Chapter 21
Drought Evaluation

21.1 Introduction

All Californians have confronted numerous challenges associated with the reduced water supplies available during the ~~current~~ recent drought. The State Water Resources Control Board (State Water Board) has taken extraordinary actions in response to the drought, including curtailing water rights, imposing statewide urban water conservation measures, and issuing Temporary Urgency Change Petition (TUCP) orders to modify flow and other requirements in the Delta and elsewhere under various water rights. This chapter uses Water Supply Effects (WSE) model simulations to compare drought years during the 1922–2003 analysis period to the more recent period of 2004–2015, specifically to the recent drought years of 2012–2015, to assess the severity of water supply effects during recent drought conditions compared to the severity of water supply effects during the 1922–2003 analysis period. In addition, this chapter includes a comparison of water supply availability and other water parameters during drought periods under baseline conditions and under the Lower San Joaquin River (LSJR) alternatives. These analyses show that: (1) water supply effects during drought conditions are adequately characterized by the WSE model during the 1922–2003 analysis period, (2) the runoff and water supply effects during the recent period of 2004–2015 are not inconsistent (i.e., more extreme) than drought conditions during the prior historical record, and (3) there are reductions in water supply diversions in many years under the different LSJR alternatives compared to baseline, particularly during dry years.

The following definitions are provided to understand the discussion in this chapter.

- A *dry year* or *dry period* is described as one or more years with less-than-average runoff. Average runoff was calculated for the WY 1922-2015 time period. More than half of the years in California are identified as dry years because much greater than average runoff in a few wet years increases the average runoff compared to the median runoff (half of the years with less runoff).
- The *runoff deficit* is the difference between the average runoff and the annual runoff within a single water-year (e.g., October–September). Each dry year has a runoff deficit.
- A *water supply diversion deficit* is the difference between the normal full water supply diversions and the available water supply diversions during the water year (WY).
- A *drought year* or *drought period* is defined as one or more years with less-than-normal full diversions for water supply, reflecting a dry year or dry year period that is severe enough to cause a water supply deficit of a specified magnitude (e.g., <80 percent of full diversions).
- *Carryover storage* is the quantity of water remaining in storage in a reservoir at the end of the WY (end-of-September), before refilling from rain and snowmelt begins, and after the end of the primary water use period. Carryover storage is an important metric for evaluating water supplies during a series of dry year(s), because reservoir storage is typically reduced during dry years to provide normal full water supply deliveries. Multiple dry years may result in a cumulative runoff deficit severe enough to reduce carryover storage such that there is also a water supply diversion deficit.

- The *maximum carryover storage* is defined as the maximum end-of-September storage that provides adequate storage capacity for flood control purposes, and the *carryover storage drawdown* is defined as the maximum carryover storage minus the actual carryover storage.

This chapter identifies dry years and dry periods from 1922–2015 and evaluates how they affect water supply. The severity of a multi-year dry period depends on two factors: (1) the duration of the dry period (i.e., consecutive years with less-than-average runoff) and (2) the cumulative runoff deficit (total of runoff deficits during the dry period). The severity of dry periods was, therefore, identified by the duration, in years, and the cumulative runoff deficit, in thousand acre-feet (TAF). Each tributary was evaluated separately, but the similarities in the dry year periods for the three tributaries were identified and described. The effects of dry years on water supply were different for each tributary because the average runoff, reservoir storage, normal full diversions for water supply, and required flow releases were different for each tributary. Generally, the ratios of factors, such as storage/runoff, water supply/runoff, and required flow releases/runoff, govern the severity of the reservoir storage drawdowns and water supply deficits on the three tributaries. The historical reservoir operations and historical water supply diversions were reviewed to compare to WSE baseline reservoir operations and water supply diversions during dry year periods. The monthly WSE baseline results for 1922–2003 provide estimates of the reservoir operations for the historical runoff with the existing reservoir releases for water supply diversions, required flows for fish habitat, downstream riparian diversions, and flood control. The WSE extended baseline results (1922–2015) provide a longer period for drought evaluation, with the existing water supply diversions and fish habitat flows calculated up to 2015. The WSE baseline results for carryover storage and water supply diversions generally match historical conditions for the years post-construction of the major reservoirs. As such, the WSE model results adequately characterize the ability of reservoir storage in each tributary to reduce drought effects, with different drought effects depending on the storage/runoff and normal full diversion/runoff ratios for each tributary. The comparison of historical conditions is described in Sections 21.6 to 21.9 in this chapter.

As described in Appendix F.1 *Hydrologic and Water Quality Modeling*, the WSE model was developed to evaluate the effects of changed instream flow requirements on water supply and other parameters. Some inputs to the WSE model were based on information from the San Joaquin Module of CALSIM between 1922 and 2003. To better understand the effects for the more recent time period (from 2004–2015), the WSE model was extended using the historical reservoir inflows and estimated monthly data for downstream local inflows, return flows, and water supply diversions, using CALSIM inputs from years with similar hydrology. Adding this time period to the WSE-simulated time period allowed two additional dry periods to be included, 2007–2009 and 2012–2015. The incorporation of 2004–2015 allowed an evaluation of the effects of the LSJR alternatives on reservoir operations, water supply, and river temperatures for the most recent years, including conditions during the recent dry periods. The 2012–2015 dry year period was similar to other 4-year dry year periods in the historical record, with drought effects (reduced normal full water supply diversions) increasing in each year of the dry period. Historical and WSE-simulated operations during the two recent dry periods (2007–2009 and 2012–2015) were similar, and the WSE-simulated operations for dry periods between 1922 and 2003 were also similar to the WSE-simulated operations for the two recent dry periods.

Chapter 2, *Water Resources*, and Chapter 5, *Surface Hydrology and Water Quality*, provides additional hydrological information for each tributary. The sections below focus on the analysis and discussion of water supply effects in drought years (less than full normal water supply diversions).

21.2 Tributary Runoff and Droughts

This section compares the tributary dry periods and droughts (water supply effects) by evaluating the annual runoff and the corresponding February–June runoff for the 1921–2015 period of record. It also describes the different water user's (i.e., water or irrigation districts) responses to recent dry year periods (i.e., droughts).

The California Department of Water Resources (DWR) has published a summary of the monthly unimpaired runoff for the Central Valley streams for WY 1921–2014 (DWR 2016). California Data Exchange Center records were used to update the monthly runoff through September 2015 (WY 2015).

Table 21-1 presents a summary of the cumulative distributions of the annual runoff, February–June runoff, and February– June fraction of annual runoff for the three eastside tributaries.[1] This information is used to summarize and compare runoff and dry year periods, particularly for the February– June period that is subject to the LSJR alternatives. This chapter describes years with lower than average runoff. The average runoff is between the 50th and 60th cumulative distribution percentiles for each of the tributaries.

Table 21-1. Cumulative Distributions of Annual (WY) and February–June Unimpaired Runoff and the February–June Fraction of Runoff for the LSJR Tributaries for 1921–2015 (95 years)

Percentile	Stanislaus Annual Runoff (TAF)	Stanislaus Feb-Jun (TAF)	Stanislaus Feb-June (fraction)	Tuolumne Annual Runoff (TAF)	Tuolumne Feb-Jun (TAF)	Tuolumne Feb-Jun (fraction)	Merced Annual Runoff (TAF)	Merced Feb-Jun (TAF)	Merced Feb-Jun (fraction)
Min	155	135	0.87	384	327	0.85	151	127	0.84
10	446	362	0.81	825	667	0.81	388	321	0.83
20	591	485	0.82	1,026	856	0.83	479	389	0.81
30	649	548	0.85	1,128	963	0.85	550	463	0.84
40	823	686	0.83	1,368	1,128	0.82	644	553	0.86
50	1,075	807	0.75	1,685	1,283	0.76	836	639	0.76
60	1,236	982	0.79	2,022	1,547	0.76	1,037	786	0.76
70	1,356	1,072	0.79	2,164	1,687	0.78	1,154	916	0.79
80	1,570	1,178	0.75	2,519	1,863	0.74	1,414	1,047	0.74
90	1,922	1,493	0.78	3,118	2,219	0.71	1,727	1,274	0.74
Max	2,954	1,994	0.67	4,630	2,887	0.62	2,790	1,830	0.66
Average	1,107	857	0.77	1,829	1,384	0.76	946	731	0.77

Source: DWR 2016.

[1] In this document, the term *three eastside tributaries* refers to the Stanislaus, Tuolumne, and Merced Rivers.

The cumulative distributions of annual unimpaired runoff for the three eastside tributaries, expressed as a fraction of the ~~mean~~ average annual runoff for 1921 to 2015, are shown in Table 21-2. The water supply conditions, defined using the fraction of average runoff, are nearly identical for the three eastside tributaries. The full water supply diversions and the maximum carryover storage can be expressed as the fraction of average runoff; the effects of dry year periods on water supply reductions (diversion deficits) depend on these diversion/runoff and carryover storage/runoff fractions.

The Stanislaus River average WY runoff was 1,107 TAF, and the average February–June runoff was 857 TAF. The reduced runoff in dry years is of particular interest for the drought analysis; the minimum runoff was 14 percent of average runoff; runoff in 10 percent of the years was less than 40~~5~~ percent of average runoff; runoff in 20 percent of the years was less than 53 percent of average runoff; runoff in 30 percent of the years was less than 59 percent of average runoff; and runoff in 40 percent of the years was less than 74 percent of average runoff. The WSE model showed average full water supply diversion for the Stanislaus River was 651 TAF (59 percent of average runoff), and the maximum carryover storage in New Melones Reservoir is 2,000 TAF (180 percent of average runoff).

The Tuolumne River average WY runoff was 1,829 TAF, and the average February–June runoff was 1,384 TAF. The minimum runoff was 21 percent of average runoff; runoff in 10 percent of the years was less than 45 percent of average runoff; runoff in 20 percent of the years was less than 56 percent of average runoff; runoff in 30 percent of the years was less than 62~~58~~ percent of average runoff; and runoff in 40 percent of the years was less than 75 percent of average runoff. Because the City and County of San Francisco (CCSF) diversions of 250 TAF are upstream of New Don Pedro Reservoir, the downstream diversions and carryover storage are expressed as the fraction of the average annual inflow to New Don Pedro Reservoir (i.e., average annual runoff minus 250 TAF). The WSE model showed average full water supply diversion for the Tuolumne River was 901 TAF (57 percent of average runoff to New Don Pedro Reservoir), and the maximum carryover storage is 1,700 TAF (108 percent of average runoff to New Don Pedro Reservoir).

The Merced River average WY runoff was 946 TAF, and the average February–June runoff was 731 TAF. The minimum runoff was 16 percent of average runoff; runoff in 10 percent of the years was less than 41 percent of average runoff; runoff in 20 percent of the years was less than 51 percent of average runoff; runoff in 30 percent of the years was less than 58~~9~~ percent of average runoff; and runoff in 40 percent of the years was less than 68 percent of average runoff. The WSE model showed average full water supply diversion for the Merced River was 632 TAF (67 percent of average runoff) and the maximum carryover storage in Lake McClure is 850 TAF (90 percent of average runoff).

Table 21-2. Cumulative Distributions of Annual (WY) and February–June Unimpaired Runoff as Fraction of Average Runoff for the for the LSJR Tributaries for 1921–2015 (95 years)

Percentile	Stanislaus Runoff (fraction)	Stanislaus Feb–Jun (fraction)	Tuolumne Runoff (fraction)	Tuolumne Feb–Jun (fraction)	Merced Runoff (fraction)	Merced Feb–Jun (fraction)
Min	0.14	0.16	0.21	0.24	0.16	0.17
10	0.40	0.42	0.45	0.48	0.41	0.44
20	0.53	0.57	0.56	0.62	0.51	0.53
30	0.59	0.64	0.62	0.70	0.58	0.63
40	0.74	0.80	0.75	0.82	0.68	0.76
50	0.97	0.94	0.92	0.93	0.88	0.87
60	1.12	1.15	1.11	1.12	1.10	1.08
70	1.23	1.25	1.18	1.22	1.22	1.25
80	1.42	1.37	1.38	1.35	1.50	1.43
90	1.74	1.74	1.71	1.60	1.83	1.74
Max	2.67	2.33	2.53	2.09	2.95	2.50
Average (TAF)	1,107	857	1,829	1,384	946	731
Average Full Water Supply Diversions	651 (59%)		901 (57% of effective inflow[a])		632 (67%)	
Carryover Storage	2,000 (180%)		1,700 (108% of effective inflow[a])		850 (90%)	

Source: Calculated from DWR 2016.

[a] For the Tuolumne River, effective inflow is 1,829 TAF/y minus 250 TAF/y removed upstream of New Don Pedro Reservoir by City and County of San Francisco.

Table 21-2 shows that unimpaired runoff in each tributary was less than 75 percent of average runoff in 4 out of 10 years (40 percent of years), and the runoff was less than 50 percent of average runoff in 2 out of 10 years (20 percent of years). Potential drought consequences under the baseline and LSJR alternatives would be different for each tributary because of different average full diversions and different maximum carryover storages relative to the average runoff. The annual baseline water supply deficits (i.e., droughts) were, therefore, slightly different for each tributary. The runoff and dry year periods for each river are described below using information from Tables 21-1 and 21-2 and graphically depicted in several figures. The potential for drought (water supply deficits), as a result of reduced runoff and reduced carryover storage in the reservoirs, is also discussed below.

The ability of surface water users in the three eastside tributaries to manage drought conditions varies and depends on numerous factors including, but not necessarily limited to, reservoir carryover storage and availability of non-surface water sources. Typically, the potential consequences for drought are more severe as the cumulative runoff deficits increase over a longer duration. Numerous dry years typically leads to greatly reduced storage and diversions. The sections that follow document some of the recent actions that water users in the three tributaries have taken during the 2012–2015 drought period. For more information regarding the water users and various applicable groundwater management plans and agricultural water management plans

(AWMPs), please refer to Chapters 2, *Water Resources*, Chapter 5, *Surface Hydrology and Water Quality*, Chapter 9, *Groundwater Resources,* and Chapter 13, *Service Providers*.

21.3 Stanislaus River

21.3.1 Runoff

The average runoff on the Stanislaus River (1921–2015) was 1,107 thousand acre feet per year (TAF/y) and the runoff was less than average in about half the years (50 out of 95 years), was less than 50 percent of average in 16 years, and was less than 25 percent of average in 2 years (1924 and 1977) (Table 21-1). The WY runoff could be used to classify five categories (20 percent of years in each). As an example, critical years (lowest 20 percent of years) would have runoff of less than 591 TAF/y (0.53 average); dry years (next lowest 20 percent of years) would have runoff of less than 823 TAF/y (0.74 average); below-normal years (middle 20 percent of years) would have runoff of less than 1,236 TAF/y (1.12 average); above-normal years (second highest 20 percent of years) would have runoff of less than 1,570 TAF/y (1.42 average); and wet years (highest 20 percent of years) would have runoff of greater than 1,570 TAF/y. The runoff in 2014 (370 TAF) and 2015 (330 TAF) were both less than half of average, but runoff has been lower in a few previous years. In lower runoff years, the February–June runoff was more than 80 percent of the total Stanislaus River runoff (Table 21-1). In wet years, rainfall runoff in December or January and snowmelt in July reduced the fraction of runoff in February–June to about 70 percent in some years.

Figure 21-1 shows the annual WY Stanislaus River runoff and February–June runoff, with the annual runoff deficits and the cumulative runoff deficits (consecutive years with runoff deficits, less than average runoff) shown as negative values for WY 1921–2015. About half of the years had greater than average runoff. There were several multi-year periods with less than average runoff (cumulative runoff deficits). The major dry year periods were 1924-1934, 1947-1949, 1959–1962, 1976–1977, 1987–1992, 2001–2004, 2007–2008, and 2012–2015. For the years with less than average runoff, the runoff deficits averaged about 50 percent of the average runoff (550 TAF).

For the Stanislaus River the average runoff was 1,107 TAF, and the cumulative runoff deficits generally increased by about 50 percent of average runoff for each year in the dry-year sequence (550 TAF runoff deficit per dry year). A 2-year dry period generally had a cumulative runoff deficit of about 1,100 TAF (although 1976–1977 had a deficit of 1,700 TAF); a 4-year dry period generally had a cumulative runoff deficit of 2,200 TAF (e.g., 2012–2015 had a deficit of 2,475 TAF); and a 6-year dry period generally had a cumulative runoff deficit of 3,300 TAF (e.g., 1987–1992 had a deficit of 3,600 TAF). The dry year period of 2007-2008 was typical of other historical dry periods with a cumulative runoff deficit of 1,020 TAF (46 percent of average runoff per year) and the dry year period during 2012–2015 (4 years) was typical of other historical dry periods, with a cumulative runoff deficit of 2,475 TAF, about 55 percent of average runoff each year.

Therefore, although there were more dry years with less than average runoff during the last 12 years (8 out of 12), the severity of these dry year periods (i.e., cumulative deficits) were similar to other dry year periods in the historical period of 1922–2003 used for the environmental assessment of the LSJR alternatives.

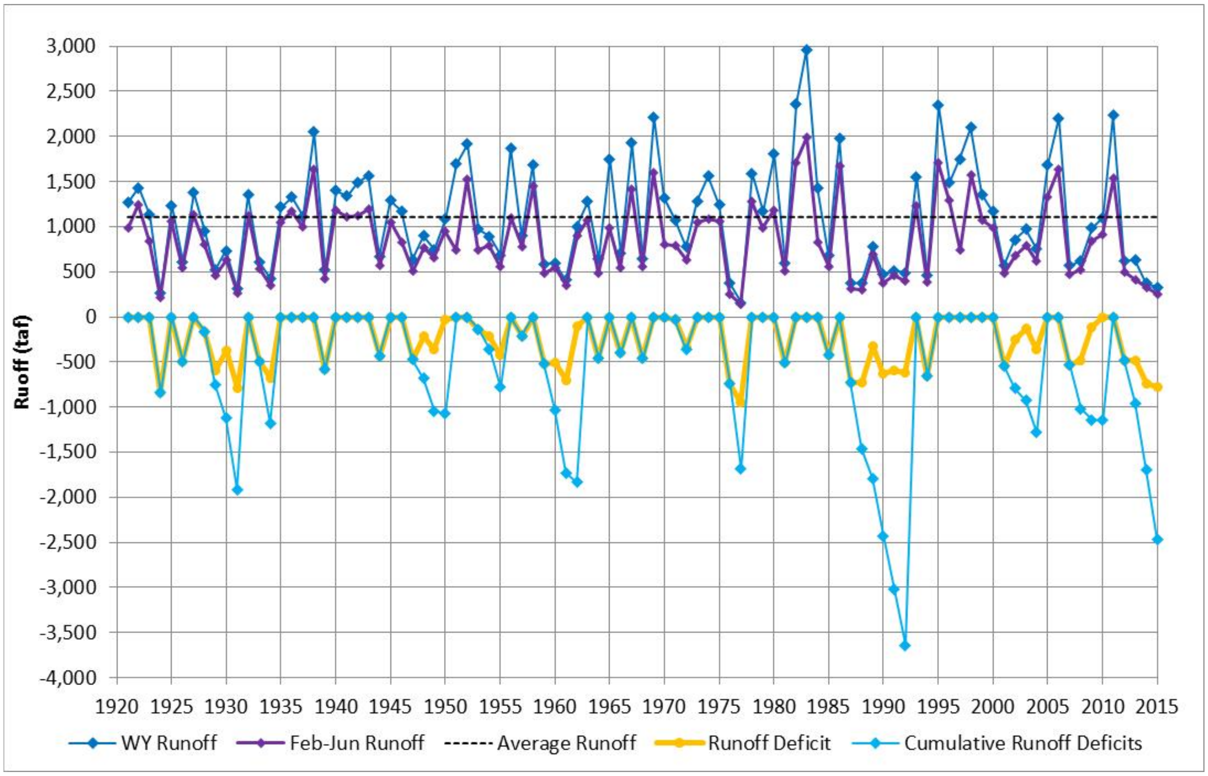

Figure 21-1. Stanislaus River Annual (WY) and February–June Unimpaired Runoff (TAF) with Annual and Cumulative Runoff Deficits for 1921–2015

21.3.2 Potential for Drought

The New Melones Reservoir has substantial carryover storage capacity of 2,000 TAF (180 percent of average runoff). Therefore, the WSE model showed average full water supply diversions of 651 TAF (59 percent of average runoff) can be maintained for several years during dry periods (Table 21-2). The upstream reservoirs on the Stanislaus River are generally operated for seasonal storage to maintain hydroelectric energy generation through the summer months. The annual inflow to New Melones Reservoir is, therefore, similar to the annual runoff.

Prior to the construction of New Melones Reservoir, minimum streamflow requirements were specified in the State Water Board's Water Right Decision 1422 (D-1422). After this decision, minimum streamflow requirements have been increased on the Stanislaus River by various agencies through different mechanisms, including: the California Department of Fish and Wildlife (formerly the California Department of Fish and Game) as part of the 1987 fisheries agreement; the Central Valley Project Improvement Act Anadromous Fish Restoration Program (AFRP); the Vernalis Adaptive Management ~~Program~~ Plan (VAMP) (2000–2012), that modified the State Water Board's Water Right Decision ~~D-~~1641 (revised March 15, 2000) Vernalis flows during April and May; and the National Marine Fisheries Service (NMFS) as part of its 2009 biological opinion (BO) Stanislaus River reasonable and prudent alternative (RPA), including Action 3.1.3 (NMFS BO). The five flow schedules identified by NMFS in Appendix 2E of the BO (NMFS 2009) are applied depending on a combination of runoff and storage; the minimum release flows require 185 TAF (dry years), which is 17 percent of the average runoff, and the maximum release flows require 590 TAF (wet years), which is 54 percent of the average runoff.

The recent drought (2012–2015) provides evidence of the importance of the New Melones Reservoir carryover storage for full water supply diversions on the Stanislaus River. The carryover storage was full (2,000 TAF) in 2011 and was reduced by about 500 TAF in 2012, 2013, and 2014 (with relatively high diversions of about 550 TAF each year). The carryover storage at the end of WY 2014 was about 520 TAF. The low runoff conditions again in 2015 resulted in reduced diversions (425 TAF) and very low carryover storage (267 TAF).

Allocating more of the Stanislaus River runoff for streamflow requirements over time has generally reduced the potential refilling of New Melones reservoir in normal and wet years. This has generally caused greater carryover storage drawdowns in dry years. The baseline drought conditions assessed with the WSE model were small (less than 5% of years with less than 80 percent of full diversions), but increased flows under the LSJR alternatives and deliveries of full contract amounts in more years would likely increase the severity of drought conditions (more years with greater diversion deficits) for the Stanislaus River (Table 21-3).

21.3.3 Drought Water Management

The Oakdale Irrigation District (OID) and South San Joaquin Irrigation District (SSJID) both have prepared AWMPs that include the efficient water management practices required by the 2009 Water Conservation Bill. They both have water resources plans to improve the operational efficiency and encourage water conservation measures within the districts. OID and SSJID have developed drought bulletins in 2015 for informing their users of activities related to the drought. The emergency drought bulletin explains,

> The two districts have been in negotiations with the federal Bureau of Reclamation (which operates New Melones Reservoir), the National Marine Fisheries Service and the State Water Resources Control Board (SWRCB), urging the approval of a Temporary Urgency Change Petition to…provide for springtime 'pulse flows' for steelhead and salmon on the Stanislaus, base flows for the fish in the river through December, and adequate supplies of water for each district, given serious conservation measures both districts are taking (SSJID 2015).

This type of management proposal is anticipated to maintain enough water in New Melones Reservoir at the end of September (irrigation season) to meet flows for spawning salmon through December 31 (SSJID 2015). The plan would also help the districts to keep Lake Tulloch (the regulating reservoir downstream of New Melones Reservoir) at normal operational levels (for recreation) through September (SSJID 2015).

SSJID drought bulletins also encourage water conservation and facilitate water allocation and private groundwater transfers within the district. The drought bulletin of April 6, 2015 includes this summary of conditions in 2015:

> The water supply picture looks increasingly grim for the coming growing season. California's governor declared a State of Emergency throughout the state due to severe drought conditions on April 1, 2015. With very little precipitation this past winter, farmers will be relying more on pumping groundwater, having to severely conserve whatever surface water they may have available to them, potentially fallowing crops, and when possible and/or necessary, transferring water allocations between their own parcels, or to other growers' farm operations. A limit of 36 inches of irrigation water per parcel will be in effect because the ongoing drought threatens the District's water supply in 2015, and will most likely worsen in 2016. A 10-day rotation schedule was also confirmed. SSJID's drought task force has already met with many of our growers to review their past year's water consumption history (SSJID 2015).

Table 21-3. Cumulative Distribution of WSE Baseline Annual (WY) Water Supply Diversions for 1922–2015

Average Runoff (TAF)	1,107		Average Inflow (TAF)	1,577	Average Runoff (TAF)	945
Average Full Diversion (TAF)	651		Average Full Diversion (TAF)	901	Average Full Diversion (TAF)	632
Percentile	Stanislaus Baseline Diversion (TAF)	% Full Diversion	Tuolumne Baseline Diversion (TAF)	% Full Diversion	Merced Baseline Diversion (TAF)	% Full Diversion
Max	792	100	1,050	100	687	100
90	724	100	957	100	668	100
80	703	100	931	100	656	100
70	685	100	901	100	633	100
60	676	100	886	100	625	100
50	656	100	869	100	618	100
40	627	100	856	100	599	100
30	615	100	824	99	579	99
20	582	99	775	92	547	92
10	549	92	614	67	419	63
Min	268	50	392	43	137	21
Average	635	98	840	93	574	91

Water received by the Stockton East Water District (SEWD)/Central San Joaquin Water Conservation District (CSJWCD) from New Melones Reservoir through their contract with the U.S. Bureau of Reclamation (USBR) and their temporary contracts with OID/SSJID (2000–2010) has been used to reduce some of the need for groundwater pumping for irrigation and urban water supply in the SEWD/CSJWCD service areas (including the City of Stockton). SEWD/CSJWCD have developed conjunctive water management facilities in order to reduce groundwater pumping in normal years so that additional groundwater pumping can provide full water supply in drought years without reducing long-term average groundwater levels (i.e., sustainable pumping). CSJWCD, for example, has developed surface irrigation facilities for about 10,000 acres that are normally irrigated from groundwater pumping. This irrigated land uses about 30 TAF per year and reduces groundwater pumping by approximately this amount.

SEWD worked with Calaveras County to obtain additional surface water supply from Hew Hogan Reservoir on the Calaveras River. This reservoir (317 TAF storage) was completed in 1964 and provides an average yield of about 150 TAF, which reduces groundwater pumping for the land irrigated with surface water (SEWD 2014). Some fraction of this surface water infiltrates from the conveyance channels and from the irrigated lands; SEWD installs check dams along the Calaveras River, Mormon Slough, and other channels to increase the infiltration area. SEWD has developed about 50 acres of recharge ponds that have an infiltration rate of 0.5 foot/day, providing 9 TAF of annual recharge. The most recent recharge project involves winter spreading on irrigated lands downstream of the Farmington flood control dam; the full project could include 1,200 acres of land that would be flooded for 60 days each winter and provide about 35 TAF of infiltration (SEWD 2014). These conjunctive water management facilities have better prepared SEWD and CSJWCD water users for the limited surface supplies during this drought (e.g., No New Hogan Reservoir supplies were available in 2015).

Given the information provided in drought bulletins by SSJID, and as discussed in Chapter 9, *Groundwater Resources*, reductions in the surface water supply during drought years would likely result in a return to groundwater pumping for some users within the SSJID and OID service areas, and for most users within SEWD/CSJWCD. The 1998 agreement with SSJID/OID includes a drought provision; the full contract amount (600 TAF) is reduced to inflow plus 1/3 of the inflow deficit, when the inflow is less than 600 TAF. The 2014 runoff was 370 TAF, the water supply diversions were 515 TAF, and the carryover storage was 520 TAF. The 2015 runoff was 329 TAF, the water supply diversions were 425 TAF and the carryover storage was 267 TAF. No water was available for the SEWD/CSJWCD contract in 2014 or 2015.

21.4 Tuolumne River

21.4.1 Runoff

The average runoff for the Tuolumne River was 1,829 TAF/y, and the runoff was less than average in about half of the years (50 out of 95 years), was less than 50 percent of average in 15 years, and was less than 25 percent of average in 1 year (1977) (Table 21-1). The WY runoff could be used to classify five categories (20 percent of years in each). For example, critical years (lowest 20 percent of years) would have runoff of less than 1,026 TAF/y (0.56 average); dry years (next lowest 20 percent of years) would have runoff of less than 1,368 TAF/y (0.75 average); below-normal years (middle 20 percent of years) would have runoff of less than 2,022 TAF/y (1.11 average); above-normal years (second highest 20 percent of years) would have runoff of less than 2,519 TAF/y (1.38 average); and wet years (highest 20 percent of years) would have runoff of greater than 2,519 TAF/y. The runoff in 2014 (601 TAF) and 2015 (602 TAF) were less than 40 percent of average; runoff has been similar in a few previous years. In lower runoff years, the February–June runoff provided more than 80 percent of the total Tuolumne River runoff (Table 21-1). In wet years, rainfall runoff in December or January and snowmelt in July reduced the fraction of runoff in February–June to about 75 percent in some years.

Figure 21-2 shows the annual WY Tuolumne River runoff and February–June runoff, with the annual runoff deficits and the cumulative runoff deficits (consecutive years with runoff deficits) shown as negative values for WYs 1921–2015. About half of the years had greater than average runoff. There were several multi-year dry periods with less-than-average runoff (cumulative runoff deficits). The major dry periods were 1924–1934, 1947–1949, 1959–1962, 1976–1977, 1987–1992, 2001–2004, 2007–2008, and 2012–2015. For the years with less than average runoff, the runoff deficits averaged about 50 percent of the average runoff (915 TAF). These were the same dry years as identified for the Stanislaus River because the precipitation patterns (i.e., rainfall and snowfall) are nearly identical for these two watersheds.

For the Tuolumne River the average runoff was 1,829 TAF, and the cumulative runoff deficits generally increased by about 50 percent of average runoff for each year in the dry-year sequence (915 TAF runoff deficit per dry year). A 2-year dry period generally had a cumulative runoff deficit of about 1,830 TAF (although 1976–1977 had a deficit of 2,600 TAF); a 4-year dry period generally had a cumulative runoff deficit of 3,660 TAF (e.g., 2012–2015 had a deficit of 4,150 TAF); and a 6-

year dry period generally had a cumulative runoff deficit of 5,500 TAF (e.g., 1987–1992 had a deficit of 5,400 TAF). The dry year period of 2007–2008 was typical of other historical dry periods with a cumulative runoff deficit of 1,675 TAF (46 percent of average runoff per year) and the dry year period during 2012–2015 (4 years) was typical of other historical dry periods, with a cumulative runoff deficit of 4,143 TAF, about 55 percent of average runoff each year.

Therefore, although there were more dry years with less than average runoff during the last 12 years (8 out of 12), the severity of these dry year periods (i.e., cumulative deficits) were similar to other dry year periods in the historical period of 1922–2003 used for the environmental assessment of the LSJR alternatives.

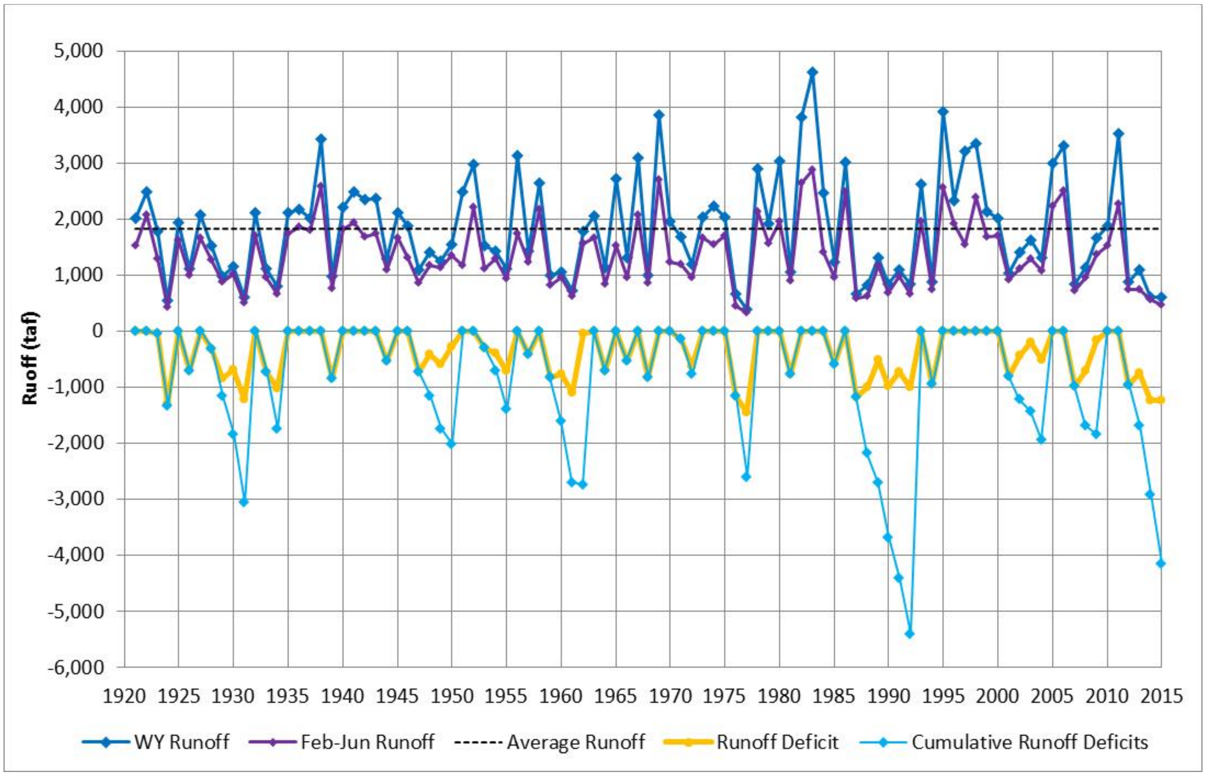

Figure 21-2. Tuolumne River Annual (WY) and February–June Unimpaired Runoff (TAF) with Annual and Cumulative Runoff Deficits for 1921–2015

21.4.2 Potential for Drought

The New Don Pedro Reservoir has a large carryover storage maximum of 1,700 TAF (93 percent of average runoff). Because the CCSF water supply diversions of about 250 TAF/y are upstream of New Don Pedro Reservoir, this drought evaluation for the Tuolumne River assumes that the effective runoff (New Don Pedro inflow) was reduced each year by the 250 TAF upstream diversion. Therefore, the average annual inflow to New Don Pedro Reservoir was 1,579 TAF, the maximum carryover storage is about 108 percent of average inflow, and the WSE model showed average full water supply diversion was 901 TAF, about 57 percent of average effective inflow (Table 21-2).

Required New Don Pedro Reservoir releases for required flows were specified in the original Federal Energy Regulatory Commission (FERC) license (1966) and modified in the 1995 settlement agreement. The original FERC license required 118 TAF (8 percent of average New Don Pedro inflow) in normal years and 64 TAF (4 percent of average inflow) in dry years. The 1995 settlement (based on FERC-mandated fish investigations) increased the required flow releases to 95 TAF (6 percent of average inflow) in the driest years to a maximum of 310 TAF (20 percent of average inflow) in years with greater-than-average runoff.

Allocating more of the Tuolumne River runoff for minimum streamflow requirements has generally reduced the potential refilling of New Don Pedro Reservoir in normal and wet years, and has caused greater carryover storage drawdown in dry years. The combination of average full water supply diversions (57 percent of average inflow) and increased required flows (41 percent of average runoff for WSE baseline conditions) has increased the WSE baseline drought years (with less than 80 percent of average full diversions) to about 15 percent of the years (Table 21-3). The baseline drought conditions assessed with the WSE model were moderate (15 percent of years with less than 80 percent of average full diversions), and increased flows under the LSJR alternatives would likely increase drought conditions (more years with greater diversion deficits) for the Tuolumne River.

21.4.3 Drought Water Management

Both Turlock Irrigation District (TID) and Modesto Irrigation District (MID) have AWMPs (TID 2012; MID 2012), and both participate in regional groundwater management plans (for additional information regarding regional groundwater management plans and the irrigation districts' AWMPs see Chapters 9, *Groundwater Resources*; 11, *Agricultural Resources*; and 13, *Service Providers*). Water shortage procedures for these two irrigation districts are described in their AWMPs. The normal surface irrigation allocation for both TID and MID is 48 inches; however, these allocations were reduced in years with less-than-full water diversions. Both districts use increased groundwater pumping to augment the surface deliveries, but they have a limited number of district wells or rented (private) wells (TID 2012; MID 2012). Both districts describe their water operations as conjunctive (i.e., combination of surface water diversions and groundwater pumping), because the seepage from canals, regulating reservoirs, and infiltration from the irrigated lands results in a substantial groundwater recharge in most years (TID 2012; MID 2012).

TID's AWMP indicates that beginning in 2013, allotments were no longer to be used in water-short years; the TID Board of Directors would determine if the dry year rate schedule should be used and the amount of water available on a per-acre basis. This determination would be based on projected runoff, including the possibility of the occurrence of consecutive dry years, carryover storage, flows required to be delivered to the lower Tuolumne River, and the availability of rented pumps. Groundwater pumping was expected to increase progressively in each drought year as surface supplies decreased. TID's AWMP acknowledged that even with conjunctive water management in the service area, groundwater was not an unlimited supply, and the availability of groundwater may decline over time due to declining water levels from increased pumping and reduced recharge from irrigation canals. The 2014 runoff was 601 TAF, the water supply diversions were 560 TAF, and the carryover storage was 780 TAF. The 2015 runoff was 602 TAF, the water supply diversions were 450 TAF and the carryover storage was 644 TAF.

21.5 Merced River

21.5.1 Runoff

The average runoff was 946 TAF/y, and the runoff was less than average in more than half of the years (54 out of 95 years), was less than 50 percent of average in 18 years, and was less than 25 percent of average in 1 year (1977) (Table 21-1). The WY runoff could be used to classify five categories (20 percent of years in each). For example, critical years (lowest 20 percent of years) would have runoff of less than 479 TAF/y (0.51 average); dry years (next lowest 20 percent of years) would have runoff of less than 644 TAF/y (0.68 average); below-normal years (middle 20 percent of years) would have runoff of less than 1,037 TAF/y (1.10 average); above-normal years (second highest 20 percent of years) would have runoff of less than 1,414 TAF/y (1.50 average); and wet years (highest 20 percent of years) would have runoff of greater than 1,414 TAF/y. The runoff in 2014 (239 TAF) and 2015 (175 TAF) were less than 25 percent of average; the runoff has only been this low in 1924 and 1977. In lower runoff years, the February–June runoff provided more than 80 percent of the total Merced River runoff (Table 21-1). In wet years, rainfall runoff in December or January and snowmelt in July reduced the fraction of runoff in February–June to about 75 percent in some years.

Figure 21-3 shows the annual Merced River WY runoff and February–June runoff, with the annual runoff deficits and the cumulative runoff deficits (consecutive years with runoff deficits) shown as negative values for WY 1921–2015. About half of the years had greater than average runoff. There were several multi-year periods with less-than-average runoff (cumulative runoff deficits). The major dry year periods were 1924–1934, 1947–1949, 1959–962, 1976–1977, 1987–1992, 2001–2004, 2007–2008, and 2012–2015. For the years with less than average runoff, the runoff deficits averaged about 50 percent of the average runoff (475 TAF). These were the same dry years as identified for the Stanislaus and Tuolumne Rivers because the precipitation patterns (*i.e.,* rainfall and snowfall) are nearly identical for these three watersheds.

For the Merced River, the average runoff was 945 TAF, and the cumulative runoff deficits generally increased by about 50 percent of average runoff for each year in the dry-year sequence (475 TAF runoff deficit per dry year). A 2-year dry period generally had a cumulative runoff deficit of about 950 TAF (although 1976–1977 had a deficit of 1,500 TAF); a 4-year dry period generally had a cumulative runoff deficit of 1,900 TAF (e.g., 2012–2015 had a deficit of 2,450 TAF); and a 6-year dry period generally had a cumulative runoff deficit of 2,850 TAF (e.g., 1987–1992 had a deficit of 3,000 TAF). The dry year period of 2007–2008 was typical of other historical dry periods, with a cumulative runoff deficit of 860 TAF (46 percent of average runoff per year), and the dry year period from 2012–2015 (4 years) was more severe than most historical dry periods, with a cumulative runoff deficit of about 2,460 TAF (65 percent of average runoff each year) on the Merced River.

Therefore, although there were more dry years with less than average runoff during the last 12 years (8 out of 12), the severity of these dry year periods (i.e., cumulative deficits) were similar to other dry year periods in the historical period of 1922–2003 used for the environmental assessment of the LSJR alternatives.

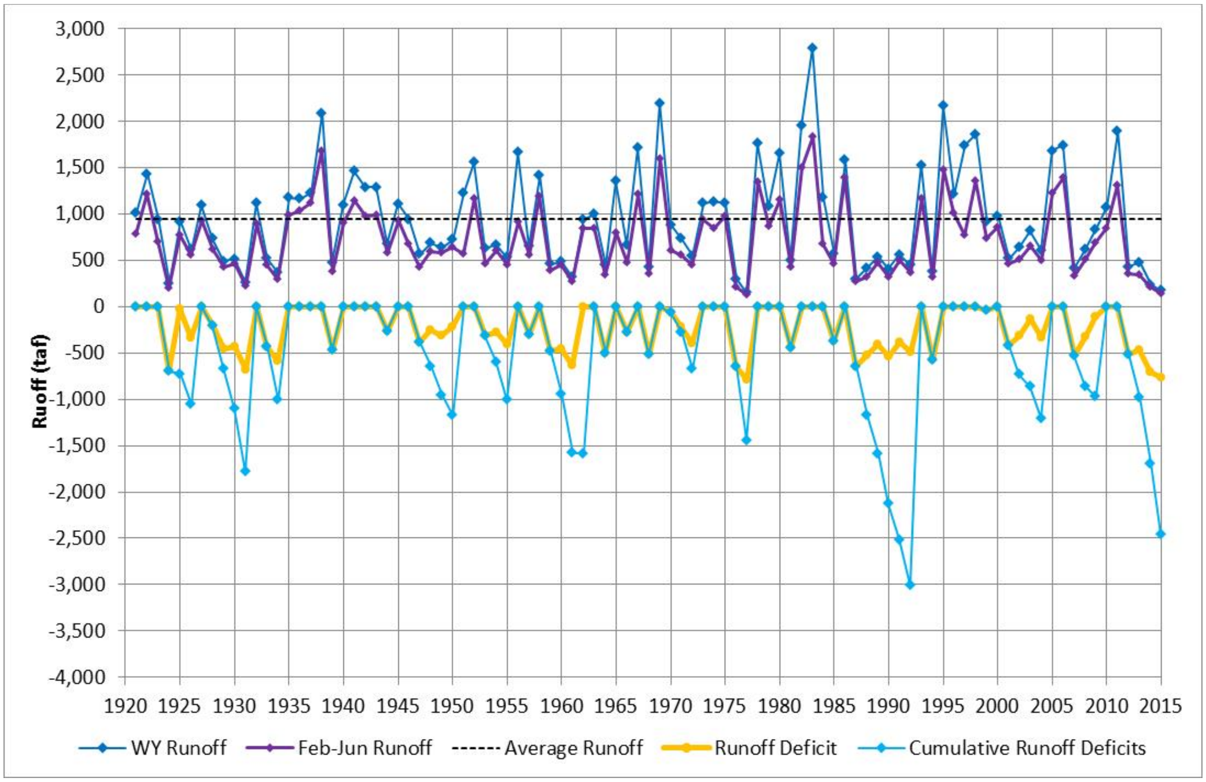

Figure 21-3. Merced River Annual (WY) and February–June Unimpaired Runoff (TAF) with Annual and Cumulative Runoff Deficits for 1921–2015

21.5.2 Potential for Drought

Lake McClure has a maximum capacity of 1,024 TAF, but the carryover storage is limited to 850 TAF (90 percent of average runoff) by the COE maximum flood-control storage. The WSE model showed average full water supply diversion for the Merced River was 632 TAF (67 percent of average runoff) (Table 21-2). Three separate agreements jointly control required minimum flows (FERC license, Cowell Diversions, and Davis-Grunsky contract). Normal year fish flow requirements are about 175 TAF (18 percent of average runoff) and dry year flow requirements are about 100 TAF (10 percent of average runoff).

The combination of average full water supply diversions (67 percent of average runoff), moderate carryover storage (90 percent of average runoff) and relatively low required release flows (17 percent of average runoff for WSE baseline conditions) increased the WSE baseline drought years (with less than 80 percent of full diversions) to about 10 percent of the years (Table 21-3). The baseline drought conditions assesses with the WSE model were moderate (15 percent of years with less than 80 percent of average full water supply diversions) and increased flows under the LSJR alternatives would likely increase drought conditions (more years with greater diversion deficits) for the Merced River.

21.5.3 Drought Water Management

The general water supply strategy for Merced ID and Merced County, to maximize surface water deliveries in order to minimize the groundwater pumping for agricultural water supply in normal years, is described in the Merced Integrated Regional Water Management Plan (RMC 2013). This plan covers approximately 600,000 acres in the northeast portion of Merced County, including the 490,000-acre Merced groundwater subbasin. The Integrated Regional Water Management Program (IRWMP) suggests that Merced ID and Merced County rely on more groundwater pumping in dry years to provide as much of the full agricultural and urban supplies as possible for all water users.

The Merced IRWMP includes several water conservation measures (urban and agricultural) and several projects to increase surface water deliveries (new pipelines and pumps) or to increase groundwater recharge (spreading basins). Two of these, the Highlands Groundwater Conservation Project and the expanded Cressey Groundwater Recharge Project were included in the 2014 IRWMP Drought Grant Application (Merced ID 2014). These two projects, which provide good examples of how Merced ID responds during dry periods, are summarized below.

The Highland Groundwater Conservation Project would deliver surface water to about 700 acres instead of pumping groundwater in normal years. During dry years when surface water diversions are limited, the existing wells would be available for pumping (i.e., conjunctive use). Merced ID has surface water supply that could be provided in this area, but infrastructure is currently not sufficient to convey water to the entire area. The water supply for this area is about 2,500 AF/y (e.g., 3.5 AF/acre); increased diversions from the Merced River would reduce groundwater pumping by this amount in most years (8 out of 10). During drought years (2 out of 10), groundwater pumping would be resumed. (Merced ID 2014.)

The Cressey Groundwater Recharge Project would expand an existing recharge basin to provide drought relief by increasing groundwater supplies in normal years in the Merced groundwater subbasin. The Cressey Recharge Basin Enlargement Project, sponsored by Merced ID, is the second phase of an ongoing recharge project. The project would enlarge the existing recharge basin from 8 acres to 13 acres. The existing recharge basin began operations in 2011 and is capable of recharging 2.75 acre-feet per acre per day (AF/y); the existing ponds recharge about 24 AF/y and the expanded ponds could recharge about 38 AF/y. The annual recharge depends on the number of days when surface water can be delivered to the ponds. The existing operations of the main canal are limited to the irrigations months. (Merced ID 2014.) The 2014 runoff was 239 TAF, the water supply diversions were 210 TAF, and the carryover storage was 122 TAF. The 2015 runoff was 175 TAF, the water supply diversions were 20 TAF, and the carryover storage was 87 TAF.

21.6 Evaluation of Recent Historical Reservoir Operations 1970–2015

The reservoirs on each of the SJR tributaries provide seasonal and multi-year storage to support seasonal water supply diversions. The reservoirs allow seasonal and carryover storage of the runoff, provide flood control benefits (temporary storage of high inflows with subsequent releases to maintain the seasonal flood control storage), allow diversions of the seasonal irrigation demands, and provide required river releases for fish habitat and downstream riparian diversions. The historical reservoir operations are described with the allocation of annual runoff for water supply diversions and carryover storage. In many years, the runoff is greater than the water supply diversions, and carryover storage is increased. Additional water can be released as flood-control releases or required river releases, as needed. In years when runoff is less than the water supply diversions, the carryover storage is reduced to supply the required river releases and water supply diversions. In years when the runoff and carryover storage is not sufficient, the water supply diversions are reduced.

The monthly WSE baseline results for 1922–2003 provide estimates of the reservoir operations for the historical runoff with the existing reservoir releases for water supply diversions, required flows for fish habitat, downstream riparian diversions, and flood control. The WSE extended baseline results (1922–2015) provide a longer period for drought evaluation, with the existing water supply diversions and fish habitat flows calculated up to 2015. The WSE baseline results are expected to more closely match the historical reservoir operations in the most recent years, when the required release flows and water supply diversions were similar to those specified in the WSE model. Because this chapter is focused on drought conditions, the extended WSE baseline water supply diversions are summarized for each tributary to indicate the potential for drought conditions. Because the WSE model calculates a different full water supply diversion for each year based on each year's water demand, the annual diversions were compared to the full diversions for each year to determine water supply deficits.

Table 21-3 summarizes the extended WSE baseline diversions for 1922–2015 for each tributary, with the diversions expressed as a fraction of the specified WSE-modeled full diversion for each year (varies by about +/- 10 percent from year to year). The cumulative distributions of the annual diversions are given in 10 percent increments (i.e., 1 out of 10 years). The average runoff and the average full diversion for each tributary are given for reference. The frequency of diversion deficits greater than 10 percent of full diversions (moderate), 20 percent of full diversions (substantial) or 30 percent of full diversions (severe) can be compared. For example, the fraction of years with less than 80 percent of full diversions (>20 percent deficit) can be compared: the Stanislaus River diversions were less than 80 percent of full diversions in about 20 percent of the years; the Tuolumne River diversions were less than 80 percent of full diversions in about 15 percent of the years (interpolated from the 20 percent and 10 percent values); and the Merced River diversions were less than 80 percent of full diversions in about 15 percent of the years (interpolated from the 20 percent and 10 percent values). The recent historical reservoir operations and extended WSE baseline results for 1970–2015 for each tributary are described and discussed in the sections that follow.

21.7 Stanislaus River Diversions and Carryover Storage

21.7.1 Historical

Figure 21-4 shows the Stanislaus River runoff and average runoff along with historical diversions and end-of-September reservoir carryover storage drawdown for WY 1970–2015. Drought years are identified as years with substantial diversion deficits (e.g., <80 percent full diversions). The historical diversions from WY 1970–2015 were generally above 500 TAF, with a maximum of about 600 TAF in a few years. The full contract diversions were increased from 600 TAF to 755 TAF in 1997 (as a result of SEWD and CSJWCD receiving water). The historical diversions were often less than the contract maximum, but historical records do not provide an explanation for this difference, which could include water transfers between users. The historical reservoir carryover storage drawdown was generally effective in minimizing diversion deficits in most years. The historical reservoir operations in 2012–2015 show reduced diversions to about 515 TAF in 2014, and reduced carryover storages to about 520 TAF in 2014. The low Stanislaus River runoff of 329 TAF in 2015 and reduced carryover storage in 2014 resulted in low diversions (425 TAF) and low carryover storage (267 TAF) in 2015.

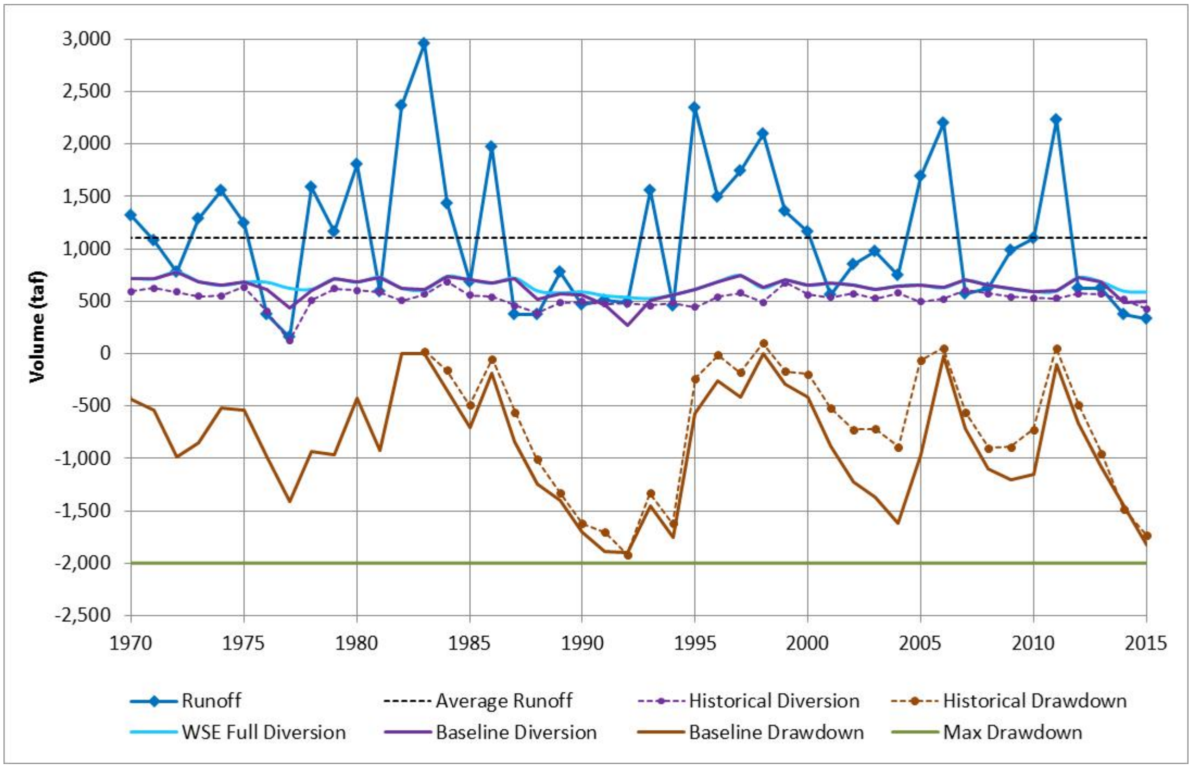

Figure 21-4. Stanislaus River Runoff with Historical and WSE Baseline Diversions, Diversion Deficits and Carryover Storage Drawdowns for WY 1970–2015

21.7.2 WSE Baseline

The Stanislaus River WSE-modeled full diversions averaged 651 TAF, and annual diversions were 100 percent of full diversions in 70 percent of the years (Table 21-3). The annual WSE baseline diversions were less than 92 percent of full diversions in 10 percent of the years, were less than 80 percent of full diversions in less than 5 percent of the years. The minimum Stanislaus River WSE baseline diversions (in 1992) were 50 percent of average full diversions.

The WSE model baseline results are also shown in Figure 21-4. The WSE baseline results were higher than the historical diversions and lower than the historical carryover storage patterns. The WSE baseline diversions were often higher than historical diversions because the full contract diversions of 755 TAF were included in the WSE baseline. The WSE baseline required release flows (e.g., flows required by the RPA) were considerably higher than the historical release flows. The WSE baseline carryover storage pattern was almost identical to the historical carryover storage for 1987–1994, but the WSE carryover storage was much less than historical carryover storage for 2000–2005, was slightly less than historical in 2007–2010, and was very similar for 2012–2015. The differences in the carryover storage can be caused by differences in diversions, differences in the required releases, or differences in the flood control releases; the differences in New Melones Reservoir storages appear to be caused by slightly higher WSE diversions during these recent dry year periods. Generally, the WSE baseline provides a very accurate calculation of drought conditions for the Stanislaus River, caused by the combination of dry year periods, with higher full water supply diversions and higher required flow releases.

Historical operations and the extended WSE baseline results demonstrate that New Melones Reservoir storage can sustain full water supply diversions through several dry years. The severity of drought years for the Stanislaus River can be determined by the distribution of diversion deficits as a percentage of full diversions. For the extended WSE baseline diversions in 1922–2015, there were 10 years (11 percent of years) with a deficit of >65 (10 percent of average full diversions), and 3 years (3 percent of years) with a deficit of >130 TAF (20 percent of average full diversions). If greater than a 20 percent water supply diversion deficit is used to identify drought years, the Stanislaus River extended WSE baseline diversions were reduced to less than 80 percent of full diversions in about 3 percent of the years.

21.8 ~~21.7.3~~ Tuolumne River Diversions and Carryover Storage

21.8.1 ~~21.7.4~~ Historical

Figure 21-5 shows the Tuolumne River runoff and average runoff along with historical diversions and carryover storages for WY 1970–2015. Drought years are identified as years with substantial diversion deficits (e.g., <80 percent full diversions). The historical diversions from La Grange Dam for MID/TID from WY 1970–1995 were generally about 1,000 TAF, with a maximum of 1,100 TAF in a few years. A full diversion target of 1,000 TAF for the MID/TID canals was assumed for the historical analysis.

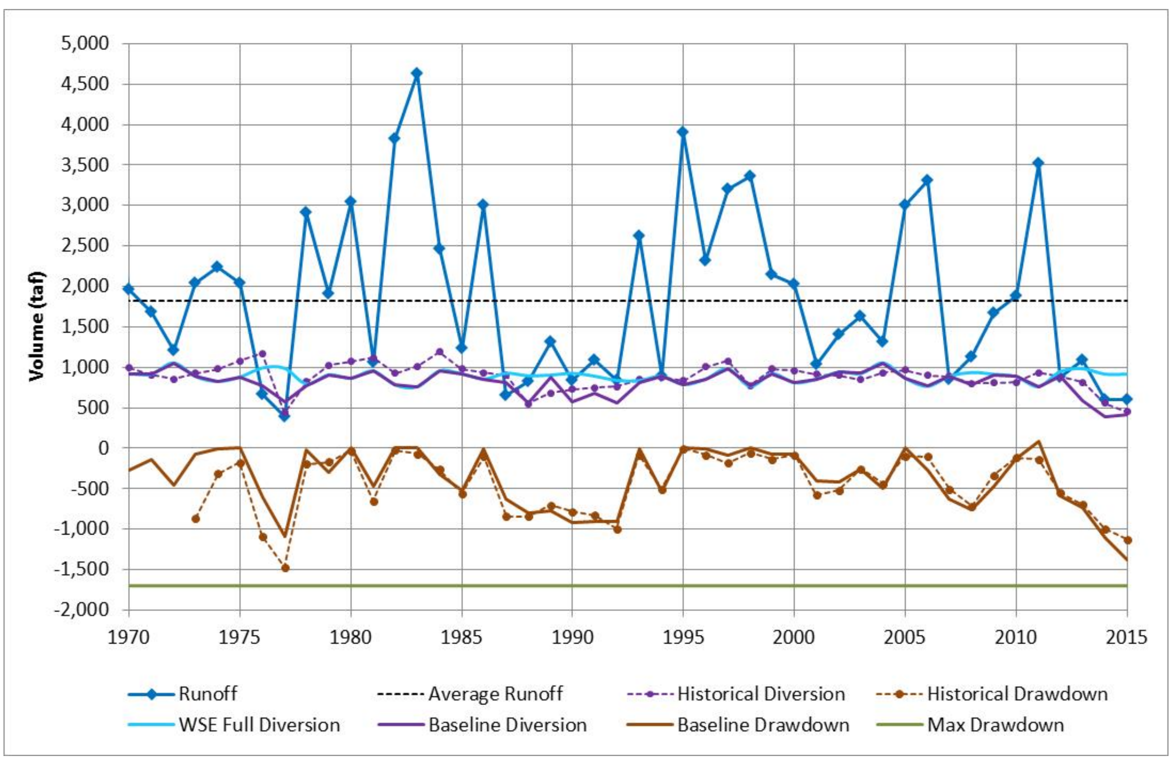

Figure 21-5. Tuolumne River Runoff with Historical and WSE Baseline Diversions, Diversion Deficits and Carryover Storage Drawdowns for WY 1970–2015

The historical diversions were less than 1,000 TAF in 1977 and 1978, in 1988–1994, and in 1998. The historical New Don Pedro Reservoir carryover storage was reduced in most of the dry years. However, because the CCSF has a large water bank in New Don Pedro Reservoir, and because MID/TID also maintain a moderate carryover storage, the carryover storage was only rarely less than 1,000 TAF (carryover storage deficit of more than 750 TAF). The minimum historical carryover storage was 250 TAF in 1977, and was 750 TAF in 1992.

The historical reservoir operations during 2012–2015 showed reduced diversions to about 560 TAF in 2014 and reduced carryover storage to 780 TAF in 2014. The low Tuolumne River runoff of 602 TAF in 2015 and reduced carryover storage in 2014 resulted in low diversions (450 TAF) and low carryover storage (644 TAF) in 2015.

21.8.2 ~~21.7.5~~ WSE Baseline

The Tuolumne River WSE model full diversions averaged 901 TAF, and annual diversions were 100 percent of full diversions in 60 percent of the years (Table 21-3). The annual WSE baseline diversions were less than 92 percent of full diversions in 20 percent of the years, were less than 67 percent of full diversions in 10 percent of the years, and the minimum diversions were 43 percent of full diversions in 2014 (Table 21-3).

The extended WSE baseline results are also shown in Figure 21-5. The WSE model showed average full diversions were 901 TAF, which generally matched the historical MID/TID diversions for 1970–2015. The WSE baseline diversions averaged 840 TAF (93 percent of full diversions) with diversion deficits in most of the same years as historical diversion deficits. The WSE baseline carryover storage pattern was nearly identical to the historical New Don Pedro Reservoir storage; the WSE diversions and carryover storage for the Tuolumne River was very close to the historical operations. The general agreement between the historical operations and the WSE model results indicate that the new Don Pedro reservoir operations have not changed substantially during the 1970–2015 period. Although the historical and WSE model diversions fluctuated somewhat differently, the average diversions were similar (882 TAF for historical and 813 TAF for WSE model results) and the required flows were also similar, so the reservoir drawdown in dry year periods was similar. Generally, the WSE baseline provides a very accurate calculation of drought conditions for the Tuolumne River.

Historical operations and the extended WSE baseline results demonstrate that New Don Pedro reservoir storage can sustain full water supply diversions through several dry years. The severity of drought years for the Tuolumne River can be determined by the water supply diversion deficits as a percentage of full diversions. For the extended WSE baseline diversions in 1922–2015, there were 19 years (20 percent of years) with a deficit of >90 (10 percent of average full diversions), and 13 years (14 percent of years) with a deficit of >180 TAF (20 percent of average full diversions). If greater than a 20 percent water supply diversion deficit is used to identify drought years, the Tuolumne River extended WSE baseline diversions were reduced to less than 80 percent of full diversions in about 14 percent of the years (1 or 2 out of 10).

21.9 ~~21.8~~ Merced River Diversions and Carryover Storage

21.9.1 ~~21.8.1~~ Historical

Figure 21-6 shows the Merced River runoff and average runoff along with historical diversions and carryover storages for WY 1970–2015. Drought years are identified as years with substantial diversion deficits (e.g., <80 percent full diversions). The historical diversions from the Merced River for the Merced ID canals were about 550 TAF; this was assumed as the full diversion for the historical analysis. The historical diversion were less than 500 TAF in 1977, 1988–1993, 2008, and in 2012–2015. The historical Lake McClure carryover storage (maximum of 850 TAF) was reduced in most of the dry years. The historical carryover storage was 100 TAF in 1977, was about 100–200 TAF in 1988–1992, was reduced to 120 TAF in 2014, and was 87 TAF in 2015.

The historical reservoir operations during 2012–2015 showed reduced diversions of 210 TAF and reduced carryover storage of 122 TAF in 2014. The low Merced River runoff and reduced carryover storage in 2014 resulted in very low diversions (20 TAF) and very low carryover storage (87 TAF) in 2015.

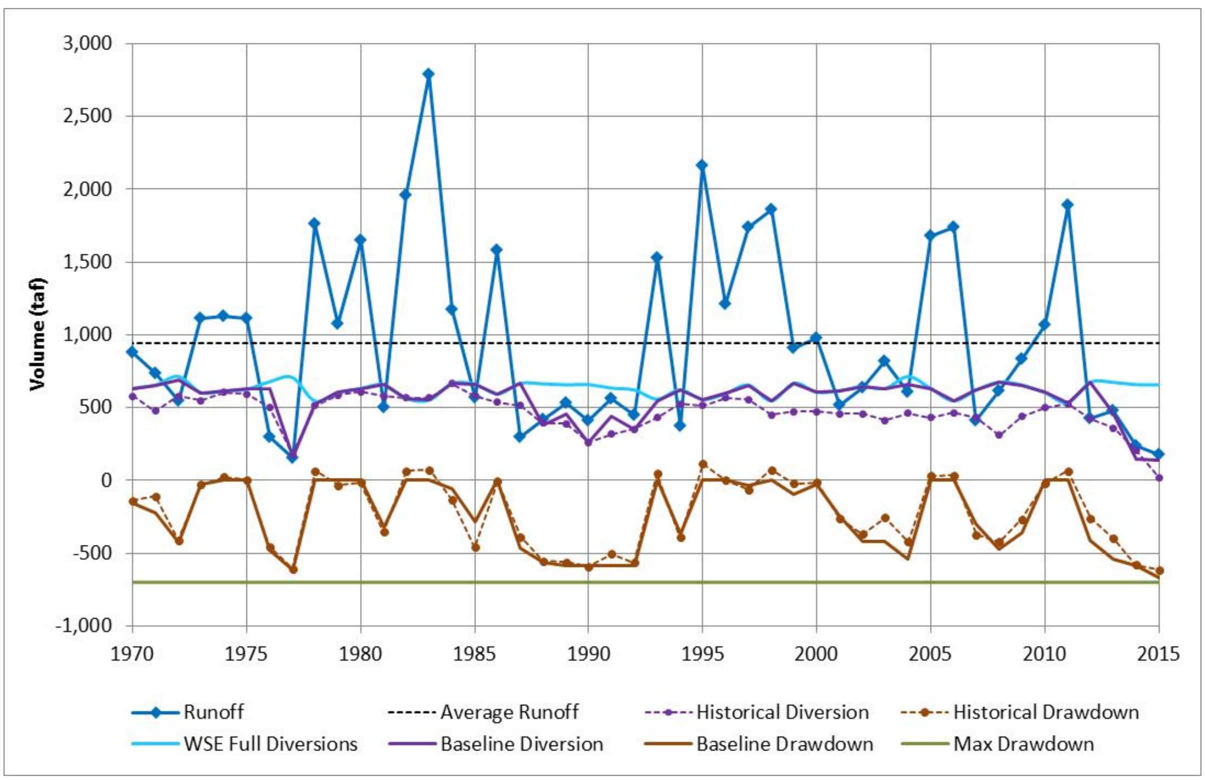

Figure 21-6. Merced River Runoff with Historical and WSE Baseline Diversions, Diversion Deficits and Carryover Storage Drawdowns for WY 1970–2015

21.9.2 ~~21.8.2~~ WSE Baseline

The WSE model showed Merced River full diversions averaged 632 TAF, and annual diversions were 100 percent of full diversions in 60 percent of the years (Table 21-3). The annual WSE baseline diversions were less than 92 percent of full diversions in 20 percent of the years, were less than 63 percent of full diversions in 10 percent of the years, and the minimum Merced River WSE baseline diversions of 137 TAF (in 2015) were 21 percent of full diversions.

The extended WSE baseline results are also shown in Figure 21-6. The WSE model showed average full diversions were 632 TAF (including the riparian diversions of about 50 TAF) and the WSE baseline diversions averaged 574 TAF (91 percent of full diversions). The WSE baseline diversions were higher than the historical diversions, with diversion deficits in most of the same years. The WSE baseline carryover storage pattern was also nearly identical to the historical carryover storages. Overall the extended WSE baseline provides an accurate match with the historical Lake McClure operations for 1970–2015.

Historical operations and the extended WSE baseline results demonstrate that Lake McClure storage can sustain full water supply diversions through only a few dry years. The severity of drought years for the Merced River can be determined by the diversion deficits as a percentage of full diversions. For the WSE baseline diversions in 1922–2015, there were 18 years (19 percent of years) with a deficit of >63 (10 percent of average full diversions), and 14 years (15 percent of years) with a deficit of >126 TAF (20 percent of average full diversions). If greater than a 20 percent water supply diversion deficit is used to identify drought years, the Merced River extended WSE baseline diversions were less than 80 percent of full diversions in about 15 percent of the years (1 or 2 out of 10).

21.10 ~~21.9~~ LSJR Alternatives and Water Supply Operations

The monthly WSE model used for this recirculated substitute environmental document (SED) evaluation of the LSJR flow objective alternatives calculated the reservoir operations and diversions for the 1922–2003 monthly runoff (or reservoir inflow). The extended WSE model matched the recent historical operations for 2004–2015 very well, as described in the previous section. The extended WSE model-calculated annual results for water supply diversions, required river releases, flood-control releases, reservoir evaporation, and carryover storage for each LSJR alternative are summarized and compared with the baseline results for each tributary.

The WSE model results indicate that implementing the LSJR alternatives would result in more years with drought conditions (i.e., reduced water availability and thus reduced water supply diversions). Increasing the February–June flows under the LSJR alternatives would reduce the reservoir carryover storage in dry years and would reduce the water supply diversions in dry year periods. Although some years with high runoff (and flood-control spills) would still provide full diversions and maximum carryover storage, most years would have reduced storage and/or reduced diversions. This section summarizes the extended WSE baseline and LSJR alternative annual results, showing and describing the likely release flows under each LSJR alternative and corresponding changes in carryover storage and water supply diversions for each tributary. The increased drought years and increased diversion deficits are summarized as the cumulative distribution of water supply diversions for each alternative (Tables 21-7a, 21-b, 21-c, 21-d, and 21-e) for each of the tributaries.

21.10.1 ~~21.9.1~~ Stanislaus River Operations

Figure 21-7a shows the Stanislaus River annual runoff and extended WSE modeled annual results for the baseline flow requirements[2] and the baseline flows at Ripon that includes reservoir spills in a few years, for 1922–2015. The baseline release flows are a relatively large fraction of the runoff because the baseline required flows include the RPA flow schedules. The WSE baseline required flows averaged 484 TAF (44 percent of runoff); the flows at Goodwin (with spills) averaged 437 TAF (40 percent of runoff); and the flows at Ripon, with about 100 TAF (9 percent or runoff) of local inflows, averaged 536 TAF (48 percent of runoff). The Stanislaus River baseline flows were substantially higher than the required flows (because of reservoir spills) in a few years. The flow requirements were about 500 TAF/y (range of 250 TAF/y to 750 TAF/y) and the release flows were greater than 1,000 TAF in only 5 years (about 1 out of 20 years). The WSE baseline New Melones reservoir spills averaged 52 TAF (5 percent of inflow); spills were infrequent because of the large carryover storage capacity of New Melones Reservoir (180 percent of average runoff).

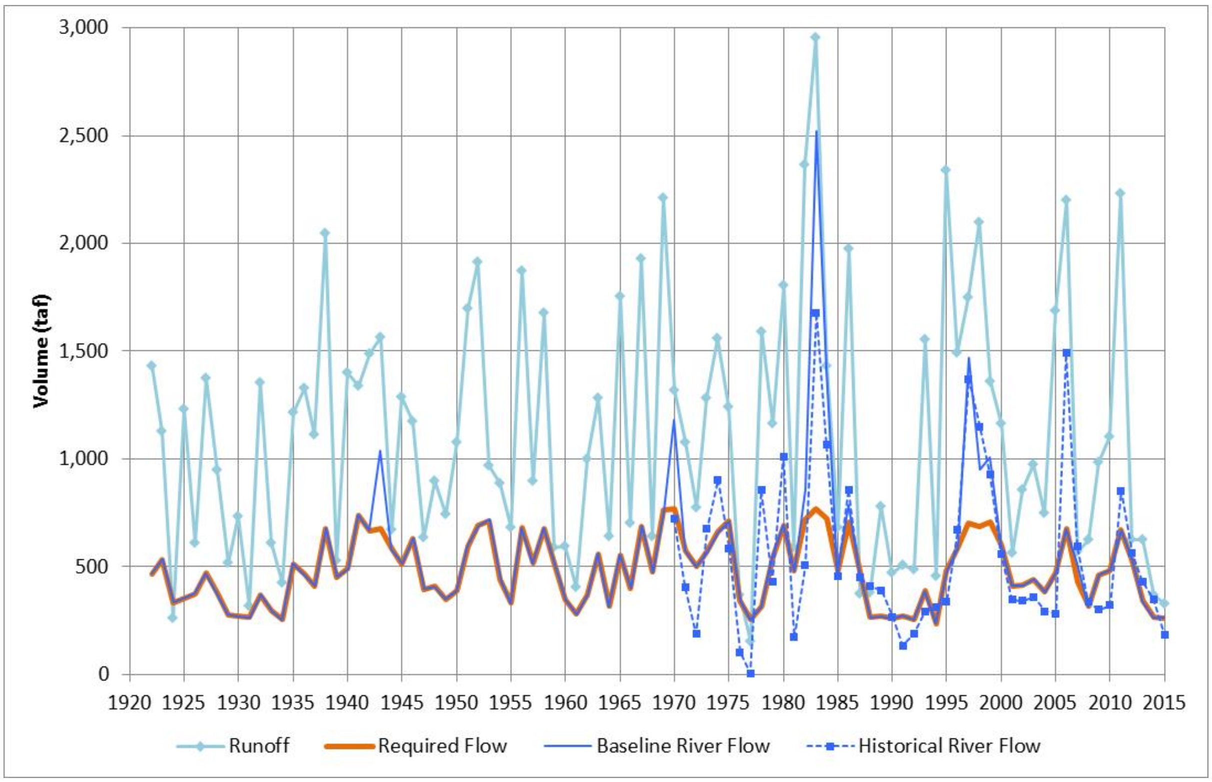

Figure 21-7a. WSE Baseline Required Flows and Release Flows at Ripon Compared with Stanislaus River Runoff and Recent Historical Flows

[2] Note the term flow requirements or required flows is used in this section and on several figures to define those flows that are either required under previous or existing agreements (e.g., flow requirements for VAMP) or would be required under the different LSJR alternatives (e.g., LSJR Alternative 3 would have a flow requirement of 40 percent unimpaired flow).

Figure 21-7b shows the extended WSE-modeled annual results for the baseline and flow objective alternatives release flows for the Stanislaus River at Ripon for 1922–2015. The existing flow requirements are specified at Goodwin, while the LSJR flow objectives were specified in the WSE model at Ripon, where the flows included the local inflow of about 100 TAF/y. LSJR Alternative 2 required flows averaged 482 TAF (44 percent of runoff), and release flows (including a few years with reservoir spills) averaged 444 TAF (40 percent of runoff) at Goodwin and 543 TAF (49 percent of runoff) at Ripon. LSJR Alternative 3 required flows averaged 576 TAF (52 percent of runoff) and release flows averaged 512 TAF (46 percent of runoff) at Goodwin and 610 TAF (55 percent of runoff) at Ripon. LSJR Alternative 4 required flows averaged 720 TAF (65 percent of runoff) and release flows averaged 640 TAF (58 percent of runoff) at Goodwin and 739 TAF (67 percent of runoff) at Ripon. All of the LSJR alternatives increased the fraction of runoff released for required flows, but LSJR Alternative 2 was similar to the baseline flows, because the baseline required flows (e.g., RPA schedules) were generally about 20 percent of the February–June runoff. LSJR Alternatives 3 and 4 increased the annual required flows and released flows in almost every year for the Stanislaus River because the New Melones Reservoir storage is large and reservoir spills occurred in only a few years under baseline.

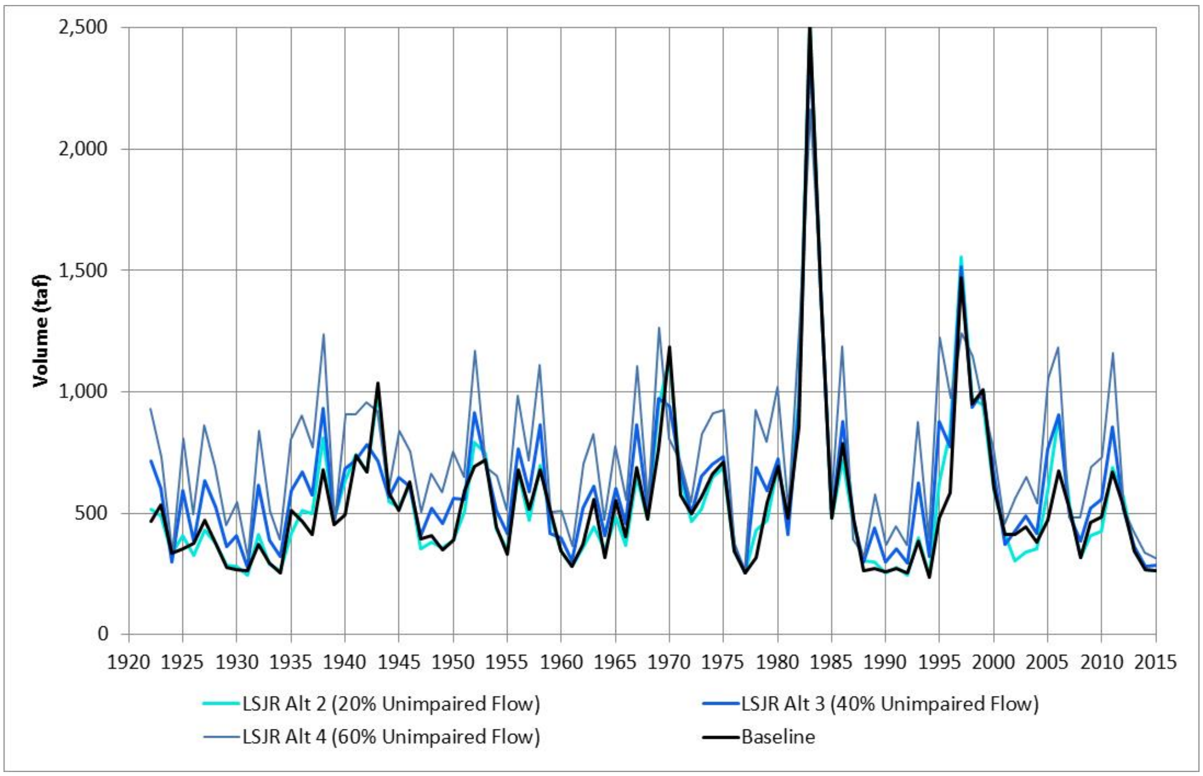

Figure 21-7b. WSE Baseline and LSJR Flow Objective Alternative Results for Stanislaus River Annual Flows at Ripon (TAF) for 1922–2003

Figure 21-7c shows the WSE-modeled annual results for New Melones carryover storage for the baseline and flow objective alternatives for 1922–2015. The baseline carryover storage was rarely full (2,000 TAF maximum) because the reservoir storage is almost twice the average runoff and several dry years are generally needed to reduce the storage, while several wet years are generally needed to refill the storage. The WSE baseline carryover storage was nearly full in only 6 years (1969, 1982, 1983, 1998, 2006, and 2011). The baseline carryover storage was low (<750 TAF) at the end of each major dry year period (e.g., 1929–1936, 1949–1950, 1961–1964, 1977, 1988–1994, 2002–2004, and 2014–2015). The New Melones Reservoir storage was large enough to provide nearly full diversions in many dry years, even with the relatively high required flows (e.g., RPA schedules). The WSE model showed carryover storages with LSJR alternatives were sometimes lower than the baseline storages, but the WSE-modeled carryover storages for the LSJR alternatives remained above 700 TAF[3]. This reduced the water supply diversions in years when the baseline carryover storage was less than 750 TAF. LSJR Alternatives 2 and 3 had similar carryover storage patterns, but LSJR Alternative 4 caused the carryover storage to be much less when compared to LSJR Alternatives 2 and 3 in several years (e.g., 1939–1946, 1952–1953, and 1969).

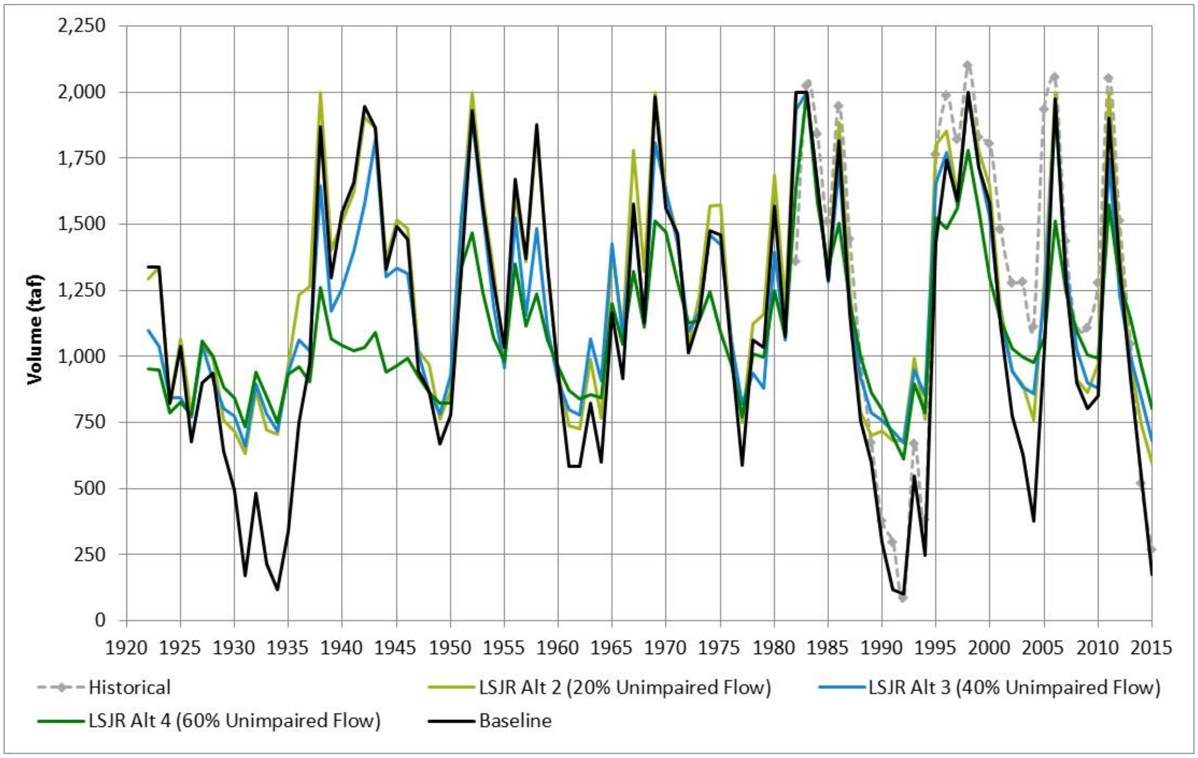

Figure 21-7c. WSE Baseline and LSJR Flow Objective Alternative Results for New Melones Carryover Storages for 1922–2015

Figure 21-7d shows the extended WSE-modeled annual results for Stanislaus River water supply diversions for the baseline and flow objective alternatives for 1922–2015. The baseline diversions fluctuated with the WSE-model full diversions (full water supply demands), generally between 550 TAF and 750 TAF. Baseline diversions were reduced in the major dry year periods (e.g., 1929–1936, 1976-1977, 1988–1994, 2002–2005 and 2013–2015). The average baseline Stanislaus River diversions were 635 TAF (57 percent of runoff). Under the LSJR alternatives, reduced diversions were largely the result of the increased flow requirements and the increased minimum carryover storage between the baseline and LSJR alternatives. The average annual diversion under LSJR Alternative 2 was reduced to 619 TAF (56 percent of runoff). The average annual diversion for LSJR Alternative 3 was reduced to 553 TAF (50 percent of runoff), and the average annual diversion for LSJR Alternative 4 was reduced to 426 TAF (39 percent of runoff). Whereas the baseline diversions were reduced only after several dry years once the carryover storage was reduced (to about 250

[3] This was because the WSE model included an assumption that the carryover storage would not be reduced below 750 TAF.

TAF), the increased minimum carryover storage (750 TAF) and the increased flow objectives reduced the diversions in more years. The increased carryover storage and increased required flows under the LSJR alternatives reduced the diversions to a smaller fraction of the average runoff (57 percent of runoff for the baseline, 56 percent of runoff for LSJR Alternative 2, 50 percent of runoff for LSJR Alternative 3, and 39 percent of runoff for LSJR Alternative 4).

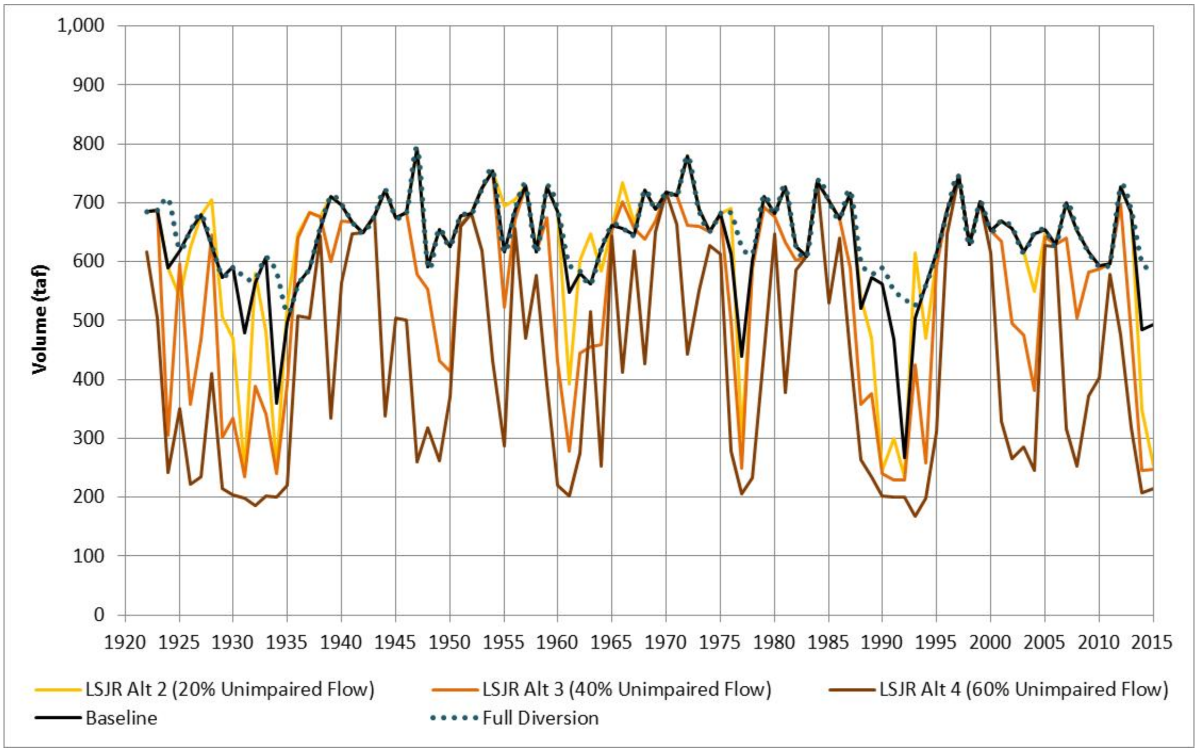

Figure 21-7d. WSE Baseline and LSJR Flow Objective Alternative Results for Stanislaus River Water Supply Diversions for 1922–2015

Table 21-4a gives a comparison of the cumulative distribution of the extended WSE model Stanislaus River water supply diversions for the LSJR alternatives for 1922–2015. There are many years with higher-than-average runoff that allowed full Stanislaus River water supply diversions under baseline conditions, even with the relatively high baseline required flows (44 percent of average runoff). The large storage capacity of New Melones Reservoir allowed full diversions in several dry year periods; reduced water supply diversions were calculated in about 10 percent of the years and the average annual diversion was 635 TAF for the WSE baseline. The LSJR Alternative 2 diversions were reduced in about 20 percent of the years; the increased minimum carryover storage requirement caused diversion deficits earlier in each dry year period, but the average annual diversion for LSJR Alternative 2 was only slightly reduced (619 TAF). The LSJR Alternative 3 diversions were reduced in about 50 percent of the years. The increased minimum carryover storage requirement shifted some of the diversion deficits, and the higher required flows reduced the diversions substantially (more than 20 percent of full diversions) in about 10 percent of the years. The average annual diversion for LSJR Alternative 3 was reduced by 12 percent of the average full diversions to 553 TAF. The LSJR Alternative 4 diversions were reduced in about 80 percent of the years. The increased minimum carryover storage requirement shifted some of the diversion deficits, and the higher required flows reduced the diversions substantially (more than 20 percent of full diversions) in about 65 percent of the years. The average annual diversion for LSJR Alternative 4 was reduced by 30 percent of the average full diversion to 426 TAF. The largest reductions in diversions for the LSJR alternatives occurred in drought years, when the baseline diversions were already reduced.

Table 21-4a. Cumulative Distributions of WSE Model Stanislaus River Diversions for LSJR Alternatives for 1922–2015

Average Runoff (TAF)			1,107					
Average Full Diversion (TAF)			651					
Percentile	Stanislaus Baseline Diversion (TAF)	% Full Diversion	Stanislaus LSJR Alt 2 Diversion (TAF)	% Full Diversion	Stanislaus LSJR Alt 3 Diversion (TAF)	% Full Diversion	Stanislaus LSJR Alt 4 Diversion (TAF)	% Full Diversion
Max	792	100	792	100	753	100	745	100
90	724	100	726	100	701	100	650	99
80	703	100	705	100	681	100	627	95
70	685	100	688	100	669	100	579	90
60	676	100	680	100	648	98	503	73
50	656	100	661	100	622	96	411	60
40	627	100	647	100	588	85	330	49
30	615	100	616	100	477	76	273	44
20	582	99	582	95	390	66	233	37
10	549	92	469	79	285	46	203	34
Min	268	50	235	43	230	40	167	32
Average	635	98	619	95	553	85	426	65
Average Deficit (TAF)		16		32		98		225

Figure 21-7e shows the overall effects of the extended WSE baseline and LSJR alternatives on the Stanislaus River diversion deficits. This graph illustrates the basic concept that reservoir operations are a three-way balance between the runoff and: (1) required release flows, (2) full water supply diversions, and (3) carryover storage. The sum of the annual LSJR alternatives release flow requirements (TAF) and full diversions (TAF) are plotted as a function of the runoff (TAF). The sum of the average full water supply diversions and the required flows represents the total water demands for each year. The WSE model-calculated diversion deficits are also plotted as a function of runoff. The sum of the baseline flow requirements and full diversions were generally higher than runoff, until the runoff was greater than 1,000 TAF. When the runoff was less than the average runoff, full water supply diversions required carryover storages to be reduced to supplement the runoff. The baseline diversion deficits generally increased with lower runoff, and there were some diversion deficits when runoff was less than about 1,500 TAF. The LSJR alternatives increased the water needed for required release flows and full water supply diversions, and generally resulted in larger diversion deficits. The sum of the full diversions and the required flows for LSJR Alternative 3 were generally higher than runoff until runoff was greater than 1,500 TAF. The sum of the full diversions and the required flows for LSJR Alternative 4 were generally higher than runoff until runoff was greater than 1,750 TAF.

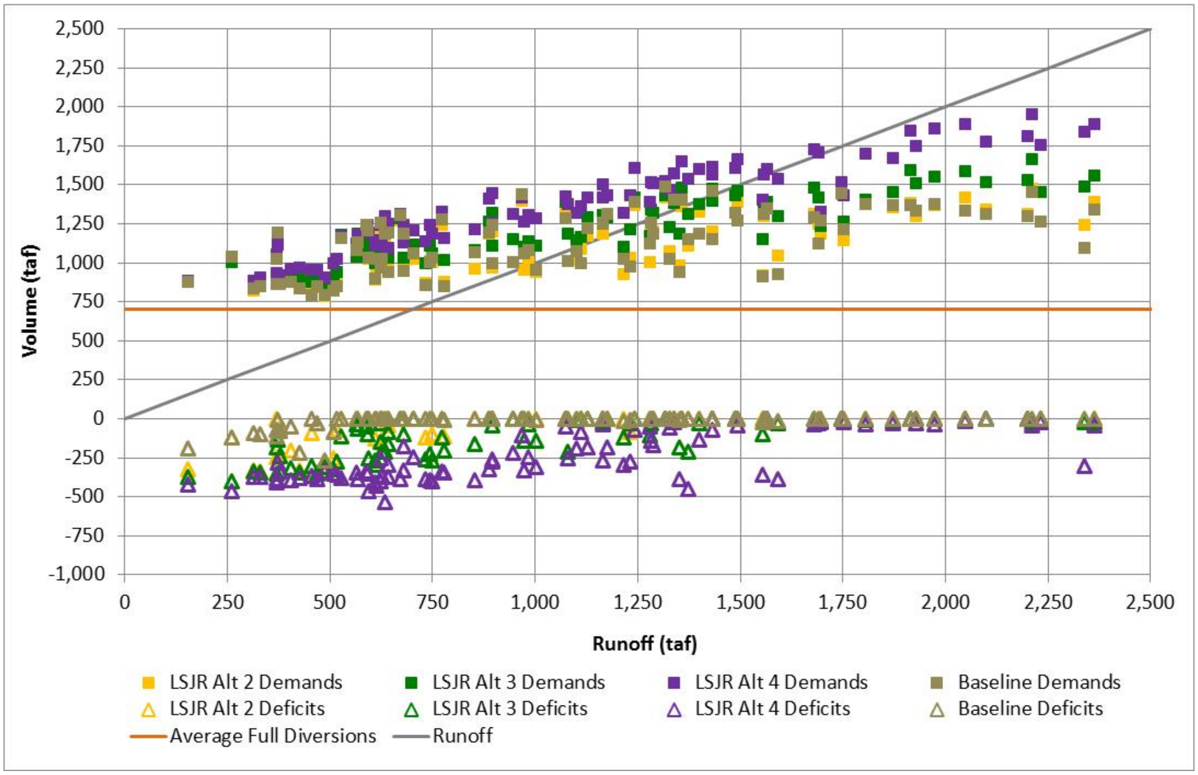

Figure 21-7e. Relationships between Stanislaus River Runoff, Sum of Alternative Flow Requirements and Full Water Supply Diversions, and Diversion Deficits for 1922–2015

21.10.2 ~~21.9.2~~ Tuolumne River Operations

Figure 21-8a shows the Tuolumne River annual runoff and extended WSE-modeled annual results for the baseline required flows at La Grange and the baseline flows at Modesto that included reservoir spills in about half of the years (58 out of 94), for 1922–2015. The WSE baseline required flows averaged 443 TAF (28 percent of inflow), the release flows at La Grange (with spills) averaged 683 TAF (43 percent of inflow) and the total flows at Modesto, with about 215 TAF (14 percent of inflow) of local inflows, averaged 897 TAF (57 percent of inflow). The Tuolumne River baseline flows are substantially higher than the required flows (because of reservoir spills) in many years. The baseline required flows were about 500 TAF/y (range of 200 TAF/y to 800 TAF/y) and the release flows were greater than 1,000 TAF in about 38 years (4 out of 10 years). The WSE baseline New Don Pedro Reservoir spills averaged 454 TAF (29 percent of inflow).

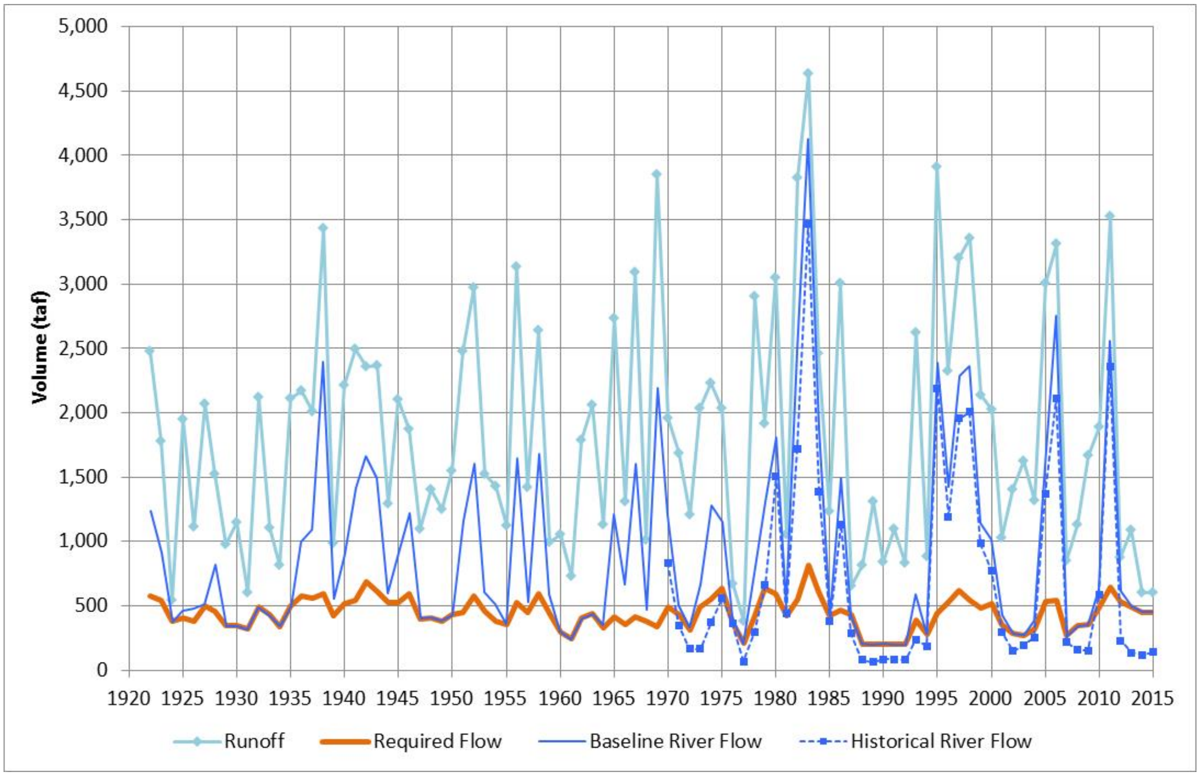

Figure 21-8a. WSE Baseline Required Flows and Release Flows at Modesto Compared with Tuolumne River Runoff and Recent Historical Flows

Figure 21-8b shows the extended WSE-modeled annual results for the baseline and LSJR alternative release flows at Modesto compared to the annual New Don Pedro Reservoir inflow (i.e., runoff minus 250 TAF) for the Tuolumne River for 1922-2015. The baseline minimum flows are required at La Grange, while the required flows for the LSJR alternatives were specified in the WSE model at Modesto, where the flows included the local inflow of 215 TAF/y. The LSJR Alternative 2 required flows averaged 525 TAF (33 percent of inflow) and the LSJR Alternative 2 release flows (including reservoir spills) averaged 702 TAF (45 percent of inflow) at La Grange and 916 TAF (58 percent of inflow) at Modesto. Spills were reduced to an average of 392 TAF (25 percent of inflow). The LSJR Alternative 3 required flows averaged 774 TAF (49 percent of inflow) and the LSJR Alternative 3 release flows averaged 802 TAF (51 percent of inflow) at La Grange and 1,016 TAF (64 percent of inflow) at Modesto. Spills were reduced to an average of 242 TAF (15 percent of inflow). The LSJR Alternative 4 required flows averaged 1,048 TAF (66 percent of inflow) and the LSJR Alternative 4 release flows averaged 978 TAF (62 percent of inflow) at La Grange and 1,192 TAF (76 percent of inflow) at Modesto. Spills were reduced to an average of 143 TAF (9 percent of inflow). The LSJR alternatives increased the fraction of runoff released for required flows and reduced the fraction of the reservoir inflow that was released for flood control (spills).

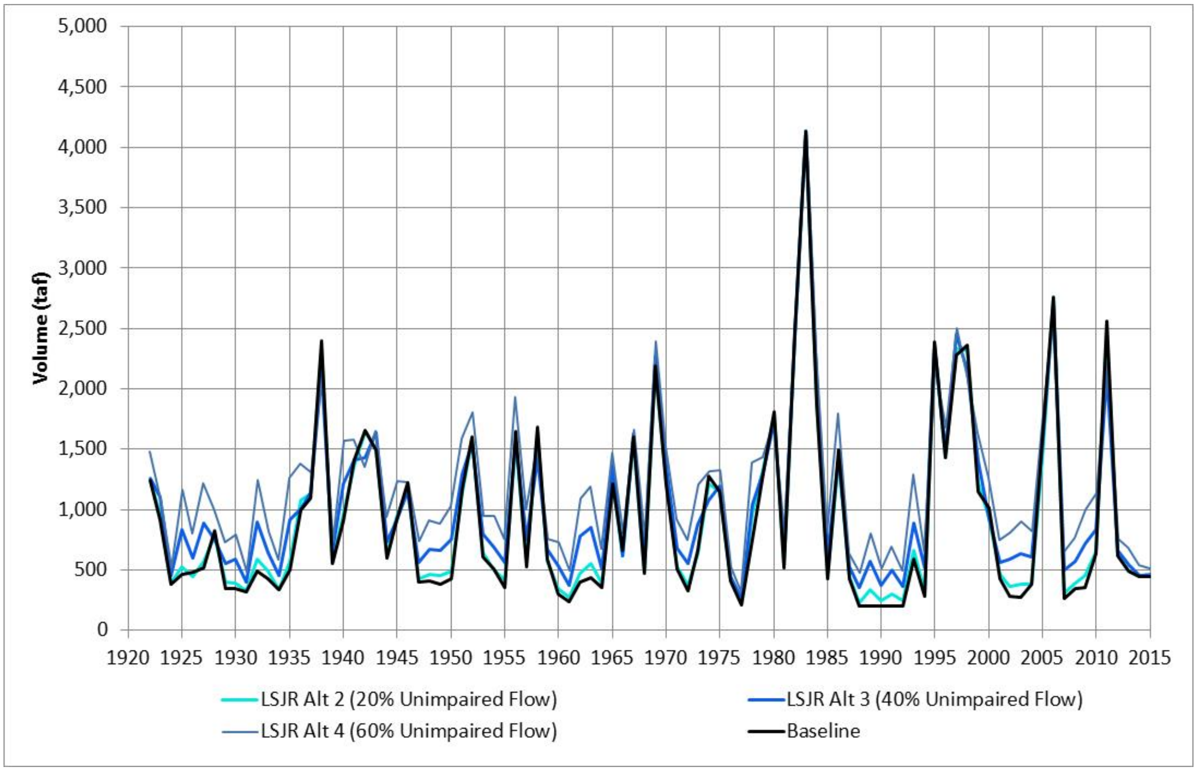

Figure 21-8b. WSE Baseline and LSJR Flow Objective Alternative Results for Tuolumne River Annual Flows at Modesto (TAF) for 1922–2015

Figure 21-8c shows the extended WSE-modeled annual results for New Don Pedro Reservoir carryover storage for the baseline and flow objective alternatives for 1922–2015. The baseline carryover storage was full (1,700 TAF maximum) in about 25 percent of the years. The baseline carryover storage was low (<1,000 TAF) at the end of each major dry year period (e.g., 1929–1934, 1947–1950, 1960–1962, 1977, 1988–1992, 2008, and 2013–2015). The New Don Pedro Reservoir storage was large enough to provide nearly full diversions in many dry years. The WSE model carryover storages with the flow objective alternatives were sometimes lower, because the higher required flows reduced the carryover storage in some years; but many other years had similar carryover storages because although the alternative flow objectives increased the required flows from February–June, the higher release flows reduced reservoir spills and so the carryover storages remained similar.

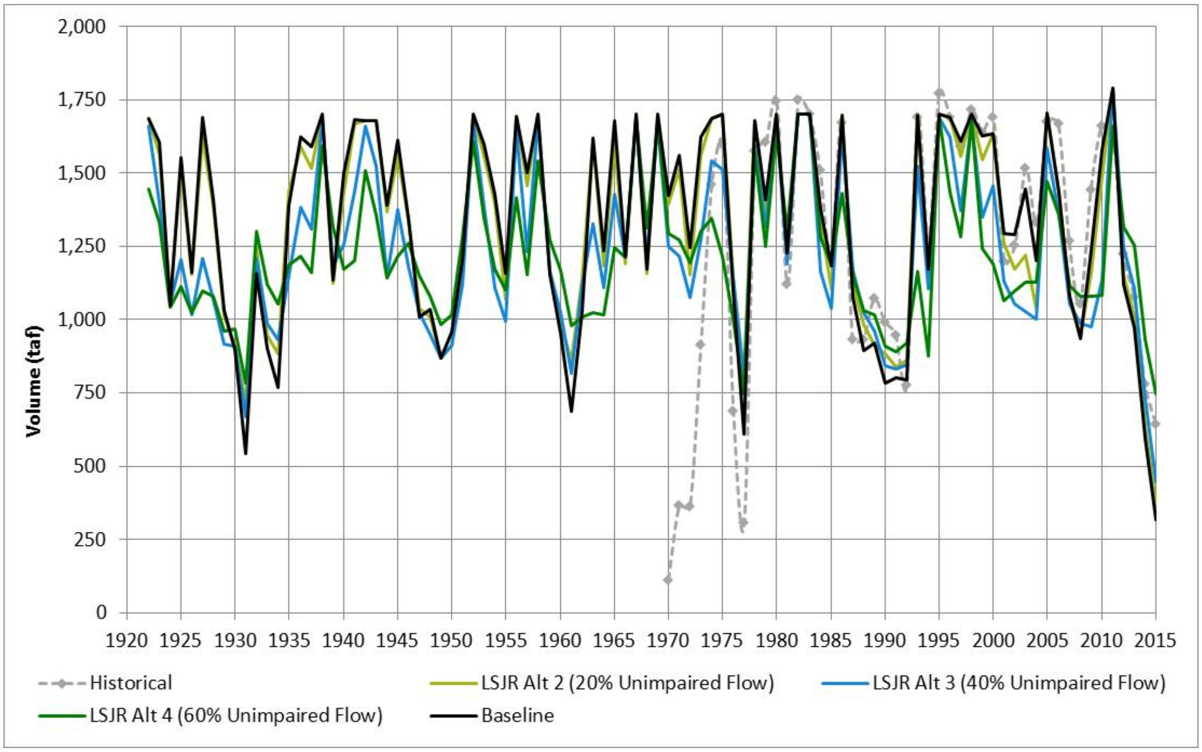

Figure 21-8c. WSE Baseline and LSJR Flow Objective Alternative Results for New Don Pedro Carryover Storages for 1922–2015

Figure 21-8d shows the extended WSE-modeled annual results for Tuolumne River water supply diversions for the baseline and LSJR alternatives for 1922–2015. The baseline diversions fluctuated with the WSE model full diversions (full water supply demands), generally between 800 TAF and 1,000 TAF. Baseline diversions were reduced to less than 800 TAF in a few years. The average baseline Tuolumne River diversions were 840 TAF (53 percent of inflow). The average annual diversion for LSJR Alternative 2 was reduced to 820 TAF (52 percent of inflow). The average annual diversion for LSJR Alternative 3 was reduced to 722 TAF (46 percent of inflow) and the average annual diversion for LSJR Alternative 4 was reduced to 545 TAF (35 percent of inflow).

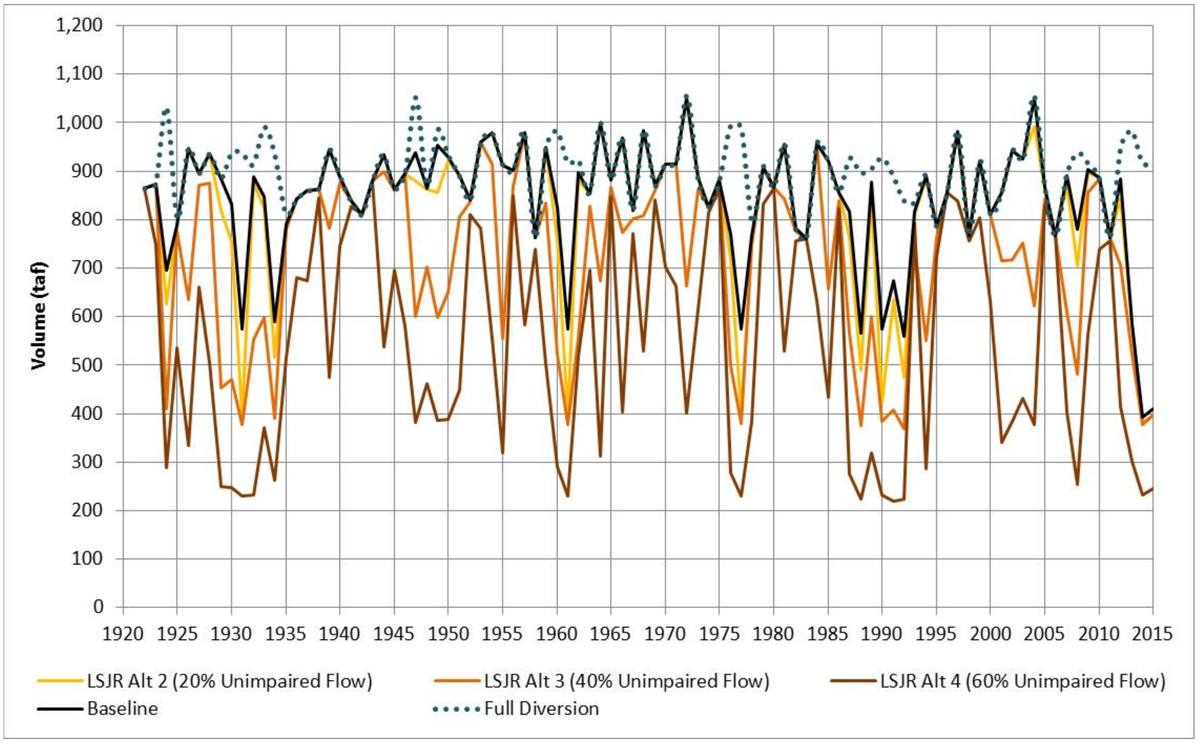

Figure 21-8d. WSE Baseline and LSJR Flow Objective Alternative Results for Tuolumne River Water Supply Diversions for 1922–2015

Table 21-4b gives a comparison of the cumulative distribution of WSE-modeled Tuolumne River water supply diversions for the LSJR alternatives for 1922–2015. There were many years (approximately half of the years) with higher than average runoff that allowed full Tuolumne River water supply diversions under baseline conditions. The large storage capacity of New Don Pedro Reservoir allowed full diversions in several dry year periods; reduced water supply diversions were calculated in about 20 percent of the years, and the average annual diversion for the baseline was 840 TAF. The LSJR Alternative 2 diversions were reduced in about 25 percent of the years; the average annual diversion for LSJR Alternative 2 was reduced slightly to 820 TAF. The LSJR Alternative 3 diversions were reduced in about 50 percent of the years; the diversions were reduced substantially (more than 20 percent of full diversions) in about 40 percent of the years. The average annual diversion for LSJR Alternative 3 was reduced to 722 TAF. The LSJR Alternative 4 diversions were reduced in about 80 percent of the years the diversions were reduced substantially (more than 20 percent of full diversions) in about 65 percent of the years; the diversions were less than half of full diversions in 45 percent of the years. The average annual diversion for LSJR Alternative 4 was reduced to 545 TAF.

Table 21-4b. Cumulative Distributions of WSE Model Tuolumne River Diversions for LSJR Alternatives for 1922–2015

Average Runoff (TAF)		1,827						
Average Full Diversion (TAF)		901						
Percentile	Tuolumne Baseline Diversion (TAF)	% Full Diversion	Tuolumne LSJR Alt 2 Diversion (TAF)	% Full Diversion	Tuolumne LSJR Alt 3 Diversion (TAF)	% Full Diversion	Tuolumne LSJR Alt 4 Diversion (TAF)	% Full Diversion
Max	1,050	100	1,050	100	982	100	879	100
90	957	100	957	100	898	100	836	99
80	931	100	921	100	867	100	787	96
70	901	100	895	100	857	100	740	84
60	886	100	879	100	823	97	655	74
50	869	100	862	100	774	94	532	57
40	856	100	842	100	746	82	436	49
30	824	99	810	98	647	67	384	40
20	775	92	764	85	554	60	297	31
10	614	67	595	60	408	44	245	27
Min	392	43	382	40	368	38	220	23
Average	840	93	820	91	722	80	545	61
Average Deficit (TAF)		61		81		179		356

Figure 21-8e shows the overall effects of the WSE baseline and LSJR alternatives on the Tuolumne River diversion deficits. This graph illustrates the basic concept that reservoir operations are a three-way balance between the runoff and: (1) required release flows, (2) full water supply diversions, and (3) carryover storage. The sum of the annual LSJR alternatives release flow requirements (TAF) and full diversions (TAF) are plotted as a function of the runoff (TAF). The sum of the average full water supply diversions and the required flows represents the total water demands for each year. The full diversions include the 250 TAF upstream diversions to CCSF. The WSE model calculated diversion deficits are also plotted as a function of runoff. The sum of the baseline flow requirements and full diversions were generally higher than runoff, until the runoff was greater than 1,500 TAF. When the runoff was less than the average runoff, full water supply diversions required carryover storages to be reduced to supplement the runoff. The baseline diversion deficits generally increased with lower runoff, and there were some diversion deficits when runoff was less than about 1,250 TAF. The LSJR alternatives increased the water needed for required release flows and full water supply diversions, and generally resulted in larger diversion deficits. The sum of the full diversions and the required flows for LSJR Alternative 3 were generally higher than runoff until runoff was greater than 2,000 TAF. The sum of the full diversions and the required flows for LSJR Alternative 4 were generally higher than runoff until runoff was greater than 2,500 TAF.

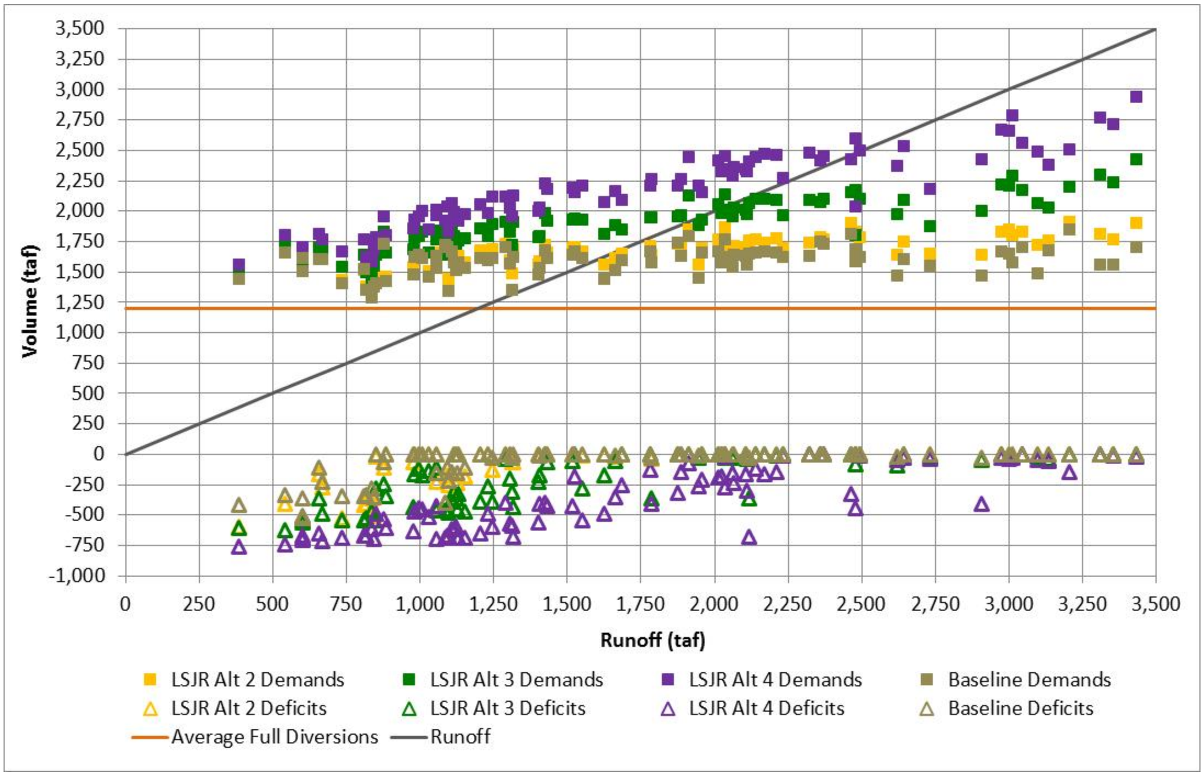

Figure 21-8e. Relationships between Tuolumne River Runoff, Sum of Alternative Flow Requirements and Full Water Supply Diversions, and Diversion Deficits for 1922–2015

21.10.3 ~~21.9.3~~ Merced River Operations

Figure 21-9a shows the Merced River annual runoff and extended WSE-modeled annual results for the baseline required flows at the Crocker-Huffman Dam and the baseline flows at Stevinson that included reservoir spills in many years, for 1922–2015. The baseline release flows at Stevinson were a relatively small fraction of the runoff in years without reservoir spills, and a larger fraction of runoff in years with spills. The WSE baseline required flows averaged 229 TAF (24 percent of runoff); the release flows at Crocker-Huffman Dam (with spills and about 50 TAF for Cowell Agreement diversions) averaged 382 TAF (40 percent of runoff); and the total flows at Stevinson, with 118 TAF (13 percent of runoff) of local inflows minus 50 TAF for riparian diversions, averaged 450 TAF (48 percent of runoff). The Merced River baseline flows were substantially higher than the required flows (because of reservoir spills) in several years. The required flows were about 200 TAF/y (range of 100 TAF/y to 400 TAF/y) and the release flows were greater than 500 TAF in about 25 years (3 out of 10 years). The WSE baseline Lake McClure spills averaged 222 TAF (23 percent of runoff).

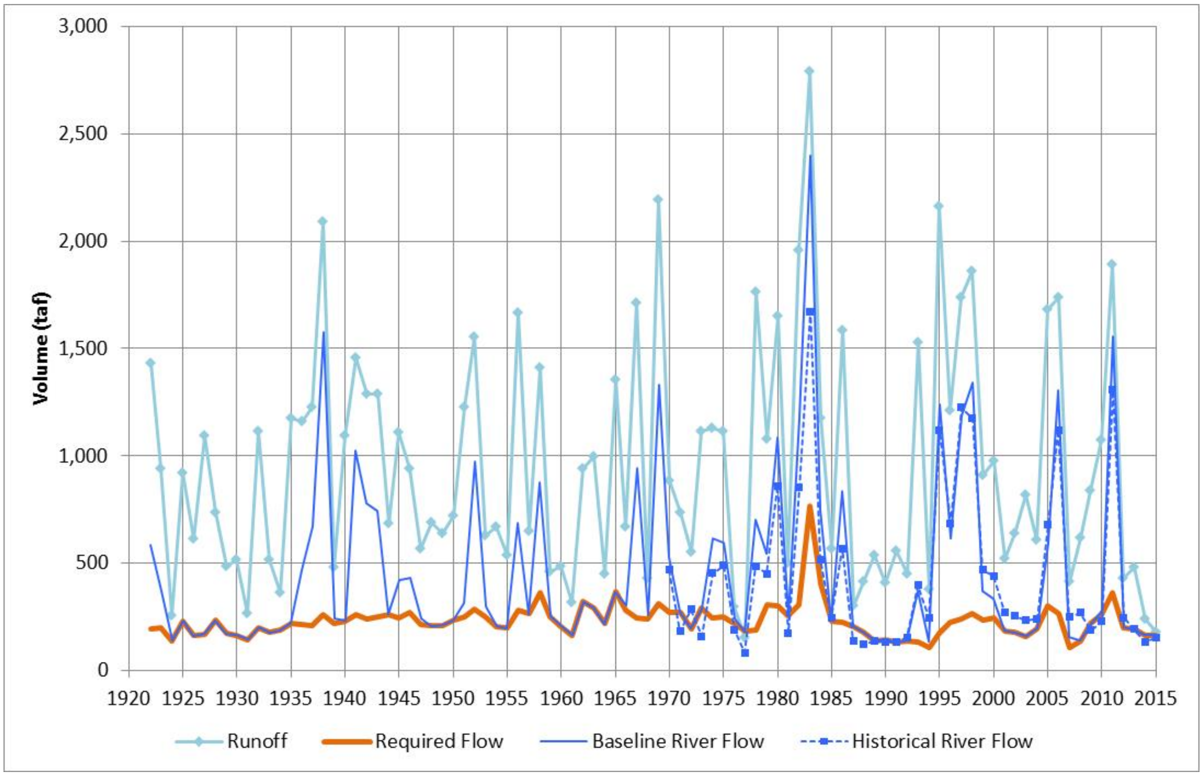

Figure 21-9a. WSE Baseline Required Flows and Release Flows at Stevinson Compared with Merced River Runoff and Recent Historical Flows

Figure 21-9b shows the extended WSE-modeled annual results for the baseline and LSJR alternatives release flows for the Merced River at Stevinson for 1922–2015. The LSJR Alternative 2 required flows averaged 288 TAF (30 percent of runoff), and the LSJR Alternative 2 release flows (including a few years with reservoir spills) averaged 414 TAF (44 percent of runoff) at Crocker-Huffman Dam and 482 TAF (51 percent of runoff) at Stevinson. The spills were reduced to 195 TAF (21 percent of runoff).The LSJR Alternative 3 required flows averaged 420 TAF (44 percent of runoff), and the LSJR Alternative 3 release flow averaged 475 TAF (50 percent of runoff) at Crocker-Huffman Dam and 543 TAF (57 percent of runoff) at Stevinson. The spills were reduced to 123 TAF (13 percent of runoff). The LSJR Alternative 4 required flows averaged 562 TAF (59 percent of runoff), and the LSJR Alternative 4 release flows averaged 561 TAF (59 percent of runoff) at Crocker-Huffman Dam and 630 TAF (67 percent of runoff) at Stevinson. The LSJR Alternative 4 spills were reduced to 68 TAF (7 percent of runoff).

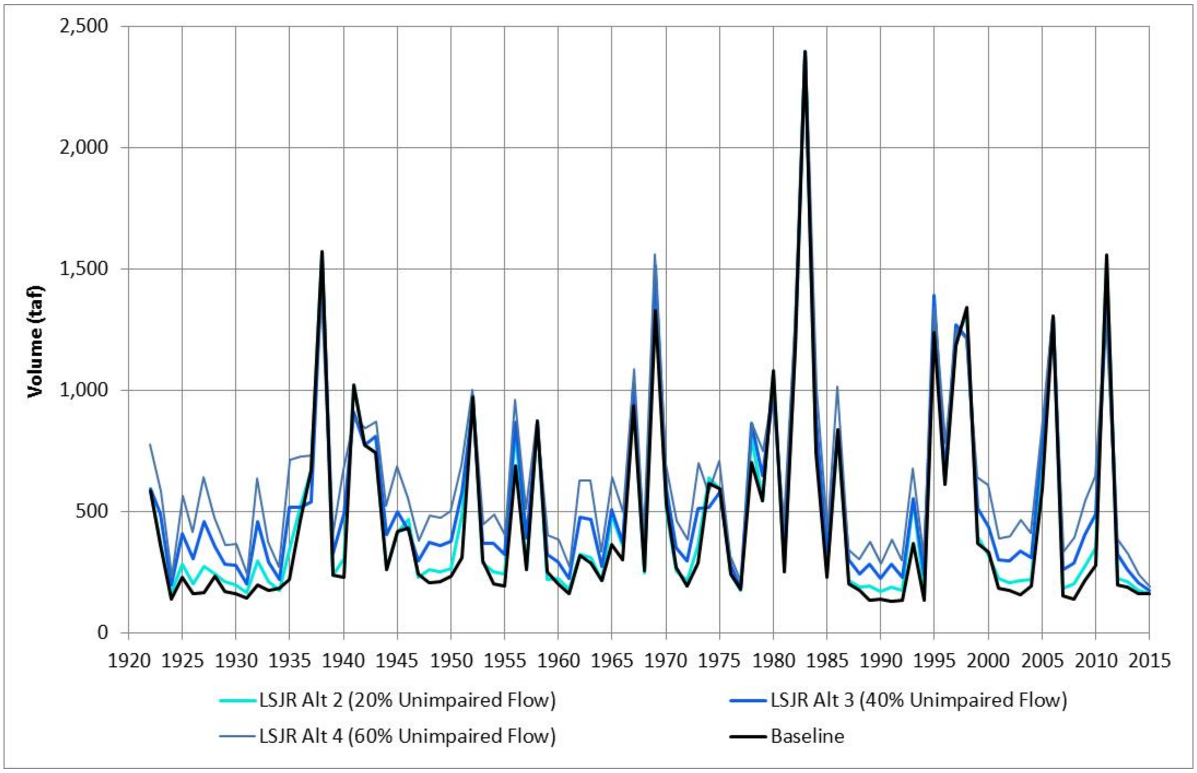

Figure 21-9b. WSE Baseline and LSJR Flow Objective Alternative Results for Merced River Annual Flows at Stevinson (TAF) for 1922–2015

Figure 21-9c shows the extended WSE-modeled annual results for Lake McClure carryover storage for the baseline and flow objective alternatives for 1922–2015. The baseline carryover storage was often full (700 TAF maximum) because the reservoir storage is less than the average runoff. The baseline carryover storage was low (<125 TAF) at the end of each major dry year period. The Lake McClure storage was large enough to provide nearly full diversions in some dry years, with reduced carryover storage, but the carryover storages for the LSJR flow objective alternatives were higher in some years, because a minimum carryover of about 250 TAF was assumed in the WSE model.

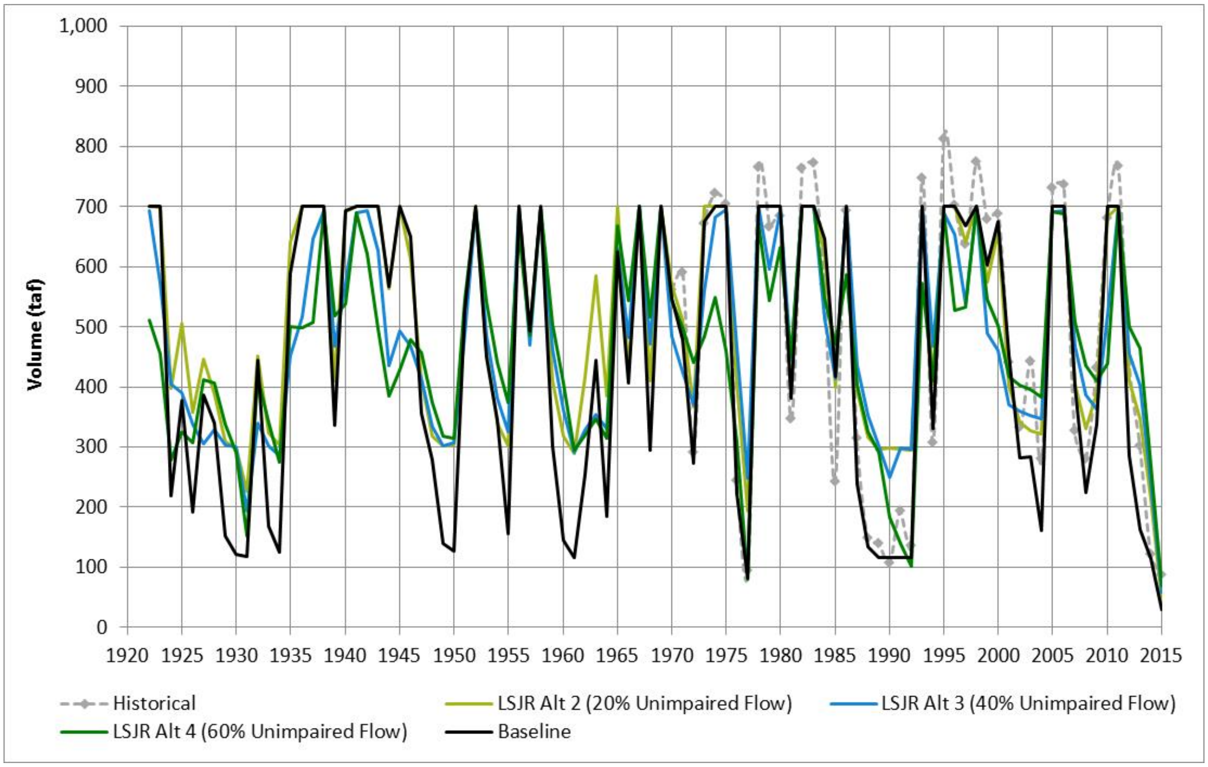

Figure 21-9c. WSE Baseline and LSJR Flow Objective Alternative Results for Lake McClure Carryover Storages for 1922–2015

Figure 21-9d shows the extended WSE-modeled annual results for Merced River water supply diversions for the baseline and LSJR flow objective alternatives for 1922–2015. The baseline diversions fluctuated with the WSE-modeled full diversions (water supply demands), generally between 550 TAF and 700 TAF. Baseline diversions were reduced in about 20 percent of the years. The average annual baseline Merced River diversion was 574 TAF (61 percent of runoff). The average annual diversion for LSJR Alternative 2 was reduced to 540 TAF (57 percent of runoff). The average annual diversion for LSJR Alternative 3 was reduced to 480 TAF (51 percent of runoff) and the average annual diversion for LSJR Alternative 4 was reduced to 395 TAF (42 percent of runoff).

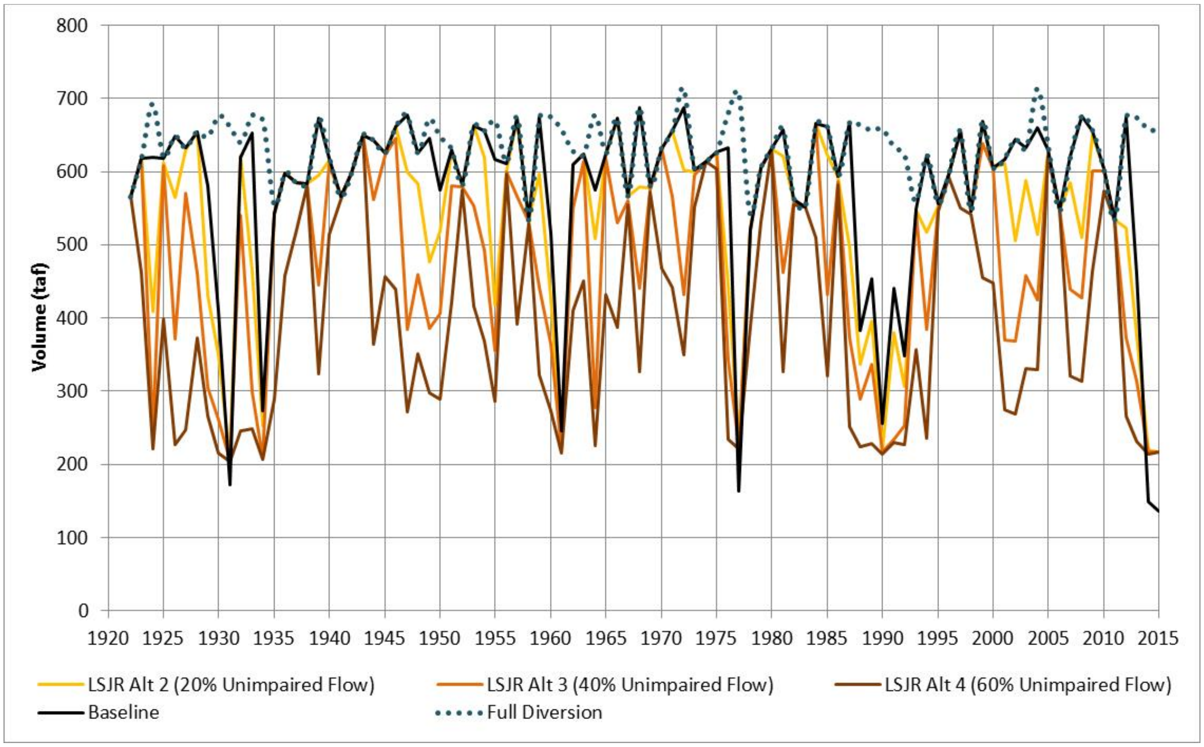

Figure 21-9d. WSE Baseline and LSJR Flow Objective Alternative Results for Merced River Water Supply Diversions for 1922–2015

Table 21-4c gives a comparison of the cumulative distribution of extended WSE model Merced River water supply diversions for the LSJR flow objective alternatives for 1922–2015. There were many years with higher-than-average runoff that allowed full Merced River water supply diversions under baseline conditions. The moderate storage capacity of Lake McClure allowed full diversions in some dry years but reduced water supply diversions were calculated in about 20 percent of the years and the average annual diversion was 574 TAF for the WSE baseline. The LSJR Alternative 2 diversions were reduced in about 40 percent of the years; the average annual diversion for LSJR Alternative 2 was reduced to 540 TAF. The higher required flows reduced the diversions substantially (more than 20 percent of full diversions) in about 25 percent of the years. The LSJR Alternative 3 diversions were reduced in about 50 percent of the years. The higher required flows reduced the diversions substantially (more than 20 percent of full diversions) in about 45 percent of the years. The average annual diversion for LSJR Alternative 3 was reduced to 480 TAF. The LSJR Alternative 4 diversions were reduced in about 75 percent of the years. The higher required flows reduced the diversions substantially (more than 20 percent of full diversions) in about 70 percent of the years; the diversions were less than half of full diversions in 40 percent of the years. The average annual diversion for LSJR Alternative 4 was reduced to 395 TAF.

Table 21-4c. Cumulative Distributions of WSE Model Merced River Diversions for LSJR Alternatives for 1922–2015

Average Runoff (TAF)			945					
Average Full Diversion (TAF)			632					
Percentile	Merced Baseline Diversion (TAF)	% Full Diversion	Merced LSJR Alt 2 Diversion (TAF)	% Full Diversion	Merced LSJR Alt 3 Diversion (TAF)	% Full Diversion	Merced LSJR Alt 4 Diversion (TAF)	% Full Diversion
Max	687	100	674	100	665	100	650	100
90	668	100	650	100	621	100	579	99
80	656	100	624	100	601	100	551	98
70	633	100	613	100	581	99	511	77
60	625	100	600	100	560	98	441	69
50	618	100	584	99	541	87	379	58
40	599	100	562	94	458	70	326	49
30	579	99	532	84	422	61	288	44
20	547	92	472	70	361	54	247	38
10	419	63	358	53	255	39	224	33
Min	137	21	209	32	205	31	204	31
Average	574	91	540	85	480	76	395	62
Average Deficit (TAF)		58		92		152		226

Figure 21-9e shows the overall effects of the WSE baseline and LSJR alternatives on the Merced River diversion deficits. This graph illustrates the basic concept that reservoir operations are a three-way balance between the runoff and: (1) required release flows, (2) full water supply diversions, and (3) carryover storage. The sum of the annual LSJR alternatives release flow requirements (TAF) and full diversions (TAF) are plotted as a function of the runoff (TAF). The sum of the average full water supply diversions and the required flows represents the total water demands for each year. The WSE model calculated diversion deficits are also plotted as a function of runoff. The sum of the baseline flow requirements and full diversions were generally higher than runoff, until the runoff was greater than 800 TAF. When the runoff was less than the average runoff, full water supply diversions required carryover storages to be reduced to supplement the runoff. The baseline diversion deficits generally increased with lower runoff, and there were some diversion deficits when runoff was less than about 600 TAF. The LSJR alternatives increased the water needed for required release flows and full water supply diversions, and generally resulted in larger diversion deficits. The sum of the full diversions and the required flows for LSJR Alternative 3 were generally higher than runoff until runoff was greater than 1,000 TAF. The sum of the full diversions and the required flows for LSJR Alternative 4 were generally higher than runoff until runoff was greater than 1,250 TAF.

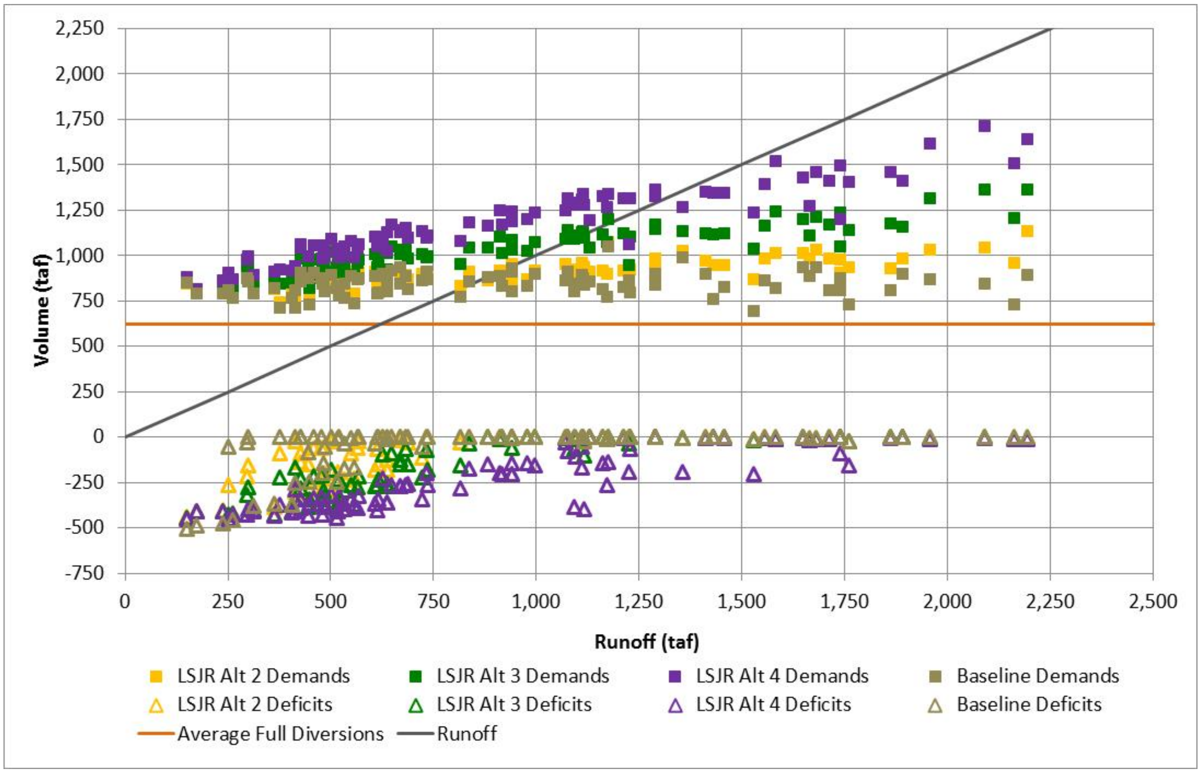

Figure 21-9e. Relationships between Merced River Runoff, Sum of Alternative Flow Requirements and Full Water Supply Diversions, and Diversion Deficits for 1922–2015

21.11 ~~21.10~~ Adaptive Implementation Measures for Consideration

The adaptive implementation methods described in Chapter 3, *Alternatives Description*, could potentially be implemented in all years, including during dry years (less than average runoff), to manage flows in a manner that allows consideration of other beneficial uses, such as water supply for agricultural and municipal uses, as long as intended benefits to fish and wildlife beneficial uses are not reduced. Below is a summary of the four adaptive implementation methods, each of which allows changes based on best available scientific information.

1. Adjust the specified annual February–June unimpaired flow[4] requirement by either increasing or decreasing the requirement to a percentage within the specified range. For LSJR Alternative 2 (20 percent unimpaired flow), the percent of unimpaired flow may be increased to a maximum of 30 percent. For LSJR Alternative 3 (40 percent unimpaired flow), the percent of unimpaired flow may be decreased to a minimum of 30 percent or increased to a maximum of 50 percent. For LSJR Alternative 4 (60 percent unimpaired flow), the percent of unimpaired flow may be decreased to a minimum of 50 percent.

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

2. Allow the total amount of water during February through June period to be managed as a total volume and released at varying rates, rather than maintaining a constant percentage of unimpaired flow.
3. Release a portion of the February through June unimpaired flow volume after June to prevent adverse effects to fisheries from implementation of the February through June unimpaired flow requirement. The volume of water to be shifted to later in the year would be limited as described in Chapter 3.
4. Modify the February–June Vernalis base flow requirement of 1,000 cfs to a rate between 800 and 1,200 cfs.

The flexibility afforded by adaptive implementation using the four methods may be especially useful during dry years as a means of reasonably protecting fish and wildlife beneficial uses. As described in this chapter, dry years with less than 75 percent of the average runoff occur in about 40 percent of the years (4 out of 10 years). All beneficial uses would likely face water deficiencies in dry years, but adaptive implementation may allow flexibility in managing limited water supplies for fish and wildlife while considering other beneficial uses, provided that these other considerations do not reduce benefits for fish and wildlife.

21.12 ~~21.11~~ References Cited

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