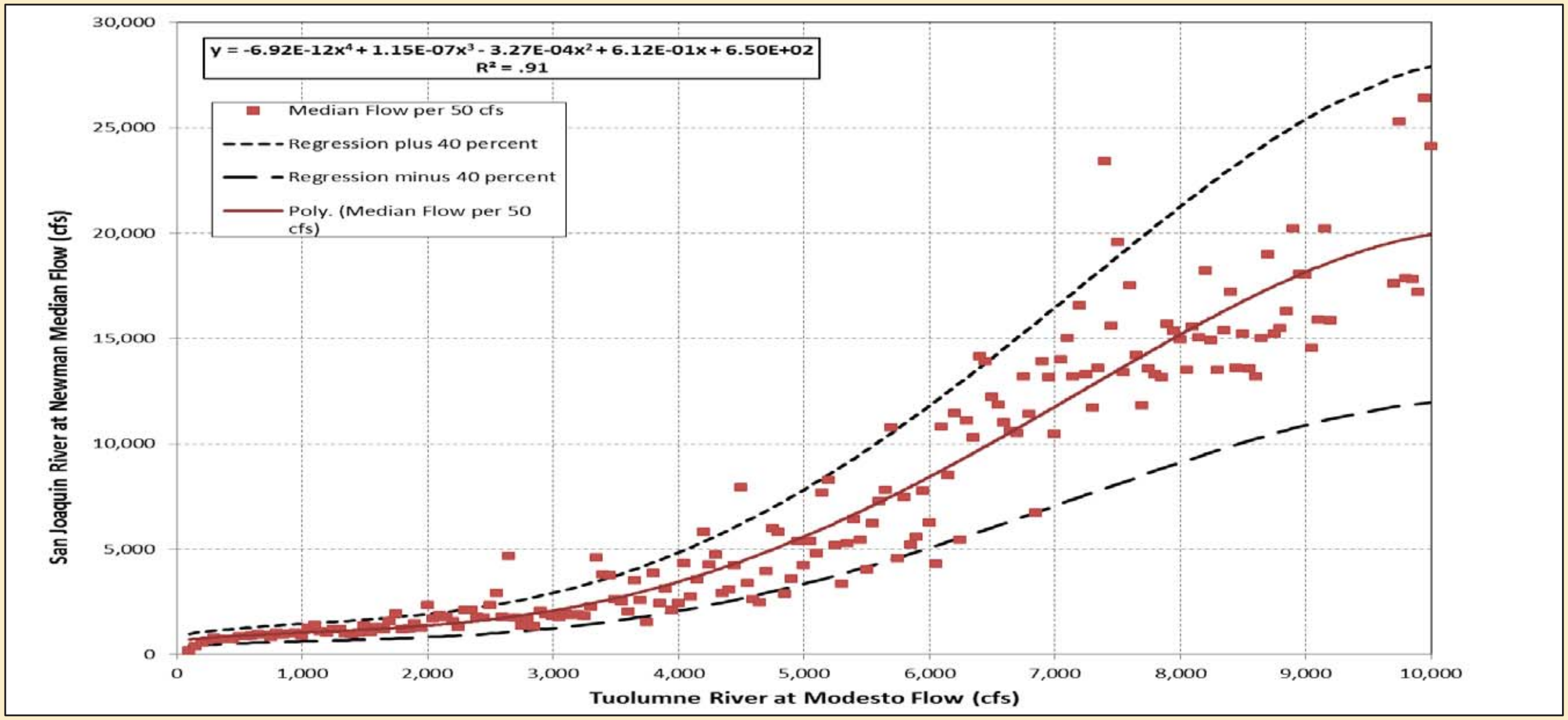


- Model B – From Model C
- Model C – San Joaquin River backwater analysis

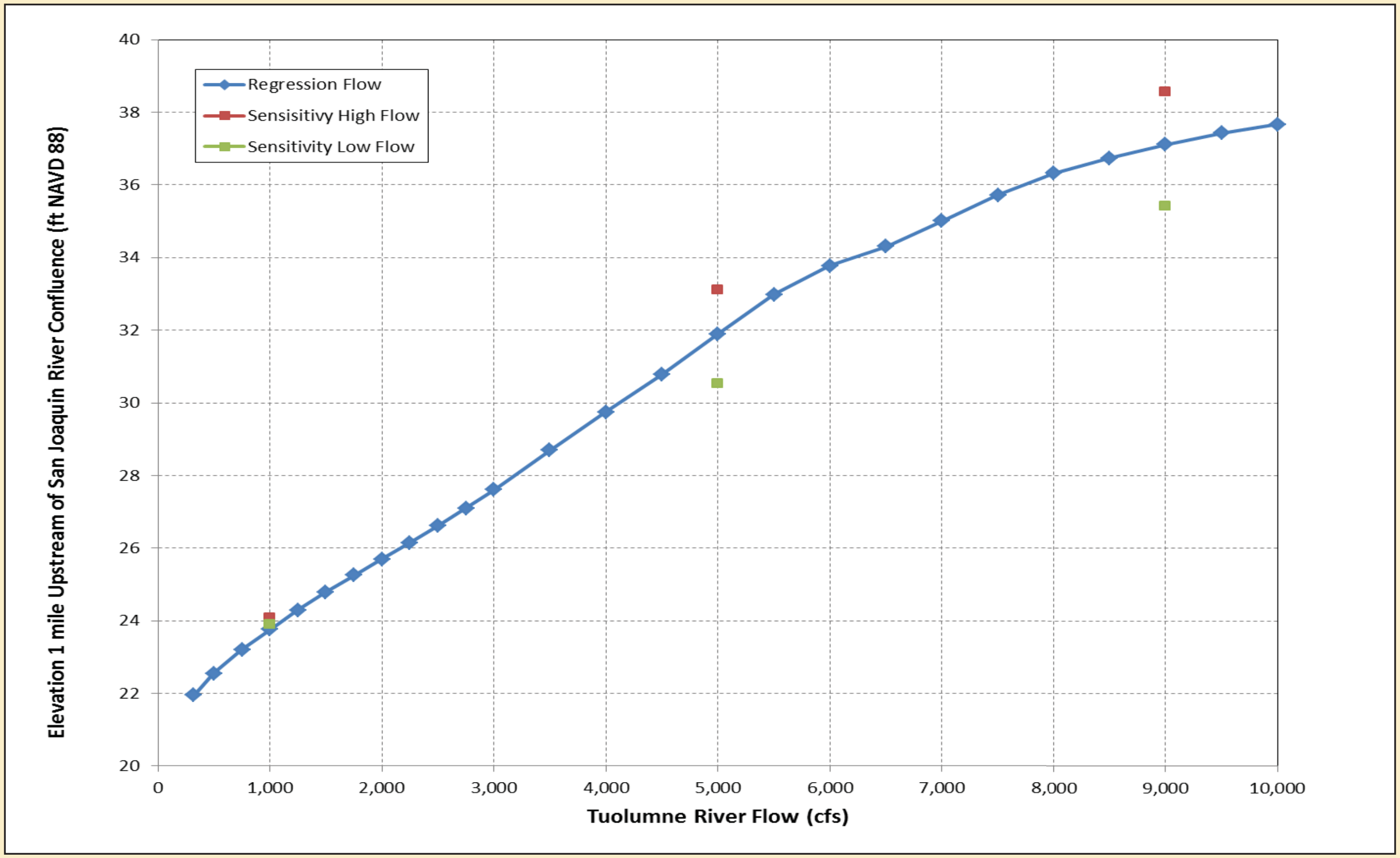
San Joaquin River Backwater Analysis

1. Use existing DWR & FEMA HEC-RAS models
2. Determine extent of backwater effects from San Joaquin River
3. Develop correlated sets of flows for Tuolumne, San Joaquin and Stanislaus Rivers (Water Years 1971 to 2012)
4. Develop a rating curve (elevation-discharge) for downstream boundary condition for Model C

Sensitivity Analysis



Model C Boundary Condition Rating Curve



Model Calibration & Validation

- Google Earth aerial photos (2005-2011)
- TID historic aerial photos (1993-1995)
- USGS gage at Modesto

Model A - Calibration and Validation

TUFLOW Model A - Calibration & Validation Reaches & Data Sources

Primary data set for calibration & validation

S. No.	USGS River Mile	Areas Included	Approximate Constant Flow / Google Earth Imagery Date						RM 50 Side Channel	Bobcat Flat RM 43 Restoration Work	
			1020 cfs	1590 cfs	1960 cfs	2040 cfs	2680 cfs	4030 cfs	490 cfs	5400-6000 cfs	5900-5600cfs
Reach 1	RM 48.5 to RM 51.6	Riffle 4A/4B	24-Jul-11	23-Feb-06		30-May-10	6/29/2005*	-	24-May-09		
Reach 2	RM 46 to RM 48.5	Riffle 5A (Basso Bridge)	24-Jul-11	23-Feb-06	-	30-May-10		11-Jun-05		-	
Reach 3	RM 44 to RM 46	Zanker Property	24-Jul-11	23-Feb-06		30-May-10	-	11-Jun-05	-		
Reach 4	RM 42 to RM 44	Bobcat Flat	24-Jul-11(RM 43 up)	23-Feb-06		30-May-10		11-Jun-05		13-Jun-10	16-Jun-11
Reach 5	RM 38 to RM 42		-	23- Feb-06(RM 40 up)	24-Apr-10	30-May-10 (RM 40 up)		11-Jun-05		-	

*Corrected date per NAIP

Legend

- Calibration Data
- Validation Data
- Limited validation

This data set was used more as a reference. The river/floodplain has changed significantly at several locations since the time of compilation of data.

S. No.	USGS River Mile	Approximate Constant Flow / TID Historic Inundation Imagery Year		
		3100 cfs	5300 cfs	8400 cfs
Reach 1	RM 48 to RM 51.6	1993	1995	1995
Reach 2	RM 46 to RM 48	1993	1995	1995
Reach 3	RM 44 to RM 46	1993	1995	1995
Reach 4	RM 42 to RM 44	1993	1995	1995
Reach 5	RM 38 to RM 42	1993	1995	1995

Model B - Calibration and Validation

TUFLOW Model B - Calibration & Validation Reaches & Data Sources

Primary data set for calibration & validation

S. No.	USGS River Mile	Areas Included	Approximate Constant Flow* / Google Earth Imagery Date			
			654 cfs	2130 cfs	2620 cfs	4050 cfs
1	RM 20 to RM 40		28-Jul-11	24-Apr-10	-	11-Jun-05
2	RM 20 to RM 25		28-Jul-11	24-Apr-10	10-Feb-06	11-Jun-05

*Previous day average flow to account for travel time from USGS La Grange gage

Legend

Calibration Data
Validation Data
Limited validation

This data set was used more as a reference. The river/floodplain has changed significantly at several locations since the time of compilation of data.

S. No.	USGS River Mile	Approximate Constant Flow / TID Historic Inundation Imagery Year		
		3100 cfs	5300 cfs	8400 cfs
2	RM 20 to RM 40	1993	1995	1995

Model C - Calibration and Validation

TUFLOW Model C - Calibration & Validation Reaches & Data Sources

A. Primary data set for calibration & validation

S. No.	USGS River Mile	Areas Included	Approximate Constant Flow* / Google Earth Imagery Date		
			900 cfs	3320 cfs	4130 cfs
1	RM 0.88 to RM 16		28-Jul-11	-	11-Jun-05
2	RM 12 to RM 16			10-Feb-06	

*USGS Modesto Gage (RM 16)

Legend

- Calibration Data
- Validation Data
- Limited validation

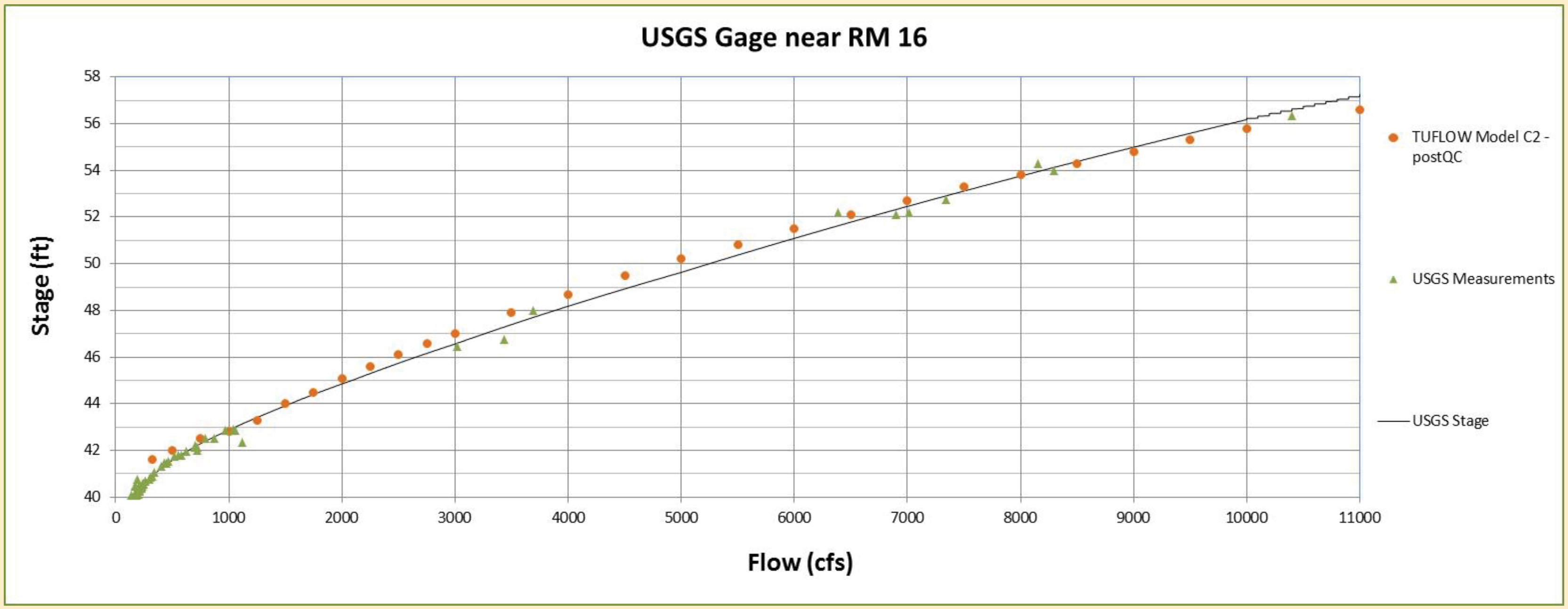
B. TID data set was used more as a reference as the river/floodplain has changed significantly at several locations since the time of compilation of data.

S. No.	USGS River Mile	Approximate Constant Flow* / TID Historic Inundation Imagery Year
		8322 cfs
2	RM 0.88 to RM 21.5	22-Apr-95

*USGS Modesto Gage (RM 16)

C. The rating curve & stage-flow measurements taken at of USGS Gage located near Modesto (near RM 16) were also used to calibrate the model for range of flows.

Model C - Calibration and Validation

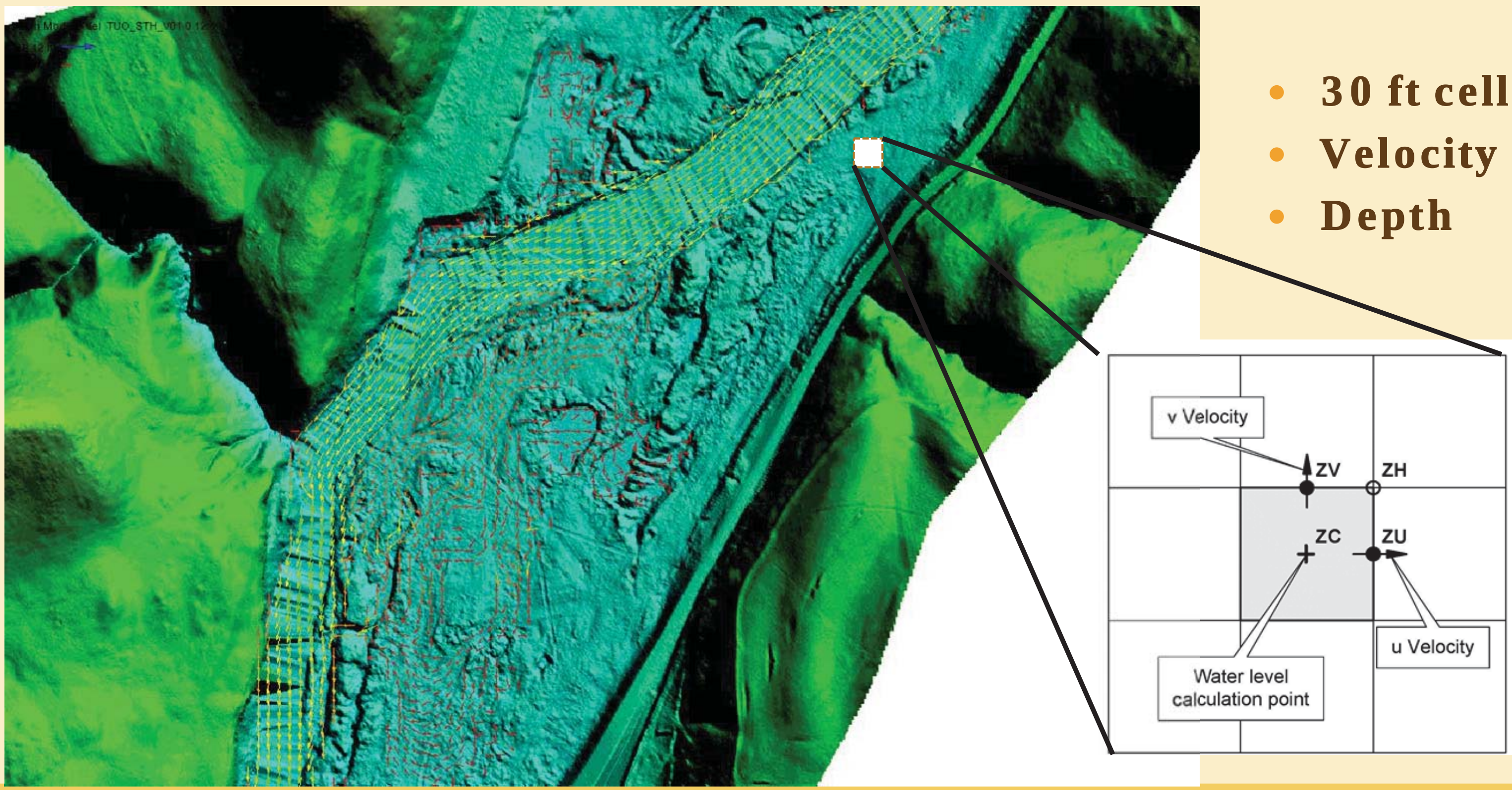


Models A, B & C - Results

- **Inundation Extents at various steady flows** (Animation)
  - 1000 to 3000 cfs @ 250 cfs interval
  - 3000 to 9000 cfs @ 500 cfs interval
- **Simulation of time varying hydrograph** (Animation)
  - 1000 to 9000 cfs and back to 1000 cfs
  - Shows flow paths, stranding potential etc.

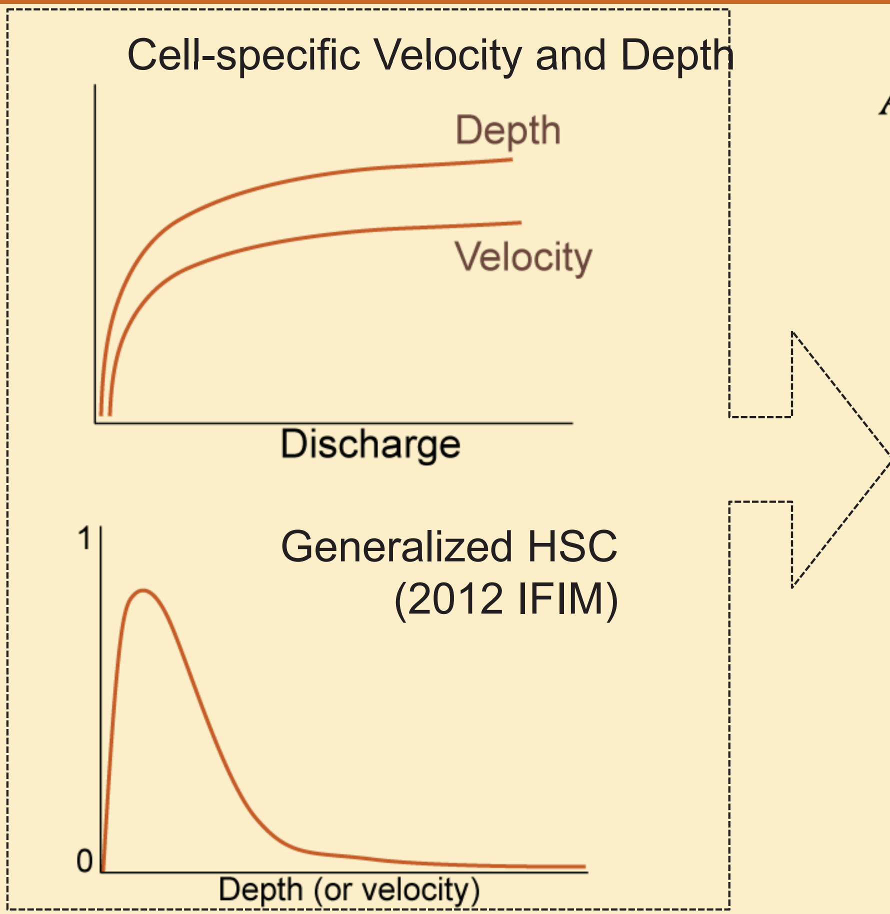
Habitat Analysis

- **Cell-specific Velocity and Depth Predictions**

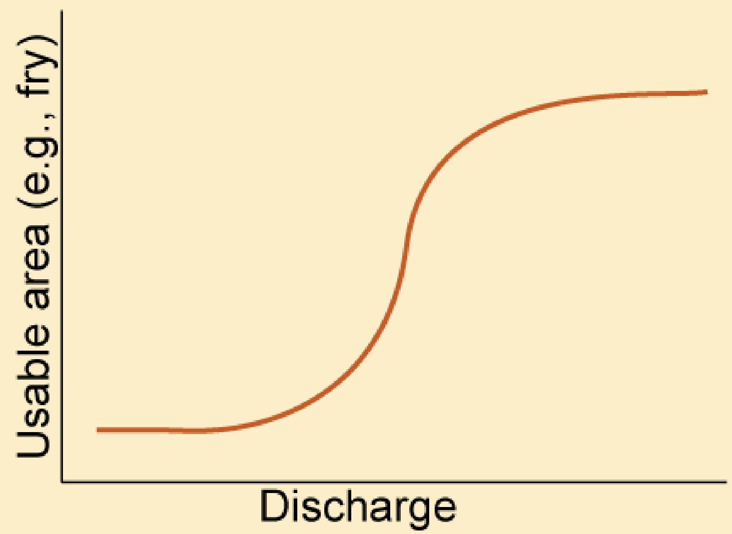


- **30 ft cell size**
- **Velocity**
- **Depth**

Habitat Analysis

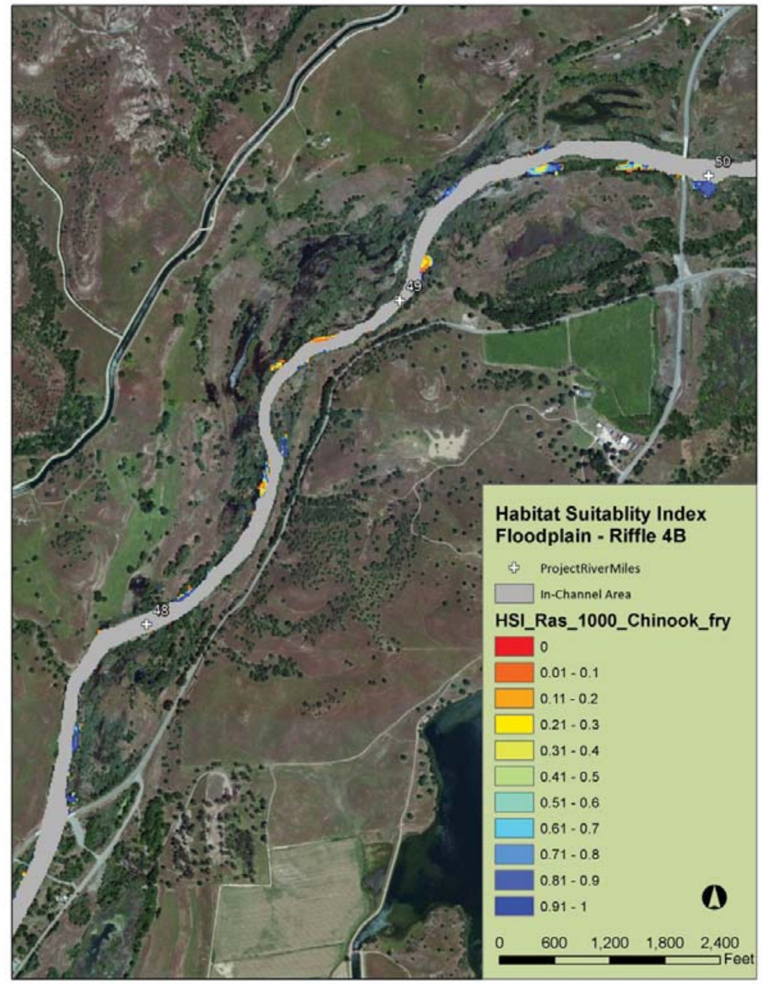


$$Area = \sum_{i=1}^{n} A_i \times HSC(depth, velocity)$$



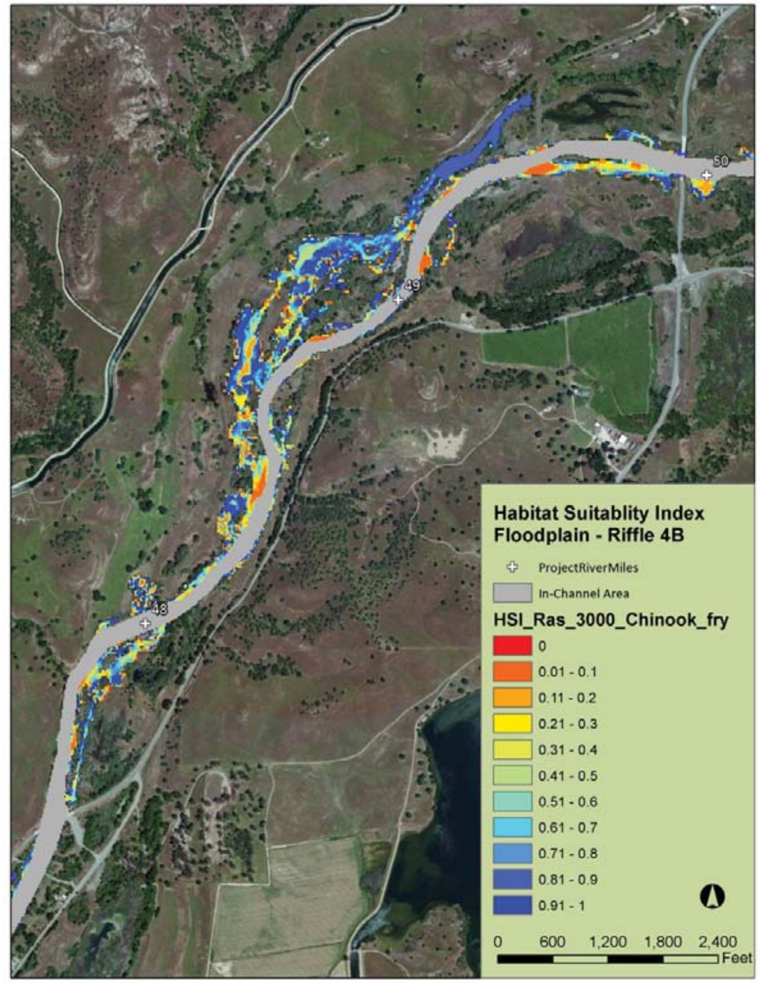
Habitat Analysis Results
Example at Riffle 4A/4B (RM 49)

- Overbank habitat at 1,000 cfs
- Little floodplain inundation evident



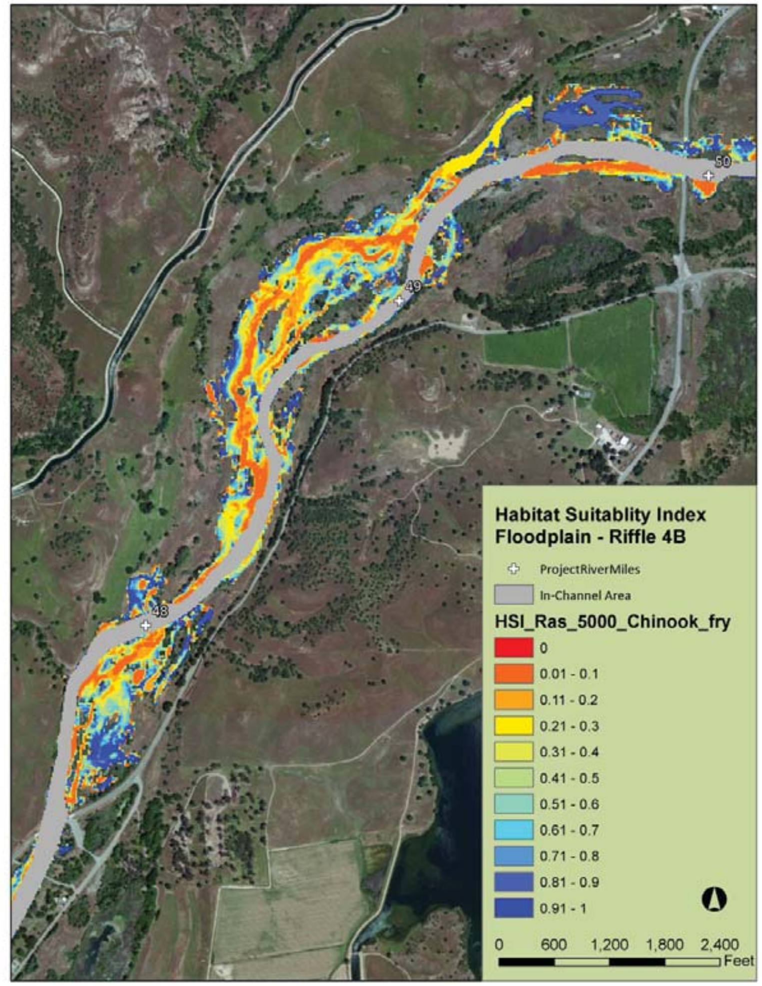
Habitat Analysis Results
Example at Riffle 4A/4B (RM 49)

- **Overbank habitat at 3,000 cfs**
- **Inundation of side-channels and floodplain**
- **Chinook fry habitat suitability (0-100%) greatest in areas with low velocities**



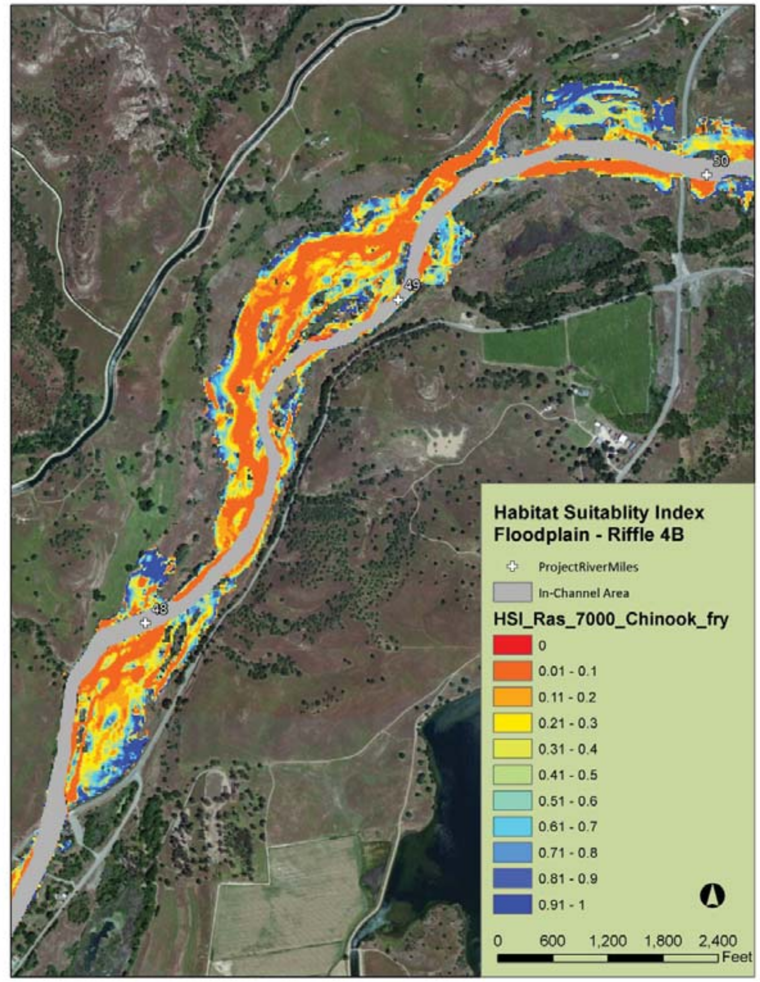
Habitat Analysis Results
Example at Riffle 4A/4B (RM 49)

- Overbank habitat at 5,000 cfs
- Broad inundation of floodplain habitat
- Chinook fry habitat suitability (0-100%) greatest in areas with low velocities



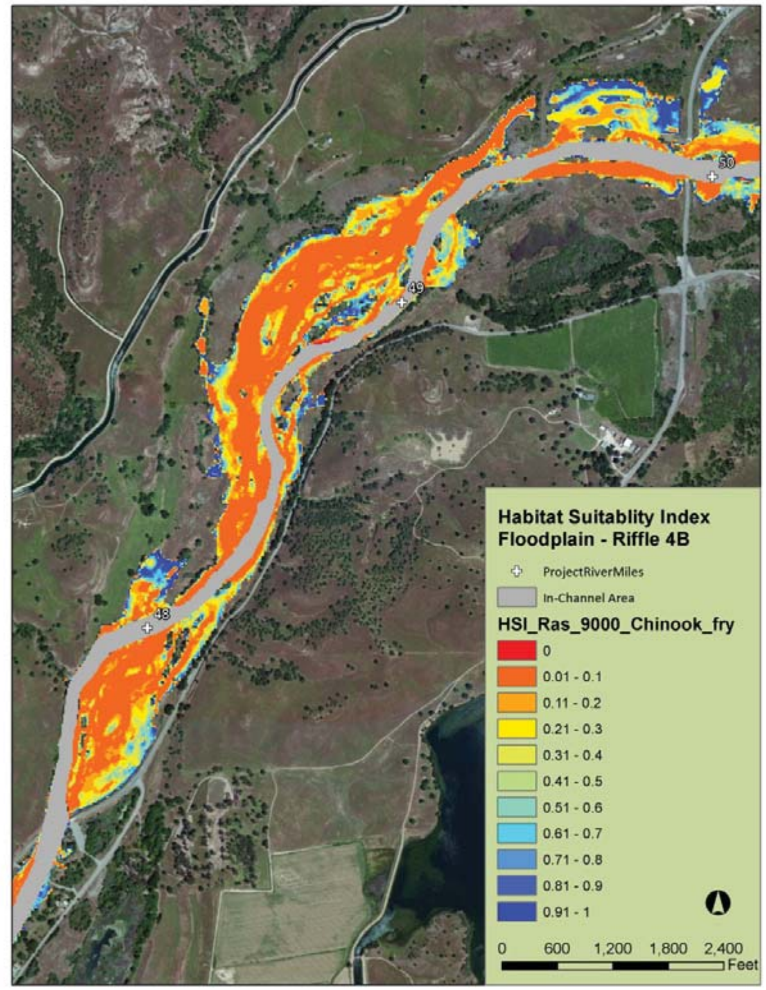
Habitat Analysis Results
Example at Riffle 4A/4B (RM 49)

- **Overbank habitat at 7,000 cfs**
- **Broad inundation of floodplain habitat**
- **Chinook fry habitat suitability (0-100%) greatest in areas with low velocities**



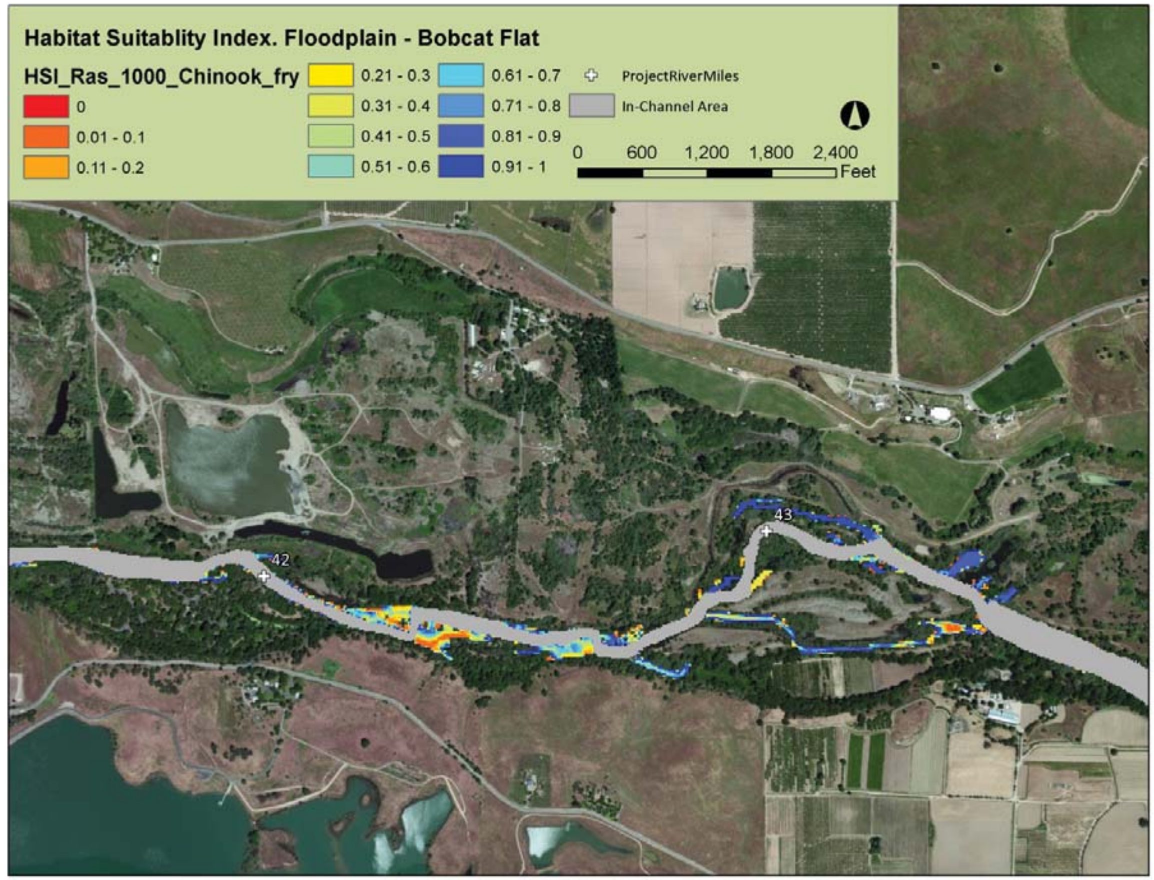
Habitat Analysis Results Example at Riffle 4A/4B (RM 49)

- Overbank habitat at 9,000 cfs
- Broad inundation of floodplain habitat
- Chinook fry habitat suitability (0-100%) greatest in areas with low velocities



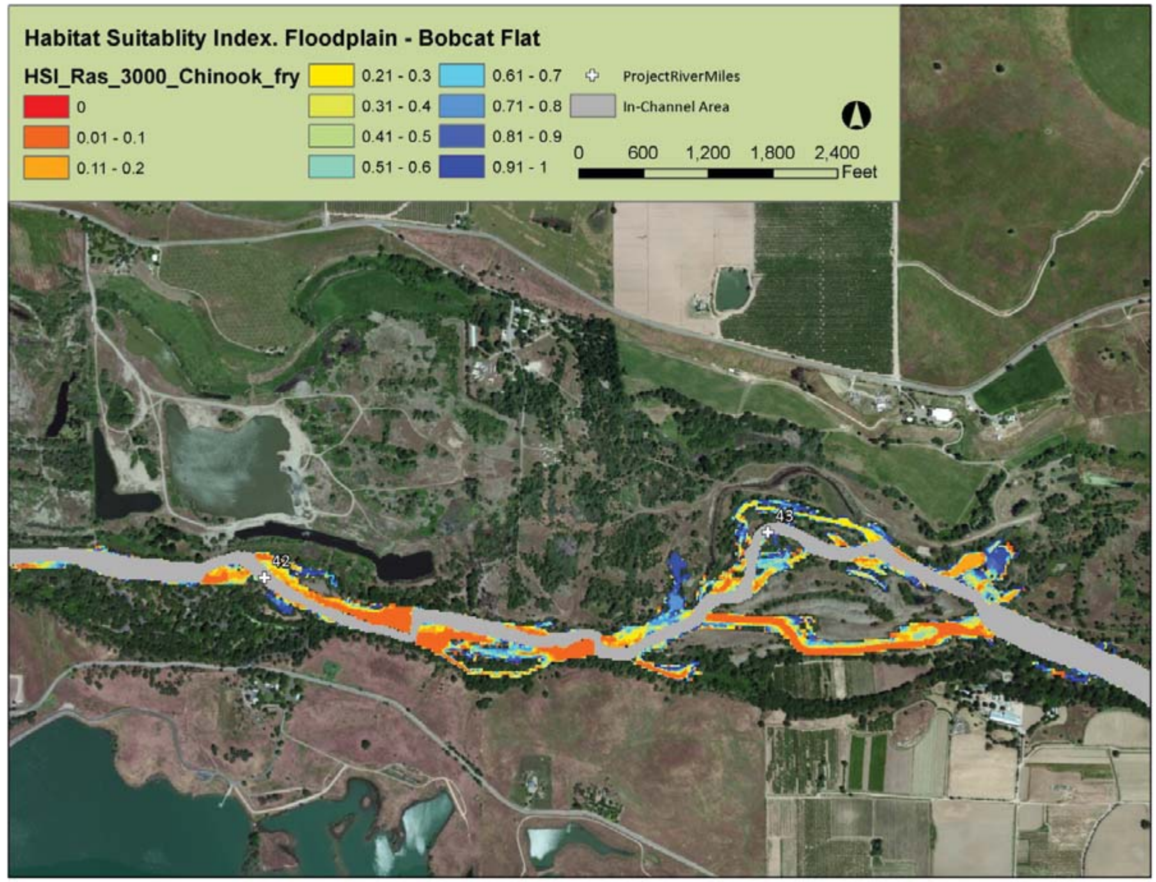
Habitat Analysis Results
Example at Bobcat Flat (RM 43)

- Overbank habitat at 1,000 cfs
- Some side channel and backwater habitat evident



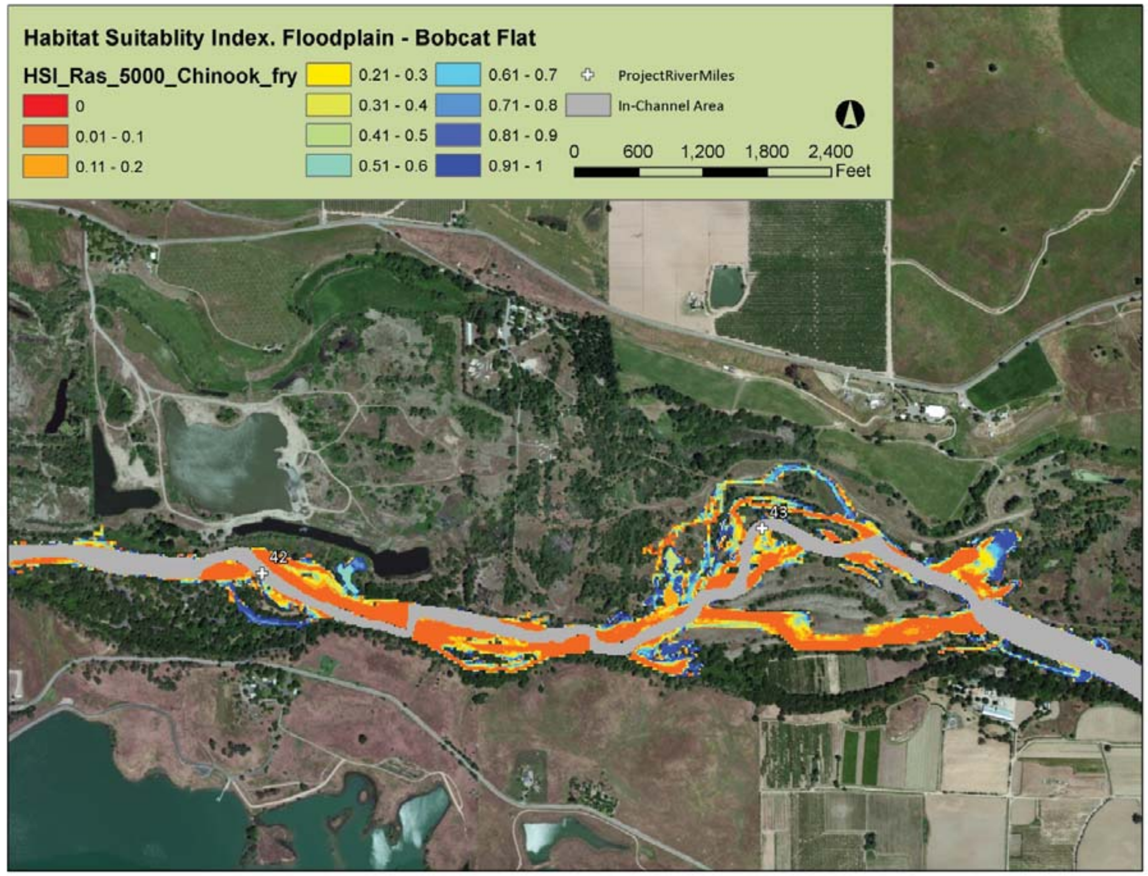
Habitat Analysis Results Example at Bobcat Flat (RM 43)

- **Overbank habitat at 3,000 cfs**
- **Increasing depths and velocities at channel margins limit Chinook fry habitat suitability**



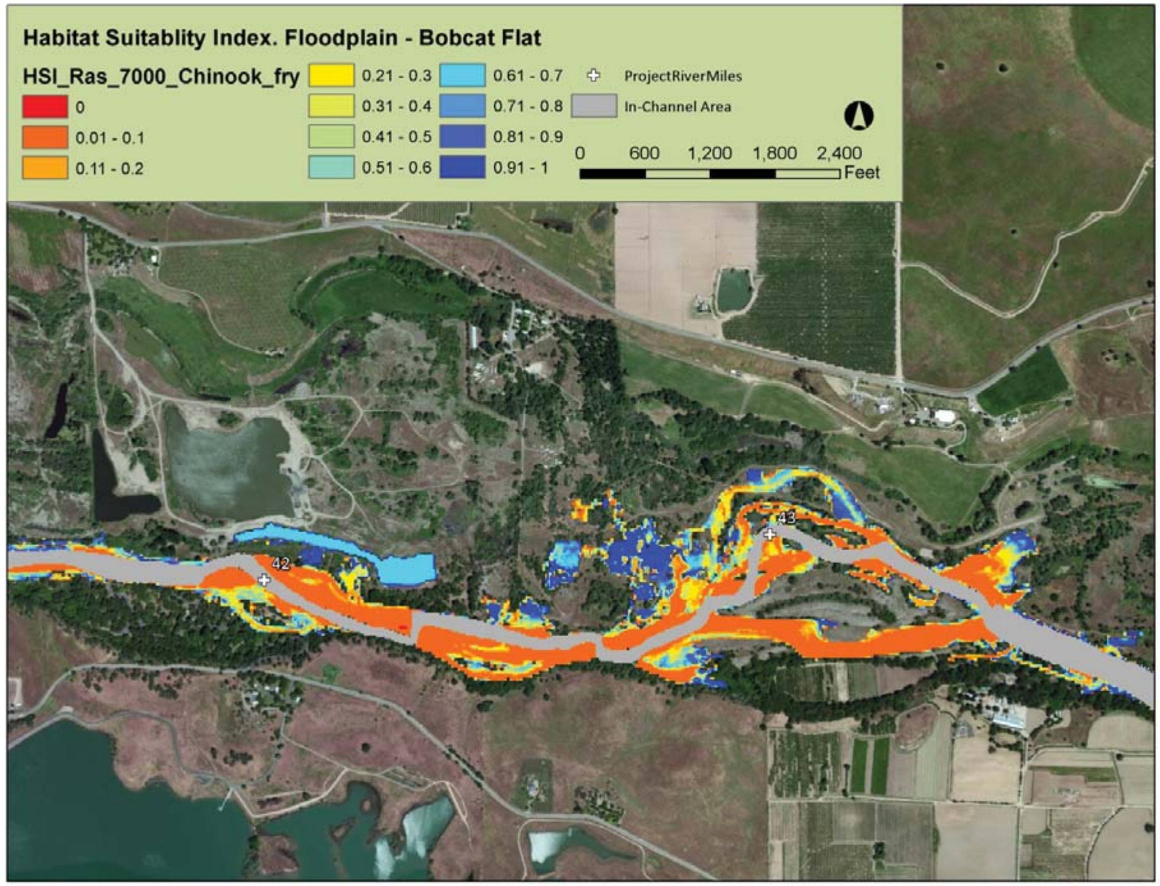
Habitat Analysis Results Example at Bobcat Flat (RM 43)

- Overbank habitat at 5,000 cfs
- Increasing depths and velocities at channel margins limit Chinook fry habitat suitability



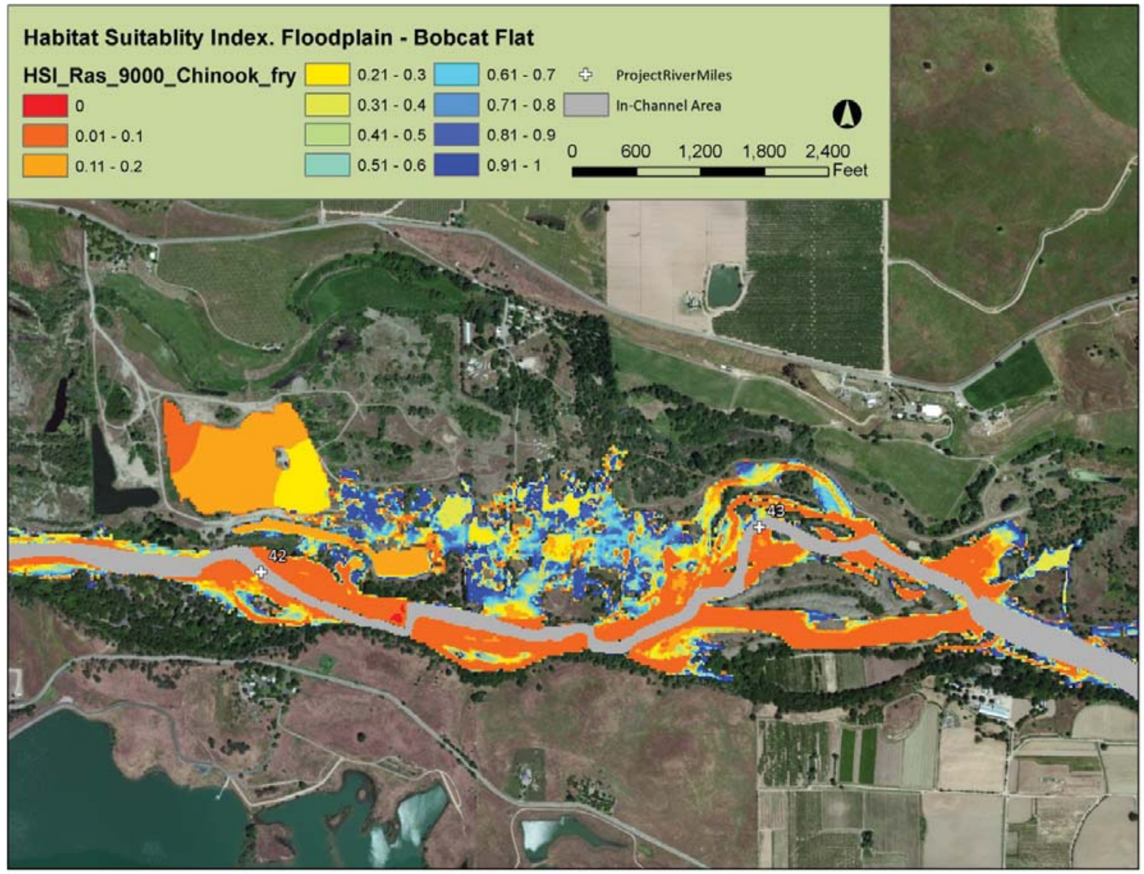
Habitat Analysis Results
Example at Bobcat Flat (RM 43)

- **Overbank habitat at 7,000 cfs**
- **Floodplain inundation in tailings areas**
- **Chinook fry habitat suitability (0-100%) greatest in shallow areas and low velocities**



Habitat Analysis Results Example at Bobcat Flat (RM 43)

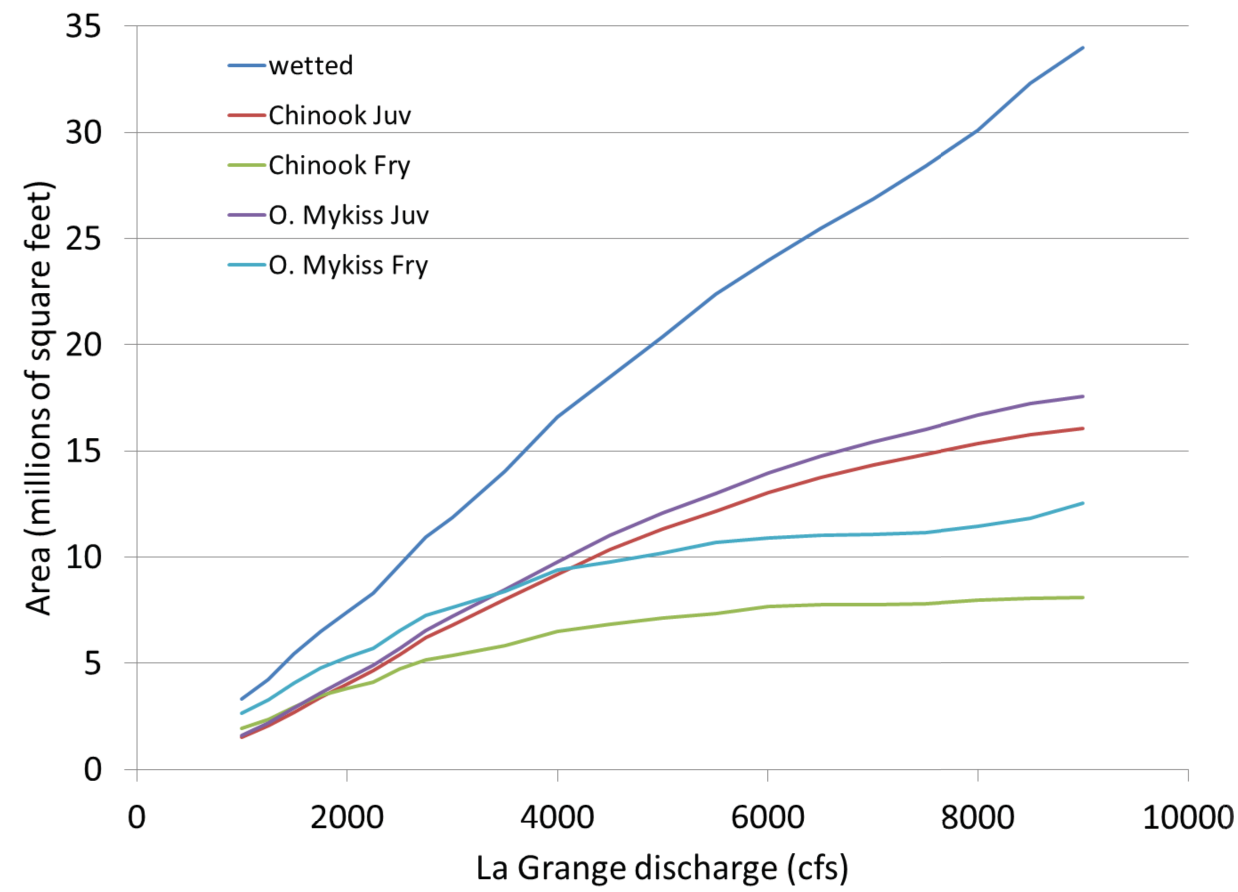
- **Overbank habitat at 9,000 cfs**
- **Floodplain inundation in tailings areas**
- **Captured mining pit**
- **Chinook fry habitat suitability (0-100%) greatest in shallow areas and low velocities**



Habitat Analysis Results
Model A

- **Approx. 60-80% of inundated area usable by Chinook and *O. mykiss* fry at the lowest flows modeled, falling to 30-40% at 9,000 cfs**

- **Approx. 50-60% of inundated area usable by Chinook and *O. mykiss* juveniles**

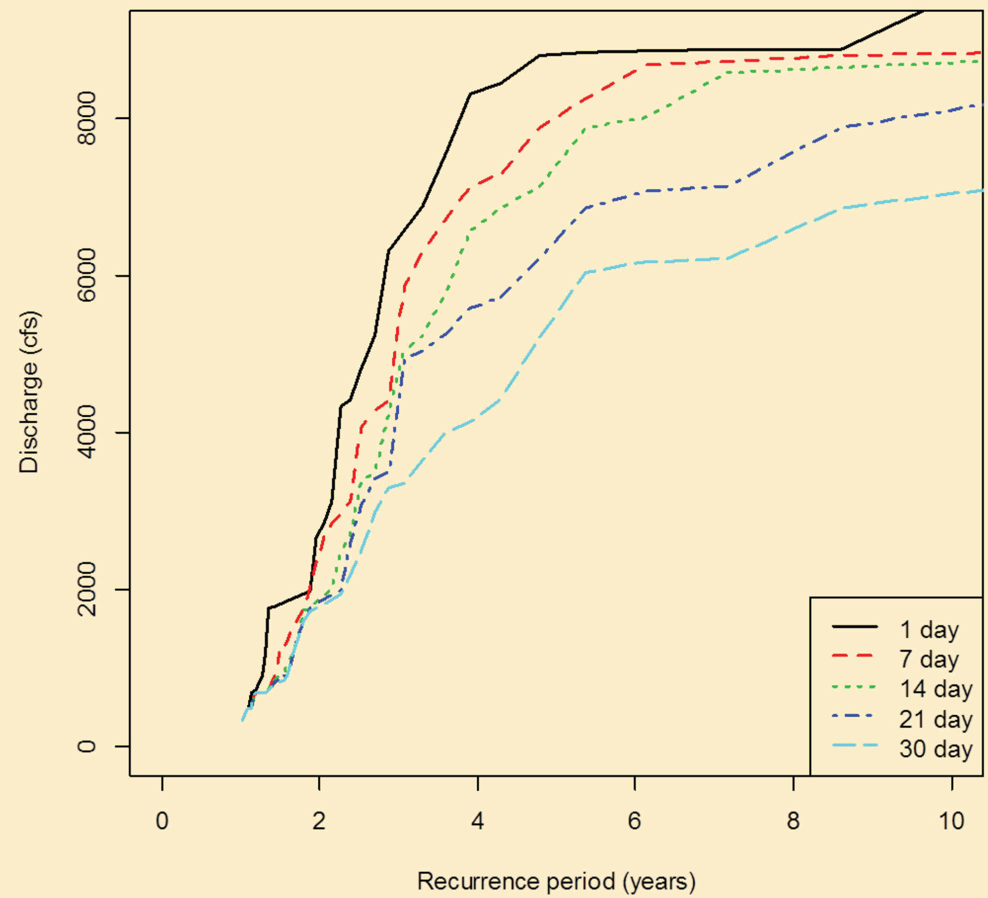


Area-Duration-Frequency Analysis

- Using Base Case hydrology (1971-2012), define floodplain inundation "events" by combinations of:
  - Duration (7, 14, 21, and 30 days)
  - Flow magnitude 1,000–9,000 cfs
- Calculate annual recurrence probabilities of each event (i.e., discharge and duration)
- Combine flow-duration frequency with TUFLOW and HSC analyses to show:
  - Total inundation area-duration-frequency (ADF)
  - Usable habitat ADF by salmonid life stage

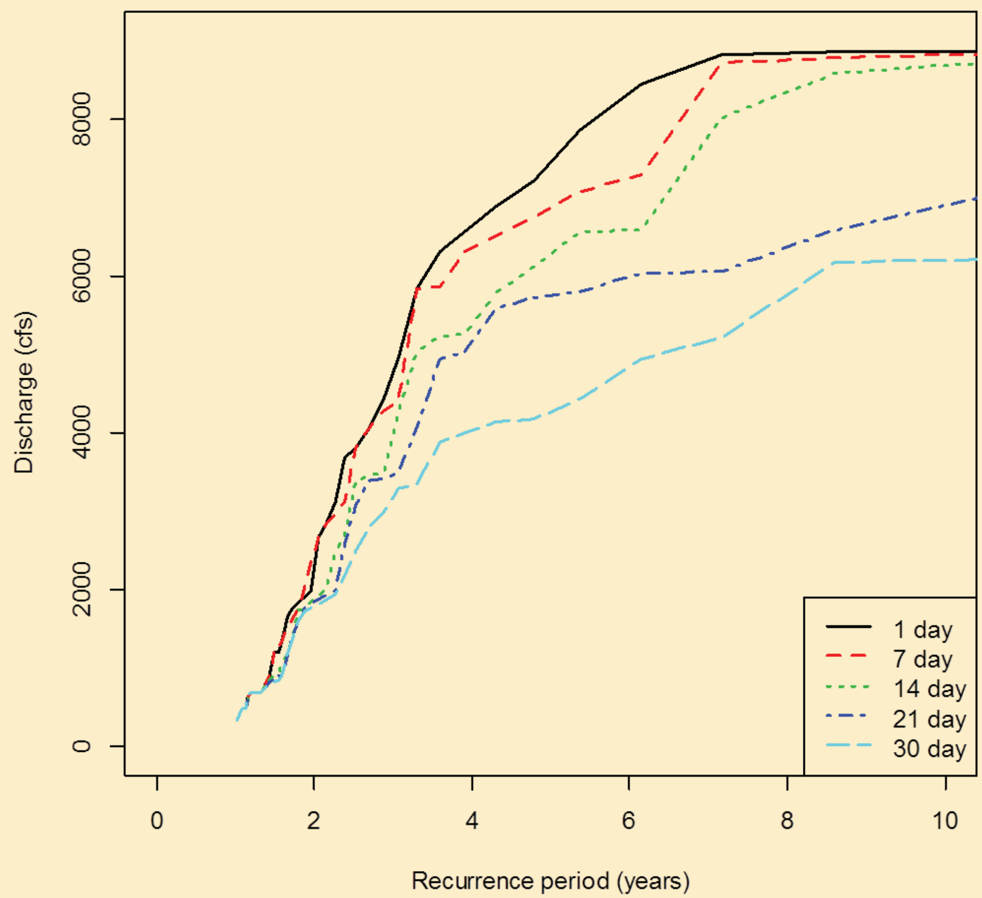
Flow Frequency Analysis Results

- **Base Case hydrology for 1971-2012**
- **Annual recurrence period for 1,000 – 9,000 cfs discharge**



Flow Frequency Analysis Results

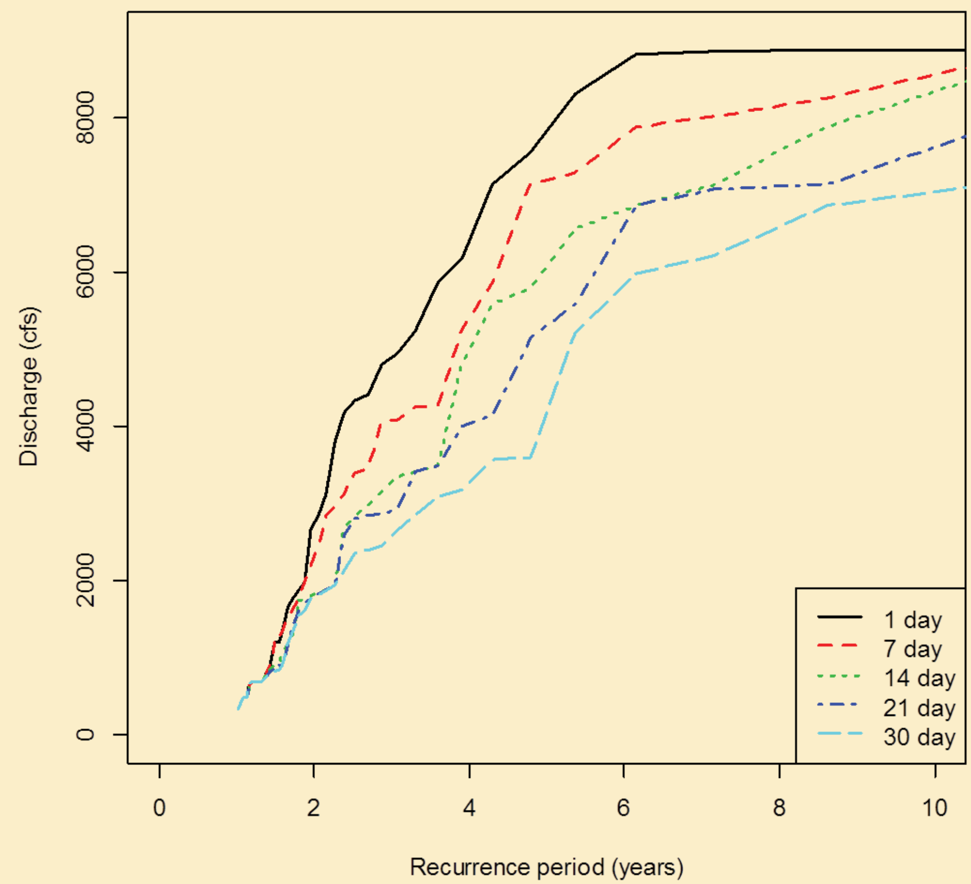
- **Base Case hydrology for 1971-2012**
- **Annual recurrence period for 1,000 – 9,000 cfs discharge between February and May**



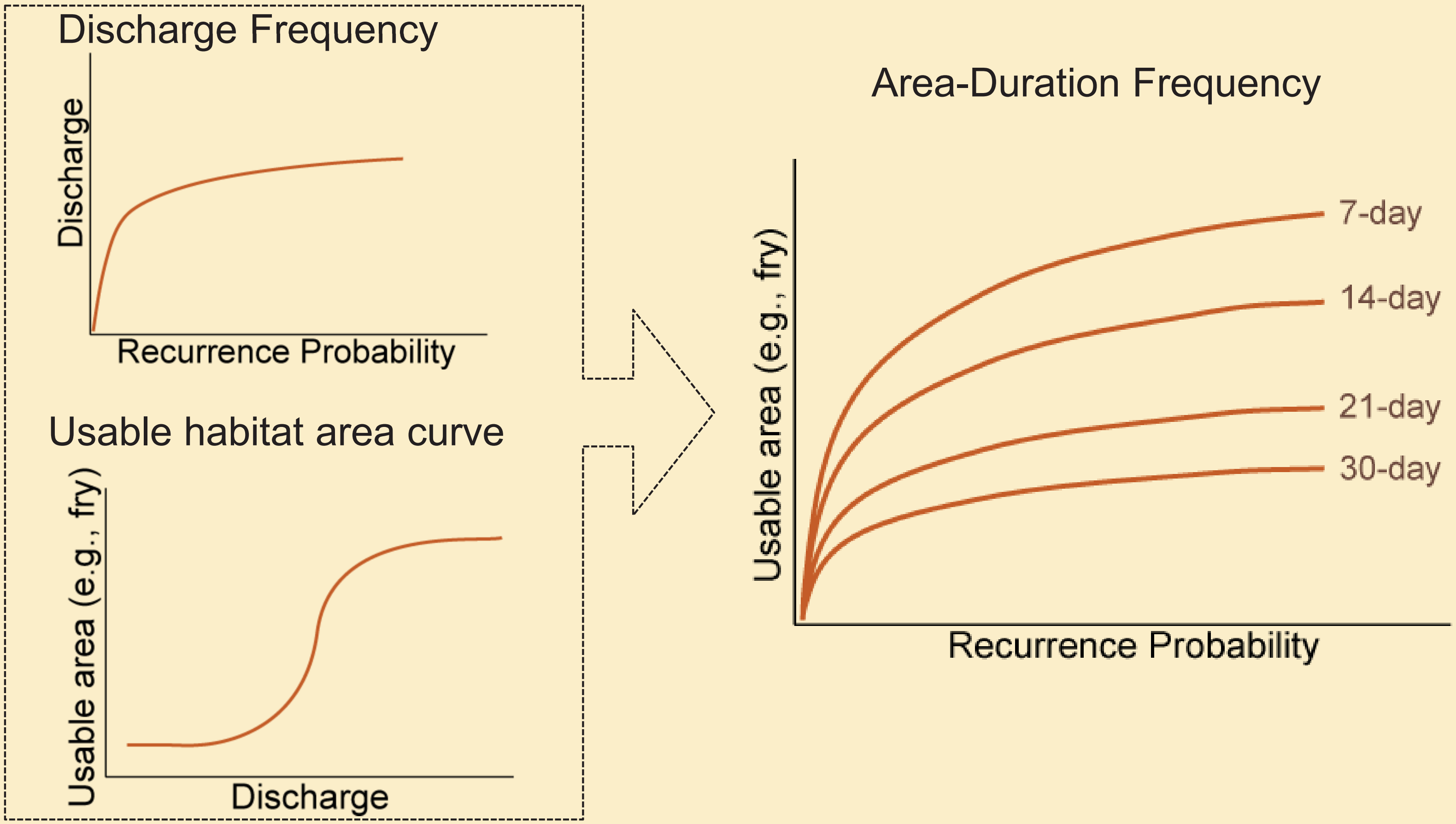
Flow Frequency Analysis Results

- **Base Case hydrology for 1971-2012**

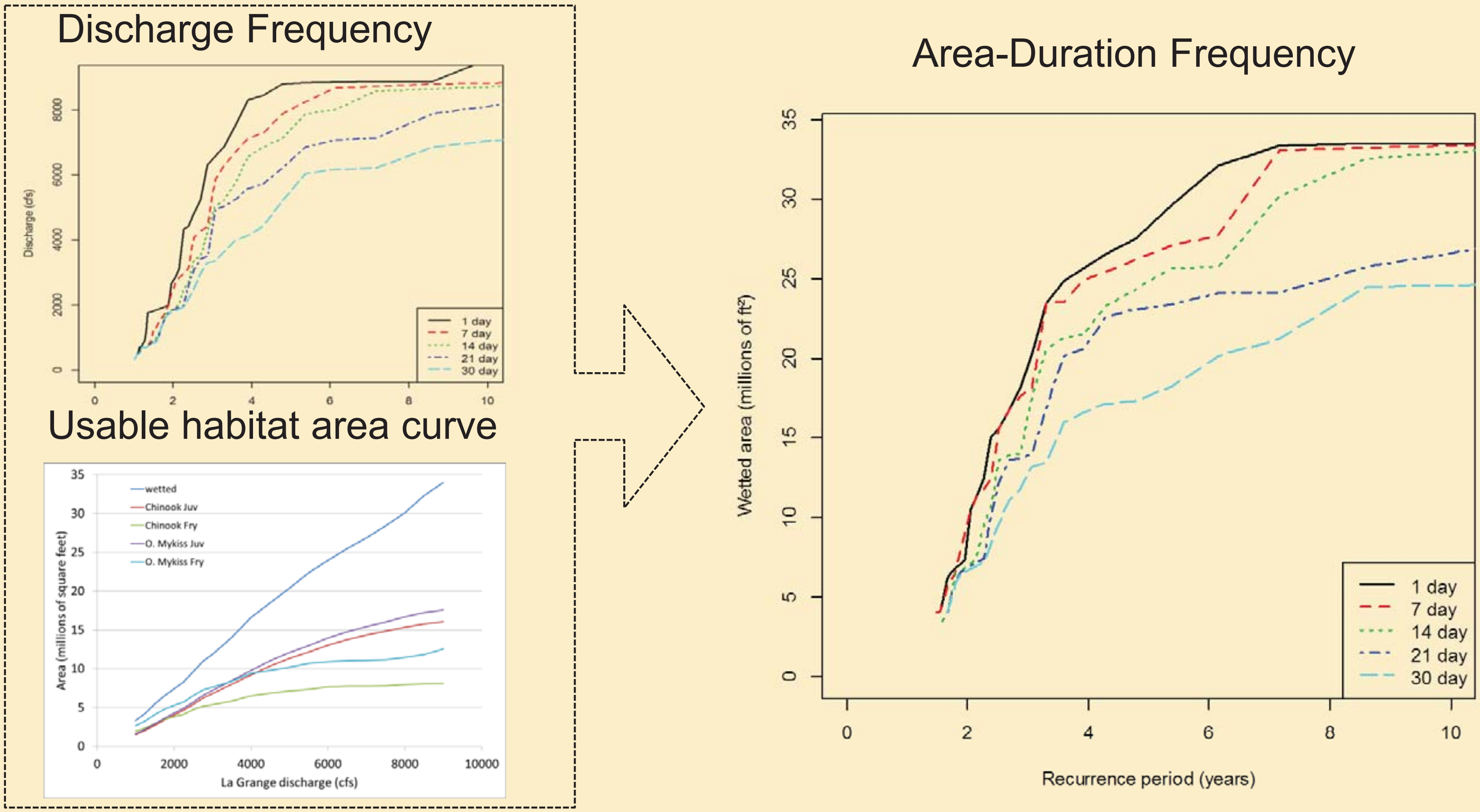
- **Annual recurrence period for 1,000 – 9,000 cfs discharge between March and September**



Area-Duration-Frequency Analysis

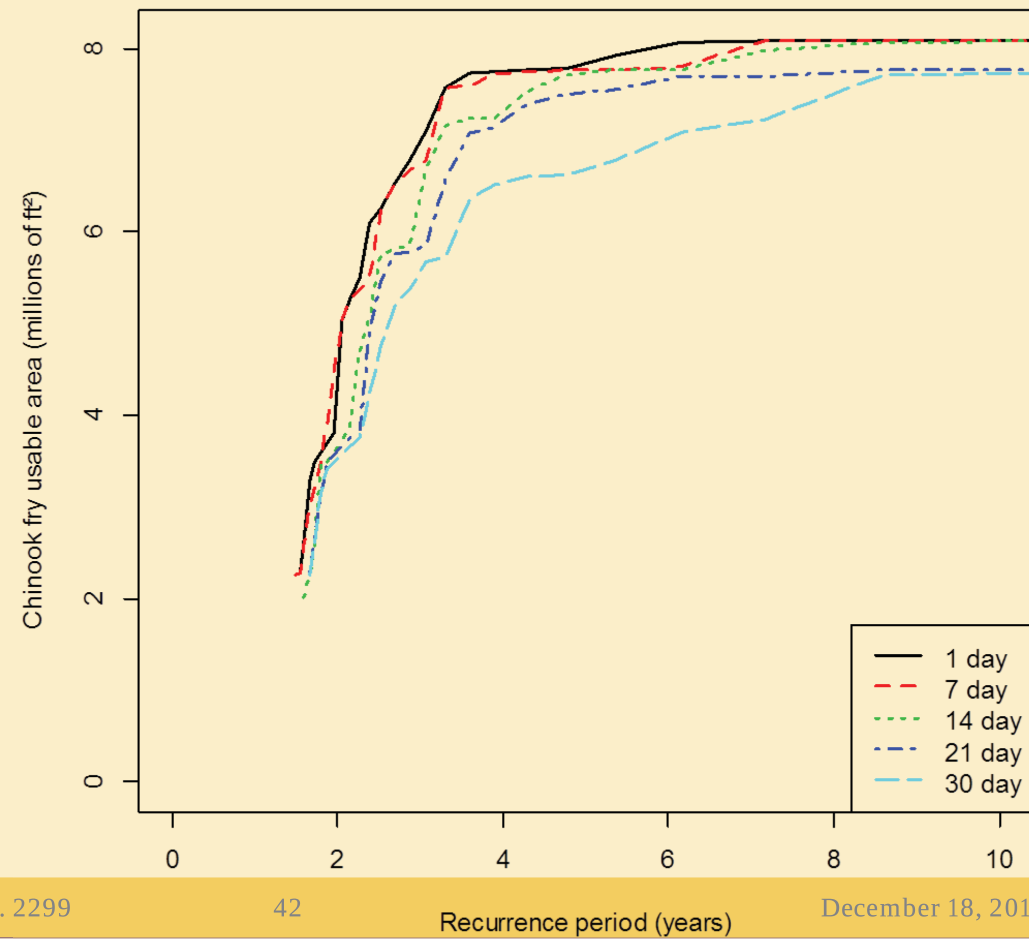


Area-Duration-Frequency Curves to Show Useable Habitat Area



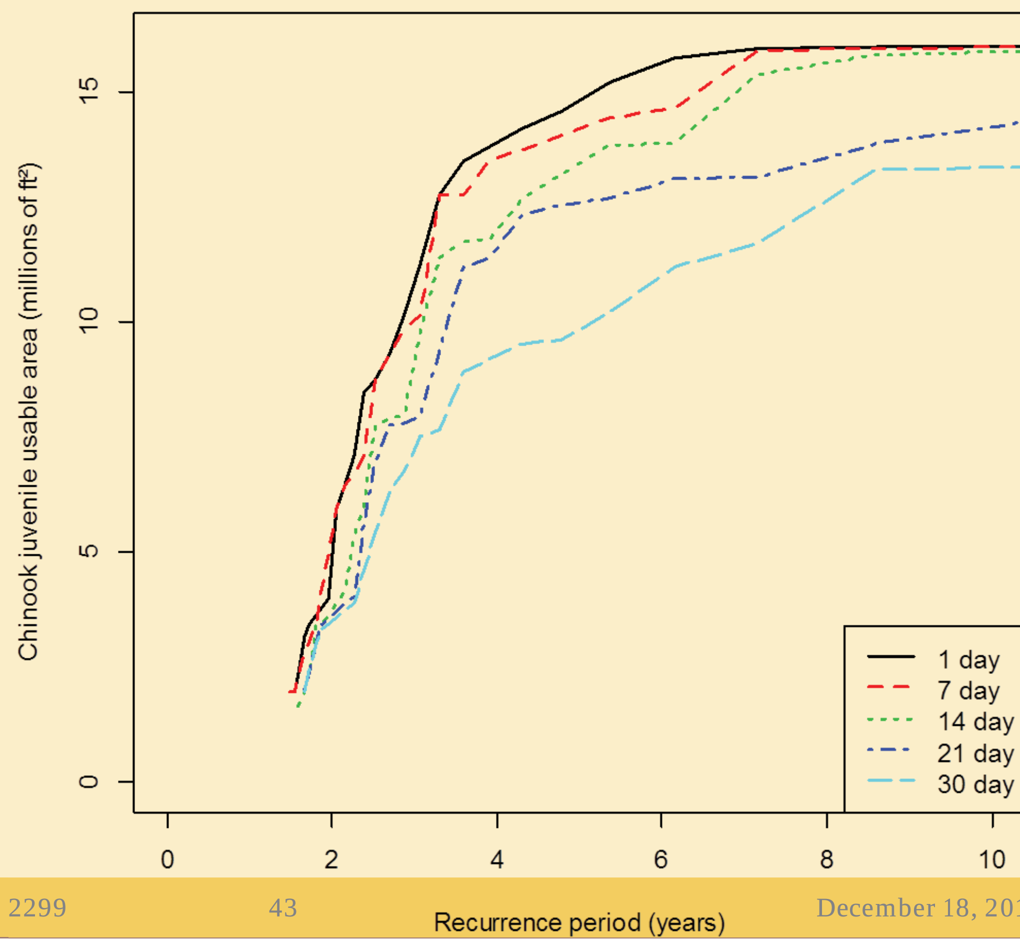
Area Duration Frequency Analysis Results for Model A

- **Base Case hydrology for 1971-2012 between *February and May***
- **Annual recurrence period for inundation of floodplain habitat for *Chinook fry***
- **Large increases in floodplain habitat inundation events (1, 7, 14, 21, 30 days) on a 2-3 yr recurrence period**



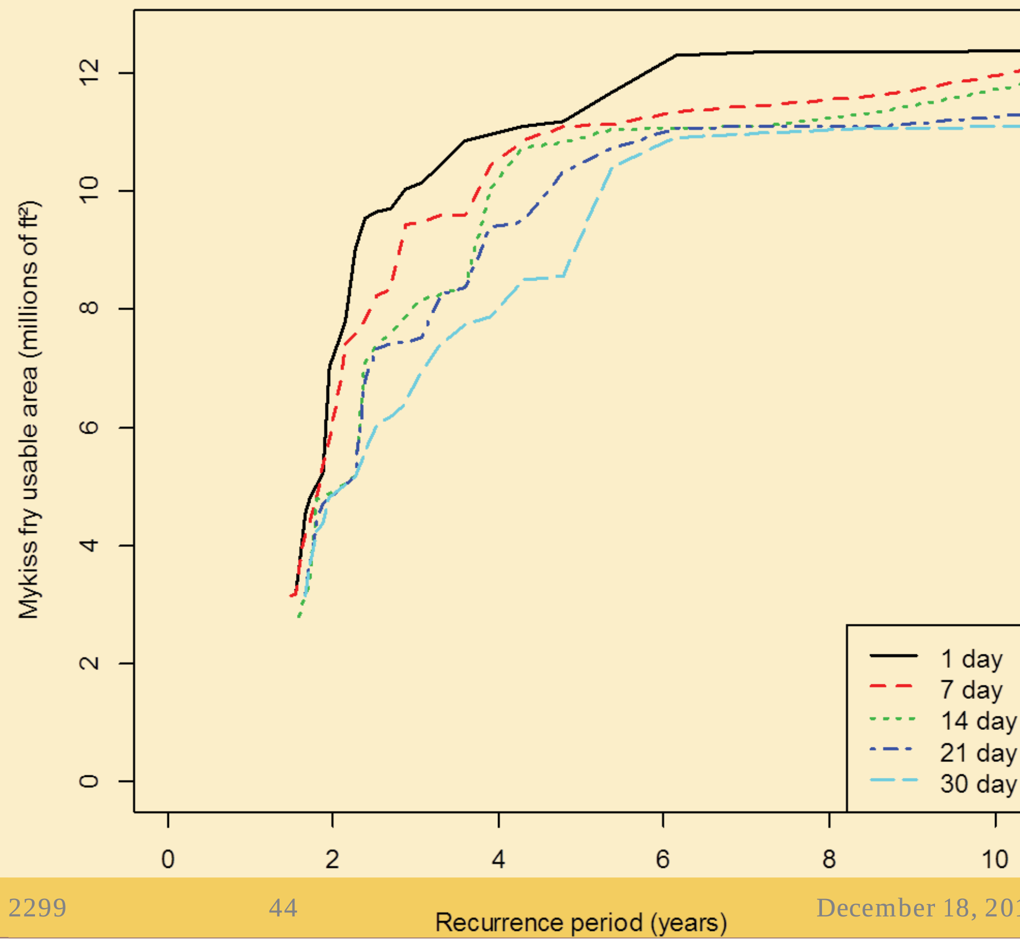
Area Duration Frequency Analysis Results for Model A

- **Base Case hydrology for 1971-2012 between *February and May***
- **Annual recurrence period for inundation of floodplain habitat for *Chinook juveniles***
- **Large increases in floodplain habitat inundation events (1, 7, 14, 21, 30 days) on a 2-3 yr recurrence period**



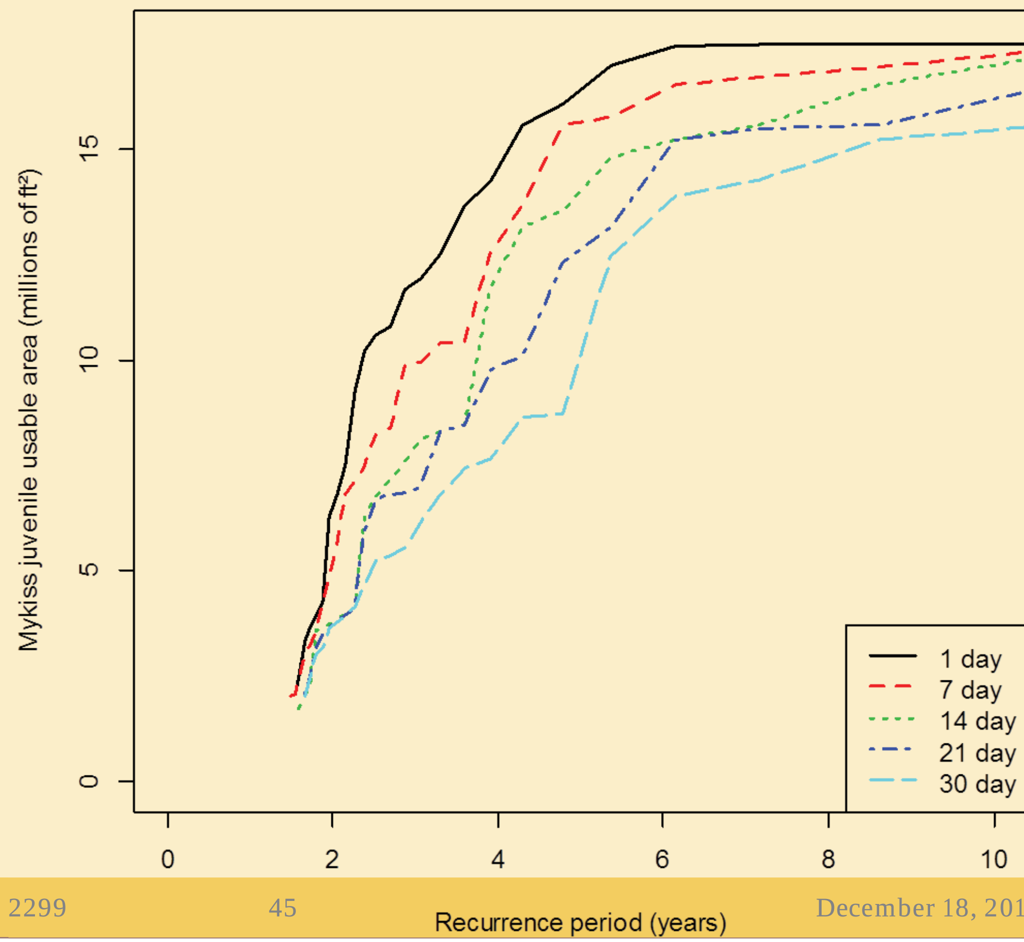
Area Duration Frequency Analysis Results for Model A

- **Base Case hydrology for 1971-2012 between *March and September***
- **Annual recurrence period for inundation of floodplain habitat for *O. mykiss fry***
- **Large increases in floodplain habitat inundation events (1, 7, 14, 21, 30 days) on a 2-3 yr recurrence period**



Area Duration Frequency Analysis Results for Model A

- **Base Case hydrology for 1971-2012 between *March and September***
- **Annual recurrence period for inundation of floodplain habitat for *O. mykiss juveniles***
- **Large increases in floodplain habitat inundation events (1, 7, 14, 21, 30 days) on a 2-3 yr recurrence period**



Habitat Analysis Summary

- **Model A – RM 52.2 to RM 40**
  - **Flows above bankfull discharge (1,500-2,000 cfs) associated with large increases in usable habitat for rearing Chinook salmon and *O. mykiss***
  - **For short duration events (e.g., 1, 7 days), approx. 200% increase in usable habitat area occurs between 1.5 to 2 year recurrence periods under the Base Case (WY1971-2012)**
  - **Longer duration inundation events lasting 14-days and occurring at a 4 year recurrence period are associated with usable habitat area increases on the order of 300%**
- **Models B and C to be provided with Draft study report**

Questions?

Photo Credit: Tuolumne River TAC

Floodplain Hydraulic Assessment Schedule

• Draft Report Preparation	November to December 2014
• Draft Report Provided to Relicensing Participants for 30-day review and comment	January 2015
• Relicensing Participant Comments Due	February 2015
• Final Report Filing with FERC	March 2015

APPENDIX C

RESPONSE TO DRAFT STUDY REPORT COMMENTS BY U.S. FISH AND WILDLIFE SERVICE

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RESPONSE TO DRAFT STUDY REPORT COMMENTS BY U.S. FISH AND WILDLIFE SERVICE

As part of the studies conducted in support of the Integrated Licensing Process (ILP) for the Don Pedro Hydroelectric Project (Project), the Turlock Irrigation District and the Modesto Irrigation District (collectively, the Districts), co-licensees of the Project, conducted a study to develop a hydraulic model for the lower Tuolumne River that simulates the interaction between flow within the main channel and the floodplain downstream of the La Grange Diversion Dam at River Mile (RM) 52.2 to the confluence with the San Joaquin River and to apply the model results to estimate floodplain juvenile salmonid rearing habitat. This study was undertaken in accordance with the FERC-approved (October 18, 2013) study plan. The draft report for W&AR-21 was provided to relicensing participants on September 3, 2015, for 30-day review. Comments on the draft report were provided on October 1, 2015 by the U.S. Fish and Wildlife Service (USFWS) and are repeated as excerpts in **bolded text below**, followed by comment responses. A copy of the USFWS letter is included at the end of this Appendix.

<u>Unimpaired Flows</u> (Fig 3.2-1 on page 3-4): "…*In order to interpret the effect of the Project on the floodplain, this graph should also present the flow exceedance curve for unimpaired flows*."

As stated in the October 18, 2013 FERC Study Plan Determination, "… an evaluation of pre-project flow conditions as requested by FWS would not inform potential license conditions (18 C.F.R Section 5.9(b)(5))."

<u>Modeling Resolution</u> (Page 4-3, 2nd complete paragraph): "... *cell size is at the wrong spatial scale relative to fry and juvenile habitat use, which is generally at a scale of one square foot. Because the data set does not support a one-foot scale, no PM&E measures should be based on this type of analysis of fry and juvenile habitat.*"

The Districts believe that selected cell size and resulting model resolution in their final report represents the best available science to address questions of floodplain habitat suitability in relation to flow. For comparison, the simplified wetted area vs flow relationships used in the older GIS-based study of the Tuolumne River (USFWS 2008) were published to assist in developing instream flow recommendations and yet provide no assessment of usable fry and juvenile habitat, let alone not meeting the 1-ft resolution requested by the USFWS commenter. Even assuming relevant habitat information is captured by simple aerial photo digitization, common mapping standard accuracy estimates (USGS Fact Sheet 171-99) at a photo scale of 1:24000 used in the GIS-based floodplain relationships are on the order of ± 40-ft, well above the 1-ft resolution discussed in the comment relative to Chinook fry and juvenile habitat use. In examining whether the requested modeling resolution has been used in other settings, the Districts found a contemporary 2D modeling effort on the Stanislaus River[1] which was implemented at a resolution of 1 m^2 (11ft^2), which is over ten times the requested resolution.

[1] Bowen, M. D., M. Gard, R. Hilldale, K. Zehfuss, and R. Sutton. 2012. Stanislaus River Discharge-Habitat Relationships for Rearing Salmonids. Prepared for Central California Area Office, Bureau of Reclamation, Folsom, California

As detailed above, the Districts are unaware of any 2D-modeling studies across as large a model domain as the 52-mile lower Tuolumne River corridor that were implemented at the requested resolution. For the modeling effort in the current study, the computational tradeoffs between reduced cell size, simulation times, and accuracy was discussed with the aid of supporting model simulations presented during Workshop No. 1 on February 13, 2014. Because the alluvial topography of the lower Tuolumne River floodplain does not appear to be hydraulically complex, a decision was made to conduct sensitivity testing which demonstrated little to no differences in predicted areas of suitable habitat across a range of TUFLOW model cell sizes from 10 to 50 ft. On March 4, 2014, draft meeting notes for Workshop No. 1 were provided to relicensing participants, including USFWS, for review and comment. No comments were received about the preferred cell size, or any other subject presented. Final meeting notes for Workshop No. 1 (included as Attachment A of this report) were later distributed to USFWS and other relicensing participants by e-mail on July 17, 2014. Again, no comments were received. Details of the sensitivity analysis presented at Workshop No. 1 are also provided in Attachment B of the study report.

<u>Modeled Study Reach Extent</u> (Page 4-3, Section 4.1.4): "*... analysis needs to be completed with the lower 0.9 miles included, in order to be consistent with the Study Plan.*"

The approved Study Plan stated that the Tuolumne River would be modeled from La Grange Diversion Dam (RM 52.2) to the Tuolumne River confluence with the San Joaquin River. The exact location of the confluence is dependent on the flows in each river. To allow results comparisons for all modeled flows, the downstream model boundary was placed at RM 0.88 to represent the Tuolumne River confluence within the San Joaquin River floodway at the highest flows modeled (9,000 cfs). More specifically, during high flow periods the flow direction, depths, and velocities downstream of RM 0.88 are controlled by conditions in the San Joaquin River floodway. No topographic breaks allow for clear separation of the Tuolumne River from the San Joaquin River floodplain habitat in this area and the TUFLOW model does not support more than one downstream model boundary location, thus, the 9,000 cfs model boundary at RM 0.88 was used for all flows modeled. The completed model is consistent with the approved Study Plan.

<u>Modeling Assumptions</u> (Section 4.1.8.2, Page 4-7): "*Assigning ponds, backwater areas and side channels bed elevations of 0.2 feet below the water surface elevation at the time the LiDAR was flown is adequate for simulating the total amount of inundated floodplain area as a function of flow, but ... is expected to greatly over-predict the amount of fry and juvenile habitat, no PM&E measures should be based on this analysis.*"

As summarized in Table 4.1-2, significant hydraulically connected features such as side channels and backwaters included detailed bathymetric data, and did not use a 0.2-ft depth assumption. While this depth assumption was reserved for ponds with little or no connectivity to the main channel, it is recognized that deeper pool habitats are generally unsuitable for fry and juvenile salmonids. Although the amount of ponded habitat makes up only a small proportion of inundated floodplain, the Study Report has been revised to exclude these areas from the final usable habitat area estimates.

<u>Methods Description</u> (Page 4-13): *"It is not clear whether this analysis considered a constant San Joaquin River flow upstream of the Tuolumne River. If a constant San Joaquin River flow was used, it should be reported with an explanation of how the chosen flow was determined."*

Attachment E of the draft report provides an analysis of backwater effects in the lower Tuolumne River and considered a range of Tuolumne and San Joaquin River flows to develop a statistical relationship between flows in the two rivers. Table 4 of Attachment E shows the stage versus discharge rating curve developed for the downstream boundary condition. Attachment E of the draft report contains a detailed analysis of how it was developed and the sensitivity of the model to the assumptions.

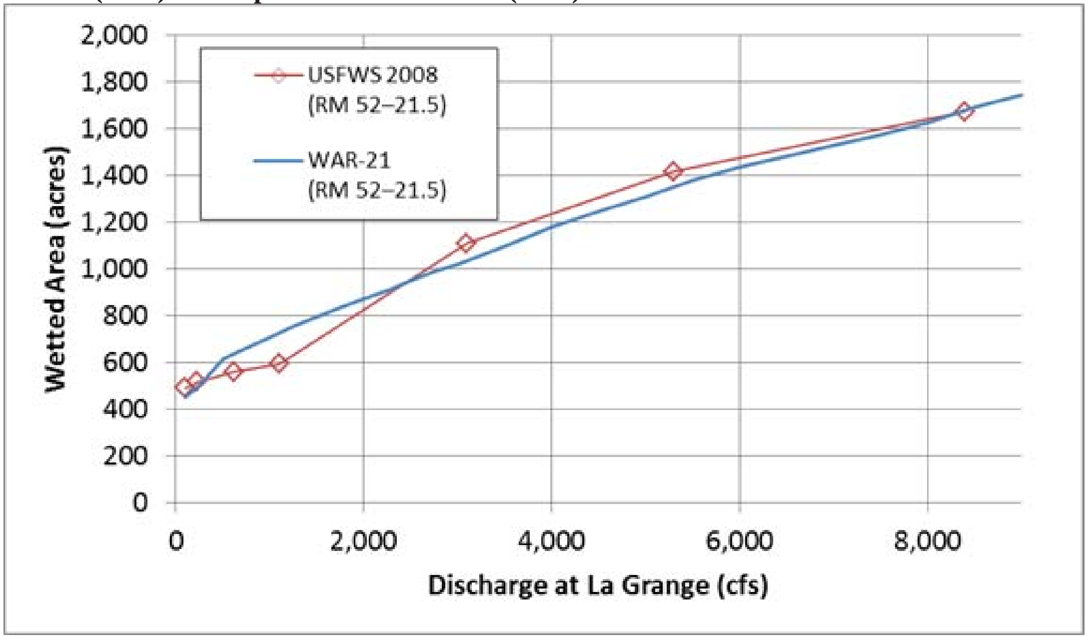
<u>Modeled Floodplain Surfaces in comparison to USFWS (2008)</u> (Section 5.2.1, Page 5-1): *"Areas within isolated portions of the floodplain created by topographic depressions, backwater areas and ponds that were inundated at the lowest flows modeled should be subtracted from the total floodplain area, because they would be perennially inundated off-channel areas, which would not be considered floodplain habitat (USFWS 2014)."*

The Districts compared inundation areas predicted by the completed TUFLOW model and those reported by USFWS (2008) and there do appear to be some differences at the 1,000 cfs level. These apparent differences may be related to isolated areas (e.g., ponds and mining pits) that were clipped out of the GIS shape files in the USFWS report. The Study Report has been modified to exclude these ponded features, resulting in approximately 30% lower usable habitat estimates at the lowest (1,000 cfs) flows modeled when compared to those presented in the Draft Study Report.

<u>Modeled Floodplain Surfaces in comparison to USFWS (2008)</u>(Section 5.2.1, Page 5-2): *"We would have expected that the floodplain delineation from the two reports would be similar for the area in common, because the U.S. Fish and Wildlife Service (2008) assumed that floodplain inundation started at 1,100 cfs, and this report used the 1,070 cfs inundation extent to delineate overbank versus in-channel areas."*

The Districts have conducted a comparison of the TUFLOW model results with the older USFWS (2008) GIS based estimates corresponding to digitized aerial imagery previously developed by the Districts in the 1990s (TID/MID 1997, Report 96-14). As stated above, there do appear to be some differences at the 1,000 cfs level but the estimates of total inundated area converge at higher flows likely due to reconnection of areas isolated at lower flows (e.g., ponds and mining pits) . The Study Report has been revised to exclude these areas from the usable habitat area estimates. Recognizing that total inundated area is a poor and misleading proxy for actual habitat use by Chinook fry and juveniles or population level benefits of floodplain inundation, the comparisons shown in Figure 1 below across the common reach (RM 52–21) show the two methods are in general agreement, at least with respect to the flow versus wetted area relationship.

Figure 1. Estimates of total wetted area versus flow from GIS analysis of aerial photos in USFWS (2008) as compared with TID/MID (2015) TUFLOW simulations.



<u>Use of Wetted Area vs Usable Habitat Area estimates (</u>**Section 5.2.2, Page 5-2): "*Total floodplain area should be used to develop PM&E measures, rather than fry and juvenile habitat ... for the following reasons: (1) issues raised above concerning cell size and bed elevations of ponds, backwater areas and side channels; (2) the 0.5 foot accuracy of LiDAR data, which can result in significant errors in fry habitat suitability, which can vary substantially with 0.5 foot variations in depth; (3) LiDAR data in areas with heavy ground vegetation, such as blackberry bushes, having elevations that are biased high due to the last return being from vegetation rather than the ground; (4) the lack of cover data to use in calculating fry and juvenile habitat; and (5) the lack of habitat use data from floodplains. With regards to the last item, fry and juvenile may use quite different microhabitat characteristics on floodplains, versus from in-channel areas. In addition, inundated floodplains provide many benefits for fry and juvenile salmonids beyond habitat. Specifically, prolonged flooding affects fry survival by providing autochthonous food resources, providing refuge from predators, reducing water temperatures particularly during downstream migrations in May and June, slowing the rate of disease infestation, diluting contaminants, and reducing entrainment (Mesick et al. 2008).*"**

Although the completed TUFLOW model may be used to report on either total wetted area or usable habitat, we disagree with the USFWS assertion that total floodplain area should be used to develop PM&E measures. Concerns regarding cell sizes and assumed bed elevations of off-channel habitats (Item 1) are fully addressed above. The remaining items raised in the comment above are addressed in the paragraphs below.

1. The vertical accuracy of the LiDAR data is estimated to be 0.15 ft (root-mean-squared)(see section 4.1.2), not 0.5 ft as suggested in the comment. There is broad agreement between

the current TUFLOW estimates and the GIS based USFWS (2008) estimates. This only further supports that there is no reason to suspect model bias regarding estimates of usable habitat.

2. Given the predominance of grassland and oak chaparral vegetation on the floodplains, concerns regarding LiDAR returns in dense vegetation are overstated as there is broad agreement between the current TUFLOW estimates and the GIS based USFWS (2008) estimates discussed above.

3. Because collection of cover data across the 52-mile model domain was considered infeasible during study planning, usable habitat estimates were made based on existing Tuolumne River habitat suitability criteria for depth and velocity, as described in the approved Study Plan.

4. Although collection of habitat use data is an approach to site-specific validation of habitat suitability criteria in instream flow studies, such surveys are not a component of every instream flow study. Extensive effort was made to develop consensus regarding the habitat suitability criteria in the Tuolumne River IFIM Study, including intensive snorkel surveys used to develop site-specific suitability criteria for Chinook salmon fry, as well as for validation of suitability criteria for other juvenile salmonid life stages (Stillwater Sciences 2013). No objections were raised by USFWS or any other party on the suitability criteria proposed to be used by the present study during the study planning phase.

Lastly, it should be noted that none of the generalized benefits of floodplain inundation attributed to Mesick et al (2008) are based on data from the Tuolumne River or other tributaries to the San Joaquin River. As documented in information reviews conducted for the *Salmond Population Information Integration and Synthesis Study* (TID/MID 2013e) and prior site-specific studies on the Tuolumne River, including juvenile health studies conducted by the USFWS[2,3], the commenter is misinformed about conditions on the Tuolumne River when it implies that several cited factors (e.g., disease, contaminants, entrainment, food supplies) are currently negatively impacting juvenile rearing of Chinook salmon within in-channel or overbank habitats. In any event, because the study objectives in the approved Study Plan were limited to examination of the seasonal timing and duration of suitable overbank rearing habitat, the issues raised in this comment do not invalidate

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[2] Nichols, K., and J.S. Foott. 2002. Health monitoring of hatchery and natural fall-run Chinook salmon juveniles in the San Joaquin River and tributaries, April - June 2001. FY 2001 Investigation Report by the U.S. Fish and Wildlife Service, California-Nevada FishHealth Center, Anderson, CA

[3] Nichols, K., J.S. Foott, and R. Burmeister. 2001. Health monitoring of hatchery and natural fall run Chinook salmon juveniles in the San Joaquin River and Delta, April - June 2000. FY2000 Investigation Report by the U.S. Fish and Wildlife Service, California-Nevada Fish Health Center, Anderson, California.

the modeling approach used or conclusions drawn for the Base Case hydrology simulation. The completed TUFLOW model represents the best available science to address questions of floodplain habitat suitability in relation to flow.

O. mykiss* Floodplain Habitat Use (Page 5-10): *"Steelhead trout (O. mykiss) are known to benefit from floodplain inundation (Sellheim et al. 2015). Conclusions and statements to the contrary, in Section 5.3.3, should be revised accordingly. Based on the similar floodplain rearing habitat requirements of Chinook salmon and O. mykiss, it is appropriate to do the O. mykiss analysis in the manner applied in the Draft Report."

In accordance with the approved Study Plan, the final report includes analysis of potential floodplain habitat use by juvenile *O. mykiss*. However, the Districts' disagree that. *O. mykiss* are known to benefit from floodplain inundation and disagree that any floodplain-related PM&E measures should be recommended on this basis. Juvenile steelhead are not known to rear in floodplain habitats to any great degree at any time of year (Bustard and Narver 1975, Swales and Levings 1989, Feyrer et al. 2006, Moyle et al. 2007). In addition to the lack of evidence of floodplain habitat use in monitoring and studies of the San Joaquin River tributaries, based on multi-year studies in the Consumnes River, Moyle et al. (2007) concluded that steelhead were not adapted for floodplain use and the few steelhead observed were inadvertent floodplain users (i.e., uncommon and highly erratic in occurrence) that were "presumably…carried on to the floodplain by accident."

The cited Sellheim et al. 2015 report appears to show habitat use of Age 0 salmonids associated with cover and velocity refuge provided by willow species along channel margin areas of the Sailor Bar gravel augmentation site inundated during recent (2011) high flows on the lower American River (LAR). However, this study does not directly examine or reference other studies examining floodplain habitat use by *O. mykiss*. Because the Sellheim et al (2015) report states that the historical LAR floodplain is isolated from the active floodway by levees and the present-day LAR does not provide sufficient connectivity between main-channel and these former floodplain habitats, the report falls far short of supporting a broad conclusion regarding alluvial floodplain habitat use by *O. mykiss*.

Juvenile Chinook survival relationships (Page 6-2):*"... there is a significant positive relationship between juvenile Chinook salmon survival and floodplain inundation downstream of La Grange Dam for the period of February 1 through June 15. We recommend that the following analysis be added to the draft report …"*

The comment and requested analysis does not fall within the scope of the approved Study Plan and does not relate to results or conclusions of the Study Report. The study objectives in the approved Study Plan were limited to examination of the seasonal timing and duration of suitable overbank rearing habitat. While the suggested linkages between floodplain inundation and differences in rotary screw trap (RST) passage are consistent with well-known relationships between discharge and smolt survival included in the FERC record, the regression presented amounts to just two groups of points at high and low inundation and violates standard statistical assumptions of regression analysis. The Districts have strong reservations regarding the suggested ad hoc regression analysis and any inferences to be made regarding the benefits of floodplain inundation on the lower Tuolumne River.

Total Usable Habitat plots **(Attachment H, pages 1-2):** ***"Add figures showing the total combining Models A, B and C."***

Although the plots provided in Attachment H were originally provided to indicate patterns of floodplain inundation and usable salmonid habitat with flow across different river sub-reaches, a combined figure showing river-wide estimates of usable habitat has been added to the Study Report in Attachment H.

BEFORE THE
UNITED STATES OF AMERICA
FEDERAL ENERGY REGULATORY COMMISSION

CERTIFICATE OF SERVICE

I hereby certify that the U.S. Fish and Wildlife Service Comments on W&AR-21 Lower Tuolumne River Floodplain Hydraulic Assessment Draft Report; Don Pedro Hydroelectric Project, P-2299; Tuolumne and Stanislaus Counties, California, has this day been electronically filed with the Federal Energy Regulatory Commission and electronically served on Parties indicating a willingness to receive electronic service and served, via deposit in U.S. mail, first-class postage paid, upon each other person designated on the service list for Project #2299, compiled by the Commission Secretary.

Dated at Sacramento, California, this 1st of October, 2015.

Aondrea Bartoo
San Francisco Bay-Delta Fish and Wildlife Office
650 Capitol Mall, Suite 8-300
Sacramento, California 95814
(916) 930-5621

United States Department of the Interior

FISH AND WILDLIFE SERVICE
San Francisco Bay Delta Fish and Wildlife Office
650 Capitol Mall, Room 8-300
Sacramento, California 95814

In Reply Refer To:

Ms. Kimberly Bose, Secretary
Federal Energy Regulatory Commission
888 First Street NE
Washington, DC 20426

OCT 01 2015

Subject: U.S. Fish and Wildlife Service Comments on W&AR-21 Lower Tuolumne River Floodplain Hydraulic Assessment Draft Report; Don Pedro Hydroelectric Project, FERC Project # P-2299; Tuolumne and Stanislaus Counties, California.

Dear Ms. Bose:

On September 3, 2015, U. S. Fish and Wildlife Service (USFWS) received the *Lower Tuolumne River Floodplain Hydraulic Assessment Draft Report* (Draft Report)for Study W&AR-21 of the Don Pedro Hydroelectric Project (FERC Project No. 2299) (Project), licensed by the Federal Energy Regulatory Commission (FERC or Commission). The following are our comments on the Draft Report.

General Comments

The study was mostly conducted in accordance with the Study Plan. Except for corrections and clarifications needed, as articulated in our comments, the Draft Report is a good starting point for quantifying the relationship between floodplain and flow in the lower Tuolumne River. Information presented in the Draft Report, with the additional information requested herein, should be useful in developing Project protection, mitigation, and enhancement (PM&E) measures.

Specific Comments

Figure 3.2-1 on page 3-4: This graph shows only flow exceedance from current operations. In order to interpret the effect of the Project on the floodplain, this graph should also present the flow-exceedance curve for unimpaired flows.

Page 4-3, 2nd complete paragraph: While the 30 foot by 30 foot cell size is appropriate for simulating the total amount of inundated floodplain area as a function of flow, it is too large for simulating fry and juvenile rearing habitat. Specifically, this cell size is at the wrong spatial scale relative to fry and juvenile habitat use, which is generally at a scale of one square foot. Because the data set does not support a one-foot scale, no PM&E measures should be based on this type of analysis of fry and juvenile habitat.

Page 4-3, Section 4.1.4: The lower 0.9 miles of the Tuolumne River was not modeled. There is no explanation of this omission, which is inconsistent with the commitment in the Study Plan to model the Tuolumne River from RM 0 to 52.2. The analysis needs to be completed with the lower 0.9 miles included, in order to be consistent with the Study Plan.

Page 4-7, Section 4.1.8.2: Assigning ponds, backwater areas and side channels bed elevations of 0.2 feet below the water surface elevation at the time the LIDAR was flown is adequate for simulating the total amount of inundated floodplain area as a function of flow, but is not adequate for simulating fry and juvenile rearing habitat. Specifically, this would result in the model significantly under-predicting depths in ponds, backwater areas and side channels, and thus over-predicting the amount of fry and juvenile habitat in these areas, since fry and juvenile habitat suitability is greatest for shallow depths. Because the analysis in this section is expected to greatly over-predict the amount of fry and juvenile habitat, no PM&E measures should be based on this analysis.

Page 4-13: It is not clear whether this analysis considered a constant San Joaquin River flow upstream of the Tuolumne River. If a constant San Joaquin River flow was used, it should be reported with an explanation of how the chosen flow was determined.

Page 5-1, Section 5.2.1: Areas within isolated portions of the floodplain created by topographic depressions, backwater areas and ponds that were inundated at the lowest flows modeled should be subtracted from the total floodplain area, because they would be perennially inundated off-channel areas, which would not be considered floodplain habitat (U.S. Fish and Wildlife Service 2014). In addition, to the extent that these areas are isolated from the main channel at a given flow, they would not provide any benefit to fry and juvenile salmonids, because they would not be accessible to fry and juvenile salmonids at such flows.

Page 5.2, Figure 5.2-1: We recommend that the Districts overlay the floodplain extent from the floodplain modeling with the empirical floodplain polygons used in U.S. Fish and Wildlife Service (2008), because the amount of floodplain area versus flow in U.S. Fish and Wildlife Service (2008) is generally more than the total in this report combining Models A, B and C. It would be expected that the combined floodplain area from this report, covering over 50 miles of the Tuolumne River, should be significantly more than the floodplain areas in U.S. Fish and Wildlife Service (2008), which only covered 30 miles of the Tuolumne River. We would have expected that the floodplain delineation from the two reports would be similar for the area in common, because the U.S. Fish and Wildlife Service (2008) assumed that floodplain inundation started at 1,100 cfs, and this report used the 1,070 cfs inundation extent to delineate overbank versus in-channel areas.

Page 5.2, Section 5.2.2: Total floodplain area should be used to develop PM&E measures, rather than fry and juvenile habitat, because the model developed in this study cannot be used to develop relationships between flow and the amount of fry and juvenile habitat for the following reasons: (1) issues raised above concerning cell size and bed elevations of ponds, backwater areas and side channels; 2) the 0.5 foot accuracy of LIDAR data, which can result in significant errors in fry habitat suitability, which can vary substantially with 0.5 foot variations in depth; (3) LIDAR data in areas with heavy ground vegetation, such as blackberry bushes, having elevations that are biased high due to the last return being from vegetation rather than the ground; (4) the lack of cover data to use in calculating fry and juvenile habitat; and (5) the lack of habitat use data from floodplains. With regards to the last item, fry and juvenile may use quite different microhabitat characteristics on floodplains, versus from in-channel areas. In addition, inundated floodplains provide many benefits for fry and juvenile salmonids beyond habitat. Specifically, prolonged flooding affects fry survival by providing autochthonous food resources, providing refuge from predators, reducing water temperatures particularly during downstream migrations in May and June, slowing the rate of disease infestation, diluting contaminants, and reducing entrainment (Mesick *et al.* 2008).

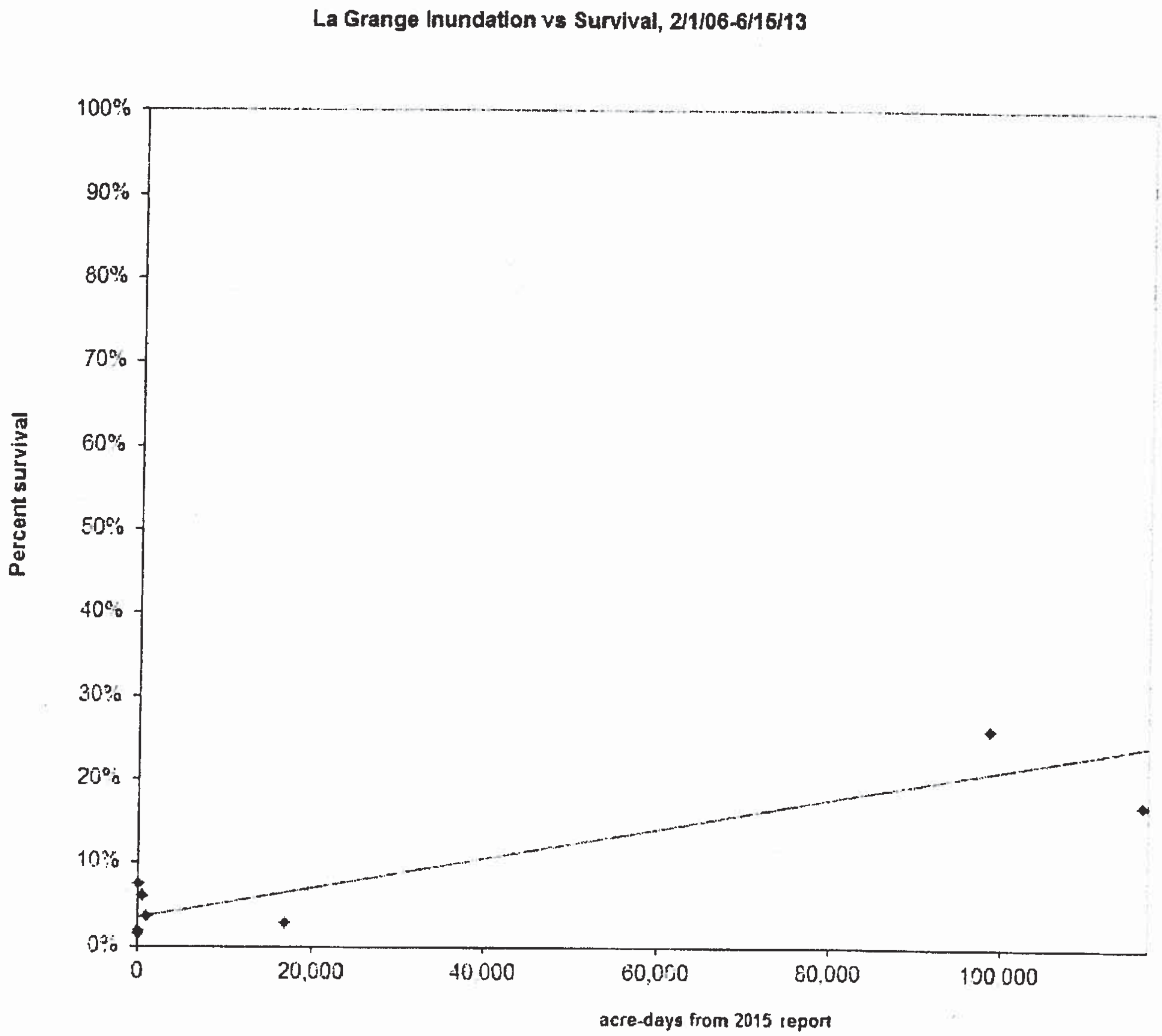

Figure 1. USFWS analysis of Draft Report data: Regression showing the relationship between percent survival of juvenile Chinook salmon in the Tuolumne River and the acre-days of floodplain inundation downstream of La Grange Dam.

Page 5-10: Steelhead trout (*Oncorhynchus mykiss*) are known to benefit from floodplain inundation (Sellheim *et al.* 2015). Conclusions and statements to the contrary, in Section 5.3.3, should be revised accordingly. Based on the similar floodplain rearing habitat requirements of Chinook salmon and *O. mykiss*, it is appropriate to do the *O. mykiss* analysis in the manner applied in the Draft Report.

Page 6-2: Our analysis of the data in this report, combined with Tuolumne River rotary screw trap data, indicates that there is a significant positive relationship between juvenile Chinook salmon survival and floodplain inundation downstream of La Grange Dam for the period of February 1 through June 15. We recommend that the following analysis be added to the draft report: (1) sum the floodplain area versus flow for Models A, B and C; (2) then subtract the floodplain area at 1,000 cfs from the floodplain area at higher flows to compute floodplain area that excluded areas within isolated portions of the floodplain created by topographic depressions, backwater areas and ponds that were inundated at the lowest flows modeled; (3) then use daily average flows from the LaGrange gage, along with the resulting flow-floodplain area relationship, to compute the number of acres of floodplain inundated each day; (4) then sum the inundated acres for the period of February 1 through June 15 each year to compute the number of acre-days of inundated floodplain each year for 2006 through 2013; (5) compute the percent survival of juvenile Chinook salmon for each of these years by dividing the total catch at the Grayson screw trap by the total catch at the Waterford screw trap; (6) then perform a linear regression of percent survival versus acre-days of inundated floodplain. For your convenience, the culmination of this analysis is included as the enclosure: *Excerpt from spreadsheet of FWS analysis of juvenile Chinook salmon survival in the lower Tuolumne River in relation to acre-days of floodplain inundation.*

The resulting regression, as shown in Figure 1, will have an r^2 value of 0.79 and predicted percent survival ranging from 3.67% with no floodplain inundation to 27.49% with 150,000 acre-days of floodplain inundation. The relationship shown in Figure 1 could be used to develop PM&E measures, which could be achieved through a combination of higher flows and floodplain restoration projects which lower floodplain elevations. For example, using the survival goals in the Scientific Evaluation Process Group's 2014 report for the Stanislaus River, the PM&E measures would be 8,400 acre-days in dry years (to achieve 5% survival), 41,000 acre-days in normal years (to achieve 10.18% survival) and 71,350 acre-days in wet years (to achieve 15% survival).

Attachment H, pages 1-2: Add figures showing the total combining Models A, B and C.

Conclusion

We appreciate the opportunity to comment on the Draft Report. If you have any questions, regarding our comments, please contact Alison Willy at (916)414-6534.

Sincerely,

Larry Rabin
Acting Field Supervisor

Enclosure

cc:
FERC #2199 Service List
Rose Staples, HDR

References

Mesick, C.F., J. McLain, D. Marston and T. Heyne. 2008. Draft limiting factor analyses and recommended studies for fall-run Chinook salmon and rainbow trout in the Tuolumne River. Report submitted to the Federal Energy Regulatory Commission. March 2007.

Sellheim, K. L., C. B. Watry, B. Rook, S. C. Zeug, J. Hannon, J. Zimmerman, K. Dove and J. E. Merz. 2015. Juvenile salmonid utilization of floodplain rearing habitat after gravel augmentation in a regulated river. River Research and Applications. Published online in Wiley Online Library (wileyonlinelibrary.com) DOI: 10.1002/rra.2876. 12pp.

Scientific Evaluation Process Group. 2014. Administrative draft of the interim objectives for restoring Chinook salmon and steelhead in the Stanislaus River report. Report prepared by Anchor QEA, LLC: Seattle, WA. December 2014.

U.S. Fish and Wildlife Service. 2008. Flow-overbank inundation relationship for potential fall-run Chinook salmon and steelhead/rainbow trout juvenile outmigration habitat in the Tuolumne River. U.S. Fish and Wildlife Service: Sacramento, CA.

U.S. Fish and Wildlife Service. 2014. Identification of the instream flow requirements for anadromous fish within the Central Valley of California and fisheries investigations. Annual progress report Fiscal Year 2014. U.S. Fish and Wildlife Service: Sacramento, CA.

Excerpt from spreadsheet of USFWS analysis of juvenile Chinook salmon survival in the lower Tuolumne River in relation to acre-days of floodplain inundation.

year	FWS 2/1-6/15 acre-day	2015 2/1-6/15 acre-day	Waterford	Grayson	% survival
1996	75019	65527			
1997	46573	57403			
1998	100814	99005			
1999	49956	42935			
2000	38471	34392			
2001	4408	3364			
2002	413	354			
2003	495	422			
2004	1811	2018			
2005	78510	69954			
2006	100,627	116,453	499,366	84,987	17.0%
2007	0	0	52,840	952	1.8%
2008	527	487	49,527	3,020	6.1%
2009	0	0	54,517	4,072	7.5%
2010	22,784	16,817	74,520	2,056	2.8%
2011	95,380	98,621	365,904	95,156	26.0%
2012	1,280	877	62,076	2,268	3.7%
2013	24	31	40,387	642	1.6%
2014	29	44			

STUDY REPORT W&AR-21

THE LOWER TUOLUMNE RIVER FLOODPLAIN HYDRAULIC ASSESSMENT

ATTACHMENT B

TUFLOW MODEL CELL SIZE SENSITIVITY ANALYSIS

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TABLE OF CONTENTS

List of Figures

List of Tables

1.0 OVERVIEW

This attachment provides figures and tables referred to in the Model Spatial and Temporal Resolution section of the study report.

Figure 1. The extent of the TUFLOW model used for cell size sensitivity analysis. Yellow stars represent the locations of water level measurements recorded at a steady flow of 3,000 cfs for the Pulse Flow Study (Stillwater Sciences 2012).

Table 1. Cell Size Sensitivity Analysis – Hydraulic model results.

S No.	*Observed WSE (ft) 3,000 cfs*	*Difference in WSE for Variuos Cell Size Models**					*Remarks*
		10 ft	**20 ft**	**30 ft**	**40 ft**	**50 ft**	
1	169.7	0.2	0.2	0.1	0.1	0.0	--
2	168.9	0.5	0.4	0.4	0.3	0.2	--
3	166.9	-0.3	-0.3	-0.4	-0.4	-0.6	Overbank
4	166.8	0.5	0.4	0.3	0.2	0.1	--
5	165.9	0.3	0.3	0.2	0.0	-0.2	--
6	165.2	-0.2	-0.3	-0.3	-0.5	-0.8	--
7	163.0	0.0	-0.3	-0.6	-0.5	-0.8	Overbank
8	162.7	0.3	0.2	0.2	0.1	0.0	--
9	162.5	0.1	0.1	0.0	-0.1	-0.1	--
10	162.3	0.1	0.1	0.0	-0.1	-0.1	--
11	161.8	-0.1	-0.1	-0.3	-0.3	-0.4	--
12	161.6	0.0	0.0	-0.3	-0.3	-0.5	--
13	161.5	0.0	-0.1	-0.1	-0.2	-0.2	--
14	161.5	0.1	0.0	0.0	-0.1	-0.1	--
15	161.3	0.0	0.0	-0.1	-0.2	-0.2	--
16	161.1	-0.1	-0.1	-0.2	-0.3	-0.3	--
17	161.0	-0.2	-0.2	-0.3	-0.4	-0.4	--
18	160.6	0.2	0.1	0.1	0.0	-0.1	--
19	158.2	-0.9	-1.0	-1.1	-1.1	-1.0	Results invalid as this downstream portion is affected by assumed boundary conditions.
20	157.0	-0.9	-0.9	-0.9	-1.0	-1.0	
21	156.9	-0.6	-0.6	-0.6	-0.7	-0.7	
22	156.5	-2.1	DRY	DRY	-1.9	-2.1	
RMSE (ft) (Lines 1 - 21)		**0.4**	**0.4**	**0.4**	**0.5**	**0.5**	
RMSE (ft) (Lines 1 - 18)		**0.2**	**0.2**	**0.3**	**0.3**	**0.4**	

* Model has only overbank geometry and does not include 1D low flow channel, Manning's n and other necessary components for calibration.

Table 2. Cell Size Sensitivity Analysis – Salmonid fry usable habitat estimates.

Cell Size (ft)	Fraction of wetted area (%)					
	Chinook Fry			*O. mykiss* Fry		
	Product	Geo. Mean	Limiting	Product	Geo. Mean	Limiting
10	29	40	32	40	48	42
20	27	39	31	39	47	40
30	27	38	30	38	46	39
40	28	39	31	38	47	40
50	26	38	30	37	46	39

Table 3. Cell Size Sensitivity Analysis – Salmonid juvenile usable habitat estimates.

Grid Size (ft)	Fraction of wetted area (%)					
	Juvenile Chinook			Juvenile *O. mykiss*		
	Product	Geo. Mean	Limiting	Product	Geo. Mean	Limiting
10	32	42	34	35	43	37
20	32	42	34	35	43	37
30	32	41	34	34	42	37
40	33	42	35	35	43	38
50	32	41	34	35	43	37

STUDY REPORT W&AR-21
THE LOWER TUOLUMNE RIVER FLOODPLAIN HYDRAULIC ASSESSMENT

ATTACHMENT C

1D/2D DOMAIN BOUNDARY, CROSS SECTION LOCATIONS AND DATA SOURCES

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1.0 SUMMARY

This attachment provides the data sources used to develop the bathymetric geometry of each 1D cross section (Table 1). This attachment also includes a series of maps that depict the locations of each cross section with its associated bathymetric data source as well as the 1D/2D domain boundary line. In producing the map series, the river centerline was altered to match the stream centerline at the time the LiDAR data was collected in 2012. Therefore, the rivers miles in the map series differ slightly from the USGS river miles.

Table 1. Lower Tuolumne River in-channel data sources.

Cross Section Attributes			
USGS River Mile	**HEC-RAS Model Station**	**Bathymetric Data Source**	**No. of Cross Sections**
0.88-4.40	0.8252-4.3666	CDWR (2014)	20
4.43-4.53	4.3978-4.5003	Interpolated	4
4.70-6.31	4.6664-6.3035	CDWR (2014)	8
6.71-6.94	6.7150-6.9575	FEMA (2013)	2
7.00-7.14	7.0087-7.1473	Interpolated	7
7.21-7.52	7.2192-7.5203	FEMA (2013)	2
7.64-7.79	7.6465-7.7963	Interpolated	4
7.82-10.74	7.8292-10.7413	FEMA (2013)	9
10.87-10.99	10.8658-10.9784	Interpolated	4
11.12-13.78	11.1007-13.6371	FEMA (2013)	8
13.99	13.8470	HDR Field Survey 2012	1
14.12-14.89	13.9709-14.7123	FEMA (2013)	3
15.04	14.8616	HDR Field Survey 2012	1
15.24	15.0666	FEMA (2013)	1
15.50	15.3283	HDR Field Survey 2012	1
15.66	15.4965	FEMA (2013)	1
15.72-15.74	15.5579-15.5776	Interpolated	2
15.84	15.6774	FEMA (2013)	1
15.86-15.93	15.6916-15.7665	Interpolated	4
15.98	15.8150	HDR Field Survey 2012	1
16.00-16.09	15.8351-15.9239	Interpolated	5
16.13	15.9601	USGS (2014a, 2014b)	1
16.17-16.21	15.9890-16.0263	FEMA (2013)	3
16.33-16.35	16.1409-16.1591	Interpolated	2
16.38-16.41	16.189-16.2138	USGS (2014a, 2014b)	2
16.49	16.2793	FEMA (2013)	1
16.53	16.3128	HDR Field Survey 2012	1
16.73	16.4905	FEMA (2013)	1
17.03	16.7579	HDR Field Survey 2012	1
17.16	16.8756	FEMA (2013)	1
17.52	17.1990	HDR Field Survey 2012	1
17.57-18.33	17.2472-17.9689	FEMA (2013)	3
18.46-18.49	18.0953-18.1288	HDR Field Survey 2012	2
18.70	18.3429	FEMA (2013)	1

Cross Section Attributes			
USGS River Mile	HEC-RAS Model Station	Bathymetric Data Source	No. of Cross Sections
18.98	18.6243	HDR Field Survey 2012	1
19.05-19.25	18.7067-18.9387	FEMA (2013)	2
19.49	19.2343	HDR Field Survey 2012	1
19.61-20.30	19.3709-20.1766	FEMA (2013)	3
20.49	20.3909	HDR Field Survey 2012	1
20.61-20.95	20.5204-20.9159	FEMA (2013)	2
21.02	21.0003	HDR Field Survey 2012	1
21.29	21.3174	FEMA (2013)	1
21.49	21.5672	HDR Field Survey 2012	1
21.63-21.82	21.7322-21.9662	FEMA (2013)	2
22.00	22.1825	HDR Field Survey 2012	1
22.26-22.44	22.4798-22.6904	FEMA (2013)	2
22.50	22.7482	HDR Field Survey 2012	1
22.55	22.8062	FEMA (2013)	1
22.59-22.62	22.8536-22.8826	TID Field Survey	2
22.78	23.0683	FEMA (2013)	1
22.83	23.1392	TID Field Survey	1
22.99	23.3244	HDR Field Survey 2012	1
23.25	23.6137	TID Field Survey	1
23.48	23.9049	HDR Field Survey 2012	1
23.50-23.85	23.9240-24.3337	TID Field Survey	3
23.98	24.4905	HDR Field Survey 2012	1
24.19	24.7347	TID Field Survey	1
24.41	24.9480	McBain and Trush (2004b)	1
24.53	25.0699	HDR Field Survey 2012	1
24.65-24.95	25.1890-25.4942	McBain and Trush (2004b)	5
25.02	25.5663	HDR Field Survey 2012	1
25.03	25.5823	Interpolated	1
25.04	25.5922	TID Field Survey	1
25.07	25.6245	McBain and Trush (2004b)	1
25.09	25.6503	TID Field Survey	1
21.12-25.36	25.6774-25.9475	McBain and Trush (2004b)	5
25.42-25.49	26.0073-26.1223	TID Field Survey	4
25.50	26.1275	HDR Field Survey 2012	1
25.54	26.1658	TID Field Survey	1
25.61	26.2474	McBain and Trush (2004b)	1
25.67	26.3109	TID Field Survey	1
25.71-25.78	26.3528-26.4306	McBain and Trush (2004b)	2
25.79-25.8	26.4409-26.4552	TID Field Survey	2
25.86	26.5125	McBain and Trush (2004b)	1
25.95-25.97	26.603-26.6222	TID Field Survey	2
26.05-27.98	26.7028-28.5435	HDR Field Survey 2012	5
28.23-28.40	28.7500-28.9000	Interpolated	3
28.60-29.47	29.1201-29.9195	HDR Field Survey 2012	3

Cross Section Attributes			
USGS River Mile	**HEC-RAS Model Station**	**Bathymetric Data Source**	**No. of Cross Sections**
29.54	29.9800	Interpolated	1
29.66-30.15	30.0853-30.5497	TID Field Survey	7
30.25	30.6561	HDR Field Survey 2012	1
30.34-30.42	30.7390-30.8268	Stillwater (2013)	3
30.52	30.9218	HDR Field Survey 2012	1
30.64-31.02	31.0461-31.4475	TID Field Survey	9
31.07	31.4911	HDR Field Survey 2012	1
31.18-31.35	31.6042-31.7817	TID Field Survey	3
31.48	31.9232	HDR Field Survey 2012	1
31.56-31.75	32.0006-32.2089	TID Field Survey	5
31.95-31.97	32.4279-32.445	Stillwater (2013)	2
32.01-36.09	32.4861-36.8374	TID Field Survey	50
36.11-36.45	36.8642-37.2503	Stillwater (2013)	11
36.49-36.67	37.2926-37.5083	TID Field Survey	5
36.70-36.74	37.5353-37.5818	Stillwater (2013)	3
36.82-37.83	37.7200-38.8828	TID Field Survey	21
37.90-41.66	38.9536-42.1508	McBain and Trush (2004a)	60
41.67	42.1600	TID Field Survey	1
41.71	42.1800	McBain and Trush (2004a)	1
41.73-41.76	42.1900-42.2400	TID Field Survey	3
41.78	42.2600	McBain and Trush (2004a)	1
41.80	42.2806	TID Field Survey	1
41.81	42.2900	McBain and Trush (2004a)	1
41.83-41.84	42.3062-42.32	TID Field Survey	2
41.86-41.88	42.3359-42.3543	McBain and Trush (2004a)	2
41.91-42.01	42.3934-42.4897	TID Field Survey	4
42.11-42.27	42.5777-42.7519	McBain and Trush (2004a)	5
42.29-42.3	42.775-42.7834	TID Field Survey	2
42.36-45.77	42.8509-46.2700	McBain and Trush (2004a)	97
45.78-46.92	46.2985-47.4044	TID/MID (2013b)	21

2.0 REFERENCES

California Department of Water Resources (CDWR). 2014. Central Valley Floodplain Evaluation and Delineation (CVFED) hydraulic models

Federal Emergency Management Agency (FEMA). 2013. HEC-RAS modeling of the Tuolumne River and Dry Creek, Stanislaus County, CA. Prepared by HDR Engineering for FEMA in conjunction with the California Department of Water resources (CDWR) as part of the Cooperating Technical Partners Program.

McBain & Trush, Inc. 2004a. Coarse Sediment Management Plan for the Lower Tuolumne River. Revised Final. Prepared for Tuolumne River Technical Advisory Committee, Turlock and Modesto Irrigation Districts, USFWS Anadromous Fish Restoration Program and the CALFED Bay Delta Authority. Arcata, CA.

_____. 2004b. Tuolumne River Floodway Restoration – Project Design approach and Rationale. Prepared for Tuolumne River Technical Advisory Committee. February 2004.

Stillwater Sciences. 2013. Lower Tuolumne River Instream Flow Study. Final Report. Prepared by Stillwater Sciences, Davis, California for Turlock and Irrigation District and Modesto Irrigation District, California. April.

Turlock Irrigation District and Modesto Irrigation District (TID/MID). 2013b. Spawning Gravel in the Lower Tuolumne River Study Report (W&AR-04). Attachment to Don Pedro Hydroelectric Project Updated Study Report. December 2013.

U.S. Geological Survey (USGS). 2014a. Email correspondence with Patricia Orlando, Public Information Officer at the USGS Sacramento Field office, Sacramento CA. November 4, 2014.

_____. 2014b. Email correspondence with Susan Brockner, Hydrologic Technician at the USGS Sacramento Field office, Sacramento CA. October 30, 2014.

TUFLOW 1D-2D Domain Boundary Line

Cross Section Source

2014 DWR-CVFED HEC-RAS Model

Interpolated

0 250 500 1,000

Feet

N

Floodplain Hydraulic Modeling

Don Pedro Project (FERC No.2299)

Map information was compiled from the best available sources.
No warranty is made for its accuracy or completeness.
Data Sources: Hydrography - USGS NHD, TID/MID;
Data is NAD83, State Plane CA Zone 3 U.S. Ft.

TUFLOW 1D-2D Domain Boundary Line

Cross Section Source

2014 DWR-CVFED HEC-RAS Model

0 250 500 1,000
Feet

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TUFLOW 1D-2D Domain Boundary Line

Cross Section Source

2014 DWR-CVFED HEC-RAS Model

Interpolated

0 250 500 1,000
Feet

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TUFLOW 1D-2D Domain Boundary Line

Cross Section Source

2014 DWR-CVFED HEC-RAS Model

FEMA-CVFED HEC-RAS Model

0 250 500 1,000
Feet

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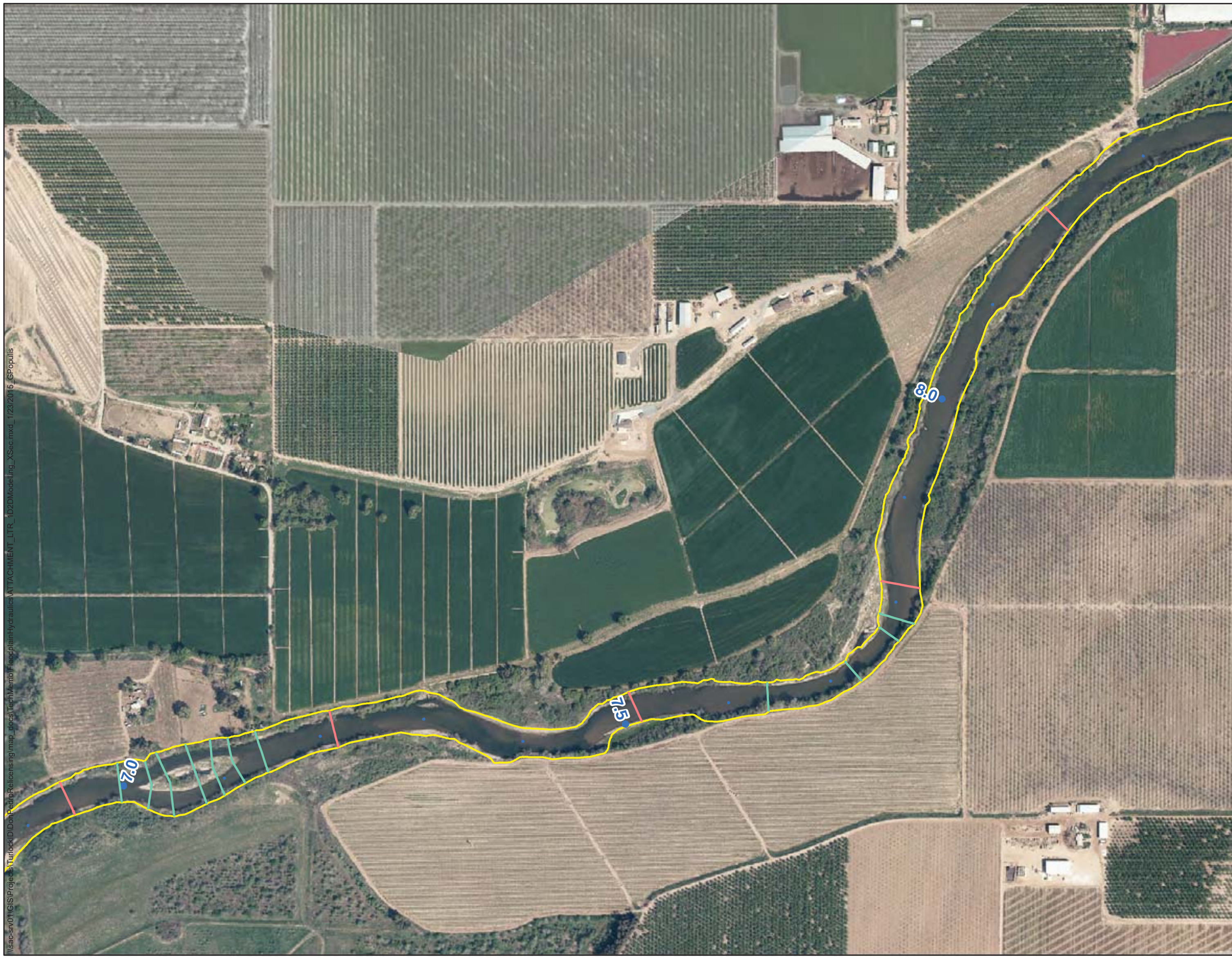

TUFLOW 1D-2D Domain Boundary Line

Cross Section Source

FEMA-CVFED HEC-RAS Model

Interpolated

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Feet

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TUFLOW 1D-2D Domain Boundary Line

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FEMA-CVFED HEC-RAS Model

0 250 500 1,000
Feet

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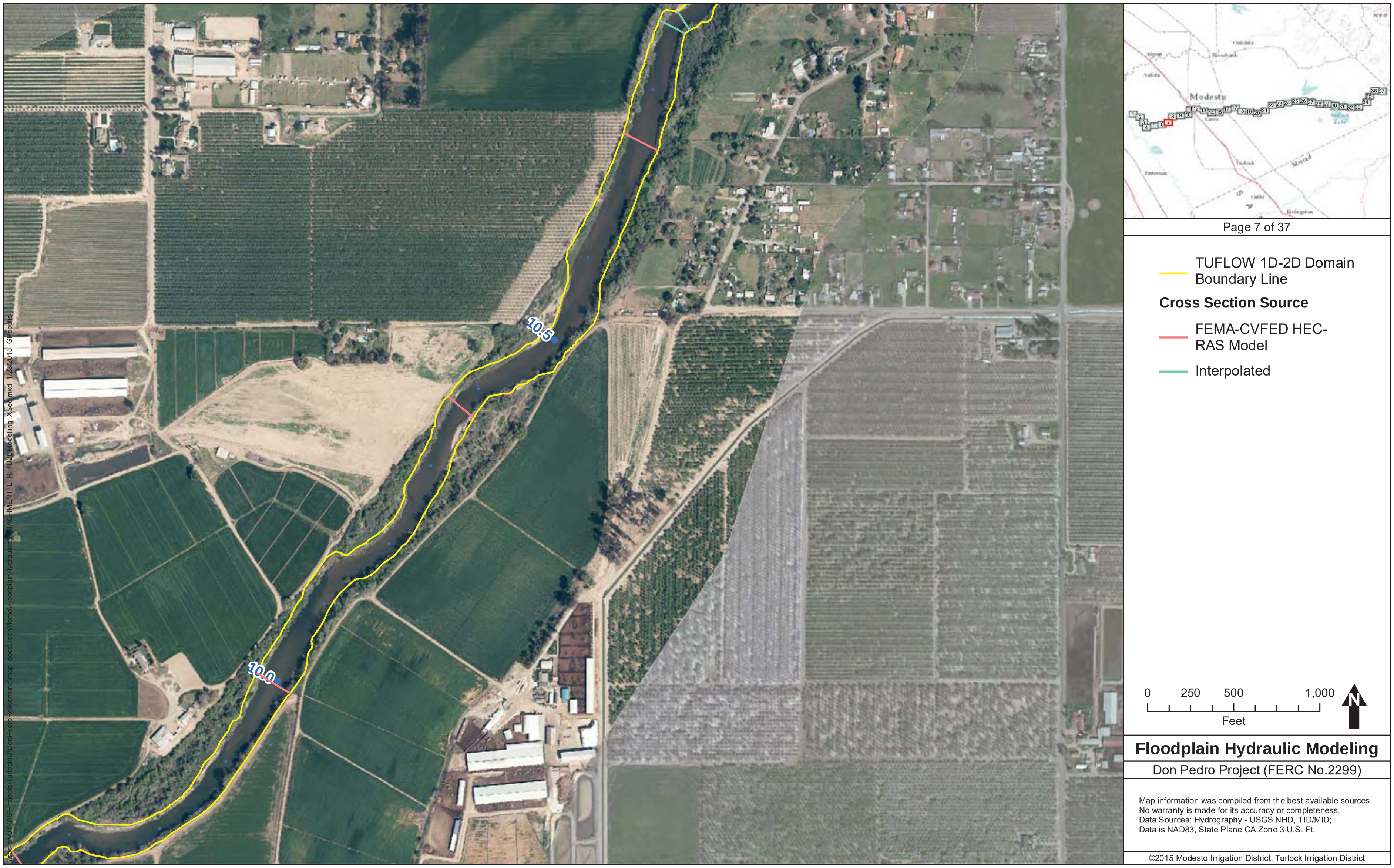

TUFLOW 1D-2D Domain Boundary Line

Cross Section Source

FEMA-CVFED HEC-RAS Model

Interpolated

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Feet

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Cross Section Source

FEMA-CVFED HEC-RAS Model

Interpolated

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Feet

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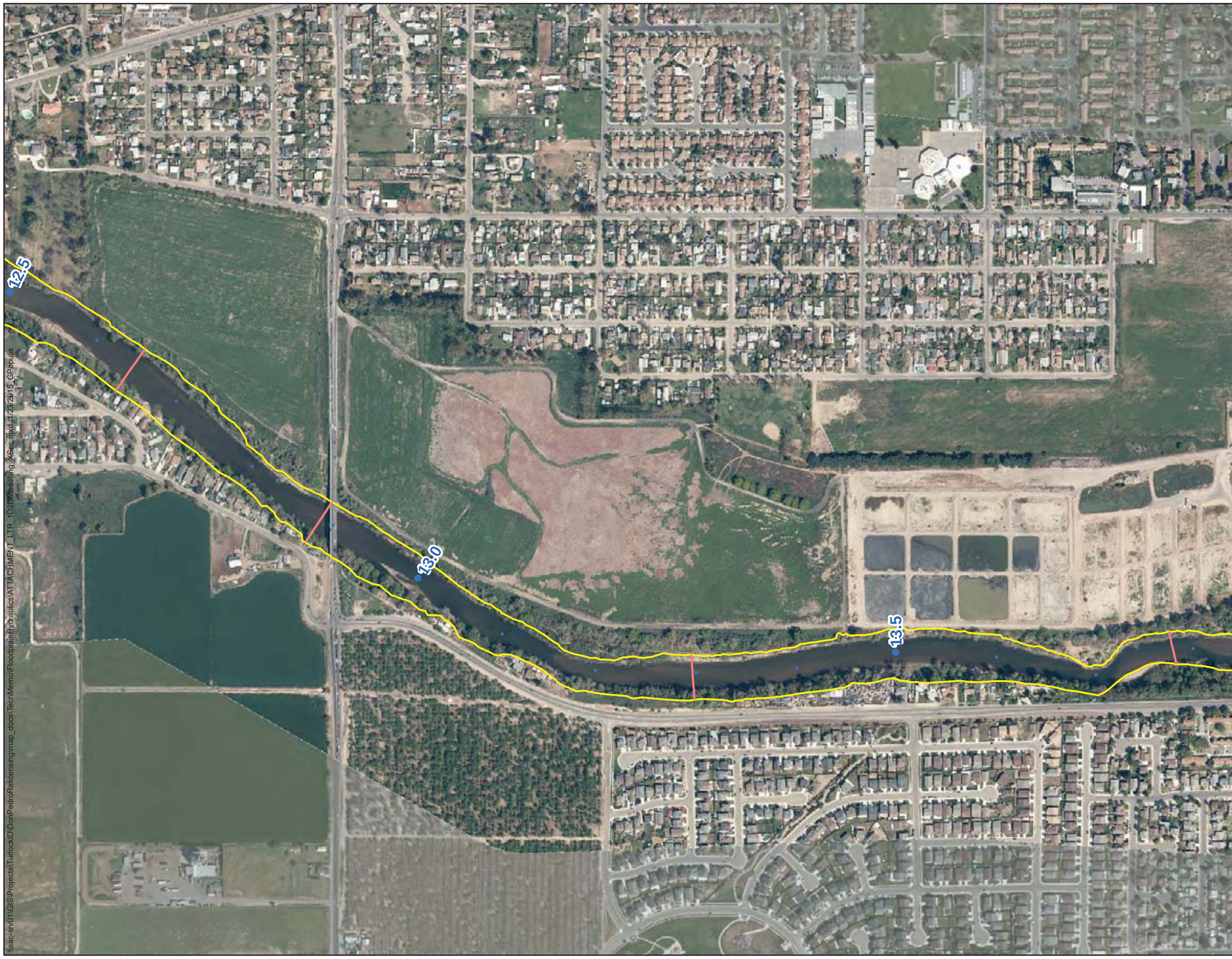

Page 9 of 37

TUFLOW 1D-2D Domain Boundary Line

Cross Section Source

FEMA-CVFED HEC-RAS Model

0 250 500 1,000
Feet

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TUFLOW 1D-2D Domain Boundary Line

Cross Section Source

2012 HDR Survey

FEMA-CVFED HEC-RAS Model

0 250 500 1,000
Feet

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TUFLOW 1D-2D Domain Boundary Line

Cross Section Source

- 2012 HDR Survey
- FEMA-CVFED HEC-RAS Model
- Interpolated
- USGS Gage Cross Sections

0 250 500 1,000
Feet

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TUFLOW 1D-2D Domain Boundary Line

Cross Section Source

- 2012 HDR Survey
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- USGS Gage Cross Sections

0 250 500 1,000
Feet

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TUFLOW 1D-2D Domain Boundary Line

Cross Section Source

2012 HDR Survey

FEMA-CVFED HEC-RAS Model

0 250 500 1,000
Feet

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TUFLOW 1D-2D Domain Boundary Line

Cross Section Source

2012 HDR Survey

FEMA-CVFED HEC-RAS Model

0 250 500 1,000
Feet

N

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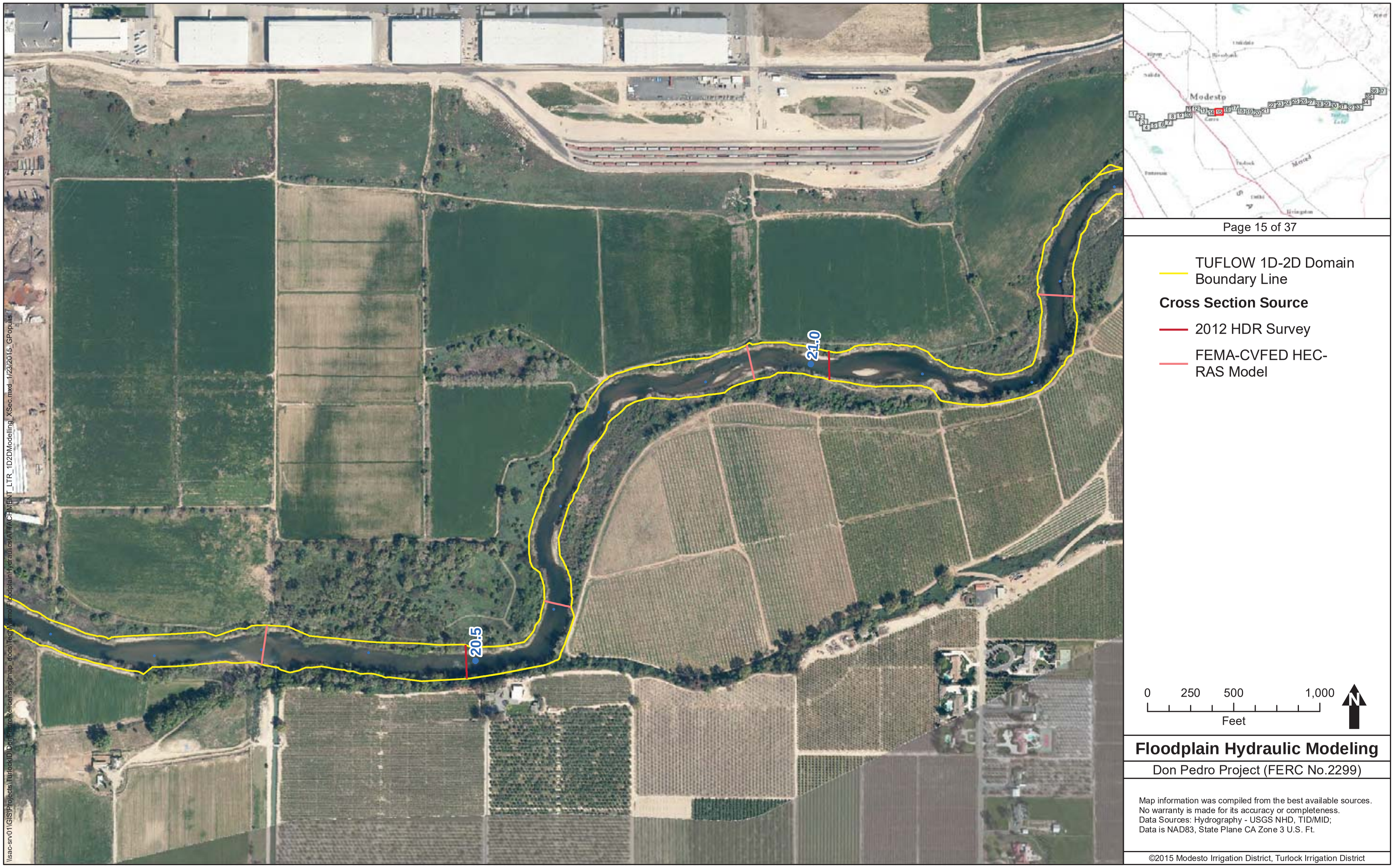

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TUFLOW 1D-2D Domain Boundary Line

Cross Section Source

2012 HDR Survey

2014 FEMA HEC-RAS Model

2014 TID Survey

FEMA-CVFED HEC-RAS Model

0 250 500 1,000

Feet

N

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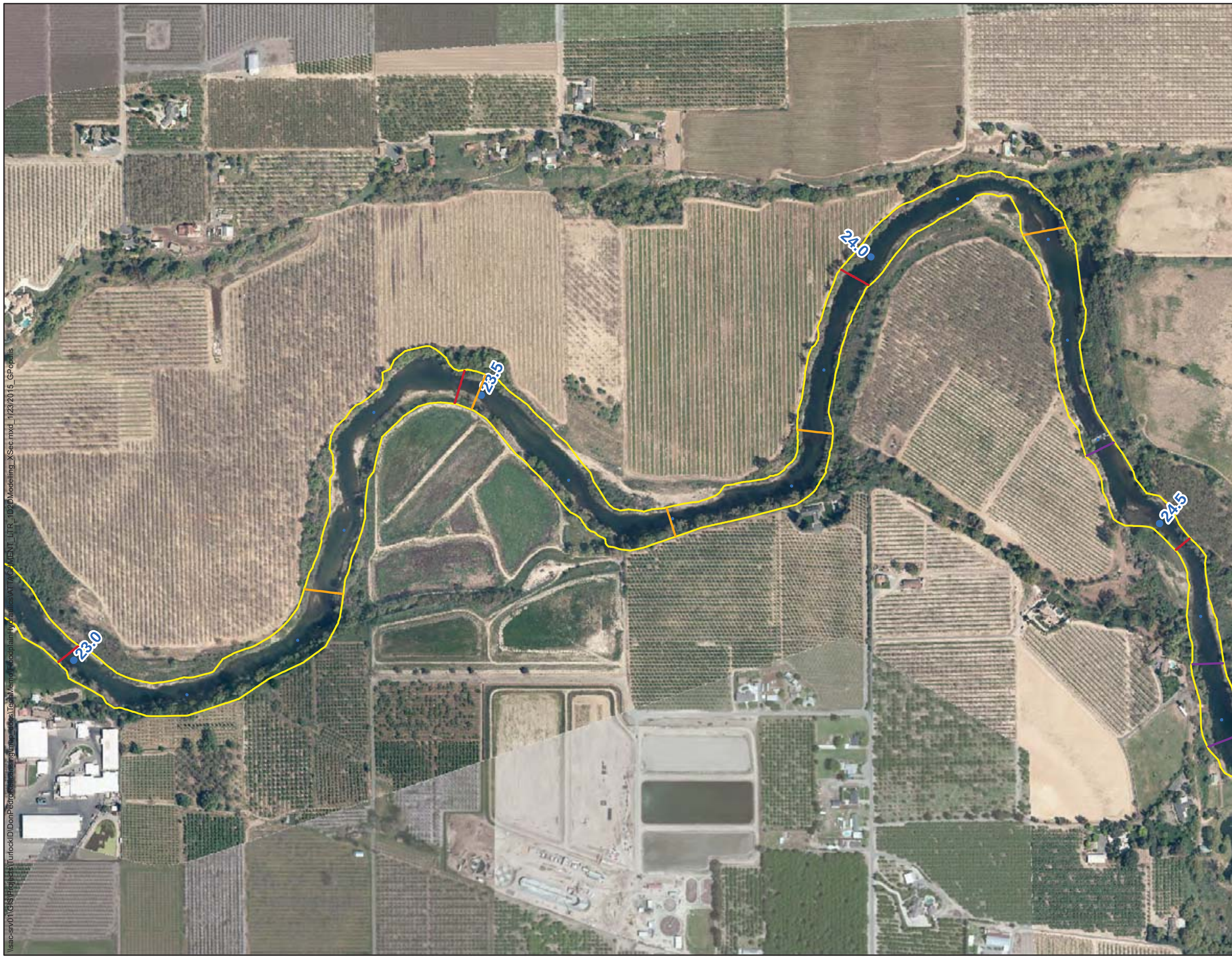

Page 17 of 37

TUFLOW 1D-2D Domain Boundary Line

Cross Section Source

2012 HDR Survey

2014 TID Survey

McBain&Trush SRP 9/10 Restoration

0 250 500 1,000

Feet

N

Floodplain Hydraulic Modeling

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TUFLOW 1D-2D Domain Boundary Line

Cross Section Source

- 2012 HDR Survey
- 2014 TID Survey
- Interpolated
- McBain&Trush SRP 9/10 Restoration

0 250 500 1,000
Feet

N

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TUFLOW 1D-2D Domain Boundary Line

Cross Section Source

2012 HDR Survey

0 250 500 1,000
Feet

N

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TUFLOW 1D-2D Domain Boundary Line

Cross Section Source

2012 HDR Survey

Interpolated

0 250 500 1,000
Feet

N

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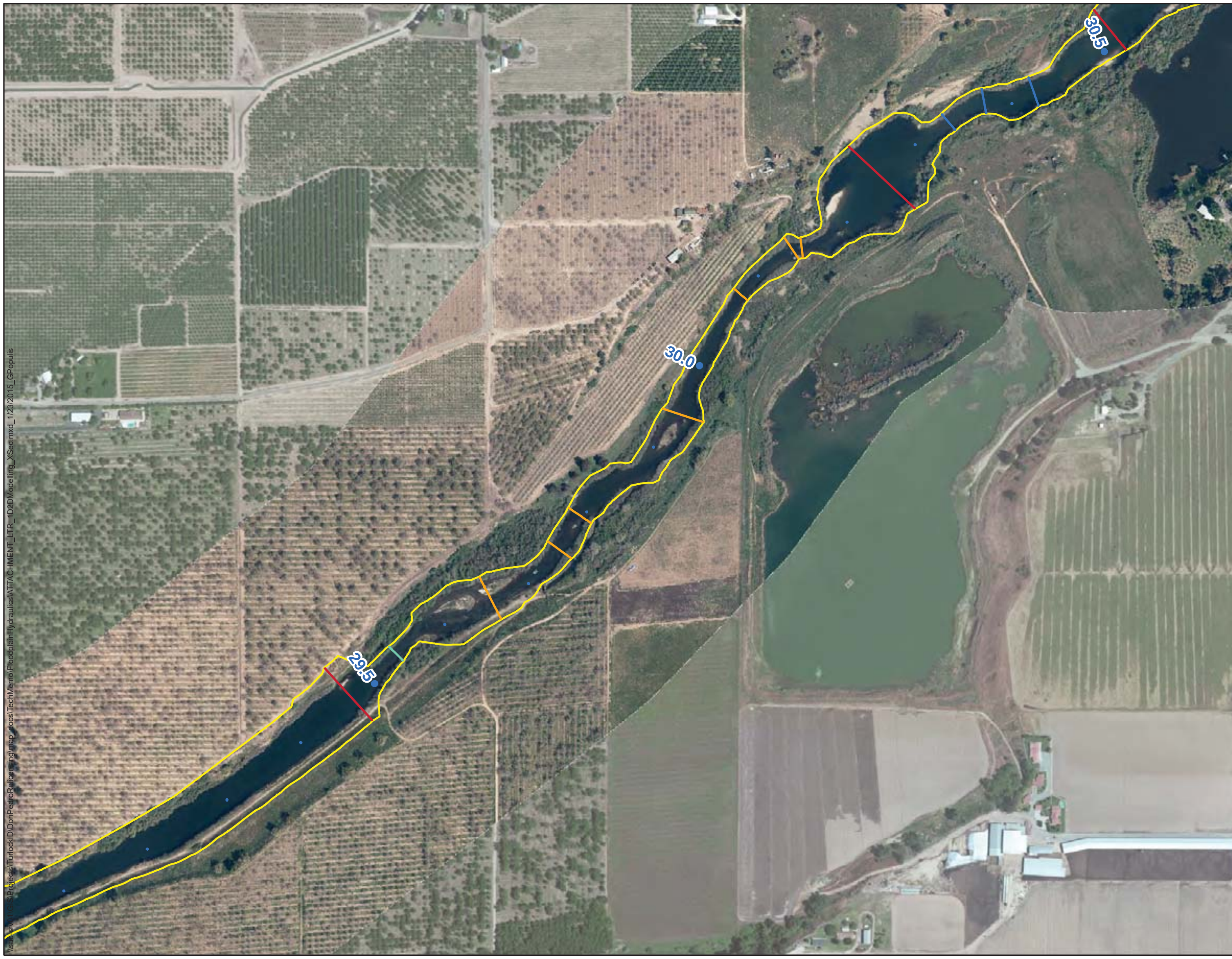

TUFLOW 1D-2D Domain Boundary Line

Cross Section Source

2012 HDR Survey

2013 Stillwater IFIM

2014 TID Survey

Interpolated

0 250 500 1,000
Feet

Floodplain Hydraulic Modeling

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TUFLOW 1D-2D Domain Boundary Line

Cross Section Source

2012 HDR Survey

2014 TID Survey

0 250 500 1,000
Feet

N

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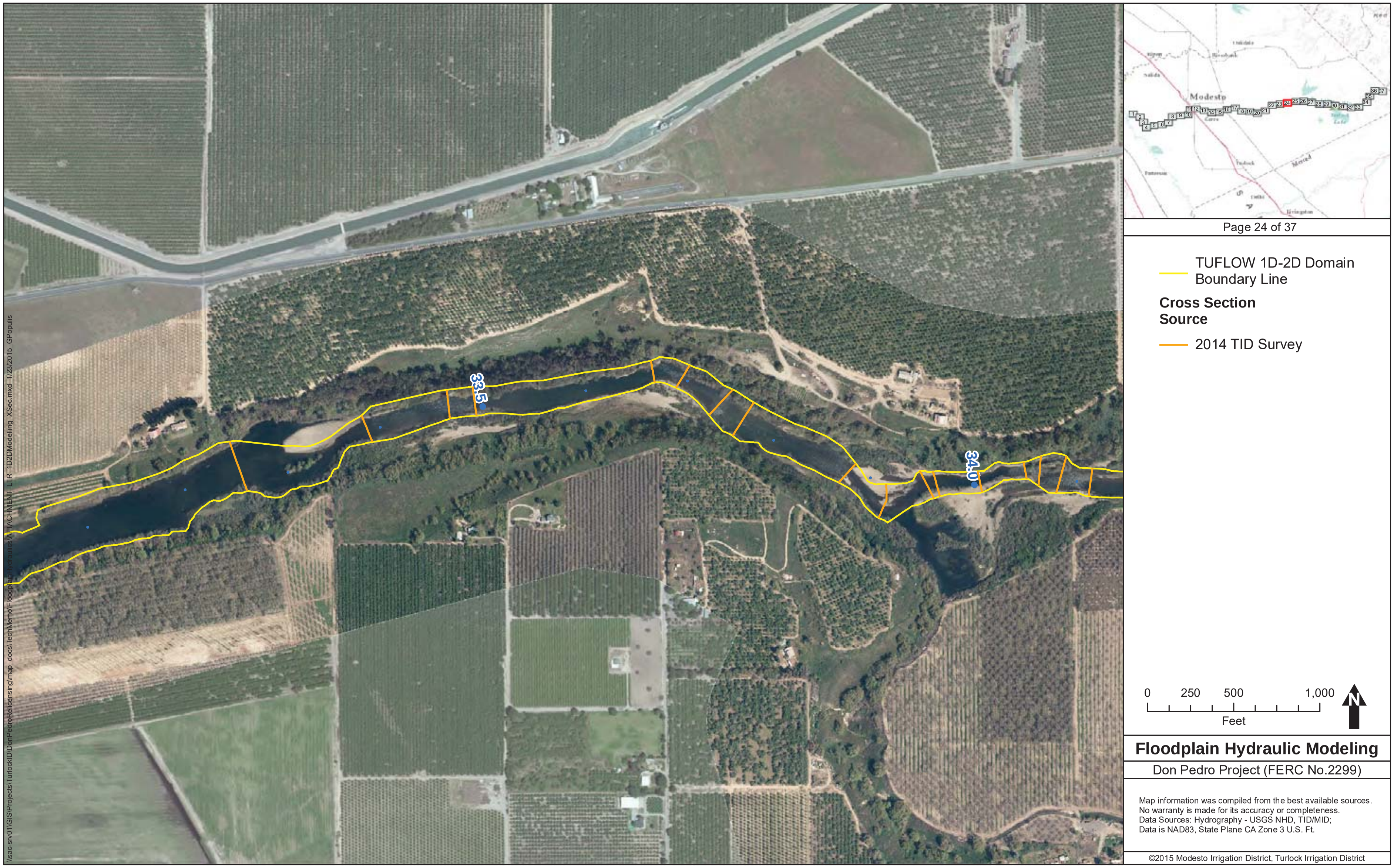

TUFLOW 1D-2D Domain Boundary Line

Cross Section Source

2014 TID Survey

0 250 500 1,000
Feet

N

Floodplain Hydraulic Modeling

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TUFLOW 1D-2D Domain Boundary Line

Cross Section Source

2014 TID Survey

0 250 500 1,000
Feet

N

Floodplain Hydraulic Modeling

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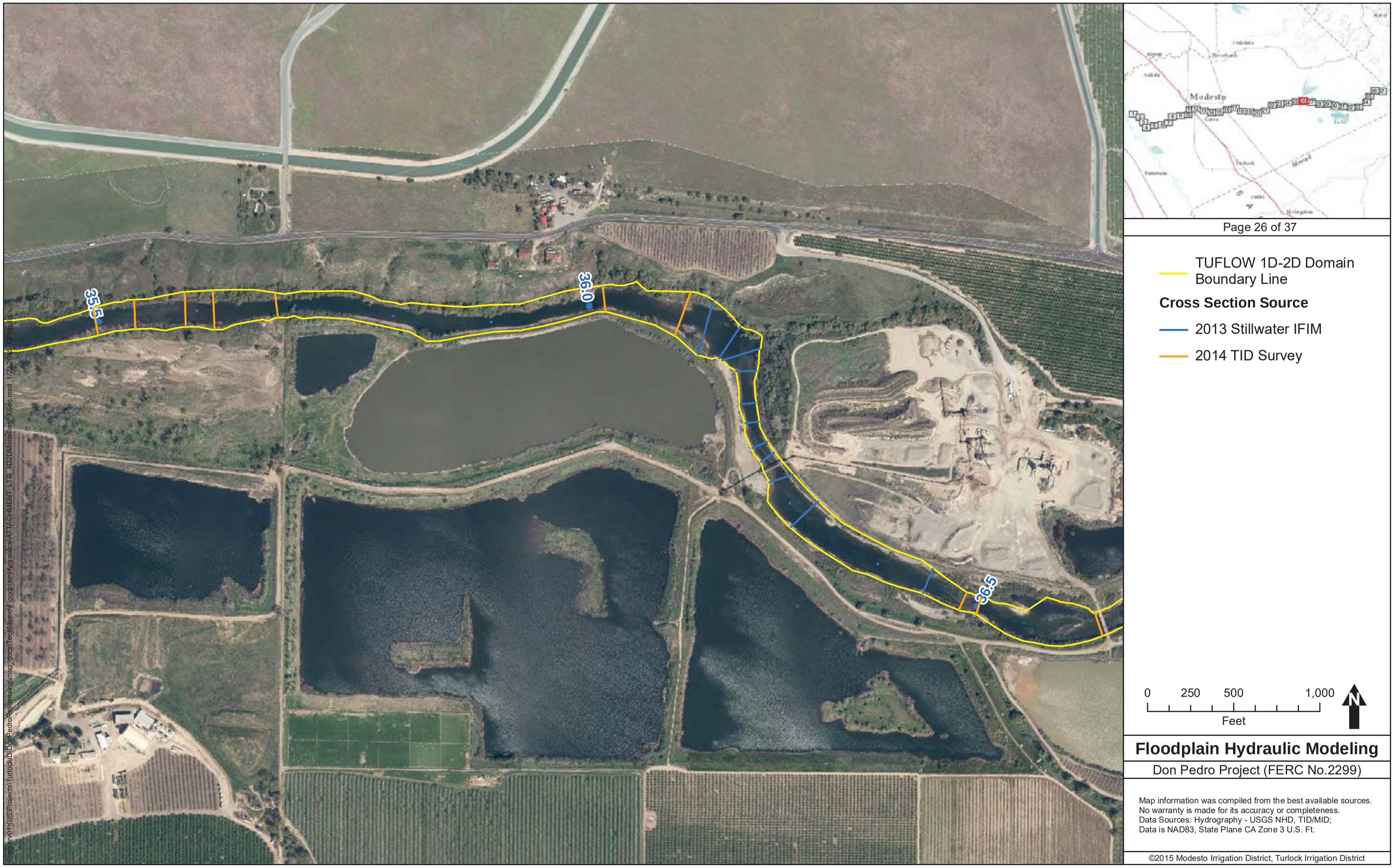
36.0
35.5
36.5
Modesto
Page 26 of 37
TUFLOW 1D-2D Domain Boundary Line
Cross Section Source
2013 Stillwater IFIM
2014 TID Survey
0
250
500
1,000
Feet
N
Floodplain Hydraulic Modeling
Don Pedro Project (FERC No.2299)
Map information was compiled from the best available sources.
No warranty is made for its accuracy or completeness.
Data Sources: Hydrography - USGS NHD, TID/MID;
Data is NAD83, State Plane CA Zone 3 U.S. Ft.
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Floodplain Hydraulic Modeling

Don Pedro Project (FERC No.2299)

Map information was compiled from the best available sources.
No warranty is made for its accuracy or completeness.
Data Sources: Hydrography - USGS NHD, TID/MID;
Data is NAD83, State Plane CA Zone 3 U.S. Ft.

TUFLOW 1D-2D Domain Boundary Line

Cross Section Source

- 2005 Bathymetry
- 2014 TID Survey
- Interpolated

0 250 500 1,000
Feet

N

Floodplain Hydraulic Modeling

Don Pedro Project (FERC No.2299)

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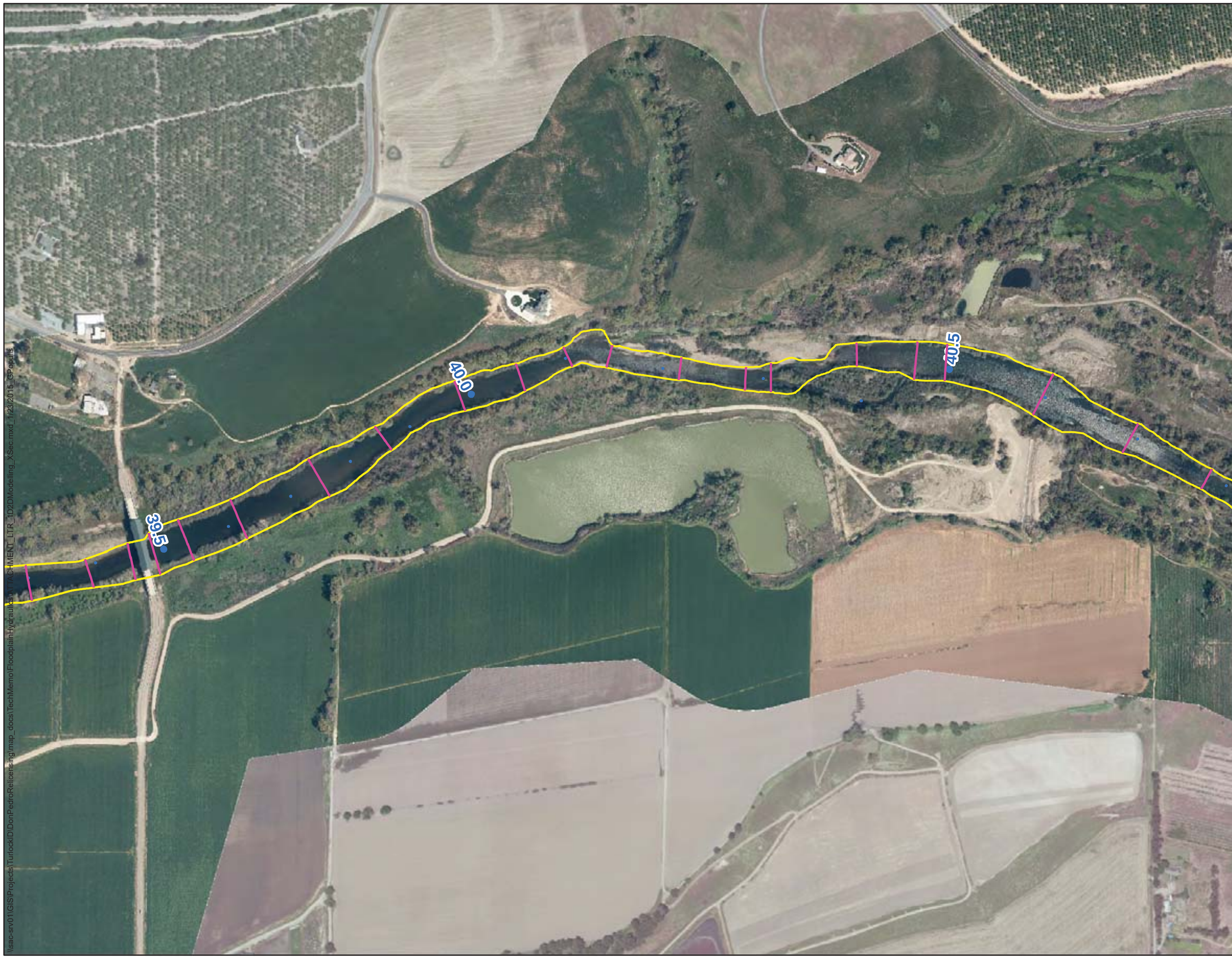

TUFLOW 1D-2D Domain Boundary Line

Cross Section Source

2005 Bathymetry

0 250 500 1,000
Feet

N

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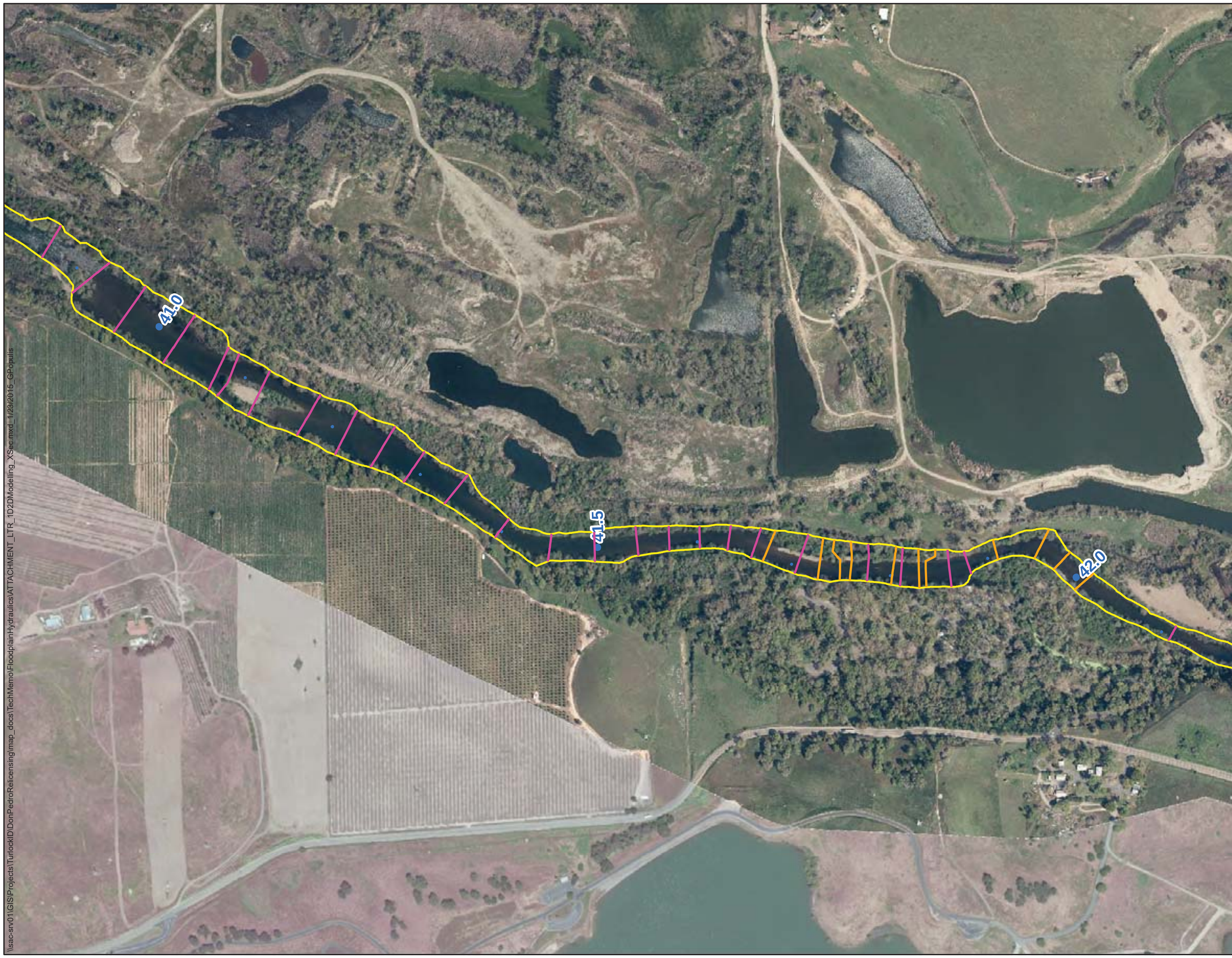

TUFLOW 1D-2D Domain Boundary Line

Cross Section Source

2005 Bathymetry

2014 TID Survey

0 250 500 1,000

Feet

N

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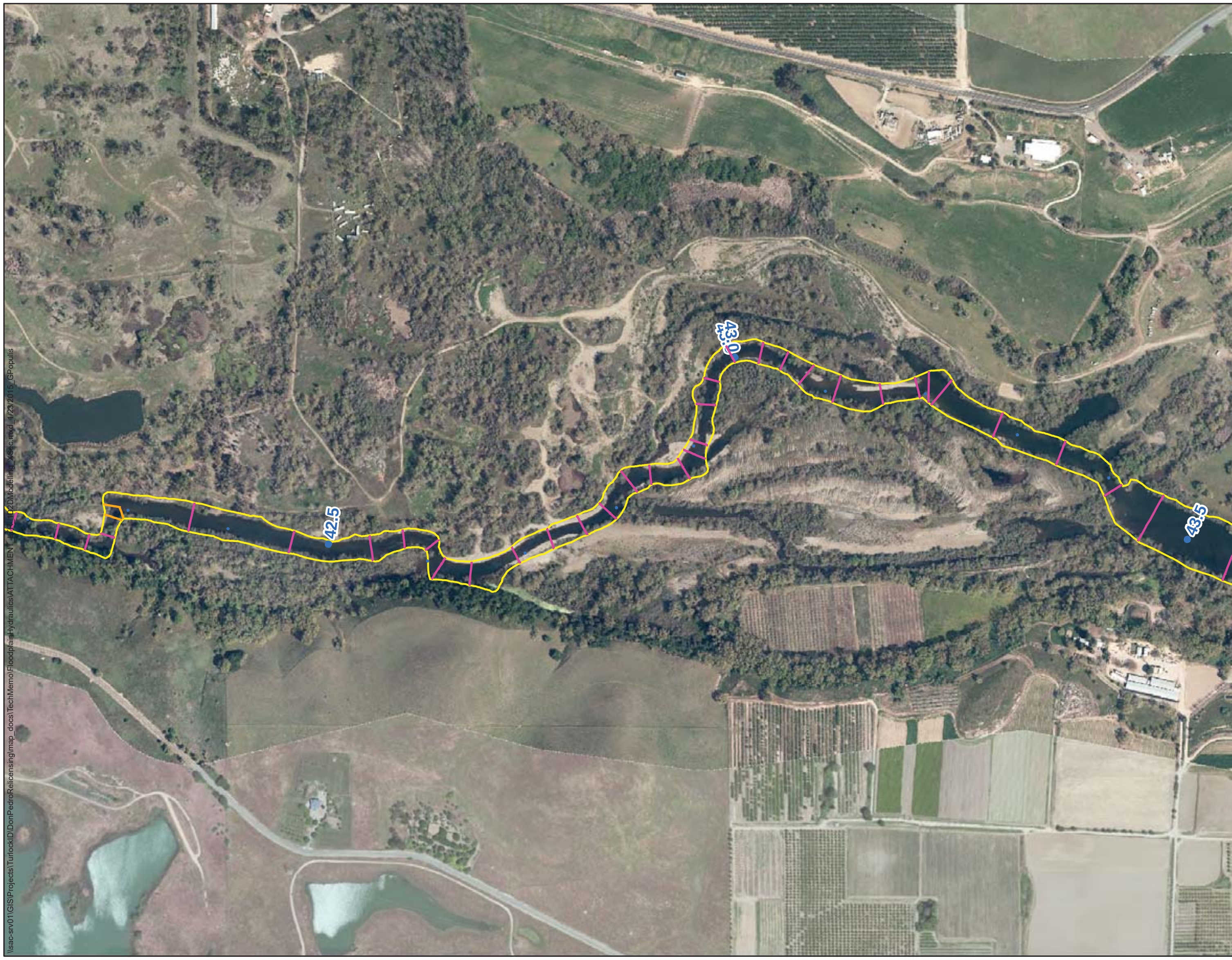

TUFLOW 1D-2D Domain Boundary Line

Cross Section Source

2005 Bathymetry

2014 TID Survey

0 250 500 1,000

Feet

N

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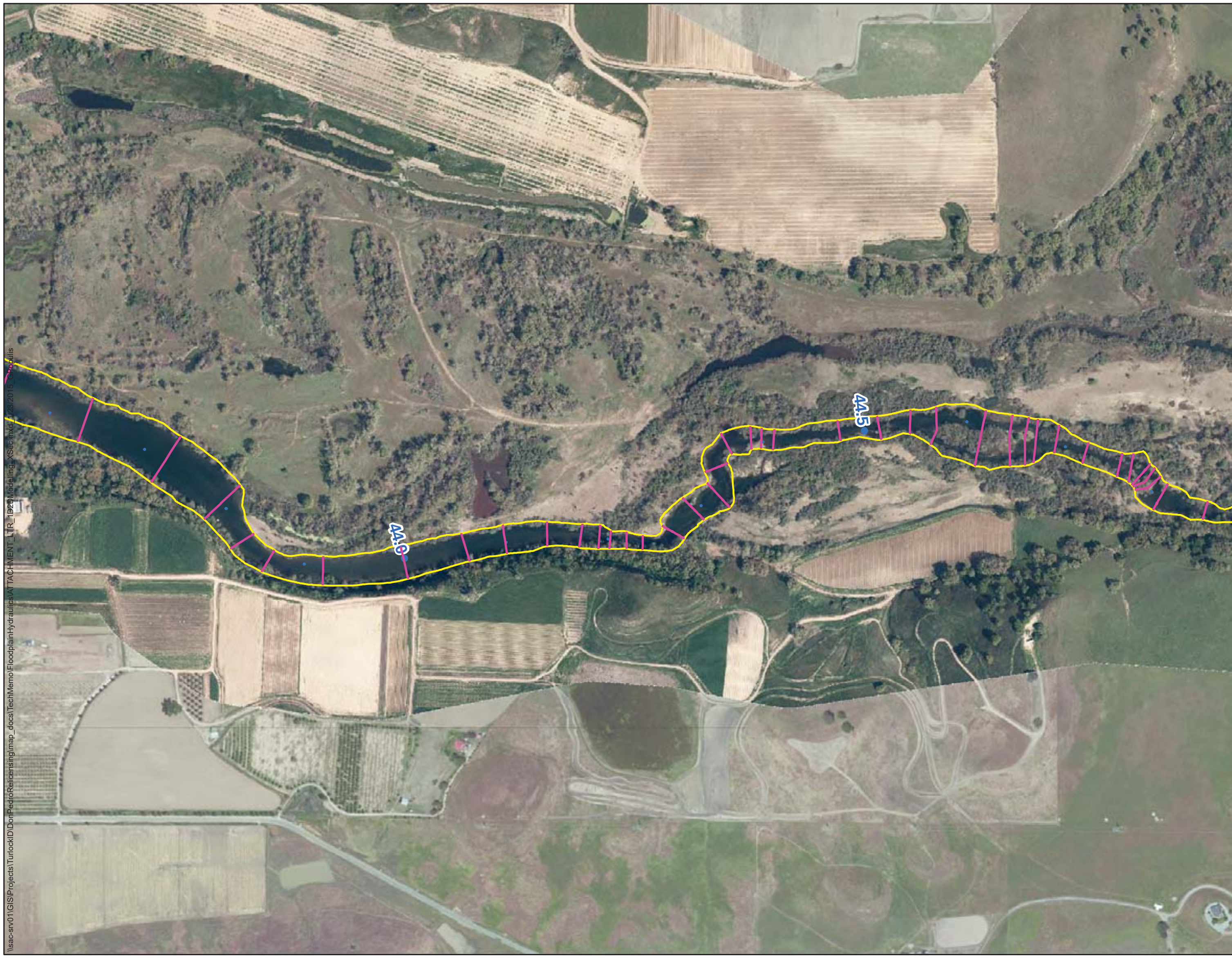

TUFLOW 1D-2D Domain Boundary Line

Cross Section Source

2005 Bathymetry

0 250 500 1,000
Feet

N

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TUFLOW 1D-2D Domain Boundary Line

Cross Section Source

2005 Bathymetry

2012 Bathymetry

0 250 500 1,000

Feet

N

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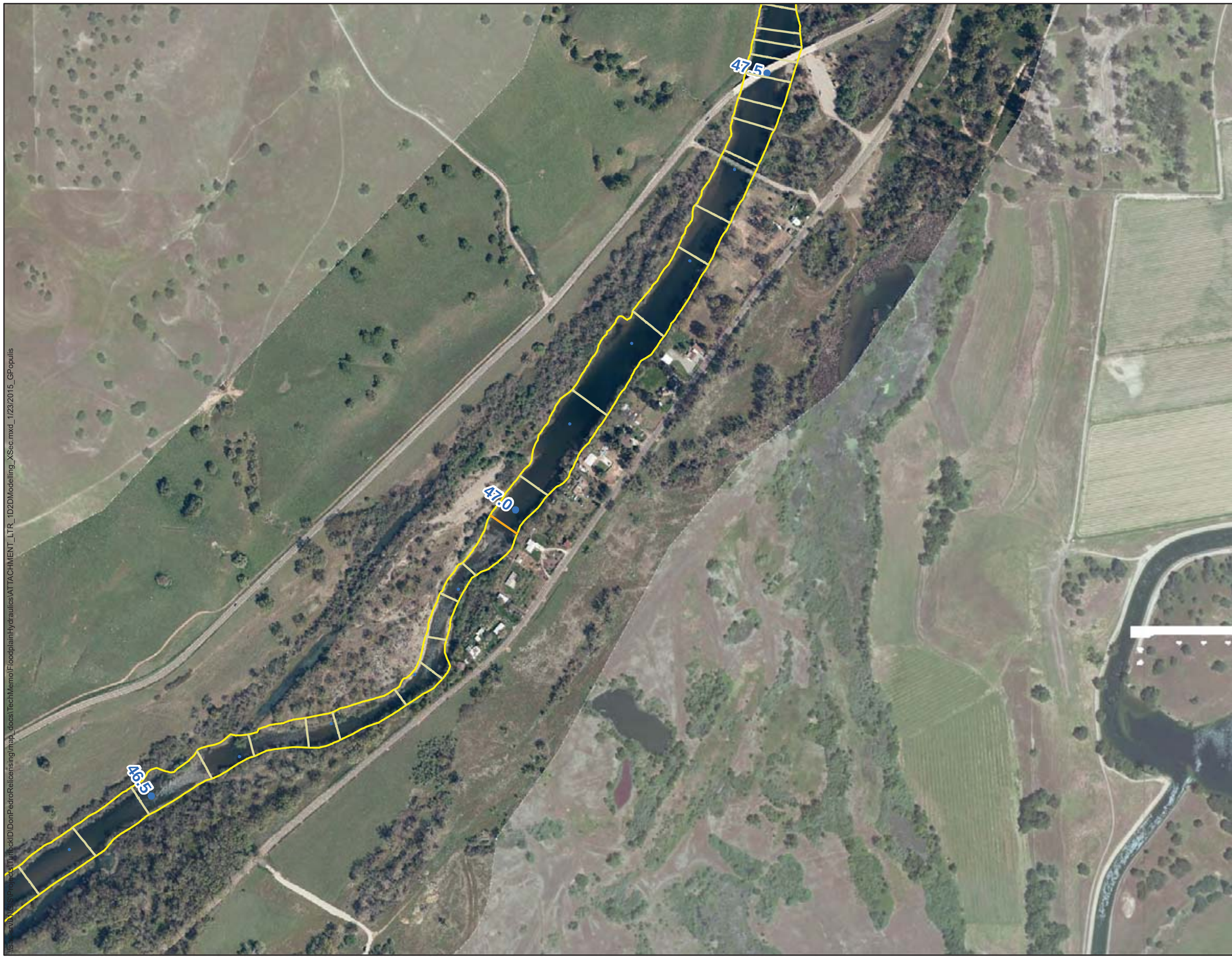

TUFLOW 1D-2D Domain Boundary Line

Cross Section Source

2012 Bathymetry

2014 TID Survey

0 250 500 1,000
Feet

N

Floodplain Hydraulic Modeling

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TUFLOW 1D-2D Domain Boundary Line

Cross Section Source

2012 Bathymetry

0 250 500 1,000
Feet

N

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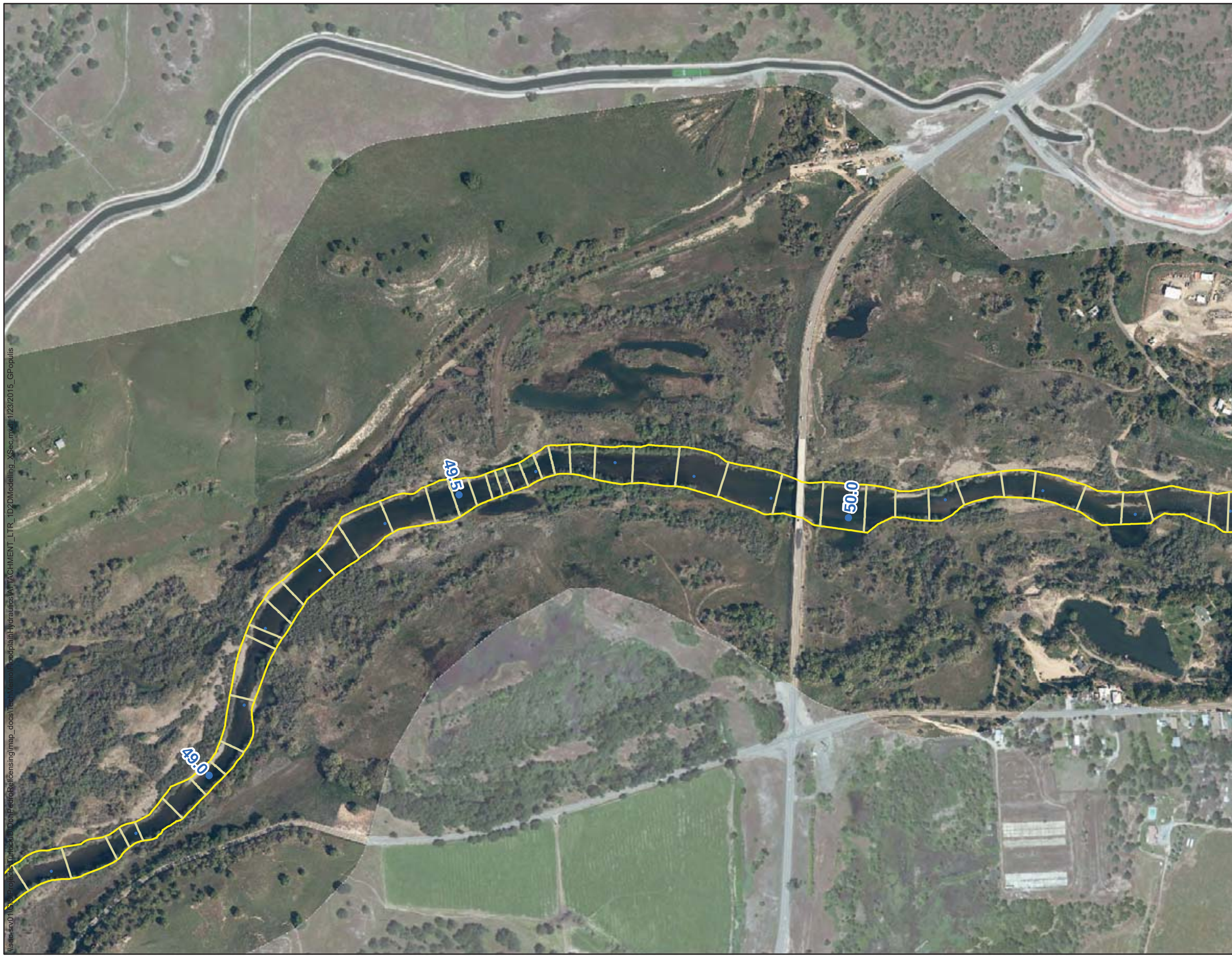

TUFLOW 1D-2D Domain Boundary Line

Cross Section Source

2012 Bathymetry

0 250 500 1,000
Feet

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STUDY REPORT W&AR-21

THE LOWER TUOLUMNE RIVER FLOODPLAIN HYDRAULIC ASSESSMENT

ATTACHMENT D

2D OVERBANK MANNING'S N ROUGHNESS COEFFICIENTS

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1.0 ROUGHNESS COEFFICENT EXAMPLES

This attachment supplements the discussion of overbank roughness coefficients in the study report. Table 1 provides roughness coefficient values for different land use and land cover categories.

Table 1. 2D domain roughness coefficient values.

Roughness Value	Description
0.03	Smooth and flat – pavement
0.04	Bare earth with gravel or finer substrate
0.05	Some herbaceous vegetation, grass, or large cobbles
0.06	Backwater areas choked with Water Hyacinth, agriculture, or irregular bedrock
0.07	Sparse permanent vegetation or low lying shrubs
0.08	Oak woodland, Cottonwood, or Aspen with some canopy spacing
0.09	Dense young riparian vegetation
0.10	Permanent dense forest (riparian or upland)
0.15	Low density residential
0.20	Industrial/Commercial
0.35	High density residential or Industrial/Commercial

Below, photos taken during fieldwork by TID in 2014 and images clipped from aerial flyover video flown May 18, 2012, exemplify the most common Manning's n designations used in the study (Figures 1 – 24).

Figure 1. Mannings n is equal to .04.

Figure 2. Mannings n is equal to .04.

Figure 3. Mannings n is equal to .04.

Figure 4. Mannings n is equal to .04.

Figure 5. Mannings n is equal to .04.

Figure 6. Mannings n is equal to .04.

Figure 7. Mannings n is equal to .05.

Figure 8. Mannings n is equal to .05.

Figure 9. Mannings n is equal to .05.

Figure 10. **Mannings n is equal to .05.**

Figure 11. Mannings n is equal to .06.

Figure 12. Mannings n is equal to .06.

Figure 13. Mannings n is equal to .06.

Figure 14. Mannings n is equal to .06.

Figure 15. **Mannings n is equal to .07.**

Figure 16. Mannings n is equal to .08.

Figure 17. Mannings n is equal to .08.

Figure 18. Mannings n is equal to .10.

Figure 19. Mannings n is equal to .10.

Figure 20. Mannings n is equal to .10.

Figure 21. Mannings n is equal to .10.

Figure 22. Mannings n is equal to .10.

Figure 23. Mannings n is equal to .10.

Figure 24. Mannings n is equal to .10.

STUDY REPORT W&AR-21
THE LOWER TUOLUMNE RIVER FLOODPLAIN HYDRAULIC ASSESSMENT

ATTACHMENT E

SAN JOAQUIN RIVER BACKWATER EFFECTS IN THE TUOLUMNE RIVER

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1.0 PURPOSE

As part of the *Lower Tuolumne River Floodplain Hydraulic Assessment* (W&AR-21), 1-D/2-D modeling is being conducted in three separate sub-reaches (Models A, B, and C) to assess juvenile salmonid floodplain habitat along the Tuolumne River from river mile (RM) 52.2 to RM 0 at the confluence with the San Joaquin River (SJR). In support of modeling in Reach C (RM 21.5 to RM 0), the boundary condition assessment presented herein examines the potential range of stage-discharge relationships near the confluence. There are two goals for the boundary condition analysis: 1) to determine the upstream extent of backwater effects in the Tuolumne River due to SJR and Stanislaus River flows, and 2) to develop a representative rating curve near the Tuolumne River SJR confluence to use as the downstream boundary condition for Model C.

2.0 ANALYSIS OF TUOLUMNE RIVER BACKWATER EXTENT

The hydraulic analysis combines portions of two existing HEC-RAS flood flow models originally developed by the California Department of Water Resources (DWR) covering the SJR system. One of the DWR flood models includes approximately 6 river miles of the lower Tuolumne River and the other extends approximately 17 river miles further upstream for a total DWR-modeled reach length in the Tuolumne River of approximately 23 miles. The combination of DWR models (combined model) of the SJR extends from the Crows Landing USGS Gage, located 23 miles upstream of the confluence of the Tuolumne River and the SJR River and 11.5 miles downstream of the Merced River, to the Vernalis Gage, located 16.5 miles downstream of the SJR and Tuolumne River confluence. The Stanislaus River, 2.75 miles upstream of the Vernalis Gage, is included in the combined model, which examines the potential influences of flow magnitudes in both the SJR and Stanislaus River on backwater in the Tuolumne River. A map of the model extent and gage locations is shown in Figure 1.

Representative flows and boundary conditions were developed from analyses of the following stream gages:

- USGS 11290000 TUOLUMNE R A MODESTO CA (1895 to present)
- USGS 11303000 STANISLAUS R A RIPON CA (1940 to present)
- USGS 11274550 SAN JOAQUIN R NR CROWS LANDING CA (1995 to present)
- USGS 11274000 SAN JOAQUIN R NR NEWMAN CA (1912 to present)
- USGS 11303500 SAN JOAQUIN R NR VERNALIS CA (1923 to present)

The rating curve (downloaded from USGS) associated with the Vernalis Gage is used to define the water surface elevations at the downstream boundary of the combined model. The Crows Landing Gage is used to verify the water surface elevation of the modeled inflow at the upstream boundary of the combined model. There are no gaged inflows between the Crows Landing Gage and the Tuolumne River confluence.

The Tuolumne River floodplain model being developed as part of W&AR-21 considers flows from 1,000 cfs to 9,000 cfs. The floodplain habitat area would primarily be used by juvenile salmonids during the months of February through May, inclusive. Therefore, the analysis of backwater effects considered SJR flows occurring over this seasonal period. To develop representative sensitivity scenarios for testing the extent of backwater effects on the Tuolumne due to SJR flows, we plotted flows from the SJR Newman gage against flows recorded by the Tuolumne River Modesto gage (RM 16.2) for the months of February through May over the period WY 1971-2012, shown in Figure 2. The Crows Landing gage has a shorter period of record so was not used for the analysis to ensure consideration of the full range of possible flows in the SJR related to flows in the Tuolumne River over the study period. However, the Crows Landing gage defines the upstream boundary of the model so it is important to understand the correlation with flow at this location with flow at the Newman gage, 6.5 miles upstream. The comparison for the available period of record at Crows Landing gage is shown in Figure 3 and indicates some small variability in accretion and losses between the gages, with a linear regression slope of 1.07. This tight correlation indicates that using the range of SJR flows observed at the Newman gage as the HEC-RAS model inflow is justifiable for assessing the extent of backwater effects within the Tuolumne River.

The HEC-RAS model also includes the Stanislaus River, approximately 8 miles downstream of the Tuolumne River. A comparison of flows within the Tuolumne and Stanislaus rivers is shown in Figure 4. This figure indicates wide scatter and minimal correlation between flows.

To test sensitivity of stage within the Tuolumne River to flows within the SJR and Stanislaus River, we developed eight flow scenarios based on the minimum and maximum habitat model flows in the Tuolumne River and the approximate maximum range of observed flows in the SJR and Stanislaus River at those Tuolumne River flows based on visual interpretation of the graph in Figure 2. The minimum flow in the SJR associated with the 1,000 cfs Tuolumne River case was set to 500 cfs, slightly higher than the observed minimum, for model stability. The tested scenarios are outlined in Table 1.

Table 1. Flows selected for boundary condition model sensitivity scenarios.

Scenario Number	Tuolumne River Flow cfs	SJR Flow cfs	Stanislaus River Flow cfs
1	9,000	25,000	7,000
2			500
3		10,000	7,000
4			500
5	1,000	15,000	4,000
6			500
7		500	4,000
8			500

3.0 RESULTS OF BACKWATER ASSESSMENT

A comparison of HEC-RAS model results is shown in Figure 5, which illustrates the water surface profiles on the Tuolumne River from its confluence with the SJR. The profiles indicate that there are essentially no backwater effects occurring on the Tuolumne River upstream of the Carpenter Road Bridge near RM 13.

Table 2 show differences in Tuolumne River water surface elevations at several locations for the cases where flows in the Tuolumne River and SJR were held constant to demonstrate the impact of varying flows in the Stanislaus River. The impact is relatively insignificant, with a maximum difference of 0.27 ft at the first Tuolumne River cross section, approximately 0.5 miles upstream of its confluence, falling to less than 0.2 ft approximately 1.8 miles upstream and less than 0.1 ft about 2.7 miles upstream.

Table 2. Relative stage differences examining potential impact of flow magnitude in the Stanislaus and Tuolumne rivers.

Channel Distance	Scenario 1 Stage minus Scenario 2 Stage	Scenario 3 Stage minus Scenario 4 Stage	Scenario 5 Stage minus Scenario 6 Stage	Scenario 7 Stage minus Scenario 8 Stage
miles	ft	ft	ft	ft
0.5	0.19	0.27	0.05	0.21
1.8	0.03	0.16	0.05	-0.19
2.7	0.03	0.10	0.05	-0.08

Table 3 demonstrates the upstream influence on Tuolumne River water surface elevations due to different flows in the SJR. The results indicate that over the approximate maximum range of observed flows, water surface elevations vary at the confluence by up to 12.2 ft for the lowest study flow of 1,000 cfs in the Tuolumne. The backwater effect of SJR flows extends approximately 10 to 13 miles upstream of the confluence.

Table 3. Relative stage differences indicating potential impacts of flows in the SJR and Tuolumne River.

Channel Distance	Scenario 1 Stage minus Scenario 3 Stage	Scenario 2 Stage minus Scenario 4 Stage	Scenario 5 Stage minus Scenario 7 Stage	Scenario 6 Stage minus Scenario 8 Stage
miles	ft	ft	ft	ft
0.5	3.40	3.49	12.07	12.23
9.0	0.16	0.17	1.13	1.10
10.5	0.10	0.10	0.60	0.58
12.5	0.05	0.05	0.20	0.19
13.5	0.04	0.04	0.10	0.09

4.0 RATING CURVE DEVELOPMENT

The 2-D hydraulic model of the Tuolumne River floodplain being developed in the W&AR-21 study will require a stage-discharge rating curve to represent the downstream boundary condition at the confluence of the Tuolumne River and SJR for the range of study flows being examined. The impact analysis demonstrates that the backwater effects of the SJR on the Tuolumne River can extend up to approximately RM 13, indicating that habitat analysis within this region may be substantially influenced by the choice of rating curve. To determine a representative stage-discharge rating curve we first establish a table of flows in the SJR and Stanislaus Rivers for each of the 21 model flows in the Tuolumne River (every 250 cfs from 1,000 cfs to 3,000 cfs, and every 500 cfs from 30,000 cfs to 9,000 cfs) and then use the HEC-RAS model to simulate elevations at the confluence.

To determine a correlation of flows between the Modesto gage (Tuolumne River) and the Newman Gage (SJR), we calculated the median flow in the SJR for every 50 cfs in the Tuolumne River. For example, for a Tuolumne River flow of 100 cfs, we found the median of all SJR flows associated with Tuolumne River flows between 75 cfs and 125 cfs. Figure 6 shows the relationships for the months of February through May, the primary months of interest for habitat analysis, and for all months for water years 1971 to 2012. A fourth order polynomial relationship provides the best fit regression between the data sets and works well for both the target habitat months and consideration of all months.

We applied the same analysis for the more scattered flows in the Stanislaus River and found a power relationship to be the best fit. This relationship is less important because the influence of flow variability on water surface elevation within the Tuolumne River is small. Note that sensitivity runs indicated that the downstream boundary condition on the SJR, represented by the rating curve at the Vernalis Gage, has no impact on water surface elevation in the Tuolumne River.

Table 4 provides the regression results in the SJR and Stanislaus River for each study flow in the Tuolumne River based on the regression equations shown in Figures 6 and 7. The flows in the SJR are also prorated based on the linear correlation between flows at the Newman and Crows Landing gages shown in Figure 3 to adjust for the location of the upstream boundary of the HEC-RAS model. The water surface elevation in the Tuolumne River, shown in the final column, at approximately RM 0.9 is the downstream boundary location for the 2-D model.

Table 4. Regression flows used to develop boundary condition rating curve.

Tuolumne River Flow	SJR Flow	Stanislaus River Flow	Tuolumne River Water Surface Elevation at RM 0.9
cfs	cfs	cfs	ft
320	872	459	22.0
500	949	580	22.6
750	1,038	716	23.2
1,000	1,115	832	23.8
1,250	1,188	935	24.3
1,500	1,267	1,028	24.8
1,750	1,359	1,114	25.3
2,000	1,470	1,194	25.7
2,250	1,608	1,270	26.2
2,500	1,778	1,341	26.6
2,750	1,985	1,410	27.1
3,000	2,233	1,475	27.6
3,500	2,867	1,599	28.7
4,000	3,699	1,714	29.7
4,500	4,738	1,822	30.8
5,000	5,983	1,925	31.9
5,500	7,420	2,023	33.0
6,000	9,025	2,117	33.8
6,500	10,762	2,207	34.3
7,000	12,586	2,294	35.0
7,500	14,438	2,378	35.7
8,000	16,250	2,460	36.3
8,500	17,941	2,538	36.7

Tuolumne River Flow	SJR Flow	Stanislaus River Flow	Tuolumne River Water Surface Elevation at RM 0.9
cfs	cfs	cfs	ft
9,000	19,421	2,615	37.1
9,500	20,588	2,690	37.4
10,000	21,328	2,763	37.7

5.0 SENSITIVITY ANALYSIS

To investigate sensitivity of the rating curve we assumed a "high flow" and "low flow" relationship between flows in the Tuolumne River and SJR based on plus-and-minus 40 percent of the flow determined from the regression equation shown in Figure 8. An analysis of the median absolute deviation (MAD) indicates an average (and median) deviation of approximately 30 percent. We chose a broader range of plus-and-minus 40 percent to envelope most of the median flows. Sensitivity flows and water surface elevations for selected study flows in the Tuolumne River are given in Table 5. The rating curve with sensitivity results shown for several flows is displayed in Figure 8. The results indicate insignificant differences at the lowest study flow of 1,000 cfs and a range of 3.2 ft at the highest study flow of 9,000 cfs. The difference in elevation for the 9,000 cfs sensitivity flows drops to less than 0.1 ft approximately 11 miles upstream from the confluence.

Table 5. Sensitivity results for selected study flows.

Tuolumne River Flow	SJR Regression Flow/Elevation		SJR High Flow/Elevation		SJR Low Flow/Elevation	
cfs	cfs	ft	cfs	ft	cfs	ft
1,000	1,115	23.8	1,561	24.1	668	23.9
5,000	5,983	31.9	8,376	33.1	3,589	30.5
9,000	19,421	37.1	27,191	38.6	11,652	35.4

6.0 DATUM ADJUSTMENT

The DWR model and the W&AR-21 Model C were developed using different sets of surface elevation data for the overbank regions. (The channel portion of both models is based on the same set of survey data.) Both surfaces are derived from high-resolution LiDAR data flown in different years. The DWR surface was processed using ground controls based on the Geoid03 model, while the W&AR-21 study used the Geoid09 model. The geoid is a model of global mean sea level that is used to measure precise surface elevations. The elevation differences between the two geoid models vary with location. In the vicinity of the Tuolumne and San Joaquin River confluence the Geoid03 surface is 0.373 ft higher than the Geoid09 surface.

A comparison of elevations of semi-permanent features, such as roads and levees, near the confluence shows approximately 0.4 ft to 0.5 ft difference between the two models. For example, the left bank of the downstream boundary cross section from Model C is 0.40 ft higher and the levee beyond the left bank is 0.44 ft higher than the DWR model. To account for this elevation difference the rating curve was adjusted for flows above the banks (greater than 6,500 cfs) to be 0.40 feet higher. Figure 9 shows the elevation difference between the two surfaces.

7.0 CONCLUSIONS

The analysis demonstrates that the backwater effect of flows in the SJR can extend up the Tuolumne River a maximum of approximately 13 miles near the Carpenter Road Bridge for the flows being considered in the W&AR-21 study. This may affect the floodplain habitat estimated to occur by the Tuolumne River TUFLOW model. Flows in the Stanislaus River have a very small backwater effect on the Tuolumne River.

Using the flow regressions developed between stream gages in the San Joaquin, Stanislaus and Tuolumne rivers as described above, the resulting Figure 10 provides a representative stage-discharge rating curve to be used for the TUFLOW model downstream boundary condition.

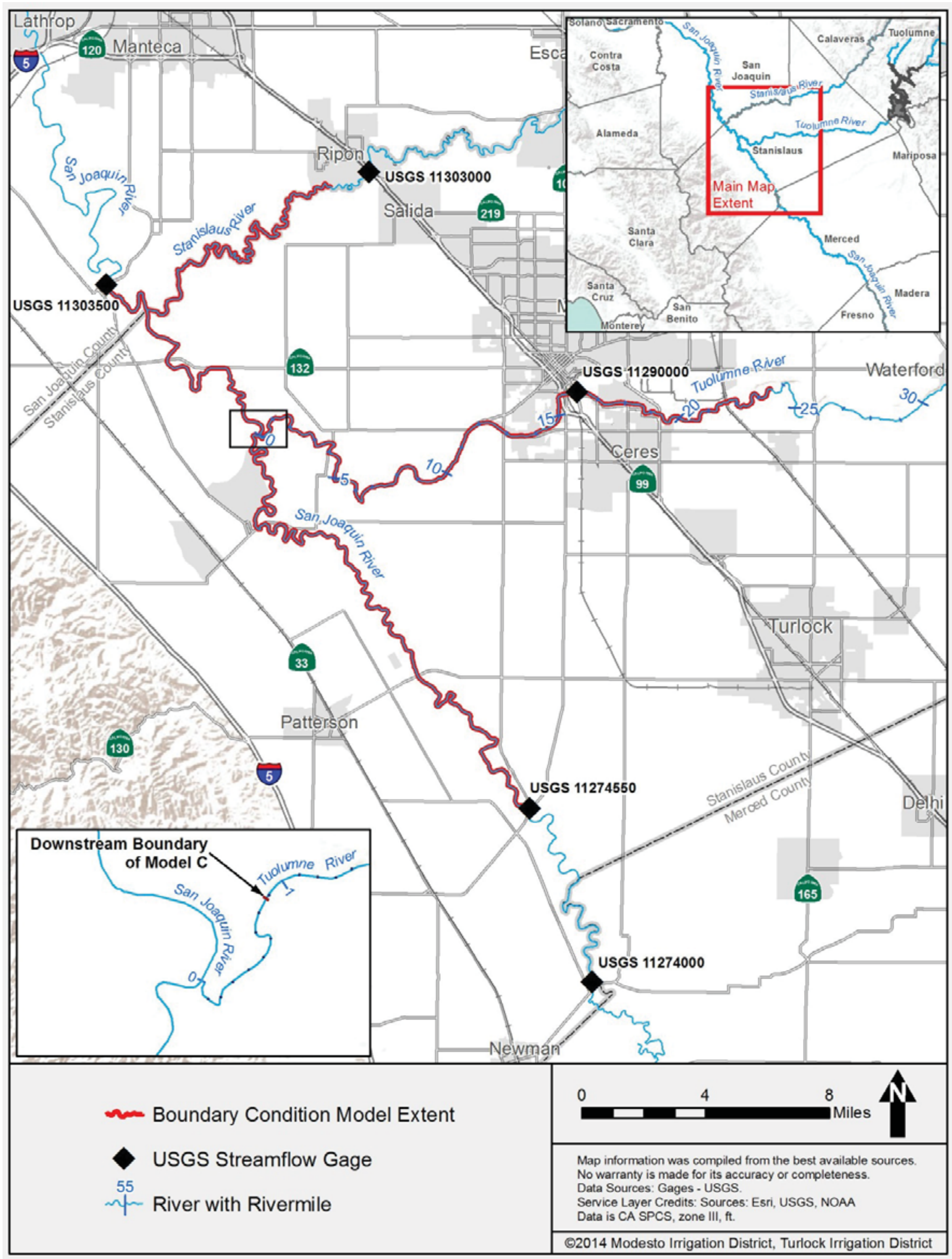

Figure 1. **Location map depicting boundary condition model extents, USGS gage locations and the location for the rating curve.**

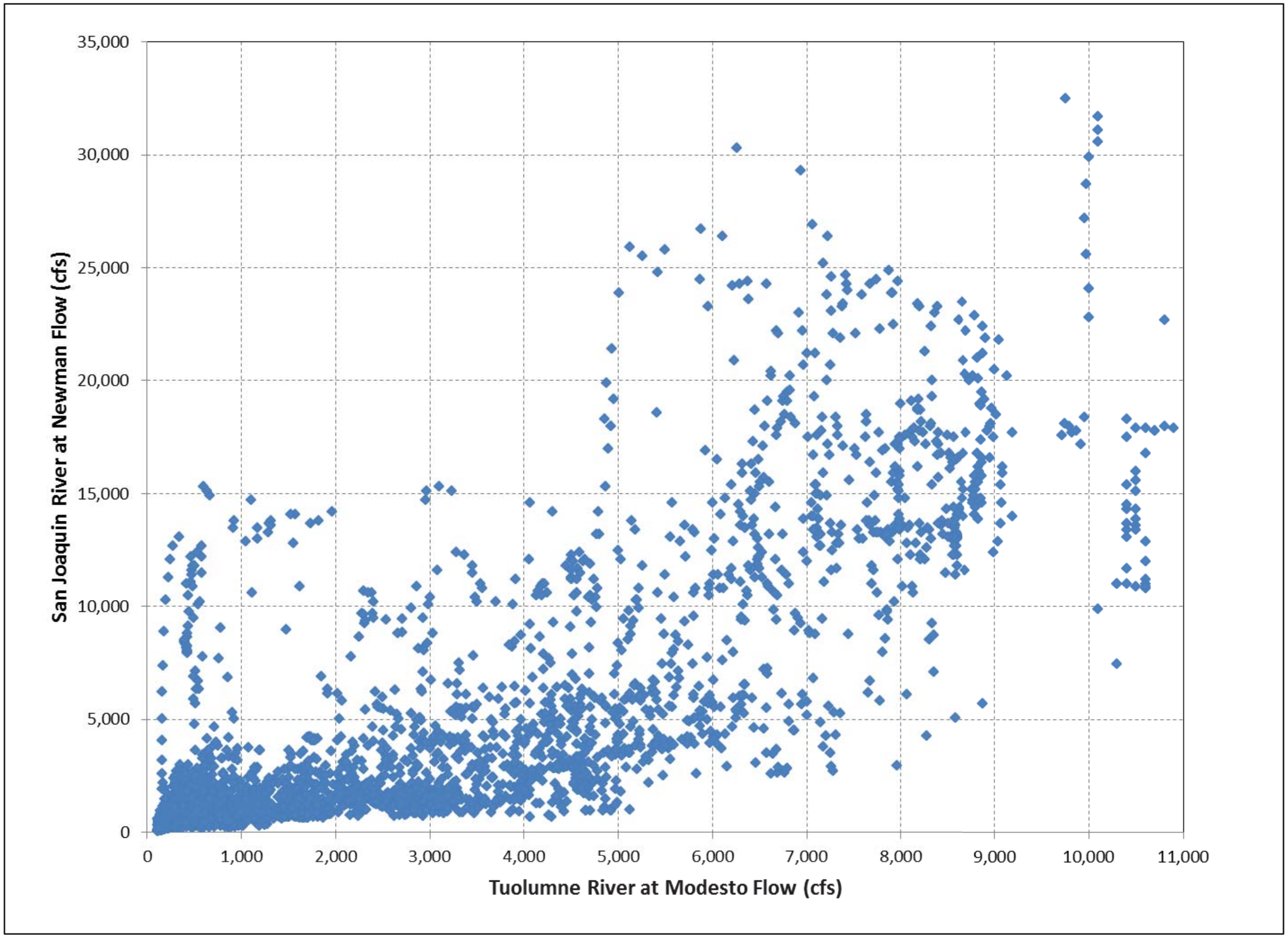

Figure 2. Comparison of flow in San Joaquin and Tuolumne Rivers, February through May, WY 1971-2012.

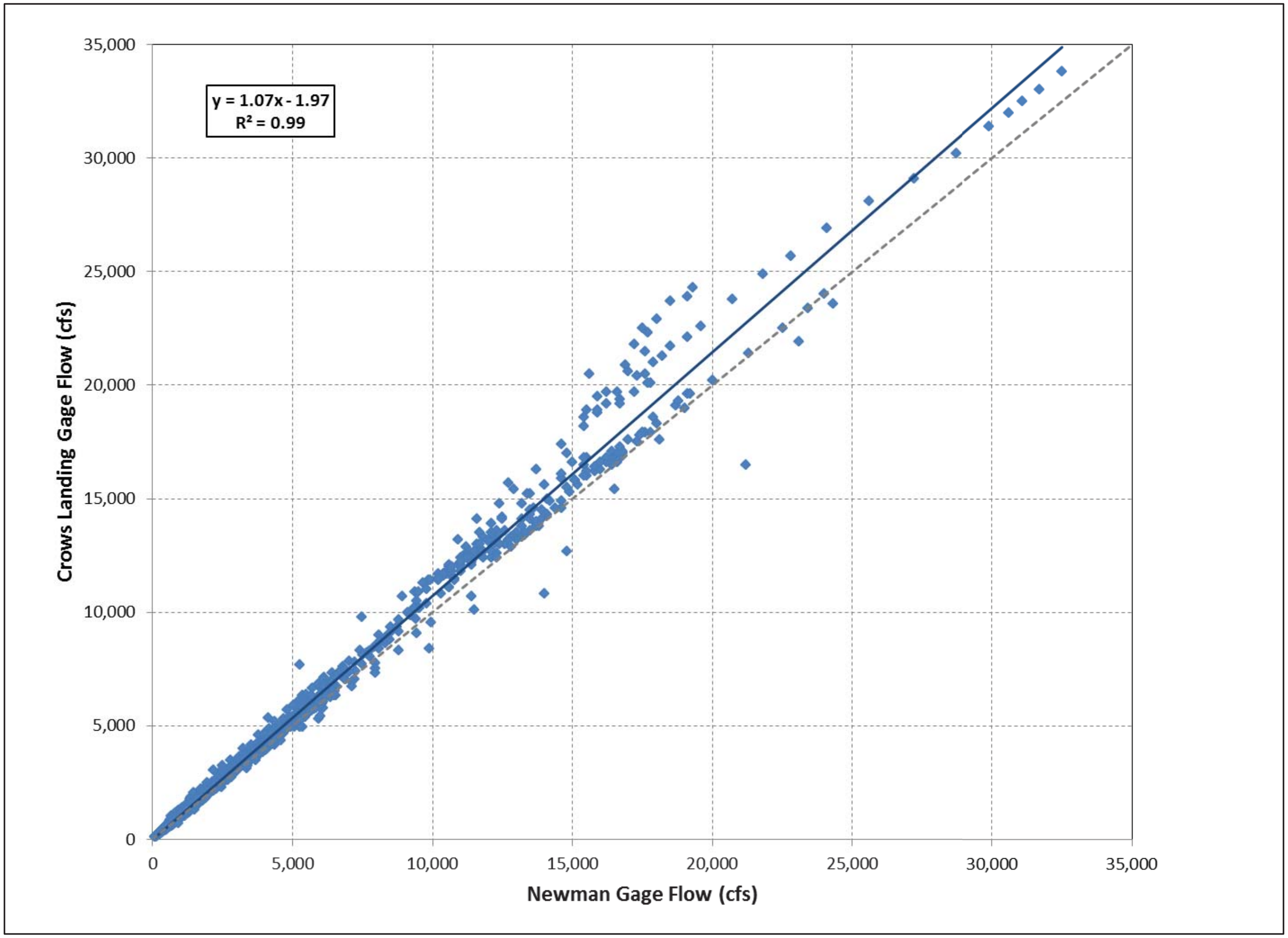

Figure 3. Comparison of Crows Landing and Newman Gage flow, February through May, 1996 to 2014.

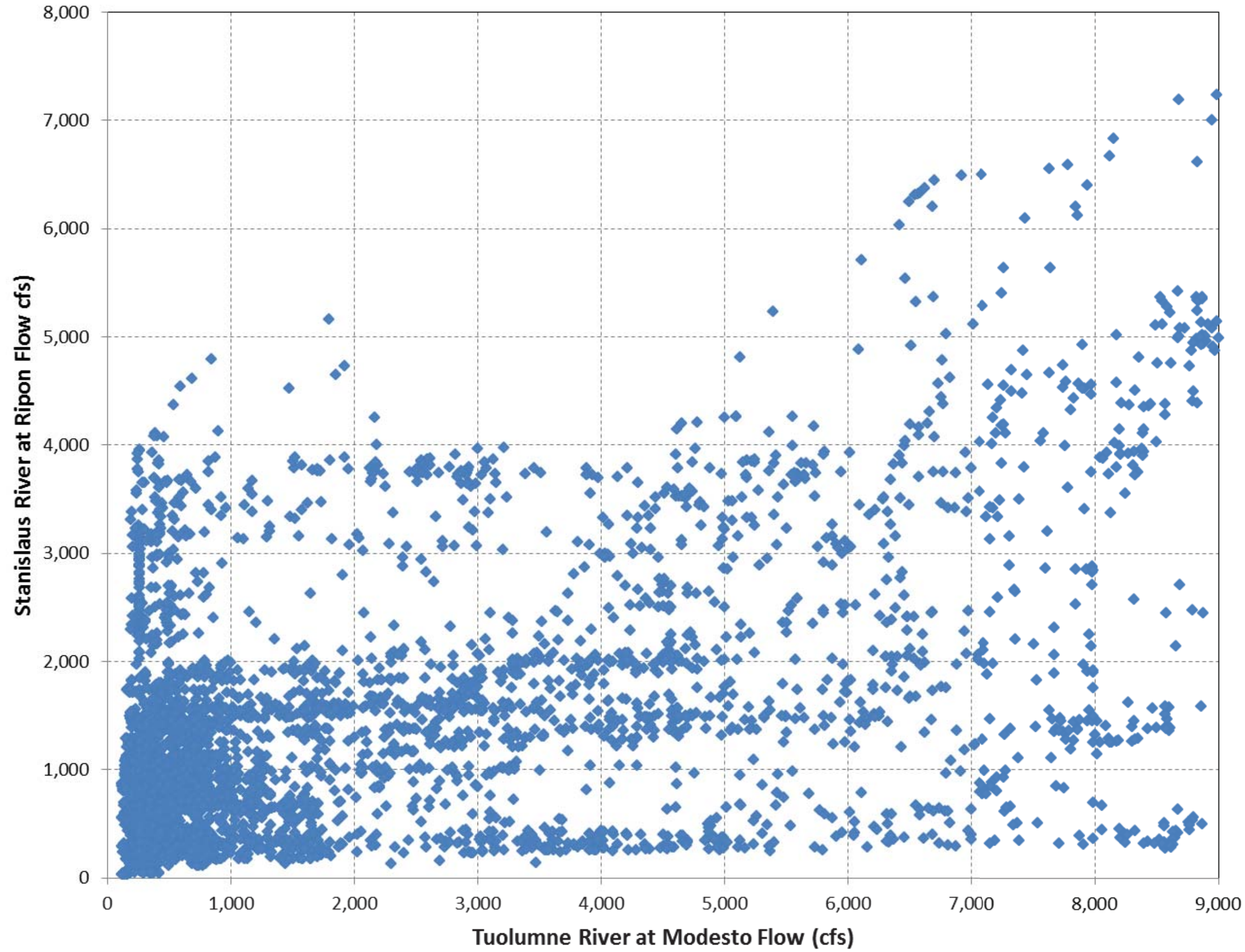

Figure 4. **Comparison of flow in Tuolumne and Stanislaus Rivers, February through May, WY 1971 to 2014.**

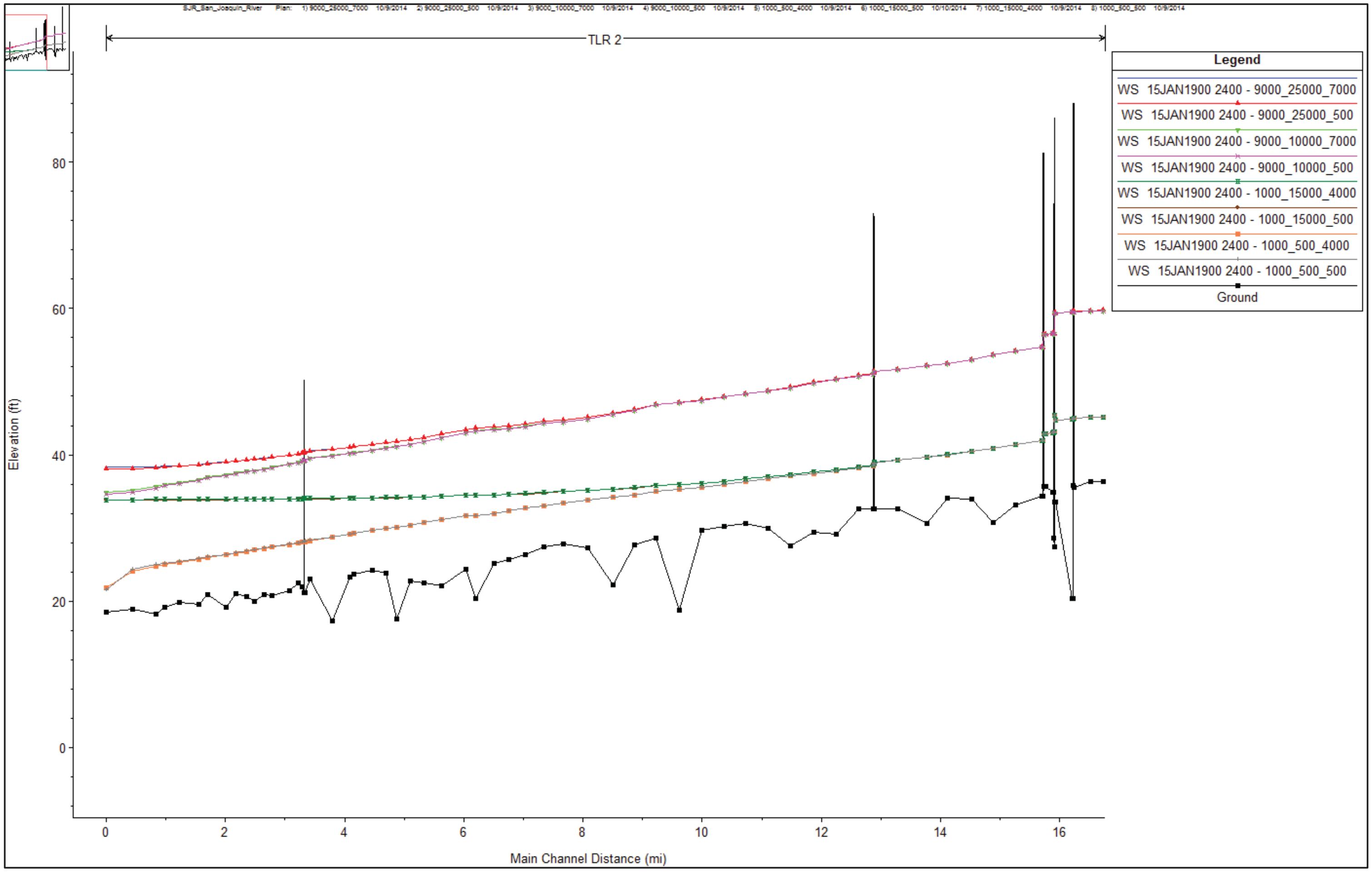

Figure 5. **HEC-RAS water surface elevation profiles for sensitivity scenarios For Tuolumne Reach from confluence with the San Joaquin River.**

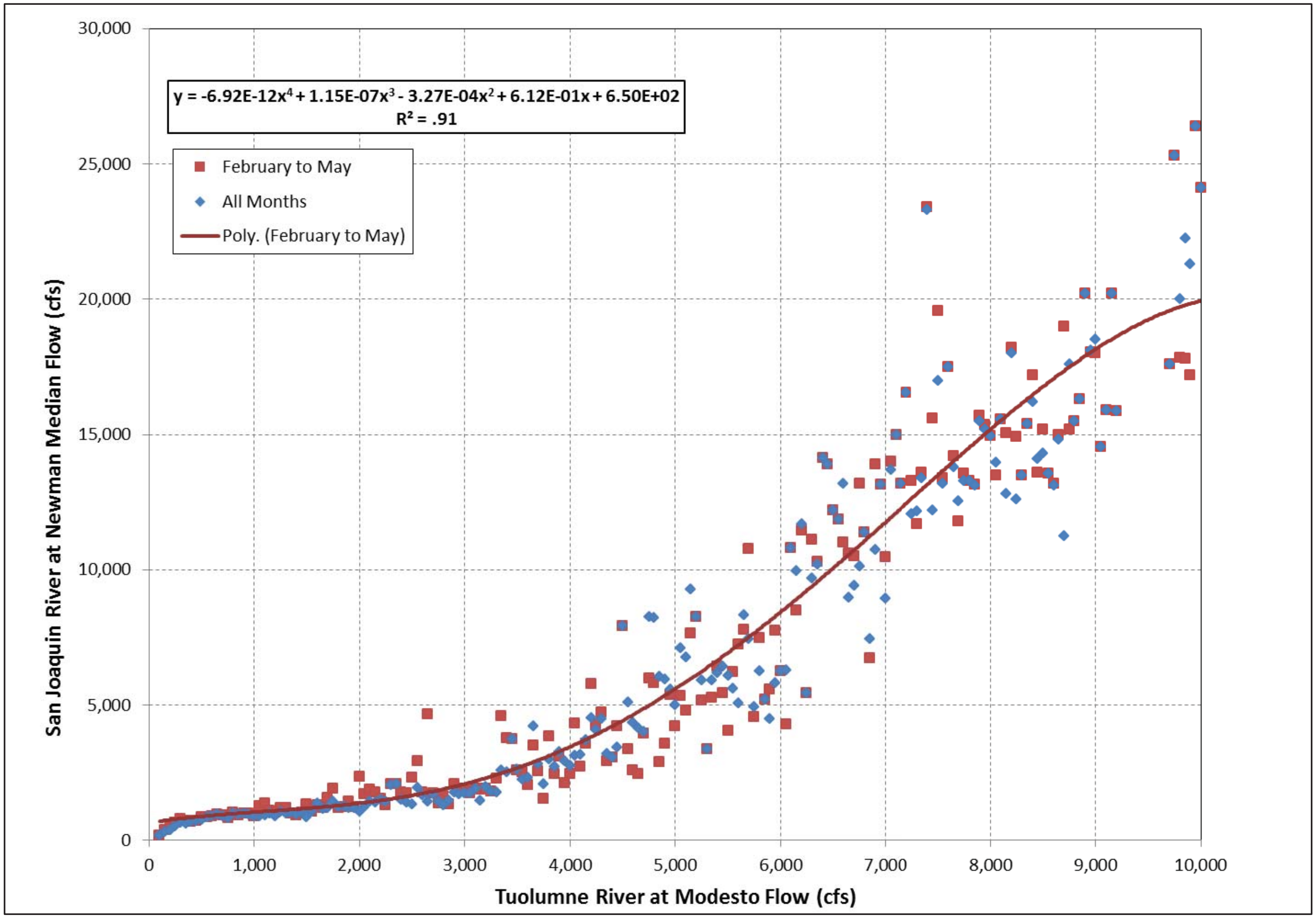

Figure 6. Correlation of median flow in San Joaquin River for 50 cfs intervals of flow in Tuolumne River, Water Years 1971 to 2012.

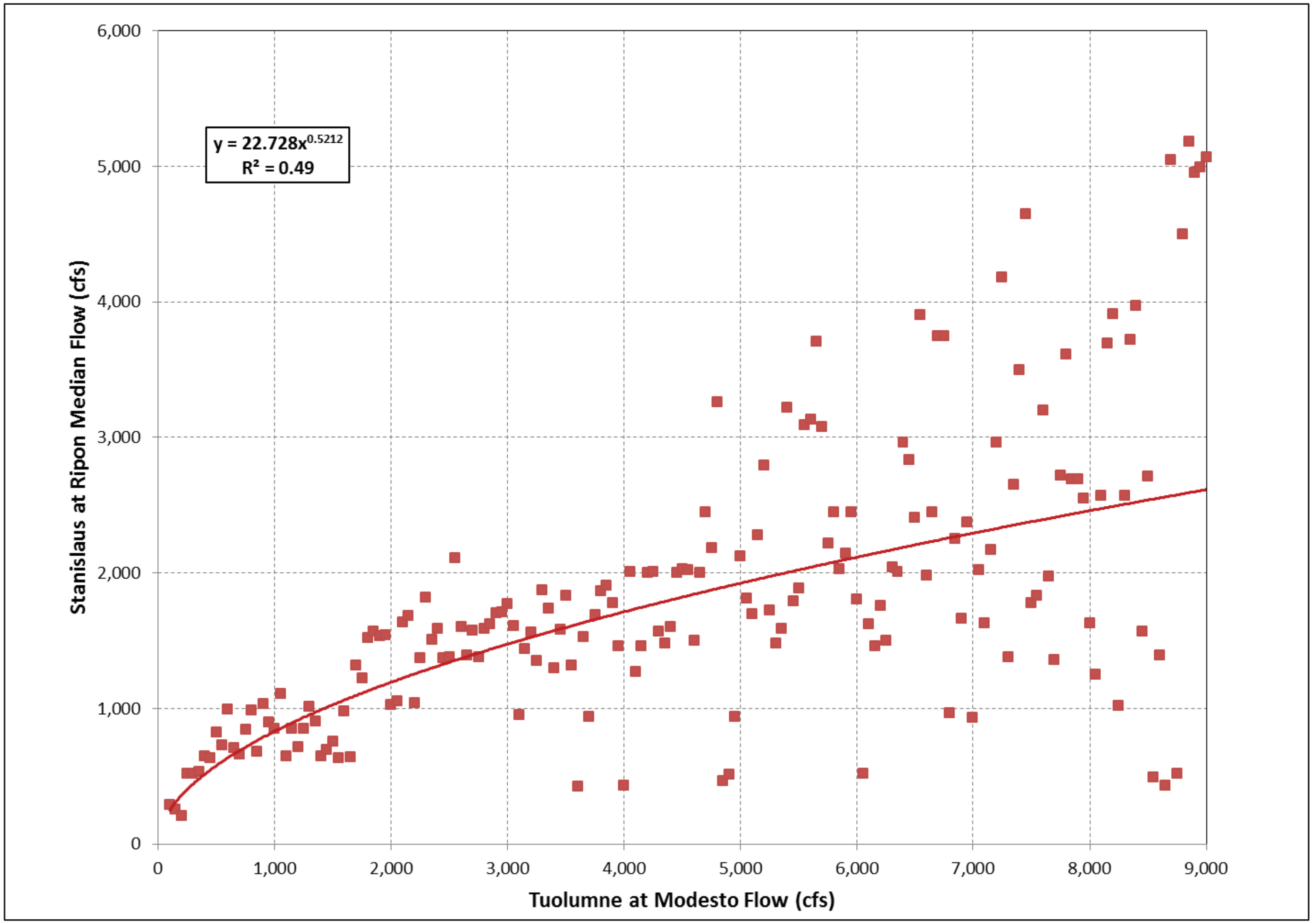

Figure 7. **Correlation of flow in Tuolumne with median flow in Stanislaus River for 50 cfs intervals, Water Years 1971 to 2012.**

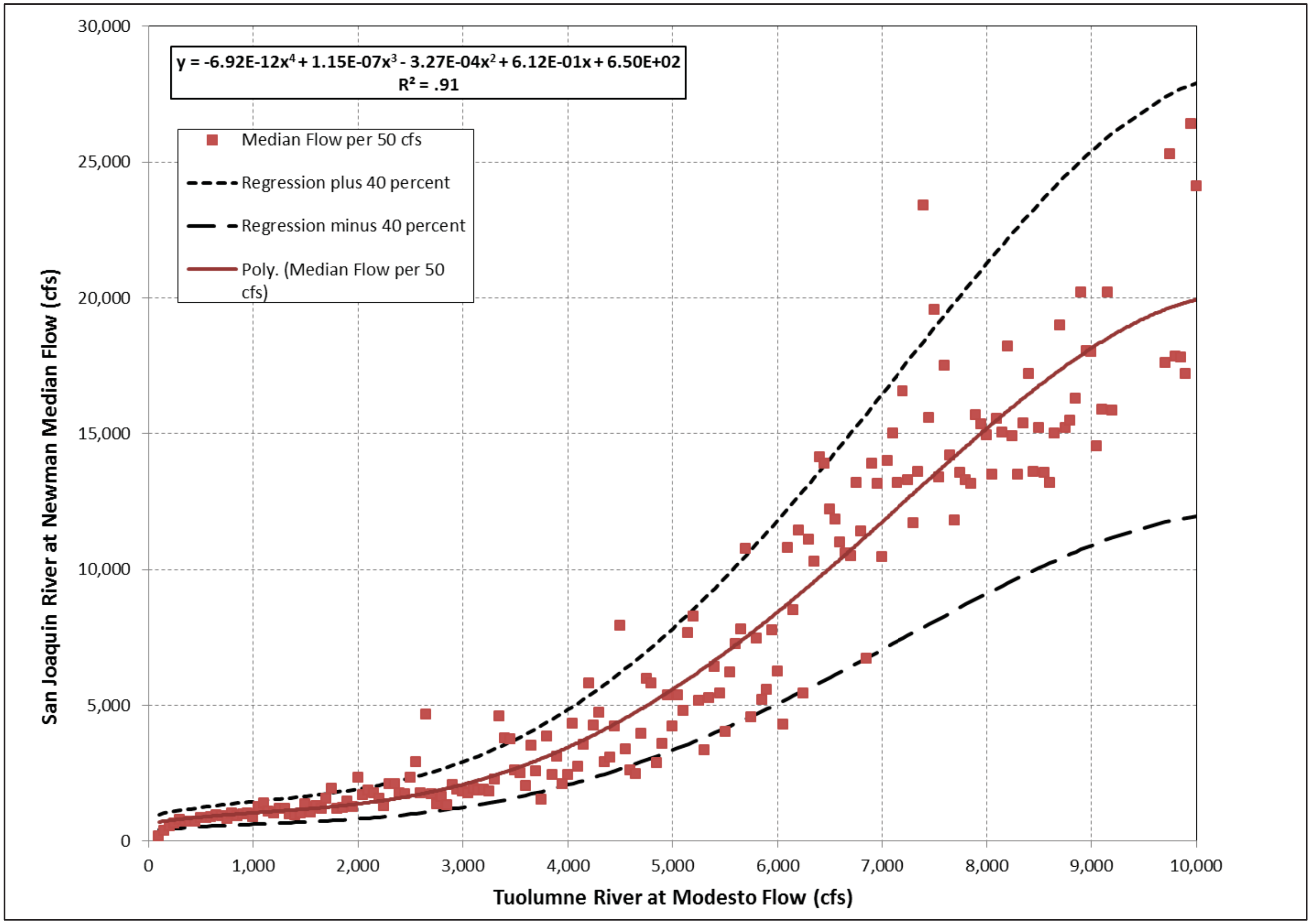

Figure 8. **Sensitivity analysis curves relating median flows in San Joaquin River for 50 cfs intervals of flows in Tuolumne River, Water Years 1971 to 2012.**

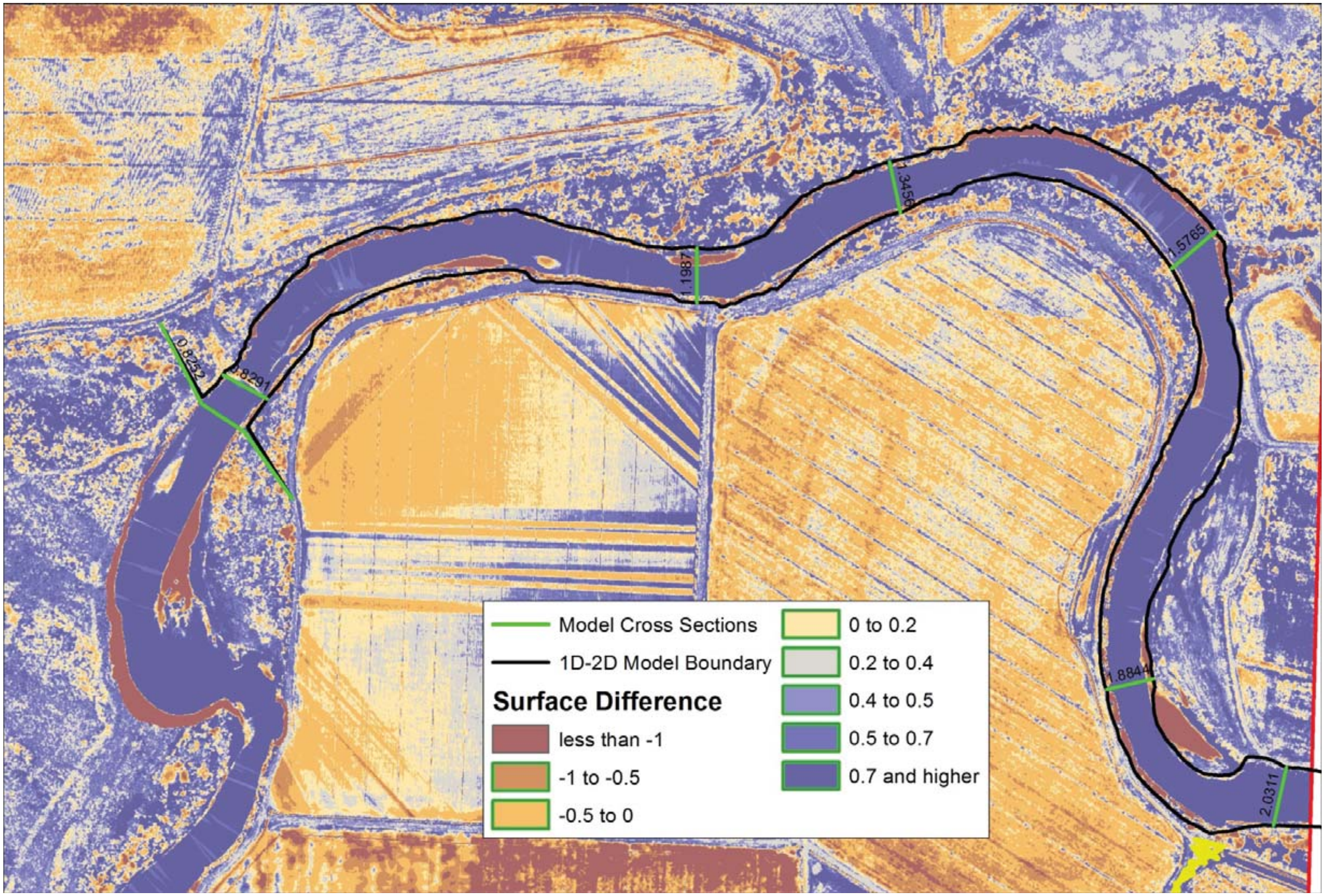

Figure 9. Difference in model terrain surfaces between DWR and W&AR-21 Model C. Levee features are consistently 0.4 to 0.5 ft higher, while some farmland areas have been eroded or compacted.

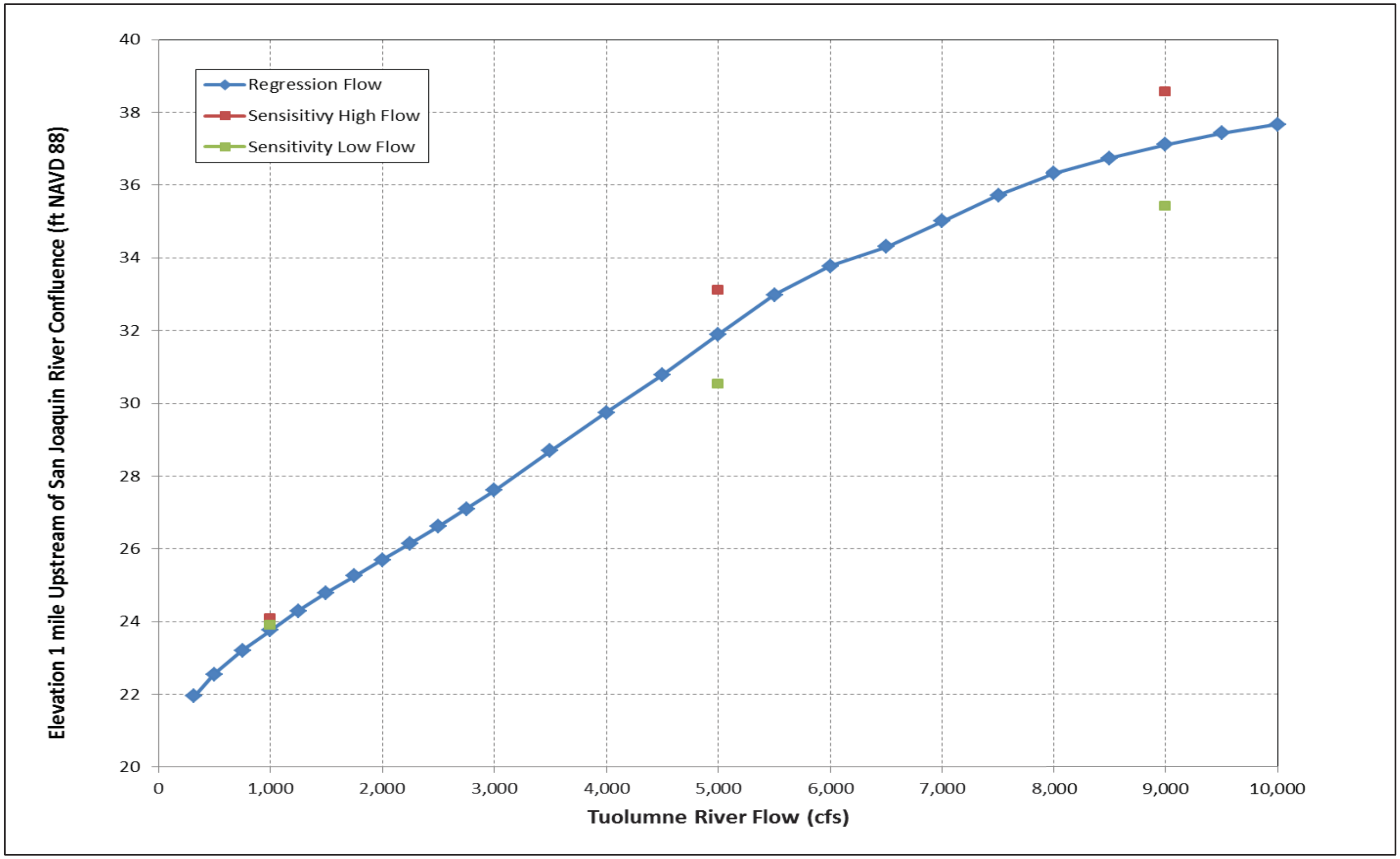

Figure 10. Model C boundary condition rating curve at RM 0.9.