Chapter 6
Changes in Hydrology and Water Supply

6.1 Introduction

This chapter describes the changes in hydrology and water supply that could occur as a result of the proposed Plan amendments. These potential changes are described for the regions subject to new flow requirements (the Sacramento River watershed, Delta eastside tributaries, and Delta [Sacramento/Delta]), and regions that receive Sacramento/Delta water supplies that may be reduced as a result of the proposed Plan amendments (the San Francisco Bay Area [Bay Area], San Joaquin Valley, Central Coast, and Southern California).

The Sacramento Water Allocation Model (SacWAM) is a model that helps estimate the potential changes to hydrology and water supply that could occur as a result of the Plan amendments. SacWAM simulates flow and diversions in the Sacramento/Delta under 1922 through 2015 hydrologic conditions. The year 1922 is not considered because it is identical across all scenarios. The 1923 through 2015 range is used for all incremental analyses and scenario comparisons.

SacWAM scenarios described in this chapter are presented as a range of potential instream flow changes in increments of ten, from 35 percent up to 75 percent unimpaired flow (referred to as *scenarios* or *flow scenarios*). These modeled scenarios are later grouped into three alternatives, with each alternative encompassing a range of percent unimpaired flow. The three alternatives are then compared to baseline conditions in the environmental analysis (Chapter 7) of this Staff Report in order to evaluate the potential environmental impacts associated with the proposed Plan amendments. The scenarios represent a range of tributary inflows in recognition that tributaries may have unique needs and conditions (e.g., cold water pool needs, implementation of complementary ecosystem actions, drought) and to allow for adjustments up or down within a given numeric range in order to meet those needs. Model results are presented for changes in hydrology under various scenarios, including changes in streamflows and reservoir levels, and changes in Sacramento/Delta water supply under various scenarios.

This chapter also describes changes in groundwater supply, including a discussion of groundwater use, groundwater recharge and management, how groundwater supply is modeled in SacWAM, and the potential changes in groundwater use and supply that could occur with implementation of the proposed Plan amendments. Further, it describes other water management actions that may be utilized to offset reductions in surface water from the proposed Plan amendments because, in many cases, such actions are feasible and reasonably foreseeable. It includes a discussion of groundwater storage and recovery, water transfers, water recycling, and conservation measures. Many of these types of actions are already being implemented in response to increasing water scarcity from a variety of factors, including growth, environmental needs, drought, and climate change. This chapter includes a discussion of information from water management plans regarding future use of other supplies in each of the regions. This discussion is intended to provide general information for context about how each region may respond to reduced Sacramento/Delta surface supply. While the proposed Plan amendments cannot be considered the impetus for alternative water planning actions, the process may increase the need for other water supplies and accelerate efforts to manage and plan more carefully. These actions must be taken into account in the environmental analysis. It is not possible to quantify with any precision the exact nature, location, or amount of water supply reduction offset that may be realized in any specific area, but for the purposes of this planning effort, it will be useful to understand the dynamics of alternative water supply and use.

6.1.1 Presentation of Results

Understanding the appropriate use of model results is important. The changes in surface water available for consumptive use under the various scenarios are estimated by comparing SacWAM-modeled results for baseline conditions with SacWAM-modeled results for the various scenarios. The modeled results represent the overall system changes caused by replacing one set of requirements with another (see detail below and the detailed assumptions in Appendix A1, *Sacramento Water Allocation Model Methods and Results*, and Appendix A1a, *Methods for Estimating Regional Sacramento/Delta Surface Water Supply for Agricultural and Municipal Use*). Actual historical real-time operations may vary from modeled operations, resulting in different water availability outcomes than those calculated here. Nonetheless, the model results are a good tool for comparing the scenarios for relative effects on water supply and hydrology. Because it is simulating hypothetical conditions, SacWAM is not intended to be used in a real-time predictive manner. SacWAM results are intended to be used in a comparative manner, which allows for assessing the changes in system operations and resulting incremental effects between scenarios. Model results are presented throughout the chapter in graphical and tabular formats that facilitate comparison of the statistical properties of streamflow, reservoir storage, and water supply among modeling scenarios.

Boxplots are used to broadly characterize the distributions of monthly or annualized numerical results. As illustrated in Figure 6.1-1, a boxplot shows the range of modeled or observed values from low values (bottom of boxplot) to high values (top of boxplot). Minimum and maximum values are shown as horizontal lines, or whiskers, at the boxplot's vertical extremes. When used to portray streamflow data, these whiskers represent the driest and wettest hydrologic conditions, respectively. The 25th percentile of the streamflow data distribution is the line at bottom of the grey box, and the 75th percentile of the streamflow data distribution is the line at the top of the grey box. The 25th percentile, corresponding to drier conditions, represents the point at which a quarter of streamflow values are lower than the value shown on the y-axis; the 75th percentile, corresponding to wetter conditions, represents the point at which 75 percent of streamflow values are lower than the value shown on the y-axis. The shaded box between the 25th and 75th percentile represents the central 50 percent of data, which means that 50 percent of values fall within the range of the box, 25 percent of the data points fall below the range of the box, and 25 percent of the data points fall above the range of the box. The horizontal line inside the box indicates the median, which represents the 50th percentile or the point at which 50 percent of the values are lower. The x-axis of a boxplot represents the month for monthly data, with scenarios indicated by colored shading. For annualized results, the x-axis is used to indicate the modeling scenario.

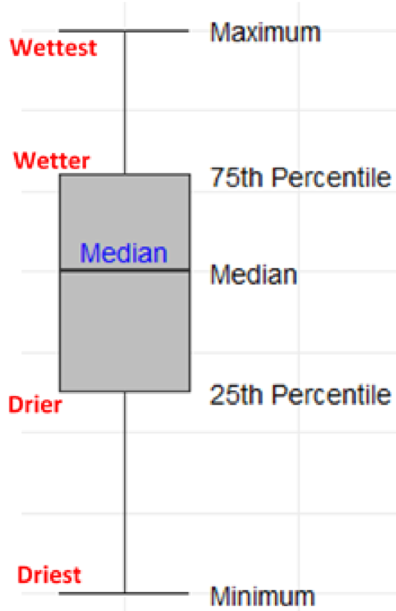


Figure 6.1-1. Generic Boxplot Example

When a finer examination of the statistical distribution of results may be needed, results are presented as exceedance curves. An exceedance curve shows the frequency with which a given value is equaled or exceeded within a data set. In this document, exceedance curves are plotted with the percent of values equaled or exceeded on the x-axis, and the variable of concern on the y-axis (Figure 6.1-2). In this chapter, exceedance curves are generally used to characterize the distribution of reservoir storage volumes.

Tabular summaries of streamflow and water supplies are also presented throughout the chapter. Cumulative distribution tables characterize distributions of results similarly to boxplots and exceedance curves, as discussed above. Additionally, average values by water year type are presented when relevant, particularly for water supply results. In the presentation of results, unless otherwise noted, water year type is defined by the Sacramento Valley historical classification system which includes five water year types in ascending levels of water availability: critical (C), dry (D), below normal (BN), above normal (AN), and wet (W). For annualized results such as surface water supply within a region, values for the flow scenarios are generally presented as differences from the corresponding value for the baseline condition. A positive value indicates more flow or water supply than baseline, while a negative value indicates less flow or water supply than baseline.

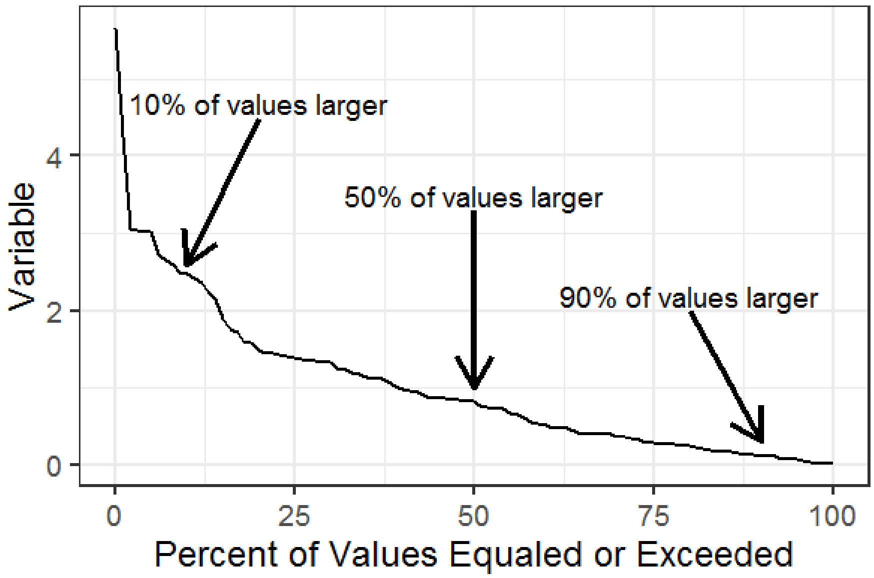


Figure 6.1-2. Generic Exceedance Curve Example

Flow rates are presented in cubic feet per second (cfs), and volumes in thousand acre-feet (TAF) unless otherwise specified. Within this chapter, results are aggregated to the scales of the seven regions described in Section 2.8, *Existing Water Supply*. Streamflow and reservoir results are presented using representative locations. Graphical and tabular summaries for representative locations and all reservoirs within the SacWAM model domain are presented in Appendix A1, *Sacramento Water Allocation Model Methods and Results*.

6.2 SacWAM Model Assumptions

6.2.1 Baseline Assumptions

The process for updating the Bay-Delta Plan has been ongoing since 2009, with a revised Notice of Preparation (NOP) issued for the Sacramento/Delta update to the Bay-Delta Plan in 2012. Since the project NOP and revised NOP, there have been changes to regulations that affect reservoir operations, streamflow requirements, and Delta operations. Updates to the Biological Opinions (BiOps) and issuance of an Incidental Take Permit (ITP) have changed the requirements for operation of the SWP and CVP, though under most circumstances actual operations have not significantly changed. The project baseline includes requirements as they have been implemented in recent years in an attempt to represent the existing conditions; these regulatory assumptions are listed in Table 6.2-1. Changes to Fall X2, San Joaquin inflow to export (I:E) limits, Old and Middle River (OMR) reverse flow limits, and the American River Flow Management Standard (FMS) are discussed briefly below.

The 2008 USFWS BiOp (^USFWS 2008) included an action to provide improved Delta smelt habitat in the Delta during September and October following above normal and wet water years, commonly known as *Fall X2*. The 2008 USFWS BiOp required maintenance of X2[1] no greater than 74 and 81 kilometers (km) following wet and above normal years, respectively. The action was implemented with various modifications pursuant to litigation in 2011 and reinitiations of consultation in 2017 and 2019 (^USFWS 2019), generally resulting in September and October X2 positions of approximately 75 km in those years (DWR 2023). This action was altered in the 2019 Long-Term Operations Proposed Action (LTO PA) and USFWS BiOp to require maintenance of X2 at 80 km in September and October following both wet and above normal years. The California Department of Fish and Wildlife 2020 ITP (^CDFW 2020 ITP) added a block of flow to support X2 at 80 km in July and August and Suisun Marsh Salinity Control Gate operations known as the *summer action*. The SacWAM baseline incorporates the new 80-km Fall X2 action and the summer action following wet and above normal years.

Another change in the 2019 BiOps was removal of the San Joaquin I:E limits that had been included in the 2009 National Marine Fisheries Service (NMFS) BiOp (^NMFS 2009 BiOp). A similar export limit was applied to SWP operations by the 2020 ITP (^CDFW 2020 ITP). The new requirement allows greater exports during years that are classified as wet using the San Joaquin watershed classification system but otherwise requires SWP to limit exports according to its share of the San Joaquin I:E requirement as previously defined in the NMFS 2009 BiOp. During litigation of the 2019 BiOps and the ongoing reconsultation process, the CVP effectively has been operating to the requirement as applied to the SWP. The SacWAM baseline incorporates the San Joaquin I:E limit as formulated in the 2020 ITP, but applied to both SWP and CVP exports.

The 2019 BiOps and 2020 ITP include OMR reverse flow limits similar to those previously implemented through the 2008 and 2009 BiOps. The changes consist largely of more prescriptive triggers and formalized procedures for determining allowable OMR reverse flow levels. The SacWAM baseline incorporates OMR limits as defined by the 2019 BiOps and 2020 ITP.

Finally, the 2019 LTO PA included changes to the American River FMS previously implemented by the 2009 NMFS BiOp. These changes are incorporated into the SacWAM baseline.

The baseline from which impacts and benefits are measured for this project represents how the SWP and CVP have been operating in recent years and how they will likely continue to operate absent any updates to the Water Quality Control Plan. Table 6.2-1 lists the specific requirements included in the baseline model simulation.

The SacWAM boundary condition at Vernalis was developed using a CalSim 3 simulation based on the *2021 Delivery Capability Report* (DWR 2022) specified to include State Water Board Water Right Decision 1641 (D-1641) Vernalis minimum monthly flows and salinity requirements. In the absence of Vernalis Adaptive Management Plan (VAMP) implementation of “pulse flows” in the period April 15 through May 15, minimum monthly flows from February through April 14 and May 16 through June were applied to the April 15 through May 15 period, at the tier based on water year type and applicable footnotes. Additionally, reservoir flood-release spills, other instream flow requirements such as BiOp-required flows from the Stanislaus River, Federal Energy Regulatory Commission (FERC) Settlement Agreement flows from the Tuolumne River, FERC instream flows from the Merced River, and other local accretions combine to produce the total resulting flow at Vernalis. The Delivery Capability Report study includes San Joaquin River restoration flows and recapture above Vernalis.

[1] X2 is the location in the Bay-Delta where the tidally averaged bottom salinity is 2 parts per thousand. It is expressed as the distance in kilometers from the Golden Gate Bridge.

Table 6.2-1. SacWAM Baseline Model Assumptions

Regulation	Action/Objective
State Water Board Water Right Decision 1641	Water quality objectives
	Minimum net Delta outflow index
	Export limits (exports to imports [E:I])
	Export limits (San Joaquin River imports to exports [I:E])
	Delta Cross Channel closures
	San Joaquin River Vernalis minimum flow [a]
	Table 4 (spring X2)
2019 Biological Opinions	American River Flow Management Standard
	Old and Middle Rivers
	Delta Cross Channel closures [b]
	Fall action (Fall X2)
2020 Incidental Take Permit	Suisun Marsh Salinity Control gate operations (summer)
	Summer action
	Fall action (Fall X2)
	Old and Middle Rivers
	San Joaquin I:E [c]

[a] Vernalis shoulder flows are assumed to apply for the entire pulse period.
[b] The Delta Cross Channel may be closed as early as October pursuant to the 2019 Biological Opinions.
[c] The 2020 Incidental Take Permit I:E export limit was assumed to apply to SWP *and* CVP.

Water use in the Delta is estimated by including Delta net channel depletions for the heart of the Delta; diversions for the municipalities of Tracy and Antioch, as well as agricultural use by Byron Bethany Irrigation District are modeled separately. Other diversions for use outside of the Delta region such as SWP and CVP and Contra Costa Water District (CCWD) also are simulated separately from Delta depletions. The net channel depletions used in SacWAM are based on the Delta Channel Depletions model results produced by DWR that have been used in many previous planning studies (e.g., Sites Reservoir, Delta Conveyance, Delivery Capability Report).

6.2.2 Unimpaired Flow Scenario Assumptions

The general approach to using SacWAM to assess the effects of Plan amendments is to simulate new flow requirements as a percentage of unimpaired flow (UF) throughout the model domain and adjust carryover (end-of-September) storage targets to maintain cold water pools for downstream fisheries. All the baseline regulatory requirements discussed in Section 6.2.1, *Baseline Assumptions*, were assumed to apply in the flow scenarios. Detailed descriptions of the model assumptions for each tributary, CVP and SWP operations, and Delta operations can be found in Appendix A1, *Sacramento Water Allocation Model Methods and Results*.

New instream flow requirements based on a percentage of the unimpaired flow were added above rim reservoirs, below rim reservoirs, at the mouths of each major tributary to the Sacramento River and Delta, and at locations along the Sacramento River for each month. Rim reservoirs are the large water supply reservoirs that "rim" the valley floor and provide water supply, flood control, hydropower, and recreation on tributaries in the Sacramento River watershed and Delta eastside tributaries.

A full list of flow requirement locations can be found in Appendix A1, *Sacramento Water Allocation Model Methods and Results*. Multiple instream flow requirements were added on each tributary to represent the assumption that all users in the watershed, whether upstream or downstream, would be responsible for contributing to the new modeled instream flow requirement. As described in Chapter 5, *Proposed Changes to the Bay-Delta Plan for the Sacramento/Delta*, the instream flows could be further sculpted to maximize benefits to fish and wildlife, including targeted pulses to cue migration, summer cold water releases, base flows, and other functions. Delta outflow is linked to tributary inflows and is intended to be implemented in a coordinated manner to the extent possible. Because flows may be tailored to the needs of each tributary, every exact permutation of flow is not known; however, for the purpose of the environmental analysis, it was assumed that each tributary provides its proportional share of the numeric inflow requirement so that the range of flow scenarios is sufficient to illustrate the potential changes that may result from the proposed Plan amendments.

Delta outflow requirements in the flow scenarios include all regulatory requirements included in the baseline scenario described in Section 6.2.1, *Baseline Assumptions*, in addition to a new inflow-based Delta outflow requirement. The Delta outflow requirement for each of the flow scenarios assume that the outflow required would be based on the percent of unimpaired tributary flow required to reach the Delta, the same percent of local unimpaired flows into the Delta, and the existing required flow from the San Joaquin River. The percent of unimpaired flow required to reach the Delta includes the percent of unimpaired flows from Cache and Putah Creeks, Sacramento River at Freeport, the Mokelumne River above the Cosumnes, the Cosumnes River above the Mokelumne River, and the Calaveras River above the Delta. The required flows from the San Joaquin River assume the base flows required under D-1641 without the April-May pulse and without VAMP pulse flows.

A large part of the demand during the irrigation season is met through delivery of water stored in reservoirs. The amount of water delivered versus the amount retained in a reservoir as carryover storage is an operational decision that can change from year to year. For modeling purposes, reservoir operation assumptions regarding deliveries versus carryover storage are incorporated into the model in various ways. Reservoir end-of-September storage was targeted to maintain cold water throughout the year. For reservoirs with documented or clear historical storage-temperature relationships, storage thresholds sufficient to maintain cool release temperatures were incorporated into the modeling. Storage-temperature relationships used to inform modeled carryover targets are described in Appendix A1c, *Preliminary Assessment of Effect of Reservoir Storage on Reservoir Release Temperatures* The specific targets included in the flow scenarios are specified in Appendix A1, *Sacramento Water Allocation Model Methods and Results*. For example, for Folsom Reservoir, historical operations show that when end-of-September storage is above 400 TAF, cooler downstream temperatures are more often achieved. In the modeling scenarios, CVP allocations were adjusted to maintain end-of-September storage above 400 TAF as frequently as baseline storage. Maintaining the similar end-of-September carryover storage for cold water pool among all scenarios was not possible. It is possible that cold water habitat could be adequately protected at lower levels than set in the model and that tailored operational management will result in more surface water available, thereby reducing associated impacts.

No changes to the model scenarios were assumed for Delta operational requirements that affect interior Delta flows such as OMR requirements and Delta Cross Channel (DCC) gate operations. The baseline simulation includes restrictions on OMR reverse flows implemented in the BiOps for long-term operations of the SWP and CVP that also were included in each of the flow scenarios. D-1641 and NMFS BiOps include rules for operations of the DCC that are incorporated into the baseline and flow scenario simulations.

Delta net channel depletions are the sum of consumptive uses from agricultural diversions, natural riparian evapotranspiration, and seepage to groundwater. Delta channel depletions are difficult to measure for various reasons, including inadequate measuring of agricultural diversions, return flows, and seepage, but are estimated to be as high as 1.3 million acre-feet (MAF) annually. Recent studies have made some progress in estimating depletions from evapotranspiration from the Delta (Medellín-Azuara et. al. 2018); however, many uncertainties still exist. Water users in the Delta would be subject to the proposed inflow-based Delta outflow objective. As such, their diversions may be reduced depending on the specific circumstances of those diversions, including their water right priorities, the degree to which the diversions contribute to net depletions, and the hydrological conditions. Some municipalities in the Delta are modeled explicitly in SacWAM, but the degree to which other users of water in the Delta would be reduced is not modeled explicitly in the SacWAM scenarios. To the degree that reductions in these depletions occur due to the proposed Plan amendments, they would result in lower water supply costs in other regions and higher costs in the Delta, but they would not result in additional overall water supply costs. These effects are evaluated qualitatively in the Staff Report due to the above-referenced data limitations. As part of the proposed Plan amendments, the State Water Board would develop and refine depletion estimates for the purpose of implementing the proposed Plan amendments.

Groundwater pumping in the model scenarios was constrained to be no greater than the corresponding monthly value of groundwater pumping from the baseline scenario.[2] This assumption is intended to result in a maximal estimate of the total surface water supply reductions likely to result from adoption of the proposed Plan amendments, although it underestimates the potential impacts on groundwater. SacWAM results for changes in groundwater are presented in Section 6.5, *Changes in Groundwater Supply*, and more detailed groundwater impacts are analyzed in Chapter 7 (see Section 7.12.2, *Groundwater*) that considers a range of potential effects depending on the increased use of groundwater resources in response to reduced surface water supplies.

6.2.3 Climate Change

Anticipated changes in hydrology and water supply associated with climate change are not explicitly modeled using SacWAM for this Staff Report. Historically, climate change has not been analyzed in the Bay-Delta Plan updates because the Board is required to review the plan every 3 years; therefore, current climate conditions are more appropriate to analyze given the short-term nature of the Plan. Bay-Delta Plan updates have become less periodic, however, so the Plan has taken on a longer time horizon, and recent years of hydrologic extremes have highlighted the necessity of considering climate change in the Staff Report.

There is great uncertainty of how global change may affect the local climate in the study area. Changes in sea level, wind, temperature, and precipitation all may have large effects on the hydrology and available water supply. SacWAM modeling of climate change is not included at this time because of the uncertainty and lack of detailed climate change information required to produce inputs to the model. With the recent downscaling work using the Coupled Model Intercomparison Project Phase 6 (referred to as CMIP6) global climate projections, the latest climate change inputs at

[2] The allowance of pumping 0.1 percent greater than baseline was included to ensure numerical stability of the model. See Appendix A1, *Sacramento Water Allocation Model Methods and Results*, for further explanation.

the scale required to become inputs to SacWAM are being developed by consultants and DWR, and are scheduled to be available in early 2024 (Eyring et al. 2023). Additionally, ongoing refinements of SacWAM have made it easier to incorporate climate change inputs in the future. Section 2.6, *Climate Change and Drought*, in Chapter 2 discusses climate change and drought under existing conditions and relevant uncertainties about the future conditions. Section 4.6, *Climate Change*, in Chapter 4 describes how climate change could exacerbate aquatic ecosystem stressors. Climate change also is addressed in more detail in the environmental analyses for the proposed Plan amendments and various alternatives.

6.3 Changes in Hydrology

6.3.1 Flows

This section presents a summary of findings related to the SacWAM modeling results for streamflows. Results are presented as general patterns and groupings of tributaries that show similar responses. Detailed graphical and tabular summaries of results for all tributaries can be found in Appendix A1, *Sacramento Water Allocation Model Methods and Results*.

Modeling results for representative tributary streamflows are generally presented as the tributary outflow, or flow at the mouth of the given tributary. These tributary mouth locations were selected for analysis because streamflows at the mouth of a tributary represent the tributary watershed's total contribution to Delta inflows, an important focus of the proposed Plan amendments. Tributary streamflows for the Mokelumne River are presented for the Mokelumne River upstream of its confluence with Dry Creek and the Cosumnes River, and tributary streamflows for the Cosumnes River are presented for the Cosumnes River upstream of its confluence with Dry Creek. These Mokelumne and Cosumnes River locations represent the total contribution of these watersheds to Delta inflows.

Modeling results are included for both the tributary mouth and for one or more upstream locations for Butte Creek (near Chico and at mouth), the Feather River (at Oroville and at mouth), and the Sacramento River (below Shasta Dam and at Freeport). Presentation of multiple sites on these rivers is important due to significant hydrologic differences in portions of each watershed. The upper canyon reaches of Butte Creek (represented by Butte Creek near Chico) have limited hydrologic changes due to interbasin diversions and transfers compared to the lower valley reaches (represented by Butte Creek at mouth) where significant volumes of water are imported from the lower Feather River. The Feather River also exhibits very different hydrology immediately below Lake Oroville compared to the mouth of the river because the Yuba and Bear Rivers join the Feather River, and several large interbasin diversions and transfers occur in the intervening reach. Finally, to assess the cumulative contributions of tributary streamflows on the Sacramento River, modeling results are assessed below Shasta Dam to represent contributions from the headwater tributaries and at Freeport to represent contributions from the lower Sacramento River tributaries.

Discussions of hydrology in the following section generally focus on the drier (near 25th percentile), median (50th percentile), and wetter (near 75th percentile) conditions as the best representation of typical hydrologic patterns. The maximum and minimum monthly streamflow values represent extreme single events (0th and 100th percentiles, or the minimum and maximum monthly flows modeled) rather than streamflows that occur under typical hydrologic conditions (e.g., not extremely wet or extremely dry conditions) and therefore are less informative in the context of anticipated changes in hydrology.

6.3.1.1 Sacramento River Region and Delta Eastside Tributaries

Overall, the SacWAM modeling results show distinct hydrologic patterns for unregulated tributaries and regulated tributaries.[3] Findings for each are presented separately below. Monthly streamflow condition boxplots are shown below for each grouping. Boxplots for each individual tributary are included in Appendix A1, *Sacramento Water Allocation Model Methods and Results*.

Regulated Tributary Streamflows

Regulated tributaries are tributaries that contain a major storage reservoir or other large-scale flow-regulating infrastructure. In the Sacramento River watershed and Delta eastside tributaries regions, the following tributaries to the Sacramento River and the Delta are considered regulated tributaries: American River, Bear River, Cache Creek, Calaveras River, Clear Creek, Feather River, Mokelumne River, Putah Creek, Sacramento River, Stony Creek, and Yuba River. Several of these tributaries are part of the CVP and SWP. Other regulated tributaries have local water projects that provide hydropower generation, water supply within the basin, and flood control for downstream inhabitants.

While each regulated tributary exhibits unique hydrology, water storage, demand, and operations, a number of general patterns are observed. In the flow scenarios streamflows generally increase over baseline during late winter through spring months, decrease during late summer months, and remain relatively unchanged during early winter months.

The following sections describe the SacWAM streamflow results for each of the major regulated tributaries. Monthly streamflows are presented by water year, which runs from October through September. In the following boxplots the x-axis (horizontal axis) represents the month, and the y-axis (vertical axis) represents the modeled monthly streamflow, in cfs. Several boxplots are shown for each month, corresponding to individual modeled scenarios. SacWAM-modeled flow scenarios (scenarios) include the existing condition scenario, or baseline (white box), 35 scenario (navy blue box), 45 scenario (medium blue box), 55 scenario (light blue box), 65 scenario (blue-green box), and 75 scenario (green box).

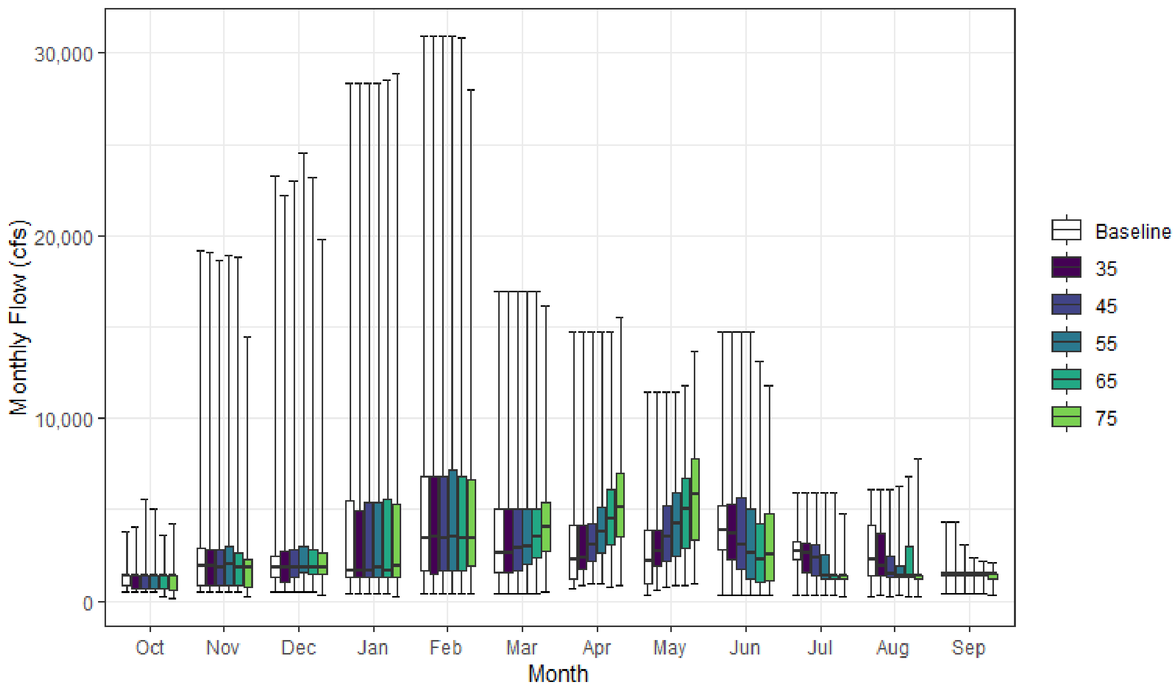
American River

Development in the upper American River includes hydropower projects such as the Middle Fork Project and the Upper American River Project in addition to hydropower generation by Pacific Gas and Electric Company (PG&E) and El Dorado Irrigation District. While these hydropower projects store a portion of the springtime runoff and release the stored water in summer, they do not have as large of an effect on the flow regime as the larger rim reservoirs. The SacWAM results show very little change in flows above Folsom Reservoir in the 35 through 55 scenarios and relatively small increases in May and August in the 65 and 75 scenarios.

Streamflows below Folsom Reservoir are released for diversion for urban uses along the lower American River, as well as Delta outflow and export as part of the CVP. Much of the CVP demand for

[3] The terms *regulated* and *unregulated* here refer to whether or not a tributary has a dam and reservoir capable of controlling flows.

water outside of the American River watershed is in summer months; therefore, the baseline flows on the lower American River are often highest during summer—other than winter flood control releases. In the flow scenarios, changes in flows follow the general pattern described above where flows increase over baseline during late winter through spring months, decrease during summer months, and remain relatively unchanged during early winter months (Figure 6.3-1). The largest increase in the flow scenarios occurs in May when the average monthly flow increases from 3,008 cfs to 3,426, 4,441, and 5,848 cfs in the 35, 55, and 75 scenarios, respectively. The average total January through June increases in streamflow on the lower American River are 34 TAF, 139 TAF, and 280 TAF in the 35, 55, and 75 scenarios, respectively.



Changes in flows represent the typical patterns for Project tributaries.
cfs = cubic feet per second

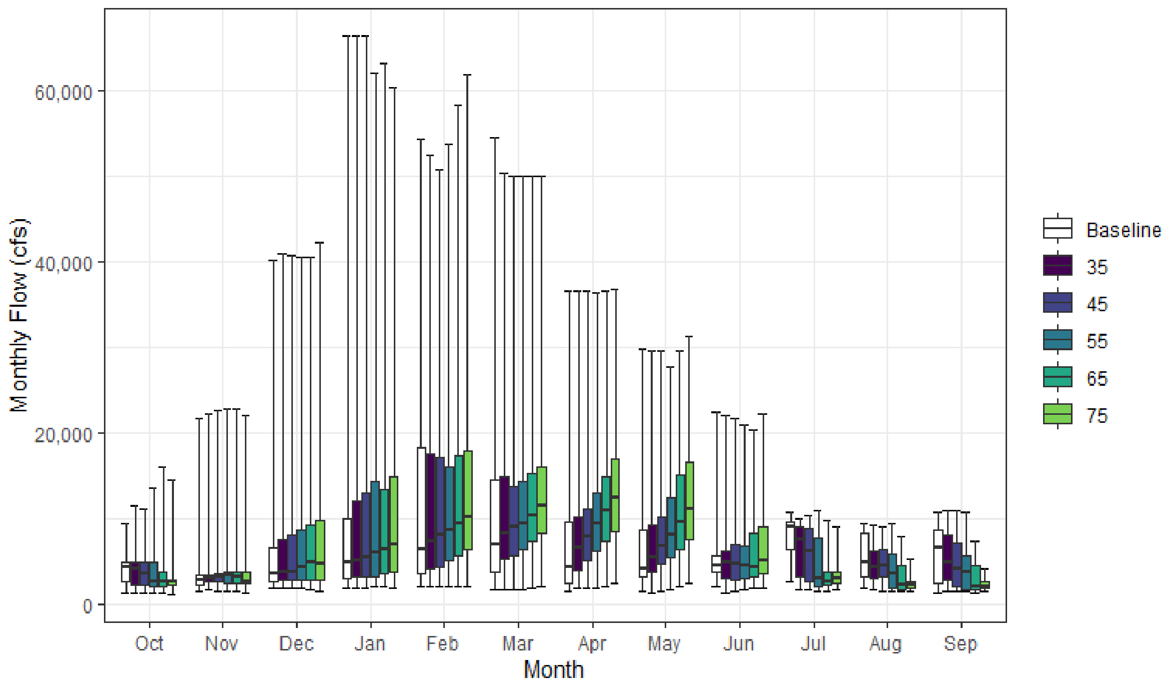
Figure 6.3-1. Changes in Hydrology across the Scenarios for the American River above the Sacramento River

Feather River

As described in detail in Chapter 2, *Hydrology and Water Supply*, the Feather River drains a very large area with a large range of elevation and geology. The upper Feather River watershed has four main forks, with many reservoirs and hydropower projects. The largest of these projects is Lake Almanor, with storage of about 1 MAF on the North Fork of the Feather River. Additionally, water is diverted out of the upper watershed via the Toadtown Canal to Butte Creek, and water is diverted into the South Fork Feather via the Slate Creek Tunnel from the Yuba River watershed. Even with the extensive hydropower development on the upper Feather River, the SacWAM results show very minimal changes to streamflows above Oroville Reservoir.

Streamflows on the lower Feather River are controlled by releases from Oroville and Thermalito Reservoirs for flood control, in-basin demands, Delta outflow, and export by the SWP. Downstream demands, Delta outflow needs, and export operations typically occur in July through September and produce high flows in the baseline simulation during these months. Reservoir operators try to store as much winter runoff and springtime snowmelt as possible in Oroville Reservoir, which effectively suppresses the streamflows in the lower Feather River during these months in the baseline simulation. In the flow scenarios, the flow requirements result in increased flows in winter and spring, with the largest increases occurring in April and May (Figure 6.3-2). The average total January through June increases in streamflow on the lower Feather River are 164 TAF, 460 TAF, and 1,113 TAF in the 35, 55, and 75 scenarios, respectively.

Because more water is bypassed by Oroville Reservoir in spring, less water is available for in-basin diversions and export in summer, which results in lower streamflows on the lower Feather River in July through September in the flow scenarios.

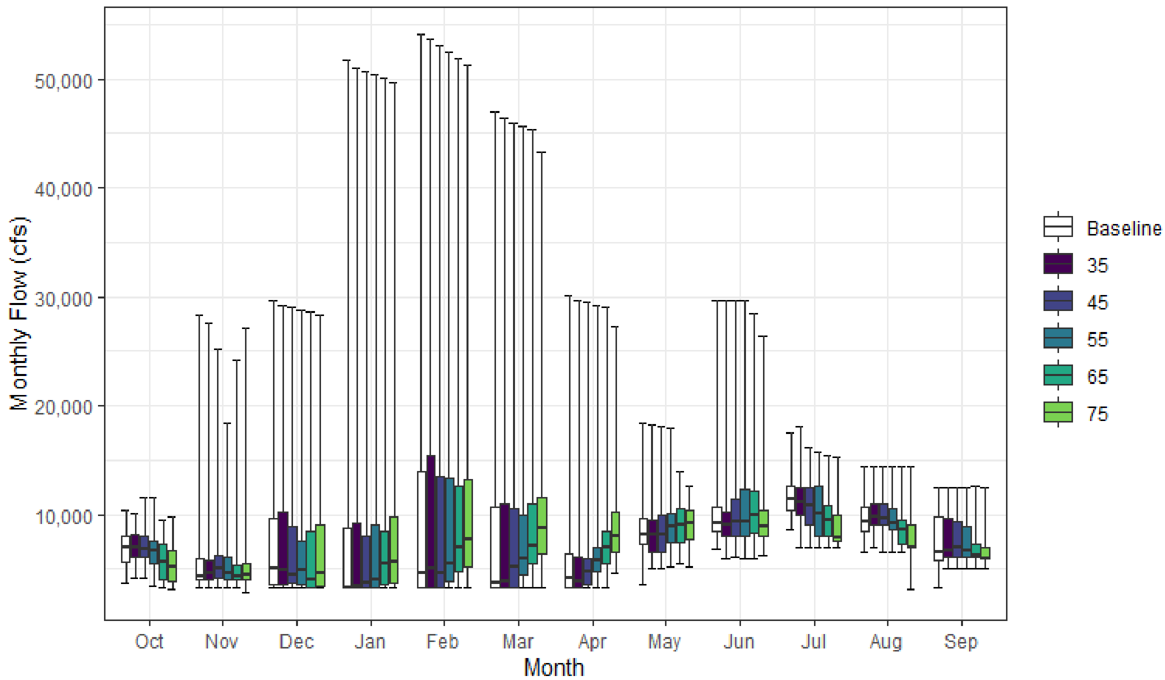


Changes in flows show patterns similar to other Project tributaries.
cfs = cubic feet per second

Figure 6.3-2. Changes in Hydrology across the Scenarios for the Feather River above the Sacramento River

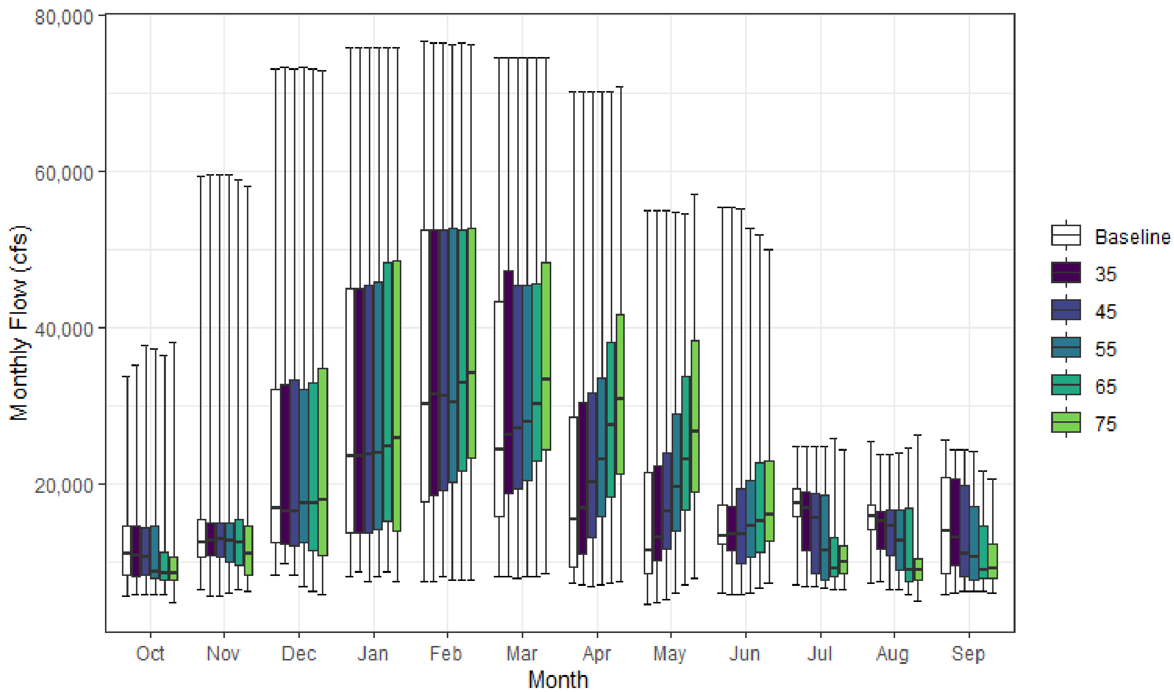
Sacramento River

Baseline streamflows on the Sacramento River below Keswick Reservoir are generally lower than unimpaired conditions in winter and spring and higher in summer and fall, as described in Chapter 2, *Hydrology and Water Supply*. Releases from Keswick Reservoir are controlled by flood operations, agricultural demands in the Sacramento Valley, stream temperature requirements, Delta demands (including salinity control and fish and wildlife protection), and exports. Like the Feather River and American River, flows in the flow scenarios generally increase in late winter and spring and decrease in summer (Figure 6.3-3). Downstream on the Sacramento River, similar patterns are observed at Freeport although at a larger scale (Figure 6.3-4). Increases in flow at Freeport are greatest in April and May, with an average increase of 1,374 cfs, 5,222 cfs, and 11,382 cfs in the 35, 55, and 75 scenarios, respectively. The average total January through June increase in flow is 251 TAF, 890 TAF, and 2,067 TAF in the 35, 55, and 75 scenarios, respectively.



cfs = cubic feet per second

Figure 6.3-3. Changes in Hydrology across the Scenarios for the Sacramento River below Keswick Reservoir



cfs = cubic feet per second

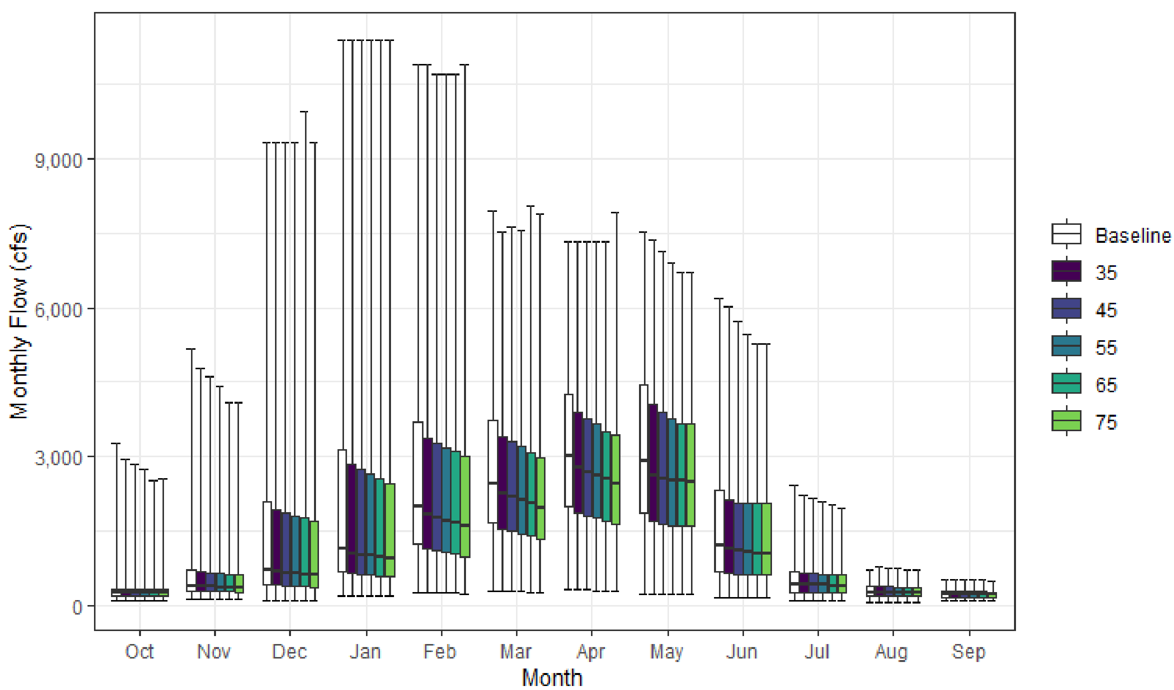
Figure 6.3-4. Changes in Hydrology across the Scenarios for the Sacramento River at Freeport

Yuba River

Yuba and Bear River operations are intertwined in that a large portion of the mean annual flow from the Yuba River is diverted through canals to the Bear River watershed, as discussed in *Changes in Interbasin Diversions* in Section 6.3.1.3, *Sacramento-San Joaquin Delta*. In the flow scenarios, less water is diverted to the Bear River watershed, which increases the streamflows on the Middle and South Forks of the Yuba River as well as the lower Yuba River.

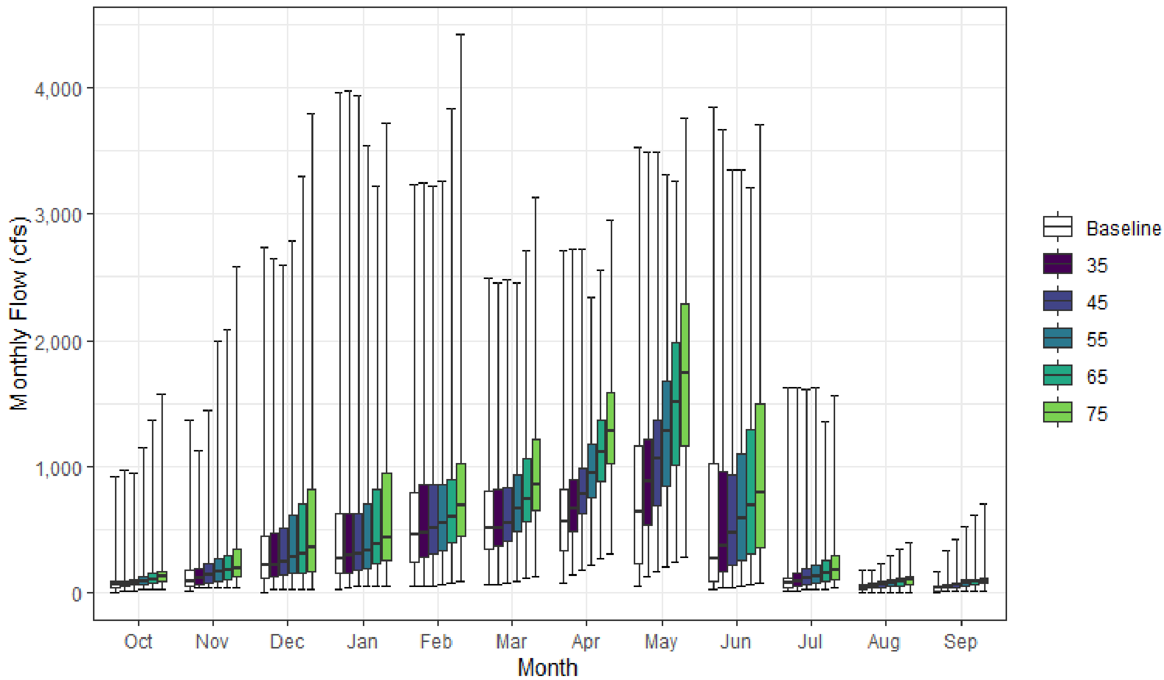
Because the Yuba River has three distinct forks that all enter the New Bullards Bar and Englebright Reservoirs separately, and because of the interbasin diversions, flow requirements were included on all three forks above New Bullards Bar and Englebright Reservoirs. Flows on the North Yuba River above New Bullards Bar are typically lower in the scenarios than baseline because less water is diverted from the Middle Fork (Figure 6.3-5). Flows in the Middle and South Forks are much higher in winter and spring in the scenarios relative to baseline because more water is maintained within these basins (e.g., Figure 6.3-6).

In some circumstances, these changes could affect the amount and timing of water available for hydropower operations. The effects of the proposed requirements on energy resources are discussed in Section 7.8, *Energy*, which contains an integrated discussion of the effects of changes in hydrology on hydropower facilities both in the upper watersheds and at the rim dams.



cfs = cubic feet per second

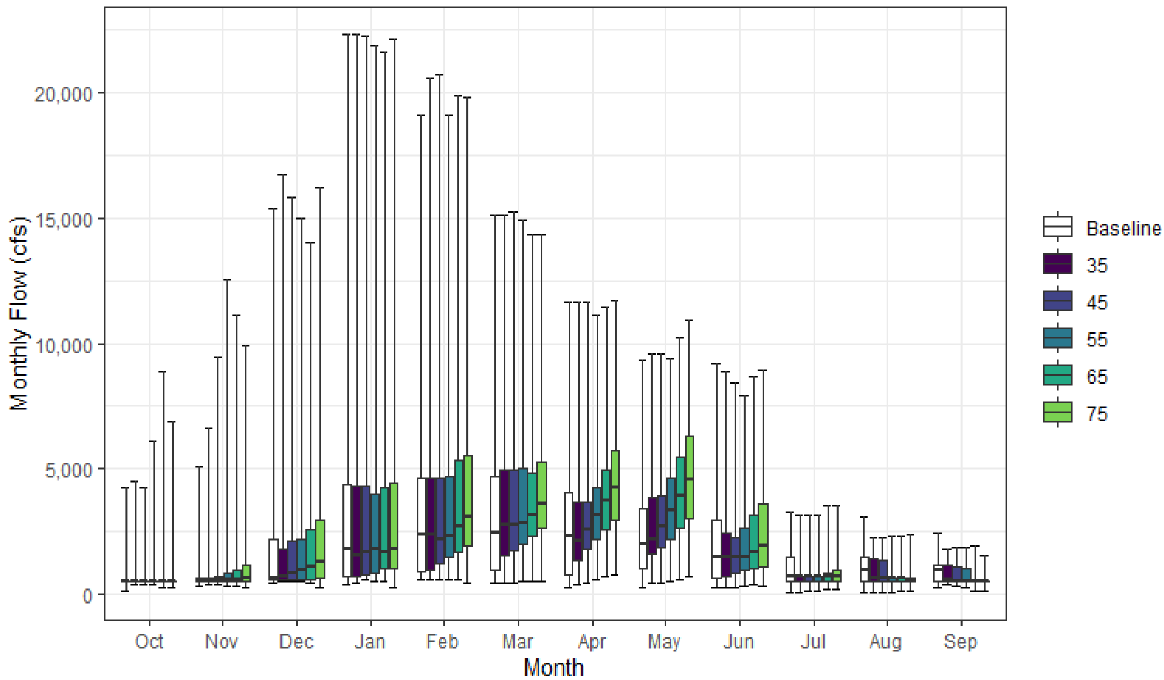
Figure 6.3-5. Changes in Hydrology across the Scenarios for the North Fork Yuba River above New Bullards Bar Reservoir



cfs = cubic feet per second

Figure 6.3-6. Changes in Hydrology across the Scenarios for the South Fork Yuba River above Englebright Reservoir

Streamflows on the lower Yuba River are generally higher in February through June in the scenarios when more flow is required to leave the Yuba River watershed (Figure 6.3-7). In August and September, flows are frequently lower in the scenarios because the releases from New Bullards Bar Reservoir are reduced in these months. The largest increase in flows in the scenarios is in May when flows on the lower Yuba River above the Feather River are on average 311 cfs, 859 cfs, and 1,693 cfs higher in the 35, 55, and 75 scenarios, respectively. The average total January through June increase in flow is 52 TAF, 140 TAF, and 362 TAF in the 35, 55, and 75 scenarios, respectively.

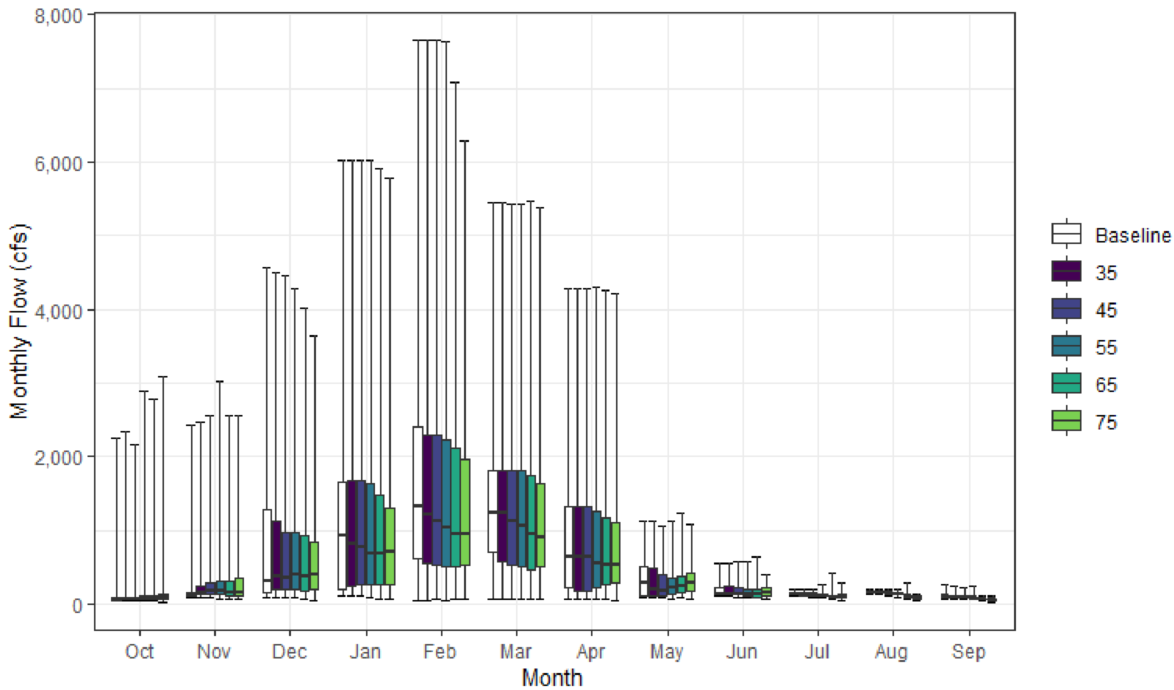


cfs = cubic feet per second

Figure 6.3-7. Changes in Hydrology across the Scenarios for the Yuba River above the Feather River

Bear River

As mentioned above in the discussion of the Yuba River and further described in Section 6.3.1.4, *Changes in Interbasin Diversions*, Bear River and Yuba River operations are related. Unimpaired flow requirements in the scenarios require more flow to remain in the Middle and South Fork Yuba River; therefore, less water is diverted to the Bear River. With less Yuba River water supplementing the flow of the Bear River, streamflows above Camp Far West Reservoir are lower, and the flows on the Lower Bear River above the Feather River also are generally lower (Figure 6.3-8). The largest reductions in releases from Camp Far West Reservoir occur in February; because the reservoir is often lower going into the flood season, there are fewer flood releases in winter months. The average total January through June decrease in flow at the mouth of the Bear River is 8 TAF, 23 TAF, and 54 TAF in the 35, 55, and 75 scenarios, respectively.



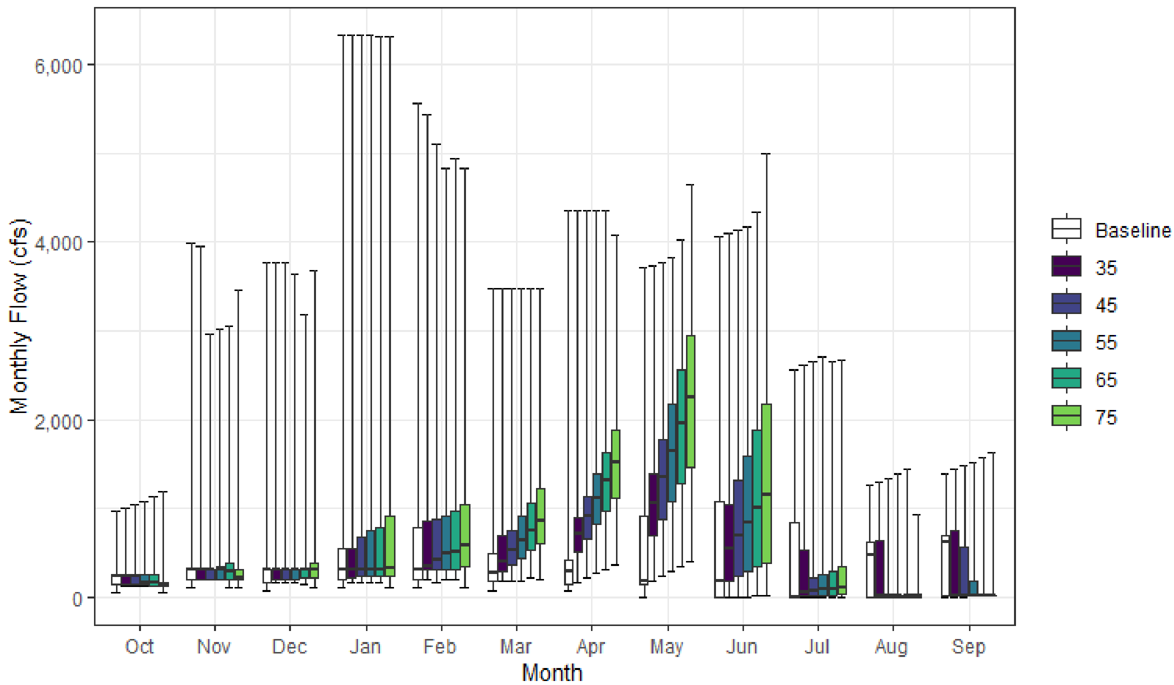
cfs = cubic feet per second

Figure 6.3-8. Changes in Hydrology across the Scenarios for the Bear River above the Feather River

Mokelumne River

Mokelumne River operations include upper watershed hydropower operations, smaller diversions to foothill communities, storage in Pardee and Camanche Reservoirs, diversions to the Bay Area, and diversions to agricultural and urban uses upstream of the Delta. Changes to Mokelumne River operations in the flow scenarios result in higher streamflows in winter and spring and lower flows in summer and fall (Figure 6.3-9). This pattern of changes in flows is observed in the upper watershed above Pardee Reservoir and in the lower watershed inflow to the Delta. In the lower watershed, the greatest increase in flows is between baseline and the 35 scenario because the baseline spring flows are relatively low, as discussed in Chapter 2, *Hydrology and Water Supply*. The average total January through June increase in flow is 66 TAF, 146 TAF, and 245 TAF in the 35, 55, and 75 scenarios, respectively.

Unimpaired flow requirements also result in lower end-of-April storage and frequently higher end-of-September storage in Camanche Reservoir, as discussed in Section 6.3.2.1, *Sacramento River Watershed and Delta Eastside Tributaries Rim Reservoirs*. Diversions for water supply to the Bay Area and for agricultural use in the lower watershed are increasingly reduced with the increasing flow scenarios (see Section 6.4, *Changes in Surface Water Supply*).

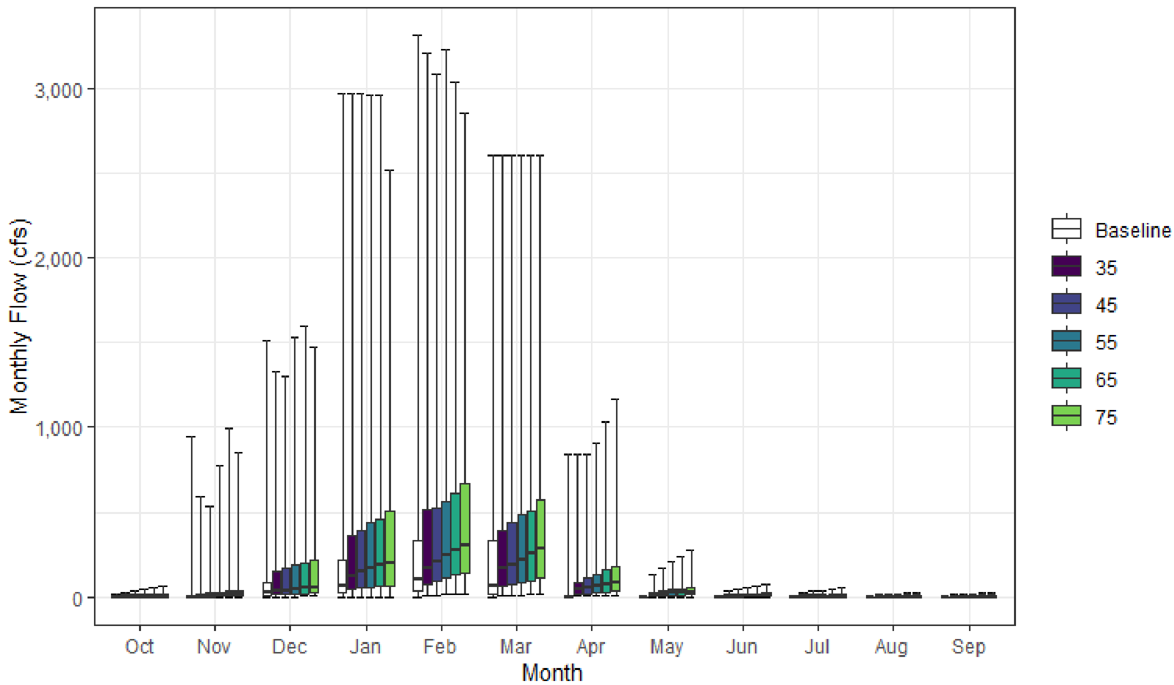


During spring months (March through May), there is a larger increase in flow between the baseline simulation and the 35 scenario.
cfs = cubic feet per second

Figure 6.3-9. Changes in Hydrology across the Scenarios for the Mokelumne River above the Confluence with the Cosumnes River

Calaveras River

Calaveras River operations include storage regulation in New Hogan Reservoir and downstream diversions to agriculture and urban users. Additionally, Calaveras River water is supplemented with diversions from the Stanislaus River. Streamflows on the Calaveras River above the Delta increase most dramatically in January through April between the baseline and the 35 scenario and then continue to increase in these months with the higher flow scenarios (Figure 6.3-10). In the drier months of June through October, the increases in streamflow are much smaller because the unimpaired flow on the Calaveras River is very low in these months. The average total January through June increase in flow is 11 TAF, 23 TAF, and 33 TAF in the 35, 55, and 75 scenarios, respectively.



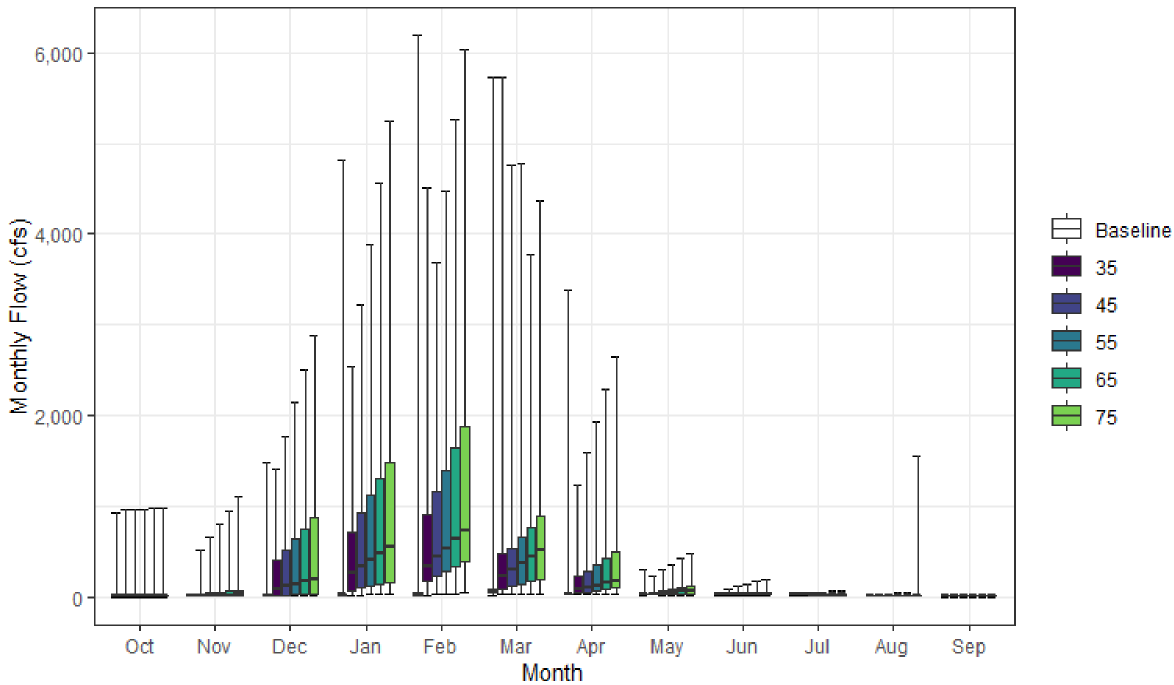
During winter and early spring (January through April), there is a larger increase in flow between the baseline simulation and the 35 scenario.
cfs = cubic feet per second

Figure 6.3-10. Changes in Hydrology across the Scenarios for the Calaveras River Inflow to the Delta

Putah Creek

Putah Creek operations include storage regulation in Lake Berryessa and diversions from Putah Creek at the Putah Diversion Dam to Putah South Canal. The flow scenarios result in increases to streamflows in winter and spring below Lake Berryessa, with the result of lower storage in Lake Berryessa at the start of the irrigation season. Lower end-of-April storage (discussed in Section 6.3.2.1, *Sacramento River Watershed and Delta Eastside Tributaries Rim Reservoirs*) reduces the ability to deliver stored water to the Putah South Canal.

Similar to the Calaveras and Mokelumne Rivers, during winter and spring months (January through April), there is a large increase in streamflows between the baseline and the 35 scenario and a smaller incremental increase as the flow scenarios increase (Figure 6.3-11). The average total January through June increase in flow is 35 TAF, 82 TAF, and 133 TAF in the 35, 55, and 75 scenarios, respectively.

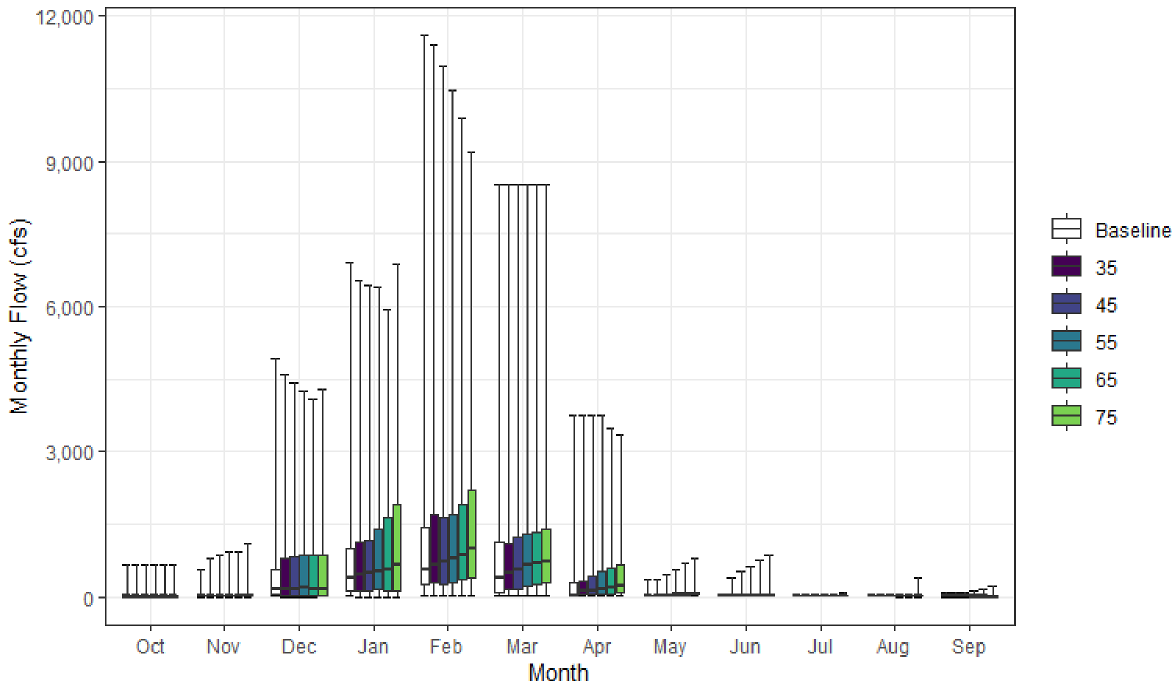


During winter and early spring (January through April), there is a larger increase in flow between the baseline simulation and the 35 scenario.
cfs = cubic feet per second

Figure 6.3-11. Changes in Hydrology across the Scenarios for Putah Creek above the Yolo Bypass

Cache Creek

Operations on Cache Creek include storage regulation in Clear Lake and Indian Valley Reservoir, minor urban diversions directly from Clear Lake, and agricultural diversions at Capay Diversion Dam. The UF requirements in the scenarios result in increased streamflows in January through April (Figure 6.3-12). The changes from baseline are much smaller the rest of the year except in months with extreme events. The average total January through June increase in flow is 5 TAF, 18 TAF, and 56 TAF in the 35, 55, and 75 scenarios, respectively.



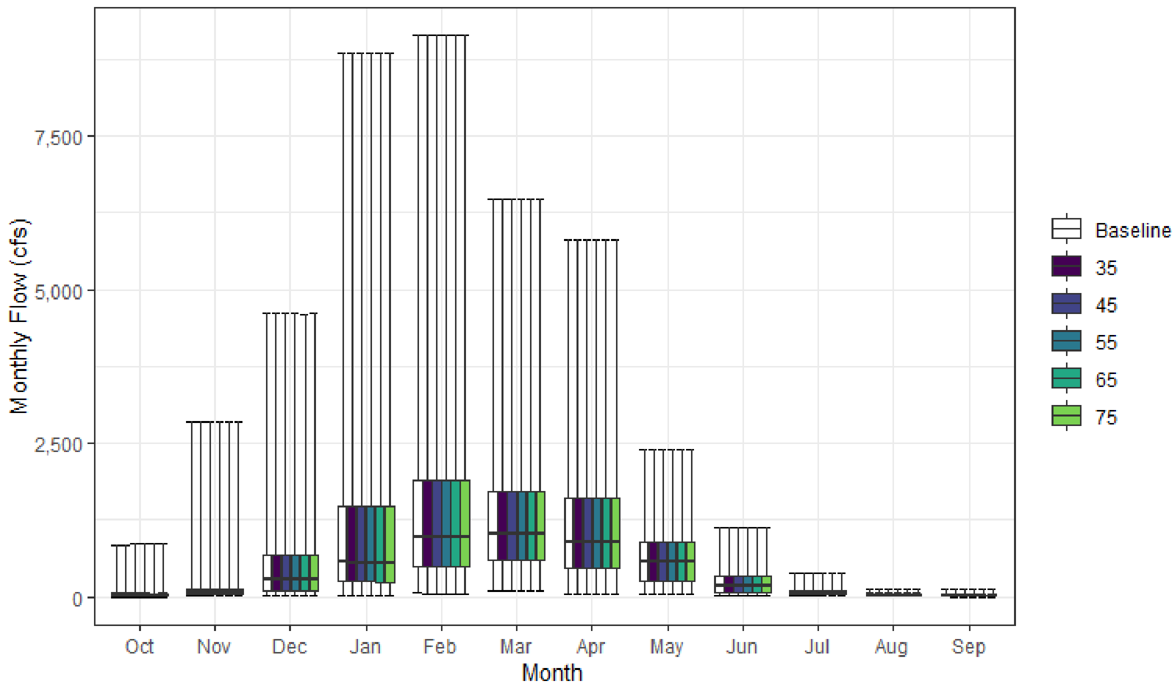
During winter and early spring (January through April), streamflows are progressively higher as the flow requirements increase in the scenarios.
cfs = cubic feet per second

Figure 6.3-12. Changes in Hydrology across the Scenarios for Cache Creek above the Yolo Bypass

Unregulated Tributary Streamflows

Unregulated tributaries are tributaries that lack a major storage reservoir or other flow-regulating infrastructure. There are two general categories of unregulated tributaries in the Sacramento River watershed and Delta eastside tributaries: (1) unregulated tributaries that exhibit low surface water demand relative to water availability; and (2) unregulated tributaries that exhibit higher surface water demand relative to water availability.

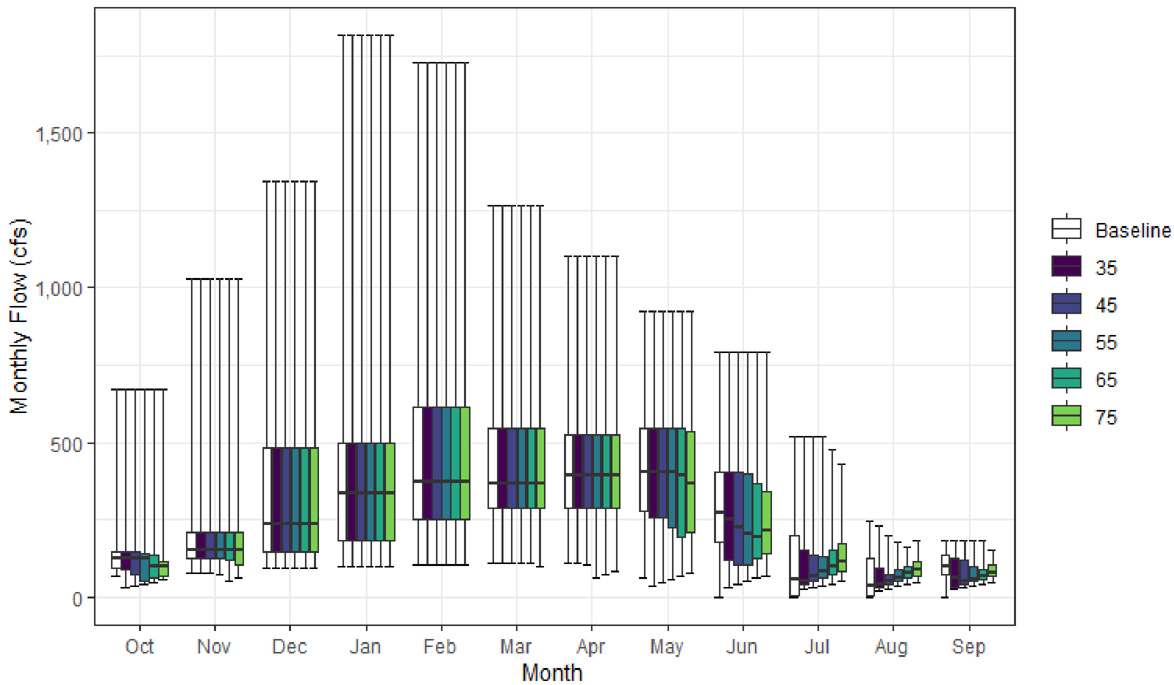
For unregulated tributaries with low surface water demand, streamflows generally remain unchanged between model scenarios. Tributaries that fall under this category include Battle Creek, Big Chico Creek, and the Cosumnes River. Unregulated tributaries with low surface water demand tend to be less hydrologically altered compared with tributaries with higher surface water demand. These tributaries also tend to exhibit higher percentages of unimpaired flow under baseline compared with tributaries with higher surface water demand (see Chapter 2, *Hydrology and Water Supply*). As a result, conditions in these tributaries are unlikely to change under all flow scenarios. The Cosumnes River (Figure 6.3-13) shows this representative tributary streamflow pattern for unregulated tributaries with low surface water demand.



Changes represent the typical patterns for unregulated tributaries with low water demand.
cfs = cubic feet per second

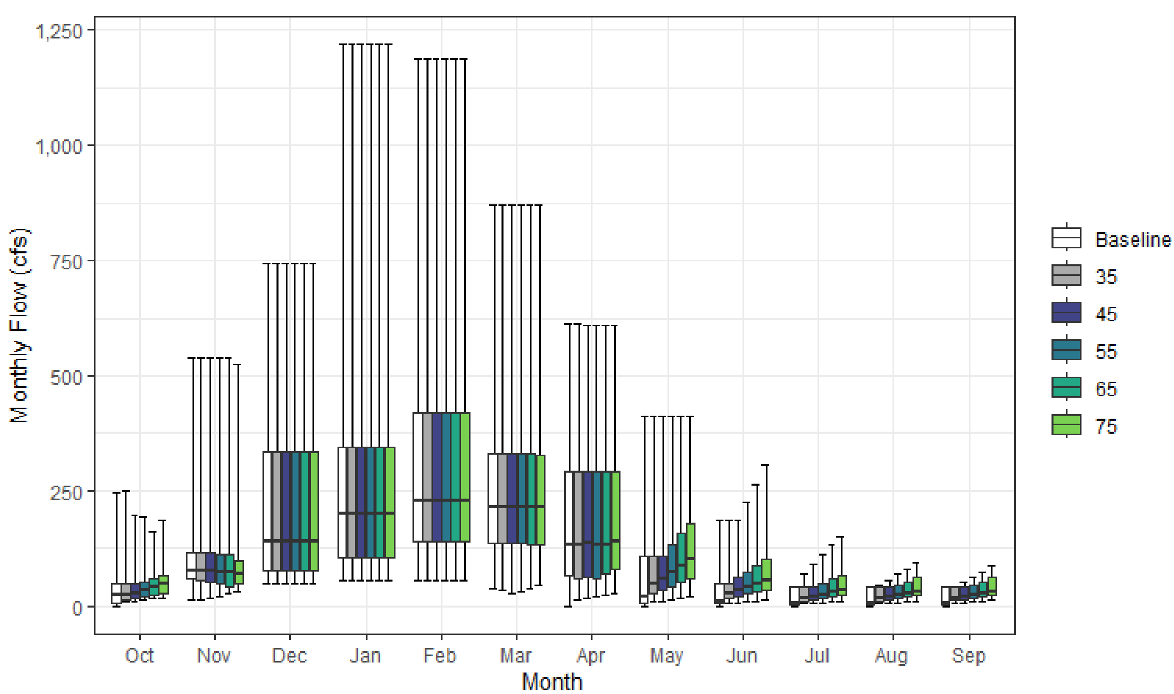
Figure 6.3-13. Changes in Hydrology across the Scenarios for the Cosumnes River

For unregulated tributaries with higher surface water demand, streamflows vary little between model scenarios during winter months, but generally show increases in streamflows during late spring through early fall (May through September). Examples of tributaries that fall under this category include Antelope Creek, Mill Creek, Deer Creek, and Thomes Creek. For these tributaries, surface water demand tends to be low during winter and higher during late spring through early fall due to seasonal consumptive water use (e.g., irrigation use). Surface water availability also tends to be lowest during the irrigation season. Based on the model results, a flow requirement in the range of the 35 through 75 scenarios is likely to result in increased streamflows and reduced summer surface water diversions for these tributaries but is unlikely to alter streamflows during winter months. Mill Creek (Figure 6.3-14) and Antelope Creek (Figure 6.3-15) show this representative tributary streamflow pattern for unregulated tributaries with higher surface water demand. Detailed results for Antelope, Deer (not shown), and Mill Creeks should be interpreted with caution due to the limited spatial resolution of agricultural demands in SacWAM.



Changes represent the typical patterns for unregulated tributaries with high surface water demand.
Modeled reductions in flow result from limitations in the spatial resolution of agricultural demands in SacWAM.
cfs = cubic feet per second

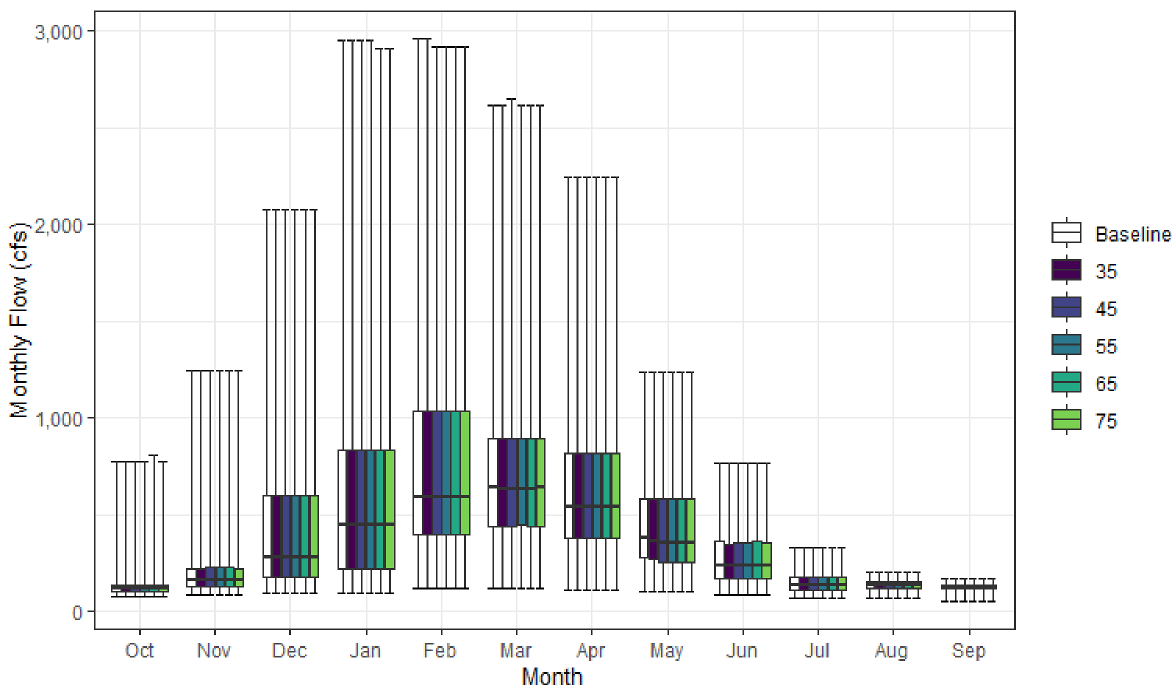
Figure 6.3-14. Changes in Hydrology across the Scenarios for Mill Creek



Changes represent the typical patterns for unregulated tributaries with high surface water demand.
cfs = cubic feet per second

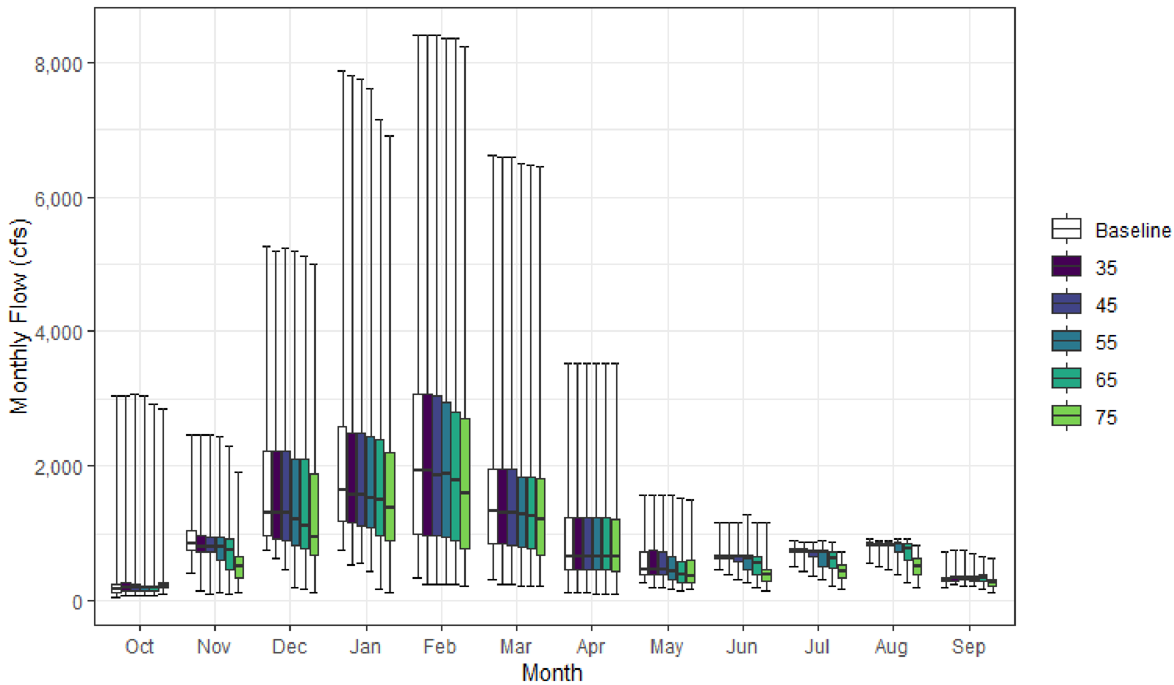
Figure 6.3-15. Changes in Hydrology across the Scenarios for Antelope Creek

The upper watershed of Butte Creek contains several small hydropower projects, but lacking a major storage reservoir, the reach upstream of Chico is essentially unregulated. Butte Creek currently receives water from the West Branch of the Feather River watershed through the Toadtown Canal. The volume of water imported through the Toadtown Canal is small, but it is cold and provides habitat benefits for spring-run Chinook salmon in Butte Creek. SacWAM model results show minimal changes in Toadtown Canal flows, so the modeled flow of Butte Creek near Chico (Figure 6.3-16) is essentially unchanged across scenarios. Additional Feather River water is imported to Butte Creek downstream of Chico via the Thermalito Complex. As a result of reductions in imported Feather River water, the flow scenarios generally show lower streamflows at the mouth of Butte Creek than under the baseline (Figure 6.3-17).



cfs = cubic feet per second

Figure 6.3-16. Changes in Hydrology across the Scenarios on Butte Creek near Chico

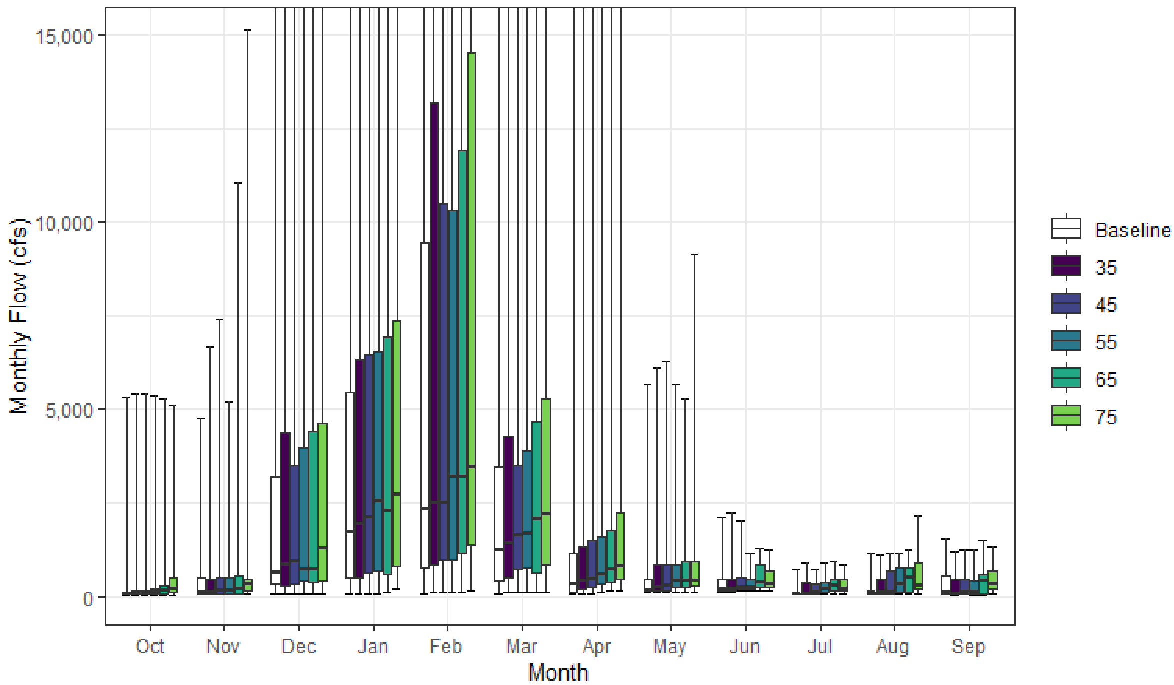


Changes represent a unique hydrologic pattern resulting from changes to interbasin water diversions and return flows.
cfs = cubic feet per second

Figure 6.3-17. Changes in Hydrology across the Scenarios for Butte Creek near Butte Slough

6.3.1.2 Sacramento Valley Flood Bypasses

Increases in streamflow on the mainstem Sacramento River result in very small changes in the frequency and magnitude of spills into the Sutter and Yolo Bypasses. The Yolo Bypass Salmonid Habitat Restoration and Fish Passage Project (Big Notch Project) is expected to increase the frequency and magnitude of spills into the Yolo Bypass from the Sacramento River, but the Big Notch Project is not included in the SacWAM modeling. However, increases in outflows from Cache and Putah Creeks produce substantial increases in flow in the lower half of the Yolo Bypass into the Delta (Figure 6.3-18). Increased flows on the lower Yolo Bypass may lead to increases in surface area inundation and floodplain habitat.



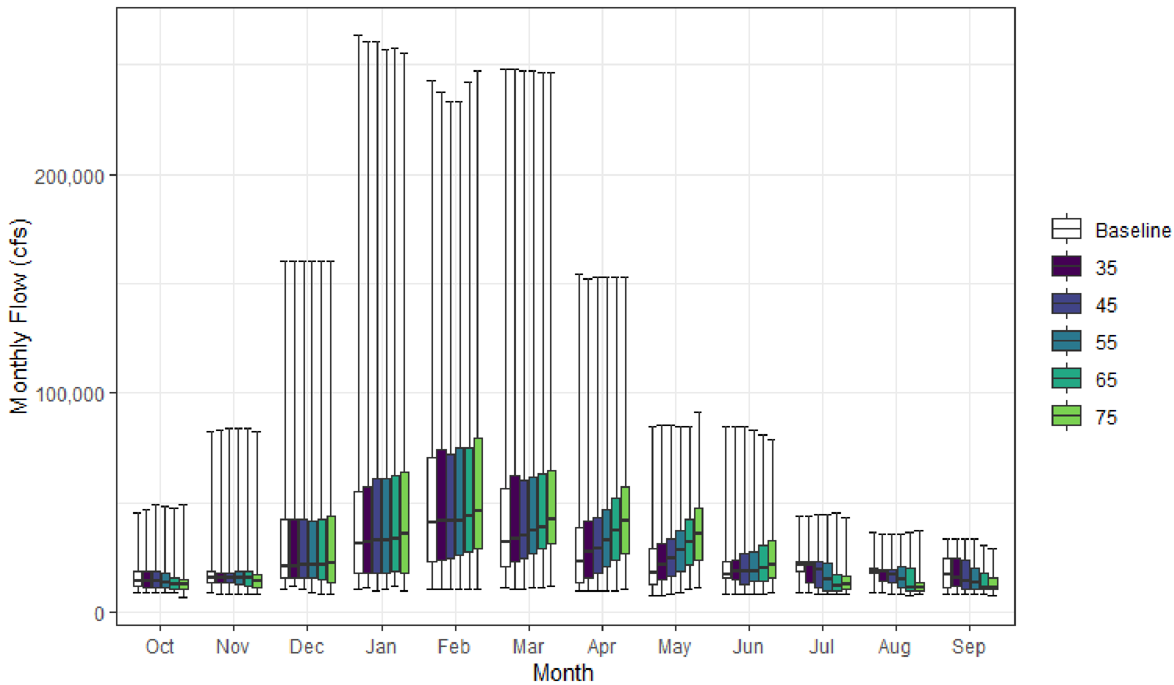
cfs = cubic feet per second

Figure 6.3-18. Changes in Hydrology across the Scenarios for Yolo Bypass below Putah Creek Inflow

6.3.1.3 Sacramento-San Joaquin Delta

Delta Inflow, Outflow, and X2

Delta inflow is the sum of tributary inflows, as well as local runoff to the Delta. Given the substantial development of storage on the larger regulated tributaries, the changes in Delta inflow across model scenarios resemble those seen for a regulated tributary. Inflow generally increases with increasing flow requirements during January through June and decreases in July through October (Figure 6.3-19). The increase in winter and spring Delta inflow is from flows bypassing reservoirs and diversions to meet the increased flow requirements throughout the watershed. The decrease during summer and fall results from a decrease in stored water available for export and salinity control. However, greater spring outflows push the salinity field downstream, reducing the volume of water needed to maintain salinity control during following months. Reductions during fall can also be caused by a reduced need to create flood space in reservoirs due to reduced carryover storage under wetter conditions. This pattern also shows up in reductions in the largest flows observed in winter (e.g., the maximum values for January and February in Figure 6.3-19). Although the timing of Delta inflow is altered in the flow scenarios, annual average Delta inflow is higher in the flow scenarios for all water year types except for wet years in the 35 scenario (Table 6.3-1). Reduction in Delta inflow in this case averages less than 1 percent of baseline flows.



Delta inflow generally increases during December through June and decreases during July through November.
cfs = cubic feet per second

Figure 6.3-19. Changes in Delta Inflow across the Scenarios

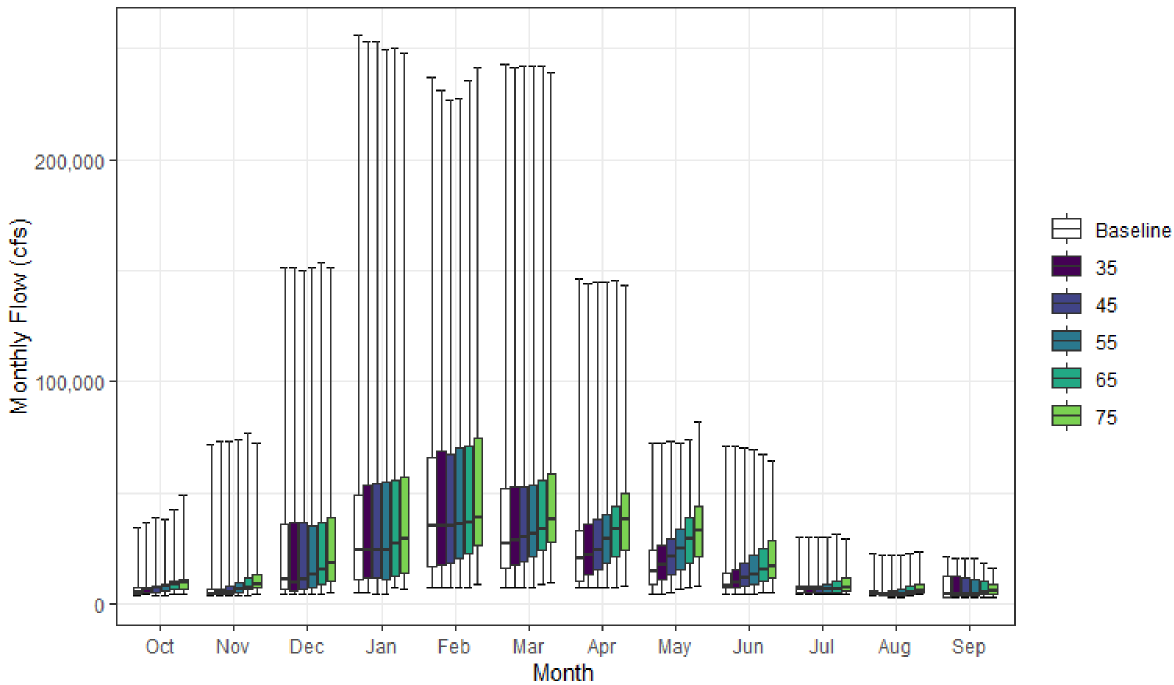
Table 6.3-1. Total Annual Delta Inflow Average by Water Year Type and Scenario: Change from Baseline (thousand acre-feet)

Water Year Type	Baseline	35	45	55	65	75
Critical	9,685	217	381	481	891	1,247
Dry	13,179	159	216	512	1,124	1,831
Below Normal	16,870	455	553	734	1,025	1,904
Above Normal	24,362	366	634	790	720	1,758
Wet	35,903	-26	61	376	800	891
All	21,575	193	312	543	919	1,458

Delta outflow generally increases in all months.
cfs = cubic feet per second

Delta outflow displays a similar pattern to Delta inflow during winter and spring, showing a roughly linear increase with the increasing flow scenarios during November through June (Figure 6.3-20). In contrast to Delta inflow, however, Delta outflow generally increases during all months, except for reductions in the 35 to 55 scenarios during August and for the highest flows in some months.

As discussed above for Delta inflow, most reductions in Delta outflow result from reductions in upstream storage (and less frequent and smaller magnitude flood spills) and a reduction in the flow needed to maintain salinity control. The flow reductions are small under dry conditions but can be substantial, although rare, in the wettest conditions. On an annual average scale, Delta outflow increases in all scenarios, in all water year types, except in the 35 scenario in wet years (Table 6.3-2).



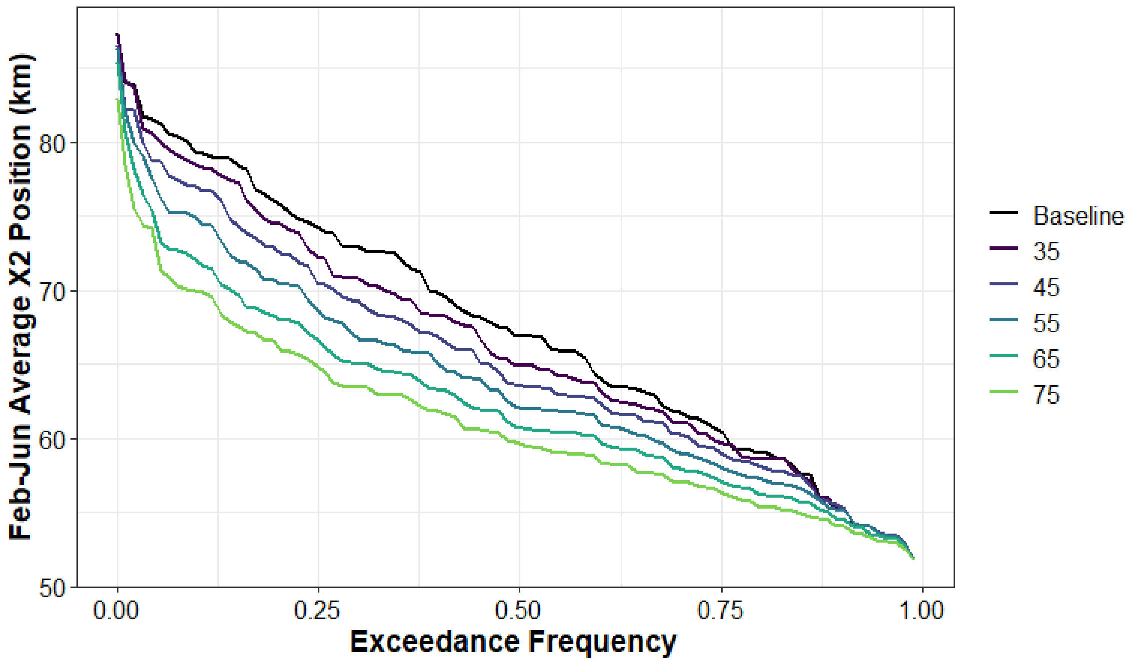
Delta outflow generally increases in all months.
cfs = cubic feet per second

Figure 6.3-20. Changes in Delta Outflow across the Scenarios

Table 6.3-2. Changes in Total Annual Delta Outflow Average by Water Year Type and Scenario (thousand acre-feet)

Water Year Type	Baseline	35	45	55	65	75
Critical	5,535	183	555	1,060	1,844	2,695
Dry	7,439	600	1,124	2,006	3,266	4,671
Below Normal	10,657	649	1,196	2,078	3,348	4,911
Above Normal	18,005	391	843	1,803	2,990	4,722
Wet	28,714	-3	219	763	1,967	3,200
All	15,489	333	737	1,466	2,625	3,960

As discussed in Section 6.2, *SacWAM Model Assumptions*, the SacWAM flow scenarios do not include changes to requirements for D-1641 Table 4, also known as *spring X2*. Together with existing flow requirements, the flow requirements added in the scenarios produce Delta outflows that are higher and X2 locations that are consistently lower (closer to Golden Gate) than baseline, especially in spring months (Figure 6.3-21). The largest changes in X2 position are in the critical and dry years (Table 6.3-3). For example, in spring of dry years, the X2 position on average is 2 km, 6 km, and 10 km lower in the 35, 55, and 75 scenarios, respectively (Table 6.3-3).



X2 position generally decreases during February through June, and the largest changes are in the drier years.
km = kilometers

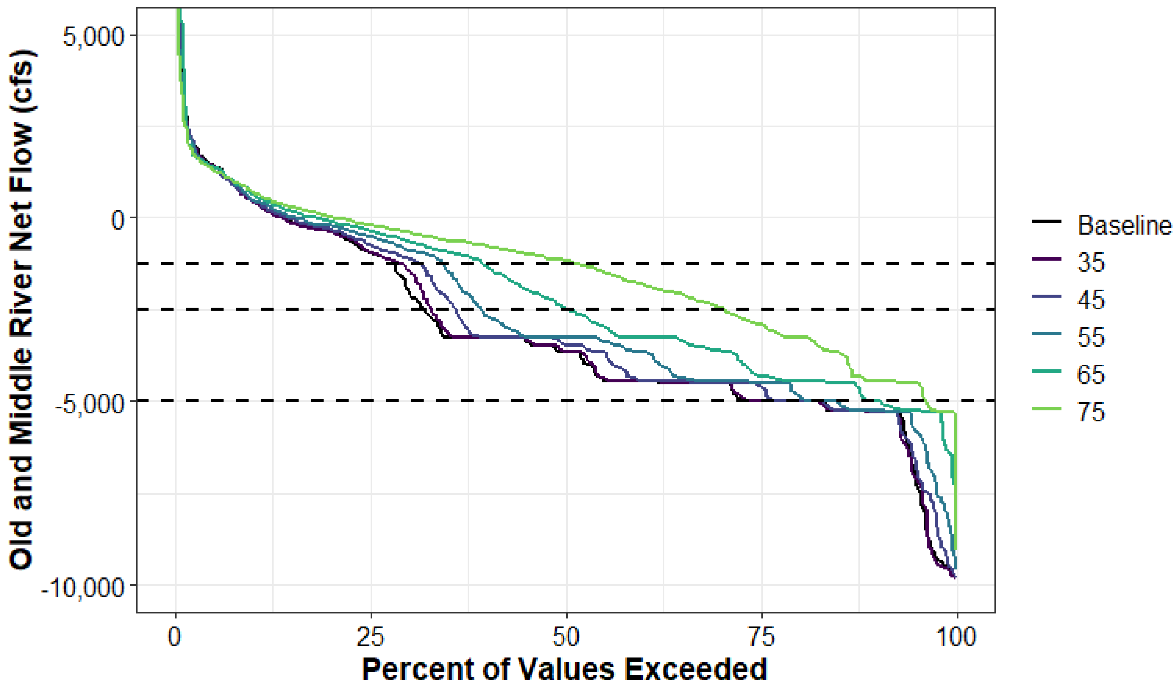
Figure 6.3-21. Exceedance of Spring Average X2 Position

Table 6.3-3. February through June Average X2 Position by Water Year Type and Scenario (kilometers)

Water Year Type	Baseline	35	45	55	65	75
Critical	80	79	78	76	74	72
Dry	74	72	70	68	66	64
Below Normal	68	66	65	63	62	60
Above Normal	62	61	61	60	58	57
Wet	58	58	57	57	56	55
All	68	67	65	64	63	61

Interior Delta Flows

The proposed Plan amendments include new and modified interior Delta flow requirements for DCC gate closures, OMR reverse flows, and export constraints to protect native migratory and estuarine species from entrainment effects in the southern Delta associated with CVP and SWP diversion activities. The proposed Plan amendments are consistent with existing BiOp and ITP requirements as described in Chapter 5, *Proposed Changes to the Bay-Delta Plan for the Sacramento/Delta*. The expected effects of adding these new requirements are largely consistent with the range of conditions that exist under baseline conditions and therefore would not result in significant changes in hydrology or water supply outside the range experienced under baseline conditions. SacWAM results indicate that OMR reverse flows are less negative than baseline in the flow scenarios because exports are reduced to meet the higher Delta outflow requirements (Figure 6.3-22). Further summaries of interior Delta flow results are found in Chapter 3, *Scientific Knowledge to Inform Fish and Wildlife Flow Recommendations*, Section 7.6.2, *Aquatic Biological Resources*, and Appendix A1, *Sacramento Water Allocation Model Methods and Results*.



Magnitudes of reverse flows are generally reduced in the scenarios relative to baseline
cfs = cubic feet per second

Figure 6.3-22. Monthly Exceedance Frequency Distribution of Old and Middle River Net Flow for December through June (cubic feet per second) Changes in Interbasin Diversions

Interbasin diversions are water projects that divert water from one watershed to another. These projects are primarily designed to generate electricity; however, some of them have a water supply component for agriculture and urban use. New instream flow requirements as modeled in SacWAM generally result in lower flows through interbasin diversions because more water is required to remain in the stream downstream of the diversions.

Table 6.3-4 summarizes the interbasin diversions modeled and indicates whether changes are observed in the flow scenarios. Detailed results for each of the diversions can be found in Appendix A1, *Sacramento Water Allocation Model Methods and Results*. The largest changes to interbasin diversions and associated reservoir operation, occur in the upper Yuba and Bear Rivers. An example of an interbasin diversion for the upper Yuba and Bear Rivers is provided in Figure 6.3-23. The following paragraphs describe changes in streamflows on the Yuba and Bear Rivers and changes in operations of the PG&E and Nevada Irrigation District Yuba-Bear, Drum-Spaulding Projects as a representative example of how interbasin diversions could be affected by the proposed Plan amendments.

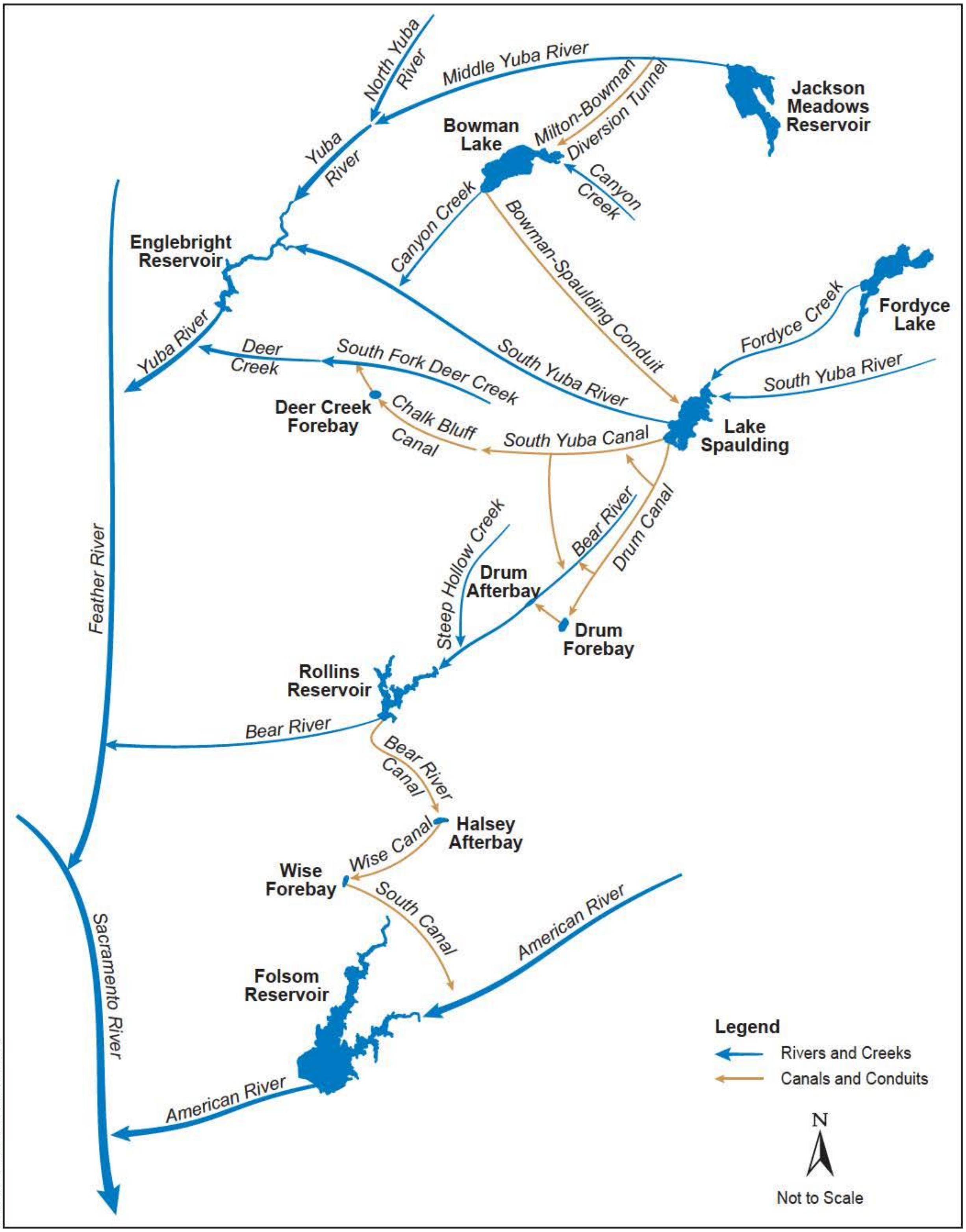


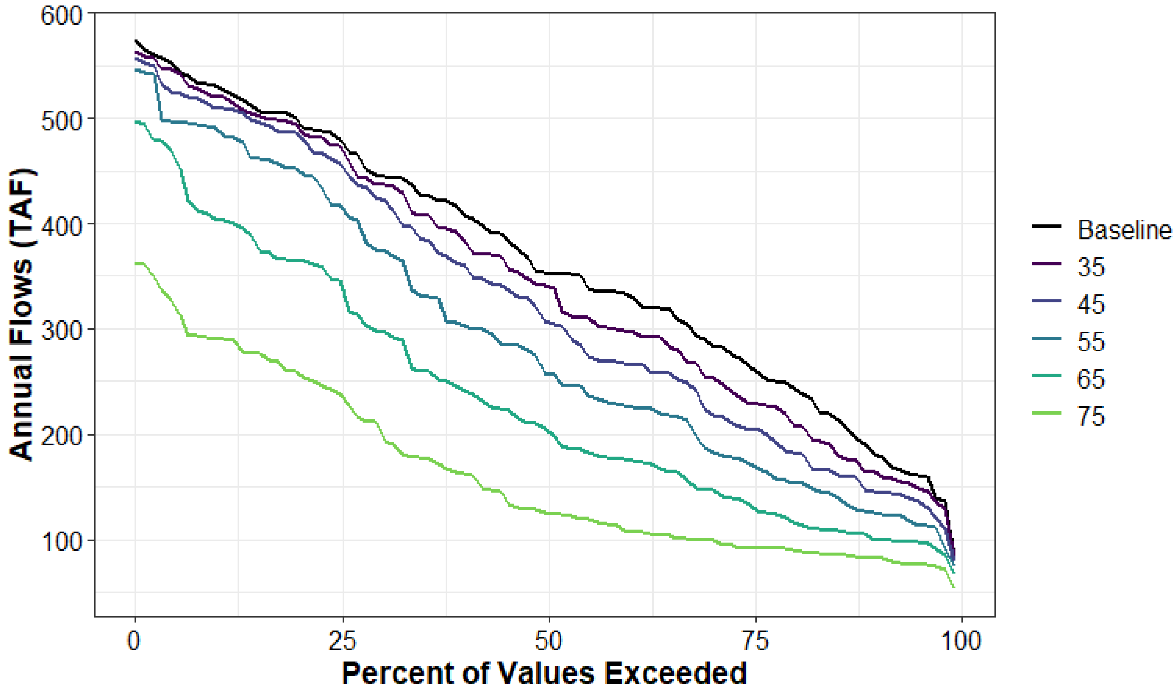
Figure 6.3-23. Example of an Interbasin Diversion (Yuba-Bear Project)

Table 6.3-4. Potentially Affected Upper Watershed Interbasin Diversions

Interbasin Transfers	From	To	Operations Affected?
Clear Creek Tunnel	Trinity River	Clear Creek	No
Toadtown Canal	West Branch Feather River	Butte Creek	Minimal
Slate Creek Tunnel	Slate Creek (Yuba)	South Fork Feather River	Minimal
Milton-Bowman Tunnel	Middle Yuba River	Canyon Creek (South Yuba River)	Yes
Bowman-Spaulding Conduit	Canyon Creek (South Yuba River)	South Yuba River	Yes
Drum Canal	South Yuba River	Bear River	Yes
South Yuba Canal	South Yuba River	Bear River	Yes
South Canal	Bear River	American River	Yes
Hell Hole Tunnel	Middle Fork American River	Rubicon River	Yes
Camp Creek Diversion Tunnel	Camp Creek	Sly Park Creek	No
Jenkinson Lake-Camino Conduit	Sly Park Creek	South Fork American River	No

The Yuba-Bear and Drum-Spaulding Projects divert water from the Middle Yuba River via the Milton-Bowman Tunnel to Canyon Creek (a tributary of the South Yuba River) and then from Canyon Creek to the South Yuba River. From the South Yuba River, water is diverted through the South Yuba Canal and the Drum Canal to the Bear River. As modeled in SacWAM, the flow scenarios frequently require more water to flow down the South and Middle Forks of the Yuba River than occurs under baseline conditions, which reduces the diversions to the Bear River via the Drum Canal (Figure 6.3-24). Along with less water transferred to the Bear River, storage levels in Bowman, Lake Fordyce, Jackson Meadows, and Lake Spaulding Reservoirs are lower; and less water is transferred from the Bear River to the American River via the Bear River Canal and ultimately the South Canal.

Reductions in reservoir levels and changes in flows in the conduits or stream reaches could result in environmental effects, as discussed in the energy, biological resources, aesthetics, and recreation analyses in Chapter 7, *Environmental Analysis*. However, as discussed above, implementation of the proposed Plan amendments could differ from the upper watershed flow requirements included in the model, resulting in potentially smaller changes.



TAF = thousand acre-feet

Figure 6.3-24. Exceedance Frequency Distribution of Annual Drum Canal Total Inflow (thousand acre-feet)

6.3.1.4 Streamflows in Other Regions

The SacWAM results show that Sacramento/Delta supplies to other regions would be reduced under the 35 through 75 scenarios compared with baseline conditions. These changes could affect reservoir levels in export reservoirs that receive Sacramento/Delta supplies. In response to reduced Sacramento/Delta supplies, reservoir operators could reduce the demand on the reservoir or reduce storage in the reservoir. Either of these two responses could result in lower streamflows below the reservoir. Changes in reservoir storage in other regions are discussed further below.

Export reservoirs in other regions and their receiving streams are not explicitly modeled in SacWAM. Many of the streams below the export reservoirs have streamflow requirements that would not allow for reductions below the historical minimum flows (see Table 6.3-5). Downstream flow requirements are not applicable to export reservoirs that do not impound a natural stream or river, such as San Luis Reservoir and Lake Perris; these and other off-stream export reservoirs are excluded from Table 6.3-5. Some export reservoirs are located on naturally intermittent waterways, such as Castaic Lake (located on Castaic Creek), and downstream flow requirements may not apply during periods when there are no natural reservoir inflows. Annual volumes of imported water far exceed natural inflows to some export reservoirs. For example, for the West Fork of the Mojave River, approximately 795 TAF of water flows through Silverwood Lake annually, of which approximately 14 TAF is natural inflow and the remaining 781 TAF (98 percent) is SWP water imported from the Sacramento/Delta (DWR 2016b).

Table 6.3-5 provides an overview of reservoir release and downstream flow requirements associated with larger export reservoirs in the Bay Area, Central Coast, and Southern California regions that receive Sacramento/Delta water supplies. Other smaller reservoirs, such as Quail Lake (capacity 5 TAF), also receive Sacramento/Delta supplies, and additional reservoirs also could receive Sacramento/Delta supplies indirectly through water transfers or agreements.

Table 6.3-5. Existing Reservoir Release and Downstream Flow Requirements for Export Reservoirs in the San Francisco Bay Area, Central Coast, and Southern California Regions

Reservoir	Stream and River Basin	Geographic Region	Source of Sacramento/ Delta Supply	Current Reservoir Release or Downstream Flow Requirements	Document
Lake Del Valle	Arroyo del Valle (Alameda Creek watershed)	Bay Area	South Bay Aqueduct	A live, flowing stream must be maintained from Del Valle Dam to a gaging station on Arroyo del Valle (gage operated by Alameda County Flood Control and Water Conservation District Zone 7, formerly USGS gage #11176600). Lake Del Valle releases must be sufficient to supply downstream senior water right holders.	Water Rights permits 11319 and 11320
Anderson Reservoir	Coyote Creek	Bay Area	CVP Deliveries	Release to downstream channel to extent necessary to satisfy downstream prior rights and/or extent not authorized under license.	Water Rights licenses 10607 and 7212
Lake Cachuma	Santa Ynez River (Santa Ynez River watershed)	Central Coast	Coastal Branch Aqueduct	Order WR 2019-0148 requires that, during below normal, dry, or critical water years, the instream flow requirements are those in the NMFS 2000 Biological Opinion (NMFS 2000); in wet or above normal water years, the instream flow requirements are greater than those in NMFS 2000 Biological Opinion.	Order WR 2019-0148 NMFS 2000 Biological Opinion (U.S. Bureau of Reclamation operation and maintenance of the Cachuma Project on the Santa Ynez River in Santa Barbara County, California)

Reservoir	Stream and River Basin	Geographic Region	Source of Sacramento/ Delta Supply	Current Reservoir Release or Downstream Flow Requirements	Document
Pyramid Lake	Piru Creek (Santa Clara River watershed)	Southern California	West Branch California Aqueduct	Releases from Pyramid Dam into Piru Creek are required to match natural inflow into Pyramid Lake to the extent operationally feasible and consistent with safety requirements (generally, all natural inflow up to 18,000 cfs). Releases are also made for downstream consumptive water use.	401 Water Quality Certification for the Re-operation of Pyramid Dam for the California Aqueduct Hydroelectric Project FERC Project No. 2426; Order WQ 2009-0007
Lake Piru	Piru Creek (Santa Clara River watershed)	Southern California	Lake Piru does not directly receive SWP imports but is located below Pyramid Lake on Piru Creek	Habitat Water Releases from Santa Felicia Dam of 7 cfs during October 1 through December 31, and 7–20 cfs during January 1 through September 30, depending on precipitation conditions. Migration Water Releases of at least 200 cfs during January 1 through May 31, if rainfall-induced discharge at 8:00 AM exceeds 200 cfs and the following day's mean daily discharge is expected to exceed 200 cfs.	401 Water Quality Certification for Operational Changes at the Santa Felicia Dam Project, FERC Project No. 2153
Castaic Lake	Castaic Creek (Santa Clara River watershed)	Southern California	West Branch California Aqueduct (receives inflows from Pyramid Lake via the Angeles Tunnel)	Castaic Lake is operated such that releases match natural inflows. Natural inflows to Castaic Lake are intermittent (may naturally be 0 cfs).	Pre-application document: South SWP Hydropower Relicensing, FERC Project No. 2426

Reservoir	Stream and River Basin	Geographic Region	Source of Sacramento/ Delta Supply	Current Reservoir Release or Downstream Flow Requirements	Document
Silverwood Lake	West Fork Mojave River (Mojave River watershed)	Southern California	East Branch California Aqueduct	DWR does not use local natural inflows to Silverwood Lake for SWP purposes or intend to operate Silverwood Lake for flood control. However, the instantaneous natural outflow to the West Fork Mojave River may not be equal to the instantaneous natural inflow due to operational constraints and other issues/ considerations. The current Devil Canyon Project FERC license does not include an instream flow requirement for the West Fork Mojave River downstream of Silverwood Lake.	Pre-application document: Devil Canyon Project Relicensing, FERC Project No. 14797
Diamond Valley Lake	Warm Springs Creek (Santa Margarita River watershed)	Southern California	East Branch California Aqueduct (receives water from Silverwood Lake via the Inland Feeder)	None identified. Streamflow records for Warm Springs Creek near Murrieta, CA (USGS #11042800) show that there is no flow in Warm Springs Creek for many days each year.	

cfs = cubic feet per second, FERC = Federal Energy Regulatory Commission; NMFS = National Marine Fisheries Service; USGS = U.S. Geological Survey; WR = Water Right

The reservoir release and downstream flow requirements summarized in Table 6.3-5 may be subject to future changes from issuance of new Water Right Orders or Decisions, FERC licenses, and other future regulatory requirements. For example, the South State Water Project (FERC Project No. 2426) and the Devil Canyon Project (FERC Project No. 14797) are undergoing relicensing and are operating under annual licenses until relicensing is completed. The South State Water Project includes Pyramid Lake, Castaic Power Development facilities, and other infrastructure; the Devil Canyon Project includes Silverwood Lake and other infrastructure.

As shown in Table 6.3-5, many streams below export reservoirs have streamflow requirements that would not allow for reductions below the historical minimum flows. However, some of these streamflow requirements are based on reservoir storage; if reservoir storage is reduced, the streamflow requirements also are reduced. Further, it is possible that existing flow requirements may change in the future. Therefore, there is uncertainty in how reservoir operators may respond to reduced exports, and it is possible that streamflows below export reservoirs receiving Sacramento/Delta supplies may be reduced.

6.3.2 Reservoir Storage and Elevation

This section presents a summary of findings related to the SacWAM results for end-of-April and end-of-September reservoir storage for major storage reservoirs located on Sacramento/Delta tributaries. The storage patterns for the rim reservoirs and reservoirs in the upper watersheds above the rim reservoirs are discussed separately before a brief discussion of total carryover storage by watershed. Finally, potential changes to reservoir storage for export reservoirs are discussed. Appendix A1, *Sacramento Water Allocation Model Methods and Results*, also presents summary graphs and tables for end-of-April and end-of-September reservoir storage and elevation for modeled reservoirs. The end-of-April values are presented to represent the storage at the end of the wet season going into the irrigation season. The end-of-September values were chosen to represent carryover storage because they are at the end of the dry season and prior to the typical onset of fall precipitation. The end-of-September values are the initial condition for the reservoir in a new water year and serve as a safety factor for water supply and downstream flow control. Without carryover storage, a dry year or series of dry years could leave reservoirs empty, or with no water remaining to meet outflow and downstream temperature requirements. While greater levels of carryover storage increase certainty of supply and downstream control, they leave less space to capture additional water during the wet season.

6.3.2.1 Sacramento River Watershed and Delta Eastside Tributaries Rim Reservoirs

Operations of the rim reservoirs are increasingly constrained under the modeled scenarios because new instream flow requirements limit the ability to store water in spring and cold water pool requirements limit how far rim reservoirs can be drawn down in the drier years. In general, this results in lower storage at the end of April entering the irrigation season, and less total water being released in summer months. The actual level of a given reservoir could differ from that modeled as operations are refined with increased understanding of actions needed to protect cold water habitat.

Summaries of reservoir storage included in this section are shown to characterize the type of changes in reservoir operation throughout the Sacramento River watershed and Delta eastside tributaries regions.[4] A typical exceedance frequency chart is shown for each similar group of reservoirs, with individual charts included in Appendix A1, *Sacramento Water Allocation Model Methods and Results*. The following rim reservoirs are included in this analysis: Folsom Reservoir (American River), Camp Far West Reservoir (Bear River), Clear Lake (Cache Creek), New Hogan Reservoir (Calaveras River), Oroville Reservoir (Feather River), Pardee Reservoir (Mokelumne River), Camanche Reservoir (Mokelumne River), Lake Berryessa (Putah Creek), Shasta Reservoir (Sacramento River), Black Butte Reservoir (Stony Creek), and New Bullards Bar Reservoir (Yuba River). Figure 6.3-25 depicts each of these reservoirs.

[4]This does not imply that the responsibility for meeting the streamflow objectives is limited to areas below the rim reservoirs or the rim reservoirs themselves. In most cases, a holistic watershed-wide approach will be necessary to meet the proposed Delta inflow objectives.

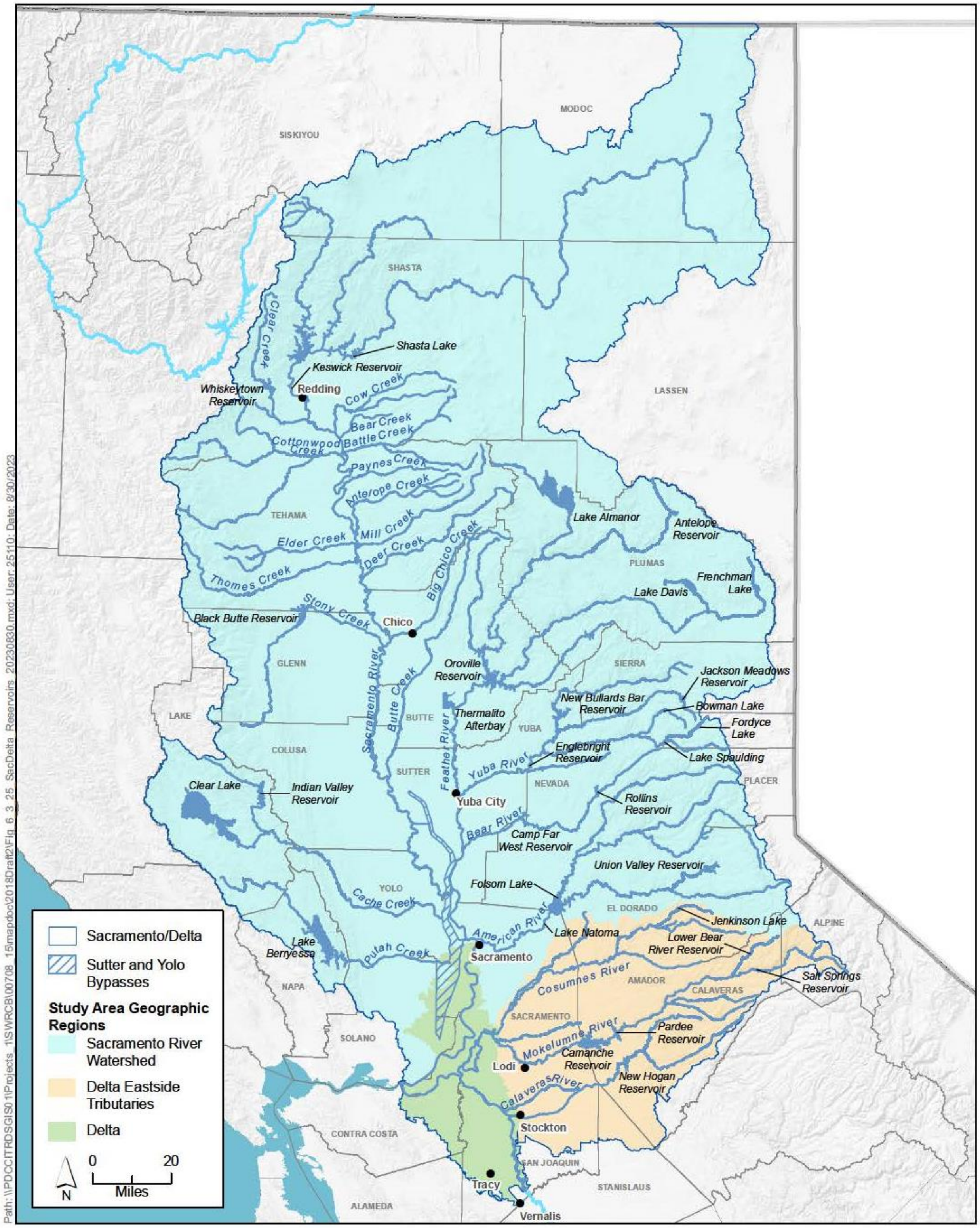


Figure 6.3-25. Reservoirs in the Sacramento/Delta

The tables below show changes in average end-of-April storage for all years and critical years (Table 6.3-7 and Table 6.3-8) and average end-of-September carryover storage for all years and critical years (Table 6.3-8 and Table 6.3-9).

Reregulating reservoirs such as Keswick, Nimbus, Thermalito, and Englebright, along with Whiskeytown Reservoir on Clear Creek, are not dynamically simulated in SacWAM and therefore do not show changes in storage in the modeled flow scenarios. Storage in these reservoirs is not expected to change with proposed Plan amendments because the reservoirs do not act as inter-month or inter-annual storage; rather, they are operated to “smooth” out daily or weekly hydropower peak flows from the large powerhouses below the rim reservoirs.

End-of-April storage is typically lower in the scenarios than baseline because the unimpaired flow requirements require a bypass of reservoir inflow, whereas in the baseline scenario, all reservoir inflow that is not required to be released for existing flow requirements, existing downstream demand, or flood control is stored (Table 6.3-6 and Table 6.3-7). The times when end-of-April storage is higher in the scenarios than baseline occur when the end-of-September storage from the previous year was sufficiently higher in the scenarios to carry through to April. This can occur in the lower unimpaired flow scenarios during drier years, when flood control releases are not necessary.

In general, for the 35, 45, and 55 scenarios, the rim reservoirs are operated similarly or more conservatively than under baseline conditions, meaning they show either increases in carryover storage or relatively minor decreases in carryover storage. The purpose of simulating this type of reservoir operation is to maintain as much or more cold water pool for use at the end of the season than under baseline conditions, as a representation of the cold water narrative objective. Appendix A1, *Sacramento Water Allocation Model Methods and Results*, and Appendix A1c, *Preliminary Assessment of Effect of Reservoir Storage on Reservoir Release Temperatures*, provide more detail on how the carryover targets were developed and how they were implemented in SacWAM. For the 65 and 75 scenarios, there is a greater tendency toward reductions in carryover storage (Table 6.3-8 and Table 6.3-9). It is not feasible to maintain greater carryover storage for cold water pool in all reservoirs in all scenarios. Under average conditions (Table 6.3-8), carryover storage under the flow scenarios tends to be similar to or less than baseline carryover storage, with carryover storage tending to be lower under the higher flow scenarios and for Black Butte Reservoir under all flow scenarios. Under the higher flow scenarios, the combination of reduced spring storage and downstream water demands may result in reduced carryover storage. Carryover storage is more important and harder to maintain under dry conditions, so comparisons of carryover storage for critical years (Table 6.3-9) may be more informative regarding the effects of operations modeled for the proposed Plan amendments.

Table 6.3-6. Average End-of-April Storage (thousand acre-feet) and Percent Differences from Baseline in Rim Reservoirs in the Scenarios for All Years

Reservoir	Baseline TAF	35 TAF / (%)	45 TAF / (%)	55 TAF / (%)	65 TAF / (%)	75 TAF / (%)
Black Butte Reservoir	114	-18 / (-16)	-26 / (-23)	-37 / (-32)	-49 / (-43)	-63 / (-55)
Camanche Reservoir	291	-7 / (-2)	-21 / (-7)	-29 / (-10)	-43 / (-15)	-76 / (-26)
Camp Far West	92	-1 / (-2)	-3 / (-3)	-5 / (-6)	-14 / (-15)	-28 / (-30)
Clear Lake	1,084	-20 / (-2)	-27 / (-2)	-34 / (-3)	-39 / (-4)	-41 / (-4)
Folsom Lake	734	-17 / (-2)	-44 / (-6)	-72 / (-10)	-144 / (-20)	-299 / (-41)
Lake Berryessa	1,180	-41 / (-3)	-113 / (-10)	-81 / (-7)	-250 / (-21)	-287 / (-24)
New Bullards Bar Reservoir	820	34 / (4)	5 / (1)	-41 / (-5)	-103 / (-13)	-264 / (-32)
New Hogan Reservoir	176	-12 / (-7)	-21 / (-12)	-21 / (-12)	-36 / (-20)	-67 / (-38)
Oroville Reservoir	2937	-205 / (-7)	-364 / (-12)	-535 / (-18)	-596 / (-20)	-873 / (-30)
Pardee Reservoir	174	-2 / (-1)	-3 / (-2)	-5 / (-3)	-9 / (-5)	-12 / (-7)
Shasta Lake	4,086	29 / (1)	-18 / (-0)	-154 / (-4)	-343 / (-8)	-492 / (-12)

TAF = thousand acre-feet

Table 6.3-7. Average End-of-April Storage (thousand acre-feet) and Percent Differences from Baseline in Rim Reservoirs in the Scenarios for Critical Years

Reservoir	Baseline TAF	35 TAF / (%)	45 TAF / (%)	55 TAF / (%)	65 TA F/ (%)	75 TAF / (%)
Black Butte Reservoir	62	-25 / (-40)	-29 / (-47)	-35 / (-57)	-40 / (-64)	-42 / (-68)
Camanche Reservoir	161	39 / (24)	29 / (18)	32 / (20)	16 / (10)	-12 / (-7)
Camp Far West	86	-6 / (-7)	-11 / (-13)	-19 / (-23)	-40 / (-46)	-56 / (-66)
Clear Lake	954	-22 / (-2)	-28 / (-3)	-32 / (-3)	-33 / (-4)	-30 / (-3)
Folsom Lake	504	-9 / (-2)	-23 / (-5)	-41 / (-8)	-154 / (-31)	-305 / (-60)
Lake Berryessa	808	83 / (10)	38 / (5)	117 / (14)	-34 / (-4)	-2 / (-0)
New Bullards Bar Reservoir	680	36 / (5)	-34 / (-5)	-101 / (-15)	-193 / (-28)	-313 / (-46)
New Hogan Reservoir	95	8 / (8)	-1 / (-1)	1 / (2)	-11 / (-12)	-36 / (-38)
Oroville Reservoir	1,856	-52 / (-3)	-246 / (-13)	-369 / (-20)	-374 / (-20)	-601 / (-32)
Pardee Reservoir	167	-3 / (-2)	-6 / (-4)	-9 / (-5)	-13 / (-7)	-14 / (-8)
Shasta Lake	2,882	56 / (2)	-18 / (-1)	-52 / (-2)	-194 / (-7)	-213 / (-7)

TAF = thousand acre-feet

Table 6.3-8. Average Carryover Storage (thousand acre-feet) and Percent Differences from Baseline in Rim Reservoirs in the Scenarios for All Years

Reservoir	Baseline TAF	35 TAF / (%)	45 TAF / (%)	55 TAF / (%)	65 TAF / (%)	75 TAF / (%)
Black Butte Reservoir	52	-9 / (-17)	-11 / (-21)	-14 / (-26)	-16 / (-30)	-20 / (-38)
Camanche Reservoir	240	2 / (1)	-9 / (-4)	-16 / (-7)	-30 / (-13)	-64 / (-27)
Camp Far West	49	-0 / (-1)	-1 / (-1)	-3 / (-6)	-11 / (-23)	-18 / (-37)
Clear Lake	896	-8 / (-1)	-10 / (-1)	-11 / (-1)	-10 / (-1)	-4 / (-0)
Folsom Lake	606	-15 / (-2)	-21 / (-3)	16 / (3)	-35 / (-6)	-190 / (-31)
Lake Berryessa	971	7 / (1)	-44 / (-4)	18 / (2)	-126 / (-13)	-135 / (-14)
New Bullards Bar Reservoir	605	70 / (12)	50 / (8)	18 / (3)	-10 / (-2)	-134 / (-22)
New Hogan Reservoir	103	3 / (3)	-1 / (-1)	11 / (11)	4 / (4)	-23 / (-22)
Oroville Reservoir	2037	-107 / (-5)	-200 / (-10)	-264 / (-13)	-156 / (-8)	-309 / (-15)
Pardee Reservoir	188	2 / (1)	2 / (1)	2 / (1)	1 / (0)	-1 / (-1)
Shasta Lake	2879	74 / (3)	18 / (1)	-94 / (-3)	-173 / (-6)	-115 / (-4)

TAF = thousand acre-feet

Table 6.3-9. Average Carryover Storage (thousand acre-feet) and Percent Differences from Baseline in Rim Reservoirs in the Scenarios for Critical Years

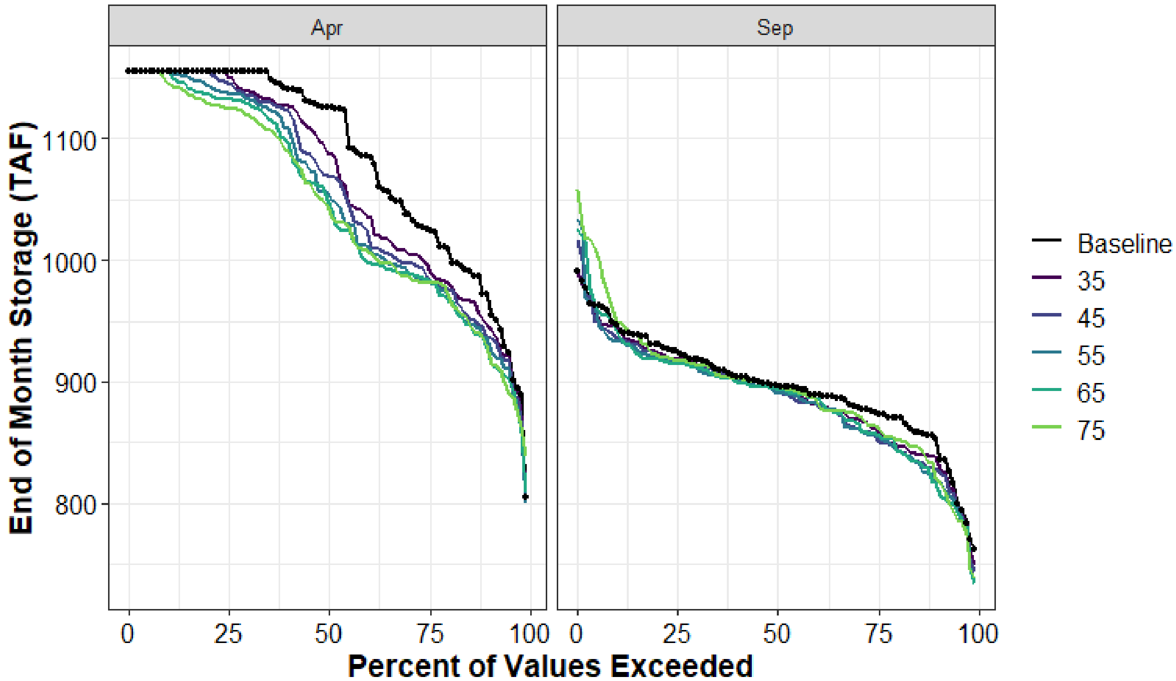
Reservoir	Baseline TAF	35 TAF / (%)	45 TAF / (%)	55 TAF / (%)	65 TAF / (%)	75 TAF / (%)
Black Butte Reservoir	26	-4 / (-17)	-5 / (-21)	-6 / (-24)	-6 / (-25)	-7 / (-26)
Camanche Reservoir	118	41 / (35)	25 / (21)	26 / (22)	18 / (16)	-10 / (-8)
Camp Far West	31	1 / (4)	1 / (3)	-1 / (-4)	-1 / (-4)	-3 / (-10)
Clear Lake	836	-15 / (-2)	-20 / (-2)	-21 / (-3)	-22 / (-3)	-18 / (-2)
Folsom Lake	363	-35 / (-10)	-7 / (-2)	14 / (4)	-83 / (-23)	-215 / (-59)
Lake Berryessa	611	155 / (25)	130 / (21)	216 / (35)	92 / (15)	138 / (23)
New Bullards Bar Reservoir	478	36 / (7)	-14 / (-3)	-57 / (-12)	-122 / (-25)	-180 / (-38)
New Hogan Reservoir	52	24 / (47)	17 / (32)	18 / (34)	6 / (12)	-14 / (-27)
Oroville Reservoir	951	204 / (21)	55 / (6)	-21 / (-2)	-19 / (-2)	-186 / (-20)
Pardee Reservoir	179	10 / (6)	10 / (6)	10 / (5)	5 / (3)	-6 / (-4)
Shasta Lake	1518	436 / (29)	377 / (25)	451 / (30)	327 / (22)	381 / (25)

TAF = thousand acre-feet

Each reservoir would be affected differently by the proposed Plan amendments, but the modeled responses to the flow scenarios can be loosely divided into several types.

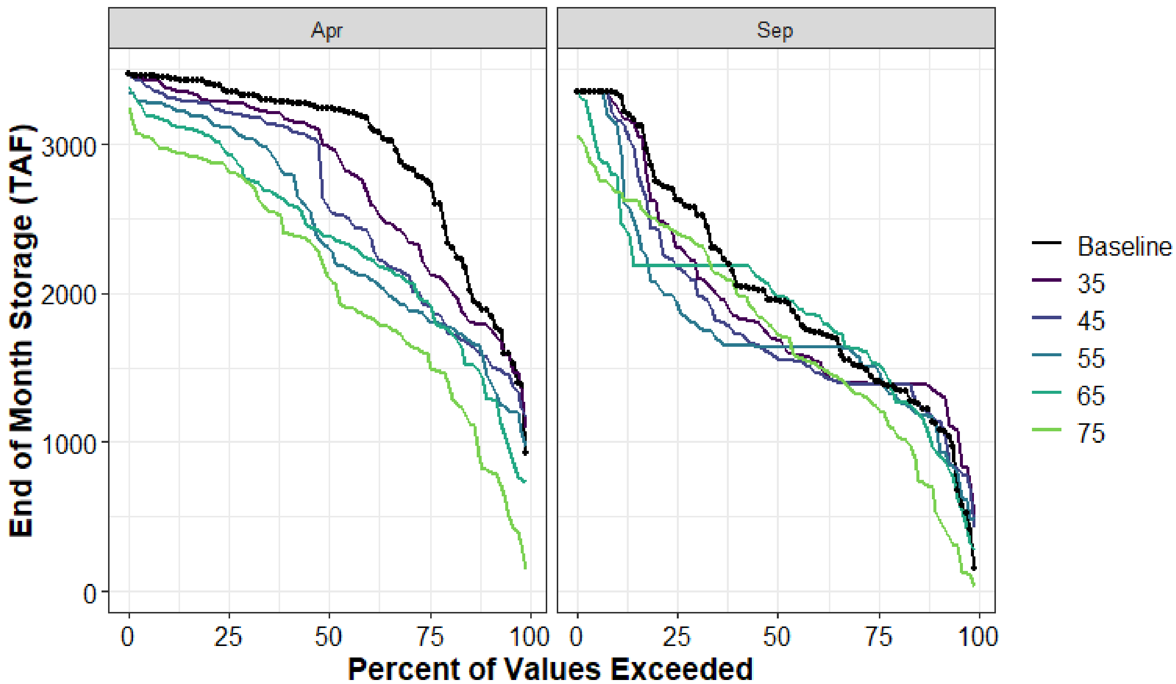
- **Little change in carryover storage:** Clear Lake (Figure 6.3-26) and Pardee Reservoirs show little change in storage. Clear Lake shows little change from baseline because it is a natural lake with limited control of reservoir level, and Pardee Reservoir shows little change in storage because Pardee Reservoir is operated to maintain storage while Camanche Reservoir downstream is more affected by changes in operation.
- **Increase in carryover storage under lower flow scenarios under critical-year conditions:** For some reservoirs, carryover storage objectives have more effect under drier critical-year conditions and contribute to higher carryover storage compared with baseline, particularly for Camanche, Berryessa, Oroville (Figure 6.3-27), and Shasta Reservoirs (Figure 6.3-28).
- **Average and critical years show similar pattern:** Camp Far West (Figure 6.3-29), Folsom, and New Bullards Bar Reservoirs generally show patterns of little change in carryover for the lower flow scenarios and reductions in carryover for the higher flow scenarios, both for average year and critical year results.
- **Decreases in carryover storage:** Black Butte (Figure 6.3-30) shows decreases in carryover storage under both average and critical year conditions for all flow scenarios. Black Butte Reservoir storage declines in the scenarios dramatically because it was assumed that no viable carryover target exists to maintain downstream conditions conducive to spawning of anadromous fish.

Clear Lake shows little change from baseline because it is a natural lake with limited control of reservoir level. Figure 6.3-26 shows that while end-of-April storage is typically lower than baseline in all the scenarios, the end-of-September storage is much closer to baseline.



Reservoir storage remains nearly unchanged (less than 10 percent difference from baseline) under all storage conditions and all flow scenarios.
TAF = thousand acre-feet

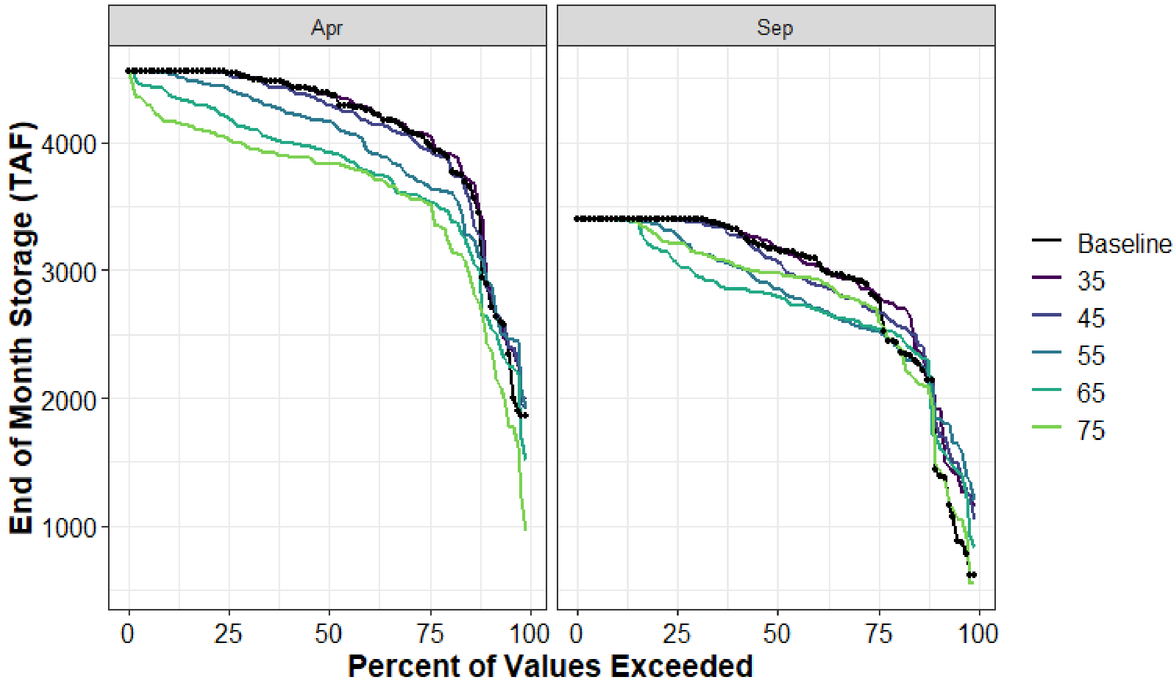
Figure 6.3-26. Clear Lake Reservoir End-of-April and End-of-September Carryover Storage



End-of-April storage is lower in all scenarios compared to baseline. Carryover storage is lower in the wetter years in all scenarios and remains similar to the baseline in the 35, 45, and 55 scenarios in the driest 25 percent of years.
TAF = thousand acre-feet

Figure 6.3-27. Oroville Reservoir End-of-April and End-of-September Carryover Storage

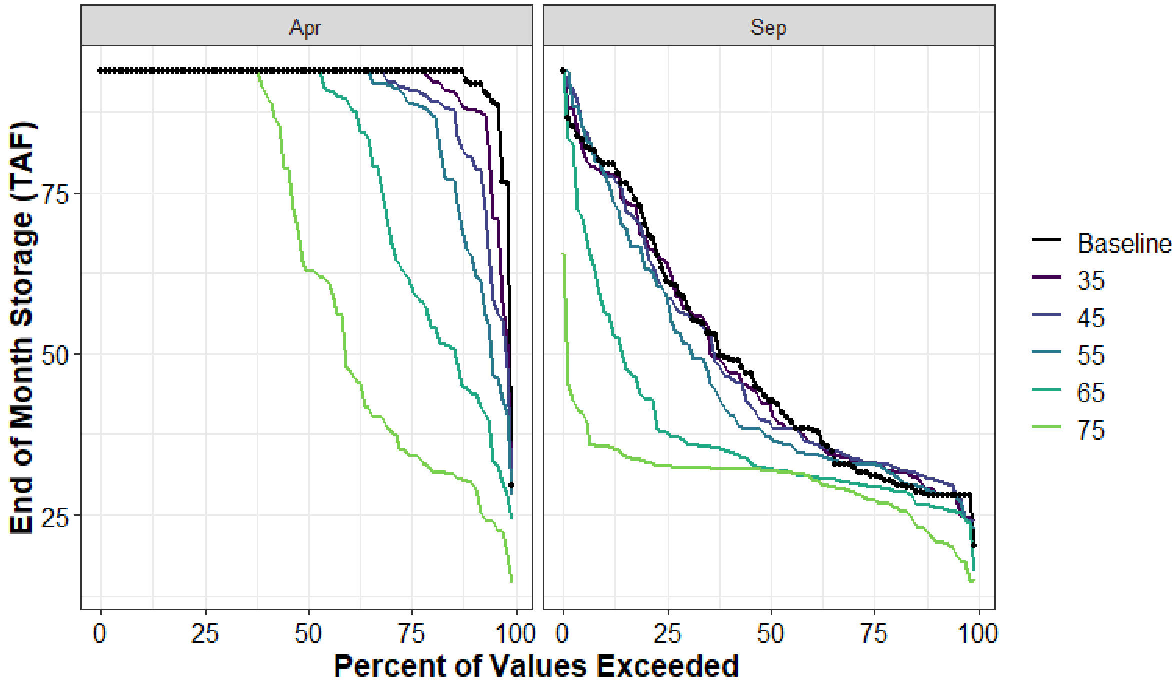
Shasta Reservoir shows end-of-September carryover storage that increases under lower storage conditions and decreases under the higher storage conditions (Figure 6.3-28). This pattern is similar to that observed for Berryessa, Oroville, and Camanche Reservoirs, in that end-of-September reservoir storage increases from baseline under lower storage conditions.



The end-of-April storage is lower in the wetter years and closer to the baseline in the drier years. Shasta Reservoir end-of-September carryover storage increases under lower storage conditions.
TAF = thousand acre-feet

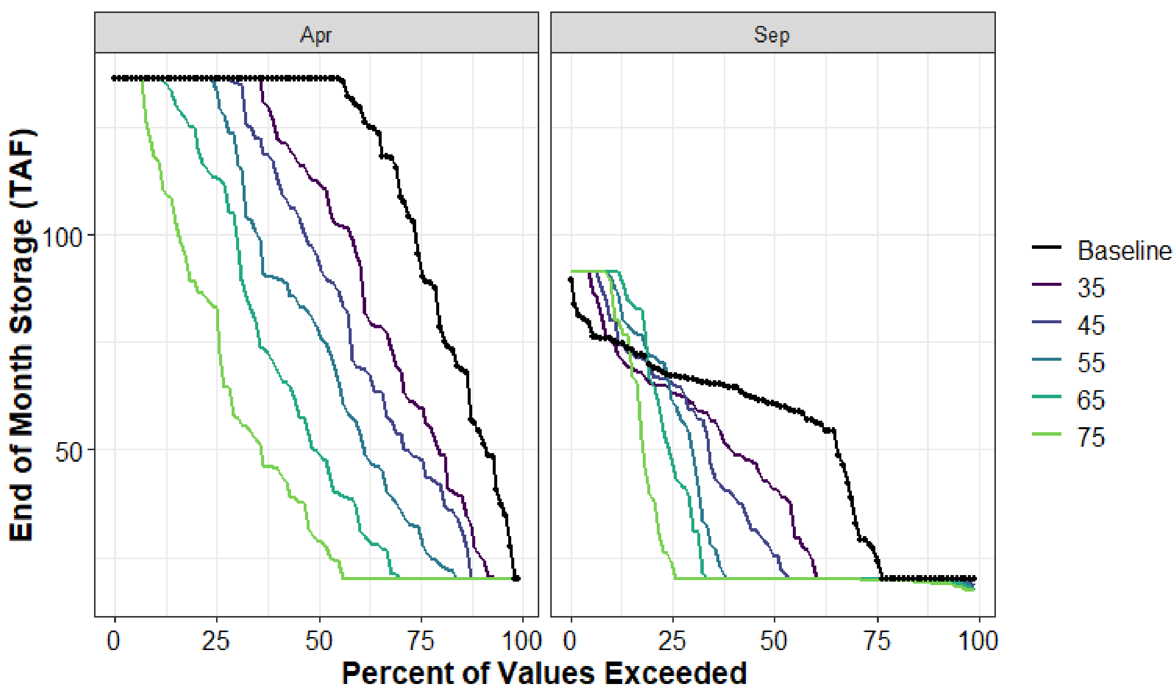
Figure 6.3-28. Shasta Reservoir End-of-April and End-of-September Carryover Storage

While some reservoirs show little change from baseline, others show substantial decreases in storage levels. Reservoirs that are not capable of supporting cold water fisheries downstream were not operated to maintain cold water pool in SacWAM, such as Black Butte Reservoir (Figure 6.3-30). For some other reservoirs, it was not possible to maintain end-of-September carryover in the higher flow scenarios because of lower end of spring storage and the large demands for water downstream. These reservoirs include Camp Far West (Figure 6.3-29), Folsom, New Bullards Bar, and Camanche Reservoirs. These reservoirs present substantial difficulties for reconciling a high percent unimpaired flow regime with high carryover and continued reliance for water supply.



Camp Far West Reservoir end-of-April and end-of-September carryover storage decreases substantially from the baseline scenario in the 65 and 75 scenarios.
TAF = thousand acre-feet

Figure 6.3-29. Camp Far West Reservoir End-of-April and End-of-September Carryover Storage



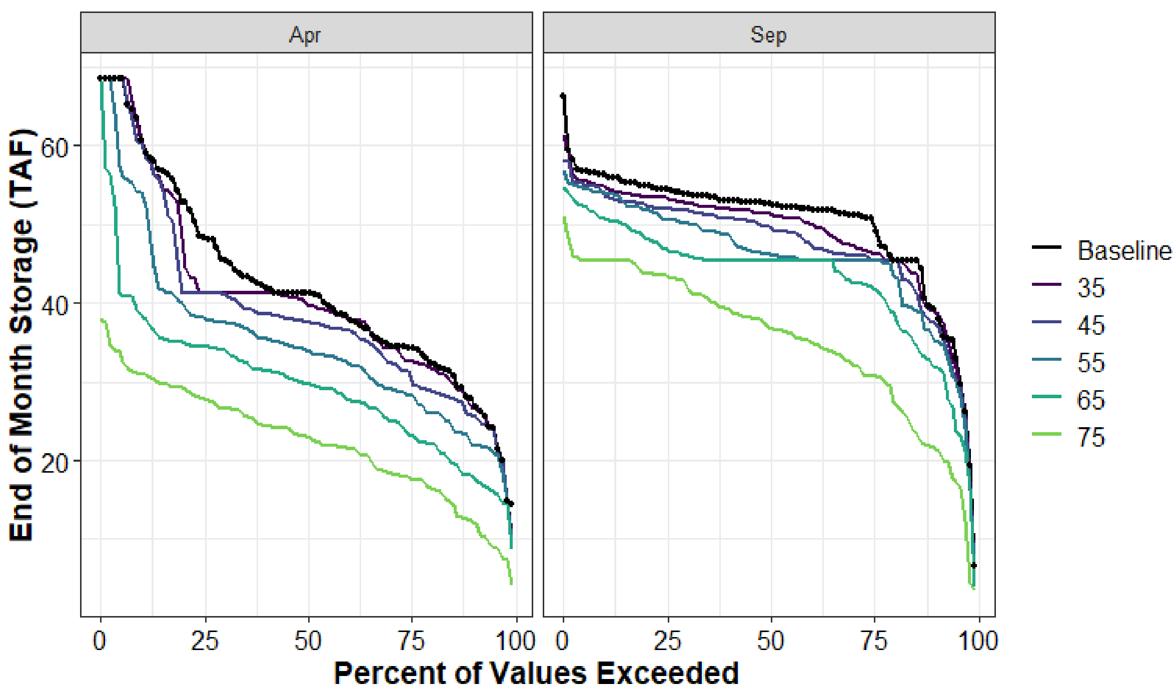
Black Butte Reservoir end-of-April and end-of-September carryover storage decreases substantially from the existing scenario in all the flow scenarios.
TAF = thousand acre-feet

Figure 6.3-30. Black Butte Reservoir End-of-April and End-of-September Carryover Storage

6.3.2.2 Upper Watershed Reservoirs

Most of the upper watershed reservoirs in the Sacramento River watershed and Delta eastside tributaries regions show no significant change in storage in any of the flow scenarios. Twelve of the 43 upper watershed reservoirs have potential to see large changes in operation under each of the modeling scenarios, particularly facilities that include interbasin diversions that move water from one watershed to another.

DWR reservoirs such as Antelope Reservoir, Lake Davis, and Frenchman Reservoir, with a combined maximum storage of about 162 TAF, may be required to bypass inflow or release from storage to meet the new flow requirements, resulting in lower reservoir levels. Increased inflow requirements into Pardee Reservoir could result in lower storages in Salt Springs and Lower Bear River Reservoirs because more water would be required to bypass the reservoirs in spring. Reduced transfers to the Bear River would lower storage levels in Bowman, Lake Fordyce, Jackson Meadows, Rollins, and Lake Spaulding Reservoirs. End-of-September storage for Bowman Reservoir is shown in Figure 6.3-31 to illustrate the pattern observed in the modeling of these reservoirs. Again, the modeling scenarios represent only one possible operation of these systems. The proposed Plan amendments provide for one or more tributaries to meet flow requirements so long as narrative objectives are met. Parties may develop operational scenarios that reduce the drawdown effects currently reflected in the modeling scenarios.



Changes in end-of-April and end-of-September carryover storage across the scenarios for Bowman Reservoir represent the typical storage patterns in the upper Yuba River watershed associated with interbasin diversions.
TAF = thousand acre-feet

Figure 6.3-31. Bowman Reservoir End-of-April and End-of-September Carryover Storage

6.3.2.3 Reservoir Fluctuation

Some resources are affected by vertical fluctuation in water surface elevation. Vertical fluctuations are related to reductions in reservoir storage, but do not necessarily follow the same patterns because fluctuation in elevation depends on patterns of refilling as well as reservoir geometry.

SacWAM results include reservoir elevations for 49 reservoirs, including all rim reservoirs and the reservoirs most likely to be affected by the proposed Plan amendments. Of these, 30 were reoperated in SacWAM and show changes associated with the proposed Plan amendments. Most of the 19 reservoirs that were not reoperated are reregulating reservoirs or hydropower reservoirs that are not expected to be affected by a reduction in interbasin transfers. For reservoirs affected by the flow scenarios due to increased bypasses of reservoir inflow, reservoir storage is affected by the balance between meeting current and future demands for water supply and retaining cold water pool in the reservoir. This balance could be further refined in the future as a result of further analysis.

Table A1-145 in Appendix A1, *Sacramento Water Allocation Model Methods and Results* shows average annual fluctuations in water surface elevation calculated as the average of annual maximum minus average minimum water surface elevations. Most of the changes in fluctuation are negative, indicating less fluctuation associated with the flow scenarios. The few locations with increased reservoir fluctuation include East Park and Stony Gorge Reservoirs for all flow scenarios (East Park Reservoir supplies water to Stony Gorge Reservoir), San Luis Reservoir (all scenarios except the 75 flow scenario), Rollins and Hell Hole Reservoirs (affected by reduction in interbasin diversions under the 65 and 75 flow scenarios). All of these increases are less than 20 feet.

6.3.2.4 Total Carryover Storage by Tributary Watershed

Because of the inherent flexibility built into the Plan amendments for implementation of flow requirements and given that specific water rights allocations are not necessarily represented with precision in the modeling of flow scenarios, how the flow requirements are met may vary from the specific scenarios modeled in this Staff Report. It is informative to examine total watershed storage, as summarized in Table 6.3-10 (average total watershed carryover storage) and Table 6.3-11 (critical year total watershed storage). Most watersheds show a decrease in average carryover storage in the flow scenarios relative to baseline, with larger decreases observed for higher flow requirements. The largest modeled decrease is 43 percent for the Stony Creek watershed under the 75 scenario. In the 55 scenario, the largest modeled decrease in carryover storage is 26 percent in the Stony Creek watershed. A few watersheds show small increases in average carryover storage in the 35 and 45 scenarios (Putah, Yuba, and Calaveras watersheds). Total watershed carryover storage during critical years increases in the 35 and 45 scenarios in most of the watersheds except the American River, Stony Creek, Yuba River, and Cache Creek watersheds (Table 6.3-11).

Table 6.3-10. Average End-of-September Watershed Total Storage for Baseline (thousand acre-feet) and Percent Difference from Baseline for the Flow Scenarios

Watershed	Baseline TAF	35 (%)	45 (%)	55 (%)	65 (%)	75 (%)
American	1,105	-1	-2	1	-5	-24
Bear	113	0	-1	-3	-12	-26
Cache	1,010	-1	-2	-3	-4	-5
Calaveras	103	3	-1	11	4	-22
Clear	234	0	0	0	0	-1
Cosumnes [a]	31	0	0	0	0	0
Feather	3,226	-3	-6	-8	-5	-10
Mokelumne	642	0	-3	-5	-9	-18
Putah	971	1	-4	2	-13	-14
Sacramento [b]	2,901	3	1	-3	-6	-4
Stony	134	-14	-19	-26	-34	-43
Yuba	872	8	5	2	-2	-18

[a] The only reservoir represented in SacWAM in the Cosumnes watershed is Sly Park Reservoir, which does not show any change to operations in any of the scenarios.

[b] Sacramento River watershed total storage in this context represents Shasta Lake and Keswick Reservoir storage, excluding storage in all other watersheds listed in the table.

Table 6.3-11. Average Critical Year End-of-September Watershed Total Storage for Baseline (thousand acre-feet) and Percent Difference from Baseline for the Flow Scenarios

Watershed	Baseline TAF	35 (%)	45 (%)	55 (%)	65 (%)	75 (%)
American	832	-4	-1	1	-13	-35
Bear	87	4	4	0	-3	-9
Cache	865	-1	-1	-1	-1	-1
Calaveras	52	47	32	34	12	-27
Clear	234	0	0	0	0	-3
Cosumnes [a]	23	0	0	0	0	0
Feather	1980	10	3	-1	-1	-9
Mokelumne	460	9	2	0	-6	-18
Putah	611	25	21	35	15	23
Sacramento [b]	1540	28	24	29	21	25
Stony	78	-36	-43	-50	-58	-60
Yuba	708	5	-2	-8	-19	-32

[a] The only reservoir represented in SacWAM in the Cosumnes watershed is Sly Park Reservoir, which does not show any change to operations in any of the scenarios.

[b] Sacramento River watershed total storage in this context represents Shasta Lake and Keswick Reservoir storage, excluding storage in all other watersheds listed in the table.

The observed increases in carryover storage result from carryover targets intended to protect cold water habitat below rim reservoirs. (See Section 6.2, *Changes in Hydrology*, and Appendix A1, *Sacramento Water Allocation Model Methods and Results*, for further discussion of modeling assumptions.) Changes in surface water supply are sensitive to the carryover targets (see Section

6.4, *Changes in Surface Water Supply*). If less carryover is needed to protect cold water habitat, water supply effects in the lower flow scenarios or critical years may be reduced. Likewise, if more carryover is needed for cold water habitat protection, water supply effects would be larger than those estimated in Section 6.4.

6.3.2.5 Reservoirs in Other Regions

Southern California, San Francisco Bay Area, and Central Coast export reservoirs are not explicitly modeled in SacWAM; however, exports are reduced under the flow scenarios, which could result in lower reservoir storage. Exceptions to this include Los Vaqueros Reservoir and San Luis Reservoir, which are modeled in SacWAM, and results show increased storage in many scenarios.

How operators of export reservoirs may operate these reservoirs with less imported water is uncertain; however, two possibilities are discussed here: reservoirs could be lower, or no change could occur. Historical observations of storage in export reservoirs during periods of lower exports show lower storage patterns for some reservoirs. Understanding the roles these reservoirs play in the water supply reliability for local regions suggests that average storage may not be reduced when inflow is reduced in the long term. These two possibilities are discussed below.

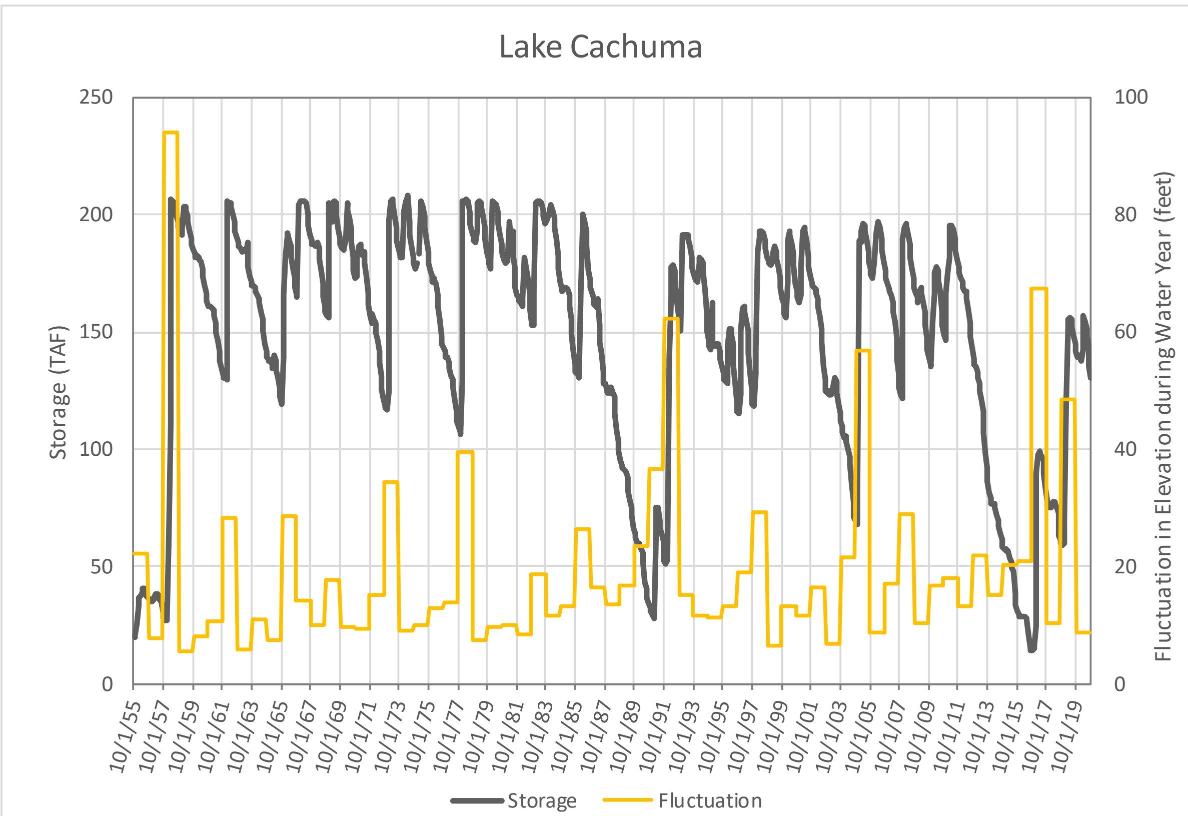
Historical responses to droughts were evaluated with California Data Exchange Center (CDEC) data from seven Southern California reservoirs that receive Sacramento/Delta supplies through the California Aqueduct (Silverwood Lake, Castaic Lake, Lake Piru, Lake Cachuma, Lake Perris, Pyramid Lake, and Diamond Valley Lake) and one northern California reservoir supplied by exports through the South Bay Aqueduct (Lake Del Valle) (Table 6.3-12). This analysis suggests that, when Sacramento/Delta supplies are reduced, some but not all, reservoirs store less water.

Table 6.3-12. Representative Terminal Reservoirs and Their Historical Response to Reduced Water Supply during Drought

Reservoir	Storage Capacity (thousand acre-feet)	Drought Response	Drainage
Lake Del Valle	77 – but rarely exceeds 40	None	Arroyo del Valle/Alameda Creek
Silverwood Lake	75	Almost none	Mojave River
Lake Perris	130/75 [a]	Almost none	Perris Valley Storm Drain/San Jacinto River
Pyramid Lake	171	None	Piru Creek/Santa Clara River
Castaic Lake	324	Moderate	Castaic Creek/Santa Clara River
Lake Cachuma	205	Strong	Santa Ynez River
Diamond Valley Lake	810	Strong	Warm Springs Creek/Santa Margarita River
Lake Piru	83 according to multiple sources – but storage data frequently shows values close to 90	Moderate	Piru Creek/Santa Clara River

[a] Storage capacity reduced due to dam safety concerns in the event of a large earthquake.

Historical drought response for the seven reservoirs shows that Castaic Lake, Lake Cachuma, Diamond Valley Lake, and Lake Piru storage typically is reduced during drought periods. Reservoir storage data for the period of record is shown graphically for Lake Cachuma as a representative reservoir that displays a strong drought response (Figure 6.3-32). In dry periods, such as in the late 1980s and 2014–2015, storage is reduced to minimum levels and does not refill in winter and spring. Assuming that reduced Sacramento/Delta supplies under the flow scenarios would lead to reduced inflow to export reservoirs and that demand from the reservoirs remained constant, storage could be reduced as shown for Lake Cachuma. For Lake Cachuma, reduced water supply is associated with increased fluctuation in annual water surface elevation (Figure 6.3-32). Because annual water use is relatively stable, annual drawdown is about the same regardless of ability to refill. The largest fluctuations occur upon refilling after there have been multiple years of drawdown without filling.



TAF = thousand acre-feet
CDEC = California Data Exchange Center

Figure 6.3-32. Historical Storage and Water Level Fluctuation in Lake Cachuma (CDEC Station CCH)

The historical reservoir operations indicate that some reservoirs are operated to maintain high reservoir storage even during periods of low water supply. These reservoirs are generally relatively small (75- to 171-TAF storage capacity) and include Lake Del Valle, Silverwood Lake, Lake Perris, and Pyramid Lake. While Lake Perris does not seem to have responded much to drought conditions, there was a brief reduction in storage that occurred during 2005 due to concern about dam stability during a large earthquake.

Many export reservoirs are operated as last-resort drought supply that are rarely relied upon. In the various scenarios, where long-term exports are reduced, reservoir operators could respond by reducing the long-term demand on the reservoir by developing alternative supplies or reducing demand (more discussion on other supplies and demand management is included in Section 6.6, *Other Water Management Action*). If operators responded with long-term planning considering the reduced Sacramento/Delta supply, they may operate the reservoir as they have historically by maintaining the storage for severe droughts. In this case, there would be no change to the current storage patterns in the flow scenarios.

6.4 Changes in Surface Water Supply

The discussion that follows characterizes changes in the available surface water supply under various flow scenarios. For convenience, the study area has been divided into seven regions for water supply analysis purposes based on geography and water supply, as shown in Figure 2.8-1a. The water supply regions in the study area are Sacramento River watershed, Delta eastside tributaries, Delta, Bay Area, Central Coast, San Joaquin Valley, and Southern California. Water supply is summarized by where the water is ultimately supplied, not by where the water may be diverted. For example, water is diverted from the Mokelumne River for use in the Bay Area region; this water is included in the Bay Area water supply discussion, not in the Delta eastside tributaries region discussion. Only a portion of the total water supply to each region may be affected by the proposed Plan amendments; this portion is termed *Sacramento/Delta supply* or *Sacramento/Delta water* (see Section 6.4.2, *Sacramento/Delta Water in the Study Area*). In some regions, the Sacramento/Delta supply makes up only a very small percentage of the total water supply, indicating that even the highest flow scenarios have a minimal effect on the total water supply to that region.

The water supply estimates presented in this section do not include conveyance losses, water held in storage, or water diverted to non-consumptive uses such as hydropower. The values summarized in the graphs and tables in this section are annual total volumes by water year of total Sacramento/Delta supply to the study regions. These amounts are further broken out into agricultural, municipal, and refuge uses. The SacWAM methods used to represent the changes in water supply in each scenario are described in Appendix A1a, *Methods for Estimating Regional Sacramento/Delta Surface Water Supply for Agricultural and Municipal Use*. This section first discusses Sacramento/Delta water supply from the Bay-Delta watershed, followed by more detailed discussions of Sacramento/Delta water supply in context with other supplies in each of the different regions of the study area.

Graphical and tabular summaries are given of cumulative distributions of annual surface water supply by modeling scenario (boxplots and cumulative distribution tables) and tabular summaries of average annual water supply by the historical Sacramento Valley 40-30-30 Hydrologic Classification water year type. The water year type classification includes five year types in ascending levels of water availability: critical (C), dry (D), below normal (BN), above normal (AN), and wet (W). In the SacWAM simulation period of 93 water years, 16 percent are critical, 23 percent are dry, 18 percent are below normal, 13 percent are above normal, and 30 percent are wet.

6.4.1 Total Water Supply

Water supplied to beneficial uses goes to a variety of uses such as agriculture, urban (municipal and industrial), and wildlife refuges.[5] The sources of water supplies range from local surface water supplies, groundwater, and water imported from across the state. The proposed instream flow requirements and cold water storage requirements affect each of the uses differently depending on the use and the source of water supply. The total regional water supply is estimated using historical water deliveries data (see Section 2.8, *Existing Water Supply*), and the portion of the surface water supply that may be affected by the proposed Plan amendments is estimated by SacWAM. As described in Section 6.2, *SacWAM Model Assumptions*, SacWAM simulations assumed no change in groundwater pumping for each of the scenarios. Therefore, the Sacramento/Delta supply results presented here include only surface water. Note that, in response to reductions in Sacramento/Delta supply, water users may seek to obtain more water from groundwater resources in areas where groundwater is available. In addition, changes in water supplies could reduce the level of applied water, which in turn could reduce incidental groundwater recharge (e.g., recharge from conveyance losses and deep percolation). This is discussed in more detail elsewhere in this Staff Report, including in Section 6.6, *Other Water Management Actions*, and in Section 7.12.2, *Groundwater*.

Table 6.4-1 shows annual average water supply to each region in the study area by type of use (agriculture, urban, and refuge). Total water supply (surface water, other sources, and groundwater) is estimated using historical water deliveries data (Section 2.8, *Existing Water Supply*). Baseline Sacramento/Delta supply is estimated using SacWAM results and methods described in Section 2.8. Reductions in Sacramento/Delta supply are obtained from SacWAM results for the flow scenarios and methods described in Section 2.8. The following sections provide further detail on each of the regions and uses.

[5] For the purposes of this document, a reference to *municipal use* includes domestic and industrial uses unless otherwise specified. The terms *urban* and *municipal and industrial (M&I)* are also sometimes used in this document to generally reference municipal water supplies.

Table 6.4-1. Annual Average Water Supplied to Each Region in the Study Area (thousand acre-feet per year)

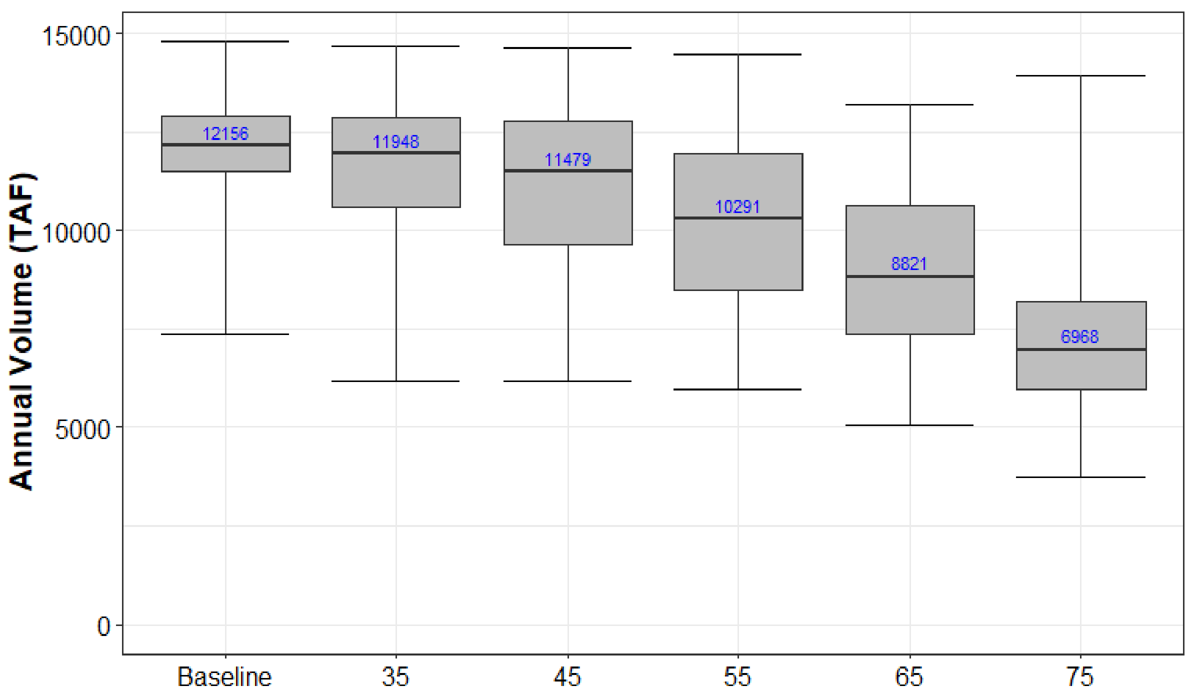
		Sacramento River Watershed	Delta Eastside Tributaries	Delta	San Francisco Bay Area	Central Coast	San Joaquin Valley	Southern California	Study Area Total
Historical Water Deliveries Data	Total	8,050	986	1,368	1,251	1,334	18,437	9,449	40,875
	Agriculture	6,773	824	1,185	137	1,055	16,803	4,863	31,640
	Municipal	826	154	136	1,089	279	1,053	4,518	8,055
	Wetland	451	8	48	26	0	581	68	1,182
Baseline	Sac/Delta	5,320	205	1,154	698	86	2,819	1,675	11,957
	Agriculture	4,641	124	1,136	27	37	2,422	14	8,401
	Municipal	480	81	18	670	49	99	1,661	3,058
	Refuge	199	0	0	0	0	298	0	497
35	Sac/Delta	5,110 (-4%) [-3%]	185 (-10%) [-2%]	1,154 (0%) [0%]	632 (-9%) [-5%]	83 (-3%) [0%]	2,781 (-1%) [0%]	1,583 (-5%) [-1%]	11,528 (-4%) [-1%]
	Agriculture	4,467	111	1,136	21	36	2,387	14	8,172
	Municipal	464	74	18	611	47	95	1,569	2,878
	Refuge	179	0	0	0	0	298	0	477
45	Sac/Delta	4,986 (-6%) [-4%]	177 (-14%) [-3%]	1,153 (0%) [0%]	583 (-16%) [-9%]	78 (-9%) [-1%]	2,673 (-5%) [-1%]	1,435 (-14%) [-3%]	11,085 (-7%) [-2%]
	Agriculture	4,363	107	1,135	18	34	2,288	12	7,957
	Municipal	450	70	19	565	43	88	1,422	2,657
	Refuge	174	0	0	0	0	298	0	472
55	Sac/Delta	4,714 (-11%) [-8%]	161 (-21%) [-4%]	1,150 (0%) [0%]	518 (-26%) [-14%]	67 (-22%) [-1%]	2,440 (-13%) [-2%]	1,225 (-27%) [-5%]	10,275 (-14%) [-4%]
	Agriculture	4,131	96	1,132	13	30	2,069	11	7,482
	Municipal	427	66	18	504	38	77	1,214	2,344
	Refuge	156	0	0	0	0	294	0	450

		Sacramento River Watershed	Delta Eastside Tributaries	Delta	San Francisco Bay Area	Central Coast	San Joaquin Valley	Southern California	Study Area Total
65	Sac/Delta	4,234 (-20%) [-13%]	142 (-31%) [-6%]	1,140 (-1%) [-1%]	442 (-37%) [-20%]	48 (-44%) [-3%]	1,950 (-31%) [-5%]	1,019 (-39%) [-7%]	8,975 (-25%) [-7%]
	Agriculture	3,705	83	1,124	10	17	1,611	9	6,559
	Municipal	397	59	16	432	32	64	1,010	2,010
	Refuge	133	0	0	0	0	275	0	408
75	Sac/Delta	3,478 (-35%) [-23%]	127 (-38%) [-8%]	1,134 (-2%) [-1%]	381 (-45%) [-25%]	37 (-57%) [-4%]	1,504 (-47%) [-7%]	757 (-55%) [-10%]	7,418 (-38%) [-11%]
	Agriculture	3,039	74	1,120	6	13	1,212	7	5,471
	Municipal	372	53	14	375	24	49	750	1,637
	Refuge	67	0	0	0	0	242	0	309

The historical water deliveries data values represent an estimate of the total annual supplies to each region, and the values presented for the flow scenarios represent the Sacramento/Delta surface water portion as modeled from SacWAM. The percentages in round parentheses represent the estimated reduction in Sacramento/Delta supply, while those in square brackets represent the estimated reduction relative to total supply for each flow scenario. When comparing historical water deliveries data estimates to SacWAM results, the reader should keep in mind that they are not meant to be an exact comparison because of differences in methods and time periods. However, these comparisons are presented to give a general idea of the magnitudes of changes relative to the total supply. More information on the differences in the methods can be found in Section 2.8, *Existing Water Supply.*

6.4.2 Sacramento/Delta Water in the Study Area

Sacramento/Delta water is defined here as the portion of the surface water supply to regions that originates in or is diverted from waterbodies in the Sacramento River watershed, Delta eastside tributaries, and Delta regions, and may be affected by the proposed Plan amendments. Because groundwater supply was assumed not to change in the SacWAM modeling, Sacramento/Delta supply includes only surface water supplies. Only a portion of the water supplied to each of the regions is derived from surface water from the Sacramento/Delta watershed. For example, the values reported below for changes in water supply to the Southern California region include only the portion of supply from the SWP, which makes up about 18 percent of the total water supplied to the Southern California region, as explained in Chapter 2, *Hydrology and Water Supply*. Estimates and assumptions about changes in groundwater supplies are discussed in Section 6.5, *Changes in Groundwater Supply*. Baseline annual Sacramento/Delta supply ranges from approximately 7.3 to 14.8 MAF (Figure 6.4-1). Average annual Sacramento/Delta supply is about 12 MAF (Table 6.4-2). Generally, the wetter the conditions, the higher the water supply due largely to more water being available in wetter years and less being available in drier years. Critical year Sacramento/Delta supplies average about 69 percent of wet year supplies (Table 6.4-2).



TAF = thousand acre-feet

Figure 6.4-1. Annual Sacramento/Delta Supply

Table 6.4-2. Annual Water Year Type Average Annual Sacramento/Delta Supply for Baseline and Change from Baseline (thousand acre-feet)

Water Year Type	Baseline	35	45	55	65	75
Critical	9,305	-1,054	-1,512	-2,232	-3,149	-4,253
Dry	11,563	-596	-1,379	-2,630	-3,886	-5,375
Below normal	12,149	-384	-947	-1,937	-3,486	-5,413
Above normal	12,334	-129	-481	-1,278	-2,887	-4,749
Wet	13,394	-123	-267	-695	-1,945	-3,439
All	11,957	-428	-871	-1,682	-2,981	-4,538

Overall, as expected, Sacramento/Delta water supply decreases with increasing flow requirements. Reductions are the least in wet years and generally the greatest in critical, dry, and below normal years. In the 35 scenario, water supply reductions are lowest of the scenarios, with average reductions about 428 TAF/yr (4 percent of the Sacramento/Delta supply) and the largest reductions about 1,054 TAF/yr (11 percent of critical year Sacramento/Delta supply) in critical years. In the 45 scenario, Sacramento/Delta water supply is reduced by 871 TAF/yr (7 percent of Sacramento/Delta supply), on average. In the 55 scenario, Sacramento/Delta water supply reductions become more significant at over 1,682 TAF/yr (14 percent of Sacramento/Delta supply), on average. In the 65 scenario, average Sacramento/Delta water supply reductions are higher; results show about 1,945 TAF/yr (15 percent of wet year Sacramento/Delta supply) decrease in wet years and the largest reductions in dry years of about 3,886 TAF/yr (34 percent of dry year Sacramento/Delta supply). In the 75 scenario, average water supply reductions are about 4,538 TAF/yr (38 percent of Sacramento/Delta supply), with the largest reductions in below normal years of about 5,413 TAF/yr (45 percent of below normal Sacramento/Delta supply) (Table 6.4-2). In the higher flow scenarios, the system is operated more conservatively at times to maintain storage for cold water pool, which results in larger reductions in below normal and dry years than in critical years.

Between approximately one-third and one-half of Sacramento/Delta supplies are exported by the CVP and SWP via south Delta pumping facilities, with higher export rates in wetter years (Table 6.4-3). These supplies are subsequently delivered to the Bay Area, Central Coast, San Joaquin Valley, and Southern California regions, as discussed in greater detail in Section 2.8, *Existing Water Supply*, and in the regional summaries that follow. Reductions in export supplies are estimated to account for roughly 50 to 60 percent of overall Sacramento/Delta supply reductions, with larger proportional reductions in the higher flow scenarios.

Table 6.4-3. Water Year Type Annual Average South-of-Delta Exports for Baseline and Change from Baseline (thousand acre-feet)

Water Year Type	Baseline	35	45	55	65	75
Critical	2,890	40	-161	-561	-931	-1,427
Dry	4,570	-443	-900	-1,476	-2,117	-2,809
Below normal	5,113	-196	-639	-1,330	-2,298	-2,968
Above normal	5,436	-27	-209	-1,000	-2,241	-2,914
Wet	6,423	-23	-157	-388	-1,159	-2,284
All	5,068	-140	-420	-912	-1,686	-2,471

As discussed in Chapter 2, *Hydrology and Water Supply*, and shown in Table 6.4-1, Sacramento/Delta supply is only a portion of the water supply portfolio for each of the regions. Therefore, a reduction in Sacramento/Delta supply results in a reduction in only one of the sources of supply to users in each region. The reductions in water supply in the scenarios as a percent of the total water supply available to users in any given region is much smaller than the percent reduction in Sacramento/Delta supply. For example, the annual average reduction in Sacramento/Delta supply to the Central Coast region in the 55 scenario is 22 percent, however that reduction as a percentage of the total water supply to the Central Coast region is only 1 percent (Table 6.4-1).

The entire study area covers much of the state of California; therefore, the total effects presented in this section do not show regional effects that may be larger or smaller than presented. The next few sections break up the results into regions for a more detailed discussion.

6.4.3 Sacramento/Delta Supply to the Sacramento River Watershed

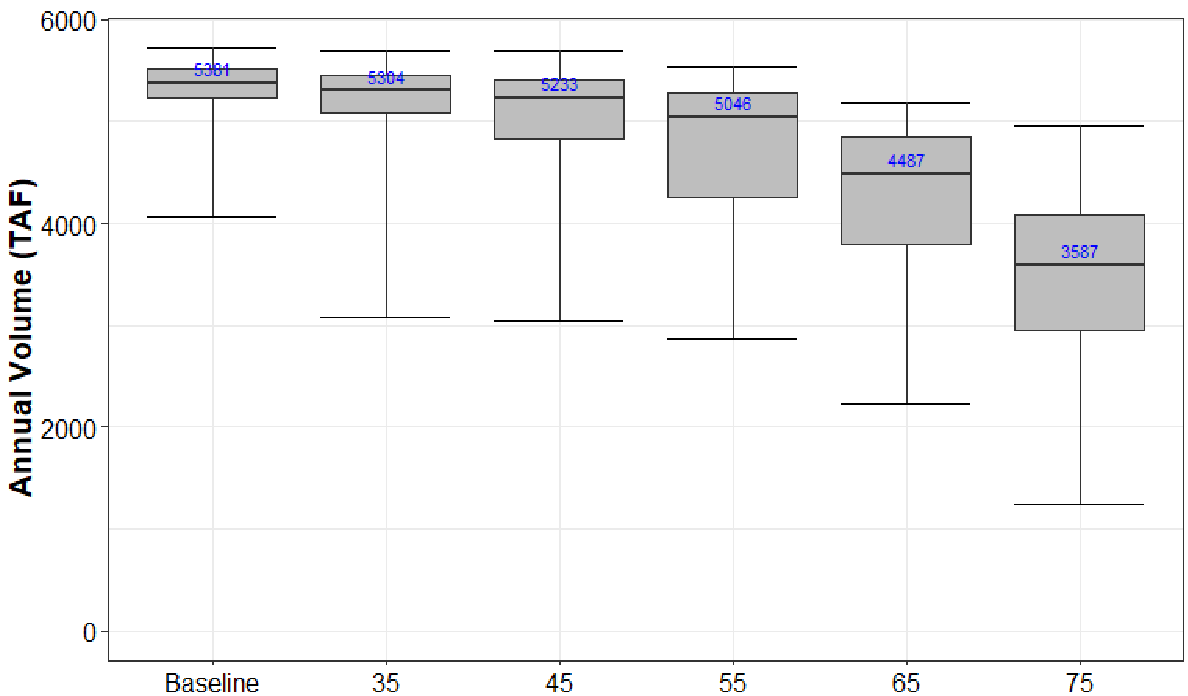
The Sacramento River watershed includes the Sacramento River and its tributaries. This region is bounded by the Sierra Nevada on the east, the Coast Ranges on the west, the Cascade and Trinity Mountains on the north, and the Bay-Delta to the south. With respect to the SacWAM domain, this includes all Water Budget Areas (WBA) except for 50, 60N, 60S, and 61N. Sacramento/Delta water supply in the Sacramento River watershed includes surface water delivered to consumptive uses in the upper watersheds and surface water delivered to agriculture, refuge, and urban uses throughout the Sacramento Valley. Sacramento/Delta water supply is primarily delivered to agriculture in the Sacramento River watershed, but municipal and industrial and refuge supplies also may be affected and therefore are discussed separately below.

SacWAM results show that in the 35, 45, and 55 scenarios, on average, there is a reduction in total annual surface supply in the Sacramento River watershed of 210 TAF, 333 TAF, and 606 TAF, respectively (Figure 6.4-2 and Table 6.4-4). In the 65 scenario, the Sacramento/Delta supply is reduced by between 522 TAF in wet years and 1,802 TAF in critical years. In the 75 scenario, Sacramento/Delta supplies are reduced by 1,842 TAF/yr on average, and the large senior uses start getting cut back regularly (Figure 6.4-2 and Table 6.4-4). A large percentage of water users in the Sacramento River watershed are CVP settlement contractors or SWP settlement contractors; as a general rule, these demands receive full supply except after other users have been severely reduced. More detail on SacWAM modeling of CVP and SWP deliveries can be found in Appendix A1, *Sacramento Water Allocation Model Methods and Results*.

Agricultural uses receive by far the most water in the Sacramento River watershed, receiving about 87 percent of the total Sacramento/Delta supply; urban uses receive about 9 percent, and refuge uses receive about 4 percent according to baseline simulations in SacWAM. Agricultural water supply is delivered by local water districts and is delivered by the CVP and SWP to senior settlement contractors in the Sacramento River watershed. In the 35 and 45 scenarios, the reductions in water supply for agriculture are less than 500 TAF in most years (Figure 6.4-3 and Table 6.4-5). In the 55 scenario, the reductions in Sacramento/Delta water supply to agriculture frequently exceed 500 TAF/yr. In the 65 scenario, the annual reductions are more than 1 MAF/yr in the below normal, dry, and critical years. In the 75 scenario, Sacramento/Delta water supply to agriculture in the Sacramento River watershed is reduced by 1,602 TAF/yr on average.

Municipal and industrial total Sacramento/Delta water supply reductions in the Sacramento River watershed are less than 75 TAF in most years in the 35 to 55 scenarios (Figure 6.4-4 and Table 6.4-6). In the 65 scenario, reductions of municipal and industrial Sacramento/Delta supplies are 83 TAF/yr on average. In the 75 scenario, reductions in Sacramento/Delta municipal and industrial water supply in the Sacramento River watershed range from 86 TAF/yr on average in wet years to 126 TAF/yr in critically dry years.

Sacramento/Delta water supplies to refuges in the Sacramento River watershed are relatively small. SacWAM results show average annual reductions in Sacramento/Delta surface supplies of 20 TAF, 25 TAF, and 43 TAF for the 35, 45, and 55 scenarios, respectively (Figure 6.4-5 and Table 6.4-7). In the higher flow scenarios, refuges start receiving less water as senior users start to get cut back more often, which results in reductions of 67 TAF/yr and 132 TAF/yr on average in the 65 and 75 scenarios, respectively.

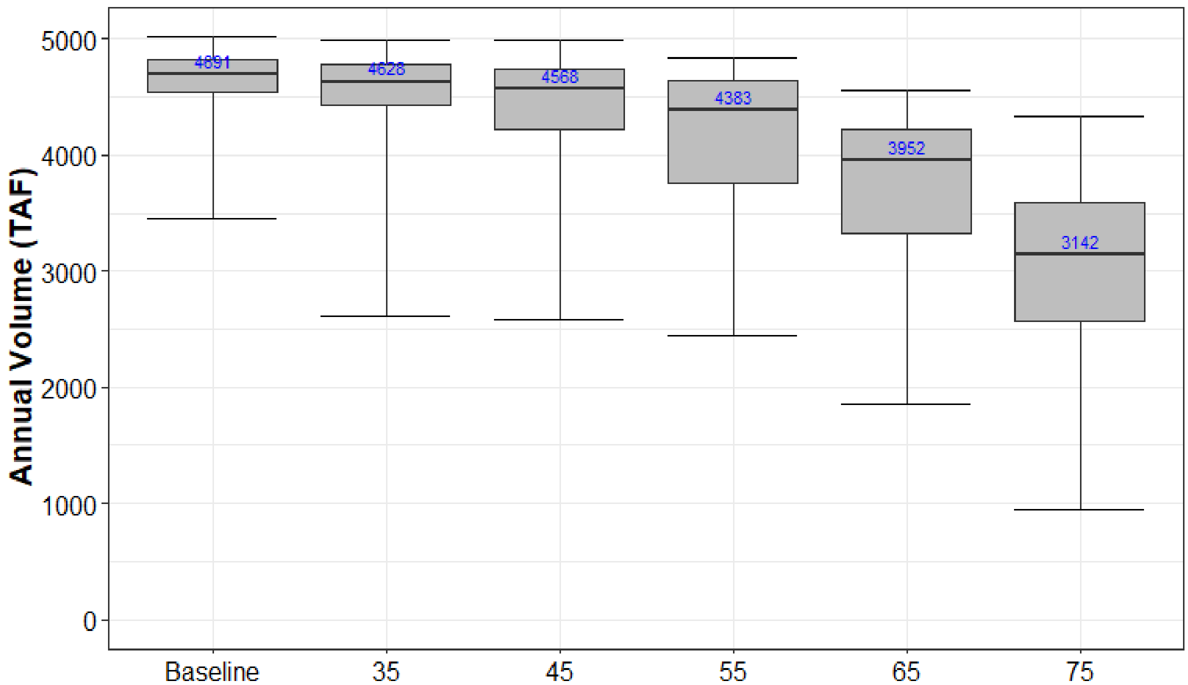


TAF = thousand acre-feet

Figure 6.4-2. Annual Total Sacramento/Delta Supply to the Sacramento River Watershed

Table 6.4-4. Annual Total Sacramento/Delta Supply to the Sacramento River Watershed Water Year Type Average: Change from Baseline (thousand acre-feet per year)

Water Year Type	Baseline	35	45	55	65	75
Critical	4,877	-879	-1,074	-1,403	-1,802	-2,472
Dry	5,335	-160	-388	-925	-1,492	-2,169
Below normal	5,439	-95	-209	-484	-1,175	-2,173
Above normal	5,422	-35	-109	-226	-668	-1,763
Wet	5,430	-32	-68	-178	-522	-1,091
All	5,320	-210	-333	-606	-1,086	-1,842

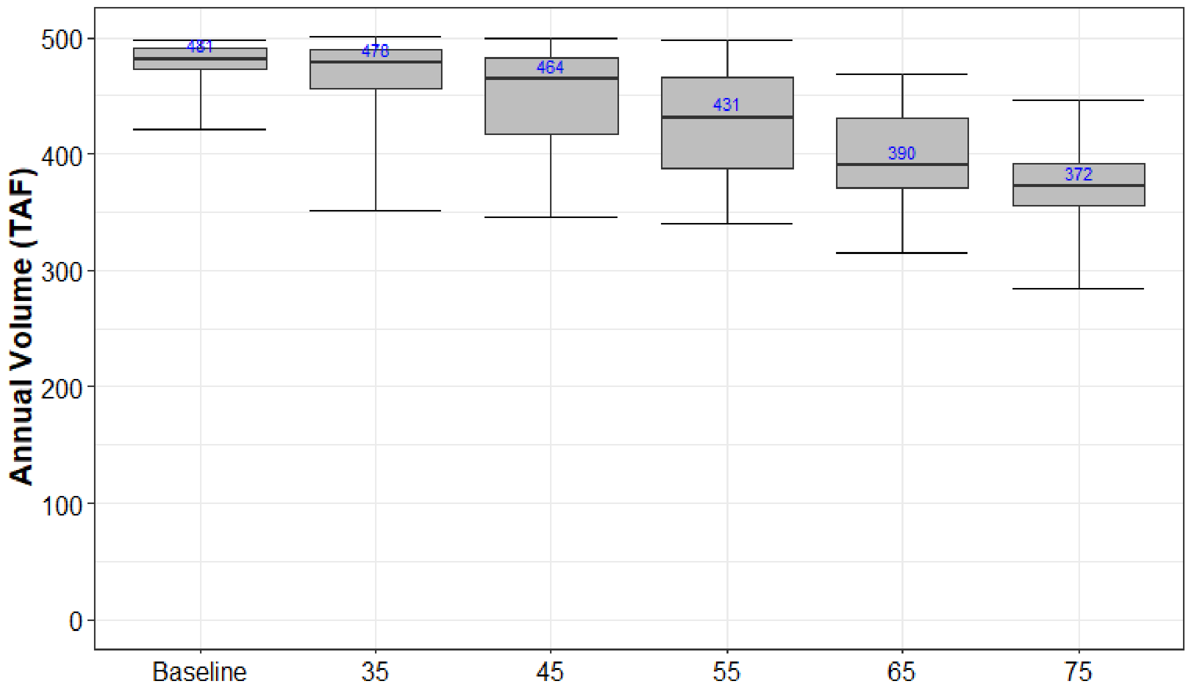


TAF = thousand acre-feet

Figure 6.4-3. Annual Sacramento/Delta Supply to Agriculture in the Sacramento River Watershed

Table 6.4-5. Annual Sacramento/Delta Supply to Agriculture in the Sacramento River Watershed Water Year Type Average: Change from Baseline (thousand acre-feet per year)

Water Year Type	Baseline	35	45	55	65	75
Critical	4,226	-743	-918	-1,208	-1,561	-2,177
Dry	4,660	-126	-313	-778	-1,288	-1,898
Below normal	4,756	-80	-173	-397	-1,011	-1,908
Above normal	4,735	-21	-84	-166	-547	-1,517
Wet	4,739	-28	-59	-153	-460	-922
All	4,641	-174	-279	-511	-937	-1,602

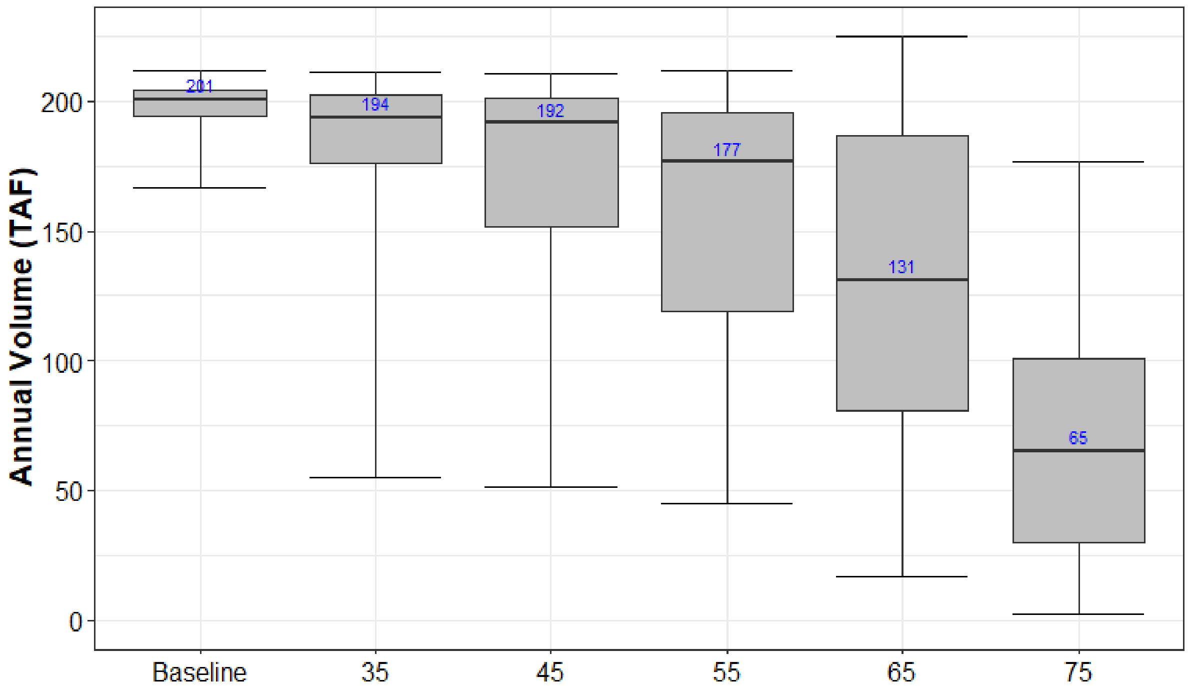


TAF = thousand acre-feet

Figure 6.4-4. Annual Sacramento/Delta Supply to Municipal and Industrial Use in the Sacramento River Watershed

Table 6.4-6. Annual Sacramento/Delta Supply to Municipal and Industrial Use in the Sacramento River Watershed Water Year Type Average: Change from Baseline (thousand acre-feet per year)

Water Year Type	Baseline	35	45	55	65	75
Critical	456	-59	-76	-88	-116	-126
Dry	473	-18	-46	-80	-104	-115
Below normal	482	-5	-21	-55	-92	-114
Above normal	487	-4	-12	-35	-70	-110
Wet	492	-1	-5	-18	-50	-86
All	480	-15	-29	-52	-83	-107



TAF = thousand acre-feet

Figure 6.4-5. Annual Sacramento/Delta Supply to Wildlife Refuges in the Sacramento River Watershed

Table 6.4-7. Annual Sacramento/Delta Supply to Wildlife Refuges in the Sacramento River Watershed Water Year Type Average: Change from Baseline (thousand acre-feet per year)

Water Year Type	Baseline	35	45	55	65	75
Critical	194	-77	-80	-107	-126	-169
Dry	201	-16	-29	-66	-100	-156
Below normal	201	-10	-16	-31	-72	-151
Above normal	199	-10	-13	-24	-51	-136
Wet	199	-3	-4	-7	-13	-82
All	199	-20	-25	-43	-67	-132

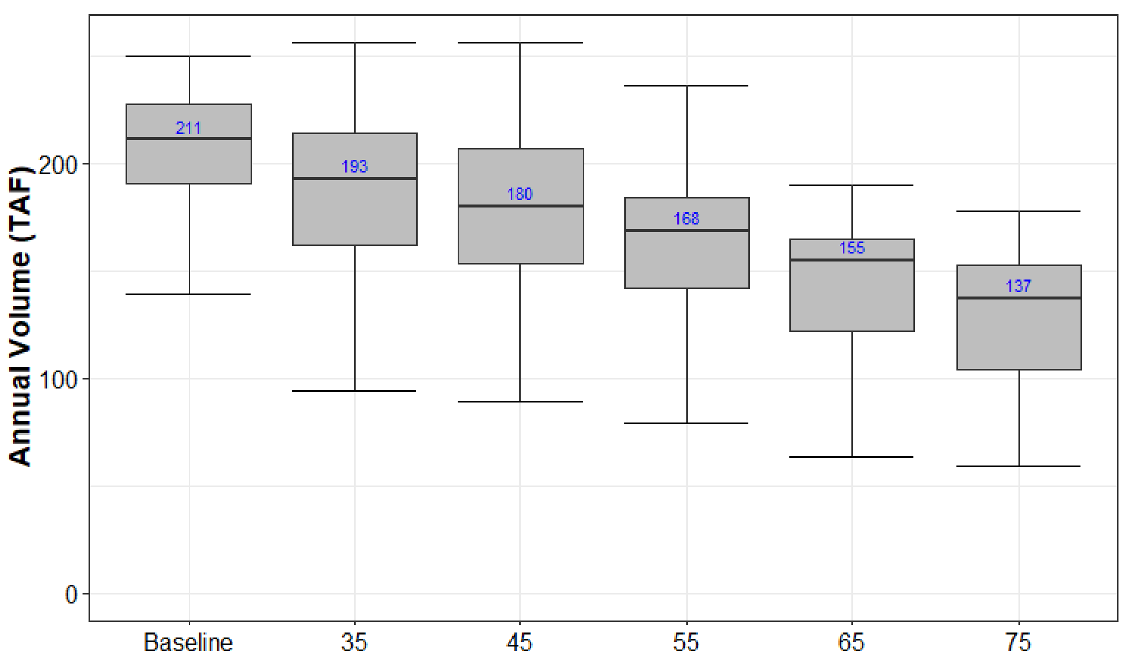
6.4.4 Sacramento/Delta Supply to the Delta Eastside Tributaries

The Delta eastside tributaries region includes the watersheds of the Cosumnes, Mokelumne, and Calaveras Rivers from the headwaters to the egal Delta boundary. With respect to the SacWAM domain, this includes WBAs 60N and 60S.

Baseline SacWAM results show that about 60 percent of the Sacramento/Delta supply used in the Delta eastside tributaries region is for agricultural use and the remaining 40 percent is for municipal and industrial use (Table 6.4-1 and Table 2.8-5 in Chapter 2, *Hydrology and Water Supply*). As shown in Table 2.8-5 and discussed in Section 6.4.1, *Total Water Supply*, the Delta eastside tributaries region relies heavily on groundwater (on average 83 percent). SacWAM simulations assumed no changes to groundwater pumping or supply; therefore, this section addresses the surface water supply to this region.

As discussed in Chapter 2, the existing condition flows on the Calaveras and Mokelumne Rivers are much less than unimpaired conditions, while the other Delta eastside tributary (the Cosumnes River) is quite close to unimpaired. Because the Calaveras and Mokelumne Rivers are so impaired under existing conditions, the unimpaired flow requirements result in large increases in streamflow, which in turn, results in relatively large decreases in water supply (also see Section 6.4.6, *Sacramento/Delta Supply to San Francisco Bay Area*, for further water supply effects of changes in flow on the Mokelumne River). SacWAM results show that in the flow scenarios, on average, there is a reduction in total annual Sacramento/Delta surface water supply in the Delta eastside tributaries region (Figure 6.4-6 and Table 6.4-8). In the 35, 45, and 55 scenarios, the annual average reduction is 20 TAF, 28 TAF, and 44 TAF, respectively. In the 65 scenario, the reductions in supply range from 58 TAF/yr average in wet years to 75 TAF/yr in critical years. As expected, the 75 scenario results show the largest reduction in Sacramento/Delta surface water supply that ranges from an average of 71 TAF/yr in wet years to an average of 83 TAF/yr in above normal years. The reductions in Sacramento/Delta supply for the 35 to 55 scenarios are 4 percent or less of the total water supplied to the Delta eastside tributaries region as estimated by historical water deliveries data (see Section 2.8, *Existing Water Supply*). In the 65 and 75 scenarios, Sacramento/Delta supply is reduced by 6 percent and 8 percent of the total water supply, respectively. (See Table 6.4-1.)

Diversions from the Calaveras and Mokelumne Rivers require larger changes from existing conditions to meet new instream flow requirements than diversions from the Cosumnes River, because the Cosumnes River is less impaired by development than the other Delta eastside tributaries, as discussed in Chapter 2.



TAF = thousand acre-feet

Figure 6.4-6. Annual Sacramento/Delta Supply to the Delta Eastside Tributaries Region

Table 6.4-8. Annual Sacramento/Delta Supply to the Delta Eastside Tributaries Region Water Year Type Average: Change from Baseline (thousand acre-feet)

Water Year Type	Baseline	35	45	55	65	75
Critical	158	-37	-43	-53	-75	-82
Dry	194	-29	-38	-48	-63	-81
Below normal	212	-20	-30	-47	-62	-79
Above normal	221	-17	-27	-46	-65	-83
Wet	228	-6	-11	-33	-58	-71
All	205	-20	-28	-44	-63	-78

Methods described in Appendix A1a, *Methods for Estimating Regional Sacramento/Delta Surface Water Supply for Agricultural and Municipal Use*, were applied to estimate changes in Sacramento/Delta supply for agricultural and municipal uses in the Delta eastside tributaries region for the flow scenarios based on SacWAM results. Table 6.4-9 presents the baseline use of Sacramento/Delta supply and changes for agriculture under the scenarios. Table 6.4-10 presents similar information for municipal and industrial use. On average, under the 55 scenario, agricultural use of surface water supply would decrease by 23 percent and municipal and industrial use, by 18 percent.

Table 6.4-9. Annual Sacramento/Delta Supply to Agriculture in the Delta Eastside Tributaries Region Water Year Type Average: Change from Baseline (thousand acre-feet per year)

Water Year Type	Baseline	35	45	55	65	75
Critical	78	-12	-14	-22	-41	-45
Dry	112	-19	-21	-26	-35	-49
Below normal	129	-16	-22	-31	-38	-50
Above normal	140	-15	-23	-36	-45	-56
Wet	148	-5	-9	-29	-46	-52
All	124	-13	-17	-29	-41	-50

Table 6.4-10. Annual Sacramento/Delta Supply to Municipal and Industrial Use in the Delta Eastside Tributaries Region Water Year Type Average: Change from Baseline (thousand acre-feet per year)

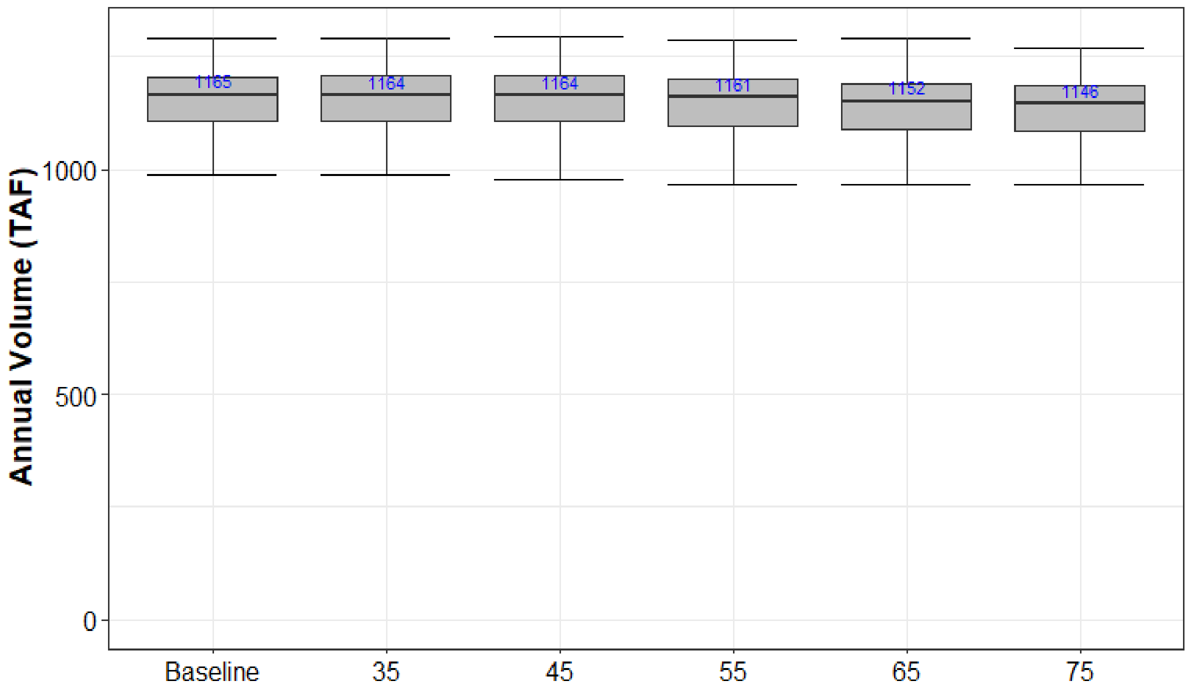
Water Year Type	Baseline	35	45	55	65	75
Critical	80	-25	-29	-31	-34	-37
Dry	82	-10	-17	-22	-28	-33
Below normal	82	-3	-8	-16	-24	-29
Above normal	81	-2	-4	-10	-20	-27
Wet	80	-1	-2	-4	-12	-19
All	81	-7	-11	-15	-22	-28

6.4.5 Sacramento/Delta Supply to the Delta

The Delta includes the tidal portions of the Sacramento, San Joaquin, and Mokelumne Rivers and communities within the Legal Delta. Water supply in this region is used primarily for agricultural uses on Delta islands (modeled as Delta depletions); CVP deliveries to the City of Tracy, Banta-Carbona Irrigation District, Byron-Bethany Irrigation District, and Westside Irrigation District; and the City of Antioch in the western Delta. With respect to the SacWAM domain, this includes WBA 50, portions of CVP Upper Delta-Mendota Canal demands, and the demand unit for the City of Antioch.

The Sacramento/Delta water delivered to the Delta region does not significantly change in the SacWAM scenarios (Figure 6.4-7 and Table 6.4-11). As explained in Chapter 5, *Proposed Changes to the Bay-Delta Plan for the Sacramento/Delta*, reduced Delta diversions may occur as a result of the proposed Plan amendments, but significant reductions are not modeled explicitly in the SacWAM scenarios due to the uncertainty in observed Delta depletions and how depletions may change if diversions were curtailed. SacWAM results show as the flow requirements increase from 35 to 75 percent unimpaired flow, the availability of water for diversion is reduced throughout the watershed. Therefore, it is likely that the frequency of insufficient natural and abandoned flows to meet Delta and other riparian diversions would increase. To the degree that such shortages occur, they would be represented in this analysis as a share of total agricultural water supply (Table 6.4-1) and overall cumulative changes in water supply. If Delta water supply is reduced to help meet outflow requirements, there would be an increase in SWP and CVP reservoir storage or an increase in water supply to other regions.

In the baseline scenario, Sacramento/Delta water supply for consumptive use is higher in the critical years (1.2 MAF) than in the wet years (1.1 MAF). The flow scenarios show the same trend (because they are nearly identical to baseline), which is caused by higher natural accretions in the wet years that offsets the need for supply, causing lower depletions. The SacWAM results for the 35 to 55 scenarios show a 1 percent or less reduction in Sacramento/Delta supply when compared with the total supply estimated using historical water deliveries data (see Section 2.8, *Existing Water Supply*). The Sacramento/Delta supply in the75 scenario is reduced by about 2 percent of the total water supplied to this region. The rare reductions in Sacramento/Delta supplies occur in a few months in the simulation when water is very scarce, such as during summer 1977.



TAF = thousand acre-feet

Figure 6.4-7. Annual Sacramento/Delta Supply to the Delta Region

Table 6.4-11. Annual Sacramento/Delta Supply to the Delta Region Water Year Type Average: Change from Baseline (thousand acre-feet per year)

Water Year Type	Baseline	35	45	55	65	75
Critical	1,199	0	-2	-6	-11	-13
Dry	1,181	1	-1	-8	-16	-25
Below normal	1,171	0	0	-6	-13	-29
Above normal	1,129	0	0	-2	-11	-22
Wet	1,111	-1	-1	-1	-17	-14
All	1,154	0	-1	-4	-14	-20

Methods described in Appendix A1a, *Methods for Estimating Regional Sacramento/Delta Surface Water Supply for Agricultural and Municipal Use*, were applied to estimate changes in Sacramento/Delta supply for agricultural and municipal uses in the Delta for the flow scenarios based on SacWAM results. Table 6.4-12 presents the baseline use and changes for agriculture. Table 6.4-13 presents similar information for municipal and industrial use. For both categories of use, the flow scenarios result in very small (<1 percent) reduction in the 55 scenario.

Table 6.4-12. Annual Sacramento/Delta Supply to Agriculture in the Delta Region Water Year Type Average: Change from Baseline (thousand acre-feet per year)

Water Year Type	Baseline	35	45	55	65	75
Critical	1,189	1	-2	-5	-9	-11
Dry	1,166	1	-1	-6	-12	-20
Below normal	1,153	-1	-1	-5	-9	-23
Above normal	1,108	0	-1	-2	-11	-16
Wet	1,086	0	-1	-1	-16	-10
All	1,136	0	-1	-4	-12	-16

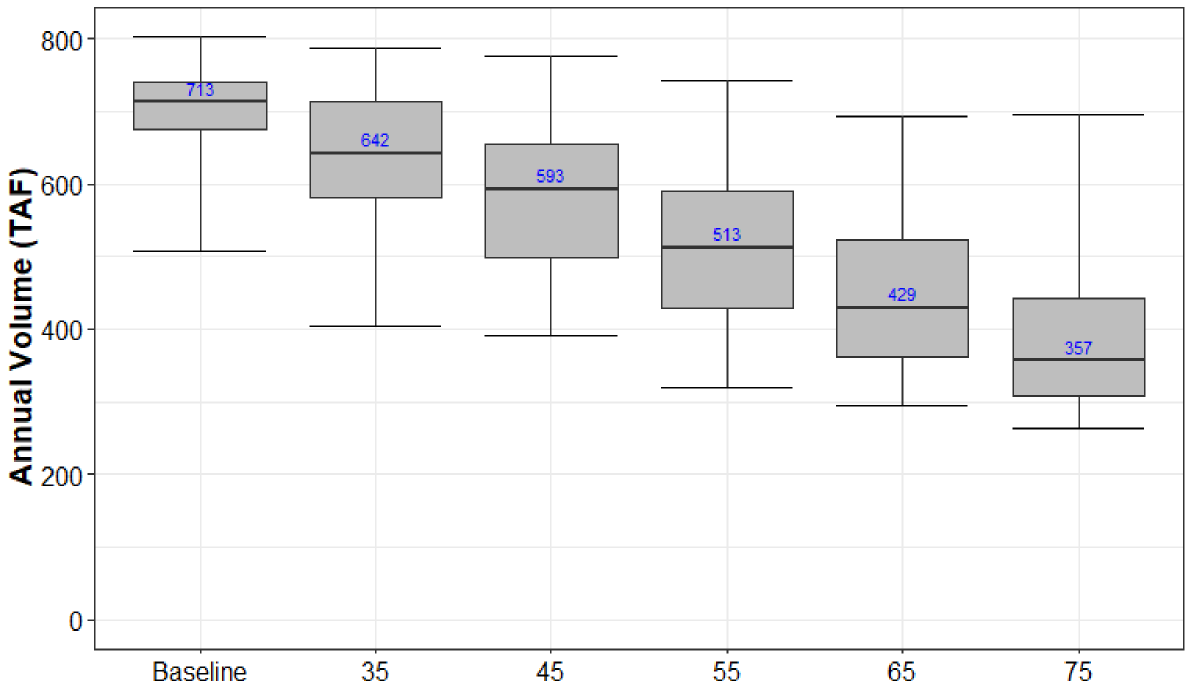
Table 6.4-13. Annual Sacramento/Delta Supply to Municipal and Industrial Use in the Delta Region Water Year Type Average: Change from Baseline (thousand acre-feet per year)

Water Year Type	Baseline	35	45	55	65	75
Critical	10	0	0	-1	-2	-2
Dry	15	1	0	-2	-3	-5
Below normal	18	0	1	-1	-4	-7
Above normal	20	0	1	1	0	-6
Wet	25	0	0	0	-1	-4
All	18	0	0	-1	-2	-4

6.4.6 Sacramento/Delta Supply to the San Francisco Bay Area

The Bay Area region includes communities that receive Sacramento/Delta supply via the Putah South Canal, North Bay Aqueduct, Contra Costa Canal, Mokelumne Aqueduct, and South Bay Aqueduct, and diversions from the western Delta to Antioch and CCWD. These communities include the North Bay (Fairfield, Suisun City, Travis Air Force Base, Napa, Benicia, Vallejo), East Bay (CCWD and EBMUD), and South Bay (portions of Santa Clara Valley Water District [Valley Water], Zone 7 Water District [Zone 7], and Alameda County Water District). Water supplies to the Bay Area from other sources outside the Sacramento River watershed, Delta eastside tributaries, and Delta regions (e.g., San Francisco Public Utilities Commission service areas from the Hetch Hetchy Project) are not included in these results because they will not be affected by the proposed Plan amendments. The vast majority of water supply to the Bay Area region goes to municipal and industrial demands, although one agricultural demand unit corresponding to a portion of Solano Irrigation District near Fairfield is included in the Bay Area region. Zone 7 also provides water for agricultural irrigation.

Baseline annual Sacramento/Delta supply to uses within the Bay Area ranges from about 500 TAF to about 800 TAF, with average water delivery of almost 700 TAF (Figure 6.4-8 and Table 6.4-14). Generally, the wetter the conditions, the higher the water delivered due largely to more water being available in wetter years and less being available in drier years.



TAF = thousand acre-feet

Figure 6.4-8. Annual Sacramento/Delta Supply to the San Francisco Bay Area Region

Table 6.4-14. Annual Sacramento/Delta Supply to the San Francisco Bay Area Region Water Year Type Average: Change from Baseline (thousand acre-feet)

Water Year Type	Baseline	35	45	55	65	75
Critical	597	-104	-151	-197	-260	-295
Dry	682	-99	-165	-236	-306	-357
Below normal	709	-72	-133	-209	-294	-362
Above normal	707	-42	-91	-170	-256	-324
Wet	752	-27	-56	-116	-191	-266
All	698	-66	-115	-180	-255	-316

Overall, as expected, less Sacramento/Delta water supply is available with increasing flow requirements. Changes in Sacramento/Delta water supply are the least in wet years and generally the greatest in critical, dry, and below normal years. In the 35 scenario, Sacramento/Delta supply to the Bay Area region is reduced by 66 TAF on average, with the largest reductions about 104 TAF in critical years. In the 45 scenario, water supply reductions are 115 TAF on average, with the largest reductions of 165 TAF in dry years. In the 55 scenario, water supply is reduced by about 180 TAF on average, with the largest reductions of 236 TAF in dry years. In the 65 scenario, average Sacramento/Delta supplies are reduced by 255 TAF, with the largest reductions in dry years of 306 TAF from baseline. In the 75 scenario, average annual supply is reduced by 316 TAF, with reductions of about 362 TAF in below normal years compared with below normal years in the baseline scenario. The reductions in Sacramento/Delta supply to the Bay Area are 14 percent or less of the total supply estimated using historical water deliveries data (see Section 2.8, *Existing Water*

Supply) in the 35 to 55 scenarios, while reductions are 20 percent and 25 percent in the 65 and 75 scenarios, respectively (as shown in Table 6.4-1).

Reductions in deliveries are not uniform across the various source tributaries, and some water users would be affected more significantly by reduced Sacramento/Delta supplies. For example, in the 55 scenario, estimated annual average supply reductions from the Mokelumne Aqueduct are 95 TAF (45 percent), 4 TAF (8 percent) through the North Bay Aqueduct, 33 TAF (62 percent) through Putah South Canal, and 39 TAF (28 percent) through the South Bay Aqueduct, with no reduction expected through the Contra Costa Canal. The larger reductions in the Mokelumne Aqueduct and Putah South Canal are caused by the larger increases in instream flow required on Putah Creek and the Mokelumne River to meet the modeled flow requirements. Further discussion of specific communities can be found in Section 7.20, *Utilities and Service Systems.*

Methods described in A1a, *Methods for Estimating Regional Sacramento/Delta Surface Water Supply for Agricultural and Municipal Use*, were applied to estimate changes in Sacramento/Delta supply for agricultural and municipal uses in the Bay Area region for the flow scenarios based on SacWAM results. Table 6.4-15 presents the baseline use and changes for agriculture. Although the delivery volume to agriculture is small relative to municipal and industrial use, the reduction is over half (52 percent) in the 55 scenario. Table 6.4-16 presents baseline and flow scenario changes for municipal and industrial use. On average, the reduction in supply is approximately 25 percent in the 55 scenario.

Table 6.4-15. Annual Sacramento/Delta Supply to Agriculture in the San Francisco Bay Area Region Water Year Type Average: Change from Baseline (thousand acre-feet per year)

Water Year Type	Baseline	35	45	55	65	75
Critical	23	-9	-13	-14	-18	-21
Dry	27	-9	-13	-16	-20	-23
Below normal	28	-9	-13	-16	-20	-23
Above normal	28	-5	-10	-14	-19	-22
Wet	29	-2	-3	-12	-13	-18
All	27	-6	-10	-14	-17	-21

Table 6.4-16. Annual Sacramento/Delta Supply to Municipal and Industrial Use in the San Francisco Bay Area Region Water Year Type Average: Change from Baseline (thousand acre-feet per year)

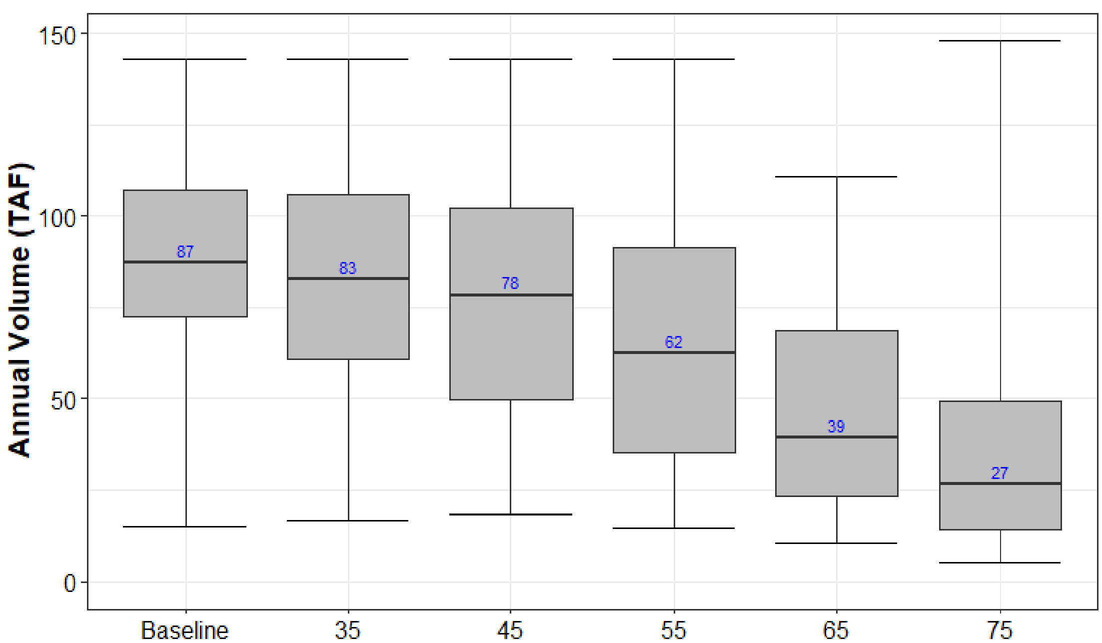
Water Year Type	Baseline	35	45	55	65	75
Critical	573	-95	-138	-183	-242	-274
Dry	655	-90	-152	-220	-286	-334
Below normal	680	-63	-120	-193	-273	-338
Above normal	680	-37	-82	-155	-237	-301
Wet	723	-25	-53	-104	-178	-248
All	670	-60	-105	-166	-238	-295

6.4.7 Sacramento/Delta Supply to Central Coast

The Sacramento/Delta water supplied to the Central Coast region discussed in this section represents a relatively small amount of Sacramento/Delta water that includes SWP and CVP deliveries for agriculture and urban uses. As discussed in Chapter 2, *Hydrology and Water Supply*, about 21 percent of the total supplies to the Central Coast region are for municipal and industrial uses and the remaining 79 percent is for agricultural uses, based on historical water deliveries data. Baseline Sacramento/Delta supply is about 6 percent of the total water supplied to the Central Coast region as estimated by SacWAM and historical water deliveries data (see Section 2.8, *Existing Water Supply*). Baseline Sacramento/Delta supplies to this region vary greatly by year type; supplies in a critical year are on average nearly half of what they are in a wet year on average.

SacWAM results show an increased annual variability in Sacramento/Delta supplies to the Central Coast region and large decreases in supply, especially in the higher flow scenarios (Figure 6.4-9 and Table 6.4-17). In the 35 scenario, there are no reductions in critical years ranging to a reduction of 7 TAF in a dry year compared with baseline. The reductions in supplies gradually increase as the flow increases to the 75 scenario, where supplies are substantially reduced. In the 75 scenario, annual average Sacramento/Delta supplies are reduced by 49 TAF. Because Sacramento/Delta supply is such a small portion of the total supply to the Central Coast region, flow requirements result in relatively small changes in the total supply. Total water supplies to the Central Coast region are reduced by less than 0.5 percent, 1 percent, and 4 percent for the 35, 55, and 75 scenarios, respectively.

Water supplies to this region from the SWP and CVP are reduced roughly equally, with slightly higher reductions to CVP contractors than SWP contractors. More details on changes to SWP and CVP deliveries can be found in Appendix A1, *Sacramento Water Allocation Model Methods and Results*.



TAF = thousand acre-feet

Figure 6.4-9. Annual Sacramento/Delta Supply to the Central Coast Region

Table 6.4-17. Annual Sacramento/Delta Supply to the Central Coast Region Water Year Type Average: Change from Baseline (thousand acre-feet)

Water Year Type	Baseline	35	45	55	65	75
Critical	40	0	-6	-13	-22	-30
Dry	76	-7	-17	-33	-47	-57
Below normal	85	-3	-12	-27	-44	-57
Above normal	90	-1	-5	-18	-43	-57
Wet	116	-1	-1	-6	-32	-44
All	86	-2	-8	-19	-37	-49

Methods described in Appendix A1a, *Methods for Estimating Regional Sacramento/Delta Surface Water Supply for Agricultural and Municipal Use*, were applied to estimate changes in Sacramento/Delta supply for agricultural and municipal uses in the Central Coast region for the flow scenarios based on SacWAM results. Table 6.4-18 presents the baseline use and changes for agriculture. The reduction in volume delivery, nearly all to the San Felipe Unit, is about 20 percent in the 55 scenario. Table 6.4-19 presents baseline and flow scenario changes for municipal and industrial use. On average, the reduction in supply is approximately 24 percent in the 55 scenario.

Table 6.4-18. Annual Sacramento/Delta Supply to Agriculture in the Central Coast Region Water Year Type Average: Change from Baseline (thousand acre-feet per year)

Water Year Type	Baseline	35	45	55	65	75
Critical	18	0	-3	-8	-13	-17
Dry	32	-1	-5	-13	-22	-27
Below normal	35	0	-2	-9	-19	-27
Above normal	37	-1	-1	-5	-19	-28
Wet	52	0	-1	-2	-23	-22
All	37	-1	-2	-7	-20	-24

Table 6.4-19. Annual Sacramento/Delta Supply to Municipal and Industrial Use in the Central Coast Region Water Year Type Average: Change from Baseline (thousand acre-feet per year)

Water Year Type	Baseline	35	45	55	65	75
Critical	22	-1	-3	-6	-9	-13
Dry	44	-5	-13	-20	-25	-30
Below normal	50	-3	-10	-18	-25	-30
Above normal	53	0	-4	-13	-24	-28
Wet	65	0	0	-4	-8	-22
All	49	-2	-6	-12	-17	-25

6.4.8 Sacramento/Delta Supply to the San Joaquin Valley

The San Joaquin Valley region includes the watershed of the San Joaquin River upstream of the Delta and the Tulare Lake Basin. With respect to the SacWAM domain, this includes WBA 61N and the primarily agricultural demands served by CVP and SWP deliveries to the San Joaquin Valley and Tulare Lake. WBA 61N is defined by the Stanislaus River to the south, and the boundaries of Oakdale Irrigation District and South San Joaquin Irrigation District to the north. Supplies to WBA 61N demands are from the Lower San Joaquin River and its tributaries, and are unchanged in the modeled scenarios. As with other regions that receive some of their supply as exports from the Delta, the only portion of the supply that is analyzed here is the portion that was exported from the Delta. The San Joaquin Valley, as discussed in Chapter 2, *Hydrology and Water Supply*, has many local supplies and relies heavily on groundwater. SWP and CVP supplies from the Delta to the San Joaquin Valley region are mainly for agriculture (86 percent) with some for urban supplies (4 percent) and the rest for refuges (10 percent). Because the urban and refuge supplies make up nearly 15 percent of all the Sacramento/Delta supply, results are presented by uses separately for this region.

Baseline SacWAM results show that Sacramento/Delta SWP and CVP deliveries to the San Joaquin Valley region have high variability based on available supply. In critical years, the average annual baseline supply is about half of the average wet year supply (Figure 6.4-10 and Table 6.4-20). The same annual variability observed in the baseline results are present throughout the scenarios, with a slight increase in variability in the 65 and 75 scenarios shown by the interquartile range or “box” sizes in Figure 6.4-10.

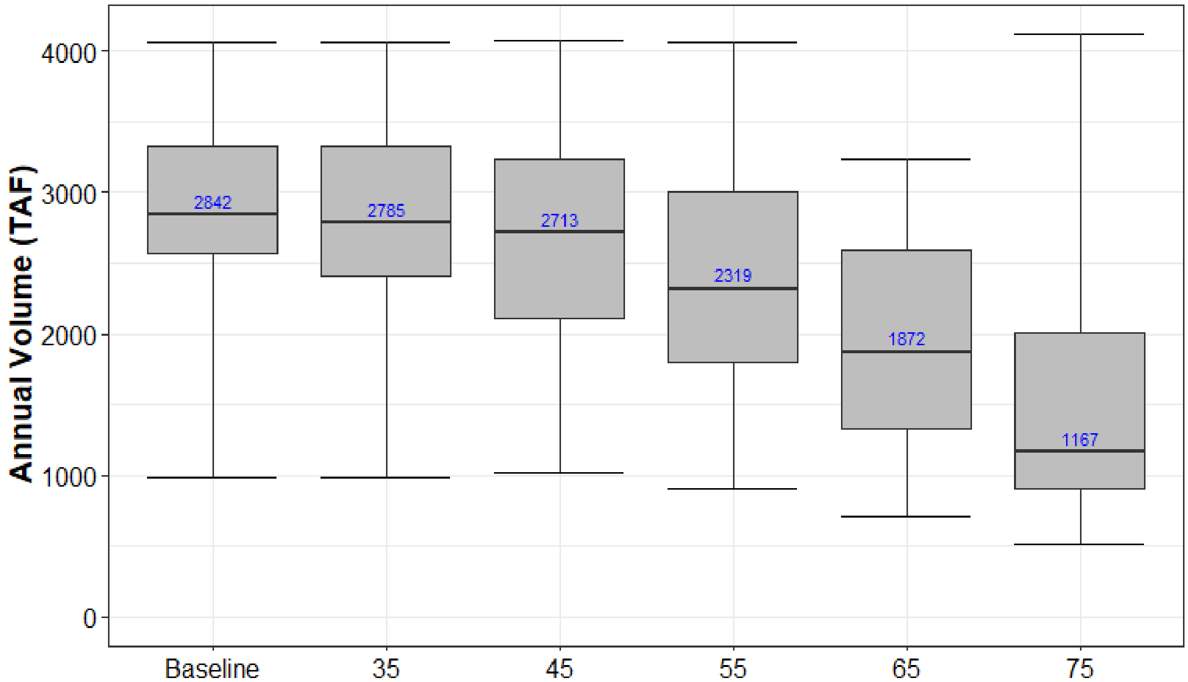
The annual Sacramento/Delta supply to the San Joaquin Valley region is reduced as the flow requirements increase (Figure 6.4-10 and Table 6.4-20). In the 35 and 45 scenarios, the annual average reductions are 38 TAF and 146 TAF, respectively. In the 55 scenario, there are larger reductions that range on average from 96 TAF in wet years to 707 TAF in dry years. Sacramento/Delta supply is not reduced as much in critical years as below normal years in the higher flow scenarios because the baseline Sacramento/Delta supply is already much reduced in these years. In the 65 scenario, reductions in Sacramento/Delta supply range on average from 682 TAF in critical years to 1,125 TAF in dry years. In the 75 scenario, the average reduction in Sacramento/Delta supply is 1,315 TAF/yr on average. While the reductions in supply amount to a significant amount of water, when compared with the total San Joaquin Valley region supply of over 18 MAF as estimated using historical water deliveries data (see Section 2.8, *Existing Water Supply*), the reductions are much smaller. The reductions in total supply amount to less than 0.5 percent, 2 percent, and 7 percent in the 35, 55, and 75 scenarios, respectively, as shown in Table 6.4-1. Agricultural and urban Sacramento/Delta supplies to the San Joaquin Valley region are reduced fairly equally in each of the scenarios; however, wildlife refuge supplies are not reduced as much (Figure 6.4-11 to Figure 6.4-13 and Table 6.4-21 to Table 6.4-23). Agricultural and urban supplies are reduced similarly to the total Sacramento/Delta supply to the San Joaquin Valley region described above. Refuge supplies were assumed to have a higher priority (same as CVP exchange contractors) and therefore show smaller reductions in the 35 through 55 scenarios except in critical years (Figure 6.4-13). In the 65 scenario, Sacramento/Delta supply to even the most senior users in the San Joaquin Valley region (such as the refuges) start to receive large reductions (23 TAF on average). In the 75 scenario, the reductions to Sacramento/Delta refuge supplies are even larger and range from 38 TAF on average in wet years to over 76 TAF on average in dry years.

SWP and CVP contractors have different contractual provisions governing their water supply deliveries. This can occur both among contractors with the same agency (SWP or CVP) and between contractors for the two different agencies, including under varying hydrologic conditions. Building the SWP and CVP facilities required the agencies managing those projects to enter into settlement or exchange contracts with senior water right holders who would otherwise be impaired by the construction of dams and reservoirs upstream. For example, Reclamation was able to build the Friant Division, which diverts the entire headwaters of the San Joaquin River in most water years, by contracting with senior water right holders downstream to provide CVP Delta water supplies via the Delta-Mendota Canal in exchange for the foregone San Joaquin River water. In doing so, Reclamation, like DWR, negotiated to provide levels of water supplies under those contracts that have not been independently verified as consistent with the scope of the historical rights. In addition, if the exchange contractors do not receive the full amount of their negotiated water supplies, they retain the right to call on the CVP Friant Division to release water to make up the difference. Similarly, settlement contractors on the Sacramento River have maintained they can default to their historical rights.

In addition to settlement and exchange contracts, DWR and Reclamation contracted with other water agencies and entities for SWP and CVP water supplies. Generally speaking, SWP contractors are allocated an acre-foot amount of maximum water supply in Table A of their individual contracts (excluding surplus water) and receive a yearly allocation based on multiplying the "Table A amount" by the percent of water available. In contrast, CVP contractors are allocated water in different tiers and priorities with contractual terms dictating the percentage of reduction based on multiple factors, including the type of use and when the contract was negotiated (e.g., the contractual allocation to Westlands Water District is larger than many other CVP contractors, but the contract is one of the first to be shorted in times of scarcity).

Because water is supplied to users in the San Joaquin Valley region under a variety of SWP and CVP contracts, the effects of the new flow requirements may be dissimilar. For example, the CVP delivers water to south-of-Delta water service contractors on the west side of the valley and also provides water under exchange contracts to users on the east side of the valley. The terms of the south-of-Delta agricultural water service contracts allow for a minimum supply of 0 precent, resulting in no supply in drier years, whereas exchange contracts allow for a minimum allocation of 77 percent.[6] Therefore the effects of the new instream flow requirements are not uniform across the San Joaquin Valley region. Additionally, more frequent "calls on Friant" may occur by exchange contractors if the CVP supply from the Delta is reduced. In this circumstance, the exchange contractors would get water from Millerton Lake (the reservoir impounded by Friant Dam) and supplies to Friant contractors in the south side of the San Joaquin Valley would be reduced. This would not change the results presented in this chapter, other than possibly an increase in seepage loss, because both the Friant contractors and the exchange contractors are within the San Joaquin Valley region. In Section 7.4, *Agriculture and Forest Resources*, there is a more detailed discussion and analysis regarding increased shortages to exchange contractors and the resulting impact on Friant contractors.

[6] In SacWAM, minimum allocations were allowed to drop below contract minimums. For more details on modeling assumptions, see Appendix A1, *Sacramento Water Allocation Model Methods and Results*.

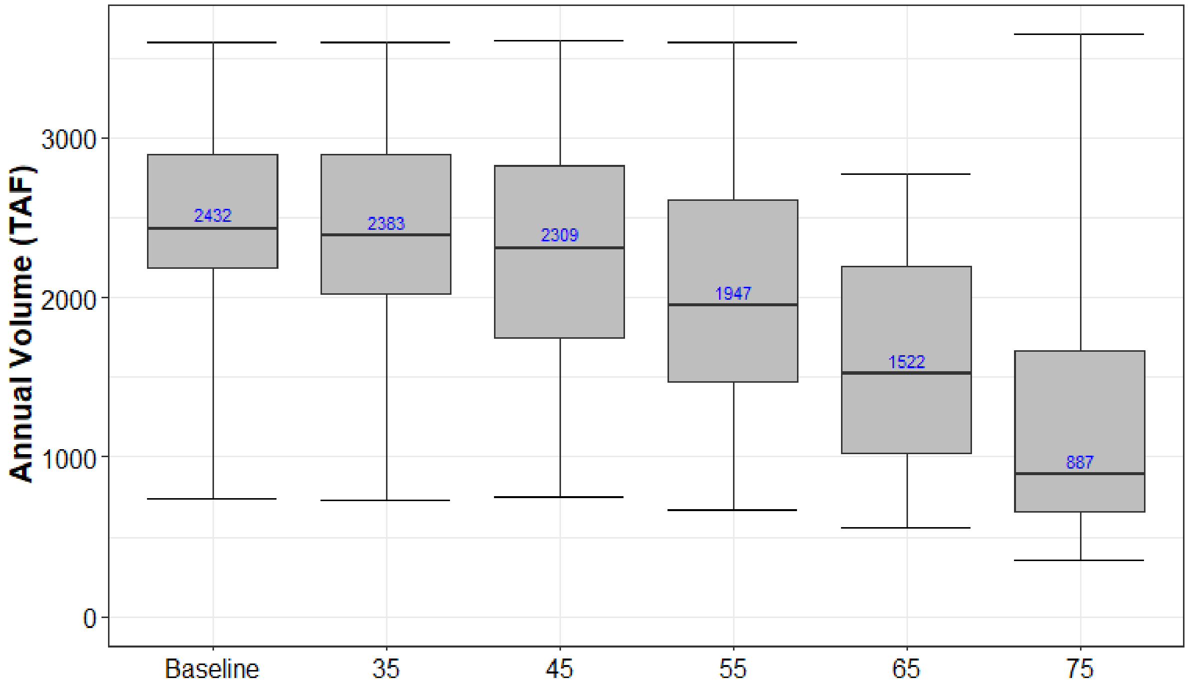


TAF = thousand acre-feet

Figure 6.4-10. Annual Sacramento/Delta Supply to the San Joaquin Valley Region

Table 6.4-20. Annual Sacramento/Delta Supply to the San Joaquin Valley Region Water Year Type Average: Change from Baseline (thousand acre-feet)

Water Year Type	Baseline	35	45	55	65	75
Critical	1,713	-5	-142	-383	-682	-945
Dry	2,630	-116	-326	-707	-1,125	-1,653
Below normal	2,810	-44	-180	-510	-972	-1,585
Above normal	2,940	3	-74	-277	-918	-1,422
Wet	3,507	-11	-22	-96	-691	-1,051
All	2,819	-38	-146	-379	-868	-1,315

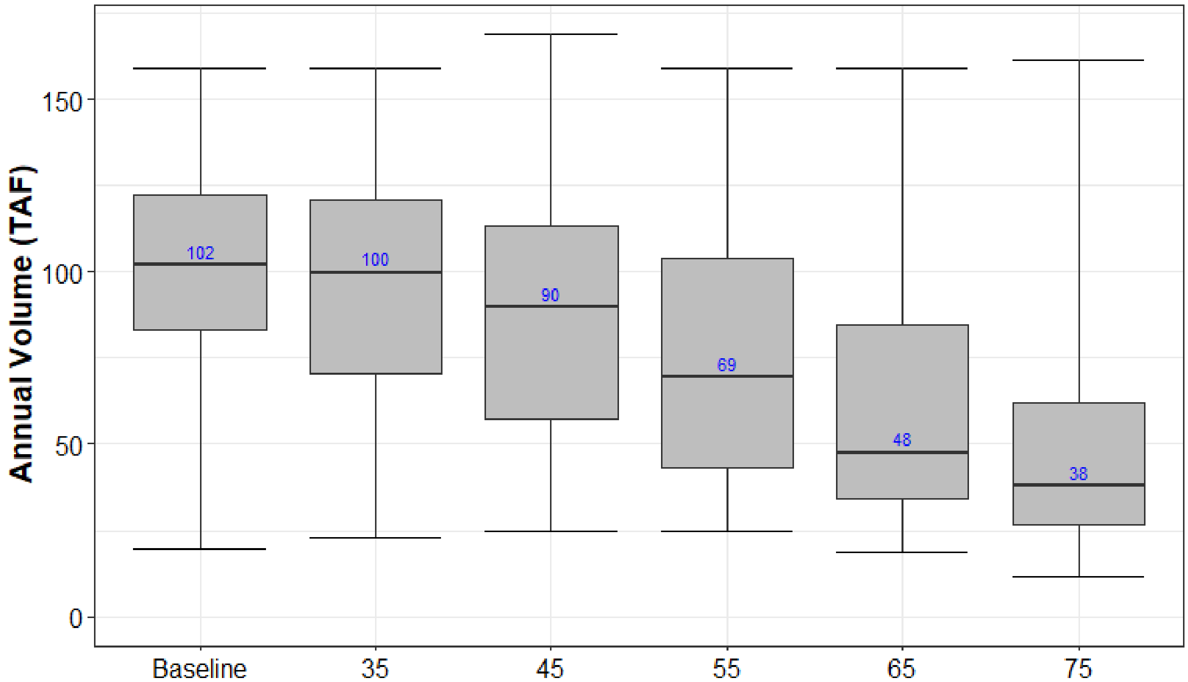


TAF = thousand acre-feet

Figure 6.4-11. Sacramento/Delta Supply to Agriculture in the San Joaquin Valley Region

Table 6.4-21. Sacramento/Delta Supply to Agriculture in the San Joaquin Valley Region Water Year Type Average: Change from Baseline (thousand acre-feet)

Water Year Type	Baseline	35	45	55	65	75
Critical	1,404	-4	-139	-365	-626	-859
Dry	2,237	-103	-299	-658	-1,048	-1,516
Below normal	2,406	-41	-162	-476	-903	-1,462
Above normal	2,530	3	-65	-250	-843	-1,319
Wet	3,069	-11	-21	-87	-661	-968
All	2,422	-34	-134	-353	-811	-1,210

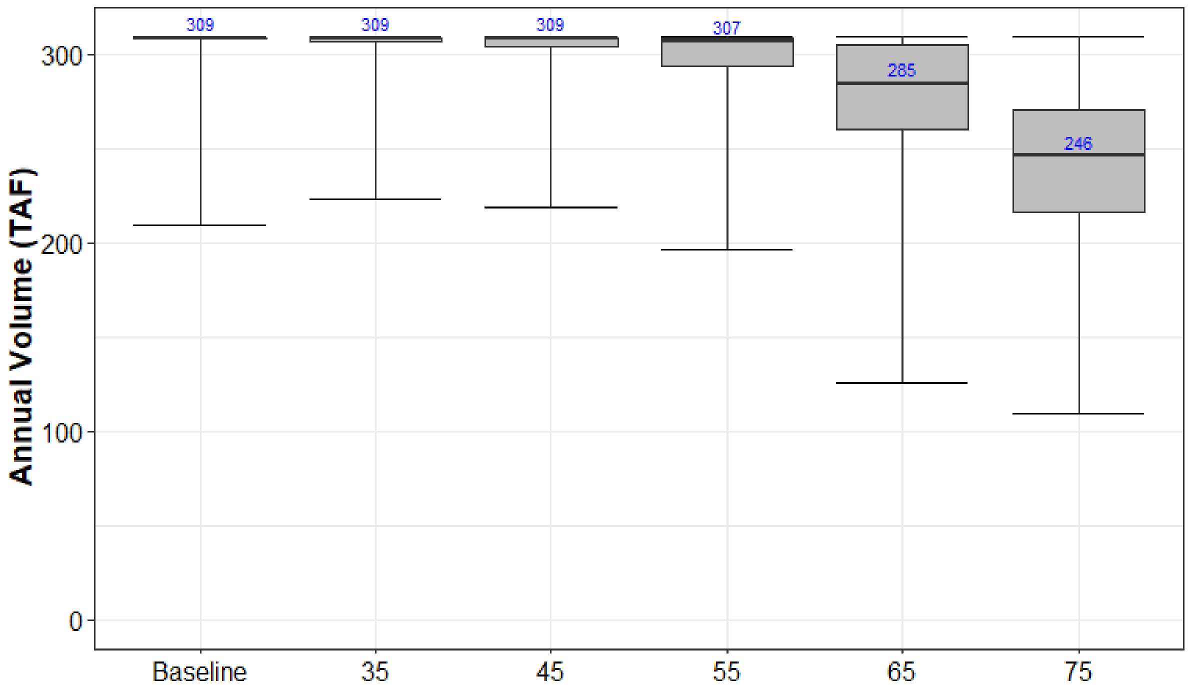


TAF = thousand acre-feet

Figure 6.4-12. Sacramento/Delta Supply to Urban Use in the San Joaquin Valley Region

Table 6.4-22. Sacramento/Delta Supply to Urban Use in the San Joaquin Valley Region Water Year Type Average Change from Baseline (thousand acre-feet)

Water Year Type	Baseline	35	45	55	65	75
Critical	46	-1	-6	-11	-19	-27
Dry	89	-11	-25	-39	-50	-61
Below normal	101	-6	-18	-34	-49	-61
Above normal	107	0	-8	-25	-48	-57
Wet	130	0	-1	-7	-17	-44
All	99	-4	-11	-22	-35	-50



TAF = thousand acre-feet

Figure 6.4-13. Sacramento/Delta Supply to Wildlife Refuges in the San Joaquin Valley Region

Table 6.4-23. Sacramento/Delta Supply to Wildlife Refuges in the San Joaquin Valley Region Water Year Type Average: Change from Baseline (thousand acre-feet)

Water Year Type	Baseline	35	45	55	65	75
Critical	263	0	3	-7	-36	-60
Dry	303	-3	-3	-9	-27	-76
Below normal	303	3	-1	0	-20	-62
Above normal	302	0	0	-2	-27	-46
Wet	307	0	0	-1	-13	-38
All	298	0	0	-4	-23	-56

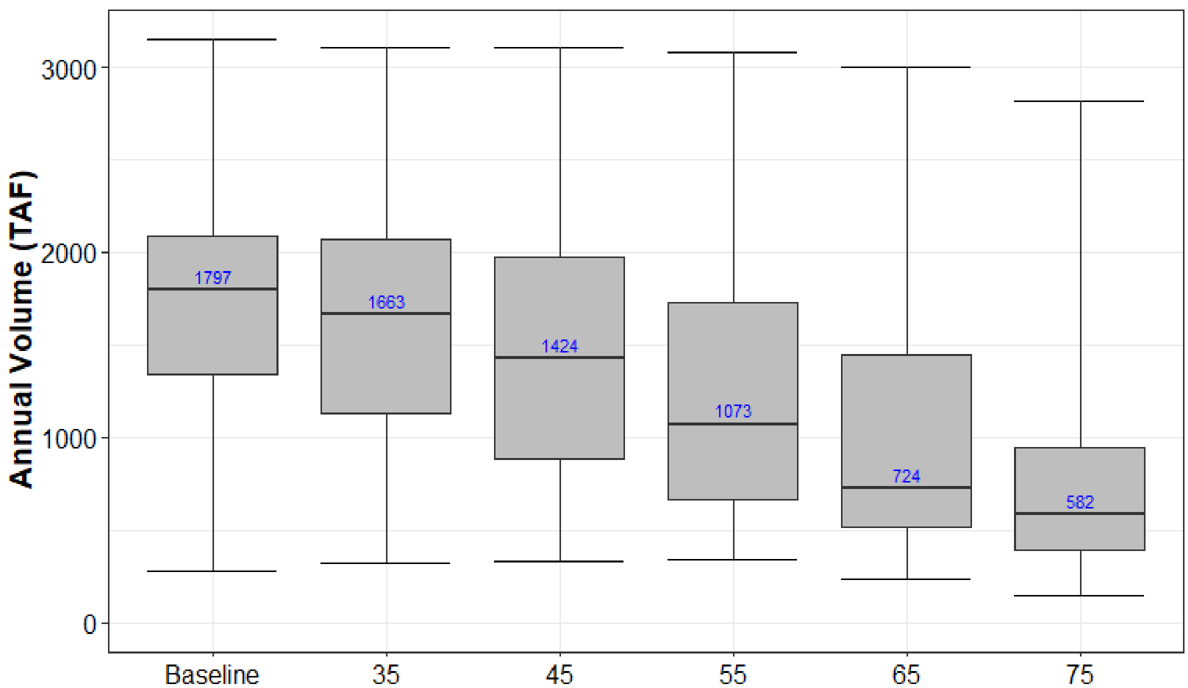
6.4.9 Sacramento/Delta Supply to Southern California

The Southern California region is comprised of the South Coast, Colorado River, and Lahontan Hydrologic Regions. The Sacramento/Delta supplies included in this analysis include only the Sacramento/Delta SWP supplies imported via the California Aqueduct. Other supplies, such as from the Owens Valley and the Colorado River, are not analyzed here.

As discussed in Chapter 2, *Hydrology and Water Supply*, nearly all the SWP water supplied to the Southern California region is for municipal and industrial uses, with some very small deliveries to local farms. Therefore, results are presented together for all Sacramento/Delta supply. As with other CVP and SWP south-of-Delta deliveries, the baseline results show large variability in deliveries from year to year. This variability also is exhibited in each of the scenarios, with more years receiving less water as the flow requirements increase (Figure 6.4-14 and Table 6.4-24).

Overall, as expected, Sacramento/Delta water supply is reduced with increasing flow requirements. Water supply reductions are the least in wet and critical years and generally the greatest in dry and below normal years. In the 35 scenario, Sacramento/Delta surface water supply reductions range from 28 TAF to 186 TAF in critical and dry year types, respectively. In the 45 scenario, Sacramento/Delta water supply reductions are about 240 TAF on average, with reductions of about 443 TAF in dry years. In the 55 scenario, Sacramento/Delta water supply is reduced by 450 TAF on average from baseline, with the largest reductions of 673 TAF in above normal years. In the 65 scenario, average Sacramento/Delta water supply is reduced 656 TAF/yr on average and over 925 TAF/yr in above normal and below normal year types. In the 75 scenario, Sacramento/Delta supplies are reduced by 918 TAF/yr average with the largest reductions in below normal years of 1.12 MAF. As in the San Joaquin Valley region, supply reductions often are not as large in the drier years because the baseline supply is already very low in these years.

The SacWAM results show large reductions in Sacramento/Delta supplies for communities in Southern California; however, as discussed in Chapter 2, *Hydrology and Water Supply*, these Sacramento/Delta supplies make up only a portion of this region's total water supply portfolio. Sacramento/Delta supplies represent approximately 18 percent of the total water supplied to the region as estimated by historical water deliveries data and SacWAM results (see Section 2.8, *Existing Water Supply*). Therefore, reductions in the Sacramento/Delta supply in the 35, 55, and 75 scenarios result in 1-percent, 5-percent, and 10-percent reductions in total supply, respectively, as shown in Table 6.4-1.



TAF = thousand acre-feet

Figure 6.4-14. Sacramento/Delta Supply to the Southern California Region

Table 6.4-24. Sacramento/Delta Supply to the Southern California Region Water Year Type Average: Change from Baseline (thousand acre-feet)

Water Year Type	Baseline	35	45	55	65	75
Critical	722	-28	-95	-177	-297	-417
Dry	1,465	-186	-443	-673	-837	-1,034
Below normal	1,723	-150	-382	-655	-925	-1,127
Above normal	1,825	-37	-175	-541	-927	-1,079
Wet	2,250	-45	-107	-265	-434	-903
All	1,675	-92	-240	-450	-656	-918

Methods described in Appendix A1a, *Methods for Estimating Regional Sacramento/Delta Surface Water Supply for Agricultural and Municipal Use*, were applied to estimate changes in Sacramento/Delta supply for agricultural and municipal uses in the Southern California region for the flow scenarios based on SacWAM results. Table 6.4-25 presents the baseline use and changes for agriculture. The volume delivered to agriculture is very small compared to municipal use; the reduction is about 29 percent in the 55 scenario. Table 6.4-26 presents baseline and flow scenario changes for municipal and industrial use. On average, the reduction in supply to municipal and industrial use is approximately 27 percent in the 55 scenario.

Table 6.4-25. Annual Sacramento/Delta Supply to Agriculture in the Southern California Region Water Year Type Average: Change from Baseline (thousand acre-feet per year)

Water Year Type	Baseline	35	45	55	65	75
Critical	6	0	-1	-2	-3	-4
Dry	13	-2	-4	-6	-7	-9
Below normal	15	-1	-3	-6	-8	-10
Above normal	16	0	-1	-5	-8	-9
Wet	20	0	-1	-2	-4	-8
All	14	-1	-2	-4	-6	-8

Table 6.4-26. Annual Sacramento/Delta Supply to Municipal and Industrial Use in the Southern California Region Water Year Type Average: Change from Baseline (thousand acre-feet/year)

Water Year Type	Baseline	35	45	55	65	75
Critical	715	-28	-94	-176	-295	-413
Dry	1,452	-184	-440	-667	-830	-1,025
Below Normal	1,709	-149	-379	-649	-917	-1,117
Above Normal	1,809	-37	-174	-536	-919	-1,070
Wet	2,230	-45	-106	-263	-430	-895
All	1,661	-92	-238	-446	-651	-910

6.5 Changes in Groundwater Supply

This section includes a short discussion of groundwater in the SacWAM domain that characterizes groundwater use in the study area as well as a more qualitative description of changes that could occur to groundwater supply with the implementation of the proposed Plan amendments. SacWAM includes a model representation of groundwater pumping, incidental recharge from deep percolation and conveyance losses, and stream-groundwater interactions for the Sacramento River watershed and the Delta eastside tributaries regions. SacWAM does not include simulation of these groundwater flows in the Delta, south of the Delta, or in the Bay Area. As discussed above in Section 6.2, *Changes in Hydrology*, the model assumptions for the flow scenarios assumed no substantial increase in groundwater pumping in SacWAM (see Appendix A1, *Sacramento Water Allocation Model Methods and Results*).

Historical water deliveries data is used to provide estimates of the 2005 to 2015 average annual total groundwater use in the study area (see Section 2.8, *Existing Water Supply*). Analysis of that data finds that approximately 17.3 MAF of groundwater is used annually within the study area, or roughly 42 percent of total use from all sources of supply (Table 6.5-1 and Table 2.8-1) (see Section 2.8). Groundwater accounts for approximately 43 percent of the total supplies to agriculture, 41 percent to municipal water uses, and 23 percent of the total supplies to managed wetlands.

Table 6.5-1. Average Annual Groundwater Use by Geographic Region and Sector, 2005–2015 (thousand acre-feet)

	Sector			
Geographic Region	Agriculture	Municipal	Managed Wetlands	Total Groundwater Use
Sacramento River watershed	2,272	387	20	2,679
Delta eastside tributaries	545	53	0	597
Delta	34	40	0	74
San Francisco Bay Area	80	184	0	264
San Joaquin Valley	9,034	823	251	10,107
Central Coast	968	196	0	1,164
Southern California	792	1,590	0	2,382
Total	13,725	3,272	271	17,267

Source: Table 2.8-2, Chapter 2, *Hydrology and Water Supply*.

Historically, in areas with adequate groundwater, the local response to decreased surface water availability has been to use more groundwater. Irrigation districts serving multiple farms may have their own wells with water that is pumped directly into distribution systems. Municipalities generally rely on multiple sources of water to provide protection against shortages and unanticipated failures in parts of the delivery systems. Municipal wholesalers who rely on surface water often have one or more groundwater wells that may serve as supplemental or backup supplies. In both the Sacramento River and San Joaquin River Valleys, many communities rely solely on groundwater.

The proposed Plan amendments have the potential to affect groundwater levels due to potential changes in groundwater pumping and changes in managed and incidental recharge. If the full amount of reduced surface water supply is assumed to be replaced by groundwater pumping, then there would be essentially no change to the amount of water applied to irrigated fields, and the volume of water recharged due to excess application of irrigation water would remain relatively constant. However, the increased groundwater pumping would result in lower groundwater levels. Because only a portion of the applied water results in recharge (with a considerable amount of the total volume of pumped groundwater lost through evapotranspiration), there would be a larger reduction in groundwater levels under maximum replacement groundwater pumping. The actual response of water users to reduced surface water supplies from the Sacramento/Delta is expected to include some increases in groundwater pumping to replace some of the reduced surface supplies, but not at volumes sufficient to replace all reductions to surface water supplies.

With higher flow requirements, there would be less applied water for irrigation of agricultural lands, which would in turn cause reductions in incidental groundwater recharge from transmission losses and deep percolation in both the Sacramento/Delta and areas that receive water from the Sacramento/Delta. Higher instream flows would be expected to increase groundwater recharge from stream-aquifer interactions (i.e., streambed seepage) in the Sacramento/Delta due to more water remaining in the streams, but to a lesser degree than the reductions to incidental recharge from less applied water. Overall, these changes would result in a net reduction in groundwater recharge in the Sacramento/Delta as well as areas that receive Sacramento/Delta water. With no change to groundwater pumping (i.e., no replacement groundwater pumping) and a net reduction in groundwater recharge, groundwater levels could decrease compared to the baseline condition, as the instream flow requirement increases. Lastly, higher instream flow requirements could also mean less surface water would be available for managed recharge projects such as recharge basins or injection wells.

There is uncertainty regarding areal recharge rates, stream-groundwater interactions, and groundwater pumping in many parts of the study area. Precisely how these physical processes may change, and how users may respond to reduced surface water availability are difficult to determine based on other regulatory requirements and groundwater availability. In the Sacramento Valley, groundwater supplies are generally plentiful where pumping takes place in shallow alluvial aquifers that maintain high levels due to regular recharge from natural runoff. In these areas, it is possible that water users could turn to groundwater supplies if their surface water supplies were limited by the proposed Plan amendments. In mountainous areas of the Sacramento River watershed that have access to groundwater from fractured rock, such as the foothills of the Coast Ranges, Sierra Nevada, and Southern Cascades, groundwater availability is less certain; therefore, these supplies may be less likely to be used to make up for reductions in surface water supplies from the Sacramento/Delta. In the San Joaquin Valley and other regions, many groundwater basins are critically overdrafted (California Statewide Groundwater Elevation Monitoring [CASGEM] and subsequent Sustainable Groundwater Management Act [SGMA] 2019 Basin Prioritization determinations [see Section 7.12.2, *Groundwater*]) and as such are not likely to serve as an additional source of supply in place of reduced Sacramento/Delta supplies. Changes in groundwater supply are factored into the regional portfolio assessments at the end of this section.

The changes in groundwater supply would largely be dependent on other regulatory requirements, the SGMA in particular. SGMA requires local public agencies, in alluvial groundwater basins designated as high and medium priority and subject to the Act, to halt overdraft and balance levels of pumping and recharge. In basins subject to SGMA, local public agencies are required to form groundwater sustainability agencies (GSA) that develop, adopt, and implement groundwater sustainability plans (GSP) to manage basins sustainably. GSAs, through their GSPs, must determine the best approach to manage their groundwater and surface water resources in order to ensure that their basin is operated within its sustainable yield, as defined by SGMA, including projects, programs, and enforcement actions that will be taken to achieve sustainability. SGMA authorizes GSAs to regulate, limit, and suspend groundwater extractions in order to achieve basin-wide sustainability.

6.6 Other Water Management Actions

6.6.1 Overview

The estimates of reduced Sacramento/Delta supplies described above do not factor in all of the flexibility that water users have or could develop to continue to meet water supply needs with reductions of Sacramento/Delta surface water supplies, including other water supplies and conservation. As described in Chapter 2, *Hydrology and Water Supply*, many water users have made significant investments to diversify their water supply portfolios and the proposed Plan amendments could lead to further diversification beyond that which has occurred due to existing or potential population growth, drought, environmental needs, climate change, economic factors, and other reasons. Those efforts include groundwater storage and recovery and sustainable management projects, water transfers, water recycling, desalinated supplies, and conservation measures. These other water supply sources and water conservation must be considered in the context of the modeled reductions in Sacramento/Delta surface water supplies that may result from the proposed Plan amendments, particularly given that reducing reliance on the Delta and improving regional self-reliance is a state mandate (Wat. Code, § 85021) and a prominent component of the Delta Plan (reflected in regulatory policy WR P1, Appendix G, and performance measures). The degree to which other water management actions are available in a particular region can reduce the environmental impacts and economic effects from the proposed Plan amendments. However, environmental impacts that could result from development and use of these other supplies must be analyzed. The environmental effects of increased use of other water management actions are analyzed in Chapter 7. Other potential sources of alternative water supplies that involve construction of future projects, such as desalination plants and new or modified reservoirs, are analyzed in Section 7.22, *New or Modified Facilities*.

The other water management actions described in this section are consistent with many of the actions described in the Water Resilience Portfolio developed by state agencies in response to Governor Newsom's Executive Order N-10-19. The Water Resilience Portfolio identifies over 100 recommended actions to maintain and diversify California's water supplies, protect and enhance natural ecosystems, build connections, and be prepared. Many of the Water Resilience Portfolio actions aim to increase water use efficiency; promote water recycling, reuse, and wastewater projects; and diversify water supplies to reduce regional and local reliance on any one source. For example, Water Resilience Portfolio Action 2 promotes greater efficiency of water use in all sectors. Water Resilience Portfolio Action 4 sets a statewide water recycling and reuse goal of 2.5 MAF/yr in the next decade. Water Resilience Portfolio Action 5 supports cities and towns to make stormwater capture a larger component of their water supply. The Water Resilience Portfolio also describes actions to help regions secure groundwater supplies by supporting the transition to sustainable use (Water Resilience Portfolio Action 3) and, depending on local circumstances, promotes the use of desalination technology where it is cost-effective and environmentally appropriate (Water Resilience Portfolio Action 6). Water Resilience Portfolio Action 15 encourages investment in upper watersheds to protect water quality and water supply. Water Resilience Portfolio Action 21 encourages the water transfer process to be simplified and expedited. The Water Resilience Portfolio acknowledges that it will take time, effort, and funding to carry out the recommended actions; and the pace of implementation will vary depending on project feasibility, resource availability, and competing priorities. The Water Resilience Portfolio identifies funding sources (e.g., state revolving funds, one-time bonds) that could be leveraged to achieve many of the goals of the Water Resilience Portfolio.

The following sections provide information regarding the current and potential future use of other water management actions by water users who may experience reductions in Sacramento/Delta supplies under the proposed Plan amendments. It is anticipated that these other actions could be used in place of some portion of the reduction in Sacramento/Delta supplies that may result from the proposed Plan amendments. It is not possible to quantify exactly how the various water users that may experience reduced Sacramento/Delta supplies will manage their water supply portfolios in response to reduced supplies, and this type of quantification is beyond the scope of detail required in this planning process. However, potential responses can be described generally, with some quantification using agency water supply planning documents, modeling tools, historical and recent responses to drought, and other information.

6.6.1.1 Groundwater Storage and Recovery

Groundwater storage and recovery (also known as *managed groundwater recharge* or *groundwater banking*) involves storage of water for later recovery by intentionally recharging groundwater basins when excess surface water or other water sources are available, for example during years of above-average surface water supply or through storing recycled water or stormwater in groundwater basins for future use. Groundwater storage and recovery is also part of conjunctive management or use that involves coordinated management of surface water and groundwater resources to maximize the availability and reliability of water supplies in a region. Groundwater storage and recovery projects can help to mitigate water supply reductions due to drought and other surface water supply shortages; reduce groundwater overdraft and land subsidence; maximize water availability; reduce reliance of surface water supplies in a manner that protects fish and wildlife, aesthetics, recreation, and other uses; protect water quality; and protect groundwater-dependent ecosystems, as well as other benefits.

SGMA encourages conjunctive management of surface water and groundwater resources. The Water Code also requires agricultural water suppliers to implement efficient water management practices, including increased conjunctive use, where locally cost effective, technically feasible, and in a manner consistent with the safe yield of the groundwater basin. The current California Water Plan included estimates from 2013 of potential increased use of groundwater storage and recovery in the range of 500 to 1,000 TAF. (^DWR 2014) Managed groundwater recharge is already utilized extensively throughout the study area. It is estimated that more than 20 of approximately 500 groundwater basins are currently storing and banking groundwater, mostly in urban sectors in Southern California (^DWR 2014). Several aquifer storage and recovery programs are also located in the San Joaquin Valley. The Kern Water Bank is the largest of these projects, located in a naturally occurring aquifer in the southern San Joaquin Valley.

Several local irrigation districts are working on their own projects to manage groundwater storage. These efforts are described in a 2014 study, *Integrating Storage in California's Changing Water System* (Lund et al. 2014) which finds that many water agencies are actively evaluating groundwater storage expansion options, including water banking; agencies include the Semitropic Water Storage District, Sacramento and San Joaquin Counties, Orange County Water District, and Eastern Municipal Water District. The study estimates that these projects would lead to approximately 22 MAF in expanded groundwater storage capacity. The study also identifies potential advantages as drivers of these efforts, including local control, support, and use, and lower conveyance costs.

In April 2018, DWR released its final report on *Water Available for Replenishment* (WAFR Report), which also highlights the importance of diversified water resources portfolios. The WAFR Report acknowledges that the State Water Board is in the process of developing and implementing updates to the Bay-Delta Plan for the reasonable protection of fish and wildlife beneficial uses and that comprehensive consideration of balancing competing uses was not included in WAFR estimates. (DWR 2018) In addition, the WAFR Report notes there are increasing uncertainties associated with surface water supplies from the SWP and CVP, particularly imported supplies. The WAFR Report makes clear that a diversified water supply portfolio is needed at the local, regional, and state level and that conservation, recycling, desalination, additional reservoir storage and conveyance, stormwater capture, and water transfers are all needed for California to simultaneously bring sustainability to its groundwater basins, cope with climate change, and improve the resiliency of its water system (DWR 2018). DWR acknowledges that the water estimated to be available for replenishment of groundwater basins in the WAFR Report may not actually be available for replenishment depending on other competing uses of water and further water availability analyses, including formal water availability analyses required by the State Water Board in order to obtain an appropriative water right.

In addition to managed groundwater recharge projects, decentralized groundwater recharge actions are also occurring with low impact development (LID) projects designed to allow stormwater runoff to infiltrate into the ground. Stormwater discharges regulated through NPDES permits may also act as a resource and recharge to groundwater when properly managed. The Water Boards are actively involved in initiatives to improve the management of storm water as a resource. (See 2018 Strategy to Optimize Resource Management of Storm Water [recognizing the value of storm water as a resource that can be managed more effectively to improve both water quality and water supply; capture and infiltration of storm water as sustainable groundwater management measure].)

Groundwater storage and recovery can be an effective approach in long-term water supply planning, so long as it does not impair surface water beneficial uses. In many areas, Sacramento/Delta supplies have been used to alleviate already declining groundwater levels. Decreases in Sacramento/Delta supplies could cause reductions in managed groundwater recharge and could affect planning for future increases in the volume of water recharged and extracted from aquifers. Even with new instream flow requirements that may limit surface water supplies, opportunities will remain for managed groundwater recharge from high-runoff events, treated wastewater, and stormwater. Managed recharge projects are factored into the regional portfolio assessments at the end of this section.

6.6.1.2 Water Transfers

Water transfers, which include exchanges and purchases of water, are an important component of water resource management in California. The extensive network of water conveyance infrastructure developed through state, federal, and locally funded projects, most notably the CVP and SWP, is used to facilitate water transfers. Water can be transferred from a seller to a buyer through networks of rivers, canals, aqueducts, and pipelines. Although the SWP and CVP are the most extensive storage and conveyance projects involved in transfers, many major local and regional water suppliers are involved in transfers, especially inbasin transfers.

Table 6.6-1 provides the average annual volume of temporary water transfers that occurred through market transactions by region from 2007 through 2016 (WestWater Research). The table reflects only temporary lease transactions and does not include permanent sales, transactions within adjudicated groundwater basins, or exchange agreements that do not involve monetary compensation. The top row of the table identifies the source region for the water transfers, and the first column identifies the regions that are purchasing the water supplies. For example, the table shows that entities located within the Sacramento River watershed region have temporarily transferred approximately 157 TAF on average to the San Joaquin Valley over the 10-year period. The majority of the Southern California water transfers are associated with the Colorado River, highlighting the Colorado River's importance as a source of water for transfers. On average, approximately 1.026 MAF have been temporarily transferred on an annual basis from and within the selected regions over the period of analysis.

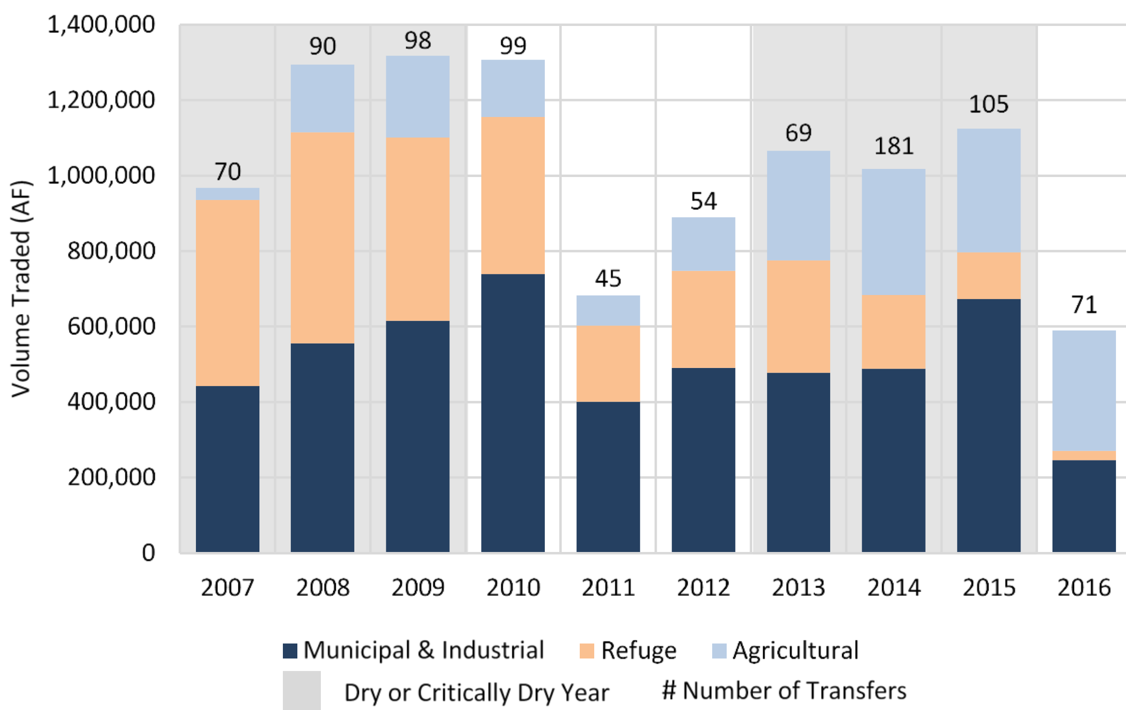
Table 6.6-1. Summary of Market-Based Water Transfers, by Region (Annual Average – thousand acre-feet per year)

	Water Transferred From:							
Water Transferred To: Geographic Region	Sacramento River Watershed	Delta Eastside Tributaries	Delta	San Francisco Bay Area	San Joaquin Valley/ Tulare Lake	Central Coast	Southern California	Total of Water Transferred to
Sacramento River watershed	49.8	0	0	0	0	0	0	49.8
Delta eastside tributaries	0	4.1	0	0	8.5	0	0	12.6
Delta	0	0	0.4	0	7.8	0	0	8.2
San Francisco Bay Area	10.4	0.6	4.2	1.4	2.6	0.5	0.8	20.5
San Joaquin Valley	157.3	3.4	1.0	3.2	332.1	0	1.0	498
Central Coast	1.2	0	0	0	0.4	1.2	3.1	5.9
Southern California	55.1	0	6.8	0	31.8	0	337.3	431
Total of Water Transferred from	273.8	8.1	12.4	4.6	383.2	1.7	342.2	1,026

Source: WestWater Research, unpublished data.

As indicated in Table 6.6-1, much of the water transferred within the state has come from three regions: Southern California, which includes the Colorado River; the Sacramento River watershed; and the San Joaquin Valley. Colorado River water is transferred to water agencies located within the South Coast primarily under long-term agreements with Palo Verde Irrigation District, Imperial Irrigation District, and others. Water from agricultural users in the Sacramento River watershed is transferred through the Delta primarily during drier years to satisfy water needs for south-of-Delta irrigators, cities, and wildlife refuges.

Figure 6.6-1 summarizes the temporary transfers identified above by year and type of buyer. The annual volume traded has ranged from approximately 0.6 to 1.3 MAF. The three categories of buyers (agriculture, urban, and refuges) have been active every year although refuge water acquisitions have declined as the purchases by agricultural producers have increased. As shown in Figure 6.6-1, urban uses receive the largest volume of temporary transfers in most years. The number, type, and transaction volume of water transfers are highly correlated with the hydrologic water year type, with increased activity during dry and critically dry water years.



Source: WestWater Research, unpublished data.
AF = acre-feet

Figure 6.6-1. Total Volume Traded by Buyer Sector—All Areas, 2007–2016

Information from the Public Policy Institute of California (PPIC 2012) on both temporary and permanent transfers shows that water transfer volumes have grown in California in recent decades. Short-term trades accounted for roughly three-quarters of all transfers in the 1980s and 1990s; however, as of 2003 to 2011 they accounted for less than one-half of all transfers and only one-quarter of the total volume of water transferred. During that period, long-term and permanent water transfers represented the largest volume of water transferred. Long-term transfers are leases of more than 1 year, for example, the long-term transfers within the Yuba Accord. Permanent transfers amount to an outright sale of the rights to use the specified amount of water in perpetuity or for the remaining duration of the contract in question. Leases of contract allocations involve transfers of actual deliveries. Between 2003 and 2011, agricultural water districts were the principal suppliers of transfer water, providing water for roughly 80 percent of all long-term and permanent contracts, 85 percent of short-term transfers, and 95 percent of the total volume of water transferred. (PPIC 2012.) Table 6.6-2 summarizes the destination use of long-term and permanent contracts from 1979 to 2012.

Table 6.6-2. Destination Use of Long-Term and Permanent Contracts

	Number	Total Maximum Volume (TAF/yr)	Average Maximum Volume (TAF/yr)	Average Duration (years)	Share of Total Volume (%)*
Long-term contracts (1979–2012)	52	1,676	32	22	
Cities	25	936	37	33	71
Mixed uses [a]	5	339	68	28	4
Environment [b]	9	201	22	11	21
Agriculture	13	199	15	8	4
Permanent contracts (1998–2012)	52	328	6	–	
Cities	23	158	7	–	48
Mixed uses	2	26	13	–	8
Environment	16	38	2	–	12
Agriculture	11	107	10	–	32

Source: PPIC 2012.
TAF/yr = thousand acre-feet per year
[a] PPIC (2012) categorizes Mixed Uses as purchases by agencies with significant urban and agricultural uses.
[b] PPIC (2012) categorizes Mixes Uses as purchases by agencies with significant urban and agricultural uses.

Water transfers among agencies with rights to use water within the same large projects (CVP, SWP, and Colorado River) dominated the market, accounting for over 60 percent of all transfers since the mid-1990s, and 80 percent of all transfers not involving direct state or federal government purchases. The "open market"—transfers between agencies within different projects or not belonging to projects at all—accounts for less than one-fifth of all transactions. (See Table 6.6-3.) (PPIC 2012.)

Table 6.6-3. Water Transfers in California by Type of Market, Volume Committed (acre-feet)

Year	Total Transfers	Direct Government Purchases	Within CVP	Within SWP	Within Colorado River Project	"Open Market"
2000	1,423,515	222,548	525,126	386,205	110,000	179,636
2001	1,689,258	625,380	574,608	169,668	110,000	209,602
2002	1,377,956	504,300	260,013	204,132	110,000	299,511
2003	2,075,631	453,584	326,038	247,889	660,290	387,830
2004	2,005,480	384,928	476,517	198,565	619,700	325,770
2005	2,037,878	338,389	546,252	219,406	619,700	314,131
2006	1,905,903	260,733	479,629	240,598	619,700	305,243
2007	1,995,490	426,431	410,529	213,833	619,700	324,997
2008	2,086,382	379,163	459,084	265,850	619,700	362,585
2009	2,221,663	453,272	445,118	244,407	664,195	414,671
2010	2,223,907	399,099	543,793	292,504	625,622	362,890
2011	2,107,580	398,476	529,471	265,138	619,700	294,796
Total	33,018,568	7,717,426	8,984,681	3,840,131	7,707,307	4,769,025

Source: PPIC 2012.

Urban demand has grown, with cities seeking to firm up supplies to support population growth and diminishing sources such as the Colorado River. As a result, water market transactions tend to be long-term and permanent. Most transactions are local, with fewer infrastructure, institutional, and legal constraints or objections from other parties. In Southern California, within-region transfers account for two-thirds of all purchases, almost entirely due to the long-term transfers of Colorado River water from agricultural districts in Imperial County to Los Angeles and San Diego metropolitan water providers (PPIC 2012).

Many water transfers become a form of flexible system reoperation linked to many other water management strategies, including surface water and groundwater storage, conjunctive management, conveyance efficiency, water use efficiency, water quality improvements, and planned crop shifting or crop idling for the specific purpose of transferring water. These linkages often result in increased beneficial use and reuse of water overall and are among the most valuable aspects of water transfers (^DWR 2014).

The volume of water that can be transferred through a conveyance facility is affected by several factors, including hydrologic conditions, regulatory requirements regarding conveyance facility operations such those included in biological opinions and other state or federal permits and licenses, and the availability of space in the conveyance facility. While water transfers from north to south potentially would be more limited as a result of the proposed Plan amendments, transfers between water users within a region could be an effective strategy for meeting local demands or responding to shortages associated with longer droughts or disruptions in deliveries.

It is difficult to predict with certainty how reduced Sacramento/Delta surface water supplies will affect water transfers. With new instream flow and cold water habitat requirements, overall supplies of water from the Sacramento/Delta will decline. This may result in less water available for transfer. At the same time, it could incentivize transfers as the value of transfer water increases, leading to transfers from lower value temporary crops to higher value municipal uses and permanent crops. In addition, groundwater substitution and pumping transfers could be less feasible due to SGMA.

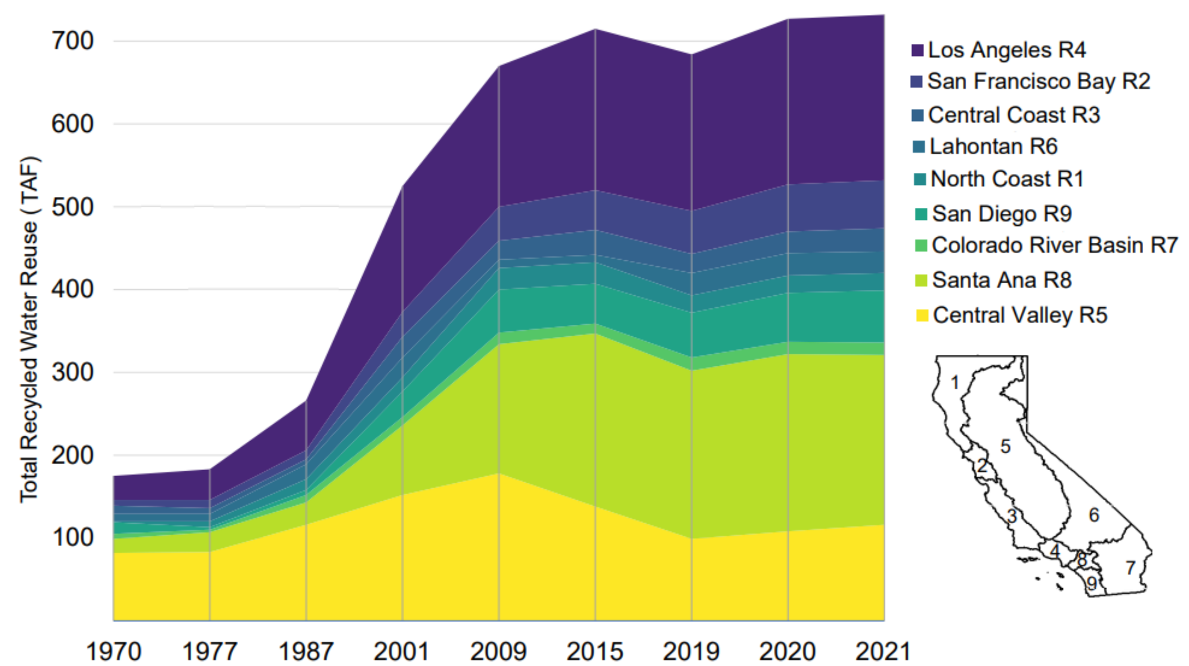
6.6.1.3 Recycled Water

Recycled water can be used in water-scarce areas of the state to supplement or replace existing water supplies. The state has been active in developing legislation, adopting resolutions and policies, setting goals for recycled water use, and funding recycled water projects. The degree to which recycled water use is available in a particular region can reduce the environmental impacts and economic effects from reduced Sacramento/Delta supply.

Recycled water is primarily municipal wastewater that has been treated in a wastewater facility and complies with recycled water regulations for a specific beneficial use. It is generated by treating domestic wastewater to make the water suitable for a direct beneficial use that would not otherwise occur. There are different required levels of treatment corresponding to the proposed use of the recycled water. Use of recycled water is part of the state's larger strategy to develop more resilient water supplies and increase regional self-reliance. Recycled water use can help reduce local water scarcity and can be a cost-effective solution for bringing supply and demand into a better balance. The California Legislature has expressed its intent that the state undertake all possible steps to encourage development of water recycling facilities so that recycled water may be made available to help meet the state's growing water needs. (Wat. Code, § 13512.)

In 1977, the State Water Board adopted the Policy with Respect to Water Reclamation in California, encouraging reclamation of water. In 1991, the Water Recycling Act established numeric goals of recycling 0.7 MAF of recycled water per year by 2000 and 1 MAF of recycled water per year by 2010. (Wat. Code, § 13577). The State Water Board adopted the Recycled Water Policy in 2009, including the numeric goals for recycled water use, providing a rationale for funding recycled water projects, salt and nutrient management planning, as well as permitting requirements for landscape irrigation and groundwater recharge, among other things. The Policy was updated in 2013 and amended in 2018 (SWRCB 2018a). To support water supply diversity and sustainability and to encourage the increased use of recycled water in California, the 2018 amendment includes a goal to increase the use of recycled water to 1.5 MAF by 2020 and to 2.5 MAF by 2030 (SWRCB 2018b). The amendment also includes narrative goals to reuse all dry weather direct discharges of treated wastewater to enclosed bays, estuaries and coastal lagoons, and ocean waters that can be viably put to a beneficial use, and to maximize the use of recycled water in areas where groundwater supplies are in a state of overdraft, to the extent that downstream water rights, instream flow requirements, and public trust resources are protected.

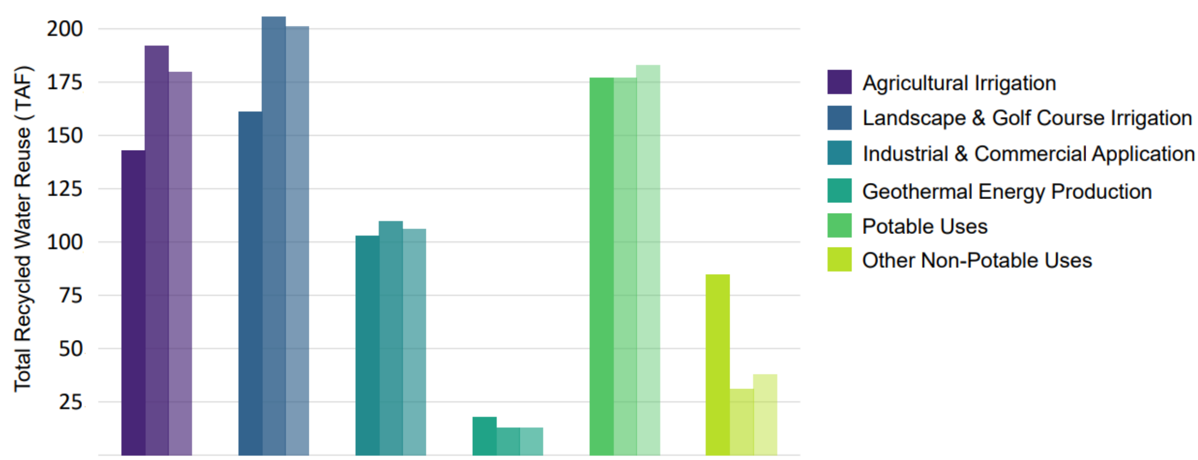
Agencies involved with the treatment, conveyance, or beneficial use of recycled water reported that 714,000 acre-feet of treated municipal wastewater were beneficially reused in California in 2015, an increase of approximately 45 TAF since 2009 (SWRCB 2015). Wastewater treatment plants and recycled water producers have been required to submit volumetric annual reports since 2019. The recycled water use increased from 686 TAF in 2019 to 732 TAF in 2021 (Figure 6.6-2) despite the decline in influent volume over the same period (from 3.69 MAF in 2019 to 3.41 MAF in 2021).



Source: SWRCB 2022a, p. 5.
TAF = thousand acre-feet

Figure 6.6-2. Reuse in California from 1970 to 2021 by Regional Water Board

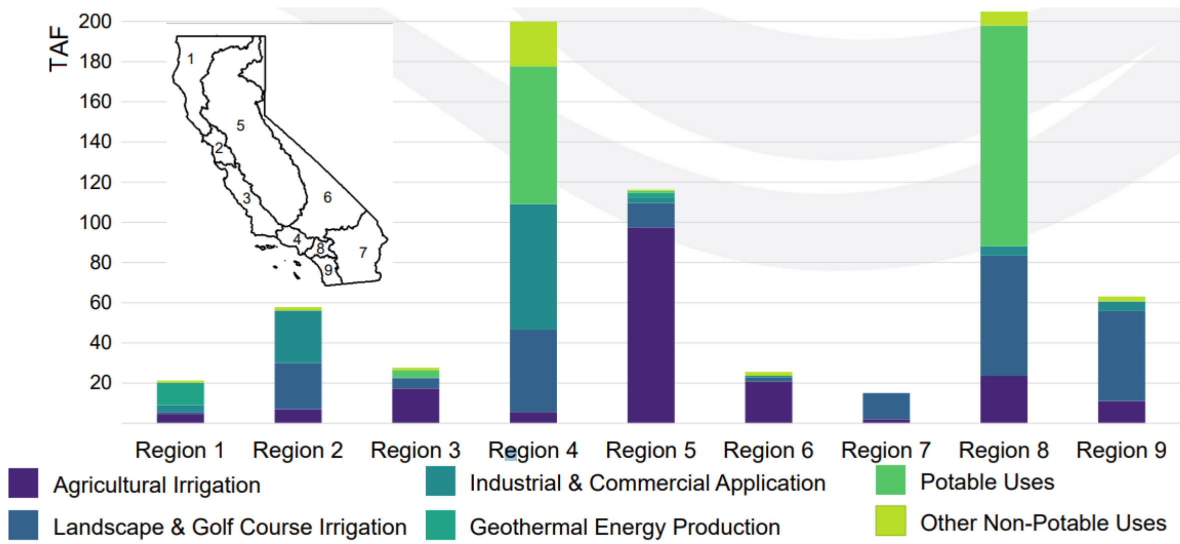
Recycled water is commonly used on agricultural crops, golf courses, parks, public landscaping, and industrial facilities; for environmental enhancement of wetland areas; and to help prevent seawater intrusion. In 2020 and 2021, the largest use of recycled water statewide was landscape and golf course irrigation (27 percent), followed by agricultural irrigation (25 percent), and potable uses (24 percent) (Figure 6.6-3).



Source: SWRCB 2022a, p. 4.
TAF = thousand acre-feet

Figure 6.6-3. 2019–2021 Recycled Water Comparison

Water recycling has become a fully integrated resource option in many parts of the state (Figure 6.6-4). Data from urban water management plans (presented in 2020 UWMP's Table 6-6, *Methods to Expand Future Recycled Water Use*) indicate that water recycling will continue to occur in all regions of California, with the majority in the Southern California region (up to an additional 177 TAF/yr by 2045) and Bay Area and San Joaquin Valley regions (up to an additional 20 TAF/yr each by 2045). Water treatment and reuse is expected to augment water portfolios in multiple regions.



Source: SWRCB 2022b, p. 10.
TAF = thousand acre-feet

Figure 6.6-4. 2021 Recycled Water Use by Regional Water Board

6.6.1.4 Water Conservation

Water conservation is often considered the fastest, easiest, and most cost-effective way to extend existing supplies. Through voluntary and required actions, water users statewide have made significant investments to manage demand through improved water use efficiency and water conservation measures. The degree to which water conservation and efficiency are established in a particular region can reduce the environmental impacts and economic effects from reduced Sacramento/Delta supply.

The Water Conservation Act of 2009 (SBx7-7) required the state to reduce urban water consumption by 20% by the year 2020 and encourages both urban and agricultural water providers to implement conservation strategies, monitor water usage, and report data to DWR. California's recent historic drought included the driest 4-year period, the warmest 3 years, and the smallest Sierra snowpack in state history that prompted a concerted conservation effort with promising results that help inform continued water management.

The Governor's May 2016 Executive Order B-37-16 required state agencies to develop a long-term plan to better prepare the state for future droughts and make conservation a California way of life. In response, several state agencies (DWR, State Water Board, the Public Utilities Commission, Department of Food and Agriculture, and the Energy Commission) released a plan in April 2017 that describes recommendations to (1) use water more wisely; (2) eliminate water waste; (3) strengthen local drought resistance; and (4) improve agricultural water use efficiency and drought planning. (DWR et al. 2017)

Assembly Bill 1668 and Senate Bill 606 (together, the 2018 conservation legislation) established a new foundation for long-term improvements in water conservation and drought planning to adapt to climate change. The 2018 conservation legislation amended existing law to provide expanded and new authorities and requirements to enable permanent changes actions for those purposes, improving the state's water future for generations to come.

Urban Water Conservation

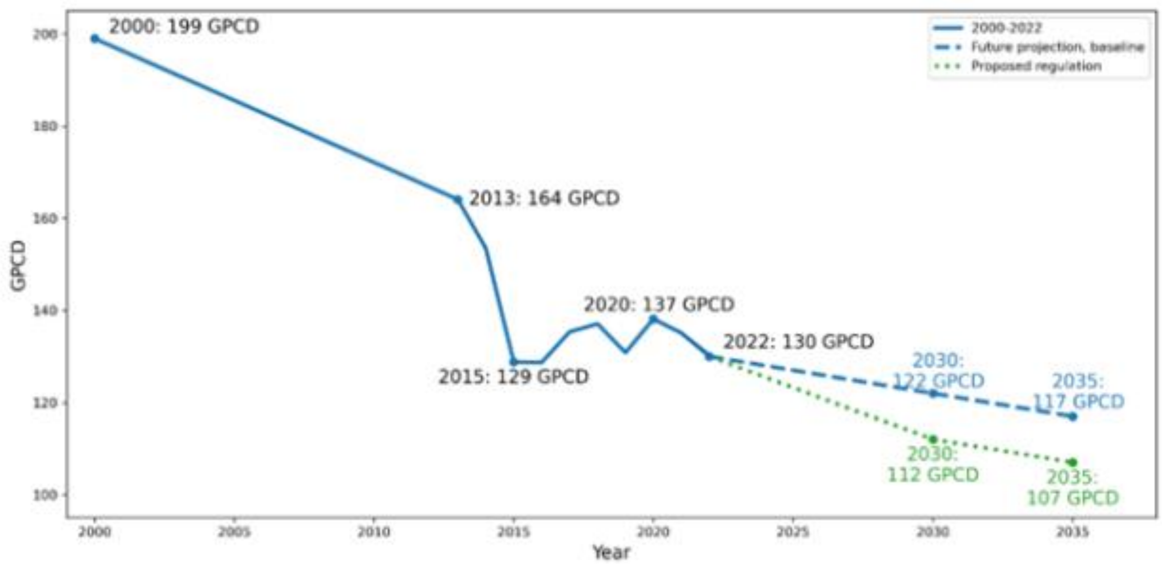
In 1983, the California Legislature enacted the Urban Water Management Planning Act. The law requires municipal water suppliers serving more than 3,000 customers or supplying more than 3,000 acre-feet of water annually to prepare and update Urban Water Management Plans (UWMPs) every 5 years, demonstrating water supply reliability in normal, single dry, and multiple dry years. UWMPs are intended to provide a framework for long-term water planning and to ensure that adequate municipal water supplies exist to meet existing and future demands. Urban water suppliers are required to coordinate with local planning agencies to assess those needs based on projected development, population growth, and other factors. The 2020 UWMP Guidebook encourages urban water suppliers to include information demonstrating progress toward reduced reliance on water supplies from the Delta (DWR 2021).

One of the water-planning fundamentals required of each urban wholesale and retail water supplier is to develop an effective water shortage contingency plan (WSCP) that specifies opportunities to reduce demand and augment supplies under numerous, and even unpredictable, water shortage conditions (DWR 2021). Certain elements of the WSCP are required by the Water Code, including specific response actions that align with standard water shortage levels corresponding to progressive ranges of up to 10-, 20-, 30-, 40-, and 50-percent shortages and greater than a 50-percent shortage. Shortage response actions include locally appropriate supply augmentation actions, locally appropriate demand reduction actions to adequately respond to shortages, locally appropriate operational changes, and additional mandatory prohibitions against specific water use practices that are in addition to state-mandated prohibitions and appropriate to the local conditions.

Emergency urban water conservation regulation was adopted by the State Water Board between 2014 and 2022 to respond to the drought State of Emergency declared in 2014. The emergency urban water conservation regulation, among other things, required a mandatory 25-percent statewide reduction in potable urban water use. The mandatory reductions in water use were repealed, but remaining provisions prohibit wasteful water practices for all Californians and ban decorative grass watering (non-functional turf irrigation) in commercial, industrial, and institutional areas. (SWRCB 2022c.)

In carrying out the 2018 conservation legislation, the State Water Board is developing regulation that will propose a new way of managing urban water use by establishing unique goals for each urban retail water supplier and providing communities with the flexibility to implement locally appropriate solutions. Collectively, these measures are envisioned to move the state from the temporary emergency conservation measures in effect during the drought to a more durable approach that will ensure that all communities are improving water use efficiency and extending their supplies.

In 2000, California's urban water use averaged 199 gallons per capita per day (GPCD), according to the 20×2020 Water Conservation Program report (DWR et al. 2013 as cited in State Water Board 2023). With the passage of the Water Conservation Bill of 2009 (SBx7-7), the state sought to reduce per capita water use by 20 percent by 2020. As shown in Figure 6.6-5, between 2000 and 2013, average statewide per capita water use decreased from 199 to 164 GPCD. Between 2013 and 2015, emergency conservation regulations and tremendous drought responses by local agencies and their customers resulted in average statewide water use dropping from 164 to 129 GPCD, a 21-percent savings in 2 years (SWRCB 2022d). Since then, California has experienced some rebound, peaking at 137 GPCD in 2020 (the beginning of the hot, dry conditions associated with the current drought) and again dropping by the end of 2022, averaging 130 GPCD (SWRCB 2022d). Absent additional regulation, average statewide total urban water use is forecasted to decline from an average of 130 GPCD in 2022 to 117 GPCD in 2035 (Figure 6.6-5).



GPCD = gallons per capita per day

Figure 6.6-5. Past and Forecasted Statewide Urban Water Use, in Gallons per Capita per Day, with and without the Proposed Regulation

Agricultural Water Use Efficiency

Agricultural water use efficiency is often expressed as "net water savings," or the reduction of irrecoverable flows, rather than applied water reductions. Applied water is often reused multiple times on the same farm or in the same region. Reuse of applied water is the main reason why the quantity of saved water in the agricultural setting is much smaller than in the urban setting. Often, increased water use efficiency, along with other management practices, allow for an increase in crop yield without increasing the amount of irrigation water. For the same amount of water used, an increase in crop yield translates into increased water productivity. Management practices to improve agricultural water use efficiency can include advances in irrigation technology, fertilizer technology, crop selection, and genetically modified crop development.

California has 8.5 million acres of irrigated cropland (PPIC 2023). The California Water Plan reported that, from 2001 to 2010, there was a reduction in the use of gravity irrigation systems as growers have been moving toward more frequent use of more water-efficient pressurized irrigation systems such as sprinkler, drip, and micro spray. Between 2001 and 2010, drip/micro irrigation usage increased from 15 to 30 percent, while gravity irrigation methods decreased from 67 to 43 percent. Land acreage irrigated by drip/micro irrigation methods increased by 16 percent between

2001 and 2011, while the acreage of land irrigated by surface irrigation methods decreased by 13 percent (Orang et al. 2011).

SBx7-7 required agricultural water suppliers that provide water to more than 25,000 irrigated acres (excluding recycled water) to develop and adopt agricultural water management plans every 5 years.[7] These plans must include reports on the implementation status of specific efficient water management practices that were required under SBx7-7. The 2018 Water Conservation Legislation requires agricultural water suppliers to set annual water budgets and prepare for drought. However, there are currently no regulatory water conservation or water efficiency targets or mandates for agricultural water use. The California Water Plan indicates that there is a large degree of uncertainty regarding future increases in agricultural water use efficiency.

On the basis of a review of previous efficiency studies, Pacific Institute and Natural Resources Defense Council (2014) estimated that agricultural water use could be reduced by 5.6 million to 6.6 MAF/yr, or by about 17 to 22 percent, while maintaining productivity and total irrigated acreage. Projects funded through grant programs, such as the Agricultural Water Use Efficiency and State Water Efficiency and Enhancement Program (SWEEP) (DWR and CDFA 2017) could help to enhance future agricultural water use efficiency and water conservation. These programs support conveyance enhancements and on-farm agricultural water use efficiency improvements. The California Department of Food and Agriculture estimates that SWEEP projects help save over 140 TAF of water annually (CDFA 2023). Additionally, water quality programs for agriculture (e.g., Irrigated Lands Regulatory Program) provide additional incentive to implement efficient irrigation management programs (e.g., timing, uniformity testing), technologies (e.g., spray, drip irrigation, tailwater return) as methods to minimize discharge of waste to surface water and percolation to groundwater.

6.6.1.5 Desalination

Desalination is the removal of salts from saline waters to produce water suitable for human consumption or irrigation. Existing facilities in California desalinate sea water for coastal communities and brackish groundwater for inland water users, many of which have provided high-quality water to their customers for more than 10 years. Desalinated water is produced using either brackish water (water with salt content of less than 10,000 mg/L), or seawater (salinity in a range of 30,000 to 44,000 mg/L). The Water Plan reports that 23 brackish groundwater and 3 ocean water desalination plants are in operation, with an annual capacity of 140 TAF located in the Bay area, Central Coast, and Southern California regions. Some urban water districts in these areas have also undertaken efforts to increase their desalinated water supplies. While construction and operational costs for desalination remain high in comparison with other water supplies, technologies have improved over time and are becoming more cost effective (especially in regions with access to brackish water), leading some communities (especially on the Central Coast) to reconsider previously deferred desalination plans. (DWR 2016).

Beginning with 2010 UWMPs, California urban water suppliers have been required to evaluate desalination as a method to meet their water resource management goals and objectives. The Water Plan projects that use of desalination will increase within the Bay area, Central Coast, and Southern

[7] Any agricultural water supplier that provides water from 10,000 irrigated acres up to 25,000 irrigated acres is exempt from this requirement unless sufficient funding has specifically been provided to that water supplier for that purpose.

California regions up to 400 TAF/yr by 2030. Specific expansions include approximately 17 proposed brackish groundwater plants scheduled for completion before 2030 with an estimated capacity of 74.6 TAF/yr; the Bay Area Regional Desalination Project with a potential design capacity of 22.4 TAF/yr; and 15 other ocean desalination projects that are currently being planned and designed with an estimated potential capacity of 382 TAF/yr. (DWR 2016)

6.6.1.6 Forest Meadow Restoration

In the Sierra Nevada, snowmelt is crucial to recharging groundwater in forest meadows, which have seasonally high water tables that support flood-tolerant herbaceous plants. The 2013 Water Plan reported that more than half of Sierra Nevada meadows are eroded by incised channels, which cause them to lose their capacity to store groundwater due to reduced overbank flooding and recharge and rapid draining of meadow aquifers. The 2013 Water Plan estimates that the potential groundwater storage benefits of meadow restoration throughout the Sierra Nevada are likely in the range from 25 to 50 TAF/yr (^DWR 2014).

6.6.2 Regional Use of Other Water Management Actions

Water service providers facing reductions in surface water supplies from the Sacramento/Delta may rely more than they do now on other existing or future water supplies, including groundwater, groundwater storage and recovery, recycled water, desalination, water exchanges, or transfers. Use of other water management actions in any particular geographic area depends on many factors, such as groundwater overdraft conditions, proximity to municipal recycled wastewater or desalination facilities, availability of water transfers, and other factors. Water management plans developed by urban and agricultural water suppliers provide information on these other existing and planned uses on a local scale. When developing UWMPs, urban water suppliers generally attempt to plan for redundancy in supplies with these other supplies (that in sum exceeds the community needs at any point in time) to ensure reliability in the face of shortages from droughts and other circumstances. To the extent that agricultural users can, they may also provide for redundancy in supplies, particularly for permanent crops.

Information from UWMPs regarding future use of other water supplies, along with examples of specific projects that recently have been implemented, is provided below. The discussion is not intended to comprehensively describe every ongoing effort in every region; rather, it is intended to provide some basic general information about how different regions may respond to reduced Sacramento/Delta surface supply. Additional information about other water supplies also is included in Section 7.20, *Utilities and Service Systems*, Section 7.4 *Agriculture and Forest Resources*, Section 7.22, *New or Modified Facilities*, and Section 8.5, *Municipal Water Supply Economic Effects*, in Chapter 8, *Economic Analysis and Other Considerations*.

6.6.2.1 Sacramento River Watershed

As described in Section 2.8, *Existing Water Supply*, water users in the Sacramento River watershed rely on local water supplies, groundwater, recycled water, CVP and SWP contracts, and inbasin water transfers and exchanges. Of the 8.1 MAF of total annual average water supplies to the Sacramento River watershed estimated using historical water deliveries data (Table 2.8-4 in Chapter 2, *Hydrology and Water Supply*), SacWAM results indicate that Sacramento/Delta surface water supplies account for approximately 5.3 MAF, including 4.6 MAF (88 percent) for agricultural uses, 0.5 MAF (9 percent) for municipal uses, and the remaining 0.2 MAF (4 percent) for wetland/refuge uses (Table 2.8-4). Average annual reductions in Sacramento/Delta supplies in the flow scenarios are estimated to range from 210 TAF in the 35 scenario to 1,842 TAF in the 75 scenario, representing a 3- to 23-percent reduction of total supplies and a 4- to 35-percent reduction of Sacramento/Delta supplies, respectively. Under the 55 scenario, estimated supply reductions are 606 TAF or 8 percent of total supplies and 11 percent of Sacramento/Delta supplies. Agricultural supplies are reduced by approximately 174, 511, and 1,602 TAF or 4, 11, and 35 percent of Sacramento/Delta supplies for the 35, 55, and 75 scenarios, respectively (Table 6.4-5). Municipal and industrial water supplies in the Sacramento River watershed are estimated to be reduced by approximately 15, 52, and 107 TAF or 3, 11, and 22 percent of municipal Sacramento/Delta supplies for the 35, 55, and 75 scenarios, respectively (Table 6.4-6).

Information for local planning sources, such as UWMPs, indicate that reductions in Sacramento/Delta supplies could be partially replaced by local groundwater pumping, groundwater storage and recovery, recycled water use, water transfers and exchanges, and agricultural and municipal water conservation. Desalination is not a viable option in this region due to lack of easy access to ocean water or brackish water.

Under baseline conditions, groundwater supplies account for about 2.7 MAF (33 percent) of the average annual water supply for the region, which includes 2.3 MAF for agricultural use, 0.39 MAF for municipal use, and 0.02 MAF for wetland/refuge use (Table 2.8-4). Groundwater levels may be lowered as a result of the proposed Plan amendments due to increased groundwater pumping and/or reduced incidental recharge in agricultural areas. It is possible that additional groundwater pumping in addition to current amounts could occur in the Sacramento River watershed to make up for reduced surface water supplies from the proposed Plan amendments, particularly in areas where groundwater supplies are generally high and accessible at shallow depths. In areas where groundwater pumping is already high and groundwater levels are declining or in areas with limited groundwater supplies (i.e., fractured-rock aquifers), it is not expected that reductions in Sacramento/Delta surface water supplies could be made up for through additional groundwater pumping. Because most groundwater subbasins in the Sacramento Valley are identified as high- or medium-priority subbasins pursuant to SGMA, it is likely that significant additional groundwater pumping could not occur on a regular basis to make up for the supply reductions. However, there may be significant additional conjunctive use of groundwater and surface water in the Sacramento River watershed and increases in localized uses of groundwater where that use comports with the requirements of SGMA. For example, the City of Sacramento is in the process of completing a multiphase municipal groundwater supply project, which will increase groundwater pumping capacity to 28 TAF/yr, a 5-TAF/yr increase from 2015 levels (City of Sacramento 2016). The City of Roseville is also developing a groundwater storage and recovery program to store surplus drinking water when precipitation is normal or above normal. The city received an operational permit for the aquifer storage and recovery program from the Central Valley Regional Water Board in 2013. As of 2015, six existing groundwater wells operated by the city have aquifer storage and recovery injection capability, and all future wells are planned to incorporate the same capability (City of Roseville 2016).

Approximately 20.3 TAF of recycled water is being used for various uses in the Sacramento River watershed (SWRCB 2015). Much of the recycled water that is used in the Sacramento River watershed is and has been used for landscape irrigation in Elk Grove since 2003 and there are plans to expand that use (Regional SAN 2014). In addition to meeting municipal landscape demands, reclaimed water could also be used for managed groundwater recharge in the Sacramento River watershed. Although recycled water is being used for agricultural purposes within the region, increased use of recycled water on agricultural lands that are far from municipal wastewater treatment plants likely is not a viable widespread option because of the high cost of installing transmission pipes and the pumping costs.

Significant amounts of water are being transferred among users in the Sacramento River watershed. These types of transfers are likely to continue under the proposed Plan amendments. However, the volume and composition of those transfers may change. Specifically, the proposed Plan amendments may reduce the overall amount of water available for transfer, which could diminish available supplies for transfer while increasing the value of those transfers thus incentivizing transfers, particularly transfers from low net revenue agricultural uses to municipal uses and high net revenue permanent crops. For example, within the Sacramento River watershed, significant amounts of transfers involve fallowing rice fields. Because there will be less water available for rice production under the proposed Plan amendments in some years, there could be fewer transfers. However, because the value of that water will be higher, there could be more transfers to uses with higher net revenues. Some regions in the Sacramento River watershed include limits on the amount of water that may be transferred that would limit significant additional expansion (PPIC 2012).

Various water conservation and efficiency efforts are underway in the Sacramento River watershed. For example, the Be Water Smart Program, sponsored by the Regional Water Authority Water Efficiency Program, includes 19 water providers, wastewater treatment facilities, and energy utilities spanning three different counties (CUWCC 2014). This regional partnership provides centralized water and energy efficiency information, offers a combined rebate, streamlines the rebate application process, and provides information about the nexus between energy and water programs. In addition, the Sacramento Valley Integrated Regional Water Management Plan (Sacramento River Settlement Contractors 2006) identified water efficiency measures for agriculture including canal lining or piping to reduce distribution system seepage and leakage, system automation and regulating reservoirs to reduce system spills, new groundwater production wells to expand conjunctive management capacity, and drainwater recycling. Grant and loan funding may be available for these types of water use efficiency efforts, including through programs such as the Agricultural Water Enhancement Program (AWEP). For example, the Anderson Cottonwood Irrigation District (ACID) Water Efficiency Improvement Project used a $2.8 million grant from AWEP to fund replacement of lateral ditches with underground pipelines to reduce water losses. These efficiency improvements enabled the water district to deliver water needed by customers despite mandatory water cutbacks during the drought in 2014 and 2015 (USDA NRCS 2011, 2015).

6.6.2.2 Delta Eastside Tributaries

Water users in the Delta eastside tributaries region rely heavily on groundwater for water supplies. Because a substantial amount of surface water in the Mokelumne River watershed is exported out of the region to the Bay Area region, local water use is less affected in the Delta eastside tributaries under the proposed Plan amendments than other regions.

Of the 986 TAF total annual water supply of the Delta eastside tributaries region estimated using historical water deliveries data (Table 2.8-5 in Chapter 2, *Hydrology and Water Supply*), SacWAM results indicate that Sacramento/Delta supplies account for approximately 205 TAF (22 percent), including 124 TAF (60 percent) for agricultural uses and 81 TAF (40 percent) for municipal uses (Table 2.8-5). Average annual reductions in Sacramento/Delta supply under the flow scenarios are estimated to be 20, 44, and 78 TAF (2, 4, and 8 percent of total supply) for the 35, 55, and 75 scenarios, respectively.

Based on available local planning information, such as UWMPs, reductions in Sacramento/Delta supply could be partially replaced by other surface water supplies, recycled water use, water transfers and exchanges, and municipal water supply conservation. Desalination is not a viable option in this region due to lack of easy access to ocean water or brackish water.

Increased local groundwater pumping is not anticipated to be viable in this region. Reductions in Sacramento/Delta supply could result in reduced groundwater levels if groundwater recharge is reduced in agricultural areas and if there are increases in groundwater pumping. The Delta eastside tributaries region relies heavily on groundwater (on average 78 percent of the total supply according to SacWAM simulations), with several basins already overutilized. The Eastern San Joaquin subbasin, which underlies much of the valley floor portion of the Delta eastside tributaries region, is identified as critically overdrafted by the SGMA 2019 Basin Prioritization. This makes additional pumping to offset reduced surface supply less likely unless groundwater basins are actively recharged and sustainably managed. Several substantial areas of depressed groundwater elevations (cone of depression or localized overdraft) already exist in the Delta eastside tributaries region, centered between Elk Grove and Stockton.

Municipal water users in the Delta eastside tributaries region rely on several water sources. The City of Stockton is the largest urban water user in the region and has a portfolio of local supplies that include purchases from neighboring water districts, diversion from the Delta, and groundwater. Because of existing groundwater overdraft, water suppliers in the region have diversified their supply sources and reduced their reliance on groundwater in recent years, including using surface water supplies from New Melones Reservoir, accessing supplies from the Delta through the Stockton Delta Water Supply Project, and implementing groundwater storage and recovery projects such as the Farmington Groundwater Recharge Program (SEWD 2016). Other decentralized stormwater capture and groundwater recharge programs also could improve aquifer conditions.

The upper watersheds in the Delta eastside tributaries region are sparsely populated and relatively undeveloped, and water use in the upper watersheds is considered low. The upper watersheds in the region contain several water suppliers, such as Calaveras County Water District. Jenkinson Lake, the only development on the Cosumnes River, is operated by the El Dorado Irrigation District. El Dorado Irrigation District currently transfers about 17 TAF/yr from Jenkinson Lake for use in the American River watershed, and additional opportunities for water transfers may also exist. However, water suppliers in the upper watersheds in the region may be unable to receive water transfers from other water users due to infrastructure limitations.

Approximately 4 TAF/yr of recycled water is used in the region (SWRCB 2015). Approximately 863 acre-feet per year of recycled water is used in Amador County for golf course and cattle grazing. Calaveras County Water District uses recycled water to irrigate golf courses and plans to expand its use of recycled water to include agricultural uses and other public activities (RMC Water and Environment 2013). There are likely additional opportunities to expand the use of recycled water, and municipal water use efficiency could improve as additional conservation measures are implemented. For instance, a North San Joaquin Water Conservation District water use efficiency project will line 7 miles of concrete pipe with PVC pipe, replace 103 turnouts with modern flow meters and pressure-controlled connections, and incorporate an automated scheduling and

Supervisory Control and Data Acquisition system. The project is expected to save 2,780 acre feet of water annually over the 30-year life of the project.

6.6.2.3 Delta

The Delta is less urbanized than adjacent regions, with relatively small municipal demand. Surface and groundwater supplies are available for agricultural irrigation, but surface water sources account for most of the region's agricultural water supply.

Of the 1.4 MAF total annual water supply to demands in the Delta region (Table 2.8-6 in Chapter 2, *Hydrology and Water Supply*), SacWAM modeling results indicate that Sacramento/Delta supplies account for approximately 1.2 MAF, including 1.14 MAF (98 percent) for agricultural uses and approximately 0.02 MAF (2 percent) for municipal uses (Table 2.8-6). For the flow scenarios, SacWAM modeling estimates very small reductions in water supply within the Delta, with average annual reductions of 0, 4, and 20 TAF (0 percent, 0 percent, and 1 percent of total supply), for the 35, 55, and 75 scenarios, respectively. However, as discussed in Section 6.4, *Changes in Surface Water Supply*, SacWAM results do not reflect actual water supply reductions that may occur if the frequency in which insufficient natural and abandoned flows to meet Delta and other riparian diversions increases under the proposed Plan amendments. Groundwater supplies contribute very little (approximately 0.06 MAF or 4 percent) of the average annual water supply for the region, and groundwater levels are not expected to change significantly due to actions that may be taken in response to the proposed Plan amendments (see Section 7.12.2, *Groundwater*).

Approximately 11 TAF of recycled water is used each year in the Delta (SWRCB 2015), primarily for agricultural irrigation or for wetlands and natural systems. Based on available local planning information, reductions in Sacramento/Delta supply could be replaced in part by increased recycled water use, water transfers and exchanges, and municipal water supply conservation.

There are two municipal areas within the Delta region that can, and already are, using recycled water: communities located along Highway 4 (Antioch to Brentwood) and communities located in the Highway 205 area (Mountain House to Tracy). The area west of Tracy has supply water that is high in salts. Resulting recycled water supplies are high in salinity and may be only marginally beneficial for agricultural use. This recycled water still could be used effectively in habitat areas or for other uses. The communities around Antioch and Oakley are recycling at about 50 percent. Much of the water is used in industrial reuse, while a lower percentage is used for eco-friendly agriculture irrigation as well as golf courses and landscaping.

Agricultural water use efficiency in the Delta is unique in that the Delta is at the lowest level, so no other communities are dependent on groundwater replenishment in this area. Reducing agricultural water use in some areas also reduces groundwater recharge rates. However, in the Delta, groundwater continues to recharge within the Delta. Permanent crops in the Delta tend to be in areas that are well drained, which may lend themselves well to microspray or types of drip irrigation.

6.6.2.4 San Francisco Bay Area

The Bay Area region relies substantially on imported water sources and groundwater storage and recovery exchange agreements. Of the 1.3 MAF total annual water supply of the Bay Area region (Table 2.8-7 in Chapter 2, *Hydrology and Water Supply*), SacWAM modeling results indicate

Sacramento/Delta supplies account for approximately 698 TAF (56 percent) of the region's total supplies under the baseline condition (Table 2.8-7); the vast majority is for municipal and industrial supply (670 TAF for municipal uses and 27 TAF for agricultural use). Average annual reductions in Sacramento/Delta supply under the flow scenarios are estimated to range from 66 to 316 TAF (from 5 to 25 percent of total supply) for the 35 and 75 scenarios, respectively, with a 180-TAF reduction under the 55 scenario (14 percent of total supply). Reductions in deliveries are not uniform, and some water users would be affected more significantly by reduced Sacramento/Delta supplies. For example, in the 55 scenario, estimated annual average supply reductions to Bay Area communities are 96 TAF (45 percent) through the Mokelumne Aqueduct to EBMUD, 4 TAF (8 percent) through the North Bay Aqueduct, 33 TAF (62 percent) through the Putah South Canal, 39 TAF (28 percent) through the South Bay Aqueduct, and no reduction expected through the Contra Costa Canal.

Groundwater supplies constitute approximately 260 TAF (21 percent) of the average annual water supply for the region, which includes 76 TAF for agricultural use and 184 TAF for municipal use (Table 2.8-7). Several Bay Area agencies have both a history of effort and plans for expanding the use of groundwater management to include purposeful recharge of both local and imported waters for storage and reuse. They also utilize storage in groundwater banks in the southern San Joaquin Valley through exchange agreements. For example, Valley Water stores water in Semitropic Groundwater Bank via an exchange program and is planning increased use of managed groundwater recharge, including for indirect potable reuse of recycled water (SCVWD 2016).

A review of Bay Area UWMPs indicate that reliance on imported water and aquifer storage and recovery exchange agreements will continue, but future efforts among wholesale water providers will expand local storage, including both surface reservoirs and groundwater recharge, and evaluation of brackish water desalination (SCVWD 2016, EBMUD 2016).

Some reductions in municipal water supplies as a result of the proposed Plan amendments may be replaced with groundwater. However, the region is unlikely to see a significant increase in new groundwater development, based on the actions and proposed plans of the area's water agencies serving the vast majority of the population. Instead, the agencies are working together in a planning effort known as Bay Area Regional Reliability (BARR), to identify projects and processes to enhance water supply reliability across the region. Potential projects include interagency interties and pipelines, treatment plant improvements and expansion, groundwater management and recharge, potable reuse, desalination, and water transfers (SCVWD 2016). In 2012, CCWD expanded its Los Vaqueros Reservoir from 100,000 to 160,000 acre-feet, increasing reliability of Sacramento/Delta water supplies for water providers within the Bay Area to help meet municipal water demands during drought periods and emergencies (CCWD 2016). The region already utilizes 41.5 TAF of recycled water, and DWR identifies potentially 23.1 TAF/yr of additional recycled water. Municipal water efficiency is already very high in this region, so the extent of water savings that could be achieved with additional conservation measures is unclear.

Compared to other regions, per-capita municipal water use in the Bay Area region is relatively low, and the region has a history of recycled water use. High water rates, cool climate, small lot sizes, and high-density developments contribute to relatively low per-capita municipal water use (^DWR 2014). Recycled water is used for many applications in the Bay Area, including agricultural irrigation, landscape irrigation, commercial and industrial purposes, and wetland replenishment.

The Bay Area region currently uses some desalinated water supplies and may expand the use of desalinated water in the region. Alameda County Water District's Newark Desalination Facility opened in 2003 and receives water from the Niles Cone Groundwater Basin, which contains some brackish water due to seawater intrusion. The 2010 production capacity of the desalination facility was 10 million gallons per day (mgd) (^DWR 2014). In addition, CCWD, EBMUD, the San Francisco Public Utilities Commission, Valley Water, and Zone 7 are jointly exploring a regional desalination project that would provide an additional water source for the region (Bay Area Regional Desalination Project). However, ocean desalination and brackish desalination remain high-cost measures (ocean desalination is higher cost than brackish desalination) compared to other sources of supply, including purchased imports from other regions.

The partnership between Solano County Water Agency and its member cities is another example of collaboration to achieve greater water savings. Solano County Water Agency manages a countywide regional Residential Water Assistance Program in conjunction with its member cities. Solano County Water Agency provides the program staffing and the cities share in the operating cost. The cities compile the list of high water users because Solano County Water Agency as a wholesaler does not have access to individual water use records. Notification letters are individually customized to suit the needs of each city (CUWCC 2014).

The Bay Area Regional High-Efficiency Clothes Washer and Energy Rebate Program was offered in the region. Water agencies worked with PG&E to provide water and energy rebates. There were 12 public water agencies in this program. From 2008 to 2010, the agencies provided over 10,000 clothes washer rebates, with a total of 9,952 AF of water savings, and over 28,948,731 kilowatt-hours of energy savings. This program was partially funded through DWR Proposition 50 grant funds (CUWCC 2014).

6.6.2.5 San Joaquin Valley

The sources of water supply for the San Joaquin Valley include the San Joaquin River, southern Sierra Nevada tributaries to the San Joaquin River and Tulare basin, groundwater, and imports from the Sacramento/Delta watershed via the CVP and SWP. Area water districts and agricultural irrigators have implemented agricultural conservation measures such as canal lining and irrigation water efficiency improvements. Municipalities in the region rely on water from groundwater, and some have contracts or agreements with water districts serving both agriculture and municipalities. However, many portions of the San Joaquin Valley have overdrafted aquifers, and long-term viability of groundwater basins is a concern.

The average annual total water use in the San Joaquin Valley was approximately 18.4 MAF for the 2005 to 2015 period (Table 2.8-8 in Chapter 2, *Hydrology and Water Supply*). Of the 18.4 MAF total annual water supply of the San Joaquin Valley, Sacramento/Delta supplies accounted for approximately 2.8 MAF (15 percent) under the baseline condition as estimated by SacWAM, including approximately 2.4 MAF for agricultural use, 0.1 MAF for municipal use, and the remaining 0.3 MAF for wetland and refuge uses (Table 2.8-8). SacWAM estimates that average annual reductions in Sacramento/Delta supply under the flow scenarios would range from 38 to 1,315 TAF (0 to 7 percent of total supply) for the 35 and 75 scenarios, respectively, with a 379-TAF reduction under the 55 scenario (13 percent of Sacramento/Delta supply and 4 percent of total supply). Groundwater supplies constitute approximately 10.1 MAF (55 percent) of the average annual water use for the region, which includes 9.0 MAF for agricultural use, 823 TAF for municipal use, and 251 TAF for wetland and refuge uses (Table 2.8-8).

Based on available local planning information, such as UWMPs, reductions in Sacramento/Delta supply could be partially replaced by storm water capture for groundwater storage and recovery, additional water recycling, and agricultural water conservation. Examples are provided in the following discussion.

Agricultural water users can rely on several sources of water. For example, Westlands Water District has CVP contracts for approximately 1.2 MAF (Reclamation 2016) although actual CVP deliveries are typically lower than the maximum contract amount. Growers in the district attempt to make up water demand deficits with groundwater pumping, water transfers, user-acquired supplies, other district supplies, and land fallowing. Groundwater use tends to be higher during drier periods when surface water is generally less available.

In the southern San Joaquin Valley, managed recharge of water in underground aquifers has been increasing, with the majority of third-party water banking taking place in Kern County due to its geography and groundwater basin characteristics. Sources of water used to recharge a groundwater basin include surface water, excess precipitation runoff, and recycled municipal wastewater. Several groundwater banking projects in this area, such as the Kern Water Bank, store surface water supplies when it is available. Occupying about 20,000 acres, the water bank contains 7,000 acres of recharge ponds which, on average, recharge at a rate of 0.3 foot per day. The amount of storage in the San Joaquin Valley's groundwater basin readily accessible to the Kern Water Bank is estimated to be about 1.5 MAF. Each of the water bank's 85 recovery wells can produce about 5 cfs (2,250 gallons per minute) of water. In a 10-month recovery program, about 240 TAF of water could be recovered. If water is recovered in successive years, well production and annual recovery will decline (Kern Water Bank Authority n.d.).

Participating water districts use groundwater recharge to provide water to the groundwater banks, and later call on the stored water to be extracted for use. Multiple water sources, including local water supplies and Sacramento/Delta supply, can be stored in these groundwater banks. Because some of the recharge of groundwater banks and exchanges in Kern County are supplied by Sacramento/Delta supplies, reductions in this surface water could affect the water banks. This could affect planning for future increases in the volume of water extracted from groundwater banks. The Fresno-Clovis Stormwater Retention Project is designed to detain and infiltrate as much precipitation runoff as possible into the underlying groundwater aquifer (FMFCD 2013), while removing most conventional storm water pollutants.

Friant Division contractors do not directly receive Sacramento/Delta water supply under Friant Division water service contracts. However, if Reclamation is unable to deliver the entire allocated amount to the San Joaquin River exchange contractors from Sacramento/Delta supply, Reclamation is required to release additional water from Friant Dam to meet these entitlements. This "call" on Friant Division water comes at the expense of the lower-priority water right holders in the Friant Division service area who would otherwise receive their allotment from water stored behind Friant Dam. Communities that rely on groundwater for drinking water supply in the San Joaquin Valley region have been facing challenges from declining water levels under the baseline condition, with critical shortages or dry wells occurring in some areas during prolonged drought periods. During the 2012-2016 drought, there was a significant increase in groundwater pumping due to reductions in surface water deliveries as farmers turned to groundwater to meet their irrigation demands (Mavens Notebook 2020). Subsidence in the area, caused by pumping excess groundwater faster than it can be recharged, has caused parts of the Friant-Kern canal to subside (or sink). The diminished capacity in the canal has resulted in reduced water deliveries in certain water years

(Reclamation 2022, Porterville Recorder 2021). The frequency and severity of these challenges likely would increase as a result of the proposed Plan amendments, even with no replacement groundwater pumping.

Several DACs are wholly reliant on groundwater for their water supply, and reductions in Friant Division deliveries ultimately reduce their supplies. For example, in 2014 and 2015, because of drought conditions, there was no allocation to Friant Division water contractors for those contract years. Because of insufficient water supplies in the Friant Division service area during this period, many domestic groundwater wells went dry (Friant Water Authority 2016). This contributed to a concentration of impacts that resulted in a first-ever major state assistance effort to provide permanent water supplies to private well owners by connecting them to public water systems Many of the wells have dried up in farming areas of the San Joaquin Valley, where farms have turned to pumping more from wells as water supplies from rivers have dwindled (LA Times 2021). In 2021, the state received reports of 969 dry household wells in California, a tenfold increase from the previous year.

Friant Water Authority also has a 60-TAF contract for delivery of municipal water to the City of Fresno, which could be reduced if a call was made on the Friant Division for San Joaquin River exchange contractor supply. The City of Fresno plans to use 25 TAF/yr of recycled water to irrigate open spaces, parks, street medians, and golf courses, and at groundwater recharge facilities.

Water users in the San Joaquin Valley region are anticipated to use additional recycled water supplies in the future. The region already utilizes 116 TAF of recycled water, and DWR identifies potentially 25 TAF/yr of additional recycled water. One water recycling project pursued by the San Luis and Delta Mendota Water Agency will upgrade the irrigation distribution system in order to reclaim and recirculate 5 TAF/yr of agricultural drainage water. The project includes replacement of intertie pumps to increase capacity (CNRA 2017). The total cost for this project is $3.6 million, with 42 percent federal contribution, 41 percent local contribution, and 17 percent Proposition 84, Integrated Water Management fund contribution.

The North Kern Water District provides surface water and groundwater to agricultural customers. The District has received up to $2 million in grants or loans to fund projects to concrete-line portions of the Calloway Canal to eliminate canal seepage losses in several miles of unlined Calloway Canal in order to improve conveyance efficiency, saving over 2.4 TAF annually, and avoiding the loss of water to the underlying groundwater, which is contaminated with pollutants (North Kern Water Storage District 2016).

6.6.2.6 Central Coast

The Sacramento/Delta water supplied to the Central Coast represents a relatively small amount of the region's total water supplies, primarily to San Luis Obispo and Santa Barbara Counties. These counties primarily depend on local surface water and groundwater sources for municipal water and only recently have started using Sacramento/Delta supply. Of the 1.3 MAF total annual water supply of the Central Coast region (Table 2.8-9 in Chapter 2, *Hydrology and Water Supply*), Sacramento/Delta supplies account for approximately 86 TAF (6 percent) under the baseline condition as estimated by SacWAM, including approximately 49 TAF for municipal uses and approximately 37 TAF for agriculture use (Table 6.4-1). Average annual reductions in Sacramento/Delta supply under the flow scenarios are estimated to range from 2 to 49 TAF (from 0-

to 4-percent reduction in total supply) for the 35 and 75 scenarios, respectively, with a 19-TAF reduction under the 55 scenario (1 percent reduction in total supply).

Groundwater supplies constitute approximately 1,164 TAF (87 percent) of the average annual water supply for the region, which includes 968 TAF for agricultural use and 196 TAF for municipal uses (Table 2.8-9). There is potential for localized effects on groundwater levels if water agencies in southwestern San Luis Obispo County and northwestern and southern Santa Barbara County offset reduced Sacramento/Delta supplies with substitute groundwater pumping.

San Luis Obispo County primarily relies on local surface water supplies, groundwater, and groundwater storage and recovery agreements. Sacramento/Delta supply is a small portion of the county's water portfolio (County of San Luis Obispo 2014). By 2035, the County anticipates increased use of groundwater, local surface water supplies, recycled water, and groundwater storage and recovery agreements (County of San Luis Obispo 2014).

Santa Barbara County primarily relies on groundwater and local surface water, including supplies from Lake Cachuma, Sacramento/Delta supply, and recycled water. Water supplies are enhanced by groundwater storage and recovery projects. Local water supplies, including groundwater and the Cachuma Project, provide a majority of the water to the region (County of Santa Barbara 2015). The City of Santa Barbara is exploring options for future water supply reliability, including stormwater capture for groundwater storage and recovery, collaborative recycled water projects, additional imported SWP water, and reoperation of the City of Santa Barbara's desalination facility (County of Santa Barbara 2015).

The Central Coast Water Authority (CCWA), a water wholesaler, provides SWP water to member agencies in San Luis Obispo and Santa Barbara Counties. To increase water supply reliability, CCWA has engaged in voluntary water exchanges and transfers with water districts in Kern County and other locations in the Central Valley with access to the SWP. CCWA has also been considering opportunities for groundwater banking and expanded use of desalination at a reactivated plant in Santa Barbara and one in San Luis Obispo County. CCWA is exploring opportunities to exchange San Luis Obispo County Flood Control and Water Conservation District's unallocated SWP water for use in Santa Barbara County (CCWA 2016).

6.6.2.7 Southern California

Southern California water sources include imported supplies from several sources, local surface water supplies and groundwater, as well as some recycled and desalinated water supplies. Sources of imported supplies to the Southern California region include the Colorado River, the Sacramento/Delta watershed via the SWP, and the Owens Valley/Mono Basin in the Eastern Sierra Nevada. In addition, water conservation and water use efficiency practices have been emphasized in the South Coast Hydrologic Region. Of the 9.45 MAF total annual water supply to the Southern California region (Table 2.8-10 in Chapter 2, *Hydrology and Water Supply*), Sacramento/Delta supplies account for approximately 1.7 MAF (18 percent) of the region's total supplies under the baseline condition as estimated by SacWAM, with the majority going toward municipal use (1,661 TAF for municipal uses and 14 TAF for agricultural use) (Table 2.8-10). Average annual reductions in Sacramento/Delta supply under the flow scenarios are estimated to range from 92 to 918 TAF (from 1- to 10-percent reduction in total supply) for the 35 and 75 scenarios, respectively, with a 450-TAF reduction under the 55 scenario (5 percent reduction in total supply).

For inland Southern California municipalities, other water supplies account for the majority of the municipal supply, including local groundwater and groundwater storage and recovery. For these agencies, Sacramento/Delta supply contributes a small fraction of their overall municipal supply (SBVMWD 2017). One of the primary water management strategies in the San Bernardino Valley is to store imported water when it its available so that it can be used during drought periods. Water stored can range from 91 to 155 TAF/yr, depending on climatic conditions (SBVMWD 2018). Sacramento/Delta supply provides less than half of Metropolitan Water District's (MWD) municipal supply, as MWD also relies upon Colorado River water, groundwater, and water from the Los Angeles Aqueduct in its service area (MWD 2016). MWD has a large regional storage portfolio that includes both dry-year and emergency storage capacity. It enables capture of surplus amounts of water in normal and wet years so that stored water can be used during conditions where additional water supplies are needed to meet demands (MWD 2016).

Groundwater supplies constitute 2,382 TAF (25 percent) of the average annual water supply for the region, which includes 792 TAF for agricultural use and 1,590 TAF for municipal uses (Table 2.8-10). There could be localized areas of effects on groundwater levels if water agencies offset reduced Sacramento/Delta supplies with substitute groundwater pumping; however, major new groundwater supply development is unlikely in Southern California except in limited circumstances. Many groundwater basins in this region are adjudicated, and many coastal or estuarine areas have existing overdraft issues. In some basins, groundwater levels remain relatively stable, indicating that seawater is replacing the freshwater deficit (^DWR 2014).

Groundwater storage and recovery projects are in use, and others are being developed. MWD reports that up to 6.8 TAF has been stored in groundwater storage and recovery facilities as of 2015 (MWD 2016). The following are some of the projects that are being pursued or implemented in the region. The Long Beach Conjunctive Use Project would store up to 13 TAF of imported water, and the Foothill Area Groundwater Storage Project would store up to 9 TAF of imported water. The Cactus Basin Recharge Project would recharge excess Sacramento/Delta supply. The Riverside North Aquifer Storage and Recovery Project is a proposed project to capture up to 12.8 TAF/yr of storm water for groundwater storage and recovery. The Santa Ana River Enhanced Recharge Project would capture up to 80 TAF/yr of precipitation for groundwater storage and recovery. (SBVMWD 2017.)

The region already utilizes 465.4 TAF of recycled water, and additional planning and investment are taking place (DWR identifies up to 101 TAF/yr additional recycled water). Palmdale Water District anticipates their only supply increase to come from additional water recycling (Palmdale Water District 2016). Member agencies of the San Bernardino Valley Municipal Water District anticipate that most of their future increases in water supply will come from water recycling (SBVMWD 2017). In 2015, 158 TAF of recycled water was used by water agencies in Los Angeles and Orange Counties for groundwater storage and recovery (MWD 2016). In 2014, MWD increased the financial incentives under its Local Resources Program for agencies to develop recycled water. MWD also established the On-Site Retrofit Pilot Program to provide rebates to customers that convert their irrigation and industrial system from potable water to recycled water. In addition, MWD established the Reimbursable Services Program to provide technical and construction assistance to its member agencies for local project development. Under this program, MWD advances funds and is reimbursed by the agency (MWD 2016). The City of San Diego is pursuing a water recycling project that will purify recycled water to drinking water standards using advanced water purification treatment processes. The first phase of the project is scheduled to produce up to 15 mgd of water by

2025. A long-term goal of 83 mgd is targeted for 2035, which would constitute approximately one-third of San Diego's future drinking water supply (City of San Diego 2016).

MWD anticipates that municipal water conserved due to changes in water efficiency requirements for plumbing fixtures is expected to increase by over 250 TAF by 2030 (MWD 2016).

The Los Angeles-Ventura County Agricultural Water Use Efficiency Program implemented by Ventura County will analyze and implement irrigation system improvements for increased agricultural efficiencies. The total cost for this project is $1.7 million. Nearly 100 percent of the funding for this project is from Proposition 84, Integrated Regional Management funds (CNRA 2017).

The South Coast Water Agency's Doheny Desalination Project (5–16 TAF/yr) is in the planning and permitting stage (South Coast Water District 2023).The Carlsbad Seawater Desalination Project, operated by the San Diego County Water Authority (SDCWA), is operational, and is expected to contribute about 56 TAF/yr in water supplies. Other seawater desalination projects in the region are in planning stages. (MWD 2016)

6.7 References Cited

6.7.1 Common References

^California Department of Water Resources (DWR). 2014. California Water Plan Update 2013. https://water.ca.gov/Programs/California-Water-Plan/Water-Plan-Updates. Accessed May 23, 2017. Volume 3, Chapter 3.

^National Marine Fisheries Service (NMFS). 2009. *Biological Opinion and Conference Opinion on the Long-Term Operations of the Central Valley Project and State Water Project*. June 4. Endangered Species Act Section 7 Consultation. Southwest Region.

^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), (Biological Opinion)*. Available: http://wwwfws.gov/sacramento/es/documents/swp-cvp_ops_bo_12-5_final_ocr.pdf.

^U.S. Fish and Wildlife Service (USFWS). 2019. *Biological Opinion for the Reinitiation of Consultation on the Coordinated Operations of the Central Valley Project and State Water Project, (Biological Opinion)*.

6.7.2 Section References

California Department of Food and Agriculture (CDFA). 2023. State Water Efficiency & Enhancement Program. Available: https://www.cdfa.ca.gov/oefi/sweep/. Accessed: September 1, 2023.

California Department of Water Resources (DWR). 2018. Water Available for Replenishment (WAFR Report). WAFR Report, 2017

California Department of Water Resources (DWR). 2021. Urban Water Management Plan Guidebook 2020. Final. March. Available: https://water.ca.gov/-/media/DWR-Website/Web-

Pages/Programs/Water-Use-And-Efficiency/Urban-Water-Use-Efficiency/Urban-Water-Management-Plans/Final-2020-UWMP-Guidebook/UWMP-Guidebook-2020---Final-032921.pdf

California Department of Water Resources (DWR). 2022. 2021 Delivery Capability Report. Available: https://water.ca.gov/Library/Modeling-and-Analysis/Central-Valley-models-and-tools/CalSim-3/DCR2021

California Department of Water Resources (DWR). 2023. Available: https://data.ca.gov/dataset/dayflow.

California Department of Water Resources (DWR) and California Department of Food and Agriculture (CDFA). 2017. *Agricultural Water Use Efficiency and State Water Efficiency and Enhancement Program*.

California Department of Water Resources (DWR), State Water Resources Control Board, California Public Utilities Commission, California Department of Food and Agriculture, and California Energy Commission. 2017. *Making Water Conservation a California Way of Life – Implementing Executive Order B-37-16*. Final Report April 2017.

California Urban Water Conservation Council (CUWCC) (now California Water Efficiency Partnership). 2014. Residential Best Management Practices Implementation Guidebook. November 21. http://www.cuwcc.org/Portals/0/Document%20Library/Resources/Publications/BMP%20Guidebooks/Residential%20BMP%20Guidebook.pdf?timestamp=1416507756791

California Department of Water Resources, State Water Resources Control Board, California Bay-Delta Authority, California Energy Commission, California Department of Public Health, California Public Utilities Commission, California Air Resources Board. 2013. "20×2020 Water Conservation Program Final Report: Landscape Water Use." CA Water Plan Update 2013, vol 4.

California Natural Resources Agency (CNRA). Report to the Legislature on the 2012-2016 Drought. 2021. Available: https://drought.unl.edu/archive/assessments/CNRA-Drought-Report-final-March-2021.pdf Accessed: March 8, 2023.

California Urban Water Conservation Council (CUWCC). 2014. *Residential Best Management Practices Implementation Guidebook*.

Central Coast Water Authority (CCWA). 2016. *2015 Urban Water Management Plan.* June 2016.

Contra Costa Water District (CCWD) 2016. *2015 Urban Water Management Plan for the Contra Costa Water District*. June 2016.

City of Roseville. 2016. *2015 Urban Water Management Plan*. Final. Prepared by West Yost Associates. May. Available: https://cdnsm5-hosted.civiclive.com/UserFiles/Servers/Server_7964838/File/Government/Departments/Environmental%20Utilities/Water/City%20of%20Roseville%20Final%202015%20UWMP.pdf.

City of Sacramento. 2016. *2015 Urban Water Management Plan*. Final. Prepared by West Yost Associates. June. Sacramento, CA.

City of San Diego. 2016. *2015 City of San Diego Urban Water Management Plan*. Final. June. San Diego Public Utilities. San Diego, CA.

County of San Luis Obispo. 2014. *San Luis Obispo County 2014 Integrated Regional Water Management Plan.* Prepared with GEI Consultants and support from Fugro Consultants, Dudek, Gutierrez Consultants, and Hollenbeck Consulting. July.

County of Santa Barbara. 2015. *Long-Term Supplemental Water Supply Alternatives Report*. Prepared by RMC Water and Environment. December. Santa Barbara, CA. Available: https://projectspace.icfi.com/bis/ep-swrcb-phases/PhaseII/09%20Admin%20Draft%20Staff%20Report/06_ModelResults_ChangesInWater/Admin%20Record/County%20of%20Santa%20Barbara%202015%20LongTermWaterSupplyReport.pdf.

East Bay Municipal Utility District. (EBMUD). 2016. *Urban Water Management Plan 2015*. Water Resources Planning Division. July. Oakland, CA.

Eyring, V., S. Bony, G. A. Meehl, C. A. Senior, B. Stevens, R. J. Stouffer, and K. E. Taylor. 2023. Overview of the Coupled Model Intercomparison Project Phase 6 (CMIP6) Experimental Design and Organization. Geosci. Model Dev., 9, 1937–1958, https://doi.org/10.5194/gmd-9-1937-2016, 2016. Available: https://gmd.copernicus.org/articles/9/1937/2016/.

Friant Water Authority. 2016. Friant Division Receives First Water Allocation Since 2013. Friant Water Line. March 18. Available: http://friantwaterline.org/friant-division-receives-first-water-allocation-since-2013/ Accessed: March 8, 2023

Kern Water Bank Authority. n.d. *FAQs*. Available: http://www.kwb.org/index.cfm/fuseaction/Pages.Page/id/352. Accessed: March 26, 2021.

Los Angeles Times. 2021. State tells San Joaquin Valley agencies that groundwater plans are flawed. Available: https://www.latimes.com/environment/story/2021-12-11/state-cites-flaws-in-san-joaquin-valley-groundwater-plans# Accessed: March 8, 2023.

Maven's Notebook. 2020. Enviro Docs: A look at the Friant Kern Canal Middle Reach Capacity Correction Project. May 27. Available: https://mavensnotebook.com/2020/05/27/enviro-docs-a-look-at-the-friant-kern-canal-middle-reach-capacity-correction-project/. Accessed: March 8, 2023

Metropolitan Water District of Southern California (MWD). 2016. *2015 Urban Water Management Plan*. June. Available: http://www.mwdh2o.com/AboutYourWater/Planning/Planning-Documents. Accessed: November 19, 2018.

National Marine Fisheries Service (NMFS). 2000. *Biological Opinion for U.S. Bureau of Reclamation Operation and Maintenance of the Cachuma Project on the Santa Ynez River in Santa Barbara County, California,* September 11, Endangered Species Act Section 7 Consultation. Southwest Region.

North Kern Water Storage District. 2016. *Calloway Canal and Water Delivery Improvements*. Application for Agricultural Water Use Efficiency 2015 Grant. March.

Pacific Institute and Natural Resources Defense Council (NRDC). 2014. *Agricultural Water Conservation and Efficiency Potential in California.* Issue Brief. IB: 14-05-F. June. Available: https://www.nrdc.org/sites/default/files/ca-water-supply-solutions-ag-efficiency-IB.pdf. Accessed: August 31, 2023.

Palmdale Water District. 2016. *Final 2015 Urban Water Management Plan for Palmdale Water District*. Prepared by Kennedy/Jenks Consultants. June.

Public Policy Institute of California (PPIC). 2023. Water Use in California. Fact Sheet. April. Prepared by Jeffrey Mount, Ellen Hanak, and Caitlin Peterson. Available: https://www.ppic.org/wp-content/uploads/jtf-water-use.pdf. Accessed: September 1, 2023.

Public Policy Institute of California (PPIC). 2012. California's Water Market, by the Numbers: Update 2012. Prepared by Ellen Hanak and Elizabeth Stryjewski. November.

RMC Water and Environment. 2013. *Mokelumne/Amador/Calaveras Integrated Regional Water Management Plan Update*. Accessed: http://www.umrwa.org/uploads/Vol_1_-_Final_MAC_Plan_Update_4feb13.pdf.

Sacramento Regional County Sanitation District (Regional San). 2014. *Regional San Water Recycling Program, 10 Year Update Report (2004–2014)*. Available: https://www.regionalsan.com/sites/main/files/file-attachments/2014_10_year_update__final.pdf. Accessed: December 28, 2017.

Sacramento River Settlement Contractors. 2006. *Sacramento Valley Regional Water Management Plan*. Prepared in cooperation with U.S. Bureau of Reclamation. January 2006.

San Bernardino Valley Metropolitan Water District (SBVMWD). 2017. *2015 San Bernardino Valley Regional Urban Water Management Plan*. Prepared by Water Systems Consulting, Inc. Amended June 2017.

Santa Clara Valley Water District (SCVWD). 2016. *2015 Urban Water Management Plan*. Report Only. May 2016. Santa Clara, CA.

Stockton East Water District (SEWD). 2016. *Draft 2015 Urban Water Management Plan*, May 2016.

State Water Contractors (SWC). 2015. State Water Contractors' Complaint against Unlawful Diversion of State Water Project Stored Water Supplies. June 16. Available: http://waterboards.ca.gov/water_issues/programs/delta_watermaster/docs/vwc15/swc_complaint.pdf.

State Water Resources Control Board (SWRCB). 2015. *2015 Municipal Wastewater Recycling Survey*. Water Recycling Funding Program (WRFP). Available: chrome-extension://efaidnbmnnnibpcajpcglclefindmkaj/https://www.waterboards.ca.gov/water_issues/programs/recycled_water/docs/2021/2015_MunicipalWastewaterRecyclingSurvey.pdf. Accessed: August 23, 2023.

State Water Resources Control Board (SWRCB). 2018a. *Resolution No 2018-0057—Adoption of an Amendment to the Policy for Water Quality Control for Recycled Water and the Staff Report with Substitute Environmental Documentation.* Available: https://www.waterboards.ca.gov/board_decisions/adopted_orders/resolutions/2018/rs2018_0057.pdf. Accessed: August 31, 2023.

State Water Resources Control Board (SWRCB). 2018b. *Water Quality Control Policy for Recycled Water.* Adopted December 11, 2019. Effective April 8, 2019. Available: https://www.waterboards.ca.gov/board_decisions/adopted_orders/resolutions/2018/121118_7_final_amendment_oal.pdf. Accessed: August 31, 2023.

State Water Resources Control Board (SWRCB). 2022a. *Volumetric Annual Reporting of Wastewater and Recycled Water—2021 Calendar Year Results.* Available: https://www.waterboards.ca.gov/water_issues/programs/recycled_water/docs/2022/volumetric-infographic-2021.pdf. Accessed: August 31, 2023.

State Water Resources Control Board (SWRCB). 2022b. *Summary of Results from the 2021 Volumetric Annual Report of Wastewater and Recycled Water in California.* Agenda Item 5. Division of Water Quality. August 2. Available: https://www.waterboards.ca.gov/water_issues/programs/recycled_water/docs/2021/2021-var-board-info-item.pdf. Accessed: August 31, 2023.

State Water Resources Control Board (SWRCB). 2022c. Index of Water Conservation Regulations. Last updated: August 4, 2022. Available: https://www.waterboards.ca.gov/water_issues/programs/conservation_portal/regs/.

State Water Resources Control Board (SWRCB). 2023. Draft Staff Framework for the Making Conservation a California Way of Life Regulation (Proposed Regulatory Framework). March 15. Available: https://www.waterboards.ca.gov/conservation/regs/docs/2023/summary-of-reg-framework.pdf.

U.S. Bureau of Reclamation (Reclamation). 2016. *Central Valley Project (CVP) Water Contractors*. Bureau of Reclamation Mid-Pacific Region. Revised March 2016. Available: www.usbr.gov/mp/cvp-water/docs/latest-water-contractors.pdf. Accessed: June 29, 2018.

U.S. Bureau of Reclamation. 2022. Friant-Kern Canal – Fact Sheet. Prepared by U.S. Department of the Interior, Bureau of Reclamation, California-Great Basin Region. Available: https://www.usbr.gov/mp/mpr-news/docs/factsheets/fkc.pdf. Accessed: March 8, 2023.rec