Master Response 3.2
Surface Water Analyses and Modeling

Overview

This master response addresses comments regarding methods and data used in the substitute environmental document (SED) hydrologic modeling, use of the Water Supply Effects (WSE) model to evaluate changes in streamflow and water supply, and surface water hydrology effects such as hydropower, flooding, sedimentation, and erosion. The Lower San Joaquin River (LSJR) flow objectives and program of implementation propose higher levels of unimpaired flows in the Stanislaus, Tuolumne, and Merced Rivers to reasonably protect fish and wildlife beneficial uses. This increase in instream flows would decrease the quantity of surface water available for diversion, principally for agriculture, compared to the current condition. Most commenters did not dispute the overall conclusion that the quantity of surface water available for diversion will decrease by approximately the same amount as the increase in instream flows. Commenters raised issues in two broad categories:

- Questions or comments regarding the data or methods of analysis used to determine the effects.
- Comments that effects would be more severe than modeled or otherwise disputing the analyses' conclusions.

Analyzing the potential benefits, significant environmental impacts, and economic effects of the proposed plan amendments at a programmatic level requires a reasonable representation of the complex water system. The water system in the plan area includes the natural stream network and water infrastructure such as dams, canals, and diversions. This master response addresses comments by providing additional context for, and additional explanation of, the geographic scope and complexity of the water system as well as the suite of models used in the SED. This master response also clarifies the operations assumptions used in the SED and addresses how some commenters with alternate conclusions either relied on operations assumptions that are inconsistent with the requirements of the plan amendments, and therefore are not reasonable, or reached conclusions that may be different but do not have a significant bearing on the reasonableness or levels of significance of the programmatic determinations in the SED. This master response primarily references information contained in Chapter 5, *Surface Hydrology and Water Quality*, and Appendix F.1, *Hydrologic and Water Quality Modeling*.

The plan area includes the LSJR and its three major tributaries, the Stanislaus, Tuolumne, and Merced Rivers (Chapter 1, *Introduction*, and Chapter 5). Each of the three major tributaries is dammed, and its flows are affected by multiple reservoirs, each including one large rim reservoir. These rivers supply the water delivery systems for seven major irrigation districts that irrigate approximately half a million acres, as well as public water supplies for municipalities such as Modesto and San Francisco. The combined storage capacity of the three major rim reservoirs is 5.45 million acre-feet and the baseline level of surface water diversions for human uses exceeds 2 million acre-feet per year, on average. One of the primary conclusions of the SED analyses is that, despite the complexity of reservoir operations, the long-term average reduction of water supply for human uses (e.g., Table ES-2 in *Executive Summary*) is roughly equal to the volume of increased streamflow required by the proposed LSJR alternatives (e.g., Table ES-13 in *Executive Summary*).

This water supply impact generally would be greater in dry and critically dry water year types (e.g., Table ES-3 in *Executive Summary*). To some extent, the timing of expected water supply shortages would depend on the manner of operation of the reservoir systems, but the relationship between the amount of water available for instream flow and the amount of water available for diversion out of streams for human uses is a tradeoff.

The analyses in the SED use a water balance model and a temperature model, along with a further evaluation of groundwater use and a crop economics model, to reasonably and credibly show how this complex system might respond to changed flow objectives. While there is almost as much debate about what model is best suited for a certain purpose as there are models, the models and evaluations used in the SED were selected because they are commonly used models or refinements of commonly used models that evaluate water operations and agricultural water use patterns. The models provide a reasonable representation of potential relative changes by comparing a baseline condition and proposed alternatives.

The model results in the SED present a range of potential operations that are generalized but sufficient in detail to evaluate water supply and other effects of the project from a programmatic perspective. This master response describes how model operations, by necessity, must include assumptions that constrain the reservoirs (e.g., do not allow them to be drained dry) to provide a reasonable set of water operations for comparison in the SED analyses. This master response also explains how numeric constraints that are used for modeling are not numeric regulatory requirements. In addition, this master response addresses other aspects of modeling the Baseline and the LSJR alternatives, including how models of the LSJR alternatives are representative of system responses to regulatory conditions, but these are not the only possible methods of operating under the plan amendments.

The models are necessarily limited in their representation of implementation-specific operations details. Project-specific details for implementation need to be determined using the technical and practical expertise of local water managers and the flexible tools available under the adaptive implementation framework in the plan of implementation. For example, the WSE model shows that the proposed LSJR flow objectives would reduce water diversions for agricultural and municipal uses. Responsible entities are likely to optimize operations plans by conjunctively managing surface and groundwater supplies and implementing active recharge of groundwater through local projects and programs. However, it is difficult to predict with certainty the ultimate mixture of surface and groundwater conjunctive use, and such details are speculative because these are dependent on local decisions and approvals. For this reason, the programmatic analysis does not, and cannot, attempt to show exactly how water system operators will respond because, as illustrated by the previous example, a complex water-storage and water-delivery system can be operated in many different ways. Among many individual factors, reservoir operators and water users must consider variable hydrology, water supply demands, the risk of future shortage, groundwater pumping capacity, groundwater availability, hydroelectric power, and existing regulations. Specific future responses will depend on many unknowable decisions. Nevertheless, the modeling analyses for the LSJR alternatives provide a reasonable representation of system operations that fully disclose the potential ranges of effects of additional flow requirements.

The program of implementation allows and encourages annual operations plans that incorporate adaptive adjustments, complementary non-flow measures, or both, to attain the numeric and narrative LSJR flow objectives with opportunities to maintain water supply reliability. This means water operators can potentially reduce some of the negative water supply effects described in the

SED analyses, but would need to develop water operation parameters that maximize the amount of water supply that can be delivered while still supporting the narrative objective and avoiding significant adverse temperature or other impacts on fish and wildlife. Stated another way, real-world responses to implementation of the proposed flow objectives may include improved solutions that minimize cost and maximize benefits when compared to programmatic model results which, while reasonable, are not designed to assess all possible project-specific tools and tradeoffs.

The proposed LSJR alternatives consist of two elements—a numeric objective and a narrative objective. The numeric element of the objective is the proposed 40 percent of February–June unimpaired flow (in an adaptive range of 30 to 50 percent), and minimum base flows to project aquatic life when the percent of unimpaired flow drops below certain levels as measured in the San Joaquin River (SJR) near Vernalis. The program of implementation specifies that the percent of unimpaired flow can be adaptively managed (Appendix K, *Revised Water Quality Control Plan*). Each alternative, as modeled in the SED, includes assumptions that meet the numeric objective and avoid significant adverse temperature or other impacts on fish and wildlife. For example, LSJR Alternative 3, the 40 percent flow alternative, is representative of system operations to achieve the 40 percent flow requirement and support the narrative objective.

The Stanislaus, Tuolumne, and Merced Rivers are salmon-bearing rivers. The narrative objective[1] is based on fish protection because the underlying fundamental project purpose and goal of the plan amendments is to provide reasonable protection for fish and wildlife beneficial uses in the LSJR watershed, including the three eastside, salmon-bearing tributaries. The numeric flow objectives provide extensive temperature benefits in the February–June period; however, supporting the narrative objective also requires that temperature increases that might otherwise occur at lower reservoir levels are minimized in other months relative to baseline.

Salmonids are a key-evaluation species in the SED used to determine impacts and describe benefits of the LSJR alternatives on aquatic resources. As a cold-blooded species, salmon cannot regulate their internal body temperature; therefore, water temperature is a primary indicator of ability to survive and thrive. Water temperature can affect growth, disease, smoltification (the physiological changes from a freshwater to a saltwater fish), competition, and, at higher levels, it can block migration or cause death. The U.S. Environmental Protection Agency (USEPA) established temperature guidance to meet the biological needs of native salmonids in each life stage. Avoiding significant adverse temperature impacts on fish and wildlife is interpreted in the modeling process as meeting the USEPA temperature criteria within 10 percent of the exceedance frequency of baseline conditions in all months.[2]

Maintaining suitable stream temperatures in general can be accomplished in two ways: 1) for the upper reaches of the tributaries, by maintaining a cold-water pool[3] as a function of reservoir storage, and 2) for the lower part of the tributaries, by increasing flows to convey cold water to lower reaches. The methods used to simulate supporting the narrative criteria in the modeling

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[1] For more information on the narrative objective, see Appendix K, *Revised Water Quality Control Plan*, Chapter IV.B.3, Master Response 2.1, *Amendments to Water Quality Control Plan*, and Master Response 3.1*, Fish Protection*.

[2] For more information on the 2003 USEPA temperature criteria for salmonids, see Chapter 19, *Analyses of Benefits to Native Fish Populations from Increased Flow between February 1 and June 30*.

[3] *Cold-water pool* refers generally to the amount of water stored within a reservoir of a low enough temperature that, when released into a river, will not degrade instream habitat for salmonid life stages. Typically, management to preserve cold-water pool involves limiting spring and early summer releases from a reservoir to ensure that some cold water remains for releases later in the summer and fall despite heating of surface layers.

process are consistent with these requirements: the carryover guidelines protect the cold-water pool used to provide suitable instream temperature conditions and increasing stream flow is used convey cold water through the tributaries.

Some commenters provided examples of alternative operations scenarios to assert that the effects presented in the SED are underestimated or otherwise incorrect. As discussed further in this master response, these alternate scenarios generally rely on operations assumptions that are inconsistent with the requirements of the plan amendments. For example, commenters asserted that there would be greater water supply effects than disclosed in the SED because operators would be obligated to drain the reservoirs fully during dry periods to fulfill water supply demands after meeting the proposed flow objectives. Reservoir operations that would frequently result in completely empty reservoirs (i.e., at *dead pool*) are inconsistent with historical observations of reservoir operations and disregard the proposed flow objectives because such operations would not conserve enough cold water to avoid significant adverse temperature impacts on fish and wildlife.

The numeric unimpaired flow objective is simple to interpret in terms of quantity of flow; however, model operations used to support the narrative objective and avoid significant adverse temperature impacts on fish and wildlife require quantitative interpretation, and dynamic evaluation of system characteristics over a long period and varying hydrologic conditions. Reservoirs can be operated in many ways to promote attainment of the narrative objective. However, the modeling of the LSJR alternatives uses a set of simplified assumptions regarding reservoir operations, referred to in the SED as carryover storage guidelines. The modeling also shifts a portion of the flow requirement to later months in certain water year types to prevent indirect temperature impacts that would otherwise occur in the absence of such guidelines. Although the plan amendments could have included prescriptive numeric objectives for instream temperature and reservoir storage objectives, such prescriptive objectives, once established through a rulemaking, would preclude water operators from using the flexibility that is inherent in the program of implementation to achieve the flow objectives in ways that would better maximize water resources for all beneficial uses.

The State Water Resources Control Board (State Water Board) reviewed all comments related to surface water hydrology and modeling and developed this master response to address recurring comments and common themes. This master response references related chapters in the 2016 Recirculated SED and master responses, as appropriate, where recurring comments and common themes overlap with other subject matter areas. For east of reference, this master response includes a table of contents after the *Overview* to help guide readers to specific subject areas and to indicate where topics of their concern are addressed. This master response addresses, but is not limited to, the following topics.

- Purpose of modeling and the appropriate use of models and model results in the SED.
- Appropriate regulatory and hydrologic conceptualization of Baseline, the No Project Alternative, and the LSJR alternatives in the WSE model.
- Reasonableness of WSE model assumptions and the use of best available information to describe water use.
- Calculation of the instream flow objective as a percent of unimpaired flow in the WSE model.
- Characterization of surface water demand in the WSE model.
- Reservoir operations constraints and carryover storage guidelines in the WSE model.

- Hydrologic accretions and depletions below dams.
- Evaluation of changes in hydropower generation.
- Water supply reliability, long-term and during multi-year drought conditions.
- Modifications to the WSE model between the 2012 Draft SED and the 2016 Recirculated SED
- HEC-5Q temperature model and appropriate modifications made to the model.

For a description of the temperature results from a biological perspective their evaluation in the SED, please see Master Response 3.1, *Fish Protection*. For information related to water quality in the southern Delta, please see Master Response 3.3, *Southern Delta Water Quality*.

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General Approach

The State Water Board is proposing to amend the Bay-Delta Plan, pursuant to its authorities under the Porter-Cologne Water Quality Control Act (Porter-Cologne Act) (Wat. Code, 13000 et seq.) and the federal Clean Water Act (U.S.C. tit. 33, § 1313). Water quality control plans provide the following guidance:

- Designate the beneficial uses of waters to be protected (such as municipal and industrial, agricultural, and fish and wildlife beneficial uses).
- Set water quality objectives for the reasonable protection of the beneficial uses or the prevention of nuisance.
- Establish a program of implementation to achieve the water quality objectives. (Wat. Code, §§ 13241, 13050, subds. (h), (j).).

As described in Appendix K, *Revised Water Quality Control Plan*, Chapter IV, *Program of Implementation*, the State Water Board will exercise its quasi-legislative or quasi-adjudicative power involving water rights and water quality to require implementation of the water quality objectives. The State Water Board may implement the objectives by conducting water right proceedings, which may include adopting regulations, conducting quasi-adjudicative proceedings, or both. The State Water Board may also use its Clean Water Act section 401 water quality certification authority or take other water quality actions to implement the water quality objectives in the Bay-Delta Plan. For additional information, see Master Response 1.2, *Water Quality Control Planning Process.*

California Health and Safety Code section 57004 requires organizations within the California Environmental Protection Agency (CalEPA) to submit for external scientific peer review the scientific basis for, or scientific portion of, any rule proposed for adoption. The State Water Board is subject to the peer review requirement because it is an agency within CalEPA and the amendments to the Bay-Delta Plan meet the definition of rule under section 57004(a)(1)(B), which includes policies adopted by the State Water Board pursuant to the Porter-Cologne Act that have the effect of a regulation. Section 57004 (a)(2) defines *scientific basis* and *scientific portions* to mean "those foundations of a rule that are premised upon, or derived from, empirical data or other scientific findings, conclusions, or assumptions establishing a regulatory level, standard, or other requirement for the protection of public health or the environment." A qualified, objective, and neutral external scientific peer review entity then prepares an evaluation of the scientific basis of the proposed rule.

In August 2011, the State Water Board, Division of Water Rights, submitted a request in accordance with the peer review guidelines for the peer review of the State Water Board's *Technical Report on the Scientific Basis for Alternative San Joaquin River Flow and Southern Delta Salinity Objectives* (Appendix C of the SED) (State Water Board 2011). The information and analytical tools described in Appendix C provided the State Water Board with the scientific basis and tools needed to evaluate potential changes to the water quality objectives in the Bay-Delta Plan and the associated program of implementation. Chapter 5 of Appendix C, *Water Supply Effects Analysis*, describes the WSE model and its use to evaluate potential changes to water supply. Specifically, the peer review of Appendix C requested reviewers provide comments regarding appropriateness of the proposed method for evaluating potential water supply impacts associated with flow objective alternatives on the SJR at Vernalis, and the Stanislaus, Tuolumne, and Merced Rivers. The peer review was generally favorable regarding the approach to evaluate the potential plan amendments. In February 2012, the State Water Board released the initial spreadsheets of the WSE model and Appendix C for the public to review.[4] A workshop on March 20, 2012 addressed the public's questions about the WSE model and other technical information released in February.

The WSE model supports a watershed-scale evaluation of changes in available supply for water diversions and a comparison of scenarios incorporating flow objectives at different fractions of unimpaired flow. It does not characterize or describe impacts on individual water rights, licenses, or other permits. The State Water Board strived to use the best available science in the development of the WSE model and relied on the peer reviewers' input that was based on their evaluation of the appropriateness of the approach to evaluate water supply and river flow effects of the plan amendments.

Water Balance Modeling for the SED

A water balance model was required to describe the hydrologic changes to the water supply and river system resulting from the proposed instream flow requirements in the plan area. As described in the book *Principles of Surface Water Quality Modeling and Control*, a model is defined as "a theoretical construct, together with the assignment of numerical values to model parameters, incorporating some prior observations drawn from field and laboratory data, and relating external inputs or forcing functions to system variable responses" (Thomann and Mueller 1987). In this case, a water balance model incorporates prior observations of inflows and outflows and demonstrates the relationship of system variables such as water supply availability and reservoir storage levels to water inflow, reservoir capacity, historical patterns of water use, and stream flow requirements.

A water balance model describes the amounts of water entering and leaving a defined system (e.g., the plan area). A water balance model is based on a specific period (e.g., daily, monthly, annually) and accounts for the movement of water within the system. Water *sources* are inflows from upstream watersheds and certain points within the system (e.g., confluence with tributaries and agricultural return drainage), and water *sinks* are sites where water leaves the system, such as downstream outflow and diversions for consumptive use. Sources and sinks are connected by a network of storage nodes representing reservoirs, non-storage nodes representing an intersection of flow paths, and conveyance channels between nodes. Values in each node or flow path (storage volume quantity or flow rate) represent hydrologic conditions at a defined point in space and time. Values for each node or flow path are calculated for a series of points in a designated study period at a time interval known as a *time step*. The time step for both CALSIM II and the WSE model is monthly, and flow values represent a monthly average storage volume or monthly average flow.

The WSE model characterizes the existing water delivery and river system in the plan area at a sufficient level of detail to support description and comparison of hydrologic conditions such as reservoir volume, agricultural and municipal water deliveries, and instream flows, in the baseline scenario and the LSJR alternative stream flow requirements.

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[4] The notice of the available WSE information is located at: https://www.waterboards.ca.gov/waterrights/water_issues/programs/bay_delta/bay_delta_plan/water_quality_control_planning/docs/noa_drafttechltr_annotated_1.pdf

CALSIM, the WSE Model, and Operations Models

The State Water Board used the widely accepted water balance model CALSIM II as the foundation and basis for the creation of the WSE model used in the SED analysis. CALSIM II is used by the California Department of Water Resources (DWR) and the U.S. Bureau of Reclamation (USBR) to evaluate and assess changes in the management of California's water resources (USBR 2005). CALSIM II functions as a sufficiently detailed representation of a complex system to assess and evaluate water operations. It has been used in many planning and regulatory processes, including those of the U.S. Fish and Wildlife Service (USFWS),[5] National Marine Fisheries Service (NMFS),[6] and USBR.[7]

CALSIM II works on a monthly time step for the years 1922 through 2003. This 82-year period of record period is appropriate for the purposes of evaluating and comparing water supply effects because it is a robust representation of the range of conditions measured in the historical spectrum between wet years, dry years, and multi-year extended drought periods. The CALSIM II water balance is only available for the 1922–2003 period and has not been updated. According to USBR, there are no plans to update CALSIM II, although a new version known as CALSIM 3 was released in December 2017 by USBR and DWR. The release timing of CALSIM 3 precluded use in this SED analysis. Thus, the water balance 1922–2003 period as characterized in CALSIM II was used in the WSE model for the SED analysis.

Figure 3.2-1 shows a schematic of the CALSIM II domain of the three eastside tributaries and the LSJR. Water balance components include inflows (I), diversions (D), return flows (R), conveyance channels (C), and major reservoirs (triangles). Nodes are denoted as numbered open circles. Each of these components is a time-series variable with monthly values for 82 years. Inflows that define gross water availability are external boundary conditions considered *static variables* because the values change from month-to-month but do not change because of the simulation. Diversions, conveyance channel flows, and reservoir storage values are *dynamic variables*, which change in response to calculations of the water balance based on the model forcing functions; i.e., water supply demands and regulatory requirements for streamflow.

The State Water Board adapted the water balance of CALSIM into a spreadsheet format (the WSE model) to assess rapidly the effects of instream flow requirements and reservoir parameter adjustments. The WSE model uses the same water balance components of inflows and return flows, similar minor diversions, and the same water balance framework as CALSIM. The WSE model is documented in Appendix F.1, *Hydrologic and Water Quality Modeling*.

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[5] U.S. Fish and Wildlife Service. 2008. *Formal Endangered Species Act Consultation on the Proposed Coordinated Operations of the Central Valley Project (CVP) and State Water Project (SWP)*. 396 pp. (USFWS 2008 BiOp)

[6] National Marine Fisheries Service. 2009. *Biological and Conference Opinion on the Long-Term Operations of the Central Valley Project and the State Water Project.* (NMFS 2009 BiOp)

[7] U.S. Bureau of Recreation. 2015. *Coordinated Long-Term Operation of the Central Valley Project and State Water Project. Final Environmental Impact Statement.*

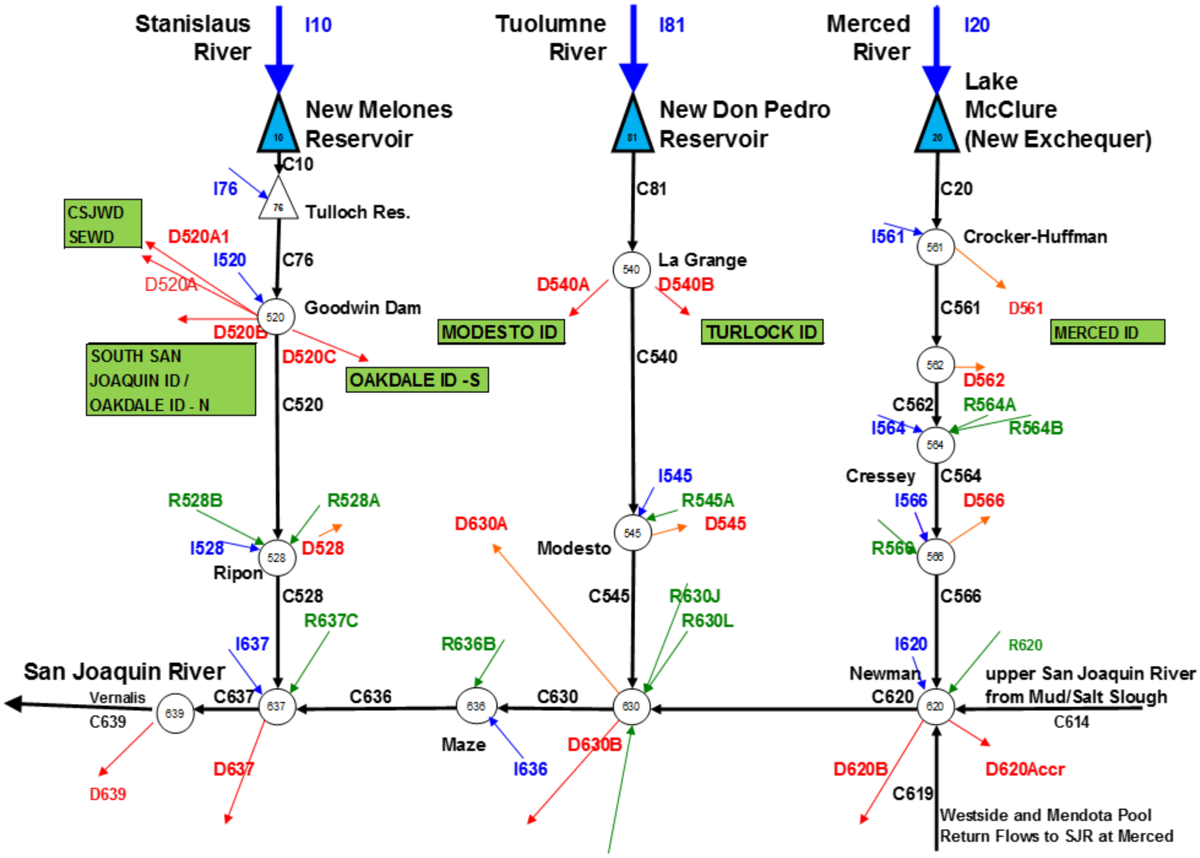

Figure 3.2-1. CALSIM II and WSE Model Water Balance Components for the Three Eastside Tributaries and the Lower San Joaquin River

Water balance models have been developed by several irrigation districts, including Merced Irrigation District (Merced ID) and the Turlock Irrigation District (TID) as a part of Federal Energy Regulatory Commission (FERC) relicensing studies (Merced ID 2015) and by San Joaquin Tributaries Authority (SJTA) as part of New Melones Reservoir operations planning, presumably on behalf of Oakdale Irrigation District (OID) and South San Joaquin Irrigation District (SSJID)(SJTA 2012). Each of these water balance models uniquely represents conditions in each river, and generally, all are thought to be credible for specific purposes. Local operations models may have a higher resolution of detail than CALSIM II, whether more detailed node segmentation, shorter time step representing finer temporal resolution such as daily rather than monthly, or potentially greater precision in operations assumptions appropriate for the relevant study. District operations models have been used to aid characterization of district water demands, as described in the sections that follow, and only for certain other aspects of district water balances contributing to district water demands and consumptive use.

The SED analysis focuses on the LSJR and the Stanislaus, Tuolumne, and Merced Rivers, although CALSIM II has a wider domain of the California Central Valley, including the Sacramento River and its tributaries. Commenters suggested that the State Water Board should have used one or another of the district operations models in the development of the SED. However, CALSIM[8] remains the best available representation of the overall water balance, as incorporated into the WSE model, representing hydrology of all three tributaries and the LSJR to Vernalis as an entirety. The dynamics of water supply allocation and reservoir reoperation; i.e., all changes in surface water dynamics between modeling scenarios of baseline and LSJR alternatives, occur within the same overall water balance framework, as described in this master response and in Appendix F.1, *Hydrologic and Water Quality Modeling*.

Modeling Assumptions

Models include simplifying assumptions for processes and variables, determinations that are reasonable and necessary for a program-level analysis of water supply storage and delivery. Assumptions are the collection of explicitly stated or implicit premises, conventions, choices, and values assigned to various model parameters and quantitative structures. These assumptions are necessary to simplify and constrain the scope of a numerical analysis. Assumptions for water balance analysis generally consist of either structural or mathematical simplifications of a complex system or estimation of physical quantities that may be widely variable or difficult to measure. Assumptions are an important element of defining the existing environment for the baseline scenario and LSJR alternatives for comparative analysis. Assumptions are based on best available information and may originate from different sources and types of studies.

The water balance diagram for CALSIM (Figure 3.2-1) is an example of a structural simplification of the water balance system for the three tributaries and the LSJR. CALSIM includes major diversions and amalgamates smaller diversions into groups that draw from a limited number of nodes. Water balance quantities are simplified to account for the inflows and outflows at each node using the spatial detail shown in Figure 3.2-1. This degree of spatial detail is sufficient for the purposes of a joint agency planning model, accounting for combined supply and demand under various conditions, reservoir storage, and outflow as a function of operations specifications such as regulatory requirements or changes in water demand.

Perhaps the most important assumption in water balance modeling for comparative analysis is inherent in the conceptual difference between the baseline scenario and historical conditions. Historical conditions were used in the original construction and development of the CALSIM model water balance so that operations reflect infrastructure conditions of the 1980s and 1990s (USBR 2005). However, the 82-year hydrologic record is applied to the system assuming modern infrastructure is in place for that entire period. The large reservoirs constructed in the 1960s and 1970s are assumed to exist from the beginning of the model period in 1922. This exercise illustrates two key points: 1) *if* the system were constructed with large reservoirs beginning in 1922 at some initial fill status, and all water diversion demands and regulatory streamflow requirements existed at that time as they do in the modern era, 2) *then* water demands can be met a certain fraction of the time over the 82-year study period and other resulting changes in the dynamic system as estimated by the model based on operations rules and constraints defined in the model code. Baseline water supply delivery volume and instream flow volumes are estimated by applying the 82-year

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[8] CALSIM will hereinafter be used to refer to CALSIM II, not any prior or later versions. CALSIM II is the version that was used in the analysis as received from USBR in 2013 (USBR 2013a, 2013b). Further information can be found in Appendix F.1, *Hydrologic and Water Quality Modeling*.

hydrologic record to the modern water supply and delivery system, stream network, and regulatory framework.

Baseline Conditions

Baseline generally reflects recent historical conditions to the extent that water use demands and system function are similar in many recent years. In general, the baseline used in this SED reflects the physical environmental conditions in 2009 as they existed under the 2006 Bay-Delta Plan, as implemented through Water Right Decision 1641 (D-1641). Assumptions for existing regulatory requirements in the context of the baseline scenario are described in Master Response 2.5, *Baseline and No Project*, and Appendix F.1, *Hydrologic and Water Quality Modeling*.

Baseline would not and should not be expected to match historical conditions in the study period. Where infrastructure and regulatory conditions do not closely coincide (e.g., prior to water supply infrastructure and regulatory requirements), baseline results differ from the historical record. Even though the period of record for the water balance (i.e., hydrologic record) in the CALSIM and WSE models is from 1922 to 2003, it is common practice to apply this sort of model to represent existing conditions outside of that period.[9]

After the factors defining an appropriate representation of baseline condition are determined, alternative scenarios are constructed by implementing changes in assumptions regarding regulatory requirements; i.e., the LSJR alternatives in the SED that incorporate new streamflow requirements at a designated percent of unimpaired flow. The resulting changes in stream flow volume, water supply delivery volume, and all other system variables are evaluated by comparison to baseline.

Other water balance assumptions are as follows:

- Existing level of development, defined as municipal and agricultural water demands and other demands such as wildlife refuges.
- Groundwater use only as it reduces the demand for surface water.
- Estimated accretions and depletions between nodes.
- Irrigation district return flows to surface water.
- Formulas and parameters constraining reservoir operations in order to maximize delivery and reliability of water supply in various conditions, while at the same time considering instream temperature needs.[10]
- Other assumptions documented in USBR 2005 describing the development of CALSIM and in Appendix F.1, *Hydrologic and Water Quality Modeling*, which describes the development and configuration of the WSE model.

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[9] See, for example, U.S. Fish and Wildlife Service. 2008. *Formal Endangered Species Act Consultation on the Proposed Coordinated Operations of the Central Valley Project (CVP) and State Water Project (SWP)* (USFWS 2008 BiOp) and National Marine Fisheries Service. 2009. *Biological and Conference Opinion on the Long-Term Operations of the Central Valley Project and the State Water Project* (NMFS 2009 BiOp).

[10] Avoiding adverse temperature impacts on fish and wildlife is interpreted in the modeling process as meeting the EPA temperature criteria within 10 percent exceedance frequency of baseline conditions.

Best Available Information

The 2016 WSE model is a reliable, efficient, and effective tool that incorporates extensive stakeholder feedback. System changes, effects, and impacts were evaluated using the most appropriate set of modeling tools and best available information to assess the potential effects of the proposed amendments. More detailed and updated information has become available over the course of developing the WSE model (between the 2012 and 2016 versions) and other modeling tools to assess the potential effects of the LSJR alternatives. The State Water Board first released the water supply effects analysis discussed in Appendix C, *Technical Report on the Scientific Basis for Alternative San Joaquin River Flow and Southern Delta Salinity Objectives*, on October 29, 2010, as the *Draft Technical Report* and included a spreadsheet for water supply effects.

The WSE model was subsequently updated based on public comments from technical experts received in 2011 and in response to the *Peer Review of Technical Report on the Scientific Basis* posted on November 21, 2011. An updated draft WSE model was released on March 5, 2012, and additional comments were addressed in the development and release of the WSE model for use in the 2012 Draft SED (published on December 31, 2012). Similarly, the 2012 WSE model was updated for use in the 2016 Recirculated SED based on comments received after the release of the 2012 Draft SED and availability of additional information including district water balance information derived from agricultural water management plans (AWMPs), specific data solicited from irrigation districts, and changes to variables used within CALSIM. The WSE model provides an appropriate level of investigation resulting in sufficient precision and accuracy to assess the effects and impacts of the proposed amendments.

Comparison of the 2012 WSE and 2016 WSE

Modeling approaches in the SED have been updated to include the best available information for inputs and assumptions, to refine precision and accuracy and appropriately assess the effects and impacts of the proposed plan amendments in the SED. The latest revisions to the WSE model were made between January 2013 and September 2016. Section ES11, *Areas of Known Controversy and Changes Made to the 2012 Draft Substitute Environmental Document*, lists the concerns raised regarding the 2012 Draft SED for which revisions were made and describes the changes in the SED. Chapter 4, *Introduction to Analysis*, Section 4.2.1, *Hydrologic Modeling,* describes those changes in more detail, including specific references to the WSE model. This section briefly describes the changes to the WSE model since the 2012 Draft SED. Appendix F.1, *Hydrologic and Water Quality Modeling*, Section F.1.2, *Water Supply Effects Modeling Methods,* describes the changes and includes assumptions and calculations used in the WSE model.

The revised WSE model provides refined estimates that would better reflect operations constraints and decisions, incorporates variable crop demands, and allows long-term tracking of monthly reservoir storage, river flows, and diversions. The 2016 version of the WSE model reflects the following changes:

- WSE modeling of the LSJR alternatives now fully represents changes in reservoir storage, including end-of-September storage, based on operations likely to occur with the proposed flow requirements.
- The 2016 Recirculated SED analysis no longer uses CALSIM directly to simulate baseline conditions. The WSE model was configured to provide a representation of baseline conditions very similar to those of CALSIM and is now used to model both the baseline and the LSJR

alternatives for the purpose of impacts analysis. The baseline and the LSJR alternatives are more directly comparable in the 2016 Recirculated SED because they are both simulated using the WSE model.

- Diversion demands for major irrigation districts are now dynamically varied based on consumptive use of applied water (CUAW) demands from CALSIM and operations efficiency estimates derived from AWMPs.
- Diversion demands have been adjusted based on comparison to results of district operations models and consideration of recent historical data
- Other associated changes are described in Appendix F.1, Section F.1.2., *Water Supply Effects Modeling Methods*.

Additional functionality in the WSE model now includes clearer formatting of results and summary and comparison tables, output of all necessary variables to assess changes to the water balance, better formatting for outputs linked to other models, and an improved user control panel to allow more flexibility in testing various scenarios.

A summary of the major assumptions used in the published versions of the WSE model (2012 and 2016) and those used in the CALSIM models that were compared to the WSE model is provided in Appendix F.1, Table F.1.2-2 and Table F.1.2-3. One of the significant updates is the use of new information from updated CALSIM scenarios. USBR provided comments on the 2012 SED and later provided an updated version of CALSIM corresponding to the issues cited in their comments. This includes representation of Central Valley Project (CVP) contractor demands and other CALSIM improvements specific to the Stanislaus River and requirements at Vernalis (USBR 2013a, 2013b). Methods for using CALSIM to develop the baseline and input assumptions are in the *Calibration Comparison* section of this master response.

Calibration Comparison

The approach used in the development and refinement of the WSE model appropriately uses many sources of data to best represent the definition of baseline conditions and to assess alternative conditions. The California Environmental Quality Act (CEQA) allows the use of models to assess impacts of a programmatic change when observed data is not available. Additionally, as limited observed data are available that specifically represent the baseline as a snapshot in time, models developed to represent the baseline must be based on other sources of information for purposes of calibration and refinement. It is within the State Water Board's discretion to decide how existing physical conditions can most realistically be described, if their determination is supported by substantial evidence.[11]

Existing conditions can be described using an average of conditions over time as a baseline or by making a determination regarding available data that best describes the environmental setting for a specific resource.[12] A lead agency may elect to use older data that are consistent across project area and sources rather than more recent data that are not consistently available across the project area. Appendix F.1 *Hydrologic and Water Quality Modeling,* Section F.1.2.1, *U.S. Bureau of Reclamation CALSIM II SJR Module* and Section F.1.2.2, *Development of the WSE Model Baseline and Alternative*

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[11] *Save Our Peninsula Committee v. Monterey County Bd. of Supervisors* (2001) 87 Cal.App.4th 99, 125; *Communities for a Better Environment, supra, 48 Cal.4th at pp. 327-328.*

[12] *Save Our Peninsula Committee, supra, 87 Cal.App.4th at p. 125*

Assumptions describe in further detail the development of the WSE model. Master Response 2.5, *Baseline and No Project* responds to comments related to development and decisions related to the SED baseline.

WSE model results for the baseline condition have been compared to CALSIM model results for the baseline condition to confirm that the WSE model produces reasonable results. Some commenters stated that a model should not be calibrated to another model. CALSIM was used to validate WSE results for baseline streamflow and diversion volumes because it is a widely accepted and rigorously reviewed planning model, and because it contains a longer available dataset for comparison than historical data alone. The other primary means of validating model results would be comparison to historical data. Comparison of model results to observed historical conditions becomes increasingly uninstructive reaching further back in history because flow regulation and water development infrastructure are not in place. CALSIM and WSE baseline results would not and should not be expected to match historical conditions in years prior to existing water supply infrastructure and regulatory requirements.

Comparison of WSE results to CALSIM results for the baseline condition is a reasonable method of validating WSE results. Comparison of CALSIM results to recent historical flow and electrical conductivity (salinity) data from 1984 to 2003 demonstrates that CALSIM provides a reasonable (accurate) representation of the baseline SJR flow and salinity conditions (Appendix C, *Technical Report on the Scientific Basis for Alternative San Joaquin River Flow and Southern Delta Salinity Objectives* and Appendix F.1 *Hydrologic and Water Quality Modeling*). This covers a period during which actual operations in the watershed were relatively similar to those modeled in the CALSIM representation of current conditions. All major eastside dams were completed and filled, and their combined effect on flows at Vernalis is present in the actual data. As the observed historical conditions become increasingly different from current conditions, validation with a baseline conditions model becomes more appropriate than calibration to historical data.

The WSE model contains two distinct baseline scenarios, as stated in Appendix F.1, Section F.1.2.2, *Development of the WSE Model Baseline and Alternative Assumptions*. Appendix F.1 uses the terms *WSE-CALSIM baseline* and *WSE-CEQA baseline*. The distinction between the two baseline scenarios is that the WSE-CALSIM baseline scenario was used to “tune” the model based on levels of diversion and consumptive use demand to corroborate with the CALSIM model results for allocations and reservoir utilization. After demonstrating sufficient similarity in allocation of water between the WSE model and CALSIM, some of the WSE model inputs and assumptions derived from CALSIM were adjusted to refine consumptive use demands and best characterize the existing condition. These adjustments, which define the WSE-CEQA baseline scenario, are stated in Appendix F.1, Table F.1.2-2. These adjustments result in consumptive use patterns that diverge slightly from the representation in CALSIM but create a better representation of the SED baseline in this agency’s discretion. Further detail on the steps for developing the baseline WSE model for the SED are described in Appendix F.1, Section F.1.2.2, *Development of the WSE Model Baseline and Alternative Assumptions*.

The calibration and corroboration used to develop the WSE model has produced a water balance model that best fits operations characteristics of the LSJR system for the SED baseline. The WSE model allows evaluation of flow requirements based on a defined percent of unimpaired flow for a comparative analysis to evaluate the LSJR alternatives. Additional detail and explanation of the calibration and corroboration process is discussed in Appendix F.1, Section F.1.2.4, *Calculation of*

Monthly Surface Water Demand, and the section entitled *Determination of Surface Water Demand, Operations Models* in this master response.

Agricultural Water Management Plans

Information from AWMPs, such as components of district water balances and associated efficiencies, was used to improve the definition of consumptive use elements in the WSE model. AWMPs were first published in 2012 as a requirement of the Water Conservation Act of 2009, and thus were not available to inform the 2012 Draft SED and 2012 WSE model. AWMPs were used to update irrigation district water balances, efficiencies, and crop-applied water use in the 2016 WSE and 2016 Recirculated SED. In the SED analysis, AWMP data generally have been used to disaggregate the total surface water demand at the point of diversion into the amount of water used by crops and other destinations such as percolating to recharge groundwater. This refined relationship is incorporated in the WSE model representation of total surface water demand, and is described in Appendix F.1, *Hydrologic and Water Quality Modeling*. Further information on the incorporation of AWMP assumptions can be found in this master response in the section entitled *WSE Model Water Balance Components*.

AWMPs were also used to characterize the total irrigated acres for each district, as described in Appendix G, *Agricultural Economic Effects of Lower San Joaquin River Flow Alternatives: Methodology and Modeling Results*. Crop distributions were used from DWR Detailed Analysis Unit surveys for consistency. For more information regarding crop distributions, see Master Response 8.1, *Local Agricultural Economic Effects and the SWAP Model*.

Updates to the AWMPs were published in 2015 and 2016. Information from more recent AWMPs was not used to update the WSE model further, because analysis was continuously underway during that period. However, the SED groundwater analysis used groundwater statistics from more recent AWMPs to characterize 2014 levels of groundwater pumping, shown in Appendix G, Table G.2-4. The groundwater impact analysis was conducted outside of, and subsequent to, analysis in the WSE model, and is discussed further in the section entitled *WSE Model Water Balance Components, Groundwater Supplementation* of this master response.

Information Requests to Irrigation Districts and Water Districts

The State Water Board, Division of Water Rights, issued information requests in September 2015 to the following agencies as part of the division’s effort to obtain and use best available information in SED analyses:

- Central San Joaquin Water District (did not respond)
- Eastside Water District (did not respond)
- Merced Irrigation District (pers. comm. Eltal)
- Modesto Irrigation District (pers. comm. Salyer)
- Oakdale Irrigation District (pers. comm. Knell)
- South San Joaquin Water District (pers. comm. Rietkerk)
- Stockton East Water District (did not respond)
- Turlock Irrigation District (pers. comm. Hashimoto)

The request for information was intended to clarify estimates for the following data points:

- Regulating reservoir evaporation and seepage.
- District maximum and minimum groundwater pumping.
- Private maximum and minimum groundwater pumping.
- Change in pumping capacity or utilization in the drought years 2014 and 2015.

Four of the seven districts responded to the information request with useful information. Some of the responses were helpful to clarify water balance data from AWMPs for use in the WSE model and SED groundwater analyses. Stockton East Water District (SEWD), Central San Joaquin Water District (CSJWD) and Eastside Water District (Eastside WD) did not respond to the inquiry. Merced ID indicated that it would require 90 days to fulfill the request but did not respond further. Examples of updated data from district responses to information requests can be found in Appendix F.1, *Hydrologic and Water Quality Modeling*, Table F.1.2-12 for Turlock Reservoir losses and F.1.2-13 for minimum groundwater pumping rates.

Extended WSE Parameters

Evaluation of an extended period including the years 2004 through 2015 was considered to a limited extent in Chapter 21, *Drought Evaluation;* however, not all local inflows and water balance parameters were available from CALSIM for the extended period. This required some values to be estimated using values from corresponding water year types, including accretions. Since this approach was not validated, results from the extended WSE model were used for illustrative purposes in Chapter 21, but were not used as a part of the impacts determinations in the SED. Additionally, as stated in Chapter 21, the 2012–2015 drought was similar to other 4-year dry periods experienced since 1922.

Calculation of Percent Unimpaired Flow

The metric of unimpaired flow is used as an index representing water supply available for all uses. Unimpaired flow is estimated by DWR as described in *California Central Valley Unimpaired Flow Data, 4th Edition, Draft* (DWR 2007). DWR has published prior estimates of California water supply in Bulletin 3, *The California Water Plan*, in 1957, superseded by updates known as the Bulletin 160 series, and earlier editions of unimpaired flow estimates (DWR 1994, DWR 2011). The DWR 2007 report provides monthly estimates of unimpaired flow for water years 1922 through 2003, at locations corresponding to the three original rim reservoirs in the plan area: Melones Reservoir on the Stanislaus River, Don Pedro Reservoir on the Tuolumne River, and Exchequer Reservoir on the Merced River.

Unimpaired flow represents the natural water production of a river basin, unaltered by upstream diversions, storage, or by export or import of water to or from other watersheds (Chapter 3, *Alternatives Description,* and Master Response 2.1, *Amendments to the Water Quality Control Plan*). It differs from natural flow because it occurs at a specific location under the current configuration of channels, levees, floodplains, wetlands, deforestation, and urbanization. Although that distinction is meaningful for valley floor areas that have experienced drastic hydrologic modification, upstream of the major reservoirs, the difference between natural and unimpaired flow is not considered significant.

Daily unimpaired flow is currently estimated by DWR and posted online at the California Data Exchange Center website and reported at three locations on the Stanislaus, Tuolumne, and Merced Rivers: at Goodwin Dam (CDEC station GDW), La Grange Dam (CDEC station TLG), and Merced Falls (CDEC station MRC) (Figure 3.2-2). The State Water Board considers DWR's Full Natural Flow (FNF) metric to be functionally equivalent to unimpaired flow at these particular locations. The percent of unimpaired flow required by the flow objective determines the size of the block of water or the water budget. Compliance with the percent of unimpaired flow objective is determined at the downstream compliance points on each river near the confluence with the LSJR. These locations are Stanislaus River at Koetitz (DWR gage KOT), Tuolumne River at Modesto (USGS gage 11290000), and Merced River near Stevenson (DWR gage MST).

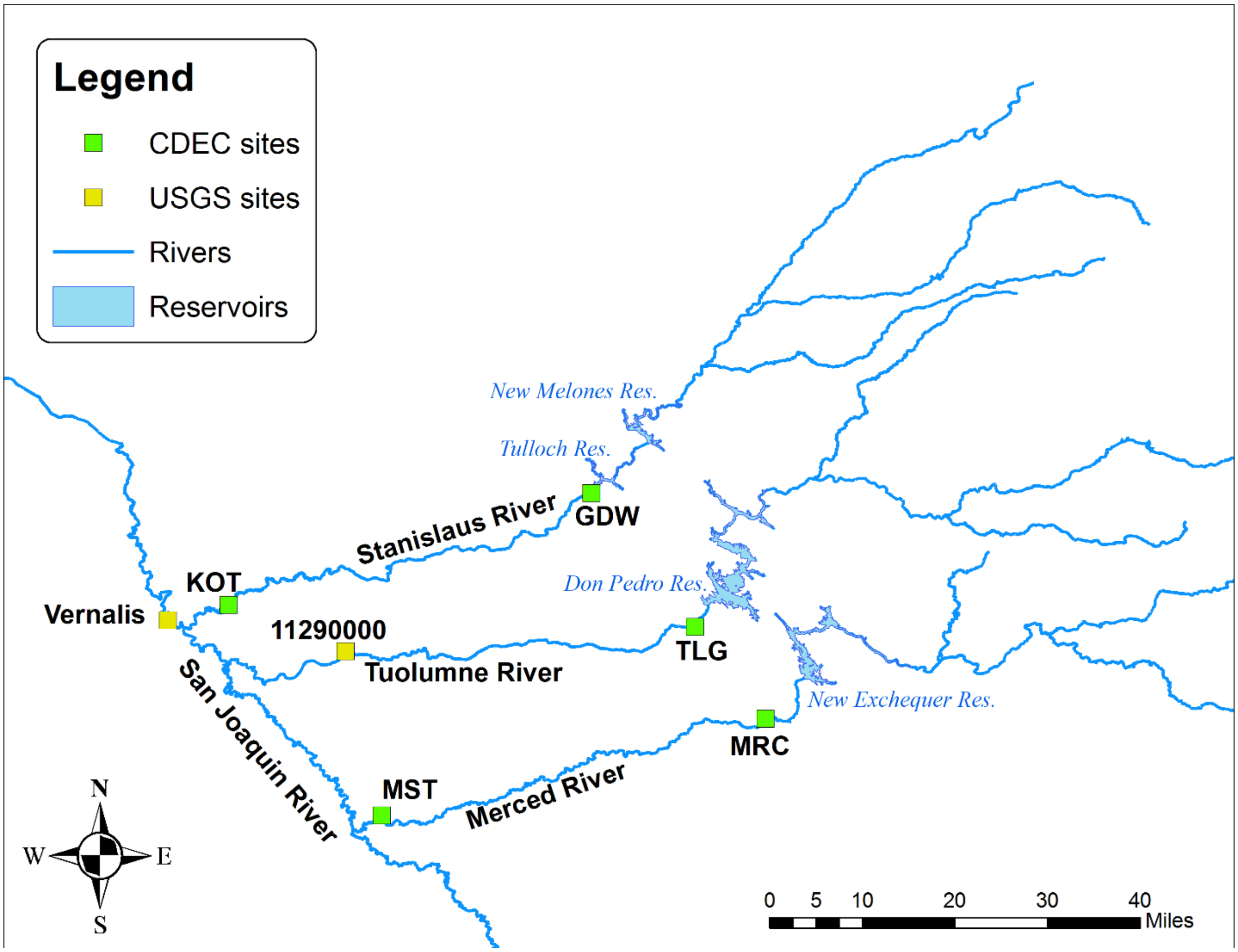

Figure 3.2-2. Unimpaired/Full Natural Flow and Compliance Locations

Unimpaired Flow versus Natural Flow

Commenters observed that unimpaired flow can differ significantly from the concept of natural flow in the valley floor because depletions, seepage, runoff, and bank overflow occur in valley floor segments, and as noted previously and because of other factors as described by DWR in their comments on the 2016 Recirculated SED and published reports (DWR 2007, 2016). Determining flow objectives based on estimates at the rim dam locations is appropriate, primarily because of the difficulties in estimating unimpaired flow in the valley floor. Unimpaired flow estimates at the rim dams, FNF locations, are the best indicators of water supply in these tributaries, as these estimates have traditionally been developed for this purpose. The estimated water supply at these locations is the amount available from the upper watersheds for all uses. FNF at these locations represents the amount of water from the upper watershed available to be diverted, stored, or made available for an instream flow objective. By contrast, contributing flows from watershed areas downstream of the rim dams, including smaller local tributaries, are difficult to estimate, occur at less-predictable frequencies and magnitudes, and are generally less subject to retention or control. As such, contributing inflows below the rim dams, in the valley floor area, are not considered part of the index metric for available unimpaired flow for determination of flow objectives for the three LSJR tributaries.[13] Furthermore, the overall fraction of valley floor contributions is relatively small (DWR 2007).

Measurement and Compliance

Compliance with the percent of unimpaired flow from February through June in each river is determined by dividing the 7-day average observed flow at the compliance stations (Appendix K, *Revised Water Quality Control Plan*, Table 3 and as shown in Figure 3.2-2) by the 7-day average calculated FNF at the FNF stations and multiplying by 100. Refinements to methods and measurements used to estimate FNF can be used for compliance if refinements improve accuracy and precision of FNF estimates.

Unimpaired flow is estimated on daily and monthly time steps; however, the daily unimpaired flows are not always available for short-term decision-making or reliable for 7-day average calculations. The daily unimpaired flow estimates frequently lag by several days and are therefore not always available for real-time decision-making. This lag occurs because the unimpaired flow estimates rely on sparse and variable data that do not necessarily reflect the actual unimpaired flow on any given day. For example, changes in reservoir volume are used to estimate unimpaired flow (DWR 2016). Reservoir volume or storage is often measured by recording changes in water surface elevation. Water surface elevation can be affected by strong winds pushing water higher or lower at the location of the gage, causing volume and unimpaired flow to be over or under estimated for that day. This type of variability evens out over longer averaging periods and daily divergences from actual unimpaired flow eventually sum to zero over time.

Dr. Francis Chung of DWR, at a State Water Board workshop in 2011, clearly stated one difficulty of considering unimpaired flow objectives: “UF [Unimpaired Flow] is an imprecise estimate requiring further improvement before being used as an operations flow criterion. Refinement is possible given careful design, time, resources and expert effort (DWR 2011).”

Challenges with existing methods for measuring flow variables and estimating unimpaired flow on a time step that is consistent with the averaging period for the LSJR numeric flow objective are recognized. The program of implementation requires the Stanislaus, Tuolumne, and Merced Working Group (STM Working Group) or State Water Board staff as necessary to work with the

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[13] Although inflows contributing to valley floor river segments below the rim reservoirs and below the FNF stations, known as *accretions*, are not considered part of the unimpaired flow index for calculating the flow requirement, accretions in the WSE model can, under some conditions, provide significant volume that contributes to meeting the flow objective, relieving dam operators and water held in reservoirs of a fraction of responsibility. This is described further in the section entitled *Accretions and Depletions*.

Delta Science Program to develop and recommend specific actions to monitor and evaluate compliance with the unimpaired flow objectives. The State Water Board or Executive Director will consider approving the measures within 180 days from the date of the Office of Administrative Law (OAL) approval of this amendment to the Bay-Delta Plan.

Model Implementation of Percent Unimpaired Flow Objectives

Generally, the WSE model interprets the percent unimpaired flow objective at each confluence reach as shown in Figure 3.2-3. Q_2, the compliance flow, is equal to the designated percentage of the unimpaired flow index. Q_1, the reservoir release, must equal Q_2 less any local inflows (accretions) and return flows, plus any diversion for consumptive use. In this way, local inflows can contribute to meeting the objective.

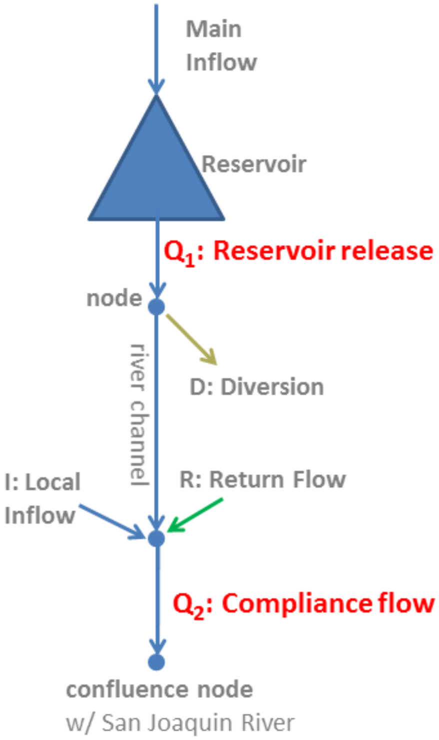

Figure 3.2-3. Water Balance Schematic Showing Reservoir Release and Compliance Point

Commenters noted that incorporation of local inflows into the effects analysis can affect the amount of flow required to meet the flow objectives. This issue is addressed in the section entitled *WSE Model Water Balance Components, Accretions and Depletions*. Appendix F.1, *Hydrologic and Water Quality Monitoring*, explains that the February–June minimum instream flow requirement is calculated as a percentage of that month's unimpaired flow, for each month from February through June, for comparing alternatives. For example, the unimpaired flow volume in the Stanislaus River in February 2003 was 55 thousand acre-feet (TAF). An unimpaired flow of 40 percent would be 22 TAF (a monthly average of 396 cubic feet per second [cfs]) for the month of February required at the confluence compliance location. Each month is calculated individually.

Some commenters objected to the use of a monthly model to evaluate effects of the LSJR flow objectives because the compliance period is a 7-day running average flow. The purpose of the WSE model analysis is to evaluate changes in water supply and the potentially significant impacts that could occur because of those changes. The total volume of water supply effects is the same whether considered on a monthly or a 7-day average. A monthly model provides relevant and reasonable information to support significance determinations.

WSE model flow results were combined with a temperature model to evaluate impacts on aquatic biological resources (Chapter 7, *Aquatic Biological Resources*) and benefits to native fish populations (Chapter 19, *Analyses of Benefits to Native Fish Populations from Increased Flow between February 1 and June 30*). Daily flow conditions and variability are relevant variables for determining the value of and effects on aquatic habitat conditions. Monthly WSE model results show a general pattern of higher monthly February–June flows under the LSJR alternatives relative to baseline flow conditions. Increased monthly flows more closely mimic the natural hydrographic condition to which native fish species are adapted, even if the WSE model does not describe daily flows.

The San Joaquin River Basin-Wide Water Temperature and EC Model (HEC-5Q temperature model) uses WSE monthly water supply results to evaluate effects of LSJR alternatives on river temperature. Monthly WSE results for stream flow and reservoir storage under each of the LSJR alternatives and baseline were used as inputs for the temperature analysis in HEC-5Q which has a sub-daily time step (6 hour). In order to convert monthly flows and reservoir conditions to daily values, a conversion tool, CALSIM II to HEC-5Q preprocessor, translates the monthly data into daily values, and interpolates to smooth the transition between monthly reservoir values. This is documented in the *San Joaquin River Basin-Wide Water Temperature and EC Model, Appendix D. CALSIM II Preprocessor for HEC-5Q Input* (CDFW 2013). The effects of flows on temperature and the subsequent effects on spawning, rearing, and migration habitat for native migratory fish are evaluated in the SED at a sub-monthly level of analysis.

CALSIM is the planning model used to simulate CVP/California State Water Project (SWP) operations. The WSE model water balance is adapted from CALSIM, and both models use a monthly time step to assess and evaluate regulatory requirements with a sub-monthly compliance period. CALSIM is used in a planning capacity to evaluate water supply effects of CVP/SWP operations constraints, such as reasonable and prudent alternatives (RPAs)[14] in biological opinions (BiOps) and water quality objectives in existing water quality control plans that have sub-monthly flow requirements. For example, DWR currently uses CALSIM, a monthly model, to plan and to model and interpret existing sub-monthly requirements of the 1995 Water Quality Control Plan. This includes the existing SJR April 15 to May 15 pulse flow objective, Delta Outflow requirements, and electrical conductivity requirements that include 14-day running average requirements. In these cases, day-weighted average monthly conditions are used in CALSIM in the estimation of flow quantities required to meet the water quality requirements.[15] Additionally, Chapter 19 and Master Response 3.1, *Fish Protection*, discuss the appropriateness of using a monthly flow to assess the effects of the LSJR alternatives with respect to aquatic habitat and aquatic species life cycles.

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[14] Reasonable and prudent alternatives are alternative methods of project implementation, offered in a biological opinion reaching a jeopardy or adverse modification conclusion that would avoid the likelihood of jeopardy to the species or adverse modification of critical habitat.

[15] Biological Assessment for the California WaterFix, July 2016, ICF 00237.15, page 5.A-13. App_5.a_calsim.pdf. http://www.westcoast.fisheries.noaa.gov/publications/Central_Valley/CAWaterFix/app_5.a_calsim.pdf

WSE Model Water Balance Components

Multiple comments on the SED are related to various components of the WSE model water balance. The following sections describe WSE model components related to the water balance of the plan area. These components include demand calculations, irrigation district water balance calculations, and tributary accretion and depletion calculations. This section also discusses how AWMP data and tributary-specific district operations models were used to inform inputs to WSE model calculations.

Readers can obtain a copy of the WSE model[16] if interested in additional detail related to the following elements: 1) water balance calculations, 2) reservoir operations and rules, 3) diversions and allocations, and 4) river flows at various locations throughout the river network.

The sections that follow respond to comments and potential confusion among commenters and SED readers related to these components of the WSE model. The section entitled *Hydrologic Modeling Process* explains how data from the WSE model are used for assessment of other resource areas. The WSE model does not compute or include results of the groundwater substitution analysis, agricultural production analysis, temperature analysis, or aquatic biological analyses; rather, these analyses use output from the WSE model for subsequent calculations (generally referred to as *post-processing*).

Incorporating multiple sources of information to provide the best characterization of variable surface water demands has required a synthesis of the characteristics of the following elements: 1) monthly and annual variation of crop water demand, 2) irrigation district water balance component fractions (i.e., accounting for other fates of diverted water in addition to crop needs), and 3) total annual consumptive use demands consistent with best available annual data described in Appendix F.1, *Hydrologic and Water Quality Monitoring*, F.1-24 through F.1-30. Synthesis of these data is described in the following sections.

The resulting values to represent the physical characteristic of surface water demands are very similar when compared to values used in CALSIM and the district operations models. As such, the adjustments reasonably made in the process of estimating total district demands for determining water use and availability for use are appropriate. Commenters presented additional model results that compare favorably to the WSE model with regard to water demand and diversions in the baseline condition. These results are discussed in the section entitled *Modeling Analyses Presented by Commenters.*

Determination of Surface Water Demand

Characterizing water demand is a core component of any water balance model. Water demand is the primary driver (also known as a *forcing function*) that determines how much water is diverted at times of sufficient supply to meet demand. An overly simplistic example of a demand function based on estimates of maximum demand or a single year's annual demand would not reduce diversions in years with high precipitation, and in that case a model might attempt to divert more water than would be needed. The WSE model, like recent versions of CALSIM, uses a climate-based, monthly demand function to represent changes in demand in differing hydrologic conditions.

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[16] The WSE model is available here: https://www.waterboards.ca.gov/waterrights/water_issues/programs/bay_delta/bay_delta_plan/water_quality_control_planning/2016_sed/index.shtml

Irrigation district demands in CALSIM are represented by a monthly time series of CUAW, which is another term for the evapotranspiration of water applied to crops. Based on this demand, the following components of the surface water demand water balance are added to generate the total demand at the point of diversion from the rivers:

- Regulated reservoir seepage and evaporation (collectively, losses from off-stream reservoirs).
- Deep percolation of applied water in excess of crop use.
- Conveyance and distribution system seepage and evaporation (collectively, distribution losses).
- Operational spills or return flows, which include field tailwater.

Additional demands are specified in the WSE model to represent demands that are not based on CUAW but instead are assumed at a fixed and unchanging demand in the analysis (e.g., municipal demands; further discussed in the following section on municipal surface water demand). Values used for each of the water balance fractions and demands are documented in Appendix F.1, *Hydrologic and Water Quality Modeling*, Section F.1.2.4, and Appendix G, *Agricultural Economic Effects of Lower San Joaquin River Flow Alternatives: Methodology and Modeling Results*.

A generalized geographic representation of the three major reservoirs, three tributaries to the LSJR, seven major irrigation districts and other demand areas is shown in Figure 3.2-4.

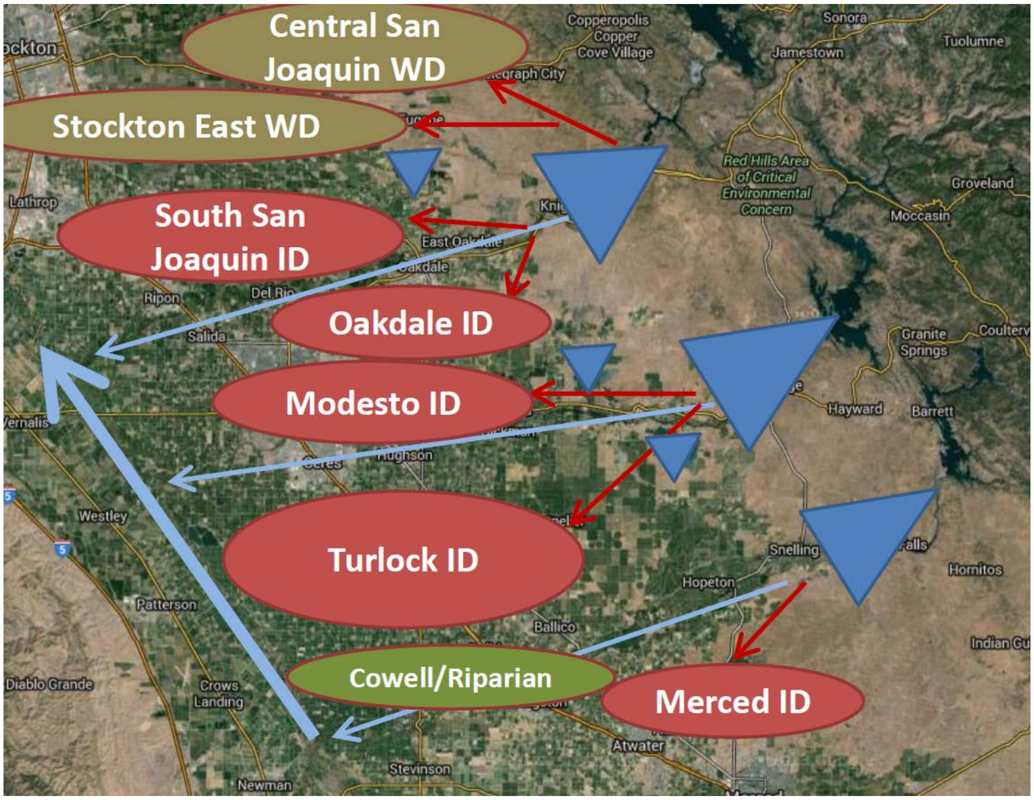

Figure 3.2-4. Geographic Generalization of Surface Water Demand Areas in the WSE Model

Crop Consumptive Use

An idealized and simple representation of total water demand for a hypothetical irrigation district could be simulated by a fixed total annual demand that varies by month. Simple models allocate water as available to meet such a fixed total demand, but in order to simulate actual variability between wet and dry years better, a more sophisticated and variable approach can be used. The WSE model is based on the CALSIM water balance, which uses a variable, climate-based crop consumptive use estimate in the form of a CUAW input from the DWR consumptive use model (USBR 2005, DWR 2005a). The consumptive use model estimates crop water demand based on acreage of each crop type and weather data for precipitation and evapotranspiration. The WSE model adapts these demands by using more recent information from AWMPs.

Variable, climate-based CUAW estimates make it possible for water balance models to represent the difference between wet years accurately, when some of crop demand is met by precipitation, therefore reducing diversion needs, and dry years, when a lack of precipitation means that the majority of crop water needs must be met through irrigation.

For example, in the CALSIM time series variable CUAW_549_PAG, which represents crops in TID, CUAW demand varies annually (Figure 3.2-5) because of differences in meteorological factors such as precipitation and evapotranspiration. Monthly values for CUAW_549_PAG are shown in Figure 3.2-6 as an example of how CUAW values also vary monthly throughout the year.

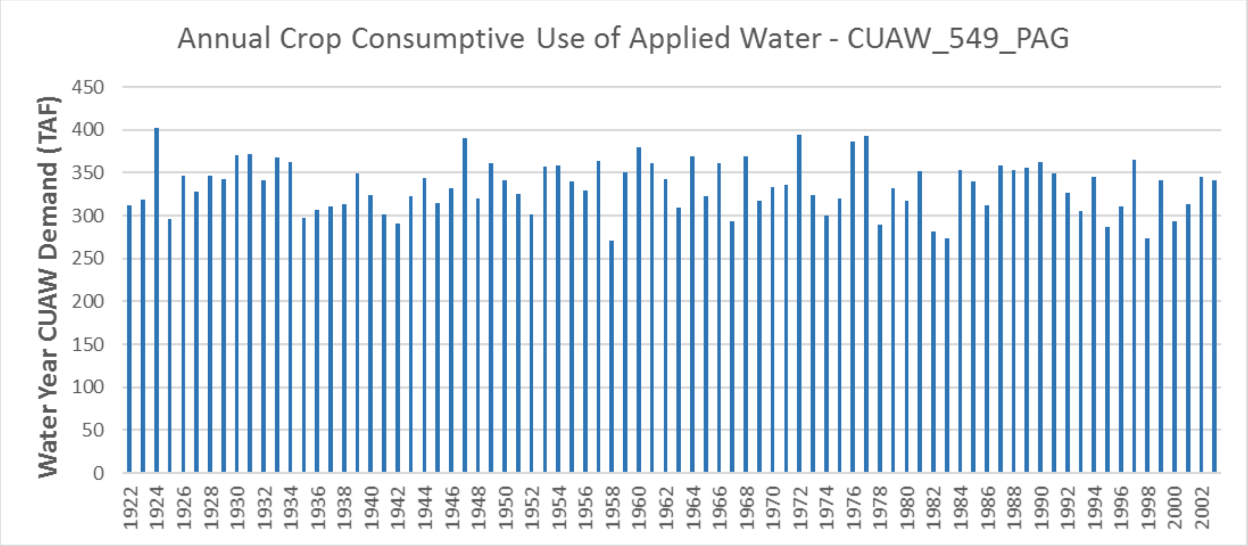

Figure 3.2-5. CUAW_549_PAG Water Year CUAW Demand for 1922–2003 from CALSIM.

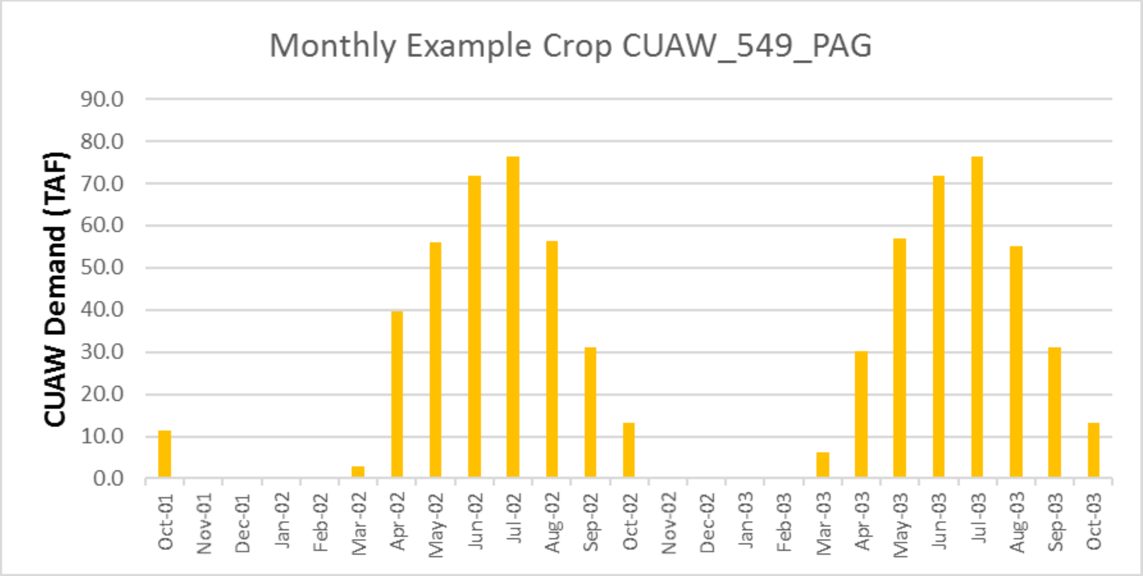

Figure 3.2-6. Example of Monthly Crop Consumptive Use of Applied Water for CUAW_549_PAG

The WSE model, like CALSIM, does not allocate water to specific crops in the model. Instead the WSE model uses CUAW as an aggregate monthly crop demand and adds the supplementary fractional components of the district water balance (derived from AWMPs), including field percolation, canal and reservoir losses, and return flows, the sum of all of which represents total surface demand. Therefore, aside from the monthly variability signal and relative magnitude of demand, the crop mix originally used for synthesizing the original CUAW time series input in CALSIM is of little consequence because the total surface demand is later adjusted. The CUAW input as applied in the WSE model is a time-varying component of the total surface demand for which diversions are allocated.

It is important to distinguish between the total surface water demand that determines the amount of water allocated and the components in irrigation districts that include, for example, distribution losses and return flows. These are used to quantify portions of the water balance such as reservoir losses (assumed constant in every year) and quantities percolated to groundwater (which vary based on quantity of surface water delivered). Crop shortages and resulting revenue effects are interpreted using output from the WSE model as input for the Statewide Agricultural Production (SWAP) model, based on a fraction of total water demand fulfilled after groundwater substitution, as described in Appendix G, *Agricultural Economic Effects of the Lower San Joaquin River Flow Alternatives: Methodology and Modeling Results*, and Master Response 8.1, *Local Agricultural Economic Effects and the SWAP Model*.

CUAW crop demand is just one portion of total surface water demand in the simplified representation of irrigation and water districts in the WSE model. For more detail, see Appendix F.1, *Hydrologic and Water Quality Monitoring*, Section F.1.2.4, *Calculation of Monthly Surface Water Demand*. Surface water demand also includes the following considerations:

- Regulation of reservoir losses.
- Deep percolation of applied water.
- Operational spills and return flows.

- Conveyance/distribution system losses.

In addition, some irrigation districts have municipal and Sphere of Influence deliveries. The combined total of each of these constituents is shown in Figure 3.2-7, including data from WSE and post-processing of model results (e.g., estimated average total groundwater use). The figure is a simplified version of the WSE model water balance components. The deep percolation and distribution loss factors are fractions of the CUAW monthly requirement that are added to represent portions of the total demand needed at the point of diversion from the rivers. The values are shown in Appendix F.1, Table F.1.2-11, *Calculation of Deep Percolation Factors and Distribution Loss Factors*.

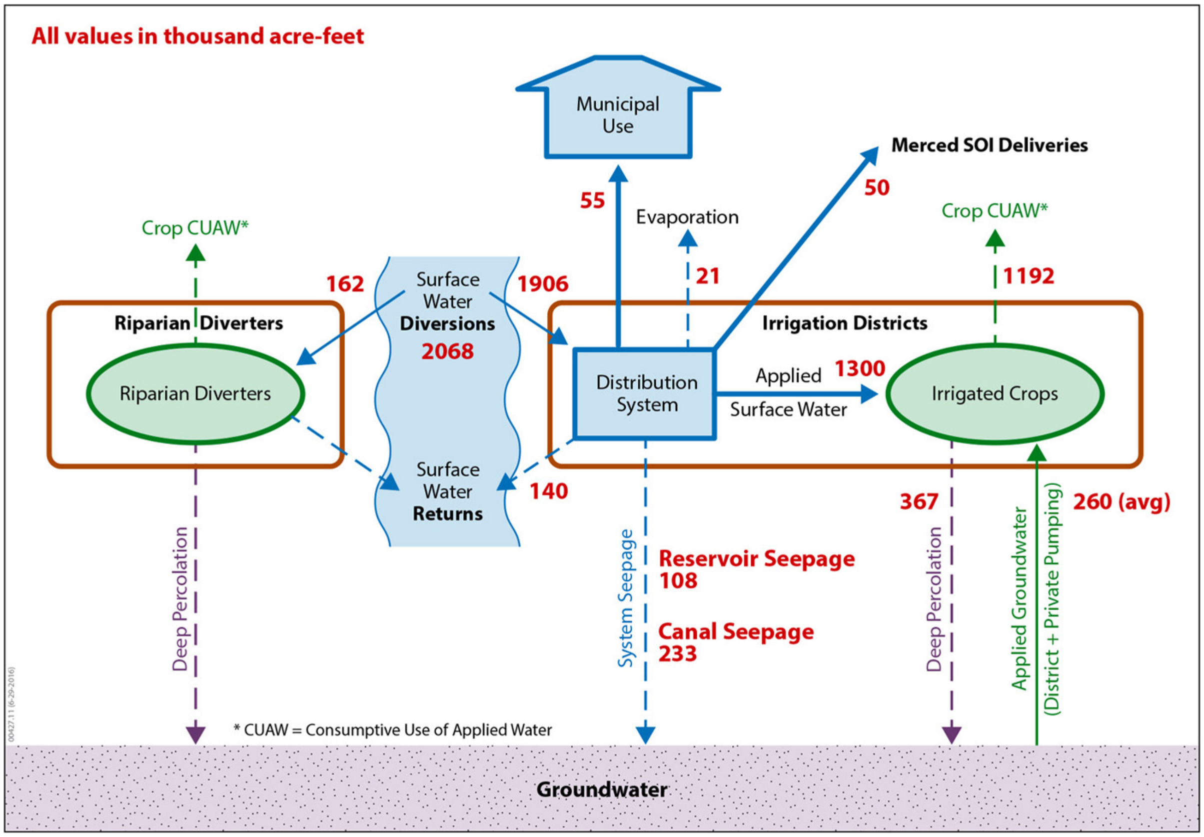

Figure 3.2-7. Average Annual Baseline Water Balance for the Combined Stanislaus, Tuolumne, and Merced Rivers below the Major Rim Dams (Source: Appendix F.1, Figure F.1.2-2)

An example of the components of total surface water demand is shown in Figure 3.2-8, which shows values incorporated from SSJID's 2012 AWMP (SSJID 2012, Table 5-1 and Table 5-13). The SSJID 2012 AWMP includes a much higher level of detail in water balances, subdivided into three subsystems: 1) main supply canal above Woodward Reservoir 2) main supply canal below Woodward Reservoir and main distribution canal system, and 3) irrigated lands. The analysis in the SED and values shown in Figure 3.2-8 and in Appendix F.1, Table F.1.2-11 are aggregated and simplified into one water balance accounting for the major components used to calculate loss fractions.

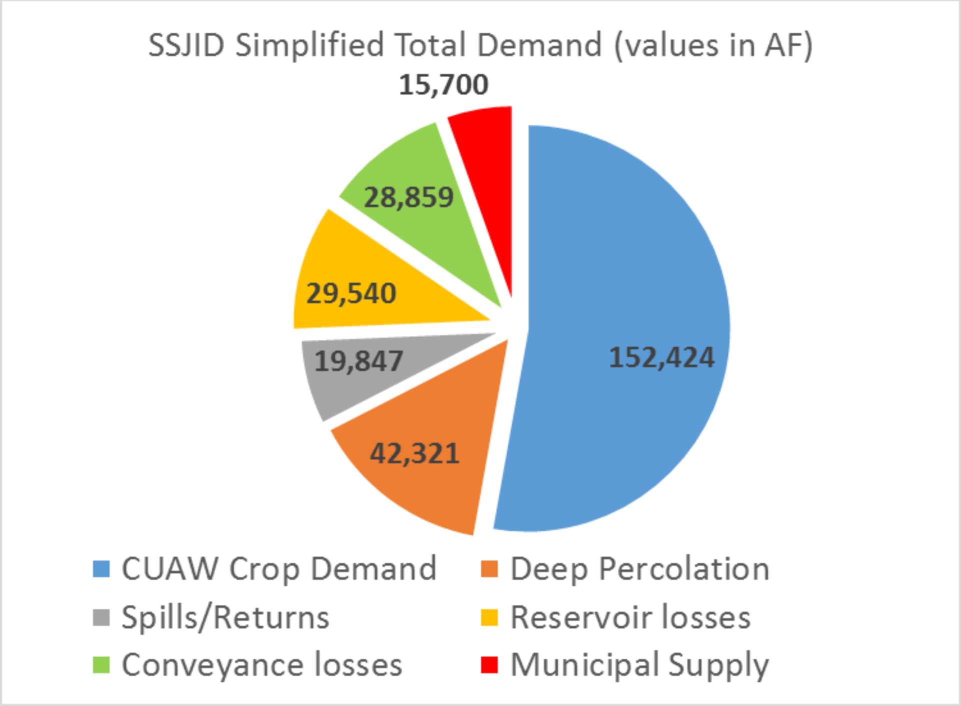

Figure 3.2-8. Example of components of Simplified Total Water Demand derived for South San Joaquin Irrigation District (after SSJID 2012) (Source: Appendix F.1, Table F.1.2-11)

Some commenters pointed out distinctions between types of district pumping: district groundwater may be pumped to canals for delivery and suffer additional losses, or drainage pumping in some cases can be reused and, in other cases, not reused in the canal system. Simplifying assumptions make the overall analysis possible considering the myriad complexities that can occur in system operation. It is necessary to tailor the varying categories of reported data into a consistent framework for the analysis.

In all districts, a limited amount of groundwater is used to meet some amount of crop CUAW and percolated fraction of applied water in all years. In SED documentation, this is referred to as *minimum groundwater pumping*; i.e., used in all years. CALSIM refers to this quantity as *nominal pumping* (USBR 2005). These values are shown in Appendix F.1 Table F.1.2-13. Minimum groundwater pumping is assumed to be applied to fields to meet CUAW with the same deep percolation fraction as conveyed surface water.

CUAW crop demand changes from year to year and from month to month. The demand components for distribution system losses and deep percolation of applied water are assumed equal to the derived percentages of applied water from AWMPs. The distribution loss and percolation fractions are derived from the simplified example, as shown in Appendix F.1, Table F.1.2-11, and applied based on the time series of adjusted CUAW to formulate the total surface water demand for each month after deducting the minimum groundwater pumping.

This is analogous to the CALSIM procedure for total demand, except the estimates of distribution losses and percolation are much more precise in the WSE model. CALSIM assumes, for many districts, that deep percolation is 30 percent and canal losses are 10 percent (USBR 2005) because AWMP data were not available at the time CALSIM was developed. The method used in the WSE model is the best way to incorporate the newly available characterizations of district water balances into the demand components of the SED analysis.

Regulating reservoir losses refer to water percolated or evaporated from the three sizable off-stream reservoirs operated by the districts: Woodward Reservoir, a 36-TAF impoundment built in 1916 by SSJID; Modesto Reservoir, of 29-TAF capacity built in 1911 by Modesto Irrigation District (MID); and Turlock Lake, with a capacity of 45.6 TAF operated by TID. Estimates of losses from these reservoirs differ in available sources, which include CALSIM, AWMPs, district operations models, and information request responses. Estimates used in WSE model district water balances are shown in Table F.1.2-12.

Values for return flows, also known as operations spills and returns, are taken directly from CALSIM time series and not modified in either baseline or alternatives, to preserve the global water balance without introducing additional complications from changes in these values. Quantities of diversions that return to the river as well as off-stream regulating reservoir losses are the first quantities deducted from the amount diverted. Some commenters asserted that return flows would decrease based on changes in district efficiencies in LSJR alternatives. Such changes are speculative and would have the effect of reducing overall demand.

Municipal Surface Water Demands

The WSE model includes assumptions of surface water deliveries of 30 TAF annually from MID to the City of Modesto, and 15.7 TAF annually from SSJID to the Degroot Water Treatment Plant for delivery to the cities of Manteca, Lathrop, and Tracy. These values represent 2009-era existing conditions for baseline that are well documented in district AWMPs (MID 2012, SSJID 2012). These amounts for municipal delivery are assumed not to change in the WSE model scenarios for the LSJR alternatives for two reasons. First, the amount of municipal supply is relatively small compared to agricultural diversion and use. Second, precise determinations about reductions in supply would be speculative and would depend on either existing or future agreements with the irrigation districts. For the purposes of the modeling analysis, these values do not change. The SED recognizes that impacts on domestic supply could occur and makes the programmatic determination that significant reductions could be experienced. The SED states in Chapter 13, *Service Providers*, “Service providers that rely heavily or primarily on surface water diversions to supply water to their service areas could experience significant reductions in water supply, depending on the various factors described above (i.e., mechanism by which they receive the water, existing policies, regulations, and the type of water use they supply)” (p.13-61).

Commenters raised several issues related to assumptions of municipal supply: first, that the impacts of shortages to municipalities are not adequately considered; second, that the SED does not consider planned future levels of surface water demand; and third, that impacts on groundwater because of municipal shortages are not adequately considered. The WSE model assessed water supply effects by estimating irrigation district demand and holding municipal uses constant. Reductions in available water supply described by the WSE model are characterized as reductions to irrigation water supply. While the potential for, and significance of, reductions to municipal water supplies are recognized in the SED, the WSE model does not simulate changes to this comparatively small fraction of overall demand. If a municipality were to receive a reduction in surface water based on the mechanism(s) it uses to obtain water (e.g., contract with an irrigation district), the reduction to agricultural deliveries would be smaller than that estimated in the LSJR alternatives.

The State Water Board recognizes that municipalities have various mechanisms (e.g., contracts, negotiated agreements, water rights) in which to obtain water supply (Chapter 13, Section 13.4.2, *Methods and Approach, LSJR Alternatives, Surface Water Supply*, and Chapter 20, *Economic Analyses*, Section 20.3.3, *Effects on Municipal and Industrial Water Supplies and Effects on Regional Economies*). The State Water Board also recognizes the unique circumstances of each service provider and acknowledges that because of these unique circumstances the State Water Board cannot predict the actual responses of each service provider. As such, the State Water Board did not model municipal demand or specific impacts on individual municipalities. However, the State Water Board uses the results of the potential surface water supply reductions calculated by the WSE model (Chapter 13, Table 13-14) and information on the various mechanisms service providers use to obtain water to qualitatively evaluate the potential effects on service providers (Section 13.4.2). The SED describes potential impacts on service providers in Chapter 13 and Chapter 17, *Cumulative Impacts, Growth-Inducing Effects, and Irreversible Commitment of Resources*.

The SED appropriately focused on impacts on existing conditions rather than future conditions. Please see Master Response 2.5, *Baseline and No Project*, for how the baseline characterizes the existing environment at the time of the 2009 Notice of Preparation. It would be speculative to make specific determinations of how irrigation districts might change deliveries to municipal suppliers in their communities that can rely both on surface and on groundwater conjunctively. The higher market value of municipal water supply suggests that it would be unreasonable to assume that the trend toward irrigation districts providing more surface water to municipal service providers would be reversed suddenly by implementation of the plan amendments.

If a municipality relies on groundwater as a reaction to reduced surface water availability, such impacts would not be additive to groundwater pumping already considered for the groundwater basin because of additional pumping, and estimated in Chapter 9, *Groundwater Resources*, and Appendix G, *Agricultural Economic Effects of Lower San Joaquin River Flow Alternatives: Methodology and Modeling Results.* The groundwater analysis (based on additional analysis of WSE results and groundwater pumping capacities) assumes that baseline levels of surface water would remain available for municipalities and attributes all surface water shortage to the irrigation districts, which is often offset by compensating groundwater pumping. As stated previously, the reason for this assumption is that the municipal share of surface water is a comparatively small portion of overall water use and is considered an important component in the analysis. Characterizing the exact nature of changes to municipal supplies of surface water would be speculative. If a portion of surface water shortage were shifted on par from irrigation districts to municipalities, such change in impact on the groundwater basin could then be attributed to municipalities rather than the irrigation districts but would not cause significant additional changes in regional groundwater supply in the basin.

Operations Models

CALSIM total diversion demands for the major irrigation districts were checked against other sources of data to ensure the best representation of the existing environment. It is difficult to take a snapshot of gross total demand because it changes from year to year. The WSE model uses CALSIM CUAW demands as a guide to the monthly and annual variability of crop water demand. However, the internal irrigation district components and loss fractions were modified and refined based on data from AWMPs. For this reason, the total demand was adjusted and validated with best judgment within the range of recent historical data and other operations models. WSE model diversion values show close agreement to diversion values produced by irrigation district models.

Recent historical data is published in AWMPs for total annual diversions for a small number of years, depending on the district. These short records do not provide a full-enough picture of demand over various conditions and water year types. The water balance models developed and endorsed by the districts for operations planning represent the best characterization of diversions over multiple decades to validate total water demand. Such models have been presented by OID/SSJID in the process of developing a revised New Melones Plan of Operation (SJTA 2012), by MID/TID as a part of the FERC relicensing process for the Tuolumne River (MID/TID 2013), and by Merced ID as a part of the FERC relicensing process for the Merced River (Merced ID 2015). These three models contain many assumptions and formulae for their unique purposes. However, the characteristics of each model's series of diversions are the components of primary interest for the purposes of SED analysis because these show each district's total diversion needs in baseline. This process is described below and in Appendix F.1, *Hydrologic and Water Quality Modeling*, Section F.1.2.4, *Calculation of Monthly Surface Water Demand*. Ultimately, the WSE model uses the total surface demand to determine the maximum diversion to allocate if ample supplies are available and if not limited by other formula (e.g., 1988 Agreement for the Stanislaus River). The values of the components are important to other parts of the analysis such as net groundwater balances and fraction of delivered water that meets crop needs, both of which are calculated in separate analyses.

Diversions in district operations models reveal total water demands in times of sufficient availability, with the distinction that at times where sufficient supply is not available, then diversion differs from demand. Appendix F.1, Section F.1.2.4, *Calculation of Monthly Surface Water Demand*, characterizes diversions from the perspective of observed canal gage data, CALSIM, operations models, AWMP data, and the two modes of the WSE model. Maximum, 75th, and median percentile statistics for each series represent slightly differing perspectives of baseline diversions when supply is sufficient to meet demands. Minimum diversions generally represent the amount diverted in shortage situations when supply is insufficient. These characteristics are shown in Appendix F.1, Tables F.1.2-16, F.1.2-17, and F.1.2-18, and Figures F.1.2-3, F.1.2-4, and F.1.2-5.

Close agreement can be seen in the time series of WSE model and district operations models for the Stanislaus, Tuolumne, and Merced Rivers in Figures 3.2-9 through 3.2-11. There are slight variations in totals between models in most years, with exceptions in how the models handle shortage situations (e.g., 1992). Overall, the match for total demand is a very close fit.

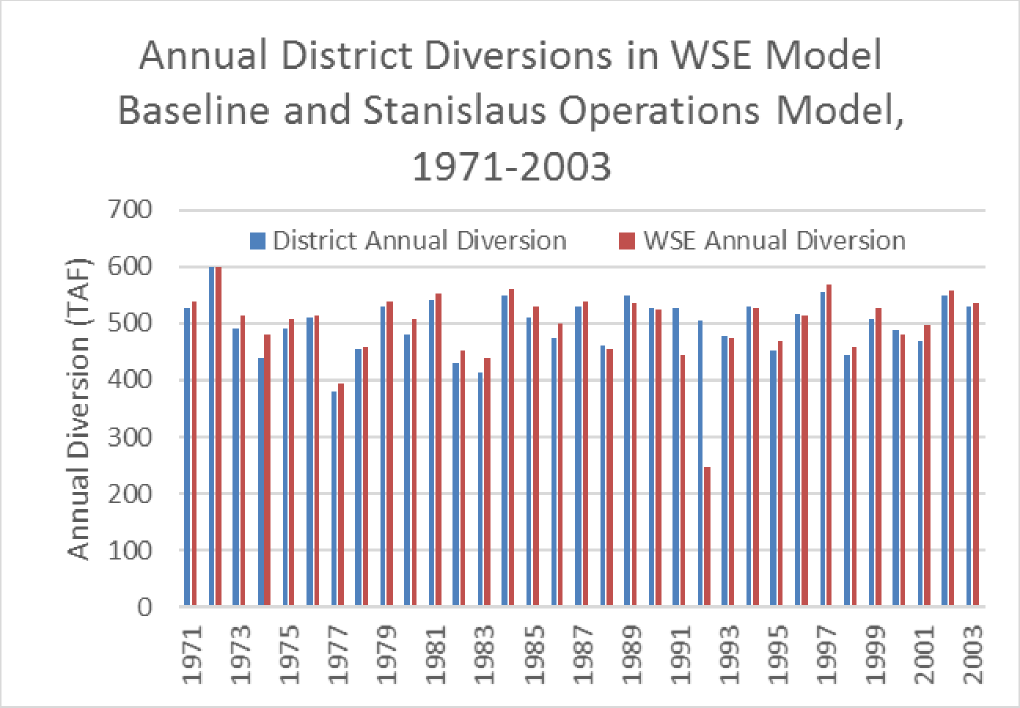

Figure 3.2-9. Comparison of District Diversions for OID/SSJID in WSE Model and Stanislaus Operations Model (Source: SJTA 2012)

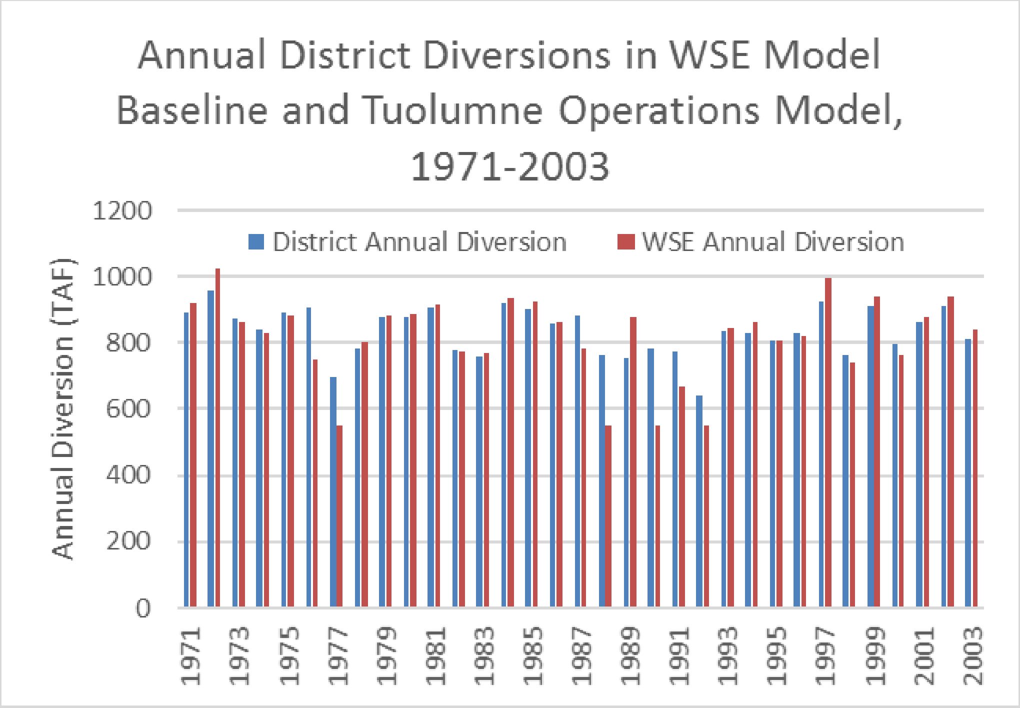

Figure 3.2-10. Comparison of District Diversions for MID/TID in WSE Model and Tuolumne Operations Model (Source: MID/ TID 2013)

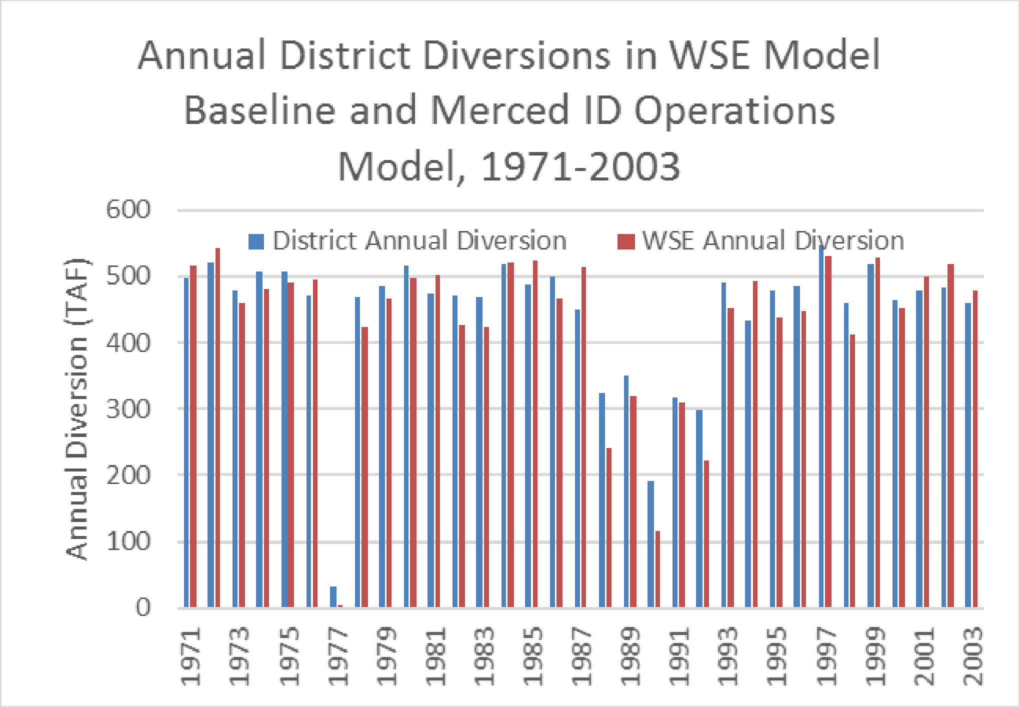

Figure 3.2-11. Comparison of District Diversions for Merced ID in WSE Model and Merced Operations Model (Source: Merced ID 2015)

The three graphs in Figures 3.2-12 through 3.2-14 show the same data in exceedance plot format showing maximum, minimum, median, and distributions comparing model diversions for each operations model and the WSE model. These figures demonstrate excellent agreement for maximum and median diversions. Each point in the plot represents one water year of diversion, rank-ordered from highest year to lowest.

Differences between the models in the few driest years (data points toward the right side of the below graphs) represent differences in model allocation schemes and allocations in shortage situations (see section entitled *Hydrologic Modeling process, Surface Water Allocation: Streamflow versus Demand versus Storage*, for an explanation of water allocation by models). However, the total irrigation district demand can be characterized by the operations model allocations in the majority of years other than in shortage situations, such as the maximum and median years, and the variability across the spectrum of years from maximum to approximately 20 percent exceedance, depending on the river. This altogether represents 80 percent of years and incorporates the observation that shortage conditions, when demand cannot be met, are incurred in less than 25 percent of years in baseline conditions. These annual values and the rank-ordered exceedance values that follow demonstrate that irrigation district demands in the WSE model baseline are very similar to those in the district operations models.

Appendix F.1, Table F.1.2-15 shows the adjustment factors applied to CUAW that were used to adjust total demands in the model baselines shown for WSE model baseline.

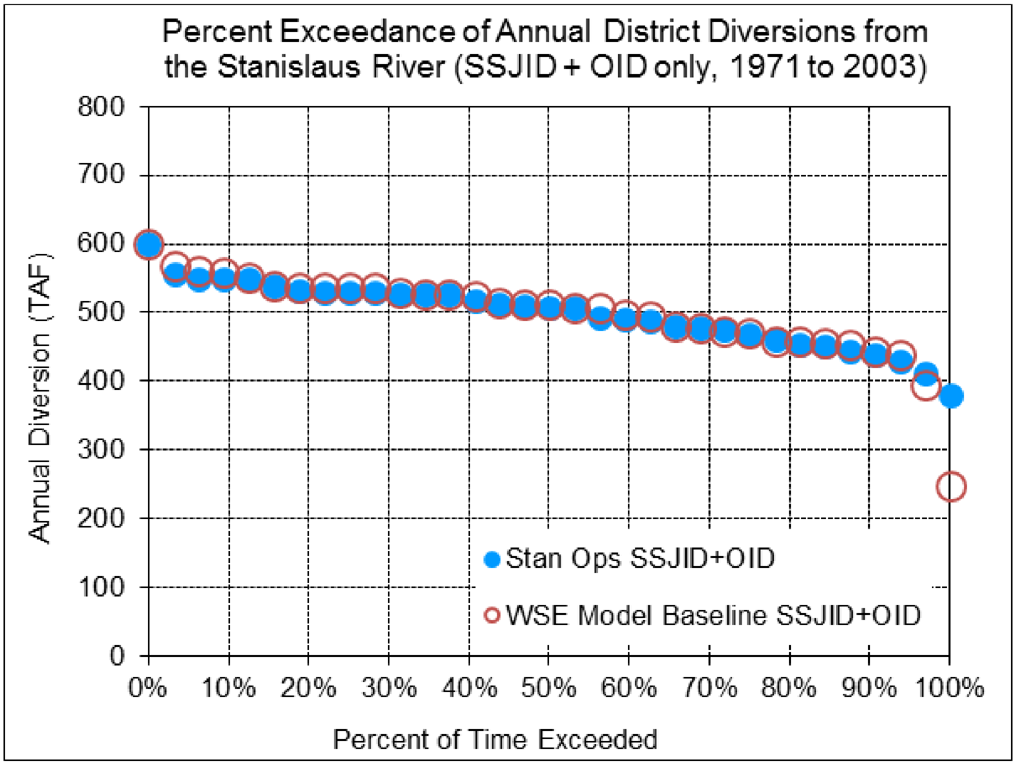

Figure 3.2-12. Percent Exceedance of District Diversions for OID and SSJID in WSE Model and Stanislaus Operations Model, 1922-2002 (Source: SJTA 2012)

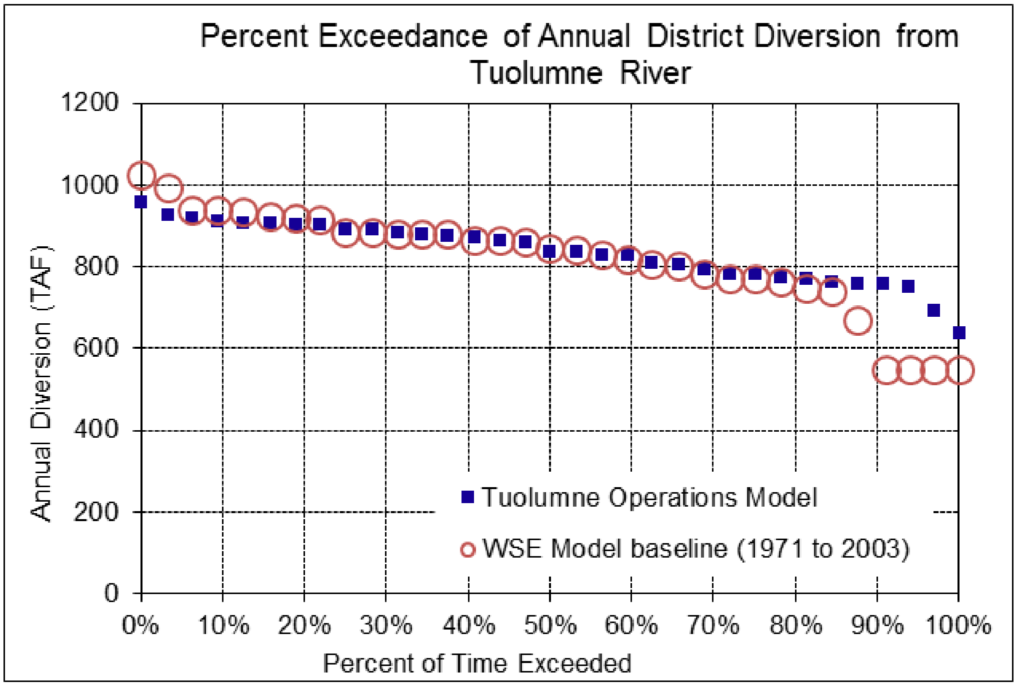

Figure 3.2-13. Percent Exceedance of District Diversions for MID/TID in WSE Model and Tuolumne Operations Model, 1971-2003 (Source: MID/TID 2013)

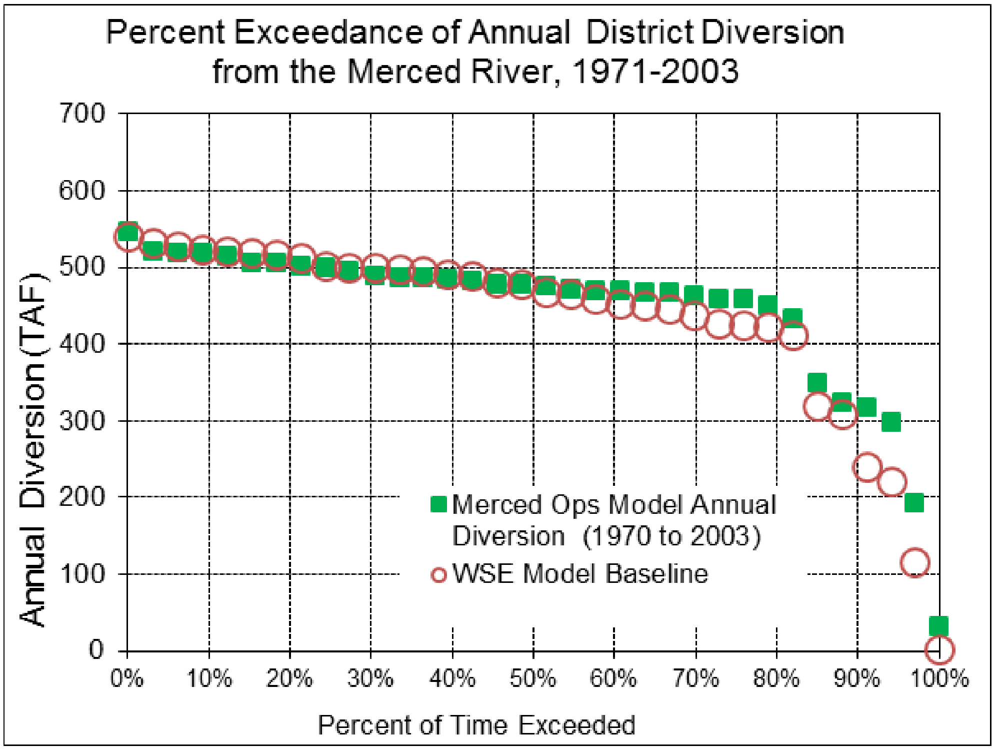

Figure 3.2-14. Percent Exceedance of District Diversions for Merced ID in WSE Model and Merced Operations Model, 1971–2003 (Source: Merced ID 2015)

Accretions and Depletions

As illustrated in Figure 3.2-3 in the section entitled *Model Implementation of Percent Unimpaired Flow Objectives*, accretions of local inflows downstream of the reservoirs and downstream of the unimpaired flow index measuring location can contribute to meeting the percent unimpaired flow objective at the downstream compliance point. Effectively, this means that the flow required to be released from upstream reservoirs may be more or less depending on the amount of local inflow.

In a general example of any river or stream, net changes in flow between two points result from the combination of the addition of local tributary streams and groundwater seepage inflows and the subtraction of any losses, which may be due to diversions, riparian uptake, seepage through the stream bed into groundwater, or potentially evaporation. These net changes are often referred to as *accretions and depletions.* A stream where flows are accreting is known as a *gaining* stream, and a stream where depletions exceed any accretions is often called a *losing* stream. This dynamic process can be highly variable over time and space, and from month to month and year to year.

With accreting flows, which can consist of inflows from tributaries such as Dry Creek in the lower Tuolumne River watershed, the *water cost* (the amount to be released from a reservoir) may be less than the percent of unimpaired flow objective. For example, if in a given month, Dry Creek and other accretions were flowing at a rate equal to 10 percent of the estimated unimpaired flow at the index location upstream, if the flow objective were 40 percent of the unimpaired flow, then 25 percent of the requirement would be met by flows from Dry Creek, and the water cost of New Don Pedro Reservoir releases would only be 30 percent of the unimpaired flow. In this example, the 40 percent unimpaired flow objective is partially met by the local inflows.

Commenters observed that because these savings are accounted for in the WSE model, which incorporates estimates of local inflows, the impacts analysis would be sensitive to long-term changes in these inflows. Commenters claimed that local inflows have declined over the past few decades, and particularly post-2003, and suggest that this would indicate a need to use an updated model to account for recent changes in dynamics of the system. Furthermore, some commenters elaborate that using the local inflows in the WSE model, which are based on the CALSIM water balance 1922 through 2003, would at times underestimate the water supply effects if local inflows were actually decreasing in recent years. This is because, in the absence of local inflows, the water cost of releases would be closer to the nominal percent of unimpaired flow, and the resulting supply shortfalls could be marginally greater and more frequent. Figure 3.2-15 illustrates the mechanism by which supply could be affected based on changes in local inflows. This figure compares a local inflow accounting for 10 percent of unimpaired flow (A) with local inflows accounting for 5 percent of unimpaired flow (B). This shortfall requires additional reservoir releases to account for this change in local inflows. The UF Index Location indicates the point of estimation of unimpaired flow on which the flow objective is based.

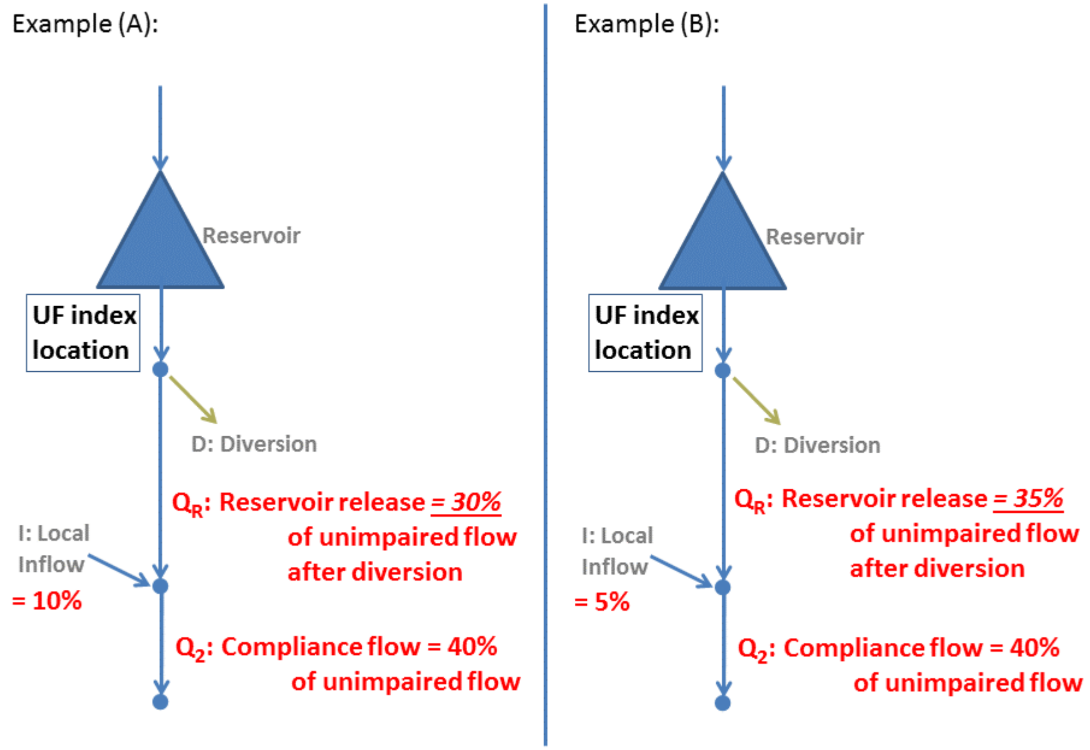

Figure 3.2-15. Examples of Required Reservoir Releases as a Function of Local Inflows

In the simplified example of Figure 3.2-15, although the flow objective is 40 percent of unimpaired flow in both (A) and (B), it makes a difference whether local inflows amount to 5 percent or 10 percent of unimpaired flow measured at the upstream location. The prior section describing unimpaired flow objectives clarifies how the upstream location is the appropriate location to determine the index for such objectives. The WSE model estimates the water cost based on the local inflows based on best available data of the CALSIM water balance and 1922–2003 period and efficiently requires reservoir releases only as necessary to meet the objectives.

Commenters claimed that it would be "problematic" to consider a compliance point downstream given travel time of a day or more from the release location, implying that it would be difficult to operate to meet flow objectives without being able to anticipate accretions of local inflows. However, the program of implementation describes a 7-day average flow as the basis of compliance with the flow objectives. Operators would have a week to adjust release flows to changing conditions based on real-time flow and precipitation data and forecasts.

Commenters also presented some hydrologic data to describe recent years and purported changes in local inflows and accretions. These data, presented in letters from Merced ID and MID/TID, are characteristically highly variable from year to year. Merced ID suggests there are trends since 2003 in the frequency of dry years, as shown in unimpaired flow values, lower annual accretions, and lower monthly accretions in the Merced River. Merced ID also claims that the Merced River has become "a losing river on an annual basis, with the exception of wet years such as 2005, 2006, and 2011." However, because of the high variability in these data, it would take many years of observations to draw robust conclusions about such trends.

The CALSIM II water balance, including accretion estimates for all three rivers used in the WSE model, is the most appropriate and long-standing information available at the time of the analysis, and is sufficiently credible to make reasonable impact assessments in the SED. Regarding comments specific to the Tuolumne River, the CALSIM monthly accretions are based on a gage comparison, where data is available, and represent the actual accretions in the river. The accretion flows in the WSE model are considered reliable for the 1922–2003 period used to determine baseline and as used for comparative purposes.

The courts have acknowledged the challenges in characterizing environmental conditions, particularly under conditions of high variability.[17] "Environmental conditions may vary from year to year and in some cases it is necessary to consider conditions over a range of time periods."[18] This can include making a determination regarding the available information and data that best depict the environmental setting for a particular resource that will inform decision-making. For example, a lead agency may elect to use older data that is consistent across geographies and sources, rather than less consistent data. Thus, it is within the State Water Board's discretion to decide how existing physical conditions can most realistically be measured, as long as their determination is supported by substantial evidence.

Comments expressed concern that accretions in the WSE model have been overestimated, which, comments further asserted, will produce results that underestimate the potential water supply effects of the LSJR alternatives. Some commenters expressed concerns about declining accretions in a highly variable water supply period based on a comparison to results from the extended period of analysis, not the 1922–2003 period of evaluation for the WSE model. Some commenters used general statements to summarize the amount of the flow requirements that could be satisfied by the accretions, stating that 20 percent of the 40 percent unimpaired flow requirement could be met by the accretions and, if underestimated, this would lead to under-reporting the impacts. Given that the

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[17] *Save Our Peninsula Committee v. Monterey County Bd. of Supervisors* (2001) 87 Cal.App.4th 99, 125; *Communities for a Better Environment, supra*, 48 Cal.4th at pp. 327-328.

[18] *Save Our Peninsula Committee,* supra, 87 Cal.App.4th at p. 125.

SED uses a comparative analysis to determine impacts, it is likely an error in accretions would not result in significant changes to the effects and result in the same impact determination.

As described in the SED, Alternative 3 evaluates a range between 30 and 50 percent of unimpaired flow, with 40 percent as the starting percentage of unimpaired flow. Accretion flows to the lower Tuolumne River can account for a significant fraction of compliance with the flow objective. The analysis of Alternative 3 encompasses the trend suggested by the commenter because, historically, drought periods have resulted in decreased accretions. If the trend in reducing accretions continues after the recent drought period and does not rebound, proportionally increased releases from New Don Pedro Reservoir would be required. In this case, the effects are still captured in the SED's analysis and the significance determinations related to Alternative 3 would remain.

Comments specifically addressing accretions on the Tuolumne River are based on a highly volatile evaluation period that does not represent the frequency and range of hydrologic conditions experienced in the plan area. This period contains several of the driest years on record and a few of the wettest years. Figure 3.2-16 shows unimpaired flow in 15-year periods from 1985 to 2000 (graph 1) and from 2000 to 2015 (graph 2) (Modesto flows subtracted from La Grange flows). [19] The commenters used the second period to support their assumption. The first period contains both extreme drought and wet periods; however; the 5-year total runoff shows that the overall water balance rebounded by the end of the 15-year period. The second period from 2000 to 2015 also contains both extreme drought and wet periods; however, the water balance does not appear to rebound fully by the end of the period. Additionally, the first part of each 15-year period shows decreasing accretions in the gage calculation. This shows that the modeled period already encompasses the effect of reduced accretions during extended drought periods.

Flows from Dry Creek to the Tuolumne River, which likely make up a large portion of the accretion in wet years, are properly represented by data used to create the CALSIM II accretions on the Tuolumne River. Although it is likely that irrigation and water districts have increased water conservation and agriculture is becoming more efficient, the data presented in the comments is not specific to conservation efforts and is solely based on the difference in flow at the two gages. The source of this difference could be driven by climate variability more than irrigation efficiency. The commenters did not rule out the potential that trends in water year type conditions are the primary drivers of the stated accretions, and thus it is possible that accretions will rebound as they did after the 1990s drought.

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[19] Model accretions in the WSE model up to 2003 are from the CALSIM water balance. Note that after water year 2003, results from the extended WSE model period, which incorporate estimates of accretions shown, were not used in the SED analysis, but were used for illustrative purposes in Chapter 21, *Drought Evaluation*, and in this section.

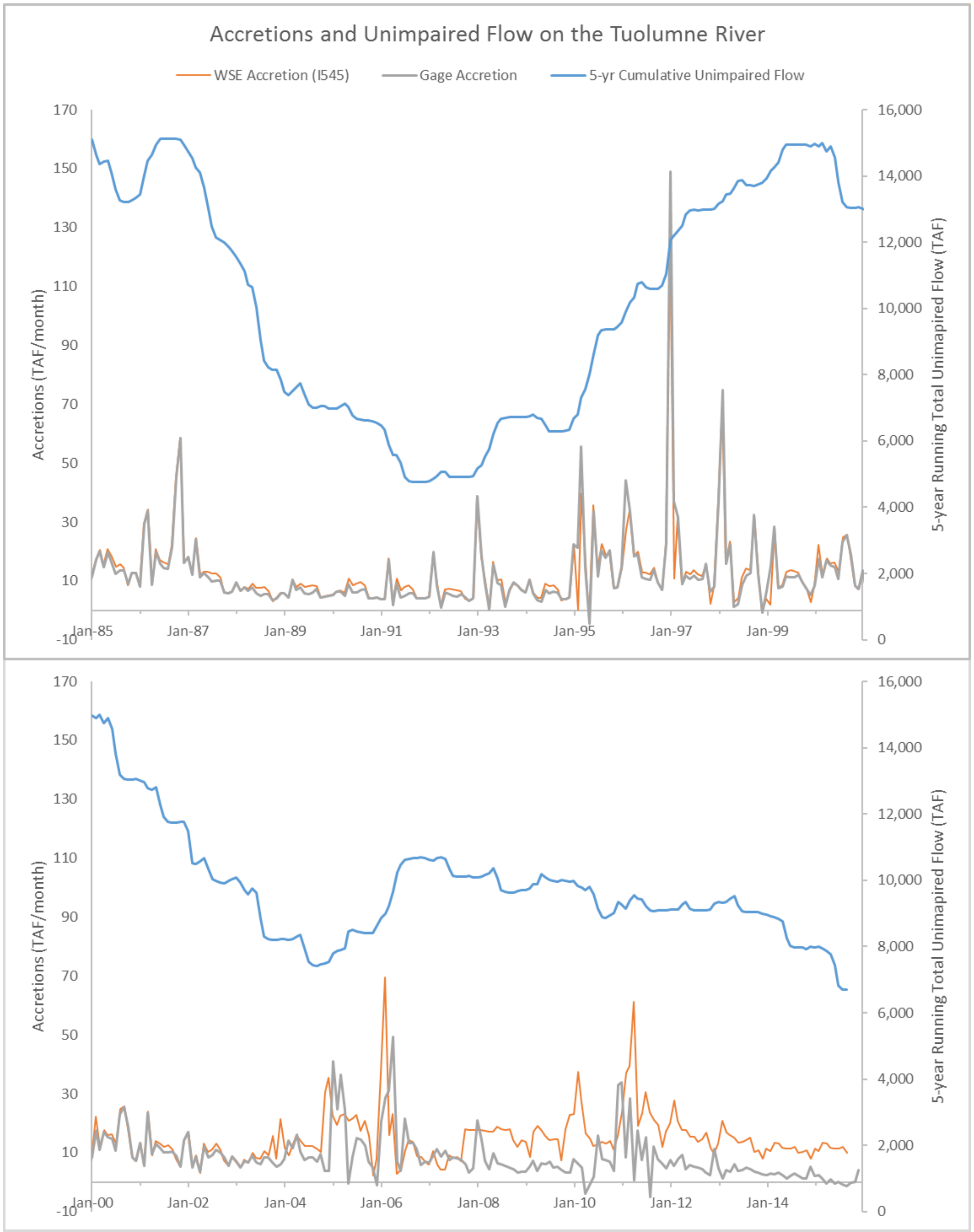

Figure 3.2-16. Monthly WSE Model and Gage-Calculated Accretion on the Tuolumne River for Two 15-Year Periods

The comments related specifically to accretions on the Tuolumne River are not based on the full period of analysis used in the SED. The commenters compared gage calculated accretions (by subtracting the flow at Modesto from the flow at La Grange) to accretions used in the WSE model presented in Chapter 21, *Drought Evaluation,* for a period from 2006 to 2015 used in the extended period of analysis. The two values are not comparable because the values in the extended period of analysis are based on surrogate years from the historical record and do not represent the 82-year period analyzed in the SED. Additionally, the SED uses accretions and depletions from CALSIM that are also calculated using gage comparisons (upstream versus downstream). The gage comparison used for CASLIM is identical to the gage comparison in comments related to the Tuolumne River for all years except the 2006 to 2015 extension period shown in the comment.

Groundwater Supplementation

A minimum level of groundwater pumping is assumed to occur in each irrigation district, either because the surface water distribution system does not reach some areas, or because the timing of diversions does not meet the growers needs, or due to other factors (Appendix F.1, *Hydrologic and Water Quality Modeling*, Section F.1.2.4, *Calculation of Monthly Surface Water Demand*). Minimum groundwater pumping is estimated based on data from the AWMPs published by the irrigation districts and directly from irrigation districts (Appendix F.1 Table F.1.2-13, *Annual Minimum Groundwater Pumping Estimates for Each Irrigation District*). Estimates based on the identified sources are adequate and sufficient for the purpose of the SED, which is a programmatic assessment. The minimum groundwater pumping amounts are those likely to occur each year regardless of water year type. However, in the WSE model in a few months in certain years, the estimated applied water demand is less than the minimum groundwater pumping for that month, so the minimum groundwater pumping is reduced to prevent demands from being over-satisfied.

Total district surface water demand along each tributary is determined as the sum of CUAW crop demand, deep percolation fraction, distribution losses, operations spills and returns, municipal and industrial surface water demands, and regulating reservoir seepage (Appendix F.1, Section F.1.2.4). Minimum pumping levels are subtracted from CUAW demand because the irrigation districts fulfill a portion of applied water demand by maintaining a certain minimum level of groundwater pumping in all years.

The groundwater impact analysis was not conducted within the WSE model. The groundwater impact analysis is a spreadsheet evaluation using outputs from the WSE model, primarily percentage of demand met by surface applied water; information extracted from various agricultural water management plans; and information provided by the irrigation districts.[20] Please see Appendix G, *Agricultural Economic Effects of the Lower San Joaquin River Flow Alternatives: Methodology and Modeling Results* for detailed description of the methodology and assumptions adopted in the groundwater impact analysis, including a complete list of inputs to the WSE model.

As discussed in Appendix G, Section G.2.2.3, *Additional Groundwater Pumping*, when minimum groundwater pumping and applied surface water are sufficient to meet crop demand, then no additional groundwater pumping is needed. When minimum groundwater pumping and applied surface water are not sufficient to meet crop demand, additional groundwater pumping is applied up to the maximum pumping level (estimated capacity). A high value for maximum groundwater pumping can reduce potential for agricultural water shortage, but it increases the potential for groundwater impacts. The amount of additional groundwater pumping required is calculated as either the remaining applied water demand after applying surface water and minimum

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[20] This spreadsheet evaluation, *Ground Water and Surface Water Use Analysis*, is available at https://www.waterboards.ca.gov/waterrights/water_issues/programs/bay_delta/bay_delta_plan/water_quality_control_planning/2016_sed/index.shtml.

groundwater pumping, or the difference between minimum and maximum groundwater pumping, whichever is smaller.

The SED uses historical 2009 levels of groundwater pumping for the baseline analyses. Moreover, the SED considers the increased use of substitute pumping and expansion of pumping capacities during the more recent drought. Additional analysis of more recent drought conditions based on 2014 levels of substitute pumping are included in Appendix G, Table G.2-4. The 2009 values are the maximum annual district and private groundwater pumping estimates presented in each district's respective AWMP (SSJID 2012; OID 2012; MID 2012; TID 2012; Merced ID 2013), while the 2014 estimates primarily are sourced from the districts' responses to the September information request letters (Rietkerk pers. comm.; Knell pers. comm.; Hashimoto pers. comm.; Sayler pers. comm.). The 2014 maximum groundwater pumping estimates are greater than the 2009 maximum groundwater estimates, except for Merced ID.

The Merced ID information request response (Eltal pers. comm.) did not report an estimate of the district's groundwater pumping capacity; therefore, Merced ID is assumed to have the same groundwater pumping capacity in 2014 as in 2009. This is reasonable because Merced ID had well-developed groundwater pumping capabilities in 2009, and it is unlikely that they significantly increased their capacity within 5 years. For further explanation on the estimate of the 2009 and 2014 levels of pumping, please see SED Appendix G, Section G.2.2.3 and Master Response 3.4, *Groundwater and the Sustainable Groundwater Management Act*.

The 2012 Draft SED analyzed both the scenario of full replacement of crop water shortages by groundwater and the effects of no replacement, which maximized assessments of the possible effects for both endpoints. As such, the 2012 Draft SED did not attempt to determine the most likely surface water storage reoperation and groundwater replacement response (*Executive Summary*, Section ES11.3, *Groundwater and Water Supply Assumptions, and the Associated Use of the SWAP Model)*. The 2016 Recirculated SED determines a likely level of groundwater replacement (2009 and 2014 infrastructure), surface water storage and reservoir reoperation, and quantity of surface water deficit not replaced by additional groundwater pumping. Although this estimate is intended to reflect the most likely balance between water supply deficit and additional groundwater pumping, the precise balance that will occur cannot be known (see Master Response 2.5, *Baseline and No Project* and Master Response 3.4, *Groundwater and the Sustainable Groundwater Management Act*, for a description of SGMA and information regarding SGMA, the baseline and the plan amendments).

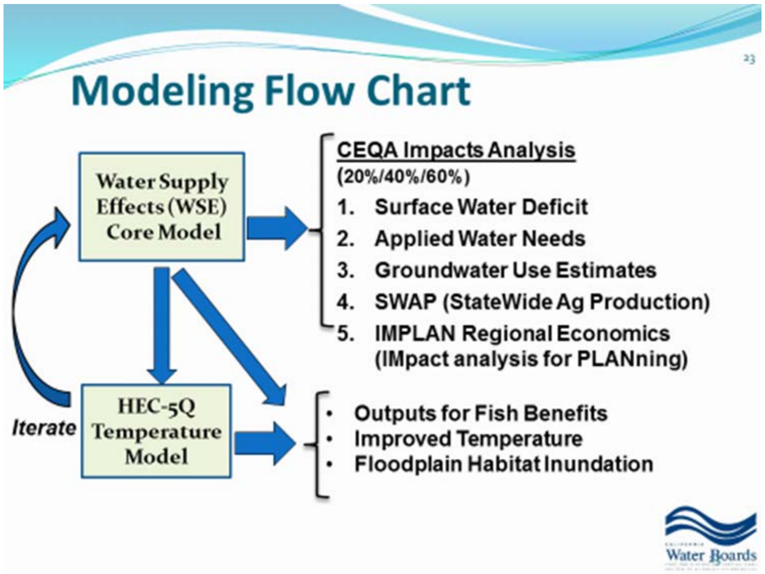
Hydrologic Modeling Process

This section describes which models are used in the SED, how they are used, and how they relate to one another. Commenters suggested that some readers do not understand the hydrologic modeling process. Commenters indicated confusion regarding information that the WSE model generates and information that is generated by other models to assess potential effects and impacts of the plan amendments. Several different models were used and each of those models may require multiple calculations to generate results, which are then used to assess potential effects of the LSJR alternatives.

The WSE model evaluates the effects on water supply for consumptive uses and instream flows under baseline conditions and the LSJR alternatives. Not all environmental effects evaluated in the SED rely on data generated by the WSE model. The WSE model contains the information necessary to estimate changes to the water balance. This includes reservoir operations, water diversions, consumptive use demand, and instream flow requirements. Hydropower generation is dependent on reservoir storage and flow released through turbines; therefore, the hydropower calculations are linked to these two variables and are contained in the WSE model spreadsheet.

Outputs from the WSE model are processed and used in additional calculations and by other models (e.g., the temperature model, groundwater substitution analysis, and agricultural production model) to assess potential effects on those resources and produce potential impact summaries for comparative analysis.

Figure 3.2-17 was presented as part of the extensive outreach on the SED and in the public technical workshops held on December 5 and 12, 2016. It was used to explain how the models and analyses are used in the SED to determine water supply, aquatic life, and economic effects of the project. The figure shows how each model builds on output from the WSE model and which resources areas and impacts are directly dependent on results from the WSE model. The IMPLAN regional economic model is dependent on output from the SWAP model, which is dependent on output from the WSE model and the AWMP crop mix information. Aquatic resource impact categories and benefits depend directly on the monthly flow outputs from the WSE model or are calculated based on flow, an output from the WSE model.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Modeling Flow Chart

Water Supply Effects (WSE) Core Model

CEQA Impacts Analysis
(20%/40%/60%)

1. Surface Water Deficit
2. Applied Water Needs
3. Groundwater Use Estimates
4. SWAP (StateWide Ag Production)
5. IMPLAN Regional Economics (IMpact analysis for PLANning)

Iterate

HEC-5Q Temperature Model

- Outputs for Fish Benefits
- Improved Temperature
- Floodplain Habitat Inundation

Figure 3.2-17. Modeling Flow Chart—Analytical Tools Used in the SED Analysis

The sections that follow collectively describe and illustrate that the WSE model, including the CALSIM II-based water balance, improvements to surface water demand estimates, and assumptions and parameters for system operation, provide a reasonable representation of system operations for describing and disclosing potentially significant water supply effects and characterizing other effects such as fish benefits. Use of WSE model results in other analyses and models, such as the groundwater evaluation, the SWAP agricultural economics model, and the temperature model, is also a logical and reasonable method for describing and disclosing potentially significant environmental effects.

In addition to this master response, Chapter 5, *Surface Hydrology and Water Quality*, and Appendix F.1, *Hydrology and Water Quality Modeling* describe in detail the mechanics and development of the hydrologic modeling analysis.

Hydrologic Modeling Steps

The WSE model is a water balance model constrained by flow requirements, water demands at diversion points, and operations at reservoirs. Flow requirements are set in the model, and the reservoirs, constrained by flood control requirements and minimum end-of-September carryover storage guidelines, operate releases to meet flow requirements and the water supply demands at points of diversion in the rivers.

The following steps explain how the models are run and how output from one model is used as input to another:

1. The WSE model is based on the CALSIM II model schematic and water balance for the plan area. The water balance is converted to a Microsoft Excel spreadsheet format, as described in Appendix F.1, *Hydrologic and Water Quality Monitoring*.
2. Certain values provided by CALSIM are updated in the WSE model. Updates to applied water demand, minimum groundwater pumping, and reservoir and distribution losses describing water use and efficiencies within irrigation districts are based on data from AWMPs and, in some cases, data from districts that responded to requests for information.
3. The flow objective for each month is determined based on the designated percent of the unimpaired flow at a specific location in each of the three tributaries.
4. The WSE model calculates resulting instream flows and water supply effects for baseline and each LSJR alternative.
5. The HEC-5Q temperature model calculates temperature conditions in the three tributaries and LSJR using monthly flow data determined by the WSE model.
6. If the temperature results produce a USEPA temperature criteria exceedance frequency that is greater than 10 percent of the baseline condition exceedance frequency, the reservoir operations constraints and flow shifting are adjusted and recalculated to reduce temperature changes to meet the 10 percent exceedance frequency while still maximizing possible deliveries. Step 4 and Step 5 are repeated. When the temperature results are within 10 percent of the baseline exceedance frequency of USEPA temperature criteria,[21] the process moves to Step 7.
7. The surface water supply effects are evaluated by assessing the reduction in surface water availability for diversions relative to baseline and the temperature effects.
8. The replacement of reduced surface water supplies by groundwater pumping is evaluated in each irrigation district (within limits established by groundwater pumping capacities)

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[21] The WSE model and HEC-5Q model are used together to describe the effects of LSJR alternatives that meet the LSJR numeric objective, support the narrative objective, and avoid significant adverse temperature impacts on fish and wildlife. Supporting the narrative objective and avoiding significant adverse temperature impacts is interpreted as not allowing temperatures higher than the USEPA temperature criteria more than 10 percent of the time compared to baseline, for all months. Thus, the *percent of the time criteria are exceeded* is referred to as the *exceedance frequency* calculated as the fraction of days exceeding the criteria at a specific location for a given month of the year.

(Appendix G, *Agricultural Economic Effects of Lower San Joaquin River Flow Alternatives: Methodology and Modeling Results*).

9. The available surface water and groundwater supplies are combined to determine the overall water supply needed and available for agriculture.
10. The calculated water supply for each irrigation year is input into the SWAP model to determine changes to crop production and revenue compared to baseline.
11. Crop production and revenue output from SWAP are then used in the IMPLAN model to determine total direct and indirect regional economic effects from changes in the agricultural sector.

After the baseline model run is complete, the WSE model is run again for the LSJR alternatives; however, the carryover storage guidelines and amount of flow shifting must be adjusted[22] to support attainment of the narrative objective, meet the numeric unimpaired flow objective, and avoid significant adverse temperature impacts on fish and wildlife. This second element is critically important, and is the subject of many comments. As depicted in Figure 3.2-17, the WSE model and the HEC-5Q temperature model are iteratively run until a reasonable representation of potential guidelines are achieved that attain the numeric LSJR flow objectives and avoid significant adverse temperature impacts on fish and wildlife for each LSJR alternative. These reasonable representations of guidelines for carryover storage, allocation of a percent draw from storage, and minimum allocations are presented in the SED and are required to re-operate the reservoir system to evaluate potentially significant environmental impacts from the LSJR alternatives. As stated in the SED, however, the carryover storage guidelines used for modeling are not themselves requirements:

> Determination of available water to supply demand is a modeling necessity to represent baseline conditions and operational envelopes for LSJR alternatives; however, these parameters, including "Maximum Allowable Draw from Storage," do not represent regulatory requirements of how the reservoir storage and use system must be operated—rather, alternatives are examples of system operation that illustrate most likely water availability as a function of additional constraints of instream flow requirements. To some extent, carryover storage guidelines have been increased over baseline to reduce indirect temperature effects that would otherwise occur because of lower storage levels. Implementation most likely will require further optimization of these parameters with balanced consideration of desired temperatures and tradeoffs with other resource values (Appendix F.1, Section F.1.2.5).

The use of a carryover storage guideline is consistent with the narrative language in the program of implementation, which states:

> When implementing the LSJR flow objectives, the State Water Board will include minimum reservoir carryover storage targets or other requirements to help ensure that providing flows to meet the flow objectives will not have adverse temperature or other impacts on fish and wildlife or, if feasible, on other beneficial uses" (Appendix K, *Revised Water Quality Control Plan*, p. 28).

Specific carryover storage targets are not established in the program of implementation in order to support site-specific solutions and avoid constraining future options. Carryover storage targets will be established in future proceedings based on site-specific information that integrates local conditions. The more detailed evaluations may identify carryover storage targets that meet the

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[22] LSJR Alternative 2 does not require flow shifting, but flow shifting is needed in LSJR Alternatives 3 and 4. Likewise, reservoir constraints related to the carryover storage guideline (i.e., maximum draw from storage, minimum allocations, and drought refill constraints) must be adjusted for each level of percent unimpaired flow.

numeric LSJR flow objective and avoid significant adverse temperature impacts on fish and wildlife while maximizing water deliveries. This means that reservoir operations that result in reduced water supply effects (i.e., greater water supply) are allowable, so long as the numeric LSJR flow objectives are met and significant adverse temperature impacts on fish and wildlife are avoided. Such further operations analyses would need to occur at the project-specific level and may require additional environmental analysis.

The models use reasonable simplifying assumptions and are run sequentially, except for the iterative step to produce temperature profiles that avoid significant adverse temperature impacts on fish and wildlife. In real-world operations, many feedback loops could inform the planning and implementation of management actions, but they are too complex and speculative to capture in the SED programmatic evaluation of the LSJR alternatives.

Surface Water Allocation: Streamflow versus Demand versus Storage

The WSE model performs the following series of calculations at each time step to determine the volume of surface water available for diversion and the subsequent water balance:

1. Calculates the flow requirements on a river-by-river basis based on the designated percent of unimpaired flow.
2. Allocates surface water to smaller riparian water rights along each tributary.
3. Determines the total volume of water available for diversion in each water year by subtracting the quantity required to meet flow requirements from forecasted inflow and assessing the volume of water available from storage.
4. Allocates available water to each water or irrigation district based on the surface water demand for each district and the appropriate allocation procedure.

More details on this process are available in Appendix F.1, *Hydrologic and Water Quality Monitoring*, Sections F.1.2.3 through 1.2.7, *Water Supply Effects Modeling—Methods* and in the sections that follow.

The 2016 WSE model allocates water based on demand. The model uses reservoir operations constraints to maintain carryover storage and increase delivery reliability. Furthermore, the model uses cold-water pool to avoid adverse temperature impacts on fish and wildlife. The 2012 WSE model used a different approach based on the water availability index (e.g., inflow plus storage) and an allocation based on the amount available. In response to comments on the 2012 Draft SED stating that State Water Board did not optimize the water availability of reservoirs and likely operations decisions of water managers, the 2016 WSE model was improved.

The amount of water available for diversion is often insufficient to meet overall gross demands in a year with low inflow and low reservoir storage. Under these conditions, the WSE model will prioritize allocations of available water based on generalized groups of water rights. Smaller diversions at points along the lower rivers, generally not part of the major irrigation districts, are considered and assumed riparian and senior to appropriative rights of the major reservoirs. The model will deliver riparian diversions first and for all years for each LSJR alternative, except in rare and extreme circumstances. For example, during three different months of critically dry conditions (February and March of 1977, and February of 1991), the model determines that a riparian diversion on the Merced River cannot be met in full under LSJR Alternative 3. In each case, the monthly riparian demand shortage is between 4,000 and 6,000 acre-feet. Under such extreme conditions, water rights might function as they did through the 2014–2016 drought, in which all diversion rates were reported, potentially leading to curtailment orders. However, such outlier circumstances are difficult to represent in model constraints because water management decisions can deviate from the norms represented in the model. The few occurrences showing that riparian rights are not fully met do not change the significance determinations for water supply effects.

Model Foresight of Water Year Inflow

Many commenters asserted that the WSE model incorporates "perfect foresight," and commenters further asserted that results are therefore unrealistic. Foresight is defined as the ability to predict what will happen or be needed in the future. In modeling the 1922–2003 period, the appropriateness of foresight is considered in three contexts: 1) seasonal foresight for annual supply allocations, 2) drought foresight for the extent of a multi-annual inflow shortfall, and 3) the entire study period as a hydrologic representation of the range of reasonably foreseeable conditions in which to evaluate water balance conditions. Although the WSE model uses seasonal foresight to anticipate inflows for March through September of each water year, it does not foresee multi-year droughts or the duration of such droughts. Rather, the annual allocation is based on logic that consistently and conservatively determines the amount to be diverted based on availability of the amount of water available in storage, the forecast for March through October of the current water year, and reservoir parameters such as the carryover storage guideline.

Seasonal foresight is the determination of water supply allocation for the March through September period. As the WSE model simulates the study period month by month, in the beginning of every March it determines available water based on inflow forecast and a decision regarding how much should be used from reservoir storage on March 1. This reservoir utilization logic is based on constraints described in the following sections and does not involve the use of foresight. Seasonal foresight incorporates the March through September inflow forecast to determine instream flow requirements (i.e., the quantity of the flow objective based on the given percent of unimpaired flow objective) and the balance available for diversion or storage. The seasonal foresight of inflow conditions through September is a reasonable estimation in the WSE model of the operations allocation process.

It is standard practice in water planning to obtain the expected value of unimpaired flow from official published forecasts available from DWR,[23] which also include a range of values corresponding to wet or dry possibilities known as 10 percent exceedance and 90 percent exceedance, respectively.[24] In this example, the expected value would correspond to the median, or 50 percent exceedance, for which it is equally likely that conditions could ultimately prove to be wetter or drier than that forecast. Uncertainty is inherent in water operations but can be difficult to

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[23] Available at https://cdec.water.ca.gov/water_cond.html.

[24] A 10 percent exceedance forecast refers to a future flow quantity that would be exceeded only 10 percent of the time, based on a historical record and/or additional information, based on the conditions at the time the forecast is made. Likewise, 90 percent exceedance would be a low estimate of flow that could be considered 90 percent likely to be exceeded for the remainder of the forecast period. A 90 percent exceedance forecast is conservative for evaluating the risk of shortage and can be used in planning operations such that there is a 90 percent chance conditions will actually be wetter than in such a plan.

incorporate into long-term planning models, which tend to be deterministic in producing precise answers without describing uncertainty in results.

The WSE model uses foresight to anticipate the monthly inflow record from CALSIM and to determine how much can be allocated, physically, based on the record in a given year. It is reasonable to assume that by March, a sufficiently accurate assessment of forecast probabilities can be made in order to plan quantities of diversions and make the necessary planting decisions. For example, by March 1, approximately two-thirds of water year precipitation has occurred, on average, as well as one-third of a water year's inflow.[25] The amount in the reservoir is known, so with this information, as well as knowledge about snowpack, soil moisture, and other weather factors, it is possible in practice to foresee in March whether a year is likely to be high availability, low availability, or somewhere in between.

Water year type indices such as those described in D-1641[26] and based on official DWR forecast data are used to determine existing flow objectives. Similar indices are used to determine flow quantities such as the New Melones Index (NMI), which has its own water year type index separate from D-1641. NMI year type is based on reservoir storage and forecast inflow through the end of the water year. NMI is used to determine contract availability for SEWD and CSJWD as per the original USBR New Melones Interim Plan of Operation and subsequent Baseline Study (USBR 1997, 2013a, 2013b), as well as instream flows in the BiOp (NMFS 2009). In practice, the NMI year type is evaluated monthly as forecasts become available beginning in February. However, the year type determination has been a matter of controversy regarding whether the 50 percent exceedance or 90 percent exceedance forecast for NMI should be used as the basis of BiOp RPA flows. The National Marine Fisheries Service (NMFS) has clarified that the intent of the BiOp was to use the 50 percent exceedance forecast. USBR and the districts in practice prefer to use the 90 percent exceedance forecast, because the lower estimate of inflows and therefore lesser year type results in less obligation of flow releases and lower water cost (Stanislaus Operations Group 2010). This minimizes the risk of over-allocating water but also results in lower flows in implementation of the BiOp.

Multiple comments asserted that the use of seasonal perfect foresight in the WSE model may incorrectly estimate or underestimate water supply effects. One commenter asserted that, "perfect foresight of reservoir inflow from March through September is clearly at odds with the real-world practice (at least on the Stanislaus) of using very dry (90 percent exceedance) estimates of coming hydrology." The commenter further asserted that this would make actual water supply allocations less than modeled allocations. While seasonal foresight in the WSE model does determine allocations based on knowledge about inflows from February through June, in practice the flow requirement will be based on the 7-day average of unimpaired flow in real time, which requires no foresight or prediction of water year type. Implementing the LSJR flow objectives requires a paradigm shift in allocation planning and reservoir operation. While the designated percentage for instream flow is no longer available for diversion, the amount of available water will become more dependent on reservoir condition and higher reservoir carryover levels can act as a buffer in allocation decisions. The *status quo* primacy of the 90 percent exceedance forecast used in practice as a conservative indicator for supply effectively minimizes requirements for instream flows and has a limited bearing on actual availability in the modeled scenarios. The commenter asserted that, "the

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[25] Data from http://cdec.water.ca.gov/cgi-progs/products/PLOT_FSI.pdf and https://www.cnrfc.noaa.gov/water_resources_update.php.

[26] Available at https://www.waterboards.ca.gov/waterrights/water_issues/programs/bay_delta/decision_1641/ Figure 1 and Figure 2, pp. 188-189.

modeled approach likely leads to overly optimistic allocations to water districts in early spring" but offers no additional support for the claim. There is little doubt that operators will divert as much supply as possible to meet demands and are effective and efficient at determining availability and risk.

Another concern regarding perfect foresight appears to be the misconception that that the WSE model uses knowledge of the 82-year hydrologic sequence to foresee upcoming droughts. This is not the case. WSE uses foresight to incorporate a given year's seasonal water supply for March through September, but does not consider future years. Reservoir storage parameters are determined such that desired carryover targets are normally maintained but relaxed to grant minimum allocations in multi-year drought conditions.[27] These parameters were developed with knowledge of the 82-year sequence and the frequency and extent of droughts in the record; however, any particular year is operated without foresight except for the allocation determination at the beginning of March.

Reservoir Operations, Reoperation, and Carryover Storage

This section describes how CALSIM and the WSE model represent reservoir operations in baseline and the use of reservoir modeling parameters (i.e., carryover storage targets and other constraints) to direct the allocation of surface water in the alternatives. Carryover storage refers to the quantity of water stored in a reservoir at the end of a water year, September 30. Guidelines or targets for carryover storage are one factor determining how much water is available for diversion in a given water year. Operators must continually consider water availability in reservoir storage and inflow forecasts to determine reservoir outflows to meet local deliveries to irrigation districts, entitlements to more senior water rights downstream, and to regulatory streamflow requirements, as well as to minimize flood risks. Irrigation districts announce an annual allocation for the irrigation season in the spring of each year. Similarly, CALSIM and WSE models use rules to determine flow requirements and deliveries, water delivery shortfalls, distribution of water shortages, and water preservation for future years. The amount of water reserved in storage strongly influences the temperature of water released that subsequently influences downstream river water temperature conditions (Chapter 19, *Analyses of Benefits to Native Fish Populations from Increased Flow between February 1 and June 30*).

The WSE model scenarios in the LSJR alternatives represent water storage and delivery operations to meet multiple objectives of maximizing water delivery to meet demands, saving some water in reservoirs, and providing minimum allocations when water supply is low. The operations constraints used in the WSE model in the baseline scenario create results that match water supply results in the CALSIM model baseline very well. Additionally, historical evidence shows that reservoir operators and water districts generally function with these goals in mind and do not, as some commenters suggested, drain the reservoirs dry to meet full demands every year. Rather, operators conserve water by allocating the available water based on the projected supply, just as the WSE model represents these actions, to provide water as reliably as possible from year to year.[28]

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[27] It is important to note that the model doesn't "know" nor does it need to know whether it is in the first, second, third, or fourth year of a drought. Water is allocated conservatively and the demand for a minimum allocation will force utilization of reservoir storage.

[28] The strategy of reducing allocations in the face of scarcity can be observed in historical district allocations reduced in 2014 and 2015, when some available water was stored as a hedge against future risk rather than consumptively used. See below section titled Water Supply Reliability for additional discussion and citations.

For example, state and federal water infrastructure project operators (CVP/SWP) determine allocations annually as a percentage of the full contracted amount or amount requested by users and contractors. Water allocation announcements generally begin in late January with a preliminary allocation and monthly adjustments through April. In effect, these annual allocations incorporate saving water for the upcoming and following years for increased reliability. Reservoirs such as New Melones that are large enough to contain multiple times the volume of typical annual runoff are specifically designed to store a significant portion of water from year to year, and over multiple years, to ensure some degree of water supply reliability in the Central Valley's highly variable climate. The section entitled *Water Supply Reliability* discusses reliability in more detail.

Reservoir Operational Parameters

Modeling parameters, such as those constraints defining carryover storage and allocation of water supply (Appendix F.1, *Hydrologic and Water Quality Monitoring*, pp.F.1-34 to 38, and Tables F.1.2-23a-c) are intrinsic to the analysis and results. This section clarifies how these parameters function together as operations assumptions to determine how much water is available to be allocated to consumptive uses.

As described in Appendix F.1, Section F.1.2.5, *Calculation of Available Water for Diversion*, the following operations parameters are used to govern reservoir operations and determination[29] of the available water for diversion and use in the WSE model:

- **Maximum Storage Levels (Flood Curves):** The maximum level allowable in the reservoir is set equal to the CALSIM flood control levels in New Melones and New Don Pedro Reservoirs (including conditional storage, when applicable) and Lake McClure. The model assumes projected filling above these levels will be evacuated within that month to maintain at or below these maximum operating levels. These flood curves are based on USACE requirements, but with some differences (USBR 2005).
- **Minimum End-of-September Storage*:*** A minimum end-of-September storage guideline was developed by iteration to determine levels protective of cold-water pool and river temperatures in the summer and fall. Projected end-of-September storage for a given year is reduced by this value to determine the amount of storage supply available for diversion for that year.
- **Minimum Diversion Level (End-of-September Relaxation):** Diversions can override the end-of September storage guideline and draw additional water from storage in the event the available surface water for diversion is less than a specified minimum level. This in effect is a relaxation in certain years to the end-of-September storage guideline. The minimum level constraint was set after trial and error to ensure there were no significant temperature impacts.
- **Maximum Allowable Draw from Storage:** The model constrains the percentage of the available storage (after holding back for minimum end-of-September storage) that is available

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[29] Determination of available water to supply demand is a modeling necessity to represent baseline conditions and operations envelopes for LSJR alternatives; however, these parameters, including "Maximum Allowable Draw from Storage," *do not* represent regulatory requirements of how the reservoir storage and use system must be operated—rather, alternatives are examples of system operation that illustrate most likely water availability as a function of additional constraints of instream flow requirements. To some extent, carryover storage guidelines have been increased over baseline to reduce indirect temperature effects that would otherwise occur because of lower storage levels. Implementation most likely will require further optimization of these parameters with balanced consideration of desired temperatures and tradeoffs with other resource values.

for diversion over the irrigation season. This limits the amount of storage that can be withdrawn to reduce potential effects on river temperatures by protecting carryover storage and the cold-water pool in the reservoirs leading into a drought sequence. Baseline “allowable draw” was determined empirically to match CALSIM patterns of allocations, similar to how a “delivery versus carryover risk curve” might be used.

- **End-of-Drought Storage Refill Requirement** (only needed in alternatives with 40+ percent of unimpaired flow, not in baseline): When reservoir levels are very low (typically after a drought sequence), the model limits the amount of inflow that can be allocated for diversion in a subsequent wet year(s). By reducing the amount of inflow that can be diverted in such years, reservoirs and associated cold-water pools recover more quickly after a drought. Without such a requirement, reservoirs otherwise would remain lower for longer after a drought, causing associated temperature impacts.

All water balance models that evaluate water supply and reservoir systems require a method of determining how much water to allocate in a given supply situation. In the WSE model, the Carryover Storage Guideline, the Maximum Allowable Draw from Storage, and the Minimum Diversion Level work together in an equation to determine how much water is allocated to diversions. Maximum storage in the WSE model is controlled by the U.S. Army Corps of Engineers (USACE) flood control curves and, in the case of New Don Pedro Reservoir, CALSIM interpretation of flood control limitations. The end-of-drought storage refill requirement is a special-case constraint that further limits water supply in years of low reservoir level and high inflow, in which the priority of filling the reservoir is key to restoring the ability to maintain carryover storage and cold pool. The end-of-drought refill requirement is described in the sections that follow.

Operations Parameters in Alternatives

Changing the operating conditions of reservoirs and water allocation priorities is referred to as *reoperation*. Reservoir operation parameters are determined by an iterative process designed to maximize water supply deliveries after LSJR flow requirements are met and significant adverse temperature impacts on fish and wildlife are avoided. The findings are subject to additional constraints developed, adjusted, and refined for each LSJR alternative based on operations objectives. This process is a reasonable method of representing operations that implement the LSJR flow objectives.

The general approach used in the WSE model to allocate water based on available supply is not unique and closely mimics determination of available supply in models such as CALSIM subject to streamflow requirements. Additional considerations of temperature effects and maintaining reliability make specific implementation of constraints (i.e., a parameter set that meets operations objectives) necessary to achieve the LSJR alternatives.[30] This process was used to establish reasonable operation parameters that were then used to conduct an analysis with sufficient resolution to evaluate water supply effects based on meeting these objectives.

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[30] Parameter sets of reservoir operations constraints are not necessarily unique in meeting project objectives. Adjustments of parameters and/or allocation algorithms in other models could provide examples of system operation that meet flow objectives, support narrative criteria, avoid significant adverse temperature impacts on fish and wildlife, and meet water supply needs. Such examples may have different patterns of reservoir storage and spills, and water supply distributed according to other priorities. The constraints specifically developed for the WSE model to represent LSJR alternatives reasonably achieve the objectives described. Additional refinement may be possible, particularly with attention to the tradeoff between carryover and temperature conditions.

The LSJR alternatives would result in unavoidable reductions in surface water supply, roughly equal to increases in river flows. Reductions in surface water supply for agriculture and municipal uses are minimized to the extent practicable by optimizing storage in reservoirs. Optimization is defined as the process of maximizing certain objectives while meeting certain constraints to reach a feasible outcome. Avoiding significant adverse temperature impacts on fish and wildlife in the modeling process requires adaptations to minimize increases in stream temperature due to changes in operation and allocation of water to meet the flow objectives.

The reservoir and water supply parameter values in the WSE model are adjusted iteratively to consider the following objectives, for each increment of percent of unimpaired flow (e.g., 20, 40, and 60 percent):

1. Achieve instream flow objectives.
2. Fulfill senior and riparian water rights downstream of major districts.
3. Maximize quantity of district diversion delivered, and minimize annual average reduction from baseline (i.e., average water supply effects).
4. Maximize reliability of a fraction of district diversion (i.e., minimum allocation of about 15 to 35 percent depending on river system; minimize acute water supply effects.
5. Prevent exceedance of USEPA optimal temperature criteria more than 10 percent of the time compared to baseline, to avoid significant adverse temperature impacts on fish and wildlife, evaluated with the HEC-5Q temperature model.
6. Do not allow reservoirs to be completely drained.
7. Do not allow reservoirs to exceed seasonal flood storage limitations.

These seven operations objectives guide development of the reservoir operation parameters for the WSE model analysis of each LSJR alternative. Objective 1 represents the project definition and requires meeting the LSJR instream flow objectives. This is a necessary element of evaluating the effects of the project. Objective 2 is a reasonable assumption and goal for water supply and river flow management because it reflects the first basic step in the California's water allocation system. Objectives 3 and 4 are consistent with water supply management goals of maximizing water supply deliveries and providing a minimum allocation during extreme dry conditions.

Objective 5 meets the flow objective and program of implementation requirement that flows provided to meet the numeric objective be managed to avoid causing significant adverse impacts on fish and wildlife beneficial uses at other times of the year. This is quantitatively interpreted in the HEC-5Q temperature model as meeting the USEPA temperature criteria within a 10 percent exceedance frequency of baseline conditions. This interpretation is consistent with science describing the importance of water temperature for Chinook salmon survival[31] and recognizes that baseline water temperature conditions often exceed USEPA criteria in late summer and fall. The HEC-5Q model generates temperature results based on WSE model streamflow and reservoir conditions. Thus, the iterative aspect of the analysis involves adjustment of WSE model parameters and evaluating temperature conditions repeatedly until temperature results meet Objective 5. These

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[31] See Chapter 19, *Analyses of Benefits to Native Fish Populations from Increased Flow between February 1 and June 30,* for a discussion regarding the importance of water temperature to salmonids. For example, in the Central Valley, Myrick and Cech (2001 page iii) suggest that "water temperature is perhaps the physical factor with the greatest influence on Central Valley salmonids, short of a complete absence of water."

results are summarized in Chapter 19, *Analyses of Benefits to Native Fish Populations from Increased Flow*, Tables 19-3, 19-6, and 19-9. Objective 5 requires establishment of carryover storage guidelines and shifting flow volumes from the February–June period to later in the summer and fall to achieve these temperature conditions.

Parameter adjustment in the WSE model is performed by evaluating instream temperature effects and water supply effects. WSE model instream flow results are used in the HEC-5Q temperature model to determine resulting instream temperature for a given alternative over a wide range of time and space. Objective 5 is a reasonable way to summarize and identify scenarios that meet the requirement in the plan amendments to avoid significant adverse temperature impacts and to screen out scenarios that do not meet this requirement in order to evaluate the potential impacts of implementing the LSJR flow objectives.

Objectives 6 and 7 are reasonable and necessary constraints for operating reservoirs to meet water supply needs and protect public safety. Allowing reservoirs to be completely drained is not a reasonable operations assumption because of potentially severe water supply and aquatic habitat impacts. Similarly, reservoir volumes in the analysis were not allowed to exceed USACE seasonal flood storage limitations due to risks to public safety.

Allowing reservoir storage to rebound post-drought by further limiting diversions in the WSE model (i.e., the drought refill constraint) provides additional benefit to Objectives 4 and 5. After meeting Objectives 1, 2, 5, 6, and 7, there is a narrow range of possibilities for meeting objectives 3 and 4 regarding average quantity of diversion and reliability.

The revisions and enhancements in the WSE model for the 2016 Recirculated SED have been successful in the evaluation of water supply effects in LSJR alternatives and meeting Objectives 1 through 7. The modeling tools and results provide a sufficiently accurate representation of the results of each reoperation scenario depicted at each tier of percent unimpaired flow streamflow objectives. The environmental impacts and associated water supply costs are disclosed for each 10 percent increment of percent of unimpaired flow and for the associated ranges that may be seen under adaptive implementation (i.e., 30 to 50 percent under LSJR Alternative 3).

The model scenarios for each LSJR alternative do not prescribe exact operations but instead represent likely effects of a reasonable implementation scenario. Basin plan objectives for instream flow do not preclude operators from flexibly meeting their own goals, considering values such as refined estimates of water supply risk and details of hydropower production, nor from exercising water rights for conjunctive use of surface water and groundwater if the objectives are met and carryover storage is maintained to prevent additional harm.

The LSJR alternatives do not prescribe operations decisions that are speculative in a programmatic context. Markets are efficient and market actors are responsive such that, after adjustment and guidance to the STM Working Group, operators could produce outcomes that may be more favorable than those described by WSE results. However, this analysis has evaluated reasonable adaptive implementation choices that represent system operation and describe water supply effects for consumptive uses, instream flows, and instream temperature effects. Further incorporation of more detailed and interlinked objectives to be optimized formally could reduce the project cost impacts, but likely not the level of significance of the water supply impacts at the various tiers of streamflow objectives analyzed.

Reservoir Carryover Storage Guidelines and Allocation Parameters

The WSE model incorporates reservoir operation assumptions, including guidelines for end-of-September carryover storage, to evaluate allocation of surface water from the three major reservoirs for the LSJR alternative streamflow requirements. The three WSE model parameters that primarily affect the water supply allocation are carryover storage guidelines, maximum allowable draw from storage, and the minimum allocations (Appendix F.1, *Hydrologic and Water Quality Monitoring*, F.1-30 to 38, and Tables F.1.2-23a-c).

Commenters asserted that WSE model parameters of water supply allocation are a novel method of simulating water supply allocation and therefore commenters objected to the use of the WSE model parameters. One commenter calls the maximum draw from storage parameter a "modeling gimmick." On the contrary, the maximum allowable draw from storage parameter is an essential element of a reasonable method to determine when diversions would need to be limited in order to preserve some amount of carryover storage in the WSE model. The parameters of maximum allowable draw from storage, carryover storage guideline, and minimum allocations work together to determine how much stored water is allocated in a given year and how much must be retained to meet objectives. A lookup table of potential diversion levels as a function of storage would work equally as well and would provide a similar result. See CALSIM description that follows.

The minimum diversion allocation is established to avoid zero supply years. Some commenters may have interpreted the carryover storage guideline as a hard limit. The minimum diversion allocation allows carryover storage guideline to be relaxed in order to make minimum diversion deliveries in drought conditions. Lower carryover guidelines than the ones used in the SED analysis would also require smaller minimum allocations, effectively functioning as a harder limit at a lower level.

Other models incorporate allocation logic to determine how much to allow to be diverted in shortage situations, including minimum allocations. In the CALSIM model, for example, Tuolumne river allocations (defined by the file *Tuolumne_dems.wresl*) are described as follows (USBR 2013c):

> Surface water allocation (as a percent of demand); based on New Don Pedro water supply: If end-of-March New Don Pedro storage is greater than 950, allocation is based on Apr-Jul inflow forecast and is looked up in a table. If end-of March NDP storage is less than 950 and the inflow forecast is less than 900, allocation is 55% of demand.

It appears from the *.wresl* code in this file that this minimum value was later adjusted to 50 percent. Notably, this minimum allocation can be directly compared to WSE model value of 50 percent for minimum district diversion. The CALSIM lookup table file *TuolAllocNormal.table* limits allocations to 85 percent when April–July inflow is between 1,600 and 2,000 TAF, decreasing to 50 percent at 1,400 TAF (USBR 2013d). Rather than a lookup table, the WSE model uses a supply equation (Appendix F.1, p. F.1-32) incorporating both the carryover storage guideline and maximum allowable draw from storage parameters together to determine supply available in a specified year until drought conditions require the minimum allocation. The calculation method in the WSE model differs from CALSIM, but the general approach (reducing the amount that can be delivered based on characterization of supply) and overall results are directly analogous. For comparison, another example of water allocation methods is the CALSIM Water Supply Index to Delivery Index function, or WSI:DI, which is another type of lookup table for CVP/SWP deliveries based on available supply and desired carryover storage (DWR 2005b).

These reservoir storage guidelines and allocation parameters were determined empirically for baseline, based on matching the 82-year period of CALSIM baseline reservoir operations and diversions, and adjusted in the LSJR alternatives.

The following summary describes the relationship of reservoir carryover storage guidelines to effects on available supply and stream temperature.

- Carryover storage guidelines in the LSJR alternatives limit available supply in many years but stabilize reservoir volume and provide some supply reliability in drought years.
- LSJR alternatives incorporate higher carryover storage guidelines than baseline, in part to preserve temperature conditions, avoid indirect temperature impacts, and conserve some water supply for future years.
- Low reservoir levels that result from lower carryover guidelines, or the absence of such guidelines, can result in diminished cold-water pool and higher release temperatures in the fall.

Tables 3.2-1 and 3.2-2 list the reservoir storage guidelines and allocation parameters used in the annual allocation.

Table 3.2-1. Baseline End-of-September Storage Guidelines, Maximum Draw from Storage, and Minimum Diversion Variables for the Eastside Tributaries

Variable	Stanislaus River	Tuolumne River	Merced River
End-of-September Storage Guideline (TAF)	85	800	115
Maximum Draw from Storage (% of available storage)	80%	65%	80%
Minimum Diversion (TAF)	0	550	0

Source: Appendix F.1, Table F.1.2-20

Table 3.2-2. LSJR Alternative 3 End-of-September Storage Guidelines, Maximum Draw from Storage, and Minimum Diversion Variables for the Eastside Tributaries

Variable	Stanislaus River	Tuolumne River	Merced River
End-of-September Storage Guideline (TAF)	700	800	300
Maximum Draw from Storage (% of available storage)	50%	50%	35%
Minimum Diversion (TAF)	210 (35%)	363 (33%)	78 (15%)

Source: Appendix F.1, Tables F.1.2 through F.1.23a-c

Commenters observed that a regulatory carryover requirement of 800 TAF for New Don Pedro Reservoir does not exist, and commenters objected to its inclusion in the baseline condition for this analysis. The 800 TAF carryover storage guideline for New Don Pedro Reservoir is appropriate for analysis because it works in combination with the minimum diversion to represent baseline conditions in the WSE model. For most of the historical record, New Don Pedro Reservoir has been observed above 800 TAF except for severe drought conditions such as 1976–1977, 1992, and 2014–

2015 (CDEC n.d.). Under these conditions, the minimum diversion parameter in the WSE model overrides the carryover storage guideline.

Drought Refill Constraint

The carryover storage guideline and associated allocation parameters function to preserve adequate cold-water pool and water supply reliability for the LSJR alternatives in the WSE model. These alternatives recognize the dynamic in which the more supply is allocated for consumptive use, the more consistently reservoirs would be drawn down to chronically lower levels compared to baseline. This dynamic occurs because supply allocated from inflow does not contribute to refilling reservoirs after severe droughts, and thus storage levels can remain low. To ensure that reservoirs can be refilled after droughts and that subsequent operations (in the WSE model) can maintain suitable carryover storage levels, the drought refill constraint is introduced.

The drought refill constraint is a special case of allocation limitation that occurs only in certain years with low reservoir storage and relatively high inflow. It functions to divert some of that inflow to storage so that adequate carryover storage levels can be restored. When the inflow is above a certain trigger and prior year carryover storage is near the carryover storage guideline (less than 110 percent of the guideline), allocations are further modified by the constraints shown in Table 3.2-3. The drought refill constraint is incurred in only 3 to 6 years of the 82-year study period in LSJR Alternative 3 and LSJR Alternative 4. The water supply impacts of this constraint are incorporated into all of the water supply data presented in the SED. In the absence of a drought refill constraint to support restoration of reservoir levels, lower reservoir levels would be more prevalent.

Table 3.2-3. Drought Refill Constraints (Diversion Constraints) and Inflow Triggers in the WSE Model

	Inflow Trigger	Diversion Constraint LSJR 2	Diversion Constraint LSJR 3	Diversion Constraint LSJR 4
Stanislaus River	700 TAF	100%	70%	50%
Tuolumne River	1000 TAF	100%	70%	50%
Merced River	800 TAF	100%	100%	50%

Temperature Effects of Carryover Storage

Carryover storage guidelines are necessary for meeting the LSJR narrative flow objective as interpreted in the WSE model. As described previously, avoiding significant adverse temperature impacts on fish and wildlife is interpreted in the modeling process as meeting the USEPA temperature criteria within a 10 percent exceedance frequency of baseline conditions. This interpretation is consistent with science describing the importance of water temperature for Chinook salmon survival[32] and minimizing frequency of adverse temperature conditions in late summer and fall months.

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[32] See Chapter 19, *Analyses of Benefits to Native Fish Populations from Increased Flow between February 1 and June 30,* for a discussion regarding the importance of water temperature to salmonids. For example, In the Central Valley, Myrick and Cech (2001 page iii) suggest that "water temperature is perhaps the physical factor with the greatest influence on Central Valley salmonids, short of a complete absence of water."

For illustrative purposes only, an additional modeling example was prepared at the request of the public that shows the potential effect of implementing flow objectives without carryover storage guidelines. For this example, which does not meet the definition of an alternative because it does not meet the requirements of the LSJR flow objective and program of implementation, the carryover storage guideline was set to zero. This modeling example is denoted as the No Carryover Storage (NCS) in the example that follows.

Figure 3.2-18 shows New Melones Reservoir storage results for baseline, 40 Percent Unimpaired Flow (LSJR Alternative 3), and 40 Percent Unimpaired Flow with No Carryover Storage guidelines (NCS), for the critical drought water years 1990 through 1991. The NCS example with the 40 percent unimpaired flow objective has a lower storage trend compared to baseline and much lower than LSJR Alternative 3 with a guideline of 700 TAF. As such, reservoir release temperature, shown in Figure 3.2-19, is elevated in summer and particularly in the fall in the NCS scenario when compared to LSJR Alternative 3 or baseline. LSJR Alternative 3 shows lower temperatures than baseline.

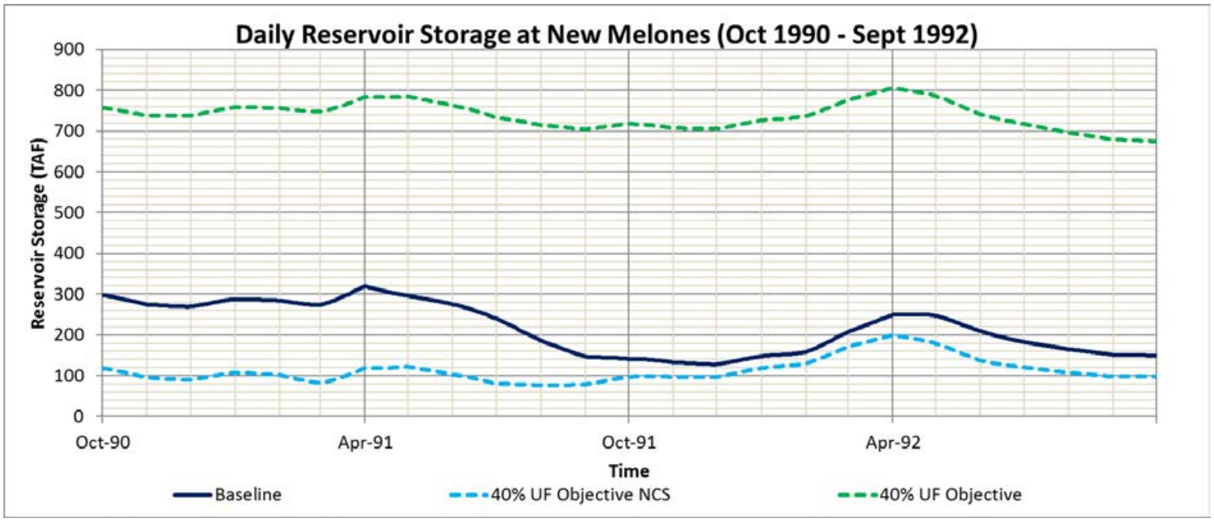

Figure 3.2-18. Daily Reservoir Storage for New Melones Reservoir for 1990–1991 for Three Scenarios

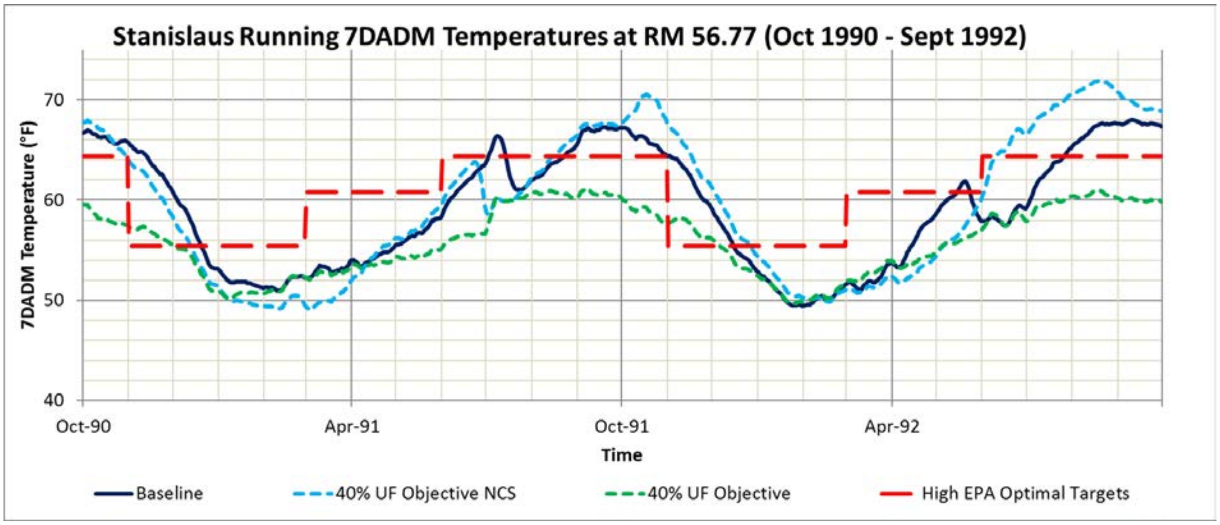

Figure 3.2-19. Daily 7DADM Temperatures at River Mile 56.77 (below Goodwin Dam) for 1989–1991 for Three Scenarios

Figure 3.2-20 shows the generalized relationship between storage and October release temperature (below Goodwin Dam) in the Stanislaus River. Lower reservoir storage in October of the worst years results in temperatures that exceed 65 degrees Fahrenheit (°F) in the baseline and NCS, and in LSJR Alternative 3, the worst years are less than 60°F. In many years with higher storage, release temperatures remain from 51 to 57°F because of adequate cold-water pool. This is near the recommended spawning and incubation criterion (55.4°F degrees F) for the upper rivers.

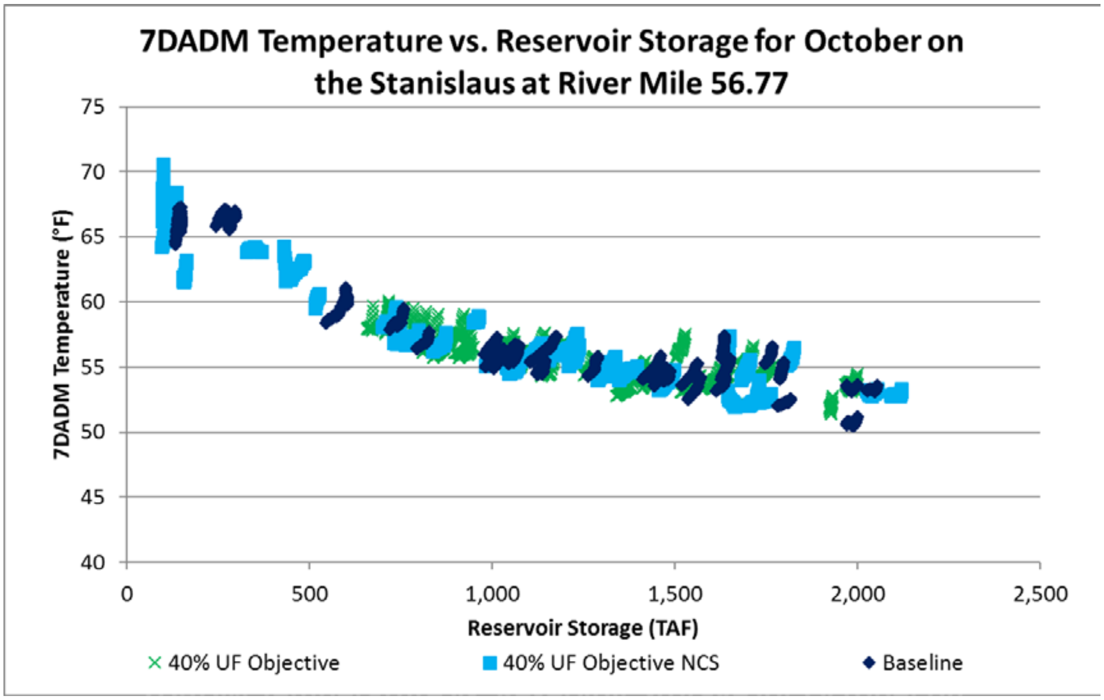

Figure 3.2-20. Stanislaus River Release 7DADM Temperature (estimated below Goodwin Dam) for Three Scenarios

Figure 3.2-21 shows the longitudinal profile of 7-day average daily maximum (7DADM) October 1991 temperatures in each of the three scenarios plus an optimal target scenario. This plot averages early and late October values when a cooling trend is expected. October 1991 can be considered a worst-case year for October temperature based on reservoir levels in each of the scenarios. Downstream temperatures approach equilibrium, and this figure averages all monthly 7DADM temperatures when a cooling trend is expected. As seen in 2014 and 2015, suitable temperatures for migrating adult salmonids (about 65°F) in many rivers and the Delta might not be observed until approximately November 1 in years with limited cold-water pool and minimal streamflow release.[33] However, the upper reaches of rivers below diversion dams are often the only cold-water habitat available for salmonids in which to spawn and incubate.

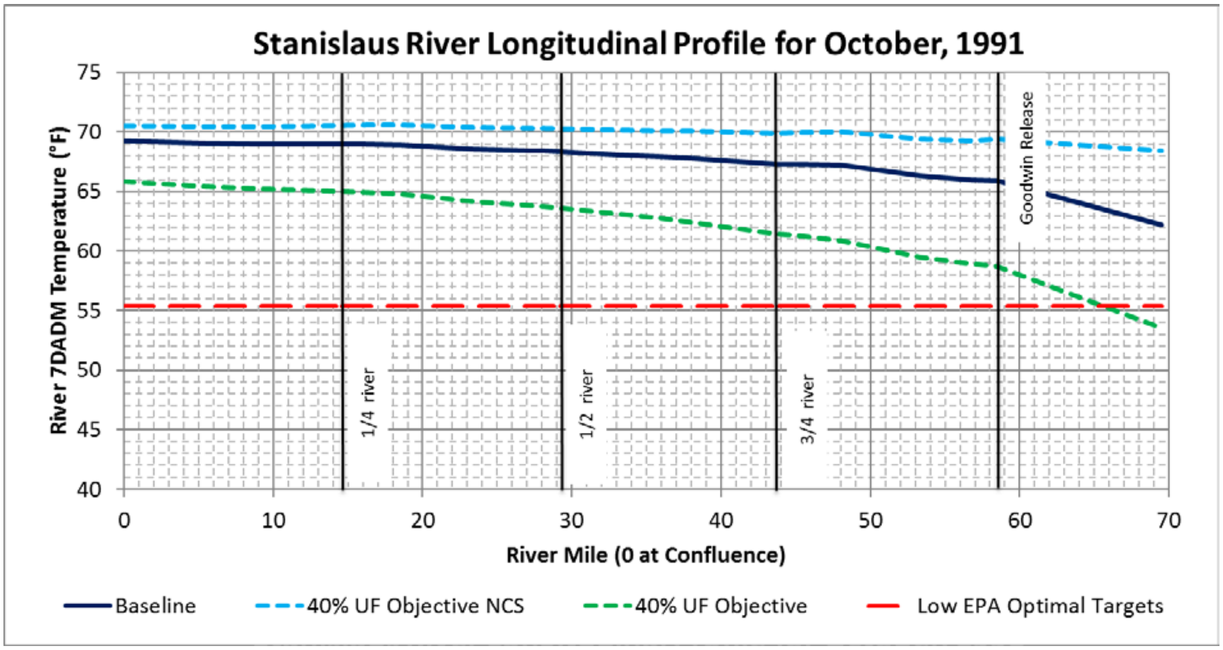

Figure 3.2-21. Longitudinal Profile of Average Stanislaus River 7DADM Temperatures in October 1991 for Three Scenarios

Figure 3.2-22 shows the percent exceedance of daily October 7DADM temperatures for all years in the 1970–2003 temperature model run. Baseline meets the USEPA spawning and incubation criterion of 55.4°F (red line) 85 percent of the time in baseline and 88 percent of the time under LSJR Alternative 3 with high carryover storage guidelines; but only 59 percent of the time in NCS. (Corresponding release flows at Goodwin are 589 cfs in baseline and 700 cfs in LSJR Alternative 3.) The NCS guideline scenario shows a higher frequency and higher magnitude of temperatures greater than the USEPA spawning and incubation criterion when compared to baseline. This example demonstrates why the plan amendments indicate, “carryover storage targets or other requirements to help ensure that flows to meet the flow objective will not have significant adverse temperature or other impacts on fish and wildlife” (Appendix K, *Revised Quality Control Plan*, p.28). In addition, the

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[33] In years of low streamflow in early fall, high temperatures are observed in the San Joaquin River at Vernalis. For example: https://nwis.waterdata.usgs.gov/nwis/uv/?ts_id=15168&format=img_stats&site_no=11303500&set_arithscale_y=on&begin_date=20141001&end_date=20151231 .

example shows why the NCS guideline does not qualify as a suitable scenario that would meet the requirements of the LSJR flow objectives and program of implementation.

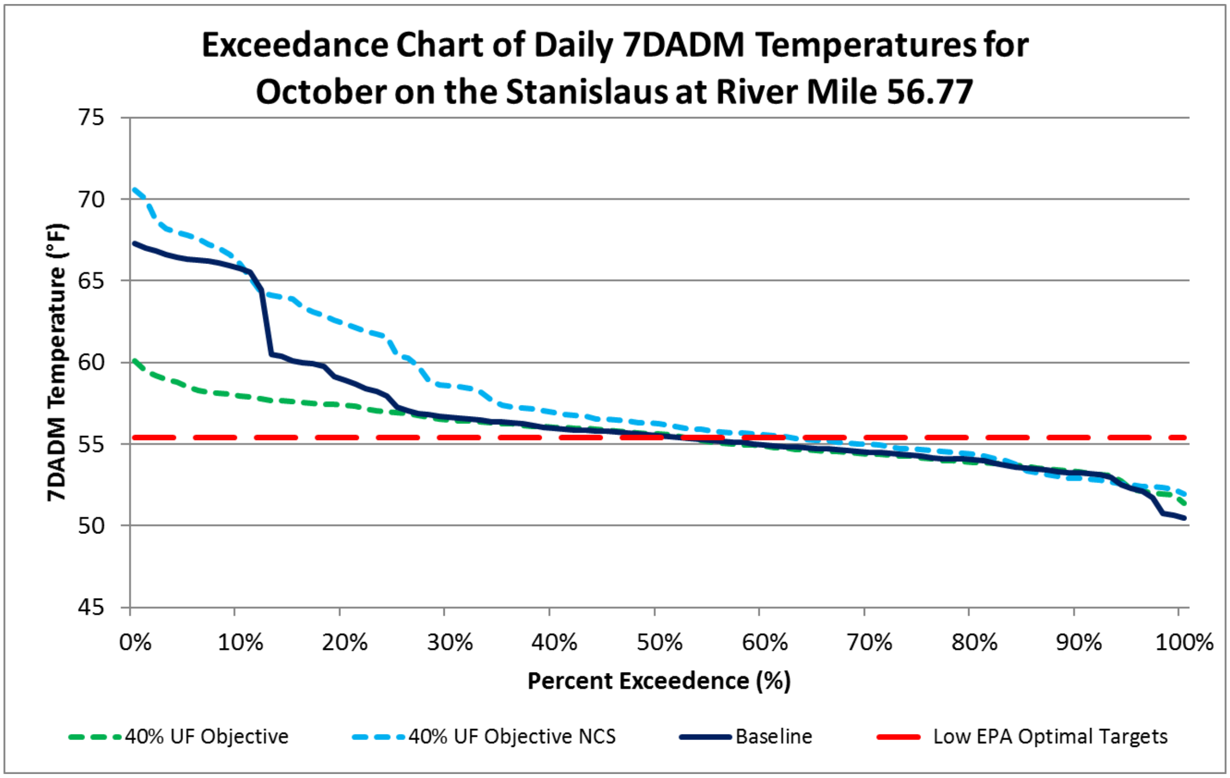

Figure 3.2-22. Percent exceedance of 7DADM temperatures at River Mile 56.77 in October for All Years (1970–2003) below Goodwin Dam in the Stanislaus River for Three Scenarios

Water Supply Reliability

The SED analysis uses a rational representation of reservoir operation that is consistent with the historical record of operating reservoirs and consistent with the goal of providing reliable water supply. There is a tradeoff between water supply reliability and maximization of available water use in any given year. The carryover storage guidelines used in WSE modeling preserve water supply from wetter years to be used in very dry years when the minimum allocation parameter is engaged and carryover storage guidelines are relaxed.

Water supply reliability depends on available supply, demand, and reservoir management choices that balance the risks and rewards of short-term and future use. Water supply reliability is generally defined as the fraction of time that a specified level of demand can be met. In a system without reservoirs, water demand would be met by the amount of natural supply available, and reliability could be described as the fraction of time that natural streamflow exceeds the level of demand.

Reservoirs improve reliability for consumptive uses by storing natural supply that exceeds demand for use later in the season or in future years. Reservoir operators balance the need to release water from the reservoir to fulfill seasonal water demand with the need to retain water in the reservoir to be available for future demand, considering the uncertainty of future inflows and the risk of drought. Multiple, successive dry years present difficult choices between releasing reservoir water to meet a portion of immediate demand or storing reservoir water for a future year with the risk of additional shortage. Water allocation decisions, therefore, depend on operators' assessment of risks and costs of not meeting future supply needs.

Multiple commenters asserted that water managers and dam operators would drain or severely reduce water volume in reservoirs in response to the LSJR flow objectives and meeting existing demands. Maximizing water deliveries to the extent of frequently draining reservoirs to dead pool is not consistent with past behavior[34] or operating to meet multiple objectives, balancing current year deliveries and storing water for future years. If maximizing current year deliveries were the only objective, then reservoirs would be empty more often than the historical record shows. The operations choice of maximizing water deliveries can reduce reliability of water supply for future years. Water supply reliability and certainty are important for domestic water supply and agricultural business decisions. Severely drawing down or draining reservoirs to maximize water deliveries increases the risk of water supply shortages if the following year is dry or the following several years are dry. Operating reservoirs this way is inconsistent with historical data that show that reservoirs are managed by conservatively balancing rewards of water deliveries this year with risk of subsequent dry years.

The management challenge for allocation of water supplies is when and how to distribute the inevitable shortage when water supply is reduced. Water supply reliability is critical to local communities and increasingly important to agricultural users to serve permanent crops, such as nut trees, in all years compared to the flexibility of annual crop plantings.[35] LSJR flow objectives, upon implementation, would reduce available water supply for consumptive uses. Historical observations of reservoir volumes and supply allocations show that water suppliers operate reservoirs and allocate water in any given year while assessing the risk of shortfall in a following year's supply. For example, in drought years 2014 and 2015, TID limited supply allocations to 20 and 18 inches per acre, respectively, compared to a normal 48 inches, with reservoir carryover supply cited as an important consideration (Holland 2014, 2015).

The WSE model simulates a reasonable and rational distribution of water supply shortages. In the case of the baseline scenario, the WSE model mimics the logic of CALSIM using the reservoir constraint parameters described previously: carryover storage guideline, maximum draw from storage, and minimum allocation. These three parameters appropriately function together to allocate supply for diversions in the baseline scenario. Even though the computational formula of allocation in the WSE model differs from that in CALSIM, the management of shortfalls in years of limited supply is essentially similar.

In the case of the LSJR alternatives, the WSE model distributes additional water supply reductions that occur because of the flow requirements. Greater supply shortfalls increase the importance of considering when (in what year types) these shortfalls should occur. WSE model parameters and processes maintain the reliability of minimum allocations in critically dry water year types by

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[34] Although photographs of mostly empty reservoirs are common images of conditions in 2014 and 2015, these are considered extreme conditions. Commenters such as OID/SSJID claimed that operators would be compelled to drain reservoirs even further and more often. The extent to which reservoirs are exercised is a matter of degree and of frequency. Commenters asserted that empty reservoirs would occur more often, affecting reliability. Such a response would be an unreasonable manner of operation, both with regard to supply reliability and to adverse temperature effects.

[35] See Master Response 8.1, *Local Agricultural Economic Effects and the SWAP Model*, regarding minimum applied water necessary to maintain permanent crops and a fraction of silage corn associated with local dairy industry needs.

reducing allocations at other times, often in above-normal and below-normal years. In other words, WSE model parameters maintain the reliability of minimum allocations by reducing the maximum that can be served more often. This is a reasonable service philosophy and simulation of reservoir operation within the LSJR alternatives.

WSE model parameters have been refined to create representations of the LSJR alternatives with realistic reliability and allocation possibilities that accurately disclose water supply effects based on distribution of available water after meeting system constraints and flow objectives. These are not the only possibilities of operation, and the allocations in the LSJR alternatives do not by themselves represent regulatory prescriptions. Alternative possibilities suggested by commenters demonstrate that it is possible to reduce reliability with lower carryover guidelines or by otherwise allocating too much water in wetter years and not saving any for drier years in consideration of usual risks and additional flow requirements. The WSE model parameters and process are a rational representation of the system and response to flow requirements and water supplies.

The ability to rely on reservoir storage in conjunction with groundwater further increases water supply reliability based on the combination of surface and groundwater supplies.

Hydrologic Modeling Analyses Presented by Commenters

Some commenters presented modeling scenarios that differ in assumptions than the alternatives in the SED, although the commenters' baseline scenarios closely match those of the SED. Comparing results for LSJR Alternative 3 (40 percent of unimpaired flow) illustrates that the primary difference between modeling examples is in the manner of operation; i.e., utilization of reservoir storage. While each of the water balance models handles allocations differently, the models generally agree regarding baseline conditions and differ slightly regarding representation of LSJR Alternative 3.

Despite myriad critiques of assumptions of the water balance modeling in the WSE model, commenters presented several analyses that support the accuracy of baseline results of the WSE model, thus supporting the general validity of water balance assumptions and allocation mechanisms for the purposes of estimating available supply. Furthermore, alternative modeling analyses for LSJR Alternative 3 similarly show reduced water supply available for diversions.

Oakdale Irrigation District and South San Joaquin Irrigation District Analysis

OID and SSJID, both in hearing testimony and comment letter, referred to a scenario they call the *pure 40 percent unimpaired flow* scenario with comparisons to their model baseline. These modeling results are detailed in Attachment A to their comment letter, a memorandum authored by Daniel B. Steiner on Nov. 16, 2016 (hereafter referred to as Attachment A). There are minor differences in baseline assumptions, and the model presented in Attachment A extends through water year 2016. The pure 40 percent unimpaired flow scenario is described as "not incorporating carryover storage targets and protocols, refill curtailments, and flow shifting" (emphasis in original).

Broad patterns of water availability described by the WSE model are similar to commenter-submitted modeling results for the baseline condition on the Stanislaus River. Both modeling approaches essentially present a reasonable interpretation of baseline conditions. Attachment A baseline results roughly correspond to the WSE model baseline with respect to average annual river release flows and average annual diversions, despite minor differences in baseline assumptions and an extended model study period to water year 2016. Attachment A baseline Goodwin releases

(1922–2003) average 451 TAF[36] and the SED baseline Goodwin releases also average 451 TAF[37] (Table 3.2-4).

Attachment A baseline diversions for OID/SSJID (1922–2003) average 503 TAF versus the SED baseline average of 510 TAF. SEWD and CSJWD diversions in Attachment A baseline average 111 TAF versus the 106 TAF in the SED baseline.[38] These diversion estimates, totaling 614 TAF and 616 TAF respectively, result from independent interpretations of water availability, streamflow requirements, and diversions to meet land use-based demand limited by the 1988 Agreement formula based on unique allocation schemes. These values are compared in Table 3.2-4. Minor differences may be important in some contexts, such as comparative evaluation of changes of these assumptions, but the models broadly agree regarding general characteristics of streamflow and diversion conditions in the baseline scenario.

WSE model reoperation parameters use reasonable assumptions interpreting potential system operations such as allowing minimum allocations and requiring carryover storage. However, commenter-suggested models show that the modeling approaches differ in their interpretation of what would happen in LSJR Alternative 3, based on a streamflow requirement of 40 percent of unimpaired flow from February through June. The pure 40 percent unimpaired flow alternative scenario in Attachment A does not include a substantial carryover storage target, except for the low minimum (dead pool) in New Melones Reservoir of 80 TAF, at which point diversions are sharply curtailed.

Notable observations from comparing the pure 40 percent unimpaired flow scenario in Attachment A and LSJR Alternative 3, are as follows: 1) much lower reservoir carryover levels (end-of-September), often at or near dead pool, 2) sustained diversions for OID/SSJID averaging 478 TAF per year (1922–2003) versus 446 TAF per year in LSJR Alternative 3,[39] and 3) lower availability for diversions for SEWD/CSJWD due to generally lower levels of New Melones, upon which CVP contract allocations are determined.

SEWD/CSJWD diversions (1922–2003) average 79 TAF in Attachment A versus 91 TAF in the SED, because the reservoir constraints in the WSE model provide for higher end-of-September carryover storage, facilitating higher allocations for SEWD/CSJWD, dry-year reliability for OID/SSJID, and protection of temperature conditions that avoid significant adverse temperature impacts on fish and wildlife. Again, the models agree on the estimated flow release at Goodwin based on modeling flow objectives, averaging 521 TAF per water year (1922–2003) in Attachment A and 524 TAF in the SED for LSJR Alternative 3.[40] Total water year diversions for OID/SSJID and SEWD/CSJWD are a

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[36] The 1922–2003 water year averages have been calculated from Attachment A to compare properly to SED 1922–2003 water year averages. Attachment A shows 1922–2015 averages that are cited in comments and hearing testimony. Differences between averaging period results are minor.

[37] State Water Board baseline instream flow annual average shown in Appendix F.1, *Hydrologic and Water Quality Monitoring*, Table F.1.3.5o at Ripon: 549 TAF. Adjustment for return flows, accretions, and diversions in the Stanislaus River: R528A + R528B+R528C + I528 –D528 = 98 TAF (these variables can be found in CALSIM and the WSE model). 549 TAF minus 98 TAF equals 451 TAF, the average annual release from Goodwin Dam.

[38] Evaluated from WSE model; also published in Table i of Attachment 1 of Appendix F.1.

[39] Attachment 1 to Appendix F.1, *Hydrologic and Water Quality Monitoring*, Appendix F.1, Table 3, Summary Table of Stanislaus River at 40 Percent Unimpaired Flow

[40] Appendix F.1, Table F.1.3l average flows of 622 TAF at Ripon less 98 TAF = 524 TAF.

combined average 557 TAF in Attachment A pure 40 percent unimpaired flow scenario (1922–2003) versus 537 TAF in the SED for LSJR Alternative 3.[41]

Table 3.2-4. Comparison of Average Annual Stanislaus River Streamflow, Diversions, and New Melones Reservoir Carryover Storage for Baseline and 40 Percent Unimpaired Flow Alternatives, in Attachment A and SED Results

	SED Baseline	OID/SSJID Attmt. A Baseline	SED-40% Unimpaired Flow (LSJR Alternative 3)	OID/SSJID Attmt. A "Pure 40% of Unimpaired Flow"
Stanislaus River at Goodwin Streamflow (TAF)	451	451	524	521
OID/SSJID Diversions (TAF)	510	503	446	478
SEWD/CJSWD Diversions (TAF)	106	111	91	79
Total Stanislaus District Diversions (TAF)	616	614	537	557
New Melones end-of-September Carryover Storage – median value (TAF)	1,124[1]	1,265	1,096[2]	750
New Melones Carryover Storage – 90% exceedance (TAF)	484[1]	511	781[2]	89
New Melones Carryover Storage – minimum (TAF)	100[1]	91	662[2]	80

[1]SED Table F.1.3-5l

[2]SED Table F.1.3-7i

Green = excellent agreement between models; yellow = disagreement between models, and red = major disagreement between models

Commenters raised the issue that comparing average results does not reveal all the potential impacts on reliability. As described in Master Response 2.3, *Presentation of Data and Results in SED and Responses to Comments*, and shown in Appendix F.1, *Hydrologic and Water Quality Monitoring*, results are shown in many forms, including complete tables, percentiles, and percent exceedance plots. It is illustrative for the example to compare the commenter's analysis in Attachment A to the SED evaluation of diversions in LSJR Alternative 3. Attachment A results for lower reservoir storage based on their chosen manner of operation are shown in Attachment A Figure 12, showing the dozen years New Melones would be at or near dead pool of 80 TAF at the end-of-September, in the 1922–2003 period. This compares with the SED in Appendix F.1, Figure F.1.3-3b, where carryover storage guidelines keep levels usually above 800 TAF and always above 600 TAF.

The effect that this manner of operation has on the reliability of water supply can be shown in Figure 3.2-23, which depicts rank-ordered annual diversions for OID/SSJID and SEWD/CSJWD in the LSJR Alternative 3 and pure 40% unimpaired flow scenarios of Attachment A. Each data point on this exceedance plot represents 1 year of diversion in the 1922–2003 period. On the left side of the

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[41] Attachment 1 to Appendix F.1, Table 3, Summary Table of Stanislaus River at 40 Percent Unimpaired Flow. Table ES-2 mean annual water supply effects includes another 20 TAF for minor diversions representing CALSIM diversion D528, for a total of 557 TAF diverted from the Stanislaus River (OID/SSJID, SEWD/CJSWD, and minor).

plot is the maximum diversion year for each series (exceeded zero percent of years). On the right side is the minimum diversion for each (exceeded in all other years), and in the center is the median value, exceeded in half of years.

The models generally agree on levels of diversion when adequate supply is available (left side of the plot). OID/SSJID diversions are allocated to meet demand and based on the 1988 Agreement; SEWD and CSJWD are allocated by contract quantities. In drier years where less diversion occurs based on lack of availability (right side of the plot), the models diverge because of the manner of allocation and reservoir carryover storage levels. OID/SSJID divert more supply in the Attachment A scenario by drawing down New Melones Reservoir. This, in turn, reduces the contract allocations to neighboring SEWD/CSJWD[42] and leads to 4 years less than 200 TAF diversion for OID/SSJID because New Melones is drained to dead pool. Dead pool conditions, which would affect stream temperatures and diversions sharply curtailed due to zero reserve, are undesirable effects and make this an unreasonable method of operation.

On the contrary, the WSE model maintains higher carryover storage levels in LSJR Alternative 3 (Appendix F.1, Figure F.1.3-3b), which contribute to cooler release temperatures and, in turn, support attainment of the narrative LSJR flow objective as well as increased reliability of using the carryover supply to deliver the 210 TAF minimum allocation when needed. The WSE model does indicate lower diversions to OID/SSJID in approximately a third of years in this example (where blue dots are lower than grey Xs), compared to the pure 40 percent unimpaired flow results of Attachment A. The manner of operation incorporating all of the reservoir constraints in the WSE model is reasonable and credible, particularly in light of the alternative operations presented.

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[42] SEWD and CSJWD contract allocations are based on the New Melones Index, which is calculated as the March 1 storage and the sum of April through September forecasted inflow. At low reservoir levels, SEWD and CSJWD allocations are drastically reduced (USBR 2013a, 2013b).

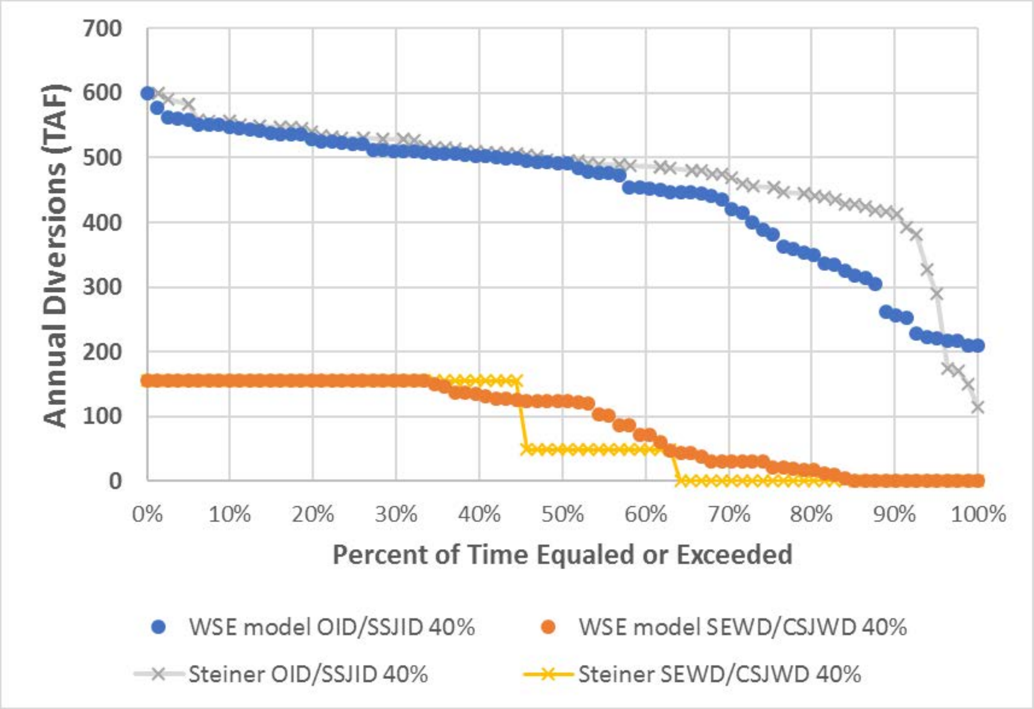

Figure 3.2-23. Percent Exceedance of Annual Water Year Diversion for OID/SSJID and SEWD/CSJWD, from the Stanislaus River based on WSE model LSJR Alternative 3 and Attachment A Pure 40 Percent Unimpaired Flow Scenarios.

As described in the section entitled *Reservoir Operations, Reoperation, and Carryover Storage*, the WSE model scenarios in the LSJR alternatives represent water storage and delivery system operations to meet multiple objectives of maximizing water delivery to meet demand for the year, saving some water for next year by storing water in reservoirs, and providing minimum allocations where possible when water supply is low. The operations constraints used in the WSE model match the CALSIM baseline very well. Additionally, historical evidence shows that reservoir operators and water districts generally function with these goals in mind and do not, as some commenters suggested, drain the reservoirs dry to meet full demands every year. Rather, operators conserve water by allocating the available water based on the projected supply, just as the WSE model represents these actions, to provide water reliably from year to year.

Modesto Irrigation District and Turlock Irrigation District Analysis

Another example of an alternative manner of operation is presented by MID/TID regarding the effects of multiple dry years and the descriptions of water supply in terms of averages. In Figure 3.2-24, the diversions presented in the unnumbered table on page 9 of the comment letter from MID/TID are presented, showing annual (water year) baseline diversions for MID/TID from 1987 through 1992, and the average value for this period from the WSE model and Tuolumne River Operations (TROps) model presented for comparison.[43] CALSIM baseline results[44] have been added

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[43] In this figure, WSE model results from the SED have been used for illustration, rather than the SEDBase WSE values in the table in the MID/TID comment letter, which are very similar but not identical to SED data.

[44] For more information regarding the SWRCB-CALSIM Baseline scenario, please refer to Appendix F.1, *Hydrologic and Water Quality Monitoring*, Section F.1.2.2, *Development of the WSE Model Baseline and Alternatives Assumptions.*

for further show that all three models may show slightly different allocations in a particular year while still having similar average values characteristic of existing conditions in the baseline scenario. The differences between each model's results arise primarily from differing allocation logic and thus available water determinations in each year based on available inflow and utilization of reservoir storage. In years when demand can be met as determined by a particular model, allocation would be limited based on differences in the characterization of total demand. In this example, the TROps baseline allocates more water in 1990 and 1991 than in 1988 and 1989.

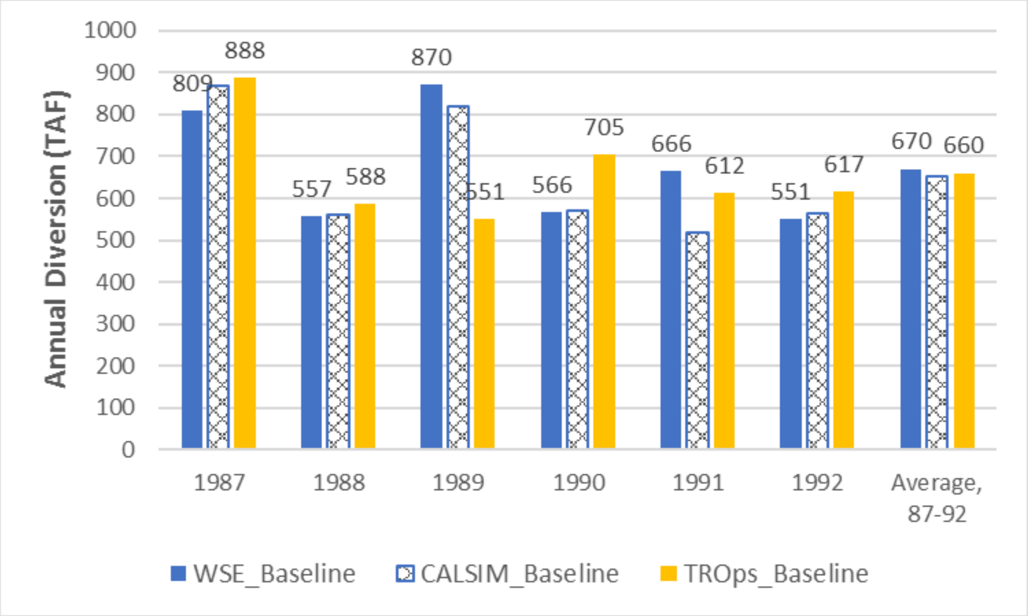

Figure 3.2-24. Annual Water Year Diversions to MID/TID from the Tuolumne River in Baseline for 1987–1992; Annual and Average Results from WSE Model Baseline, CALSIM Baseline, and TROps Baseline

The commenter asserted that from 1987 through 1992, there would be "no way of knowing" how long the drought would last; therefore, operators would be compelled to allocate more in the first year of the drought and have less available in the third year, leading to 5 years of a minimum supply (about 363 TAF). Figure 3.2-25 compares WSE model and TROps model for LSJR Alternative 3, the 40 percent of unimpaired flow scenario from 1987 through 1992. Again, the two models generally agree on the average level of diversion based on available supply, but each differs in its manner of operation and allocation.

The commenter asserted that the WSE model's reduced allocation in the first year is related to the use of perfect foresight regarding the length of the drought, which is incorrect. The WSE model allocates water supply based on the reservoir carryover guideline and maximum draw from storage parameters, which work in concert to preserve some storage in the first year and allocate it in the third year. This is simply a more conservative manner of operation, which applies in all years without needing to know how long the drought will last. This manner of operation in the WSE model restricts allocation in some years to preserve supply for other years and maintains carryover storage levels that support attainment of the narrative standard and avoid significant adverse temperature impacts on fish and wildlife.

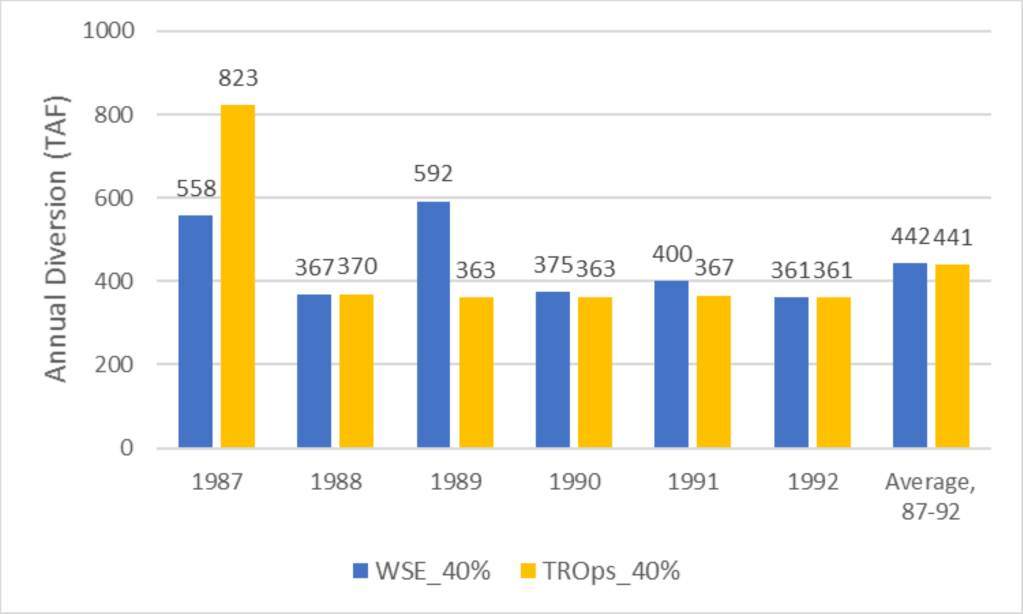

Figure 3.2-25. Annual (Water Year) Diversions to MID/TID from the Tuolumne River in LSJR Alternative 3 for 1987 through 1992; Annual and Period-Average Results from WSE model and TROps

WSE modeling for the LSJR alternatives incorporates model assumptions for increased carryover storage guidelines and flow shifting of some of the flow requirement to fall, both of which are designed to reduce temperature impacts that would otherwise occur. It is historically evident that districts make allocations more conservatively rather than incurring zero allocations and dead pool. The WSE model parameters and flow shifting are consistent with a conservative approach that allocates water based on changing conditions and incorporating risks to water supply based on flow objectives.

Adaptive Implementation

Commenters stated that the SED did not model the plan amendments and specifically point to the variety of implementation possibilities within a framework of adaptive implementation. The modeling scenarios for each of the LSJR alternatives are representative of implementation within the adaptive ranges that meets the LSJR flow objectives.

Each LSJR alternative in the WSE model was developed using reservoir operations constraints and available flexibility under the adaptive implementation framework in order to minimize water delivery reductions, meet the LSJR numeric flow objectives, and avoid significant adverse temperature impacts on fish and wildlife as required by the flow objectives and program of implementation. Please refer to previous sections and Appendix F.1, *Hydrologic and Water Quality Modeling* for additional detail. The WSE model was updated from the 2012 Draft SED WSE model in response to comments on the 2012 Draft SED to include continuous re-operation of reservoirs to maximize fish and wildlife benefits with the available water budget and minimize water supply effects.

The SED analyses show a realistic potential result of the plan amendments by modeling the LSJR alternatives with adaptive implementation in the form of shifting a fraction of flow from the

February–June period until later in the year (flow shifting). Importantly, under the adaptive implementation framework, the State Water Board may approve adaptive adjustments, such as flow shifting, or the Executive Director can approve such changes on an annual basis with the recommendation of one or more members of the STM Working Group, which includes State Water Board staff who will likely recommend flow shifting where necessary to avoid significant adverse temperature impacts. Therefore, while the scenarios presented in the SED and modeled in the WSE model do not represent all possible iterations or scenarios that may meet the objectives, they do present a conservative, rational, and feasible approach to meeting the objectives.

In practice, reservoir operations are conducted each year in attempts to minimize negative outcomes. One example is the Stanislaus Operations Group, which publishes annual reports describing implementation of the BiOp RPA governing the operations of New Melones Reservoir.[45] As described in those reports, fisheries experts issue flow schedule advice and agency concurrence based on the unique conditions that determine a water budget in a given year, in a single tributary for one season, for the best benefit to the life stage in effect, whether spawning, rearing, or migration (Stanislaus Operations Group 2018). Operational determinations at that detailed level of resolution are beyond the scope of this programmatic analysis but are the purview of STM Working Group in order to best use enhanced water budgets in the implementation of LSJR basin plan objectives.

Additional detail related to adaptive methods and implementation is discussed in Master Response 2.2, *Adaptive Implementation*. Adaptive implementation is also discussed in *Appendix K, Revised Water Quality Control Plan*, and Chapter 3, *Alternatives Description*.

Flow Shifting and Shaping

This section clarifies flow shifting and flow shaping elements of WSE modeling related to incorporation of adaptive management in describing effects of the LSJR flow alternatives. The SED *Executive Summary* states:

> The unimpaired flow objective is not intended to be implemented in a way that requires rigid adherence with a fixed percent of unimpaired flow. It is intended to determine a quantity of water that can be “shaped” or shifted in time to provide more functionally useful flows. Functionally useful flows are designed to achieve a specific function, such as increased habitat, more optimal temperatures, or a migration cue. The unimpaired flow requirement is also not intended to remain at one fixed percent, but rather to be adaptively implemented within a range of unimpaired flow in response to changing information and changing conditions.

LSJR alternatives are evaluated in the WSE model by incorporating adaptive implementation, consistent with the program of implementation, to evaluate a reasonable implementation scenario for each alternative. LSJR Alternatives 3 and 4 incorporate the use of adaptive implementation Method 3 (see conceptual illustration of LSJR Alternative 3 in Appendix F.1, *Hydrologic and Water Quality Monitoring,* Figure 3.2-26), which allows shifting water to provide a more functionally useful flow. Shifting flows reduces the risk of increased temperatures in fall due to lower reservoir storage caused by high flow releases in the spring (February through June). LSJR Alternative 2, 20 to 30 percent of unimpaired flow, does not use flow shifting because there is insufficient flow to beneficially affect fall river temperatures, and reservoirs are not substantially reduced such that temperature in the fall would be negatively affected.

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[45] Available at http://www.westcoast.fisheries.noaa.gov/central_valley/water_operations/sog.html.

Appendix F.1, Section F.1.2, *Shifting of Flow Requirement*, describes how the flow shifting and percent of unimpaired flows are incorporated for each LSJR alternative. As shown in Appendix F.1, Table F.1.2-25, LSJR Alternative 3 (for 40 and 50 percent of unimpaired flow) and LSJR Alternative 4 (50 and 60 percent of unimpaired flow) use flow shifting in wet years on the Stanislaus and Tuolumne, and in wet and above normal years on the Merced because this reduces risk of potentially adverse effects on river temperatures in the late summer and fall. The volume shifted is limited to 25 percent of the unimpaired flow requirement volume released from February through June, and is shifted to October in all years and July through November in wet years (wet and above normal years for the Merced). The volume is reallocated from February through June by reducing each month proportionally to establish the desired flow pattern and temperature profile.

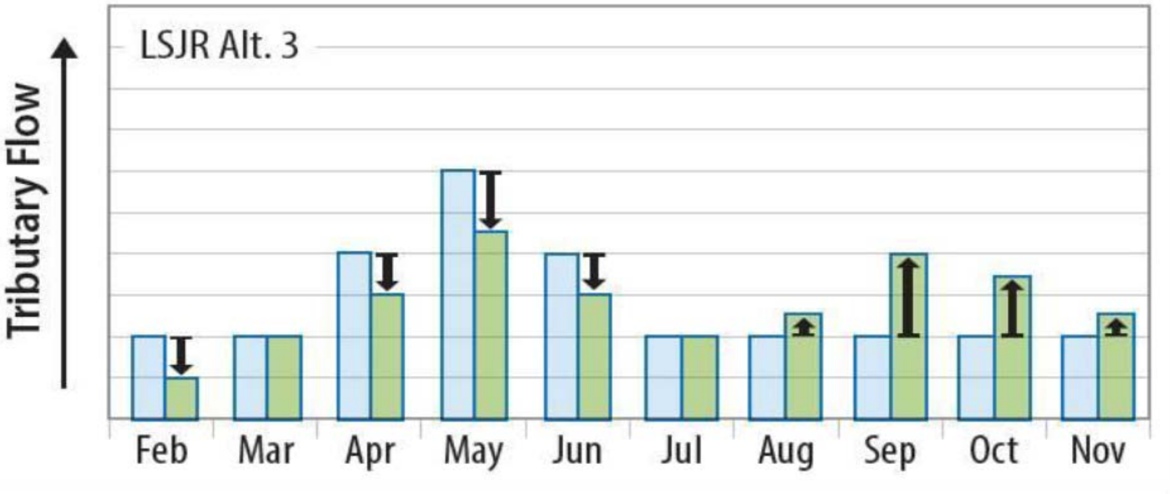

Figure 3.2-26. Generalized Illustration of Shifting of Flow Requirement to Summer and Fall (Source: Appendix F.1)

Some commenters objected to flow shifting because retaining flow outside the February–June period requires storing water in reservoirs. In many years, lack of capacity and flood control constraints would require some water to spill. This water would otherwise be stored by operators for consumptive use. Commenters stated that storing water for use later in the year would "not be feasible," and that any water stored "for fish and wildlife purposes" would spill first. This appears to be a matter of determining "whose" water is spilling, which relates to water rights that allow diversion to storage.

The WSE model reoperates reservoirs considering flood constraints and spills water when required by USACE and CALSIM flood control limitations. The WSE model does not consider the water right characteristics associated with stored water by districts or for fish and wildlife purposes in this programmatic analysis. The amount of flow shifting in the LSJR alternatives is incorporated into the amount of water supply available and associated impacts in each alternative. If water is spilled, it is properly considered not available for future diversion and use, and the impact of flow shifting is thus properly and reasonably accounted for in the analysis.

Multiple commenters appear to have confused the shaping and shifting of flow conducted for SALSIM modeling in Chapter 19, *Analyses of Benefits to Native Fish Populations from Increased Flow between February 1 and June 30,* with the shifting conducted in the WSE model. Chapter 19 contains a use advisory for SALSIM that explains that the State Water Board did not rely upon SALSIM for either its determinations or impacts or benefits. SALSIM was evaluated for limited purposes, and the approach used in the temperature model portion of the SALSIM evaluation is not the same as the approach used for assessing the effects and impacts of the LSJR alternatives and plan amendments in the SED. On the contrary, the benefits analysis of Section 19.4, *Methods: Flow and Temperature Inputs to SalSim,* applies shaping and shifting based on specified temperature targets set for the purpose of that analysis. That section states the following:

> The WSE modeling runs which were used in the SED and in SalSim are referred to as unimpaired flow runs in the following SalSim sections, and are labeled SB20%UF for example for the 20% unimpaired flow run. This is to distinguish those scenarios from other scenarios where further consideration was given to temperature, flow, and storage to optimize adult salmon production. These additional modeling runs are referred to as flow shifting runs…

In conclusion, the flow shifting used in the SalSim scenarios was for the limited purpose of illustrating how more rigorously shaped flows can result in even greater temperature benefit to aquatic habitat and not for the purpose of evaluating potentially significant environmental impacts or overall project benefits.

HEC-5Q Temperature Model

This section addresses comments regarding the application and adequacy of temperature modeling for the SED. The HEC-5Q temperature model is used to assess the effects of the LSJR alternatives on river temperatures in the three eastside tributaries and the LSJR (CDFW 2013). Chapter 5, *Surface Hydrology and Water Quality,* and Appendix F.1, *Hydrologic and Water Quality Monitoring*, provide detailed descriptions of the development and use of this model to evaluate effects and impacts in the SED.

The HEC-5Q temperature model (USACE 1998, 1986) is a simulation program developed by USACE to evaluate temperatures in rivers. The LSJR application of the HEC-5Q temperature model represents the complexities of the three-tributary river system and the LSJR for assessing alternative conditions such as operations changes, physical changes, combinations of the two, and resulting instream temperature effects. There have been several revisions of the LSJR application since the late 1990s, beginning in the Stanislaus River and extending to the other tributaries and LSJR as part of a CALFED project and subsequent peer review commencing in 2006 (CALFED 2009). The tributary reservoir and river temperatures of the 2009 model were calibrated with 1990–2007 data, including monthly reservoir temperature profile observations as well as hourly temperature measurements at several stations in each tributary river. The 2012 Draft SED used this prior version of the HEC-5Q (CALFED 2009).

Recent Development of the HEC-5Q Temperature Model

The HEC-5Q model was most recently updated and released in June 2013 (CDFW 2013). The primary updates included the addition of water quality modeling of electrical conductivity and slight adjustments to the temperature calibration, as well as a graphical user interface known as the hydrologic water quality modeling system (HWMS) (CDFW 2013). In addition, 2013 version improvements include a method of interfacing with CALSIM II that vastly improves the flexibility of evaluating programmatic and operations scenarios, such as the SED baseline and LSJR alternatives.

The 2013 HEC-5Q model includes the ability to run the model in two distinct methods: 1) to determine the effects of changes in reservoir releases, and 2) to set temperature targets that would be met by the model by automatically changing releases. The temperature model has a temperature operations function (CDFW 2013, Appendix B, System Operation for Temperature Control), which has the capability of modeling reservoir operations to try to meet downstream temperature and flow targets. Method 1 is used in the SED to assess the effects and impacts of the plan amendments.

Selection of the HEC-5Q Temperature Model

The State Water Board selected the HEC-5Q model for several reasons: 1) it was the most appropriate and readily available model at the time the SED investigation was conducted; 2) it did not need additional calibrating, as it had been extensively calibrated and peer-reviewed before its release; and 3) it allows users to run the scenarios basin-wide with the three tributaries and LSJR combined, without the need to use multiple models in parallel. Running models in parallel creates greater potential for error and the need to patch results together.

Application of the HEC-5Q Temperature Model

Commenters stated that the State Water Board applied a version of the HEC-5Q model that was not peer-reviewed. This comment likely reflects confusion raised by the following statement in Chapter 5, *Surface Hydrology and Water Quality,* Section 5.4.2, *Methods and Approach,* and Appendix F.1, *Hydrologic and Water Quality Modeling*, Section F.1.6, *Temperature Modeling*: "State Water Board modified the San Joaquin River Basin-Wide Water Temperature and EC Model," without stating what elements of the model were specifically modified.

Modifications and enhancements are to be expected in any modeling program that is continually technologically evolving with funding and support of state and federal agencies. California Department of Fish and Wildlife (CDFW) has documented enhancements and modifications up to 2013 (CDFW 2013). Additional modifications by the State Water Board include the use of WSE model inputs in place of CALSIM data, which is straightforward because the WSE model uses the same node schematic (Figure 3.2-1). Temperature output data at river locations not initially programmed in the model were needed to support the analysis for aquatic biological resources. New locations were added by working with model developers so that temperature output data at the new locations could be used in the impacts analysis in Chapter 7, *Aquatic Biological Resources*. Modifications necessary to conduct the SED analysis are consistent with the fundamental physical construction of the HEC-5Q framework and calibration that have been peer-reviewed.

The temperature model is run using monthly CALSIM output or monthly flow data formatted similarly to CALSIM output—in the case of the SED, using monthly flows from the WSE model. Monthly flow data is converted to a format compatible with the HEC-5Q model using a processing routine (code). This routine serves two purposes: 1) to allow the temperature model to perform a long-term simulation compatible with the period used in the WSE model and 2) to convert monthly output to daily values used in the temperature model. WSE monthly flow results are converted using the CALSIM-to-HEC-5Q temperature model pre-processor and used in the temperature model to determine the potential river temperature effects of the LSJR alternatives in the Stanislaus, Tuolumne, and Merced Rivers and the LSJR. The temperature model was run for the 1970–2003 period, a period with sufficient length and climatic variation to reasonably determine the potential effects of the LSJR alternatives on river temperatures.

Climate Change

Some commenters asserted that hydrologic volatility expected from climate change should be incorporated in the modeling or impact analysis, or alternatively, that the SED hydrologic analysis should only rely on WSE results from more recent years. Some commenters asserted that the combination of climate change and the plan amendments could result in greater reductions to water supply. Some commenters asserted that the implementation of the unimpaired flow objectives under the conditions of climate change would result in river flows that would not mimic historic flows.

Chapter 14, *Energy and Greenhouse Gases*, qualitatively evaluates how the LSJR and south Delta water quality (SDWQ) alternatives may be affected by climate change under Impact EG-5 for informational purposes. The hydrology effects associated with reduced water supply and reliability as a result of climate change were based on the California Water Plan Update 2013, Chapter 3, California Water Today; Volume 2 regional reports for San Joaquin River Hydrologic Region and Sacramento-San Joaquin Delta, and Chapter 22, Ecosystem Restoration (CNRA and DWR 2013). The assessment is also consistent with information contained in the Sacramento and San Joaquin Basins Climate Impact Assessment (USBR 2014, 2016).

As described in Chapter 14, Section 14.4.1, *Thresholds of Significance, GHG Emissions/Climate Change,* the California Supreme Court held that the requirements in the State CEQA Guidelines for an environmental impact report (EIR) to analyze any significant environmental effects the project might cause by bringing development and people into the area affected, and to evaluate any potentially significant impacts of locating development in other areas susceptible to hazardous conditions as identified in authoritative hazard maps, risk assessments, or land use plans, are valid to the extent they call for evaluating a project's potentially significant exacerbating effects on existing environmental hazards. The court held that this provision is valid to the extent it calls for evaluating a project's potentially significant exacerbating effects on existing environmental hazards and that CEQA's provisions are best read to focus almost entirely on how the project affects the environment, not how the environment affects the project (Cal. Code Regs., tit. 14, § 15126.2(a)).[46]

The court distinguished between requirements that consider the environment's effects on a project and those that contemplate the project's impact on the existing environment, holding that the former is invalid while the latter is entirely consistent with CEQA's concerns about environmental protection, public health, and deliberation.[47] The court noted that the CEQA statute does not proscribe consideration of existing conditions.[48] Accordingly, it held that the requirements in the State CEQA Guidelines for an evaluation of a project's potentially significant exacerbating effects on existing environmental hazards is consistent with the statute. Because the effects of the environment on a project need not be evaluated and the SDWQ and LSJR alternatives do not involve exacerbating existing environmental hazards, the analysis of how climate change might affect the project is not required but is provided in Chapter 14.

As described in Chapter 14, Section 14.2.3, *Climate Change*, climate change is expected to result in warmer temperatures and reduced snow pack. However, effects of climate change on future precipitation are uncertain and cannot be modeled precisely. This is exemplified by two recent

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[46] *California Building Industry Association v. Bay Area Air Quality Management District* (2015) 62 Cal.4th 367.

[47] *Id*. at 388.

[48] *Ibid.*

articles from *Nature*, one of which predicts more precipitation in California (Allen and Luptowitz 2017) and the other of which predicts less precipitation in California (Cvijanovic et al. 2017).

It is expected that climate change could result in increased year-to-year variations in precipitation (as identified in Chapter 14), but it is unclear whether volatility in the recent hydrologic record is a measurable manifestation of climate change or characteristic highly variable California hydrologic conditions. The SED analysis uses 82 years of hydrologic conditions that provide a robust representation of the wide variability observed in California. Evaluating recent years as indicators of climate change-induced greater hydrologic variability in a shorter period would be unlikely to affect the conclusions of the SED because the 82 years evaluated already include substantial variability that encompasses the variability observed in recent years. A key feature of hydrologic conditions in California is high year-to-year variability, which makes it difficult to discern changes in the hydrologic record over time. Although commenters suggest some evidence of changes in variability or trends, inclusion of the period from 2003 to 2016 would not change the analysis enough to alter the conclusions.

Variability in runoff over time is shown in Chapter 21, *Drought Evaluation,* Figures 21-1, 21-2, and 21-3. An essential part of WSE modeling, results, and impact analysis is the inclusion of multiple wet and dry year sequences within the 82-year modeling period, which is long enough to capture the year-to-year variability that characterizes California hydrology. A longer period than that suggested by commenters would be necessary to conclude that climate change has already increased variability. Chapter 21 is provided as an illustrative exercise to demonstrate that recent variability is similar to the 1922–2003 period.

Chapter 14 considered several factors associated with the plan amendments and climate change.

- Reduction in snow pack due to climate change could reduce water supply even without the plan amendments. The proportion of precipitation expected to fall as rain instead of snow could increase (Impact EG-5). This could result in higher winter and early spring runoff that may result in higher flood control releases. Under these conditions, flood control releases would contribute to the plan amendments without having much effect on water supply because, in general, flood control releases are not used for water supply as they typically occur during the part of the year when diversions are not needed.
- The increase in February–March flood control releases that could be expected with climate change may be reduced by implementation of the LSJR alternatives. This is because the LSJR alternatives would require increased reservoir releases, which would thereby increase the available storage space in reservoirs.
- The flow requirements are a percent of unimpaired flow and not fixed flow values. This means that if climate change results in years with less precipitation and runoff, the flow requirement would be lower.

Climate change is not included in the quantitative analysis of potential water supply effects of the plan amendments because of the uncertainty of precipitation effects as described above, in addition to inability to precisely model precipitation effects from climate change.

The State Water Board is required to prepare water quality control plans and regularly review the plans to update water quality standards. The State Water Board is currently updating the Bay-Delta Plan. Consistent with the review requirement, the program of implementation for the plan amendments includes updates to the 2006 Bay-Delta Plan upon implementation of the objectives as information becomes available through monitoring and special studies. As a result, the planning process continually accounts for changing conditions related to water quality and water planning, such as climate change. Because climate change would occur relatively slowly over many years, these mechanisms of adaptation would permit responses to climate change to occur sufficiently rapidly to protect resources to the extent possible.

The flexibility of the plan amendments, the ability of the plan amendments to allow adjustments, and the continuing water quality control planning process allow for responses to changing circumstances like climate change. Several mechanisms of adaptation are described in Chapter 14 under the discussion of impact EG-5. The adaptive implementation methods of the LSJR alternatives would provide the State Water Board and the STM Working Group the ability to respond to changing flow and water quality that may arise due to climate change as it relates to protecting beneficial uses such as fish and wildlife on the three eastside tributaries and agricultural uses in the southern Delta.

As described in Chapter 3, *Alternatives Description*, and Master Response 2.1, *Amendments to the Water Quality Control Plan*, one of the purposes and needs of the plan amendments is to increase flow variability on a pattern that is generally similar to unimpaired flow conditions to improve hydrologic conditions for fish survival. The plan amendments would not, and are not meant to, match natural flow conditions present during fish evolution. Matching natural flow would require that very little water (if any) be diverted for human consumption. Hydrologic effects of climate change could influence timing of flows to some degree, but implementation of the plan amendments would still result in more natural flow variability than under baseline conditions (Chapter 19, *Analyses of Benefits to Native Fish Populations from Increased Flow between February 1 and June 30*, and Master Response 3.1, *Fish Protection*).

Hydropower

Hydropower generation from the plan area represents a relatively small percent of the total hydropower generation in California. Energy data from 2011 and 2015 are illustrative of the small effect of hydropower generation in the plan area on energy use in California (CEC 2018). In both these years, Californians used approximately 295,000 gigawatt-hours (GWh) of electricity. In 2011, a wet year, approximately 43,000 GWh of this energy (14.6 percent) was supplied by hydropower generation within California. In 2015, a critically dry year, approximately 14,000 GWh of this energy (4.7 percent) was supplied by hydropower generation within California. Total installed hydropower capacity in California in 2009 (baseline) was approximately 13,800 megawatts, with little change since then (CEC 2017). Hydropower capacity in the plan area and extended plan area is approximately 1,500 megawatts (Chapter 14, *Energy and Greenhouse Gases*, Table 14-2a) and, therefore, represents about 11 percent of the total hydropower capacity in the state. Assuming the facilities in the plan area are used approximately as fully as the other hydropower facilities in the state, only about 1.6 percent of total electric energy use in California came from the plan area in 2011 and 0.5 percent in 2015. Changes in hydropower electricity generation due to the plan amendments have limited ability to affect grid reliability, peaking power, or over-generation.

Peaking Operations

Commenters expressed concern regarding the potential for the plan amendment effects on hydropower to limit the ability of the electric grid to respond to daily peak energy demand because of either higher flows in the spring or both lower storage and flows in the summer.

Ability to ramp power up and down during a day is an important tool to compensate for variations in demand and generation of electricity. This peaking ability is becoming more important due to increasing use of solar and wind power and the passage of California Senate Bill 350 (2015), which requires that 50 percent of California's electricity be supplied by renewable energy by 2030. As the sun moves lower in the sky toward the end of the day, solar power decreases at a time when demand for electricity peaks (Office of Energy Efficiency and Renewable Energy 2017). Increased reliance on wind and solar energy in California is increasing the need for other, more flexible power-generating facilities to compensate for variations in power generation and demand. This increasing need for a flexible power supply would occur even in the absence of the plan amendments.

Hydrologic conditions may affect daily variations in hydropower generation through the day. Under wet conditions, hydropower plants may operate close to full capacity throughout the day and during dry conditions, reductions in water availability may limit the ability to generate maximum power during periods of peak demand. However, flexibility persists under both dry and wet hydrologic conditions. Daily peaking operations can be seen in aggregated hydropower generation data collected by the California Independent System Operators (CAISO), the largest purveyor of electricity in the state (hourly hydropower generation data for individual hydropower facilities is not available from CAISO). Hourly hydropower values for 2015, a critically dry year (Figure 3.2-27) and for 2017, a wet year (Figure 3.2-28), show that substantial peaking operations occur during both wet and dry years. The comparison shows that as a percentage of average hydropower generation, peaking was greatest during the dry conditions of 2015 and smallest during the wet conditions of 2017. However, in terms of absolute values (in megawatts, not percent), peaking was greatest during 2017. These data show that hydropower can contribute to peak power demands under both wet and dry conditions.

During dry conditions, overall hydropower generation is lower, but the percent variation through the day is higher. These dry conditions are generally representative of the effect of the LSJR alternatives on summer hydropower generation. The WSE model estimated that reductions in monthly average hydropower generation would occur during the summer due to the LSJR alternatives. However, increased daily fluctuations during dry conditions can maintain peak power at a relatively high level, although daily peak generation could still be somewhat lower than during baseline or wet conditions.

The potential effects of reduced monthly and hourly peak generation during the summer is considered in the SED analysis. The SED conservatively assumes all reductions in peak power supply would be compensated primarily by increased generation at fossil-fuel powered electrical generating facilities, resulting in increased greenhouse gas emissions (Chapter 14, *Energy and Greenhouse Gases*). Furthermore, summer effects of the LSJR alternatives on grid reliability during periods of peak use were considered in the grid reliability analysis for impact EG-1. EG-1 was an assessment of grid reliability during peak daily demand during the summer when the largest effects of the LSJR alternatives would be expected to occur.

During wet conditions, overall hydropower generation is higher, but the percent variation through the day may be lower because turbines may be operating at full capacity during all hours of the day. Wet-year conditions are generally representative of the effect of the LSJR alternatives on spring hydropower generation. The WSE model estimates that increases in monthly average hydropower generation would occur during the spring due to the plan amendments. However, some peaking operations generally still occur during wet conditions and the amount of peak power is high during wet conditions, so peak demand can more easily be met.

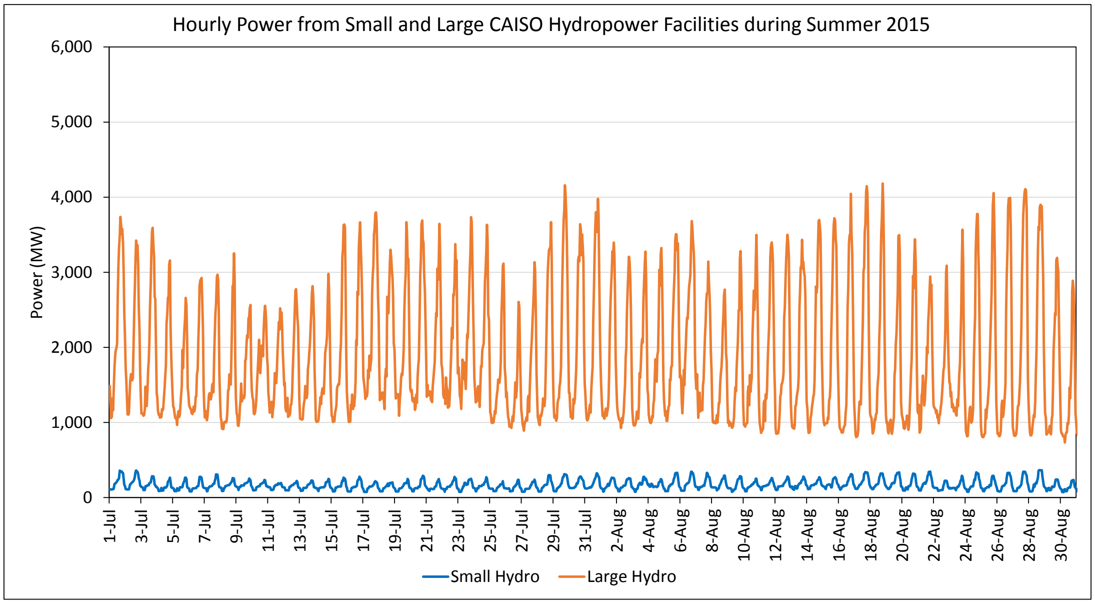

Figure 3.2-27. Hourly CAISO Hydropower Peaking Pattern during Summer 2015, a Critically Dry Year (Source: CAISO 2017)

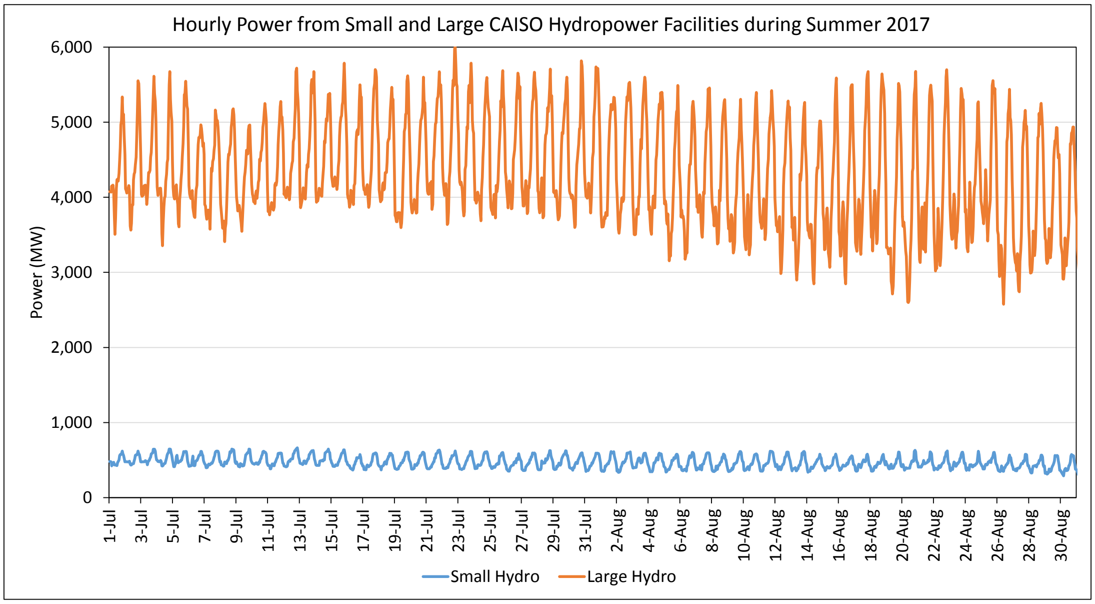

Figure 3.2-28. Hourly CAISO Hydropower Peaking Pattern during Summer 2017, a Wet Year (Source: CAISO 2017)

Potential Increases in Spring Hydropower

As described in Chapter 14, *Energy and Greenhouse Gases*, and Appendix J, *Hydropower and Electric Grid Analysis of the Lower San Joaquin River Flow Alternatives*, the LSJR alternatives could increase hydropower generation in the spring. Some commenters expressed concern that there would be too much hydropower generation in the spring and this might result in more energy than what the electric grid could handle and could result in implementation of negative pricing to balance the grid. With proper planning, however, negative pricing can be avoided. Hydropower generation is more predictable than solar or wind generation, making it easier to plan operations at other facilities to compensate for changes in hydropower generation. As described in Chapter 14, within the plan area, several balancing authorities use careful planning to regulate flow of electricity to balance energy supply and demand. In order of size, these include CAISO, the balancing authority of Northern California (BANC), and TID. There are multiple ways to avoid oversupply, including allowing some reservoir releases to bypass power turbines or scaling back generation at other electrical generating facilities. Considering the relatively small percent of California electricity provided by the hydropower plants in the plan area, any potential for springtime oversupply of electricity associated with the plan amendments is minimal compared to the potential daytime oversupply that may occur with the increasing use of solar power. CAISO is considering multiple approaches for handling increased renewable power and oversupply (CAISO 2016).

Flooding, Sediment, and Erosion

This section addresses comments on the 2016 SED regarding flooding, sediment, and erosion. Chapter 6, *Flooding, Sediment, and Erosion*, addresses channel capacity and levee conditions in the eastside tributaries and the LSJR. Information about channel capacity and current freeboard capacity was derived from DWR (n.d and 2012). DWR updated that information in December 2016 (DWR 2017a). The new report identifies changes in channel capacity reported as changes from original design capacity compared to current freeboard capacity. The report also addressed changes in channel sedimentation that affected freeboard capacity and levee stability conditions. The Chapter 6 conclusions indicate that erosion, sedimentation, levee stability, and flooding impacts remain less than significant.

Flooding

The condition of levees and associated risk factors are considered in the Chapter 6 analysis (e.g., discussion of composite condition per DWR 2012). Chapter 6, Table 6-9 shows that the alternatives would not produce different flow results for any river, in any month, for any alternative with respect to flows exceeding channel capacity. Tables 6-10, 6-11 and 6-12 show similar analysis to Table 6-9 but for the 16 wettest years out of the 82-year analysis period, which would have the greatest potential for high flows influencing sediment transport and levees. In general, the LSJR alternative flows, even in these high wettest discharge years, show modest increases in February–June peak monthly flows. These highest flows are generally below 50 percent of channel capacity.

DWR (2017a) indicates a change in freeboard capacity in the lowermost Stanislaus River from 8,000 cfs to 7,600 cfs. However, that reduction only increases the percent of capacity from 2 to 4 percent for that reach for all alternatives (Table 6-10). That change is not substantial and does not alter the less-than-significant conclusion.

DWR (2017a, Figure B-28) also identifies channel capacity changes (reported as freeboard capacity) along the SJR. Two SJR locations indicated substantial freeboard capacity reductions. They are upstream of the Stanislaus River confluence and upstream of the Tuolumne River confluence. Evaluation of LSJR alternative flows at these locations indicates no change between baseline flows and the alternative flows regarding exceeding channel freeboard capacity (i.e., equal to or greater than) nor at 50 percent nor 40 percent of channel capacity (indicators of potential seepage issues). Along the remainder of the LSJR, the identified changes indicate greater current freeboard capacity or minor decreases. Similarly, along these river stretches, the LSJR alternative flows would not increase the occurrence of flows above freeboard capacity nor at 50 percent nor 40 percent of channel capacity.

The LSJR alternative flows would generally remain in the main channel and would not affect the levee section. The DWR (2017a) report also identifies one other substantial change in the lowermost 0.75 mile of the Tuolumne River. There, the design flow of 15,000 cfs is indicated as reduced to a freeboard capacity of 2,900 cfs. The USACE floodway guideline for the Tuolumne River is 9,000 cfs. Inundation that occurs downstream is within the design standards. Additionally, the ownership at the confluence is the San Joaquin River National Wildlife Refuge (west and northeast) and River Partners (southeast), a conservation organization. These areas are conservation lands with management objectives that include levee removal, then flooding and reoccupation of levee-isolated, former floodplain (DWR 2017b, pages 5-27 to 5-30). Consequently, incidental flooding that might occur here is not considered a significant impact.

Sedimentation and Erosion

Chapter 6 indicates that sand-sized sediment moves at relatively low discharges of 2,000 cfs to 3,000 cfs compared to gravel-sized sediment, which moves at 4,500 cfs to 5,000 cfs or greater. Chapter 6 also indicates that 2,000 cfs and 3,000 cfs flows would increase and that more sand would be transported by the eastside tributaries and the SJR. However, the amount of sand moved through the system would not substantially increase streambed sedimentation nor the associated elevations of any given flood flow on adjacent levees as a result of that sedimentation, even under the revised freeboard capacities reported in the DWR (2017a). Rather, the sediment will be moved more or less evenly through the system. While there will be increases in the sand-sized sediment transported to the SJR by increased flows on the eastside tributaries for Alternatives 3 and 4, there will be concomitant increases in tributary discharges so that the received sand-sized sediment would be moved downstream.

Sand sediment transport is examined through the downstream sequence of discharges of 2,000 cfs and 3,000 cfs exceedance values (i.e., the percent of time flows would exceed these values). For Alternative 2 there is virtually no difference from baseline conditions for flows greater than 2,000 cfs and 3,000 cfs for the eastside tributaries, the SJR at the Tuolumne River, and the SJR at the Stanislaus River (Table 3.2-5 and Table 3.2-6). The latter two locations were identified by DWR (2017a) as having substantially reduced discharge capacity (freeboard capacity) and/or freeboard encroachment. For Alternatives 3 and 4, there are increases in the percent of time that the flows are greater than 2,000 cfs and 3,000 cfs, but those increases are for the entire system.

The sediment distributed along the SJR channel would not be expected to increase riverbed sedimentation substantially or associated elevations of any given flood flow on the adjacent levees. The 2,000 cfs and 3,000 cfs flows would also increase for the SJR both upstream of the Tuolumne River and upstream of the Stanislaus River. The increased SJR 2,000 cfs and 3,000 cfs flows at these two locations would result from the increase in upstream eastside tributary flows. Consequently, the downstream flow accumulation would progressively move received sediment downstream and would not cause excessive channel bed sedimentation.

This process and conclusion also applies to the SJR downstream of the Tuolumne River. Although DWR (2017a) identifies insufficient capacity along this reach, the freeboard capacity is still 37,300 cfs. In this location, the newly contributed sediment would be expected to remain in transport and not result in increased sediment deposition and associated elevation increase of any given flood flow on the adjacent levees.

The DWR (2017a) report identifies reduced channel freeboard capacity, sedimentation, encroachment, and backwater influence in the SJR upstream of the Tuolumne River confluence. However, for several river miles along the eastside SJR upstream of the Tuolumne River confluence the ownership is conservation land (River Partners). River Partners intends to remove approximately 19.8 miles of levee and 3.6 miles of revetment, allow moderate flows to reoccupy the existing meander channels, and allow active meander zone migration (DWR 2017b, pages 5-27 to 5-30). Consequently, any LSJR alternatives effects in this location would likely be beneficial.

This discussion indicates that 2,000 cfs and 3,000 cfs flows associated with the LSJR alternatives flows would not substantially affect erosion and sedimentation in the SJR. A further important consideration is that major sediment transport, flooding, and channel changes are not associated with these flows. Rather, large flood flows that approach or exceed channel capacity, such as those that occurred in 1997, 2006, and 2011, are the main controlling factor. Flood flows are the result of precipitation sequences upstream of the rim dams (snow, rain-on-snow, total volume) and flood-control storage releases, with potentially minor contributions from precipitation in the San Joaquin Valley itself. Such flows would still occur in the same manner and timing as under baseline conditions and any major impacts on channel conditions would likely be the same under the LSJR alternatives as under baseline conditions, although greater instream flow requirements associated with the LSJR alternatives could reduce the need to make flood-control releases. This is because there is sometimes more storage available in reservoirs under a higher percent of unimpaired flow (see Chapter 5, Section 5.4.2, *Methods and Approach*, and Chapter 6, Section 6.4.2, *Methods and Approach*).

Another consideration is that, broadly, climatically controlled periods of lower flows tend to increase local sedimentation while periods of higher flows move sediment through the system. This natural process has been exacerbated on the SJR by upstream storage, agricultural water use, and drought, thereby broadly increasing sedimentation in some locations along the SJR as described in DWR (2017a). During LSJR alternatives flow implementation, broad climatic periods of lower and higher flows would occur as under baseline conditions. However, sedimentation occurring during the lower end of these trends would be dampened by the minimum required LSJR alternative flows, which would maintain some sand transport through the SJR and reduce negative impacts.

Based on this discussion, local channel aggradation may occur for short periods at some locations, but the total SJR sedimentation would not be expected to be substantial. Consequently, the LSJR alternative conclusions of no significant impact with respect to flooding would not be affected by aggradation and would remain less than significant.

DWR (2017a) suggests that sedimentation is dominant along this portion of the SJR. However, the data presented in that report also show long reaches of the river where the newly determined freeboard capacity is substantially greater than the original design capacity. It is likely that some of this increased capacity is the result of channel incision increasing the overall channel capacity. Specifically, the SJR downstream of the Merced River has a large freeboard capacity increase from 45,000 cfs design flow to 56,600 cfs freeboard capacity, then a short stretch with a design flow of 45,000 cfs and a freeboard capacity increase to 82,400 cfs (first stretch with backwater influence indicated). These two stretches are straight and controlled or constrained by levees producing a narrow river channel even during high flows. The next stretch downstream has no capacities indicated but is undefined with backwater influence indicated. The next stretch is Tuolumne River to Gap in Project Levees at Grayson with the design flow of 45,000 cfs reduced to a freeboard capacity of 11,700 cfs and backwater influence indicated.

These relationships do not show overall aggradation along the SJR. Rather, they suggest the levee-constrained stretches are scouring the riverbed during high flows and transporting that sediment downstream, along with sediment delivered from upstream, to the backwater influence zones, which are less constrained by levees and where some active meandering occurs. Some of that transport is likely from the 1997 and 2006 floods as well as from the 2011 high flows. As discussed, this reach is where River Partners intends to remove levees and revetments and allow natural meander migration (DWR 2017b). Similar relationships are indicated downstream of the Stanislaus River where the design capacity of 52,000 cfs has increased to a current freeboard capacity of 59,200 cfs again in a river stretch constrained by levees. The SJR remains levee-constrained from that point downstream with no zones of backwater influence sedimentation nor reduced freeboard capacity.

Table 3.2-5. Percent Exceedance of 2,000 cfs Flows, from Upstream to Downstream (left to right)

	Merced River at Stevinson	SJR upstream of Tuolumne River	Tuolumne River at Modesto	SJR upstream of Stanislaus River	Stanislaus River at Ripon
Baseline	6	15	17	39	5
Alt 2	6	15	17	42	4
Alt 3	6	16	23	51	7
Alt 4	11	21	28	53	15

Table 3.2-6. Percent Exceedance of 3,000 cfs Flows, from Upstream to Downstream (left to right)

	Merced River at Stevinson	SJR upstream of Tuolumne River	Tuolumne River at Modesto	SJR upstream of Stanislaus River	Stanislaus River at Ripon
Baseline	4	10	13	25	2
Alt 2	4	10	12	26	2
Alt 3	3	10	14	32	2
Alt 4	4	12	20	35	6

Presentation of Results for District Surface Water Supply

Some commenters asserted that the SED's methods for aggregating impacts over time and space do not allow decision-makers to fully understand the magnitude of the water supply impacts for individual water users on a year-by-year basis. However, as discussed in Master Response 2.3, *Presentation of Data and Results in SED and Responses to Comments*, data is presented in many ways throughout the SED, not just as averages. Data is summarized using statistics, such as average, minimum, maximum, and median values. This allows the data to be presented as simplified results to easily convey summary information of potential effects. In many instances, the full set of data is presented alongside the average conditions, can be found in appendices, or can be accessed through modeling files posted on the State Water Board website.

The SED provides data and results through narrative background and explanation, analyses, and visual presentations in a sufficient level of detail to properly represent the effects and assess the impacts of the proposed plan amendments. For example, in the *Executive Summary*, Table ES-3 presents water year type averages for water supply effects of LSJR Alternative 3 overall for each of the tributaries and the plan area. In addition, Appendix F.1, *Hydrologic and Water Quality Monitoring*, Figures F.1.3-3 through F.1.3-5, present exceedance charts for tributary diversions that show the range of impacts for individual years. The underlying annual and monthly water supply data used to create these results is also available in the modeling spreadsheets posted on the State Water Board website.[49]

Some commenters requested that results for surface water diversions be presented as water year type averages for the individual irrigation districts. Tables 3.2-7 through 3.2-10 respond to this request, summarizing irrigation district surface water supplies under baseline and the LSJR alternatives averaged over all years and by year type.

Table 3.2-7. Average Annual Irrigation District Diversions under Baseline, by Year Type Conditions

Irrigation District	Avg. Annual Diversion Under Baseline					
	All Years	Wet Years	Above Normal Years	Below Normal Years	Dry Years	Critically Dry Years
	TAF	TAF	TAF	TAF	TAF	TAF
SSJID	229	220	228	239	247	221
OID	281	277	288	298	303	250
SEWD	48	70	59	40	50	12
CSJWCD	58	76	67	59	61	17
MoID	290	291	300	310	314	241
TID	553	550	574	607	617	440
MeID	445	458	485	502	513	285
Total	1,904	1,941	2,001	2,055	2,105	1,464

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[49] Available at https://www.waterboards.ca.gov/waterrights/water_issues/programs/bay_delta/bay_delta_plan/water_quality_control_planning/.

Table 3.2-8. Average Annual Irrigation District Diversions under LSJR Alternative 2, by Year Type Conditions

Irrigation District	Avg. Annual Diversion Under LSJR Alternative 2					
	All Years	Wet Years	Above Normal Years	Below Normal Years	Dry Years	Critically Dry Years
	TAF	TAF	TAF	TAF	TAF	TAF
SSJID	221	220	228	239	241	181
OID	269	277	288	298	295	193
SEWD	53	75	67	45	53	11
CSJWCD	62	80	76	65	62	18
MoID	284	291	300	307	312	214
TID	539	550	574	602	612	377
MeID	412	458	485	475	418	212
Total	1,839	1,951	2,019	2,031	1,994	1,206

Table 3.2-9. Average Annual Irrigation District Diversions under LSJR Alternative 3, by Year Type Conditions

Irrigation District	Avg. Annual Diversion Under LSJR Alternative 3					
	All Years	Wet Years	Above Normal Years	Below Normal Years	Dry Years	Critically Dry Years
	TAF	TAF	TAF	TAF	TAF	TAF
SSJID	203	218	213	223	217	143
OID	244	273	265	274	261	139
SEWD	43	74	63	44	16	0
CSJWCD	48	79	69	49	20	0
MoID	254	290	292	270	236	161
TID	470	548	556	518	437	256
MeID	350	458	470	369	245	140
Total	1,612	1,940	1,929	1,746	1,432	840

Table 3.2-10. Average Annual Irrigation District Diversions under LSJR Alternative 4, by Year Type Conditions

Irrigation District	Avg. Annual Diversion Under LSJR Alternative 4					
	All Years	Wet Years	Above Normal Years	Below Normal Years	Dry Years	Critically Dry Years
	TAF	TAF	TAF	TAF	TAF	TAF
SSJID	169	206	200	166	137	109
OID	194	255	245	191	145	92
SEWD	23	59	25	4	0	0
CSJWCD	26	66	29	5	0	0
MoID	199	281	227	183	146	104
TID	346	527	410	318	231	125
MeID	261	428	297	230	145	92
Total	1,216	1,823	1,433	1,098	804	521

References

Printed References

Allen, R.J., and R. Luptowitz. 2017. El Niño-like teleconnection increases California precipitation in response to warming. *Nature Communications*. July 6, 2017.

CALFED. 2009. *San Joaquin River Basin Water Temperature Modeling and Analysis*. Prepared by AD Consultants; Resource Management Associates, Inc.; and Watercourse Engineering, Inc.

California Data Exchange Center (CDEC). n.d. *Don Pedro Reservoir*. Available: http://cdec.water.ca.gov/cgi-progs/selectQuery?station_id=DNP&sensor_num=15&dur_code=M&start_date=1972-01-01&end_date=&geom. Accessed: June 25, 2018.

California Department of Fish and Wildlife (CDFW). 2013. *San Joaquin River Basin-Wide Water Temperature and EC Model*. June. Prepared by AD Consultants, Resource Management Associates, and Watercourse Engineering, Inc.

California Department of Water Resources (DWR). n.d. *Sacramento Valley Flood Control System and Delta and San Joaquin Flood Control System* [map]. Available: http://www.water.ca.gov/floodmgmt/docs/map_sac&sj_designflows.pdf. Accessed:

———. 1994. *California Water Plan Update*. Volume 1. Bulletin 160-93, October 1994. https://www.waterboards.ca.gov/waterrights/water_issues/programs/bay_delta/wq_control_plans/1995wqcp/admin_records/part05/328.pdf.

———. 2005a. *Description of Analytical Tools for Consumptive Use Model*. Available: http://www.water.ca.gov/waterplan/docs/tools/descriptions/CU-description.pdf. Accessed: June 20, 2018.

———. 2005b. *CalSim-II Model Sensitivity Analysis Study. Technical Memorandum Report*. October 2005. California Department of Water Resources Bay-Delta Office. Available: http://baydeltaoffice.water.ca.gov/announcement/SensitivityStudyReport.pdf. Accessed: June 20, 2018.

———. 2007. *California Central Valley Unimpaired Flow Data,* Fourth edition. Draft. May 2007. Available: https://www.waterboards.ca.gov/waterrights/water_issues/programs/bay_delta/bay_delta_plan/water_quality_control_planning/docs/sjrf_spprtinfo/dwr_2007a.pdf. Accessed: June 20, 2018.

———. 2011. *Estimating California Central Valley Unimpaired Flows* Presentation at SWRCB Workshop by Francis Chung, Ph.D., January 6, 2011.

———. 2012. *2012 Central Valley Flood Protection Plan*. June. Sacramento, CA.

———. 2016. *Estimates of Natural and Unimpaired Flows for the Central Valley of California: Water Years 1922-2014*. Available: https://www.waterboards.ca.gov/waterrights/water_issues/programs/bay_delta/california_waterfix/exhibits/docs/ccc_cccwa/CCC-SC_36.pdf. Accessed: June 15, 2018.

———. 2017a. *2017 Flood System Status Report*. Available: http://www.water.ca.gov/cvfmp/2017-cvfpp-docs.cfm. Accessed: September 23, 2017.

———. 2017b. *Basin-wide Feasibility Study San Joaquin Basin*. Draft. March 2017. Available: http://www.water.ca.gov/cvfmp/2017-cvfpp-docs.cfm. Accessed: September 23, 2017.

California Energy Commission (CEC). 2017. *California's Installed Electric Power capacity and Generation*. Last updated August 2017. Available: http://www.energy.ca.gov/renewables/tracking_progress/documents/installed_capacity.pdf. Accessed: January 2018.

California Energy Commission (CEC). 2018. *California Total System Electric Generation in Gigawatt Hours for 2011 and 2015*. Available: http://www.energy.ca.gov/almanac/electricity_data/total_system_power.html. Accessed: January 2018.

California Independent System Operators (CAISO). 2016. *Fast Facts. What the duck curve tells us about managing a green grid*. Available: file:///C:/Working%20Directory/SED-phase%201/hydropower%20MR/CAISO%202016_FlexibleResourcesHelpRenewables_FastFacts.pdf. Accessed: June 15, 2018.

California Independent System Operators (CAISO). 2017. *Hourly electric generation data by sector*. Available: http://www.caiso.com/market/Pages/ReportsBulletins/RenewablesReporting.aspx. Accessed: June 15, 2018.

California Natural Resources Agency and Department of Water Resources (CNRA and DWR). 2013. *California Water Plan Update 2013*: Chapter 3, California Water Today; Volume 2, Regional reports for San Joaquin River Hydrologic Region and Sacramento-San Joaquin Delta, and Chapter 22, Ecosystem Restoration. Available: https://www.water.ca.gov/Programs/California-Water-Plan/Water-Plan-Updates.

Cvijanovic, I., B.D. Santer, C. Bonfils, D.D. Lucas, J.C.H. Chiang, and S. Zimmerman. 2017. Future loss of arctic sea-ice cover could drive a substantial decrease in California's rainfall. *Nature Communications*. December 5.

Holland, J. 2014. Turlock Irrigation District votes to cut in half its water deliveries to farms. *Modesto Bee*. February 25. Available: http://www.modbee.com/news/local/turlock/article3161121.html. Accessed: June 20, 2018.

———. 2015. Turlock Irrigation District caps water deliveries at 40 percent of normal. *Modesto Bee* Available: http://www.modbee.com/news/local/turlock/article17010653.html. Accessed: June 20, 2018.

Merced Irrigation District (Merced ID). 2013. *Agricultural Water Management Plan*. September 3. Available: http://www.mercedid.com/default/assets/File/Merced%20ID%20Ag%20Water%20Management%20Plan%20Final.pdf. Accessed: June 20, 2018.

———. 2015. *Merced Water Operations Model and General Instructions on Model Use*. Version 5. Excel Spreadsheet.

Modesto Irrigation District (MID). 2012. *Agriculture Water Management Plan*. December. Modesto, CA. Available: http://www.mid.org/water/irrigation/documents/AgWaterManagementPlan_2012.pdf. Accessed: May 4, 2018.

Modesto Irrigation District and Turlock Irrigation District. 2013. *Don Pedro Project Project Operations/Water Balance Model, Attachment B—Model Description and User's Guide, Addendum 1, Base Case Description* and *Don Pedro Operations Model.* Version 3. Excel Spreadsheet. May.

National Marine Fisheries Service (NMFS). 2009. *Biological and Conference Opinion on the Long-Term Operations of the Central Valley Project and the State Water Project*. Southwest Region. June 4.

Office of Energy Efficiency and Renewable Energy. 2017. Confronting the Duck Curve: How to Address Over-Generation of Solar Energy. B. Jones-Albertus. October 12, 2017. Available: https://energy.gov/eere/articles/confronting-duck-curve-how-address-over-generation-solar-energy. Accessed: June 15, 2018.

San Joaquin Tributary Authority (SJTA). 2012. *Stanislaus River Metering Handouts*. October 10. New Melones operations model runs in support of DO petition discussions.

South San Joaquin Irrigation District (SSJID). 2012. *2012 Agricultural Water Management Plan.* December. Prepared by Davids Engineering, Inc. December 2012. Available: http://www.ssjid.com/assets/pdf/2012-Ag-Water-Management-Plan.pdf. Accessed: July 10, 2015.

Oakdale Irrigation District (OID). 2012. *Oakdale Irrigation District Agricultural Water Management Plan*. December. Prepared by Davids Engineering, Inc. Available: https://www.water.ca.gov/LegacyFiles/wateruseefficiency/sb7/docs/2014/plans/Oakdale%20ID%202012%20AWMP%20-%20PDF.pdf. Accessed: June 20, 2018.

State Water Board. 2011. Request for Scientific Peer Review of the Technical Report on the Scientific Basis for: 1) Alternative San Joaquin River Flow Objectives for the Protection of Fish and Wildlife Beneficial Uses and Program of Implementation; and 2) Alternative Water Quality Objectives for the Protection of the Southern Delta Agricultural Beneficial Uses and Program of Implementation. Available: https://www.waterboards.ca.gov/water_issues/programs/peer_review/docs/sanjoaquin_river_flow/081211_peer_request_ltr.pdf. Accessed: August 12, 2017.

Stanislaus Operations Group. 2010. 2010 Annual Report. Appendix C: Year Type and WSP Final. October. Available: http://www.westcoast.fisheries.noaa.gov/publications/Central_Valley/Water%20Operations/Stanislaus%20Operations%20Group/2010_sog_annual_report.pdf. Accessed:

———. 2018. *Interim Stanislaus Operations Group Advice Re: 2018 Stanislaus River Spring Pulse Flow*. March 27.

Turlock Irrigation District (TID). 2012. *Turlock Irrigation District 2012 Agricultural Water Management Plan.* December 2012. Turlock, CA. Available: https://www.water.ca.gov/LegacyFiles/wateruseefficiency/sb7/docs/2014/plans/Turlock%20ID%20Final%20AWMP%2012-11-2012.pdf. Accessed: May 4, 2018.

Thomann, R. V., and J. A. Mueller. 1987. *Principles of Surface Water Quality Modeling and Control*. Harper Collins: NY.

U.S. Army Corps of Engineers (USACE). 1986. *HEC-5 Simulation of Flood Control and Conservation Systems*. *Appendix on Water Quality Analysis*. September.

———. 1998. *HEC-5 Simulation of Flood Control and Conservation Systems. User's Manual.* Version 8.0. October.

U.S. Bureau of Reclamation (USBR). 1997. *New Melones Interim Plan of Operation*. Central Valley Operations Office, Sacramento. May 1, 1997.

———. 2004. *San Joaquin River Water Quality Module*. Version 1.00. For CALSIM II. June. Mid-Pacific Region.

———. 2005. *CALSIM II San Joaquin River Model (DRAFT).* April. Documentation by MBK Engineers for CALSIM II 2005 peer review release. Mid-Pacific Region.

———. 2013a. *Stanislaus CalSim studies of proposed SWRCB standards*. January. Prepared by Tom FitzHugh.

———. 2013b. *Assumptions for CalSim studies comparing Stanislaus deliveries under baseline and proposed SWRCB standards*.

———. 2013c. *Tuolumne River Demands*. September 3, 2002.

———. 2013d. *Tuolumne River Allocations*.

———. 2014. *West-Wide Climate Risk Assessment. Sacramento and San Joaquin Basins Climate Impact Assessment.* Available: http://www.usbr.gov/watersmart/wcra/docs/ssjbia/ssjbia.pdf.

———. 2015. *Coordinated Long-Term Operation of the Central Valley Project and State Water Project. Final Environmental Impact Statement.*

———. 2016. *SECURE Water Act Report to Congress. Chapter 8: Sacramento and San Joaquin River Basin.* March. Available: http://www.usbr.gov/climate/secure/docs/2016secure/2016SECUREReport-chapter8.pdf. Accessed: June 2018.

U.S. Fish and Wildlife Service (USFWS). 2008. *Formal Endangered Species Act Consultation on the Proposed Coordinated Operations of the Central Valley Project (CVP) and State Water Project (SWP)*. 396 pp.

Personal Communications

Eltal, Hicham. Merced Irrigation District Deputy General Manager. Letter Re: Information Request Related to Preparing Substitute Environmental Document for Update to the Water Quality Control Plan for the San Francisco Bay/Sacramento-San Joaquin Delta Estuary. Dated October 6, 2015.

Knell, Steve P. E. Oakdale Irrigation District General Manager. Memorandum Re: Responses to SWRCB Request Dated September 4, 2015. Date: October 28, 2015.

Hashimoto, Casey P. E. Turlock Irrigation District General Manager. Letter submitted via email Re: Response to “Information request related to preparing the substitute environmental document for the update to the Water Quality Control Plan for the San Francisco Bay/Sacramento-San Joaquin Delta Estuary”. Date: October 6, 2015.

Rietkerk, Peter P. E. South San Joaquin Irrigation District General Manager. Letter Re: Information Requests Related to Preparing the Substitute Environmental Documentation for the Update to the Water Quality Control Plan for the San Francisco Bay/Sacramento-San Joaquin Delta Estuary. Dated October 3, 2015.

Salyer, Greg. Modesto Irrigation District Interim General Manager. Letter Re: Modesto Irrigation District – Response to Information Request Related to Preparing the Substitute Environmental Document for the Update to the Water Quality Control Plan for the San FranciscoBay/Sacramento-San Joaquin Delta Estuary. Dated October 2, 2015.