F.1.4 Comparison of the Cumulative Distributions of Monthly Flows

The WSE model has been used to estimate the monthly flow in the three eastside tributary rivers and at SJR at Vernalis under baseline conditions and 20, 40, and 60 percent unimpaired flow, which represent typical conditions for LSJR Alternatives 2, 3, and 4. As described above, the calculated monthly flows for the 82-year period (water years 1922–2003) are summarized in tables showing monthly cumulative distributions of flows in 10th percentile increments. These monthly cumulative distributions for LSJR Alternatives 2, 3, and 4 can be graphed and compared to the monthly cumulative distributions of baseline flows. This allows the overall effects of the LSJR alternatives to be summarized and compared for each month. The monthly cumulative distributions of flows provide a good summary of the range of flows that would be observed over a number of years. These graphs summarize the probability of future monthly flow conditions under LSJR Alternatives 2, 3, and 4.

The differences between the monthly cumulative distributions of flows for the LSJR alternatives and baseline conditions provide a summary of the general monthly flow changes. Although the WSE model simulates some relatively large increases or decreases in the monthly river flows, these individual monthly changes would generally balance one another over the 82-year sequence, resulting in smaller shifts in the cumulative distributions of flows for each month or for the seasonal flow volume distribution. The comparison of monthly cumulative distributions of flows, rather than the individual monthly changes in flow, provides an appropriate measure of hydrologic changes resulting from the LSJR alternatives.

F.1.4.1 Merced River Flows

The monthly cumulative distributions for February–June flow (TAF) for LSJR Alternatives 2, 3, and 4 provide an overall summary of the February–June changes in flow compared to baseline conditions. Table F.1.4-1 gives the cumulative distribution values for the February–June flow volumes (TAF) on the Merced River. A flow volume of 60 TAF corresponds to a 5-month average flow of about 200 cfs; a flow volume of 150 TAF corresponds to an average flow of 500 cfs; a flow volume of 300 TAF corresponds to an average flow of 1,000 cfs.

Figure F.1.4-1a shows the Merced River cumulative distributions of the February–June flow volume (TAF) for baseline conditions and the LSJR alternatives for the 82-year period 1922–2003At most flow levels, the unimpaired flow simulations resulted in higher Merced River flows at Stevinson, with flows increasing incrementally as the percent of unimpaired flow increased. Above the 90th percentile (high-flow years with flood control releases), there was very little difference between baseline conditions and the unimpaired flow simulations. Flow distributions for the 30 percent and 50 percent unimpaired flow simulations, which are not shown in this graph, were intermediate between the 20 percent and 40 percent unimpaired flow simulations and the 40 percent and 60 percent unimpaired flow simulations, respectively (Table F.1.4-1).

Table F.1.4-1. Cumulative Distributions of February–June River Flow Volumes (TAF) in the Merced River at Stevinson for Baseline Conditions and the Percent Unimpaired Flow Simulations (20%–60%)

		Percent Unimpaired Flow				
Percentile	Baseline	20%	30%	40%	50%	60%
0	46	71	72	81	92	104
10	70	90	110	138	168	198
20	79	112	147	184	226	265
30	92	120	158	200	243	286
40	104	140	187	237	290	346
50	135	181	239	270	325	388
60	160	202	269	331	390	465
70	234	255	311	356	431	520
80	367	373	394	388	483	574
90	588	574	587	602	625	669
100	1,290	1,290	1,290	1,290	1,290	1,341

Figures F.1.4-1b, F.1.4-1c, F.1.4-1d, F.1.4-1e, and F.1.4-1f show the cumulative distributions of Merced River flow at Stevinson for February–June. During February, the Merced River flows were not as greatly modified by the LSJR alternatives as from March–June. This is in part because, under baseline conditions, Lake McClure is often near the maximum storage allowed for this month and much of the runoff must be released. The March and April Merced River flows were generally higher for 40 percent and 60 percent unimpaired flow than under baseline conditions. In May and June, the flows with all unimpaired flow objectives were substantially higher than under baseline conditions.

From July–January, LSJR alternatives had slightly different flows than under baseline conditions. Some of the reasons why flows may differ from baseline are listed below.

- Flood releases may be altered due to differences in reservoir storage, resulting in more or less release for flood control.
- A portion of the February–June unimpaired flow requirement for the 40, 50, and 60 percent unimpaired flow simulations can be retained for release in July–November.

Figures F.1.4-1g, F.1.4-1h, F.1.4-1i, F.1.4-1j, F.1.4-1k, F.1.4-1l, and F.1.4-1m show the cumulative distributions of Merced River flow at Stevinson from July–January. Flow differences between alternatives during these months occurred only at flow levels higher than the median flows.

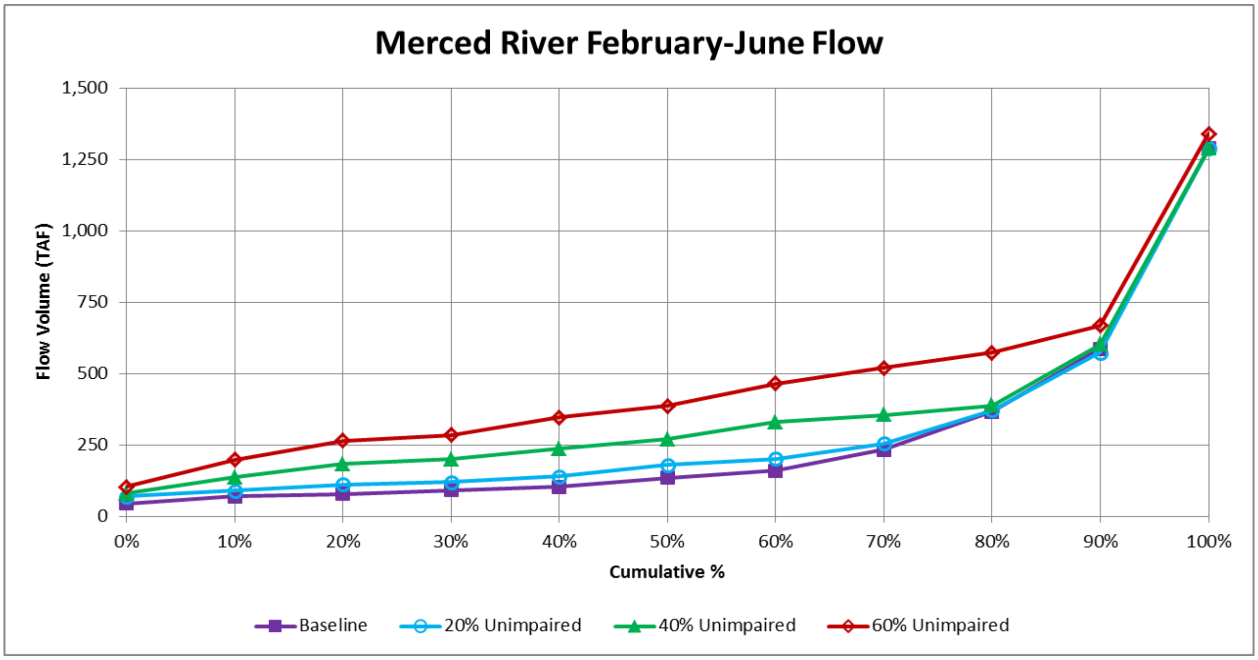


Figure F.1.4-1a. WSE-Simulated Cumulative Distributions of Merced River February–June Flow Volumes (TAF) at Stevinson for Baseline Conditions and 20%, 40%, 60% Unimpaired Flow (LSJR Alternatives 2–4)

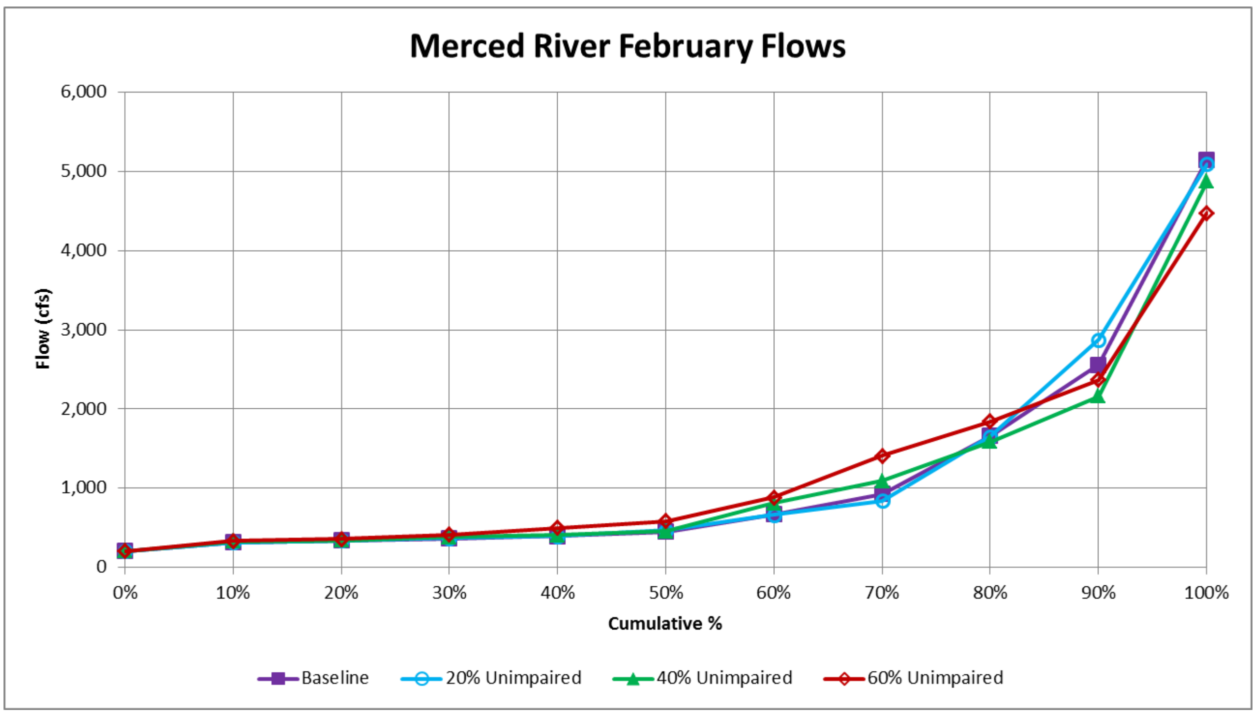


Figure F.1.4-1b. WSE-Simulated Cumulative Distributions of Merced River February Flows (cfs) at Stevinson for Baseline Conditions and 20%, 40%, 60% Unimpaired Flow (LSJR Alternatives 2–4)

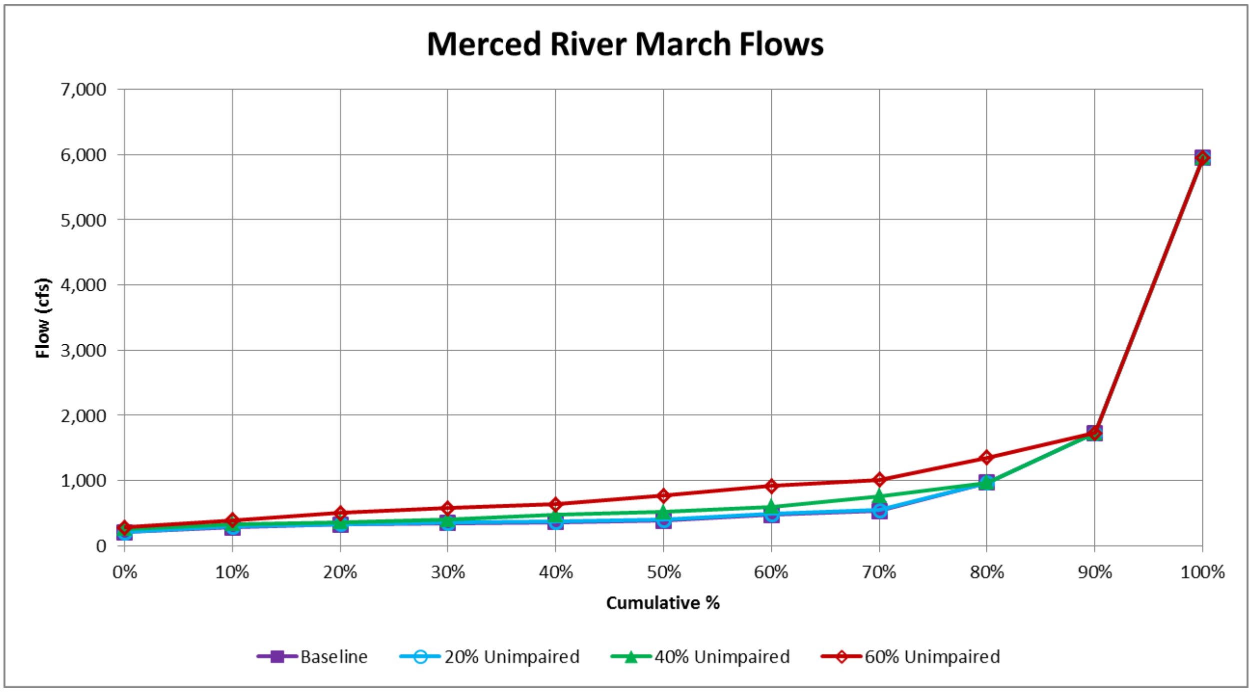


Figure F.1.4-1c. WSE-Simulated Cumulative Distributions of Merced River March Flows (cfs) at Stevinson for Baseline Conditions and 20%, 40%, 60% Unimpaired Flow (LSJR Alternatives 2–4)

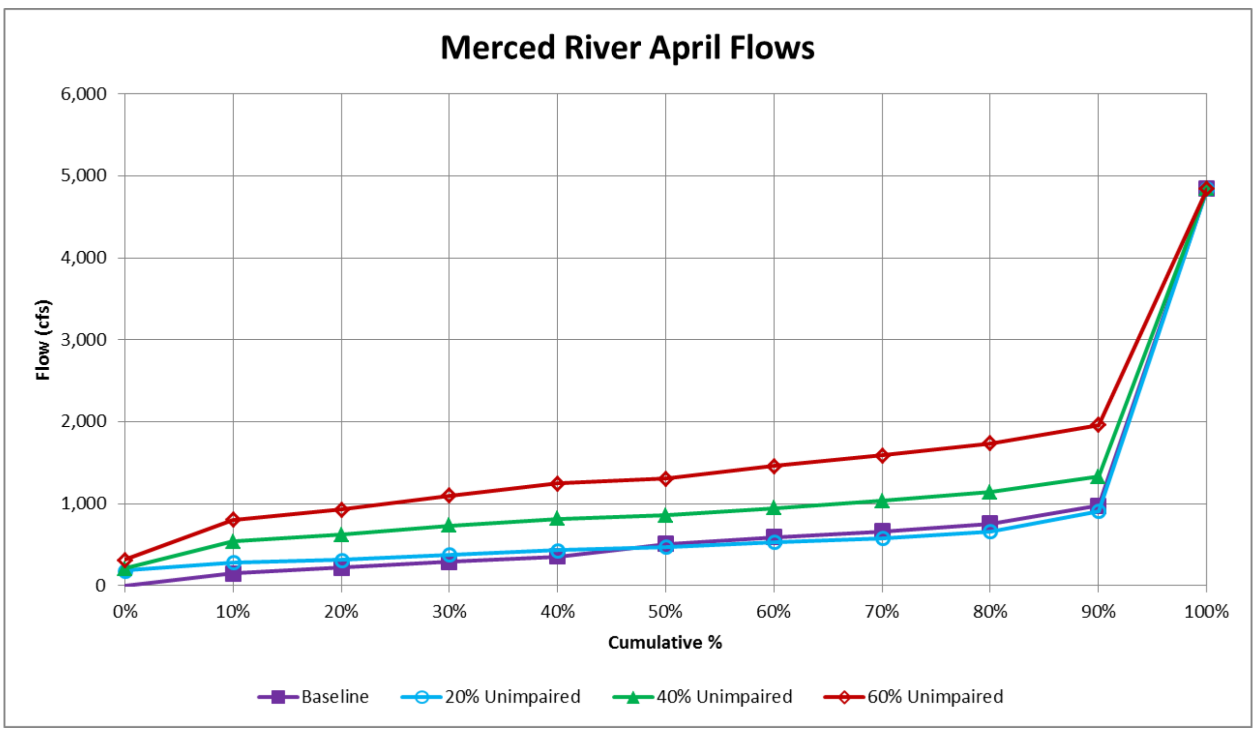


Figure F.1.4-1d. WSE-Simulated Cumulative Distributions of Merced River April Flows (cfs) at Stevinson for Baseline Conditions and 20%, 40%, 60% Unimpaired Flow (LSJR Alternatives 2–4)

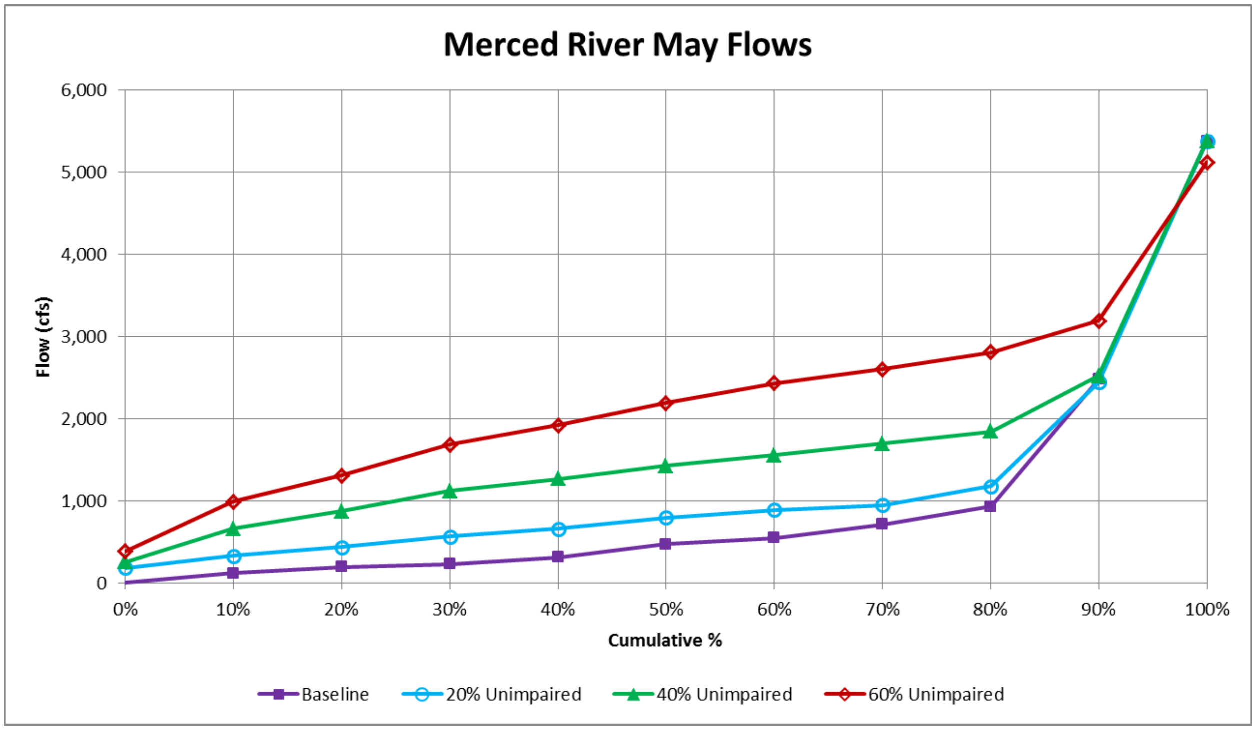


Figure F.1.4-1e. WSE-Simulated Cumulative Distributions of Merced River May Flows (cfs) at Stevinson for Baseline Conditions and 20%, 40%, 60% Unimpaired Flow (LSJR Alternatives 2–4)

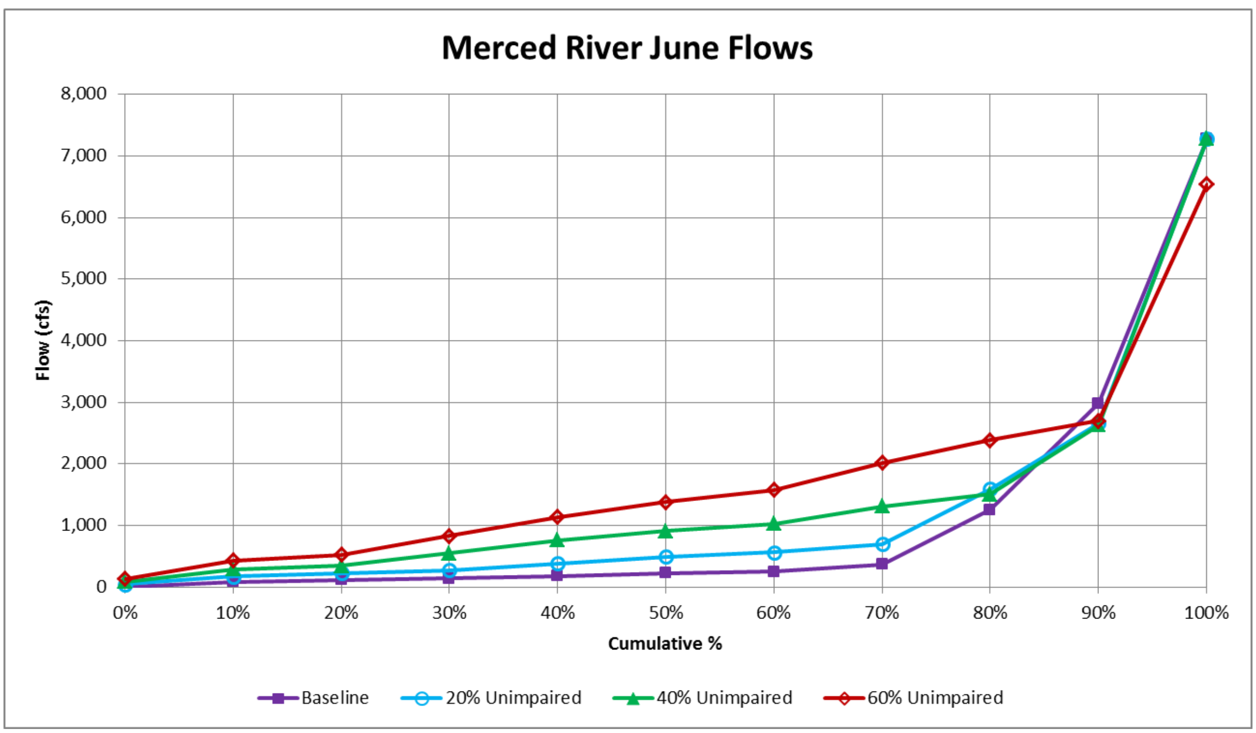


Figure F.1.4-1f. WSE-Simulated Cumulative Distributions of Merced River June Flows (cfs) at Stevinson for Baseline Conditions and 20%, 40%, 60% Unimpaired Flow (LSJR Alternatives 2–4)

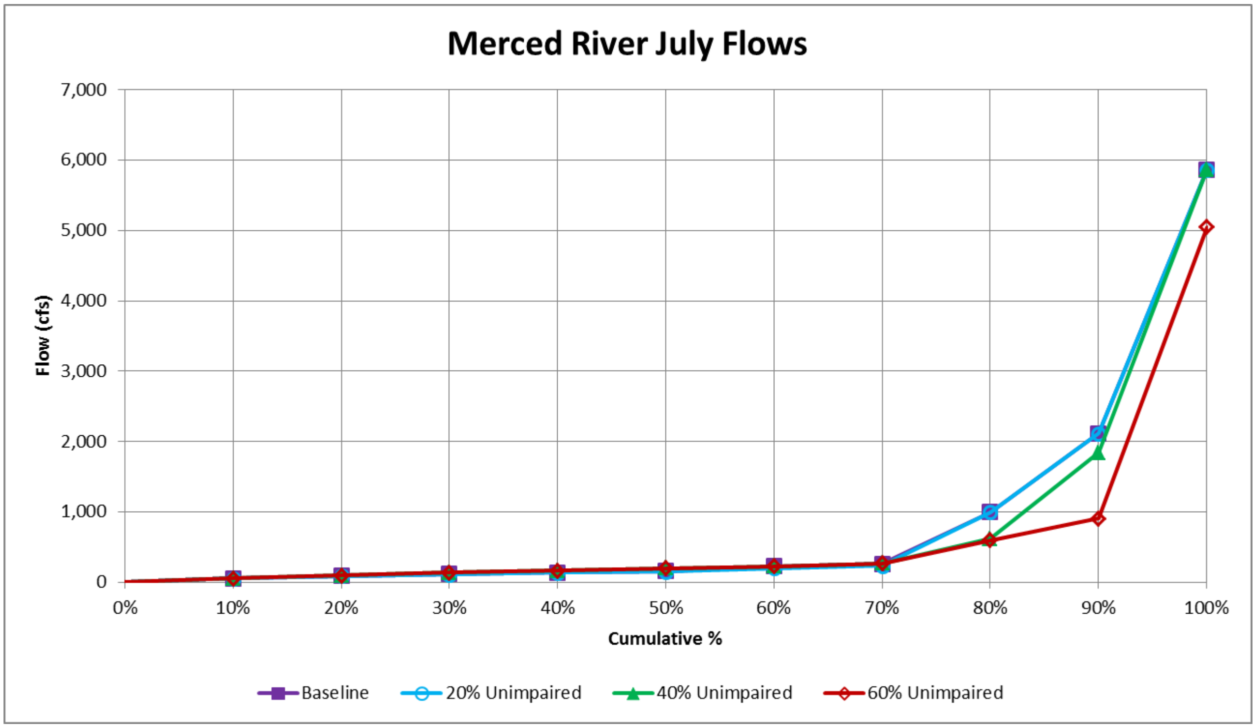


Figure F.1.4-1g. WSE-Simulated Cumulative Distributions of Merced River July Flows (cfs) at Stevinson for Baseline Conditions and 20%, 40%, 60% Unimpaired Flow (LSJR Alternatives 2–4)

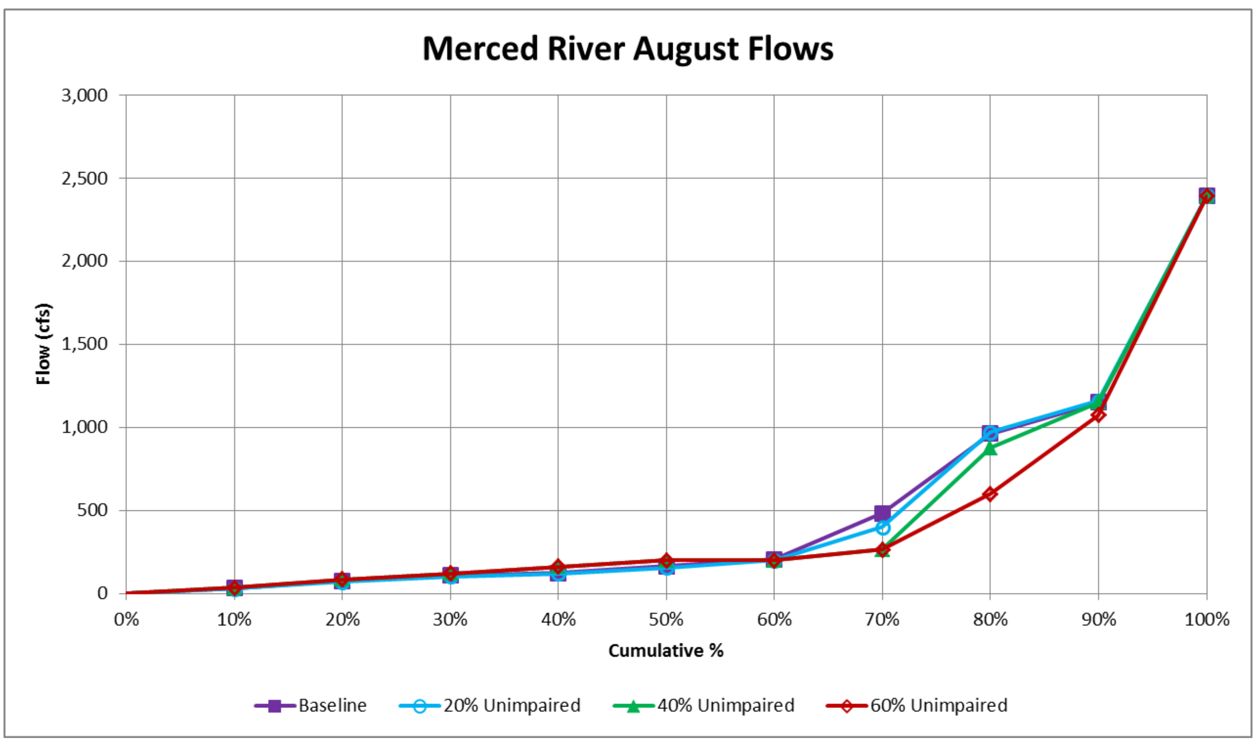


Figure F.1.4-1h. WSE-Simulated Cumulative Distributions of Merced River August Flows (cfs) at Stevinson for Baseline Conditions and 20%, 40%, 60% Unimpaired Flow (LSJR Alternatives 2–4)

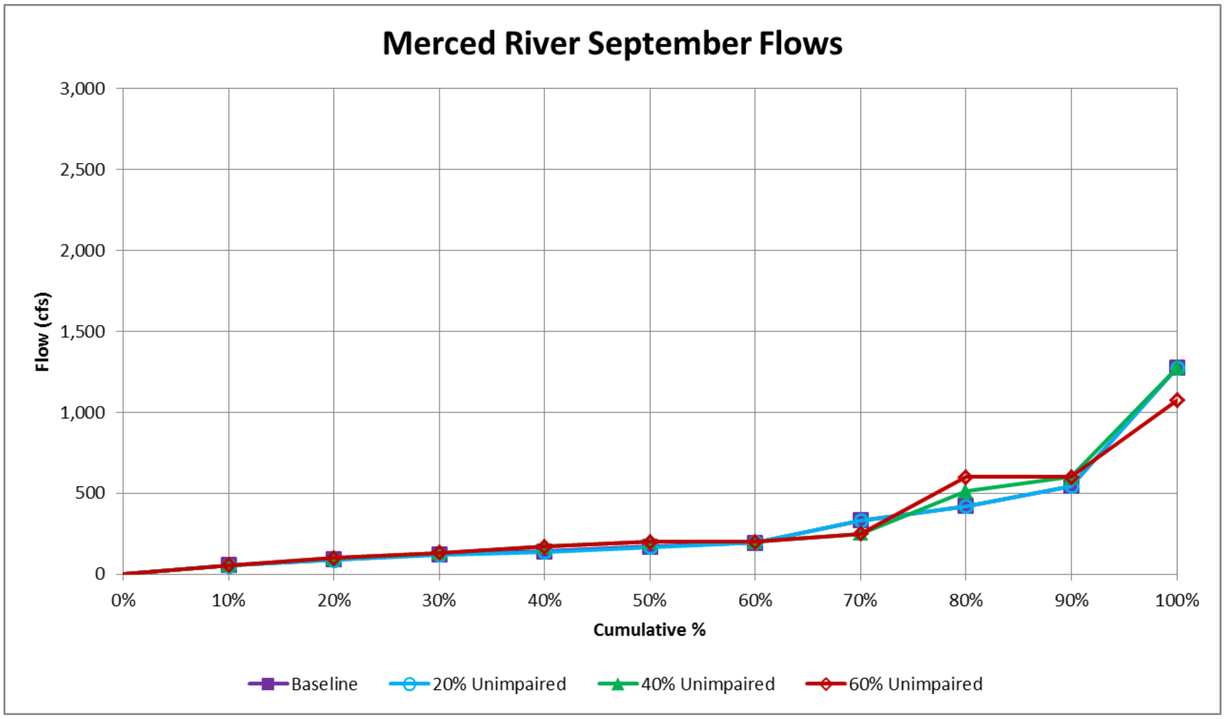


Figure F.1.4-1i. WSE-Simulated Cumulative Distributions of Merced River September Flows (cfs) at Stevinson for Baseline Conditions and 20%, 40%, 60% Unimpaired Flow (LSJR Alternatives 2–4)

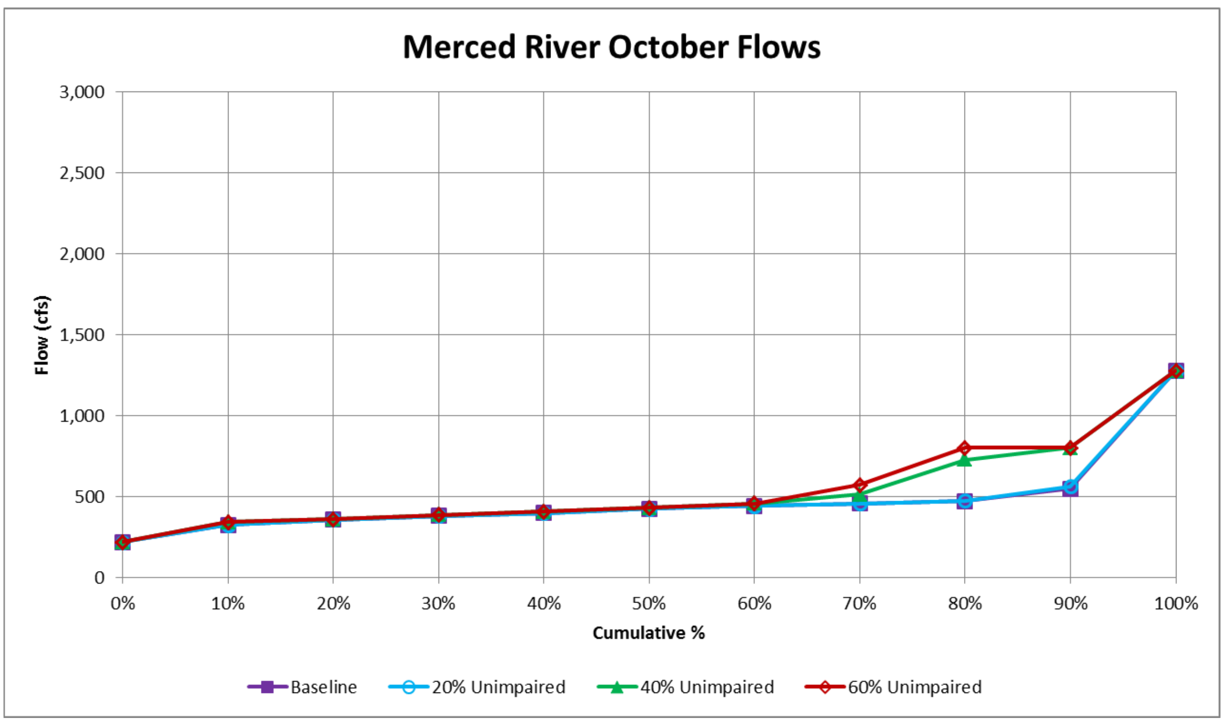


Figure F.1.4-1j. WSE-Simulated Cumulative Distributions of Merced River October Flows (cfs) at Stevinson for Baseline Conditions and 20%, 40%, 60% Unimpaired Flow (LSJR Alternatives 2–4)

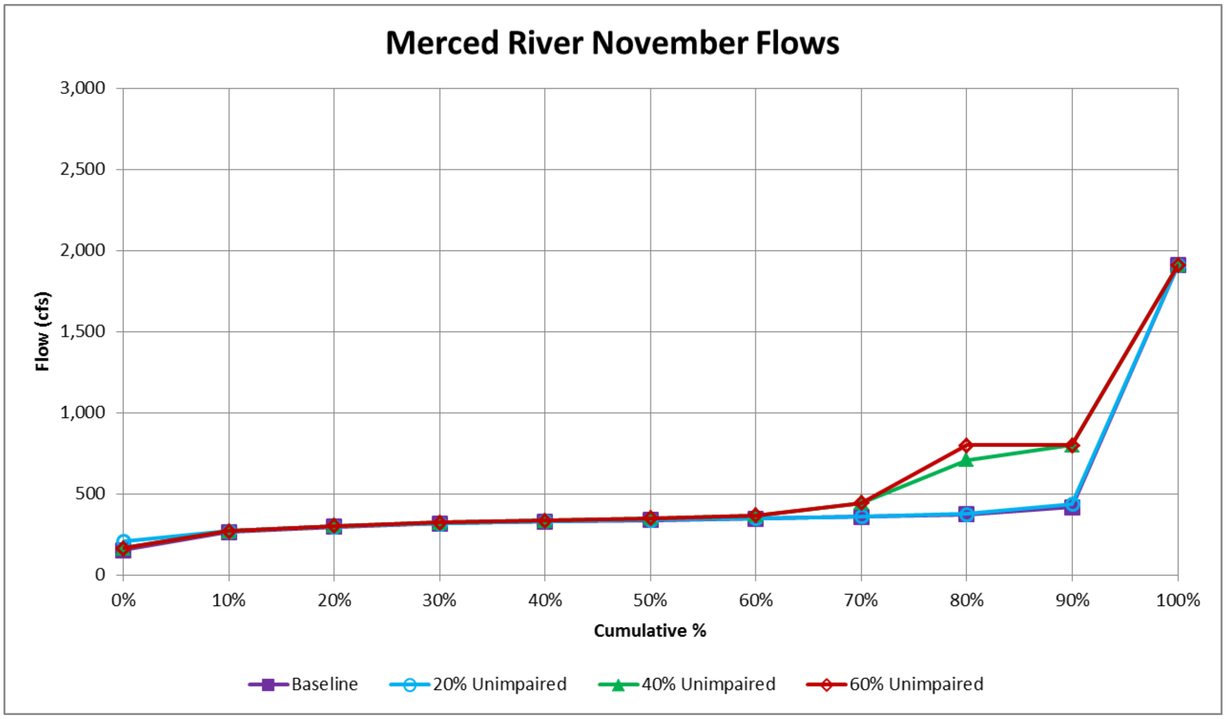


Figure F.1.4-1k. WSE-Simulated Cumulative Distributions of Merced River November Flows (cfs) at Stevinson for Baseline Conditions and 20%, 40%, 60% Unimpaired Flow (LSJR Alternatives 2–4)

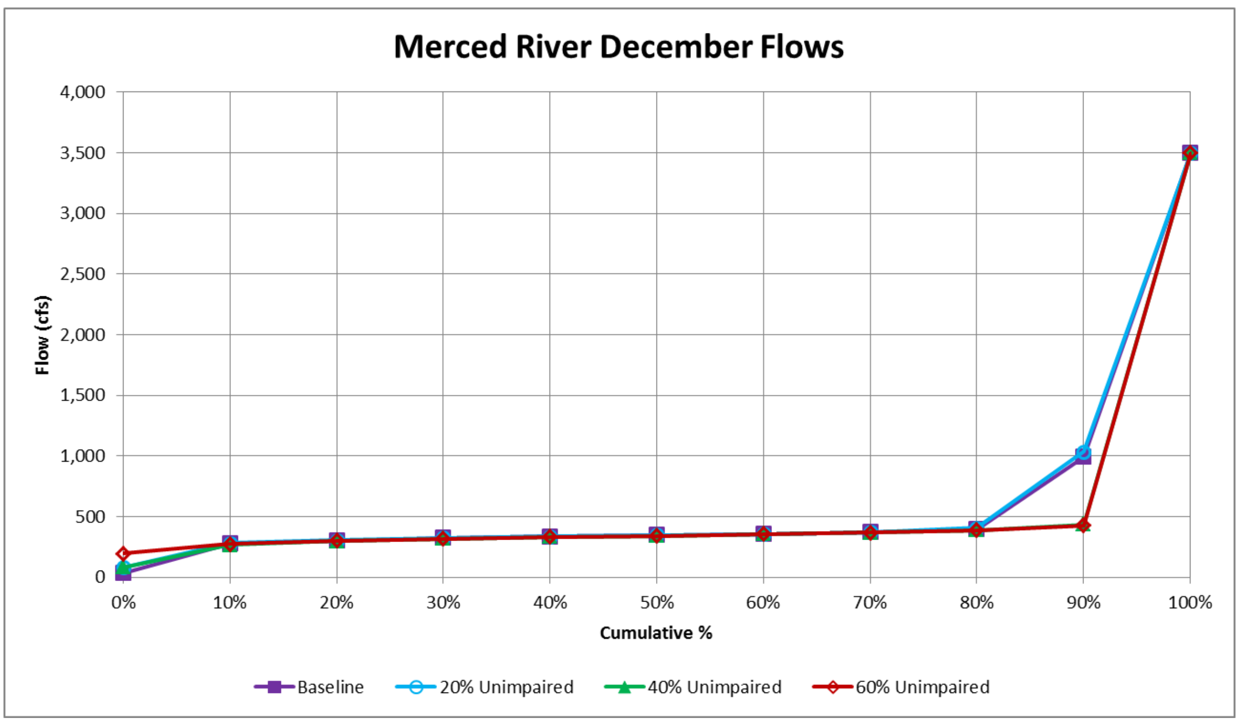


Figure F.1.4-1l. WSE-Simulated Cumulative Distributions of Merced River December Flows (cfs) at Stevinson for Baseline Conditions and 20%, 40%, 60% Unimpaired Flow (LSJR Alternatives 2–4)

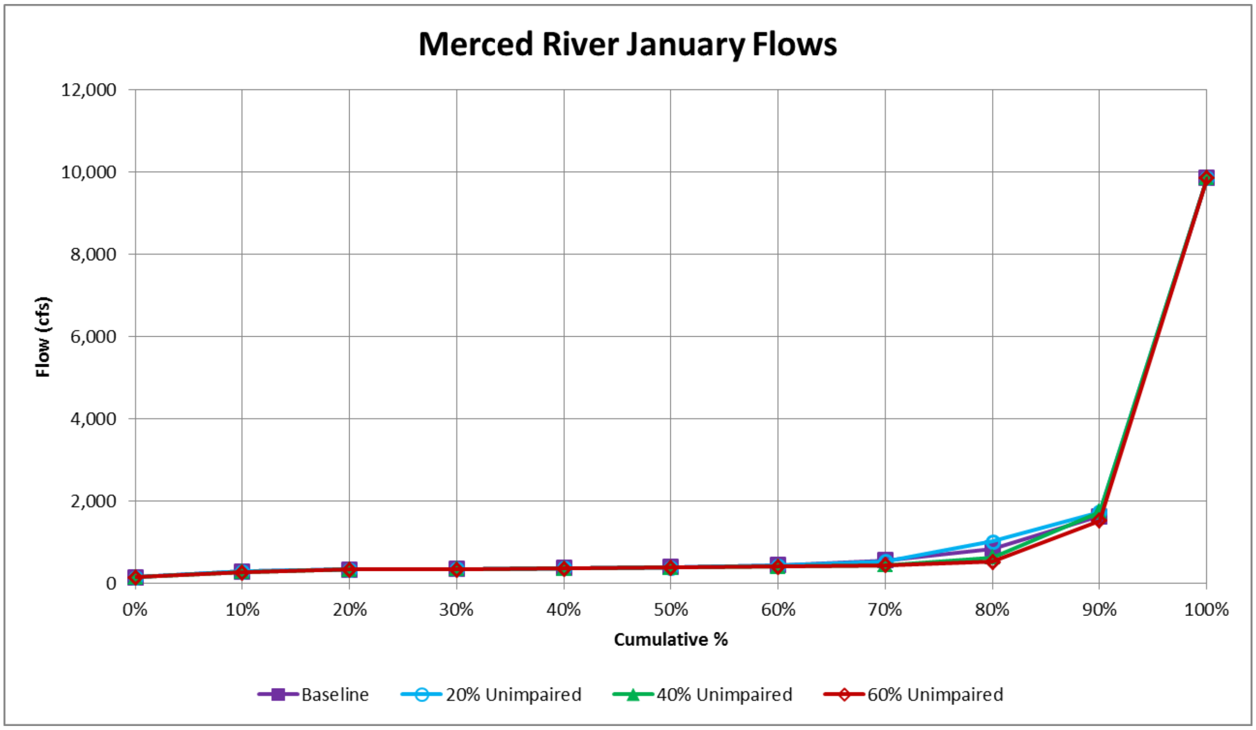


Figure F.1.4-1m. WSE-Simulated Cumulative Distributions of Merced River January Flows (cfs) at Stevinson for Baseline Conditions and 20%, 40%, 60% Unimpaired Flow (LSJR Alternatives 2–4)

F.1.4.2 Tuolumne River Flows

The monthly cumulative distributions for February–June flow (TAF) for the Tuolumne River provide an overall summary of the February–June changes compared to baseline conditions. Table F.1.4-2 gives the cumulative distributions for the February–June flow volumes (TAF) on the Tuolumne River at Modesto.

Figure F.1.4-2a shows the cumulative distributions of the February–June Tuolumne River flow volumes (TAF) at Modesto for the 82-year simulation period 1922–2003. The LSJR Alternative 2 flows were slightly greater than the baseline flows, with a median flow volume of 334 TAF for baseline and 369 TAF for LSJR Alternative 2. The cumulative distributions of the LSJR Alternatives 3 and 4 flow volumes for February–June were progressively higher than baseline. The February–June flow volumes were dominated by flood control releases in the highest runoff years (90 to 100 percent cumulative distribution). Flow distributions for the 30 percent and 50 percent unimpaired flow simulations (which are not shown in this graph) were intermediate between the 20 percent and 40 percent unimpaired flow simulations and the 40 percent and 60 percent unimpaired flow simulations, respectively (Table F.1.4-2).

Table F.1.4-2. Cumulative Distributions of February–June River Flow Volumes (TAF) in the Tuolumne River at Modesto for Baseline Conditions and the Unimpaired Flow Simulations (20%–60%)

		Percent of Unimpaired Flow				
Percentile	Baseline	20%	30%	40%	50%	60%
0	99	115	126	154	183	212
10	139	168	212	274	341	405
20	161	218	294	379	465	539
30	206	268	346	406	500	595
40	279	324	393	484	603	714
50	334	369	480	631	770	861
60	549	578	656	696	833	994
70	717	768	810	805	898	1,033
80	900	900	962	1,007	1,041	1,216
90	1,204	1,204	1,175	1,131	1,226	1,368
100	2,410	2,410	2,481	2,565	2,667	2,768

Figures F.1.4-2b, F.1.4-2c, F.1.4-2d, F.1.4-2e, and F.1.4-2f show the cumulative distributions of Tuolumne River flow at Modesto from February–June. From February–April, the baseline and LSJR Alternative 2 flows were only slightly different. During these months, the flows for LSJR Alternatives 3 and 4 were incrementally higher than flows for baseline and LSJR Alternative 2 under most flow conditions except during higher runoff years. During higher runoff years, the flows for LSJR Alternatives 3 and 4 tended to be lower than flows for baseline conditions and LSJR Alternative 2 because more reservoir capacity was available.

Because unimpaired flow is particularly high during May and June due to snowmelt, the LSJR alternatives often resulted in particularly high flows during these months (e.g., a median May flow of 4,359 cfs for LSJR Alternative 4). During May and June, flows resulted in incrementally higher Tuolumne River flows at Modesto as the unimpaired flow objective increased under each alternative (LSJR Alternatives 2, 3, and 4).

In the modeling, from July–January, river and reservoir operations generally were the same under the LSJR alternatives as under baseline conditions. However, there were some differences. Figures F.1.4-2g, F.1.4-2h, F.1.4-2i, F.1.4-2j, F.1.4-2k, F.1.4-2l, and F.1.4-2m show the cumulative distributions of Tuolumne River flow at Modesto from July–January. All of the flow differences between the LSJR alternatives during these months occurred only at flow levels higher than the median flows. In July and January, LSJR Alternative 3 (January) and LSJR Alternative 4 (July and January), were not as affected by reservoir limits (due to lower reservoir storage), resulting in lower values for the highest flows (e.g., the 80th to 100th percentiles). In a few years during October and particularly November, some extra releases were made under LSJR Alternatives 3 and 4 using water reserved for temperature control purposes.

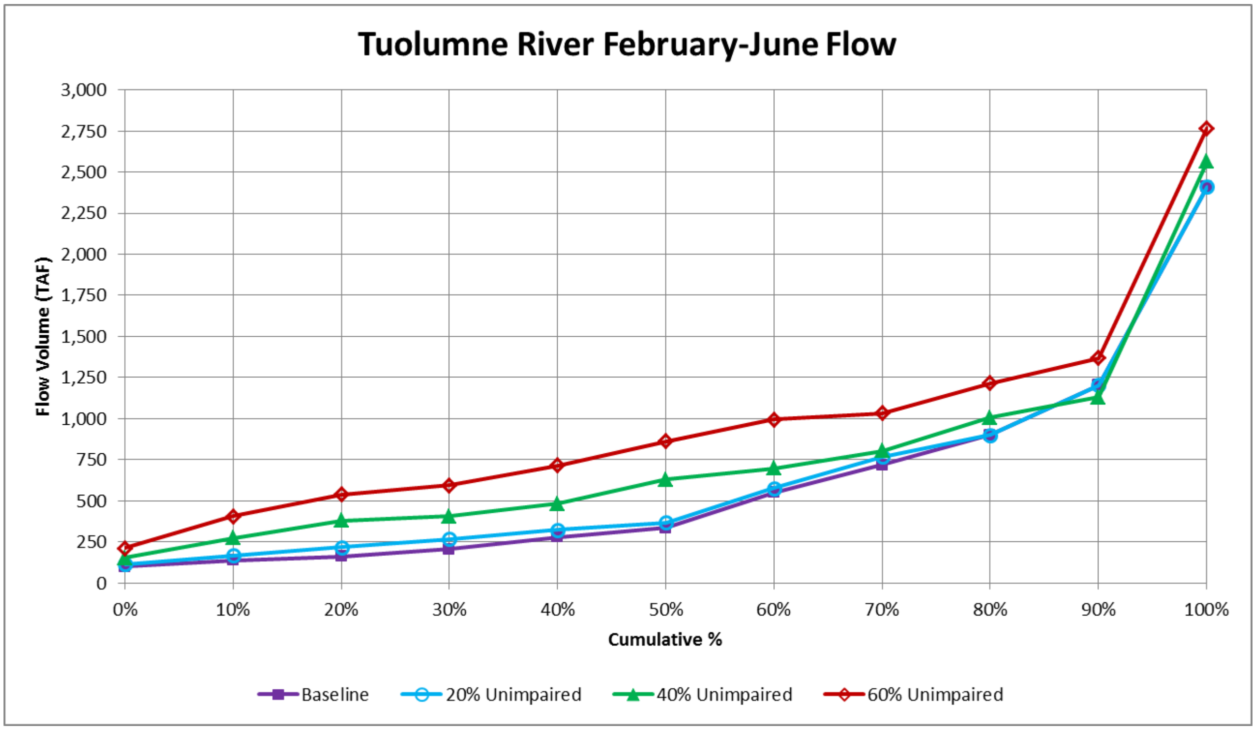


Figure F.1.4-2a. WSE-Simulated Cumulative Distributions of Tuolumne River February–June Flow Volumes (TAF) at Modesto for Baseline Conditions and 20%, 40%, 60% Unimpaired Flow (LSJR Alternatives 2–4)

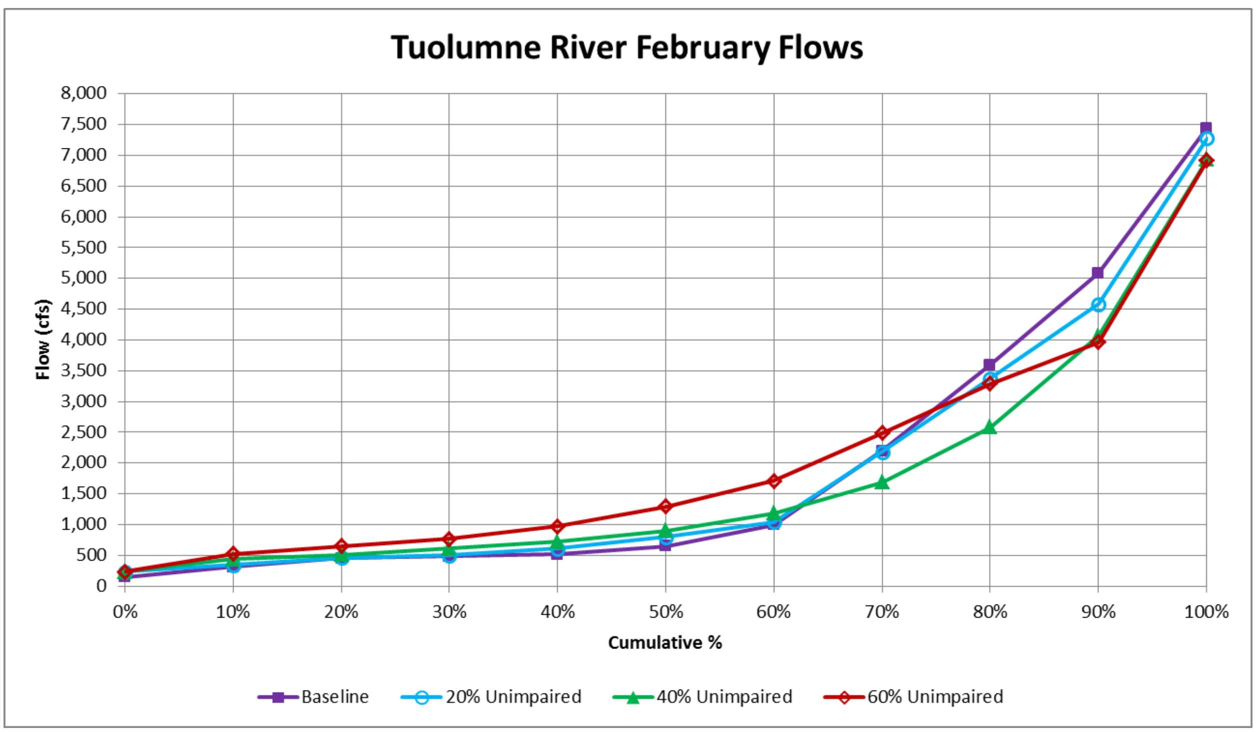


Figure F.1.4-2b. WSE-Simulated Cumulative Distributions of Tuolumne River February Flows (cfs) at Modesto for Baseline Conditions and 20%, 40%, 60% Unimpaired Flow (LSJR Alternatives 2–4)

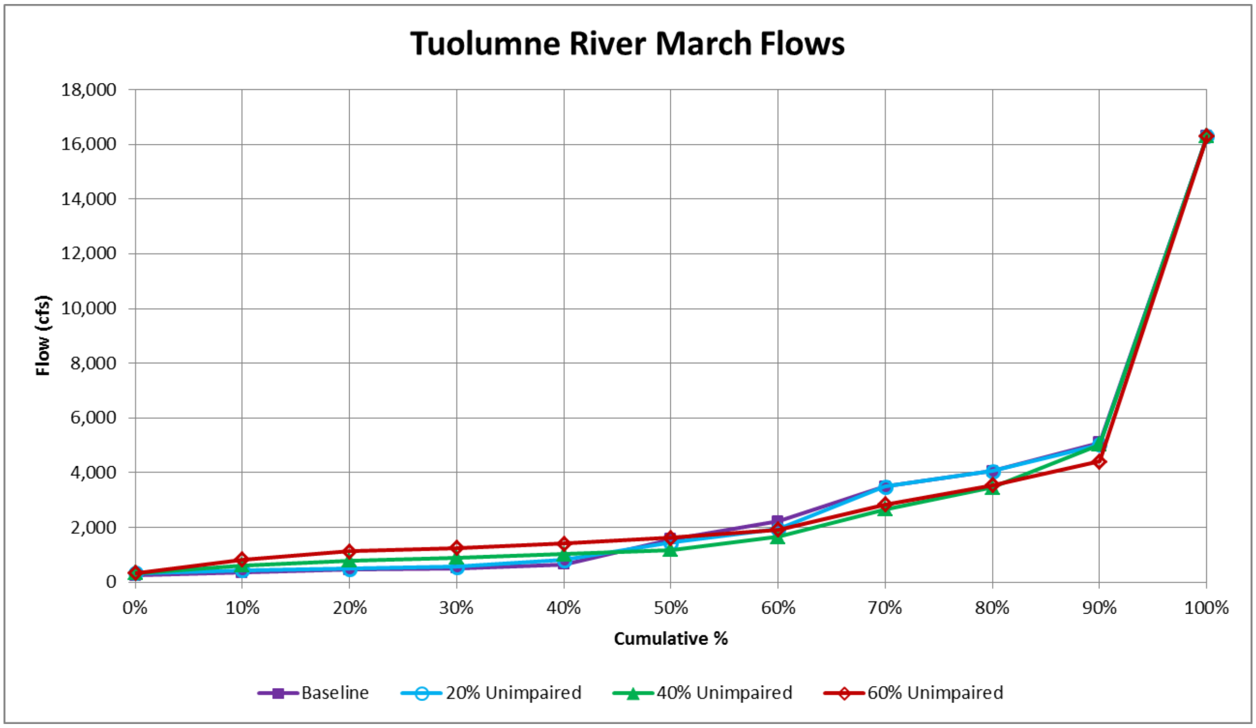


Figure F.1.4-2c. WSE-Simulated Cumulative Distributions of Tuolumne River March Flows (cfs) at Modesto for Baseline Conditions and 20%, 40%, 60% Unimpaired Flow (LSJR Alternatives 2–4)

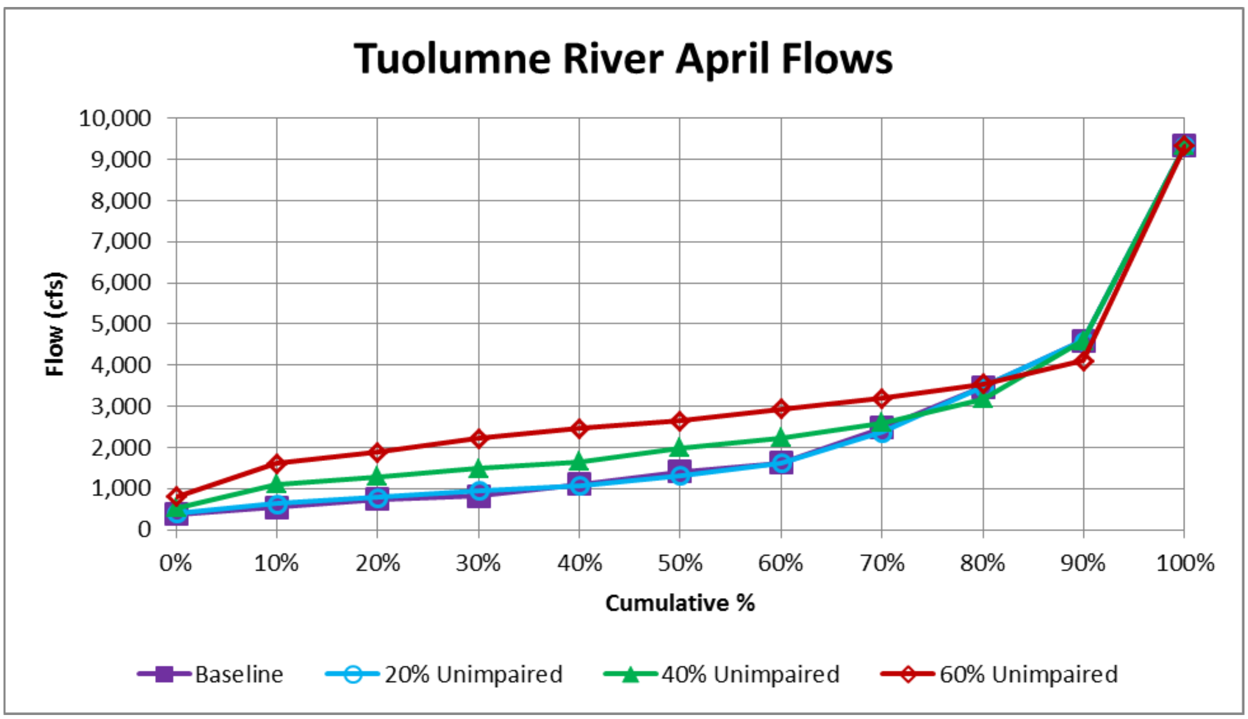


Figure F.1.4-2d. WSE-Simulated Cumulative Distributions of Tuolumne River April Flows (cfs) at Modesto for Baseline Conditions and 20%, 40%, 60% Unimpaired Flow (LSJR Alternatives 2–4)

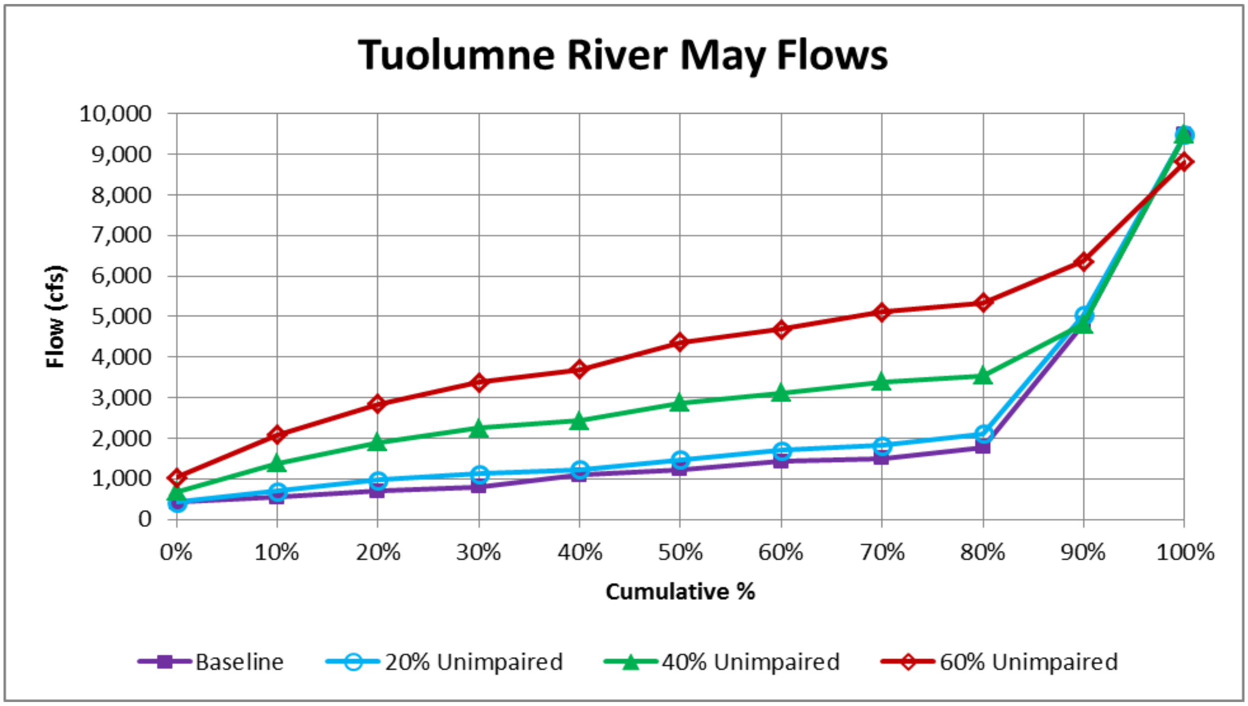


Figure F.1.4-2e. WSE-Simulated Cumulative Distributions of Tuolumne River May Flows (cfs) at Modesto for Baseline Conditions and 20%, 40%, 60% Unimpaired Flow (LSJR Alternatives 2–4)

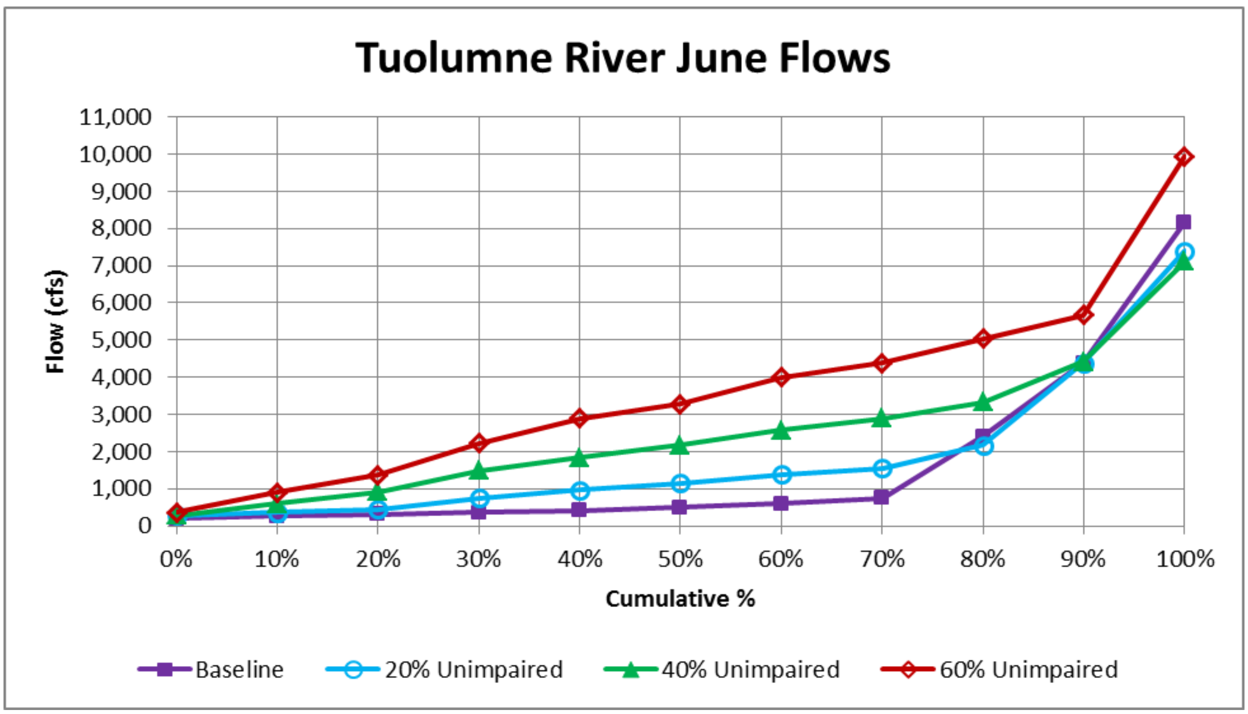


Figure F.1.4-2f. WSE-Simulated Cumulative Distributions of Tuolumne River June Flows (cfs) at Modesto for Baseline Conditions and 20%, 40%, 60% Unimpaired Flow (LSJR Alternatives 2–4)

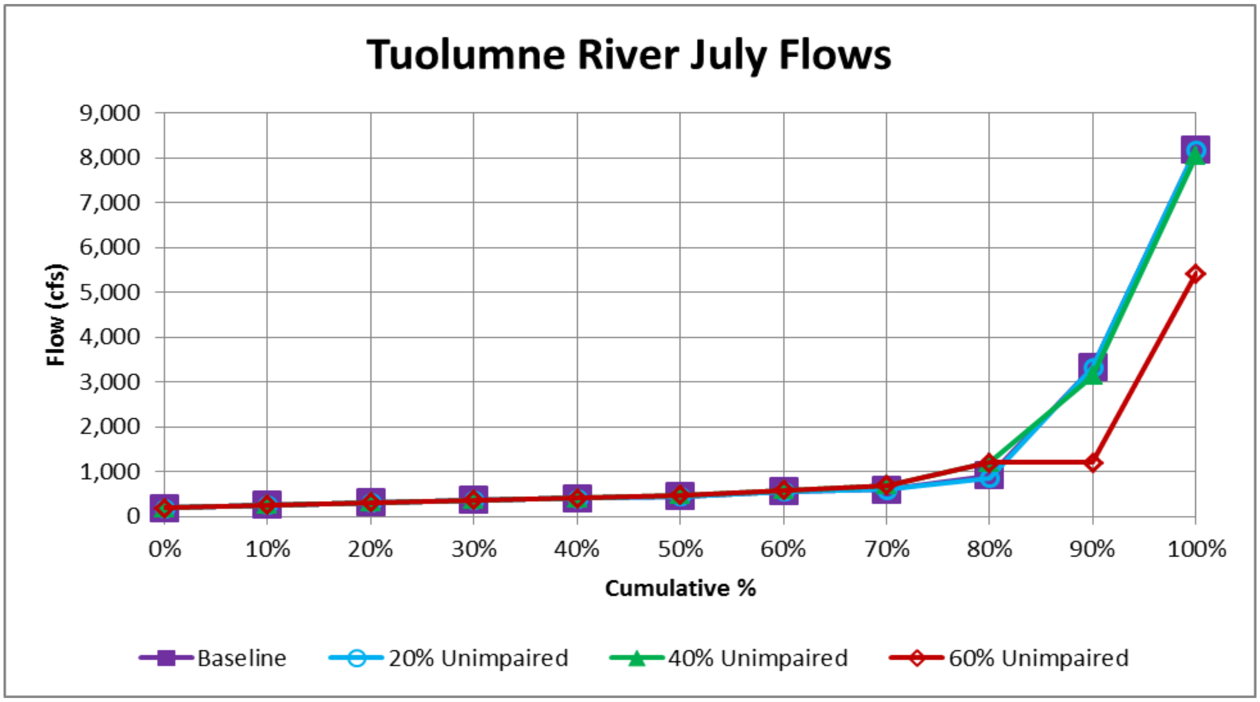


Figure F.1.4-2g. WSE-Simulated Cumulative Distributions of Tuolumne River July Flows (cfs) at Modesto for Baseline Conditions and 20%, 40%, 60% Unimpaired Flow (LSJR Alternatives 2–4)

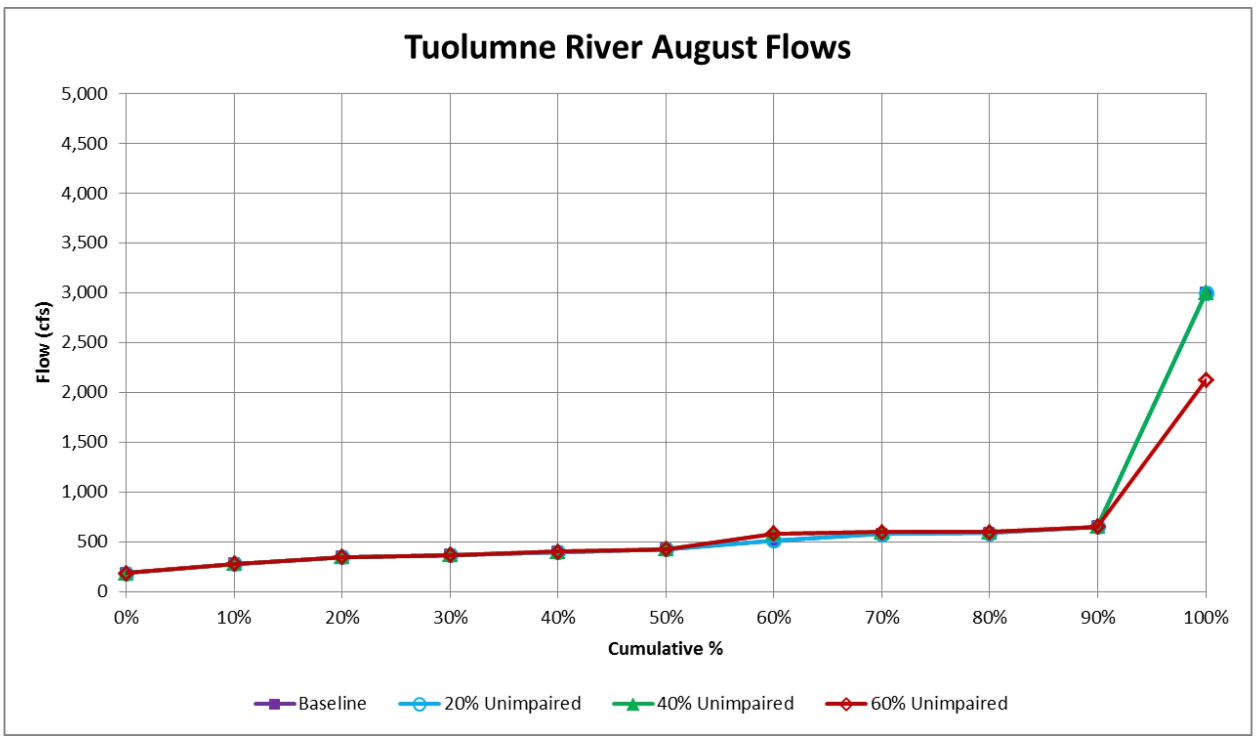


Figure F.1.4-2h. WSE-Simulated Cumulative Distributions of Tuolumne River August Flows (cfs) at Modesto for Baseline Conditions and 20%, 40%, 60% Unimpaired Flow (LSJR Alternatives 2–4)

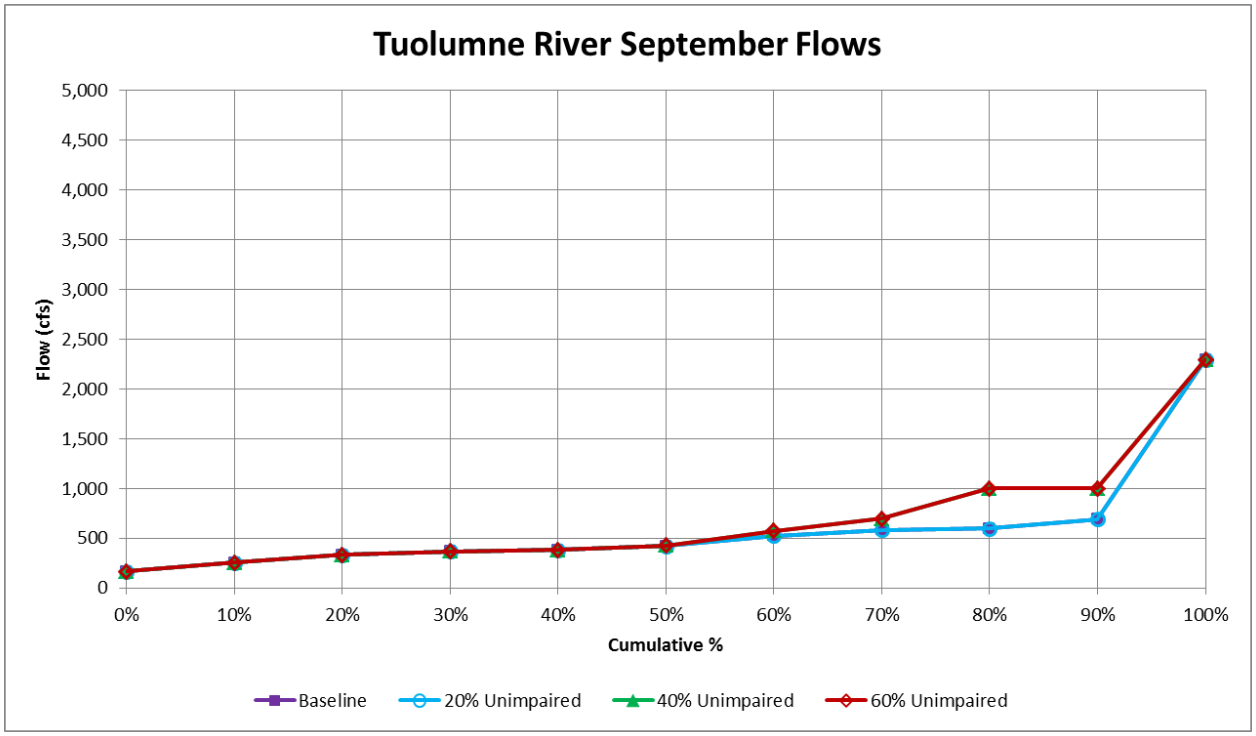


Figure F.1.4-2i. WSE-Simulated Cumulative Distributions of Tuolumne River September Flows (cfs) at Modesto for Baseline Conditions and 20%, 40%, 60% Unimpaired Flow (LSJR Alternatives 2–4)

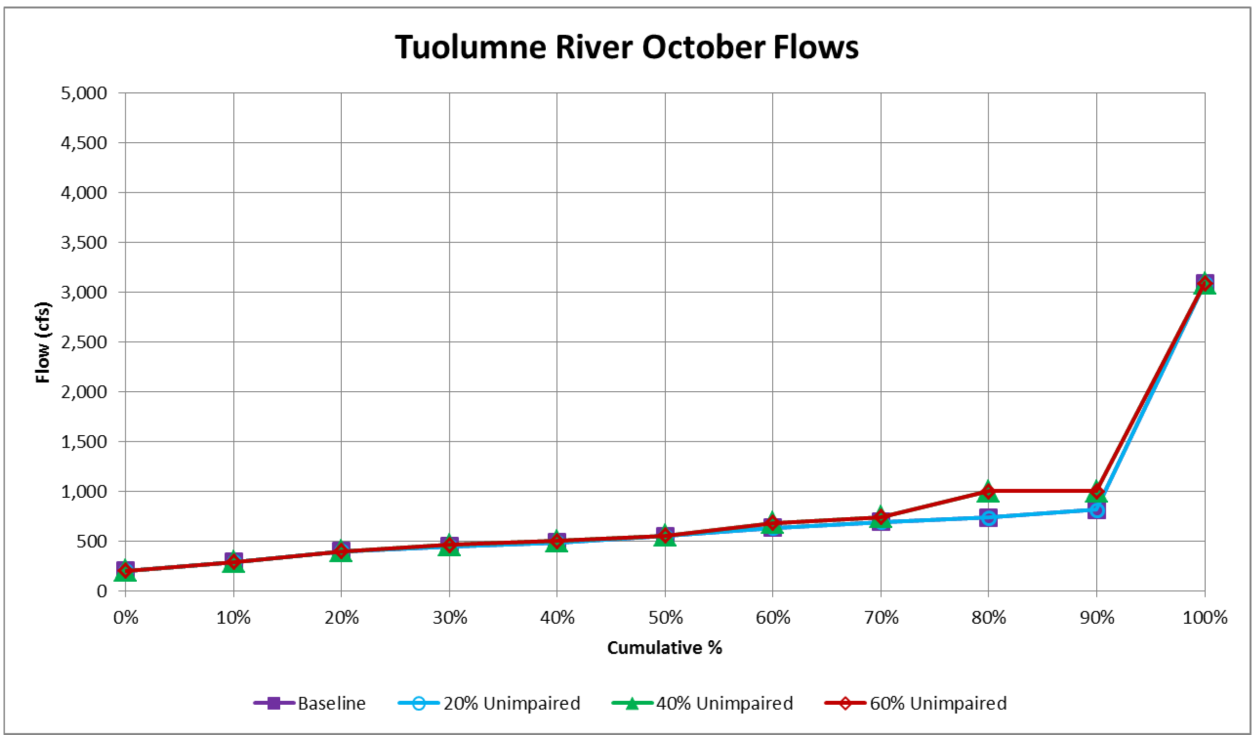


Figure F.1.4-2j. WSE-Simulated Cumulative Distributions of Tuolumne River October Flows (cfs) at Modesto for Baseline Conditions and 20%, 40%, 60% Unimpaired Flow (LSJR Alternatives 2–4)

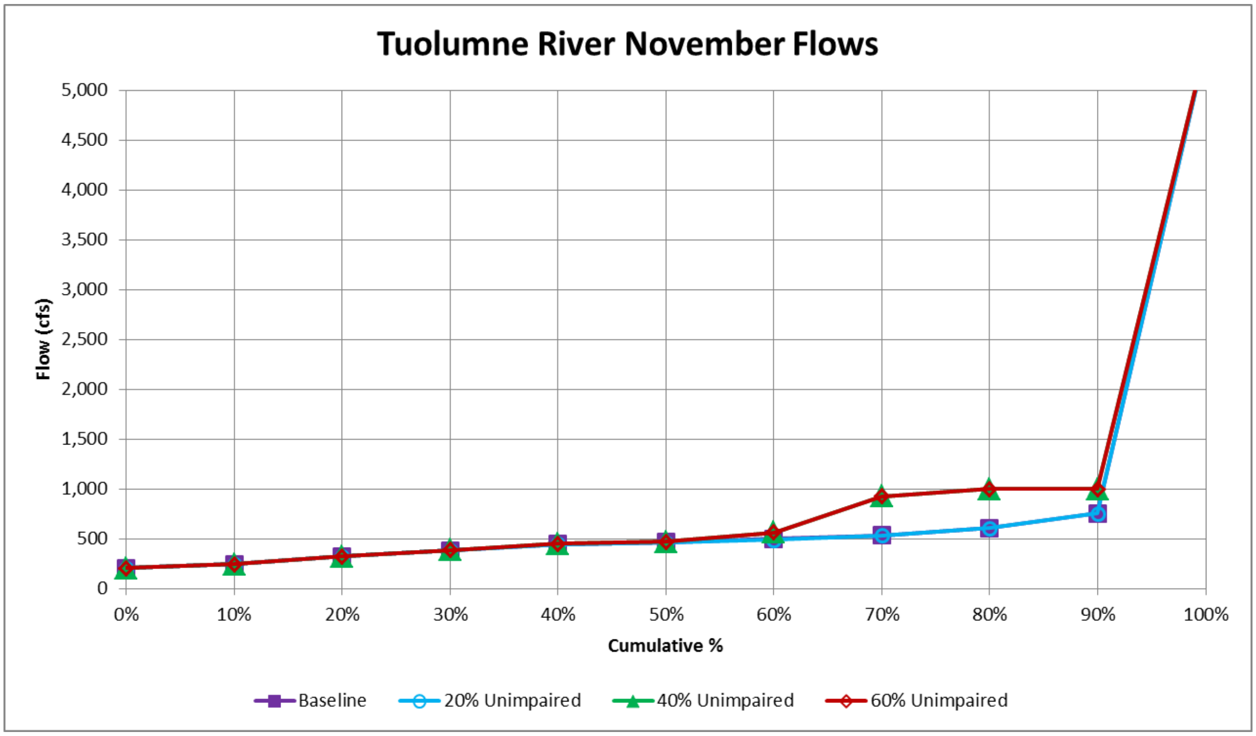


Figure F.1.4-2k. WSE-Simulated Cumulative Distributions of Tuolumne River November Flows (cfs) at Modesto for Baseline Conditions and 20%, 40%, 60% Unimpaired Flow (LSJR Alternatives 2–4)

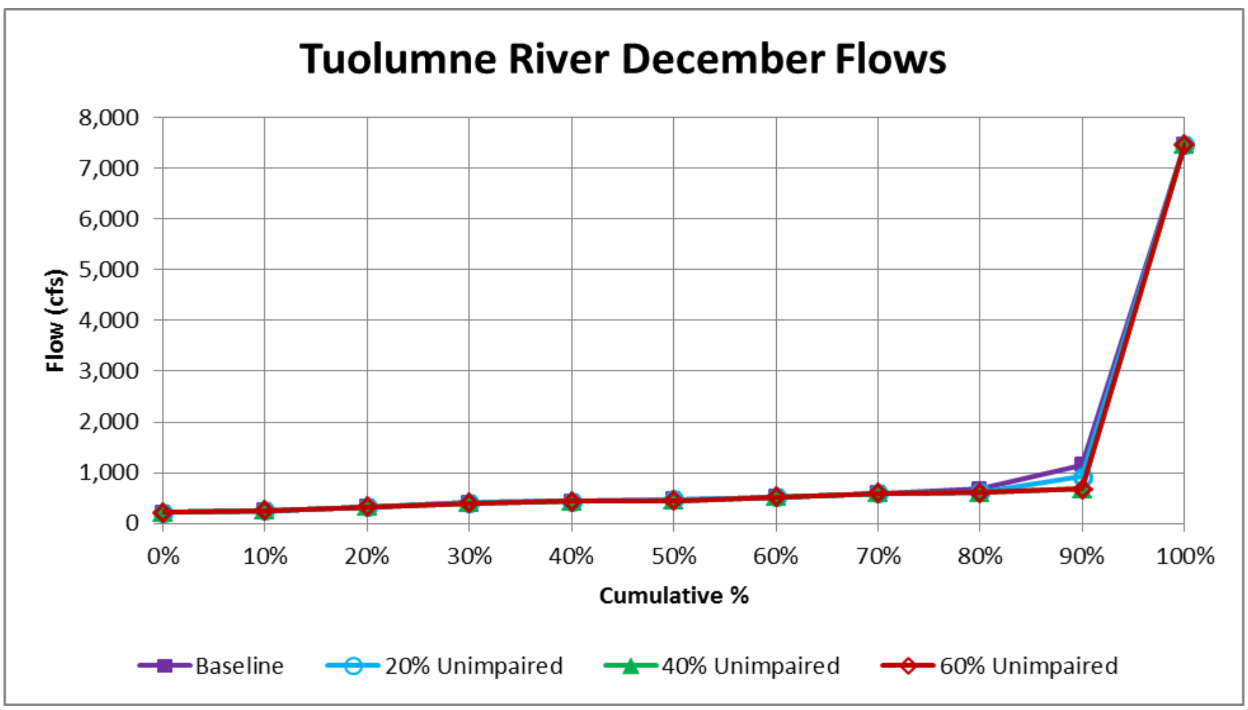


Figure F.1.4-2l. WSE-Simulated Cumulative Distributions of Tuolumne River December Flows (cfs) at Modesto for Baseline Conditions and 20%, 40%, 60% Unimpaired Flow (LSJR Alternatives 2–4)

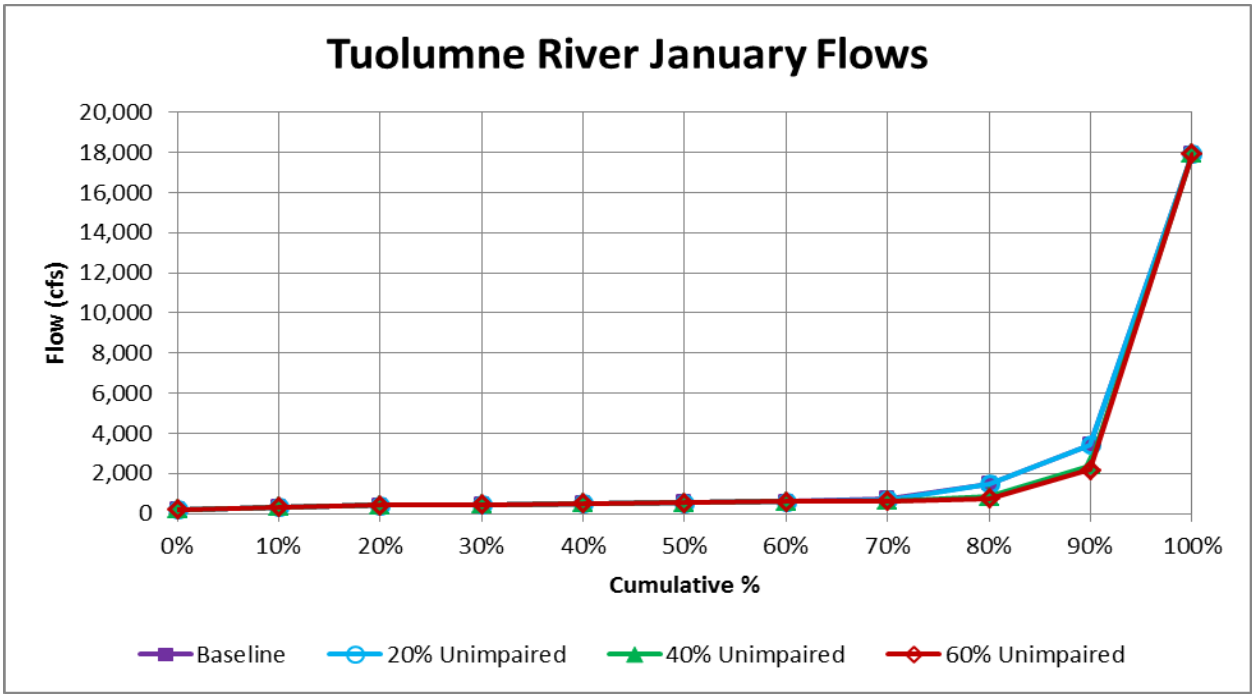


Figure F.1.4-2m. WSE-Simulated Cumulative Distributions of Tuolumne River January Flows (cfs) at Modesto for Baseline Conditions and 20%, 40%, 60% Unimpaired Flow (LSJR Alternatives 2–4)

F.1.4.3 Stanislaus River Flows

The monthly cumulative distributions for February–June flow (TAF) for the Stanislaus River for LSJR Alternatives 2, 3, and 4 provide an overall summary of the February–June changes in flow compared to baseline. Table F.1.4-3 gives the cumulative distribution values for the February–June flow volumes (TAF) on the Stanislaus River at Ripon.

Figure F.1.4-3a shows the cumulative distributions of the February–June Stanislaus River flow volumes (TAF) at Ripon for the 82-year simulation period 1922–2003. The baseline and LSJR Alternative 2 flows were very similar, with a median baseline flow volume of 283 TAF for baseline and 271 TAF for LSJR Alternative 2. The cumulative distributions of LSJR Alternatives 3 and 4 flow volumes for February–June were progressively higher than LSJR Alternative 2. The February–June flows were dominated by flood control releases in a few of the highest runoff years (i.e., greater than 90 percent cumulative distribution). Flow distributions for the 30 percent and 50 percent unimpaired flow simulations (which are not shown in this graph) were intermediate between the 20 percent and 40 percent unimpaired flow simulations and the 40 percent and 60 percent unimpaired flow simulations, respectively (Table F.1.4-3).

Table F.1.4-3. Cumulative Distributions of February–June River Flow Volumes (TAF) in the Stanislaus River at Ripon for Baseline Conditions and the Percent Unimpaired Flow Simulations (20%–60%)

		Percent of Unimpaired Flow				
Percentile	Baseline	20%	30%	40%	50%	60%
0	91	98	112	113	118	122
10	124	130	147	159	185	225
20	153	161	190	207	243	294
30	204	191	245	254	283	330
40	246	243	277	317	391	432
50	283	271	302	360	426	494
60	317	295	341	413	507	596
70	377	410	425	447	541	630
80	443	446	500	484	577	668
90	494	517	554	613	718	848
100	1,185	1,185	1,185	1,220	1,337	1,472

Figures F.1.4-4b, F.1.4-4c, F.1.4-4d, F.1.4-4e, and F.1.4-4f show the cumulative distributions of Stanislaus River flow at Ripon from February–June. During these months, the flows for LSJR Alternative 2 were similar to the baseline flows. The flows for LSJR Alternatives 3 and 4 were incrementally higher than flows for baseline conditions and LSJR Alternative 2 under most flow conditions. However, at low to moderate flow levels, the percentages of increase from April–June were generally less than the percentages of increase on the Merced and Tuolumne Rivers because the baseline releases were already relatively high.

Baseline and LSJR alternative flows are usually similar from July–January. Figures F.1.4-4g, F.1.4-4h, F.1.4-4i, F.1.4-4j, F.1.4-4k, F.1.4-4l, and F.1.4-4m show the cumulative distributions of Stanislaus River flow at Ripon from July–January. All of the flow differences between alternatives during these months occur only at flow levels higher than the median flows. Decreases in the highest flows (e.g., 100th percentile in July, August, and January) were most likely caused as a result of LSJR Alternative 4 and sometimes LSJR Alternative 3 having more reservoir capacity, thereby reducing releases for flood control. During July, September, and October, the 70th and 80th percentile flows for LSJR Alternatives 3 and 4 were slightly higher than the flows for baseline conditions and LSJR Alternative 2, potentially resulting from the release of water reserved for temperature control purposes (i.e., adaptive implementation flow shifting). On the Stanislaus River, flow may also be affected by releases for salinity control in the Delta and changes in NMFS BO flows associated with changes in reservoir storage (NMI).

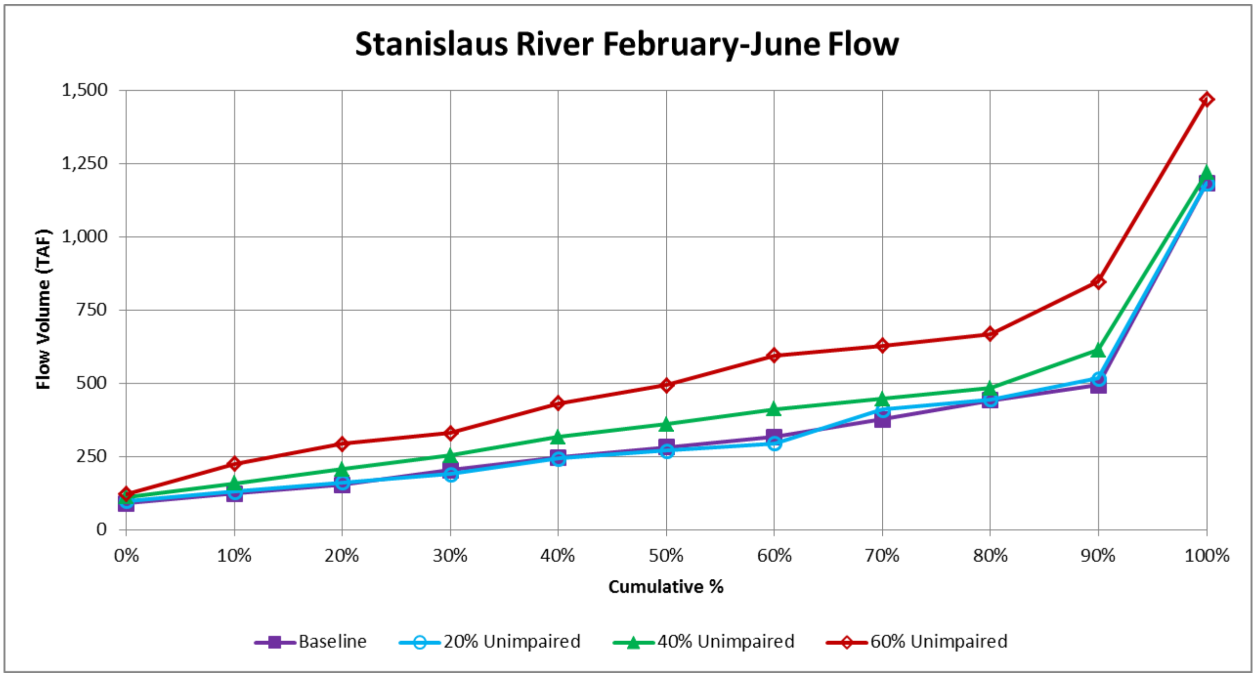


Figure F.1.4-3a. WSE-Simulated Cumulative Distributions of Stanislaus River February–June Flow Volumes (TAF) at Ripon for Baseline Conditions and 20%, 40%, 60% Unimpaired Flow (LSJR Alternatives 2–4)

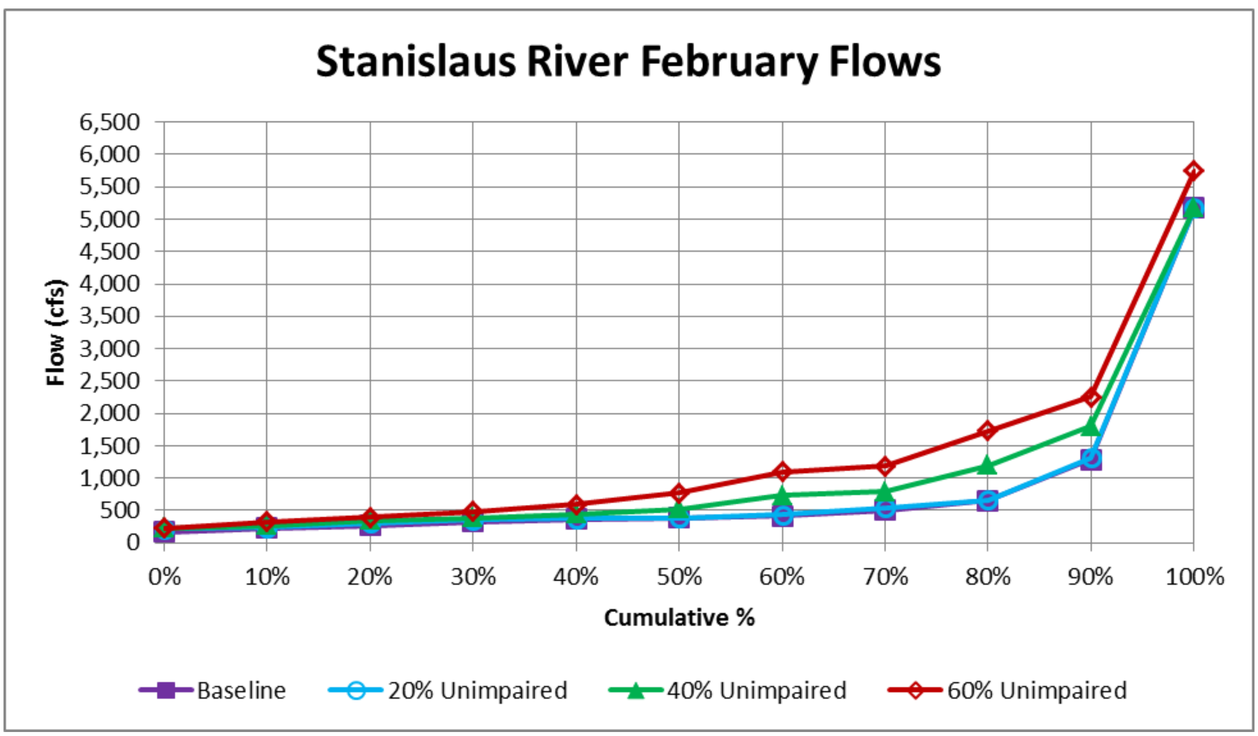


Figure F.1.4-3b. WSE-Simulated Cumulative Distributions of Stanislaus River February Flows (cfs) at Ripon for Baseline Conditions and 20%, 40%, 60% Unimpaired Flow (LSJR Alternatives 2–4)

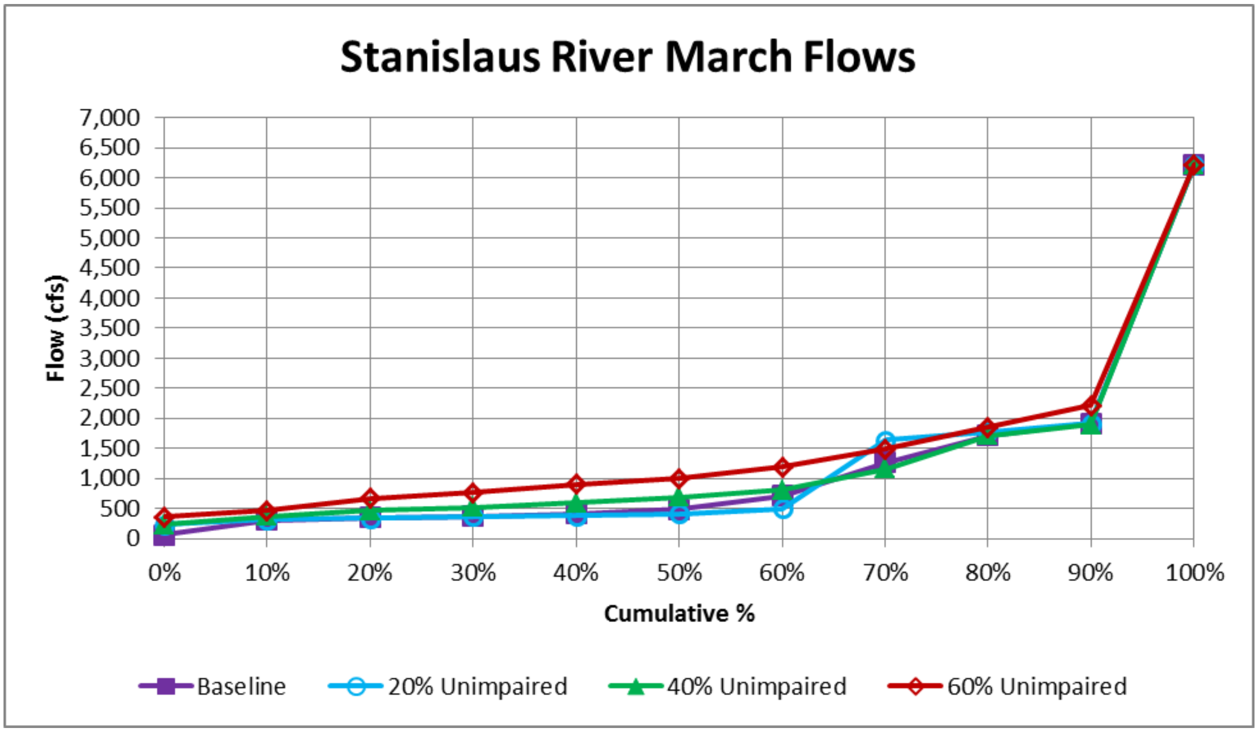


Figure F.1.4-3c. WSE-Simulated Cumulative Distributions of Stanislaus River March Flows (cfs) at Ripon for Baseline Conditions and 20%, 40%, 60% Unimpaired Flow (LSJR Alternatives 2–4)

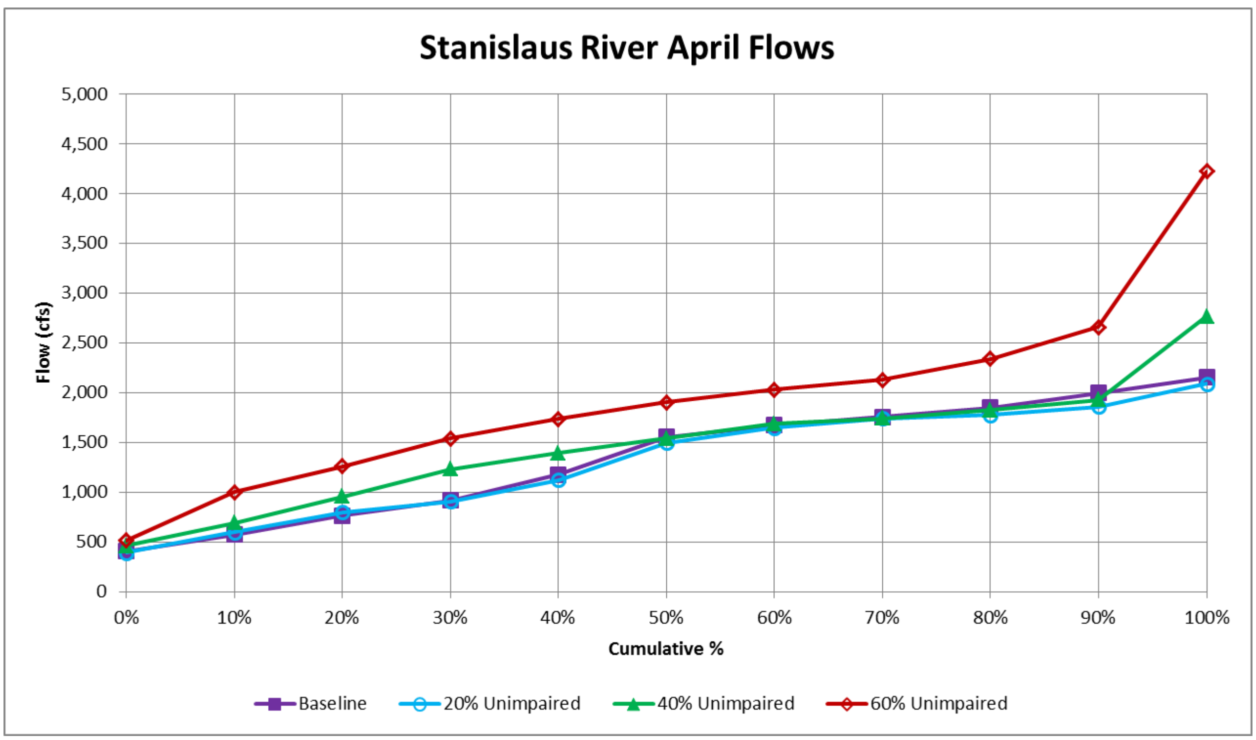


Figure F.1.4-3d. WSE-Simulated Cumulative Distributions of Stanislaus River April Flows (cfs) at Ripon for Baseline Conditions and 20%, 40%, 60% Unimpaired Flow (LSJR Alternatives 2–4)

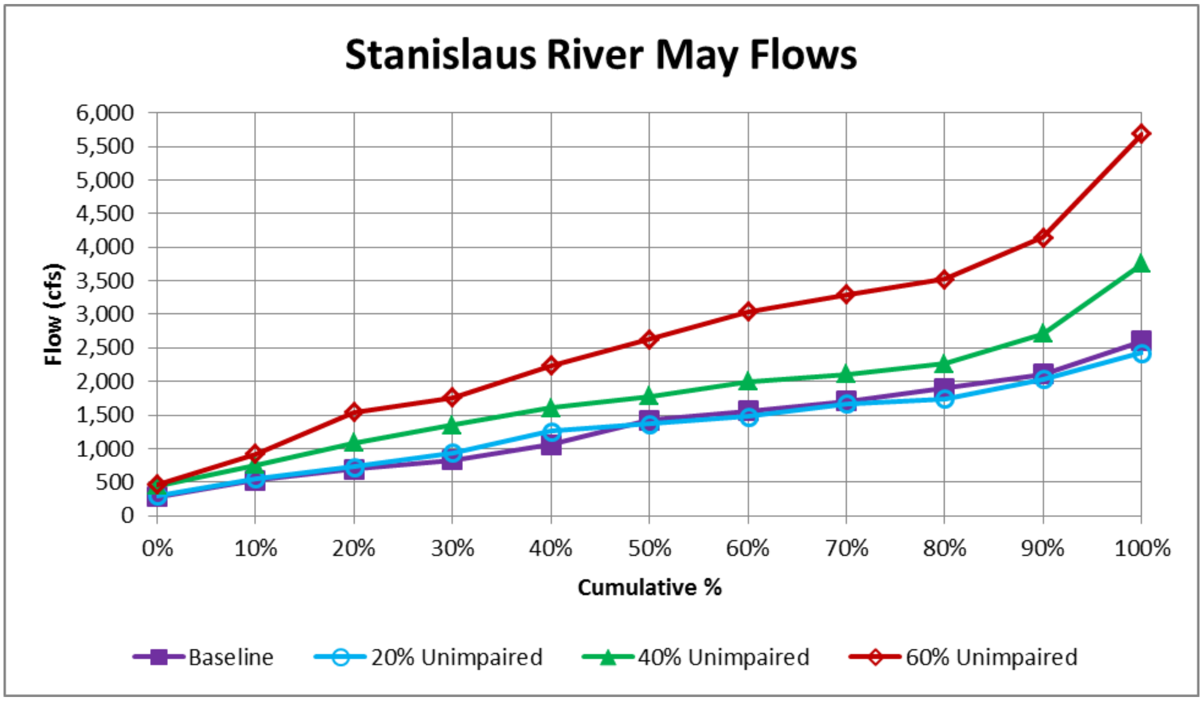


Figure F.1.4-3e. WSE-Simulated Cumulative Distributions of Stanislaus River May Flows (cfs) at Ripon for Baseline Conditions and 20%, 40%, 60% Unimpaired Flow (LSJR Alternatives 2–4)

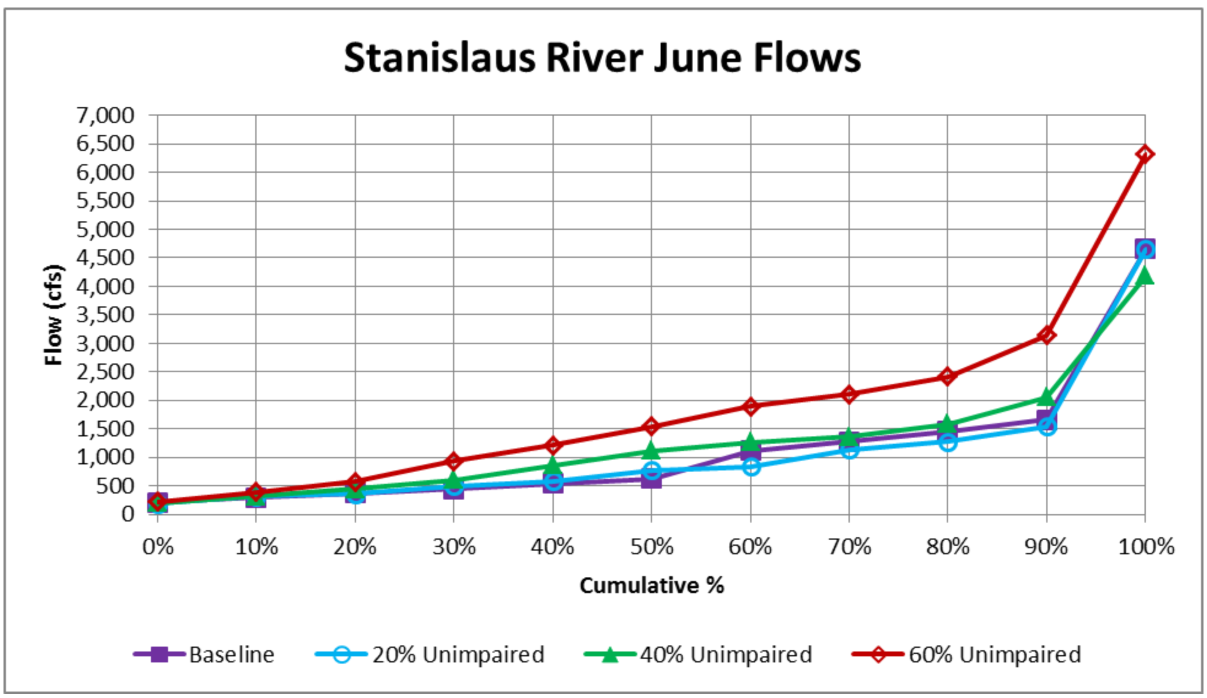


Figure F.1.4-3f. WSE-Simulated Cumulative Distributions of Stanislaus River June Flows (cfs) at Ripon for Baseline Conditions and 20%, 40%, 60% Unimpaired Flow (LSJR Alternatives 2–4)

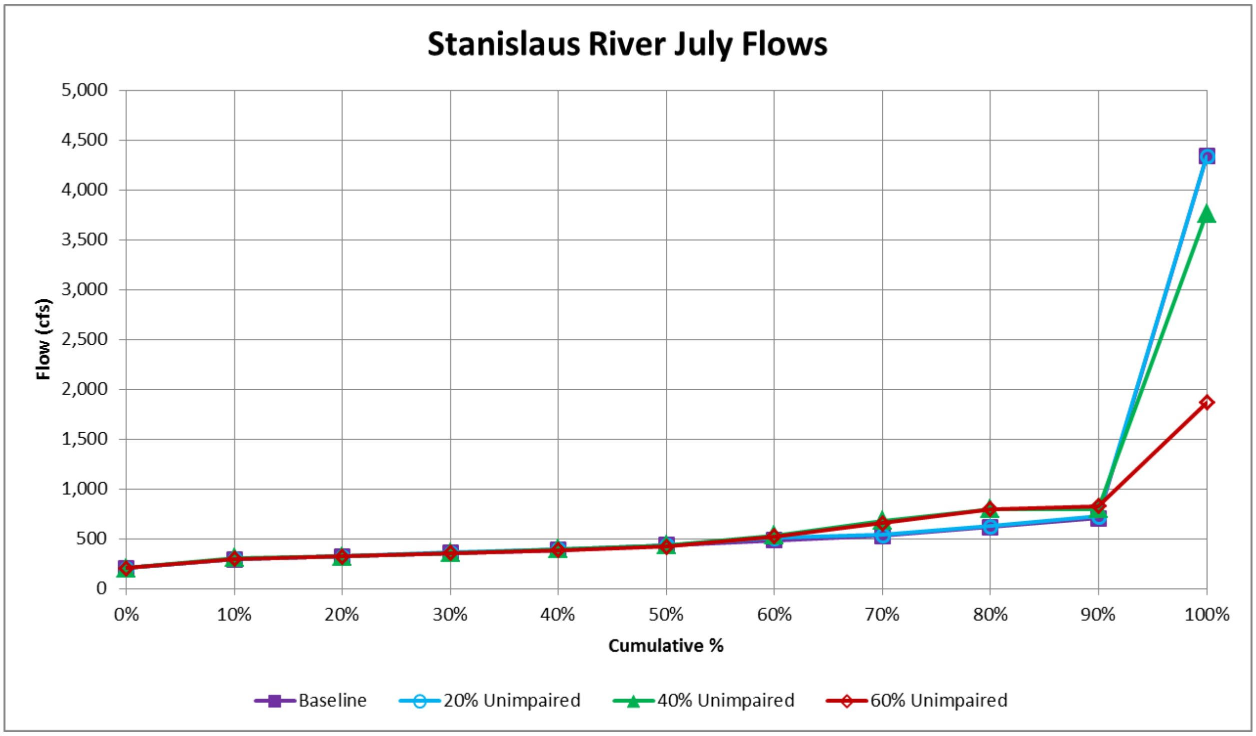


Figure F.1.4-3g. WSE-Simulated Cumulative Distributions of Stanislaus River July Flows (cfs) at Ripon for Baseline Conditions and 20%, 40%, 60% Unimpaired Flow (LSJR Alternatives 2–4)

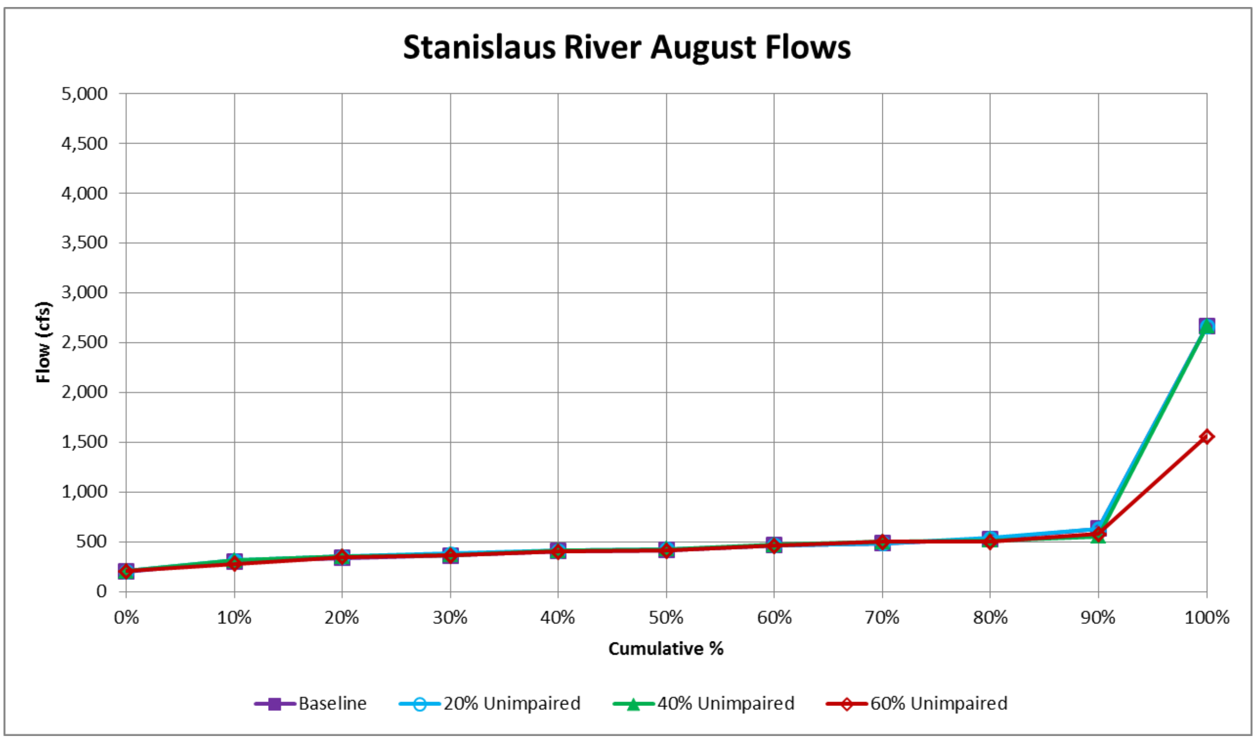


Figure F.1.4-3h. WSE-Simulated Cumulative Distributions of Stanislaus River August Flows (cfs) at Ripon for Baseline Conditions and 20%, 40%, 60% Unimpaired Flow (LSJR Alternatives 2–4)

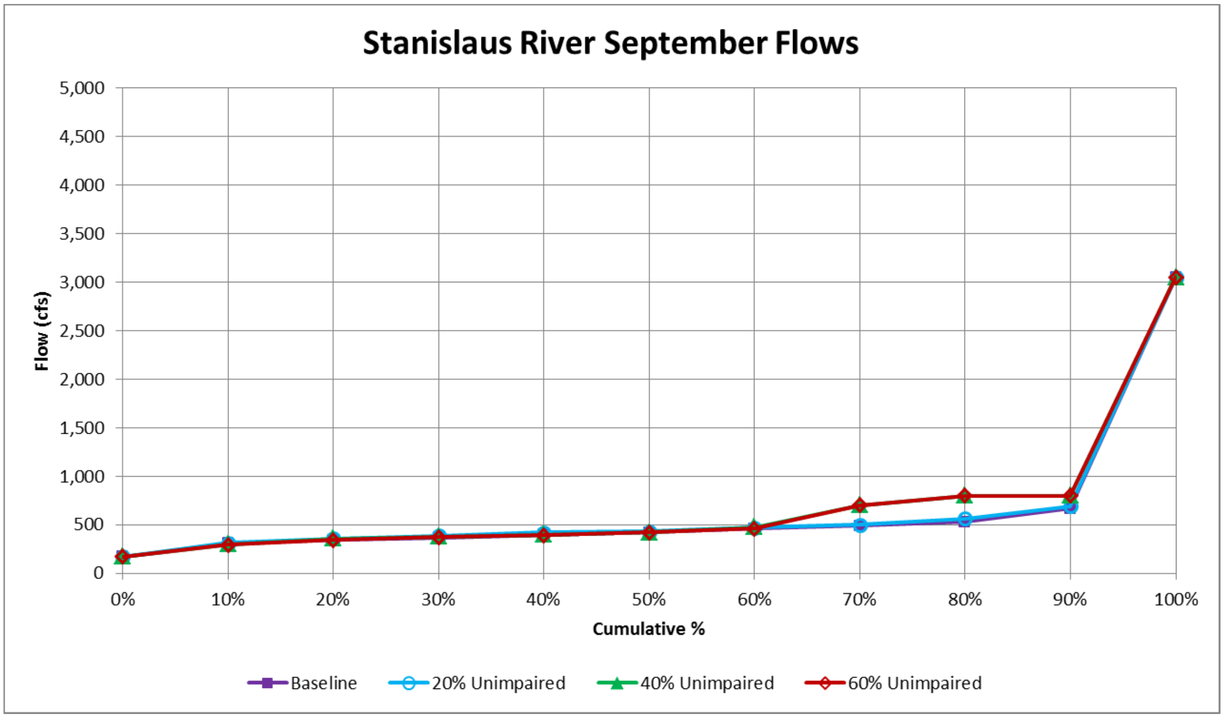


Figure F.1.4-3i. WSE-Simulated Cumulative Distributions of Stanislaus River September Flows (cfs) at Ripon for Baseline Conditions and 20%, 40%, 60% Unimpaired Flow (LSJR Alternatives 2–4)

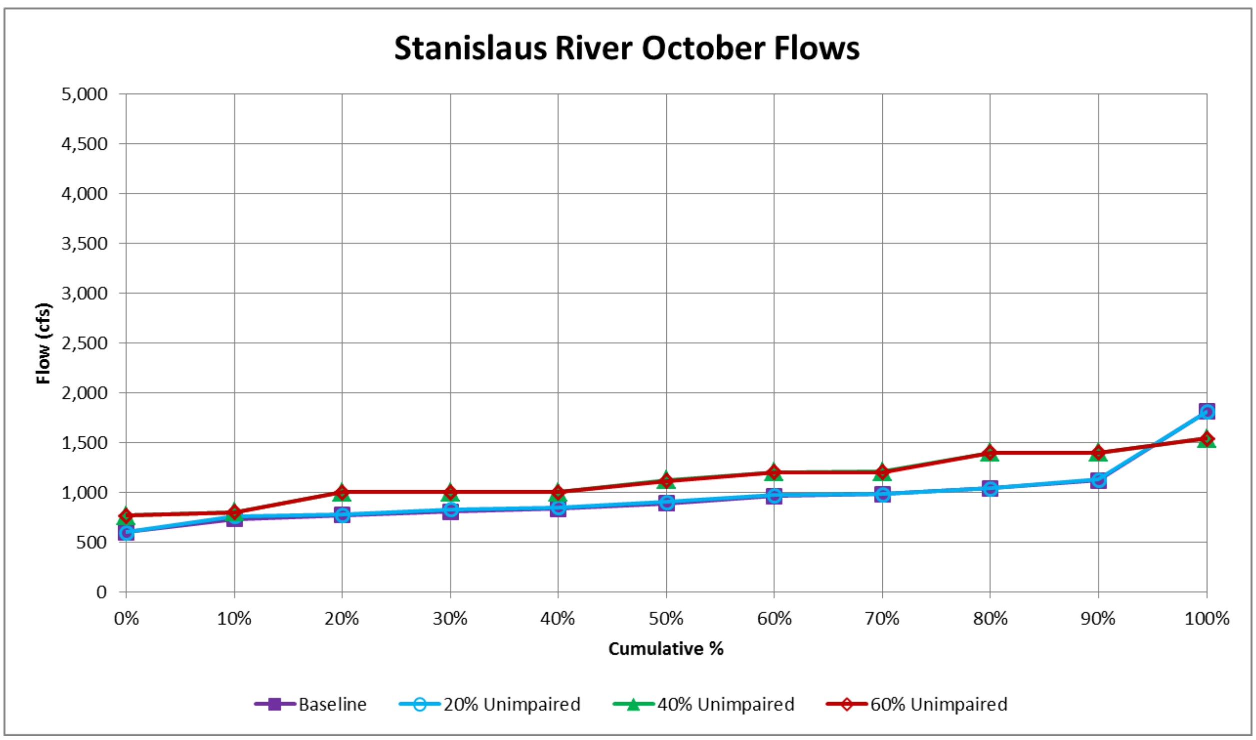


Figure F.1.4-3j. WSE-Simulated Cumulative Distributions of Stanislaus River October Flows (cfs) at Ripon for Baseline Conditions and 20%, 40%, 60% Unimpaired Flow (LSJR Alternatives 2–4)

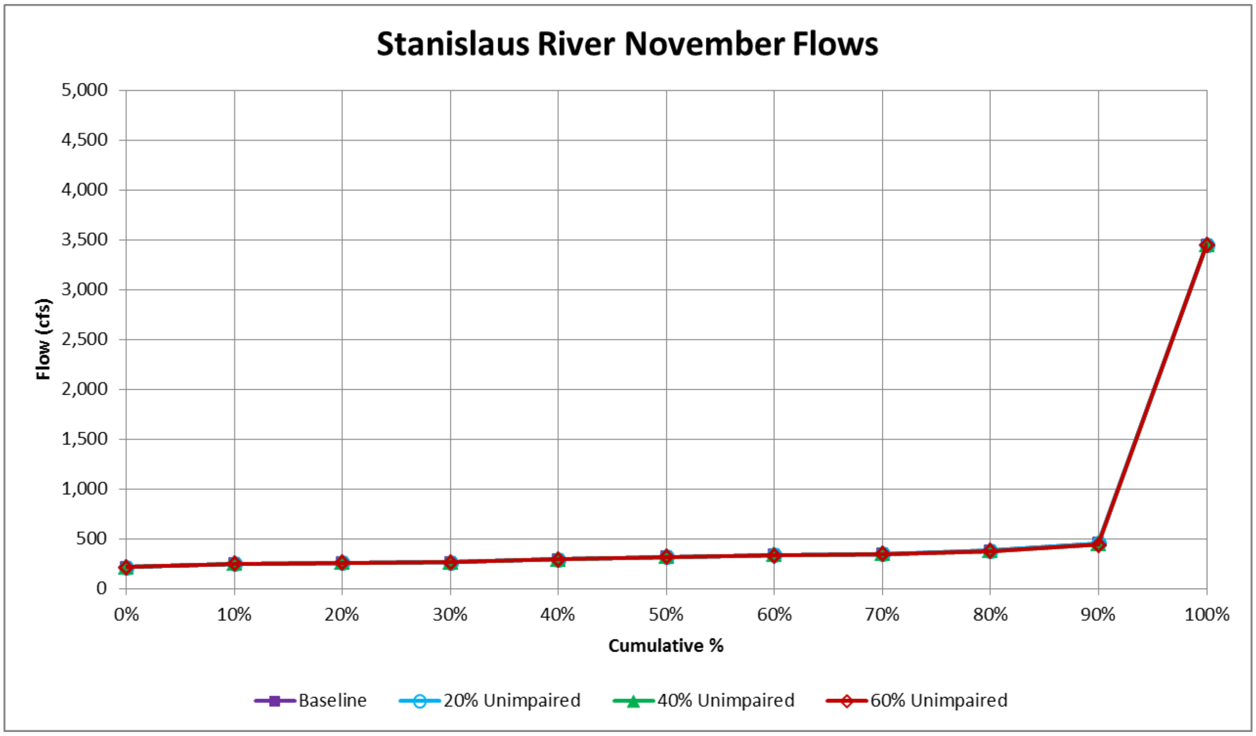


Figure F.1.4-3k. WSE-Simulated Cumulative Distributions of Stanislaus River November Flows (cfs) at Ripon for Baseline Conditions and 20%, 40%, 60% Unimpaired Flow (LSJR Alternatives 2–4)

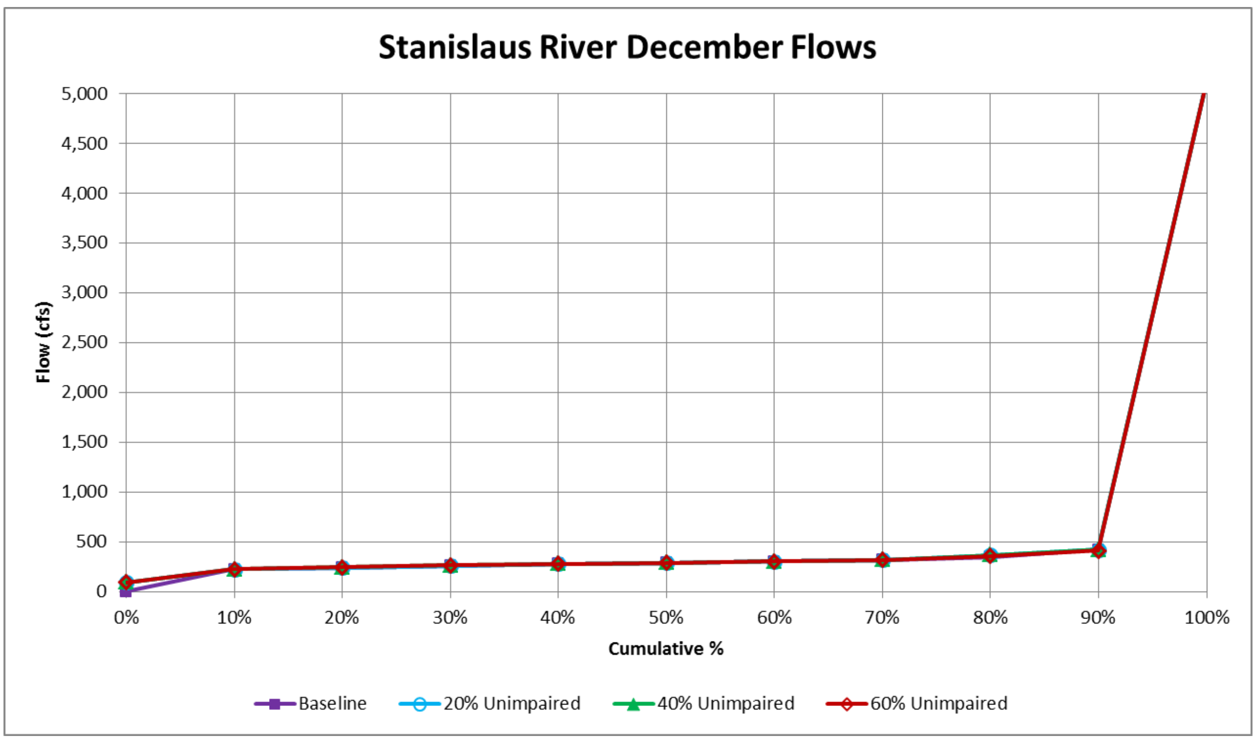


Figure F.1.4-3l. WSE-Simulated Cumulative Distributions of Stanislaus River December Flows (cfs) at Ripon for Baseline Conditions and 20%, 40%, 60% Unimpaired Flow (LSJR Alternatives 2–4)

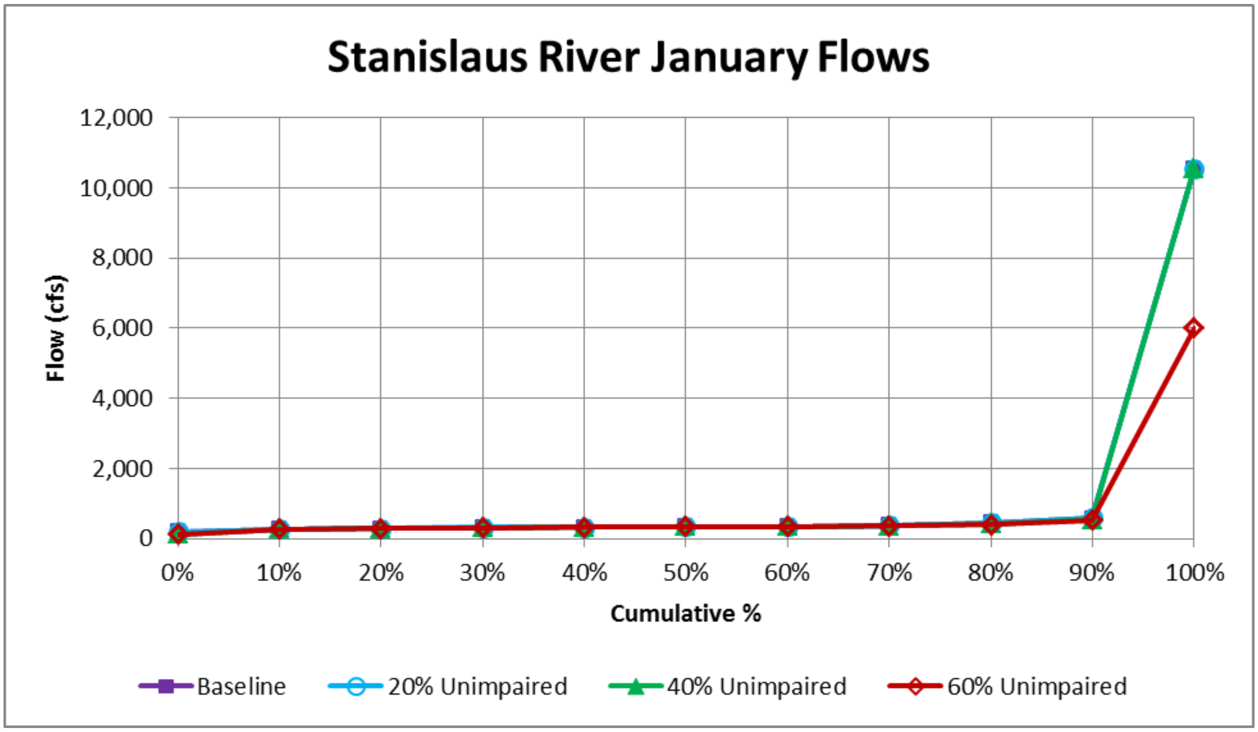


Figure F.1.4-3m. WSE-Simulated Cumulative Distributions of Stanislaus River January Flows (cfs) at Ripon for Baseline Conditions and 20%, 40%, 60% Unimpaired Flow (LSJR Alternatives 2–4)

F.1.4.4 SJR at Vernalis Flows

The monthly cumulative distributions for February–June flow (TAF) for the SJR at Vernalis for LSJR Alternatives 2, 3, and 4 provide an overall summary of the February–June changes compared to baseline. Table F.1.4-4 gives the cumulative distribution values for the February–June flow volumes (TAF).

The SJR at Vernalis flows are the sum of the three eastside tributary flows; the flow from upstream of the Merced River; and flows from groundwater seepage, creeks, and other drainages that enter the SJR downstream of the Merced River. The SJR at Vernalis flows are influenced by the baseline water quality objectives (i.e., EC and flow).

Figure F.1.4-4a shows the cumulative distributions of the February–June SJR at Vernalis flow volumes. The LSJR Alternative 2 flows were similar to baseline flows, but were generally a little higher (increase in February–June median flow volume of about 118 TAF). The cumulative distributions for LSJR Alternatives 3 and 4 for February–June were progressively higher than baseline and LSJR Alternative 2. Compared to baseline conditions, LSJR Alternative 3 would increase the February–June Vernalis median flow volume by about 633 TAF; LSJR Alternative 4 would increase the February–June SJR at Vernalis median flow volume by about 1,016 TAF. Average increases in flow from February–June would be less than the increases in median flows, about 288 TAF for LSJR Alternative 3 and 728 TAF for LSJR Alternative 4. For baseline and LSJR Alternatives 2 and 3, the February–June flow volumes were dominated by flood control releases in about 10 percent of the years. Flow distributions for the 30 percent and 50 percent unimpaired flow simulations (which are not shown in this graph) were intermediate between the 20 percent and 40 percent unimpaired flow simulations and the 40 percent and 60 percent unimpaired flow simulations, respectively (Table F.1.4-4).

Table F.1.4-4. Cumulative Distributions of February–June River Flow Volumes (TAF) of SJR at Vernalis for Baseline Conditions and the Unimpaired Flow Simulations (20%–60%)

		Percent of Unimpaired Flow				
Percentile	Baseline	20%	30%	40%	50%	60%
0	364	381	389	417	460	504
10	444	513	598	716	805	940
20	604	668	847	977	1,110	1,277
30	785	835	962	1,048	1,239	1,420
40	935	930	1,093	1,307	1,505	1,721
50	1,103	1,221	1,460	1,736	1,948	2,119
60	1,509	1,487	1,671	1,926	2,163	2,526
70	1,904	1,949	2,096	2,213	2,429	2,727
80	2,508	2,573	2,635	2,623	2,883	3,230
90	3,554	3,568	3,629	3,718	4,025	4,425
100	9,415	9,415	9,487	9,606	9,825	10,112
Average	1,742	1,797	1,916	2,030	2,227	2,470

Figures F.1.4-4b, F.1.4-4c, F.1.4-4d, F.1.4-4e, and F.1.4-4f show the cumulative distributions of SJR flow at Vernalis from February–June. The baseline February flows were similar to most of the LSJR alternative flows. Between March and May, the Vernalis flows associated with LSJR Alternatives 3 and 4 increased relative to baseline flow, such that by May, the median flows under LSJR Alternative 4 were over 10,000 cfs. However, by May, the Vernalis flows for LSJR Alternative 2 were only slightly greater than the baseline flows. The June pattern of flows was similar to May, although flows were slightly reduced.

In general, from July–January, river and reservoir operations were similar under the LSJR alternatives as under baseline conditions. Figures F.1.4-4g, F.1.4-4h, F.1.4-4i, F.1.4-4j, F.1.4-4k, F.1.4-4l, and F.1.4-4m show the cumulative distributions of SJR flow at Vernalis from July–January. The flow differences between alternatives during these months were relatively small and occurred only at flow levels higher than the median flows. There are several possible reasons why LSJR alternative flows may sometimes differ from baseline flows and each other during these months. Where there were differences in the highest flows, the differences were often caused by LSJR Alternatives 3 and 4 having more reservoir capacity, thereby reducing releases for flood control. Most other differences were generally caused by the release of retained water under LSJR Alternatives 3 and 4 for temperature control purposes. However, some differences were also caused by other factors such as variable releases for salinity control at Vernalis and changes in NMFS BO flows for the Stanislaus River associated with changes in reservoir storage.

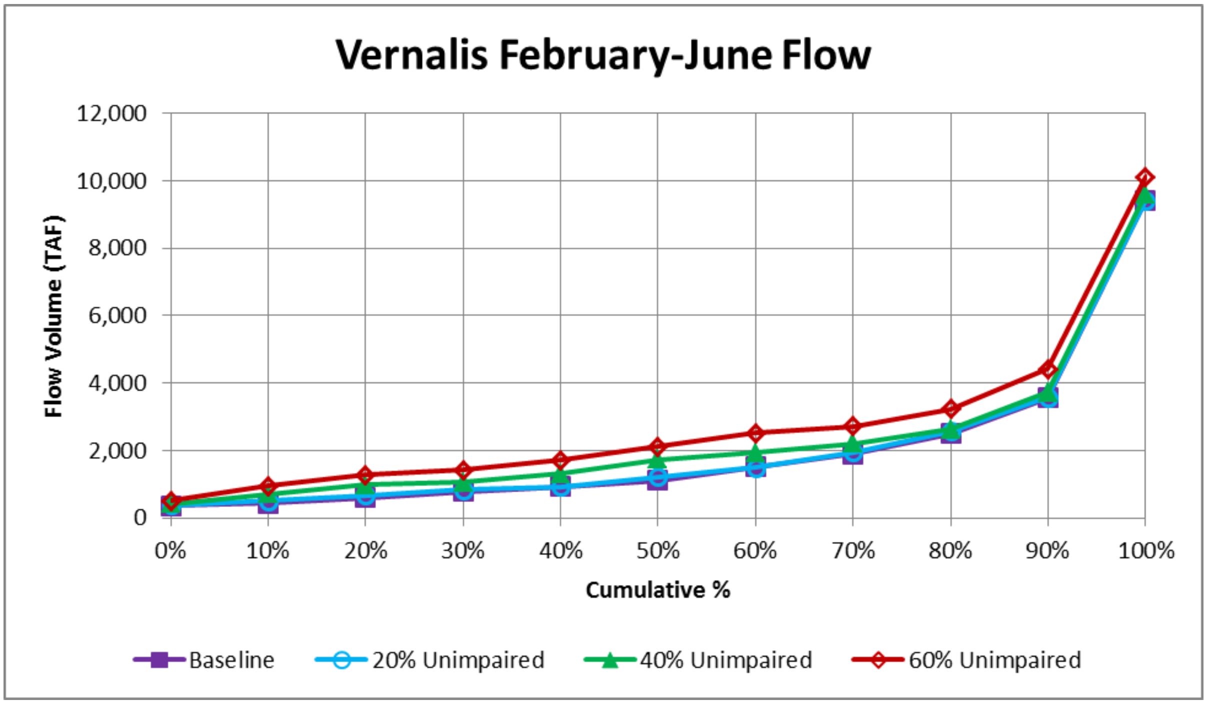


Figure F.1.4-4a. WSE-Simulated Cumulative Distributions of SJR at Vernalis February–June Flow Volumes (TAF) for Baseline Conditions and 20%, 40%, 60% Unimpaired Flow (LSJR Alternatives 2–4)

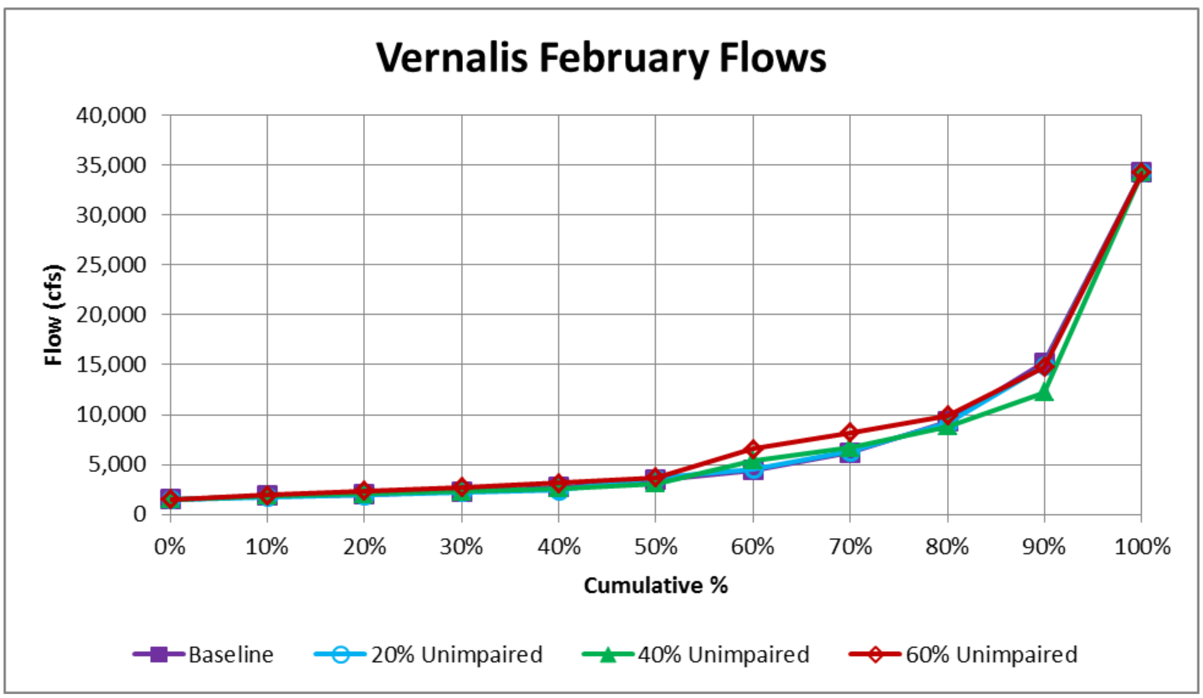


Figure F.1.4-4b. WSE-Simulated Cumulative Distributions of SJR at Vernalis February Flows (cfs) for Baseline Conditions and 20%, 40%, 60% Unimpaired Flow (LSJR Alternatives 2–4)

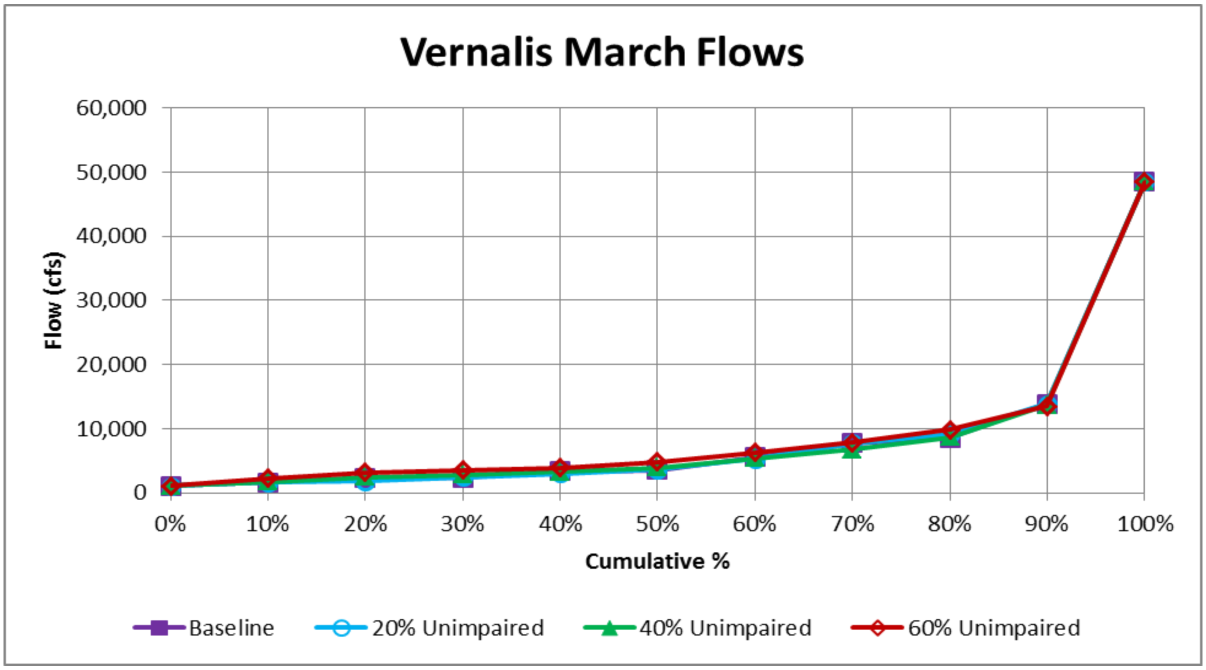


Figure F.1.4-4c. WSE-Simulated Cumulative Distributions of SJR at Vernalis March Flows (cfs) for Baseline Conditions and 20%, 40%, 60% Unimpaired Flow (LSJR Alternatives 2–4)

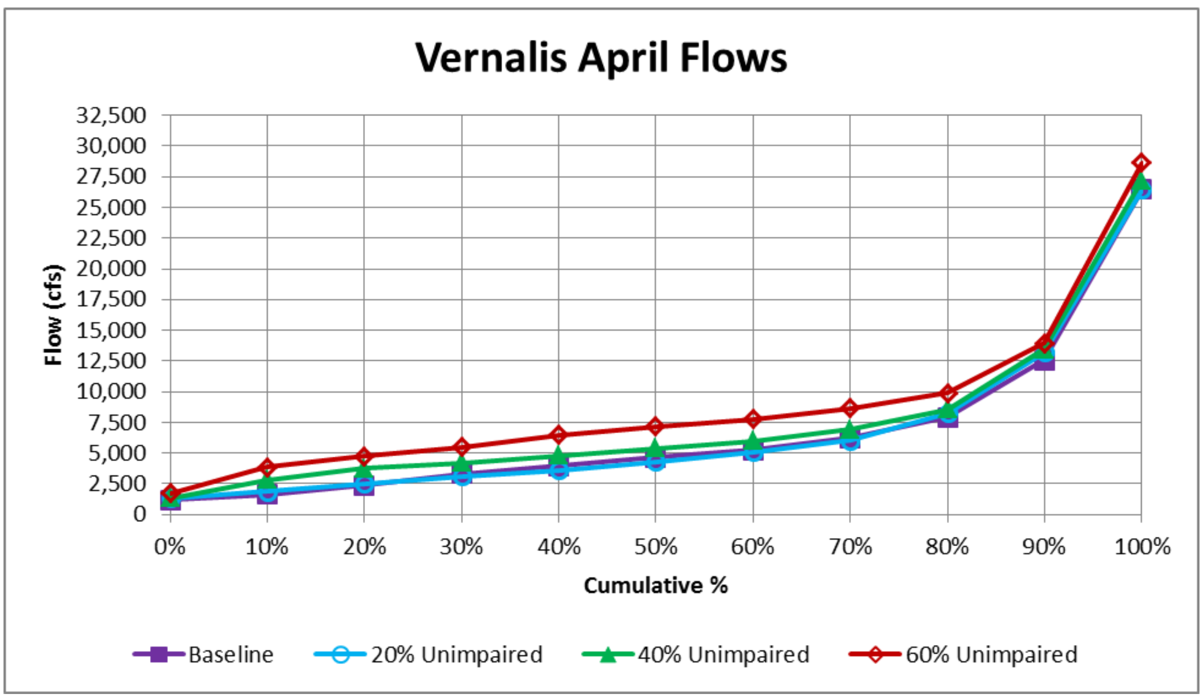


Figure F.1.4-4d. WSE-Simulated Cumulative Distributions of SJR at Vernalis April Flows (cfs) for Baseline Conditions and 20%, 40%, 60% Unimpaired Flow (LSJR Alternatives 2–4)

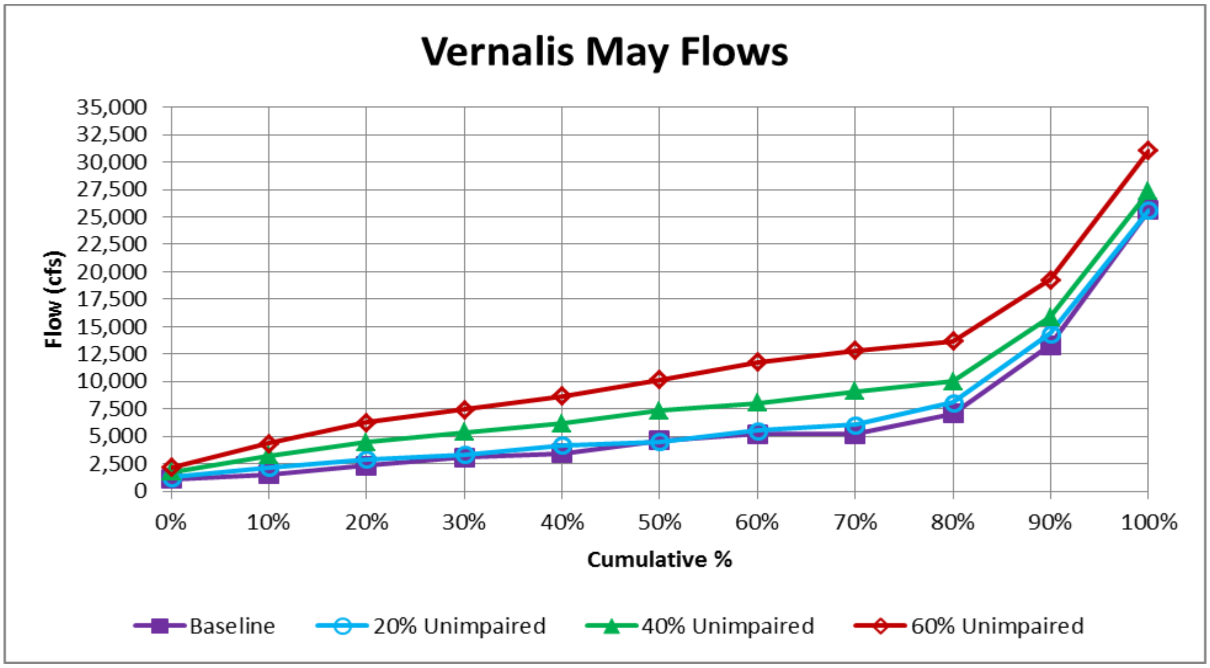


Figure F.1.4-4e. WSE-Simulated Cumulative Distributions of SJR at Vernalis May Flows (cfs) for Baseline Conditions and 20%, 40%, 60% Unimpaired Flow (LSJR Alternatives 2–4)

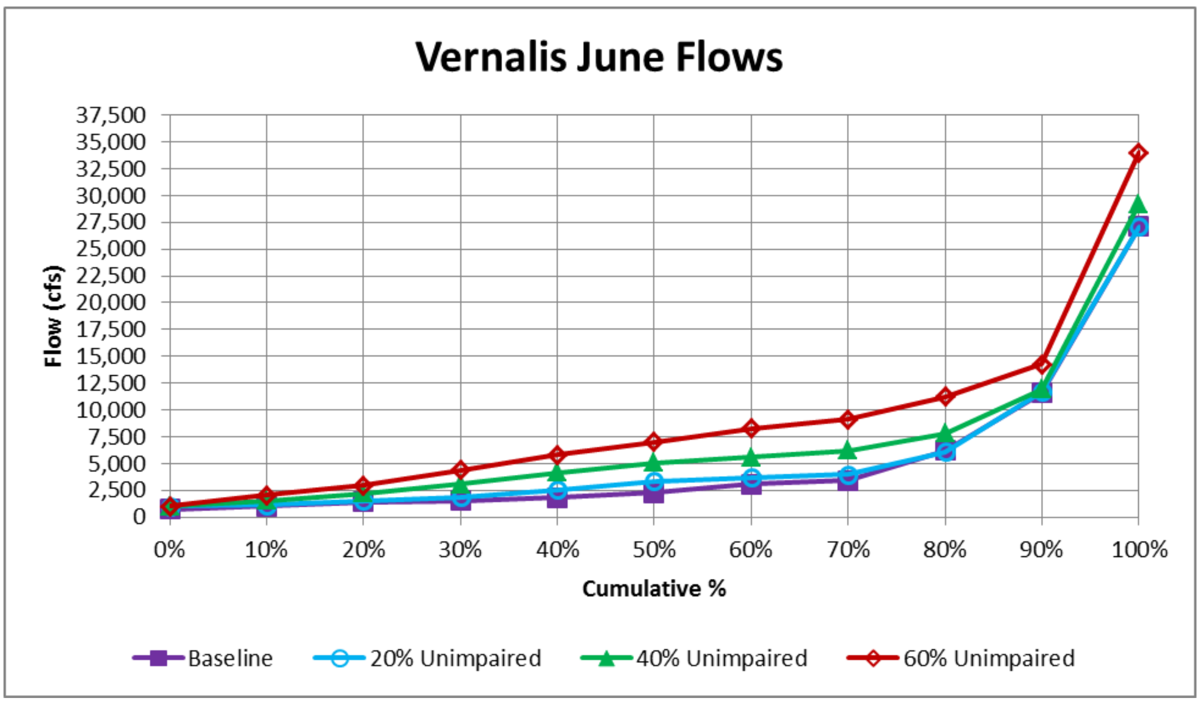


Figure F.1.4-4f. WSE-Simulated Cumulative Distributions of SJR at Vernalis June Flows (cfs) for Baseline Conditions and 20%, 40%, 60% Unimpaired Flow (LSJR Alternatives 2–4)

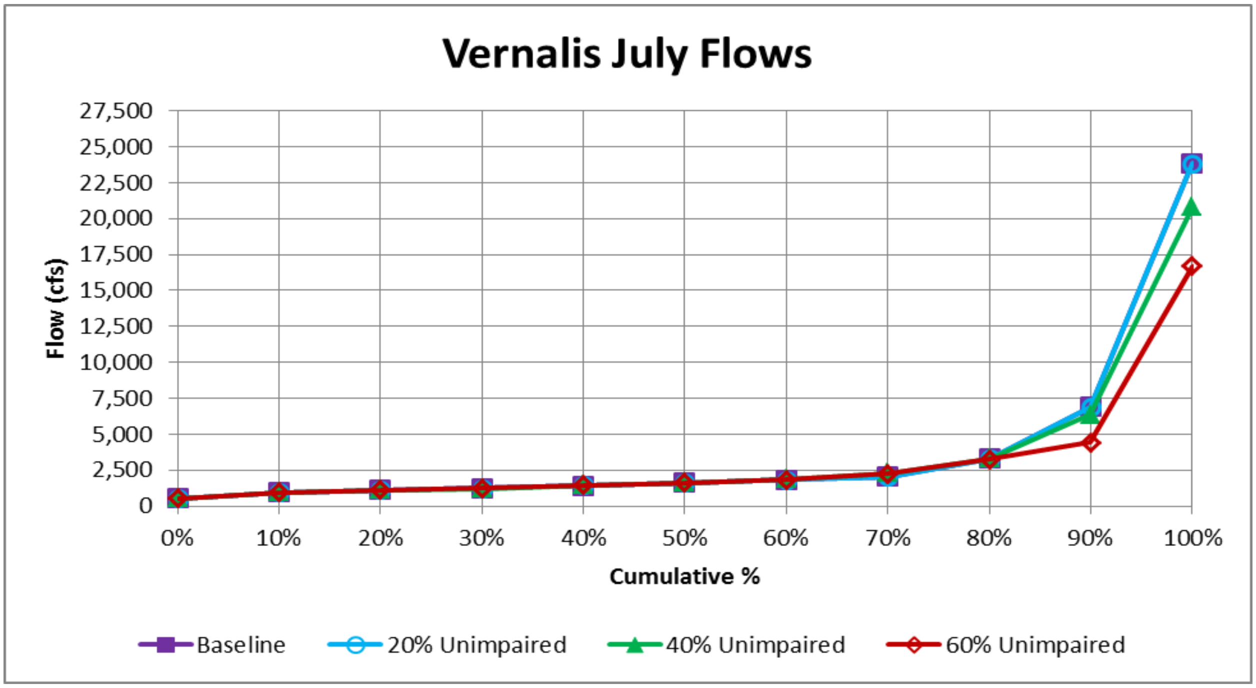


Figure F.1.4-4g. WSE-Simulated Cumulative Distributions of SJR at Vernalis July Flows (cfs) for Baseline Conditions and 20%, 40%, 60% Unimpaired Flow (LSJR Alternatives 2–4)

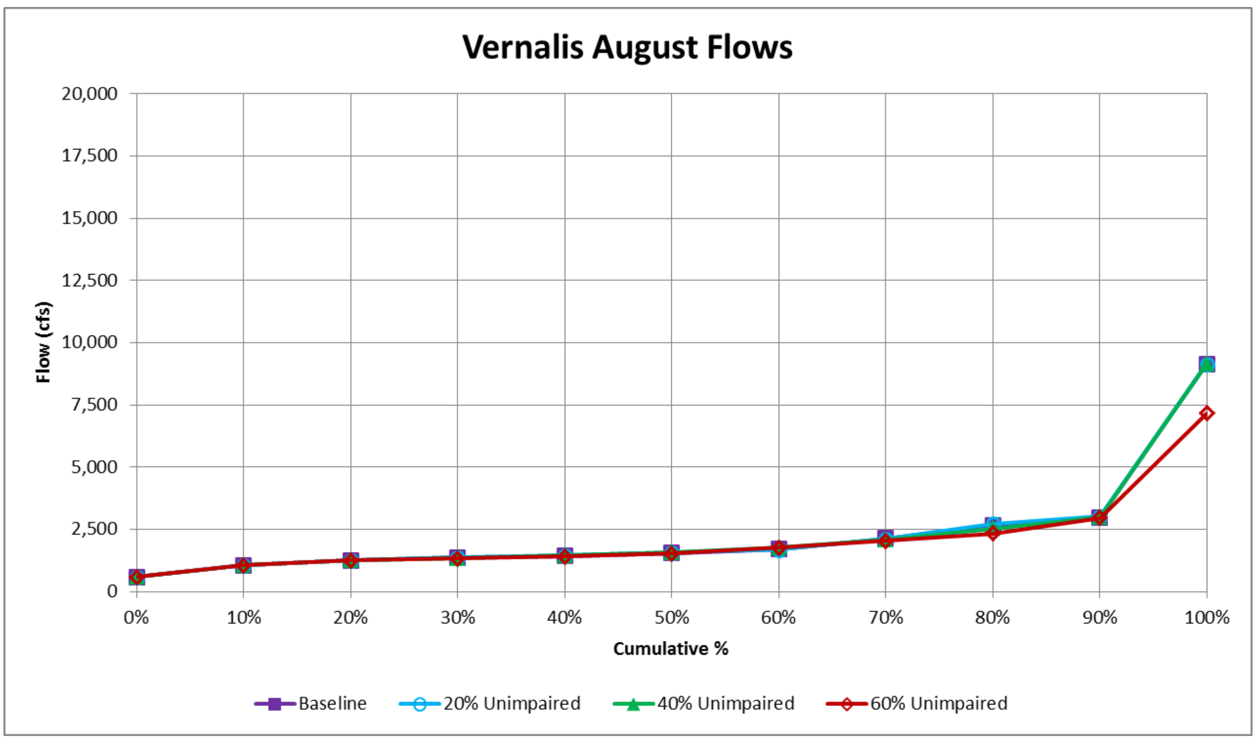


Figure F.1.4-4h. WSE-Simulated Cumulative Distributions of SJR at Vernalis August Flows (cfs) for Baseline Conditions and 20%, 40%, 60% Unimpaired Flow (LSJR Alternatives 2–4)

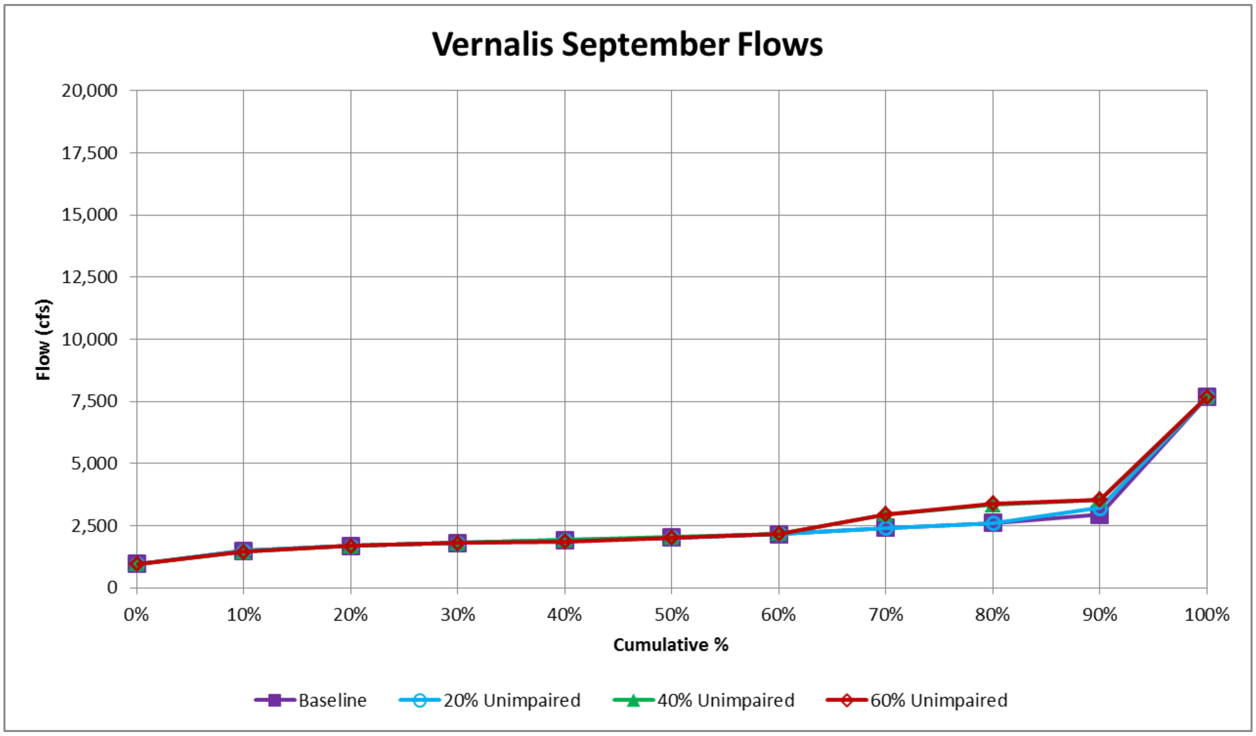


Figure F.1.4-4i. WSE-Simulated Cumulative Distributions of SJR at Vernalis September Flows (cfs) for Baseline Conditions and 20%, 40%, 60% Unimpaired Flow (LSJR Alternatives 2–4)

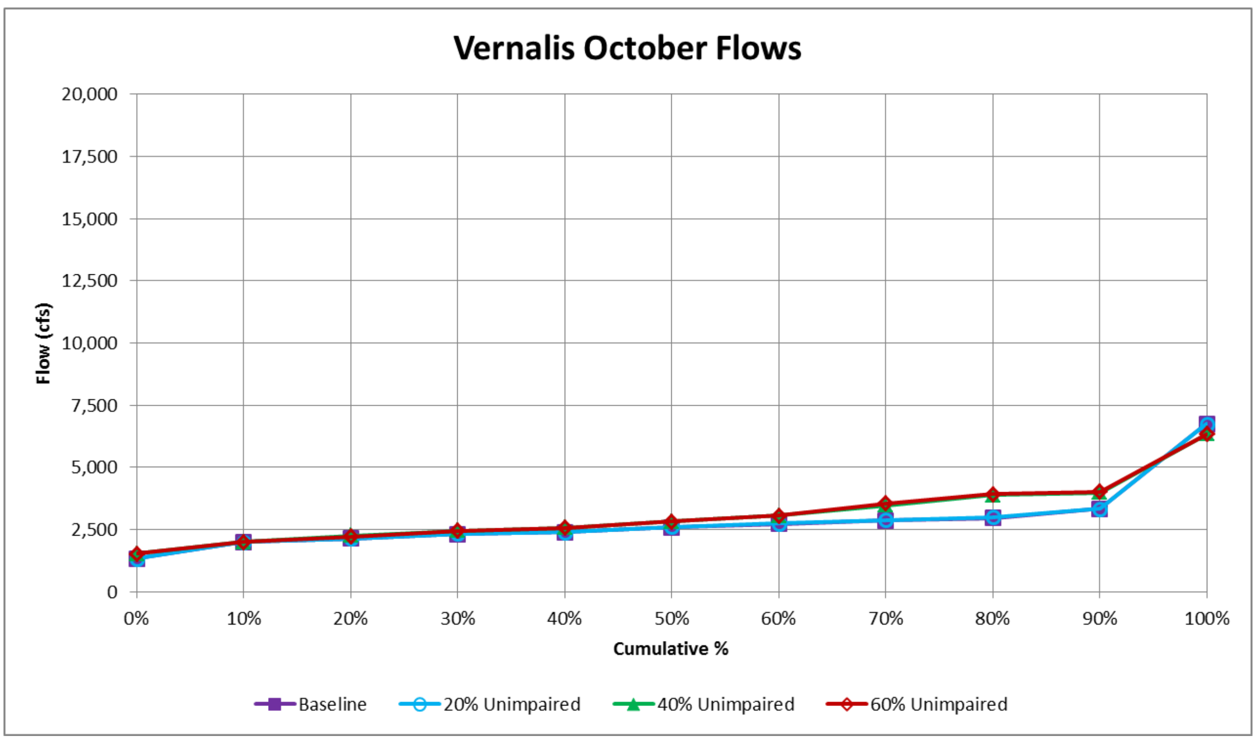


Figure F.1.4-4j. WSE-Simulated Cumulative Distributions of SJR at Vernalis October Flows (cfs) for Baseline Conditions and 20%, 40%, 60% Unimpaired Flow (LSJR Alternatives 2–4)

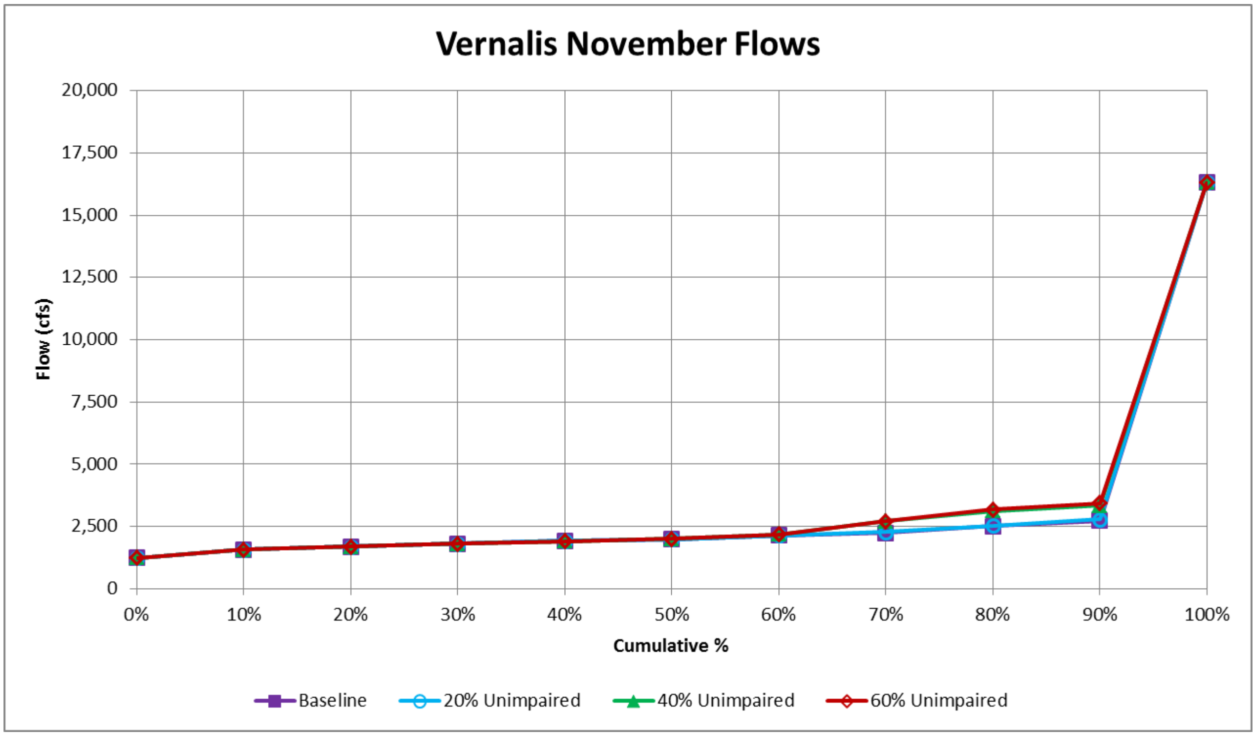


Figure F.1.4-4k. WSE-Simulated Cumulative Distributions of SJR at Vernalis November Flows (cfs) for Baseline Conditions and 20%, 40%, 60% Unimpaired Flow (LSJR Alternatives 2–4)

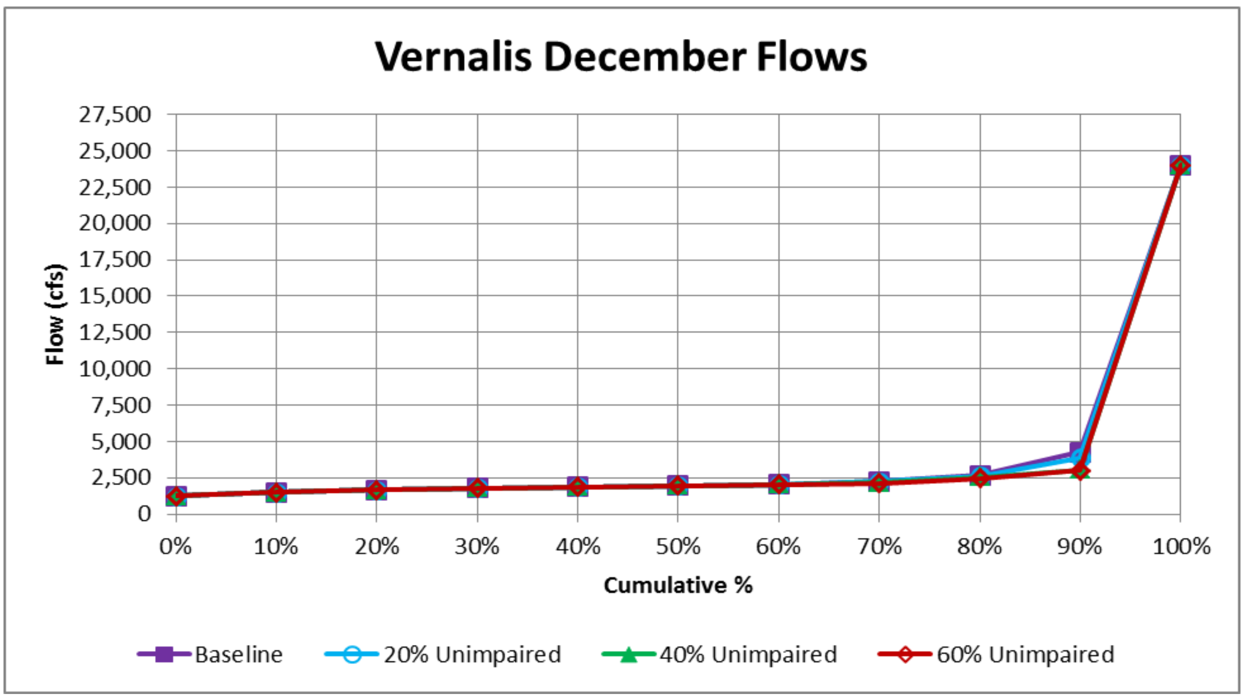


Figure F.1.4-4l. WSE-Simulated Cumulative Distributions of SJR at Vernalis December Flows (cfs) for Baseline Conditions and 20%, 40%, 60% Unimpaired Flow (LSJR Alternatives 2–4)

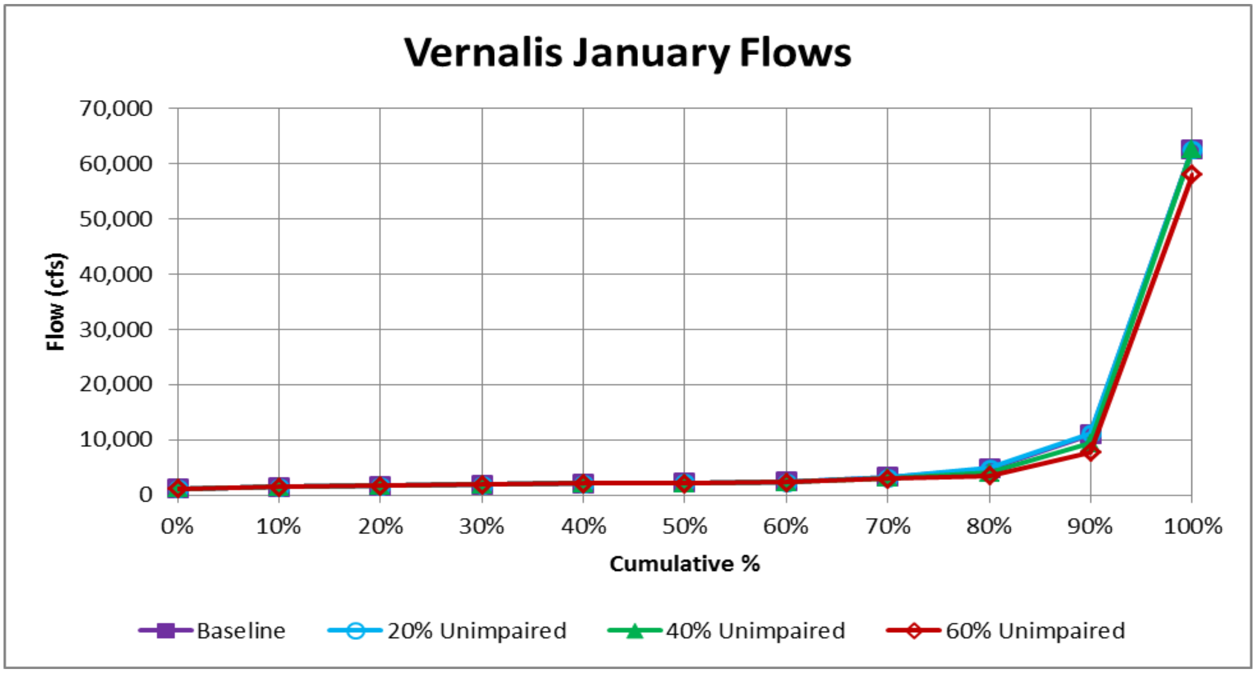


Figure F.1.4-4m. WSE-Simulated Cumulative Distributions of SJR at Vernalis January Flows (cfs) for Baseline Conditions and 20%, 40%, 60% Unimpaired Flow (LSJR Alternatives 2–4)

F.1.5 Salinity Modeling

This section contains the modeling methods and results of estimating the effects of the LSJR alternatives on salinity (EC) at Vernalis and in the southern Delta. EC at Vernalis was simulated with the WSE model using a ratio based on CALSIM results. The CALSIM model is discussed in more detail in Section F.1.2.1, *Water Supply Effects Methods*. Vernalis EC objectives were met in the WSE model by ensuring that enough flow was maintained at Vernalis to meet the EC objectives. Southern Delta EC values were estimated using empirically derived relationships with Vernalis EC. Alternative effects were determined by comparing the LSJR alternatives to baseline conditions.

F.1.5.1 Salinity Modeling Methods

The salinity calculations are based on salinity estimates calculated by the CALSIM model used in the development of the WSE baseline discussed above. CALSIM flow and salinity at Vernalis were used to develop the alternative salinity at Vernalis subject to the LSJR alternative flow. The WSE model roughly estimates the salinity at Vernalis for the entire 82 year period of modeling. The CALSIM EC was adjusted to approximate the inverse of the flow change ratio. The WSE model estimates the adjusted EC at Vernalis as:

*Adjusted Vernalis EC = CALSIM EC * (CALSIM Flow/Adjusted Flow)* (Eqn. F.1-14)

For example, a Vernalis flow increase of 10 percent will reduce the Vernalis EC by almost 10 percent. A flow reduction of 10 percent will increase the EC by almost 10 percent. Reservoir releases for the Stanislaus River sometimes had to be increased in the WSE in order to meet the Vernalis EC objective, generally when the Vernalis flow was relatively low.

CALSIM values were used as a starting point because the CALSIM results include the 82-year period of estimated salinity and because CALSIM closely matches recent historical salinity at Vernalis (Figure F.1.5-1). A discussion of improvements to the CALSIM SJR EC calculations and evaluation of the performance of the model for calculating EC at Vernalis is available in the USBR (2004) document, Technical Memorandum, Development of Water Quality Module. CALSIM II has a water quality module, which provides estimates of salinity at Vernalis. This module uses a "link-node" approach that assigns salinity values to major inflows to the SJR between Lander Avenue and Vernalis and calculates the resulting salinity at Vernalis using a salt mass balance equation. Inflows from the west side of the SJR are also broken out and calculated as the return flows associated with various surface water diversions and groundwater pumping (USBR 2004). The CALSIM model assumes constant flow to EC relationships (i.e., EC = a x flow-b) for the SJR above the Merced, Tuolumne, and Stanislaus Rivers to estimate the salinity at Vernalis.

In Figure F.1.5-1, monthly average observed salinity data from the California Data Exchange Center (CDEC) at Vernalis (DWR 2010a) are plotted together with the CALSIM II estimates of salinity at Vernalis for water years 1994 through September 2003. This represents a period commencing shortly after temporary agricultural flow barriers in the southern Delta were regularly installed through to the end of the overlapping CALSIM II simulation period.

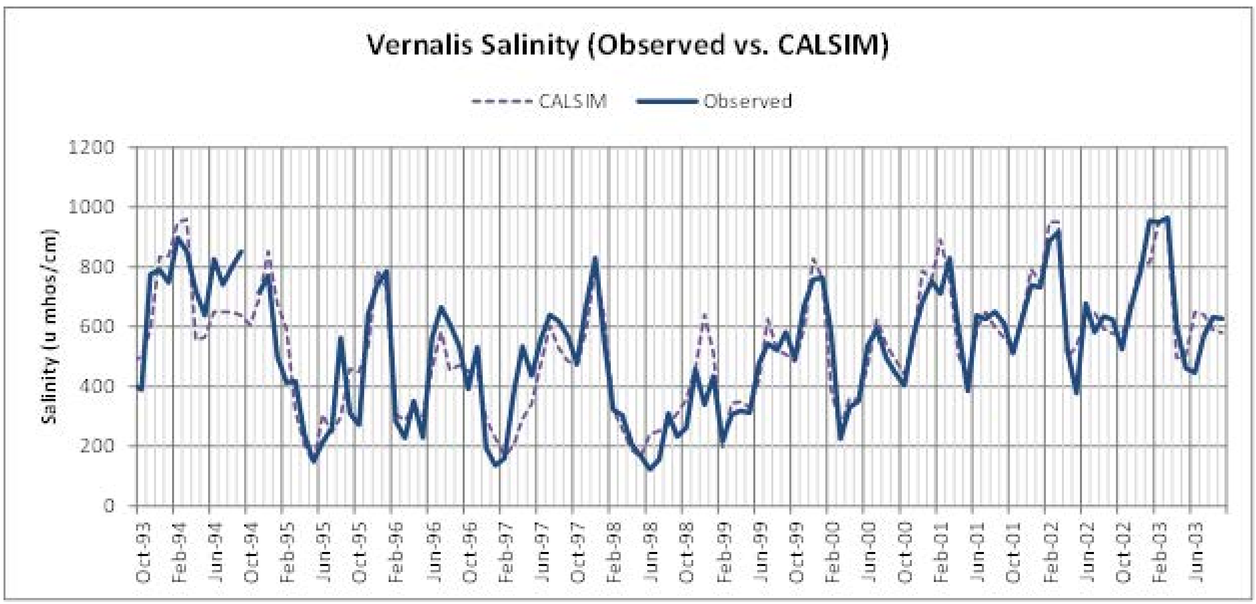


Figure F.1.5-1. Comparison of CALSIM II Salinity Output at Vernalis to Monthly Average Observed Data at the Same Location for Water Years 1994–2003)

Southern Delta EC Increments

In order to estimate the resulting EC at the interior Delta stations, a simplified approach was taken using historical data. Simple calculations of the southern Delta EC values were made based on the historical EC increases between Vernalis and the southern Delta stations for 1985–2010 (described in detail in Appendix F.2, *Evaluation of Historical Flow and Salinity Measurements of the Lower San Joaquin River and Southern Delta*). The EC increment can be described as the increase in salinity from the Vernalis station to the next station due to additional salt introduced downstream from Vernalis. These calculated EC increases between Vernalis and the southern Delta compliance stations (Brandt Bridge, Union Island, and Tracy Boulevard) were assumed to be reasonable approximations for purposes of salinity impact assessment.

Figure F.1.5-2a shows the measured EC increments between Vernalis and Brandt Bridge or between Vernalis and Old River at Union Island as a function of the Vernalis flow. The measured EC increments generally are reduced when the Vernalis flow is higher. An example flow-dilution relationship is shown on the graph for 100,000/flow (cfs) and for 200,000/flow (cfs). Some EC increments are higher and some are lower, but this appears to be a reasonable approach for estimating the southern Delta EC based on the Vernalis EC and Vernalis flow. The review of the historical EC data suggested that the EC increment from Vernalis to Brandt Bridge or Old River at Middle River (Union Island) can be approximated with a flow-dilution relationship:

EC increase from Vernalis (μS/cm) = 100,000/SJR flow at Vernalis (cfs) (Eqn. F.1-15)

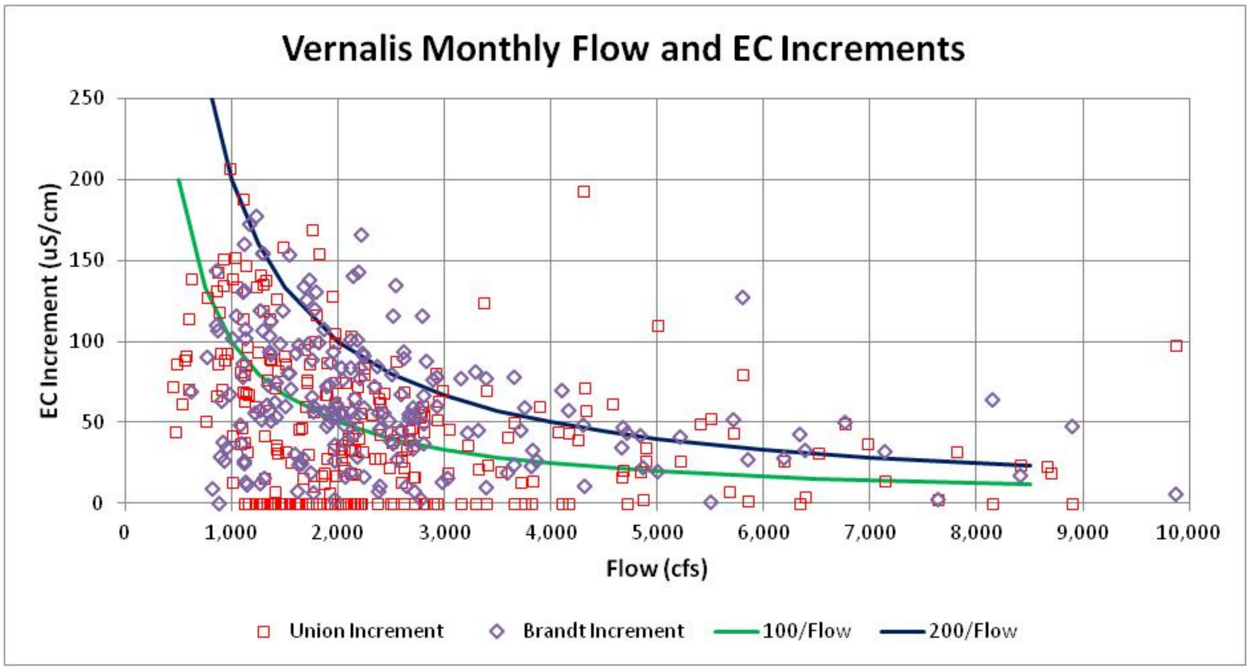


Figure F.1.5-2a. Historical Monthly EC Increments from Vernalis to Brandt Bridge and Union Island as a Function of Vernalis Flow (cfs) for Water Years 1985–2010)

Therefore, for a flow of 1,000 cfs, the EC increase (EC increment) would be 100 μS/cm. For a flow of 2,000 cfs, the EC increase would be 50 μS/cm, and for a flow of 5,000 cfs, the EC increase would be 20 μS/cm. Figure F.1.5-2b shows the measured EC increments between Vernalis and Old River at Tracy Boulevard as a function of the Vernalis Flow. The measured EC increments generally are reduced when the Vernalis flow is higher. An example flow-dilution relationship is shown on the graph for 200,000/flow (cfs) and for 400,000/flow (cfs). The EC increase at Old River at Tracy Boulevard was assumed to be three times the EC increase at Brandt Bridge:

EC increase from Vernalis (µS/cm) = 300,000/SJR flow at Vernalis (cfs) (Eqn. F.1-16)

The Tracy Boulevard station is most affected by salt sources within the Delta and limited tidal circulation in Old River between Doughty Cut and the CVP Jones Pumping plant. These calculated EC increases were assumed for purposes of salinity impact assessment and could be modified if more accurate descriptions of the southern Delta salinity relationships are determined.

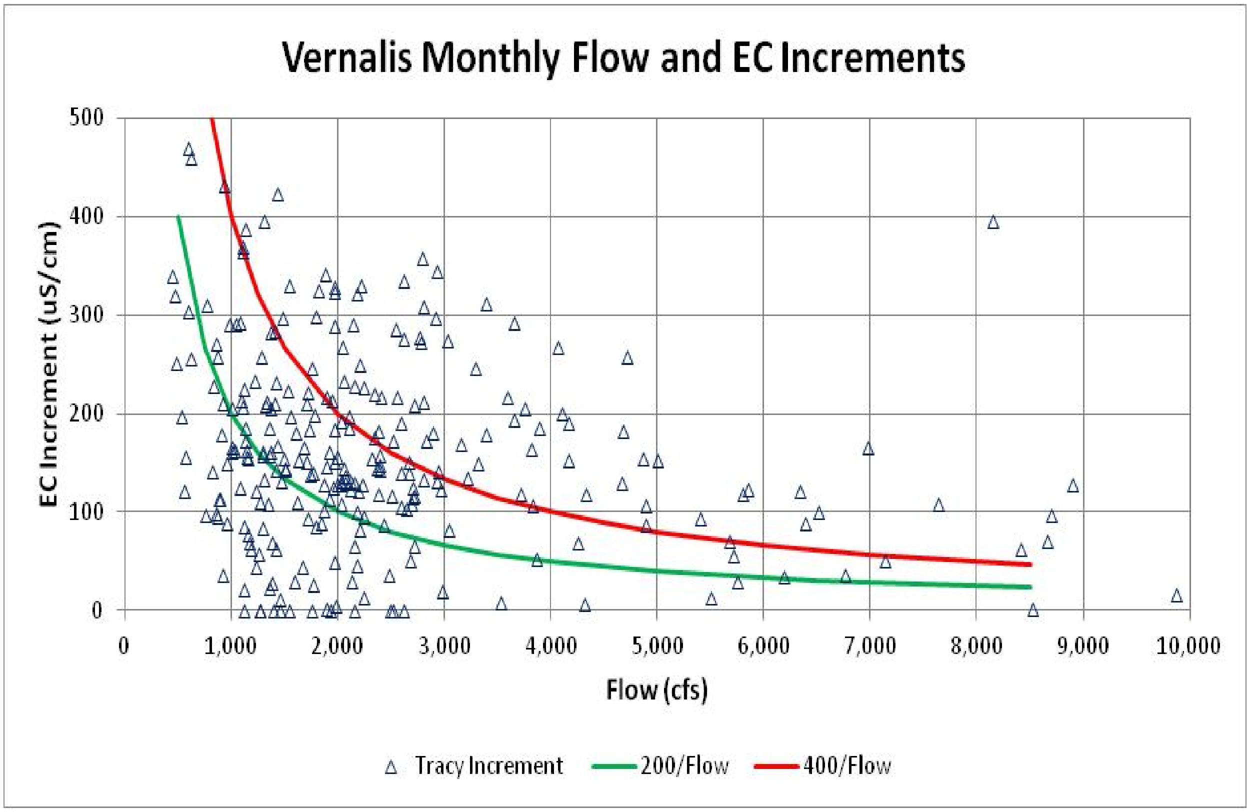


Figure F.1.5-2b. Historical Monthly EC Increments from Vernalis to Tracy Boulevard as a Function of Vernalis Flow (cfs) for Water Years 1985–2010)

F.1.5.2 Salinity Modeling Results

Baseline conditions for salinity are discussed below. The calculated changes under 20, 40, and 60 percent minimum unimpaired flow (LSJR Alternatives 2, 3, and 4) are presented and discussed below. Results for the 30 percent and 50 percent unimpaired flow simulation would be intermediate between the 20 percent and 40 percent and 40 percent and 60 percent unimpaired flow simulations respectively.

Baseline Conditions

The flow, EC, and salt load of the SJR upstream of the Merced River are assumed to remain the same for all of the LSJR alternatives. The CALSIM salt load upstream of the Merced River contributes to the CALSIM salt load at Vernalis, which is used in the Vernalis EC calculation by the WSE model.

Table F.1.5-1a shows the CALSIM-estimated SJR EC values upstream of the Merced River. This is an important location because the combination of the flow and the salinity represents the simulated upstream salt load for baseline conditions, which was assumed to remain the same for LSJR Alternatives 2, 3, and 4. The median (50 percent) monthly EC ranged from about 1,000 µS/cm to about 1,400 µS/cm (in July). The maximum monthly EC values of 1,200 µS/cm to 2,200 µS/cm correspond to the lowest flows; the lowest monthly EC values, which were less than 500 µS/cm for most months, correspond to the highest flows. The last column in Table F.1.5-1a shows the annual salt load cumulative distributions for the SJR above the Merced River (1,000 tons). A factor of 0.65 was used to convert EC in units of µS/cm to total dissolved solids (TDS) in units of mg/l. The annual salt load above the Merced River ranged from about 304,000 tons (10 percent cumulative distribution) to 663,000 tons (90 percent cumulative distribution) with an average of about 447,000 tons. This upstream salt load accounts for about 40 percent of the annual salt load for the SJR at Vernalis (average of about 1,100,000 tons). Much of the remainder of the salt load originates from tile drainage and shallow groundwater seepage to the SJR from below irrigated lands.

The baseline results for the SJR at Vernalis are summarized here using the monthly and annual cumulative distribution format tables for the period 1922–2003. Table F.1.5-1b shows the monthly and annual cumulative distributions for the baseline SJR EC at Vernalis. These baseline condition EC values were assumed to always satisfy the Vernalis EC objectives, although the historical record has occasionally shown otherwise since this EC objective was implemented in 1995 by the Bay-Delta Plan.

Table F.1.5-1a. CALSIM-Simulated Baseline Monthly Cumulative Distributions of SJR above the Merced EC (µS/cm) 1922–2003

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	Salt Load (1000 tons)
							SJR Above Merced EC (µS/cm)						
Minimum	494	331	333	290	296	317	194	201	204	239	1,085	1,135	253
10%	1,159	964	905	467	463	548	289	277	496	1,242	1,135	1,150	304
20%	1,172	1,022	1,104	791	716	791	608	790	1,048	1,309	1,143	1,156	326
30%	1,173	1,095	1,184	955	905	947	846	968	1,120	1,331	1,165	1,163	334
40%	1,174	1,185	1,245	1,117	1,010	1,040	929	1,051	1,174	1,363	1,196	1,167	340
50%	1,182	1,215	1,282	1,197	1,093	1,156	1,030	1,109	1,210	1,385	1,196	1,167	371
60%	1,200	1,227	1,303	1,255	1,173	1,232	1,171	1,125	1,252	1,411	1,196	1,168	414
70%	1,200	1,231	1,322	1,307	1,223	1,423	1,233	1,195	1,271	1,415	1,196	1,169	460
80%	1,201	1,241	1,325	1,365	1,282	1,556	1,283	1,285	1,300	1,430	1,196	1,172	532
90%	1,201	1,261	1,349	1,366	1,351	1,616	1,382	1,359	1,322	1,456	1,197	1,187	663
Maximum	1,304	1,318	1,375	1,433	1,529	2,157	1,801	1,447	1,717	1,559	1,227	1,204	1,460
Average	1,176	1,136	1,181	1,062	1,012	1,154	966	1,000	1,100	1,319	1,178	1,166	447

Note: these results are the same for all LSJR alternatives.

Table F.1.5-1b. Baseline Monthly Cumulative Distributions of SJR at Vernalis EC (µS/cm) 1922–2003

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
	SJR at Vernalis EC (µS/cm)											
Minimum	193	155	222	218	186	193	180	144	205	222	163	227
10%	440	507	606	386	296	264	245	192	334	451	420	448
20%	468	542	749	568	344	306	305	299	406	544	442	481
30%	484	584	784	672	466	337	347	341	432	573	497	495
40%	489	596	807	752	600	458	374	362	467	586	528	510
50%	496	612	813	769	684	631	413	375	528	597	547	521
60%	506	629	824	785	780	658	442	421	564	610	569	539
70%	515	645	831	798	870	791	517	461	588	629	590	552
80%	529	664	844	824	936	859	594	567	628	643	613	567
90%	547	686	867	838	1,000	1,000	676	644	682	660	655	590
Maximum	589	759	926	882	1,000	1,000	700	700	700	700	700	669
Average	492	598	770	697	655	592	435	407	508	577	535	518

Table F.1.5-1c shows the monthly and annual cumulative distributions for the baseline salt loads for the SJR at Vernalis. The monthly salt loads (proportional to the flow multiplied by the EC values) ranged from about 20,000 tons during summer months with low flow to more than 250,000 tons in some high-flow winter and spring months. These salt loads are relatively uniform throughout the year, increasing most dramatically with higher flows. The annual salt load at Vernalis ranged from 707,000 tons (10 percent cumulative distribution) to 1,693,000 tons (90 percent cumulative distribution) with a median salt load of 971,000 tons and an average of 1,118,000 tons.

The Vernalis EC results reveal an important assumption in the operations of New Melones Reservoir. In addition to the required environmental releases, New Melones releases additional water to reduce the Vernalis EC to below the objective. The baseline condition results indicate that the 1,000 µS/cm EC objective is controlling the Vernalis flow (and the New Melones release) in February and March for more than 10 percent of the years, and the 700 µS/cm EC objective is controlling flows in June and July for more than 10 percent of the years. The available EC data at Vernalis and at the southern Delta monitoring stations are described in Appendix F.2.

Table F.1.5-1c. Baseline Monthly Cumulative Distributions of SJR at Vernalis Salt Load (1,000 tons) 1922–2003

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	Annual
	SJR at Vernalis Salt Load (1,000 tons)												
Minimum	43	49	60	55	75	61	39	41	18	18	22	34	589
10%	55	56	72	68	87	87	59	53	36	32	37	46	707
20%	61	59	78	75	93	94	70	69	42	39	40	50	809
30%	64	61	81	82	98	104	82	74	47	42	42	52	859
40%	67	63	84	90	103	111	91	81	55	46	44	53	913
50%	70	64	86	92	109	118	100	89	63	52	45	55	971
60%	73	66	89	98	118	123	108	95	71	58	52	60	1,095
70%	75	68	93	122	124	130	121	108	80	69	60	64	1,196
80%	77	71	109	161	162	138	128	126	158	102	65	66	1,449
90%	80	74	147	220	258	234	145	143	209	169	68	69	1,693
Maximum	93	133	314	741	459	579	250	262	291	287	81	92	3,130
Average	69	66	103	125	139	141	104	98	90	76	50	57	1,118

Table F.1.5-1d shows the calculated monthly cumulative distributions of the EC increments between Vernalis and Brandt Bridge (and at Old River at Middle River) for the baseline flow conditions.

Table F.1.5-1d. Calculated Baseline Monthly Cumulative Distributions of the EC Increment (µS/cm) from Vernalis to Brandt Bridge and Vernalis to Old River at Middle River 1922–2003 (Overall Average of µS/cm)

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
	Brandt Bridge and Old River at Middle River EC Increment (µS/cm)											
Minimum	15	6	4	2	3	2	4	4	4	4	11	13
10%	30	37	23	9	7	7	8	8	9	14	34	34
20%	34	40	37	21	11	12	13	14	16	30	38	38
30%	35	45	44	30	16	13	16	19	29	49	47	41
40%	37	47	49	40	22	18	19	19	32	55	59	46
50%	38	50	52	45	29	29	22	22	44	62	65	49
60%	42	52	53	47	37	29	25	29	54	71	70	53
70%	43	55	56	52	44	42	30	33	65	80	73	56
80%	47	59	60	59	49	44	43	43	70	88	80	59
90%	50	64	66	68	54	62	62	65	99	104	95	67
Maximum	74	81	81	87	66	89	85	91	141	190	173	105
Average	40	50	48	41	30	31	28	29	50	65	65	50

Table F.1.5-1e shows the monthly cumulative distributions for the calculated SJR at Brandt Bridge and Old River at Middle River EC for baseline conditions. This EC is the calculated Vernalis EC plus the estimated EC increment from Vernalis to Brandt Bridge. The calculated EC at Brandt Bridge was greater than the baseline EC objectives in many months (110 of 984) because the estimated EC increase was sometimes large. The calculated EC at Brandt Bridge was greater than the EC objectives in 68 months (out of 410) during the February–June period.

Table F.1.5-1e. Calculated Baseline Monthly Cumulative Distributions of SJR at Brandt Bridge and Old River at Middle River EC (µS/cm) 1922–2003

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
SJR at Brandt Bridge and Old River at Middle River EC (µS/cm)												
Minimum	208	162	226	220	191	203	183	148	208	226	174	241
10%	471	543	630	395	304	272	252	198	342	466	453	482
20%	502	580	786	590	353	311	323	312	425	598	480	519
30%	521	629	829	698	479	348	365	362	457	623	555	541
40%	525	645	856	793	624	477	394	381	497	649	589	558
50%	534	658	866	814	709	659	436	393	584	657	612	572
60%	550	681	878	831	819	690	465	450	621	685	639	592
70%	558	700	887	851	912	835	551	499	642	710	660	606
80%	573	723	903	881	985	902	637	612	706	741	690	628
90%	597	750	935	901	1,054	1,062	730	698	757	762	761	652
Maximum	663	840	993	969	1,066	1,089	784	786	827	868	870	773
Average	532	647	818	739	686	622	463	437	558	642	600	568

Table F.1.5-1f shows the calculated monthly cumulative distributions of the assumed EC increments between Vernalis and Tracy Boulevard for baseline conditions, and Table F.1.5-1g shows the resulting monthly cumulative distributions for the calculated Old River at Tracy Boulevard EC for baseline conditions. The calculated EC at Tracy Boulevard was greater than the (baseline) EC objectives in many months (267 of 984) because the assumed EC increase was often large. The calculated EC at Tracy Boulevard was greater than the EC objectives in 114 months (out of 410) during the February–June period. Because the baseline EC objectives are the same at the southern Delta stations, these baseline EC increments will cause many EC values at the southern Delta stations to be greater than the EC objectives.

Table F.1.5-1f. Calculated Baseline Monthly Cumulative Distributions of the EC Increment (µS/cm) from Vernalis to Old River at Tracy Boulevard 1922–2003 (Overall Average of 132 µS/cm)

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
	Old River at Tracy Boulevard EC Increment (µS/cm)											
Minimum	44	18	12	5	9	6	11	12	11	13	33	39
10%	90	110	70	27	20	22	24	23	26	43	101	102
20%	101	119	112	63	32	35	38	42	48	91	113	115
30%	105	134	133	91	48	39	48	58	88	146	140	124
40%	110	141	147	121	67	54	57	58	97	164	176	139
50%	115	151	155	136	86	86	65	65	132	185	194	148
60%	126	156	159	141	111	88	76	87	163	212	209	158
70%	129	166	168	157	132	127	90	98	195	240	218	167
80%	141	177	181	177	148	132	128	130	211	265	240	178
90%	150	192	198	203	162	186	186	195	297	313	284	202
Maximum	223	243	242	262	197	267	256	274	423	571	519	314
Average	120	149	144	124	91	92	85	88	151	194	195	151

Table F.1.5-1g. Calculated Baseline Monthly Cumulative Distributions of Old River at Tracy Boulevard EC (µS/cm) 1922–2003

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
	Old River at Tracy Boulevard Bridge EC (µS/cm)											
Minimum	237	174	234	223	201	222	191	157	216	234	196	267
10%	533	615	678	414	321	295	267	210	358	495	521	550
20%	571	659	861	635	362	327	359	339	473	662	555	592
30%	590	719	915	752	506	371	400	403	512	732	653	626
40%	601	736	953	873	676	515	434	418	558	755	710	649
50%	609	757	972	907	760	715	483	435	675	785	749	673
60%	626	785	983	924	900	748	524	506	736	827	778	699
70%	645	812	999	955	997	922	611	563	767	859	803	713
80%	665	841	1,024	999	1,085	986	723	703	847	910	853	745
90%	697	878	1,072	1,036	1,161	1,186	865	826	984	980	948	786
Maximum	812	1,003	1,133	1,143	1,197	1,267	952	969	1,088	1,210	1,215	983
Average	612	746	914	821	746	684	519	495	658	772	730	669

20 Percent Unimpaired Flow (LSJR Alternative 2)

Table F.1.5-2a shows the WSE-calculated monthly cumulative distributions for the SJR at Vernalis EC for LSJR Alternative 2. These SJR at Vernalis EC values are calculated from the monthly flow changes on the three eastside tributaries and the CALSIM simulated EC values for the SJR at Vernalis. The EC values were higher than the baseline EC values whenever the Vernalis flow was increased and lower than the baseline EC values whenever the Vernalis flow was reduced. The EC changes were smallest when the baseline flow was high and the baseline EC was low. The median calculated SJR at Vernalis EC values were higher than the median baseline EC values in April but lower in May and June. On average, Vernalis EC was very slightly less with LSJR Alternative 2 (20 percent unimpaired flow) than with baseline conditions. Under LSJR Alternative 2, monthly EC values at Vernalis were sometimes lower and sometimes higher than baseline values, with the overall annual average EC values being almost the same (10 µS/cm less for LSJR Alternative 2 than baseline).

Table F.1.5-2a. SJR at Vernalis EC (µS/cm) for 20% Unimpaired Flow (LSJR Alternative 2)

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
SJR at Vernalis EC (µS/cm)												
Minimum	193	155	222	218	186	193	180	142	205	222	163	227
10%	437	501	623	380	281	263	242	187	276	451	412	428
20%	467	536	755	546	335	301	300	269	318	552	440	477
30%	480	579	794	695	489	330	357	307	345	581	498	496
40%	486	596	810	754	573	473	397	326	375	588	534	507
50%	492	612	818	777	651	631	431	342	419	601	547	519
60%	504	629	825	789	853	703	465	372	443	620	567	536
70%	514	645	832	806	912	836	497	407	464	631	580	548
80%	529	664	848	825	976	969	536	438	524	649	607	567
90%	544	686	867	848	1,000	1,000	596	502	583	663	654	585
Maximum	589	759	926	882	1,000	1,000	700	700	700	700	700	669
Average	490	595	778	700	667	608	426	355	422	581	531	512

Table F.1.5-2b shows the monthly cumulative distributions for the WSE-calculated EC for the SJR at Brandt Bridge and Old River at Middle River for LSJR Alternative 2. Table F.1.5-2c shows the monthly cumulative distributions for the WSE-calculated EC for Old River at Tracy Boulevard for LSJR Alternative 2. The EC increment at Tracy Boulevard was assumed to be three times the EC increment at Brandt Bridge. The calculated EC in the southern Delta would change primarily during the February–June period when the specified percent unimpaired flow requirement is being met. Because the monthly flows at Vernalis did not change by very much, the calculated EC values in the southern Delta did not change substantially for LSJR Alternative 2. However, whenever there was an increase in the monthly Vernalis flow, there was an reduction in the Vernalis EC and a further reduction in the southern Delta EC estimates (more dilution of agricultural drainage and wastewater discharges). There were 93 months (51 in the February–June period) with calculated EC greater than the baseline EC objectives at Brandt Bridge and 248 months (91 in the February–June period) at Tracy Boulevard (i.e., fewer exceedances than with baseline).

Table F.1.5-2b. Calculated Monthly Cumulative Distributions of SJR at Brandt Bridge and Old River at Middle River EC (µS/cm) for 20% Unimpaired Flow (LSJR Alternative 2) 1922–2003

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
					SJR at Brandt Bridge EC (µS/cm)							
Minimum	208	162	226	220	191	203	183	146	208	226	174	241
10%	468	538	636	390	288	271	250	191	302	466	445	459
20%	501	575	798	564	343	306	312	283	338	600	477	514
30%	514	624	840	725	508	343	378	324	373	633	555	541
40%	523	645	859	794	595	488	420	342	408	653	589	552
50%	528	658	868	824	682	659	462	361	452	674	616	569
60%	547	681	878	837	894	736	498	396	481	692	635	584
70%	558	700	887	857	957	876	525	433	504	713	655	603
80%	573	723	903	882	1,028	1,028	572	473	584	738	688	628
90%	595	750	935	901	1,056	1,062	641	548	661	761	757	650
Maximum	663	840	993	969	1,066	1,089	774	779	799	868	870	773
Average	530	645	826	742	698	639	453	380	462	646	596	562

Table F.1.5-2c. Calculated Monthly Cumulative Distributions of Old River at Tracy Boulevard Bridge EC (µS/cm) for 20% Unimpaired Flow (LSJR Alternative 2) 1922–2003

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
					Old River at Tracy Boulevard Bridge EC (µS/cm)							
Minimum	237	174	234	223	201	222	191	155	216	234	196	267
10%	529	611	690	410	303	288	264	200	347	495	511	520
20%	571	655	878	600	358	318	336	315	383	689	551	590
30%	586	715	925	788	542	370	421	363	422	733	658	626
40%	595	736	953	875	640	516	462	379	465	770	713	646
50%	604	757	972	916	733	715	509	395	512	793	742	666
60%	626	785	983	933	977	801	554	442	556	831	772	684
70%	644	812	999	960	1,047	956	586	500	591	859	802	713
80%	665	841	1,024	999	1,131	1,139	650	546	721	904	853	744
90%	697	878	1,072	1,036	1,169	1,185	757	630	819	980	948	786
Maximum	812	1,003	1,133	1,143	1,197	1,267	922	937	998	1,210	1,215	983
Average	610	744	923	825	760	702	506	430	543	776	725	661

40 Percent Unimpaired Flow (LSJR Alternative 3)

Table F.1.5-3a shows the monthly cumulative distribution for the WSE-calculated EC for the SJR at Vernalis for LSJR Alternative 3. The median calculated SJR at Vernalis EC values were 90 to 229 µS/cm less from March–June compared to the median baseline EC values. Table F.1.5-3b shows the monthly cumulative distributions for the calculated SJR at Brandt Bridge and Old River at Middle River EC for LSJR Alternative 3. Table F.1.5-3c shows the monthly cumulative distributions for the calculated Old River at Tracy Boulevard EC for LSJR Alternative 3. Because the monthly flows at Vernalis generally increased for LSJR Alternative 3, the southern Delta EC values were usually reduced from baseline, especially in March–June, and there were fewer months with EC greater than the EC objectives. There were 74 months (28 in the February–June period) with calculated EC greater than the baseline EC objectives at Brandt Bridge and 202 months (43 in the February–June period) at Tracy Boulevard (i.e., fewer exceedances than with baseline).

Table F.1.5-3a. SJR at Vernalis EC (µS/cm) for 40% Unimpaired Flow (LSJR Alternative 3)

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
SJR at Vernalis EC (µS/cm)												
Minimum	205	155	222	218	186	193	175	136	141	246	163	227
10%	355	409	750	414	282	288	216	168	184	428	416	361
20%	368	424	792	674	379	313	252	186	210	506	436	382
30%	404	510	807	757	448	374	285	202	242	571	511	436
40%	444	590	813	776	498	438	312	217	273	585	525	502
50%	467	612	824	785	714	541	339	234	299	589	555	524
60%	473	631	830	799	797	610	356	247	340	608	574	540
70%	479	646	841	817	863	672	389	271	372	627	592	551
80%	488	664	859	833	945	763	415	291	418	642	617	567
90%	515	688	895	855	988	925	462	316	489	663	654	585
Maximum	540	759	1,000	936	1,000	1,000	700	557	673	700	700	669
Average	443	567	807	734	649	554	341	244	323	570	538	493

Table F.1.5-3b. Calculated Monthly Cumulative Distributions of SJR at Brandt Bridge and Old River at Middle River EC (µS/cm) for 40% Unimpaired Flow (LSJR Alternative 3) 1922–2003

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
SJR at Brandt Bridge EC (µS/cm)												
Minimum	221	162	226	220	191	203	179	140	167	252	174	241
10%	381	439	791	425	290	294	223	181	196	451	452	389
20%	394	455	837	700	395	325	274	197	228	537	473	411
30%	433	547	856	794	462	394	301	215	264	614	561	471
40%	477	636	865	819	518	456	329	230	293	641	585	551
50%	506	658	875	831	750	565	358	248	322	657	625	574
60%	514	683	885	849	834	645	376	262	371	685	642	590
70%	518	702	900	872	907	705	412	285	424	710	668	605
80%	528	724	922	890	994	799	447	313	447	734	688	626
90%	573	752	963	921	1,041	978	486	346	538	762	750	653
Maximum	594	840	1,037	985	1,066	1,089	774	615	765	868	870	773
Average	479	614	856	776	679	582	362	261	352	634	603	541

Table F.1.5-3c. Calculated Monthly Cumulative Distributions of Old River at Tracy Boulevard Bridge EC (µS/cm) for 40% Unimpaired Flow (LSJR Alternative 3) 1922–2003

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
	Old River at Tracy Boulevard Bridge EC (µS/cm)											
Minimum	253	174	234	223	201	222	186	149	196	262	196	267
10%	432	499	874	447	307	305	243	191	225	479	519	448
20%	447	518	926	746	426	351	306	221	258	589	557	467
30%	492	621	952	873	487	430	340	241	286	711	655	537
40%	542	729	967	909	559	492	358	259	336	747	713	644
50%	577	757	980	924	822	621	396	274	360	790	754	673
60%	592	788	993	946	904	708	419	295	409	826	784	694
70%	599	813	1,007	971	997	778	457	323	484	865	802	715
80%	612	842	1,043	1,004	1,087	875	496	357	538	910	853	744
90%	676	881	1,088	1,059	1,149	1,085	547	421	653	980	938	790
Maximum	709	1,003	1,133	1,143	1,197	1,267	922	731	951	1,210	1,215	983
Average	552	709	954	862	739	638	403	294	411	761	733	638

60 Percent Unimpaired Flow (LSJR Alternative 4)

Table F.1.5-4a shows the monthly cumulative distributions for the WSE-calculated EC for the SJR at Vernalis for LSJR Alternative 4. The median calculated SJR at Vernalis EC values were considerably less than the median baseline EC values. The median calculated SJR at Vernalis EC values were 109 to 305 µS/cm less from February–June compared to the median baseline EC values.

Table F.1.5-4b shows the monthly cumulative distributions for the calculated SJR at Brandt Bridge and Old River at Middle River EC for LSJR Alternative 4. Table F.1.5-4c shows the monthly cumulative distributions for the calculated Old River at Tracy Boulevard EC for LSJR Alternative 4. Because the monthly flows at Vernalis were substantially increased in the February–June period for LSJR Alternative 4, the southern Delta EC values were reduced from baseline, and there were fewer months with EC greater than the EC objectives. There were 68 months (12 in the February–June period) with calculated EC greater than the baseline EC objectives at Brandt Bridge and 196 months (26 in the February–June period) at Tracy Boulevard.

Table F.1.5-4a. SJR at Vernalis EC (µS/cm) for 60% Unimpaired Flow (LSJR Alternative 4)

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
SJR at Vernalis EC (µS/cm)												
Minimum	205	155	222	235	186	162	137	113	96	286	208	227
10%	347	401	760	481	265	266	174	130	128	482	419	361
20%	365	413	798	713	334	295	201	138	146	567	497	382
30%	403	510	808	766	377	330	222	149	177	588	509	436
40%	444	590	816	780	414	381	237	155	205	605	533	507
50%	468	612	825	791	575	431	258	165	223	614	564	526
60%	473	631	832	808	638	472	288	176	255	629	576	542
70%	479	646	841	829	792	551	300	192	283	638	593	552
80%	488	664	859	847	836	610	331	203	303	659	620	565
90%	520	688	895	873	950	757	370	232	346	700	654	589
Maximum	540	759	1,000	1,000	1,000	1,000	550	438	647	700	700	669
Average	442	566	811	748	581	471	272	178	243	597	548	495

Table F.1.5-4b. Calculated Monthly Cumulative Distributions of SJR at Brandt Bridge and Old River at Middle River EC (µS/cm) for 60% Unimpaired Flow (LSJR Alternative 4) 1922–2003

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
SJR at Brandt Bridge EC (µS/cm)												
Minimum	221	162	226	237	191	170	151	121	113	292	222	241
10%	371	429	799	494	276	277	183	136	137	513	453	389
20%	391	445	842	745	348	305	214	145	159	619	539	411
30%	432	547	857	810	392	339	232	156	197	645	560	472
40%	477	636	867	826	428	397	254	164	219	664	592	556
50%	506	658	875	839	602	453	277	175	236	689	632	578
60%	514	683	885	861	672	496	304	186	274	707	648	596
70%	518	702	900	882	830	586	319	204	299	722	671	608
80%	528	724	922	901	882	641	347	219	322	734	689	621
90%	572	752	963	932	1,000	800	391	256	416	762	750	653
Maximum	594	840	1,037	1,031	1,066	1,089	609	483	736	868	870	773
Average	478	613	860	791	607	494	288	190	266	662	613	544

Table F.1.5-4c. Calculated Monthly Cumulative Distributions of Old River at Tracy Boulevard Bridge EC (µS/cm) for 60% Unimpaired Flow (LSJR Alternative 4) 1922–2003

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
	Old River at Tracy Boulevard Bridge EC (µS/cm)											
Minimum	253	174	234	240	201	185	176	134	134	304	250	267
10%	422	490	877	519	285	303	205	145	157	560	526	445
20%	441	508	936	808	369	327	236	160	181	711	626	471
30%	490	621	952	896	414	361	255	171	227	746	659	540
40%	542	729	967	920	459	431	288	184	246	771	710	652
50%	577	757	980	933	655	502	304	195	267	794	769	677
60%	592	788	996	955	741	552	332	208	303	834	791	701
70%	599	813	1,012	989	900	642	359	228	341	874	813	716
80%	612	842	1,043	1,011	979	697	385	250	386	910	852	736
90%	676	881	1,088	1,076	1,105	887	435	300	501	980	938	790
Maximum	709	1,003	1,133	1,143	1,197	1,267	725	574	914	1,210	1,215	983
Average	550	707	959	878	661	541	319	214	311	792	745	641

F.1.6 Temperature Modeling

This section includes an in-depth description of the temperature model used by the State Water Board to model river temperatures and the effects due to the LSJR alternatives. The State Water Board used the June 2013 release (CDFW 2013) of the temperature model to conduct a comparative analysis of resulting river temperatures as the June 2013 release is the most recent and well documented model of river temperatures within the San Joaquin system. The following sections only present the temperature model methods and resulting river temperatures. This section does not go in to detail regarding the specific changes in temperature and how they would affect other resources. The effects on other resources are discussed within other chapters of the SED.

The LSJR alternatives could affect water temperature by altering river flows and reservoir storage, both of which influence the monthly release temperature. To model effects on temperature in the LSJR and three eastside tributaries, the State Water Board modified the San Joaquin River Basin-Wide Water Temperature and EC Model (named here as SJR HEC-5Q model, or temperature model) developed by a group of consultants between 2003 and 2008 through a series of CALFED contracts that included peer review and refinement (CALFED 2009). The model was most recently updated by CDFW and released in June of 2013 (CDFW 2013). The temperature model uses the Hydrologic Water Quality Modeling System (HWMS-HEC5Q), a graphical user interface that employs the USACE Hydrologic Engineering Center (HEC) flow and water quality simulation model, HEC-5Q.

The temperature model was designed to provide a SJR basin-wide evaluation of temperature response at 6-hour intervals for alternative conditions, such as operational changes, physical changes, and combinations of the two. The extent of the model includes the Merced, Tuolumne, and Stanislaus River systems from their LSJR confluences to the upstream end of the major reservoirs (i.e., McClure, New Don Pedro, and New Melones, respectively). On the SJR, the upstream extent of the model is the Merced River confluence. The downstream extent of the model is the SJR at Mossdale. The model simulates the reservoir stratification, release temperatures, and downstream river temperatures as a function of the inflow temperatures, reservoir geometry and outlets, flow, meteorology, and river geometry. Calibration data was used to accurately simulate temperatures for a range of reservoir operations, river flows, and meteorology.

F.1.6.1 Temperature Model Methods

This section includes a discussion of the temperature model used to calculate river temperatures in the plan area. One of the important features in the June 2013 release of the temperature model is the interface with CALSIM II or monthly data formatted similarly to CALSIM II output (i.e., CALSIM to HEC-5Q). A pre-processing routine converts the monthly output to a format compatible with the SJR HEC-5Q model. This routine serves two purposes: 1) to allow the temperature model to perform a long-term simulation compatible with the period used in CALSIM II and 2) to disaggregate monthly output to daily values used in the temperature model.

Using the monthly output from the WSE model, the June 2013 CALSIM to HEC-5Q temperature model pre-processor was used, and the temperature model was run to determine the river temperature effects of the LSJR alternatives within the Merced, Tuolumne, and Stanislaus Rivers, and the LSJR. The WSE model was developed such that it would output flows at each location corresponding to the CALSIM II nodes. This allowed for a nearly seamless replacement of CALSIM flow values used in the HEC5Q modeling process by the WSE alternative results. The other CALSIM values needed by the temperature model are for portions of the model not affecting the temperature results along the three eastside rivers and the LSJR. Thus, data pertaining to the Upper SJR for example, was unchanged with respect to each LSJR alternative and was unchanged from the HEC-5Q download package. Given the large quantity of data produced by the temperature model, the temperature model was only run from 1970–2003. This retains a period with sufficient length and climatic variation to determine the effects of the LSJR alternatives on river temperatures.

Figure F.1.6-1 is a schematic representation of the SJR HEC-5Q model for the SJR and three eastside tributaries, including Lake McClure, New Don Pedro Reservoir, and New Melones Reservoir. The model computes the vertical distribution of temperature in the reservoirs and the longitudinal temperature distributions in the river reaches based on daily average flows and meteorology. Reservoirs represented in the model include Lake McClure, Lake McSwain, Merced Falls Reservoir, and Crocker Huffman Reservoir on the Merced River; New Don Pedro and La Grange Reservoirs on the Tuolumne River; and New Melones, Tulloch, and Goodwin Reservoirs on the Stanislaus River.

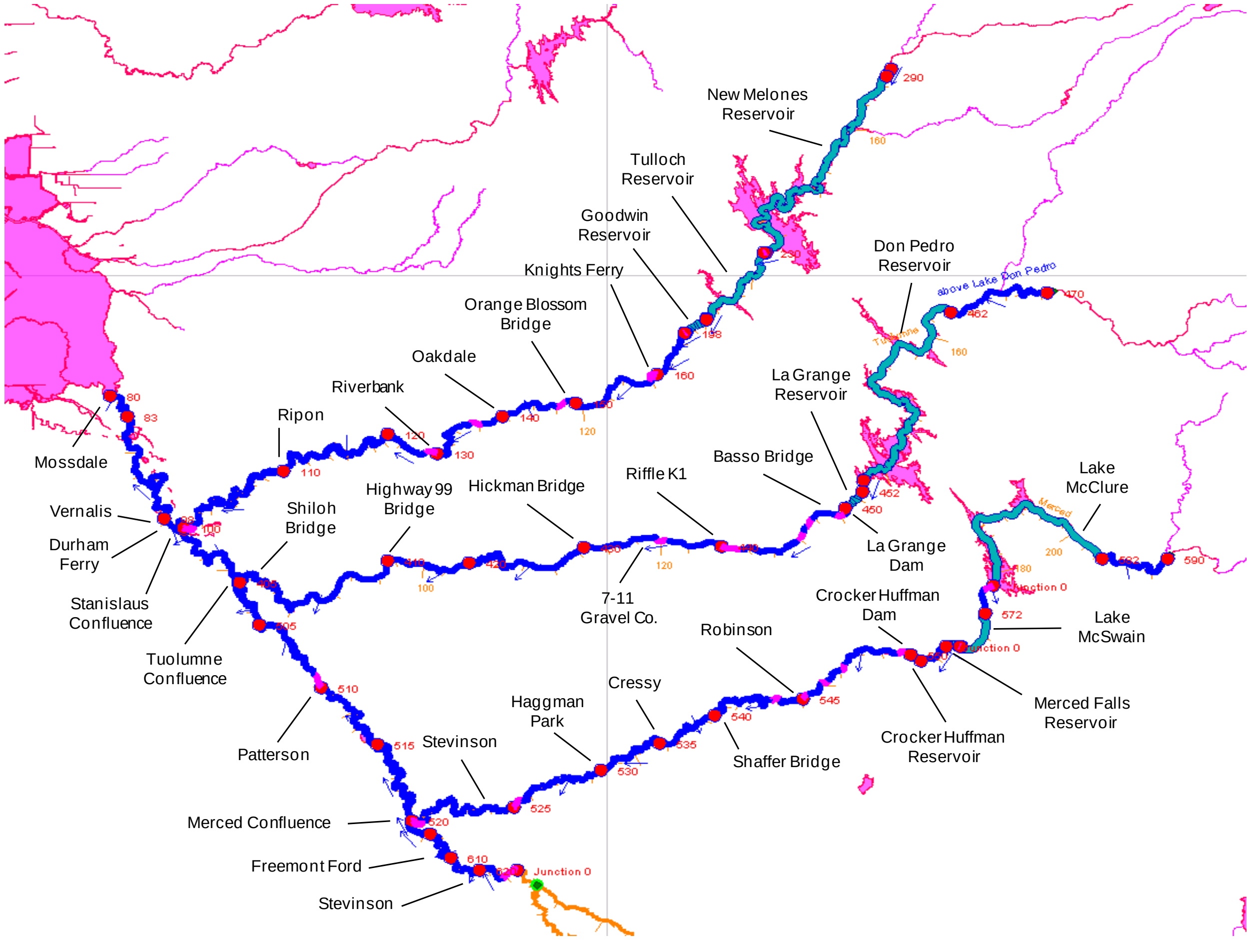


Figure F.1.6-1. The SJR Basin, Including the Stanislaus, Tuolumne, and Merced River Systems, as Represented in the HEC-5Q Model

Water Temperature Model Geometry

The river geometry is specified from measured cross-section data for each 1-mile segment. The river reaches are represented as a series of volume elements. The width, cross-sectional area, and depth vary with the flow using specified relationships developed from appropriate hydraulic computations using the measured river cross-sections. The reservoirs are simulated as a series of vertically stratified layers. The reservoir inflow distribution (vertical spread) and outlet distribution are calculated from the water temperatures (density) and specified coefficients. Vertical advection of water and heat is simulated as a mass balance once the inflow and outflow from each layer is calculated. The balance between solar heating and wind or convective (i.e., cooling at surface) mixing control the surface layer mixed depth.

The river hydraulic model uses the standard one-dimensional river backwater calculations that solve the Manning Equation from the downstream end upriver. These calculations require river cross-sections to describe the local river channel geometry. The HEC-5Q river geometry is simplified as the width at specified elevations for a range of elevations that should allow the maximum flow to be simulated. The hydraulic model can be used to determine the water elevations, with corresponding width and cross sectional area, for a range of flows. Because these sections are specified for various locations along the river, the full river geometry can be described for a range of flows. The sections can be summarized in geometry tables for the river; the river surface area (section width times river distance) and the river volume (cross-sectional area times river distance) can be determined for each section of the river or for the entire length.

Table F.1.6-1a gives the river geometry (surface area, volume, and depth) for the Stanislaus River for a range of flows from 250–10,000 cfs. The average velocity and the travel time from upstream to downstream can be calculated (from the volume, length, and flow). The travel time has been included in the table. For example, the Stanislaus River length is about 58 miles and has a surface area of 736 acres, which is equivalent to an average width of 105 feet at a flow of 250 cfs. The volume is 2,252 AF, so the average depth is 3.1 feet. The travel time for water at the low flow of 250 cfs would be about 4.5 days (109 hours). At this flow, warming would be rapid in the upstream portion of the river (during the first 1–2 days), because the difference between the equilibrium temperature and the release temperature would be greatest.

Table F.1.6-1a. Stanislaus River Geometry Calculated in the HEC-5Q Temperature Model (58-mile Length

Flow (cfs)	Surface Area (acres)	Volume (AF)	Average Depth (feet)	Travel Time (hours)
250	736	2,252	3.1	109
500	799	2,938	3.7	71
1,000	913	4,199	4.6	51
1,500	1,040	5,702	5.5	46
2,000	1,166	7,225	6.2	44
2,500	1,284	8,703	6.8	42
3,000	1,387	10,096	7.3	41
4,000	1,567	12,793	8.2	39
5,000	1,731	15,391	8.9	37
10,000	2,394	27,020	11.3	33

Table F.1.6-1b gives the river geometry (surface area, volume, and depth) for the Tuolumne River for a range of flows from 250–10,000 cfs. The travel time has been included in the table. For example, the Tuolumne River length is about 53 miles and has a surface area of 745 acres, which is equivalent to an average width of 116 feet at a flow of 250 cfs. The volume is 2,623 AF, so the average depth is 3.5 feet. The travel time for water at the low flow of 250 cfs would be about 5.3 days (127 hours). Warming would be rapid in the upstream portion of the river (during the first 1–2 days), because the difference between the equilibrium temperature and the release temperature would be greatest. At a flow of 1,000 cfs, the Tuolumne River area is 933 acres (145 feet width) and the volume is 4,519 AF, so the average depth is 4.8 feet and the travel time is 55 hours (2.3 days).

Table F.1.6-1b. Tuolumne River Geometry Calculated in the HEC-5Q Temperature Model (53-mile Length

Flow (cfs)	Surface Area (acres)	Volume (AF)	Average Depth (feet)	Travel Time (hours)
250	745	2,623	3.5	127
500	829	3,347	4.0	81
1,000	933	4,519	4.8	55
1,500	1,025	5,573	5.4	45
2,000	1,120	6,575	5.9	40
2,500	1,217	7,536	6.2	36
3,000	1,351	8,457	6.3	34
4,000	1,679	10,327	6.2	31
5,000	2,491	12,869	5.2	31
10,000	4,082	24,304	6.0	29

Table F.1.6-1c gives the river geometry (surface area, volume, and depth) for the Merced River for a range of flows from 250–10,000 cfs. The travel time has been included in the table. For example, the Merced River length is about 52 miles and has a surface area of 684 acres, which is equivalent to an average width of 109 feet at a flow of 250 cfs. The volume is 2,158 AF, so the average depth is 3.2 feet. At low flow there may be considerable volume of water in the pools upstream of riffles and runs. At a flow of 1,000 cfs, the Merced River area is 913 acres (145 feet width) and the volume is 4,696 AF, so the average depth is 4.6 feet and the travel time is 51 hours (about 2 days). The Merced River continues to spread out at higher flows, indicating limited levees or channel incision compared to the Stanislaus River.

Table F.1.6-1c. Merced River Geometry Calculated in the HEC-5Q Temperature Model (52-mile Length

Flow (cfs)	Surface Area (acres)	Volume (AF)	Average Depth (feet)	Travel Time (hours)
250	684	2,158	3.2	104
500	815	3,099	3.8	75
1,000	1,114	4,696	4.2	57
1,500	1,341	6,156	4.6	50
2,000	1,570	7,598	4.8	46
2,500	1,818	9,036	5.0	44
3,000	2,102	10,473	5.0	42
4,000	2,698	13,266	4.9	40
5,000	3,320	15,983	4.8	39
10,000	3,610	17,283	4.8	21

New Melones Reservoir on the Stanislaus River has a crest elevation of 1,135 feet and a spillway crest of 1,088 feet. There are two elevations from which to withdraw water, in addition to the spillway. The power intakes are located at an elevation of 775 feet MSL (top of the penstock) corresponding to a reservoir storage of about 200 TAF. The low-level outlet (two pipes) operates at lake elevations less than 785 feet. The old dam may affect the reservoir release temperatures at low elevations. The old dam has a crest elevation of 735 feet and a spillway elevation of 723 feet. The original outlet works are located at approximately 610 feet. When water surface elevations are above 785 feet, the power intake is used to generate hydropower. Below that elevation, the lower-elevation outlet must be used. For water levels from 785–728 feet (5 feet above the old dam spillway invert), all water is assumed to pass over the crest and/or the spillway of the old dam. Below 728 feet, all flows must pass through the old dam's low elevation outlet. The outlet elevation affects the release temperature. New Melones spillway has never been used; it would be needed if releases greater than 7,700 cfs were required. Tulloch Reservoir downstream has a low-level power outlet with a capacity of 2,060 cfs; higher outflows pass through the gated spillway.

New Don Pedro Reservoir on the Tuolumne River has a maximum storage elevation of approximately 830 feet MSL. The power intakes are located at an elevation of 535 feet (storage of about 75 TAF). The original Don Pedro Dam was inundated when the newer dam was completed. The old dam had a crest elevation of 607 feet and the spillway was located at 590 feet. Because the power outlet for the new dam is below the elevation of the old dam, all power releases must pass over the old dam, which is represented in the model as a submerged weir.

Lake McClure on the Merced River has a single outlet located in the old dam that has been incorporated into the new dam (New Exchequer). The power intakes are located at an elevation of 500 feet MSL (storage of about 25 TAF). Lake McSwain, just downstream of Lake McClure, has approximately 10 TAF of storage. The outlet is located near the bottom at approximately 370 feet MSL, 25 feet below the surface. The Lake McClure outlet temperature may be warmed in the three downstream regulating reservoirs before being released to the river at the Crocker-Huffman diversion dam (and Merced River Fish Hatchery).

Water Temperature Calibration Results

Equilibrium temperature and surface heat exchange coefficients were used to evaluate the net rate of heat transfer. Equilibrium temperature is defined as the water temperature at which the net rate of heat exchange between the water surface and the overlying atmosphere is zero. The coefficient of surface heat exchange is the rate at which heat is transferred to the water. All heat transfer mechanisms, except short-wave solar radiation, were applied at the water surface. Short-wave radiation penetrates the water surface and may affect water temperatures below the air-water interface. The heat exchange with the river bottom is a function of conductance and the heat capacity of the bottom sediment and has only a slight effect on diurnal temperature variation (i.e., behaves as slightly deeper water).

The model was calibrated using observed data within the period 1999–2007. The model used hourly meteorological data from three meteorological stations at Modesto, Merced, and Kesterson. Calibration was based on temperature profiles in the main reservoirs and time series of temperatures recorded in streams at several locations. Calibration of the reservoir temperatures was accomplished by comparing computed and observed vertical reservoirs temperature profiles both graphically and statistically. Some adjustments of the meteorological coefficients (e.g., wind speed function and solar radiation reflection) were necessary to match the seasonal surface temperatures in the reservoirs. Calibration of the river temperatures was accomplished by comparing computed and observed stream temperatures both graphically and statistically. Some adjustments of the meteorological coefficients (e.g., shading and river hydraulic parameters for width and depth) provided a close match with daily temperatures along the three eastside tributaries and the LSJR. The model bias, defined as the difference between the average computed and observed temperatures, was 0.3°F, 0.7°F, 0.3°F, and 0.3°F for the Stanislaus, Tuolumne, and Merced Rivers and LSJR, respectively. The seasonal temperature ranges were very accurately simulated at each of the river stations.

In October 2006, the initial temperature model and calibration results were favorably approved through a CALFED-sponsored peer review process. The model was refined and enhanced to provide a planning and analysis tool for the SJR stakeholders. The completed model was presented to the SJR stakeholders and became available for public use (CALFED 2009). Figure F.1.6-2a shows the comparison of measured and simulated temperatures for the Stanislaus River at Goodwin Dam (River Mile [RM] 58) for calendar years 1999–2007. This generally demonstrates the accuracy of the reservoir stratification and withdrawal simulations. The release temperatures varied from about 50°F in the winter months to about 55°F–57°F in the fall months.

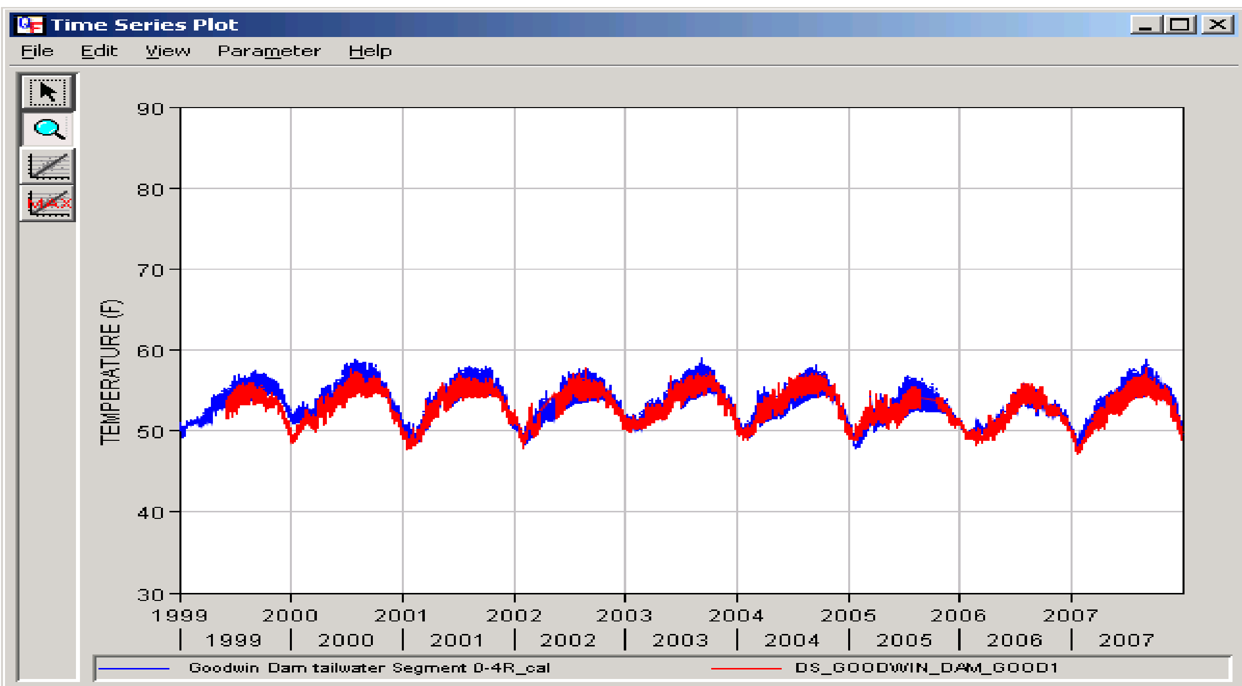


Figure F.1.6-2a. Comparison of Computed (Blue) and Observed (Red) Water Temperatures on the Stanislaus River Below Goodwin Dam (RM 58) for 1999–2007

Figure F.1.6-2b shows the comparison of measured and simulated temperatures at the mouth of the Stanislaus River downstream of Ripon. This demonstrates the general accuracy of the combination of river hydraulic calculations (i.e., depth and surface area) and the meteorological heating and solar radiation shading estimates. The river temperatures varied from about 45°F–50°F in the winter months to about 75°F–80°F in the summer months. There was considerable variation in the peak summer temperatures between years, with the lowest temperatures of about 75°F in the higher flow years of 1999 and 2006. Several of the years showed a distinct decrease in temperatures associated with the VAMP pulse flow release in mid-April to mid-May. The river temperatures were simulated to increase more rapidly during low flow conditions and to increase less during higher flows, such as during the VAMP period, with releases of about 1,500 cfs in several years. The effects of river flows on downstream warming will be described in more detail below in the evaluation of baseline temperatures. The Stanislaus River temperatures were very accurately simulated for 1999–2007.

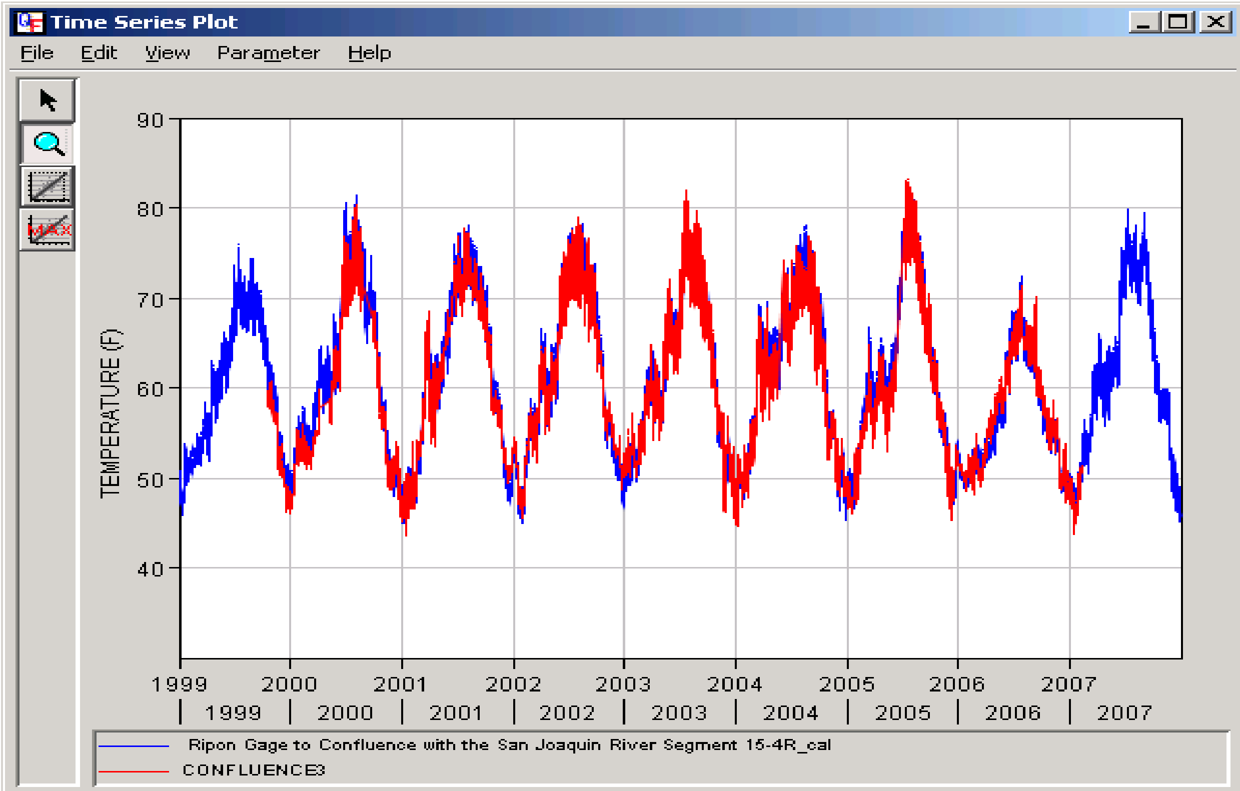


Figure F.1.6-2b.Comparison of Computed (Blue) and Observed (Red) Water Temperatures on the Stanislaus River above the SJR Confluence (RM 0) for 1999–2007

Figure F.1.6-3a shows the comparison of measured and simulated temperatures for the Tuolumne River at La Grange Dam (RM 52) for 1999–2007. The releases temperatures varied from about 50°F in the winter months to about 53°F–55°F in the fall months. The Tuolumne River temperatures were even less variable than release temperatures on the Stanislaus because the New Don Pedro Reservoir carryover storage generally remains high and because the La Grange regulating reservoir is small compared to the Tulloch and Goodwin regulating reservoirs on the Tuolumne River. Figure F.1.6-3b shows the comparison of measured and simulated temperatures at the mouth of the Tuolumne River at Shiloh Bridge (RM 3.4). The Tuolumne River temperatures varied from about 45°F–50°F in the winter months to about 80°F–85°F in the summer months. The Tuolumne River summer temperatures were slightly higher than the Stanislaus River summer temperatures, perhaps because of lower flows (longer travel time) or less shading along the Tuolumne River. The two river mouths are less than 5 miles apart and experience the same meteorology. The coolest summer temperatures were measured and simulated for 2005 and 2006. The Tuolumne River temperatures were very accurately simulated for 1999–2007.

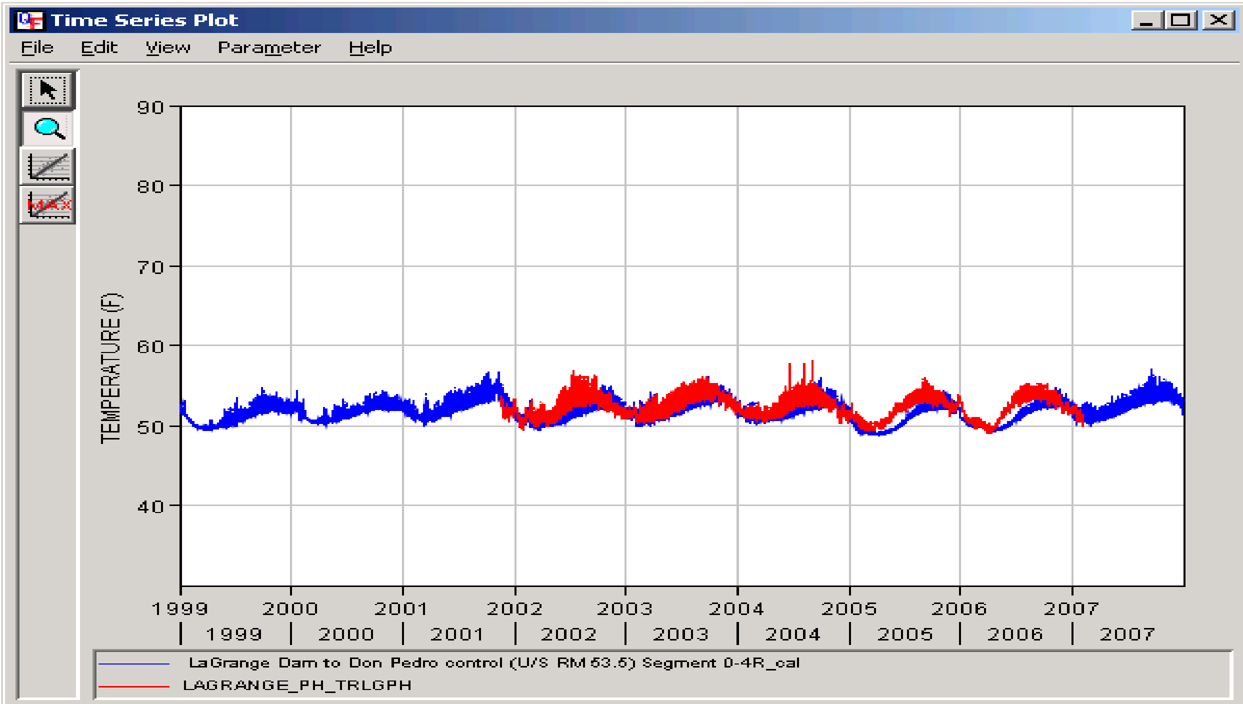


Figure F.1.6-3a. Comparison of Computed (Blue) and Observed (Red) Water Temperatures on the Tuolumne River below La Grange Dam (RM 52)

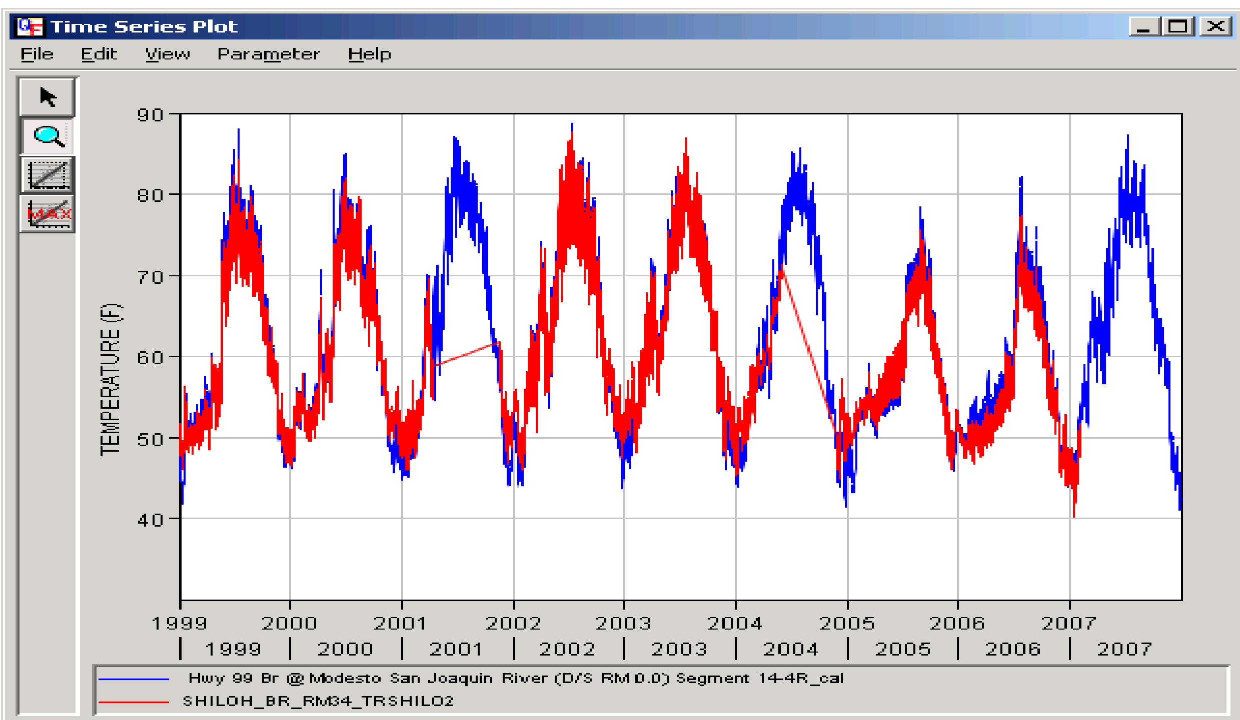


Figure F.1.6-3b. Comparison of Computed (Blue) and Observed (Red) Water Temperatures on the Tuolumne River at Shiloh Bridge (RM 3.4)

Figure F.1.6-4a shows the comparison of measured and simulated temperatures for the Merced River below McSwain Dam (RM 56) for 1999–2007. McSwain Dam is located about 6.5 miles below New Exchequer Dam. The release temperatures varied from about 50°F in the winter months to about 57°F–60°F in the fall months. The Merced River release temperatures were more variable than on the Stanislaus or Tuolumne Rivers because Lake McClure carryover storage can be very low in dry years and because McSwain Reservoir is relatively shallow, with a volume of about 8 TAF. The travel time for a flow of 2,000 cfs (to the canals and river) would be about 2 days. The release temperature remained cooler in 2005 and 2006 when the runoff was higher and the reservoir storage remained higher in the fall. There may be additional warming in the reservoirs of Merced Falls (RM 55) and Crocker-Huffman (RM 52) diversion dams. Figure F.1.6-4b shows the comparison of measured and simulated temperatures at the mouth of the Merced River for 1999–2007. The Merced River temperatures varied from about 45°F–50°F in the winter months to about 80°F–85°F in the summer months. The Merced River temperatures were very similar to the Tuolumne River temperatures. The coolest temperatures were measured and simulated in 2005 and 2006. The Merced River temperatures were very accurately simulated for 1999–2007.

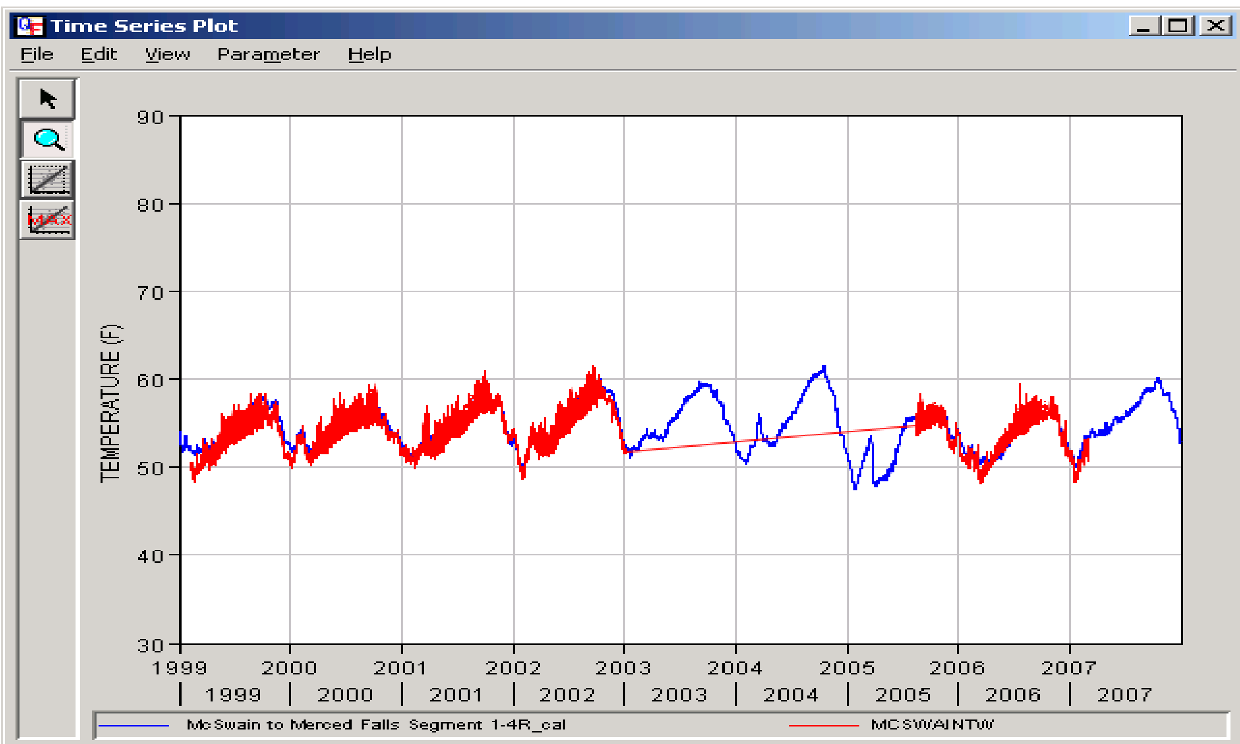


Figure F.1.6-4a. Comparison of Computed (Blue) and Observed (Red) Temperatures in the Merced River below McSwain Dam (RM 56)

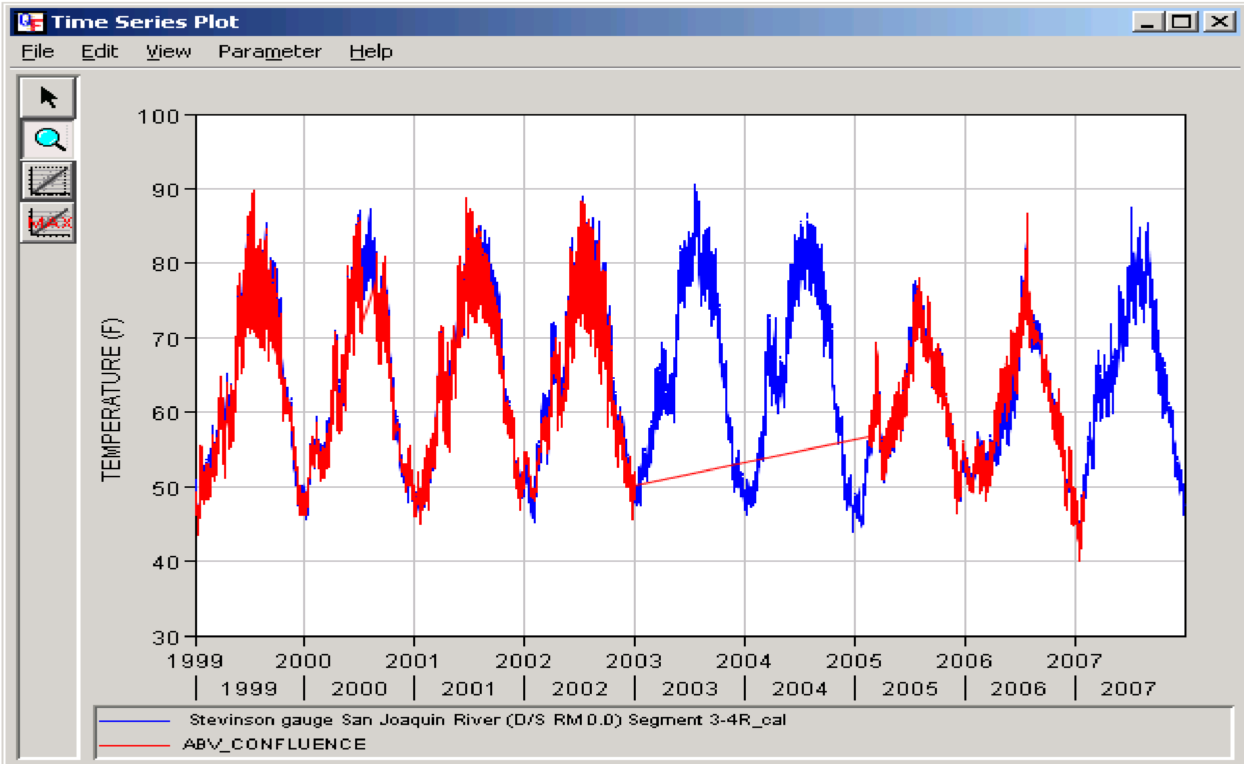


Figure F.1.6-4b. Comparison of Computed (Blue) and Observed (Red) Temperatures in the Merced River above the SJR Confluence (RM 0)

F.1.6.2 Temperature Model Results

Baseline Conditions Temperature Results

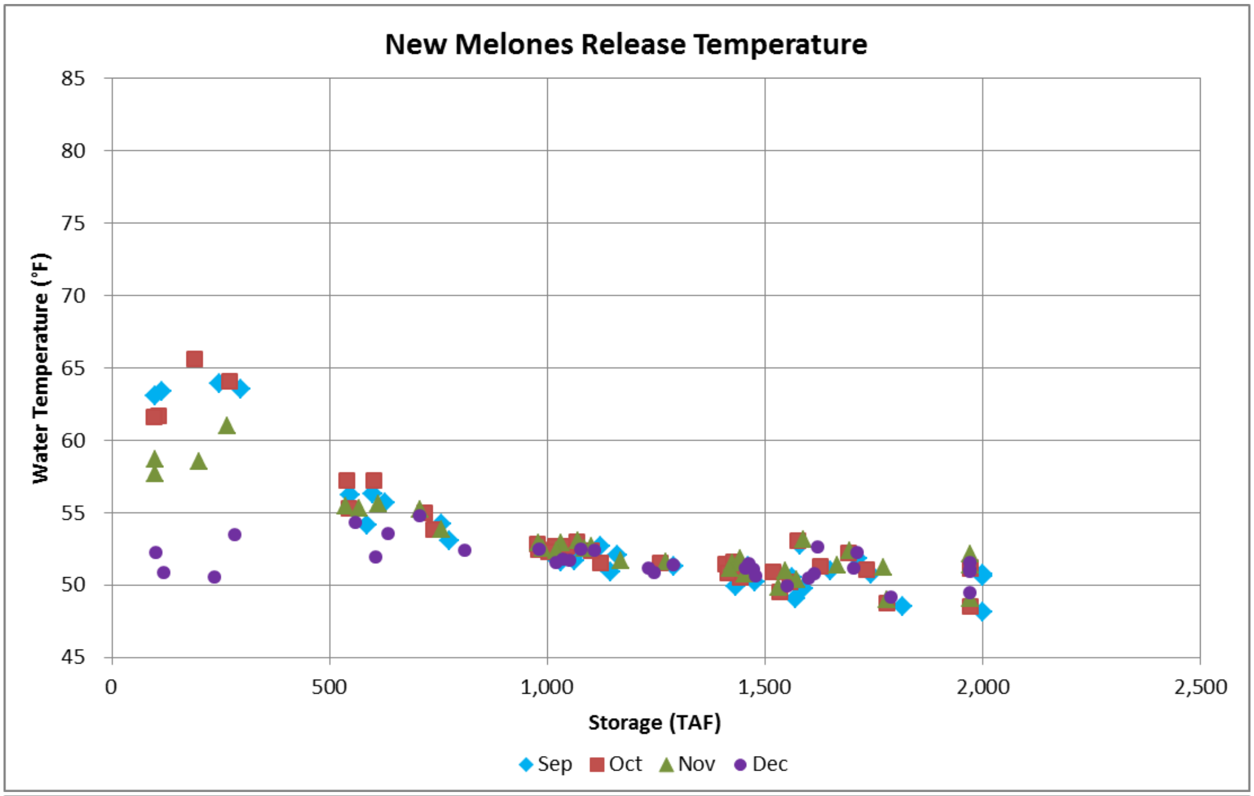
Stanislaus River Temperatures

Figure F.1.6-5a shows the simulated monthly average Stanislaus River temperatures below New Melones Reservoir and below Goodwin Dam in September–December for 1970–2003. The reservoir release temperatures for September and October generally had about the same response to changes in reservoir storage; temperatures at New Melones Reservoir were less than 55°F when New Melones storage was more than 750 TAF and were usually more than 60°F when New Melones storage was less than about 400 TAF. The September and October Goodwin temperatures were less than 55°F when New Melones storage was more than 1,000 TAF and increased to above 65°F when New Melones storage was 250 TAF or less. The November temperatures were similar to the September and October temperatures, except at lower storage when temperatures were more likely to be affected by meteorological conditions. The December temperatures at New Melones and Goodwin were 50°F–55°F regardless of storage, because the reservoir was fully mixed, and the release temperatures were controlled by the meteorology and not the reservoir storage. Based on these results, the New Melones carryover storage target of at least 700 TAF would provide a Goodwin Dam release temperature of less than 60°F from September–December.

Figure F.1.6-5b shows the simulated monthly average Stanislaus River temperatures below New Melones Reservoir, below Goodwin Dam, at RM 28.2 (approximately half way between Goodwin Dam and the confluence) and at the confluence in January–March for 1970–2003 as a function of the river flow (at the confluence). In January, temperatures were controlled by the meteorology; water temperatures were 45°F–55°F in all years, and there was no downstream warming. In February, temperatures were controlled by meteorology, and all temperatures were 45°F–55°F; there was slightly more warming when flows were less than 500 cfs. In March, temperatures were still largely controlled by meteorology; all downstream temperatures (i.e., at RM 28.2 and the confluence) were between about 47°F and 60°F. In general, the downstream warming (between Goodwin and the confluence) was less than 5°F when flows were greater than 1,500 cfs and were about 7°F when flows were less than 500 cfs.

Figure F.1.6-5c shows the simulated monthly average Stanislaus River temperatures below New Melones Reservoir, below Goodwin Dam, at RM 28.2 and at the confluence in April–June for 1970–2003 as a function of the river flow (at the confluence). In April, temperatures were controlled by the meteorology and the flow. Goodwin temperatures were about 50°F–55°F. At flows greater than 1,000 cfs, confluence temperatures were 53°F–59°F (warming of 3°F–9°F), and when flows were less than 750 cfs, confluence temperatures were 60°F–65°F (warming of 10°F). In May, temperatures at RM 28.2 and the confluence were controlled by meteorology and flow. At flows of more than 1,500 cfs, RM 28.2 temperatures were about 55°F and confluence temperatures were about 60°F. At a flow of 500 cfs, RM 28.2 temperatures were 62°F–65°F, and mouth temperatures were 64°F–70°F. In June, temperatures at RM 28.2 and the confluence were controlled by meteorology and flow. When flow was about 1,500 cfs, the average warming from Goodwin to RM 28.2 was about 5°F (55°F–60°F), and when flow was about 500 cfs, this warming was about 10°F–12°F (60°F–70°F). The confluence temperatures were about 62°F when flow was greater than 1,500 cfs and were about 70°F when flow was less than 500 cfs. Because of the relatively high spring flows on the Stanislaus (required by the NMFS BO), flows in April and May were almost always greater than 500 cfs for baseline conditions.

Figure F.1.6-5d shows the simulated monthly average Stanislaus River temperatures below New Melones Reservoir, below Goodwin Dam, at RM 28.2 and at the confluence in July–September for 1970–2003 as a function of the river flow (at the confluence). In July, as flow fell from 750 cfs to 250 cfs, Goodwin temperatures climbed from 50°F to 55°F. At flows of about 250 cfs, the Goodwin temperatures ranged from 55°F–60°F. At RM 28.2, there was a similar increase in temperature with falling flow. As flow fell from 750 cfs to 250 cfs, Goodwin temperatures climbed from 65°F to 75°F. The confluence temperatures in July were consistently about 4°F warmer than the RM 28.2 temperatures regardless of flow. In August, temperature effects were similar to those in July. Flows generally ranged from 250–650 cfs at the confluence, with Goodwin temperatures of 50°F–65°F, RM 28.2 temperatures of 65°F–75°F, and confluence temperatures of 70°F–77°F. The increase in temperature as flow was reduced from 750 to 250 cfs was greater at Goodwin than at the locations farther downstream. The September temperature patterns were similar to the August temperature patterns, but the temperatures at RM 28.2 and the confluence were slightly less than in August. Figure F.1.6-5e shows the simulated monthly average Stanislaus River temperatures below New Melones Reservoir, below Goodwin Dam, at RM 28.2 and at the confluence in October–December for 1970–2003 as a function of the river flow (at the confluence). In October, the wide range of river flows was dependent primarily on reservoir storage (higher flood control releases when storage was high). Goodwin temperatures were usually less than 55°F when the flow at the confluence was greater than 1,000 cfs, but at flows lower than 750 cfs, the Goodwin temperatures could reach as high as 65°F. The meteorological warming from Goodwin to the confluence was about 5°F regardless of the flow, except when the Goodwin temperatures were exceptionally high (more than 60°F) because the temperatures were already approaching equilibrium and there was less warming as the water moved downstream. November and December temperatures showed very little meteorological warming. In November, confluence flows were almost always less than 500 cfs, and temperatures were usually less than 55°F at all locations. However, at low flows of about 250 cfs, temperatures could be a bit higher, ranging from 55°F–60°F at RM 28.2 at the confluence. December temperatures at all locations were between about 47°F and 55°F. In some instances, particularly in December, equilibrium water temperatures were less than the New Melones release temperatures, resulting in a small amount of cooling as the water moved downstream. These temperature results illustrate the combination of factors controlling Stanislaus River temperatures. The factors affecting temperature along the river include New Melones and Goodwin release temperatures, which are indirectly proportional to New Melones storage; air temperature and meteorological warming effects as water moves downstream, especially from March–October; and the amount of flow in the river.



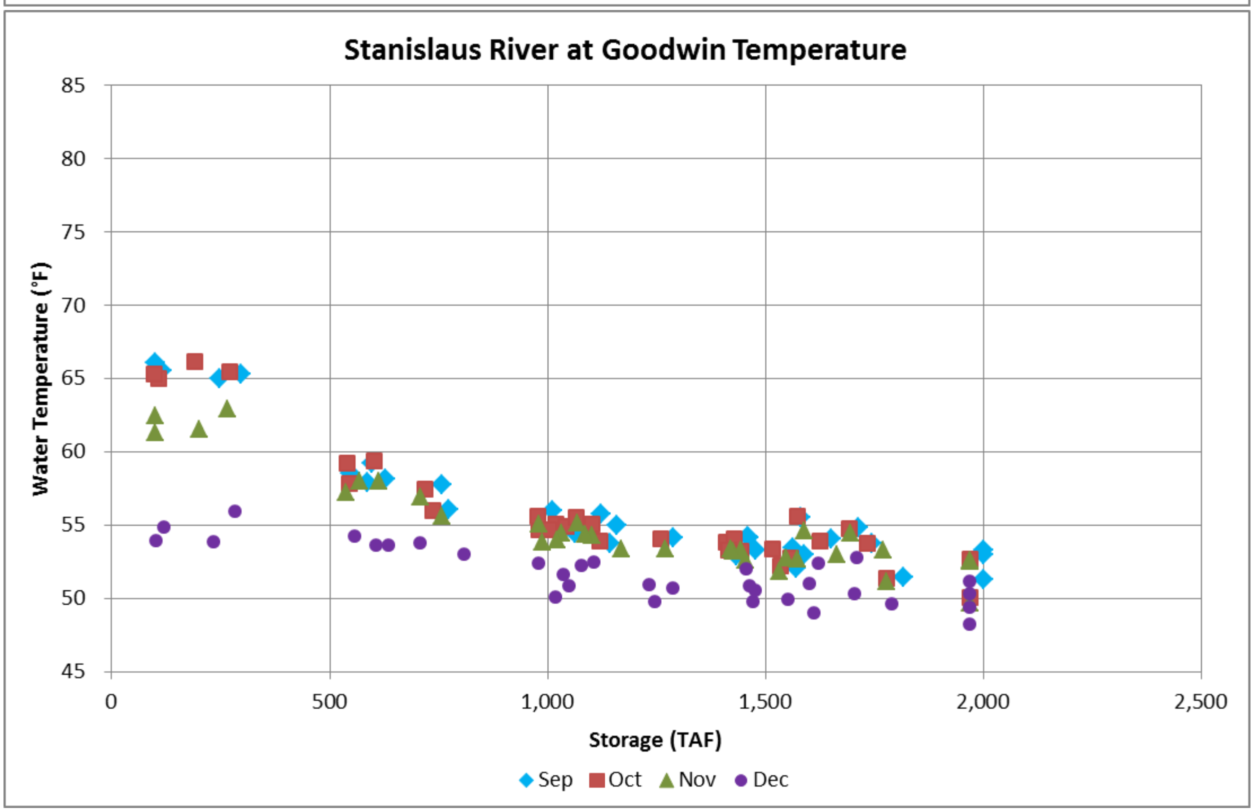


Figure F.1.6-5a. Stanislaus River Water Temperatures as a Function of New Melones Storage September–December at New Melones Dam and Goodwin Dam for Baseline Conditions 1970–2003

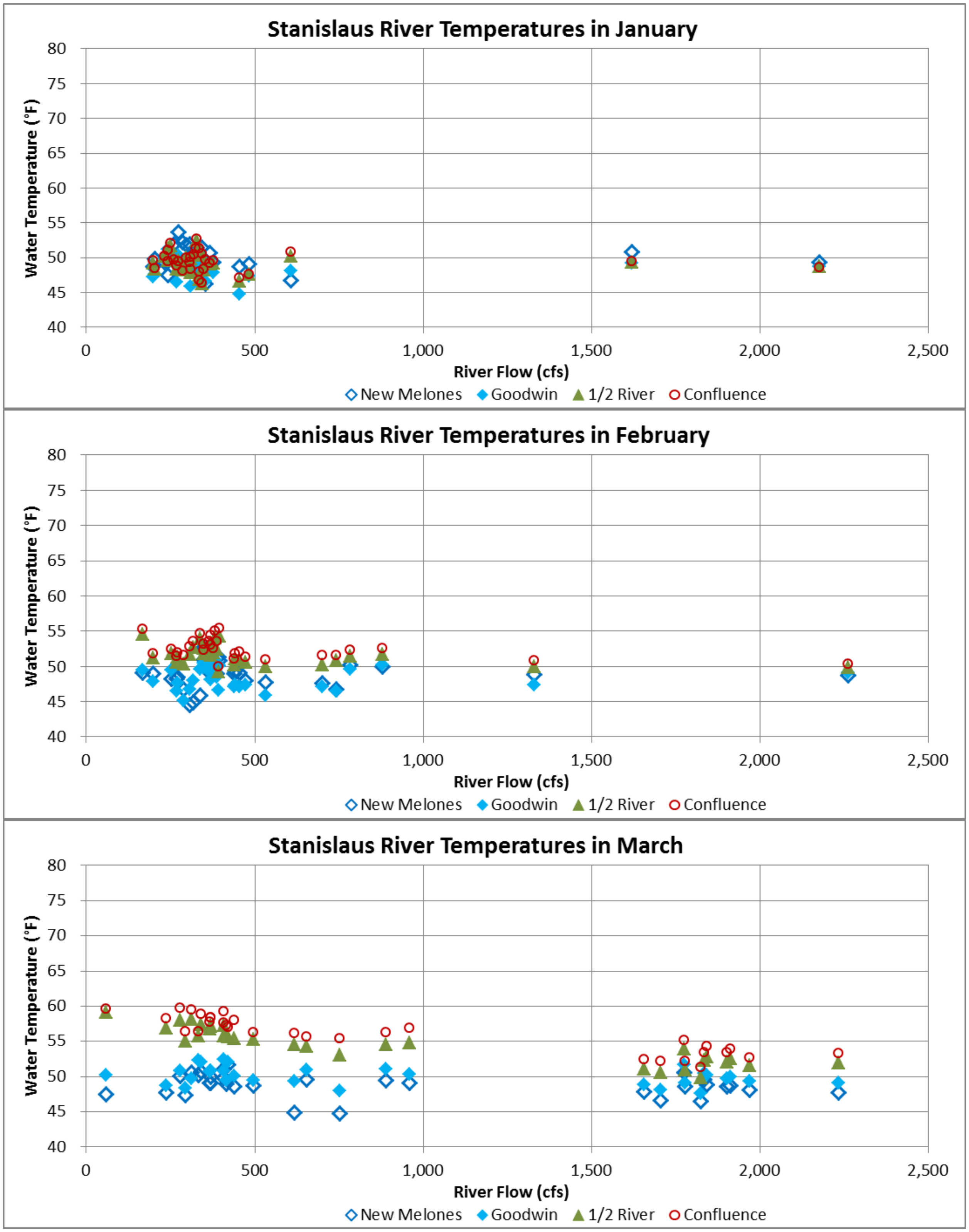


Figure F.1.6-5b. Effects of Stanislaus River Flow on Stanislaus River Water Temperatures January–March for Baseline Conditions 1970–2003

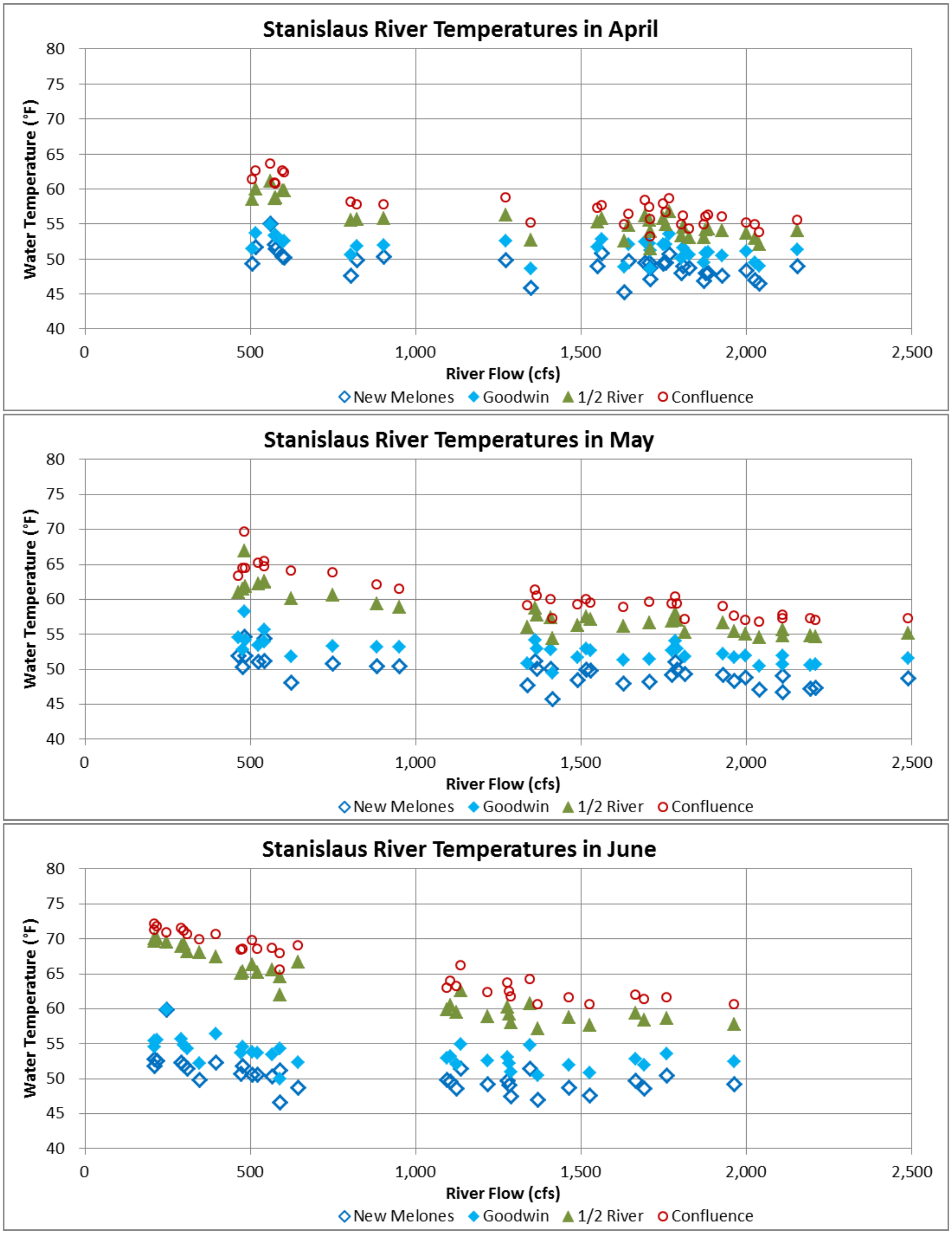
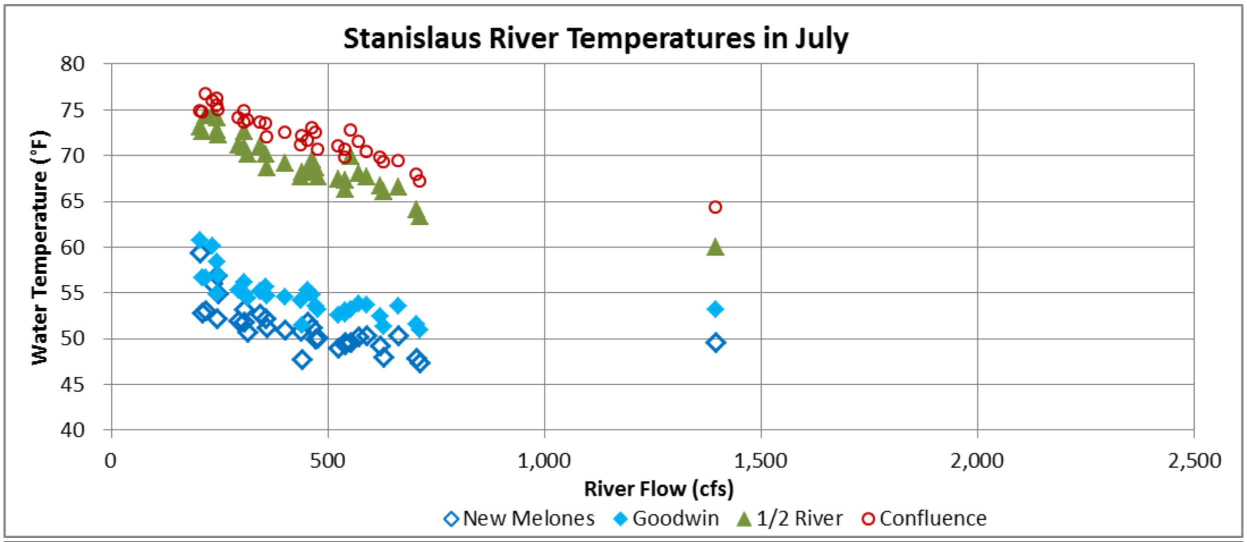
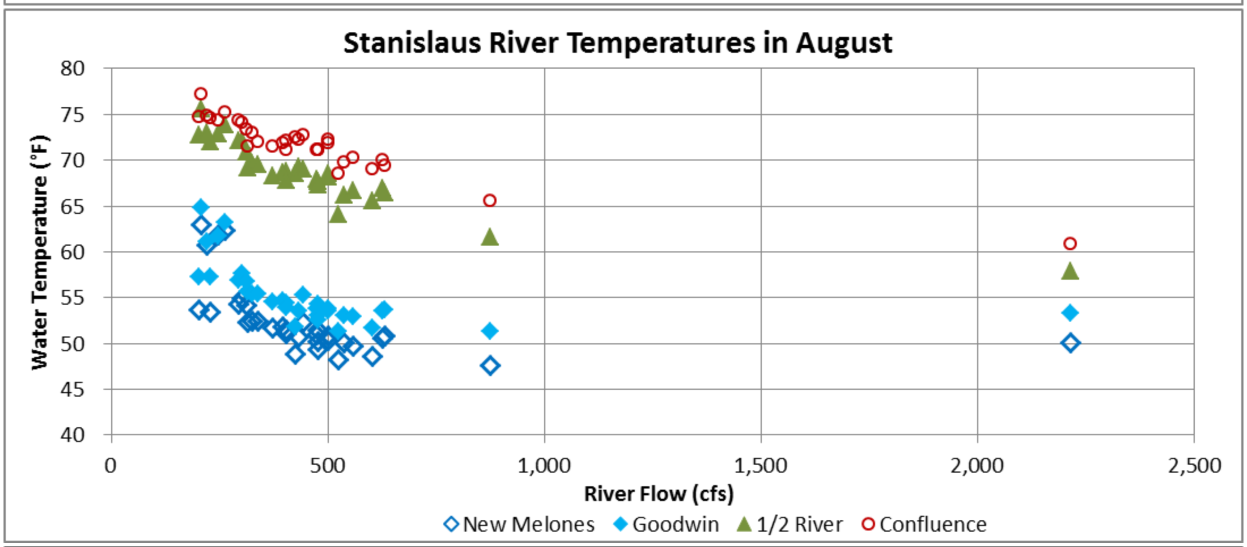


Figure F.1.6-5c. Effects of Stanislaus River Flow on Stanislaus River Water Temperatures April–June for Baseline Conditions 1970–2003





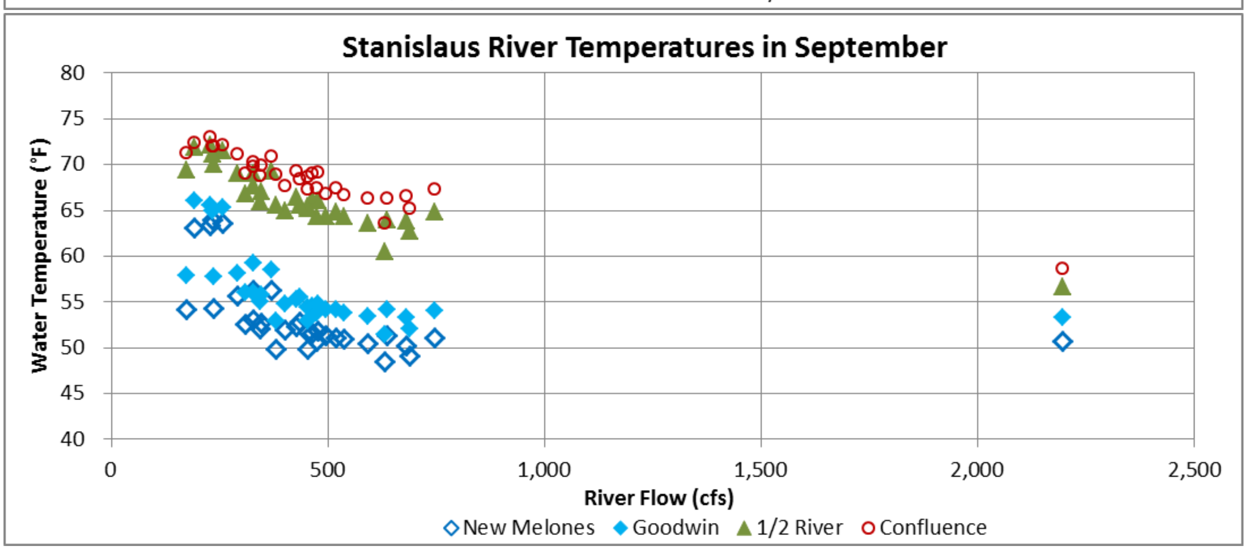


Figure F.1.6-5d. Effects of Stanislaus River Flow on Stanislaus River Water Temperatures July–September for Baseline Conditions 1970–2003

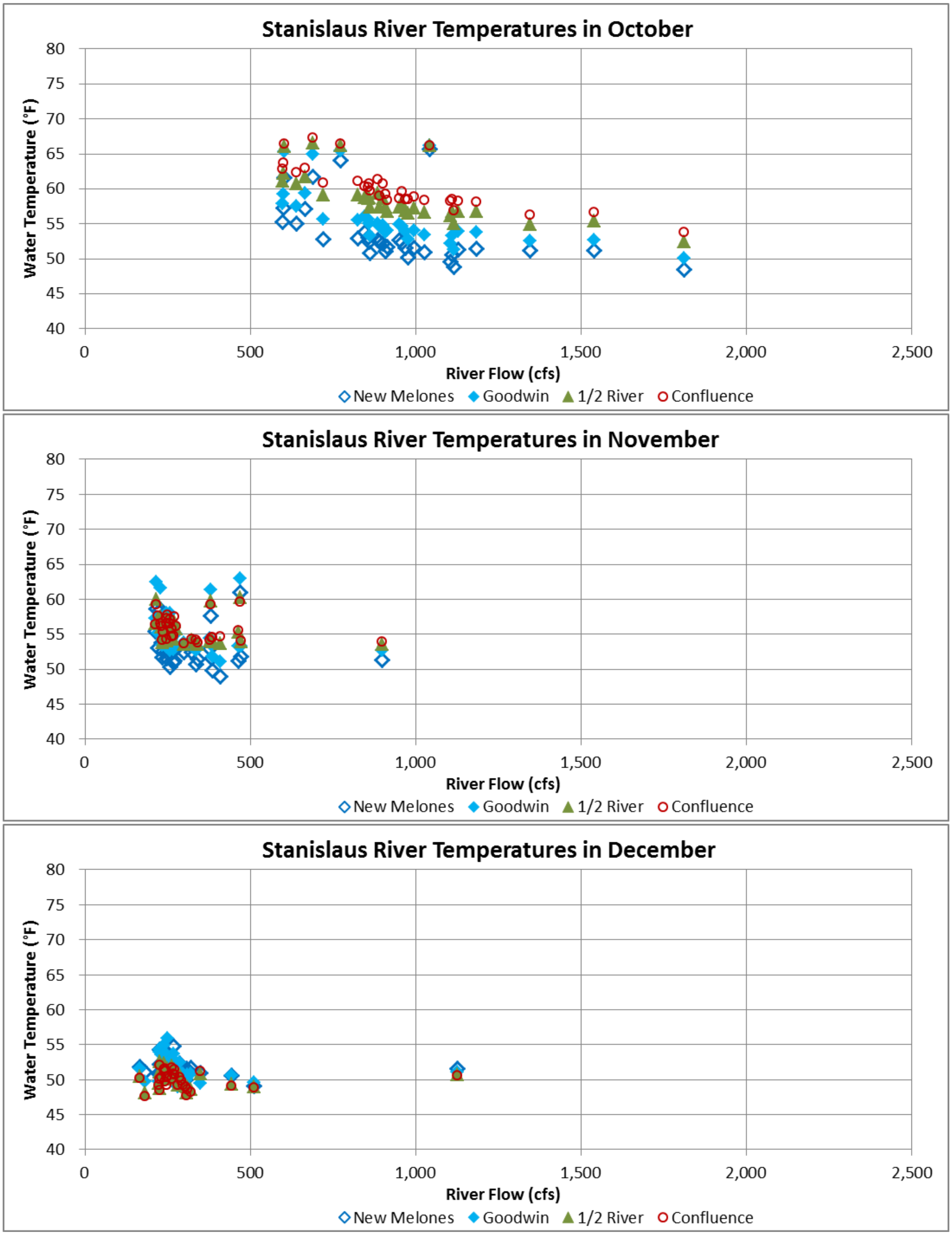


Figure F.1.6-5e. Effects of Stanislaus River Flow on Stanislaus River Water Temperatures October–December for Baseline Conditions 1970–2003

Tuolumne River Temperatures

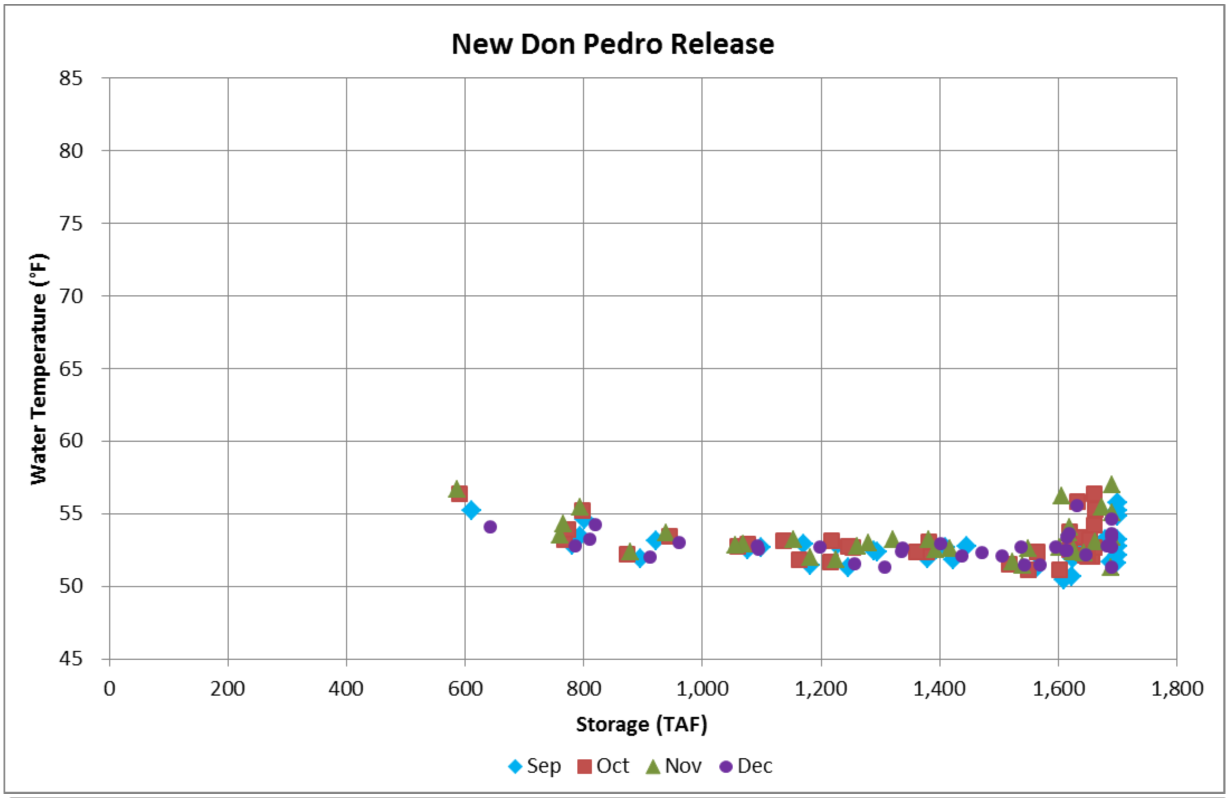
Figure F.1.6-6a shows the simulated monthly average Tuolumne River temperatures below New Don Pedro Dam and below La Grange Dam in September–December for 1970–2003. The September–December temperatures at New Don Pedro Dam were about 50°F–55°F in all months, except for a few instances when storage was less than 600 TAF or greater than 1,600 TAF. The September and October temperatures at La Grange Dam were only slightly warmer because La Grange Dam is just 2.5 miles below New Don Pedro Dam, and there isn't enough time for water released from New Don Pedro to warm significantly. Based on these results, the New Don Pedro carryover storage target of at least 800 TAF would likely provide La Grange Dam release temperatures of less than 56°F in September and October of most years.

Figure F.1.6-6b shows the simulated monthly average Tuolumne River temperatures below New Don Pedro Reservoir, below La Grange Dam, at RM 28.1 (about half way between the confluence and La Grange Dam), and at the confluence in January–March for 1970–2003 as a function of the river flow (at the confluence). During January, monthly average temperatures at all locations were between 45°F and 55°F. Sometimes there was a small amount of cooling between La Grange and the confluence because equilibrium water temperatures were less than the New Don Pedro release temperatures. During February, temperatures were slightly warmer at the confluence where temperatures ranged from about 52°F–58°F. Unlike in January, there was a small amount of warming between La Grange and the confluence (up to about 5°F at flows less than about 750 cfs). In addition, there were many instances when the temperatures at RM 28.1 were similar to the temperatures at the confluence, indicating that equilibrium temperatures had already been reached by RM 28.1. During March, there was significant longitudinal warming; at flows less than 500 cfs, temperatures increased from about 50°F at La Grange to between 60°F–65°F at the confluence.

Figure F.1.6-6c shows the simulated monthly average Tuolumne River temperatures below New Don Pedro, below La Grange, at RM 28.1, and at the confluence in April–June for 1970–2003 as a function of the river flow (at the confluence). La Grange temperatures for all three months were about 50°F, regardless of the river flow, and the downstream temperatures were controlled by the meteorology and the flow. In April, if flow was greater than 1,000 cfs, the temperature at RM 28.1 was generally slightly less than 55°F, and the temperature at the confluence was about 60°F. As flow decreased from 1,000 cfs to 400 cfs, the temperature at both locations increased by 5°F–10°F. For May conditions were similar to those in April, but temperatures were slightly warmer at downstream locations. If flow was greater than 1,000 cfs, the temperature at RM 28.1 was generally slightly more than 55°F, and the temperature at the confluence was about 60°F–65°F. As flow decreased from 1,000 cfs to 400 cfs, the temperature at both locations increased by 5°F–10°F. During June, confluence flows usually remained at or below 500 cfs, apart from a few high-flow years. When flow was less than 400 cfs, the temperature at RM 28.1 was about 75°F, and the temperature at the confluence was only slightly higher, indicating that river temperature had already reached the equilibrium temperature by RM 28.1.

Figure F.1.6-6d shows the simulated monthly average Tuolumne River temperatures below New Don Pedro, below La Grange, at RM 28.1, and at the confluence in July–September for 1970–2003 as a function of river flow (at the confluence). For all three months, La Grange temperatures were between 50°F–55°F, regardless of the river flow, and the downstream temperatures were controlled by the meteorology and the flow. During both July and August, confluence flows usually remained at or below 700 cfs, apart from a few high-flow years. In both months, for flows between 700 and 400 cfs, temperatures at RM 28.1 were consistently around 69°F, while temperatures at the confluence were between 75°F–80°F. Below 400 cfs, temperatures at RM 28.1 ranged from 75°F–80°F, while temperatures at the confluence remained around 80°F. September also shows similar longitudinal warming patterns compared to July; however, temperatures at the downstream locations are about 5°F cooler than in July and August. For all three months, at flows below 400 cfs, river temperatures have almost achieved equilibrium at RM 28.1, and there is little warming from there to the confluence.

Figure F.1.6-6e shows the simulated monthly average Tuolumne River temperatures below New Don Pedro, below La Grange, at RM 28.1, and at the confluence in October–December for 1970–2003 as a function of the river flow (at the confluence). During all three of these months, temperatures at La Grange remained at approximately 50°F–55°F. In October, longitudinal (downstream) warming was still present but was much less than in September (approximately a 15°F increase between La Grange and the confluence at flows less than 400 cfs). At flows greater than 400 cfs, temperatures at RM 28.1 were consistently slightly less than 60°F, while temperatures at the confluence were slightly less than 65°F. At flows less than 400 cfs, temperatures at RM 28.1 ranged from 60°F–65°F, while temperatures at the confluence were between 65°F–70°F. In November, there was very little downstream warming and temperatures at all locations ranged between 50°F–60°F. In December, temperatures everywhere were almost always below 55°F, while temperatures at the confluence were often cooler than temperatures at La Grange. These temperature results illustrate the combination of factors controlling Tuolumne River temperatures. The New Don Pedro and La Grange temperatures were very uniform, between 50°F and 55°F, because the New Don Pedro storage generally did not drop below 600 TAF. The meteorological warming of downstream river temperatures was substantial from March–October, with a maximum warming of about 30°F between La Grange and the confluence in July at flows less than 400 cfs. However, higher river flows reduce the maximum warming. The temperature effect of flows of 250–1,500 cfs is important because this is the typical range for the LSJR alternatives being evaluated. An increase of 250 cfs or more in March–June would have a substantial effect on reducing the downstream water temperatures at RM 28.1 and the confluence.



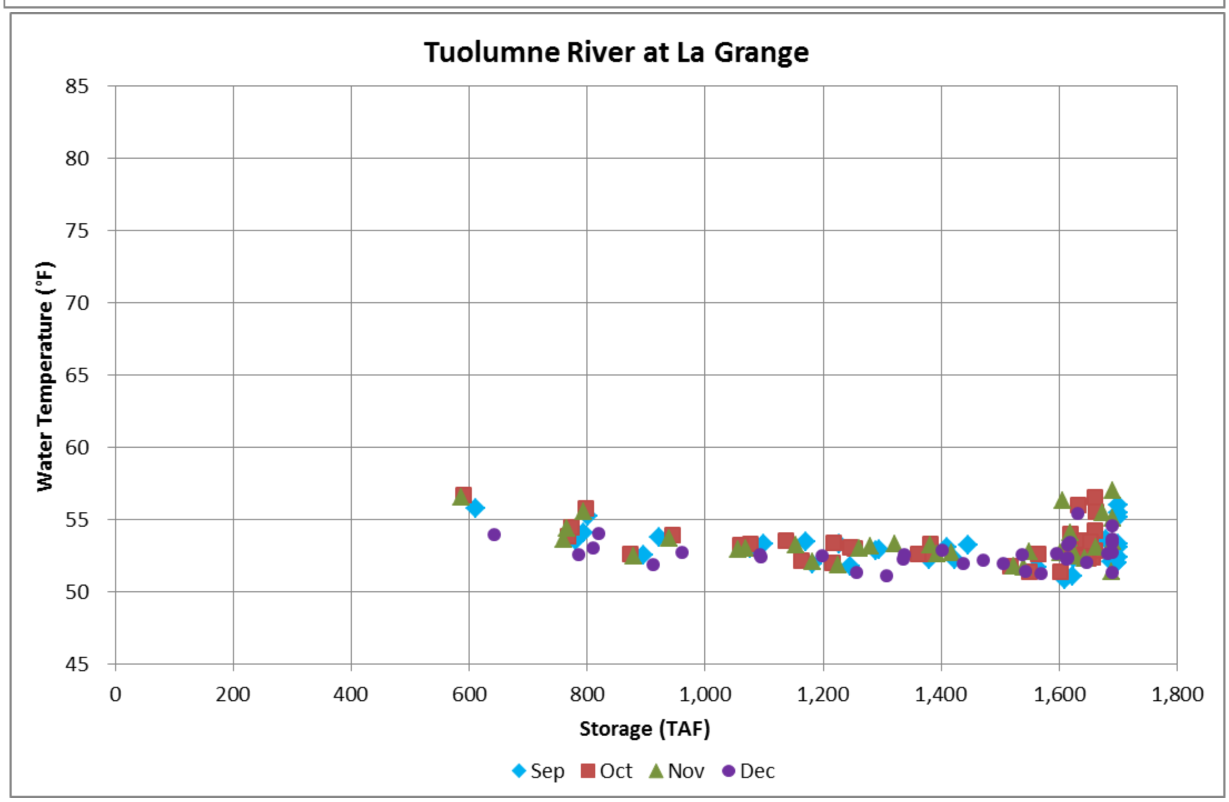


Figure F.1.6-6a. Effects of New Don Pedro Storage on New Don Pedro and La Grange Simulated Water Temperatures September–December for Baseline Conditions 1970–2003

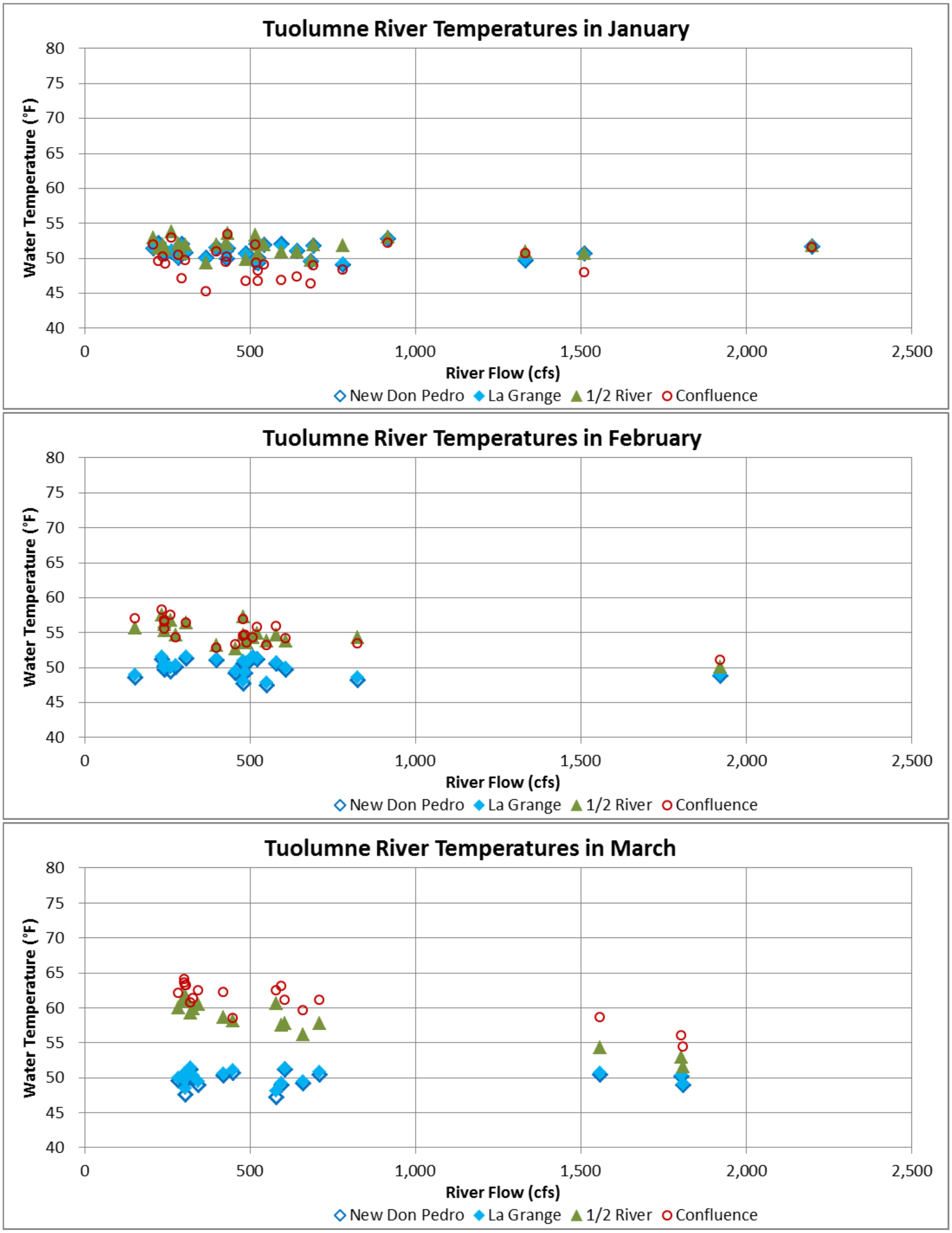


Figure F.1.6-6b. Effects of Tuolumne River Flow on Tuolumne River Water Temperatures January–March for Baseline Conditions 1970–2003

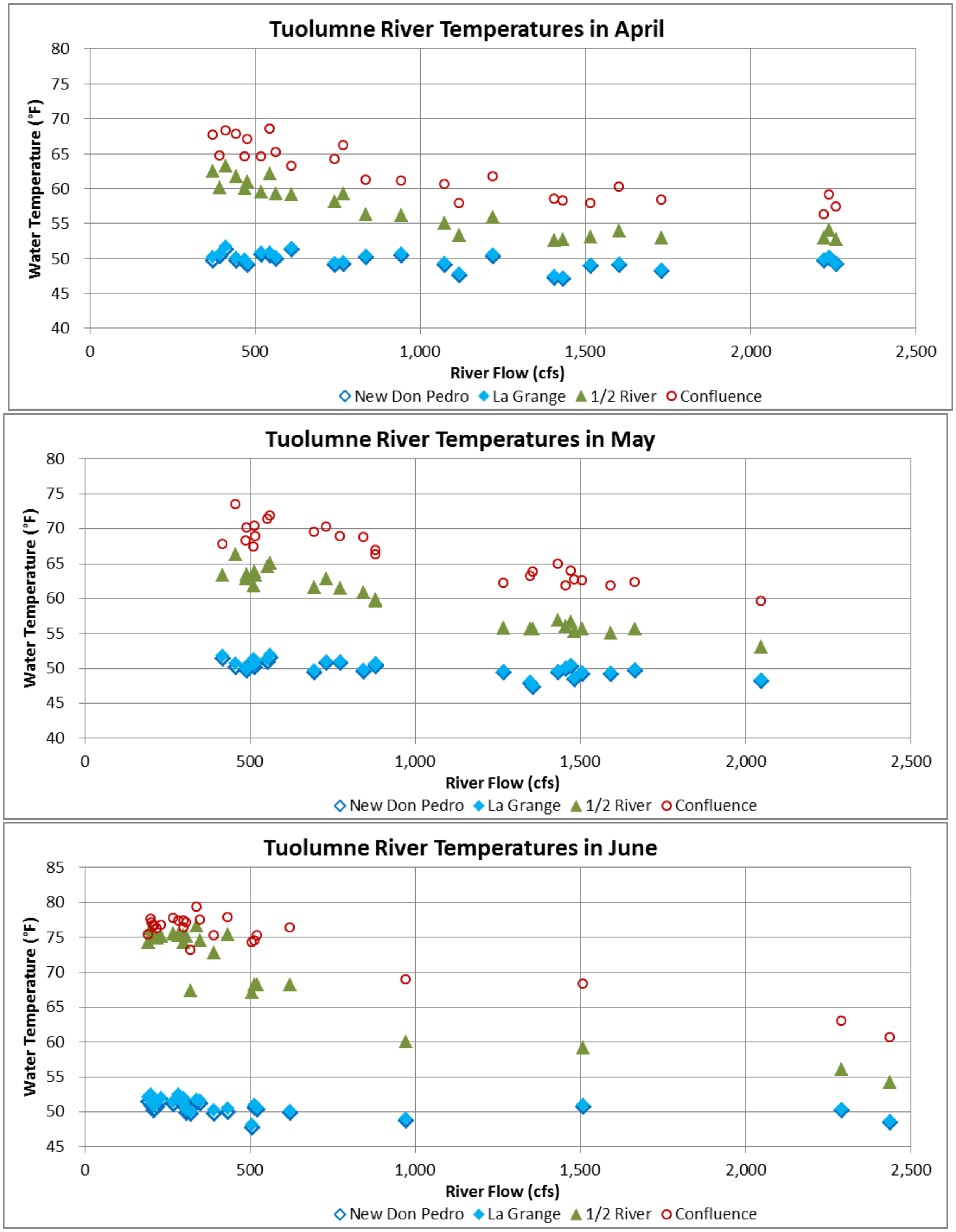
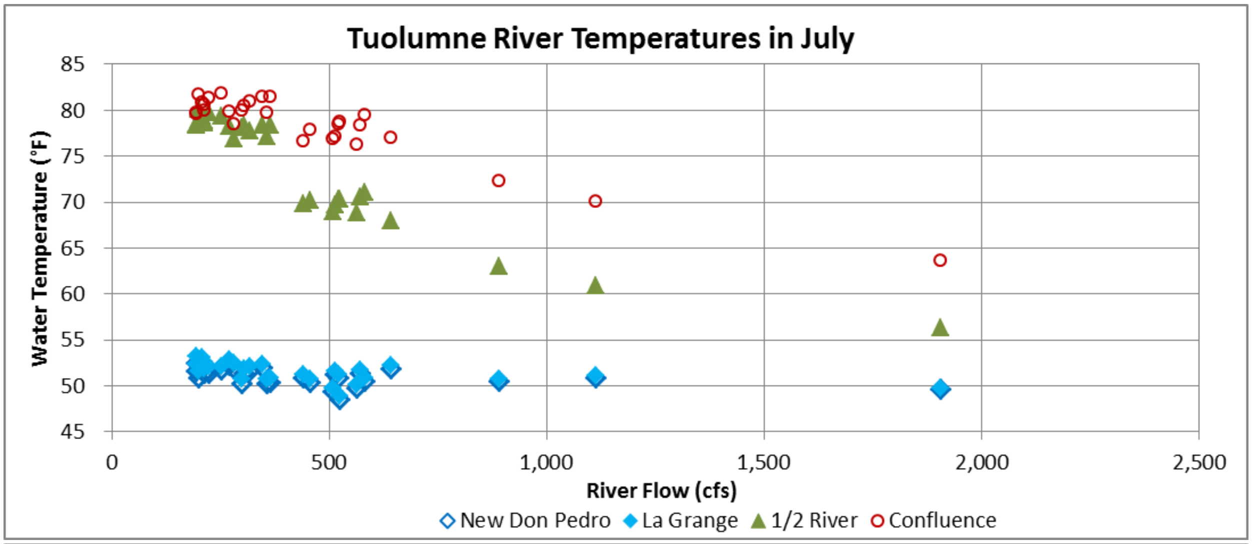
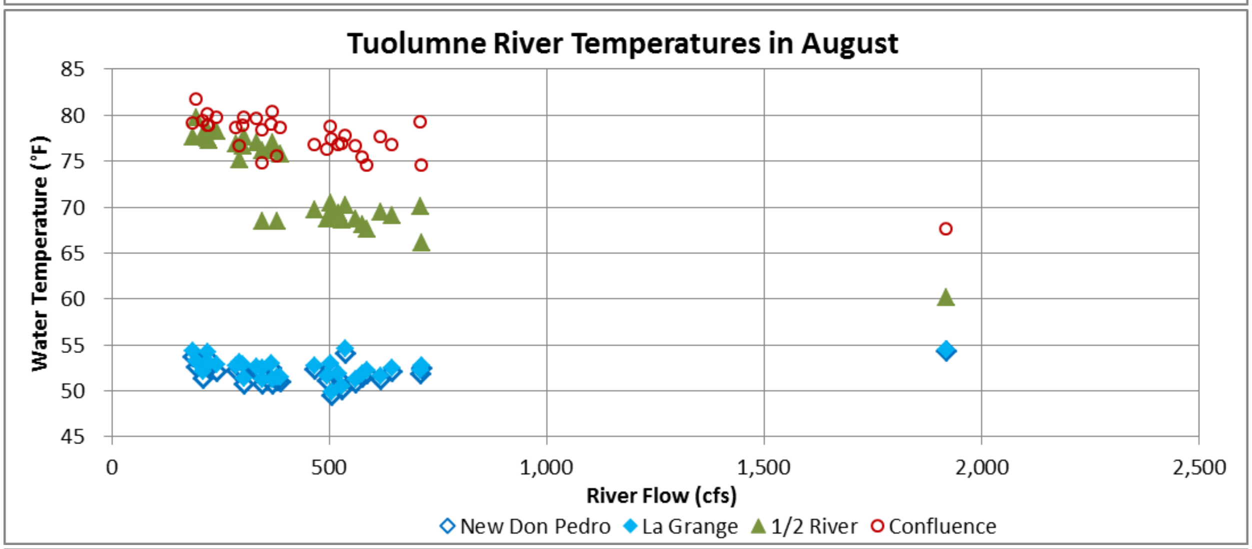


Figure F.1.6-6c. Effects of Tuolumne River Flow on Tuolumne River Water Temperatures April–June for Baseline Conditions 1970–2003





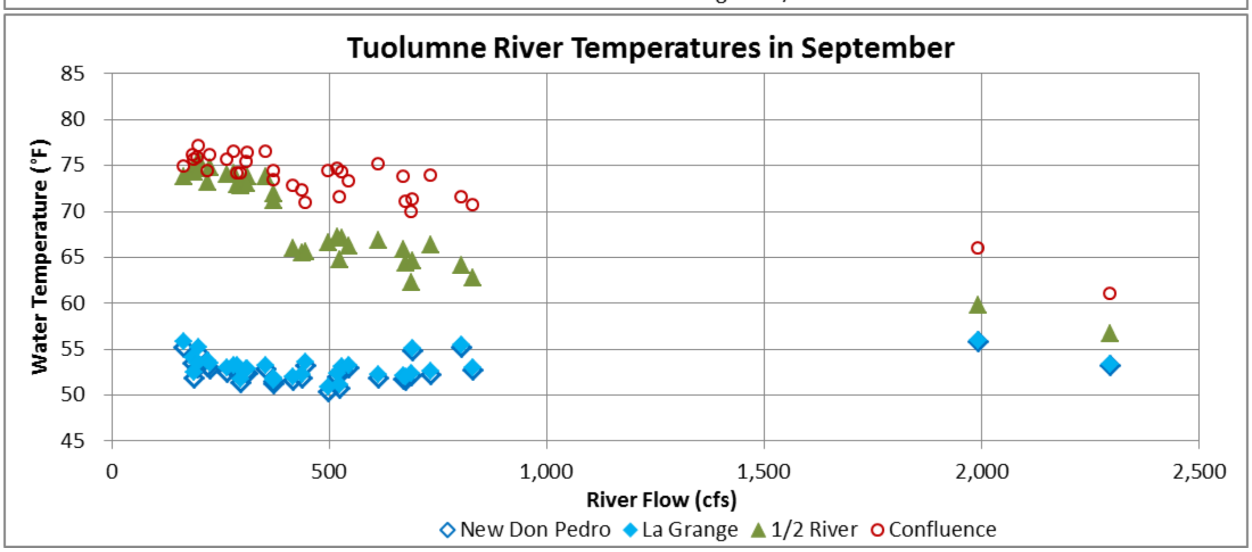


Figure F.1.6-6d. Effects of Tuolumne River Flow on Tuolumne River Water Temperatures July–September for Baseline Conditions 1970–2003

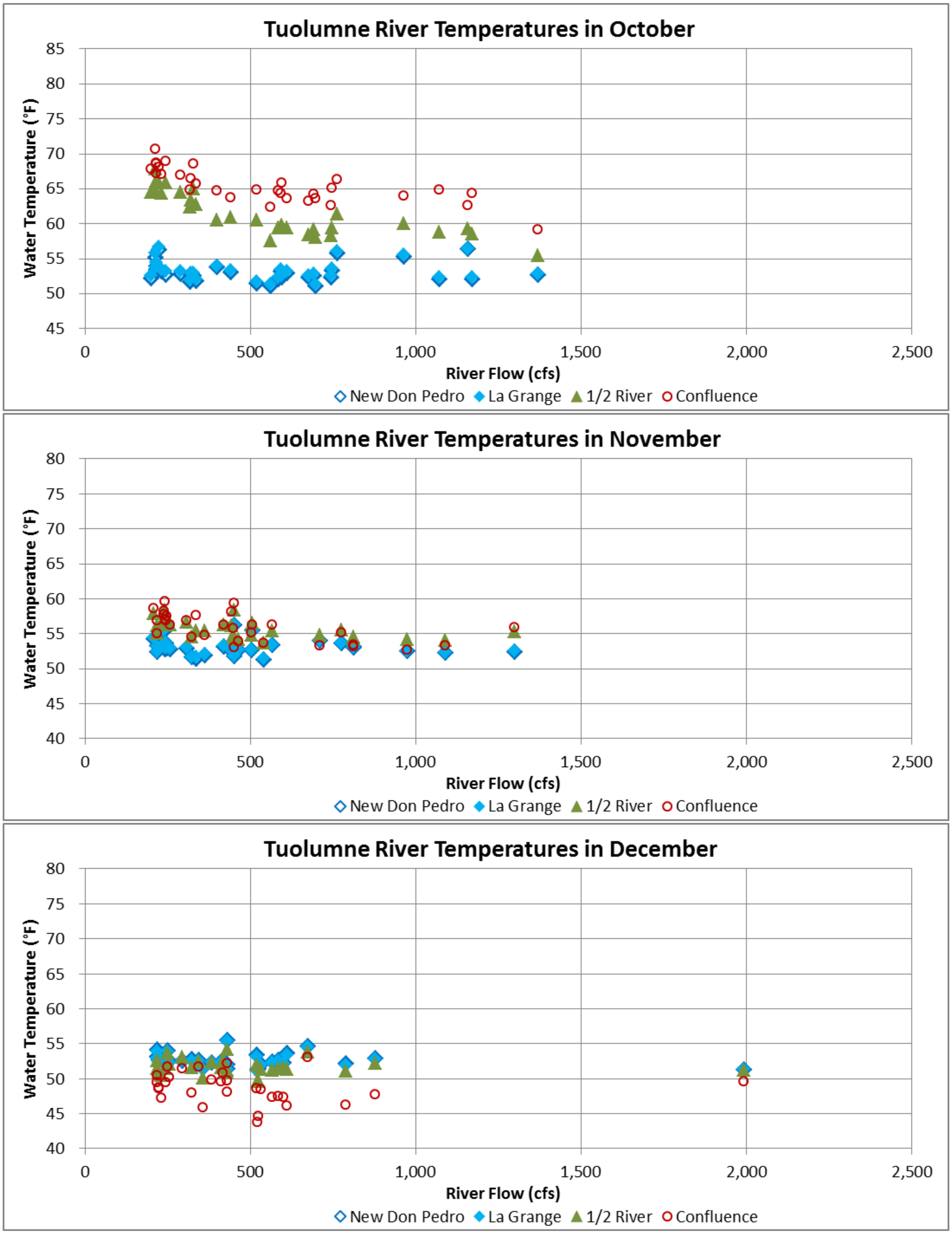


Figure F.1.6-6e. Effects of Tuolumne River Flow on Tuolumne River Water Temperatures October–December for Baseline Conditions 1970–2003

Merced River Temperatures

Figure F.1.6-7a shows the simulated monthly average Merced River temperatures at Lake McClure and below Crocker-Huffman Dam in September–December for 1970–2003. In general, there appears to be more warming along the Merced River between the Lake McClure release and the Crocker-Huffman release than along the Tuolumne River between New Don Pedro and La Grange. This is because there are a total of four dams on the Merced River. In addition to New Exchequer Dam, there is Lake McSwain, which has a small hydropower unit. The lake is about 6.5 miles long and about 80 feet deep. Merced Falls Dam is the diversion dam for the Northside Canal and is 1 mile long and about 40 feet deep. Finally, the Crocker-Huffman Dam is the diversion dam for the Merced Irrigation District Main Canal and is 3 miles long and 20 feet deep.

The September and October temperatures at Lake McClure ranged from about 50°F–70°F as Lake McClure storage was reduced from 700 to 100 TAF. In general, release temperatures from Lake McClure did not rise above 60°F until storage was below 200 TAF. The September and October temperatures at Crocker-Huffman Dam were generally a bit warmer than the temperatures at Lake McClure but usually within 5°F. In general, release temperatures from Crocker-Huffman did not rise above 60°F until Lake McClure storage was below 300 TAF. The November temperatures at Lake McClure and at Crocker-Huffman were less than 60°F when Lake McClure storage was greater than about 200 TAF. The December temperatures at both locations were approximately 50°F–55°F, regardless of storage, because the reservoir was fully mixed, and the release temperatures were controlled by the meteorology and not the reservoir storage. Based on these results, the Lake McClure carryover storage target of at least 300 TAF would likely provide a Crocker-Huffman Dam release temperature of approximately 60°F or less in September and October. Temperatures at Crocker-Huffman Dam are important for the Merced River Hatchery, which is located nearby.

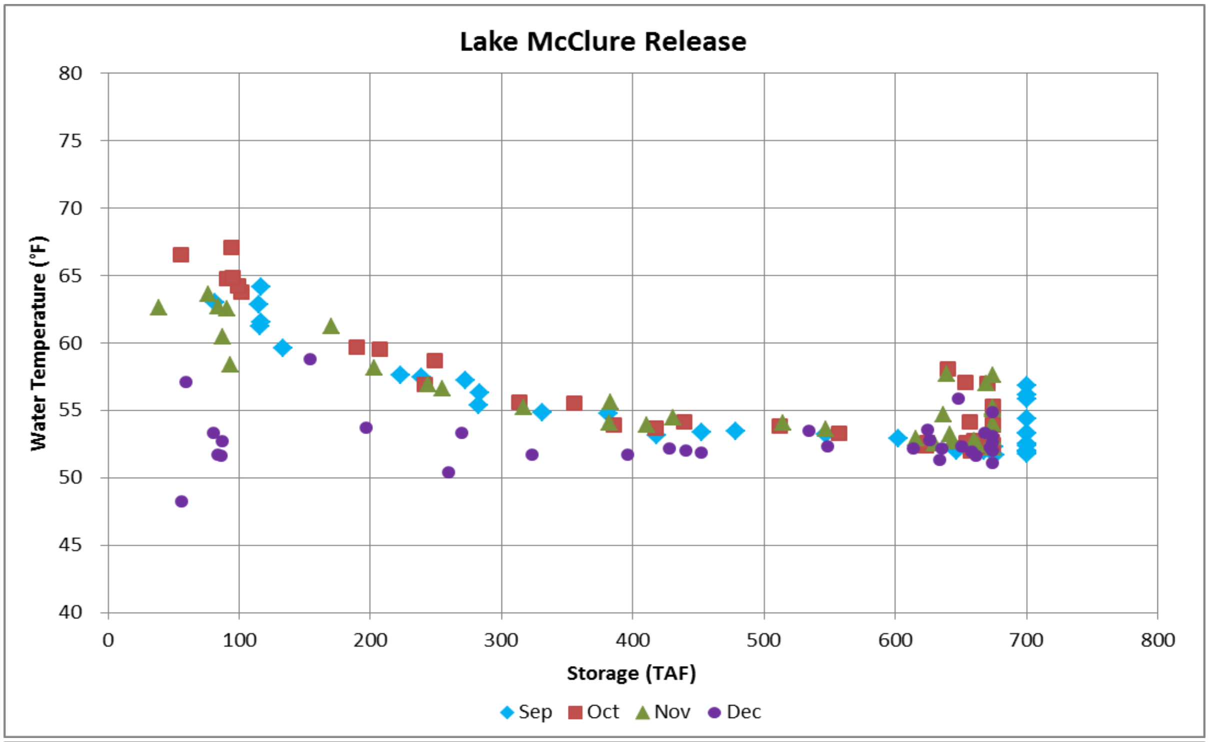
Figure F.1.6-7b shows the simulated monthly average Merced River temperatures below Lake McClure, below Crocker-Huffman, at RM 27.1 (approximately half way between Crocker-Huffman and the confluence), and at the confluence in January–March for 1970–2003 as a function of the river flow (at the confluence). During January, almost all monthly average temperatures were between 45°F and 55°F and there was little change in temperature between Crocker-Huffman and the confluence. During February, average monthly temperatures were still usually between 45 and 60°F, but there was a small amount of warming between Crocker-Huffman and the confluence (allowing some temperatures to exceed 55°F at flows less than 500 cfs). During March, there was significant longitudinal warming. At flows less than 500 cfs, monthly average temperatures increased from about 48°F at McClure to about 52°F at Crocker-Huffman. As water moved downstream, it continued to warm. By the time it reached RM 27.1, the average temperature was about 57°F–58°F. However, there was only slight warming between RM 27.1 and the confluence, indicating that at flows less than 500 cfs, March equilibrium temperatures were already reached near RM 27.1.

Figure F.1.6-7c shows the simulated monthly average Merced River temperatures below Lake McClure, below Crocker-Huffman, at RM 27.1 (approximately half way between Crocker-Huffman and the confluence) and at the confluence in April–June for 1970–2003 as a function of the river flow (at the confluence). For all three months, the downstream temperatures were controlled by the meteorology and the flow. During April, Lake McClure temperatures were usually between 45°F and 55°F, while temperatures at Crocker Huffman were a bit higher, particularly at flows less than 400 cfs. At RM 27.1, the temperature was usually between 55°F and 60°F when flow was greater than 400 cfs but increased to about 65°F at lower flows. May showed similar trends compared to April, but temperatures were about 5°F warmer at all locations. During June, confluence flows usually remained at or below 300 cfs, apart from a few high-flow years. When the flow was less than 300 cfs, Lake McClure was generally between 50°F and 55°F, Crocker-Huffman was between 55°F and 60°F, and RM 27.1 was about 75°F. For all three months, confluence temperatures were only slightly higher than temperatures at RM 27.1, indicating that river temperature had already reached equilibrium temperature by RM 27.1.

Figure F.1.6-7d shows the simulated monthly average Merced River temperatures below Lake McClure, below Crocker-Huffman, at RM 27.1, and at the confluence in July–September for 1970–2003 as a function of the river flow (at the confluence). The summer flows on the Merced River were usually very low (less than 300 cfs), and simulated temperatures at RM 27.1 and the confluence were high (70°F–80°F) in July, August, and September. Crocker Huffman and Lake McClure temperatures were also higher than in previous months, particularly at low flows. For flows less than 250 cfs and Lake McClure storage less than 200 TAF, September Crocker-Huffman temperatures got as high as 65°F–70°F. Regardless of the simulated Crocker-Huffman temperature, confluence temperatures were about 70°F–75°F. In all three months, confluence temperatures were occasionally less than temperatures at RM 27.1, suggesting that shading at the confluence was greater (i.e., slightly lower equilibrium temperature) than at RM 27.1. At flows higher than 300 cfs, the warming downstream was much less in all three months—about 10°F–12°F higher at RM 27.1 compared to Lake McClure and a few additional degrees higher at the confluence.

Figure F.1.6-7e shows the simulated monthly average Merced River temperatures below Lake McClure, below Crocker-Huffman, at RM 27.1, and at the confluence in October–December for 1970–2003 as a function of the river flow (at the confluence). For all three months, temperatures at Lake McClure and Crocker-Huffman were typically between 50°F and 60°F. However, during October and November, when Lake McClure storage was low, temperatures at the two reservoirs were sometimes greater than 60°F. In October, longitudinal (downstream) warming was still present but less than in September. Downstream temperatures were mostly between 60°F and 65°F at flows greater than 400 cfs and between 65°F and 70°F at flows less than 400 cfs. In November, there was usually no downstream warming, and downstream temperatures were in the same range as those at the Crocker-Huffman. In December, temperatures at RM 27.1 and the confluence were often slightly cooler than temperatures at Lake McClure and Crocker-Huffman.

These temperature results illustrate the combination of factors controlling Merced River temperatures. The Lake McClure and Crocker-Huffman temperatures were strongly affected by low storage in August–November. The meteorological warming of locations downstream of Lake McClure was substantial in March–October, with maximum temperatures of 75°F–80°F in July and August at RM 27.1 and the confluence. However, higher river flows reduce the maximum downstream warming. For example, reducing the river flow from 1,000 to 500 cfs in May will allow the confluence temperatures to increase by about 5°F. Reducing the flow from 500 to 250 cfs will allow the confluence temperatures to increase another 5°F. The temperature effect of flows between 250 and 1,500 cfs is important because this is the typical range for the LSJR alternatives being evaluated. An increase of 250 cfs or more in April–June could have a substantial effect on reducing the downstream water temperatures at Snelling and the mouth of the Merced River.



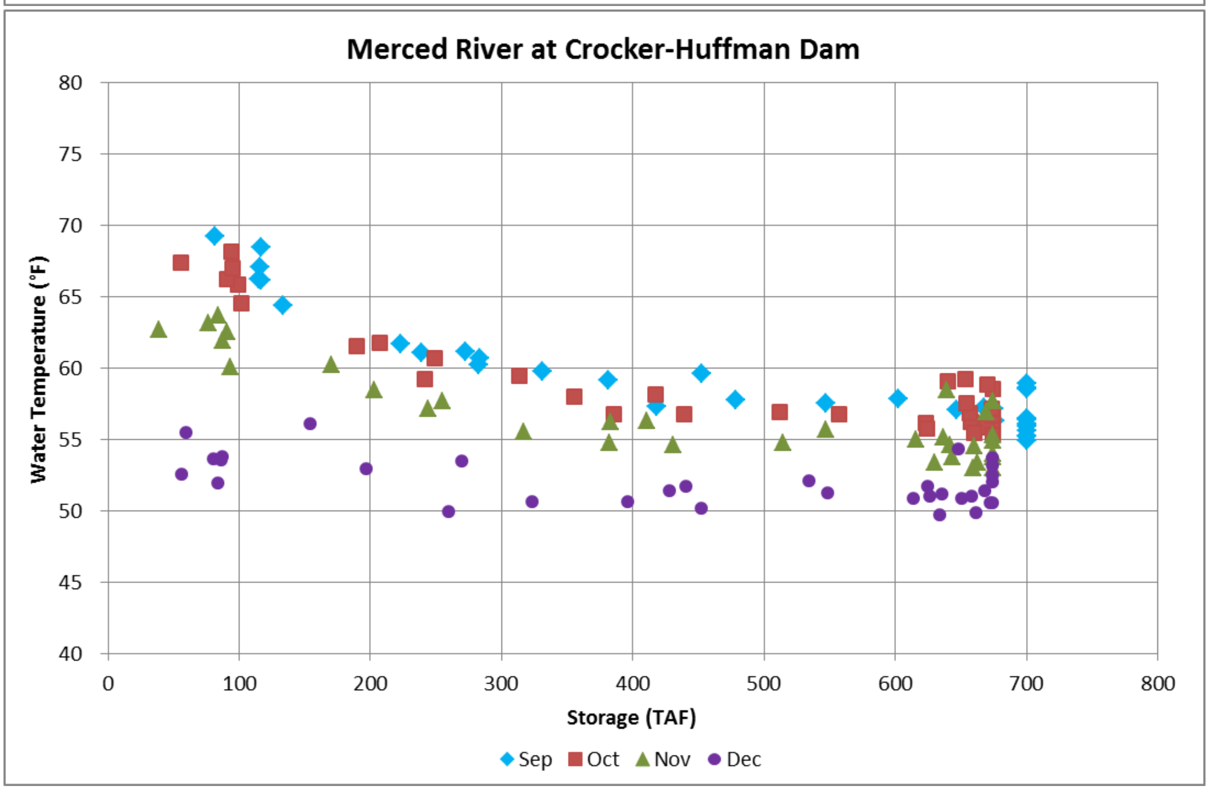


Figure F.1.6-7a. Effects of Lake McClure Storage on Lake McClure and Crocker-Huffman Release Temperatures September–December for Baseline Conditions 1970–2003

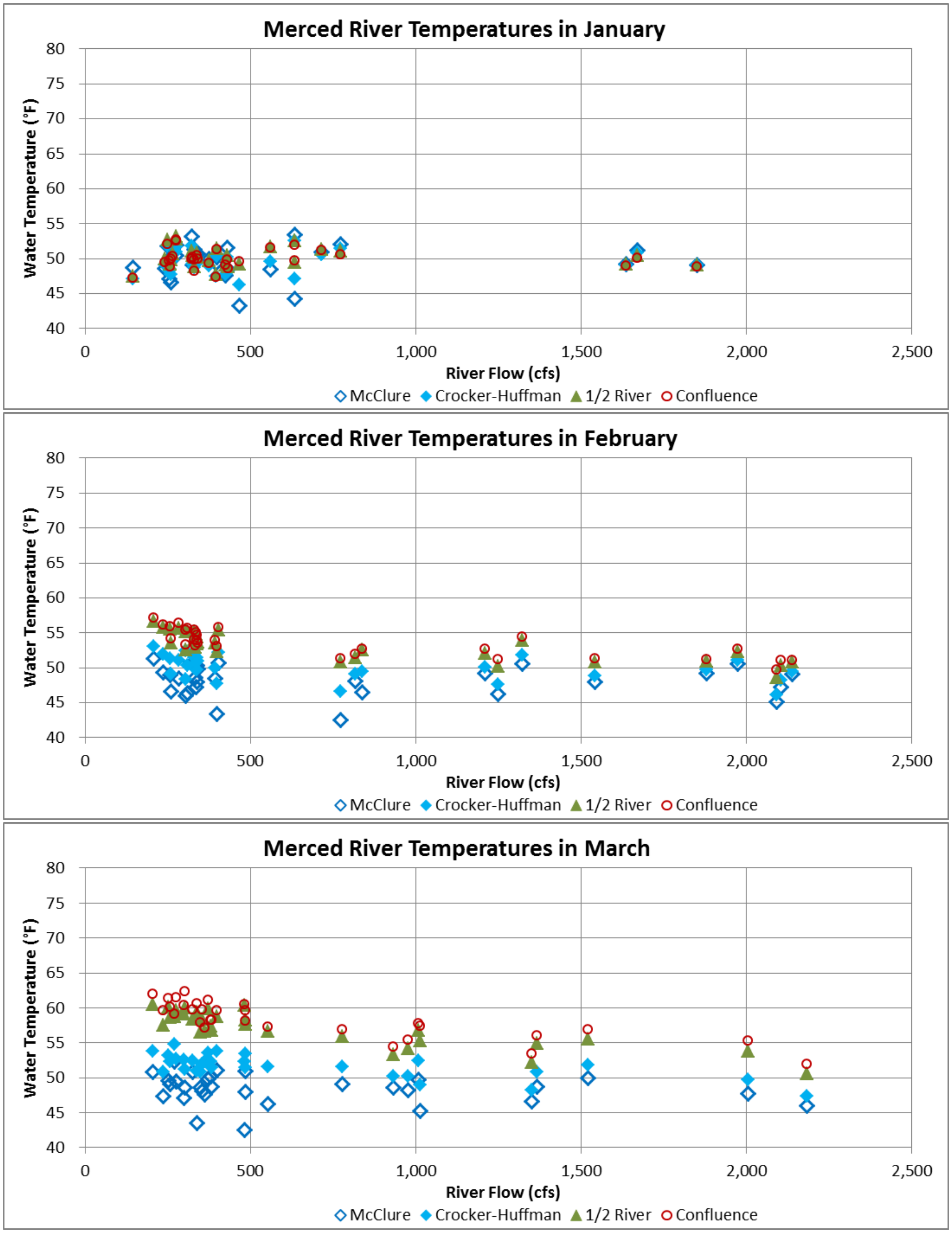


Figure F.1.6-7b. Effects of Merced River Flow on Merced River Water Temperatures in January–March for Baseline Conditions 1970–2003

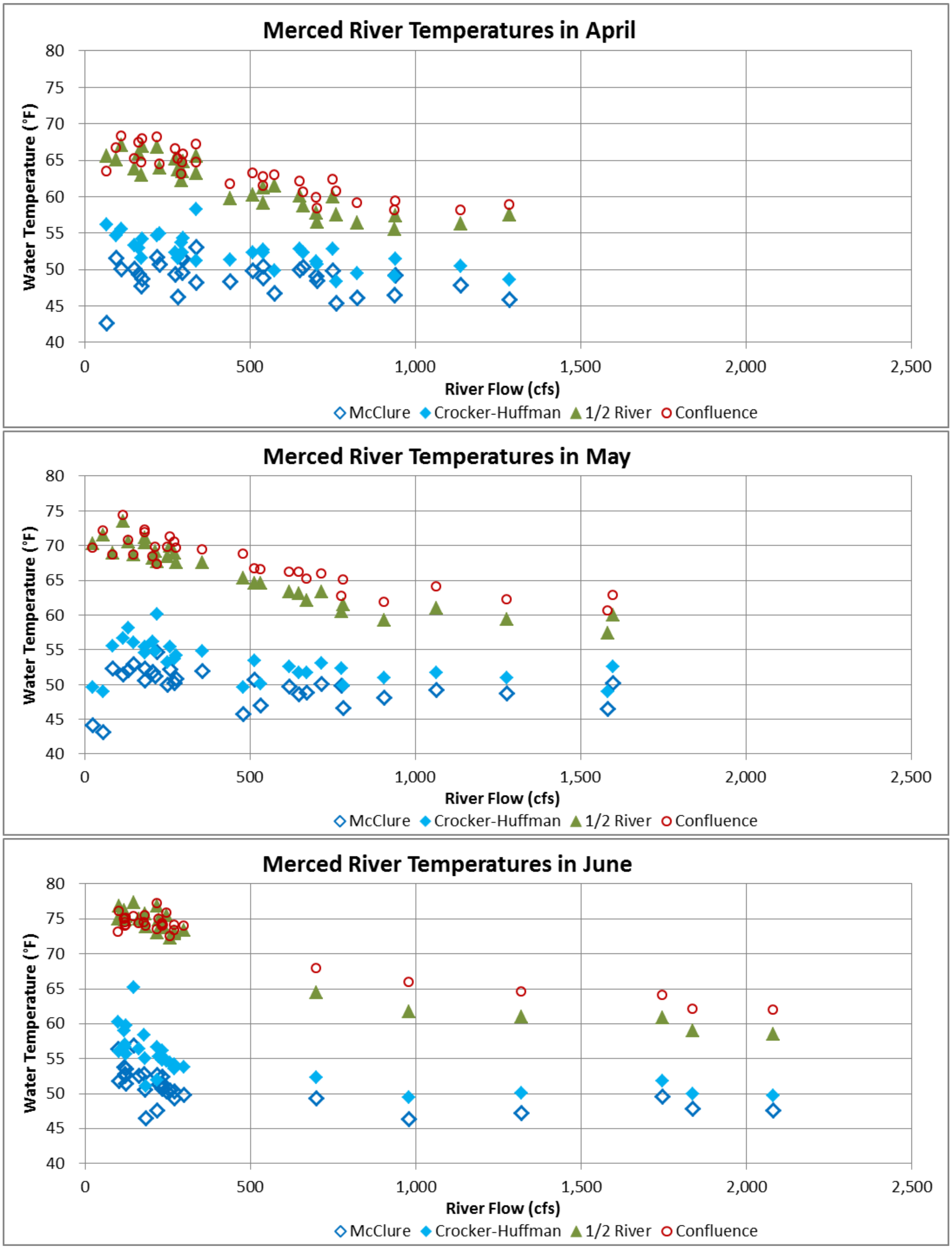


Figure F.1.6-7c. Effects of Merced River Flow on Merced River Water Temperatures in April–June for Baseline Conditions 1970–2003

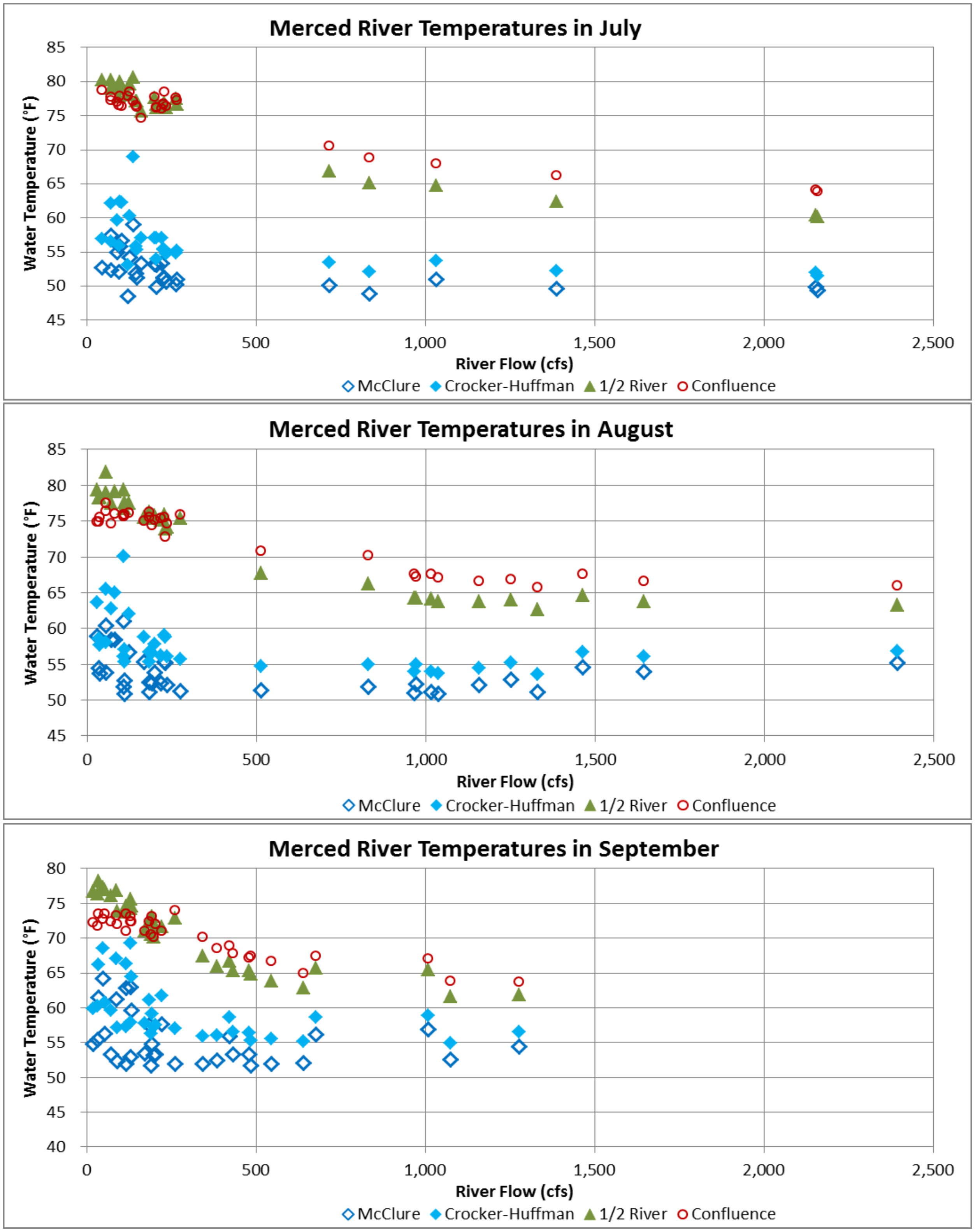


Figure F.1.6-7d. Effects of Merced River Flow on Merced River Water Temperatures July–September for Baseline Conditions 1970–2003

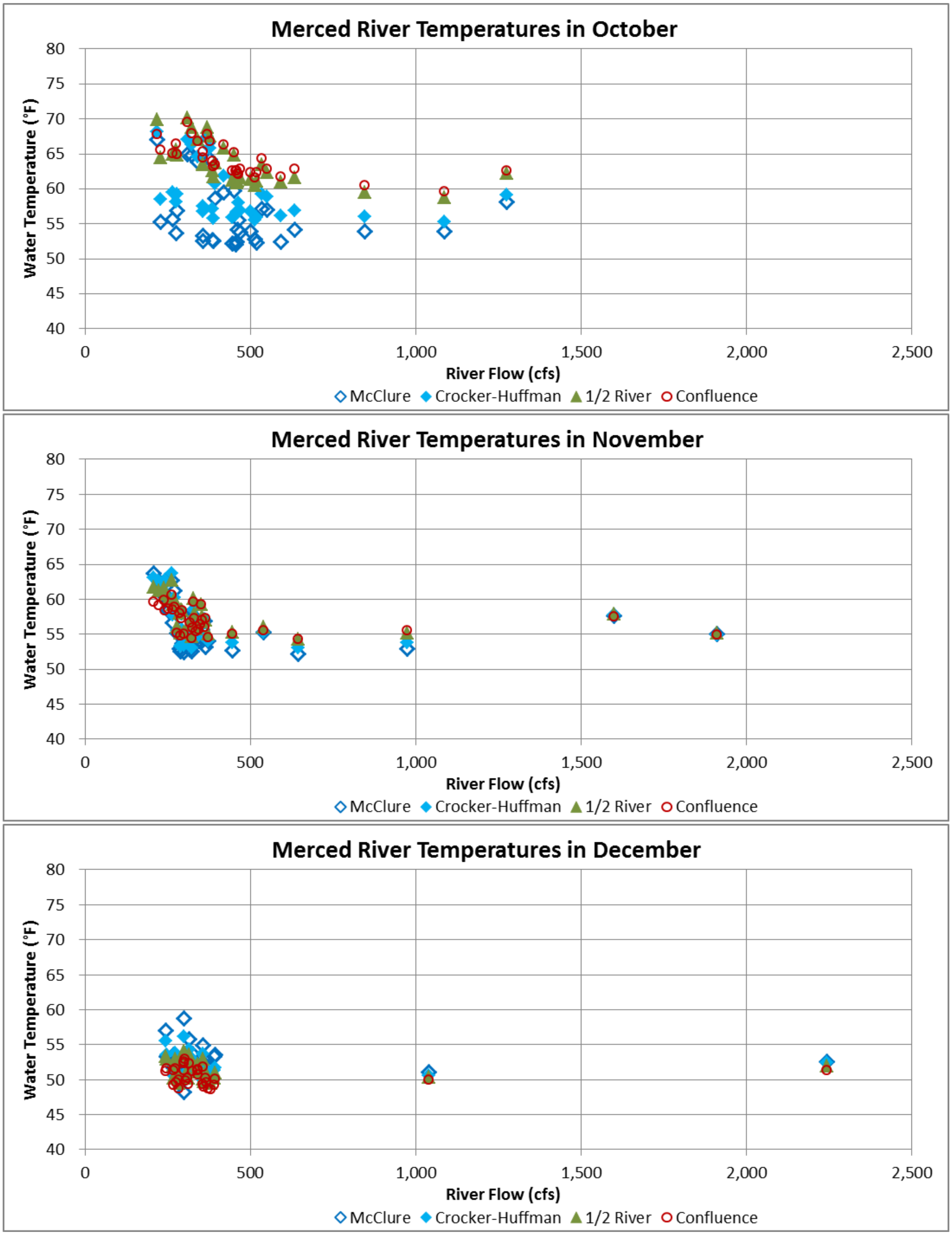


Figure F.1.6-7e. Effects of Merced River Flow on Merced River Water Temperatures October–December for Baseline Conditions 1970–2003

LSJR Alternatives Temperature Results

This discussion focuses on the temperature results for February–June, the period when the LSJR alternatives would most likely affect water temperature. In addition, this discussion focuses on a single location for each tributary, at RM 27.1 on the Merced River, at RM 28.1 on the Tuolumne River, and at RM 28.2 on the Stanislaus River. These are roughly the halfway points between the river confluences with the SJR and the upstream regulating reservoirs. These points were selected because they are good locations for capturing the general effect of flow on water temperature. In Chapter 7, *Aquatic Biological Resources*, and Chapter 19, *Analyses of Benefits to Native Fish Populations from Increased Flow Between February 1 and June 30*, water temperature results are evaluated by focusing on the time of year, river locations, and temperature criteria that are specific to individual Chinook salmon and steelhead life stages in the plan area. The calculated changes under 20, 40, and 60 percent minimum unimpaired flow (LSJR Alternatives 2, 3, and 4) are presented and discussed below. Results for the 30 percent and 50 percent unimpaired flow simulation would be intermediate between the 20 percent and 40 percent and 40 percent and 60 percent unimpaired flow simulations respectively and are shown in summary tables below.

Stanislaus River Temperatures

Figures F.1.6-8a and F.1.6-8b show the monthly average temperatures in the Stanislaus River at RM 28.2 simulated with the temperature model for baseline conditions and the LSJR alternatives plotted as a function of the monthly river flow at Ripon for February–June. For February, the temperatures were generally 47°F–55°F. The warmest temperatures corresponded to flows of less than 500 cfs. Although the LSJR alternatives generally increased flows relative to baseline in February, these flow changes generally had very little effect on RM 28.2 temperatures (generally less than 1°F change in cumulative distribution values). Because there is little meteorological warming in February, river flow increases would not substantially reduce water temperatures. In March, simulated temperatures in the Stanislaus River at RM 28.2 were 50°F–55°F when river flow was 500 cfs or more and generally increased to 54°F–60°F when river flows were less than 500 cfs. Because the March flows under LSJR Alternative 3 and 4 were generally higher than baseline flows, water temperatures tended to be lower. However, there were no substantial effects on water temperatures because meteorological warming at RM 28.2 was limited in March and water temperatures generally remained cool. The warmest temperatures were simulated for low flows of less than 500 cfs, but these temperatures were less than 60°F.

In April, the range of simulated temperatures at RM 28.2 was 50°F–62°F, with the warmer temperatures of 55°F–62°F generally simulated for the lower flows (less than 1,000 cfs). Because the April flows were always about 500 cfs or greater, no temperatures greater than 62°F were simulated. In May, the range of simulated temperatures at RM 28.2 was 53°F–66°F, which is 3°F–4°F warmer than in April. The warmer temperatures of 60°F–66°F in May were generally simulated for the lower flows (less than 1,000 cfs). Because the May flows were always about 500 cfs or greater, no temperatures of greater than 66°F were simulated in May at RM 28.2. In June, the flows were lower (lowest of about 250 cfs), and the temperatures were sometimes considerably warmer than in April and May, ranging from 55°F–70°F. The warmer temperatures of 65°F–70°F were generally simulated for the lower flows (less than 500 cfs).

The Stanislaus River warming curves (flow versus temperature) at RM 28.2 in April, May, and June indicate the general relationship between river flow and water temperatures in the upstream portion of the Stanislaus River. These figures suggest that temperature is more responsive to changes in flow when flow is less than 1,000 cfs and during warmer conditions (i.e., June).

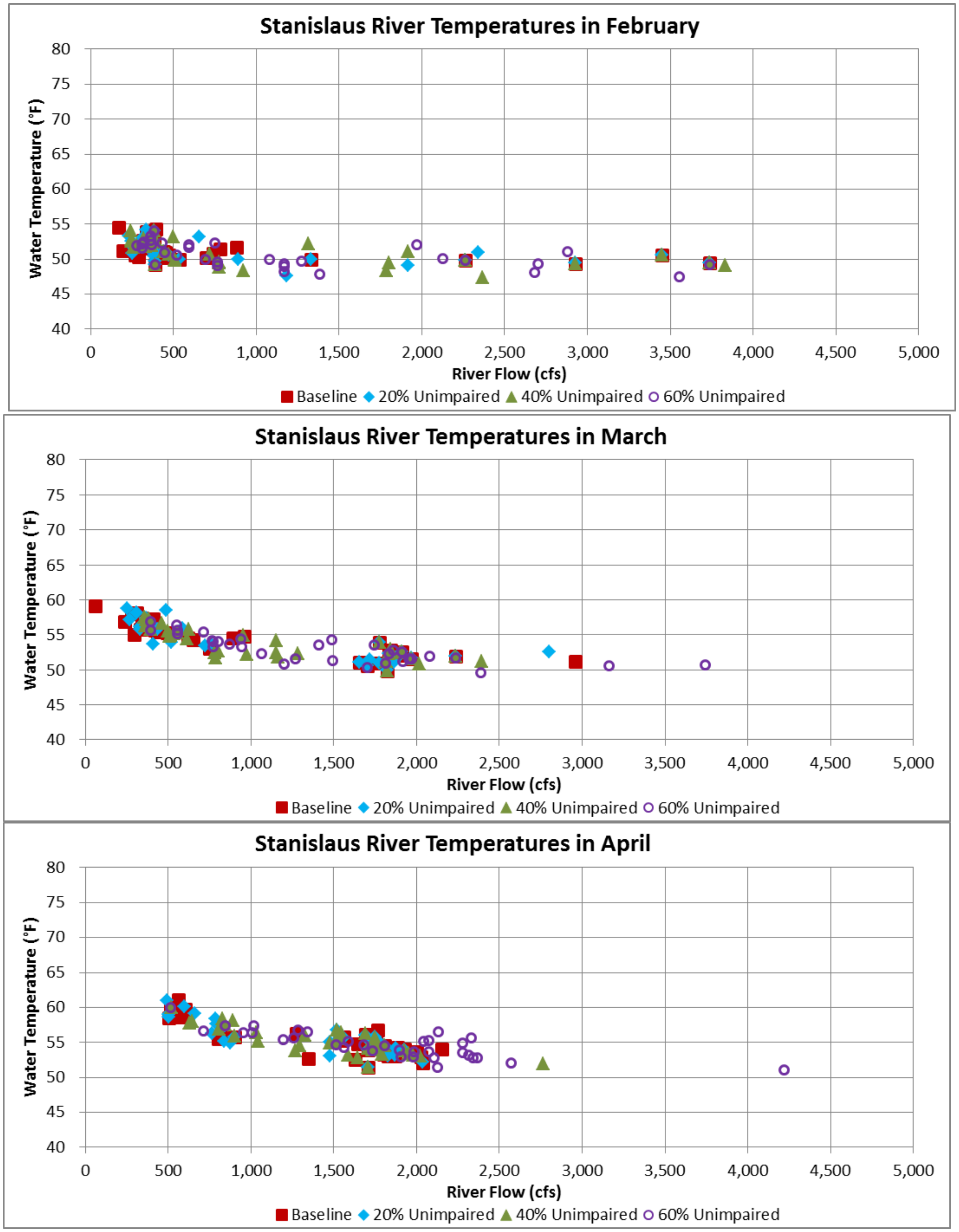


Figure F.1.6-8a. Effects of Stanislaus River Flows on Temperatures at RM 28.2 February–April for Baseline Conditions and 20%, 40%, 60% Unimpaired Flow (LSJR Alternatives 2–4) 1970–2003

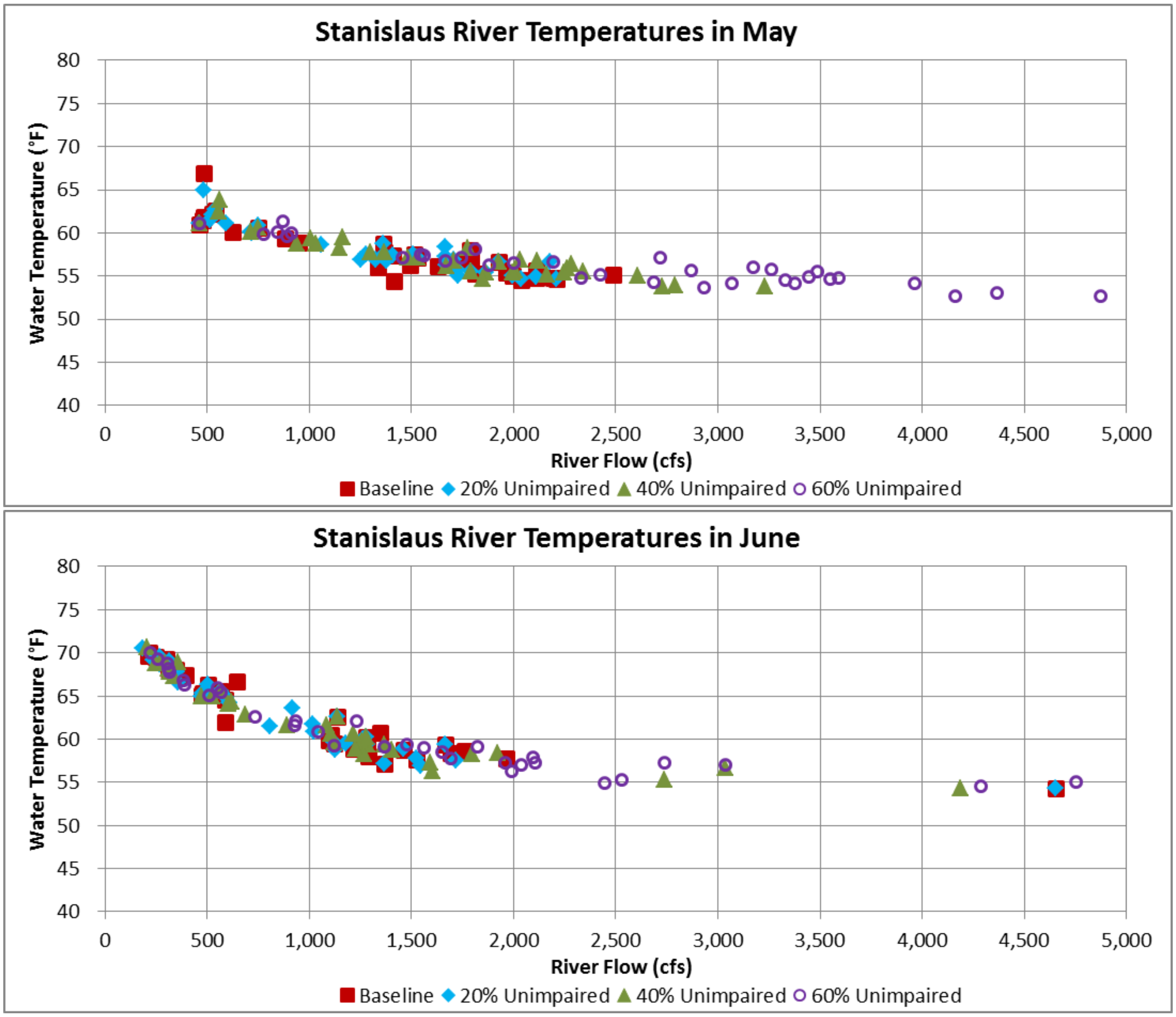


Figure F.1.6-8b. Effects of Stanislaus River Flows on Temperatures at Riverbank in May and June for Baseline Conditions and 20%, 40%, 60% Unimpaired Flow (LSJR Alternatives 2–4) 1970–2003

Tables F.1.6-2a and F.1.6-2b give the monthly cumulative distributions of average simulated water temperatures in the Stanislaus River at RM 28.2 for 1970–2003 under baseline conditions and the change in the distribution under the LSJR alternatives. Baseline average water temperatures at RM 28.2 indicate the average seasonal warming January–July is about 20°F. The monthly increase in the average temperatures February–May was about 2°F–3°F per month, and the monthly increase May–July was about 5°F–6°F per month.

Changes in temperature associated with the LSJR alternatives were dependent on the combination of change in flow and amount of meteorological warming (i.e., difference between reservoir release temperatures and equilibrium temperatures). Overall average temperature decreased by more than 1°F under the 60 percent and 50 percent unimpaired flow objectives for the months of March, May, and June.

Figures F.1.6-9, F.1.6-10, F.1.6-11, and F.1.6-12 show Stanislaus River temperature model results under baseline conditions and under LSJR Alternatives 2 and 3 (40 and 60 percent of unimpaired flow objectives Feb–June) for the water years 1985–1989, 1990–1994, 1995–1999, and 2000–2003, respectively. Each figure is composed of three separate charts to compare how reservoir storage and river flow can affect temperatures at different points along the river. Chart A shows reservoir storage at New Melones, Chart B shows the instream flows at Ripon, and Chart C gives the daily 7DADM temperature at New Melones release, Goodwin release, and 1/4 River location.

Figures F.1.6-13a and F.1.6-13b show temperature model 7DADM results at Orange Blossom Bridge (OBB) compared to monthly U.S. Environmental Protection Agency (USEPA) temperature criteria for optimal development of different fish lifestages (as described in Chapter 19) under LSJR Alternatives 2 and 3 (40 and 60 percent of unimpaired flow Feb–June) and baseline conditions for water years 1985–1989 and water years 1990–1994, respectively. These show temperature effects of reservoir levels within the major drought sequence 1989–1993.

Figures F.1.6-14, F.1.6-15, F.1.6-16, F.1.6-17, F.1.6-18, and F.1.6-19 show longitudinal monthly average 7DADM temperature results for each month of the water year 1988 under baseline conditions and the LSJR alternatives. Water year 1988 is shown because it represents a year when New Melones Reservoir storage levels were around 1 million acre feet (about half storage) under the model scenarios. Figures F.1.6-20, F.1.6-21, F.1.6-22, F.1.6-23, F.1.6-24, and F.1.6-25 show longitudinal monthly average 7DADM temperature results for each month of the water year 1990 under baseline conditions and the LSJR alternatives. Water year 1990 is shown because it represents a year in the middle of the 1989–1992 drought sequence when reservoir storage would have been low.

Table F.1.6-2a. Monthly Distribution of Stanislaus River Water Temperatures at RM 28.2 1970–2003 for Baseline Conditions and 20%, 40%, 60% Unimpaired Flow (LSJR Alternatives 2–4)

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Stanislaus River Temperatures at RM 28.2 for Baseline Conditions												
Minimum	52.4	50.0	48.0	46.2	48.4	49.2	51.4	54.4	54.3	54.8	56.6	54.5
10%	55.6	53.6	48.6	47.2	49.5	51.0	52.7	54.7	57.8	64.7	64.5	61.1
20%	56.7	53.8	49.0	48.1	50.1	51.7	53.2	55.2	58.7	66.6	66.6	63.9
30%	56.8	54.0	49.4	48.4	50.5	52.5	54.0	56.0	59.3	67.6	67.6	64.3
40%	57.3	54.2	50.1	48.9	50.9	54.0	54.3	56.7	60.3	68.1	67.9	65.0
50%	57.4	55.0	50.5	49.3	51.2	54.7	55.1	57.1	62.3	68.7	68.5	65.6
60%	58.6	55.8	50.7	49.6	51.7	55.4	55.6	57.7	65.2	69.8	68.9	66.2
70%	59.1	56.4	51.0	49.8	51.9	55.8	55.9	58.9	66.3	70.8	69.6	67.1
80%	60.9	57.1	51.4	50.3	52.6	57.0	57.4	60.8	68.1	72.4	72.1	69.2
90%	65.3	57.5	51.7	50.9	53.8	57.3	59.4	62.1	69.4	73.0	72.8	70.8
Maximum	66.6	60.2	52.6	52.4	54.5	59.1	61.1	66.9	70.0	74.5	75.6	72.2
Average	58.8	55.4	50.2	49.2	51.3	54.3	55.4	57.9	63.0	68.7	68.3	65.6
Change in Stanislaus River Temperatures at RM 28.2 for 20% Unimpaired Flow Relative to Baseline												
Minimum	0.2	0.2	0.0	0.0	-0.8	0.0	0.0	0.3	0.0	0.0	0.0	-0.3
10%	0.0	0.0	0.0	0.1	-0.2	0.0	0.4	0.3	-0.2	1.4	1.1	1.1
20%	-0.1	-0.1	0.0	0.0	-0.3	-0.4	0.5	0.4	0.5	0.1	-0.2	-0.2
30%	-0.1	0.0	-0.1	0.0	-0.6	-0.5	0.0	0.6	0.3	-0.6	-0.4	-0.2
40%	-0.2	0.0	-0.3	0.2	-0.3	-1.2	0.6	0.2	0.7	-0.1	-0.4	-0.1
50%	-0.1	-0.5	-0.3	0.0	-0.3	-0.9	0.0	0.1	0.8	-0.1	-0.5	-0.1
60%	-0.1	-0.4	-0.3	0.0	0.1	0.4	0.0	-0.2	-0.3	-0.4	0.0	-0.1
70%	-0.2	-0.7	-0.3	0.0	0.4	0.2	0.2	-0.3	-0.7	-0.6	-0.1	-0.1
80%	-1.6	-0.7	-0.2	-0.2	0.2	0.1	0.1	-0.4	-0.2	-0.8	-1.2	-0.6
90%	-4.5	-0.6	-0.3	-0.2	-0.6	0.6	-0.6	-0.8	-0.5	-0.3	-0.7	-1.4
Maximum	-4.5	-2.6	-0.3	0.0	-0.3	-0.4	-0.1	-1.9	0.5	-0.7	-1.6	-1.7
Average	-0.9	-0.5	-0.2	0.0	-0.2	-0.2	0.1	0.0	0.0	-0.2	-0.4	-0.4
Change in Stanislaus River Temperatures at RM 28.2 for 40% Unimpaired Flow Relative to Baseline												
Minimum	1.6	0.3	0.0	0.0	-1.0	0.0	0.0	-0.7	0.1	0.4	0.0	1.3
10%	-0.2	0.0	0.1	0.0	-1.0	0.1	0.3	0.0	-1.0	-1.9	1.2	-0.4
20%	-0.8	0.1	0.0	0.0	-0.8	0.0	0.2	0.1	-0.3	-3.0	-0.3	-2.6
30%	-0.6	0.1	0.0	0.2	-1.1	-0.3	-0.1	-0.4	0.0	-2.9	-0.5	-2.2
40%	-0.7	0.0	-0.3	0.1	-1.0	-1.6	0.2	-0.5	-0.5	-1.2	-0.3	-1.0
50%	-0.1	-0.1	-0.3	0.0	-0.6	-1.9	-0.1	-0.3	-1.1	-0.5	-0.6	-0.7
60%	-0.6	-0.3	-0.2	-0.1	0.0	-1.0	0.0	-0.5	-2.4	-0.6	0.1	-0.1
70%	-0.4	-0.7	-0.2	0.0	0.1	-0.9	0.4	-0.7	-1.4	0.0	0.0	0.6
80%	-1.9	-0.8	-0.3	-0.2	0.0	-1.3	-0.6	-1.8	-0.5	-1.1	-1.3	-0.8
90%	-5.4	-0.6	-0.2	-0.2	-0.9	-0.8	-1.4	-1.6	-0.7	-0.4	-0.6	-1.3
Maximum	-5.0	-2.8	-0.4	0.0	-0.5	-1.6	-1.1	-3.0	0.7	-1.0	-1.6	-1.6
Average	-1.3	-0.4	-0.1	0.0	-0.5	-0.8	-0.2	-0.7	-0.9	-1.1	-0.1	-0.8
Change in Stanislaus River Temperatures at RM 28.2 for 60% Unimpaired Flow Relative to Baseline												
Minimum	2.3	2.1	-0.2	0.0	-0.9	0.0	-0.3	-1.7	-1.0	3.2	2.8	1.6
10%	0.0	0.1	0.2	-0.2	-1.2	-0.4	0.1	-1.0	-2.6	-2.3	0.5	-0.1

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
20%	-0.1	0.4	0.2	-0.2	-1.0	-0.6	-0.2	-1.0	-1.7	-3.3	0.1	-2.1
30%	0.0	0.3	0.2	0.1	-1.2	-0.9	-0.4	-1.2	-2.0	-2.9	-0.1	-1.5
40%	-0.2	0.4	-0.2	0.4	-1.2	-2.0	-0.4	-1.4	-1.7	-1.1	0.0	-0.5
50%	0.2	-0.1	-0.3	0.1	-1.2	-2.0	-0.4	-1.2	-3.0	-0.1	-0.1	0.0
60%	-0.5	-0.2	-0.1	0.0	-0.6	-1.9	-0.5	-1.1	-3.8	0.2	0.9	1.1
70%	-0.3	-0.6	-0.2	0.0	0.1	-1.8	-0.2	-1.8	-3.5	-0.1	0.8	0.8
80%	-1.6	-0.9	-0.1	-0.1	-0.4	-2.7	-1.0	-3.1	-2.1	-0.8	-1.0	-0.5
90%	-5.4	-0.4	-0.1	-0.2	-1.4	-1.8	-2.7	-2.2	-1.4	-0.3	-0.5	-1.3
Maximum	-4.7	-2.5	-0.4	0.1	-0.5	-2.2	-1.2	-5.5	0.0	-1.2	-1.4	-1.5
Average	-0.9	-0.2	-0.1	0.0	-0.9	-1.5	-0.7	-1.7	-2.2	-1.0	0.3	-0.3

Table F.1.6-2b. Monthly Change in Distribution of Stanislaus River Water Temperatures at RM 28.2 1970–2003 for Baseline Conditions and 20%, 40%, 60% Unimpaired Flow (LSJR Alternatives 2–4)

Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Average Stanislaus River Temperatures at RM 28.2											
Baseline Average											
58.8	55.4	50.2	49.2	51.3	54.3	55.4	57.9	63.0	68.7	68.3	65.6
Change in Average Stanislaus River Temperatures at RM 28.2 relative to Baseline											
20% Unimpaired Flow Minus Baseline											
-0.9	-0.5	-0.2	0.0	-0.2	-0.2	0.1	0.0	0.0	-0.2	-0.4	-0.4
30% Unimpaired Flow Minus Baseline											
-0.7	-0.4	-0.1	0.0	-0.4	-0.6	-0.1	-0.4	-0.4	-0.5	-0.1	-0.2
40% Unimpaired Flow Minus Baseline											
-1.3	-0.4	-0.1	0.0	-0.5	-0.8	-0.2	-0.7	-0.9	-1.1	-0.1	-0.8
50% Unimpaired Flow Minus Baseline											
-1.1	-0.3	-0.1	0.0	-0.7	-1.1	-0.5	-1.2	-1.6	-1.1	0.1	-0.6
60% Unimpaired Flow Minus Baseline											
-0.9	-0.2	-0.1	0.0	-0.9	-1.5	-0.7	-1.7	-2.2	-1.0	0.3	-0.3

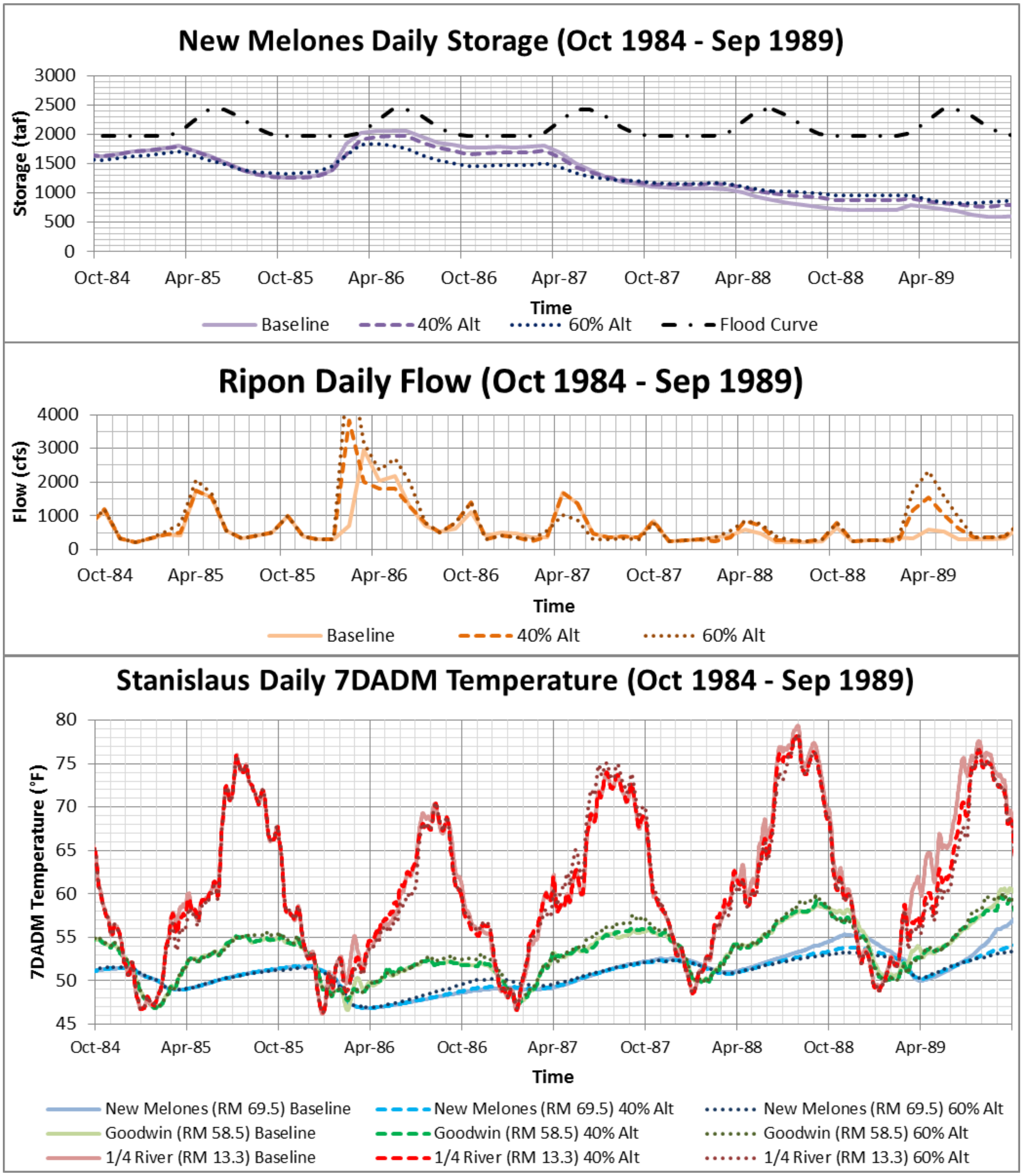


Figure F.1.6-9. Stanislaus River Temperature Model Results for LSJR Alternatives 2 and 3 (40% and 60% of Unimpaired Flow Feb–June) and Baseline for Water Years 1985–1989, Showing (a) Reservoir Storage, (b) Instream Flows, and (c) Daily 7DADM Temperature at New Melones Release, Goodwin Release, and 1/4 River Locations

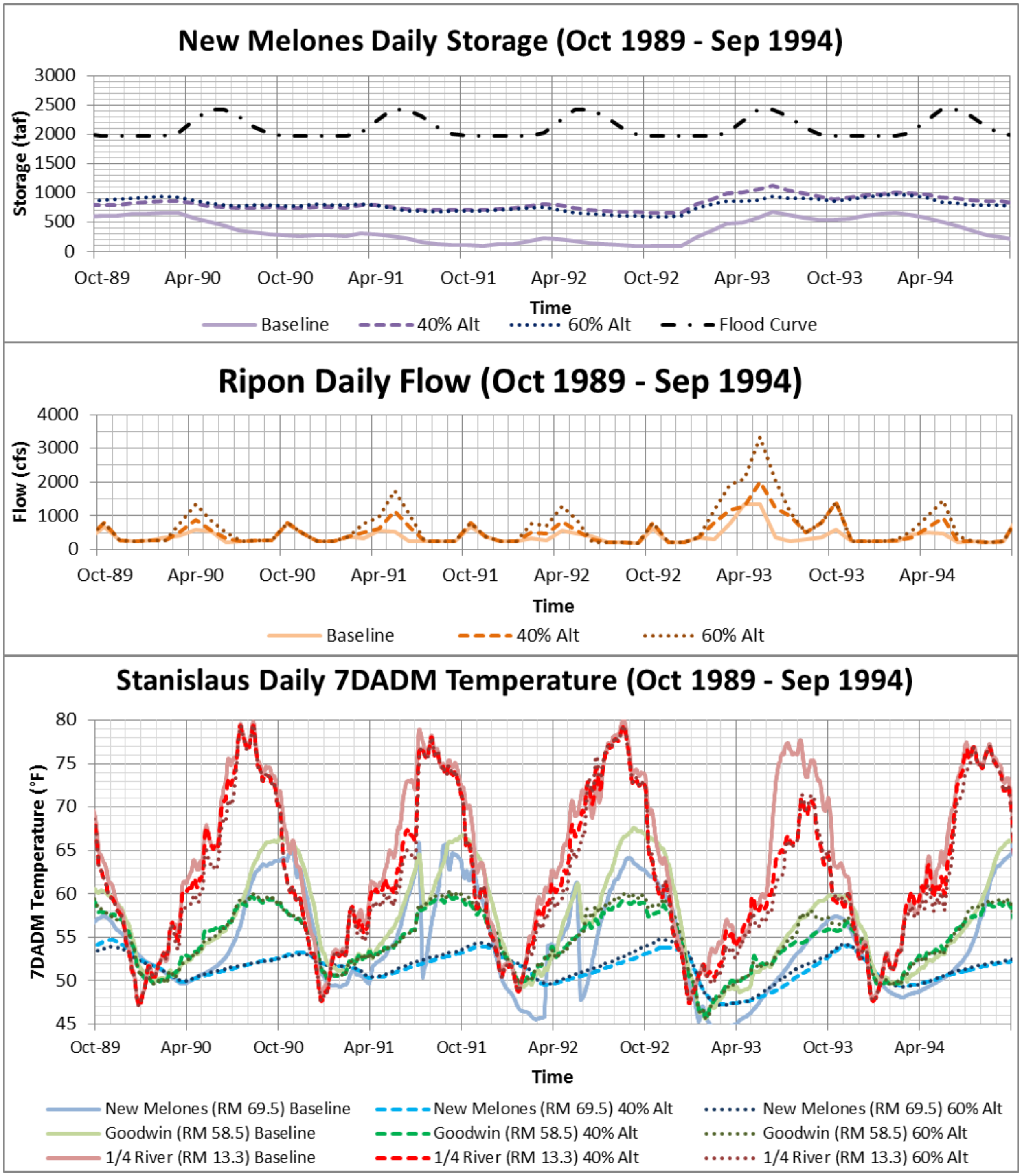


Figure F.1.6-10. Stanislaus River Temperature Model Results for LSJR Alternatives 2 and 3 (40% and 60% of Unimpaired Flow Feb–June) and Baseline for Water Years 1990–1994, Showing (a) Reservoir Storage, (b) Instream Flows, and (c) Daily 7DADM Temperature at New Melones Release, Goodwin Release, and 1/4 River Locations

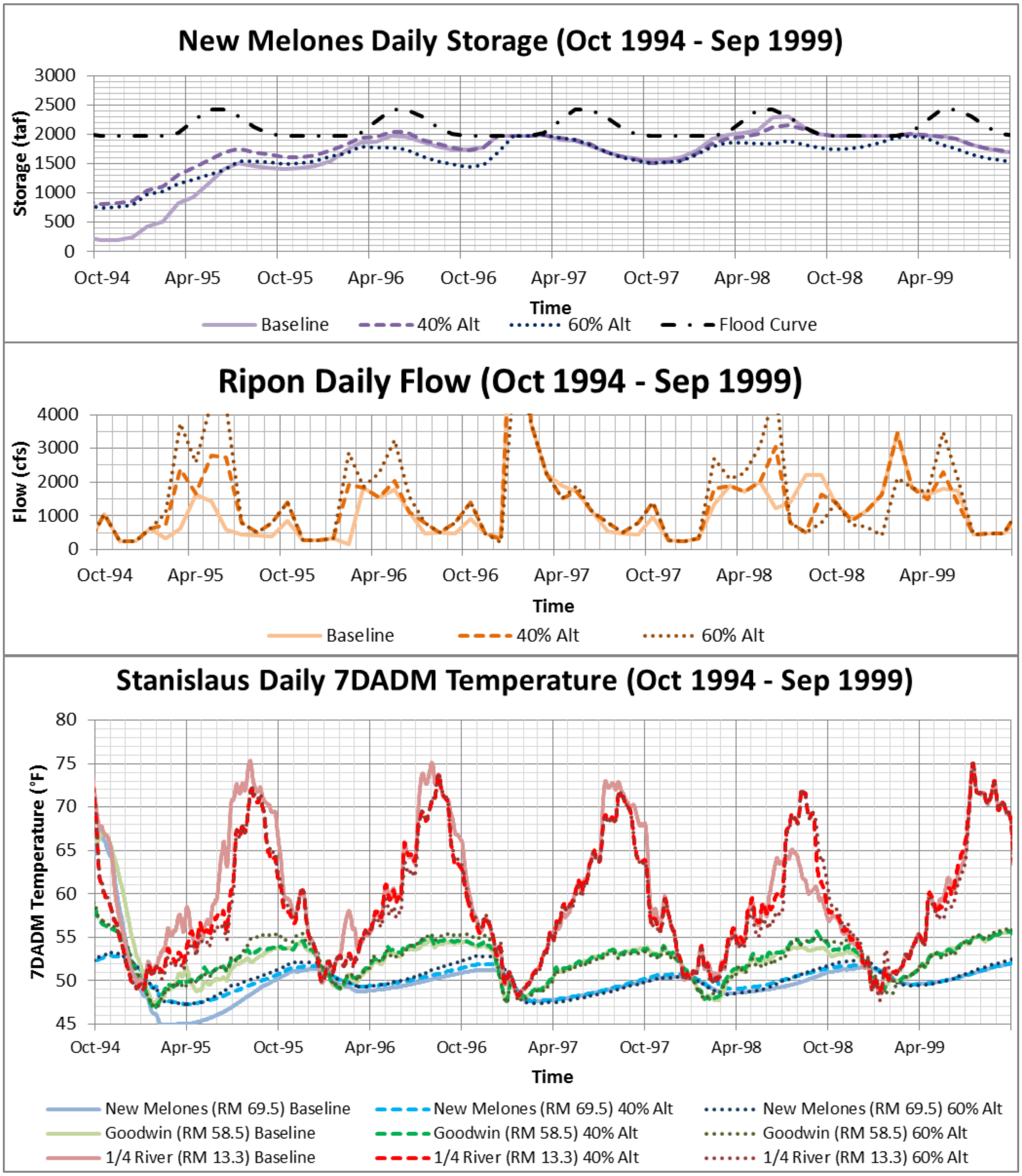


Figure F.1.6-11. Stanislaus River Temperature Model Results for LSJR Alternatives 2 and 3 (40% and 60% of Unimpaired Flow Feb–June) and Baseline for Water Years 1995–1999, Showing (a) Reservoir Storage, (b) Instream Flows, and (c) Daily 7DADM Temperature at New Melones Release, Goodwin Release, and 1/4 River Locations

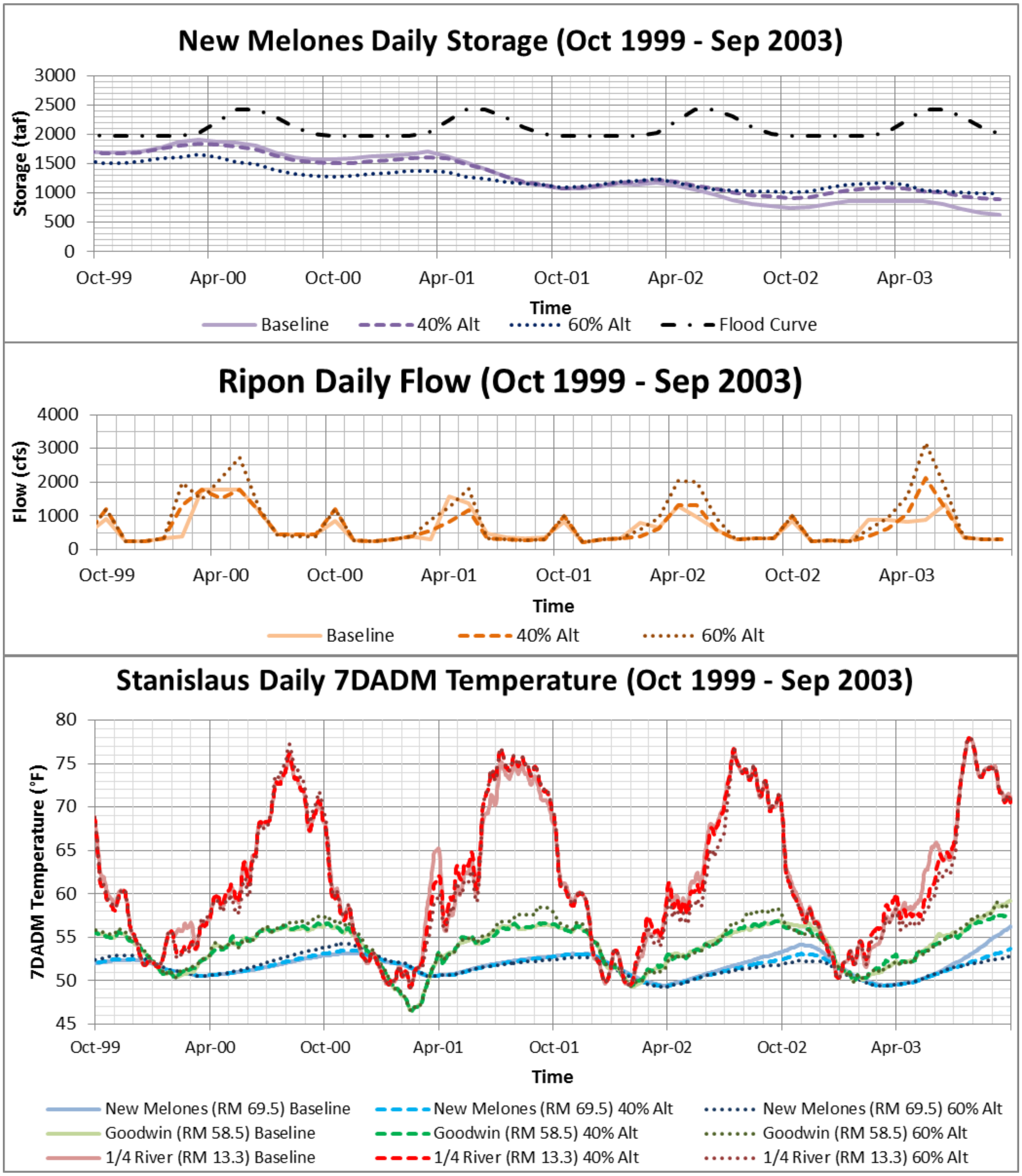
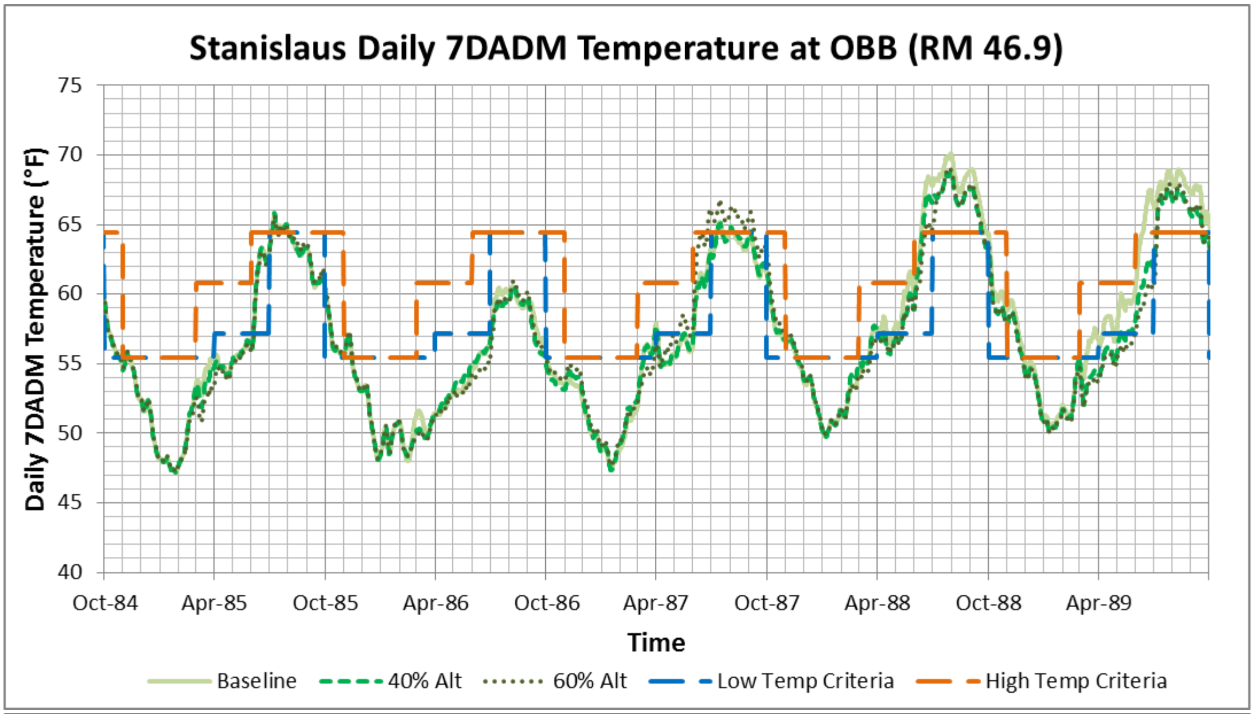


Figure F.1.6-12. Stanislaus River Temperature Model Results for LSJR Alternatives 2 and 3 (40% and 60% of Unimpaired Flow Feb–June) and Baseline for Water Years 2000–2003, Showing (a) Reservoir Storage, (b) Instream Flows, and (c) Daily 7DADM Temperature at New Melones Release, Goodwin Release, and 1/4 River Locations



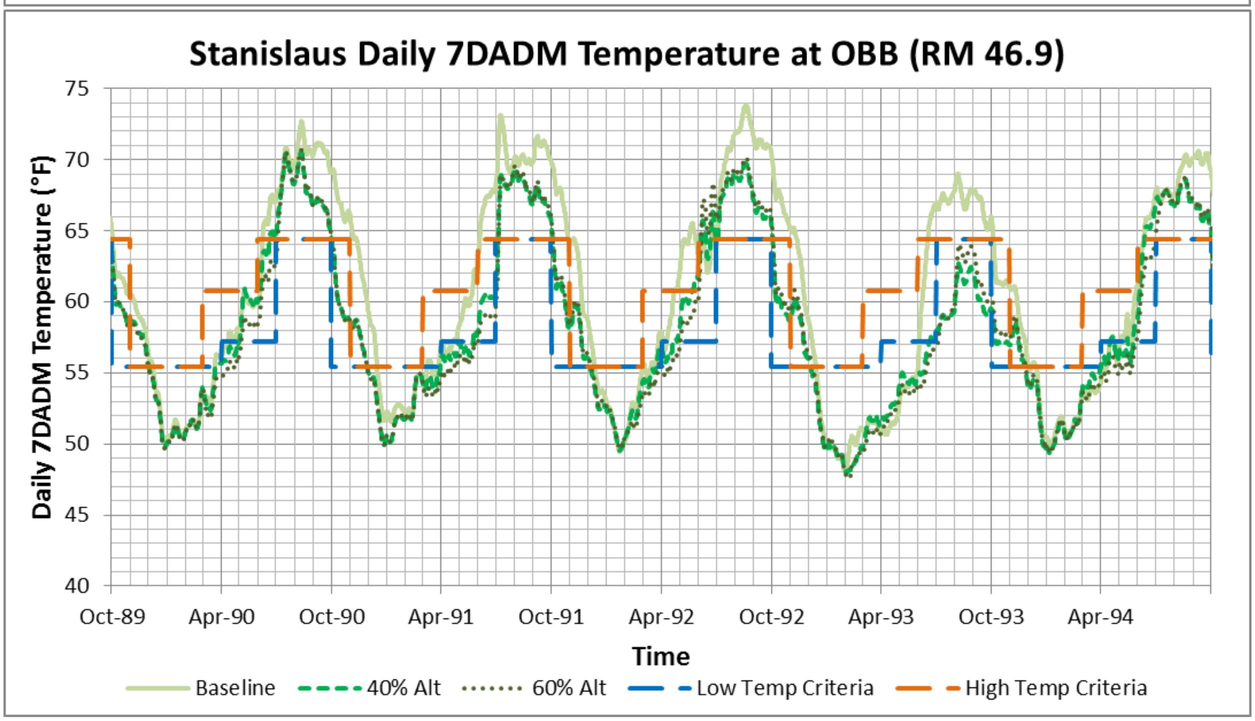
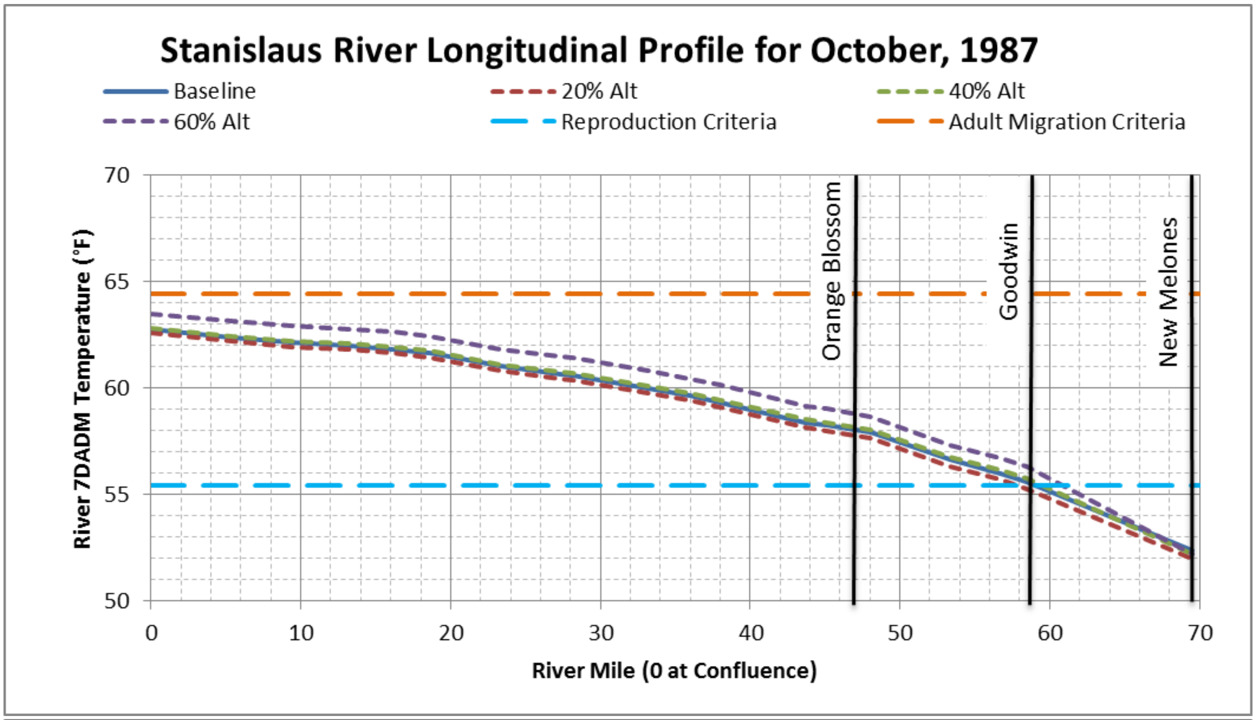


Figure F.1.6-13. Temperature Model 7DADM Results at OBB in the Stanislaus River Compared to Monthly USEPA Temperature Criteria for Optimal Development of Different Fish Lifestages under LSJR Alternatives 2 and 3 (40% and 60% of Unimpaired Flow Feb–June) for (a) Water Years 1985–1989 and (b) Water Years 1990–1994



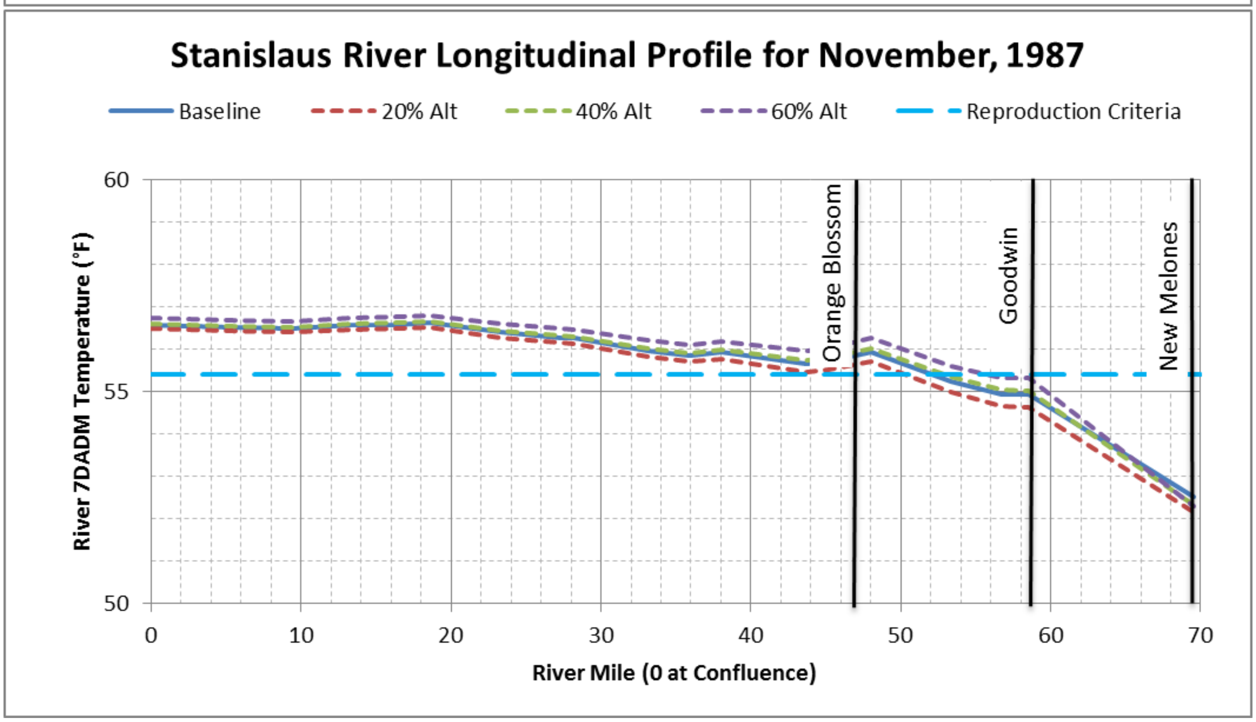
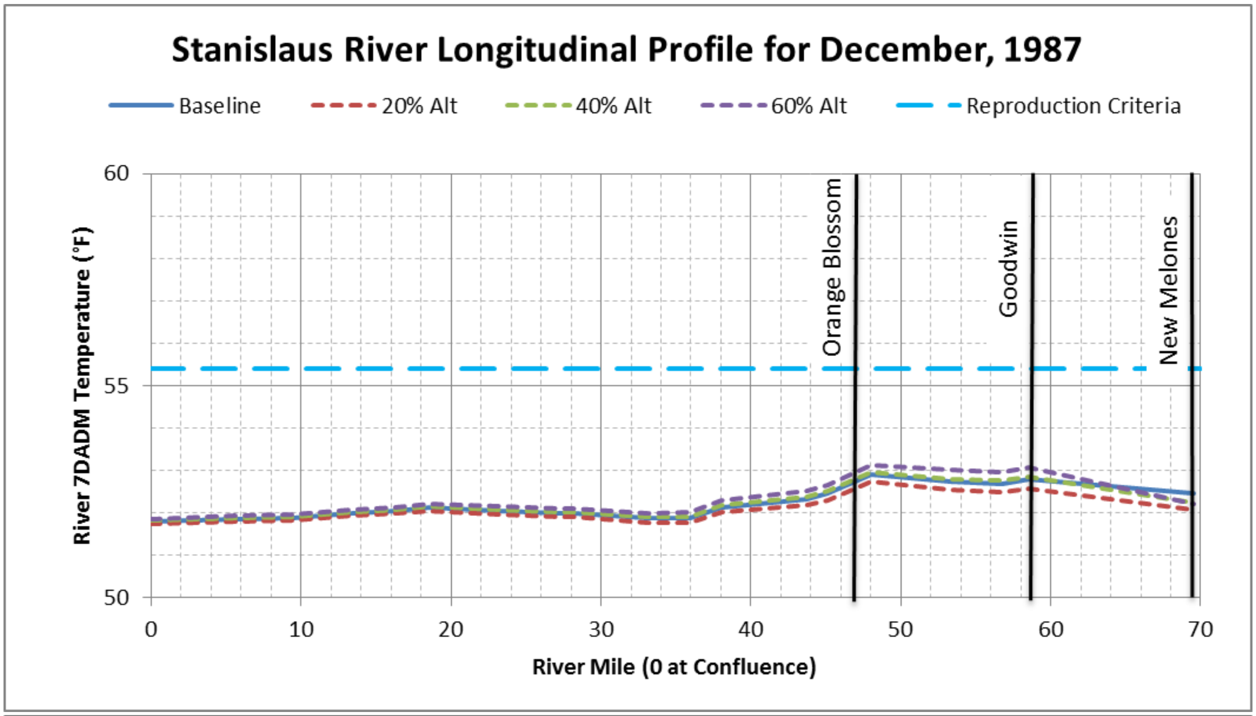


Figure F.1.6-14. Longitudinal Monthly Average 7DADM Temperature Results within the Stanislaus River for (a) October 1987 and (b) November 1987



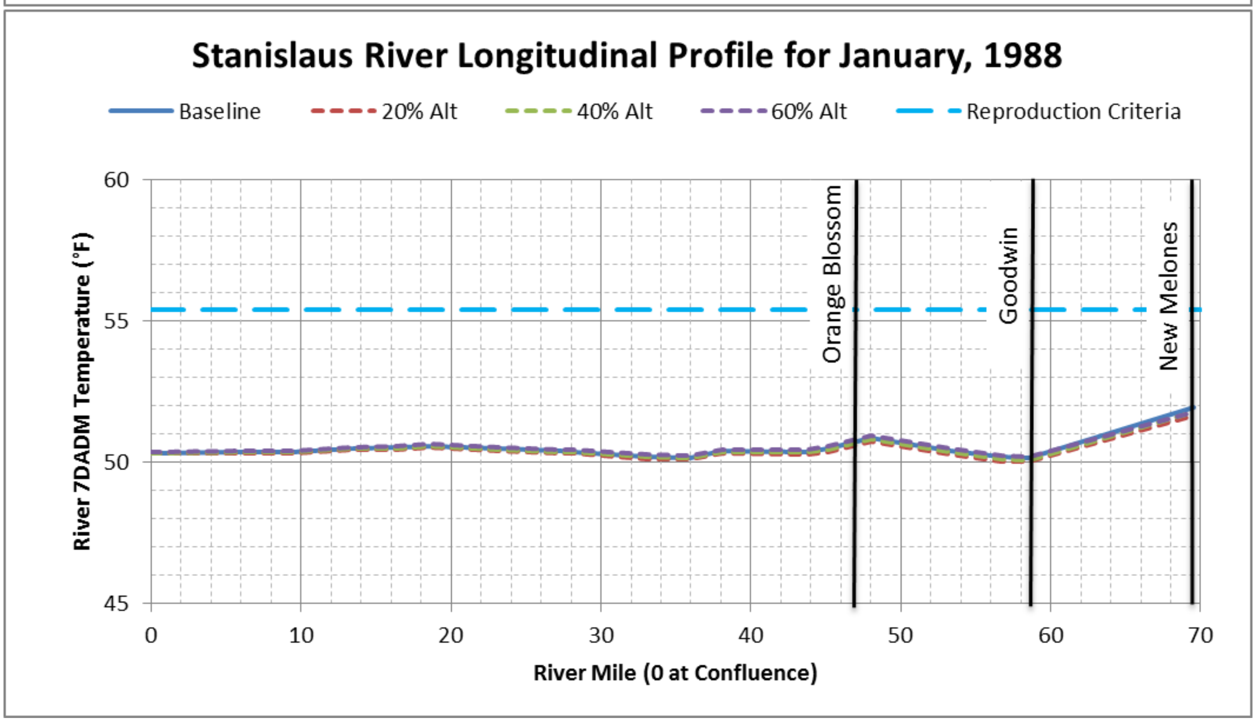
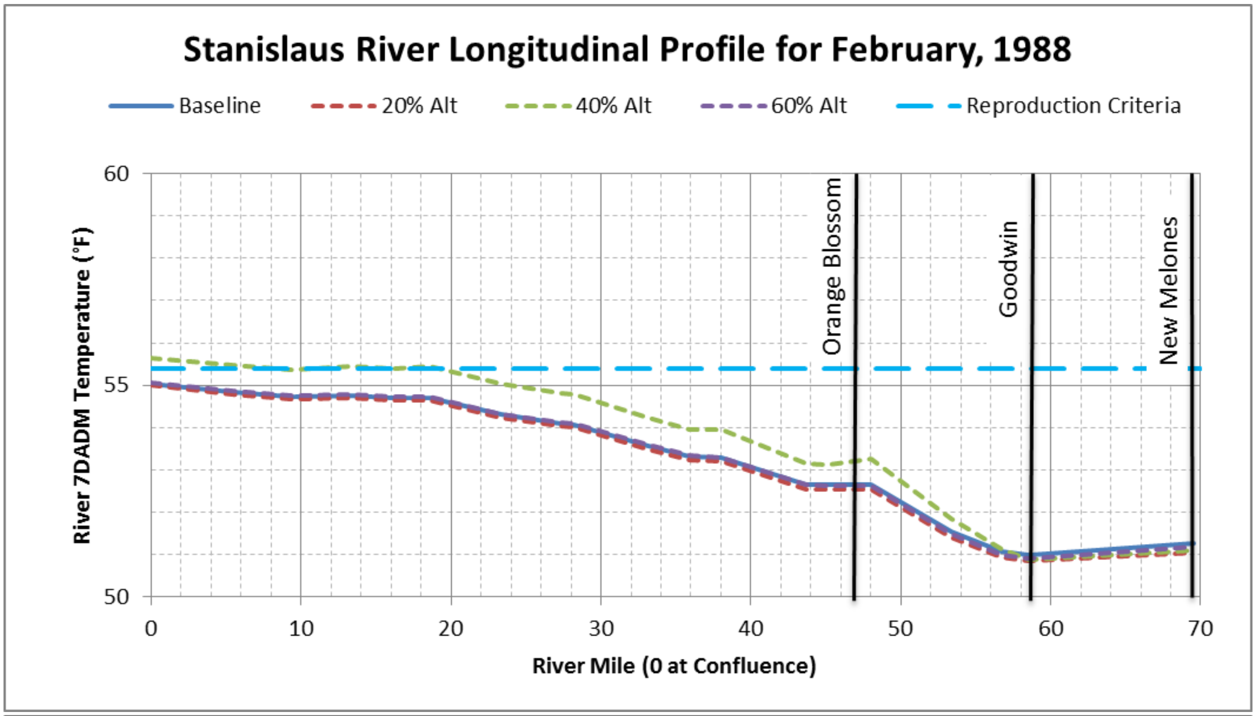


Figure F.1.6-15. Longitudinal Monthly Average 7DADM Temperature Results within the Stanislaus River for (a) December 1987 and (b) January 1988



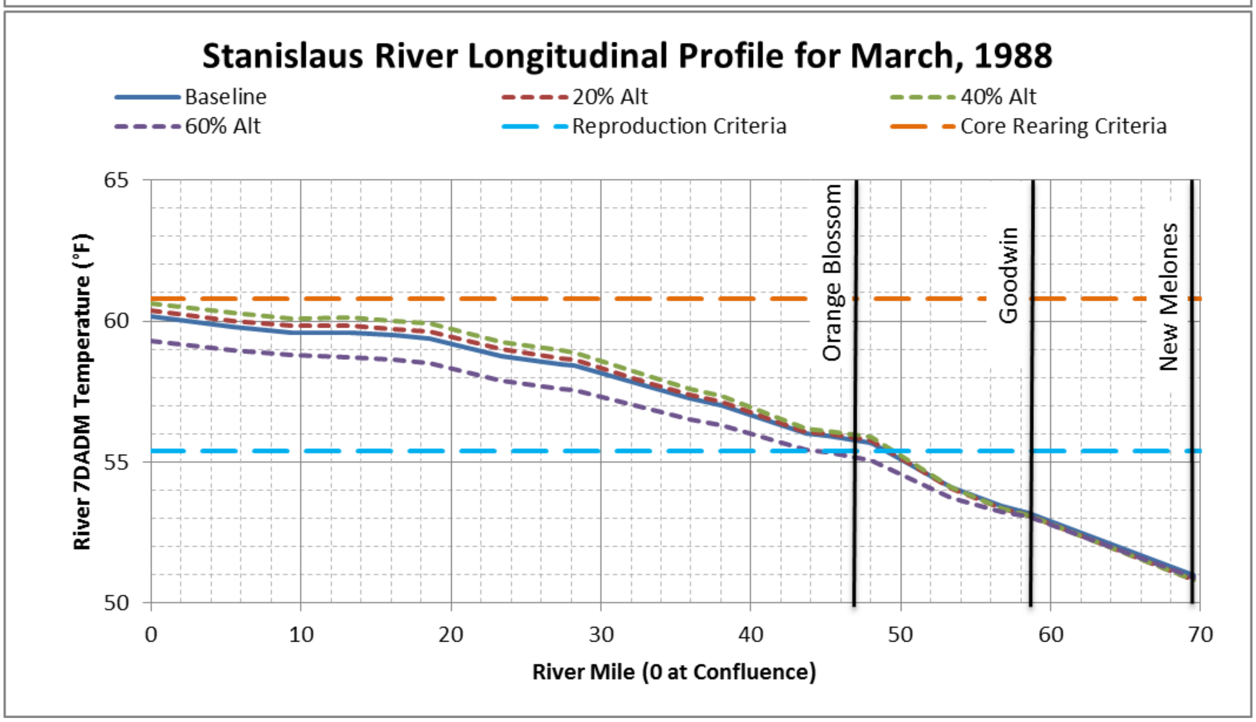
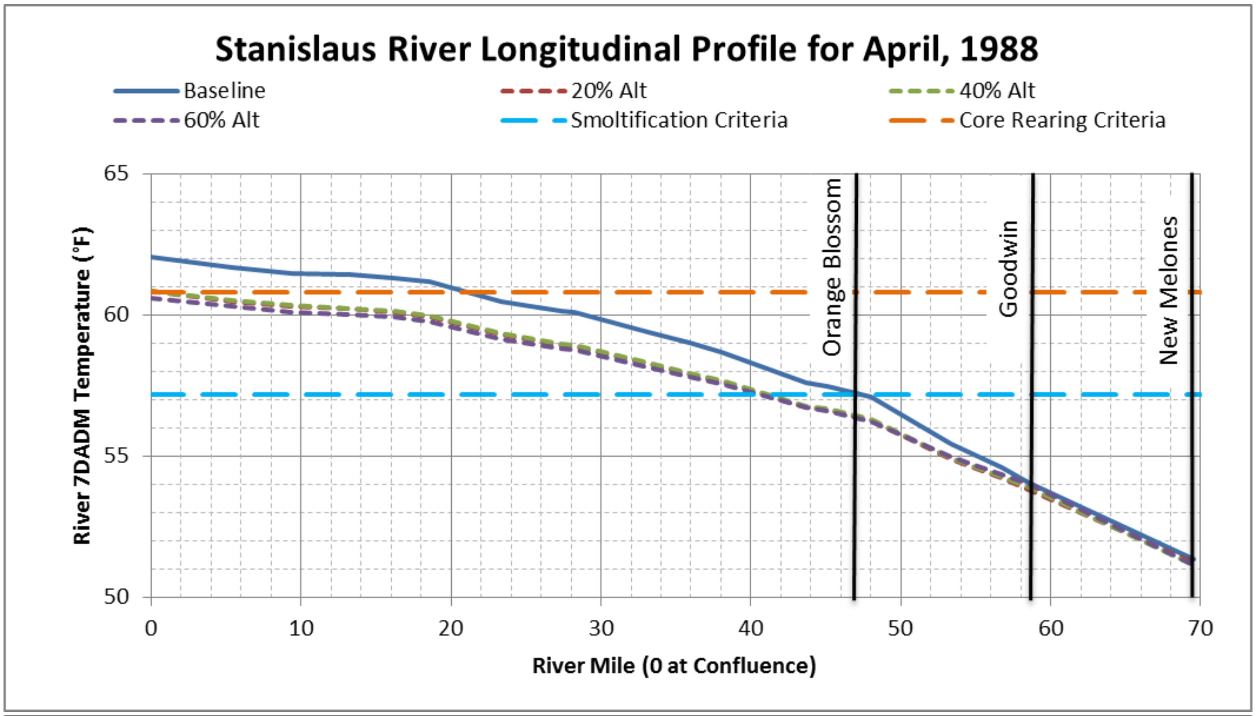


Figure F.1.6-16. Longitudinal Monthly Average 7DADM Temperature Results within the Stanislaus River for (a) February 1988 and (b) March 1988



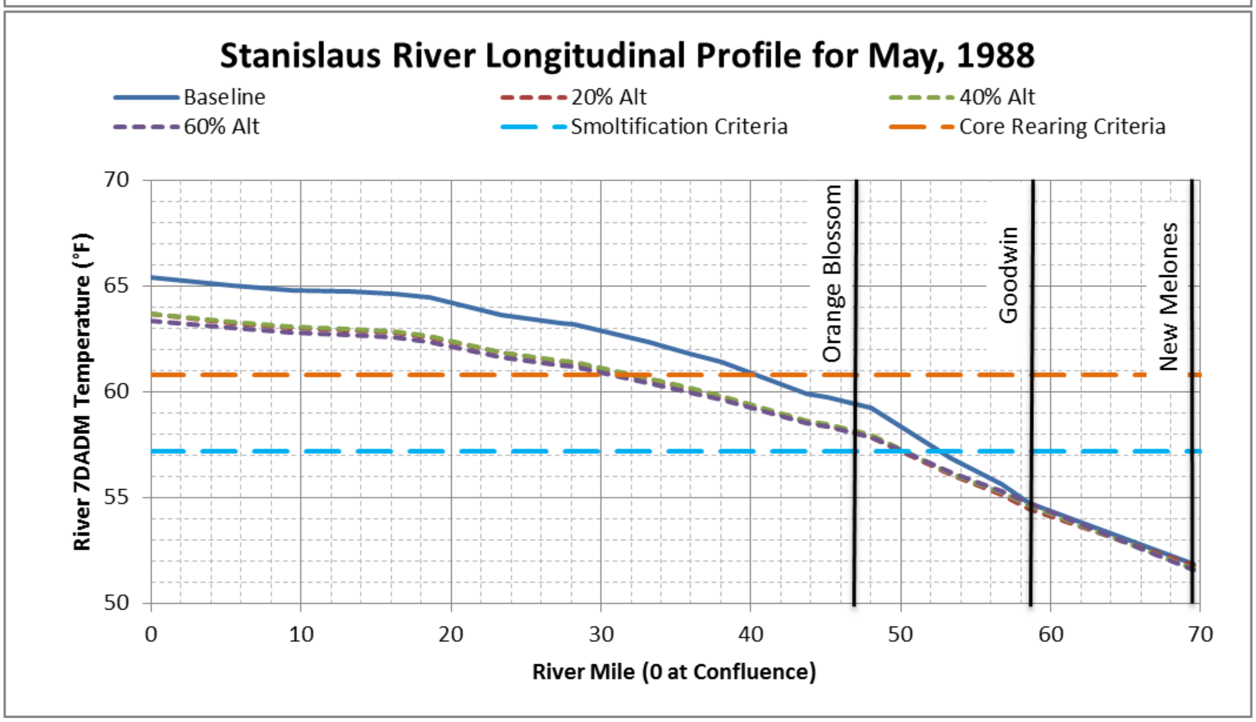


Figure F.1.6-17. Longitudinal Monthly Average 7DADM Temperature Results within the Stanislaus River for (a) April 1988 and (b) May 1988

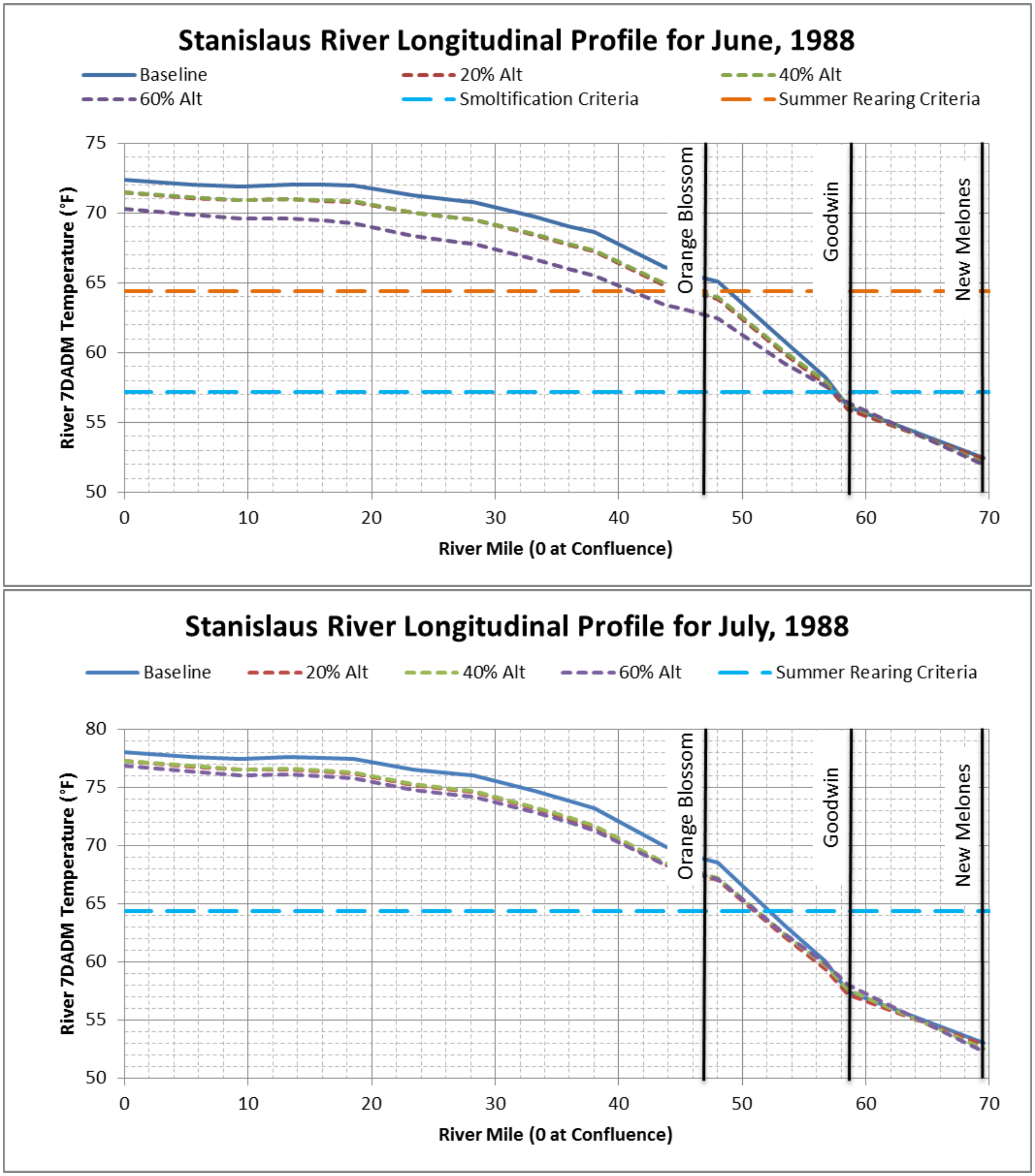


Figure F.1.6-18. Longitudinal Monthly Average 7DADM Temperature Results within the Stanislaus River for (a) June 1988 and (b) July 1988

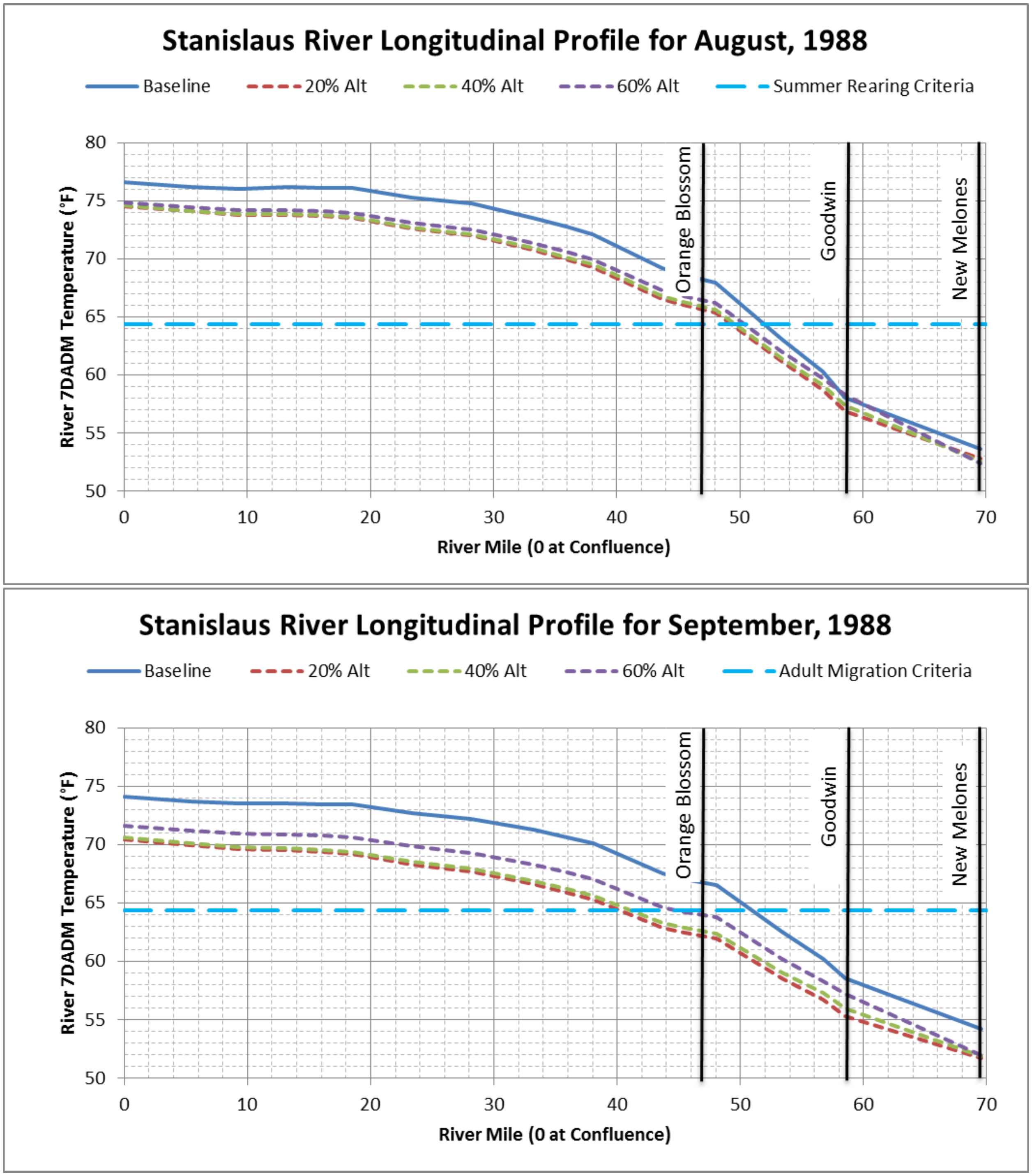


Figure F.1.6-19. Longitudinal Monthly Average 7DADM Temperature Results within the Stanislaus River for (a) August 1988 and (b) September 1988

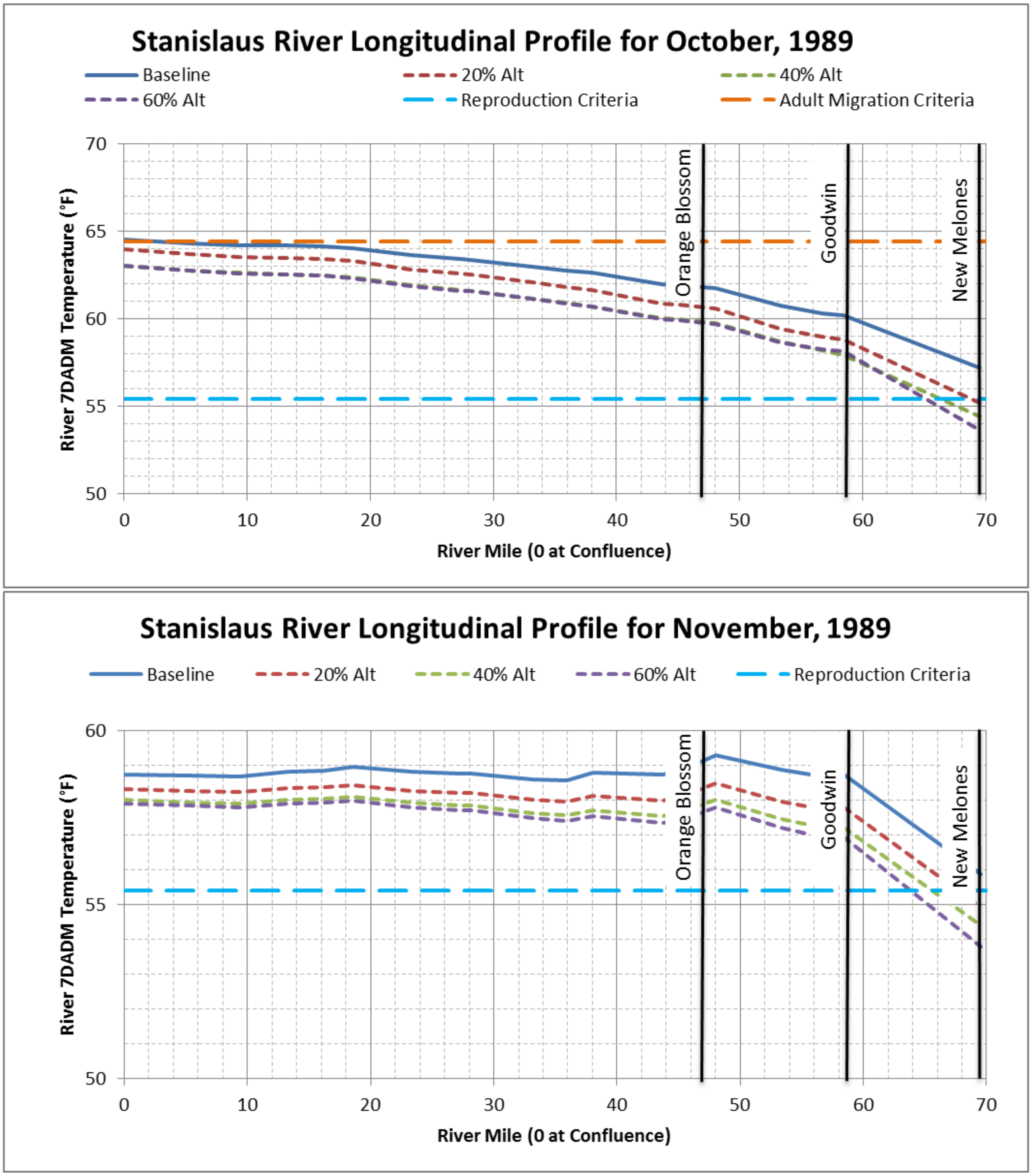
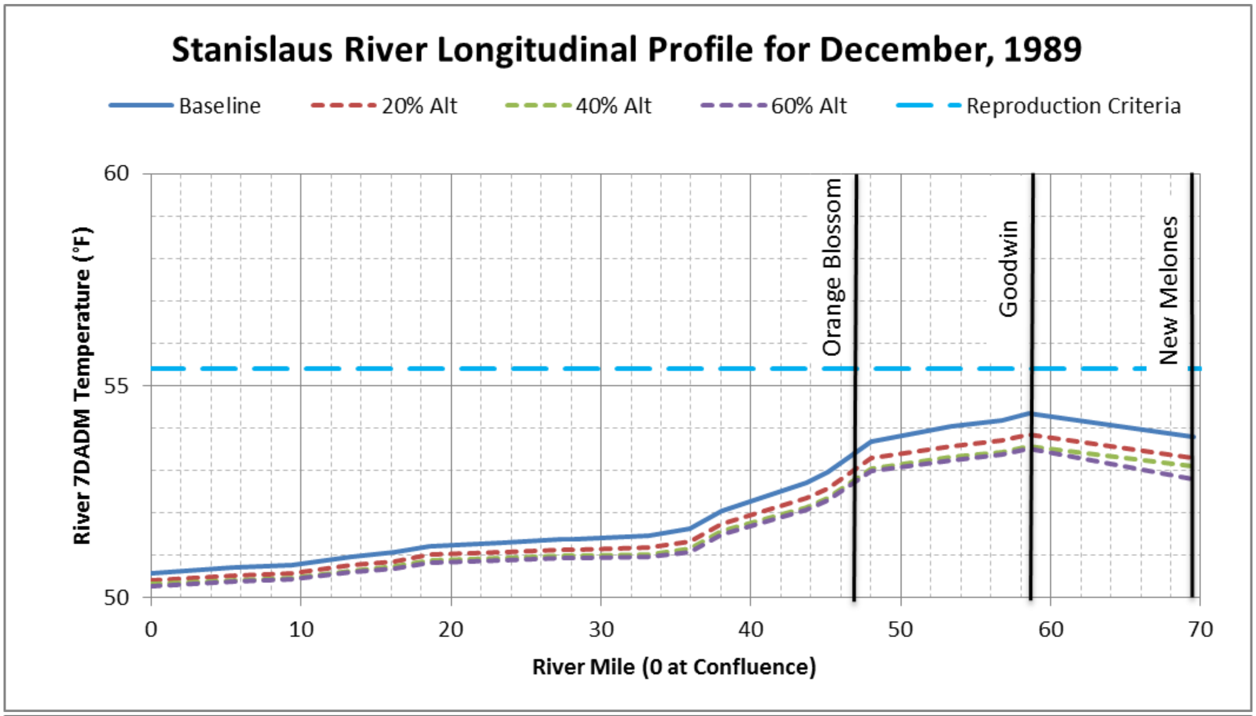


Figure F.1.6-20. Longitudinal Monthly Average 7DADM Temperature Results within the Stanislaus River for (a) October 1989 and (b) November 1989



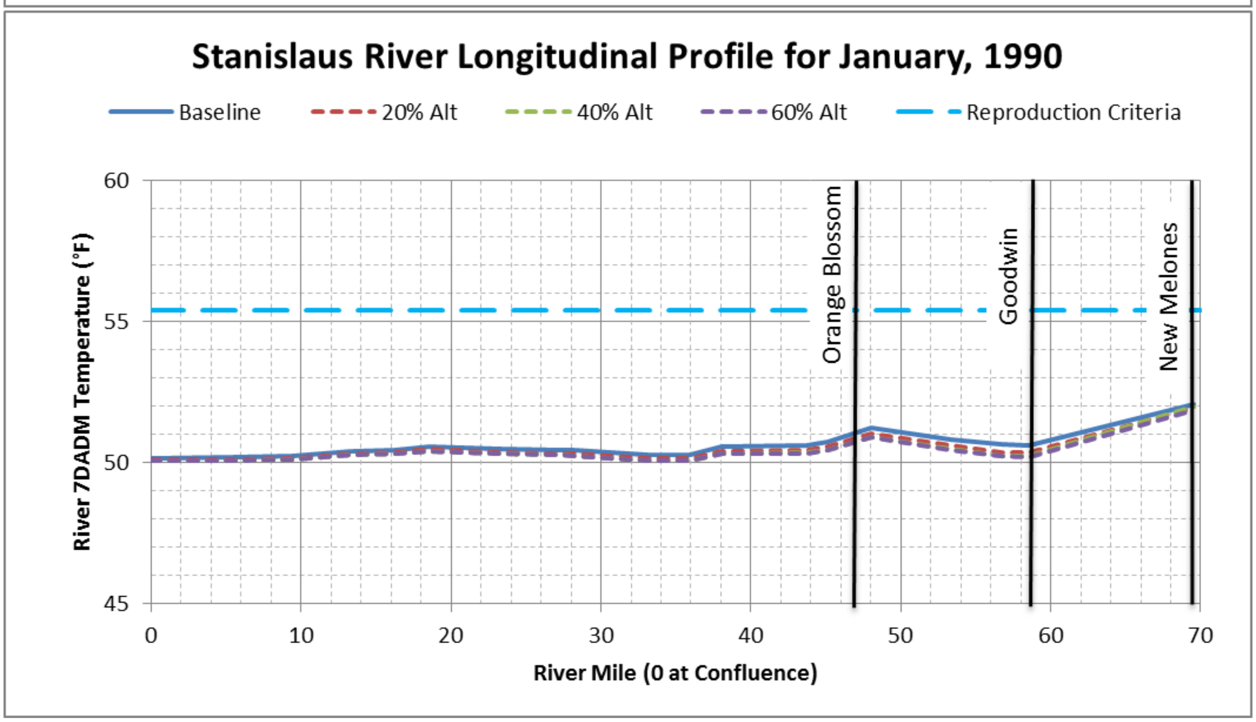
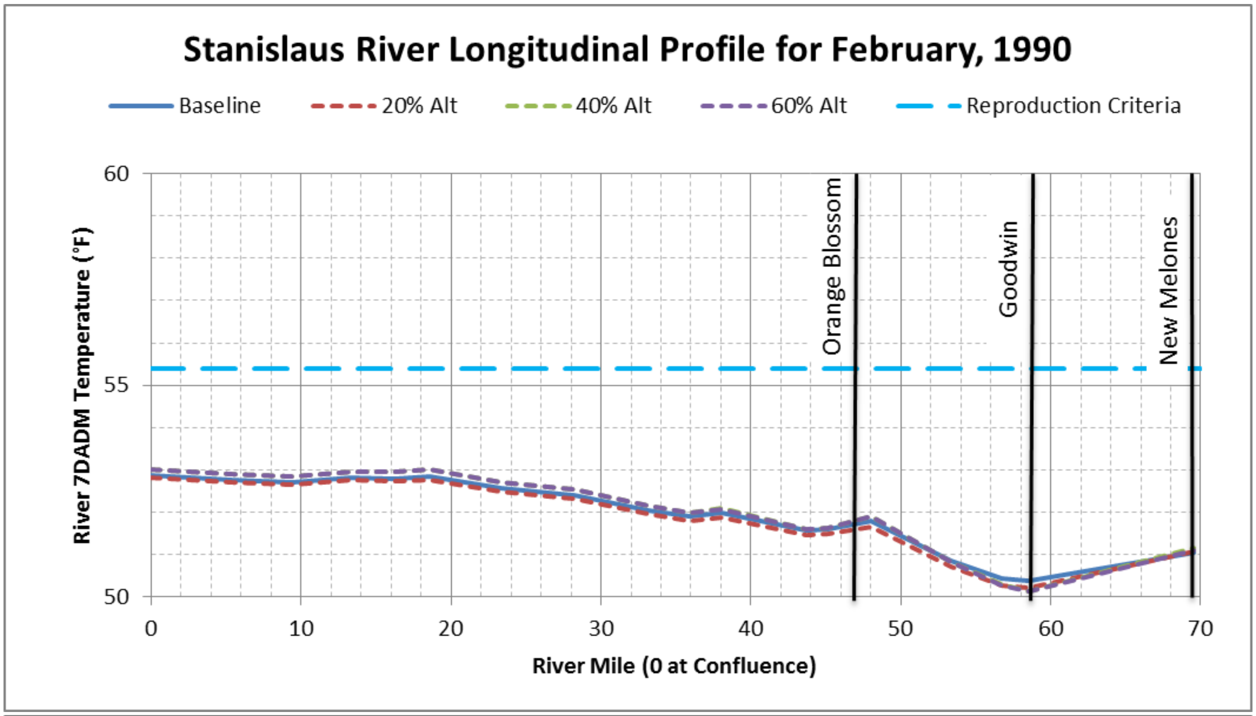


Figure F.1.6-21. Longitudinal Monthly Average 7DADM Temperature Results within the Stanislaus River for (a) December 1989 and (b) January 1990



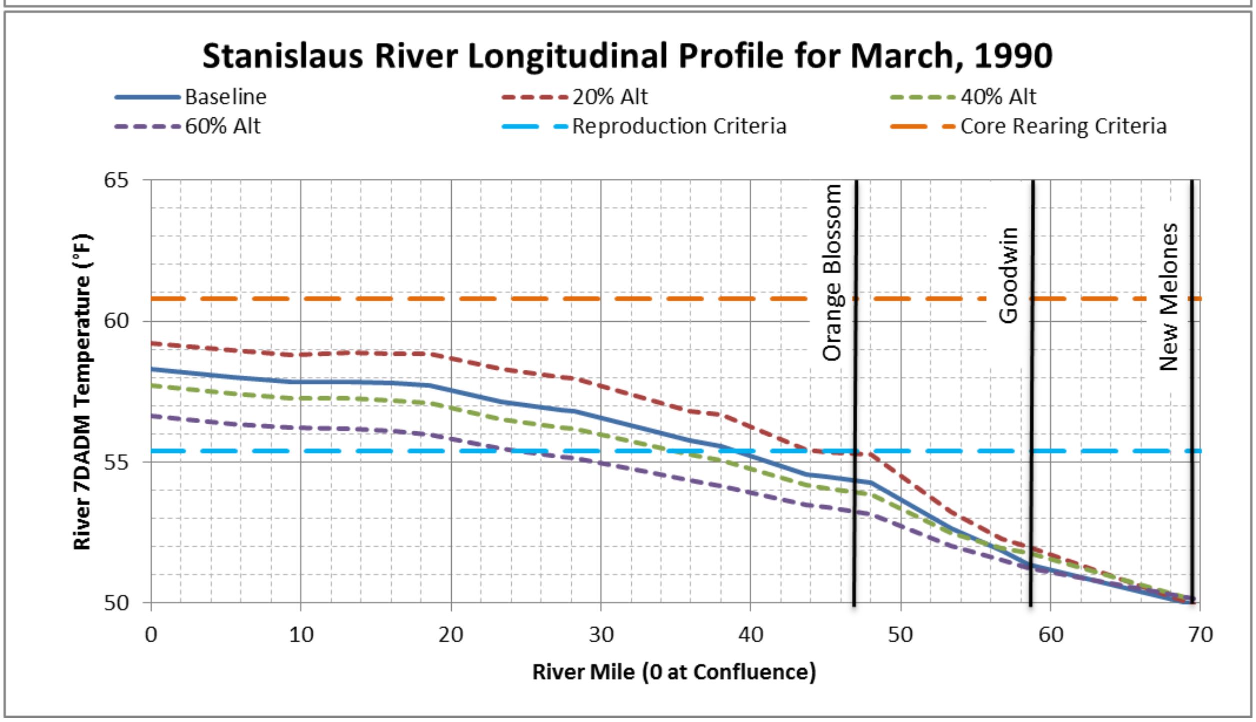
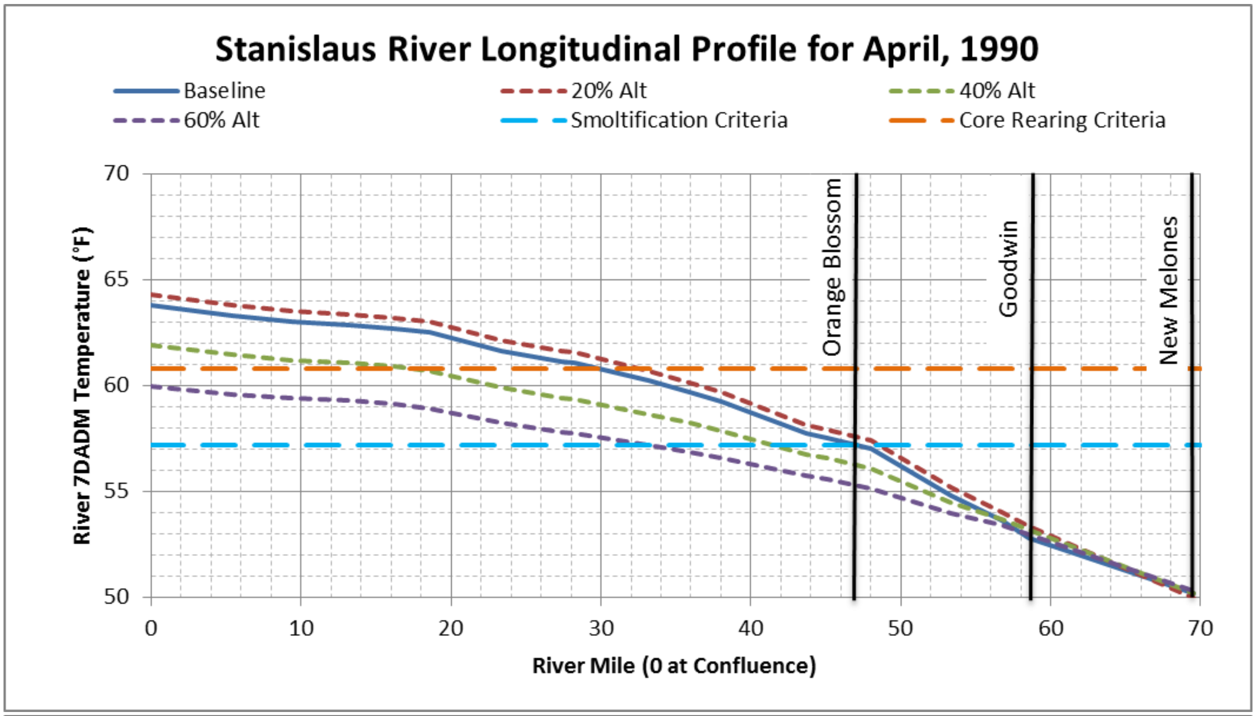


Figure F.1.6-22. Longitudinal Monthly Average 7DADM Temperature Results within the Stanislaus River for (a) February 1990 and (b) March 1990



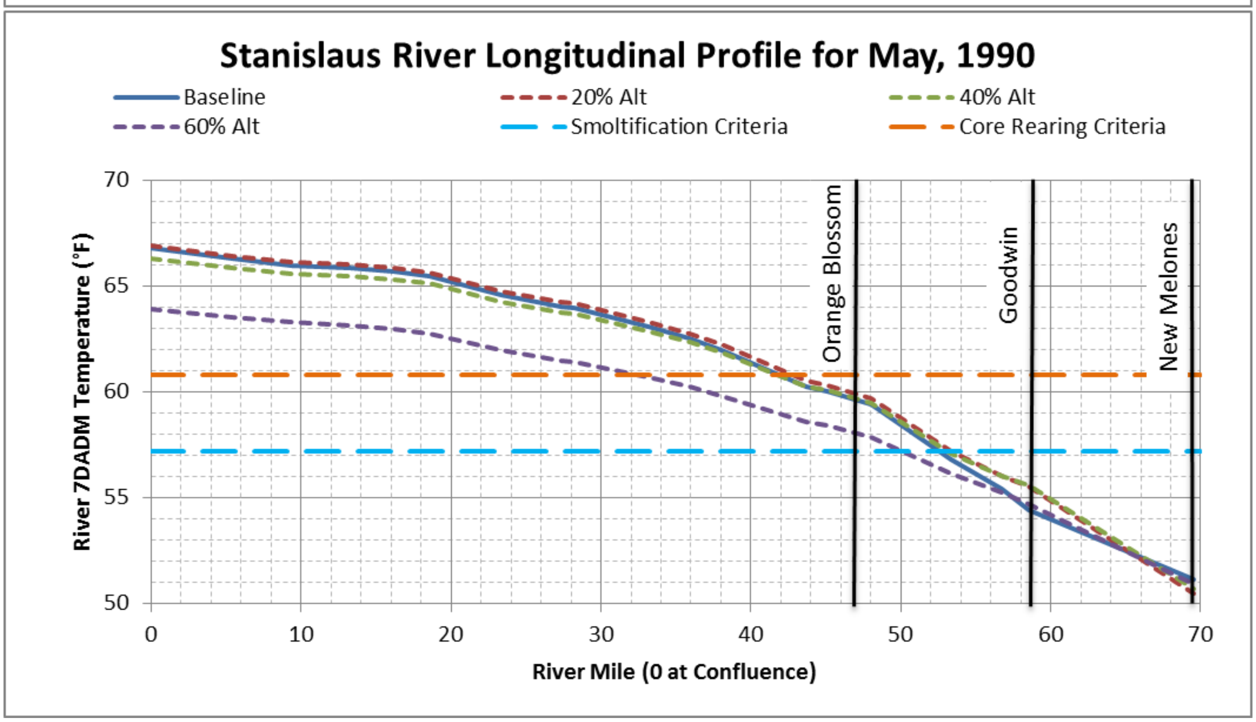
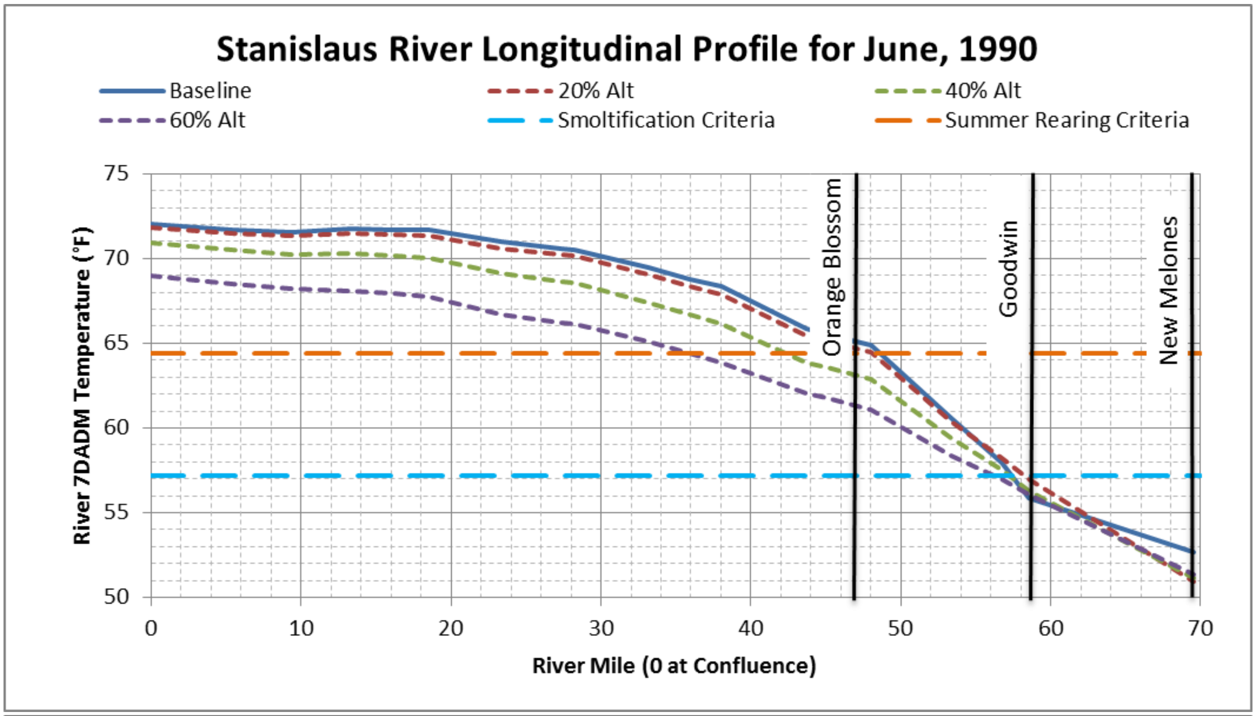


Figure F.1.6-23. Longitudinal Monthly Average 7DADM Temperature Results within the Stanislaus River for (a) April 1990 and (b) May 1990



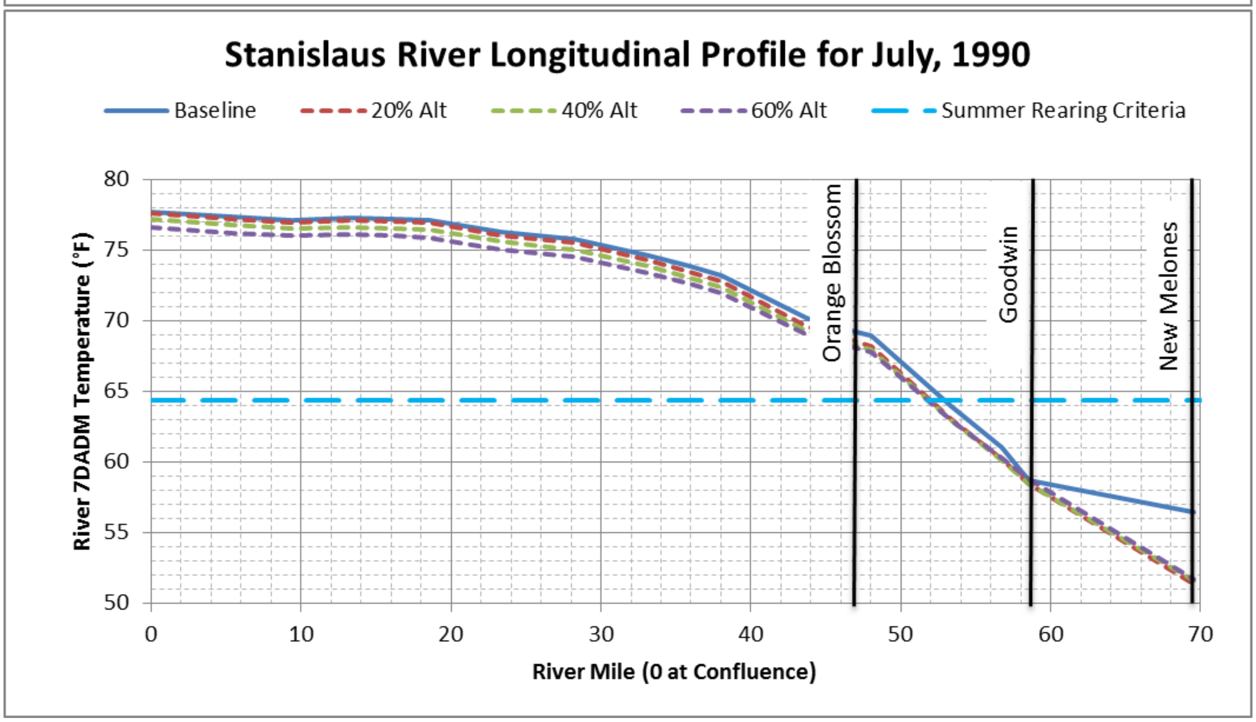
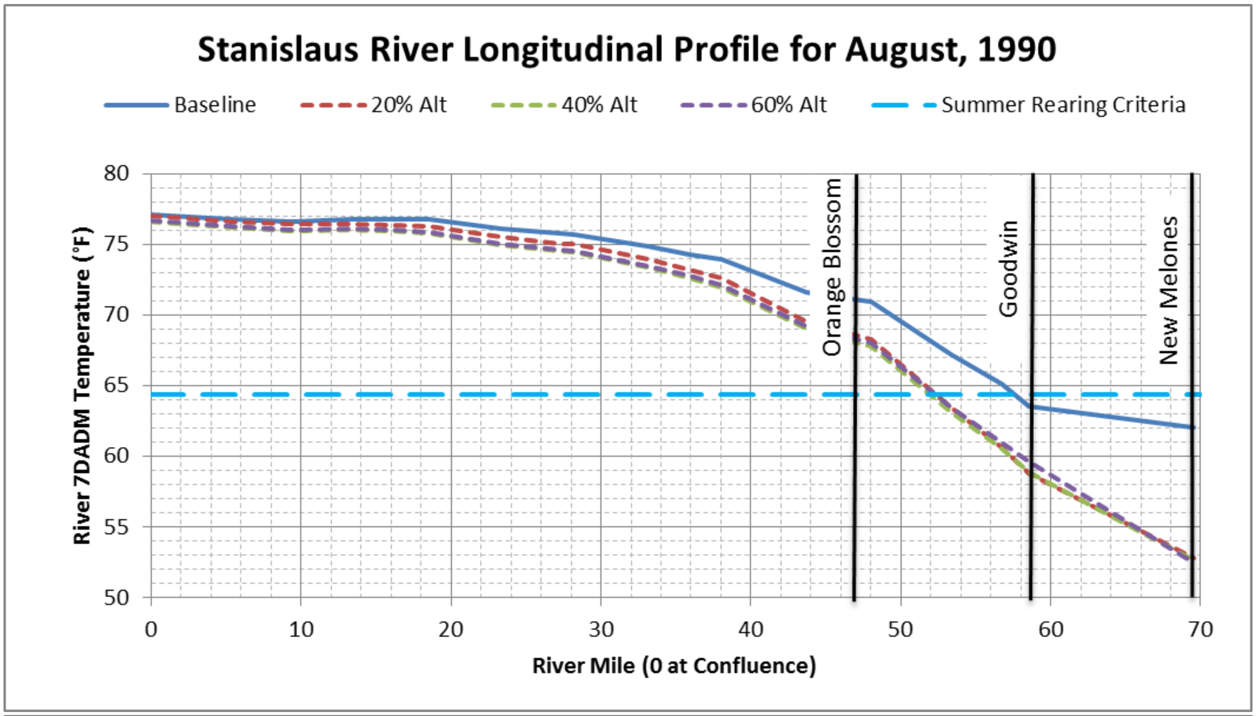


Figure F.1.6-24. Longitudinal Monthly Average 7DADM Temperature Results within the Stanislaus River for (a) June 1990 and (b) July 1990



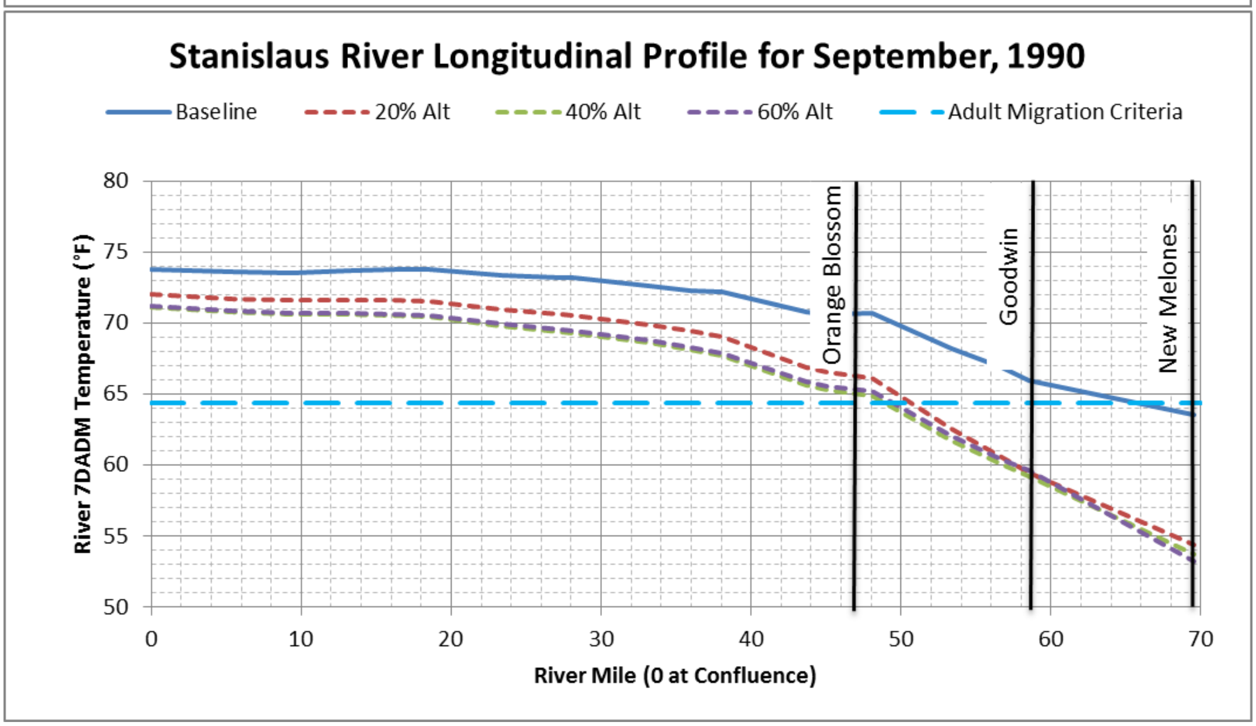


Figure F.1.6-25. Longitudinal Monthly Average 7DADM Temperature Results within the Stanislaus River for (a) August 1990 and (b) September 1990 Error! Bookmark not defined.

Tuolumne River Temperatures

Figures F.1.6-26a and F.1.6-26b show the monthly average temperatures in the Tuolumne River at RM 28.1 simulated with the SJR water temperature model for baseline conditions and the LSJR alternatives plotted as a function of the monthly river flow at Merced for February–June. For February, the temperatures were generally 48°F–57°F. The warmest temperatures corresponded to flows of less than 1,000 cfs. Although the LSJR alternatives generally increased flows relative to baseline in February, particularly under conditions of low baseline flow, these flow changes had only a small effect on RM 28.1 temperatures (decreases in temperature were generally less than 2°F). Because there is little meteorological warming in February, river flow increases would not substantially reduce water temperatures.

In March, simulated temperatures in the Tuolumne River at RM 28.1 were 49°F–52°F when river flow was 2,000 cfs or more and generally increased to 50°F–62°F when river flows were less than 2,000 cfs. Because the LSJR alternatives tended to increase the low- to mid-range flows relative to baseline (i.e., they increased all but the highest baseline flows), LSJR alternative water temperatures tended to be lower than baseline. However, there were no large effects on water temperatures because meteorological warming at RM 28.1 was limited in March and water temperatures generally remained cool. The warmest temperatures were simulated for low flows less than 500 cfs, but these temperatures remained less than 62°F.

In April, the range of simulated temperatures at RM 28.1 was 50°F to 64°F, with warmer temperatures 55°F–64°F generally simulated for the lower flows (less than 1,000 cfs). Because the April flows were always greater than 250 cfs, no temperatures of greater than 63°F were simulated. Here, the shift toward higher flows in the LSJR alternative was distinct; where flow under baseline conditions approached 400 cfs, flows under LSJR Alternatives 2, 3, and 4 didn't usually fall below about 600 cfs, 1000 cfs, and 1500 cfs, respectively. With the higher flows, the temperature at RM 27.1 was shifted down in each of the alternatives, with temperatures under LSJR Alternative 4 rarely going above 55°F. In May, the range of simulated temperatures at RM 28.1 was 51°F–66°F, about 1°F–3°F warmer than in April. The warmer temperatures of 58°F–66°F were generally simulated for the lower flows (less than 1,000 cfs). Because the May flows were always greater than 400 cfs, only a few temperatures of greater than 65°F were simulated in May at RM 28.1. Much like April, there were similar shifts toward higher flow and lower temperatures in each of the alternatives. In June, some flows were lower (lowest of about 250 cfs) and the temperatures were considerably warmer than in April and May, ranging from 53°F–77°F. The warmer temperatures of 60°F–77°F were generally simulated for the lower flows (less than 1,000 cfs).

The Tuolumne River warming curves (flow versus temperature) at RM 28.1 in April, May, and June indicate the general relationship between river flow and water temperatures in the upstream portion of the Tuolumne River. These figures suggest that temperature is most responsive to changes in flow when flow is less than 1,000 cfs and during warmer conditions (i.e., June).

Tables F.1.6-3a and F.1.6-3b give the monthly cumulative distributions of average simulated water temperatures in the Tuolumne River at RM 28.1 for 1970–2003 under baseline conditions and the change in the distribution under the LSJR alternatives. Baseline average water temperatures at RM 28.1 indicate the average seasonal warming January–July is about 19°F. This average seasonal warming is similar to the Stanislaus River average warming. The monthly increase in the average temperatures February–May was about 2°F per month, the monthly increase May–June was about 8°F, and the increase June–July was about 4°F.

Changes in temperature associated with the LSJR alternatives were dependent on the combination of change in flow and amount of meteorological warming (i.e., difference between reservoir release temperatures and equilibrium temperatures). The months of March–June showed significant drops in average monthly temperature under all the LSJR alternatives, with higher temperature reductions under higher unimpaired flow objectives. June had the highest temperature reductions, with average monthly temperatures falling 4.8°F under a 20 percent unimpaired flow objective and 9.1°F under a 60 percent unimpaired flow objective.

Figures F.1.6-27, F.1.6-28, F.1.6-29, and F.1.6-30 show Tuolumne River temperature model results under baseline conditions and under LSJR Alternatives 2 and 3 (40 and 60 percent of unimpaired flow objectives Feb–June) for the water years 1985–1989, 1990–1994, 1995–1999, and 2000–2003, respectively. Each figure is composed of three separate charts to compare how reservoir storage and river flow can affect temperatures at different points along the river. Chart A shows reservoir storage at New Don Pedro, Chart B shows the instream flows at Modesto, and Chart C gives the daily 7DADM temperature at New Don Pedro release, La Grange release, and the 1/4 River location.

Figures F.1.6-31a and F.1.6-31b show temperature model 7DADM results at 3/4 River (Tuolumne RM 38.3) compared to monthly USEPA temperature criteria for optimal development of different fish lifestages (as described in Chapter 19) under LSJR Alternatives 2 and 3 (40 and 60 percent of unimpaired flow Feb–June) and baseline conditions for water years 1985–1989 and water years 1990–1994, respectively. These show temperature effects of reservoir levels within the major drought sequence 1989–1993.

Figures F.1.6-32, F.1.6-33, F.1.6-34, F.1.6-35, F.1.6-36, and F.1.6-37 show longitudinal monthly average 7DADM temperature results in the Tuolumne River for each month of the water year 1988 under baseline conditions and the LSJR alternatives. Water year 1988 is shown because it represents a year when New Don Pedro Reservoir storage levels were around 1 million acre feet (about half storage) under the model scenarios. Figures F.1.6-38, F.1.6-39, F.1.6-40, F.1.6-41, F.1.6-42, and F.1.6-43 show longitudinal monthly average 7DADM temperature results for each month of the water year 1990 under baseline conditions and the LSJR alternatives. Water year 1990 is shown because it represents a year in the middle of the 1989–1992 drought sequence; however, New Don Pedro Reservoir levels do not show as much of a drawdown compared to the other major reservoirs in the drought period.

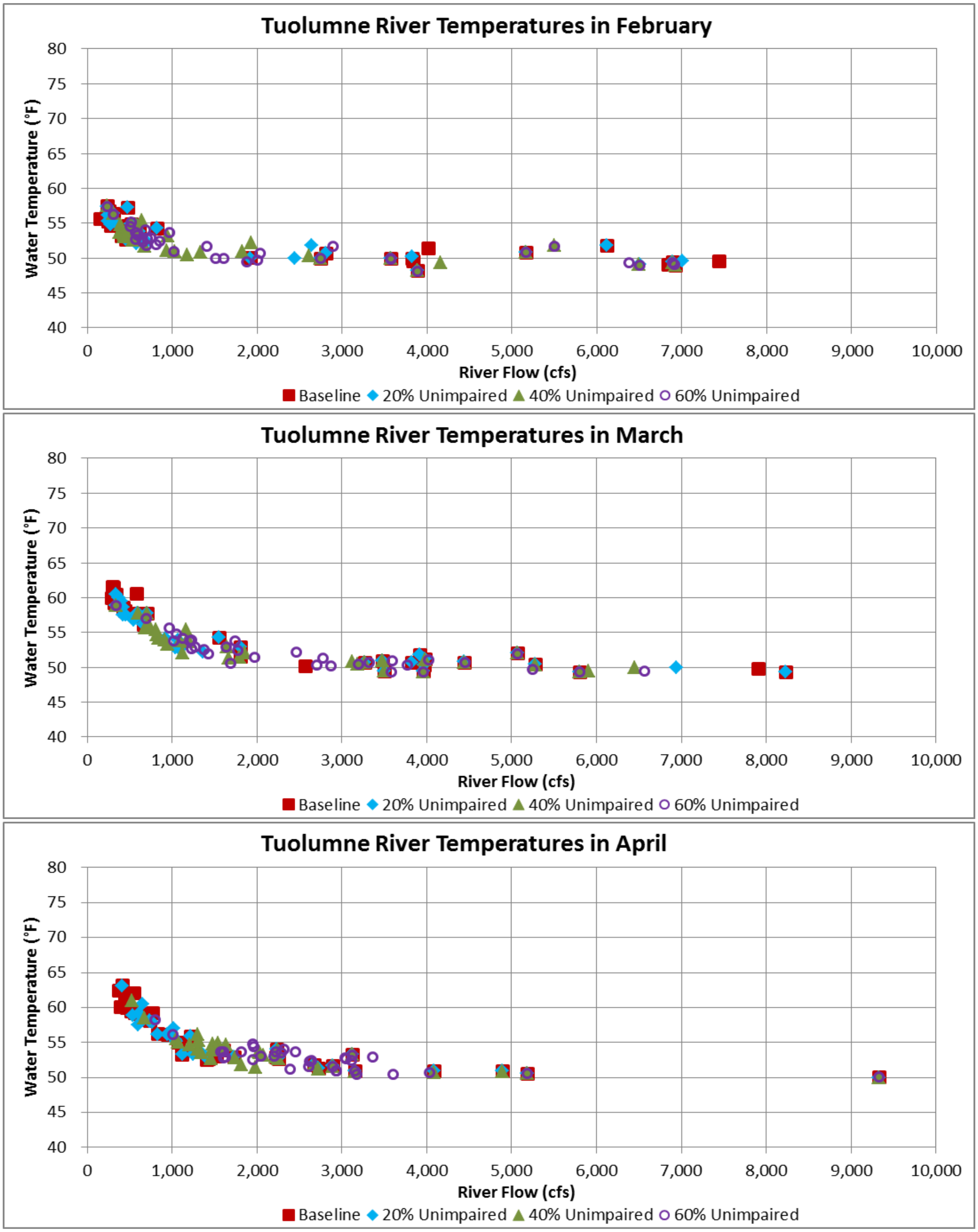


Figure F.1.6-26a. Effects of Tuolumne River Flows on Temperatures at RM 28.1 in February–April for Baseline Conditions and 20%, 40%, 60% Unimpaired Flow (LSJR Alternatives 2–4) 1970–2003

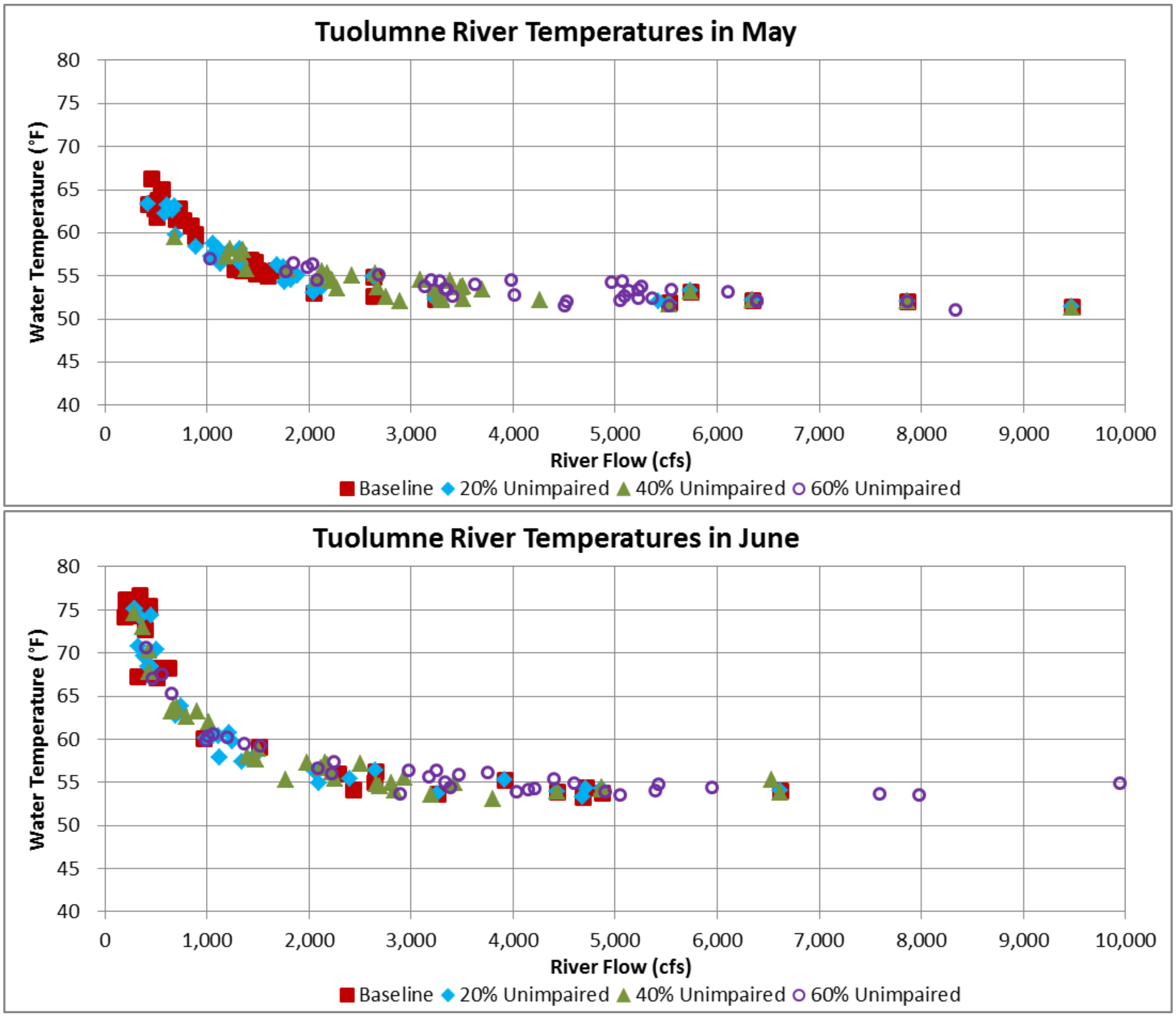


Figure F.1.6-26b. Effects of Tuolumne River Flows on Temperatures at RM 28.1 in May and June for Baseline Conditions and 20%, 40%, 60% Unimpaired Flow (LSJR Alternatives 2–4) 1970–2003

Table F.1.6-3a. Monthly Distribution of Tuolumne River Water Temperatures at RM 28.1 1970–2003 for Baseline Conditions and 20%, 40%, 60% Unimpaired Flow (LSJR Alternatives 2–4)

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Tuolumne River Temperatures at RM 28.1 for Baseline Conditions												
Minimum	55.4	53.6	49.5	49.3	48.2	49.3	50.0	51.4	53.3	55.5	59.0	56.7
10%	58.1	54.2	50.5	49.7	49.4	49.6	51.0	52.2	54.0	56.5	67.7	63.2
20%	58.6	54.6	50.9	50.0	49.9	50.3	51.8	53.2	54.7	62.2	68.5	64.7
30%	59.4	54.8	51.2	50.6	50.7	50.7	52.7	55.2	56.3	68.9	69.1	65.8
40%	59.5	55.2	51.4	50.9	52.0	51.2	53.1	55.6	67.2	70.2	69.5	66.4
50%	60.5	55.4	51.5	51.4	53.6	52.5	54.0	56.3	68.2	70.8	70.3	67.2
60%	61.6	56.2	51.9	51.9	54.2	57.3	56.1	59.8	74.3	77.7	76.1	72.6
70%	63.8	56.6	52.4	51.9	54.7	58.2	59.2	61.6	75.1	78.3	76.9	73.2
80%	64.5	57.1	52.6	52.0	55.4	59.9	59.7	63.0	75.2	78.4	77.4	73.9
90%	65.8	57.8	53.4	53.0	56.5	60.9	61.5	63.8	75.5	79.2	77.8	74.5
Maximum	67.8	58.4	54.1	53.7	57.5	61.6	63.2	66.3	76.7	80.2	79.7	75.7
Average	61.3	55.8	51.8	51.3	52.9	54.6	55.6	58.0	66.5	71.0	72.2	68.9
Change in Tuolumne River Temperatures at RM 28.1 for 20% Unimpaired Flow Relative to Baseline												
Minimum	0.0	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10%	0.2	0.1	0.0	0.0	0.0	0.0	0.0	-0.1	0.1	0.1	0.0	0.0
20%	0.0	0.1	0.0	0.0	0.0	0.1	0.0	0.1	0.4	0.0	0.0	0.0
30%	0.0	0.1	0.0	0.0	0.0	0.1	0.1	-1.0	0.0	-0.1	0.0	0.0
40%	0.0	0.0	0.0	0.0	-0.1	0.6	0.2	-0.6	-9.3	-0.5	0.1	0.0
50%	0.1	0.1	0.0	0.2	-0.6	0.2	0.0	-0.2	-8.3	-0.5	0.0	0.1
60%	0.0	0.0	0.0	0.0	-0.5	-3.2	-0.3	-2.8	-13.6	-0.8	0.0	0.0
70%	0.1	-0.1	0.0	0.0	0.0	-1.4	-2.9	-3.9	-10.8	-0.7	0.0	0.0
80%	0.0	-0.3	0.1	0.0	-0.3	-2.2	-1.8	-4.5	-5.8	-0.6	0.0	0.0
90%	-0.3	-0.2	-0.2	0.0	-0.1	-2.1	-2.8	-1.3	-2.4	-1.1	0.0	0.0
Maximum	-0.1	0.0	0.0	0.0	-0.1	-1.1	0.0	-3.0	-1.6	-0.6	0.0	0.0
Average	0.0	0.0	0.0	0.0	-0.1	-0.8	-0.7	-1.6	-4.8	-0.5	0.0	0.0
Change in Tuolumne River Temperatures at RM 28.1 for 40% Unimpaired Flow Relative to Baseline												
Minimum	0.2	0.7	0.1	0.0	0.0	0.0	0.0	-0.1	-0.3	0.0	0.0	0.0
10%	-0.9	0.3	-0.1	0.2	-0.1	0.0	-0.1	-0.1	0.0	0.5	-1.7	-3.3
20%	-0.5	0.2	0.3	0.2	0.3	0.1	-0.3	-0.9	-0.3	-2.5	-1.6	-4.3
30%	-0.4	0.2	0.1	-0.1	0.1	0.1	-0.1	-2.5	-1.4	-8.4	-1.4	-4.1
40%	-0.2	-0.2	0.1	0.1	-0.8	0.1	-0.1	-2.1	-11.8	-0.8	-0.3	-0.4
50%	-0.4	0.0	0.4	0.2	-1.2	-0.5	-0.4	-2.6	-11.4	-0.7	-0.3	0.3
60%	-0.2	-0.1	0.3	0.0	-1.1	-3.7	-2.2	-5.4	-17.0	-1.4	0.1	0.0
70%	0.2	-0.2	0.0	0.1	-1.0	-4.1	-4.7	-6.5	-15.9	-1.4	0.0	0.0
80%	0.0	-0.1	0.2	0.2	-1.4	-4.5	-4.8	-7.5	-12.1	-1.1	0.0	0.0
90%	-0.2	-0.4	-0.1	0.1	-1.6	-4.9	-6.1	-6.4	-8.9	-1.5	0.0	0.0
Maximum	-0.1	0.0	0.2	0.2	0.0	-2.7	-2.2	-6.9	-2.1	-1.3	0.0	0.0
Average	-0.2	0.0	0.1	0.1	-0.6	-1.8	-2.0	-3.8	-7.7	-1.7	-0.5	-1.2

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Change in Tuolumne River Temperatures at RM 28.1 for 60% Unimpaired Flow Relative to Baseline												
Minimum	0.2	0.7	-0.1	-0.1	-0.1	0.0	0.0	-0.3	0.2	1.4	1.1	0.0
10%	-0.3	0.6	-0.3	0.0	-0.1	0.0	-0.4	-0.2	-0.3	3.8	-1.5	-2.6
20%	0.0	0.4	0.1	0.2	-0.2	0.0	-0.8	-1.0	-0.6	-1.2	-1.2	-3.7
30%	-0.3	0.4	0.2	0.0	-0.7	-0.1	-1.2	-2.6	-1.9	-7.1	-0.8	-4.1
40%	0.2	0.0	0.2	0.2	-1.2	-0.3	-0.6	-2.5	-12.2	-0.7	-0.3	-0.3
50%	-0.5	0.4	0.4	0.2	-1.9	-0.9	-1.2	-2.9	-12.5	-0.7	-0.1	0.5
60%	-0.3	-0.1	0.4	0.0	-2.0	-5.0	-3.1	-6.0	-18.0	-1.8	0.0	0.0
70%	0.1	-0.3	0.3	0.1	-2.0	-5.3	-5.7	-7.3	-17.6	-1.7	0.0	0.0
80%	0.1	-0.2	0.5	0.2	-2.0	-6.1	-6.0	-8.5	-15.2	-1.4	0.0	0.0
90%	-0.2	-0.5	0.0	0.2	-2.1	-6.3	-7.2	-7.9	-11.6	-1.7	0.0	0.0
Maximum	-0.1	0.0	0.1	0.3	0.0	-2.8	-4.9	-9.3	-6.1	-1.6	0.0	0.0
Average	0.0	0.1	0.2	0.2	-1.2	-2.5	-2.9	-4.4	-9.1	-1.3	-0.3	-1.0

Table F.1.6-3b.Monthly Distribution of Tuolumne River Water Temperatures at RM 28.1 1970–2003 for Baseline Conditions and 20%, 40%, 60% Unimpaired Flow (LSJR Alternatives 2–4)

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Average Tuolumne River Temperatures at RM 28.1												
Baseline Average	61.3	55.8	51.8	51.3	52.9	54.6	55.6	58.0	66.5	71.0	72.2	68.9
Change in Average Tuolumne River Temperatures at RM 28.1 Relative to Baseline												
20% Unimpaired Flow Minus Baseline	0.0	0.0	0.0	0.0	-0.1	-0.8	-0.7	-1.6	-4.8	-0.5	0.0	0.0
30% Unimpaired Flow Minus Baseline	0.2	0.1	0.0	0.1	-0.5	-1.3	-1.4	-3.1	-6.6	0.2	0.1	0.2
40% Unimpaired Flow Minus Baseline	-0.2	0.0	0.1	0.1	-0.6	-1.8	-2.0	-3.8	-7.7	-1.7	-0.5	-1.2
50% Unimpaired Flow Minus Baseline	-0.1	0.1	0.2	0.2	-0.9	-2.2	-2.5	-4.3	-8.6	-1.6	-0.4	-1.1
60% Unimpaired Flow Minus Baseline	0.0	0.1	0.2	0.2	-1.2	-2.5	-2.9	-4.4	-9.1	-1.3	-0.3	-1.0

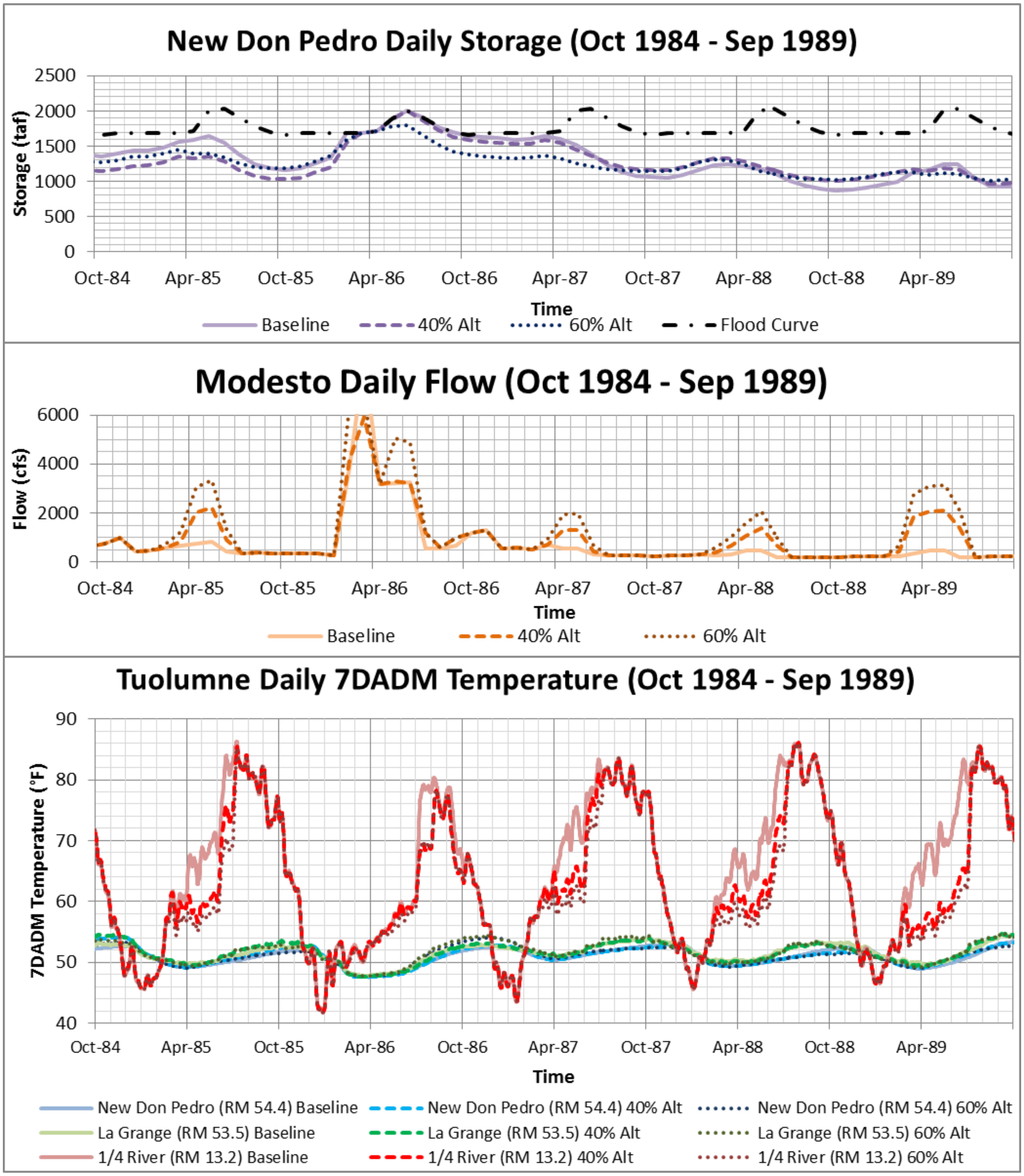


Figure F.1.6-27. Tuolumne River Temperature Model Results for LSJR Alternatives 2 and 3 (40% and 60% of Unimpaired Flow Feb–June) and Baseline Scenarios for the Water Years 1985–1989, Showing (a) Reservoir Storage, (b) Instream Flows, and (c) Daily 7DADM Temperature at New Don Pedro Release, La Grange Release, and 1/4 River Locations

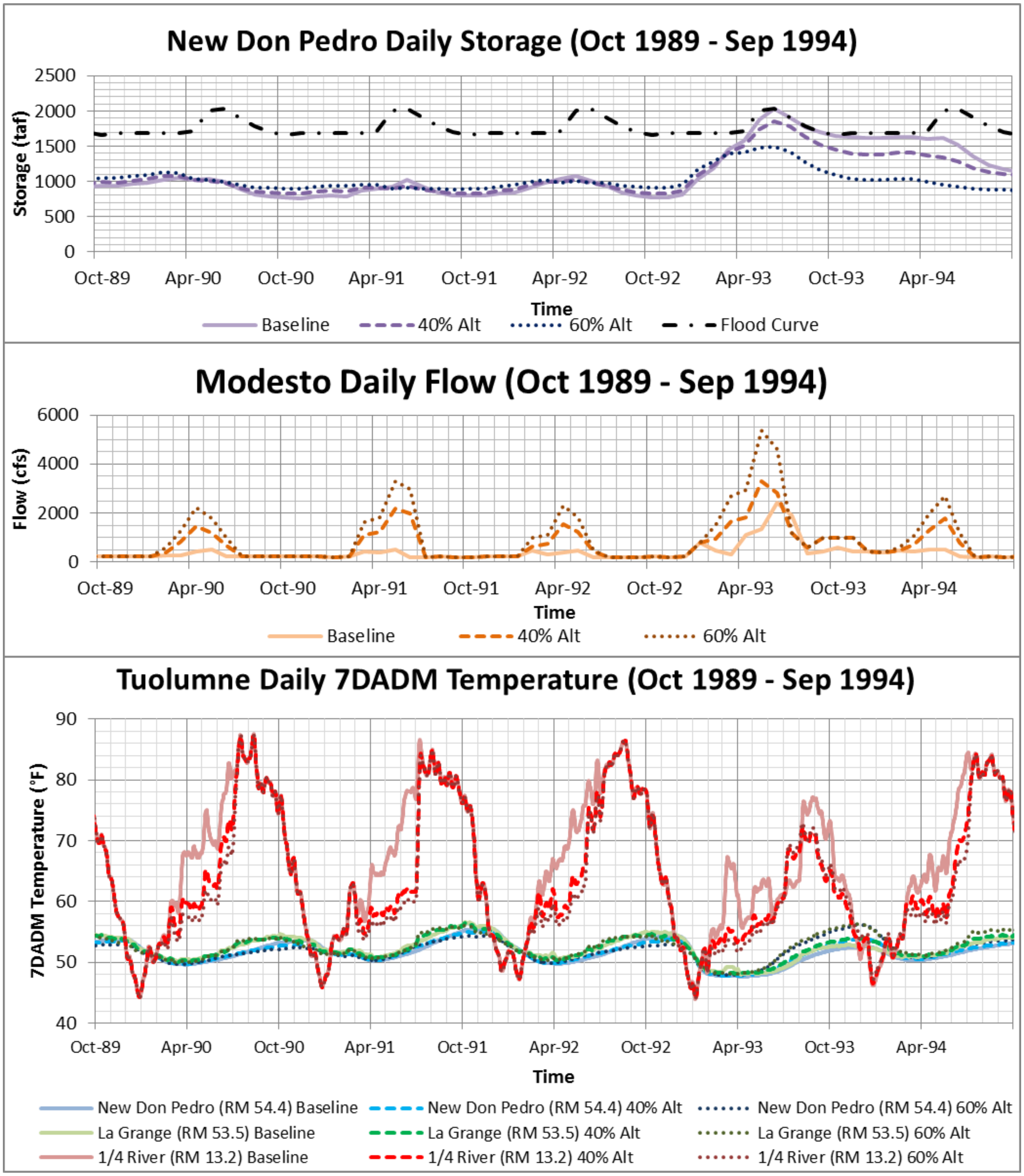


Figure F.1.6-28. Tuolumne River Temperature Model Results for LSJR Alternatives 2 and 3 (40% and 60% of Unimpaired Flow Feb–June) and Baseline Scenarios for the Water Years 1990–1994, Showing (a) Reservoir Storage, (b) Instream Flows, and (c) Daily 7DADM Temperature at New Don Pedro Release, La Grange Release, and 1/4 River Locations

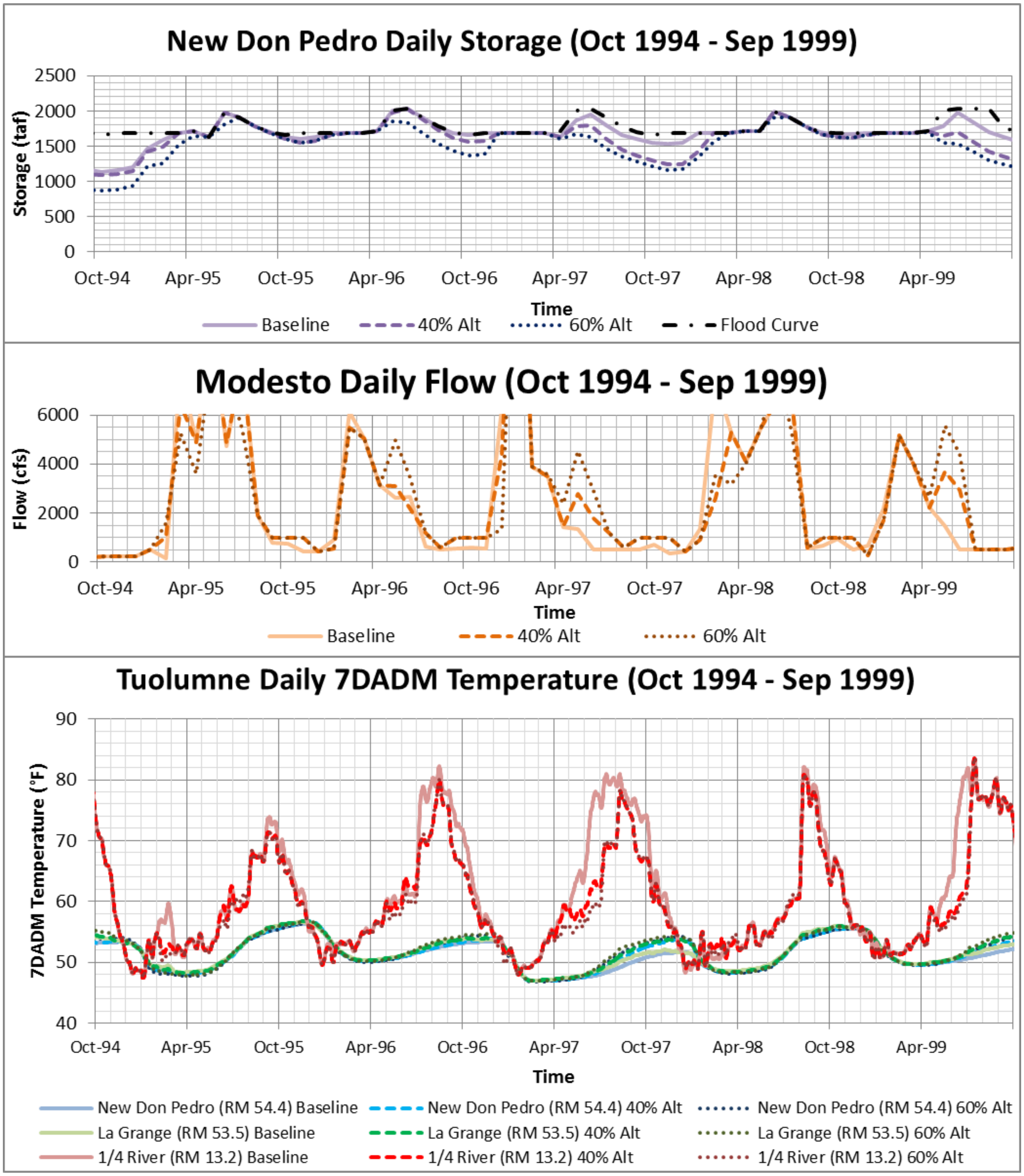


Figure F.1.6-29. Tuolumne River Temperature Model Results for LSJR Alternatives 2 and 3 (40% and 60% of Unimpaired Flow Feb–June) and Baseline Scenarios for the Water Years 1995–1999, Showing (a) Reservoir Storage, (b) Instream Flows, and (c) Daily 7DADM Temperature at New Don Pedro Release, La Grange Release, and 1/4 River Locations

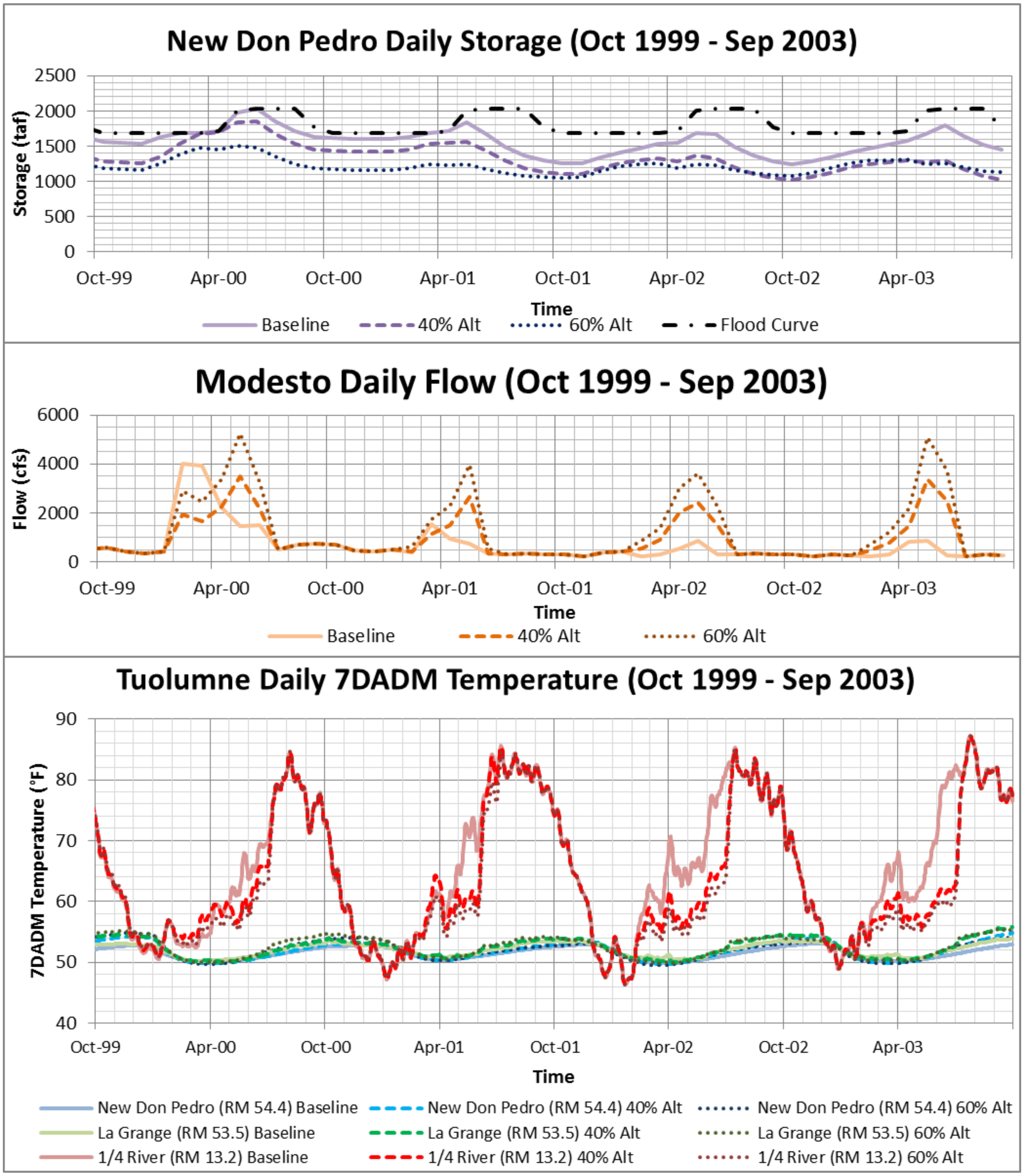
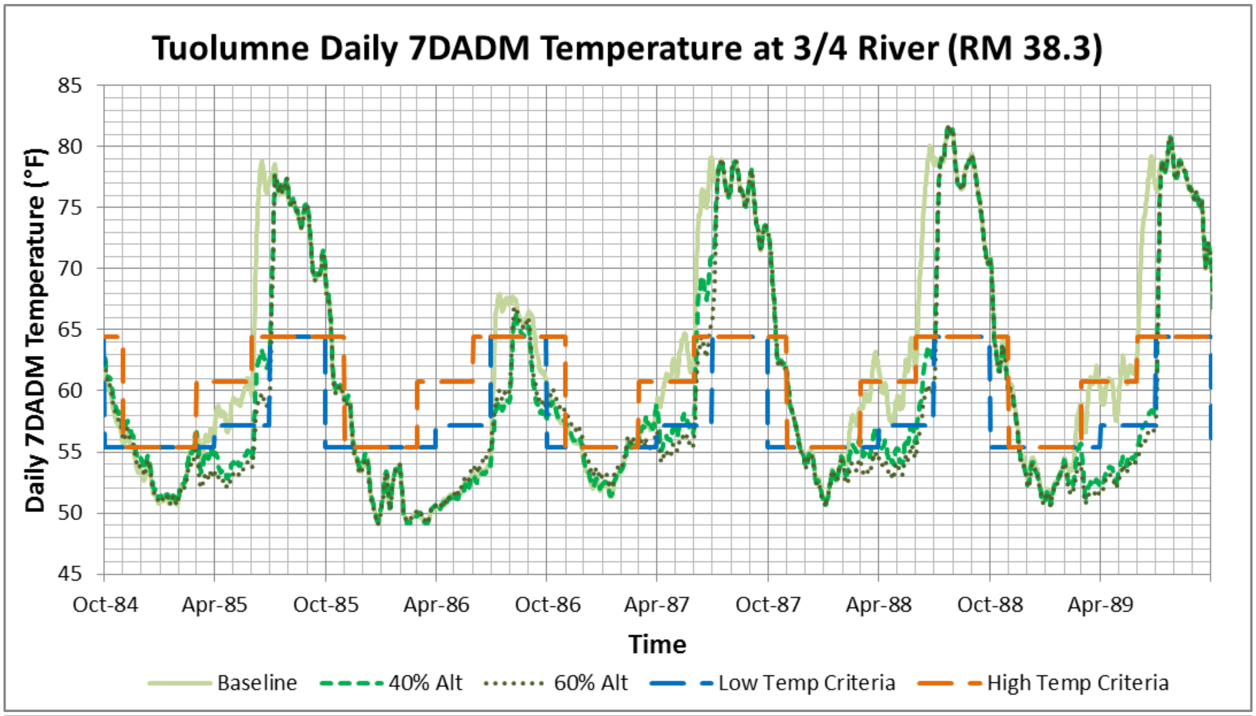


Figure F.1.6-30. Tuolumne River Temperature Model Results for LSJR Alternatives 2 and 3 (40% and 60% of Unimpaired Flow Feb–June) and Baseline Scenarios for the Water Years 2000–2003, Showing (a) Reservoir Storage, (b) Instream Flows, and (c) Daily 7DADM Temperature at New Don Pedro Release, La Grange Release, and 1/4 River Locations



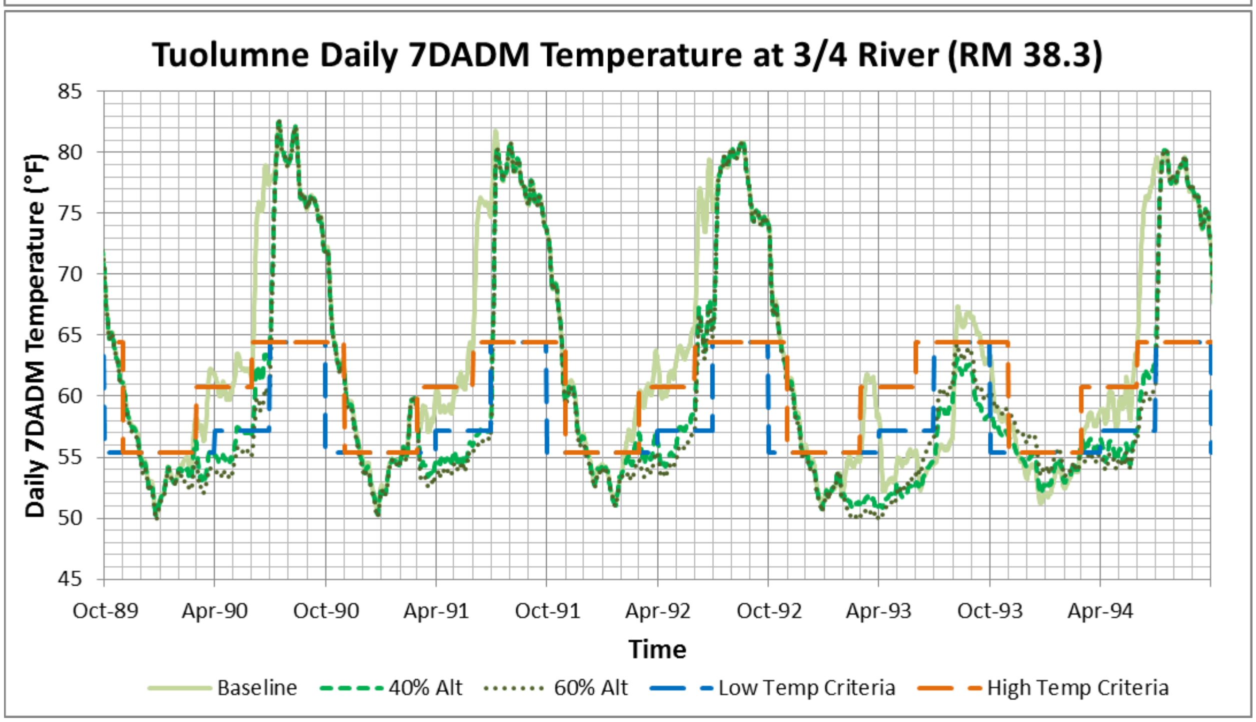


Figure F.1.6-31. Temperature Model 7DADM Results at Tuolumne RM 38.3 Compared to Monthly USEPA Temperature Criteria for Optimal Development of Different Fish Lifestages under Baseline and LSJR Alternatives 2 and 3 (40% and 60% of Unimpaired Flow Feb–June) for (a) Water Years 1985–1989 and (b) Water Years 1990–1994

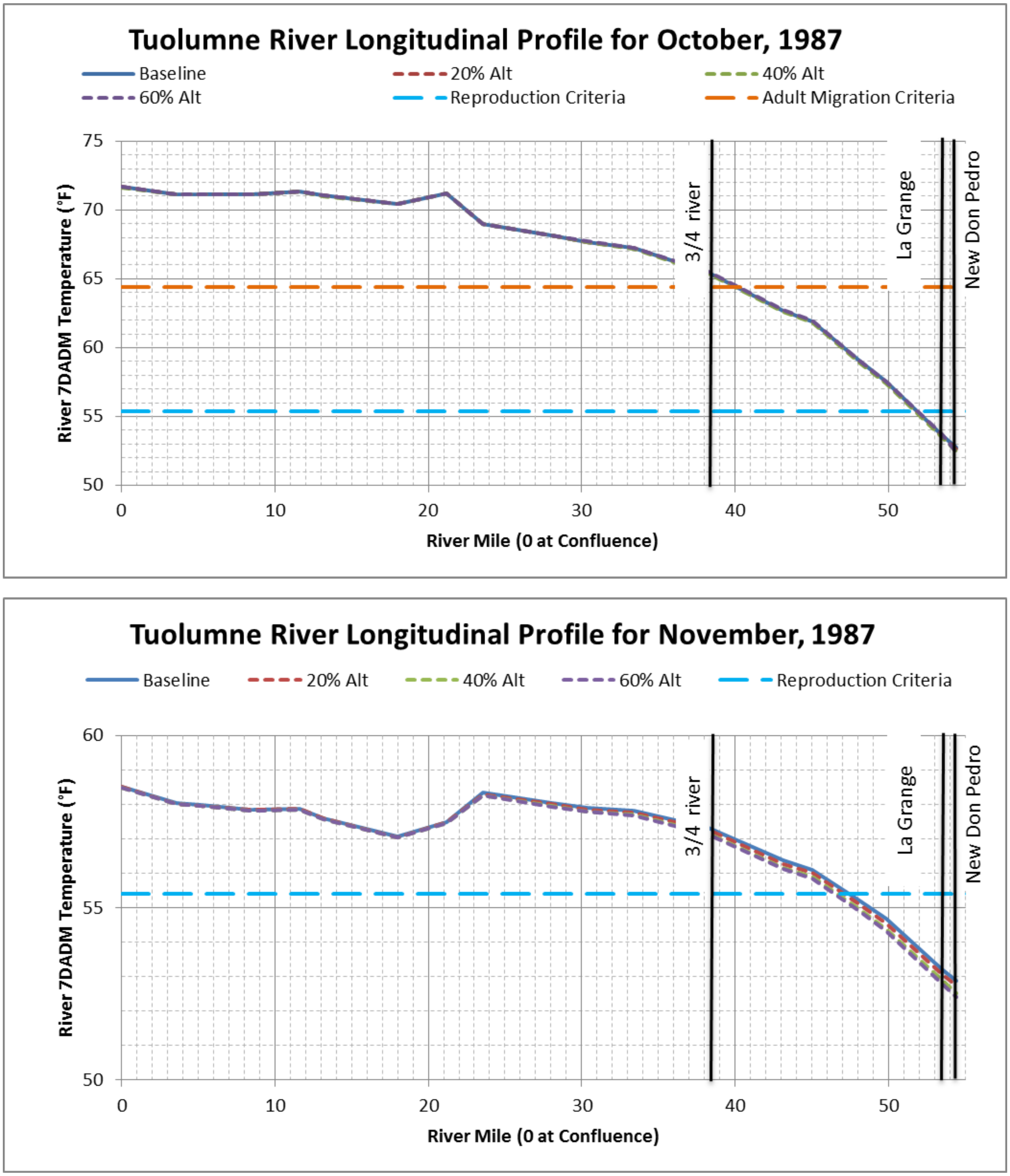
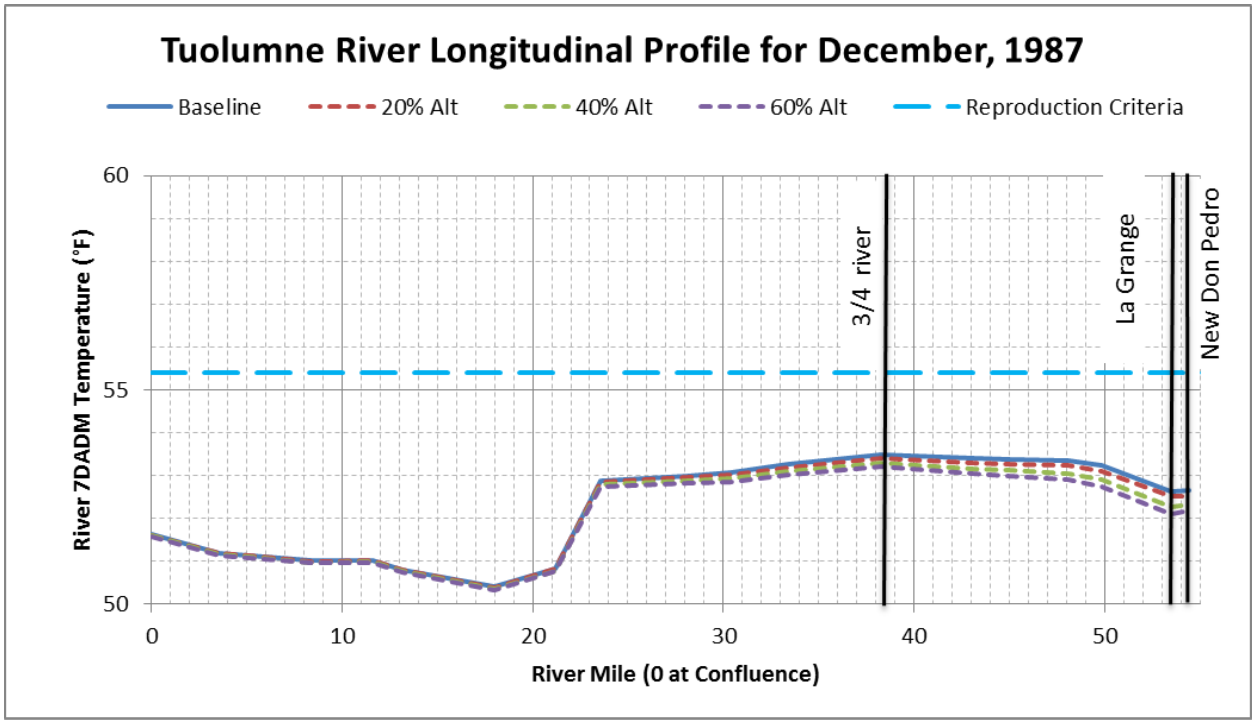


Figure F.1.6-32. Longitudinal Monthly Average 7DADM Temperature Results within the Tuolumne River for (a) October 1987 and (b) November 1987



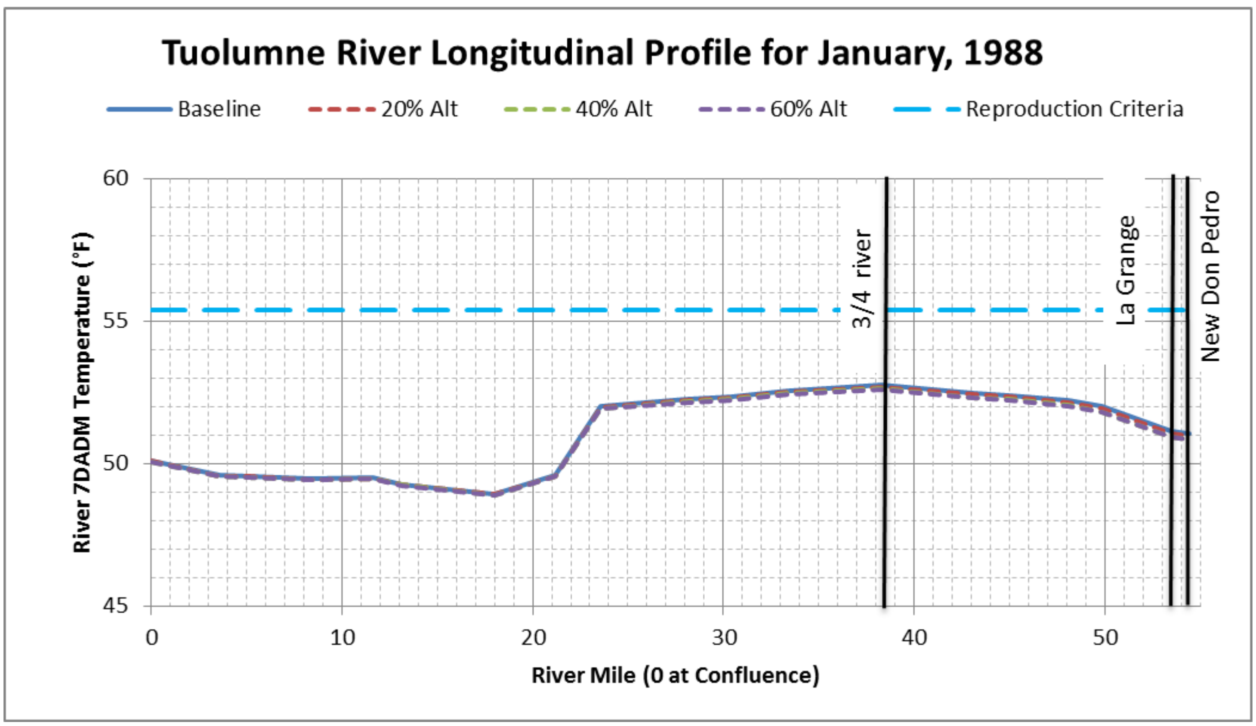
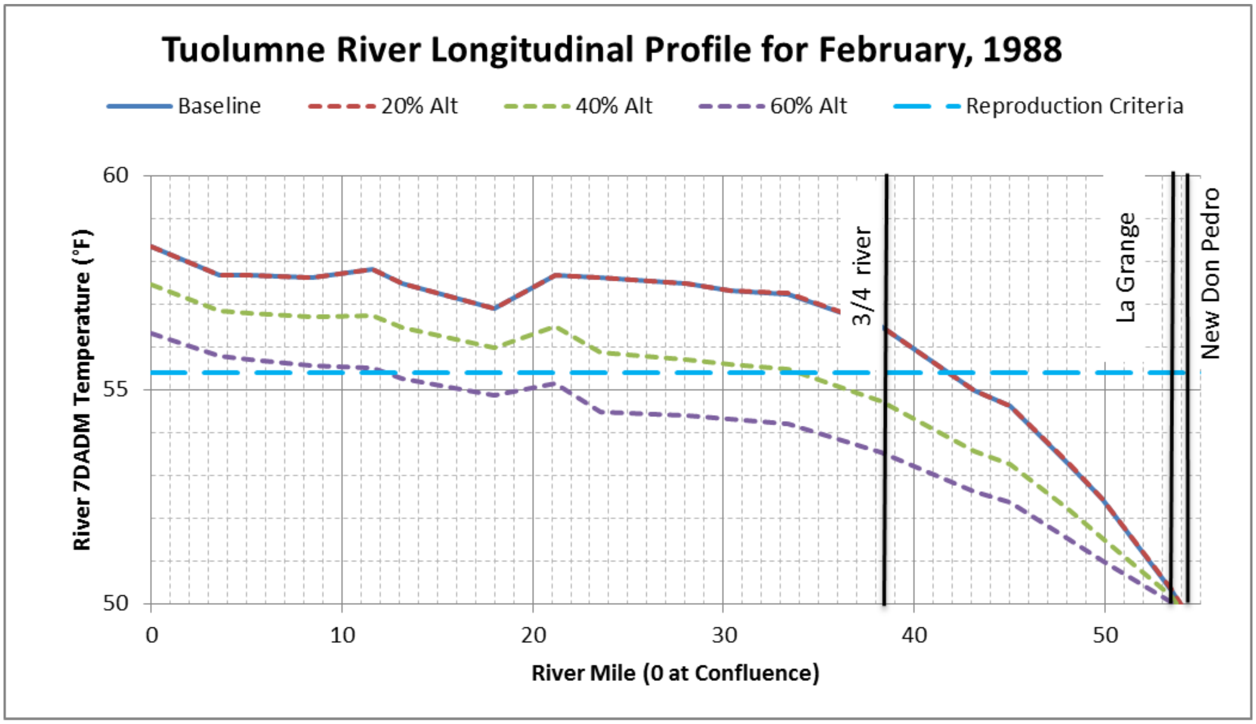


Figure F.1.6-33. Longitudinal Monthly Average 7DADM Temperature Results within the Tuolumne River for (a) December 1987 and (b) January 1988



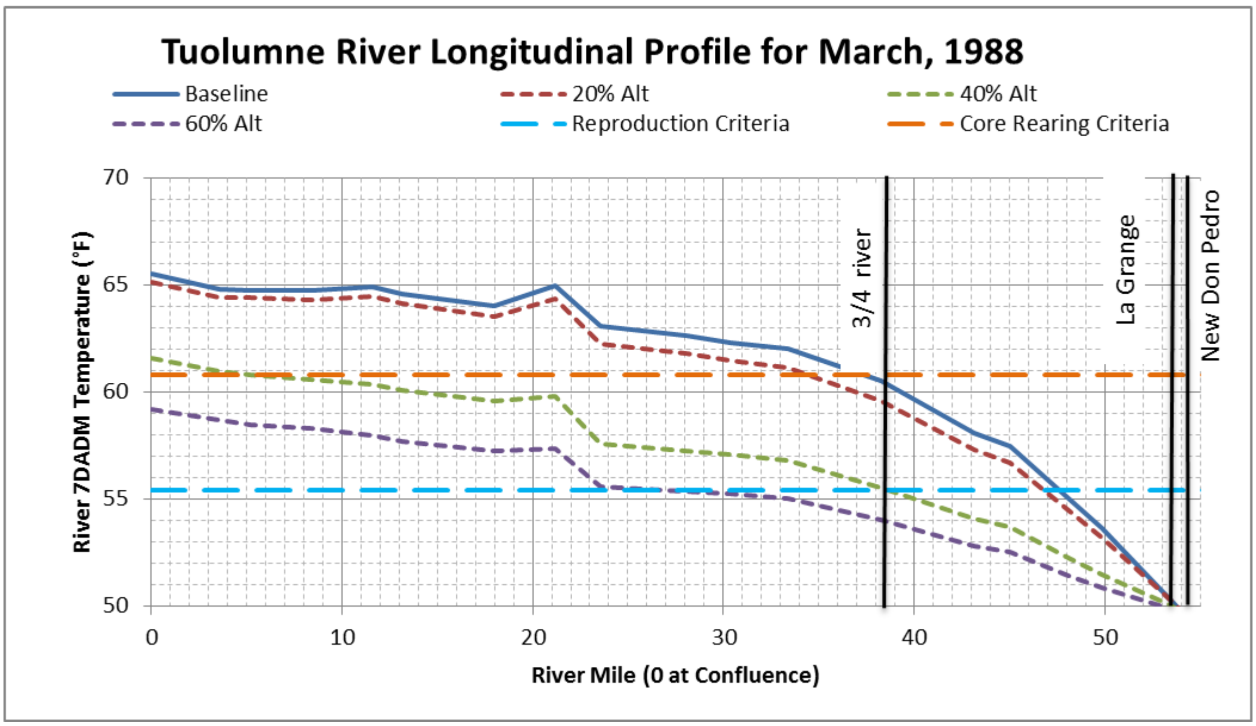
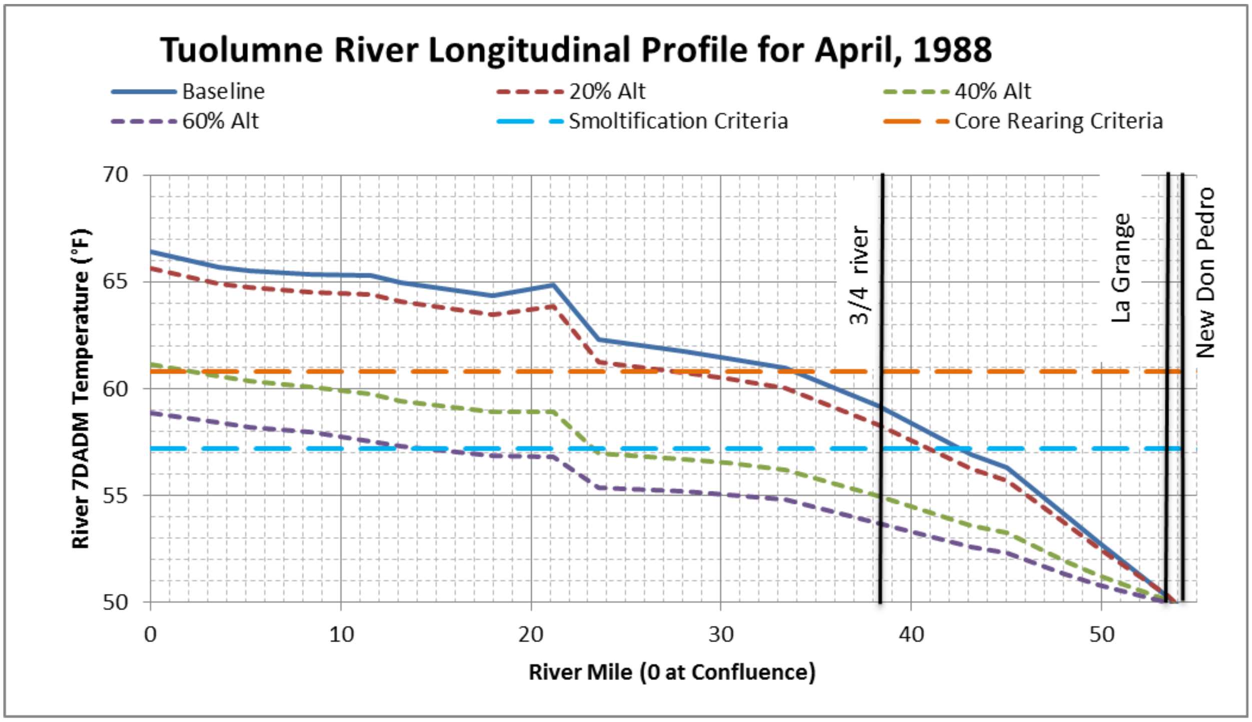


Figure F.1.6-34. Longitudinal Monthly Average 7DADM Temperature Results within the Tuolumne River for (a) February 1988 and (b) March 1988



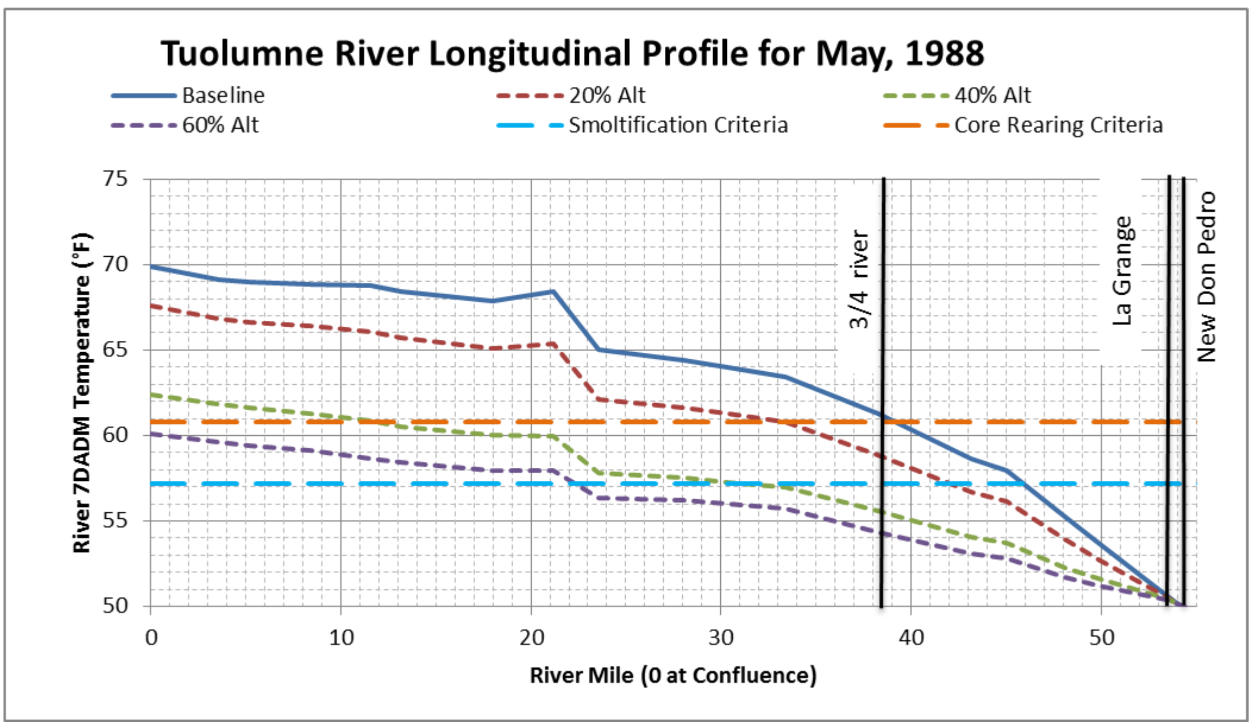


Figure F.1.6-35. Longitudinal Monthly Average 7DADM Temperature Results within the Tuolumne River for (a) April 1988 and (b) May 1988

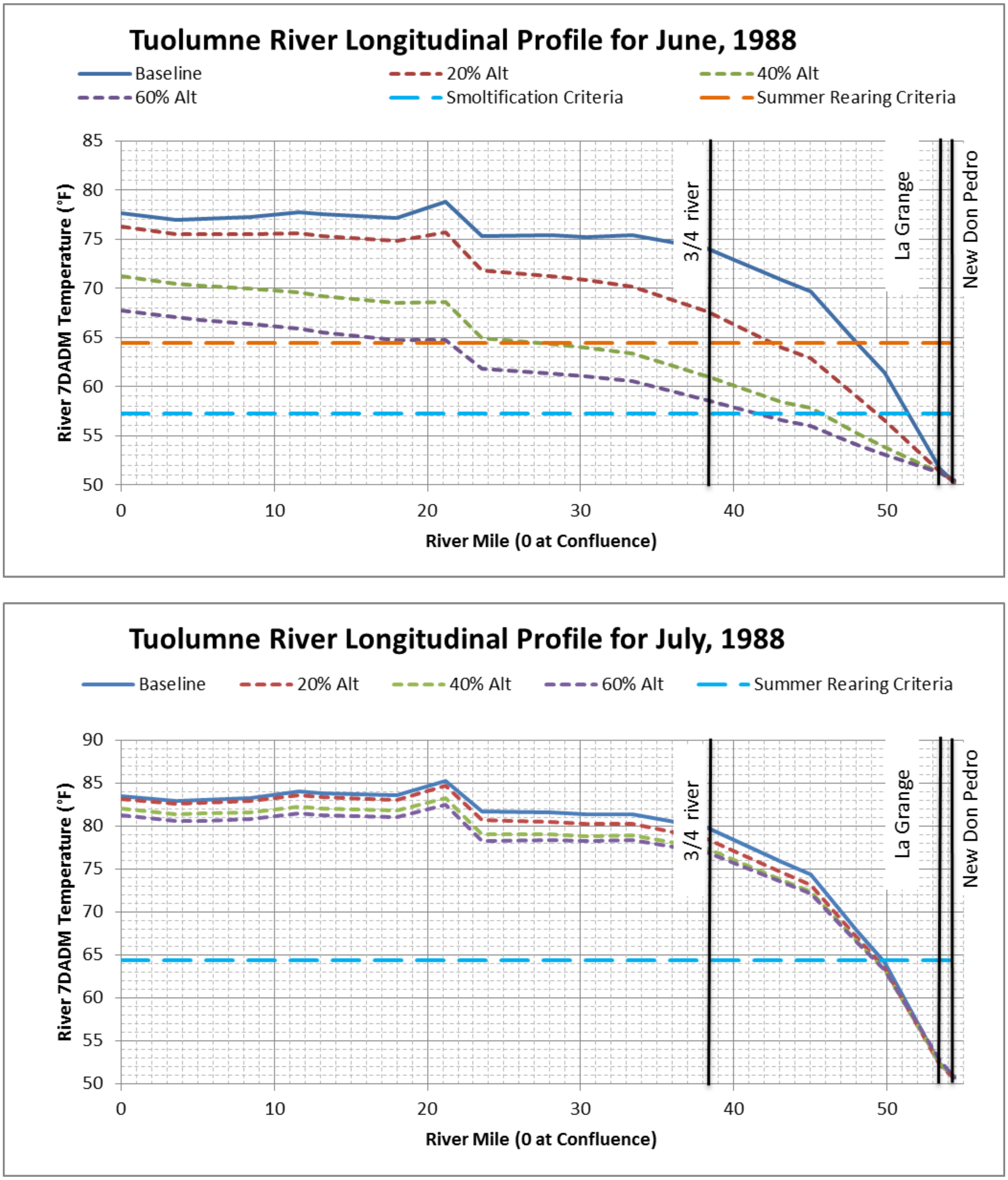
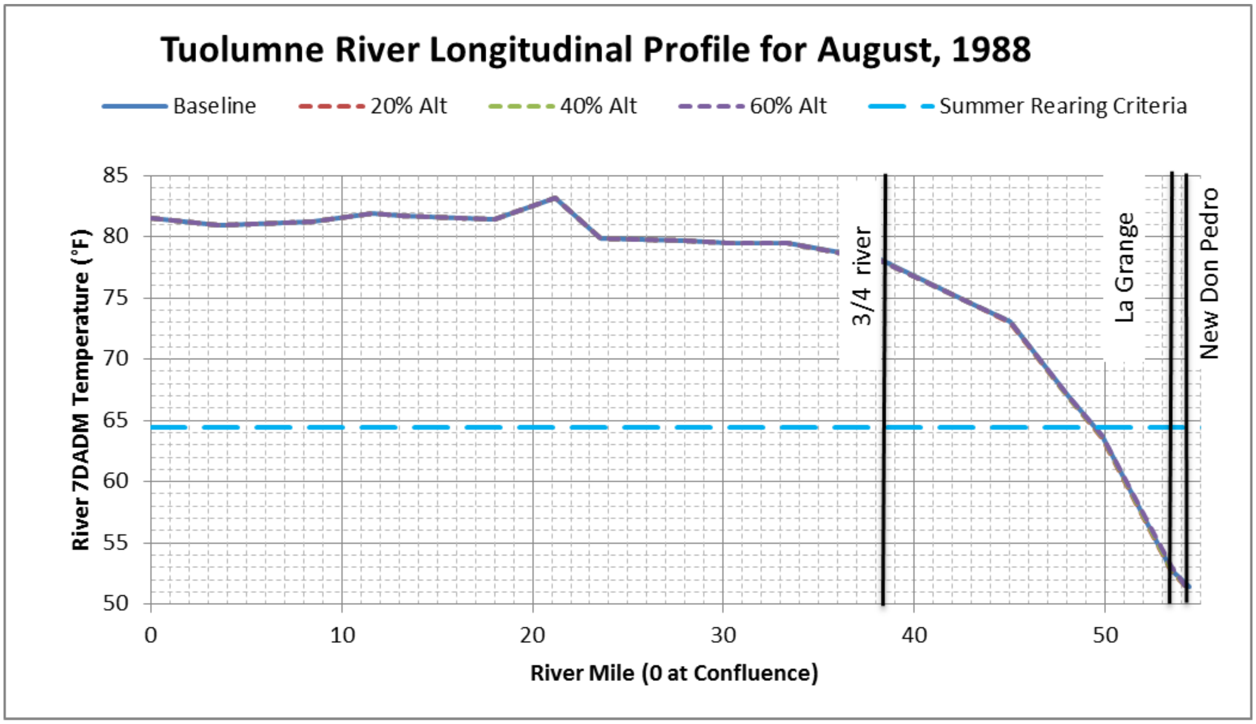


Figure F.1.6-36. Longitudinal Monthly Average 7DADM Temperature Results within the Tuolumne River for (a) June 1988 and (b) July 1988



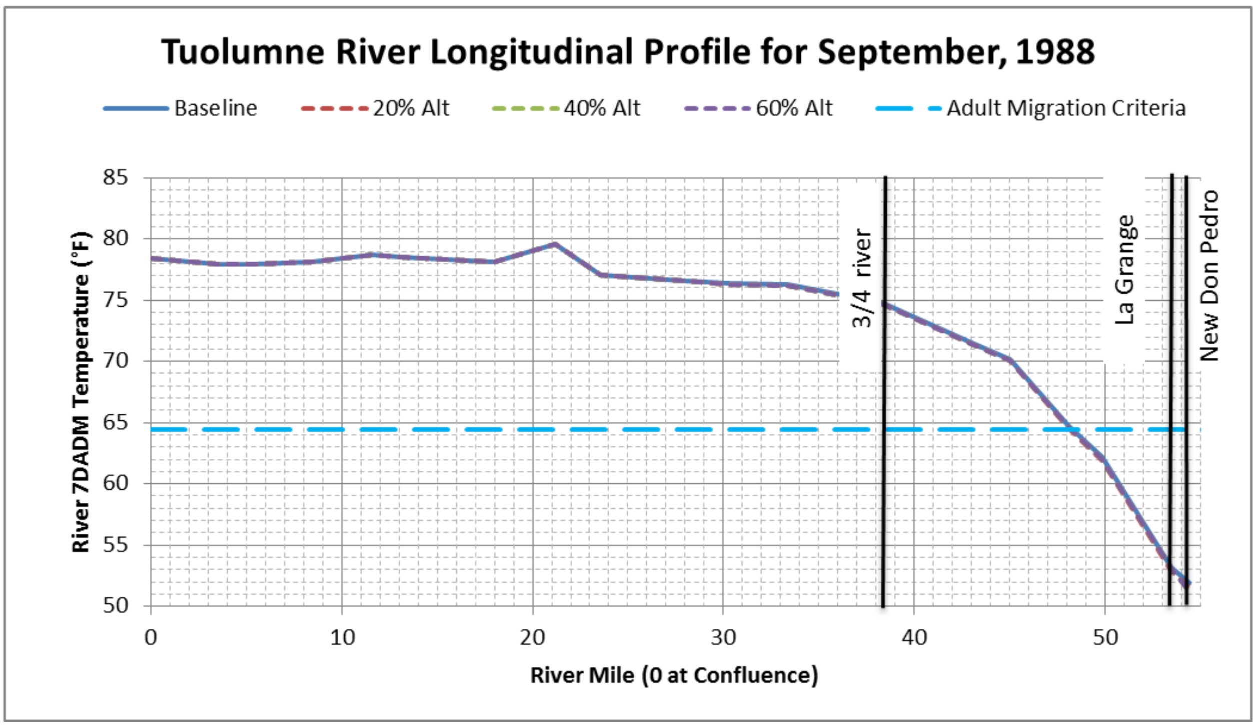


Figure F.1.6-37. Longitudinal Monthly Average 7DADM Temperature Results within the Tuolumne River for (a) August 1988 and (b) September 1988

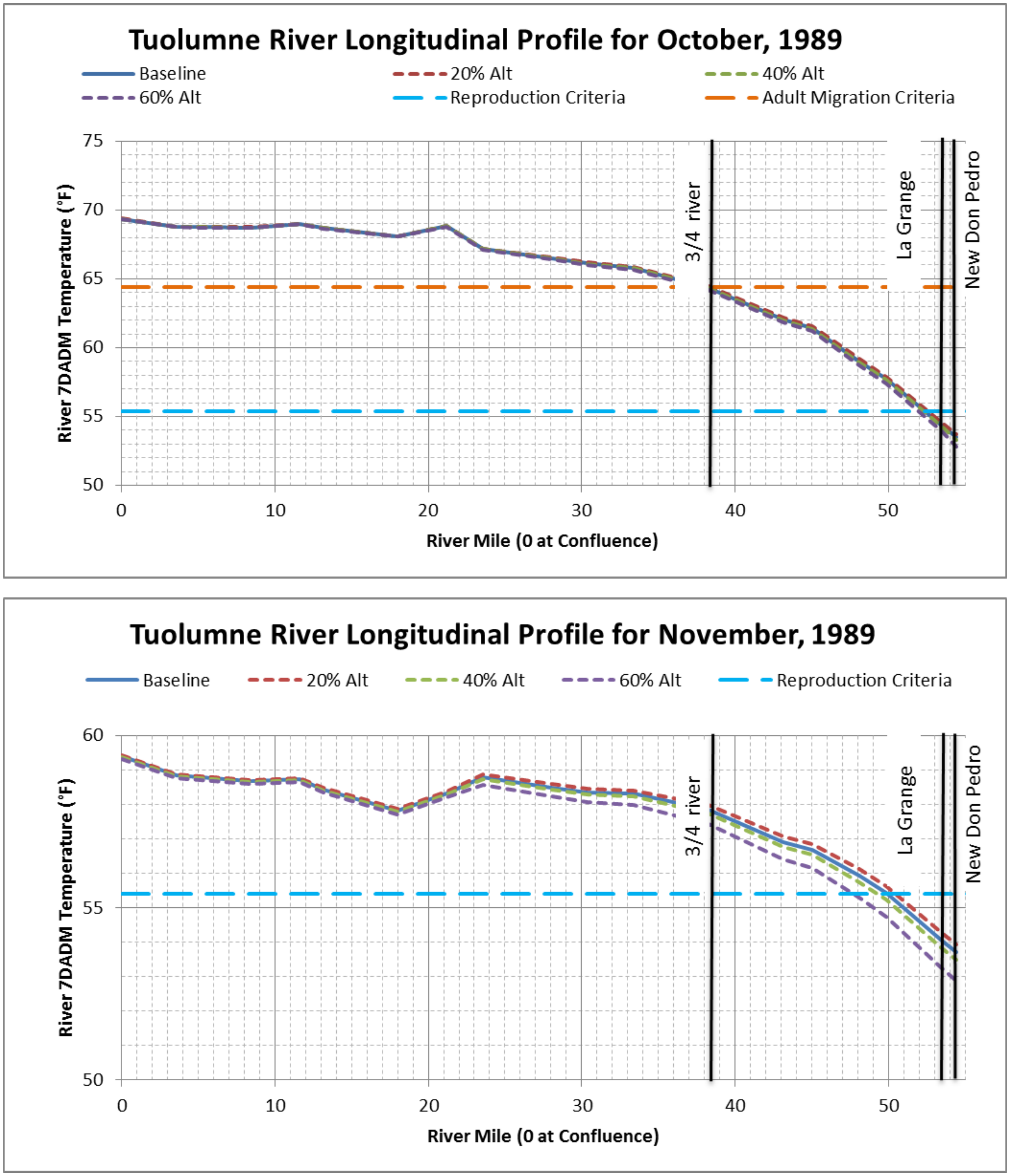
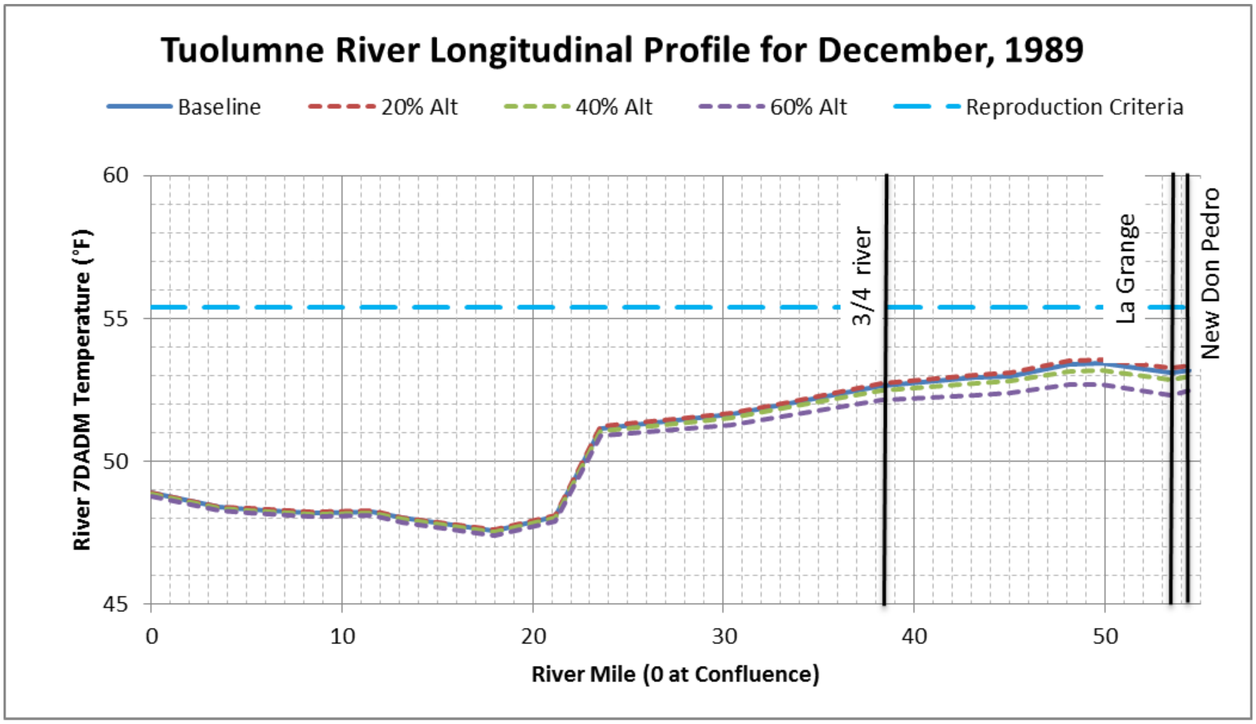


Figure F.1.6-38. Longitudinal Monthly Average 7DADM Temperature Results within the Tuolumne River for (a) October 1989 and (b) November 1989



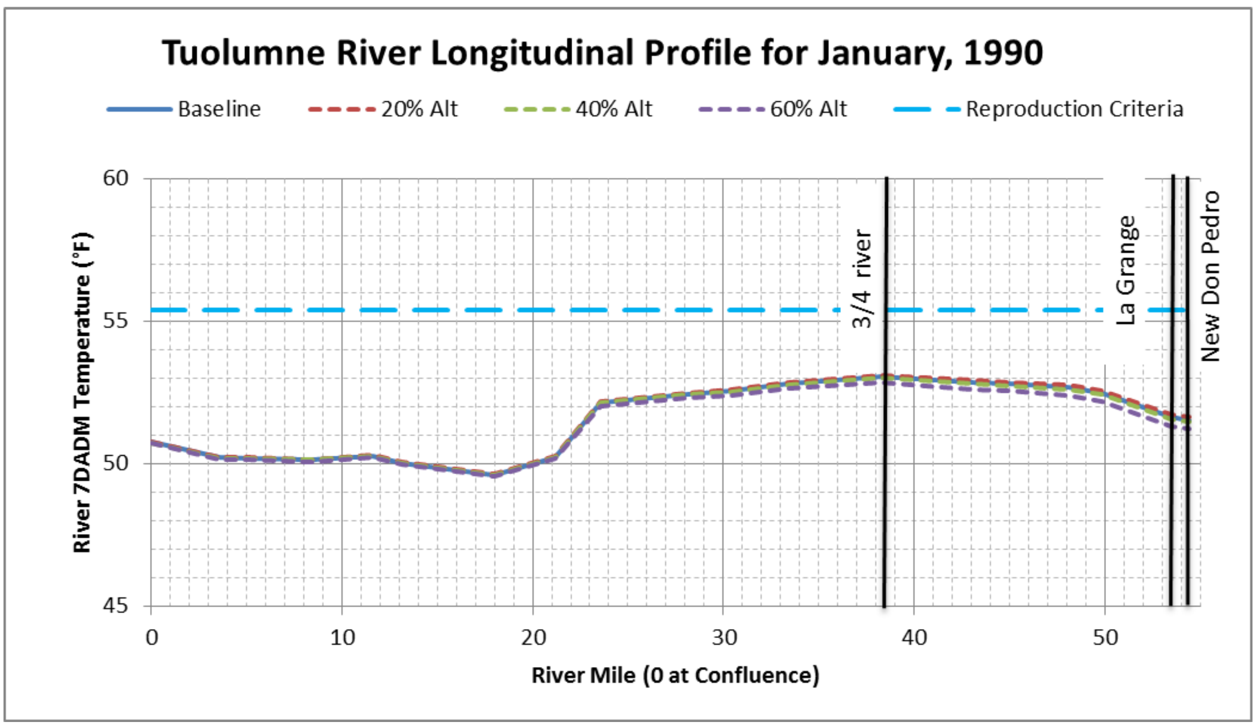
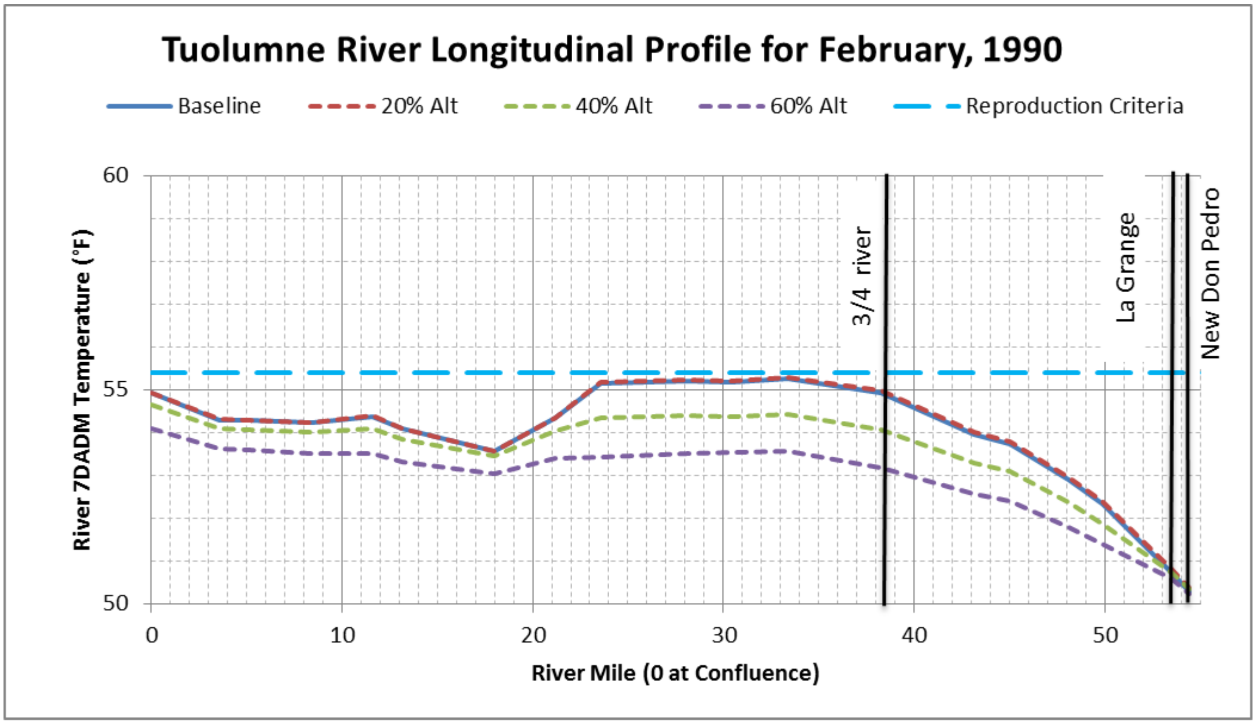


Figure F.1.6-39. Longitudinal Monthly Average 7DADM Temperature Results within the Tuolumne River for (a) December 1989 and (b) January 1990



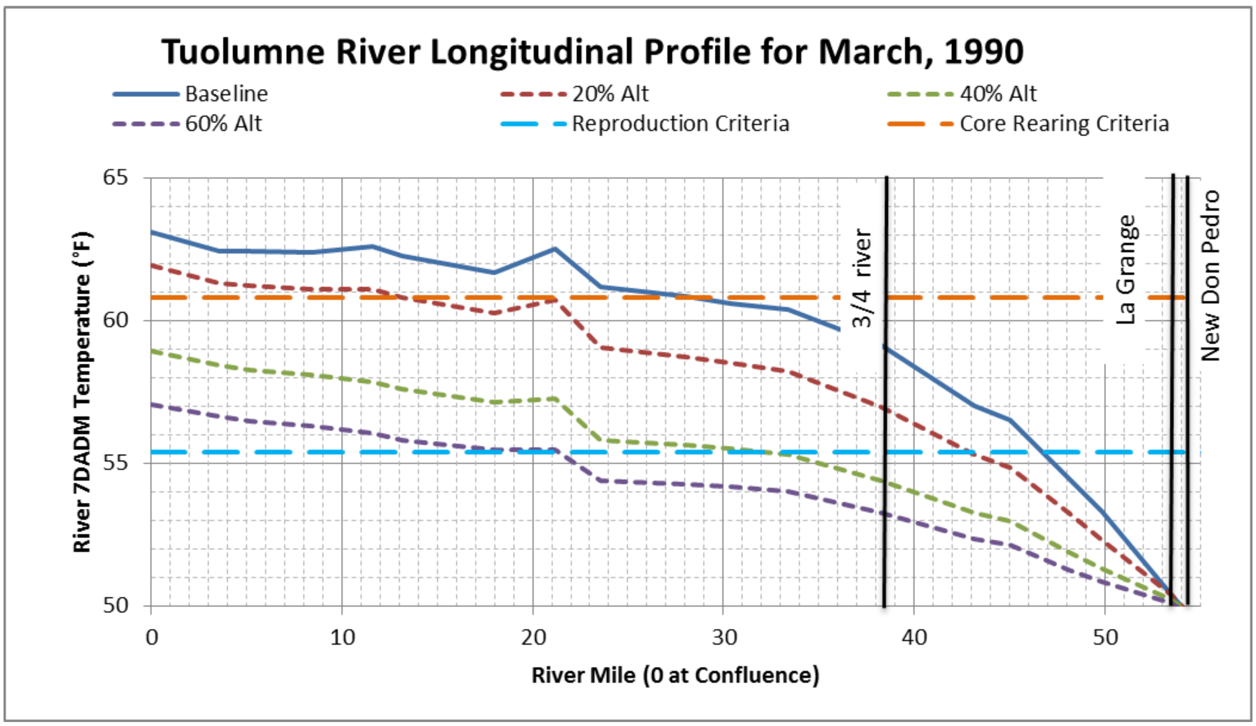
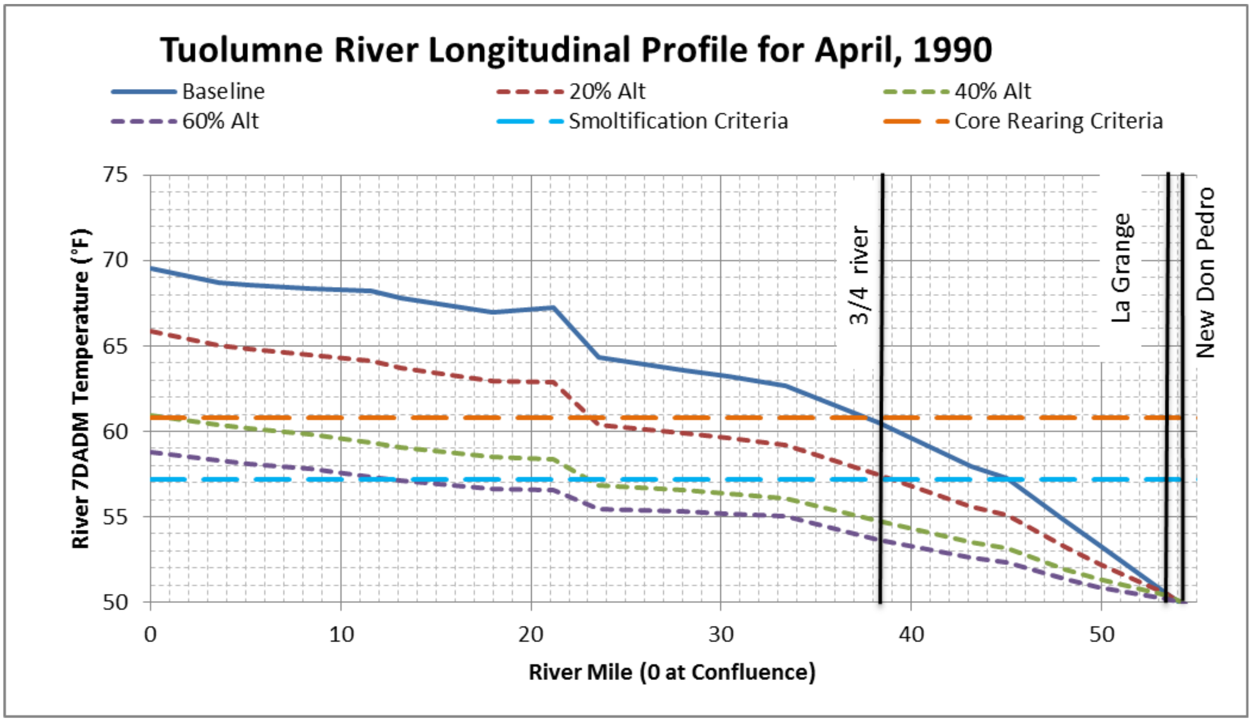


Figure F.1.6-40. Longitudinal Monthly Average 7DADM Temperature Results within the Tuolumne River for (a) February 1990 and (b) March 1990



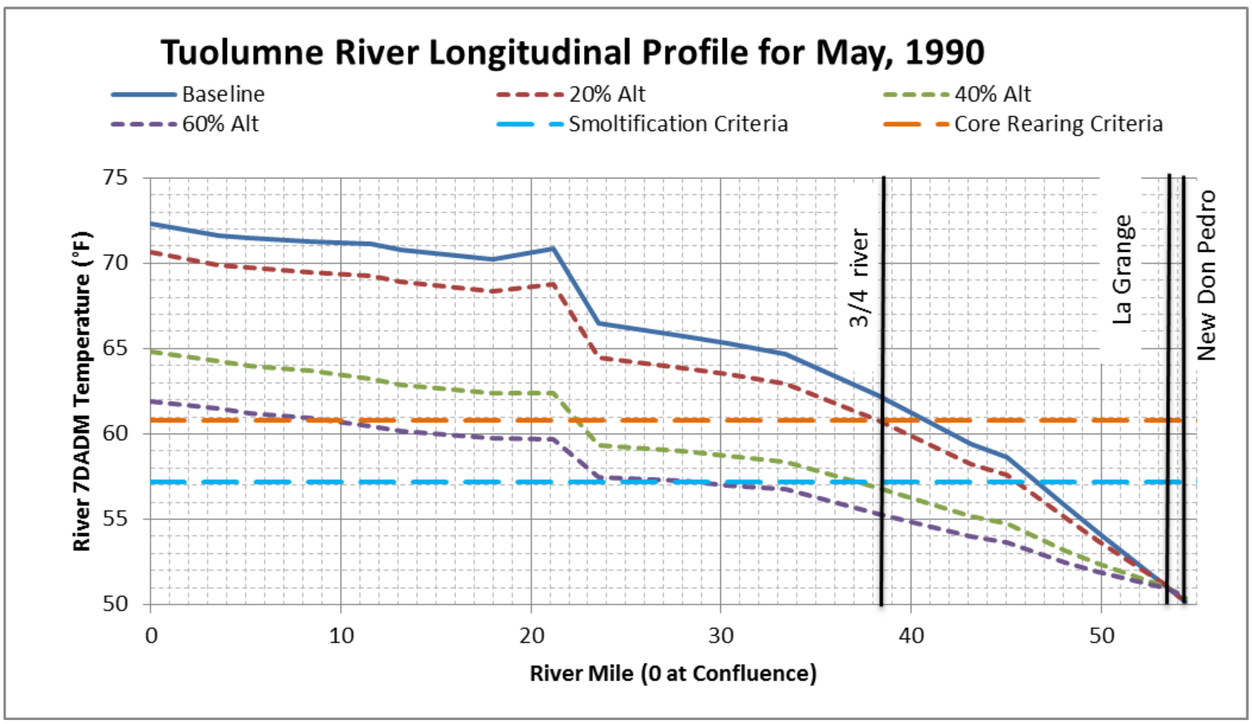
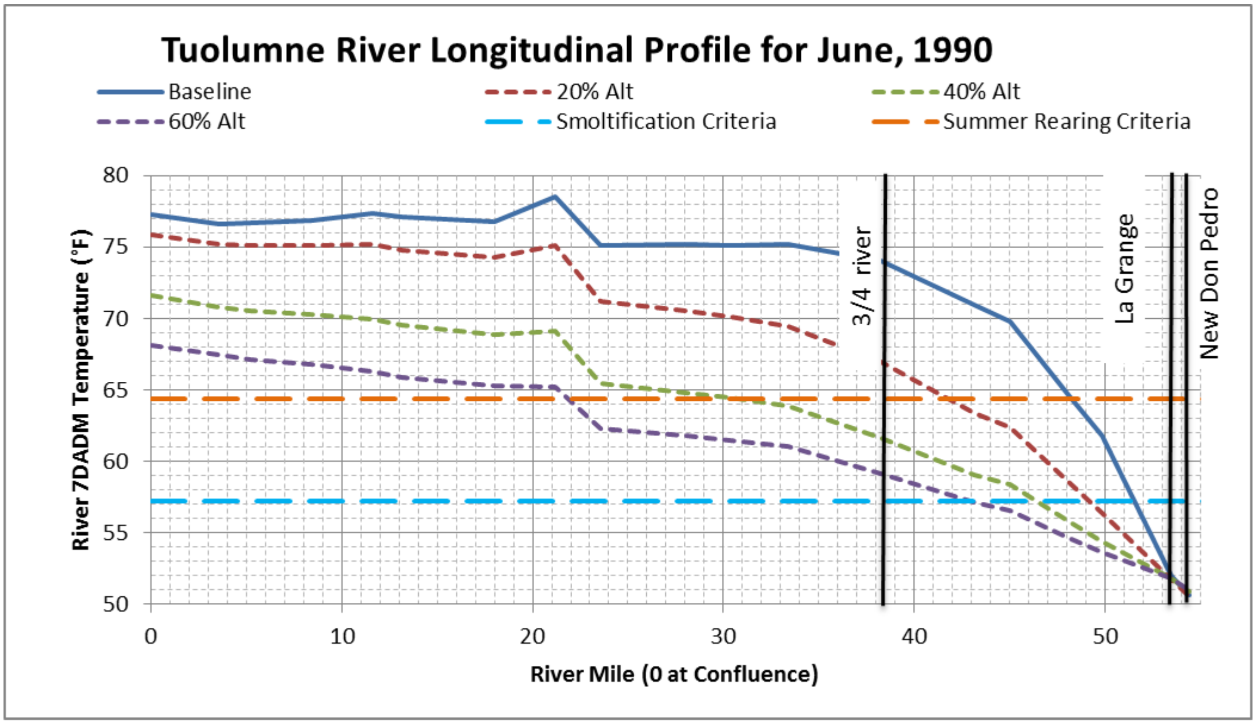


Figure F.1.6-41. Longitudinal Monthly Average 7DADM Temperature Results within the Tuolumne River for (a) April 1990 and (b) May 1990



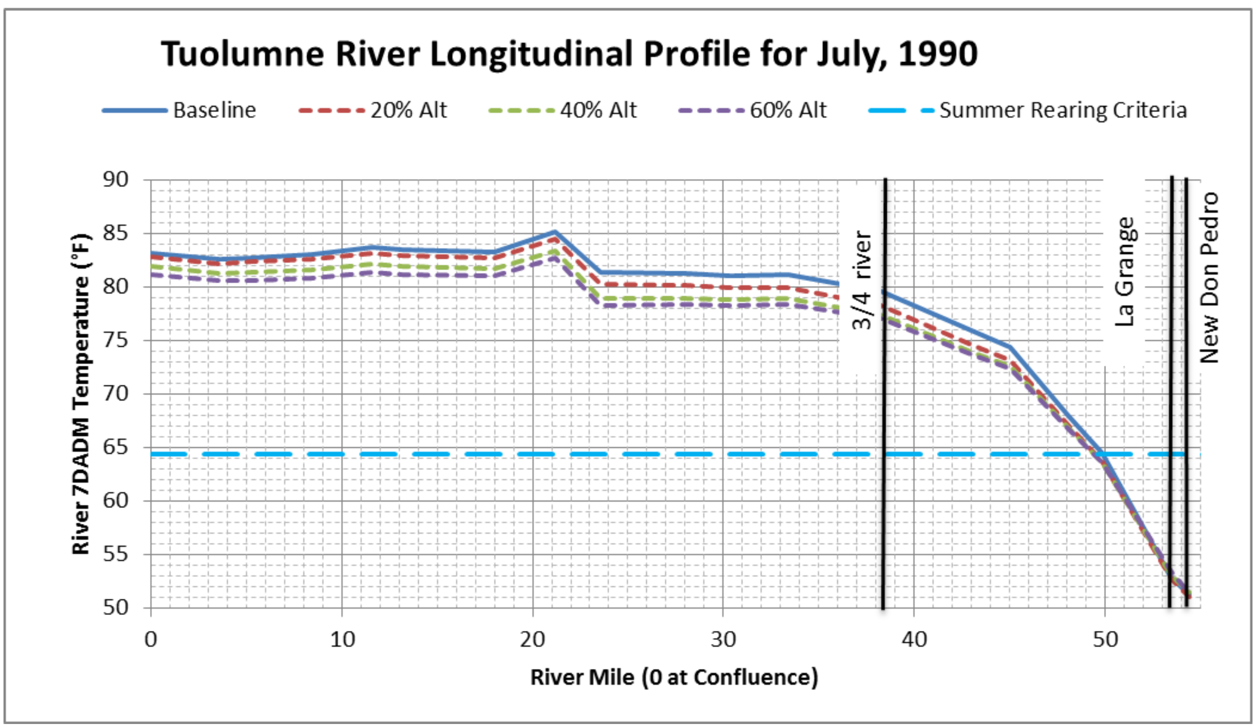


Figure F.1.6-42. Longitudinal Monthly Average 7DADM Temperature Results within the Tuolumne River for (a) June 1990 and (b) July 1990

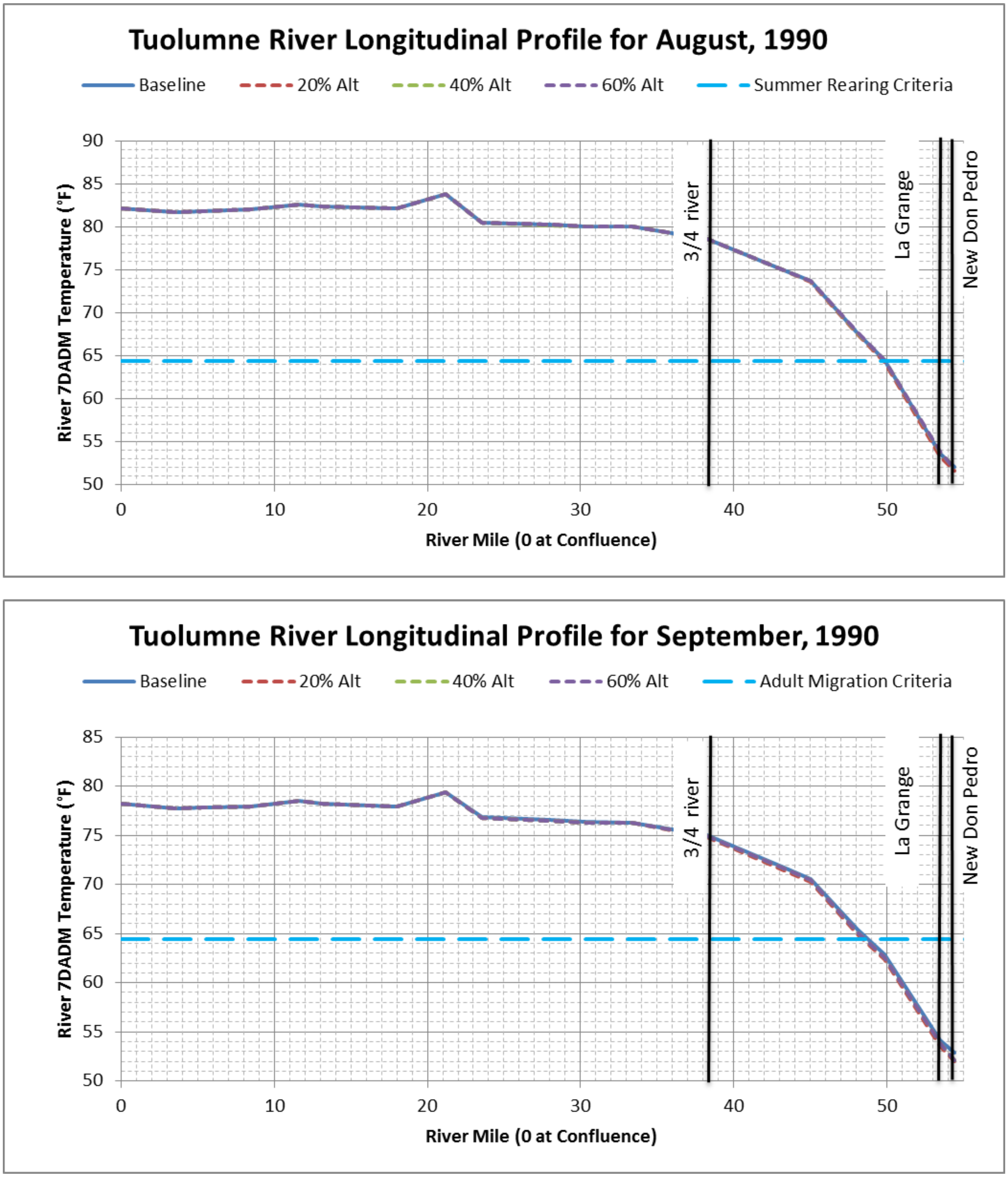


Figure F.1.6-43. Longitudinal Monthly Average 7DADM Temperature Results within the Tuolumne River for (a) August 1990 and (b) September 1990

Merced River Temperatures

Figures F.1.6-44a and F.1.6-44b show the monthly average temperatures in the Merced River at RM 27.1 simulated for baseline conditions and the LSJR alternatives, plotted as a function of the monthly river flow at Merced for February–June. For February, the temperatures were generally 49°F–56°F. The warmest temperatures corresponded to flows of about 250 cfs. Because there is little meteorological warming in February, river flow increases would not substantially reduce water temperatures.

In March, simulated temperatures in the Merced River at RM 27.1 were 50°F–55°F when river flows were 1,000 cfs or more and generally increased to 56°F–61°F when river flows were greater than 1,000 cfs. Because the LSJR alternatives tended to increase the low- to mid-range flows relative to baseline (i.e., they increased all but the highest baseline flows), LSJR alternative water temperatures tended to be lower than baseline. However, there were no large effects on water temperatures because meteorological warming at RM 27.1 was limited in March and water temperatures generally remained cool. The warmest temperatures were simulated for low flows of about 250 cfs, but these temperatures remained less than 61°F.

In April, the range of simulated temperatures at RM 27.1 was 50°F–67°F, with warmer temperatures of 60°F–67°F simulated for the lower flows (less than 500 cfs). Here, the shift toward higher flows in the LSJR alternative was distinct; where flow under baseline conditions approached 0, flows under LSJR Alternatives 2, 3, and 4 usually didn't fall below about 300 cfs, 500 cfs, and 800 cfs, respectively. With the higher flows, the temperature at RM 27.1 was shifted down in each of the alternatives, with temperatures under LSJR Alternative 4 rarely going above 60°F. In May, the range of simulated temperatures at RM 27.1 was 53°F–74°F, about 3°F–7°F warmer than in April. The warmer temperatures of 65°F–74°F were generally simulated for the lower flows (less than 500 cfs). Much like April, there were similar shifts toward higher flow and lower temperatures under each of the alternatives. In June, temperatures were considerably warmer than in April and May, ranging from 55°F–78°F. The warmer temperatures of 66°F–78°F were generally simulated for the lower flows (less than 500 cfs).

The Merced River warming curves (flow versus temperature) at RM 27.1 in April, May, and June indicate the general relationship between river flow and water temperatures in the upstream portion of the Merced River. These figures suggest that temperature is most responsive to changes in flow when flow is less than 1,000 cfs and during warmer conditions (i.e., June).Tables F.1.6-4a and F.1.6-4b give the monthly cumulative distributions of average simulated water temperatures in the Merced River at RM 27.1 for 1970–2003 under baseline conditions and the change in the distribution under the LSJR alternatives. Baseline average water temperatures at RM 27.1 indicate the average seasonal warming January–July is about 23°F. This seasonal warming is similar to the warming on the Stanislaus River at RM 28.2 and on the Tuolumne River at RM 28.1. The monthly increase in the average temperatures February–July was about 2°F–5°F per month.

Changes in temperature associated with the LSJR alternatives were dependent on the combination of change in flow and amount of meteorological warming (i.e., difference between reservoir release temperatures and equilibrium temperatures). The months of April–June showed significant drops in average monthly temperature under all the LSJR alternatives, with higher temperature reductions under higher unimpaired flow objectives. May had the highest temperature reductions, with average monthly temperatures falling 3.0°F under a 20 percent unimpaired flow objective and 6.6°F under a 60 percent unimpaired flow objective.

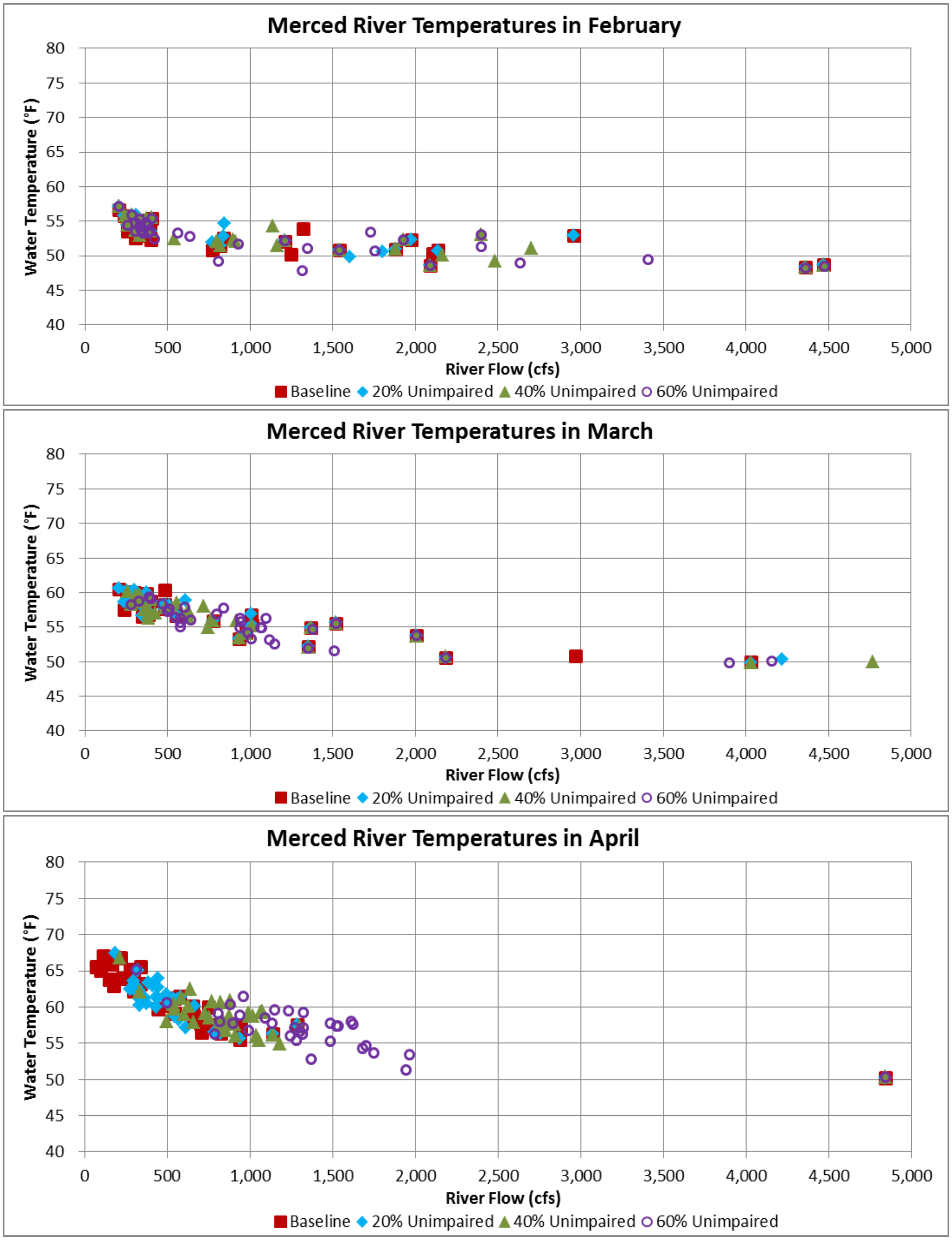
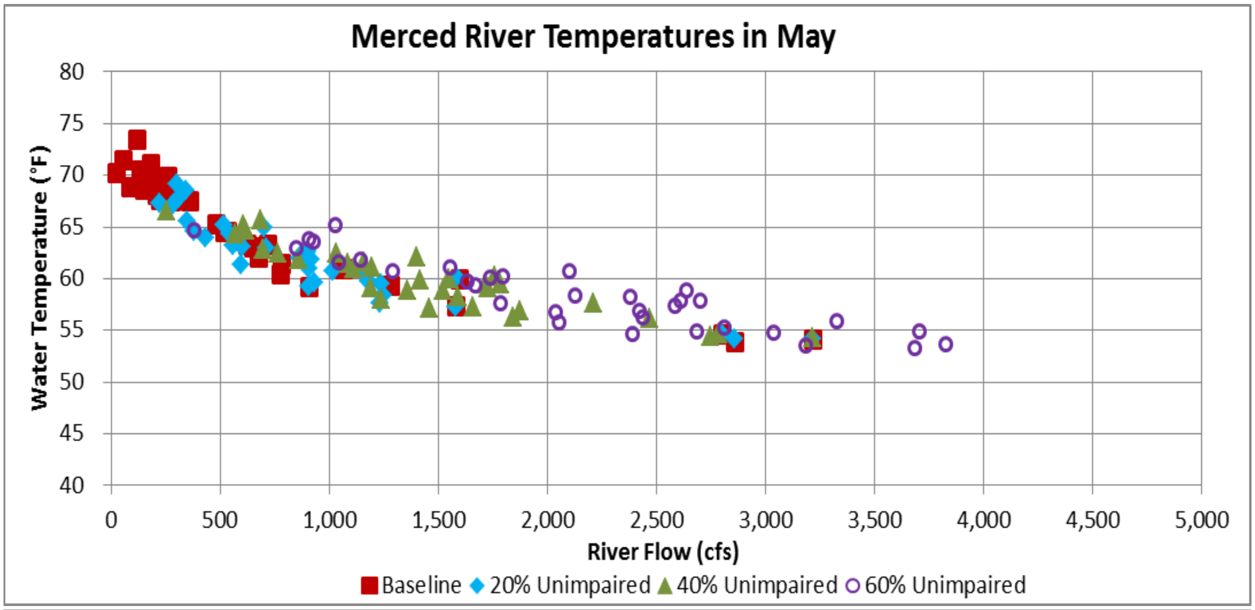


Figure F.1.6-44a. Effects of Merced River Flows on Temperatures at RM 27.1 in February–April for Baseline Conditions and 20%, 40%, 60% Unimpaired Flow (LSJR Alternatives 2–4) 1970–2003



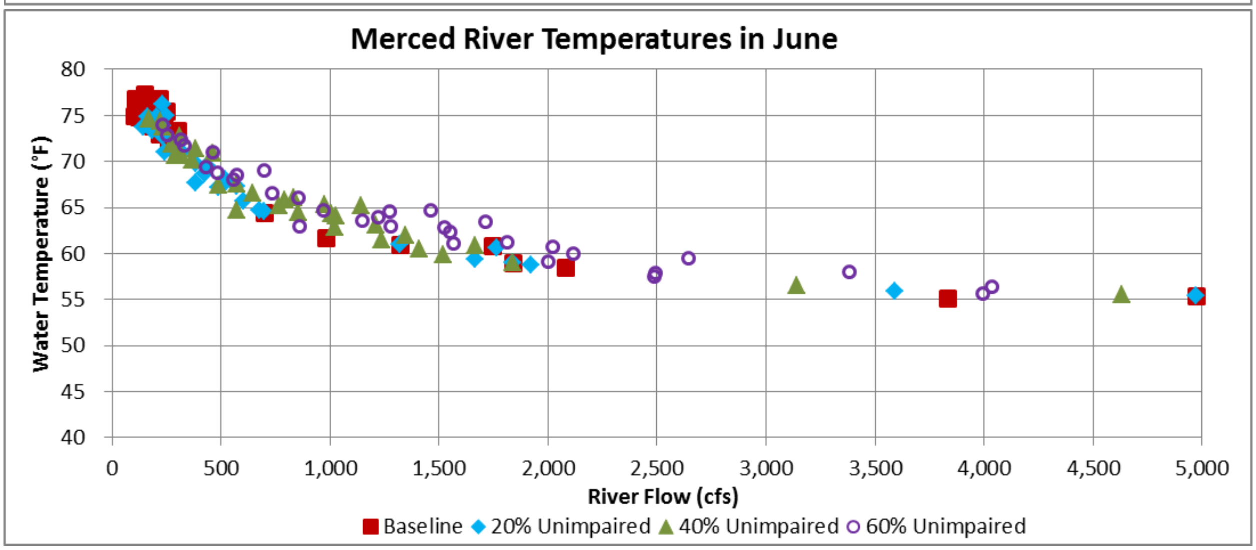


Figure F.1.6-44b. Effects of Merced River Flows on Temperatures at RM 27.1 in May and June for Baseline Conditions and 20%, 40%, 60% Unimpaired Flow (LSJR Alternatives 2–4) 1970–2003

Table F.1.6-4a. Monthly Distribution of Merced River Water Temperatures at RM 27.1 1970–2003 for Baseline Conditions and 20%, 40%, 60% Unimpaired Flow (LSJR Alternatives 2–4)

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Merced River Temperatures at RM 27.1 for Baseline Conditions												
Minimum	58.7	54.2	49.5	47.5	48.3	48.7	50.2	53.9	54.1	58.2	62.7	61.6
10%	60.9	55.1	49.7	48.6	50.2	51.2	56.4	57.9	56.4	60.3	63.8	64.1
20%	61.2	55.2	50.2	49.1	50.8	54.0	57.5	60.3	60.9	63.8	64.2	65.4
30%	61.6	56.0	50.6	49.2	51.3	55.6	59.1	62.0	71.5	74.8	66.1	66.6
40%	61.7	56.6	51.0	49.8	52.4	56.6	60.1	63.6	73.2	76.3	74.3	70.6
50%	62.6	57.1	51.2	50.0	52.9	57.1	61.9	66.4	73.9	76.7	75.4	72.1
60%	63.6	57.9	52.0	50.5	53.6	58.1	63.2	68.0	74.6	77.1	75.9	73.6
70%	64.8	58.8	52.5	50.9	54.1	58.6	63.8	68.9	75.0	77.7	76.9	74.2
80%	65.7	60.0	52.9	51.2	55.1	59.3	65.1	70.1	75.4	79.1	77.9	75.8
90%	68.6	61.1	53.4	52.3	55.5	59.9	65.8	70.9	76.1	80.1	79.0	76.8
Maximum	70.2	62.7	54.0	53.2	56.7	60.4	67.1	73.5	77.4	80.7	81.8	78.2
Average	63.6	57.7	51.6	50.2	52.8	56.5	61.3	65.1	69.9	73.1	72.5	70.9
Change in Merced River Temperatures at RM 27.1 for 20% Unimpaired Flow Relative to Baseline												
Minimum	0.0	-0.4	-0.3	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0
10%	-0.4	0.0	0.0	0.0	-0.3	-0.2	-0.1	-0.5	0.4	0.0	0.0	0.1
20%	-0.1	0.1	0.0	0.0	0.0	0.0	0.4	-0.9	-0.8	0.1	0.1	0.0
30%	-0.1	-0.2	-0.1	0.5	0.6	0.0	1.0	-1.9	-6.8	-0.4	1.3	0.0
40%	0.1	-0.4	0.0	0.3	0.4	0.2	0.4	-2.5	-5.8	-0.5	0.1	-0.2
50%	0.0	-0.1	0.0	0.3	0.5	0.4	-0.7	-4.2	-6.0	-0.4	0.0	-0.3
60%	-0.1	-0.6	-0.6	0.0	0.1	0.1	-1.9	-5.0	-4.8	-0.1	-0.1	-0.5
70%	-1.2	-0.9	-0.6	-0.1	0.4	0.0	-1.4	-4.9	-3.7	0.0	0.0	-0.2
80%	-1.3	-1.7	-0.8	0.1	-0.1	-0.3	-2.4	-5.0	-1.6	-0.4	0.0	-0.6
90%	-2.9	-1.9	-0.4	0.0	0.2	0.2	-2.3	-3.7	-1.4	-0.8	-0.4	-0.2
Maximum	-2.7	-2.5	-0.5	0.1	0.5	0.1	0.4	-4.4	-1.2	-0.1	-0.3	-0.2
Average	-0.8	-0.7	-0.3	0.1	0.2	0.1	-0.8	-3.0	-2.8	-0.3	0.1	-0.2
Change in Merced River Temperatures at RM 27.1 for 40% Unimpaired Flow Relative to Baseline												
Minimum	0.0	-0.1	-0.4	0.0	0.0	0.0	0.2	0.4	0.0	0.0	0.0	0.0
10%	-1.1	0.1	0.1	0.0	-0.7	-0.1	-0.5	-1.8	0.9	0.1	0.1	-0.1
20%	-0.3	0.4	0.1	0.0	0.2	-0.1	-0.5	-3.1	-0.2	2.7	0.4	-0.1
30%	-0.1	-0.1	-0.1	0.3	0.6	-0.4	-1.4	-3.8	-8.8	-4.8	2.8	-0.9
40%	-0.1	-0.6	0.0	0.3	-0.1	-0.6	-2.1	-4.5	-8.9	-1.7	-0.3	-0.1
50%	-0.6	-0.4	0.0	0.2	0.1	-0.5	-3.1	-6.8	-8.7	-1.0	-0.3	-0.7
60%	-0.9	-0.9	-0.5	0.0	0.1	-0.8	-4.1	-7.2	-8.6	-0.5	-0.2	-1.3
70%	-1.0	-1.4	-0.6	-0.1	0.1	-0.9	-4.4	-7.2	-7.2	-0.4	-0.3	-0.9
80%	-1.5	-1.8	-0.6	0.0	-0.2	-1.0	-4.7	-7.6	-4.6	-0.6	0.2	-0.7
90%	-2.7	-1.9	-0.5	0.0	-0.1	-0.9	-4.7	-6.4	-3.6	-1.0	-0.3	-0.1
Maximum	-2.5	-3.1	-0.3	0.2	0.5	-0.4	-0.2	-7.0	-2.8	-0.6	-0.2	0.0
Average	-1.0	-0.8	-0.3	0.1	0.0	-0.5	-2.7	-5.1	-4.7	-0.5	0.1	-0.4

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Change in Merced River Temperatures at RM 27.1 for 60% Unimpaired Flow Relative to Baseline												
Minimum	-0.1	0.8	-0.5	0.0	-0.5	0.0	0.1	-0.6	0.9	0.1	0.3	0.0
10%	-0.5	0.4	0.0	-0.1	-1.5	-0.3	-3.0	-3.3	1.2	5.5	1.4	0.3
20%	-0.3	0.5	0.2	0.1	-0.6	-1.1	-2.5	-5.1	-1.6	4.1	3.1	-0.4
30%	-0.1	-0.3	0.2	0.1	-0.1	-1.5	-2.8	-5.7	-10.4	-6.1	1.4	-1.0
40%	0.0	-0.3	0.2	0.1	0.0	-1.7	-3.2	-6.1	-10.4	-1.6	0.0	0.1
50%	-0.5	-0.5	0.2	0.1	0.2	-1.5	-4.5	-8.4	-10.3	-1.1	-0.1	-0.4
60%	-0.8	-0.8	-0.2	-0.2	-0.1	-1.9	-5.5	-8.8	-9.9	-0.5	0.2	-0.7
70%	-0.9	-1.1	-0.3	-0.2	-0.4	-2.2	-5.8	-8.6	-8.2	-0.2	-0.2	-0.5
80%	-1.1	-1.5	-0.3	0.0	-0.7	-1.6	-5.9	-8.8	-6.5	-0.4	0.5	0.0
90%	-1.5	-1.3	-0.4	0.0	-0.4	-1.5	-5.7	-7.5	-4.6	-0.8	0.0	0.1
Maximum	0.0	0.0	-0.3	0.0	0.5	-1.1	-1.8	-8.3	-3.4	-0.7	0.4	0.1
Average	-0.5	-0.5	-0.1	0.0	-0.3	-1.4	-4.2	-6.6	-5.9	0.1	0.6	-0.1

Table F.1.6-4b. Monthly Distribution of Merced River Water Temperatures at RM 27.1 1970–2003 for Baseline Conditions and 20%, 40%, 60% Unimpaired Flow (LSJR Alternatives 2–4)

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Average Merced River Temperatures at RM 27.1												
Baseline Average												
	63.6	57.7	51.6	50.2	52.8	56.5	61.3	65.1	69.9	73.1	72.5	70.9
Change in Average Merced River Temperatures at RM 27.1 Relative to Baseline												
20% Unimpaired Flow Minus Baseline												
	-0.8	-0.7	-0.3	0.1	0.2	0.1	-0.8	-3.0	-2.8	-0.3	0.1	-0.2
30% Unimpaired Flow Minus Baseline												
	-0.7	-0.7	-0.3	0.1	0.1	-0.2	-2.1	-4.4	-3.9	0.2	0.7	0.1
40% Unimpaired Flow Minus Baseline												
	-1.0	-0.8	-0.3	0.1	0.0	-0.5	-2.7	-5.1	-4.7	-0.5	0.1	-0.4
50% Unimpaired Flow Minus Baseline												
	-0.9	-0.7	-0.2	0.1	-0.1	-0.9	-3.5	-5.9	-5.4	-0.3	0.4	-0.3
60% Unimpaired Flow Minus Baseline												
	-0.5	-0.5	-0.1	0.0	-0.3	-1.4	-4.2	-6.6	-5.9	0.1	0.6	-0.1

Figures F.1.6-45, F.1.6-46, F.1.6-47, and F.1.6-48 show Merced River temperature model results under baseline conditions and under LSJR Alternatives 2 and 3 (40 and 60 percent of unimpaired flow objectives Feb–June) for the water years 1985–1989, 1990–1994, 1995–1999, and 2000–2003, respectively. Each figure is composed of three separate charts to compare how reservoir storage and river flow can affect temperatures at different points along the river. Chart A shows reservoir storage at Lake McClure, Chart B shows the instream flows at Stevinson, and Chart C gives the daily 7DADM temperature at New Exchequer Dam release, Crocker-Huffman Dam release, and 1/4 River location.

Figures F.1.6-49a and F.1.6-49b show temperature model 7DADM results at 3/4 River (Merced RM 37.8) compared to monthly USEPA temperature criteria for optimal development of different fish lifestages (as described in Chapter 19) under LSJR Alternatives 2 and 3 (40 and 60 percent of unimpaired flow Feb–June) and baseline conditions for water years 1985–1989 and water years 1990–1994, respectively. These show temperature effects of reservoir levels within the major drought sequence 1989–1992.

Figures F.1.6-50, F.1.6-51, F.1.6-52, F.1.6-53, F.1.6-54, and F.1.6-55 show longitudinal monthly average 7DADM temperature results in the Merced River for each month of the water year 1988 under baseline conditions and the LSJR alternatives. Water year 1988 is shown because it represents a year when storage levels in New Exchequer Reservoir were around 400 thousand acre feet (medium storage level) under the model scenarios. Figures F.1.6-56, F.1.6-57, F.1.6-58, F.1.6-59, F.1.6-60, and F.1.6-61 show longitudinal monthly average 7DADM temperature results for each month of the water year 1990 under baseline conditions and the LSJR alternatives. Water year 1990 is shown because it represents a year in the middle of the 1989–1992 drought sequence when Lake McClure storage levels were generally low.

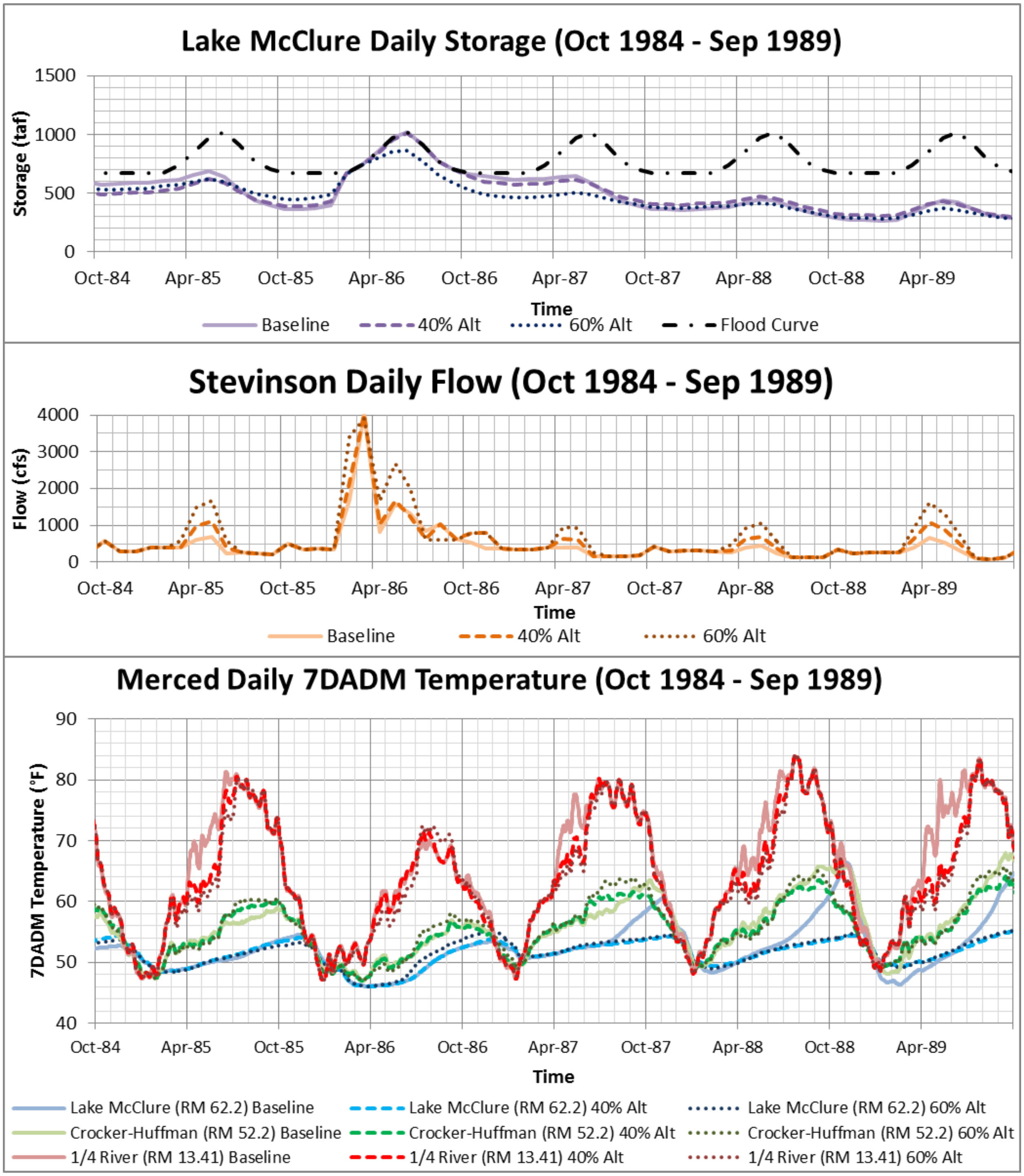


Figure F.1.6-45. Merced River Temperature Model Results for LSJR Alternatives 2 and 3 (40% and 60% of Unimpaired Flow Feb–June) and Baseline Scenarios for the Water Years 1985–1989, Showing (a) Reservoir Storage, (b) Instream Flows, and (c) Daily 7DADM Temperature at Lake McClure Release, Crocker-Huffman Dam Release, and 1/4 River Locations

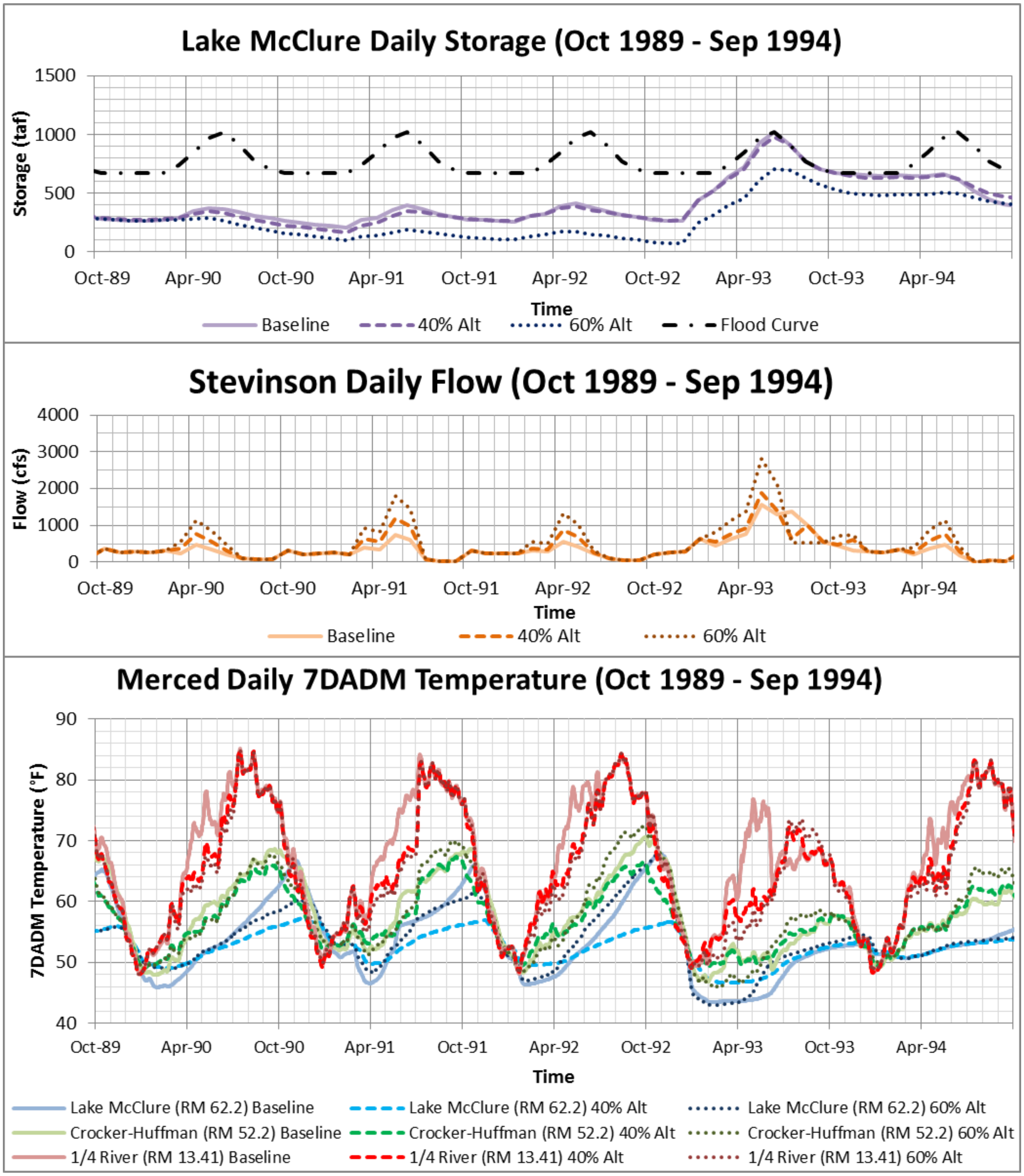


Figure F.1.6-46. Merced River Temperature Model Results for LSJR Alternatives 2 and 3 (40% and 60% of Unimpaired Flow Feb–June) and Baseline Scenarios for the Water Years 1990–1994, Showing (a) Reservoir Storage, (b) Instream Flows, and (c) Daily 7DADM Temperature at Lake McClure Release, Crocker-Huffman Dam Release, and 1/4 River Locations

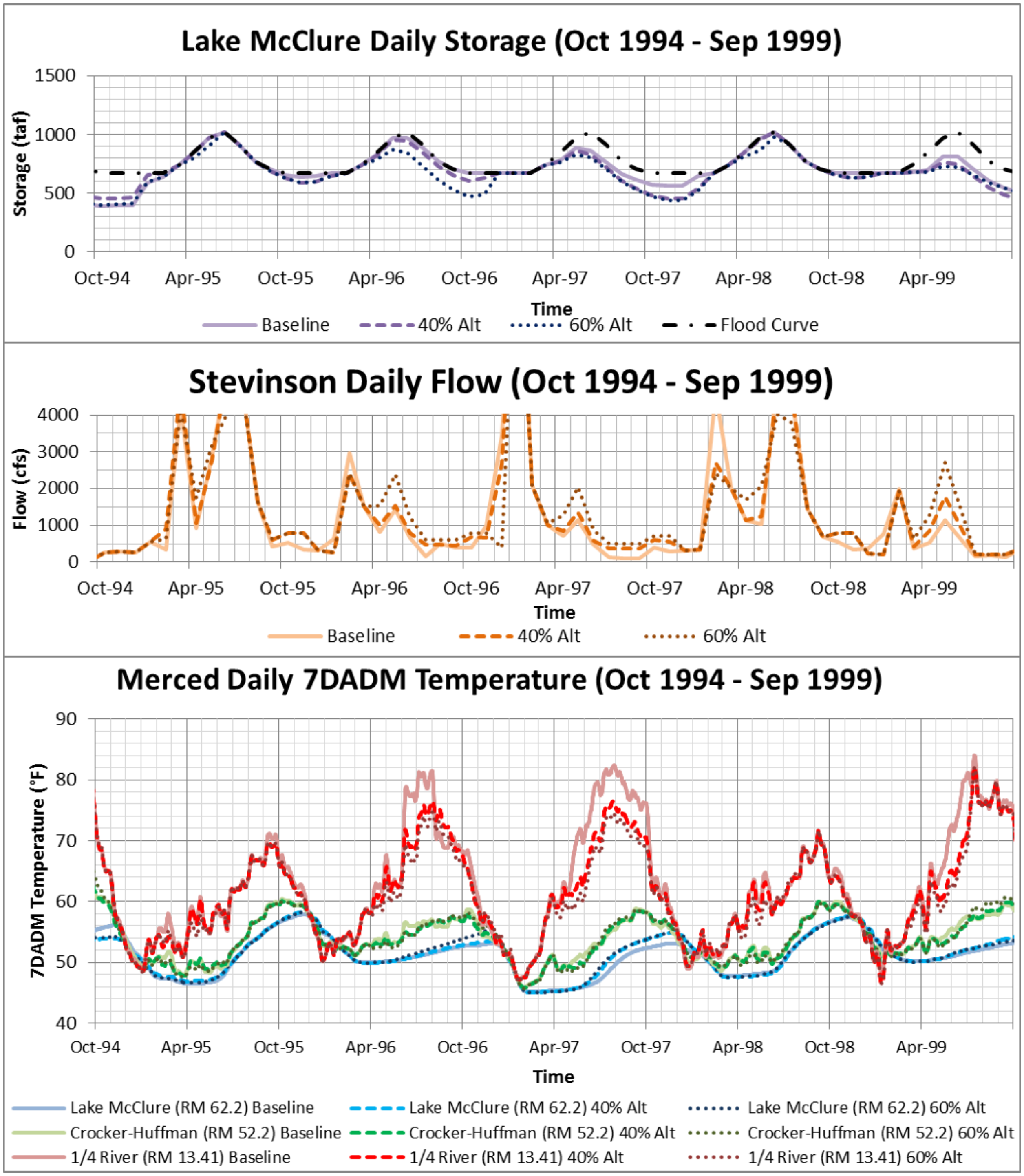


Figure F.1.6-47. Merced River Temperature Model Results for LSJR Alternatives 2 and 3 (40% and 60% of Unimpaired Flow Feb–June) and Baseline Scenarios for the Water Years 1995–1999, Showing (a) Reservoir Storage, (b) Instream Flows, and (c) Daily 7DADM Temperature at Lake McClure Release, Crocker-Huffman Dam Release, and 1/4 River Locations

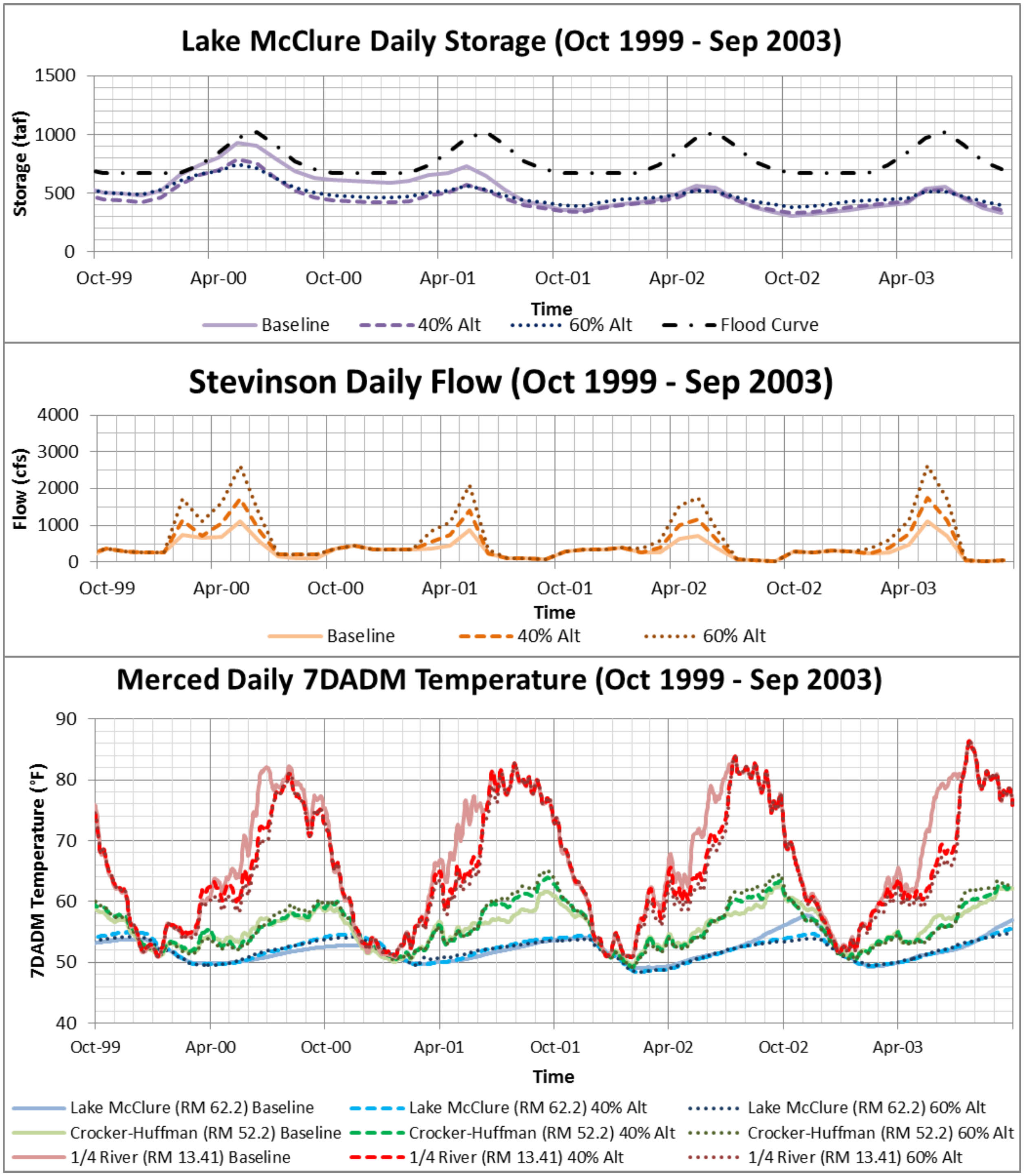
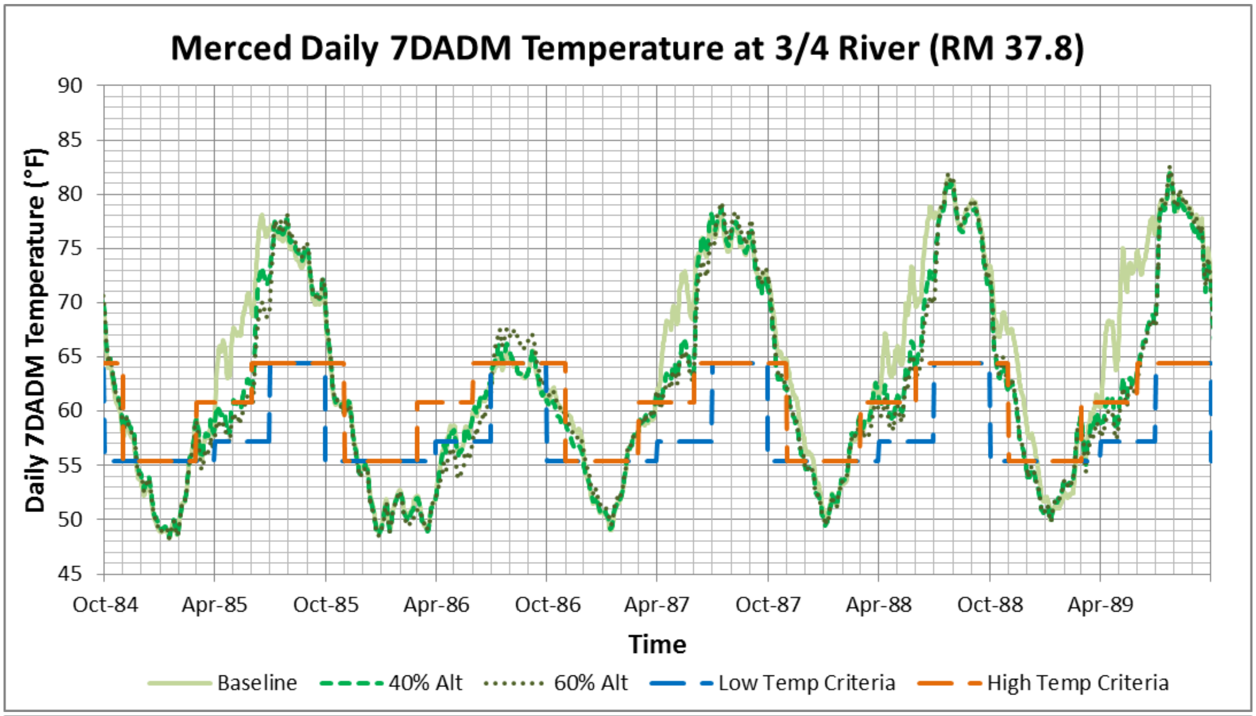


Figure F.1.6-48. Merced River Temperature Model Results for LSJR Alternatives 2 and 3 (40% and 60% of Unimpaired Flow Feb–June) and Baseline Scenarios for the Water Years 2000–2003, Showing (a) Reservoir Storage, (b) Instream Flows, and (c) Daily 7DADM Temperature at Lake McClure Release, Crocker-Huffman Dam Release, and 1/4 River Locations



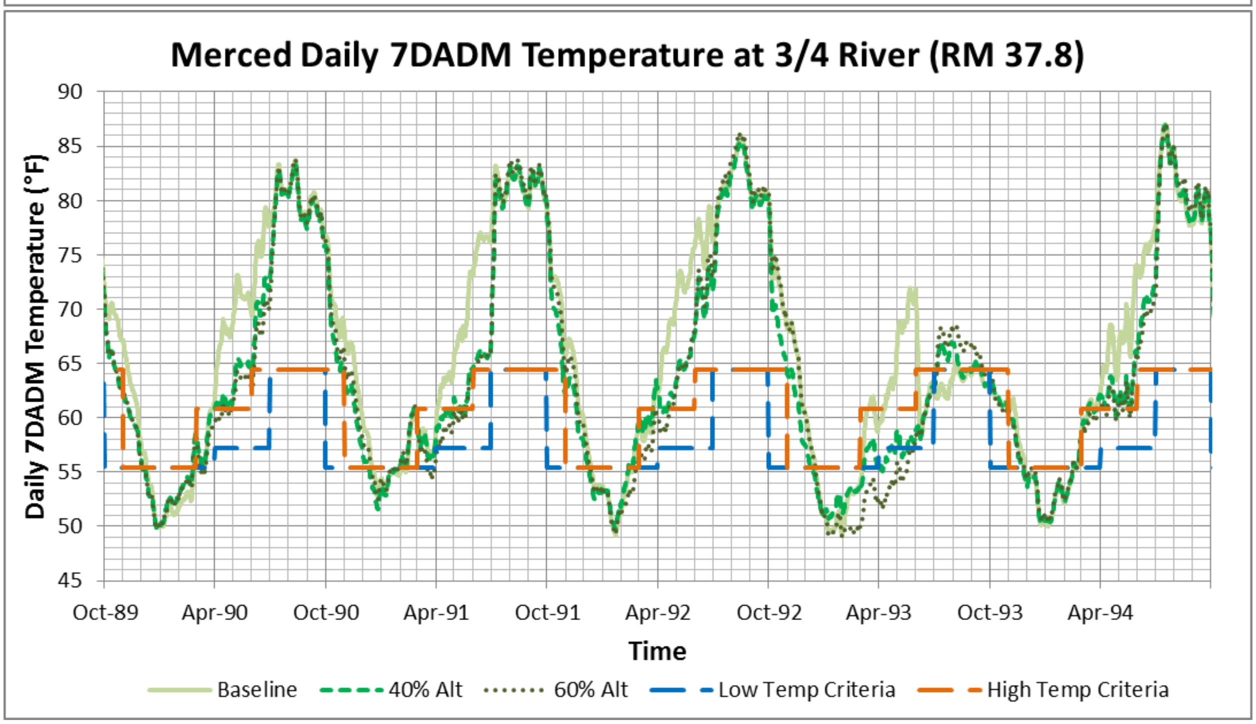
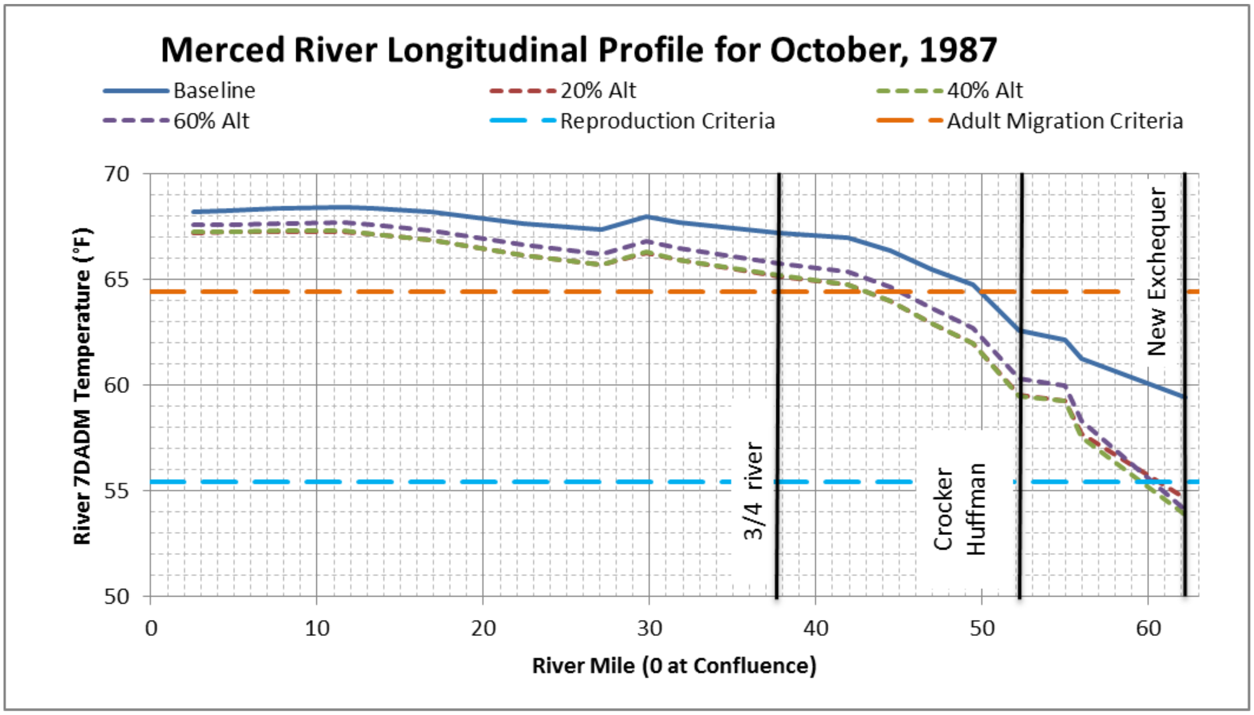


Figure F.1.6-49. Temperature Model 7DADM Results at Merced RM 37.8 Compared to Monthly USEPA Temperature Criteria for Optimal Development of Different Fish Lifestages under Baseline and LSJR Alternatives 2 and 3 (40% and 60% of Unimpaired Flow Feb–June) for (a) Water Years 1985–1989 and (b) Water Years 1990–1994



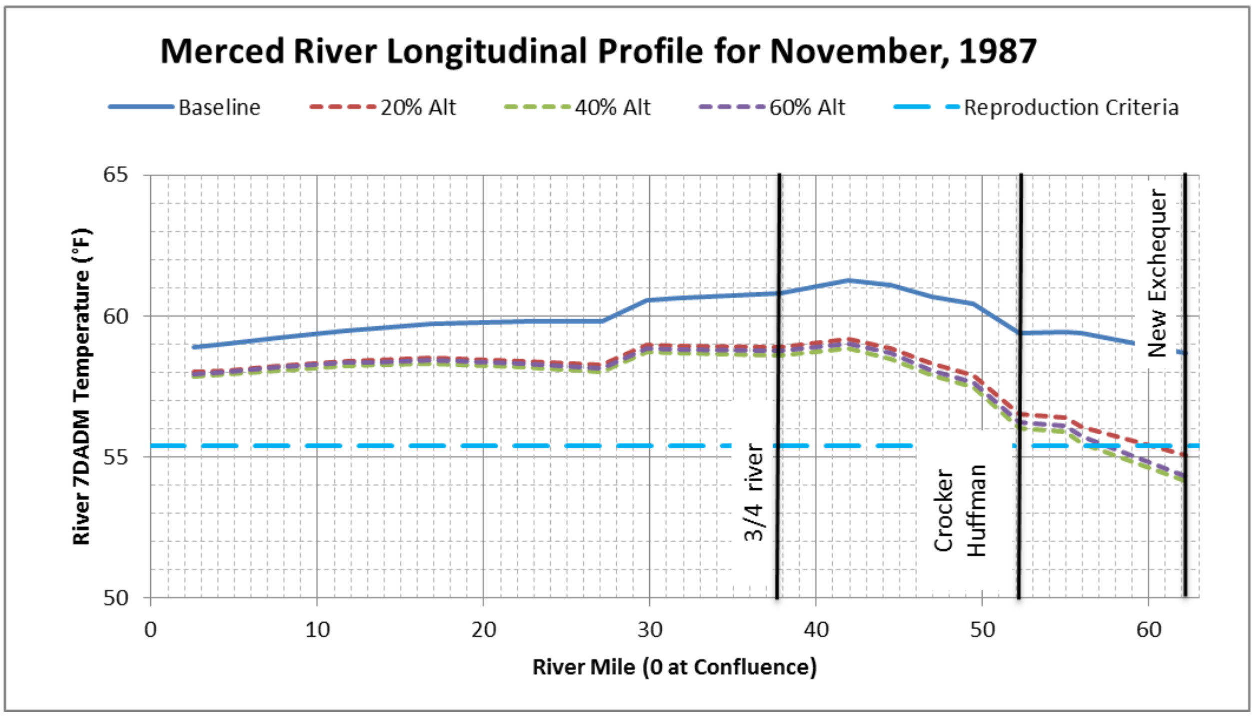
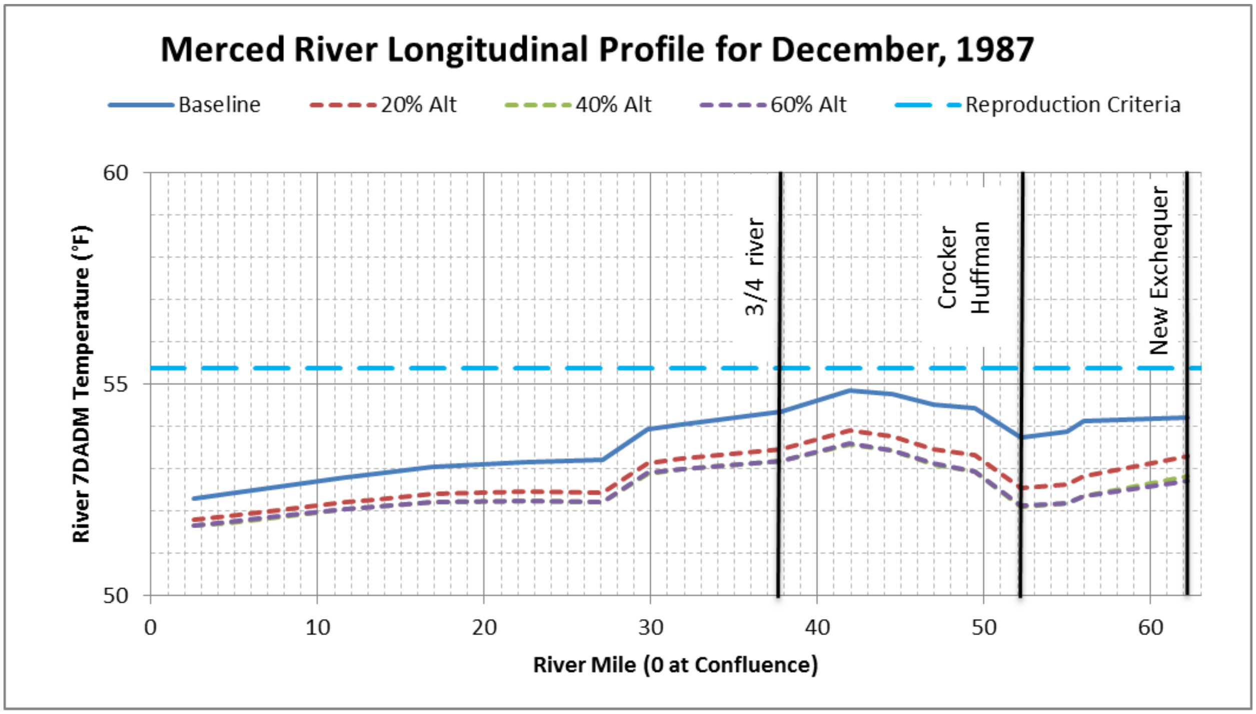


Figure F.1.6-50. Longitudinal Monthly Average 7DADM Temperature Results within the Merced River for (a) October 1987 and (b) November 1987



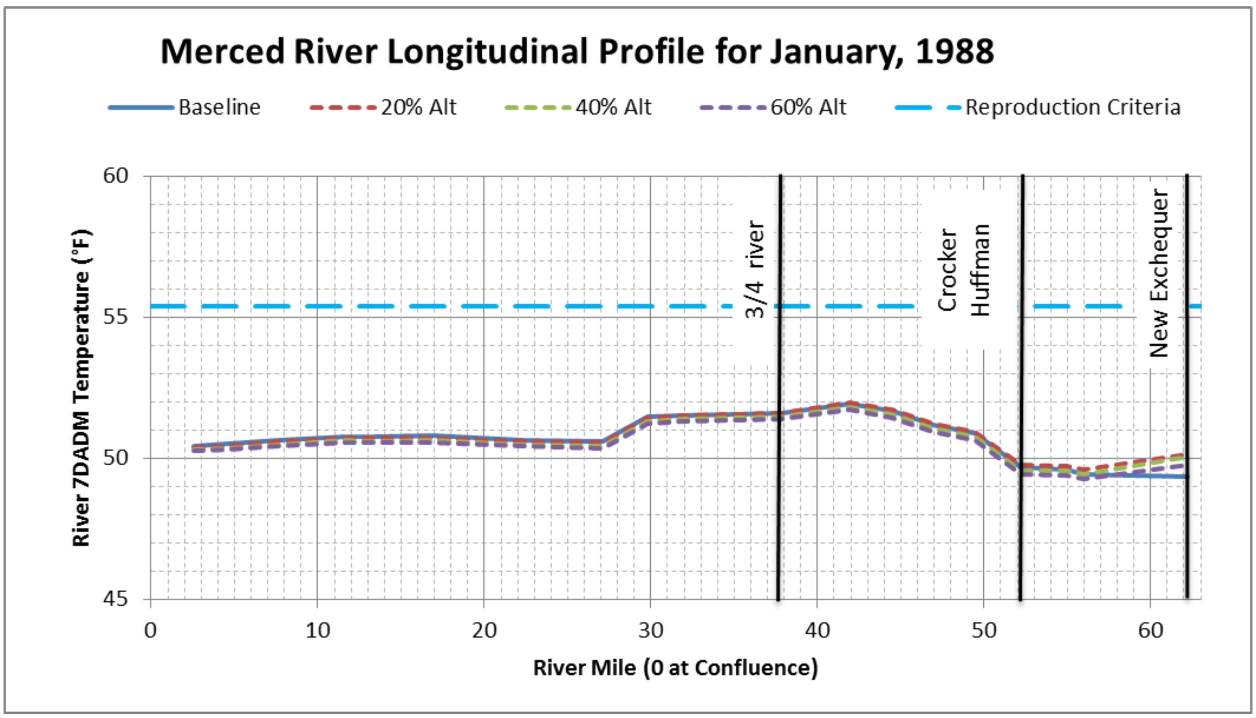
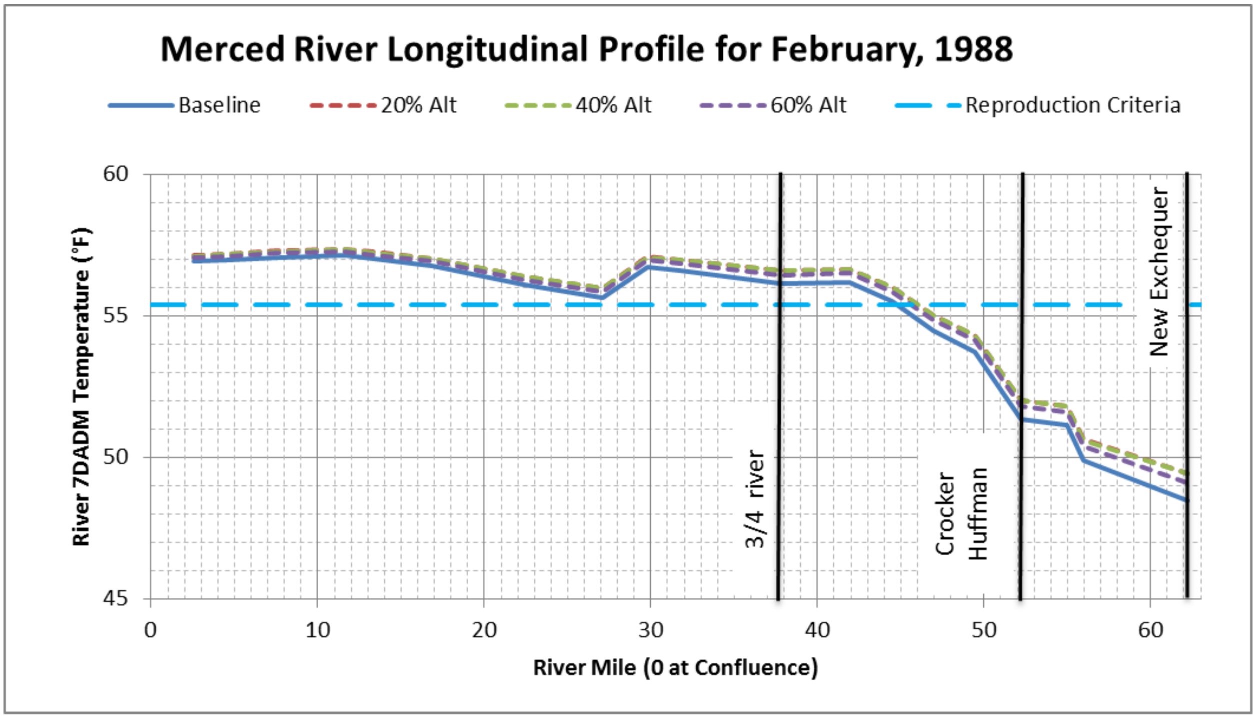


Figure F.1.6-51. Longitudinal Monthly Average 7DADM Temperature Results within the Merced River for (a) December 1987 and (b) January 1988



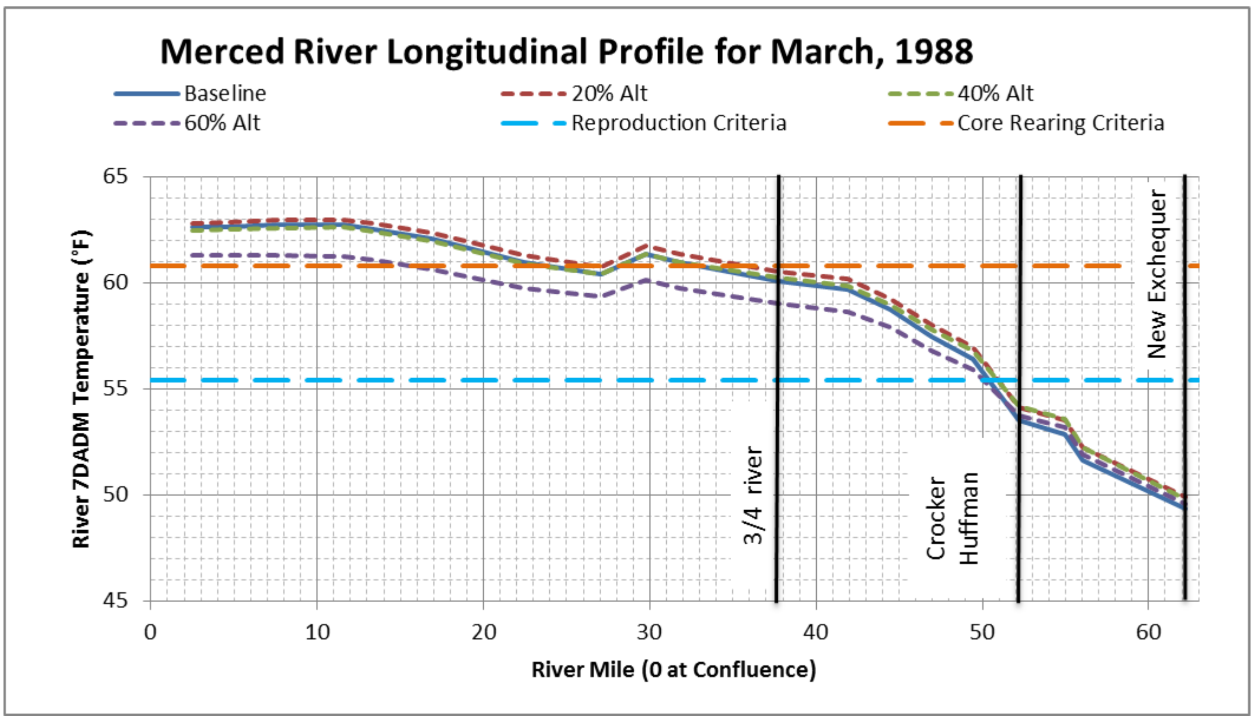
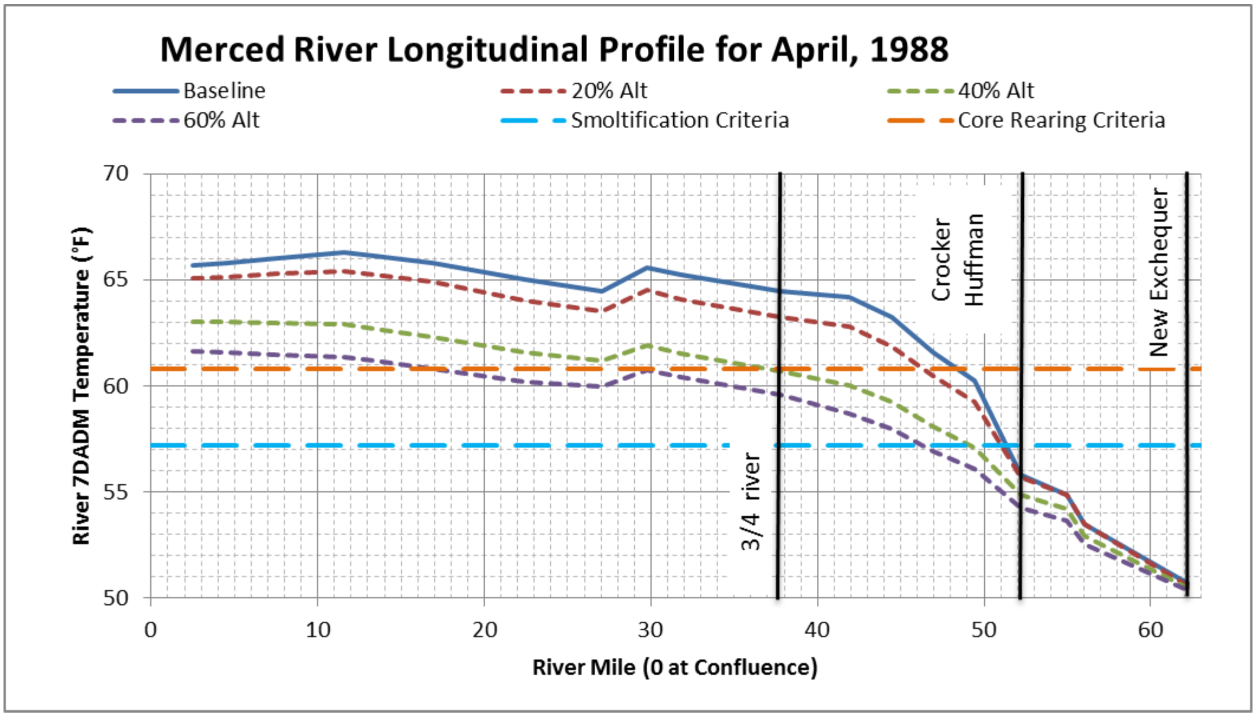


Figure F.1.6-52. Longitudinal Monthly Average 7DADM Temperature Results within the Merced River for (a) February 1988 and (b) March 1988



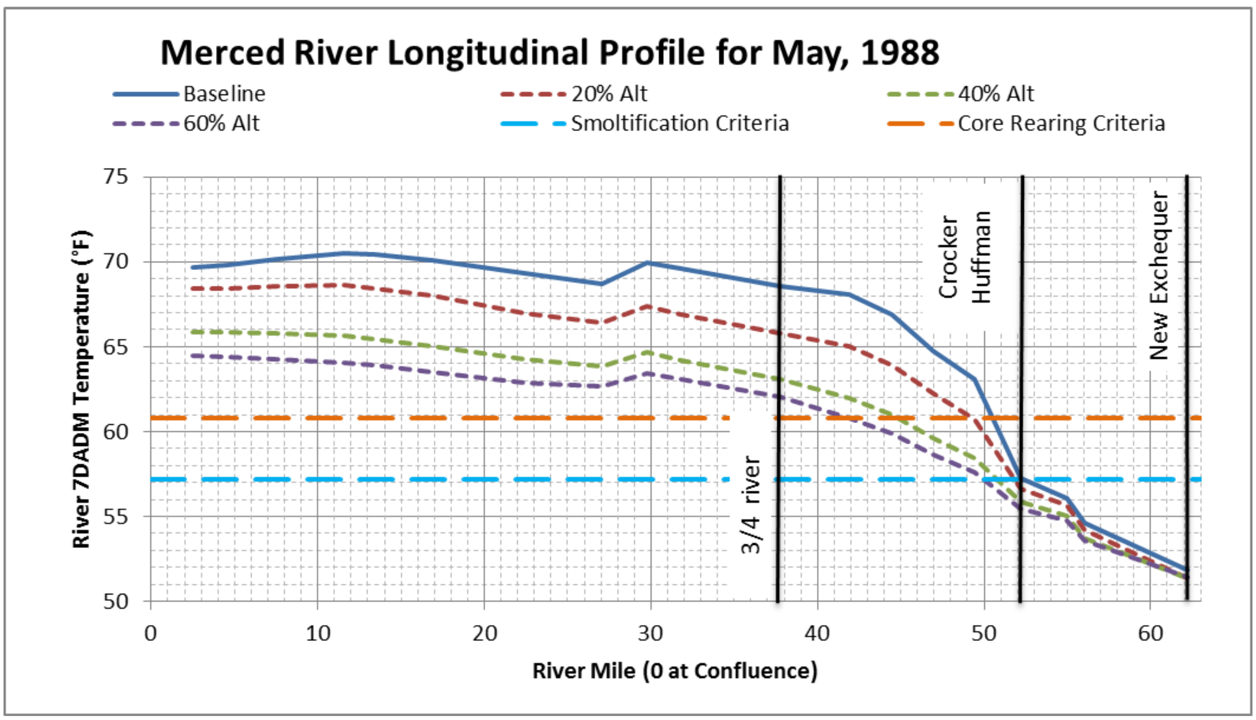
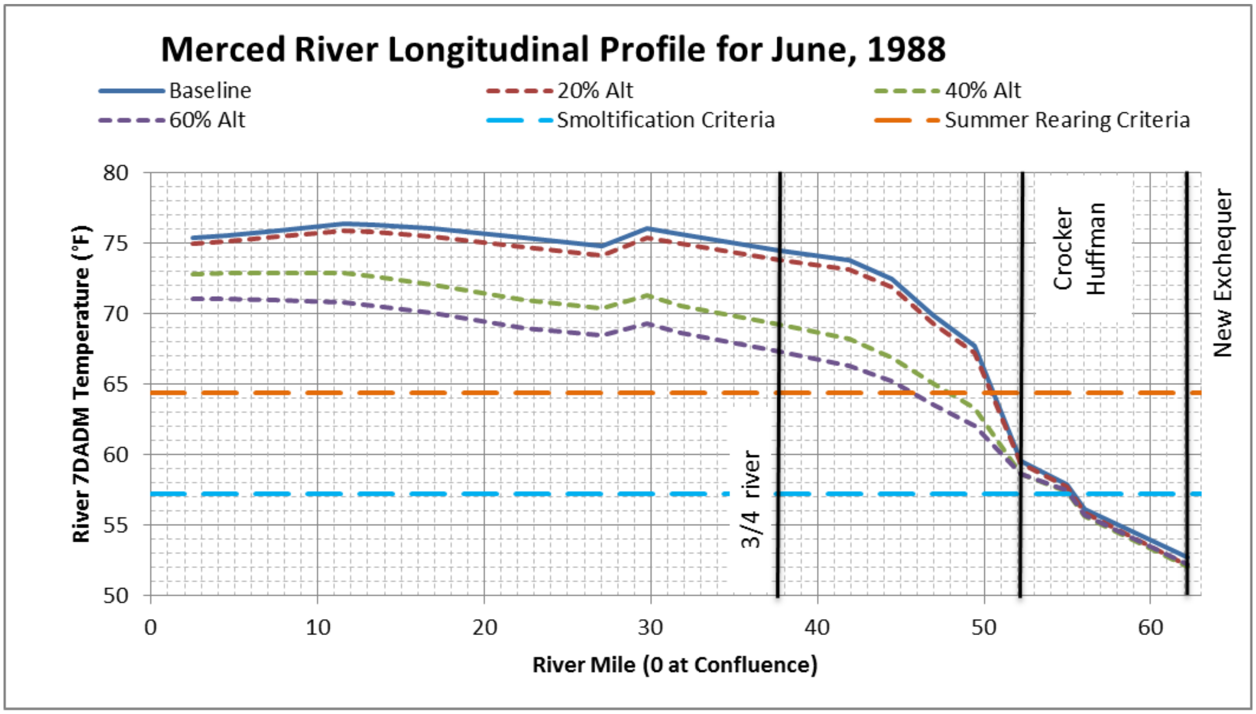


Figure F.1.6-53. Longitudinal Monthly Average 7DADM Temperature Results within the Merced River for (a) April 1988 and (b) May 1988



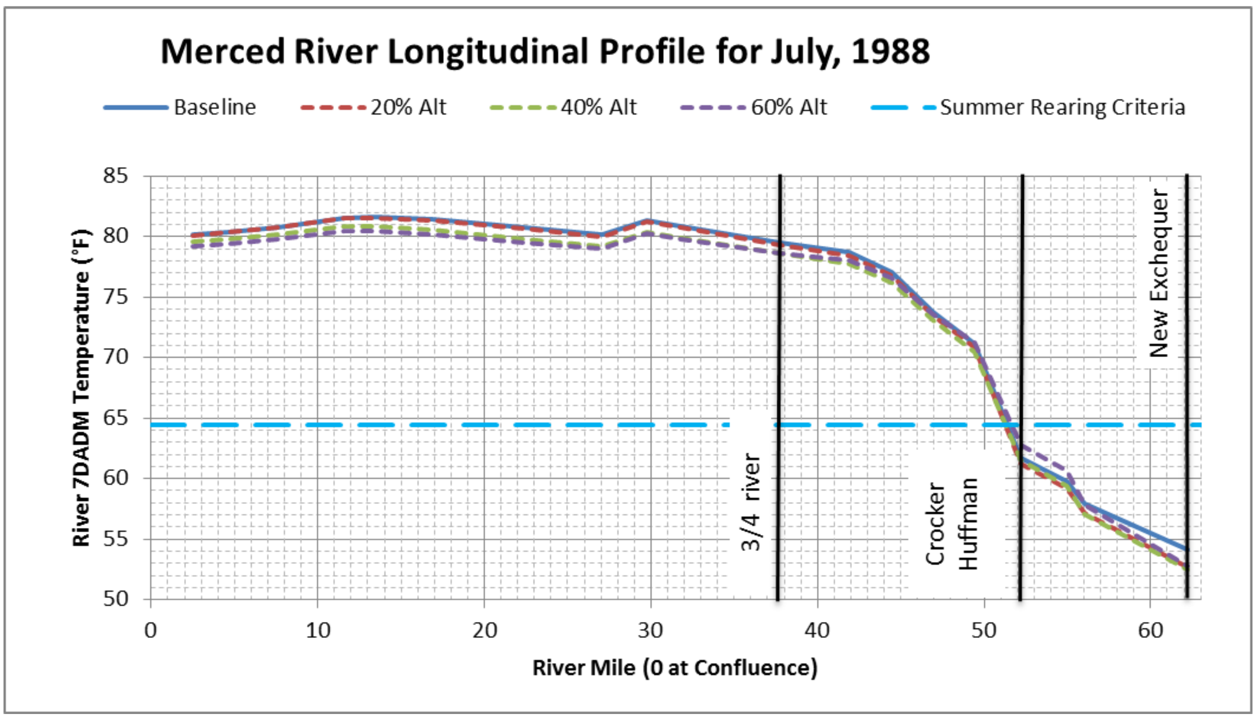
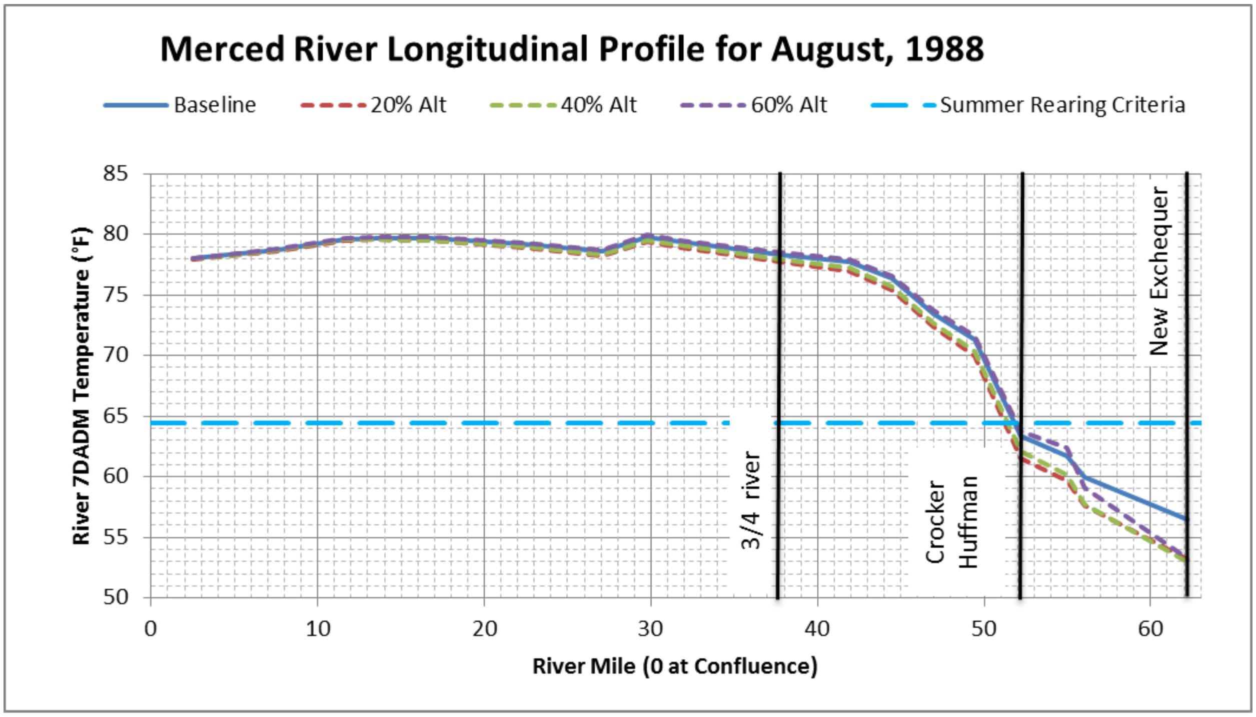


Figure F.1.6-54. Longitudinal Monthly Average 7DADM Temperature Results within the Merced River for (a) June 1988 and (b) July 1988



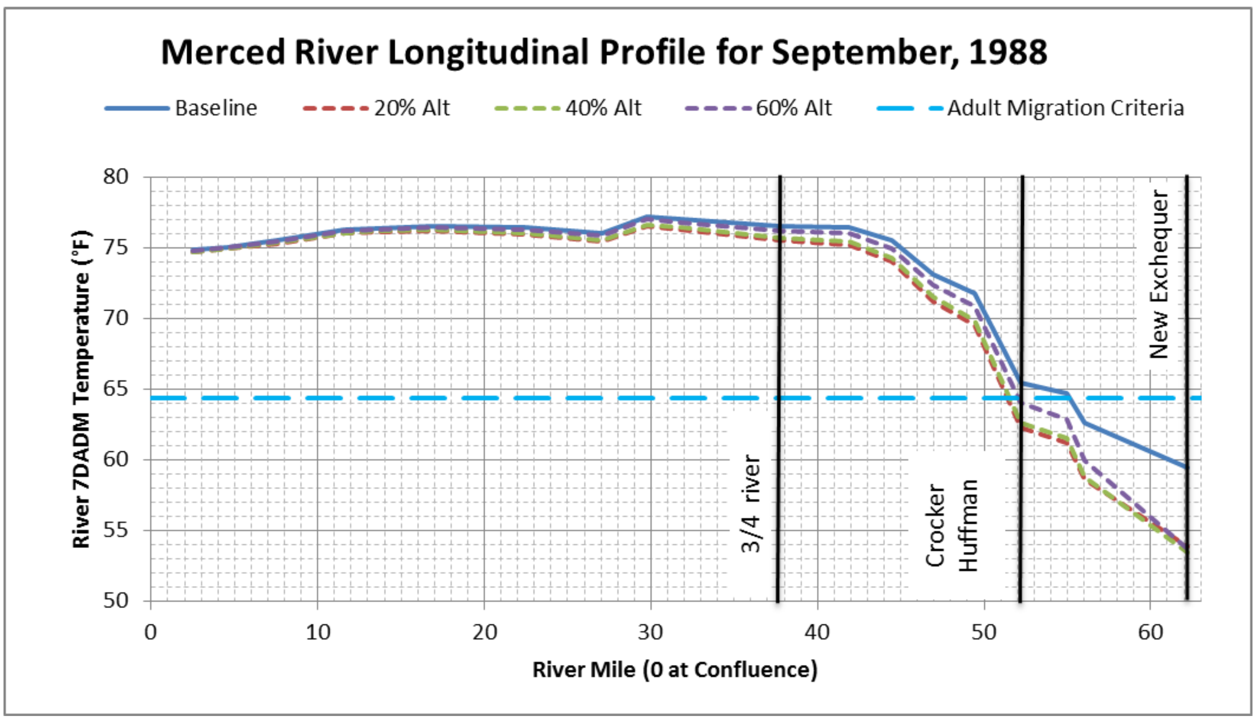
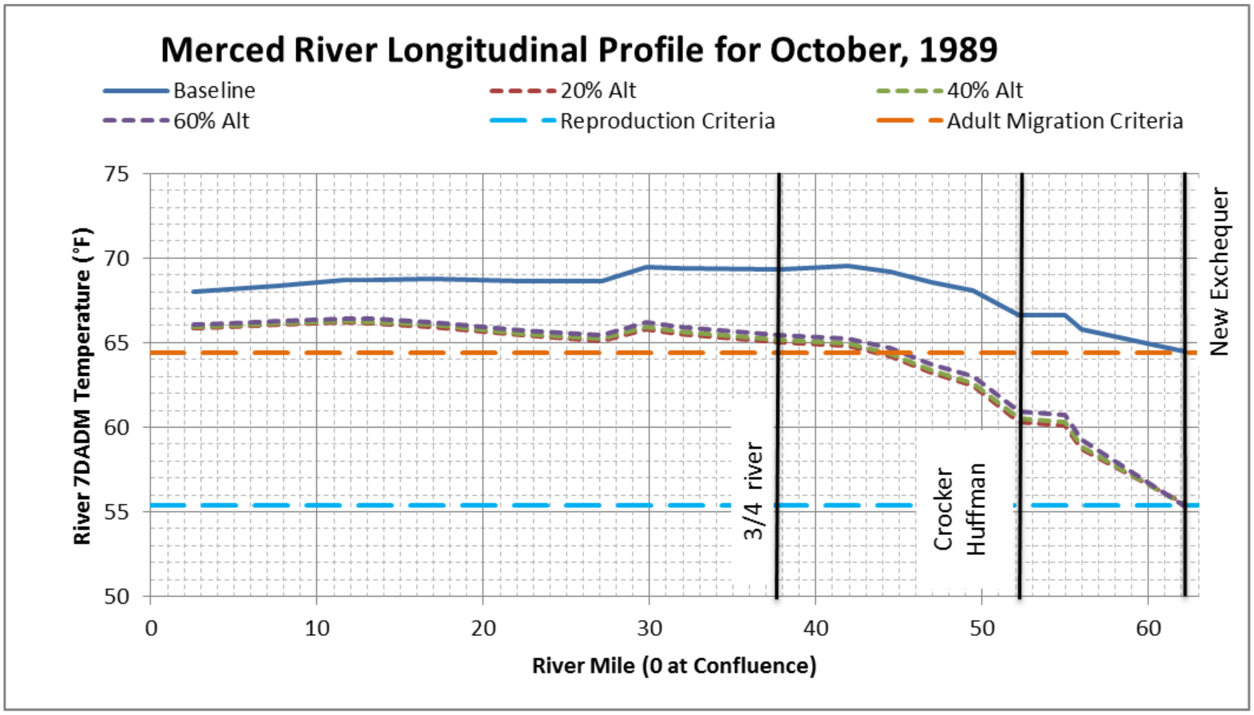


Figure F.1.6-55. Longitudinal Monthly Average 7DADM Temperature Results within the Merced River for (a) August 1988 and (b) September 1988



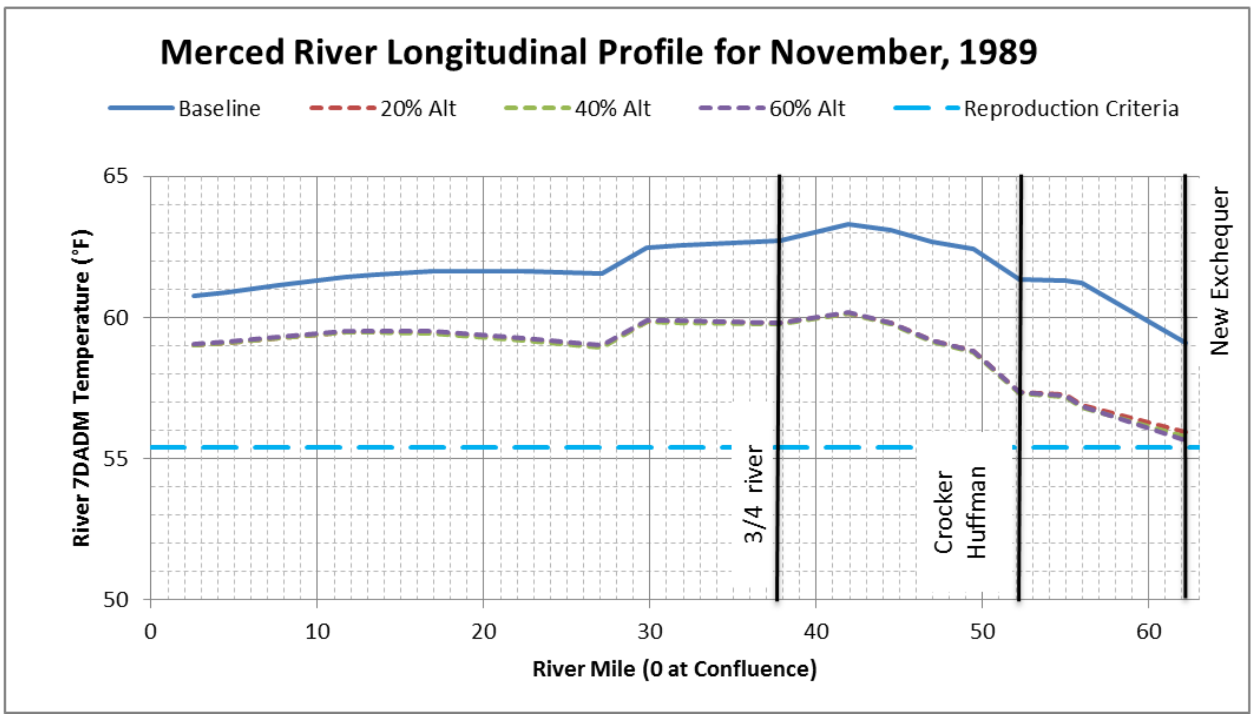
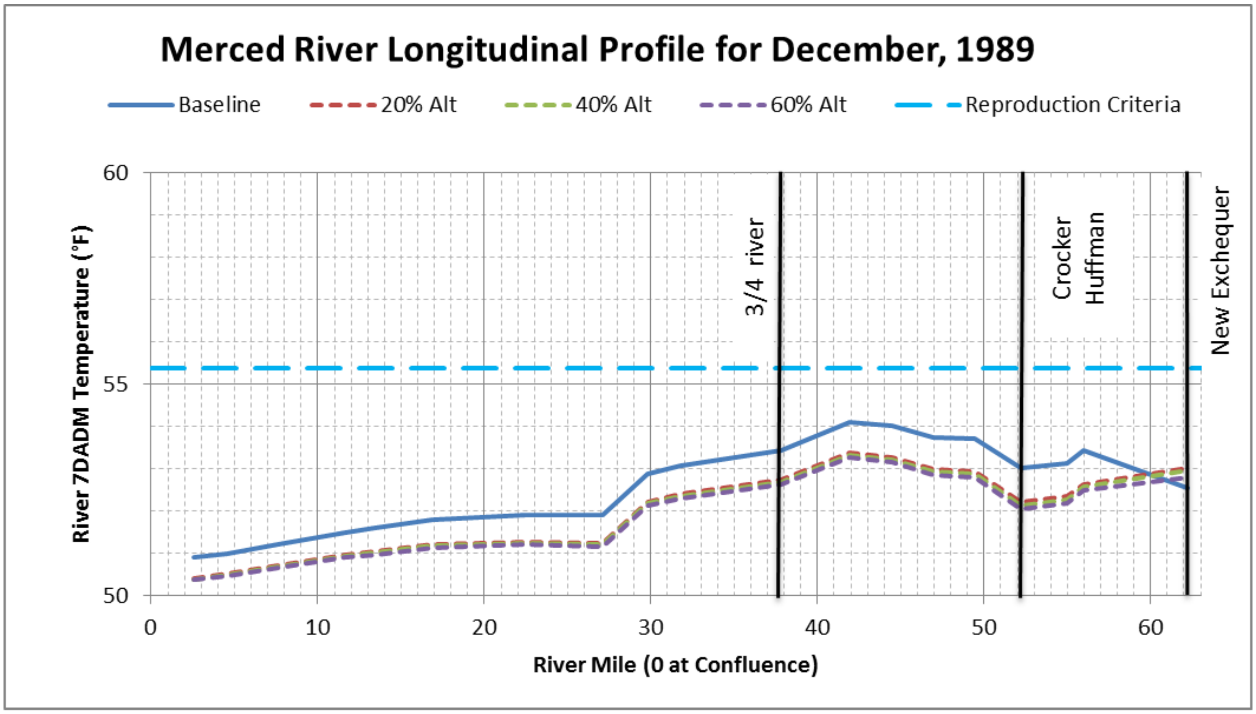


Figure F.1.6-56. Longitudinal Monthly Average 7DADM Temperature Results within the Merced River for (a) October 1989 and (b) November 1989



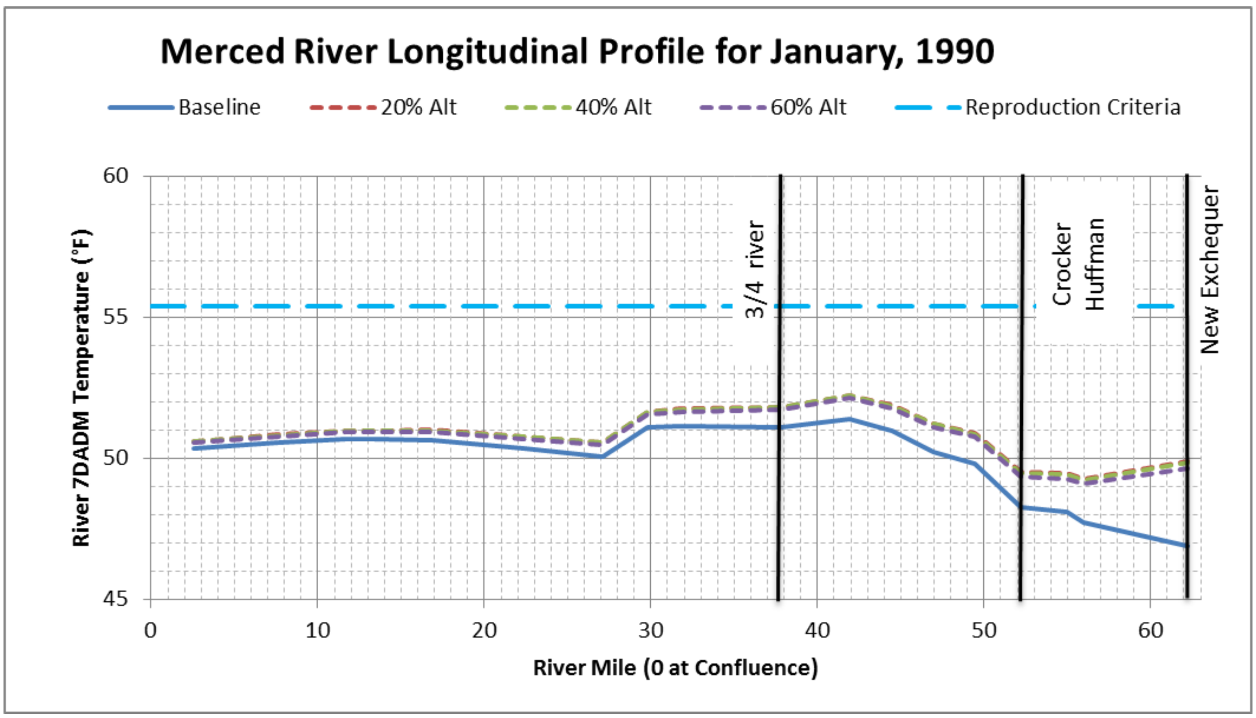
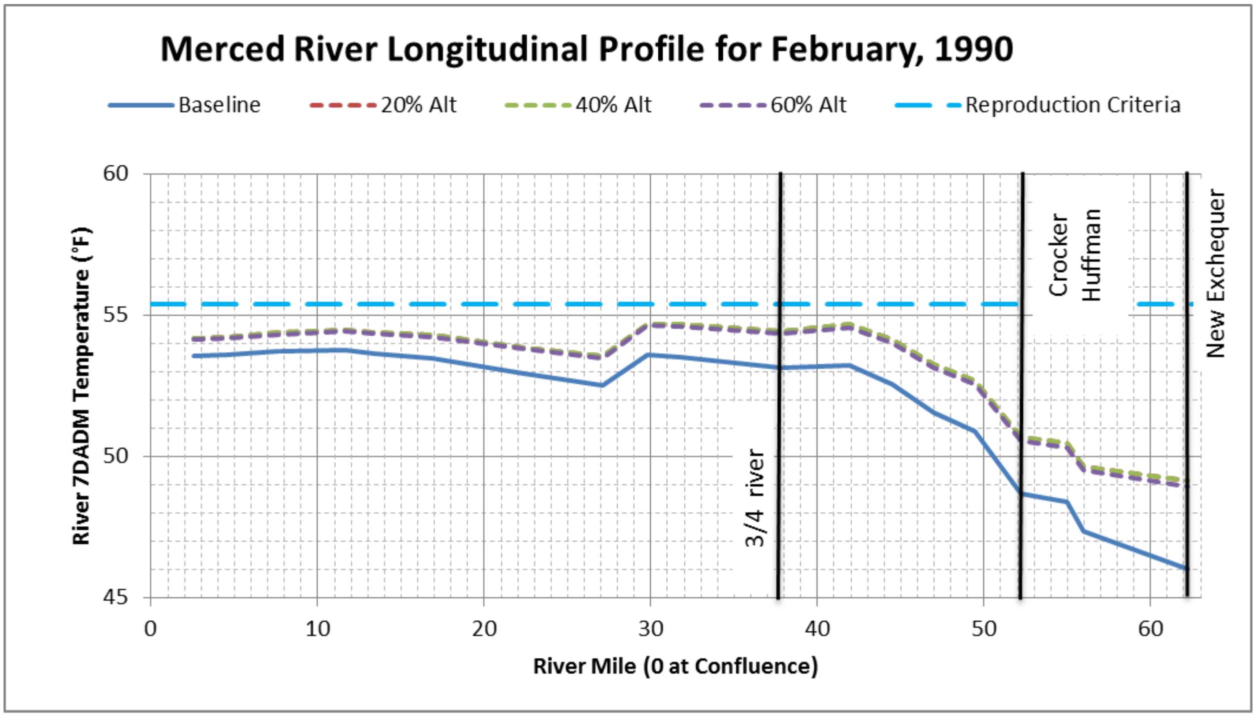


Figure F.1.6-57. Longitudinal Monthly Average 7DADM Temperature Results within the Merced River for (a) December 1989 and (b) January 1990



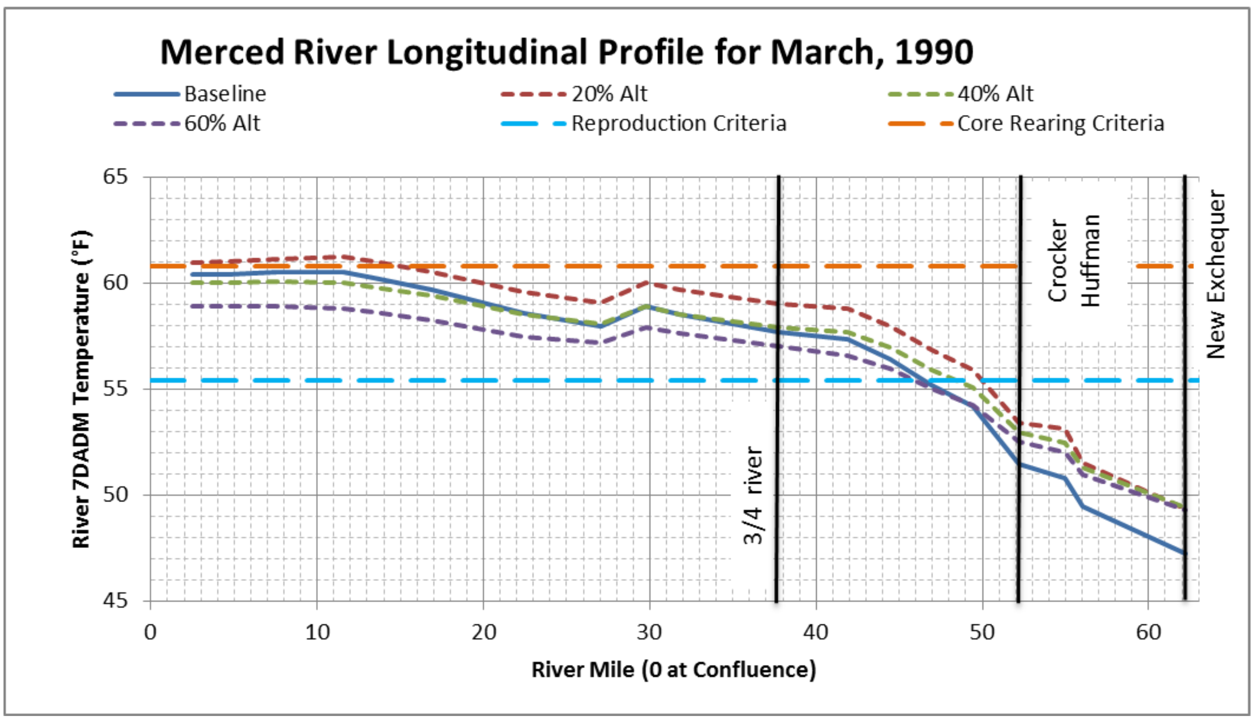
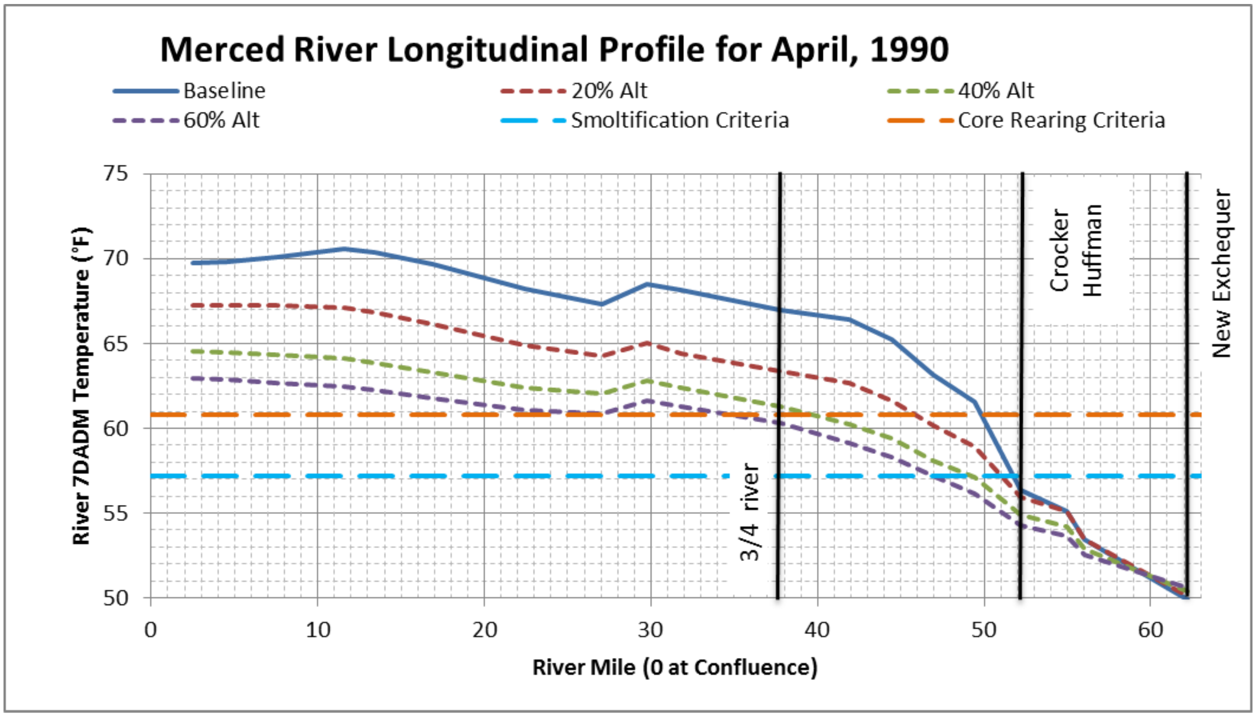


Figure F.1.6-58. Longitudinal Monthly Average 7DADM Temperature Results within the Merced River for (a) February 1990 and (b) March 1990



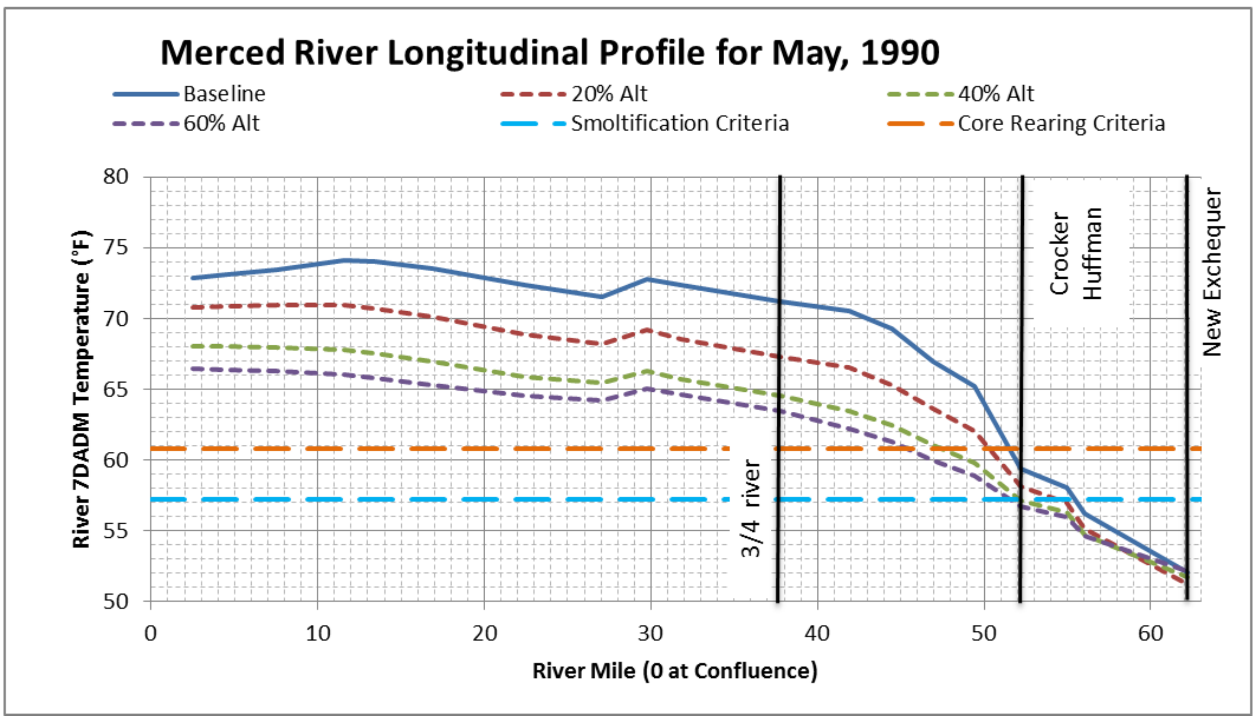
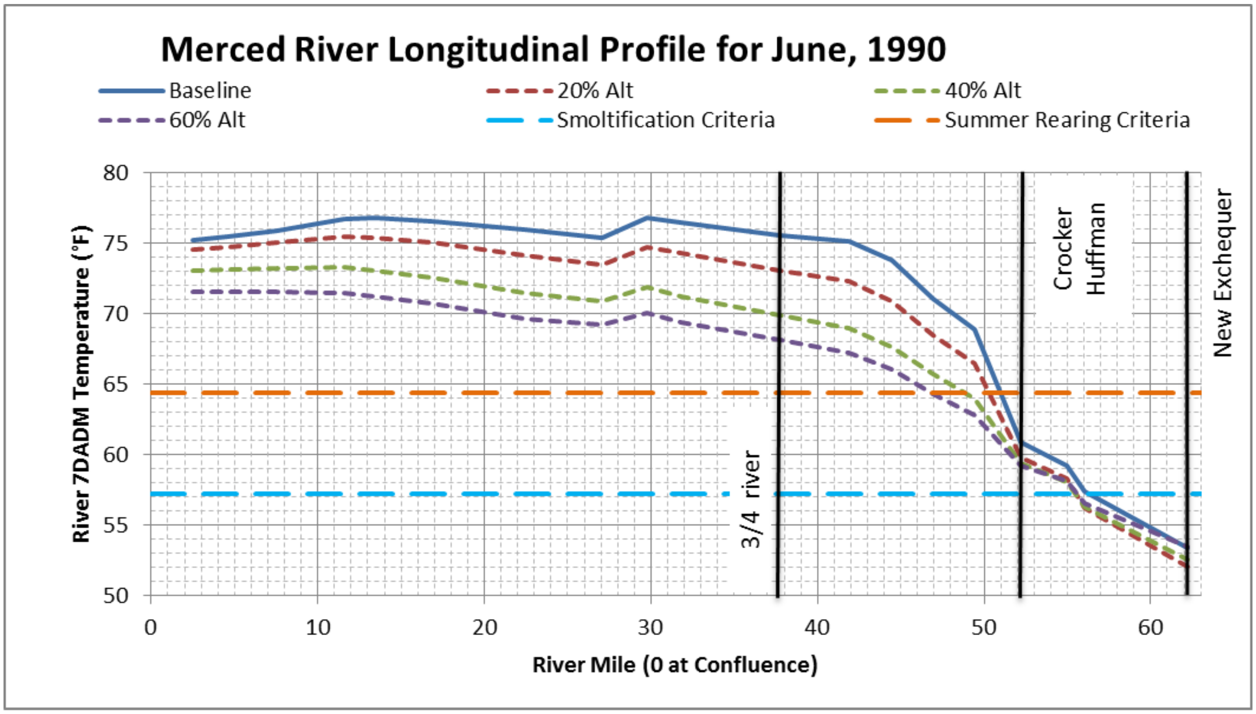


Figure F.1.6-59. Longitudinal Monthly Average 7DADM Temperature Results within the Merced River for (a) April 1990 and (b) May 1990



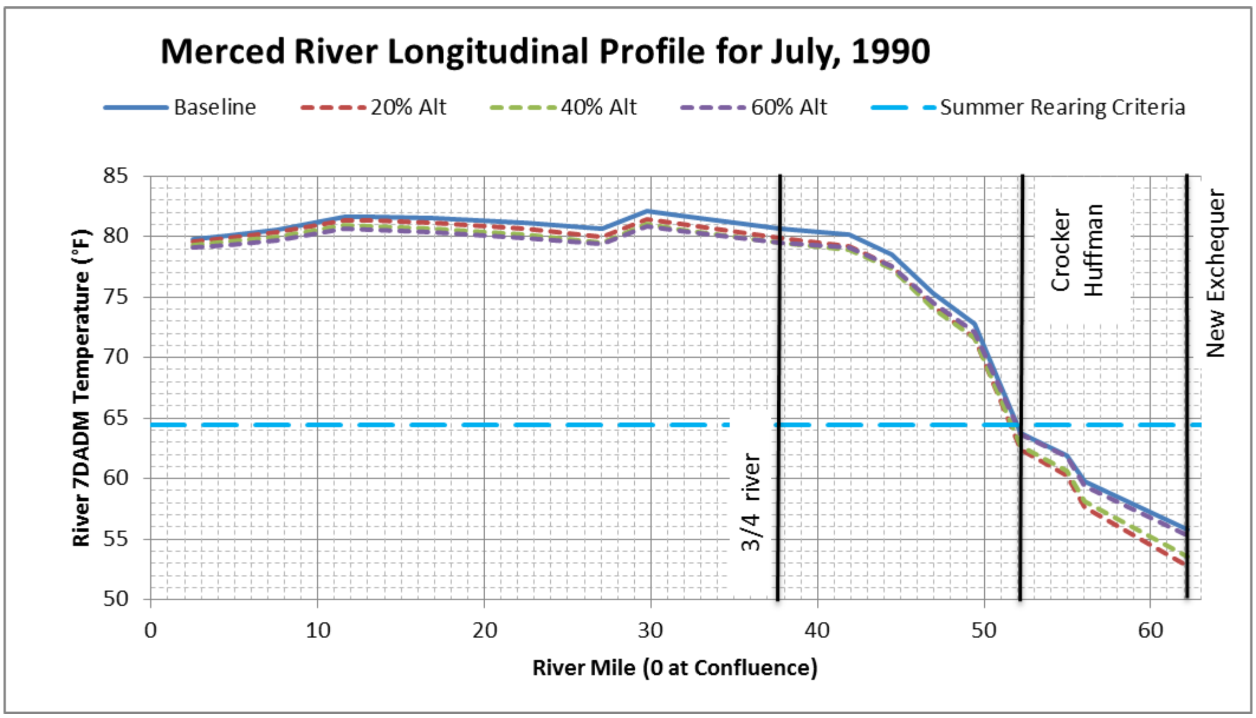
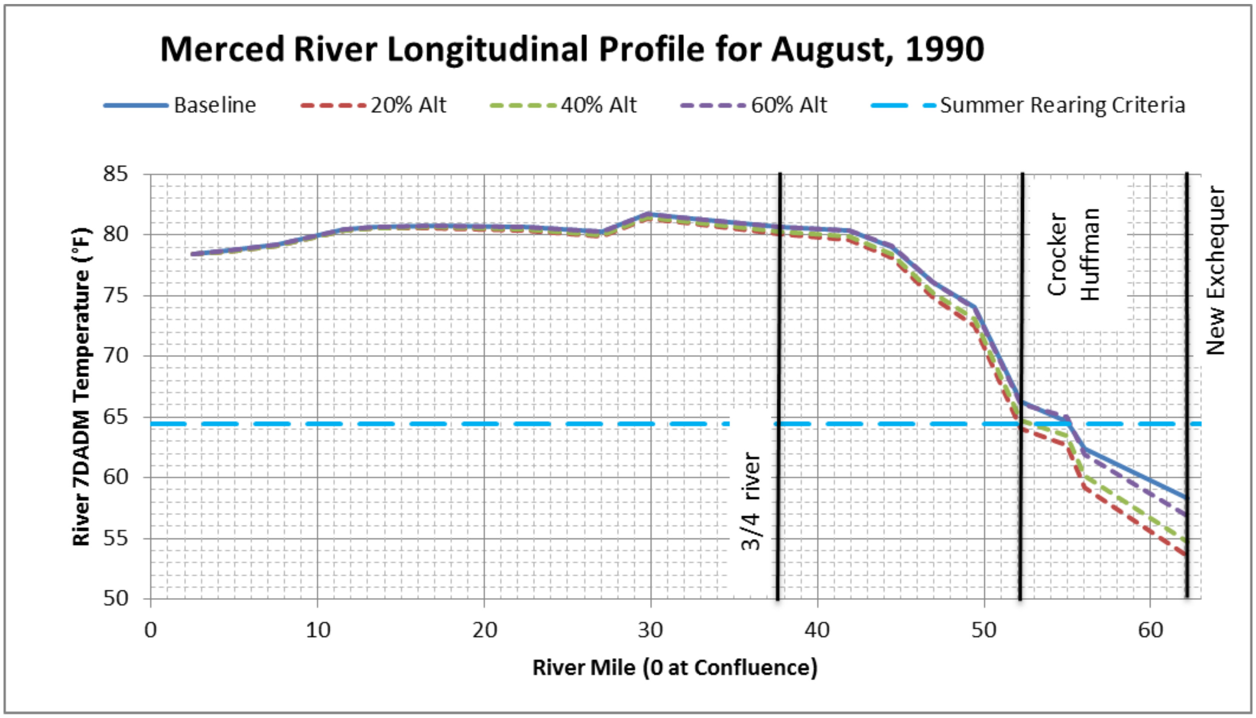


Figure F.1.6-60. Longitudinal Monthly Average 7DADM Temperature Results within the Merced River for (a) June 1990 and (b) July 1990



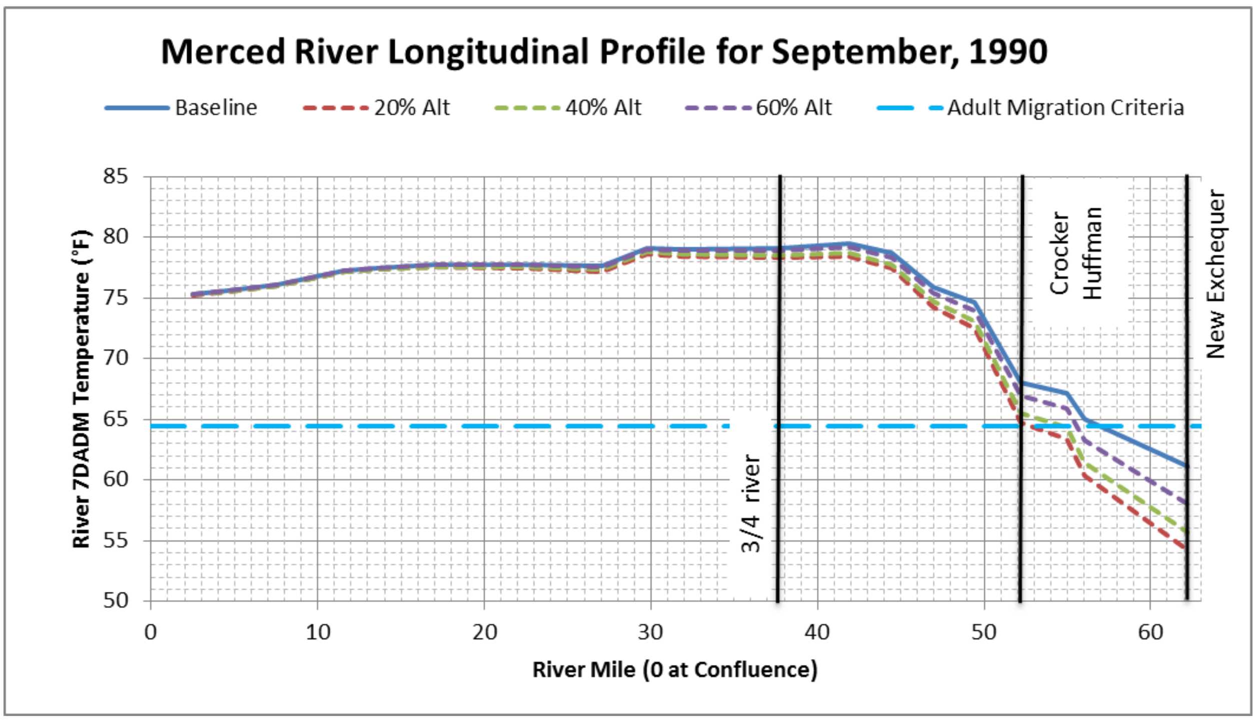


Figure F.1.6-61. Longitudinal Monthly Average 7DADM Temperature Results within the Merced River for (a) August 1990 and (b) September 1990