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Upstream Habitat Results

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C.5.2 Upstream Habitat Results

C.5.2.1 Mainstem Sacramento River

C.5.2.1.1 Steelhead

Eggs and Alevins

Upstream Spawning Habitat

The two primary potential effects of BDCP operations on habitat conditions for steelhead spawning and egg incubation on the mainstem Sacramento River relate to changes in either instream flows or seasonal water temperatures released from Shasta and Keswick Dams. The primary spawning and egg incubation period extends from January through April. Results of the CALSIM analyses of instream flows within the reach where the majority of steelhead spawning occurs (Keswick Dam to upstream of RBDD) were summarized by month and water-year type based on estimated flows at RBDD. Results of these instream flow summaries are presented in Table C.5.2-1. Monthly frequency of exceedance plots for Sacramento River flows upstream of RBDD for all months represented in Figure C.5.2-1 through Figure C.5.2-12 and specifically during the steelhead spawning and egg incubation period (January through April) in Figure C.5.2-1 through Figure C.5.2-4.

Table C.5.2-1. Mean Monthly Flows (Cubic Feet per Second) in the Sacramento River Upstream of Red Bluff Diversion Dam Year-Round

Month	Water-Year Type	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
Jan	W	28,036	27,416	29,368	30,390	30,226	30,761
	AN	16,725	16,067	16,267	16,885	17,611	16,662
	BN	9,381	9,215	9,267	9,146	9,783	10,623
	D	7,098	7,028	7,262	7,262	7,294	7,532
	C	6,143	6,389	6,497	6,942	6,620	6,160
	AVG	15,396	15,095	15,819	16,278	16,401	16,560
Feb	W	30,255	30,054	32,712	33,472	32,915	33,458
	AN	23,492	23,295	24,422	24,828	26,003	26,269
	BN	12,005	11,748	12,508	11,614	12,737	12,301
	D	8,947	9,030	8,785	8,790	8,848	8,985
	C	6,599	6,643	6,404	6,378	6,380	6,595
	AVG	18,010	17,899	18,947	19,092	19,292	19,490
Mar	W	25,004	25,034	25,473	26,210	25,488	26,347
	AN	16,599	15,943	16,222	16,428	16,878	16,160
	BN	9,333	8,924	8,438	8,474	8,994	9,018
	D	8,385	8,392	8,349	8,300	8,160	8,216

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Month	Water-Year Type	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
	C	5,999	6,175	6,126	6,101	6,334	6,377
	AVG	14,669	14,540	14,621	14,876	14,805	14,995
Apr	W	15,172	15,191	15,078	14,842	15,136	14,796
	AN	10,477	10,423	9,983	9,761	10,136	10,362
	BN	8,711	8,496	8,239	8,282	8,767	8,990
	D	7,948	7,763	7,654	7,661	7,990	8,433
	C	7,742	7,611	7,628	7,829	7,645	8,003
	AVG	10,709	10,610	10,445	10,376	10,652	10,765
May	W	12,541	12,504	11,224	10,073	11,397	10,790
	AN	10,012	10,017	9,623	10,047	10,642	11,122
	BN	8,781	8,580	8,030	7,875	9,024	8,939
	D	8,677	8,540	8,424	9,012	9,410	10,277
	C	7,746	7,721	7,956	8,348	8,278	8,615
	AVG	9,979	9,900	9,351	9,208	9,989	10,092
Jun	W	11,905	12,002	11,591	11,720	12,286	13,210
	AN	12,001	12,225	12,227	12,789	13,358	14,534
	BN	11,464	11,496	11,304	11,651	12,172	12,287
	D	11,777	11,834	12,028	12,441	12,633	13,028
	C	10,885	11,123	11,539	11,881	11,413	12,227
	AVG	11,666	11,783	11,723	12,046	12,372	13,062
Jul	W	13,255	13,418	13,937	14,525	14,132	14,586
	AN	14,129	14,381	14,594	15,142	14,649	14,716
	BN	13,011	13,090	13,272	13,258	13,304	12,205
	D	13,368	13,541	13,741	13,826	13,273	12,687
	C	13,005	12,771	12,344	12,149	12,237	11,749
	AVG	13,329	13,435	13,643	13,898	13,600	13,367
Aug	W	11,284	11,261	10,700	10,735	10,653	10,543
	AN	10,580	10,824	10,968	11,775	10,655	10,714
	BN	10,202	10,285	9,971	10,364	10,103	9,565
	D	10,747	10,913	10,610	11,143	9,591	9,034
	C	9,590	9,656	8,632	7,665	7,935	7,330
	AVG	10,630	10,719	10,292	10,464	9,929	9,600
Sep	W	9,856	12,843	12,494	13,312	8,238	7,476
	AN	6,279	8,606	9,634	10,320	7,024	6,680
	BN	5,821	5,824	6,038	5,963	6,184	5,649
	D	6,391	6,098	5,424	4,911	5,742	5,178
	C	5,887	5,645	5,279	4,838	5,161	5,393
	AVG	7,302	8,491	8,365	8,535	6,712	6,238
Oct	W	8,020	7,686	7,662	8,188	7,399	9,200
	AN	8,112	7,306	7,108	8,162	6,863	9,484
	BN	7,094	7,038	6,544	7,778	6,492	9,678
	D	6,903	6,716	6,690	7,287	6,206	8,902
	C	6,670	6,420	6,254	6,537	6,580	8,691
	AVG	7,432	7,122	6,971	7,675	6,784	9,183

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Month	Water-Year Type	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
Nov	W	9,876	11,032	10,966	10,821	9,791	9,671
	AN	8,144	8,918	9,362	9,098	7,194	6,407
	BN	6,791	7,565	7,710	7,682	6,243	5,971
	D	7,548	7,370	7,421	7,347	6,901	6,249
	C	5,811	5,905	5,805	5,703	5,329	5,186
	AVG	7,990	8,576	8,642	8,521	7,518	7,154
Dec	W	21,015	19,736	21,554	19,613	23,015	20,551
	AN	10,019	10,030	10,370	10,053	9,710	10,073
	BN	8,408	8,235	8,921	8,228	8,891	8,460
	D	7,292	7,053	7,044	7,091	7,408	7,372
	C	5,628	5,393	5,465	5,433	5,792	5,498
	AVG	11,989	11,469	12,221	11,446	12,710	11,857

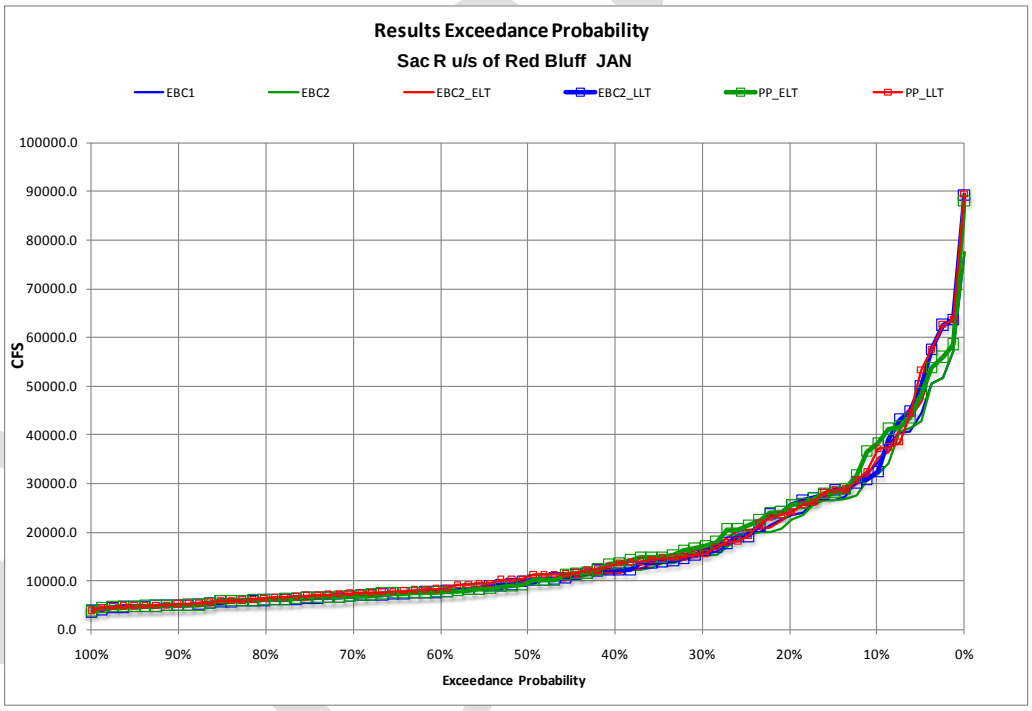

Figure C.5.2-1. Probability of Exceedance Plot for Model Scenarios of Mean Monthly Flow in the Sacramento River Upstream of Red Bluff Diversion Dam, January

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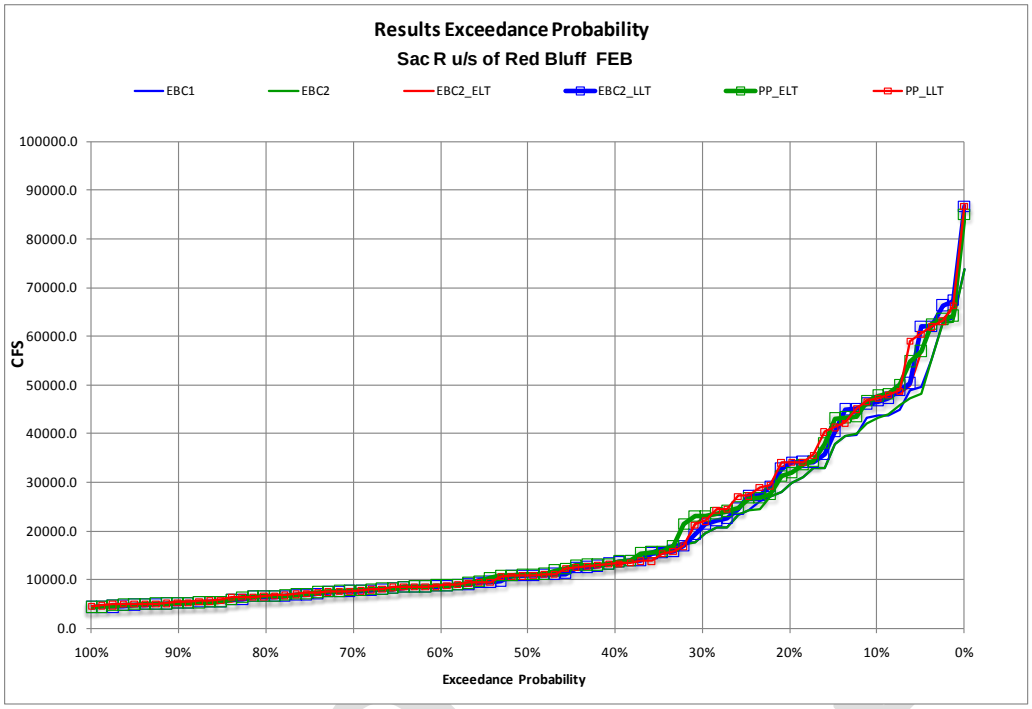

Figure C.5.2-2. Probability of Exceedance Plot for Model Scenarios of Mean Monthly Flow in the Sacramento River Upstream of Red Bluff Diversion Dam, February

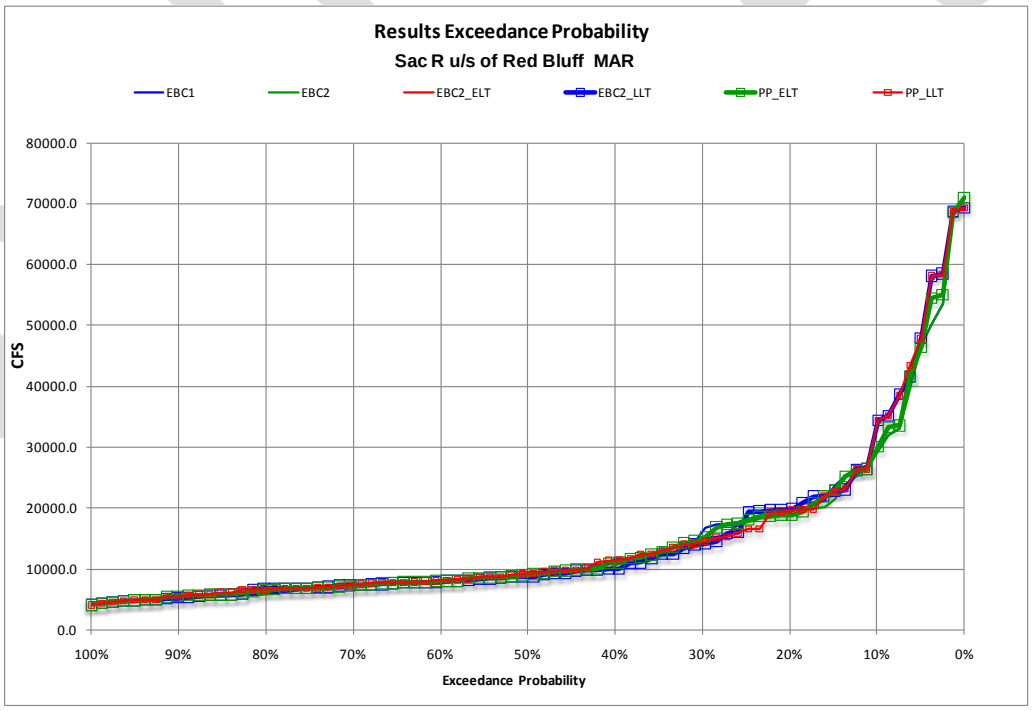

Figure C.5.2-3. Probability of Exceedance Plot for Model Scenarios of Mean Monthly Flow in the Sacramento River Upstream of Red Bluff Diversion Dam, March

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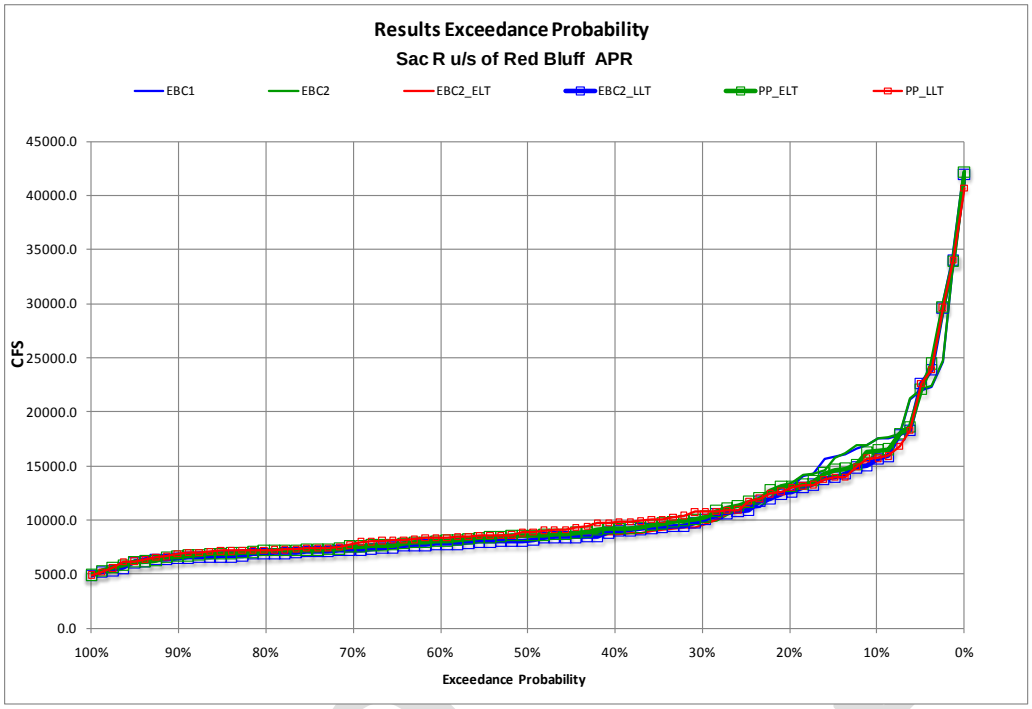

Figure C.5.2-4. Probability of Exceedance Plot for Model Scenarios of Mean Monthly Flow in the Sacramento River Upstream of Red Bluff Diversion Dam, April

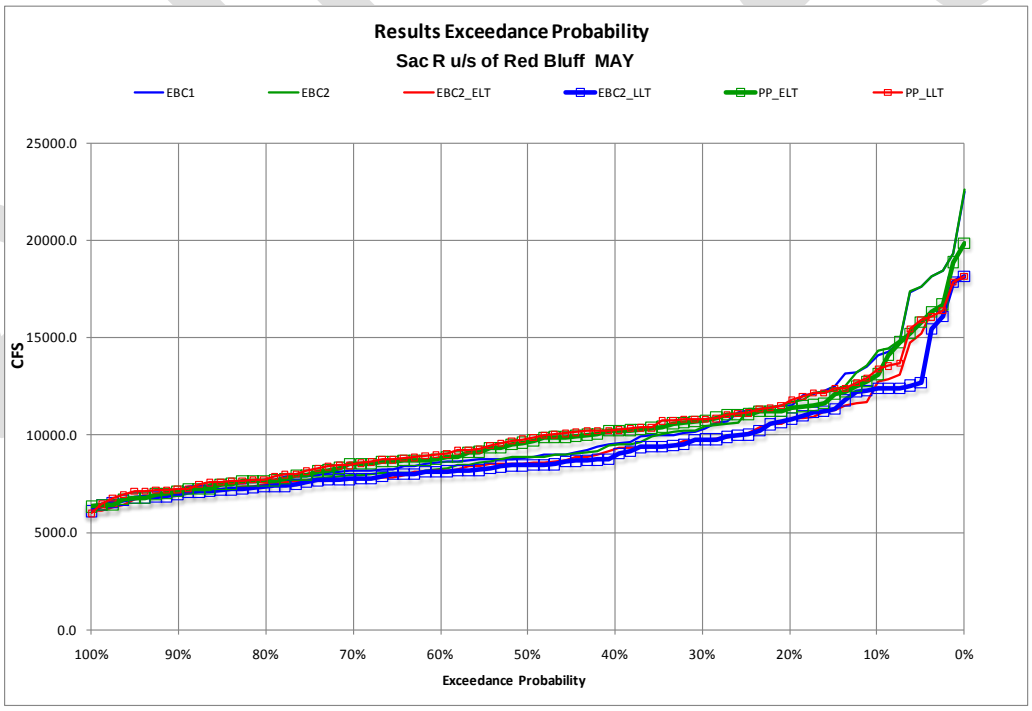

Figure C.5.2-5. Probability of Exceedance Plot for Model Scenarios of Mean Monthly Flow in the Sacramento River Upstream of Red Bluff Diversion Dam, May

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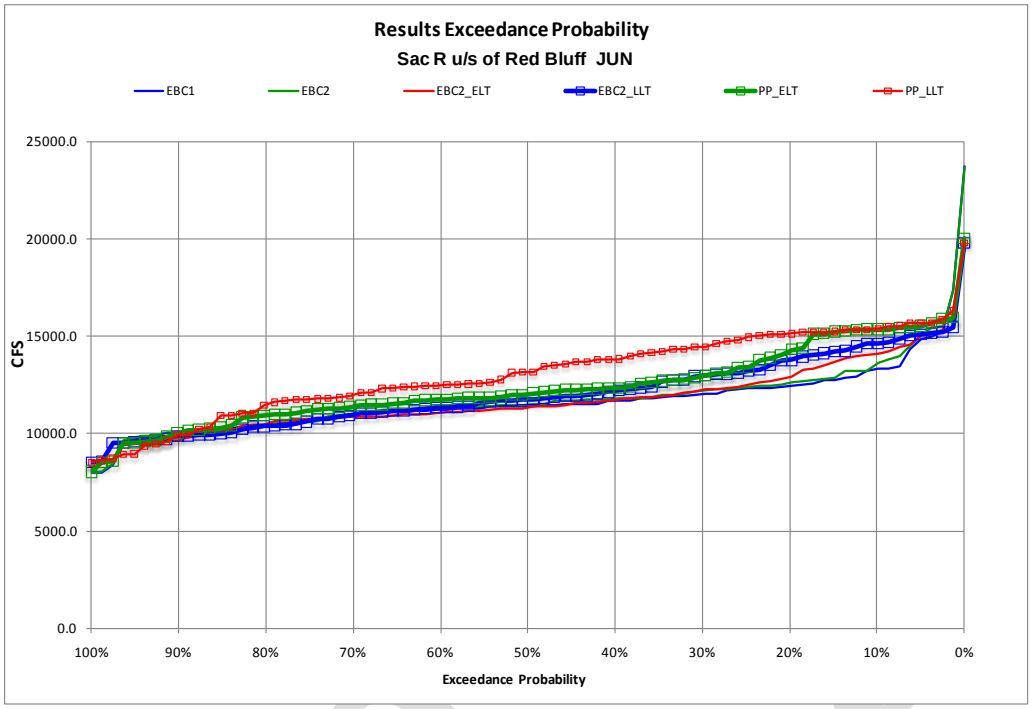

Figure C.5.2-6. Probability of Exceedance Plot for Model Scenarios of Mean Monthly Flow in the Sacramento River Upstream of Red Bluff Diversion Dam, June

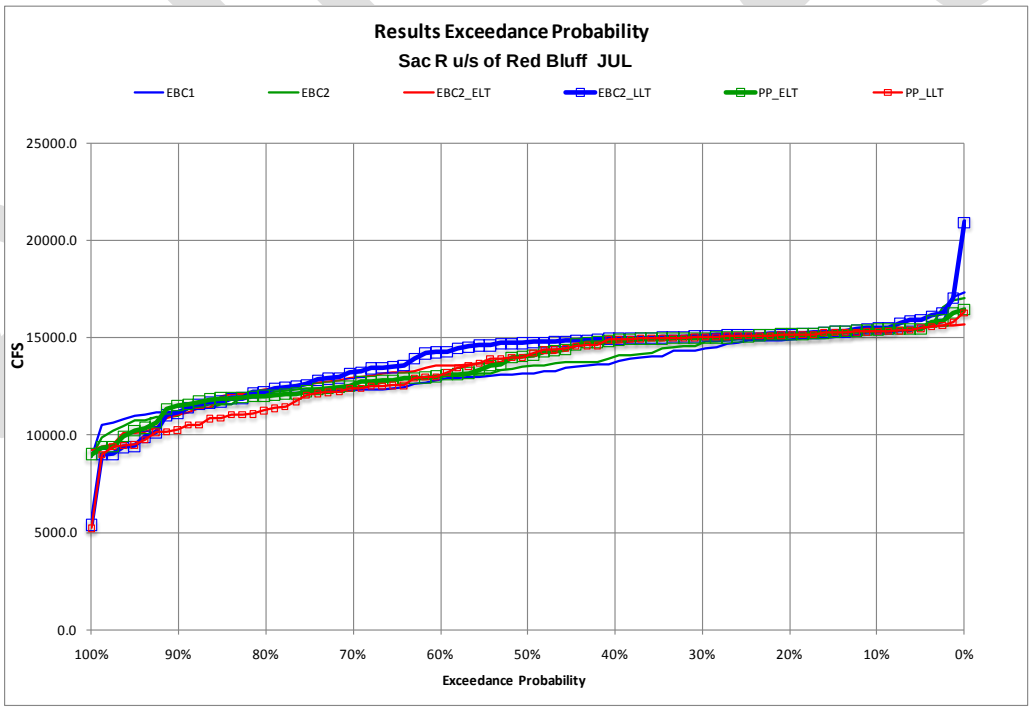

Figure C.5.2-7. Probability of Exceedance Plot for Model Scenarios of Mean Monthly Flow in the Sacramento River Upstream of Red Bluff Diversion Dam, July

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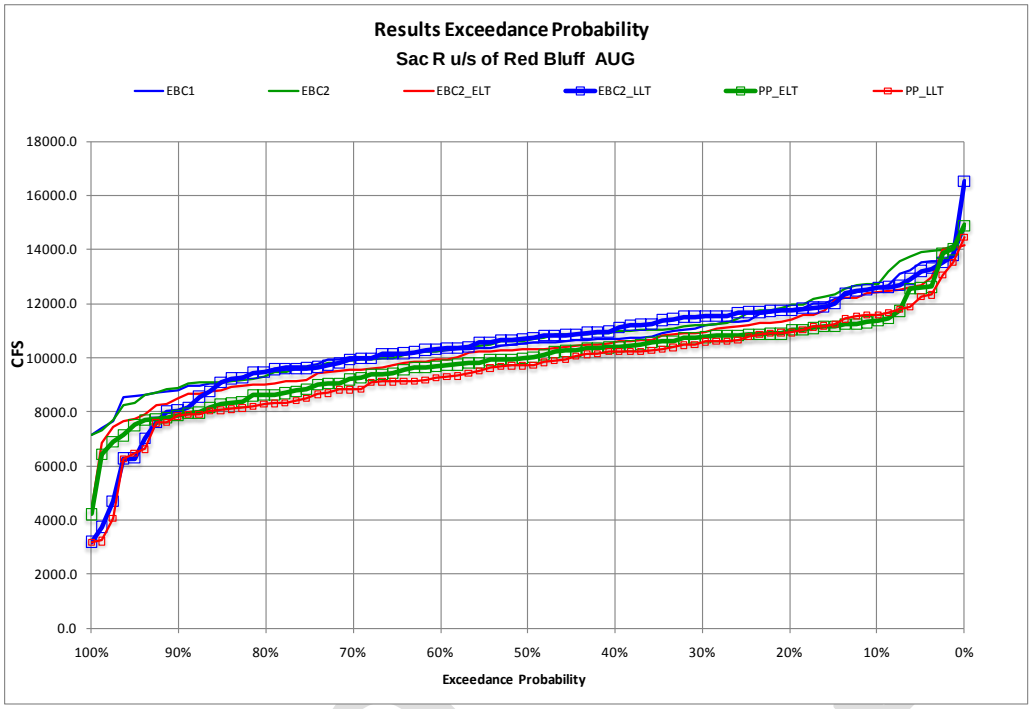

Figure C.5.2-8. Probability of Exceedance Plot for Model Scenarios of Mean Monthly Flow in the Sacramento River Upstream of Red Bluff Diversion Dam, August

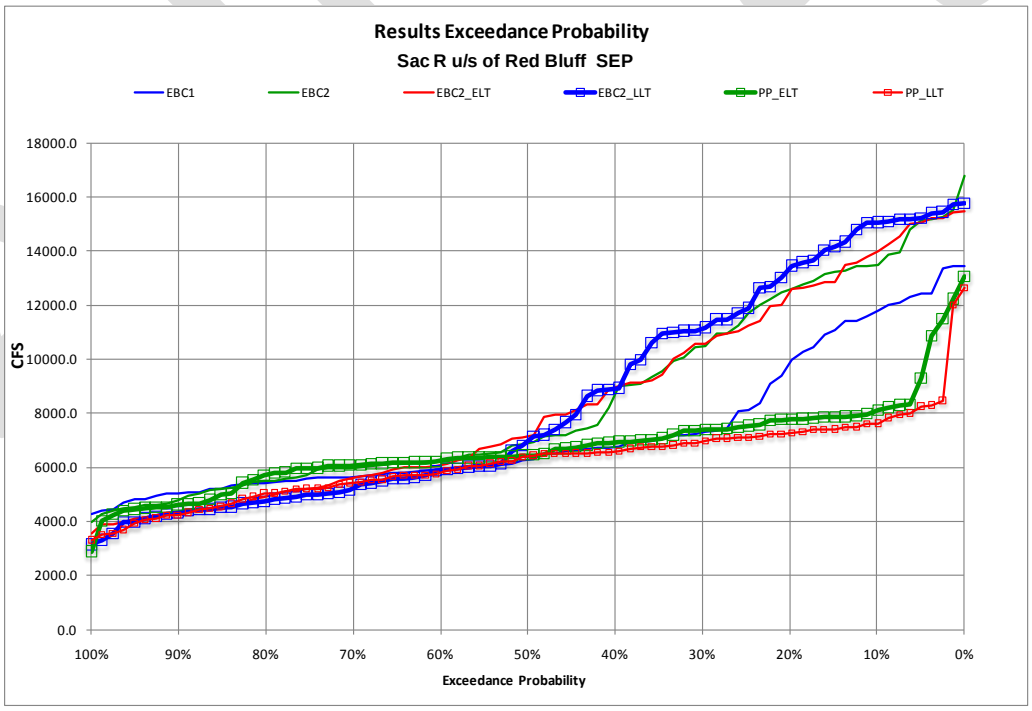

Figure C.5.2-9. Probability of Exceedance Plot for Model Scenarios of Mean Monthly Flow in the Sacramento River Upstream of Red Bluff Diversion Dam, September

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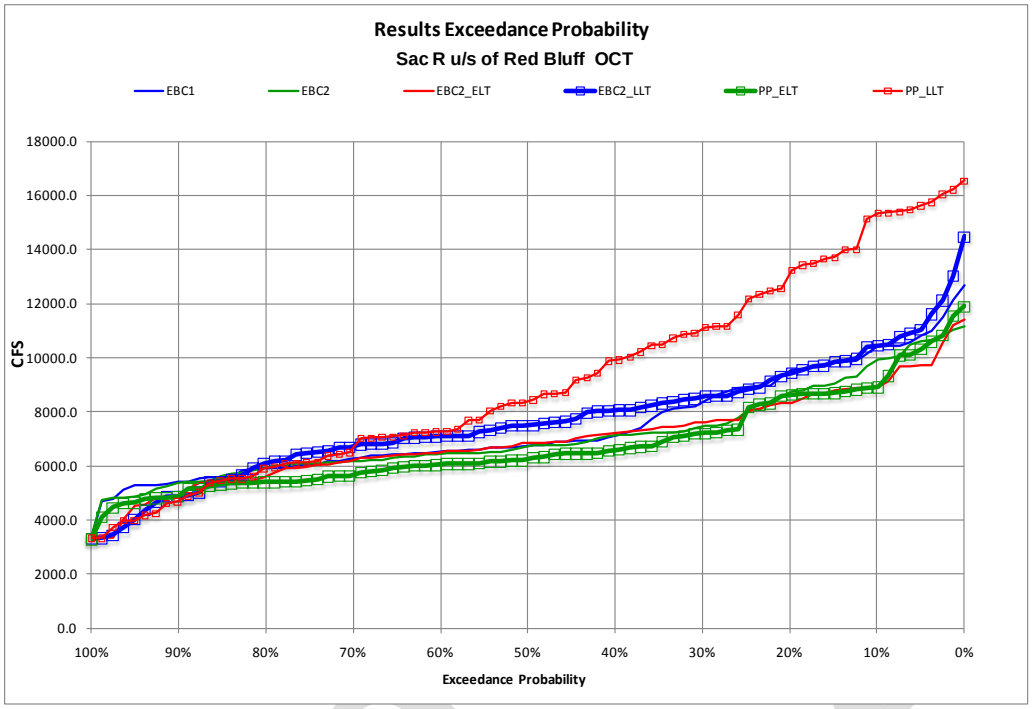

Figure C.5.2-10. Probability of Exceedance Plot for Model Scenarios of Mean Monthly Flow in the Sacramento River Upstream of Red Bluff Diversion Dam, October

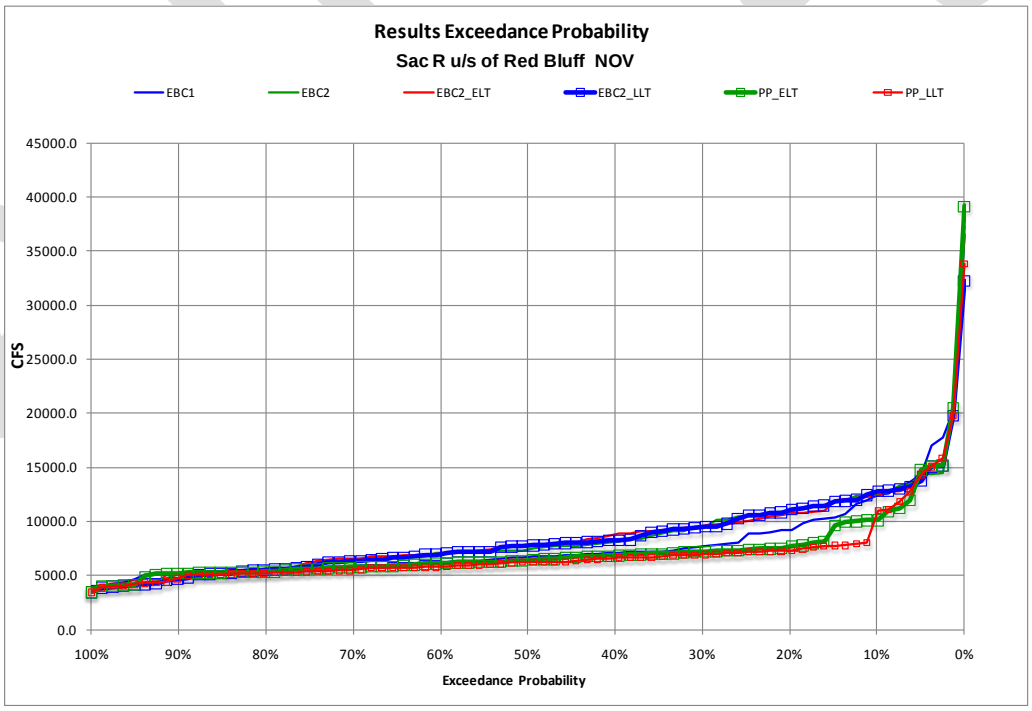

Figure C.5.2-11. Probability of Exceedance Plot for Model Scenarios of Mean Monthly Flow in the Sacramento River Upstream of Red Bluff Diversion Dam, November

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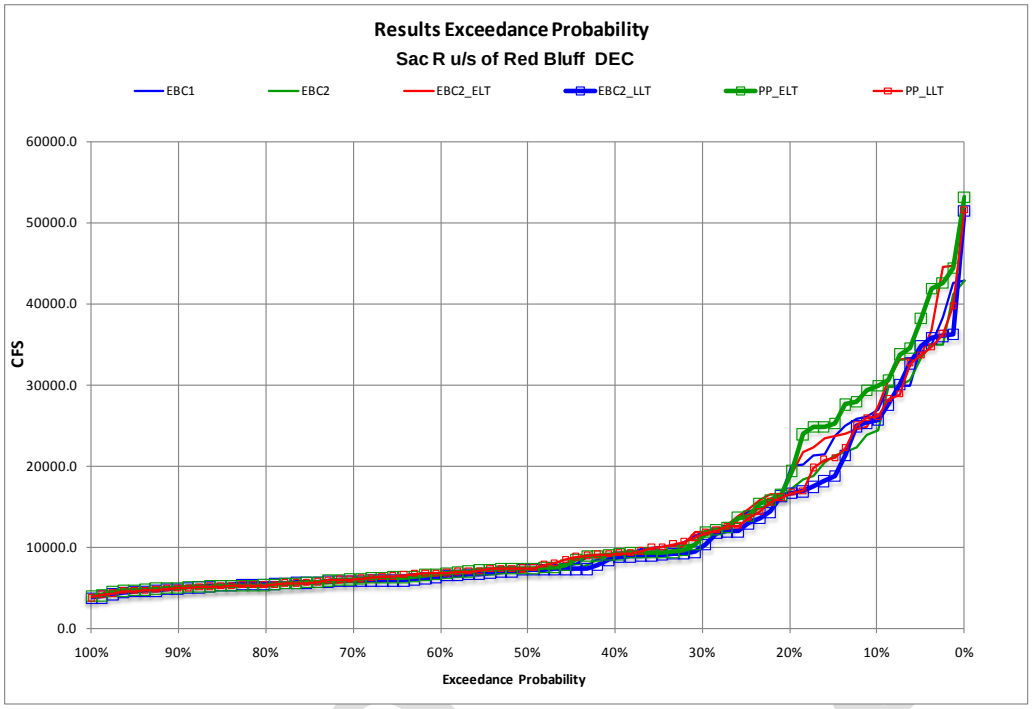

Figure C.5.2-12. Probability of Exceedance Plot for Model Scenarios of Mean Monthly Flow in the Sacramento River Upstream of Red Bluff Diversion Dam, December

Additional information on the monthly flow for each of the 82 years of CALSIM analyses, including frequency of exceedance plots by month and water-year type at the various locations used in this assessment are presented elsewhere. Results of the CALSIM analyses for each of the model scenarios were used to characterize changes in physical habitat conditions within the river and served as part of the input to the analysis of seasonal water temperatures and habitat conditions (e.g., SacEFT) for steelhead spawning and egg incubation.

SacEFT analyses of habitat conditions for steelhead spawning are based on weighted usable area (WUA) derived from the Instream Flow Incremental Method (IFIM) habitat study on the mainstem Sacramento River (U.S. Fish and Wildlife Service 2003) showed that spawning habitat conditions were classified as "good" in 48% of the years under EBC1, 51% of the years under EBC2, and 48% of the years under both EBC2_ELT and PP_ELT scenarios (Table C.5.2-2). Spawning conditions are predicted to be good in 51% of the years under EBC2_LLT and in 48% of the years under PP_LLT operations. The reduction (3%) in the habitat indices for PP_LLT relative to EBC2_LLT suggests that there would be a small reduction in the availability of suitable habitat for steelhead spawning.

High-flow events have the potential to scour redds and eggs during incubation, resulting in increased egg mortality. Results of SacEFT showed that the risk of redd scour was classified as good (reduced risk) 83% of the time for both EBC1 and EBC2, and 80% of the time for both EBC2_ELT and PP_ELT (Table C.5.2-2). Redd scour was classified as good 80% of the time for EBC2_LLT and 77% of the time for PP_LLT. The small (3%) difference in the frequency of good conditions for redd scour between EBC2_LLT and PP_LLT would be expected to result in a small increase in the risk of egg mortality under the preliminary proposal in the LLT. The effect of climate change on redd scour is at least as strong as that of the proposed project.

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Table C.5.2-2. Percentage of Years with "Good"[1] Conditions for Steelhead Habitat Metrics in the Upper Sacramento River (from SacEFT)

Metric	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
Spawning WUA	48	51	48	51	48	48
Redd Scour Risk	83	83	80	80	80	77
Egg Incubation	100	100	100	100	100	100
Redd Dewatering Risk	57	55	56	54	56	61
Juvenile Rearing WUA	41	43	45	45	38	37
Juvenile Stranding Risk	34	40	29	20	26	15

[1] Please refer to Attachment C.B, SacEFT Documentation, for definition of "good" for each performance measure.
WUA = Weighted Usable Area

Water Temperature

Steelhead are a coldwater fish species. Exposure of sensitive life stages, such as incubating eggs and rearing juveniles, to elevated water temperatures results in adverse sublethal and lethal effects. Because steelhead inhabiting the Central Valley rivers are near the southern boundary of the geographic distribution, and climate conditions are warm, the effects of seasonally elevated water temperatures have been recognized as a major stressor on salmonids under existing biological conditions. The construction of dams has limited the access of steelhead to cold water farther upstream that was used historically as spawning habitat (McEwan 2001). The potential for adverse temperature effects is expected to become worse in the future as a result of climate change. Therefore, the effects of water temperature are an important factor to consider in assessing changes in habitat suitability for salmonids as part of this effects analysis. Water temperature criteria for various life stages of salmonids in the Central Valley have been developed by the National Marine Fisheries Service (NMFS) (2009) and are used this effects analysis. The general water temperature criteria for Central Valley salmonids are shown in Table C.5.2-3. For purposes of this effects analysis, water temperature criteria of 56°F or less is identified as suitable for steelhead spawning and egg incubation and 65°F or less is identified as suitable for juvenile steelhead rearing and for juvenile and adult migration.

Water temperature in the Sacramento River immediately downstream of Shasta and Keswick Dams is determined by a number of factors that include the availability of cold water stored in the upstream reservoirs, seasonal atmospheric conditions, and the level of instream flow released to the river. Results of water temperature simulation analyses for the upper reaches of the Sacramento River were used as an indicator of changes in water temperatures that would potentially affect steelhead egg incubation. The model results were compiled monthly over the 82-year period included in the CALSIM simulations. Average monthly water temperatures predicted at Keswick Dam, Ball's Ferry, Jelly's Ferry, and Bend Bridge were then evaluated to determine the months during the steelhead egg incubation period (January–April) when temperatures exceeded 56°F. Results of the frequency of years in which monthly average temperatures exceeded the criterion are summarized in Table C.5.2-4.

Water temperatures naturally increase as a function of distance downstream of Keswick Dam as well as in response to future climate change conditions. Results showed that there were no years when the criterion was exceeded at Keswick Dam under any of the EBC or PP scenarios. At Ball's

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Ferry, there were no years in which the criterion was exceeded under EBC1, EBC2, EBC2_ELT, or PP_ELT. Under simulated late long-term conditions, mean monthly water temperatures exceeded the 56°F criterion in two years under EBC2_LLT and three years under PP_LLT. There were no consecutive years in which the criterion was exceeded at Ball's Ferry. At Jelly's Ferry, mean monthly water temperatures did not exceed the 56°F criterion in EBC1 and EBC2. Mean monthly water temperatures exceeded the 56°F criterion in three years under EBC2_ELT and PP_ELT, 10 years under EBC2_LLT, and 9 years under PP_LLT. Under EBC2_LLT and PP_LLT, there were also two years during which the criterion was exceeded consecutively. At Bend Bridge, mean monthly water temperatures exceeded the 56°F criterion in one year under EBC1 and EBC2, three years under EBC2_ELT, four years under PP_ELT, 13 years under EBC2_LLT, and 12 years under PP_LLT. Under EBC2_LLT and PP_LLT, there were also four years during which the criterion was exceeded consecutively. Based on these results, it is concluded that BDCP implementation would have no detectable effects of the frequency of suitable temperatures for steelhead egg incubation in the Sacramento River downstream of Keswick Dam. The predicted differences in exceedance frequencies among the modeled scenarios were largely due to future climate change.

Table C.5.2-3. Summary of Water Temperature Criteria for Central Valley Salmonids

River	Target Species and Life Stage	Temperature Target Point	Miles below Dam	Date	Temperature Target (°F)	Comment
Sacramento	Winter-run egg incubation	Ball's Ferry	26	4/15–9/30	56	Location depends on coldwater availability
	Winter-run egg incubation	Bend Bridge	44	4/15–9/30	56	Location depends on coldwater availability
	Spring-run incubation and winter-run rearing	Ball's Ferry	26	10/1–10/31	60	Location depends on coldwater availability
	Spring-run incubation and winter-run rearing	Bend Bridge	44	10/1–10/31	60	Location depends on coldwater availability
Clear Creek	Spring-run prespawn and steelhead rearing	Igo	7.5	6/1–9/15	60	
	Spring-run spawning and steelhead rearing	Igo	7.5	9/15–10/31	56	
American River	Steelhead rearing	Watt Avenue	13.4	5/15–10/31	65	Target based on yearly plan
Stanislaus River	Steelhead adult migration	OBB	11	10/1–12/31	56	*
	Steelhead smoltification	KF	5.5	1/1–5/31	52	*
	Steelhead smoltification	OBB	11	1/1–5/31	57	*
	Steelhead spawning and incubation	OBB	11	1/1–5/31	55	*
	Steelhead rearing	OBB	11	6/1–9/30	65	*

* Stanislaus temperatures are based on a 7-day average daily maximum temperature per the 2009 National Marine Fisheries Service (NMFS) Biological Opinion (BiOp).
Source: National Marine Fisheries Service 2009.

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Table C.5.2-4. Results of the Analysis of the 82-Year Simulation of Water Temperature in the Sacramento River during the January through April Steelhead Egg Incubation Period[1]

	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
Sacramento River at Keswick Dam						
Number of years with one or more exceedances	0	0	0	0	0	0
Number of years with two exceedances	0	0	0	0	0	0
Number of years with three exceedances	0	0	0	0	0	0
Number of years with four exceedances	0	0	0	0	0	0
Number of years with five or more exceedances	0	0	0	0	0	0
Number of consecutive years with one or more exceedances	0	0	0	0	0	0
Sacramento River at Ball's Ferry						
Number of years with one or more exceedances	0	0	0	2	0	3
Number of years with two exceedances	0	0	0	0	0	0
Number of years with three exceedances	0	0	0	0	0	0
Number of years with four exceedances	0	0	0	0	0	0
Number of years with five or more exceedances	0	0	0	0	0	0
Number of consecutive years with one or more exceedances	0	0	0	0	0	0
Sacramento River at Jelly's Ferry						
Number of years with one or more exceedances	0	0	3	10	3	9
Number of years with two exceedances	0	0	0	0	0	0
Number of years with three exceedances	0	0	0	0	0	0
Number of years with four exceedances	0	0	0	0	0	0
Number of years with five or more exceedances	0	0	0	0	0	0
Number of consecutive years with one or more exceedances	0	0	0	2	0	2
Sacramento River at Bend Bridge						
Number of years with one or more exceedances	1	1	3	13	4	12
Number of years with two exceedances	0	0	0	0	0	0
Number of years with three exceedances	0	0	0	0	0	0
Number of years with four exceedances	0	0	0	0	0	0
Number of years with five or more exceedances	0	0	0	0	0	0
Number of consecutive years with one or more exceedances	0	0	0	4	0	4

[1] Time period analyzed: January 1922 to April 2003. Analysis counted monthly exceedances above 56°F.

Coldwater pool availability is determined, to a large extent, by the volume of water in reservoir storage. The volume of reservoir storage in the spring (May) and fall (September) has been used here as an indicator of changes in reservoir storage between EBC and PP scenarios (Table C.5.2-5 and Table C.5.2-6). The frequency of exceedance analyses for Shasta Reservoir storage in May and September are shown in Figure C.5.2-13 and Figure C.5.2-14, respectively. These results indicate that Shasta Reservoir storage and, therefore, coldwater pool volume would be comparable (=not meaningfully different) between existing conditions and preliminary proposal conditions. Therefore, BDCP implementation is not expected to have a substantial effect on coldwater pool availability and

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the ability to meet downstream water temperature conditions for steelhead in the Sacramento River downstream of Keswick Dam.

Table C.5.2-5. May Water Storage Volume (Thousand Acre-Feet) in Shasta Reservoir for Model Scenarios

Water-Year Type	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
Wet	4,470	4,473	4,457	4,436	4,442	4,385
Above Normal	4,474	4,477	4,448	4,388	4,392	4,306
Below Normal	4,110	4,101	4,014	3,912	3,953	3,592
Dry	3,778	3,726	3,575	3,334	3,576	3,132
Critical	2,443	2,398	2,146	1,859	2,226	1,824

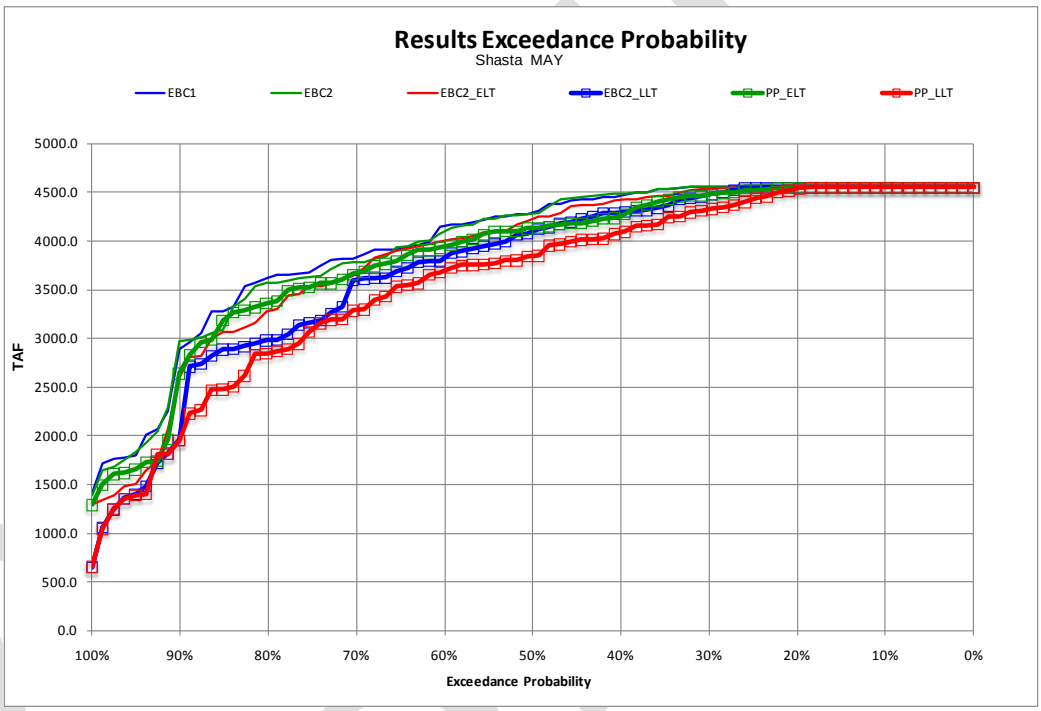

Figure C.5.2-13. Probability of Exceedance Plot for Model Scenarios of Shasta Reservoir Water Storage Volume, May

Table C.5.2-6. September Water Storage Volume (Thousand Acre-Feet) in Shasta Reservoir for Model Scenarios

Water-Year Type	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
Wet	3,317	3,137	3,020	2,805	3,211	3,026
Above Normal	3,197	3,034	2,834	2,582	2,910	2,714
Below Normal	2,872	2,857	2,705	2,518	2,597	2,304
Dry	2,455	2,407	2,253	1,944	2,273	1,900
Critical	1,187	1,182	990	805	1,108	802

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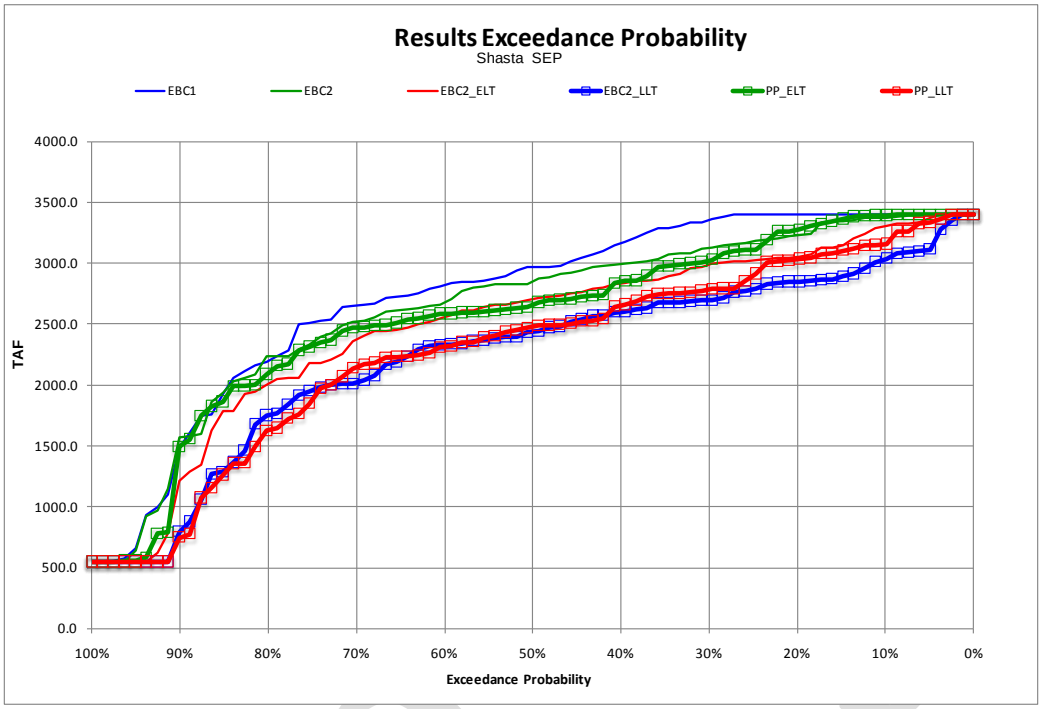

Figure C.5.2-14. Probability of Exceedance Plot for Model Scenarios of Shasta Reservoir Water Storage Volume, September

Water temperature criteria have been used as part of the basis for habitat evaluation metrics developed in the SacEFT analytical framework for assessing suitability of habitat for salmonids in the Sacramento River. Results of SacEFT analyses showed that water temperatures for steelhead egg incubation were classified as good in 100% of years for all model scenarios (Table C.5.2-2). These results reflect, in part, the fact that steelhead spawn and their eggs incubate during the winter and early spring when water temperatures in the Sacramento River are naturally cool.

Redd Dewatering

The SacEFT predicts that redd dewatering conditions would be classified as good (reduced risk of redd dewatering) in 57% of years for EBC1, 55% of the years for EBC2, and 56% of the years for both EBC2_ELT and PP_ELT (Table C.5.2-2). These results suggest that there would no substantive effect of the proposed project in the early long-term period to the risk of redd dewatering. The model predicts that redd dewatering risk would be good in 54% of the years for EBC_LLT and 61% of the years for PP_LLT. The predicted increase in the percentage of time that the risk of redd dewatering would occur for PP_LLT relative to EBC with and without climate change would be expected to contribute a small incremental adverse effect to egg survival of steelhead.

Fry and Juvenile Rearing

Rearing Habitat

Juvenile steelhead rear within the Sacramento River and its tributaries throughout the year. Changes in instream flows within the juvenile steelhead rearing areas may affect the quality and availability of rearing habitat through changes in physical characteristics of wetted channel width, water depth, and water velocities. Instream flow studies have been conducted (U.S. Fish and Wildlife

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Service 2003; Gard 2005) that provide information on the relationship between river flow and juvenile steelhead rearing habitat (referred to as weighted usable area – WUA). The WUA estimates include results of hydraulic simulations of how variables such as water depth and velocity change in response to flow, as well as information on habitat preferences and habitat suitability indices (HSI) for each fish species and life stage of interest.

The two primary potential effects of BDCP operations on habitat conditions for juvenile steelhead rearing on the mainstem Sacramento River relate to changes in either instream flows or seasonal water temperatures released from Shasta and Keswick dams. Juvenile steelhead rearing occurs throughout the year as juveniles inhabit upstream areas for a period of 1 to 2 years before migrating downstream to the ocean. Results of the CALSIM analyses of instream flows within the reach where the majority of steelhead spawning occurs (Keswick Dam to upstream of RBDD) are presented in Table C.5.2-1. Monthly frequency of exceedance plots for Sacramento River flows upstream of RBDD during the juvenile steelhead rearing period are presented in Figure C.5.2-1 through Figure C.5.2-12.

Results of water temperature simulation analyses for the upper Sacramento River were used as an indicator of changes in water temperatures that would potentially affect steelhead rearing conditions (Table C.5.2-7). This analysis uses 65°F as the threshold over which juvenile steelhead survival may be negatively affected, which is the NMFS temperature target for steelhead rearing habitat (Table C.5.2-3). During the 82-year simulation period at Keswick, one or more occurrences of temperatures exceeding 65°F are predicted to occur in 1–2 years under EBC1 and EBC2, 7–8 years under EBC2_ELT and PP_ELT, and 9 years under EBC2_LLT and PP_LLT (Table C.5.2-7). The number of consecutive years with one or more occurrences of temperature exceeding 65°F was zero under EBC1 and EBC2, six under EBC2_ELT and PP_ELT, and seven under EBC2_LLT and PP_LLT. Patterns in results at other locations in the Sacramento River (Ball's Ferry, Jelly's Ferry, and Bend Bridge) are similar to those at Keswick, although the frequency of exceedance above the 65°F water temperature threshold generally increases from Keswick to Bend Bridge. These results suggest that frequency of stressful water temperatures for steelhead rearing under current climate conditions (under EBC1 and EBC2) in the Sacramento River is predicted to increase under early and late long-term conditions in the absence of BDCP. BDCP implementation (PP_ELT and PP_LLT), however, is predicted to result in little or no increase in the frequency of these temperatures relative to baseline conditions (EBC2_ELT and EBC2_LLT).

Table C.5.2-7. Results of the Analysis of the 82-Year Simulation of Water Temperature in the Sacramento River during the Year-Round Juvenile Steelhead Rearing Period[1]

	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
Sacramento River at Keswick Dam						
Number of years with one or more exceedances	2	1	7	9	8	9
Number of years with two exceedances	0	0	4	7	2	6
Number of years with three exceedances	0	0	0	0	0	1
Number of years with four exceedances	0	0	0	0	0	0
Number of years with five or more exceedances	0	0	0	0	0	0
Number of consecutive years with one or more exceedances	0	0	6	7	6	7

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	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
Sacramento River at Ball's Ferry						
Number of years with one or more exceedances	1	1	7	10	8	10
Number of years with two exceedances	0	0	5	6	4	4
Number of years with three exceedances	0	0	0	2	0	3
Number of years with four exceedances	0	0	0	0	0	0
Number of years with five or more exceedances	0	0	0	0	0	0
Number of consecutive years with one or more exceedances	0	0	6	7	6	7
Sacramento River at Jelly's Ferry						
Number of years with one or more exceedances	1	1	7	11	8	12
Number of years with two exceedances	0	1	6	3	5	3
Number of years with three exceedances	0	0	0	5	0	5
Number of years with four exceedances	0	0	0	0	0	0
Number of years with five or more exceedances	0	0	0	0	0	0
Number of consecutive years with one or more exceedances	0	0	6	7	6	7
Sacramento River at Bend Bridge						
Number of years with one or more exceedances	1	2	7	13	8	12
Number of years with two exceedances	1	1	6	3	5	3
Number of years with three exceedances	0	0	0	5	0	5
Number of years with four exceedances	0	0	0	0	0	0
Number of years with five or more exceedances	0	0	0	0	0	0
Number of consecutive years with one or more exceedances	0	0	6	9	6	7
[1] Time period analyzed: October 1921 to September 2003. Analysis counted monthly exceedances above 65°F.						

Figure C.5.2-15 through Figure C.5.2-26 show year-round exceedance plots of water temperatures in the Sacramento River at RBDD. Figure C.5.2-18 through Figure C.5.2-25 show exceedance plots just for the months of April through November, which are the months when water temperatures could reach levels of concern for steelhead rearing.

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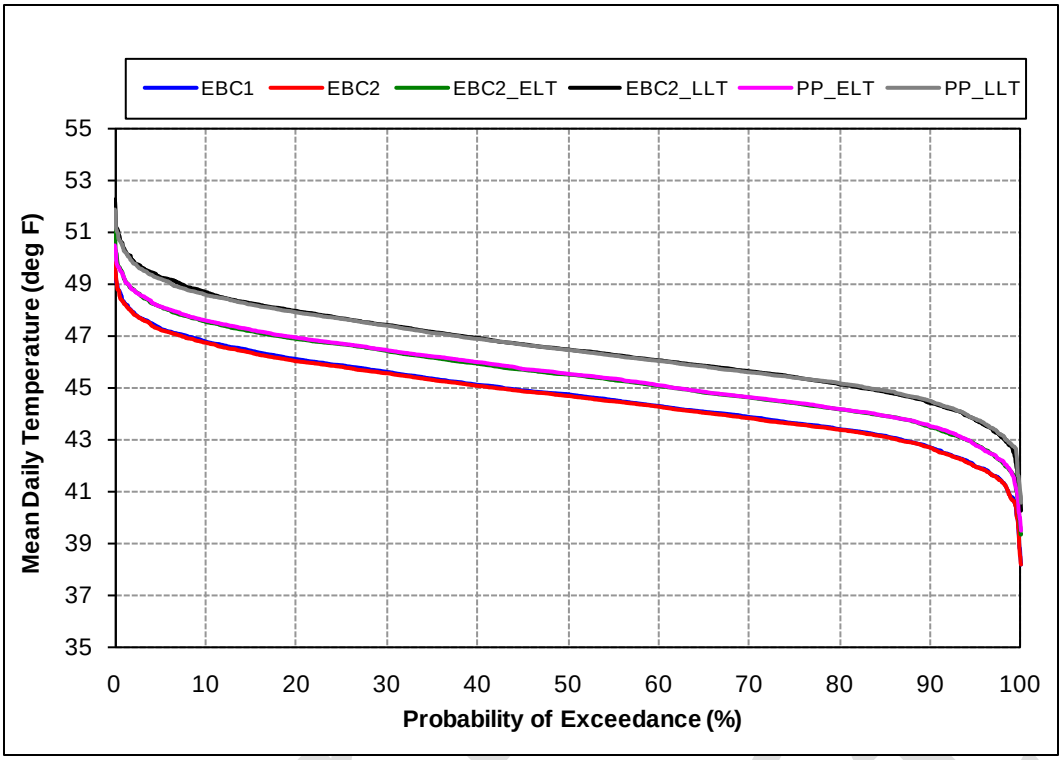

Figure C.5.2-15. Probability of Exceedance Plot for Model Scenarios of Mean Daily Water Temperature of Sacramento River at Red Bluff Diversion Dam, January

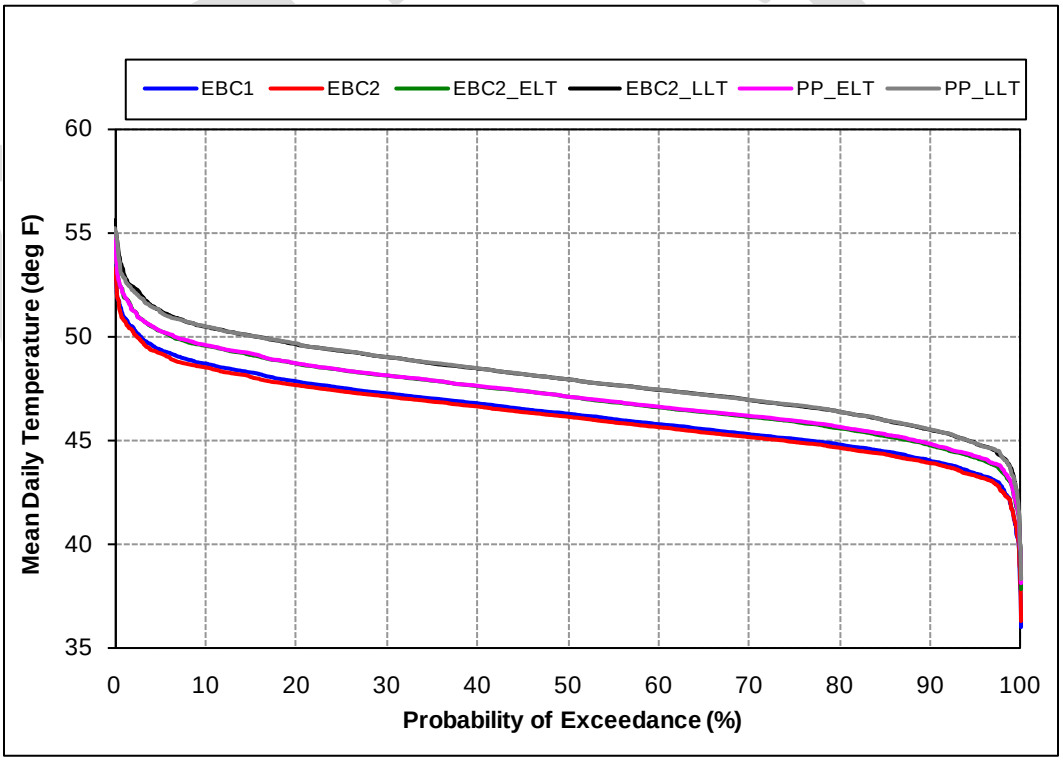

Figure C.5.2-16. Probability of Exceedance Plot for Model Scenarios of Mean Daily Water Temperature of Sacramento River at Red Bluff Diversion Dam, February

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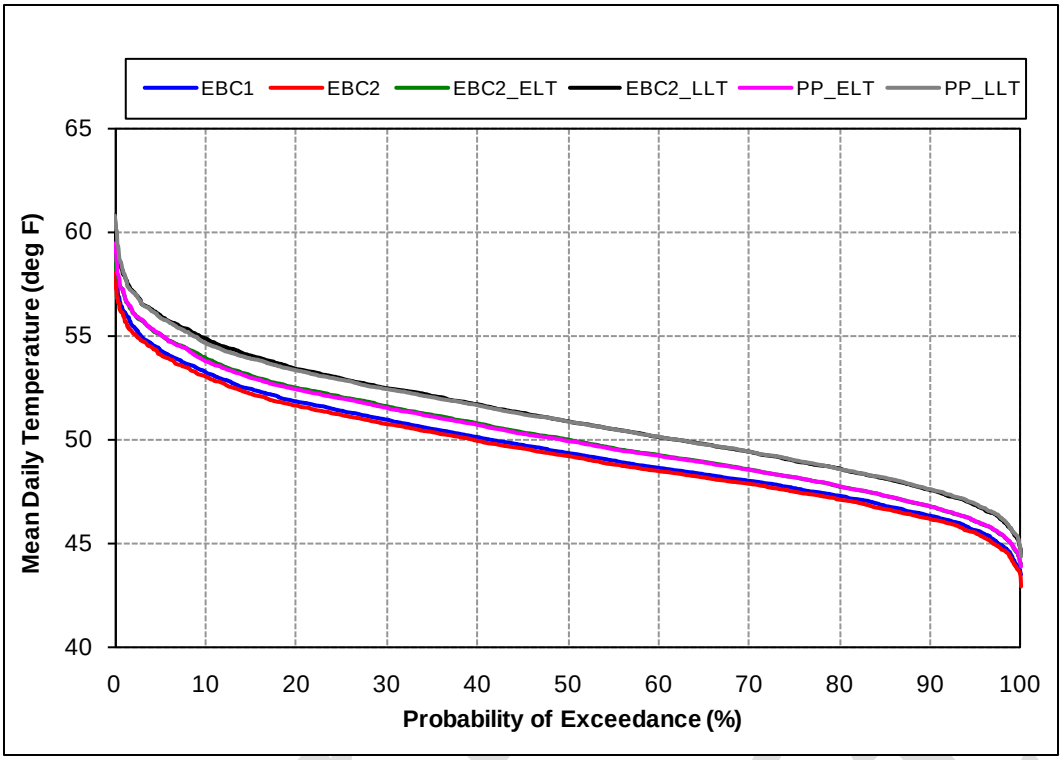

Figure C.5.2-17. Probability of Exceedance Plot for Model Scenarios of Mean Daily Water Temperature of Sacramento River at Red Bluff Diversion Dam, March

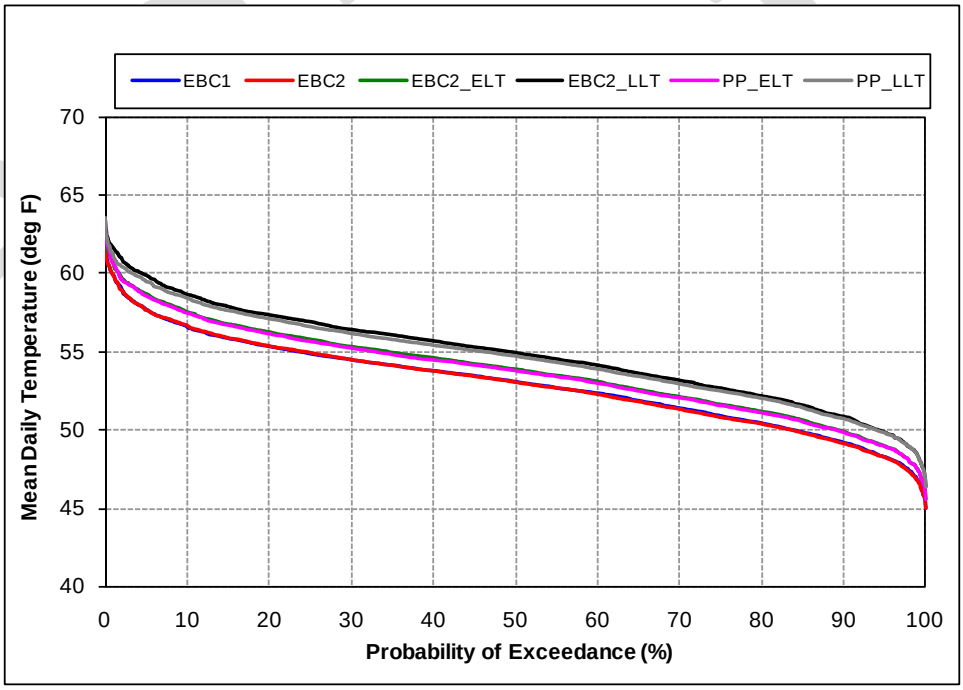

Figure C.5.2-18. Probability of Exceedance Plot for Model Scenarios of Mean Daily Water Temperature of Sacramento River at Red Bluff Diversion Dam, April

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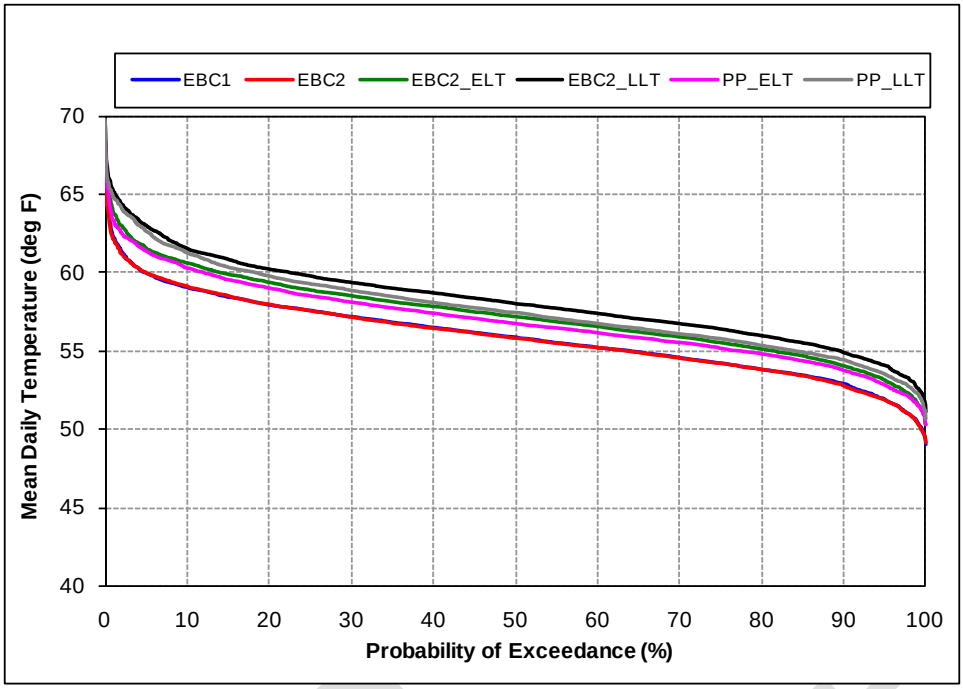

Figure C.5.2-19. Probability of Exceedance Plot for Model Scenarios of Mean Daily Water Temperature of Sacramento River at Red Bluff Diversion Dam, May

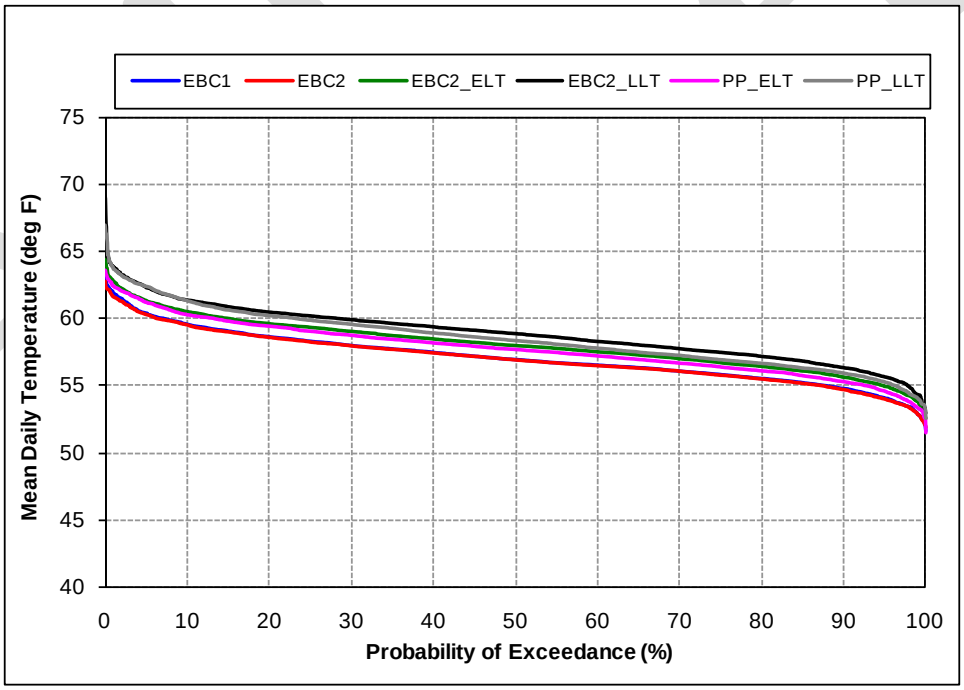

Figure C.5.2-20. Probability of Exceedance Plot for Model Scenarios of Mean Daily Water Temperature of Sacramento River at Red Bluff Diversion Dam, June

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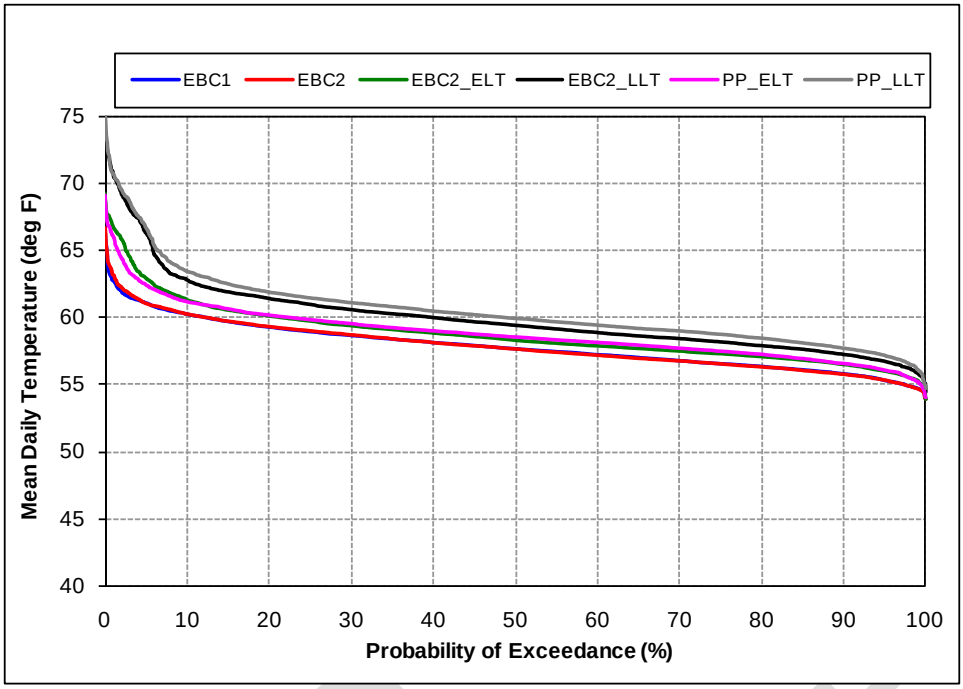

Figure C.5.2-21. Probability of Exceedance Plot for Model Scenarios of Mean Daily Water Temperature of Sacramento River at Red Bluff Diversion Dam, July

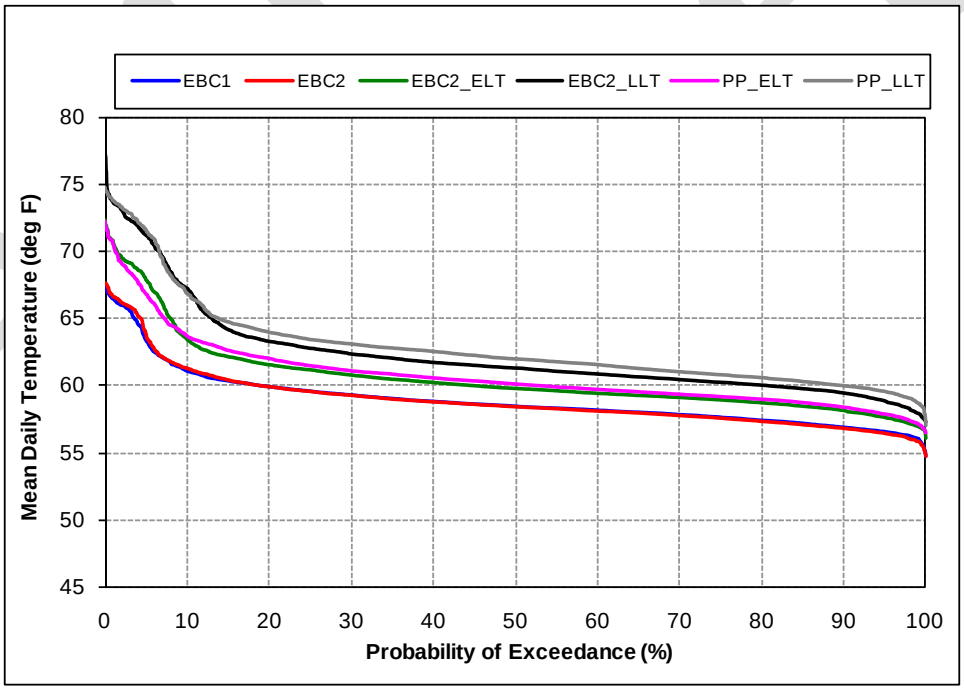

Figure C.5.2-22. Probability of Exceedance Plot for Model Scenarios of Mean Daily Water Temperature of Sacramento River at Red Bluff Diversion Dam, August

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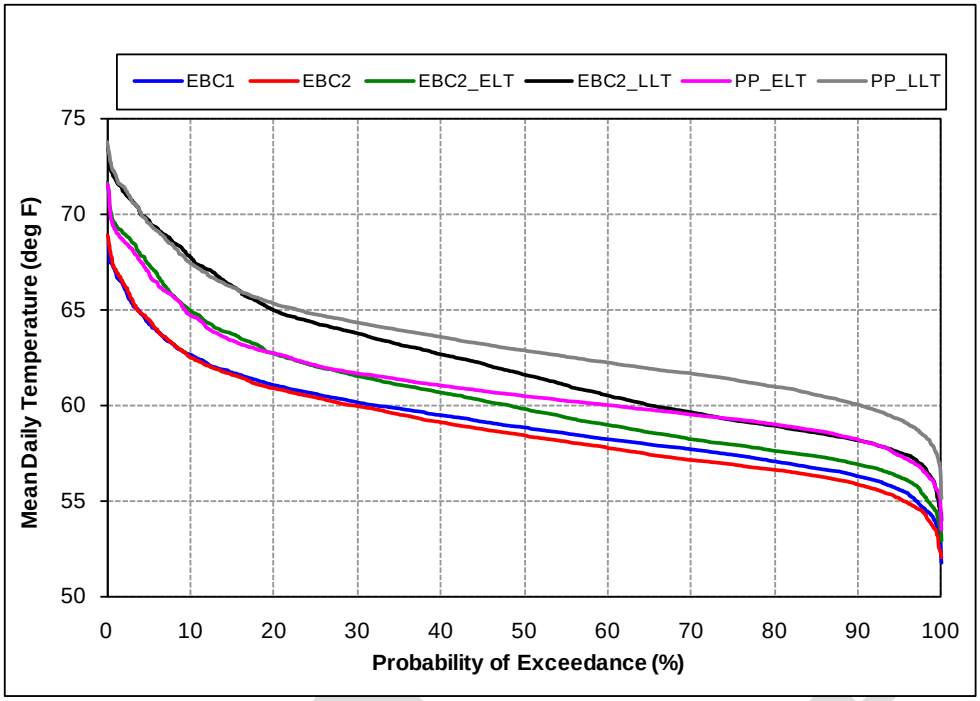

Figure C.5.2-23. Probability of Exceedance Plot for Model Scenarios of Mean Daily Water Temperature of Sacramento River at Red Bluff Diversion Dam, September

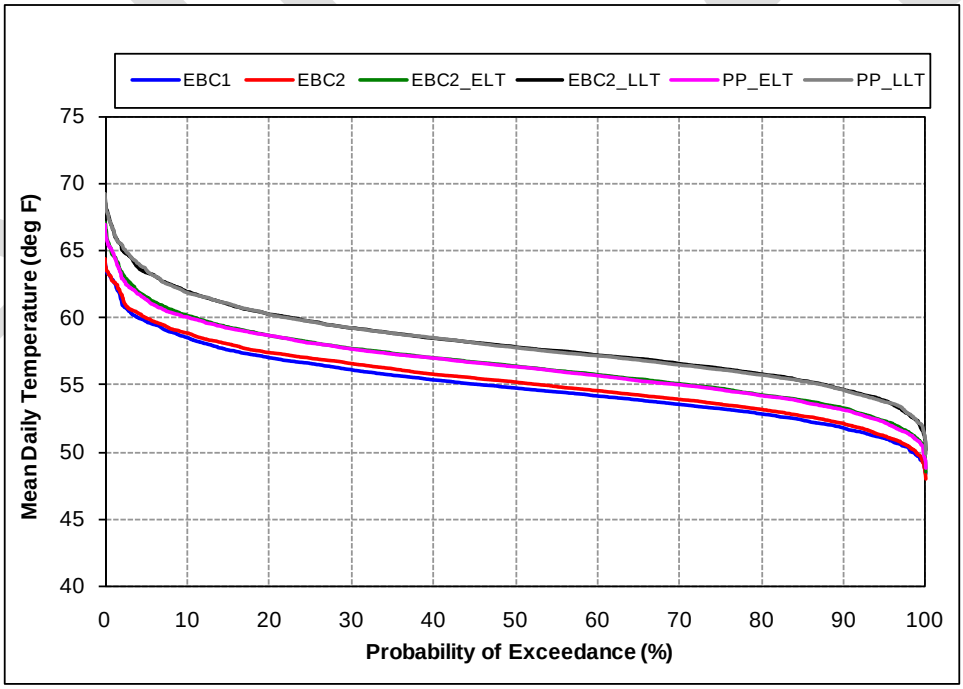

Figure C.5.2-24. Probability of Exceedance Plot for Model Scenarios of Mean Daily Water Temperature of Sacramento River at Red Bluff Diversion Dam, October

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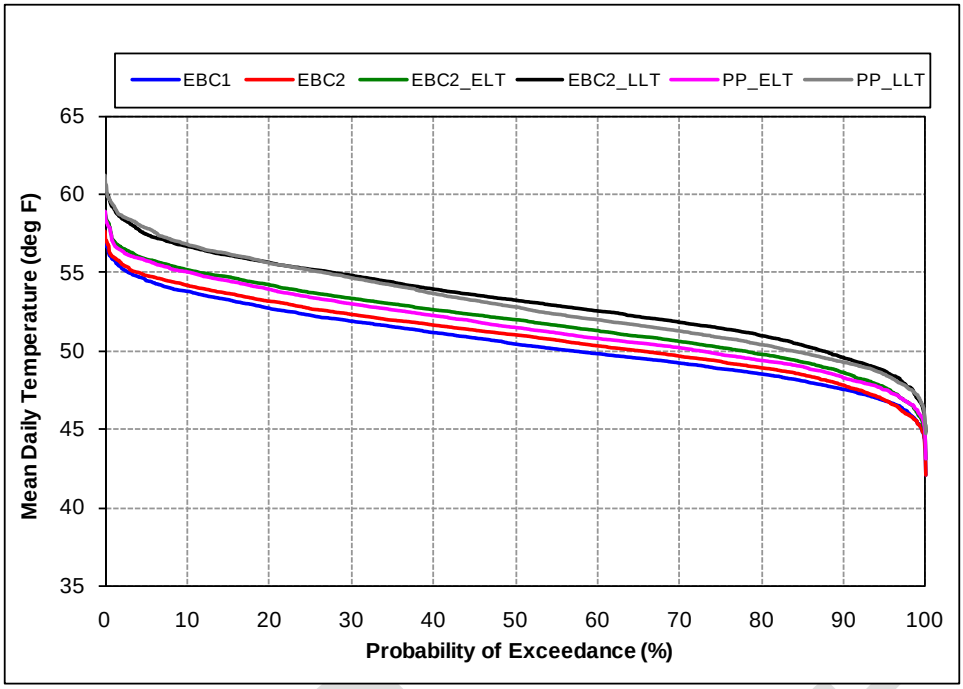

Figure C.5.2-25. Probability of Exceedance Plot for Model Scenarios of Mean Daily Water Temperature of Sacramento River at Red Bluff Diversion Dam, November

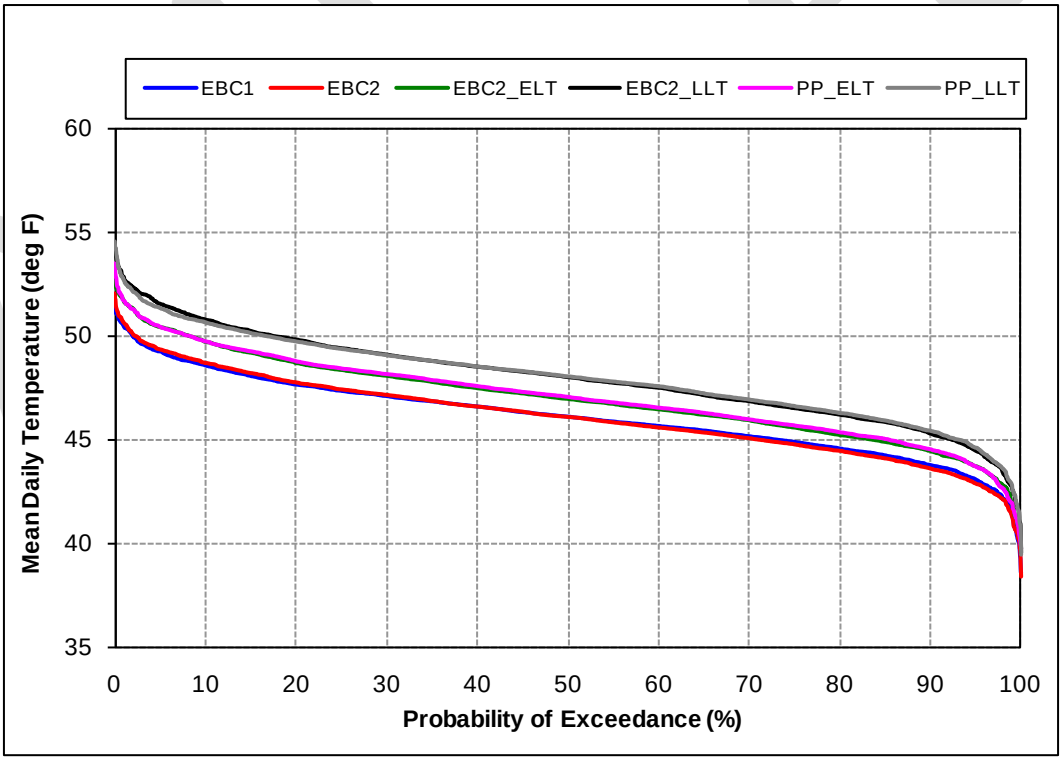

Figure C.5.2-26. Probability of Exceedance Plot for Model Scenarios of Mean Daily Water Temperature of Sacramento River at Red Bluff Diversion Dam, December

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Temperatures farther upstream to Keswick Dam, where steelhead rear year-round, are cooler than those just upstream of RBDD. The temperatures from Shasta Dam are managed to provide cool water over summer for winter Chinook egg incubation and to support all life stages of salmonids that reside in the upper reaches of the river downstream of Keswick Dam. Temperatures at Red Bluff would be below 65°F through June in most years for all EBC and PP conditions. Water temperatures are predicted to exceed 65°F with increasing frequency through the summer. The largest exceedance occurs in September when 65°F would be exceeded in approximately 5% of years under EBC1 and EBC2, in approximately 10% of years under EBC2_ ELT and PP_ELT, and in approximately 20% of years for EBC2_ LLT and PP_LLT (Figure C.5.2-23). Under early and late long-term conditions, differences in the frequency of water temperatures exceeding 65°F between EBC and PP conditions were negligible, although relatively large increases due to climate change in the frequency of water temperatures above 65°F are predicted in September (Figure C.5.2-23).

Figure C.5.2-27 through Figure C.5.2-38 show year-round exceedance plots of Sacramento River water temperatures at Keswick. Figure C.5.2-27 through Figure C.5.2-34 show exceedance plots just for the months of April through November.

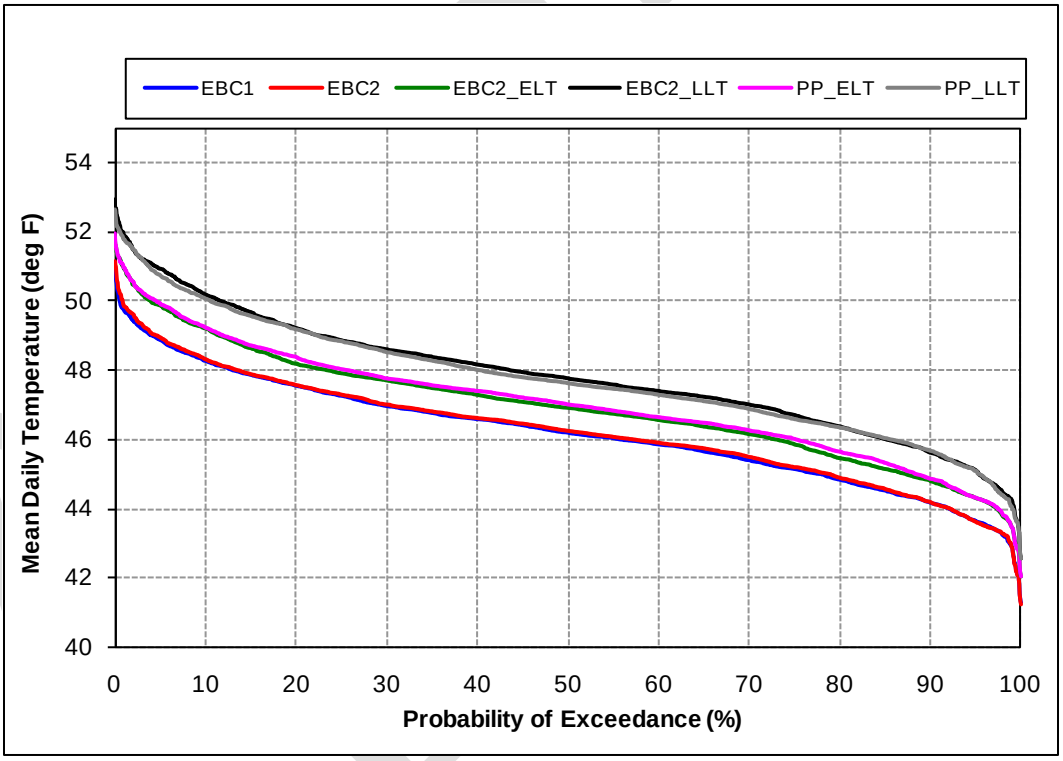

Figure C.5.2-27. Probability of Exceedance Plot for Model Scenarios of Mean Daily Water Temperature of the Sacramento River at Keswick Dam, January

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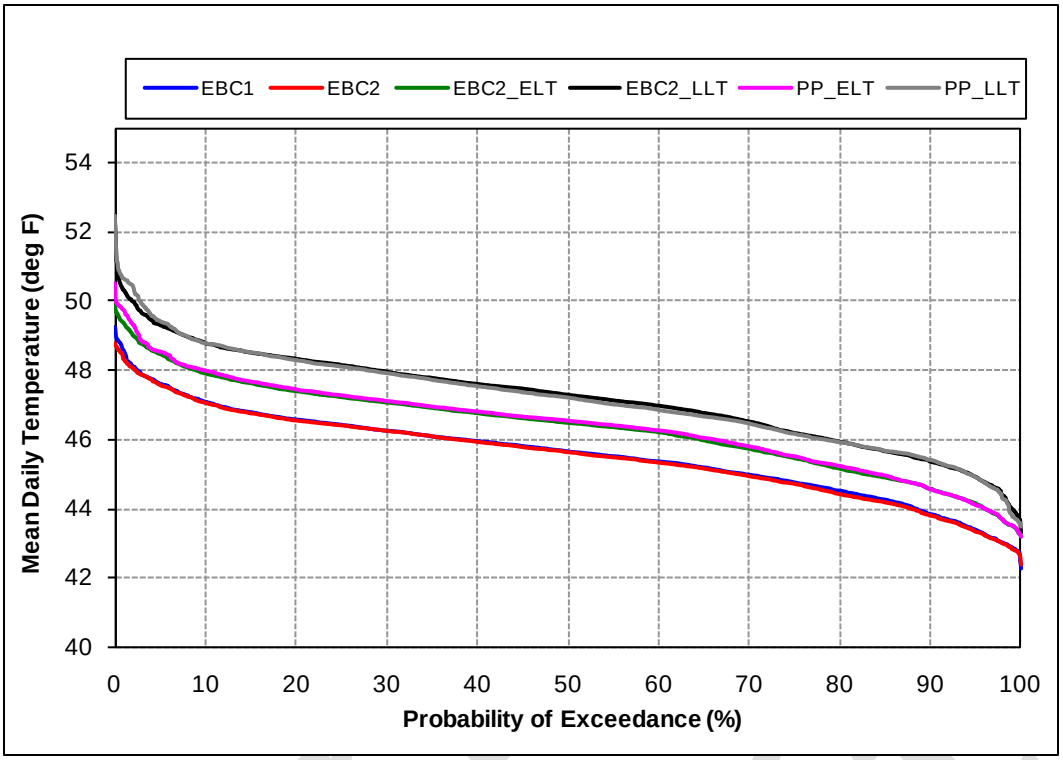

Figure C.5.2-28. Probability of Exceedance Plot for Model Scenarios of Mean Daily Water Temperature of the Sacramento River at Keswick Dam, February

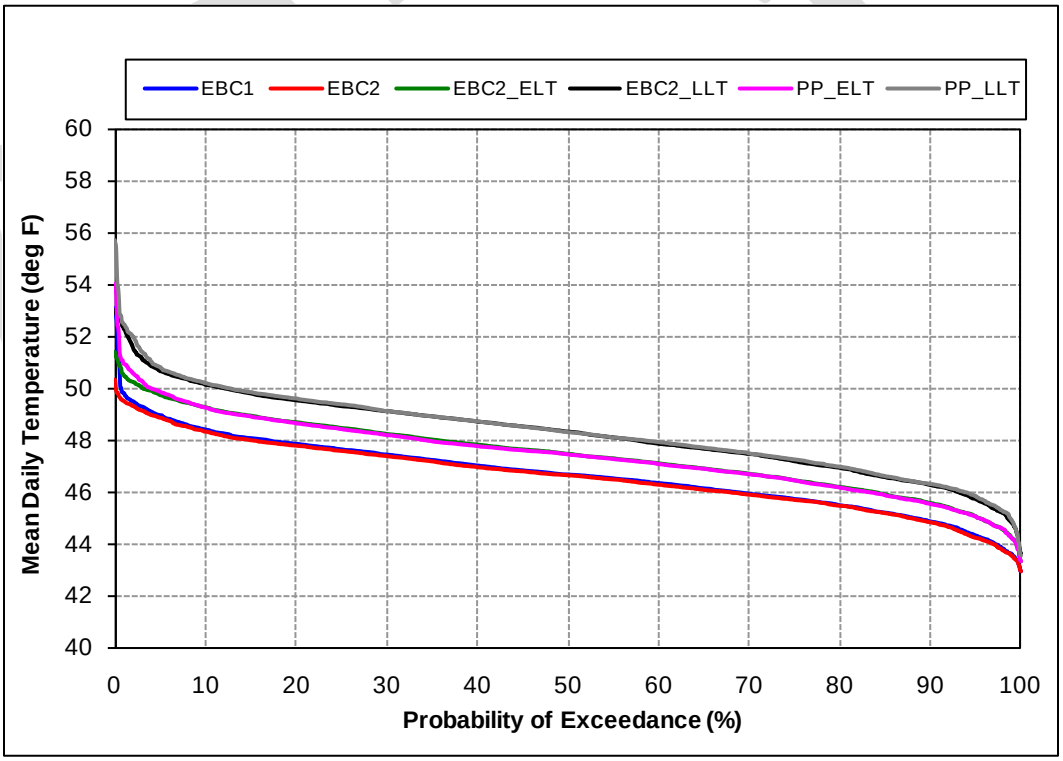

Figure C.5.2-29. Probability of Exceedance Plot for Model Scenarios of Mean Daily Water Temperature of the Sacramento River at Keswick Dam, March

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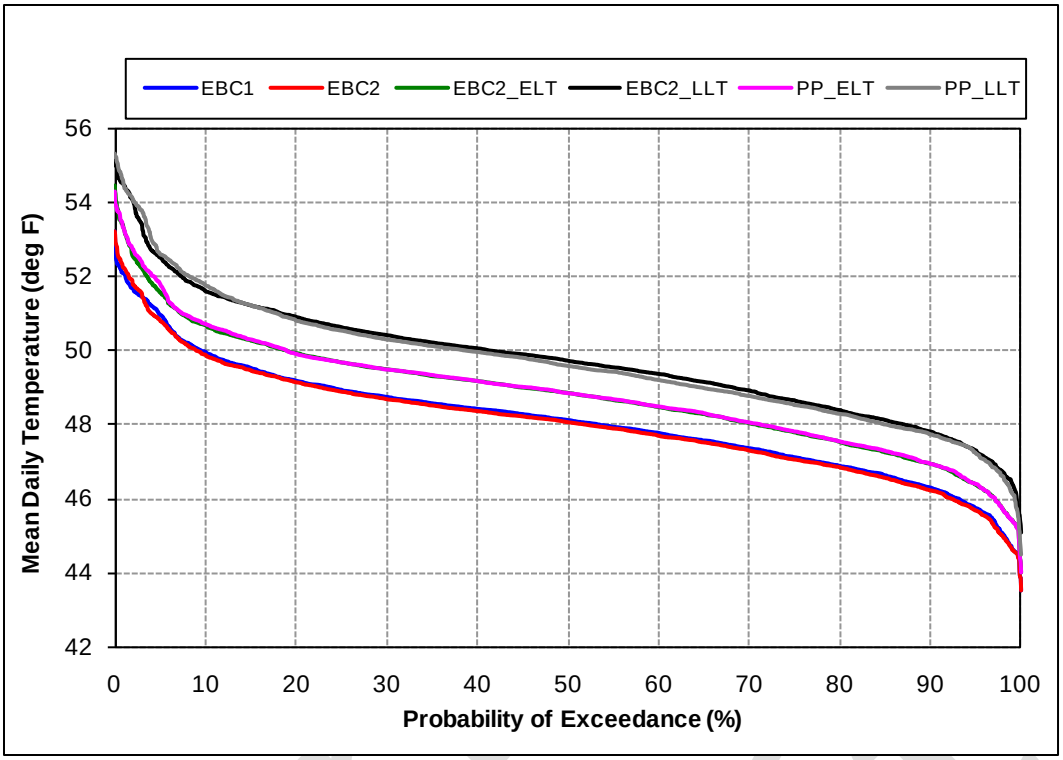

Figure C.5.2-30. Probability of Exceedance Plot for Model Scenarios of Mean Daily Water Temperature of the Sacramento River at Keswick Dam, April

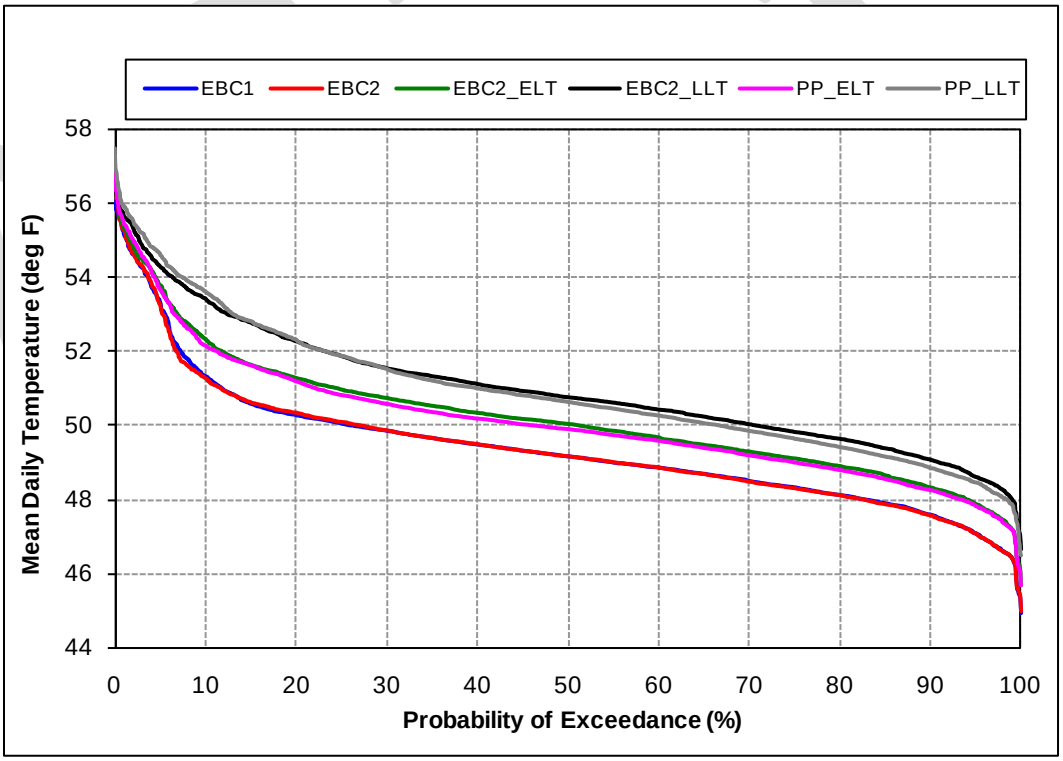

Figure C.5.2-31. Probability of Exceedance Plot for Model Scenarios of Mean Daily Water Temperature of the Sacramento River at Keswick Dam, May

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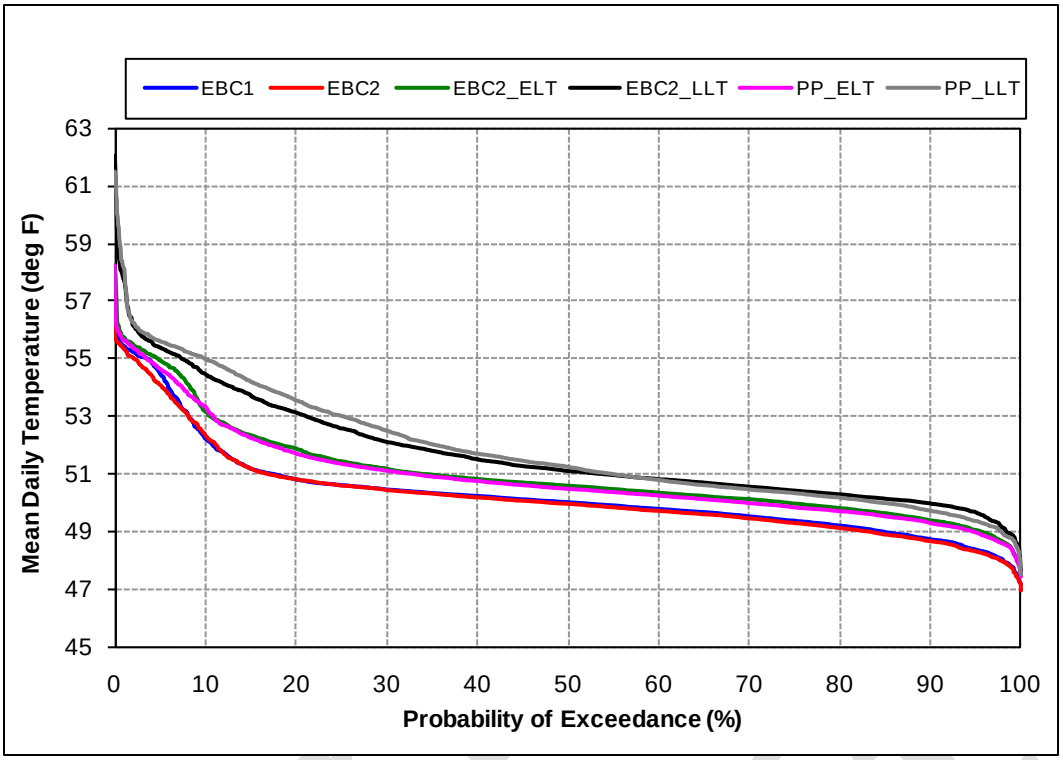

Figure C.5.2-32. Probability of Exceedance Plot for Model Scenarios of Mean Daily Water Temperature of the Sacramento River at Keswick Dam, June

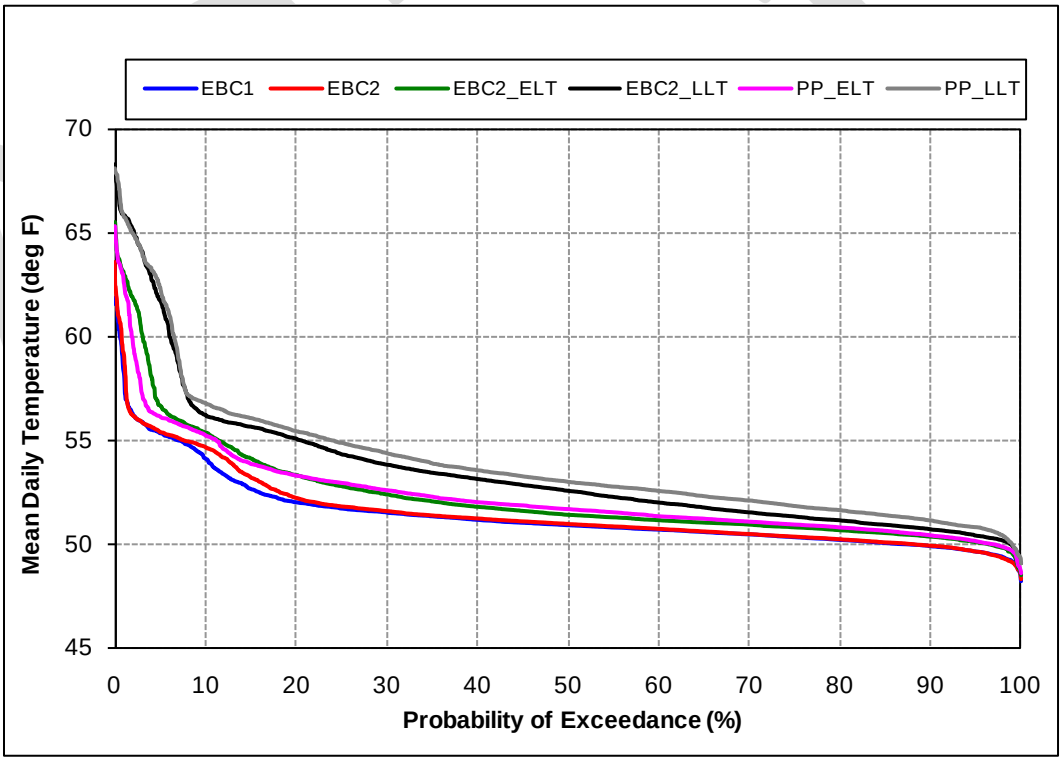

Figure C.5.2-33. Probability of Exceedance Plot for Model Scenarios of Mean Daily Water Temperature of the Sacramento River at Keswick Dam, July

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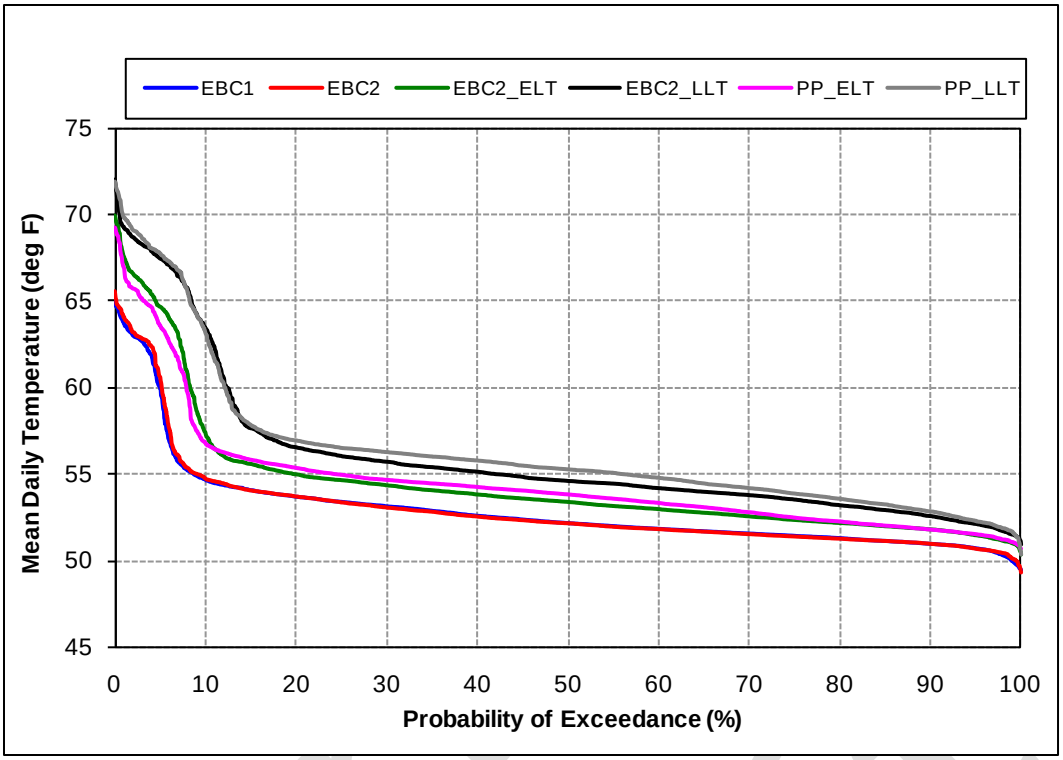

Figure C.5.2-34. Probability of Exceedance Plot for Model Scenarios of Mean Daily Water Temperature of the Sacramento River at Keswick Dam, August

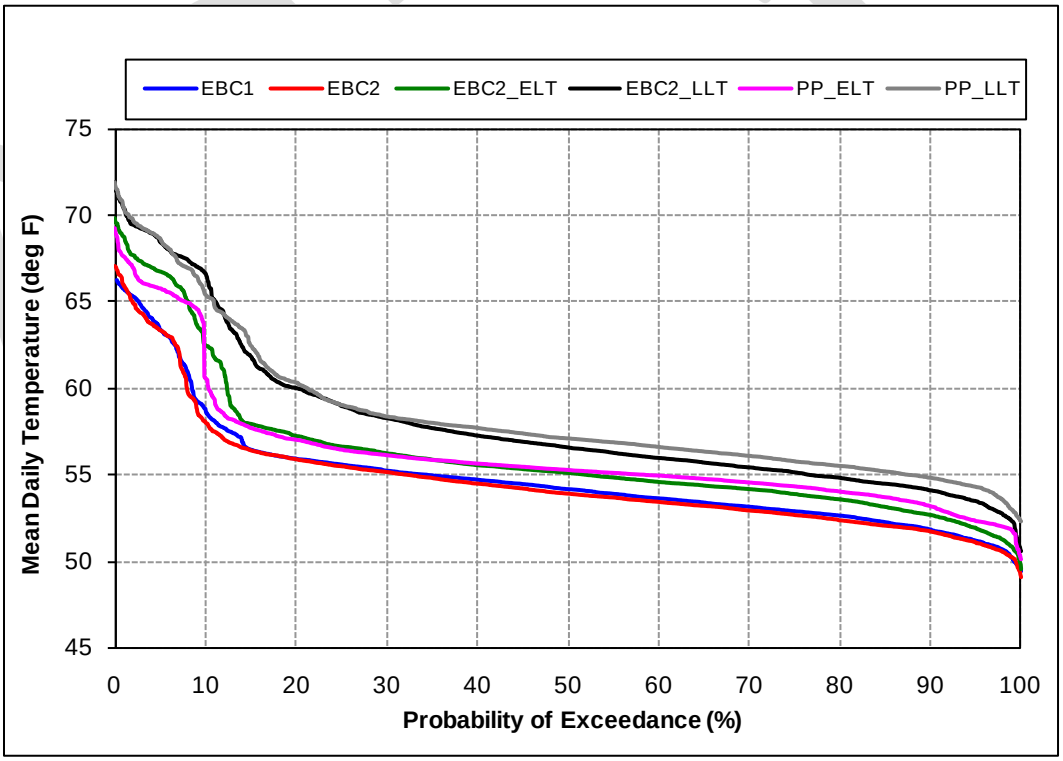

Figure C.5.2-35. Probability of Exceedance Plot for Model Scenarios of Mean Daily Water Temperature of the Sacramento River at Keswick Dam, September

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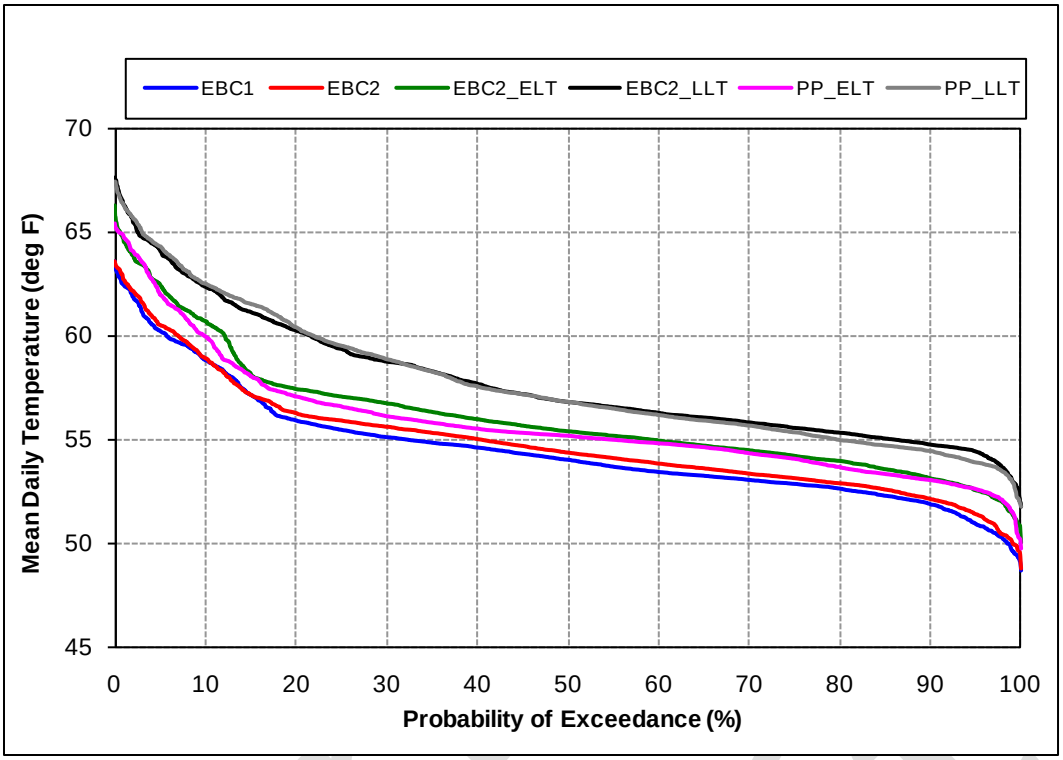

Figure C.5.2-36. Probability of Exceedance Plot for Model Scenarios of Mean Daily Water Temperature of the Sacramento River at Keswick Dam, October

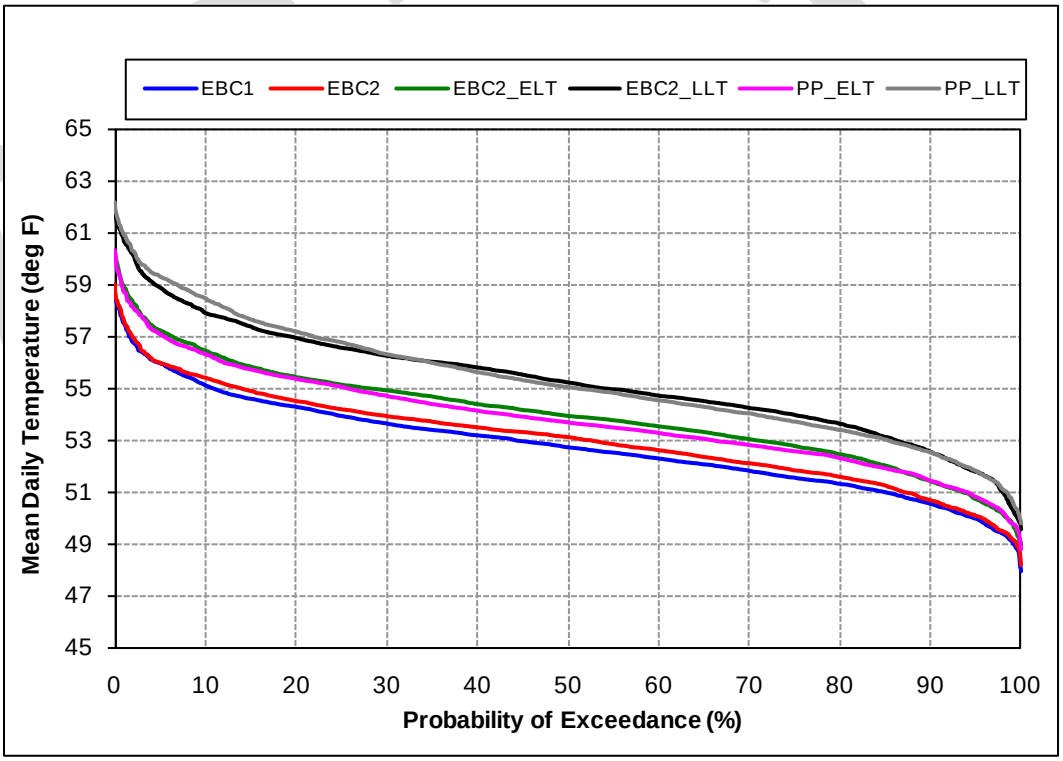

Figure C.5.2-37. Probability of Exceedance Plot for Model Scenarios of Mean Daily Water Temperature of the Sacramento River at Keswick Dam, November

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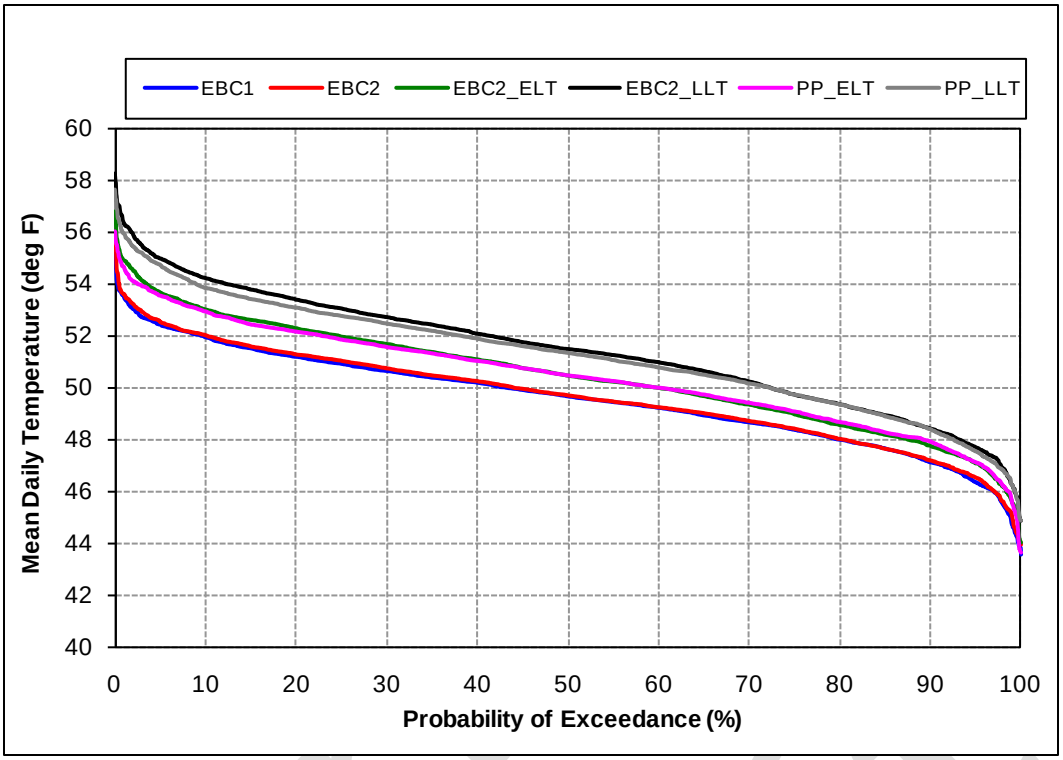

Figure C.5.2-38. Probability of Exceedance Plot for Model Scenarios of Mean Daily Water Temperature of the Sacramento River at Keswick Dam, December

These figures show that water temperature exceeds 65°F at Keswick Dam similarly between EBC2_ELT and PP_ELT, and between EBC2_LLT and PP_LLT. The small increases in water temperature are due to climate change. Regardless, differences between EBC and PP scenarios at Keswick Dam during ELT and LLT periods when water temperatures are greater than 65°F are not biologically significant.

Figure C.5.2-39 shows temperatures during August, the month of warmest water temperatures, at Hamilton City. Climate change under LLT conditions is responsible for the greatest increase in temperatures but the proposed project increases temperatures in the late long-term by about 1°F, reducing the length of river with suitable water temperature for rearing. Figure C.5.2-40 shows the number of days per year with temperatures exceeding 65°F at Hamilton City. The proposed project increases the number of days exceeding 65°F in a majority of years.

Sacramento River at Keswick flows would be relatively unchanged between scenarios in dry conditions (flow at 25th percentile; Figure C.5.2-41). There would be some changes under wet conditions (flow at 75th percentile; Figure C.5.2-42) with increased releases in the winter, likely due to flood control requirements with changes from snow to rain precipitation, and lower end of spring storage resulting in decreased releases later in the fall, primarily September.

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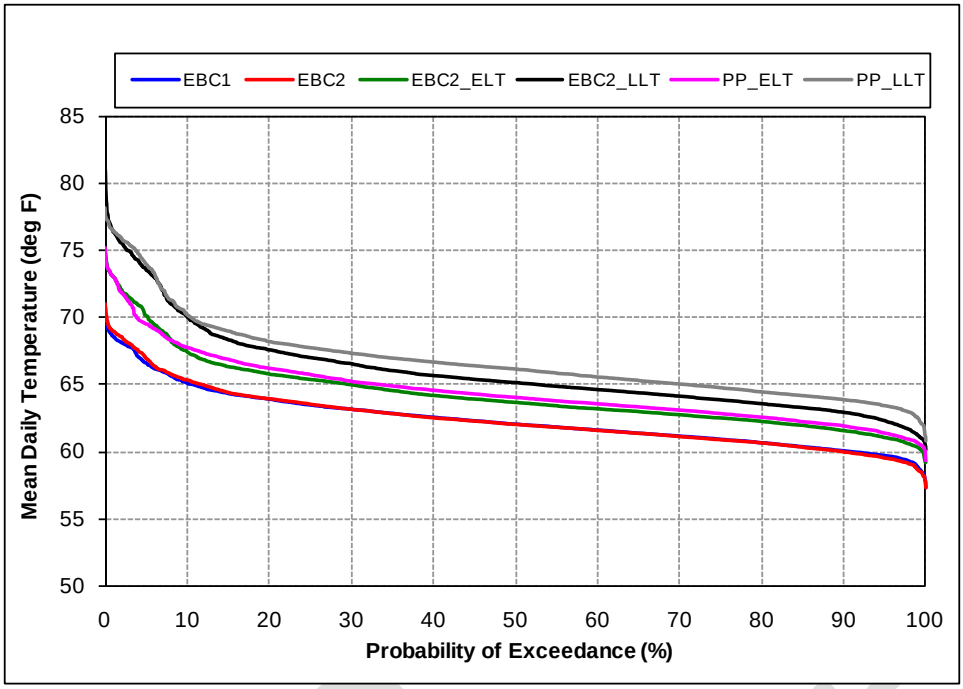

Figure C.5.2-39. Probability of Exceedance Plot for Model Scenarios of Mean Daily Water Temperature of Sacramento River at Hamilton City, August

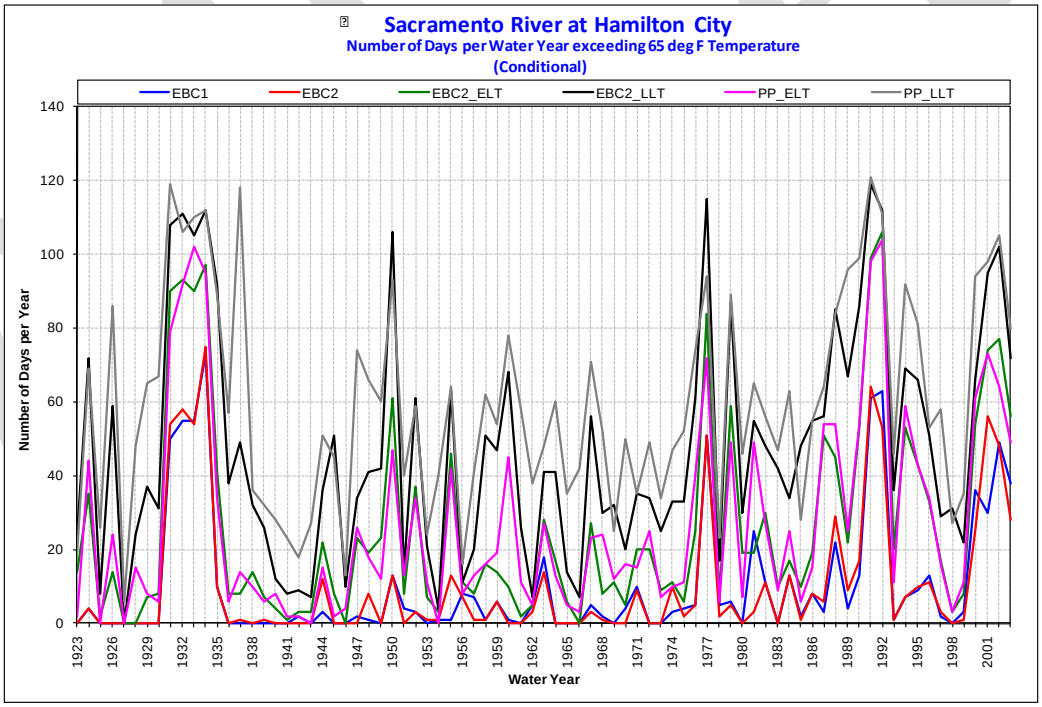

Figure C.5.2-40. Number of Days per Year during which Temperature Is Predicted to Exceed 65°F in the Sacramento River at Hamilton City under Each Model Scenario

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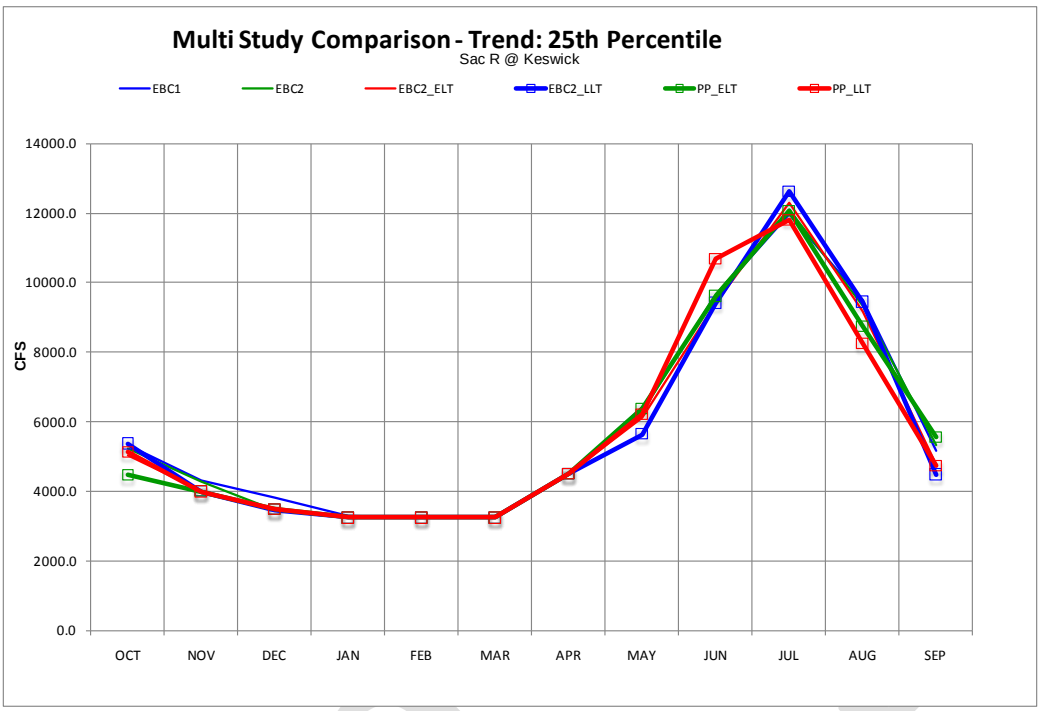

Figure C.5.2-41. Keswick Monthly Releases to the Sacramento River for Drier Conditions for Model Scenarios

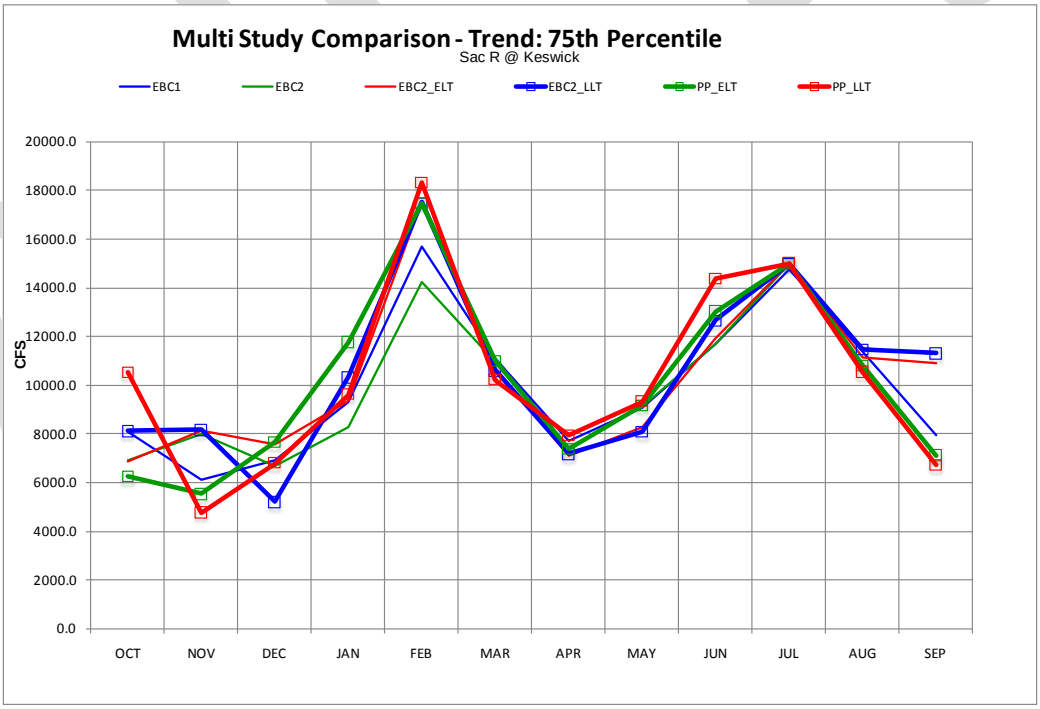

Figure C.5.2-42. Keswick Monthly Releases to the Sacramento River for Wetter Conditions for Model Scenarios

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The following figures show the predicted upper Sacramento River flows progressively down the river at Keswick (Figure C.5.2-43), upstream of RBDD (Figure C.5.2-44), Wilkins Slough (Figure C.5.2-45), and Verona (Figure C.5.2-46). Predicted flows upstream of RBDD and Wilkins Slough under PP_ELT and PP_LLT operations show an increasing trend relative to EBC2_ELT and EBC2_LLT, respectively, for the months of December through June. These mid-river areas are not heavily used by juvenile steelhead for rearing such that changes here may be inconsequential for them.

Because juvenile steelhead rear within the Sacramento River year-round, the lowest predicted monthly instream flow from CALSIM was used as one indicator of habitat conditions for juvenile rearing (Table C.5.2-8). Results of this analysis predict that flow in the Sacramento River in these comparative analyses were not substantively (less than 5%) different for PP_ELT and PP_LLT relative to EBC2_ELT and EBC2_LLT, respectively, during below-normal, dry, and critical water years. Differences in predicted Sacramento River flows are similar in wet and above-normal water years for PP_ELT relative to EBC2_ELT. The greatest reduction in predicted flows associated with BDCP operations are in wet and above-normal water years in the comparisons between EBC2_LLT and PP_LLT operations. In these comparisons, the minimum Sacramento River flow upstream of RBDD decreases under PP_LLT relative to EBC2_LLT by 712 cfs in wet years and 1,755 cfs in above-normal years. The reduction in predicted Sacramento River flow in the upper reaches of the river, particularly in wet and above-normal water years, would be expected to affect habitat quantity and quality for juvenile steelhead rearing as a result of BDCP operations, particularly in the PP_LLT scenario.

SacEFT classifies juvenile rearing habitat conditions as good in 41% of years for EBC1 and 43% of the years for EBC1 and EBC2 (Table C.5.2-2). Rearing habitat was classified as good in 45% of the years for EBC2_ELT, which decreased to 38% of the years under PP_ELT conditions, a decrease of 7%. Habitat conditions for juvenile rearing were classified as good in 45% of the years under EBC2_LLT which decreased to 37% of the years for PP_LLT, a decrease of 8%. The decrease in the percentage of years when juvenile rearing habitat was classified as good for PP_ELT and PP_LLT would be expected to contribute to a small incremental decrease in habitat conditions for steelhead.

Flow fluctuations have the potential to strand juvenile steelhead in backwater areas and along channel margins when flow is rapidly reduced. Results of SacEFT showed that the risk of juvenile stranding was classified as good (reduced risk) in 34% of years for EBC1, 40% of the years for EBC2, 29% of the years for EBC2_ELT, and 26% of the years for PP_ELT (Table C.5.2-2). Similarly, the risk of stranding was classified as good in 20% of the years for EBC2_LLT and 15% of the years for PP_LLT. The increase in the frequency of the risk for juvenile stranding of 3% for PP_ELT and 5% for PP_ LLT would be expected to contribute to a small incremental reduction in good habitat conditions and a increase in the risk of mortality to juvenile steelhead resulting from stranding for PP_ELT and PP_LLT relative to EBC2_ELT and EBC2_LLT, respectively.

Admin Draft

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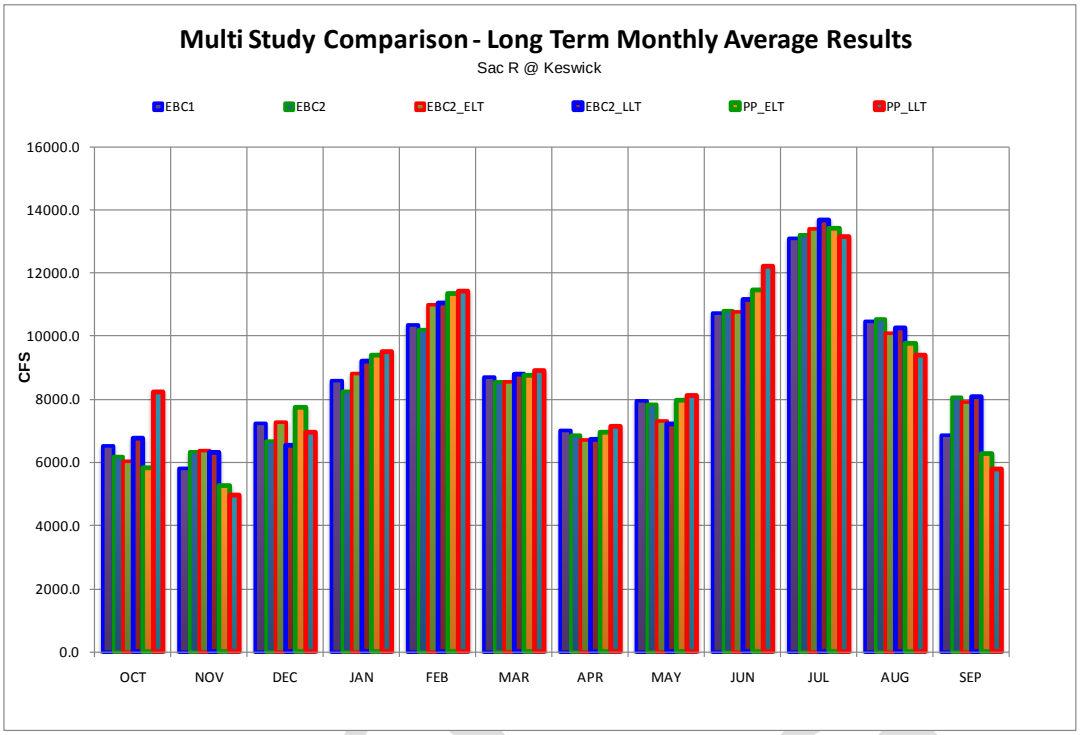

Figure C.5.2-43. Keswick Mean Monthly Releases to the Sacramento River for Model Scenarios

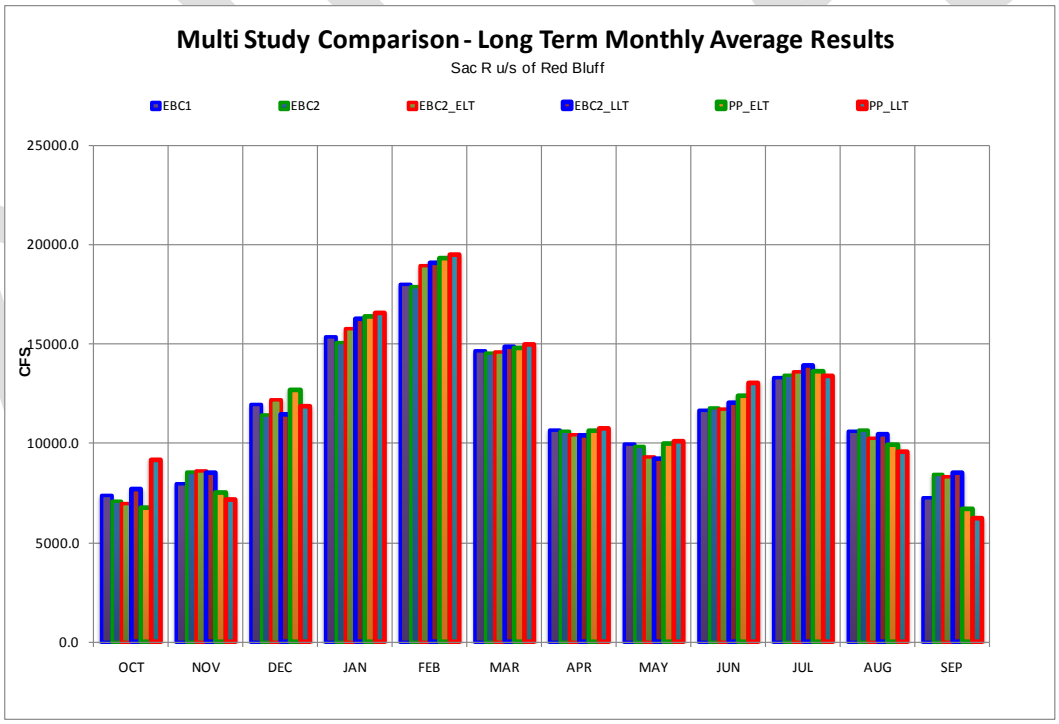

Figure C.5.2-44. Sacramento River Upstream of Red Bluff Diversion Dam Monthly Average Flows for Model Scenarios

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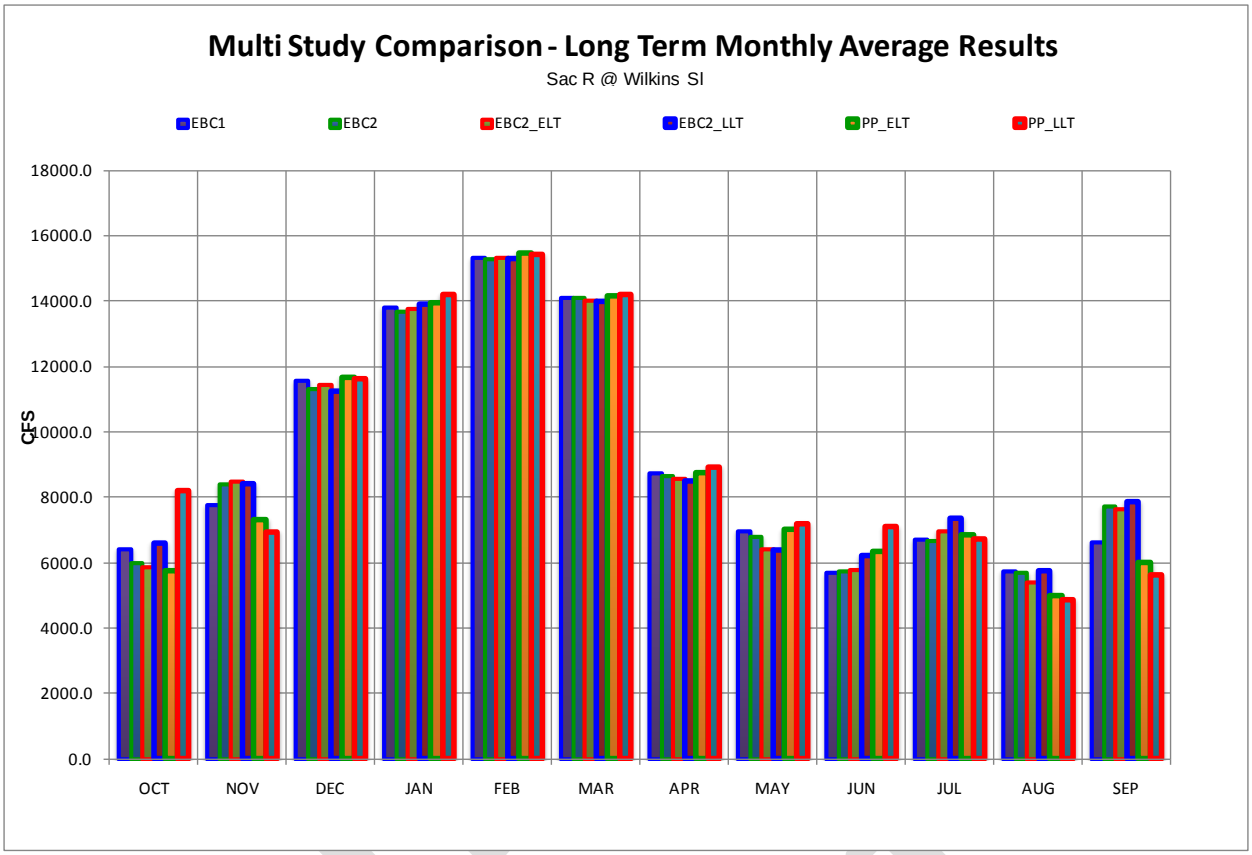

Figure C.5.2-45. Sacramento River at Wilkins Slough Monthly Average Flows for Model Scenarios

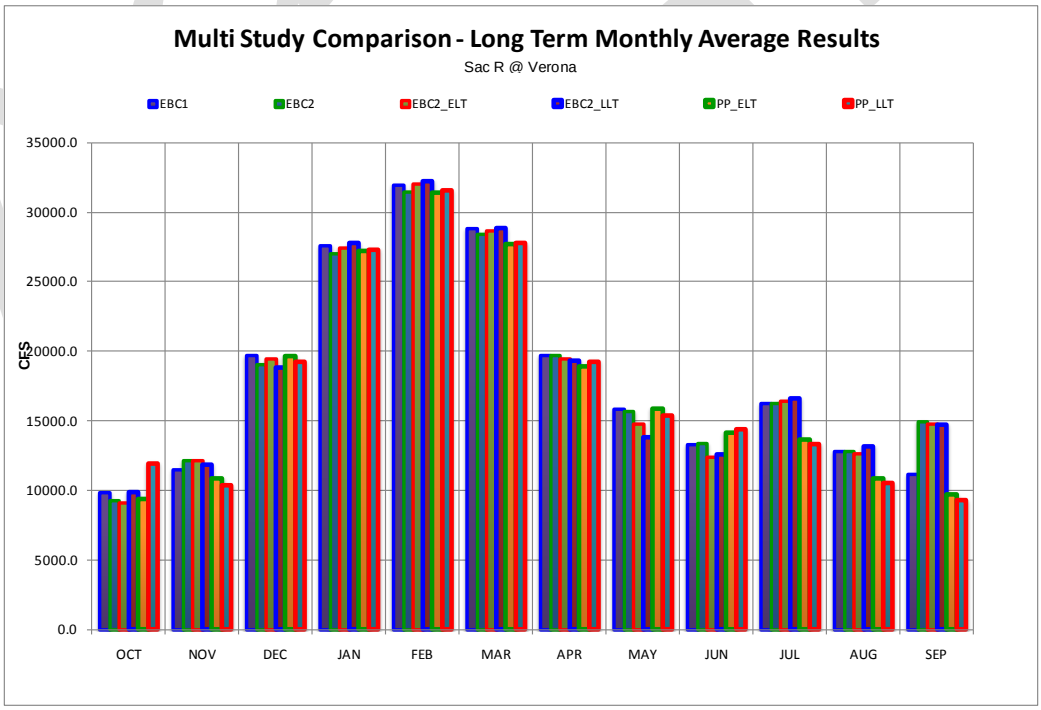

Figure C.5.2-46. Sacramento River at Verona Monthly Average Flows for Model Scenarios

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Table C.5.2-8. Minimum Mean Monthly Flow (Cubic Feet per Second) in the Sacramento River Upstream of Red Bluff Diversion Dam for Model Scenarios

Water-Year Type	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
Wet	8,020	7,686	7,662	8,188	7,399	7,476
Above Normal	6,279	7,306	7,108	8,162	6,863	6,407
Below Normal	5,821	5,824	6,038	5,963	6,184	5,649
Dry	6,391	6,098	5,424	4,911	5,742	5,178
Critical	5,811	5,393	5,279	4,838	5,161	5,186
Minimum flows typically occurred in September and October.						

Adult

Water Temperature

For this analysis, it has been assumed that adult steelhead migrate upstream in the Sacramento River system during the fall, winter, and early spring months (September through March) (McEwan 2001).

Results of water temperature simulation analyses for the upper Sacramento River were used as an indicator of changes in water temperatures that would potentially affect migrating and holding adult steelhead conditions during September through March (Table C.5.2-7). This analysis used 65°F as the threshold over which adult steelhead survival may be negatively affected, which is the NMFS temperature target for steelhead rearing habitat (Table C.5.2-3). Results of the frequency of years in which monthly average temperatures exceeded the criterion are summarized in Table C.5.2-9. Water temperatures at Keswick Dam are predicted to exceed 65°F in one or more months in 2 and 1 years in the EBC1 and EBC2 scenarios, respectively. Water temperatures at Keswick Dam exceeded the threshold in one or more months in 7 and 8 years under EBC2_ELT and EBC2_LLT scenarios, respectively. Water temperatures at Keswick Dam exceeded the threshold in one or more months in 9 years under both PP scenarios. Under no scenario are there are no years in which water temperatures are predicted to exceed the threshold in two or more months. There are no consecutive years in which there is at least one predicted exceedance under EBC1 and EBC2. However, there are 6 years in which there is at least one predicted exceedance under both EBC2_ELT and PP_ELT and 7 years in which there is at least one predicted exceedance under both EBC2_ELT and PP_LLT. Water temperatures naturally increase as a function of distance downstream of Keswick Dam as well as in response to future climate change conditions. This is predicted in the results of this analysis where the number of exceedances generally increases from upstream at Keswick to downstream at Bend Bridge, despite similar patterns in results among model scenarios within each location (Table C.5.2-8). Based on these results it was concluded that water temperatures would be expected to be suitable for steelhead egg incubation immediately downstream of Keswick Dam under existing biological conditions (EBC1 and EBC2) with the frequency of years exceeding 65°F increasing with distance downstream of the dam and in response to future climate change. These changes were largely independent of BDCP operations.

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Table C.5.2-9. Results of the Analysis of the 82-Year Simulation of Water Temperature in the Sacramento River during the September through March Steelhead Adult Migration Period[1]

	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
Sacramento River at Keswick Dam						
Number of years with one or more exceedances	2	1	7	9	8	9
Number of years with two exceedances	0	0	0	0	0	0
Number of years with three exceedances	0	0	0	0	0	0
Number of years with four exceedances	0	0	0	0	0	0
Number of years with five or more exceedances	0	0	0	0	0	0
Number of consecutive years with one or more exceedances	0	0	6	7	6	7
Sacramento River at Ball's Ferry						
Number of years with one or more exceedances	1	1	7	10	8	10
Number of years with two exceedances	0	0	0	0	0	0
Number of years with three exceedances	0	0	0	0	0	0
Number of years with four exceedances	0	0	0	0	0	0
Number of years with five or more exceedances	0	0	0	0	0	0
Number of consecutive years with one or more exceedances	0	0	6	7	6	7
Sacramento River at Jelly's Ferry						
Number of years with one or more exceedances	1	1	7	11	8	12
Number of years with two exceedances	0	0	0	0	0	0
Number of years with three exceedances	0	0	0	0	0	0
Number of years with four exceedances	0	0	0	0	0	0
Number of years with five or more exceedances	0	0	0	0	0	0
Number of consecutive years with one or more exceedances	0	0	6	7	6	7
Sacramento River at Bend Bridge						
Number of years with one or more exceedances	1	1	7	13	8	12
Number of years with two exceedances	0	0	0	0	0	0
Number of years with three exceedances	0	0	0	0	0	0
Number of years with four exceedances	0	0	0	0	0	0
Number of years with five or more exceedances	0	0	0	0	0	0
Number of consecutive years with one or more exceedances	0	0	6	9	6	7
[1] Time period analyzed: September 1922 to March 2003. Analysis counted monthly exceedances above 65°F.						

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C.5.2.1.2 Winter-Run

Eggs and Alevins

Upstream Spawning Habitat

Winter-run Chinook salmon eggs are subject to potential effects of preliminary proposal operations on habitat conditions affecting egg incubation success through (1) changes in seasonal water

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temperatures within the river reach where incubation occurs that result in increased or decreased egg/embryo mortality, and (2) redd dewatering as a result of flow reductions after the redd has been constructed and the eggs are incubating, which exposes the eggs to dewatering and increased egg mortality. The primary seasonal spawning and egg incubation period extends from May through September. CALSIM analysis of instream flow within the reach where the majority of winter-run Chinook salmon spawning occurs (i.e., Keswick Dam to Red Bluff Diversion Dam) were based on estimated flows at RBDD and are summarized by month and water-year type based on estimated flows upstream of RBDD and are presented in Table C.5.2-1. Monthly frequency of exceedance plots for Sacramento River flows at RBDD during the winter-run Chinook salmon spawning and egg incubation period (May through September) are presented in Figure C.5.2-5 through Figure C.5.2-9. For each model scenario, CALSIM was used to characterize changes in physical habitat conditions within the river and provided partial input to the analysis of seasonal water temperatures and habitat conditions for winter-run Chinook salmon spawning and egg incubation.

The CALSIM model predicts a general increase in flows upstream of RBDD under PP_ELT and PP_LLT during wet and above-normal years compared to EBC2_ELT and EBC2_LLT, respectively, except during September. Flows are predicted to be fairly similar between EBC1, EBC2 and PP conditions in below-normal, dry, and critical water years, although flows under PP conditions are predicted to be lower in August compared to EBC2 conditions in dry water years. In general, predicted EBC1 flows upstream of RBDD are similar to EBC2 flows, except during September in wet and above-normal water years and July in critical water years, in which EBC1 flows 2,400–3,000 cfs are lower than in EBC2.

The SacEFT model classifies spawning habitat conditions based on WUA, which was derived from the River 2D simulation model, fitted to data obtained and parameterized by Mark Gard (USFWS 2005a). River2D's calculations depend on spatially explicit measurements of velocity, depth and gravel size. Flow–WUA relationships for multiple segments of the river were developed by Gard to predict the effect of flow on WUA in each river segment. Although SacEFT operates on a daily time step, results are presented in terms of the percent of years that are classified as “good,” which is defined differently for each parameter analyzed (see SacEFT documentation for further details). SacEFT classifies spawning habitat conditions as good in 58% of the years under both EBC1 and EBC2 (Table C.5.2-10). Habitat conditions based on WUA are predicted to be less for PP_ELT, with classification of 35% of the habitat as good, relative to EBC2_ELT, with classification of 46% of the habitat as good. Habitat conditions for spawning under PP_LLT conditions would be classified as good in 23% of years, compared to 32% for EBC2_LLT. The reduction in WUA predicted under BDCP operations was, in large part, a result of instream flow reductions in September and to a lesser extent flow reductions in July and August (Table C.5.2-1). These results suggest that habitat conditions for spawning would decline in the future in response to climate change and the PP. Differences between EBC2 and PP model scenarios (11% under ELT and an additional 9% under LLT conditions) in habitat indices suggest that there would be a reduction in the availability of suitable habitat for winter-run Chinook salmon spawning under PP conditions. The biological significance of a reduction in available spawning habitat varies at the population level in response to a number of factors, including adult escapement. For those years when adult escapement is less than the carrying capacity of the spawning habitat, a reduction in area is expected to have little or no population level effect. In years when escapement is high and exceeds carrying capacity of the reduced habitat, competition among spawners for space (e.g., increased redd superimposition) may increase resulting in reduced reproductive success. The reduction in the frequency of years when spawning habitat conditions are considered to be good has the potential to result in reduced

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reproductive success and abundance of winter-run Chinook salmon. The magnitude of potential effect to the population dynamics of winter-run Chinook salmon is evaluated in Appendix G, *Fish Population Analysis Using IOS and OBAN Winter-Run Salmon Lifecycle Models*.

Table C.5.2-10. Percentage of Years with "Good"[1] Conditions for Winter-Run Chinook Salmon Habitat Metrics in the Upper Sacramento River (from SacEFT)

Metric	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
Spawning WUA2	58	58	46	32	35	23
Redd Scour Risk	98	98	98	98	98	98
Egg Incubation	97	97	88	74	89	72
Redd Dewatering Risk	26	28	29	29	22	24
Juvenile Rearing WUA	50	40	37	25	57	42
Juvenile Stranding Risk	20	32	32	31	12	5

[1] Please refer to Attachment C.B, SacEFT Documentation for definition of "good" for each performance measure.
[2] WUA=Weighted Usable Area.

High-flow events have the potential to scour redds during incubation, resulting in increased egg mortality. SacEFT classifies the risk of redd scour as good (low risk of scour) in 98% of the years for EBC1, EBC2, EBC2_ELT, PP_ELT, EBC2_LLT, and PP_LLT conditions (Table C.5.2-10). Therefore, no change in redd scour risk is expected to occur under BDCP operations.

Water Temperature

The number of months and number of consecutive years in which the winter-run Chinook salmon water temperature criteria of 56°F (Table C.5.2-3) was not met during the egg incubation period (May–September) under each model scenario was determined using monthly CALSIM data. Results of the analysis are summarized in Table C.5.2-11. The frequency of water temperatures exceeding a 56°F criterion were generally comparable between EBC1, EBC2 and PP operations. The frequency of months with water temperatures greater than 56°F increased with distance downstream of Keswick Dam and in response to future climate change. Differences were observed between EBC2_LLT and PP_LLT conditions. There are 48 years in which temperatures are predicted to exceed 56°F in one month under EBC2_LLT compared to 57 years under PP_LLT. There are 7 years in which temperatures are predicted to exceed 56°F in two months under EBC2_LLT compared to 21 years under PP_LLT. Patterns among model scenarios in predicted results are similar further downstream at Ball's Ferry, Jelly's Ferry, and Bend Bridge, although exceedances are more common. The increase in upper Sacramento River water temperatures under future climate change and as a result of BDCP operations would be expected to contribute to increased egg mortality for winter-run Chinook salmon.

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Table C.5.2-11. Results of Monthly Analysis of Water Temperature Simulations in the Upper Sacramento River during the May through September Winter-Run Chinook Salmon Egg Incubation Period[1]

	EBC1	EBC2	EBC2 ELT	EBC2 LLT	PP ELT	PP LLT
Sacramento River at Keswick Dam						
Number of years with one or more exceedances	13	16	27	49	25	58
Number of years with two exceedances	4	4	4	7	6	21
Number of years with three exceedances	2	2	6	9	5	9
Number of years with four exceedances	0	0	0	1	0	2
Number of years with five or more exceedances	0	0	0	0	0	0
Number of consecutive years with one or more exceedances	8	13	21	39	17	50
Sacramento River at Ball's Ferry						
Number of years with one or more exceedances	47	42	61	79	72	81
Number of years with two exceedances	9	9	26	29	38	35
Number of years with three exceedances	5	3	9	26	8	24
Number of years with four exceedances	2	4	6	11	5	13
Number of years with five or more exceedances	1	1	2	6	3	8
Number of consecutive years with one or more exceedances	37	34	57	79	70	81
Sacramento River at Jelly's Ferry						
Number of years with one or more exceedances	74	70	81	81	81	82
Number of years with two exceedances	25	19	22	10	28	7
Number of years with three exceedances	10	11	23	18	24	26
Number of years with four exceedances	8	8	17	24	14	25
Number of years with five or more exceedances	3	3	11	29	11	24
Number of consecutive years with one or more exceedances	74	67	81	81	82	82
Sacramento River at Bend Bridge						
Number of years with one or more exceedances	81	78	82	82	82	82
Number of years with two exceedances	33	30	14	2	14	2
Number of years with three exceedances	12	16	16	8	20	18
Number of years with four exceedances	13	11	25	28	28	22
Number of years with five or more exceedances	8	9	23	44	19	40
Number of consecutive years with one or more exceedances	81	77	82	82	82	82

[1] Time period analyzed: May 1922 to September 2003. Analysis counted monthly exceedances above 56°F.

SacEFT classifies incubation temperature conditions for winter-run salmon eggs as good in 97% of years for EBC1 and EBC2 and 88% to 89% of years EBC2_ELT and PP_ELT, and 72% to 74% of years for EBC2_LLT and PP_LLT (Table C.5.2-10). These results suggest that incubation temperature conditions under PP_ ELT and PP_LLT would be comparable to EBC2_ELT and EBC2_LLT, respectively, but that future climate change will reduce incubation temperature conditions.

Results of the Reclamation egg mortality model (Figure C.5.2-47, Table C.5.2-12) suggest that egg mortality in the early and late long-term under the PP_ELT and PP_LLT will be comparable to EBC2_ELT and EBC2_LLT, respectively. Larger differences in mortality are predicted between EBC2, EBC2_ELT and EBC2_LLT than between EBC2 and PP within the same time periods, suggesting that future climate change will have a greater effect on egg mortality than the BDCP. Egg mortality under EBC1 is not meaningfully different from EBC2 in any water-year type.

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Like the Reclamation egg mortality model, results of SALMOD suggest that increased egg mortality of winter-run is almost entirely due to climate change (Figure C.5.2-48). Egg mortality under EBC1 is predicted to be similar to EBC2.

Figure C.5.2-49 reports egg mortality from the Reclamation Egg Mortality Model between the four Sacramento River Chinook salmon runs. Egg mortality is highest for spring-run and lowest for late fall–run Chinook salmon. Differences in average mortality are greater between the climate change scenarios than between EBC2 and proposed project conditions within a climate change scenario (e.g., ELT and LLT).

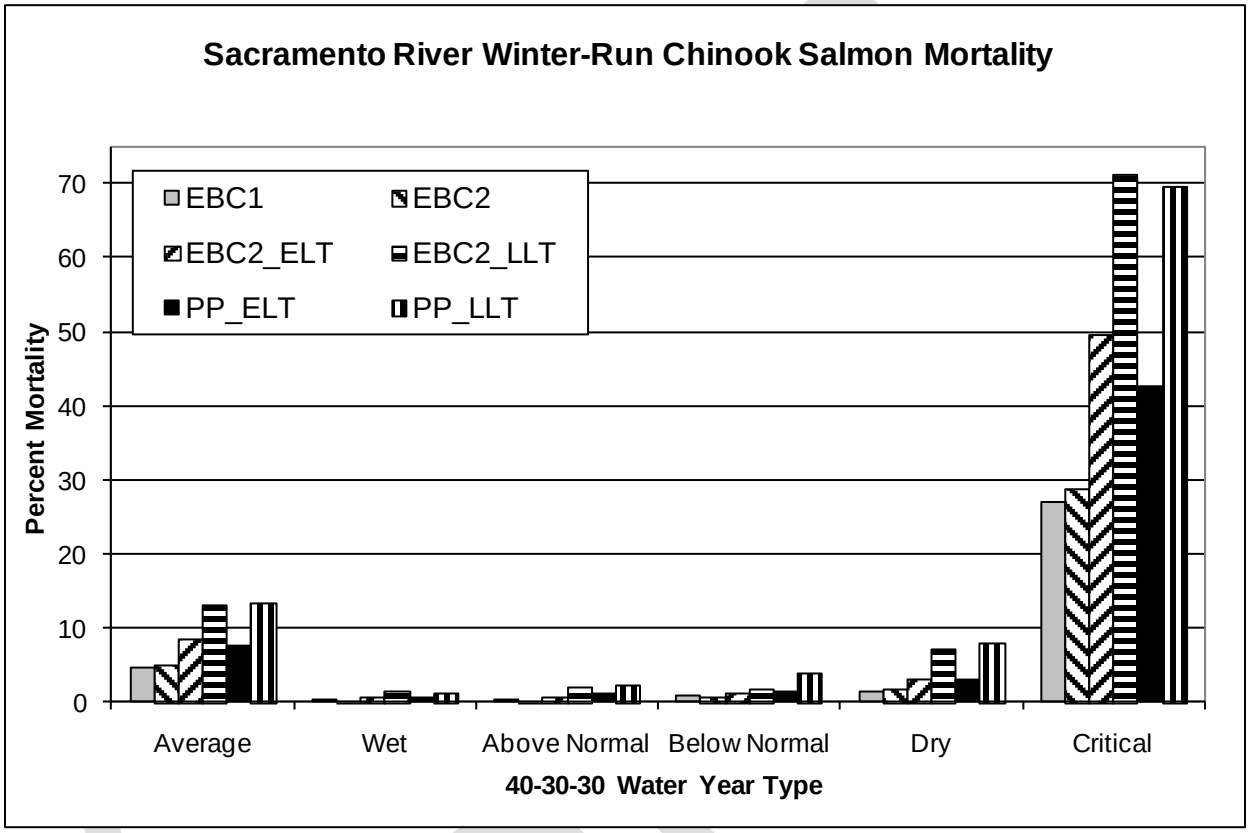

Figure C.5.2-47. Sacramento River Winter-Run Chinook Average Egg Mortality under Each Model Scenario for Each Water-Year Type and for All Years from the Reclamation Egg Mortality Model

Table C.5.2-12. Egg Mortality Percentages for Winter-Run Chinook in the Mainstem Sacramento River (Egg Mortality Model)

Water-Year Type	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
Wet	0.4	0.4	0.8	1.5	0.7	1.5
Above Normal	0.5	0.4	0.9	2.1	1.0	2.3
Below Normal	1.0	0.9	1.3	1.8	1.5	4.0
Dry	1.5	1.8	3.1	7.4	3.0	8.0
Critical	26.9	29.0	49.7	71.2	42.7	69.5
Average	4.7	5.0	8.7	13.3	7.6	13.6

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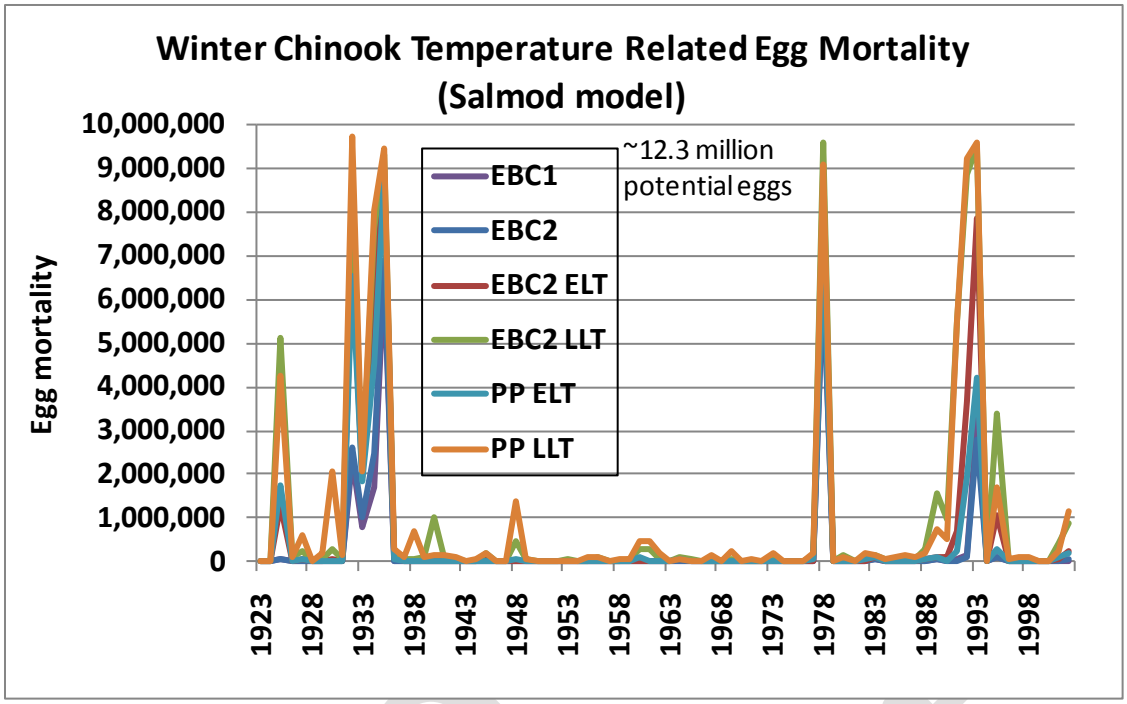

Figure C.5.2-48. Winter-Run Chinook Temperature-Related Egg Mortality under Each Model Scenario (SALMOD)

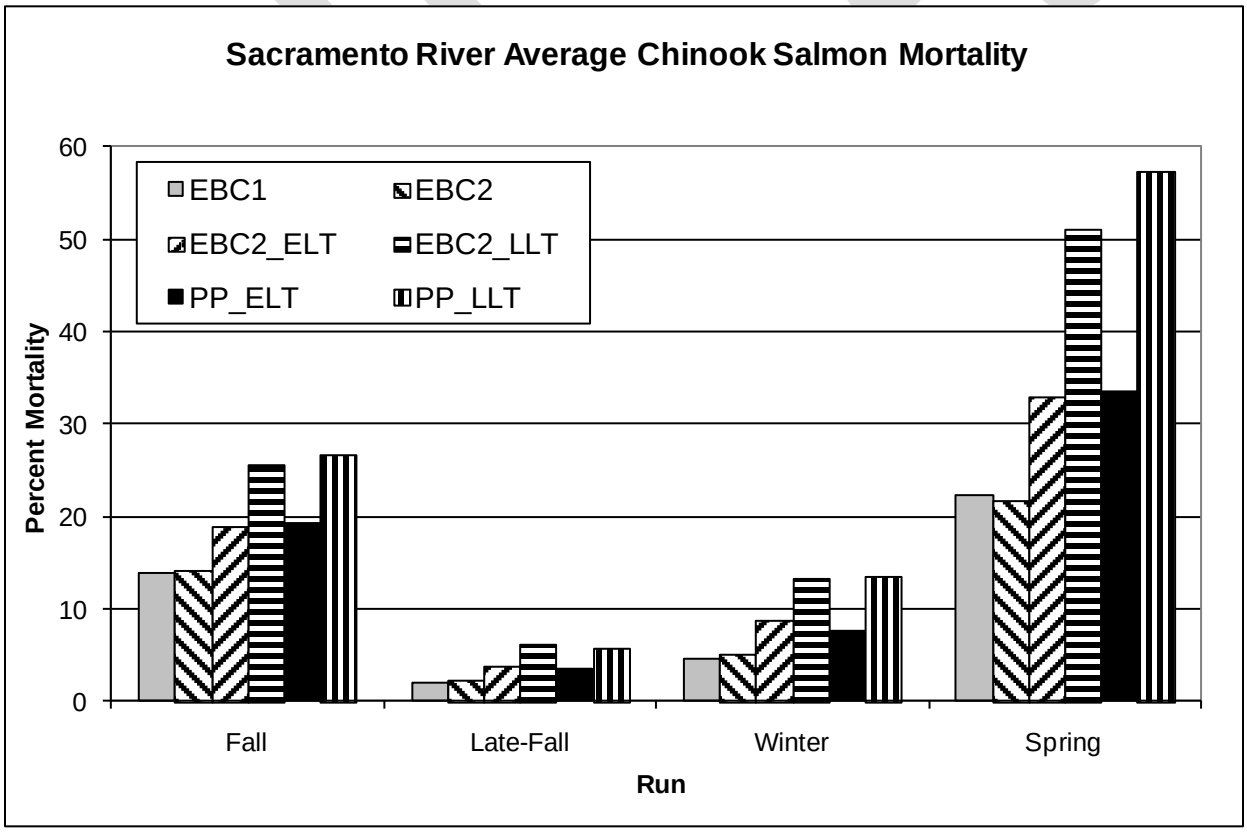

Figure C.5.2-49. Average Chinook Salmon Egg Mortality under Each Model Scenario for the Four Sacramento River Mainstem Runs from the Egg Mortality Model

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Winter-run salmon spawn during May through September when seasonal Redding area air temperatures are high and the Sacramento River is warmest. The portion of the river where suitable water temperatures occur for successful egg incubation depends on the temperature of water released from Shasta and Keswick dams, the rate of instream flow, and atmospheric conditions that result in river warming. When storage of cold water in Shasta Reservoir is reduced, the amount of cold water available to be released is reduced, and the temperature of the water at the point of release to the river increases. As part of Shasta and Keswick dam operations, management of coldwater reservoir pool storage volumes is an important factor in determining winter-run Chinook salmon habitat suitability and egg mortality. September storage in Shasta Reservoir provides an important indicator of coldwater pool volume available to support Sacramento River habitat for winter-run Chinook and other salmonids. Table C.5.2-5 and Table C.5.2-6 provide a summary of Shasta Reservoir May and September storage. May and September exceedance frequency analysis for Shasta storage is summarized in Figure C.5.2-13 and Figure C.5.2-14. Results of egg mortality estimates for winter-run Chinook salmon in the mainstem Sacramento River show that (1) egg mortality increases substantially during critically dry water years in all cases as a result of depleted Shasta Reservoir coldwater pool storage and increased temperatures of water released to the mainstem Sacramento River during the winter-run incubation period; (2) egg mortality under EBC1 is similar to EBC2; (3) a trend toward increasing egg mortality in the future exists as a result of increased air and water temperatures associated with climate change and changes in expected future hydrologic conditions; (4) the effects of climate change on winter-run Chinook salmon egg mortality are expected to become greater with time for EBC2 and PP conditions; and (5) increases in egg mortality are predicted to be comparable for PP_ELT and PP_LLT relative to EBC2_ELT and EBC2_LLT. The small increases in egg mortality under PP operations (when compared to EBC2) are partially reflected by reductions in September river flow, and to a lesser extent July and August flow (Table C.5.2-1). The reduction in egg mortality for EBC2 and PP conditions in the future in wet, above-normal, and below-normal water years, when compared to dry and critically dry years, reflects (1) efforts to manage coldwater pool storage within Shasta Reservoir, (2) a combination of greater reservoir storage in wetter years and reduced river flows in dry and critical years, resulting in increased exposure to elevated water temperature, and (3) effects of increased climate change. These improved habitat conditions, based on coldwater pool management and reduced water temperatures downstream of Keswick Dam, would be expected to improve winter-run Chinook salmon egg survival. Egg mortality was comparable under future EBC2 and PP conditions in critically dry water years. The depletion of coldwater storage within Shasta Reservoir in critically dry water years contributes to a substantial increase in egg mortality under all conditions.

Redd Dewatering

The potential risk of redd dewatering and egg mortality is a function of river flow during spawning and subsequent flow reductions during the incubation period. SacEFT classifies the risk of winter-run Chinook salmon redd dewatering in the mainstem Sacramento River as good (reduced dewatering risk) in 26% of years for EBC1, 28% of years for EBC2, 29% of years for EBC2_ELT, and 22% of years for PP_ELT (Table C.5.2-10). The risk of redd dewatering is classified as good in 29% of years for EBC2_LLT and 24% of years for PP_LLT. Increased risk of redd dewatering under PP_ELT and PP_LLT operations appears to be largely related to instream flow reduction in September and, to a lesser extent, August (Table C.5.2-1). The small (5%–7%) increase in risk of redd dewatering for PP_ELT and PP_LLT relative to EBC2_ELT and EBC2_LLT, respectively, is expected to contribute to a small increase in egg mortality risk.

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Fry and Juvenile Rearing

Rearing Habitat

Upstream juvenile winter-run salmon rearing occurs during August through December before migrating downstream to the ocean. SacEFT classifies upstream juvenile winter-run salmon rearing habitat as good in 50% of years for EBC1 and 40% of years for EBC2 (Table C.5.2-10). Habitat was classified as good in 37% of years for EBC2_ELT and 57% of years for PP_ELT. Results for LLT scenarios showed a similar trend, with habitat classified as good in 25% of years for EBC2_LLT and 42% of years for PP_LLT. These results suggest that the quality and quantity of suitable habitat for juvenile winter-run Chinook salmon rearing is expected to decline over time in response to changes in climate; however, the frequency of years with good habitat conditions is predicted to increase substantially for PP_ELT and PP_LLT relative to EBC2_ELT and EBC2_LLT (20% and 17% difference, respectively). It is expected that this increased frequency would benefit juvenile winter-run salmon rearing in the future when compared to EBC2. Monthly frequency of exceedance plots for Sacramento River flows upstream of RBDD predicted by CALSIM during the juvenile rearing period (August through December) are presented in Figure C.5.2-22 through Figure C.5.2-26. Flow rates under EBC1 are predicted to be generally similar to flows under EBC2, except in September in wet and above-normal water years and during November in below-normal water years, during which flows are lower under EBC1 than under EBC2. Flows under PP conditions are predicted to be generally similar to those under EBC2 in the future, except for moderately lower flows under the PP in September of wet and above-normal years compared to existing conditions in both the ELT and LLT.

SacEFT classifies juvenile stranding risk for winter-run Chinook salmon as good (low risk of stranding) in 20% of years under EBC1 and 32% of years under EBC2 (Table C.5.2-10). Stranding risk was classified as good in 32% of years under EBC2_ELT and 12% of years under PP_ELT, a 20% decrease. Stranding risk was classified as good in 31% of years under EBC2_ELT and 5%of years under PP_ELT, a 26% decrease. This increase in stranding risk under the preliminary proposal is due to larger flow changes during August through December juvenile stranding period (Table C.5.2-1).

Figure C.5.2-18 through Figure C.5.2-25 show exceedance plots of Sacramento River water temperatures upstream of RBDD for April through November, which are the months when water temperatures could reach levels of concern for rearing winter-run Chinook salmon. Results of temperature monitoring suggest that during the spring, summer, and fall, water temperatures upstream at Keswick Dam are consistently cooler than those at RBDD. Frequency of exceedance plots for Keswick Dam release temperatures during the period from April through November are presented in Figure C.5.2-30 through Figure C.5.2-37.

Temperatures at RBDD are predicted to be below 65°F April through June for EBC1, EBC2 and PP conditions (Figure C.5.2-18 through Figure C.5.2-20). From July through October, water temperatures could exceed 65°F at times (Figure C.5.2-21 through Figure C.5.2-24). The largest exceedance is predicted to occur in August, when 65°F would be exceeded in approximately 5% of years under EBC2, approximately 8% of years in EBC2_ELT, and 13% of years in the EBC2_LLT. However, differences between proposed project and EBC2 scenarios within time periods are predicted to be small. The main difference is in the LLT scenario when proposed project conditions would have water temperatures about 1°F higher compared to EBC1 and EBC2 in years when water temperature is below 65°F at RBDD. This would result in a reduction in the length of river with

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suitable rearing habitat, but suitable temperatures would be maintained within the primary winter-run salmon rearing habitat. Figure C.5.2-30 through Figure C.5.2-37 indicate that water temperature is never expected to exceed 65°F at Keswick Dam under the current climate, but could exceed 65°F in 5% of years in the ELT and 8% of years in the LLT due to the effects of climate change. Differences in water temperatures between EBC1, EBC2 and PP scenarios in the upper Sacramento River within ELT and LLT time periods are predicted to be small.

Winter-run Chinook salmon rear in the Sacramento River downstream of RBDD through the summer and fall, migrating downstream from spawning and incubation habitat. Winter-run Chinook salmon rear in downstream areas during the cooler periods of the year, when temperatures are generally not a problem. Figure C.5.2-39 shows temperature exceedance during August, the month of warmest water temperatures at Hamilton City. Climate change is expected to contribute the greatest increase in temperatures, but PP_LLT conditions would increase temperatures by about 1°F, reducing the length of river with suitable water temperature for rearing. Figure C.5.2-40 shows the number of days per year when temperatures exceed 65°F at Hamilton City. Proposed project conditions would increase the number of days exceeding 65°F in a majority of years. This is likely to reduce emigration success for winter-run Chinook in the future.

Results of Sacramento River water temperature simulation analyses at RBDD, by month over the 82-year model period, were used to assess the number of months when water temperatures during the juvenile rearing period (August–December) exceeded 65°F. Analysis results are summarized in Table C.5.2-13. The number of years in which water temperatures exceeded 65°F was generally comparable between EBC2 and PP scenarios. There was a general increase in the frequency of higher temperatures through time as a result of future climate change and with distance downstream from Keswick Dam.

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Table C.5.2-13. Results of the Analysis of Water Temperature Simulation in the Sacramento River during the August through December Winter-Run Juvenile Rearing Period[1]

	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
Sacramento River at Keswick Dam						
Number of years with one or more exceedances	2	1	7	9	8	9
Number of years with two exceedances	0	0	4	7	2	7
Number of years with three exceedances	0	0	0	0	0	0
Number of years with four exceedances	0	0	0	0	0	0
Number of years with five or more exceedances	0	0	0	0	0	0
Number of consecutive years with one or more exceedances	0	0	6	7	6	7
Sacramento River at Ball's Ferry						
Number of years with one or more exceedances	1	1	7	10	8	10
Number of years with two exceedances	0	0	5	8	4	7
Number of years with three exceedances	0	0	0	0	0	0
Number of years with four exceedances	0	0	0	0	0	0
Number of years with five or more exceedances	0	0	0	0	0	0
Number of consecutive years with one or more exceedances	0	0	6	7	6	7
Sacramento River at Jelly's Ferry						
Number of years with one or more exceedances	1	1	7	11	8	12
Number of years with two exceedances	0	1	6	8	5	8
Number of years with three exceedances	0	0	0	0	0	0
Number of years with four exceedances	0	0	0	0	0	0
Number of years with five or more exceedances	0	0	0	0	0	0
Number of consecutive years with one or more exceedances	0	0	6	7	6	7
Sacramento River at Bend Bridge						
Number of years with one or more exceedances	1	2	7	13	8	12
Number of years with two exceedances	1	1	6	8	5	8
Number of years with three exceedances	0	0	0	0	0	0
Number of years with four exceedances	0	0	0	0	0	0
Number of years with five or more exceedances	0	0	0	0	0	0
Number of consecutive years with one or more exceedances	0	0	6	9	6	7

[1] Time period analyzed: August 1922 to December 2003. Analysis counted monthly exceedances above 65°F.

Results of a similar water temperature analysis for the upper reaches of the Sacramento River as juvenile winter-run Chinook salmon are migrating downstream showed that predicted average monthly temperatures at Keswick Dam, Ball's Ferry, Jelly's Ferry, and Bend Bridge were constantly within the range considered to be suitable (65°F or less) under all model scenarios between November and April (Table C.5.2-14).

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Table C.5.2-14. Results of Monthly Analysis of Water Temperature Simulation in the Upper Sacramento River during the November through April Winter-Run Juvenile Chinook Salmon Migration Period[1]

	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
Sacramento River at Keswick Dam						
Number of years with one or more exceedances	0	0	0	0	0	0
Number of years with two exceedances	0	0	0	0	0	0
Number of years with three exceedances	0	0	0	0	0	0
Number of years with four exceedances	0	0	0	0	0	0
Number of years with five or more exceedances	0	0	0	0	0	0
Number of consecutive years with one or more exceedances	0	0	0	0	0	0
Sacramento River at Ball's Ferry						
Number of years with one or more exceedances	0	0	0	0	0	0
Number of years with two exceedances	0	0	0	0	0	0
Number of years with three exceedances	0	0	0	0	0	0
Number of years with four exceedances	0	0	0	0	0	0
Number of years with five or more exceedances	0	0	0	0	0	0
Number of consecutive years with one or more exceedances	0	0	0	0	0	0
Sacramento River at Jelly's Ferry						
Number of years with one or more exceedances	0	0	0	0	0	0
Number of years with two exceedances	0	0	0	0	0	0
Number of years with three exceedances	0	0	0	0	0	0
Number of years with four exceedances	0	0	0	0	0	0
Number of years with five or more exceedances	0	0	0	0	0	0
Number of consecutive years with one or more exceedances	0	0	0	0	0	0
Sacramento River at Bend Bridge						
Number of years with one or more exceedances	0	0	0	0	0	0
Number of years with two exceedances	0	0	0	0	0	0
Number of years with three exceedances	0	0	0	0	0	0
Number of years with four exceedances	0	0	0	0	0	0
Number of years with five or more exceedances	0	0	0	0	0	0
Number of consecutive years with one or more exceedances	0	0	0	0	0	0

[1] Time period analyzed: November 1921 to April 2003. Analysis counted monthly exceedances above 65°F.

Mean monthly flows at RBDD (Figure C.5.2-44) and Wilkins Slough (Figure C.5.2-45) are predicted to increase when comparing the EBC2_ELT and PP_ELT, and EBC2_LLT and PP_LLT for December through June. These differences are expected to benefit rearing and migration conditions for juvenile winter-run Chinook salmon. This is the primary period when juvenile winter-run Chinook salmon are present in this long middle reach of the Sacramento River.

Flows and temperature effects on Chinook salmon juvenile rearing habitat upstream of RBDD were also evaluated using the SALMOD model. The primary output from SALMOD is a direct assessment

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of project effects based on estimates of the number of juvenile Chinook salmon emigrating past RBDD. Figure C.5.2-50 and Figure C.5.2-51 present a time series and exceedance plot of poduction for each model scenario. Figure C.5.2-52 reports the difference from EBC2. Juvenile production is predicted to be slightly higher under PP_ELT relative to EBC2_ELT and similar between EBC2_LLT and PP_LLT. Climate change appears to be a major driver of production; ELT model scenarios with and without the preliminary proposal are lower than EBC1 and EBC2 (under current climate), and LLT model scenarios with and without the preliminary proposal are even lower. Production is predicted to typically be the lowest under all model scenarios during major historical dry periods (1929–1934, 1976–1977, and 1987–1992).

Gard (2005) developed flow–habitat relationships for juvenile Chinook salmon rearing habitat in the Sacramento River. Relationships were developed for winter-, fall-, and late fall–run Chinook salmon in the flow range from 3,250 cfs to 30,000 cfs. In general, flow versus weighted usable area curves were flat or had a peak below 5,000 cfs in all reaches except the reach upstream of the Anderson-Cottonwood Irrigation District (ACID) dam when boards are removed (i.e., from November through March). That reach had two peaks: at low-flows (less than 5,000 cfs) and at higher flows of around 25,000 cfs. Overall, the flow differences between PP scenarios result in only very slight differences in WUA and are probably not biologically meaningful to rearing salmon. SALMOD modeling results suggest that flow changes between EBC2 and PP scenarios result in little effect on survival upstream of RBDD.

Smolt-equivalent temperature-related mortality is shown in Figure C.5.2-53 and habitat-related mortality is shown in Figure C.5.2-54. Temperature-related mortality varies with water-year type and is predicted to occur primarily in the driest years. Some habitat-related mortality occurs in most years under all scenarios, except for years when temperature-related mortality is high. Few eggs survive to the fry life stage in years of high-temperature-related mortality; therefore, habitat limitations are low when the number and density of juvenile salmon is reduced. No clear patterns between EBC1, EBC2 and proposed project scenarios are apparent in habitat-related mortality. Figure C.5.2-55 and Figure C.5.2-56 display exceedance plots of temperature- and habitat-related mortality. Temperature-related mortality is expected to occur in fewer years than habitat-related mortality, but in years of high-temperature mortality, a total production is reduced, likely affecting ultimate adult production. This could affect population viability if entire brood years have very low adult returns, particularly if returns are low in successive years.

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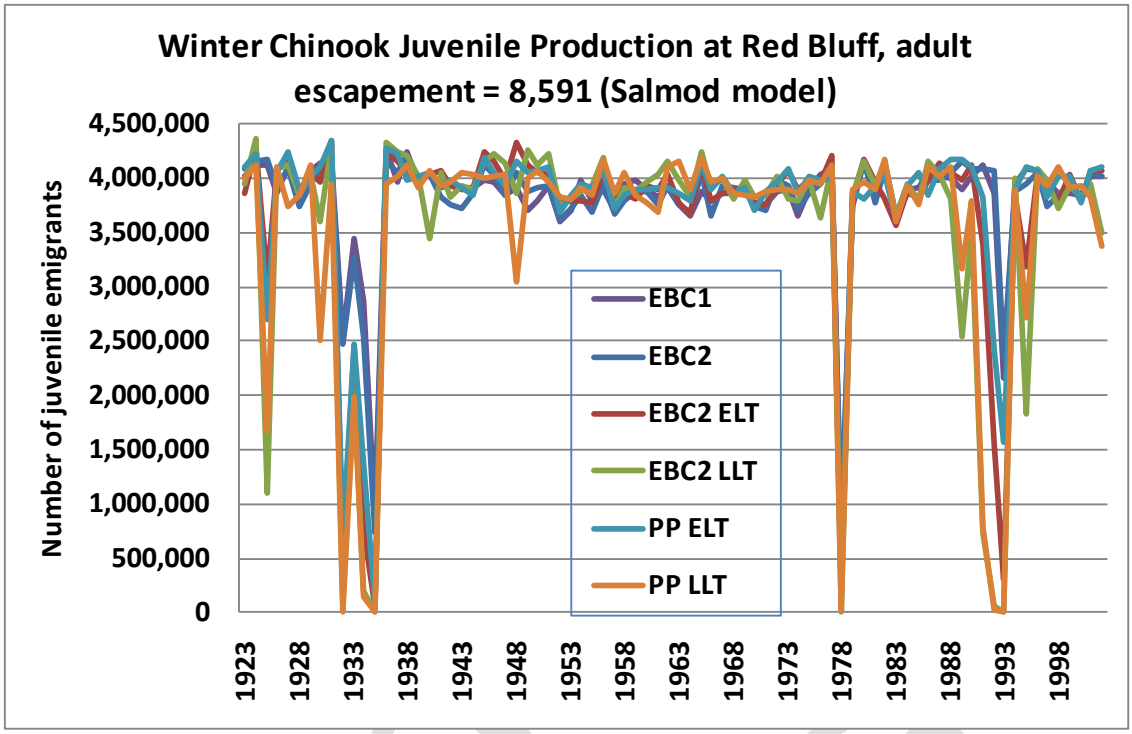
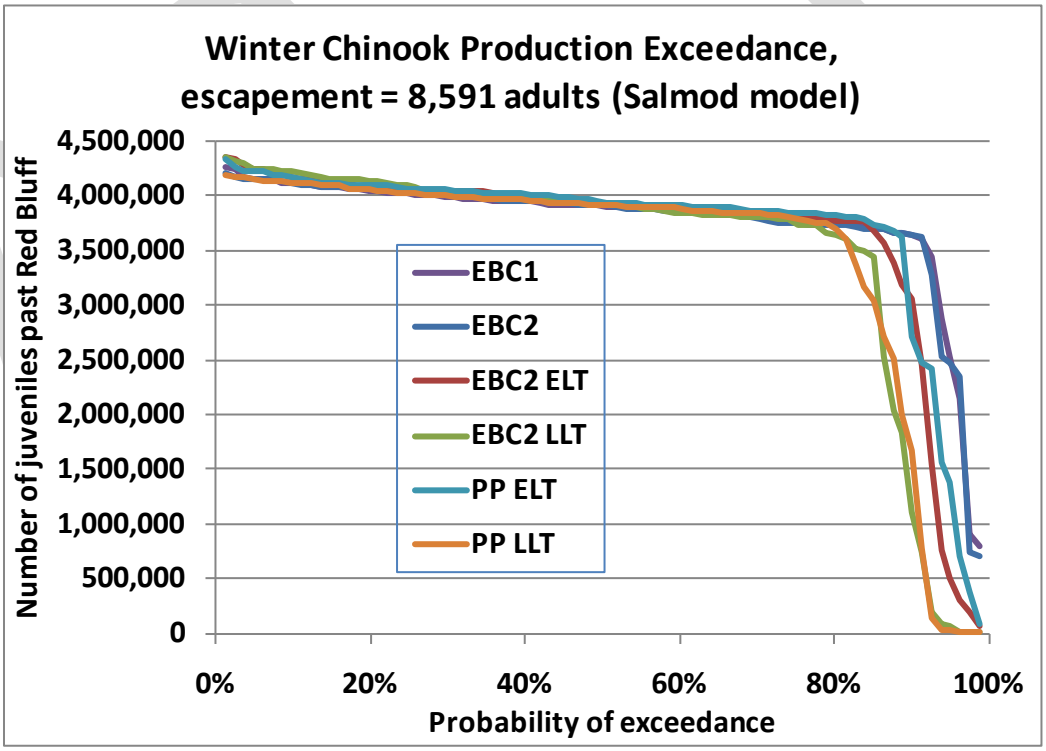


Note: All life stages are combined and converted to smolt equivalents.

Figure C.5.2-50. Number of Winter-Run Chinook Juveniles Emigrating Past Red Bluff under Each Model Scenario (SALMOD)



Note: All life stages are combined and converted to smolt equivalents.

Figure C.5.2-51. Winter-Run Chinook Production Exceedance Probability under Each Model Scenario (SALMOD)

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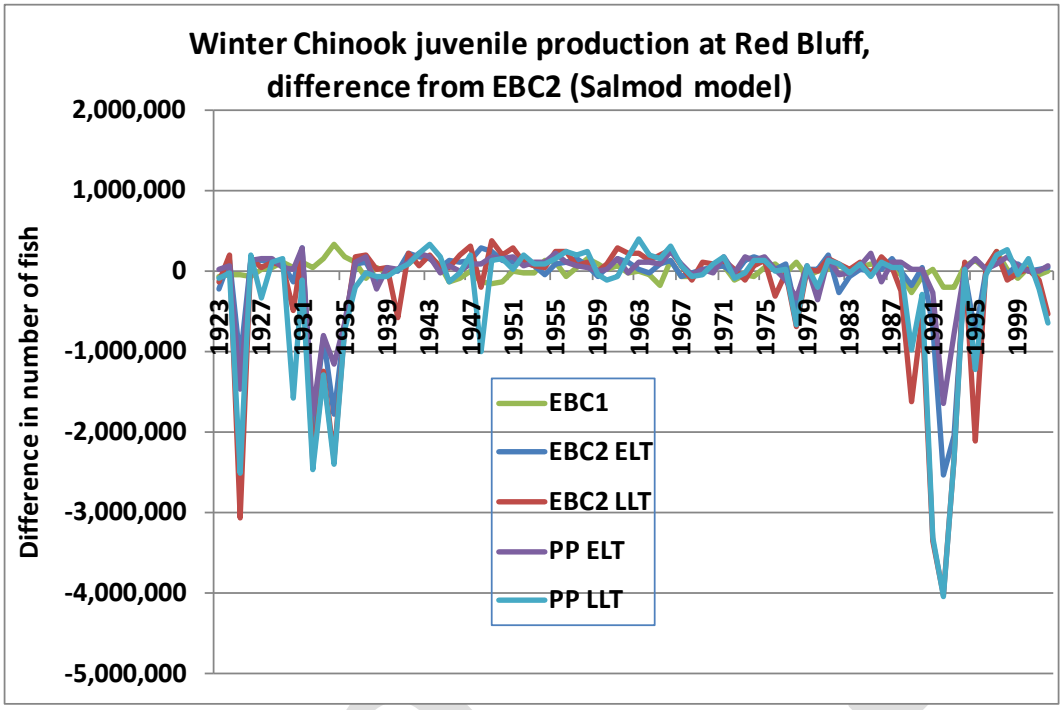
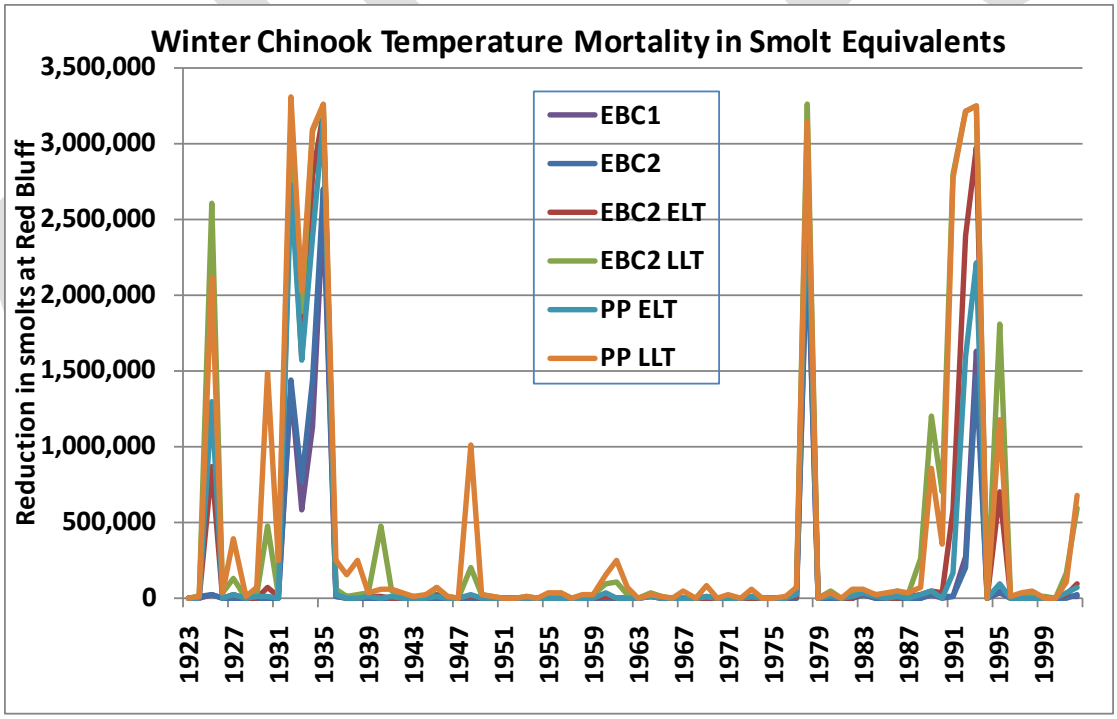


Figure C.5.2-52. Winter-Run Chinook Difference in Egg Mortality under Each Model Scenario Compared to Existing Biological Conditions (SALMOD)



Note: All life stages are combined and converted to smolt equivalents.

Figure C.5.2-53. Winter-Run Chinook Temperature-Related Mortality (Egg through Smolt) under Each Model Scenario (SALMOD)

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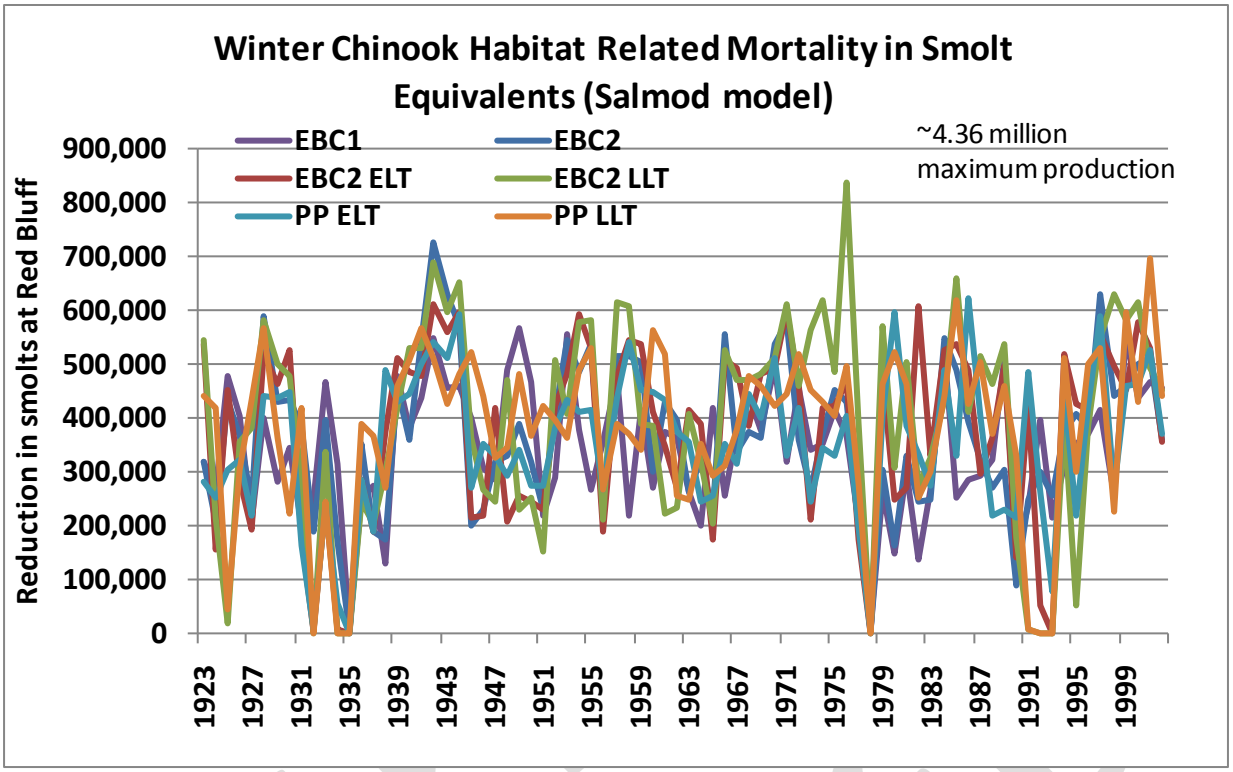
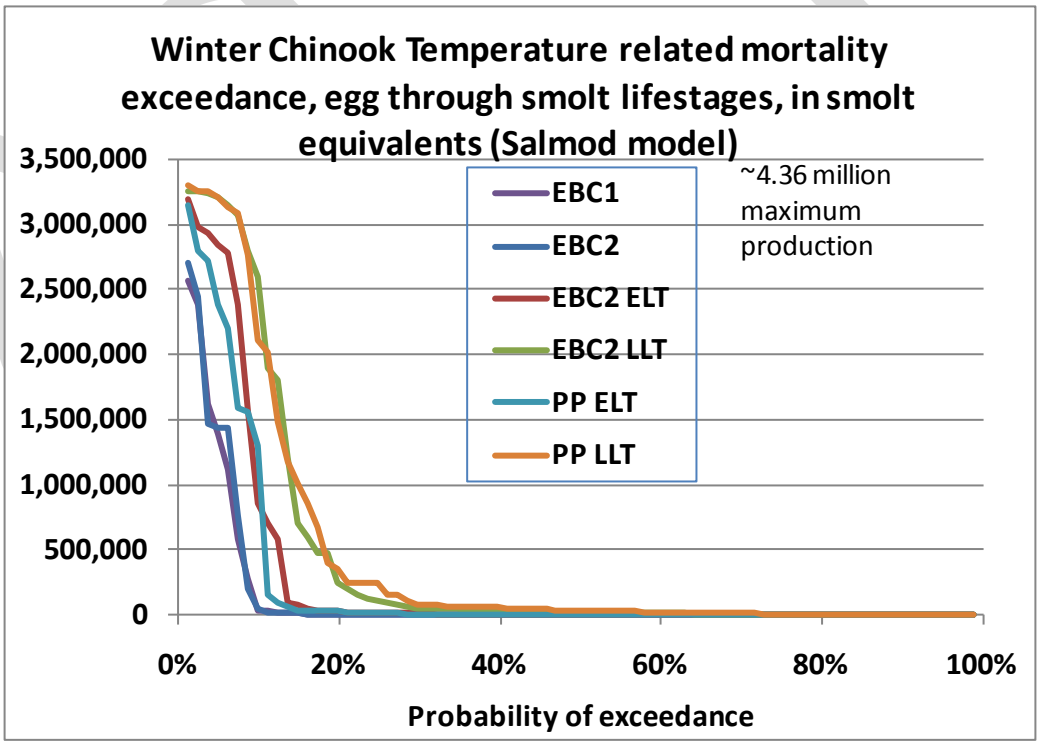


Note: All juvenile life stages are combined and converted to smolt equivalents.

Figure C.5.2-54. Winter-Run Chinook Habitat-Related Mortality under Each Model Scenario (SALMOD)



Note: All life stages are combined and converted to smolt equivalents.

Figure C.5.2-55. Winter-Run Chinook Salmon Temperature-Related (Egg through Smolt) Mortality Exceedance under Each Model Scenario (SALMOD)

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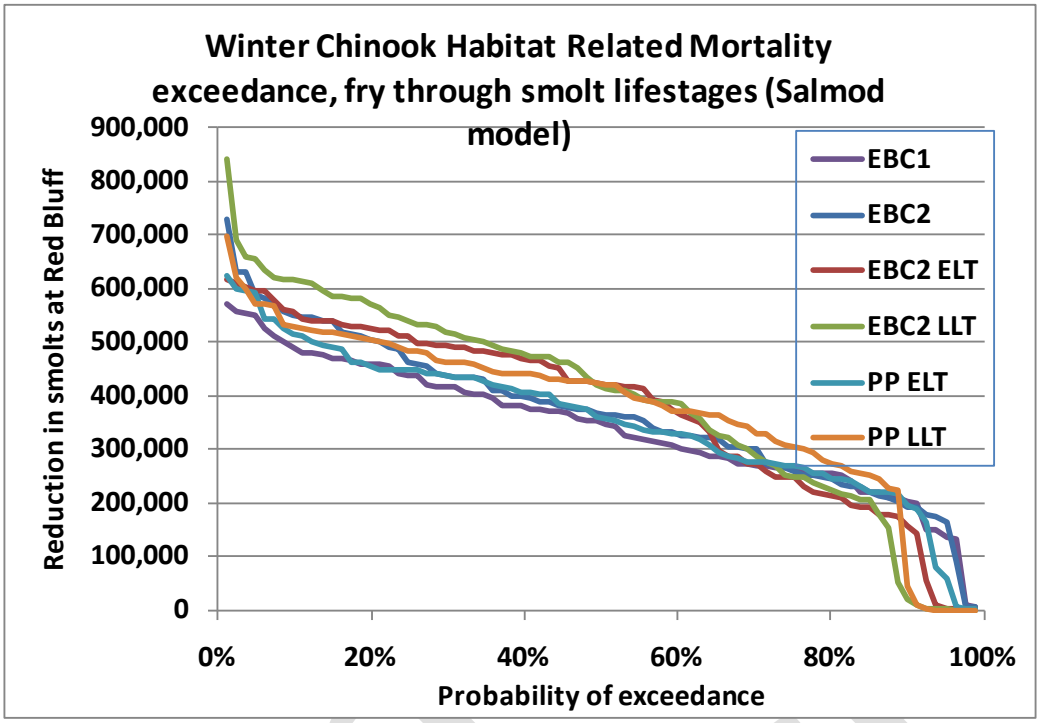

Note: All life stages are combined and converted to smolt equivalents.

Figure C.5.2-56. Winter-Run Chinook Habitat-Related Mortality Exceedance under Each Model Scenario (SALMOD)

SALMOD-generated estimates of juvenile winter-run Chinook salmon production are summarized in Table C.5.2-15. These results reflect changes in habitat quality and quantity based on habitat estimates each year over the 82-year CALSIM period and assume an adult escapement each year of 8,591 adult winter-run Chinook salmon.

Table C.5.2-15. Winter-Run Chinook Salmon Juvenile Production Estimates for Model Scenarios from SALMOD

	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
Minimum	803,935	703,344	59,877	13,459	94,234	8,809
Maximum	4,265,595	4,199,200	4,348,962	4,355,292	4,339,058	4,188,346
Average	3,789,180	3,776,827	3,666,881	3,522,375	3,729,442	3,506,450
Change from EBC2_ELT					62,561	
Change from EBC2_LLT						-15,925

Habitat-related mortality occurs in all years except those with high-temperature mortality, but never exceeds 20% of the maximum total juvenile production potential at RBDD (~4.36 millions smolt equivalents, as projected by SALMOD; Figure C.5.2-54). There are slight differences in habitat-related mortality between EBC1, EBC2 and PP scenarios, but they are not expected to cause population-level effects. The weighted usable area curves for Chinook salmon rearing in the upper Sacramento River are relatively flat such that flow changes within the managed ranges are predicted to produce small changes in rearing habitat availability (Gard 2005). A comparison of winter-run Chinook escapement to juvenile emigrants at RBDD screw traps shows potential evidence of a stock-

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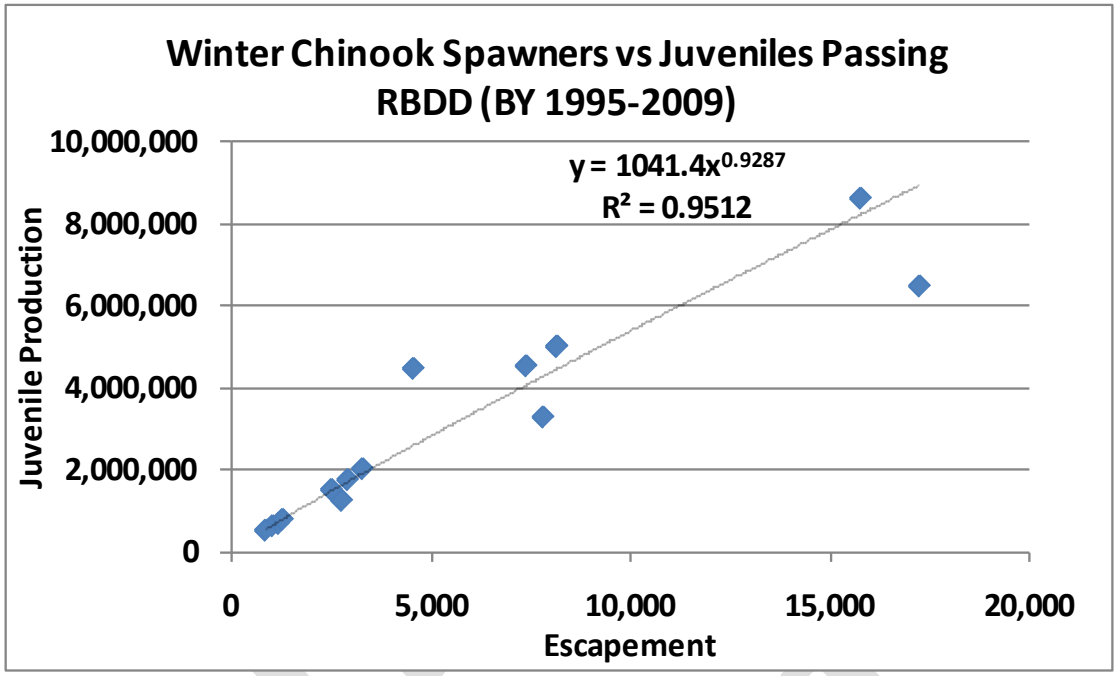
recruitment relationship (Figure C.5.2-57). However, the possible effect appears to be small. The model predicts that all fry mature upstream of RBDD at the escapement used (8,591 adults, based on 1999–2006 escapement data from GrandTab 2008) but RBDD trap data indicate that a high proportion of juveniles emigrate past RBDD as fry.



Note: Data from GrandTab and U.S. Fish and Wildlife Service screw trap weekly reports.

Figure C.5.2-57. Relationship between Winter-Run Chinook Salmon Spawning Escapement and Subsequent Juvenile Production Passing Red Bluff Diversion Dam, Brood Years 1995 through 2009

Results of these analyses show (1) there is a wide range of mortality estimates among years for all of the conditions modeled (range between minimum and maximum estimates of mortality); (2) based on average conditions, estimated juvenile winter-run Chinook salmon production for the PP_ELT and PP_LLT is not different from EBC2_ELT and EBC2_LLT conditions (within 5%); and (3) when comparing the EBC2 to EBC2_ELT and EBC2_LLT, there appears to be a consistent trend of reduced juvenile production as a result of climate change. The change in juvenile production for EBC2 and proposed project conditions is consistent with the observation that egg mortality, particularly in critically dry water years, increased substantially in the future in response to climate change for EBC2 and PP_ELT and PP_LLT conditions. In contrast, SacEFT results (presented above) indicated a 26% increase in good habitat rearing conditions for fry under PP_ELT and 23% under PP_LLT operations. Lifecycle populations model results for winter-run Chinook salmon (IOS and OBAN) integrate across all life stages as discussed in Appendix G, *Fish Population Analysis*.

The predicted production of juvenile winter-run Chinook salmon varies substantially among years (comparison of predicted minimum and maximum for each model scenario; Table C.5.2-15). Factors that affect juvenile production among years include adult escapement (which holds constant in these model simulations); interannual variation in instream flows that affect the quantity and quality of suitable habitat (e.g., water depths and velocities); and exposure to elevated water temperatures. Typically juvenile production and survival are higher in years when river flows are higher (up to the point when higher flows increase depth and velocity beyond the preferred range)

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and water temperatures are reduced. Reduced juvenile production and survival typically occurs when river flows are low and water temperatures are elevated. Juvenile production model predictions were generally similar across model scenarios based on both the average annual and maximum production estimates (Table C.5.2-15). In contrast, there was substantial variation in minimum production estimates among scenarios. The highest minimum estimate (803,935 individuals) was for EBC1 conditions, which were not subject to either BDCP operations or future climate change. The minimum production declined substantially under ELT conditions to 59,877 individuals for EBC2_ELT and 94,234 individuals for PP_ELT operations. Under LLT conditions with greater effects of climate change on hydrology and water temperatures, the minimum production estimates declined further to 13,459 individuals under EBC2_LLT and 8,809 individuals under PP_LLT conditions. These results suggest that the severity of adverse conditions becomes greater over time in response to future climate change conditions.

A second index of habitat conditions is the predicted change in smolt-equivalent mortality associated with each of the conditions as summarized in Table C.5.2-16. For this analysis, loss estimates have been normalized across size classes of juvenile salmon based on estimated size-specific survival for juvenile Chinook salmon to produce a smolt-equivalent mortality for comparison. Estimates reflect the reduction in smolt-equivalent production in the Sacramento River.

Table C.5.2-16. Winter-Run Chinook Salmon Smolt-Equivalent Mortality Due to Habitat Conditions for Model Scenarios from SALMOD

	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
Minimum	4,909	4,071	72	0	54	0
Maximum	569,365	728,362	614,492	840,513	622,837	698,126
Average	341,879	367,199	375,249	392,303	352,642	378,257
Change from EBC2_ELT					-22,607	
Change from EBC2_LLT						-14,046

Results of these analyses show (1) there is a wide range of mortality estimates among years for all of the conditions modeled (range between minimum and maximum estimates of mortality); (2) based on average conditions, mortality estimates for the PP_ELT and PP_LLT are not different compared to EBC1 and EBC2 (within 5%); and (3) when comparing the EBC2 to the EBC2_ELT and EBC2_LLT conditions, there appears to be a consistent trend through time of increasing mortality as a result of climate change.

A third indicator of habitat conditions for juvenile winter-run Chinook salmon production and survival is the estimate of smolt-equivalent mortality attributable to exposure to adverse water temperatures. Results of these analyses are summarized in Table C.5.2-17. Loss estimates were normalized across size classes of juvenile salmon to produce a smolt-equivalent mortality for comparison, and estimates reflect the reduction in smolt-equivalent production in the Sacramento River.

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Table C.5.2-17. Winter-Run Chinook Salmon Smolt-Equivalent Temperature Mortality for Model Scenarios from SALMOD

	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
Minimum	0	0	594	594	76	603
Maximum	2,567,015	2,703,677	3,252,003	3,252,003	3,149,741	3,307,197
Average	126,827	133,306	267,984	420,427	230,843	437,735
Change from EBC2_ELT					-37,141	
Change from EBC2_LLT						-17,308

Results of these analyses show comparable trends for juvenile winter-run Chinook salmon. Habitat conditions are similar for juveniles maturing between the EBC1, EBC2 and proposed project conditions. Habitat conditions are expected to decline for EBC2_ELT and EBC2_LLT, and for PP_ELT and PP_LLT in response to climate change. These results also show that there is a wide range of habitat responses and variation among years over the 82-year period included in this simulation. The best habitat conditions are predicted to occur in wet years and the worst habitat conditions are predicted to occur in critically dry water years under the EBC1, EBC2, PP_ELT, and PP_LLT.

Adult

Water Temperature

Adult winter-run Chinook salmon migrate upstream in the mainstem Sacramento River during winter (December through February) and hold in the upper river reaches through the spring and early summer (e.g., December through July) prior to spawning in May through September.

Outputs from CALSIM and the Sacramento River Water Quality Model were used to compare seasonal water temperatures in the mainstem Sacramento River among model scenarios. Modeling results for the reach immediately downstream of Keswick Dam to RBDD between December and July suggest that water temperatures are typically within suitable habitat range (<65°F) for winter-run Chinook salmon migration and holding under EBC1, EBC2 and PP conditions. Reduced water temperatures during the late spring and summer reflect coldwater pool management within Shasta Reservoir to meet a 56°F temperature target between May 15 and September 30 for egg incubation. Habitat conditions for holding, pre-spawn adults would be suitable under EBC1 and both EBC2 and BDCP operations (Table C.5.2-18). There were no months during the early long-term when water temperatures exceeded the 65°F criterion under any of the model scenarios. During the late long-term, there was a small increase in the frequency of average monthly temperatures in the upper Sacramento River exceeding 65°F due to future climate change. The frequency of months exceeding 65°F also increased geographically under BDCP operations in the late long-term from 1 month at Keswick Dam to 3 months at Ball's Ferry, to 5 months at both Jelly's Ferry and Bend Bridge (Table C.5.2-18). There were no years at any location or in any model scenario when the frequency of exceedance was greater than 1 month within a year under ELT or LLT conditions.

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Table C.5.2-18. Results of Monthly Analysis of Water Temperature Simulation in the Upper Sacramento River during the December through July Winter-Run Adult Chinook Salmon Migration Period[1]

	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
Sacramento River at Keswick Dam						
Number of years with one or more exceedances	0	0	0	0	0	1
Number of years with two exceedances	0	0	0	0	0	0
Number of years with three exceedances	0	0	0	0	0	0
Number of years with four exceedances	0	0	0	0	0	0
Number of years with five or more exceedances	0	0	0	0	0	0
Number of consecutive years with one or more exceedances	0	0	0	0	0	0
Sacramento River at Ball's Ferry						
Number of years with one or more exceedances	0	0	0	2	0	3
Number of years with two exceedances	0	0	0	0	0	0
Number of years with three exceedances	0	0	0	0	0	0
Number of years with four exceedances	0	0	0	0	0	0
Number of years with five or more exceedances	0	0	0	0	0	0
Number of consecutive years with one or more exceedances	0	0	0	0	0	2
Sacramento River at Jelly's Ferry						
Number of years with one or more exceedances	0	0	0	5	0	5
Number of years with two exceedances	0	0	0	0	0	0
Number of years with three exceedances	0	0	0	0	0	0
Number of years with four exceedances	0	0	0	0	0	0
Number of years with five or more exceedances	0	0	0	0	0	0
Number of consecutive years with one or more exceedances	0	0	0	2	0	2
Sacramento River at Bend Bridge						
Number of years with one or more exceedances	0	0	0	5	0	5
Number of years with two exceedances	0	0	0	0	0	0
Number of years with three exceedances	0	0	0	0	0	0
Number of years with four exceedances	0	0	0	0	0	0
Number of years with five or more exceedances	0	0	0	0	0	0
Number of consecutive years with one or more exceedances	0	0	0	2	0	2
1 Time period analyzed: December 1921 to July 2003. Analysis counted monthly exceedances above 65°F.						

C.5.2.1.3 Spring-Run

Eggs and Alevins

Upstream Spawning Habitat

Instream flows within the Sacramento River at RBDD during the spring-run Chinook salmon spawning and incubation period (September through January) are shown in Table C.5.2-1, Figure C.5.2-1 and Figure C.5.2-9 through Figure C.5.2-12. Flows are predicted to be reduced in September in wet and above-normal years due to the PP and were comparable between EBC1, EBC2 and PP conditions in below-normal, dry, and critical years. PP flows in October through January are predicted to be lower during November in the ELT (7% to 23% decrease) and LLT (9 to 30% decrease), and higher during October in the LLT (12% to 33% increase).

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The SacEFT model classifies spring-run spawning habitat conditions as good in 71% of years under EBC1 and 56% of the years under EBC2 (Table C.5.2-19). Spawning habitat conditions are classified as good in 56% of the years for EBC2_ELT and in 86% of the years for PP_ELT, a 30% difference in the frequency of years when spawning habitat conditions are considered to be good, although flows are not 30% higher during the spawning period under PP_ELT compared to EBC2_ELT (Table C.5.2-1). Because flow–WUA relationships developed by Gard are nonlinear, an increase in flow does not necessarily correspond to an increase in WUA or, in this case, spawning habitat conditions for spring-run Chinook salmon. Spawning habitat conditions during the LLT period are classified as good in 50% of years for EBC2_LLT and 77% of years for PP_LLT, a 27% difference. These results indicate that habitat conditions for spawning are expected to decline in the future in response to climate change, but that PP conditions provide a higher frequency of years having good habitat conditions relative to EBC2. This will potentially result in increased reproductive success and abundance of spring-run Chinook salmon.

Table C.5.2-19. Percentage of Years with "Good"[1] Conditions for Spring-Run Chinook Salmon Habitat Metrics in the Upper Sacramento River (from SacEFT)

	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
Spawning WUA[2]	71	56	56	50	86	77
Redd Scour Risk	100	100	100	100	100	100
Egg Incubation	86	85	65	33	73	23
Redd Dewatering Risk	51	37	42	35	59	43
Juvenile Rearing WUA	22	23	24	21	26	21
Juvenile Stranding Risk	18	20	21	15	18	15

[1] Please refer to Attachment C.B, SacEFT Documentation, for definition of "good" for each performance measure.
[2] WUA=Weighted Usable Area

High-flow events have the potential to scour redds during incubation, resulting in increased embryonic mortality. SacEFT results showed that the risk of redd scour was classified as good (reduced risk) in 100% of the years for all model scenarios (EBC1, EBC2, EBC2_ELT, PP_ELT, EBC2_LLT, and PP_LLT) (Table C.5.2-19). Based on these results, it was concluded that the risk of spring-run salmon redd scour and embryo mortality is low for existing biological conditions and BDCP conditions.

Water Temperature

Spring-run Chinook salmon spawning and incubation primarily occur in the Sacramento River between Keswick Dam and RBDD. This analysis assumed that embryo exposure to water temperatures in excess of 56°F would result in adverse impacts on reproductive success, including egg mortality. Spring-run salmon spawn in the late summer and early fall, when seasonal air temperatures in the Redding area are high and, therefore, the Sacramento River is subject to warming. The area of the river where suitable water temperatures occur for successful egg incubation (for this assessment egg incubation refers to unfertilized eggs and developing embryos, including the alevin stage before the young salmon emerges from the gravel as a fry) depends on the temperature of water released to the river from Shasta and Keswick dams, the rate of instream flow, and atmospheric conditions that result in river warming as the water travels downstream from the dam. When coldwater storage in Shasta Reservoir is reduced, the amount of cold water available for

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release is reduced and the temperature of the water at the point of release to the river is increased. Under these conditions, the length of river downstream of Keswick Dam that maintains suitable water temperatures for spring-run Chinook salmon egg incubation and hatching is reduced and eggs that were spawned in the downstream areas are exposed to increased water temperature and increased egg mortality. Shasta Reservoir storage during spring (May) and early fall (September) months that would affect coldwater pool storage and Sacramento River water temperatures are summarized in Table C.5.2-5, Table C.5.2-6, Figure C.5.2-13 and Figure C.5.2-14.

Results of water temperature simulation analyses for the Sacramento River at Keswick, Ball's Ferry, Jelly's Ferry, and Bend Bridge for each month over the 82-year CALSIM modeling period were compiled to assess potential changes in the frequency of occurrence of water temperatures greater than 56°F. Results of the analysis are summarized in Table C.5.2-20.

Table C.5.2-20. Results of Monthly Analysis of Water Temperature Simulation in the Upper Sacramento River during the September through January Spring-Run Salmon Egg Incubation Period[1]

	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
Sacramento River at Keswick Dam						
Number of years with one or more exceedances	16	19	35	59	26	58
Number of years with two exceedances	11	13	17	26	21	29
Number of years with three exceedances	1	1	7	19	4	25
Number of years with four exceedances	0	0	0	0	0	0
Number of years with five or more exceedances	0	0	0	0	0	0
Number of consecutive years with one or more exceedances	10	13	28	54	20	51
Sacramento River at Ball's Ferry						
Number of years with one or more exceedances	46	38	58	76	69	80
Number of years with two exceedances	14	14	29	50	28	49
Number of years with three exceedances	0	0	0	7	0	7
Number of years with four exceedances	0	0	0	0	0	0
Number of years with five or more exceedances	0	0	0	0	0	0
Number of consecutive years with one or more exceedances	37	30	51	75	66	80
Sacramento River at Jelly's Ferry						
Number of years with one or more exceedances	59	53	70	80	79	81
Number of years with two exceedances	15	16	38	57	34	57
Number of years with three exceedances	0	0	0	4	0	5
Number of years with four exceedances	0	0	0	0	0	0
Number of years with five or more exceedances	0	0	0	0	0	0
Number of consecutive years with one or more exceedances	53	44	68	80	79	81
Sacramento River at Bend Bridge						
Number of years with one or more exceedances	68	60	77	80	81	81
Number of years with two exceedances	16	17	39	60	36	58
Number of years with three exceedances	0	0	0	4	0	5
Number of years with four exceedances	0	0	0	0	0	0
Number of years with five or more exceedances	0	0	0	0	0	0
Number of consecutive years with one or more exceedances	66	54	77	80	81	81

[1] Time period analyzed: September 1921 to January 2003. Analysis counted monthly exceedances above 56°F.

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Results of these analyses show that the frequency of years with water temperatures greater than 56°F in one or more months increased with distance downstream of Keswick Dam as well as in response to future climate change. The frequency of years with water temperatures exceeding a 56°F criterion was generally comparable between EBC1 and EBC2, and between EBC2 and BDCP operations in the early and late long-term, with some exceptions. The frequency of exceedances above 56°F is predicted to be slightly lower under PP_ELT compared to EBC2_ELT at Keswick, but slightly higher at Ball's Ferry and Jelly's Ferry. In the LLT, the frequency of exceedances are generally similar between EBC2_LLT and PP_LLT. This increase in temperatures in the future under climate change would be expected to contribute to increased egg mortality for spring-run Chinook salmon.

The SacEFT model classifies water temperatures for egg survival as good in 86% of years for EBC1, 85% of years for EBC2, 65% for EBC2_ELT, and 73% for PP_ELT, suggesting an overall decline in conditions attributable to future climate change, and a small (6%) improvement for PP_ELT conditions relative to EBC2_ELT (Table C.5.2-19). In addition, water temperatures are classified as good in 33% of years for EBC2_LLT, and 23% for PP_LLT, indicating that PP_LLT conditions would be worse for spring-run egg incubation relative to EBC2_LLT. Therefore, the greatest effect on conditions for spring-run salmon egg incubation would come from future climate change, although the BDCP is predicted to adversely affect spring-run eggs, as well.

Spring-run Chinook salmon egg mortality estimates as predicted by the Reclamation Egg Mortality Model are summarized in Table C.5.2-21 and Figure C.5.2-58. Egg mortality is predicted to be marginally higher under EBC1 than EBC2 in wet, above-normal, and below-normal, and critical water years and lower in dry water years. Egg mortality is predicted to be higher under PP_ELT than EBC2_ELT in wet, above-normal, and below-normal water years and lower in dry and critical years. Egg mortality is predicted to be higher under PP_LLT than EBC2_LLT in wet, above-normal, below-normal, and dry water years and similar between EBC2_LLT and PP_LLT in critical water years. Averaging across water-year types, egg mortality is predicted to be similar between EBC2_ELT and PP_ELT and 6% higher under PP_LLT relative to EBC2_LLT.

Table C.5.2-21. Egg Mortality Percentages (%) for Model Scenarios for Spring-Run Chinook in the Mainstem Sacramento River (from the Reclamation Egg Mortality Model)

Water-Year Type	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
Wet	10.1	8.9	14.0	24.8	17.3	34.7
Above Normal	13.2	9.8	16.0	35.0	21.5	43.4
Below Normal	11.9	11.8	21.1	41.3	23.5	53.6
Dry	19.7	22.5	40.7	76.4	37.1	75.1
Critical	73.9	71.2	92.1	96.3	85.2	96.2
Average	22.4	21.8	33.0	51.1	33.4	57.2

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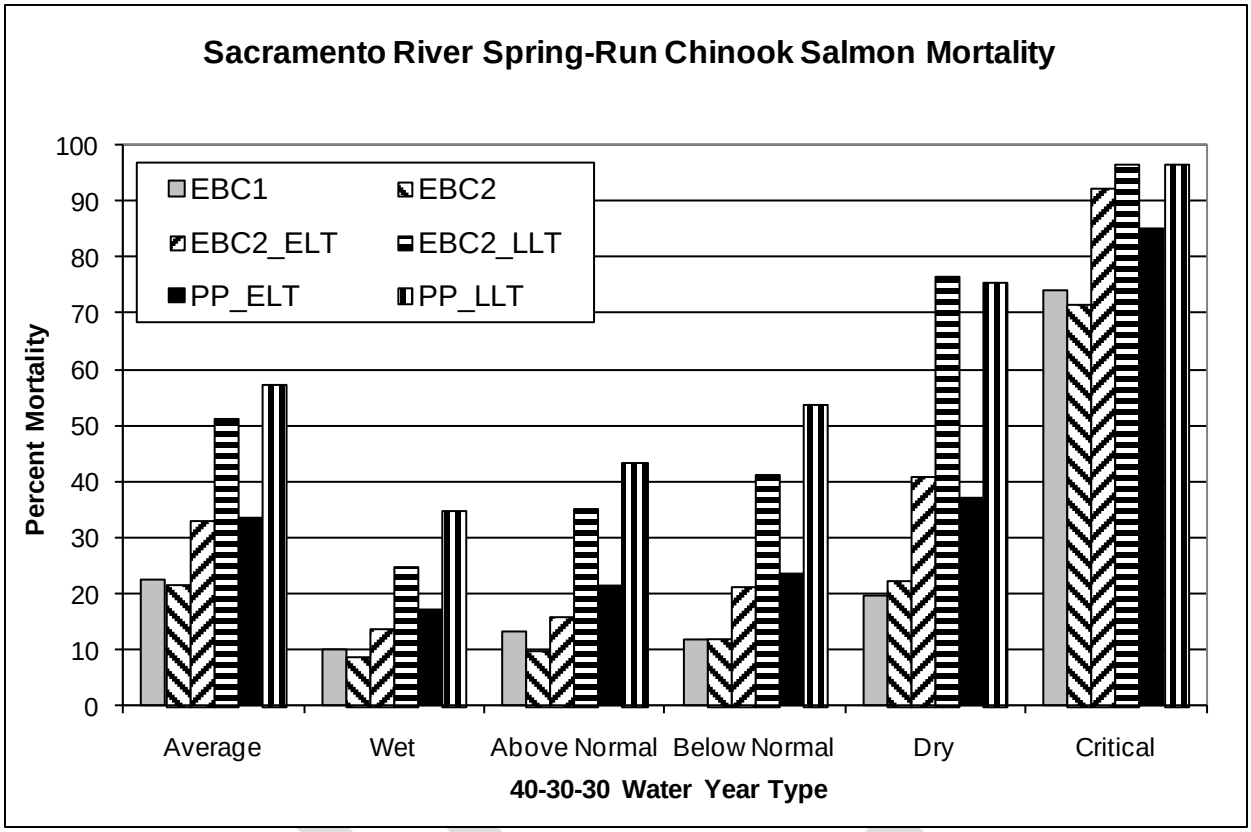

Figure C.5.2-58. Sacramento River Spring-Run Chinook Average Egg Mortality under Each Model Scenario for Each Water-Year Type and for All Years from the Reclamation Egg Mortality Model

There is an apparent discrepancy in results of the SacEFT model and Reclamation egg mortality model with regard to conditions for spring-run salmon eggs in the ELT. SacEFT predicts that water temperatures would improve (an 8% increase in good conditions) for spring-run salmon eggs between EBC2_ELT and PP_ELT, while the Reclamation egg mortality model predicts no difference on average across water-year types between EBC2_ELT and PP_ELT. The Reclamation egg mortality model does predict an increase in egg mortality in wetter conditions (wet, above-normal, and below-normal years) under PP_ELT when compared to EBC2_ELT, but also predicts a decrease in egg mortality under drier conditions (dry and critical years) under PP_ELT. The SacEFT uses mid-August through early March as the egg incubation period, based on Vogel and Marine (1991), and the reach between ACID Dam and Battle Creek for redd locations. Reclamation egg mortality model uses the number of days after Julian week 33 (mid-August) that it takes to accumulate 750 temperature units to hatching and another 750 temperature units to emergence. Temperatures units are calculated by subtracting 32°F from daily river temperature and are computed on a daily basis. As a result, egg incubation duration is generally mid-August through January, but is dependent on river temperature. The Reclamation model uses the reach between ACID Dam and Jelly's Ferry (approximately 5 river miles downstream of Battle Creek), which includes 95% of spawning locations based on 2001–2004 redd survey data (Reclamation 2008). These differences in egg incubation period and location likely account for difference between model results. Although the SacEFT model has been peer-reviewed, the Reclamation egg mortality model has been extensively reviewed and used in prior biological assessments and biological opinions. Therefore, both results are considered valid and were considered in drawing conclusions about spring-run egg mortality in the Sacramento River.

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Spring-run Chinook experience the highest temperature-related egg mortality of the mainstem Sacramento River runs. They spawn at the end of the temperature control season after winter-run Chinook have mostly transitioned from egg incubation to juvenile rearing. Cold water is often depleted by the time spring-run Chinook spawn and their eggs are incubating, and river temperatures rise even as air temperatures are decreasing in the fall. Spawning spring-run Chinook abundance in the mainstem Sacramento River is at a low level, possibly due to the water temperature effects of using most of the cold water for winter-run Chinook. Nearly all spring-run Chinook production occurs in the tributaries. Differences between BDCP scenarios within time periods were low (Figure C.5.2-58). During critical water years, when very high mortality occurred, PP_ELT provided slightly better egg survival relative to EBC2_ELT, but there was no difference for PP_LLT relative to EBC2_LLT (Figure C.5.2-58). Differences between EBC2 and PP conditions in other water-year types were small in the early long-term. In the late long-term, mortality tended to be higher under PP conditions relative to the EBC2 in wet, average, above-normal, and below-normal years, while slightly lower than EBC2 in dry years.

Spring-run Chinook salmon egg mortality estimates for the mainstem Sacramento River show that (1) temperature-related egg mortality is greater for spring-run Chinook salmon than any other Chinook salmon race (Figure C.5.2-49); (2) egg mortality increases substantially during dry and critically dry water years (approaching 100%) in all cases as a result of depleted coldwater pool storage in Shasta Reservoir and increased temperatures of the mainstem Sacramento River; (3) average egg mortality is predicted to be greater under EBC1 than EBC2; (4) egg mortality is predicted to increase in the future due to climate change-induced increased air and water temperatures and also due to changes in expected future hydrologic conditions; and (5) the effects of climate change on egg mortality increase over time for both EBC2 and PP conditions. High levels of egg mortality, particularly in critically dry water years in the future for EBC2 and PP conditions, would be expected to have major population-level effects on abundance, year class strength, and dynamics of Sacramento River spring-run Chinook salmon. The biological significance of effects of high egg mortality for spring-run salmon on the Sacramento River, at a population level, is reduced by the fact that the majority of spawning occurs in tributaries such as Deer, Mill, and Butte creeks that are not affected by BDCP operations, but are affected by future climate change.

Redd Dewatering

The risk of redd dewatering in the mainstem Sacramento River is a function of river flow during spawning and subsequent flow reductions during the egg incubation period. The SacEFT model classifies the risk of redd dewatering as good (reduced risk of adverse effects) in 51% of years for EBC1, 37% for EBC2, 42% for EBC2_ELT and 59% for PP_ELT (Table C.5.2-19). The SacEFT model classifies the risk of redd dewatering as good in 35% of years for EBC2_LLT and 43% for PP_LLT, a difference of 8%. These results indicate that redd dewatering risk is expected to decrease by 8 to 17% under the BDCP relative to existing biological conditions. There is no consistent influence of future climate change on redd dewatering risk.

Fry and Juvenile Rearing

Rearing Habitat

The primary seasonal period for juvenile spring-run Chinook salmon rearing extends year-round in the Sacramento River and from November through June in the Feather River. Results of the CALSIM analyses of instream flows within the reach where the majority of juvenile rearing occurs (Keswick

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Dam to RBDD) were summarized by month and water-year type based on estimated flows at RBDD. Results of these instream flow summaries are presented in Table C.5.2-1 and generally show no differences between existing biological conditions and the preliminary proposal, except for lower flows under the preliminary proposal during September in wet and above-normal years in both the early and late long-term. October flows tend to increase under the preliminary proposal in the late long-term in all water-year types, while November flows are lower under the preliminary proposal in all water-year types in both the early and late long-term. From April through June, there is a slight increase in flows of most water-year types in the early and late long-term. Flows under preliminary proposal conditions increase compared to EBC2 conditions in the late long-term in critical water years during September and October and in dry water years during October.

Monthly frequency of exceedance plots for Sacramento River flows at RBDD during the juvenile rearing period are presented in Figure C.5.2-1 through Figure C.5.2-12. Results of the SRWQM for the upper Sacramento River were used as inputs to SALMOD and other analyses. Results of the detailed water temperature modeling were summarized as the average monthly temperature at RBDD for each month of the 82-year CALSIM analysis. The frequency of months in which the temperature exceeded 65°F were compiled and summarized in Table C.5.2-7. Results of the analysis show that the frequency of years in which water temperatures are generally good for juvenile spring-run Chinook salmon rearing (less than 65°F) in the upper Sacramento River were comparable between EBC1, EBC2 and BDCP operations; however, as would be expected with future climate change, the frequency of years with greater temperatures increases between the ELT and LLT periods for both EBC2 and BDCP operations. In addition, the frequency of years with higher water temperatures increases with distance downstream of Keswick Dam.

The SacEFT model classifies juvenile rearing habitat as good in 22% and 23% of years under EBC1 and EBC2, respectively (Table C.5.2-19). The model classifies juvenile rearing habitat as good in 24% for EBC2_ELT, 26% of years for PP_ELT, 21% of years for EBC2_LLT, and 21% of years for PP_LLT. These results suggest that juvenile rearing conditions under PP_ELT and PP_LLT would be comparable to or better than conditions under EBC2_ELT and EBC2_LLT, respectively. The frequency of years at which SacEFT predicts good for juvenile spring-run salmon rearing habitat is approximately one-quarter of the years under all model scenarios. The relatively low frequency of good years for juvenile rearing reflects seasonal hydrologic conditions and operations in the mainstem Sacramento River and is expected to result in reduced survival and abundance of spring-run Chinook salmon under all model scenarios.

SALMOD was used to evaluate the influence of both water temperature and instream flow on spring-run Chinook salmon under each model scenario. Spring-run Chinook salmon SALMOD runs used an adult escapement rate of 1,000. SALMOD predicts that the spring-run production under PP_ELT and PP_LLT was higher than production under EBC1 and EBC2 (Figure C.5.2-59, Figure C.5.2-60, and Figure C.5.2-61). Production in all ELT and LLT model scenarios is predicted to be greater than in EBC1 and EBC2. Production under the PP_ELT and EBC2_ELT scenarios is predicted to be generally similar. Production under the PP_LLT is predicted to be lower than under EBC2_LLT, although population-level effects are uncertain. The predicted reduction in production under PP_LLT relative to EBC2_LLT is predicted to be smaller than predicted differences between time periods.

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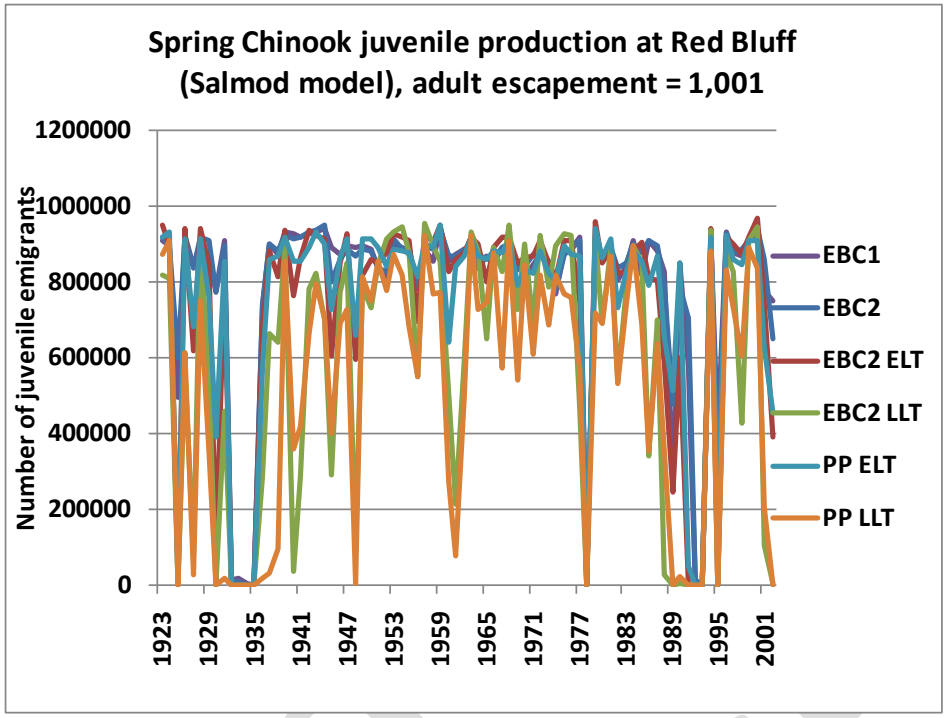

Figure C.5.2-59. Spring-Run Chinook Production at Red Bluff Diversion Dam for Model Scenarios

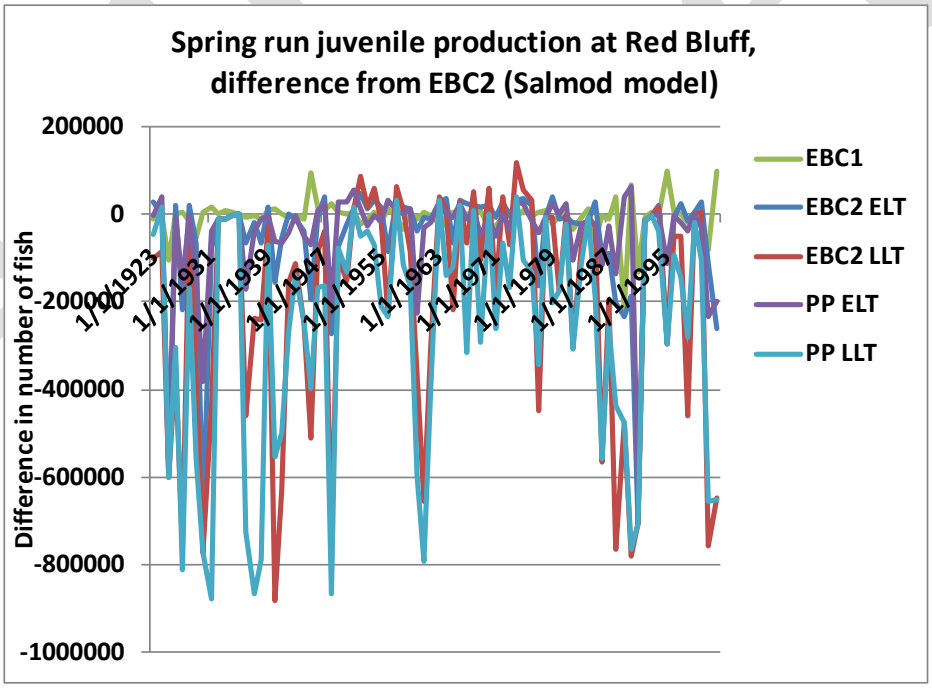

Figure C.5.2-60. Spring-Run Chinook Salmon Production at Red Bluff Diversion Dam for Model Scenarios

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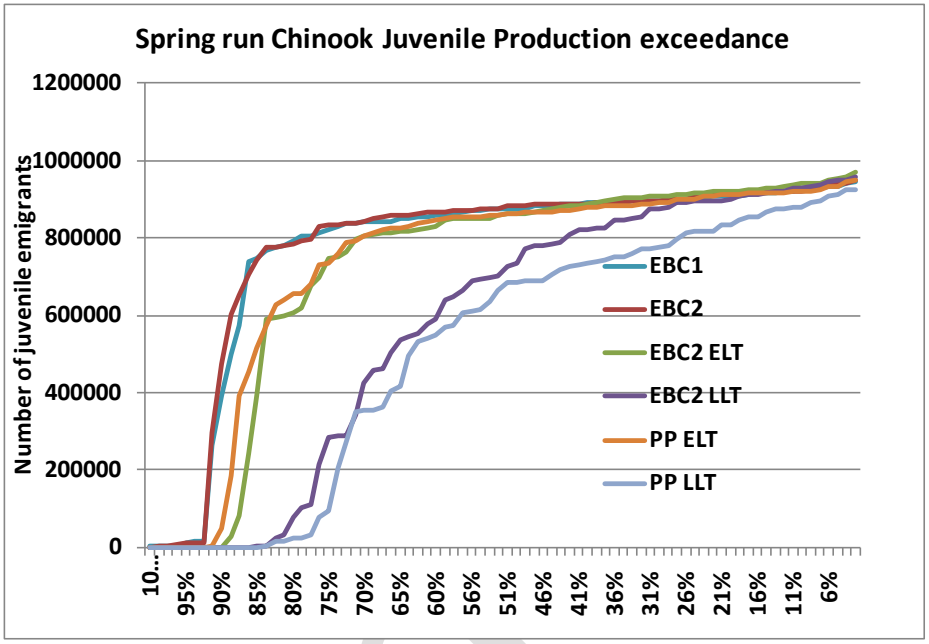

Figure C.5.2-61. Spring-Run Chinook Production Exceedance for Model Scenarios

Spring-run Chinook salmon spawn during the early fall (September–October) when Shasta Reservoir water temperatures released into the river are considered suboptimal for egg incubation. Juvenile rearing occurs during the winter and spring when temperatures are cool. SALMOD was used to predict smolt-equivalent temperature mortality (exposure to elevated water temperatures). SALMOD predicts that mortality would occur primarily in the egg incubation life stage, with virtually no temperature-related mortality during other life stages (Figure C.5.2-62 through Figure C.5.2-65). Greater smolt-equivalent mortality is expected to occur during LLT periods, regardless of whether it was an EBC or PP scenario in response to increased water temperatures associated with future climate change.

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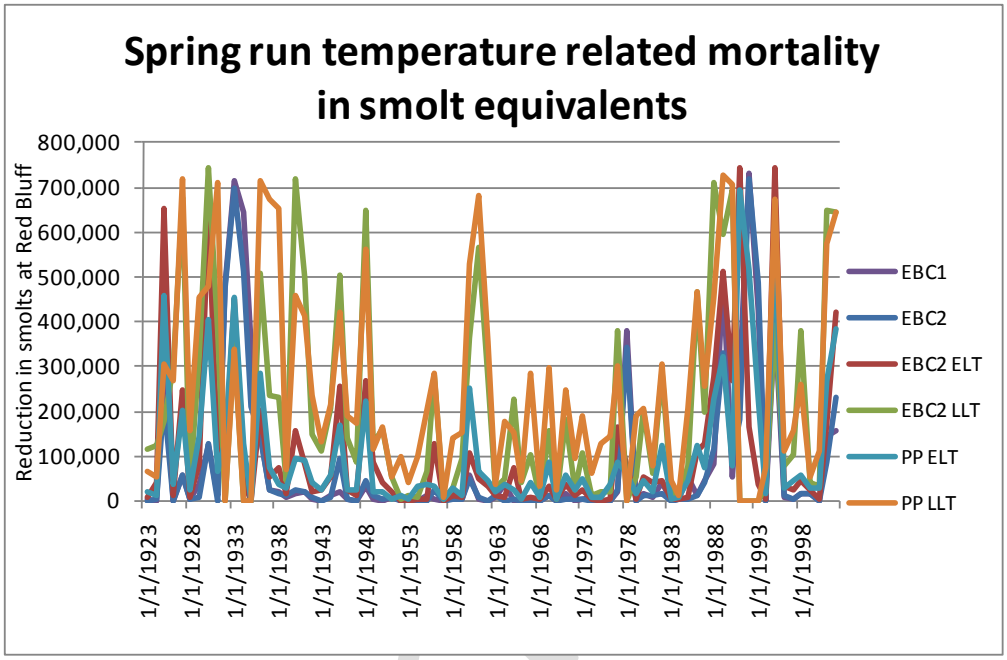

Figure C.5.2-62. Spring-Run Chinook Temperature-Related Mortality for Model Scenarios

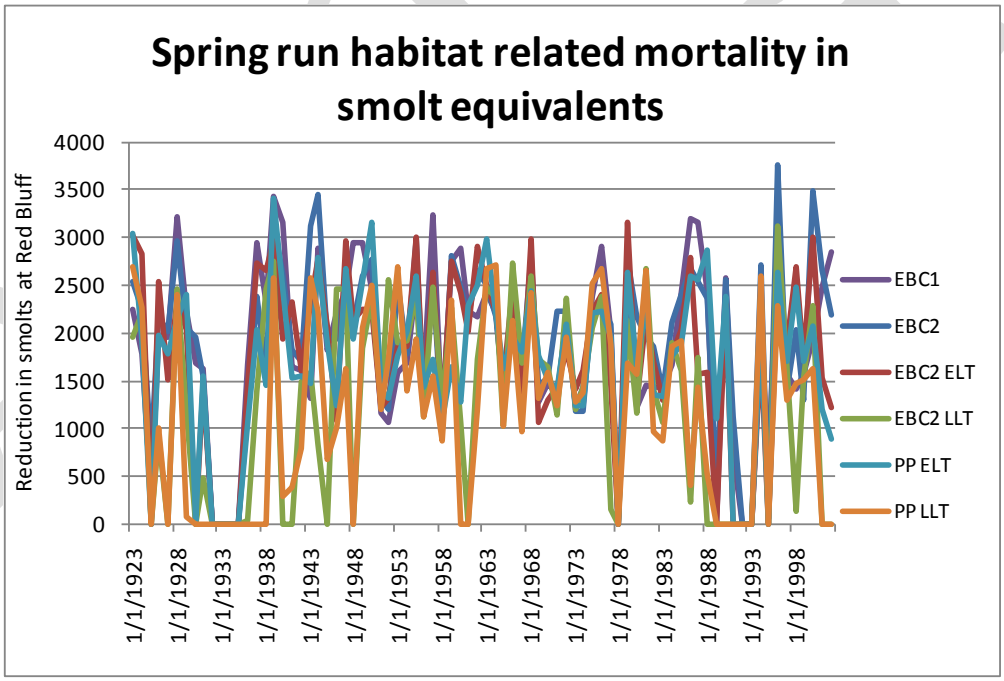

Figure C.5.2-63. Spring-Run Chinook Habitat-Related Mortality for Model Scenarios

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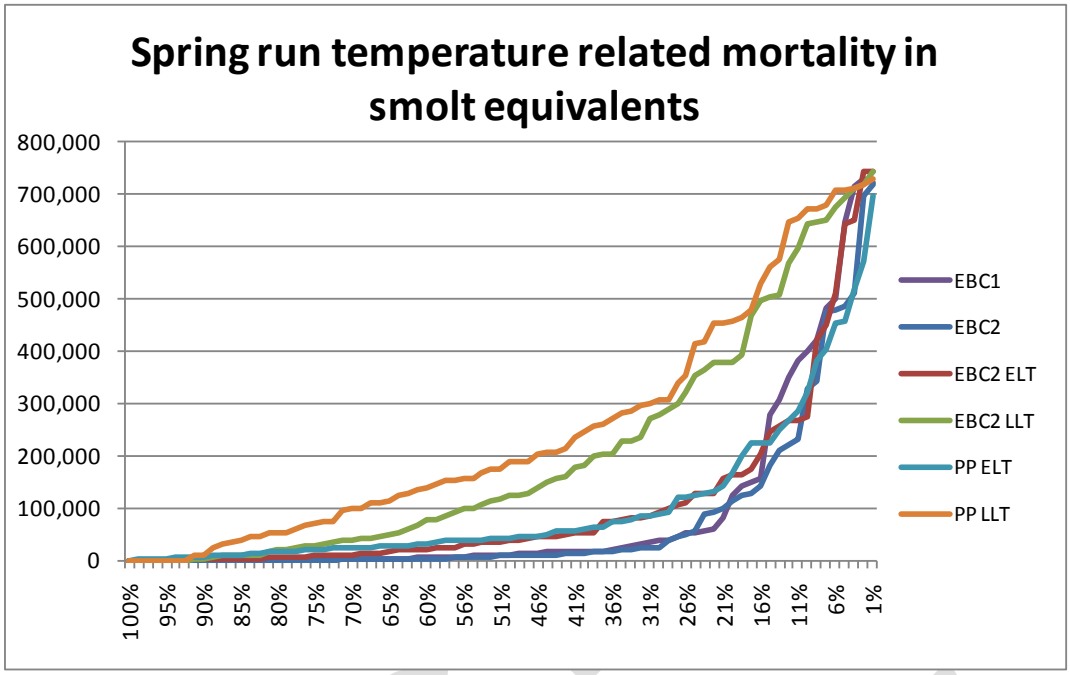

Figure C.5.2-64. Spring-Run Chinook Temperature-Related Mortality Exceedance for Model Scenarios

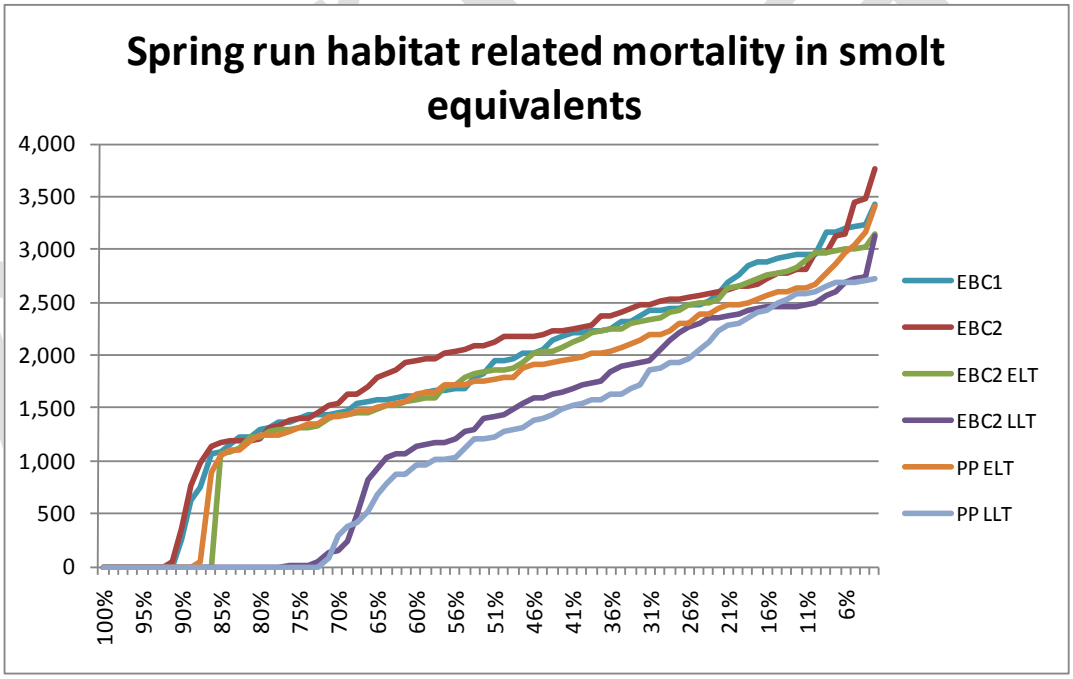

Figure C.5.2-65. Spring-Run Chinook Habitat-Related Mortality Exceedance for Model Scenarios

Juvenile spring-run Chinook salmon are potentially vulnerable to stranding in backwater and channel margin areas when instream flows are rapidly reduced during the rearing period. The risk of juvenile stranding was evaluated using SacEFT. Modeled risk of stranding for EBC1 and EBC2 is classified as good (reduced risk) in 18% and 20% of years, respectively (Table C.5.2-19). The frequency of years classified as good for reduced stranding conditions is predicted to be 21% for EBC2_ELT and 18% for PP_ELT. The frequency of years classified as having good conditions is

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predicted to be 15% for both EBC2_LLT and PP_LLT. The marginally lower frequency (3%) of years having low risk of standing for PP_ELT would not be expected to contribute to an increase in the mortality risk for rearing juvenile spring-run Chinook salmon.

Adult

Water Temperature

Adult spring-run Chinook salmon migrate upstream into the mainstem Sacramento River during the spring months (March through August, with peak migration in April through May) and hold in the upper river reaches through the spring and early summer months (April through August) prior to spawning and eggs incubating (September through January).

Results of water temperature simulations over the 82-year period of CALSIM analyses for the Sacramento River at Keswick Dam, Ball's Ferry, Jelly's Ferry, and Bend Bridge were compiled to assess the frequency of months in which predicted average temperatures exceeded 65°F during the April through August period of adult upstream migration and holding by pre-spawning adult spring-run salmon. Results of the analysis are summarized in Table C.5.2-22. Results of this analysis show that at Keswick Dam water temperatures are typically within the range that would provide suitable habitat for adult spring-run holding. There were no exceedances above 65°F under the EBC1 and EBC2 scenarios. The 65°F criterion was exceeded in one month in 4 years under EBC2_ELT and 2 years under PP_ELT conditions. The frequency increased to 7 years for both EBC2_LLT and PP_LLT operations. There was one year in which the criterion was exceeded in two consecutive months under PP_LLT conditions, reflecting the effects of future climate change in combination with BDCP operations. As expected, the frequency of years exceeding the criterion increased as a function of distance downstream, as reflected in results for Ball's Ferry, Jelly's Ferry, and Bend Bridge. These changes in habitat conditions, however, were independent of BDCP operations at each location and time period.

Overall, mainstem Sacramento River water temperature modeling results (reach downstream of Keswick Dam to RBDD) during the peak adult spring-run Chinook salmon migration and holding periods predict that water temperatures are typically within suitable ranges (less than 65°F) for spring-run Chinook salmon for all model scenarios. The reduced water temperatures during the spring and summer reflect coldwater pool management within Shasta Reservoir to protect adults and to provide suitable temperatures for egg incubation in the fall.

Table C.5.2-22. Results of the Analysis of Water Temperature Simulation in the Sacramento River during the April through August Spring-Run Adult Migration Period[1]

	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
Sacramento River at Keswick Dam						
Number of years with one or more exceedances	0	0	4	7	2	7
Number of years with two exceedances	0	0	0	0	0	1
Number of years with three exceedances	0	0	0	0	0	0
Number of years with four exceedances	0	0	0	0	0	0
Number of years with five or more exceedances	0	0	0	0	0	0
Number of consecutive years with one or more exceedances	0	0	2	5	0	5

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	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
Sacramento River at Ball's Ferry						
Number of years with one or more exceedances	0	0	5	8	4	7
Number of years with two exceedances	0	0	0	2	0	3
Number of years with three exceedances	0	0	0	0	0	0
Number of years with four exceedances	0	0	0	0	0	0
Number of years with five or more exceedances	0	0	0	0	0	0
Number of consecutive years with one or more exceedances	0	0	2	5	2	5
Sacramento River at Jelly's Ferry						
Number of years with one or more exceedances	0	1	6	8	5	8
Number of years with two exceedances	0	0	0	5	0	5
Number of years with three exceedances	0	0	0	0	0	0
Number of years with four exceedances	0	0	0	0	0	0
Number of years with five or more exceedances	0	0	0	0	0	0
Number of consecutive years with one or more exceedances	0	0	4	5	2	5
Sacramento River at Bend Bridge						
Number of years with one or more exceedances	1	2	6	8	5	8
Number of years with two exceedances	0	0	0	5	0	5
Number of years with three exceedances	0	0	0	0	0	0
Number of years with four exceedances	0	0	0	0	0	0
Number of years with five or more exceedances	0	0	0	0	0	0
Number of consecutive years with one or more exceedances	0	0	4	5	2	5
[1] Time period analyzed: April 1922 to August 2003. Analysis counted monthly exceedances above 65°F.						

C.5.2.1.4 Fall-/Late Fall–Run

Eggs and Alevins

Upstream Spawning Habitat

Sacramento River instream flows at RBDD during the fall-run Chinook salmon spawning and egg incubation period (October through January) are shown in Table C.5.2-1, Figure C.5.2-1, and Figure C.5.2-10 through Figure C.5.2-12). Results of instream flow modeling during the late fall–run Chinook salmon egg incubation period (February through May) are summarized in Table C.5.2-1 and Figure C.5.2-2 through Figure C.5.2-5. Instream flows and, therefore, physical habitat conditions were generally comparable between EBC and PP operations for both races. One exception is during October, when flows are predicted to be ~1,100 to 2,000 cfs greater under PP_LLT than EBC2_LLT. However, flows during November are predicted to be ~600 to 2,700 cfs lower under the PP_LLT than EBC2_LLT. These results suggest that, in the late long-term, small beneficial effects on flow from the proposed project are expected during October and small adverse effects on flow are predicted to occur during November.

Availability of suitable spawning habitat for fall-run and late fall–run Chinook salmon was evaluated using the SacEFT model. SacEFT classifies spawning habitat conditions for fall-run Chinook salmon as good in 48% and 43% of years under EBC1 and EBC2, respectively (Table C.5.2-23). SacEFT classifies spawning habitat conditions as good in 43% of years under EBC2_ELT and 58% of years under

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PP_ELT, an increase of 15%. During the late long-term period, SacEFT classifies spawning habitat conditions as good in 35% of years under EBC2_LLT and 43% of years under PP_LLT, an increase of 8%. These results show that conditions are expected to improve (greater frequency of years with good habitat conditions) under preliminary proposal operations in both the early and late long-term periods.

Table C.5.2-23. Percentage of Years with "Good"[1] Conditions for Fall-Run Chinook Salmon Habitat Metrics in the Upper Sacramento River (from SacEFT)

	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
Spawning WUA[2]	48	43	43	35	58	43
Redd Scour Risk	63	69	67	67	67	70
Egg Incubation	94	94	89	69	89	68
Redd Dewatering Risk	28	28	29	27	30	29
Juvenile Rearing WUA	33	35	38	40	35	34
Juvenile Stranding Risk	33	25	23	20	29	28

[1] Please refer to Attachment C.B, SacEFT Documentation, for definition of "good" for each performance measure.
[2] WUA = Weighted Usable Area

SacEFT model results were used to evaluate redd scour risk as a result of high-flow exposure. For fall-run Chinook salmon, the percentage of years having good conditions (reduced risk of redd scour) was 63% and 69% under EBC1 and EBC2, respectively; 67% under EBC2_ELT, PP_ELT, and EBC2_LLT; and 70% under PP_LLT (Table C.5.2-23). These results suggest that the risk of redd scour during the fall-run Chinook salmon incubation period would be comparable between existing biological conditions and proposed project operations.

For late fall–run Chinook salmon, SacEFT predicts that spawning habitat would be good in 52% of the years under EBC1 and EBC2 (Table C.5.2-24). SacEFT classifies spawning habitat conditions as good in 48% of years under EBC_ELT and 43% under PP_ELT, a reduction of 5%. Results for the late long-term comparison are similar; spawning habitat conditions are classified as good in 48% of years under EBC2_LLT and 43% of years under PP_LLT, a decline of 5%. A reduction of 5% under both early and late long-term periods indicates that changes in instream flows associated with preliminary proposal operations are expected to contribute to a small reduction in available late fall–run Chinook salmon spawning habitat.

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Table C.5.2-24. Percentage of Years with "Good"[1] Conditions for Late Fall-Run Chinook Salmon Habitat Metrics in the Upper Sacramento River (from SacEFT)

	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
Spawning WUA[2]	52	52	48	48	43	43
Redd Scour Risk	83	84	81	77	80	78
Egg Incubation	100	100	100	100	100	98
Redd Dewatering Risk	62	60	56	57	56	55
Juvenile Rearing WUA	45	45	57	63	46	37
Juvenile Stranding Risk	72	68	60	46	57	46

[1] Please refer to Attachment C.B, SacEFT Documentation, for definition of "good" for each performance measure.
[2] WUA = Weighted Usable Area

SacEFT classifies redd scour risk during egg incubation as good (low risk) in 83% and 84% of years under EBC1 and EBC2, respectively, 81% of years under EBC2_ELT, 80% of years under PP_ELT, 77% of years under EBC2_LLT, and 78% of years under PP_LLT. These results indicate that the risk of late fall–run Chinook salmon redd scour during egg incubation would be comparable between all model scenarios.

Water Temperature

Fall-run/late fall–run Chinook salmon spawning and egg incubation occurs primarily in the reach of the Sacramento River between Keswick Dam and RBDD. It was assumed that egg exposure to water temperatures in excess of 56°F during the incubation period would result in adverse impacts on reproductive success, including egg mortality.

Fall-run salmon spawn in the late fall and early winter (October through December), when seasonal air temperatures in the Redding area are declining. The area of the river where suitable water temperatures occur for successful egg incubation depends on the temperature of water released to the river from Shasta and Keswick dams, the rate of instream flow, and atmospheric conditions that result in river warming as the water travels downstream. When coldwater storage in Shasta Reservoir is reduced, the amount of cold water available for release is reduced, and the temperature of the water at the point of release to the river is increased. Under these conditions, the length of river downstream of Keswick Dam that maintains suitable water temperatures for fall-run Chinook salmon egg incubation and hatching is reduced and eggs incubating in the downstream areas are exposed to increased water temperature and mortality.

Late fall–run Chinook salmon spawn during the late fall and early winter, when seasonal water temperatures have typically declined due to cooling daytime and nighttime atmospheric temperatures to levels that are suitable for egg incubation in the mainstem river.

The potential effects of exposure to elevated water temperatures for fall-run Chinook salmon eggs incubating in the mainstem Sacramento River were evaluated using results of SacEFT. The model classifies egg incubation conditions as good in 94% of the years under both EBC1 and EBC2 (Table C.5.2-23). During the early long-term period, the percentage of years classified as having good egg incubation temperatures declines to 89% under both EBC2_ELT and PP_ELT. During the late long-term period, SacEFT classifies egg incubation as good in 69% of years under EBC2_LLT and 68% of years under PP_LLT. Results of these analyses indicate that the percentage of good conditions for

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fall-run Chinook salmon egg incubation would be comparable between existing biological conditions and proposed project operations during both the early and late long-term periods. Instead, the large degradation in egg incubation conditions through time independent of the BDCP suggest that climate change will have moderate adverse effects on fall-run egg incubation.

The Reclamation salmon egg mortality model was used to estimate the change in egg survival under the BDCP over a wide range of hydrologic and environmental conditions. Egg mortality model results provide an important indicator regarding changes in habitat suitability for fall-run and late fall-run Chinook salmon spawning and successful egg incubation. Results of the fall-run Chinook salmon egg mortality estimates under each model scenario are summarized in Figure C.5.2-66 and Table C.5.2-25.

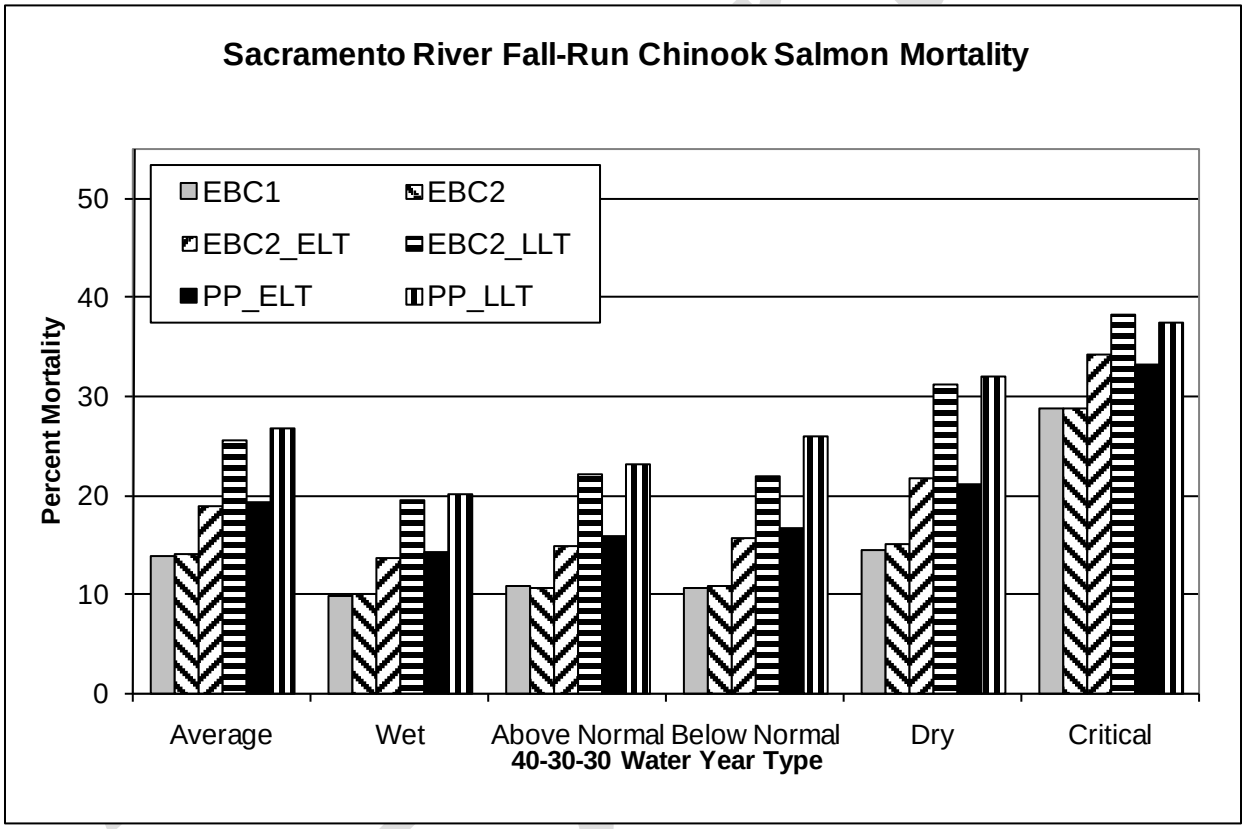

Figure C.5.2-66. Sacramento River Fall-Run Chinook Average Egg Mortality under Each Model Scenario for Each Water-Year Type and for All Years from the Reclamation Egg Mortality Model

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Table C.5.2-25. Egg Mortality Percentages for Fall-Run Chinook in the Mainstem Sacramento River (Egg Mortality Model)

Water-Year Type	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
Wet	9.8	9.9	13.5	19.4	14.3	20.0
Above Normal	10.9	10.5	14.9	22.0	16.0	23.1
Below Normal	10.6	10.8	15.5	21.8	16.6	26.0
Dry	14.5	15.0	21.7	31.2	21.2	32.0
Critical	28.7	28.6	34.2	38.1	33.2	37.3
Average	13.9	14.1	18.9	25.6	19.3	26.7

Egg mortality estimates for fall-run Chinook salmon in the mainstem Sacramento River show that (1) egg mortality under EBC1 and EBC2 are not meaningfully different; (2) mortality increases substantially during critically dry water years in all cases as a result of depleted coldwater pool storage in Shasta Reservoir and increased temperatures of water released to the mainstem Sacramento River during the fall-run salmon egg incubation period; (3) increased egg mortality in the future is expected as the result of increased effects of climate change on air and water temperatures and changes in expected future hydrologic conditions; (4) the effects of climate change on fall-run Chinook salmon egg mortality become greater as time passes under both EBC2 and PP operations; and (5) egg mortality is similar between EBC2_ELT and PP_ELT and between EBC2_LLT and PP_LLT.

Exposure of incubating late fall–run Chinook salmon eggs to elevated water temperatures was evaluated using the SacEFT model. SacEFT classifies egg incubation conditions for late fall–run as good in 98% under late long-term proposed project operations and 100% under all other scenarios and time periods (Table C.5.2-24). Thus, egg incubation conditions would be comparable under all of the conditions evaluated. The high frequency of good egg incubation temperatures for late fall–run Chinook salmon reflects the fact that spawning occurs during the winter months and eggs incubate during a period when natural seasonal water temperatures are cold and provide suitable conditions for egg incubation.

Results of the Reclamation egg mortality model for late fall–run Chinook salmon are summarized in Table C.5.2-26 and Figure C.5.2-67. The model predicts that (1) temperature-related egg mortality for late fall-run is substantially less than that for other Chinook salmon races because the late fall–run egg incubation period occurs when water temperatures are typically more suitable for egg incubation (Figure C.5.2-49); (2) egg mortality is not predicted to increase during dry and critically dry water years as a result of depleted Shasta Reservoir coldwater pool storage because water temperatures released to the mainstem Sacramento River during the late fall–run salmon incubation period are naturally cold; (3) increased egg mortality in the future is predicted as a result of climate change effects on air and water temperatures and changes in expected future hydrologic conditions, although these future changes are substantially less for late fall–run salmon compared to other runs; (4) the effects of climate change on late fall–run Chinook salmon egg mortality become greater through time under both EBC2 and PP model scenarios; and (5) egg mortality is predicted to be slightly lower under PP_ELT and PP_LLT relative to EBC2_ELT and EBC2_LLT, respectively, suggesting a slight benefit of the preliminary proposal.

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Table C.5.2-26. Egg Mortality Percentages for Late Fall–Run Chinook in the Mainstem Sacramento River (Egg Mortality Model)

Water-Year Type	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
Wet	2.0	2.2	3.7	6.2	3.3	5.4
Above Normal	2.5	2.4	4.3	7.0	3.6	6.2
Below Normal	1.5	1.7	3.2	5.5	3.2	6.4
Dry	2.6	2.7	4.5	7.4	4.2	5.9
Critical	2.0	2.0	3.2	4.8	3.0	4.5

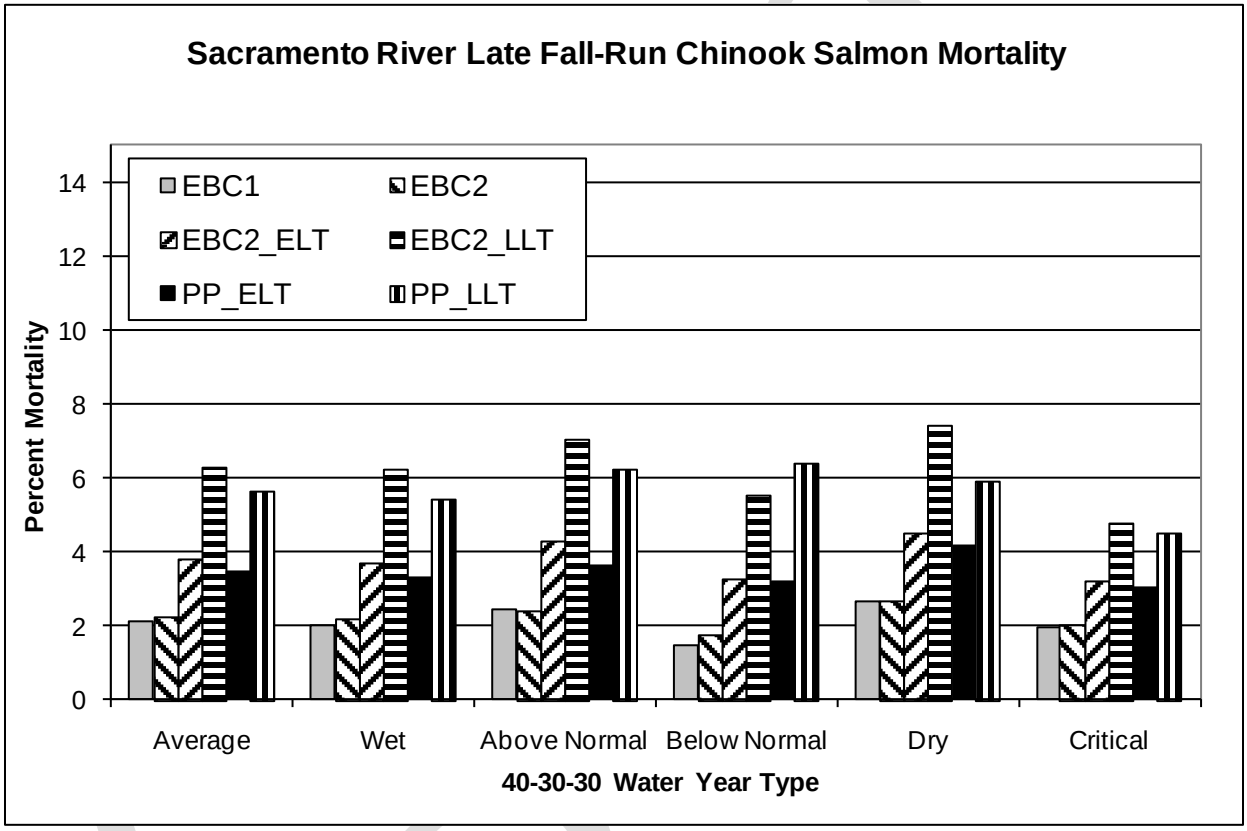

Figure C.5.2-67. Sacramento River Late Fall–Run Chinook Average Egg Mortality under Each Model Scenario for Each Water-Year Type and for All Years from the Reclamation Egg Mortality Model

Redd Dewatering

SacEFT classifies redd dewatering risk for fall-run Chinook salmon as good (reduced risk of redd dewatering) in 28% of years under both EBC1 and EBC2, 29% of years under EBC2_ELT, and 30% of the years under PP_ELT (Table C.5.2-23). Results during the late long-term period were similar, with good conditions predicted in 27% of years under EBC2_ELT and 29% of years under PP_LLT. These results suggest that the risk of redd dewatering is comparable between EBC1, EBC2, and PP operations during both the early and late long-term periods. The incremental differences in the risk of redd dewatering between EBC and PP scenarios are not expected to greatly affect the survival of incubating eggs or the abundance of juvenile salmon produced in the upper mainstem Sacramento River. The low estimated frequency of good conditions (approximately 25%) under both EBC2 and

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PP reflects a high risk of redd dewatering for fall-run Chinook salmon that has population-level consequences, although this is independent of BDCP operations.

SacEFT classifies redd dewatering risk for fall-run Chinook salmon as good in 62% and 60% of years under EBC1 and EBC2, respectively, 56% of years under both EBC2_ELT and PP_ELT, 57% of the years under EBC2_LLT, and 55% of the years under PP_ELT (Table C.5.2-23). These results indicate that the risk of redd dewatering for late fall–run Chinook salmon would be comparable between EBC and PP scenarios.

Fry and Juvenile Rearing

Rearing Habitat

SacEFT classifies habitat conditions for juvenile fall-run Chinook salmon rearing in the upper mainstem Sacramento River as good in 33% and 35% of years under EBC1 and EBC2, respectively, 38% under EBC2_ELT, 35% under PP_ELT, 40% under EBC2_PLT, and 34% under PP_LLT (Table C.5.2-23). The number of years in which juvenile habitat conditions are predicted to be good is 5% lower under PP_ELT relative to EBC2_ELT and 6% lower under PP_LLT relative to EBC2_LLT. These reductions are expected to contribute to a small adverse effect of the BDCP on available juvenile rearing habitat.

Instream flows in the Sacramento River at RBDD during the juvenile fall-run Chinook salmon rearing period (January through May) are shown in Table C.5.2-1 and Figure C.5.2-1 through Figure C.5.2-5. The analysis predicts that instream flows and, therefore, physical habitat were mostly comparable between existing biological conditions and proposed project operations. One exception is that average May flows under PP_ELT and PP_LLT are ~1,000 cfs higher than under EBC2_ELT and EBC2_LLT, respectively, in above-normal, below-normal, and dry water years.

SacEFT classifies stranding risk as good (lower risk due to lower magnitude and frequency of flow fluctuations during the rearing period) in 33% and 25% of years under EBC1 and EBC2, respectively (Table C.5.2-23). SacEFT classifies stranding risk as good in 23% of years under EBC2_ELT and 29% of years under PP_ELT, a difference of 6%. In the late long-term, EFT classifies stranding risk as good in 20% of years under EBC2_LLT and 28% of years under PP_LLT, a difference of 8%. The decrease in magnitude and frequency of flow fluctuations and, therefore, increase in the percentage of years when juvenile rearing habitat is considered to be good in the mainstem Sacramento River predicted under the preliminary proposal suggests that the preliminary proposal will provide a small benefit to juvenile fall-run Chinook salmon.

The SALMOD model was used to evaluate potential changes in juvenile fall-run Chinook salmon rearing habitat in the Sacramento River. SALMOD used a fall-run adult escapement of 59,653 salmon (based on 1999–2006 escapement data from GrandTab 2008). The model predicts that production would be highest under EBC1 and EBC2, followed by EBC2_ELT and PP_ELT (Figure C.5.2-68 through Figure C.5.2-70). Production would be lowest under EBC2_LLT and PP_LLT. Differences between EBC2_ELT and PP_ELT and between EBC2_LLT and PP_LLT are predicted to be smaller than differences between implementation periods. These results suggest that reductions in future fall-run juvenile production are primarily due to changes in climate, increasing the magnitude and frequency of flow fluctuations and minimally due to the preliminary proposal.

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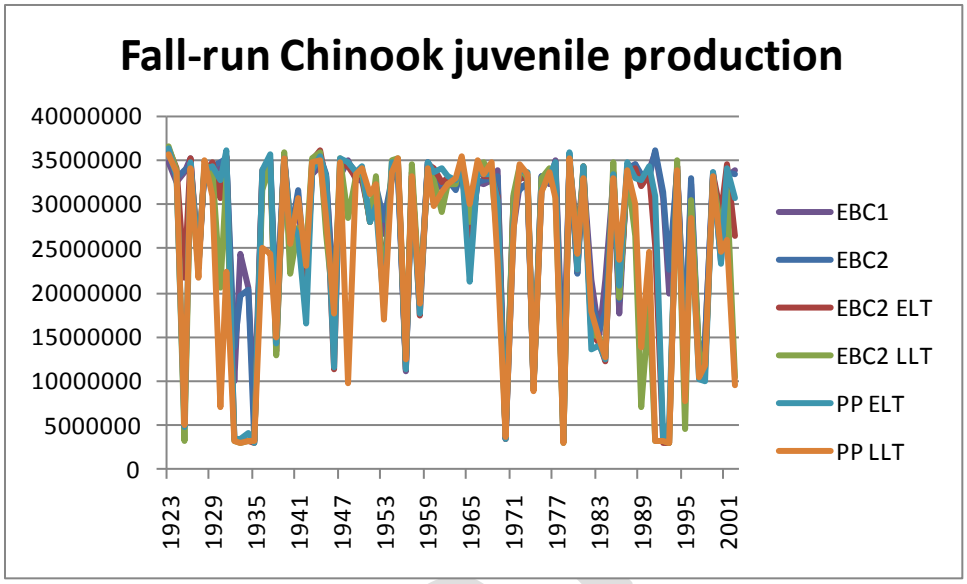

Figure C.5.2-68. Fall-Run Chinook Production at Red Bluff Diversion Dam (SALMOD Model)

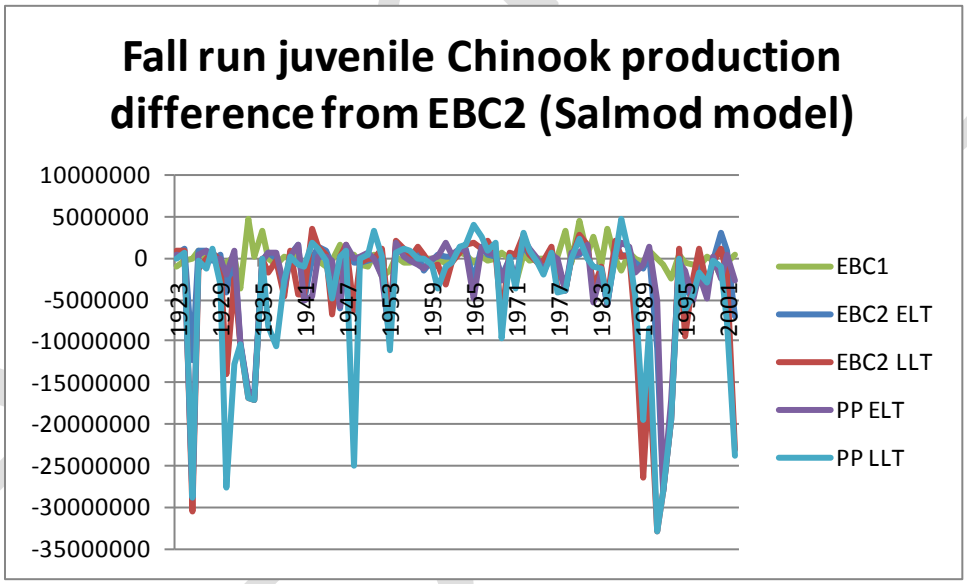

Figure C.5.2-69. Difference in Fall-Run Chinook Salmon Production at Red Bluff Diversion Dam (SALMOD Model)

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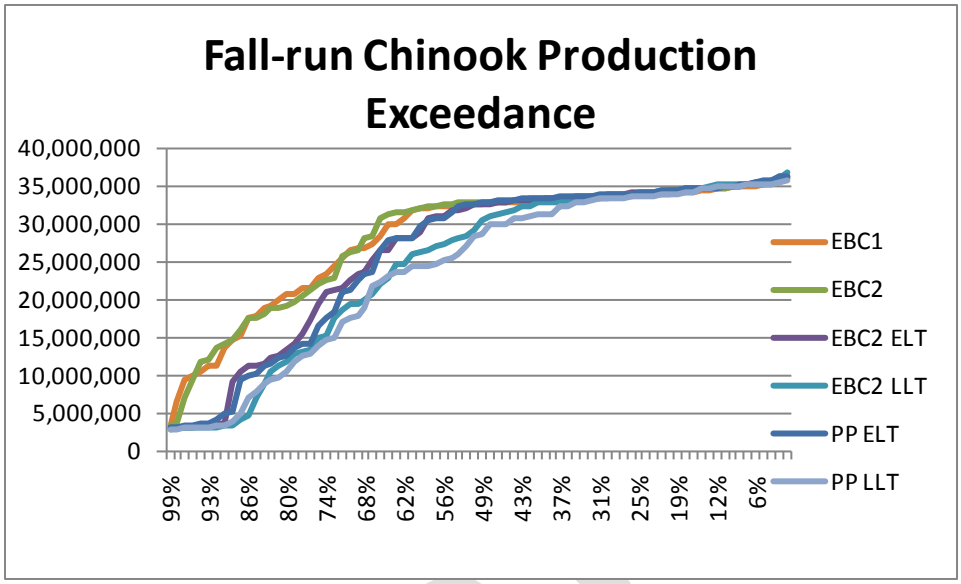

Figure C.5.2-70. Fall-Run Chinook Production Exceedance (SALMOD Model)

Fall-run Chinook spawn during the fall, when water temperatures in releases from Shasta Reservoir can be suboptimal for egg incubation. Juvenile rearing occurs during the winter and spring when temperatures are cool. Smolt-equivalent temperature mortality occurred primarily in the egg incubation life stage, with temperature-related mortality during other life stages dependent on water-year type. Smolt-equivalent mortality is predicted by SALMOD to be greater during the late long-term period than the other two periods (Figure C.5.2-71 and Figure C.5.2-72). There is a small increase in temperature-related mortality due to the preliminary proposal in the late long-term period, but this effect is negligible compared to the effect of climate change.

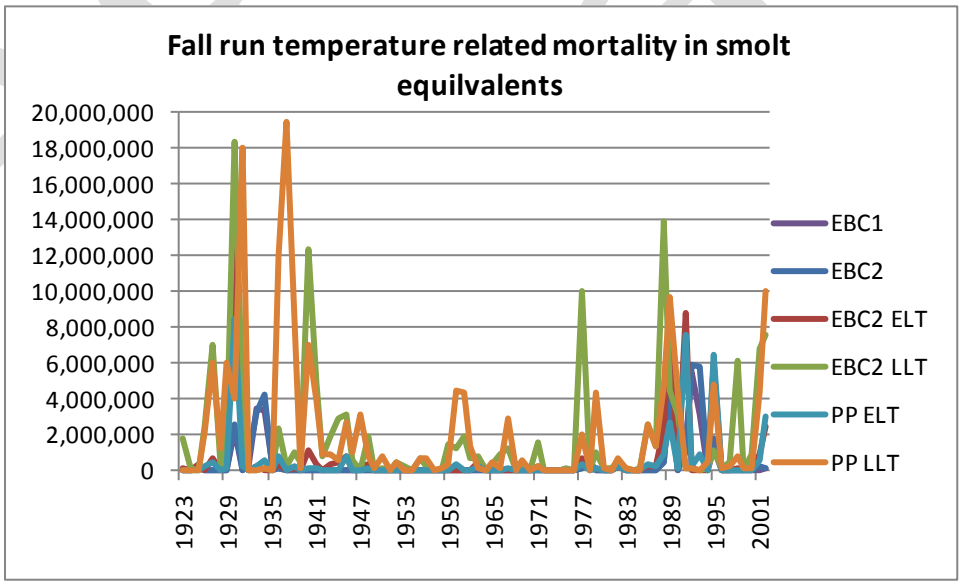

Figure C.5.2-71. Fall-Run Chinook Temperature-Related Mortality (SALMOD Model)

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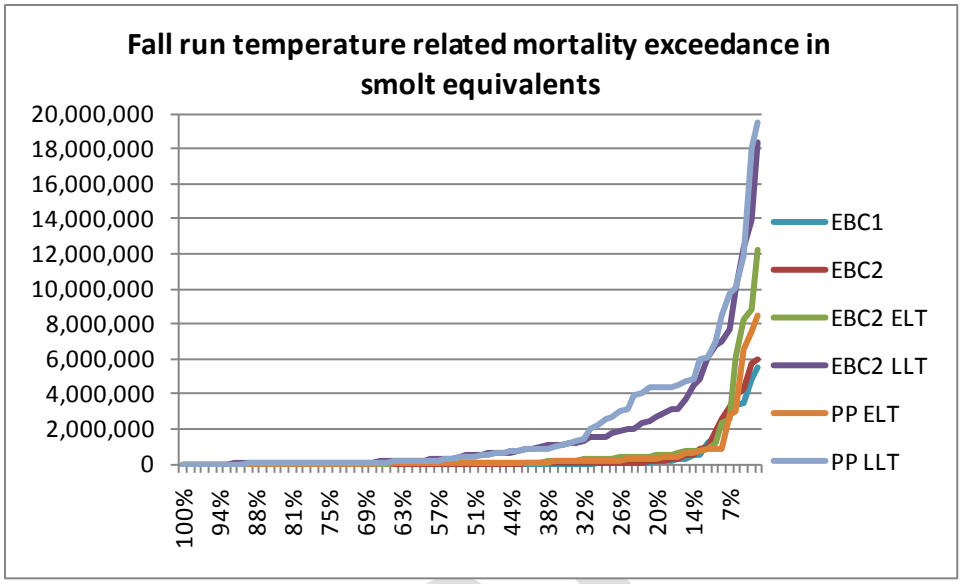

Figure C.5.2-72. Fall-Run Chinook Temperature-Related Mortality Exceedance (SALMOD Model)

Habitat-related fall-run smolt mortality predicted by SALMOD is presented in Figure C.5.2-73 and Figure C.5.2-74. SALMOD predicts a slight reduction in mortality under EBC2_ELT and PP_ELT relative to EBC1 and EBC2. Likewise, SALMOD predicts a slight reduction in mortality under EBC2_LLT and PP_LLT relative to EBC2_ELT and PP_ELT. There are negligible differences in predicted mortality between EBC1 and EBC2 and between EBC2_ELT and PP_ELT. There is a small reduction in mortality associated with PP_LLT relative to EBC2_LLT. These results suggest that habitat-related fall-run smolt mortality will decrease through time and, in the late long-term, will be further reduced by the preliminary proposal.

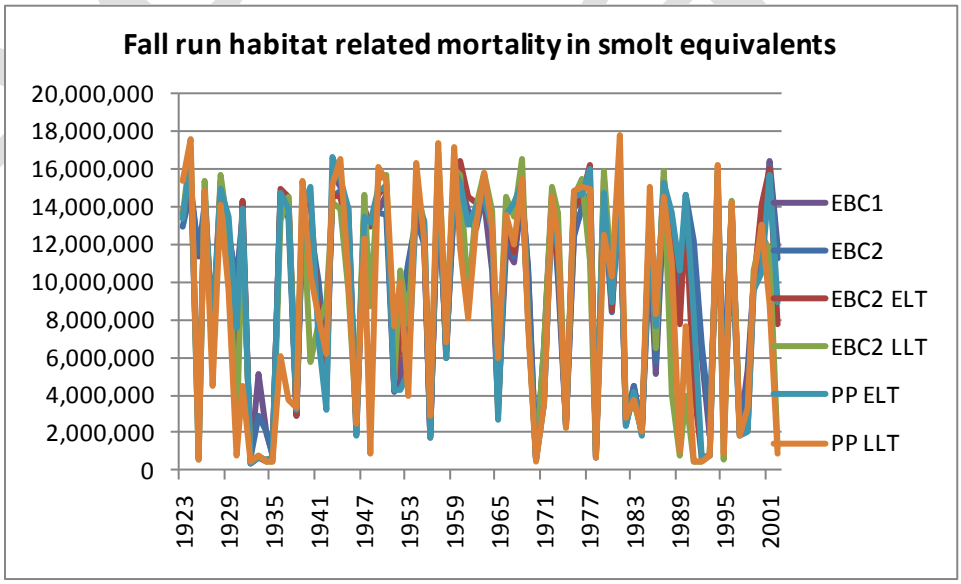

Figure C.5.2-73. Fall-Run Chinook Habitat-Related Mortality (SALMOD Model)

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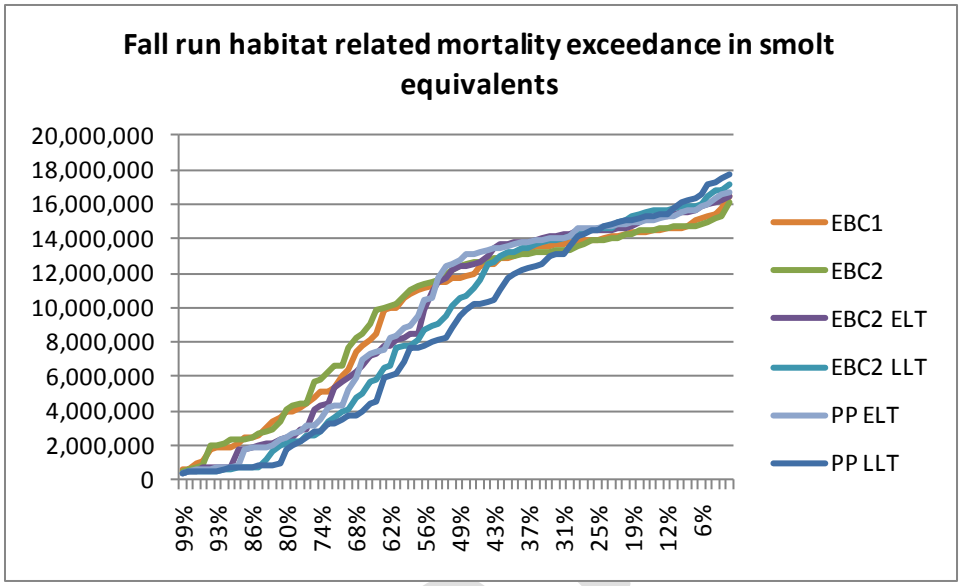

Figure C.5.2-74. Fall-Run Chinook Habitat-Related Mortality Exceedance (SALMOD Model)

Late fall-run Chinook salmon rear within the upper Sacramento River year-round. Average predicted instream flows upstream of RBDD (Table C.5.2-1 and Figure C.5.2-1 through Figure C.5.2-12) are mostly comparable between EBC1, EBC2, and PP model scenarios. One notable exception is the 2,000–6,000 cfs reduction in average September flows in PP_ELT and PP_LLT relative to EBC2_ELT and EBC2_LLT, respectively, in both wet and above-normal years. Further, October flows in PP_LLT are predicted to be 1,000 to 2,000 cfs higher, depending on water-year type, than under EBC2_LLT. These differences are due to differences in Fall X2 criteria between EBC2 and PP. Because EBC2 has the Fall X2 standard in place, which results in additional releases in the fall months compared to PP. In addition, October Keswick releases are higher to meet Rock Slough salinity standards, which controls more frequently in the PP_LLT scenario due to increasing salinity intrusion over summer and fall because of the sea level rise and restoration.

SALMOD used a late fall-run adult escapement of 12,051 salmon. Late fall-run production results are presented in Figure C.5.2-76 through Figure C.5.2-77. SALMOD predicts that production under EBC1 and EBC2 will be similar and both will be greater than production under EBC2_ELT and PP_ELT. Production under PP_ELT is predicted to be marginally greater than production under EBC2_ELT. Production under EBC2_ELT and PP_ELT is predicted to be greater than production under EBC2_LLT and PP_LLT. Production under EBC2_LLT and PP_LLT is predicted to be similar. These results suggest that there is a small benefit of the preliminary proposal in the ELT, but this effect is negligible relative to the large negative effects of future climate change.

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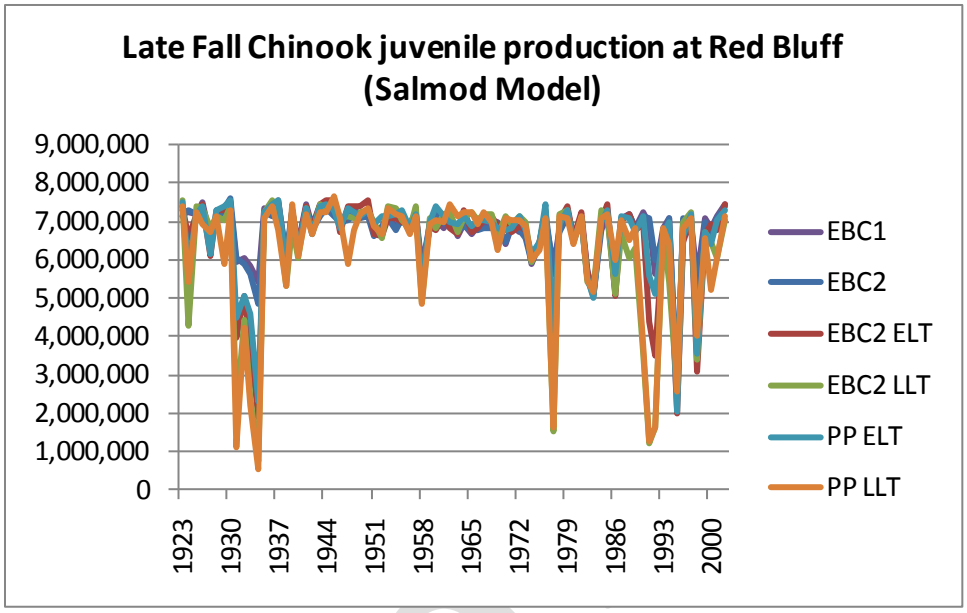

Figure C.5.2-75. Late Fall–Run Chinook Production at Red Bluff Diversion Dam (SALMOD Model)

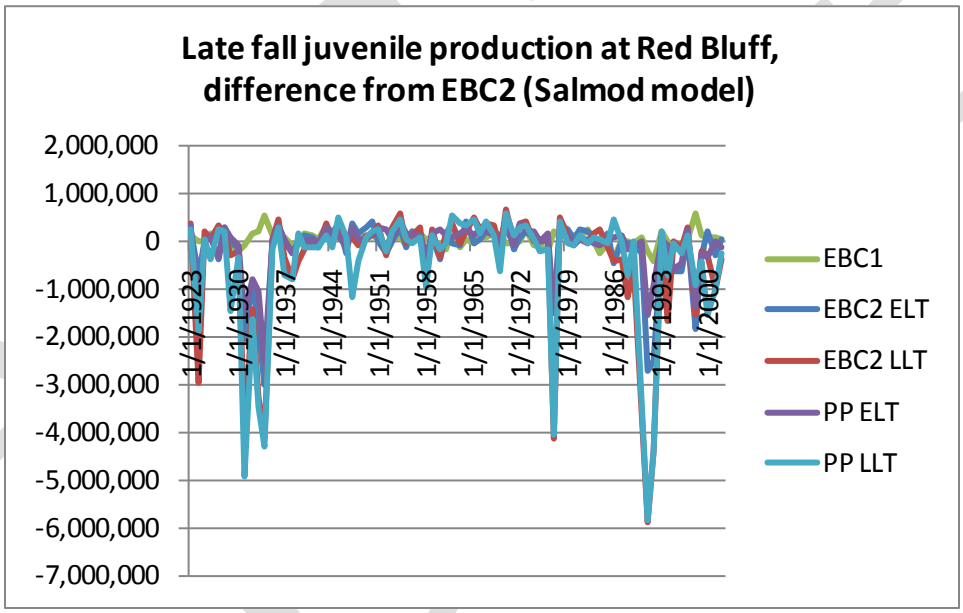

Figure C.5.2-76. Difference in Late Fall–Run Chinook Salmon Production at Red Bluff Diversion Dam (SALMOD Model)

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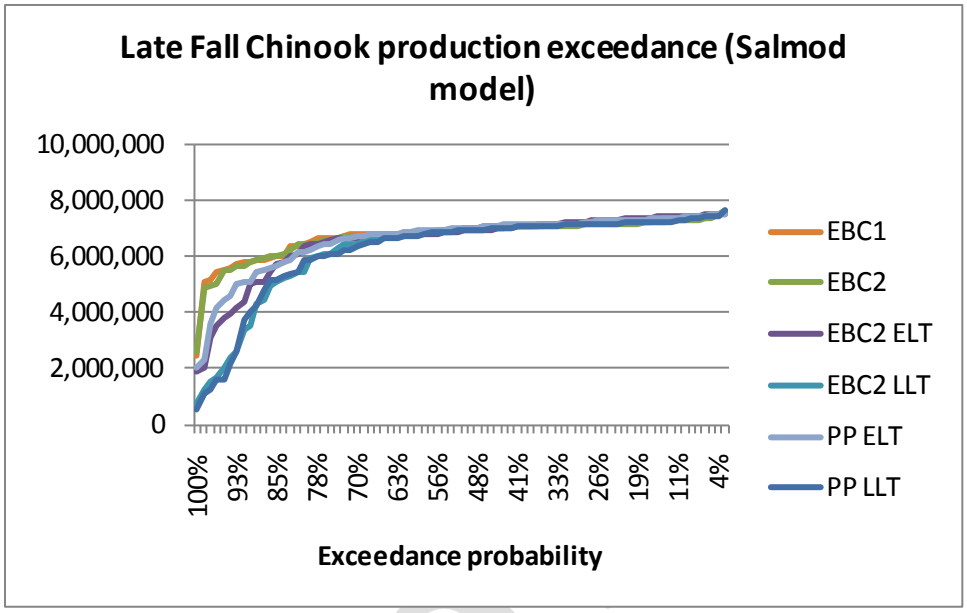

Figure C.5.2-77. Late Fall–Run Chinook Production Exceedance (SALMOD Model)

Late fall–run Chinook spawn during the winter when water temperatures are generally suitable for egg incubation. Juvenile rearing occurs during the spring as temperatures warm. Average monthly simulated water temperatures for the upper Sacramento River were compiled from the 82-year CALSIM simulation period. The frequency of months during the late fall–run egg incubation period (February–May) exceeding 56°F and the frequency of months during the juvenile rearing period (year-round) exceeding 65°F were compiled. Results of the analysis for egg incubation and juvenile rearing are summarized in Table C.5.2-27 (egg incubation) and Table C.5.2-7 (juvenile rearing). Results of these analyses show that water temperatures are seasonally cool during the February through May egg incubation period in the upper reaches of the Sacramento River. Water temperatures increased during the spring months with the greatest increases occurring at locations further downstream of Keswick Dam. Late spawning Chinook salmon that used habitat further downstream may experience additional egg mortality depending on the rate of embryonic development and emergence of fry. Water temperatures in the upper reaches of the Sacramento River were typically suitable for juvenile rearing (less than 65°F) in most years (Table C.5.2-7). The number of years with water temperatures exceeding 65°F was comparable or lower for BDCP operations when compared to EBC2 in the early and late long-term. The frequency of years having higher temperatures increased as a function of distance downstream of Keswick Dam and as a function of future climate change. These differences, however, were independent of BDCP operations.

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Table C.5.2-27. Summary of the Frequency of Water Temperatures in the Sacramento River that Exceeded 56°F during the February through May Late Fall–Run Chinook Salmon Egg Incubation Period[1]

	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
Sacramento River at Keswick Dam						
Number of years with one or more exceedances	0	0	0	0	0	0
Number of years with two exceedances	0	0	0	0	0	0
Number of years with three exceedances	0	0	0	0	0	0
Number of years with four exceedances	0	0	0	0	0	0
Number of years with five or more exceedances	0	0	0	0	0	0
Number of consecutive years with one or more exceedances	0	0	0	0	0	0
Sacramento River at Ball's Ferry						
Number of years with one or more exceedances	3	4	9	19	9	18
Number of years with two exceedances	0	0	0	2	0	3
Number of years with three exceedances	0	0	0	0	0	0
Number of years with four exceedances	0	0	0	0	0	0
Number of years with five or more exceedances	0	0	0	0	0	0
Number of consecutive years with one or more exceedances	0	2	4	10	6	11
Sacramento River at Jelly's Ferry						
Number of years with one or more exceedances	11	12	33	53	24	44
Number of years with two exceedances	0	0	2	7	2	5
Number of years with three exceedances	0	0	0	0	0	0
Number of years with four exceedances	0	0	0	0	0	0
Number of years with five or more exceedances	0	0	0	0	0	0
Number of consecutive years with one or more exceedances	9	9	21	44	14	29
Sacramento River at Bend Bridge						
Number of years with one or more exceedances	16	18	40	64	35	52
Number of years with two exceedances	1	1	2	12	2	10
Number of years with three exceedances	0	0	0	0	0	0
Number of years with four exceedances	0	0	0	0	0	0
Number of years with five or more exceedances	0	0	0	0	0	0
Number of consecutive years with one or more exceedances	10	10	32	62	28	45

[1] Time period analyzed: February 1922 to May 2003. Analysis counted monthly exceedances above 56°F.

SALMOD results for late fall-run Chinook salmon temperature-related smolt mortality are presented in Figure C.5.2-78 and Figure C.5.2-79. Temperature-related mortality is predicted to be lowest under EBC1 and EBC2 and highest under EBC2_LLT and PP_LLT. There are effects of the preliminary proposal predicted in either the ELT or LLT implementation periods. These results indicate that temperature-related mortality increases are a result of future climate change and not the preliminary proposal.

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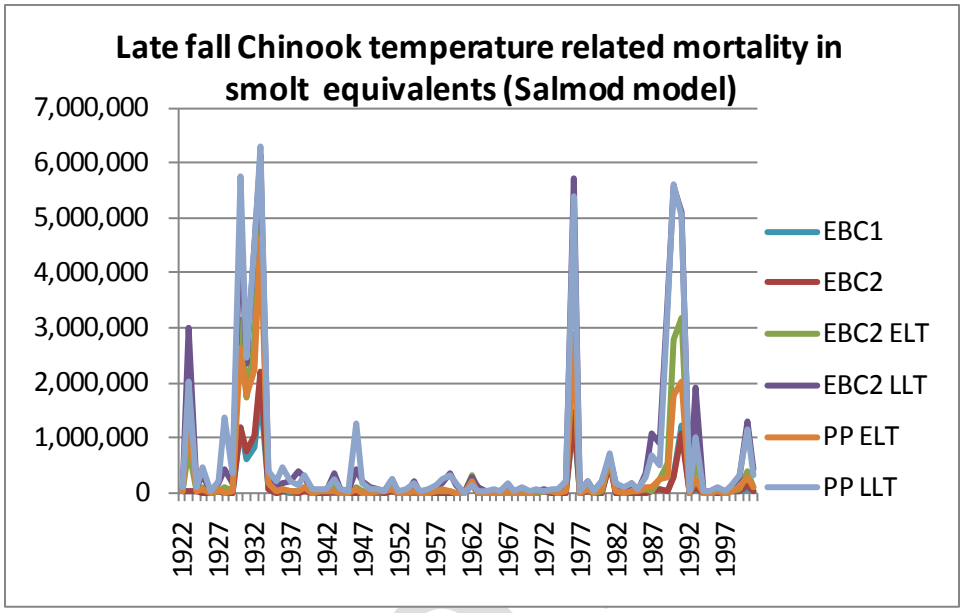

Figure C.5.2-78. Late Fall–Run Chinook Temperature-Related Mortality (SALMOD Model)

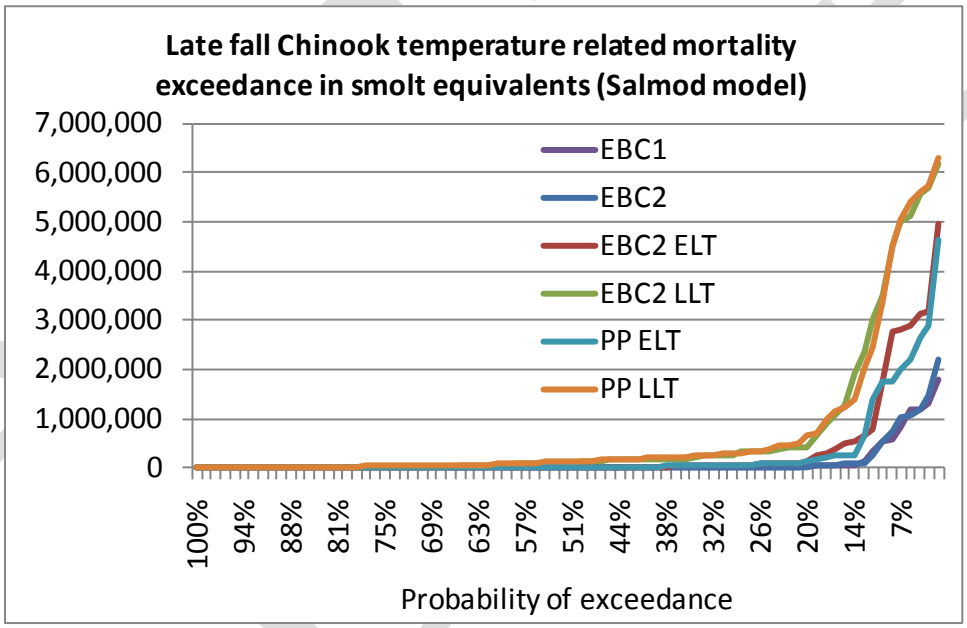

Figure C.5.2-79. Late Fall–Run Chinook Temperature-Related Mortality Exceedance (SALMOD Model)

SALMOD results for late fall-run Chinook salmon habitat-related smolt mortality are presented in Figure C.5.2-80 and Figure C.5.2-81. Habitat-related mortality is predicted to be large in most years but differs very little among model scenarios. This is likely due to the relatively flat WUA versus flow curves for Chinook salmon (Gard 2005). Temperature-related mortality is predicted to overshadow habitat-related mortality in the years of high temperature-related mortality, when reservoir storage is likely to be low.

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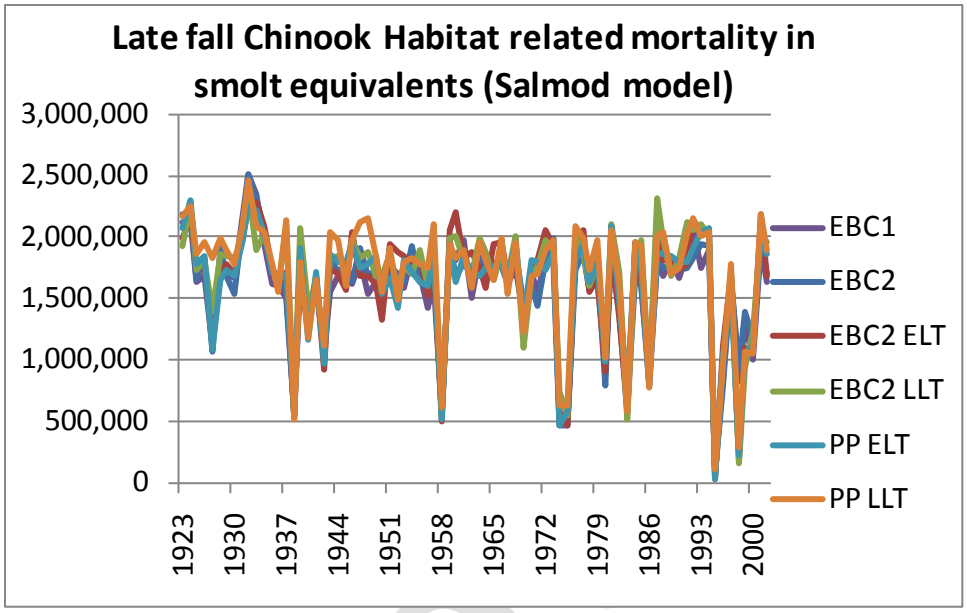

Figure C.5.2-80. Late Fall–Run Chinook Habitat-Related Mortality (SALMOD Model)

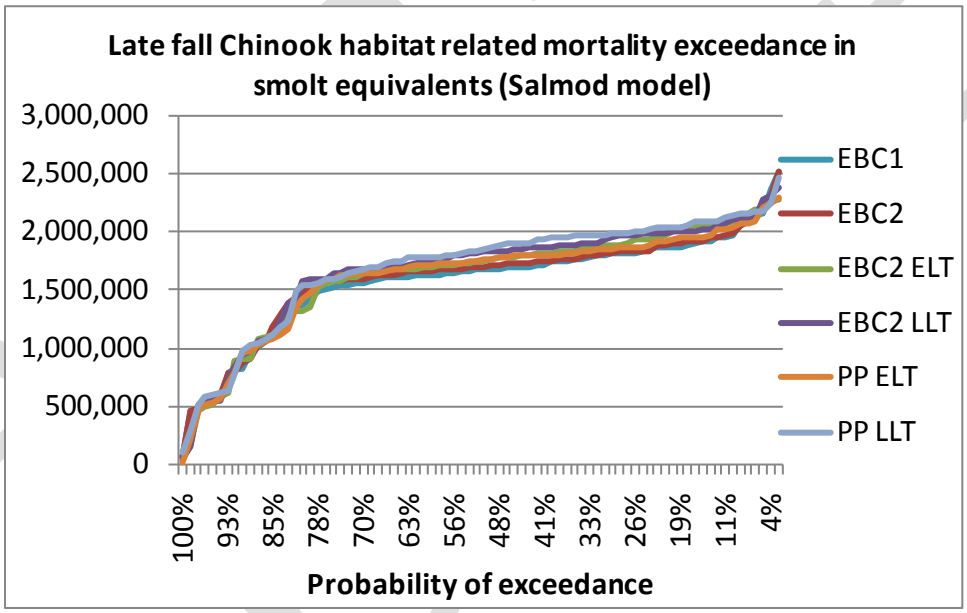

Figure C.5.2-81. Late Fall–Run Chinook Habitat-Related Mortality Exceedance (SALMOD Model)

Rearing habitat conditions for juvenile late fall–run Chinook salmon in the mainstem Sacramento River were also evaluated using SacEFT. SacEFT classifies juvenile rearing habitat as good in 45% of years under both EBC1 and EBC2 (Table C.5.2-24). During the early long-term period, the percentage of years having good juvenile rearing habitat conditions is predicted to be 57% under EBC2_ELT and 46% under PP_ELT, a reduction of 11% due to the preliminary proposal. During the late long-term period, the percentage of years having good juvenile rearing habitat conditions is predicted to be 63% under EBC2_LLT and 37% under PP_LLT, a reduction of 26% due to the preliminary proposal. Reducing the percentage of years with good juvenile rearing conditions is expected to contribute to a reduction in rearing habitat quantity, quality, and availability for juvenile late fall–run Chinook salmon due to the preliminary proposal.

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SacEFT also assessed the risk of stranding of juvenile late fall–run Chinook salmon resulting from rapid flow reductions. Good conditions (reduced risk of stranding) according SacEFT are predicted to occur in 72% and 68% of years under EBC1 and EBC2, respectively. During the early long-term period, the percentage of years that are classified as having good juvenile stranding conditions was 60% under EBC2_ELT and 57% under PP_ELT. During the late long-term period, the percentage of years with good juvenile stranding conditions was 46% under both EBC2_LLT and PP_LLT. These results indicate that there is a negligible effect of the preliminary proposal on late fall-run juvenile stranding conditions in the upper Sacramento River.

Adult

Water Temperature

Sacramento River water temperatures during the fall-run (September–October; Figure C.5.2-23 and Figure C.5.2-24) and late fall–run (December–February; Figure C.5.2-15, Figure C.5.2-16, and Figure C.5.2-26) adult migration periods have been historically cool (i.e., <65°F). Conditions for adult migration are generally expected to be suitable under all EBC1, EBC2, and PP scenarios.

C.5.2.1.5 Splittail

Because most splittail are only upstream in the Sacramento River from February through June for spawning and rearing, and there is high overlap among all lifestages during this period, this analysis combines all lifestages together. Important distinctions among life stages are discussed where necessary.

Spawning and Rearing Habitat

Inundated floodplain habitat is the most important habitat for splittail spawning and rearing because splittail population dynamics are largely driven by floodplain spawning in wet years, when this habitat is most available. Effects of the preliminary proposal on this habitat are described below in Section C.6.4, *Delta Habitat (Plan Area) Results*. Splittail spawning and larval and juvenile rearing also occur in channel margin and side-channel habitat upstream of the Delta. These habitats are likely to be especially important during dry years, when flows are too low to inundate the floodplains (Sommer et al. 2007). In recent years, splittail have been found upstream as far as the RBDD in the Sacramento River. Backwater location was the only habitat factor that rearing splittail were found to select in upstream locations (Feyrer et al. 2005). An unknown, but likely relatively small, fraction of Sacramento River juveniles migrate upstream to rear through the summer, fall and winter in off-channel habitats in the upper Sacramento River. These fish migrate to the Delta and Suisun Marsh the following spring (Moyle et al. 2004; Feyrer et al. 2005).

Side-channel habitats are affected by changes in flow because greater flows cause more flooding, thereby increasing availability of such habitat, and because rapid reductions in flow dewater the habitats, potentially stranding splittail eggs and rearing larvae. Effects of the BDCP on flows in years with low-flows are expected to be most important to the splittail population because in years of high-flows, when most production comes from floodplain habitats, the upstream side-channel habitats contribute relatively little production. Simulated flows in the Sacramento River at Wilkins Slough were used to investigate the potential effects of BDCP operations on side channel habitat availability on the mainstem Sacramento River. This analysis was limited to flows during February through June because these are the most important months for splittail spawning and larval and

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juvenile rearing and the months in which splittail are most likely to be upstream in the Sacramento River.

Monthly average flows during February through June by water-year type are presented in Table C.5.2-28 and differences between pairs of model scenarios are presented in

Table C.5.2-29. A probability of exceedance plot is presented in Figure C.5.2-82. Results show that, during February through April, there is generally little difference (<5%) in flows between EBC2_ELT and PP_ELT and between EBC2_LLT and PP_LLT in the drier water-year types (below-normal, dry, and critical) when splittail are most likely to use side channel habitat in the Sacramento River. May flows in below-normal, dry, and critical years are 4%–19% higher under PP_ELT and PP_LLT relative to EBC2_ELT and EBC2_LLT, respectively, due to increased releases at Keswick. June flows in below-normal and dry years are 6%–10% higher under PP_ELT and PP_LLT relative to EBC2_ELT and EBC2_LLT, respectively, but are similar in critical years between EBC2_ELT and PP_ELT and between EBC2_LLT and PP_LLT. These results indicate that similar amounts of side channel habitat are available for splittail spawning and rearing in the Sacramento River under the preliminary proposal relative to existing conditions during February through April, and there is a small increase in available side channel habitat with the preliminary proposal in May and June.

Table C.5.2-28. Mean Monthly Flows (Cubic Feet per Second) in the Sacramento River at Wilkins Slough, February through June

Month	Water-Year Type	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
Feb	W	20,039	19,993	20,153	20,235	20,181	20,259
	AN	19,332	19,264	19,342	19,332	19,943	19,390
	BN	14,659	14,508	14,659	14,476	14,881	14,800
	D	11,552	11,624	11,508	11,544	11,549	11,721
	C	8,574	8,595	8,335	8,303	8,310	8,537
	AVG	15,476	15,445	15,469	15,466	15,609	15,610
Mar	W	18,336	18,386	18,463	18,473	18,464	18,532
	AN	17,853	17,804	17,824	17,743	17,923	17,830
	BN	12,365	12,173	11,681	11,712	12,147	12,230
	D	11,469	11,511	11,414	11,322	11,353	11,527
	C	8,291	8,474	8,404	8,380	8,611	8,641
	AVG	14,269	14,280	14,192	14,165	14,303	14,368
Apr	W	14,570	14,571	14,496	14,313	14,551	14,341
	AN	11,566	11,489	11,341	11,102	11,429	11,698
	BN	8,545	8,395	8,169	8,240	8,668	8,940
	D	6,763	6,631	6,516	6,551	6,836	7,314
	C	5,768	5,728	5,745	5,951	5,744	6,105
	AVG	10,100	10,028	9,922	9,879	10,107	10,284
May	W	11,724	11,607	10,716	9,712	10,887	10,387
	AN	8,521	8,452	8,195	8,726	9,153	9,755
	BN	6,995	6,780	6,343	6,241	7,182	7,212
	D	5,995	5,833	5,784	6,427	6,663	7,634
	C	5,342	5,288	5,515	5,908	5,819	6,157
	AVG	8,256	8,129	7,757	7,697	8,332	8,529

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Month	Water-Year Type	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
Jun	W	8,509	8,435	8,230	8,423	8,879	9,837
	AN	7,793	7,896	7,987	8,595	9,032	10,262
	BN	7,241	7,259	7,209	7,636	7,904	8,180
	D	7,289	7,348	7,645	8,162	8,135	8,685
	C	7,137	7,356	7,782	8,305	7,625	8,450
	AVG	7,719	7,759	7,826	8,239	8,388	9,160

Table C.5.2-29. Difference (Percent Difference) between Pairs of Model Scenarios in Mean Monthly Flows in the Sacramento River at Wilkins Slough, February through June

Month	WY Type	EBC1 vs. PP_ELT	EBC1 vs. PP_LLT	EBC2 vs. PP_ELT	EBC2 vs. PP_LLT	EBC2_ELT vs. PP_ELT	EBC2_LLT vs. PP_LLT
Feb	W	142 (0.7%)	219 (1.1%)	188 (0.9%)	266 (1.3%)	28 (0.1%)	24 (0.1%)
	AN	611 (3.2%)	58 (0.3%)	679 (3.5%)	127 (0.7%)	601 (3.1%)	58 (0.3%)
	BN	222 (1.5%)	140 (1%)	374 (2.6%)	292 (2%)	222 (1.5%)	324 (2.2%)
	D	-3 (0%)	170 (1.5%)	-74 (-0.6%)	98 (0.8%)	41 (0.4%)	177 (1.5%)
	C	-263 (-3.1%)	-36 (-0.4%)	-284 (-3.3%)	-57 (-0.7%)	-25 (-0.3%)	234 (2.8%)
	AVG	133 (0.9%)	134 (0.9%)	165 (1.1%)	166 (1.1%)	140 (0.9%)	145 (0.9%)
Mar	W	127 (0.7%)	196 (1.1%)	78 (0.4%)	147 (0.8%)	0 (0%)	59 (0.3%)
	AN	70 (0.4%)	-23 (-0.1%)	120 (0.7%)	27 (0.1%)	100 (0.6%)	87 (0.5%)
	BN	-219 (-1.8%)	-136 (-1.1%)	-27 (-0.2%)	57 (0.5%)	466 (4%)	518 (4.4%)
	D	-116 (-1%)	58 (0.5%)	-158 (-1.4%)	16 (0.1%)	-61 (-0.5%)	205 (1.8%)
	C	320 (3.9%)	350 (4.2%)	138 (1.6%)	167 (2%)	207 (2.5%)	261 (3.1%)
	AVG	35 (0.2%)	100 (0.7%)	23 (0.2%)	88 (0.6%)	111 (0.8%)	203 (1.4%)
Apr	W	-19 (-0.1%)	-229 (-1.6%)	-20 (-0.1%)	-229 (-1.6%)	55 (0.4%)	29 (0.2%)
	AN	-137 (-1.2%)	132 (1.1%)	-60 (-0.5%)	209 (1.8%)	87 (0.8%)	596 (5.4%)
	BN	123 (1.4%)	395 (4.6%)	273 (3.2%)	545 (6.5%)	499 (6.1%)	700 (8.5%)
	D	73 (1.1%)	551 (8.2%)	205 (3.1%)	683 (10.3%)	320 (4.9%)	763 (11.6%)
	C	-24 (-0.4%)	337 (5.8%)	16 (0.3%)	377 (6.6%)	-1 (0%)	154 (2.6%)
	AVG	7 (0.1%)	185 (1.8%)	79 (0.8%)	256 (2.6%)	186 (1.9%)	406 (4.1%)
May	W	-837 (-7.1%)	-1337 (-11.4%)	-720 (-6.2%)	-1220 (-10.5%)	172 (1.6%)	676 (7%)
	AN	633 (7.4%)	1234 (14.5%)	701 (8.3%)	1303 (15.4%)	958 (11.7%)	1029 (11.8%)
	BN	186 (2.7%)	216 (3.1%)	402 (5.9%)	432 (6.4%)	838 (13.2%)	970 (15.5%)
	D	668 (11.1%)	1639 (27.3%)	830 (14.2%)	1801 (30.9%)	879 (15.2%)	1208 (18.8%)
	C	478 (8.9%)	816 (15.3%)	532 (10.1%)	870 (16.4%)	305 (5.5%)	249 (4.2%)
	AVG	76 (0.9%)	273 (3.3%)	203 (2.5%)	400 (4.9%)	575 (7.4%)	832 (10.8%)
Jun	W	371 (4.4%)	1329 (15.6%)	445 (5.3%)	1403 (16.6%)	649 (7.9%)	1414 (16.8%)
	AN	1239 (15.9%)	2469 (31.7%)	1136 (14.4%)	2366 (30%)	1045 (13.1%)	1667 (19.4%)
	BN	663 (9.2%)	939 (13%)	645 (8.9%)	921 (12.7%)	695 (9.6%)	544 (7.1%)
	D	846 (11.6%)	1396 (19.1%)	787 (10.7%)	1337 (18.2%)	490 (6.4%)	522 (6.4%)
	C	488 (6.8%)	1313 (18.4%)	269 (3.7%)	1094 (14.9%)	-156 (-2%)	145 (1.8%)
	AVG	669 (8.7%)	1441 (18.7%)	629 (8.1%)	1402 (18.1%)	562 (7.2%)	921 (11.2%)

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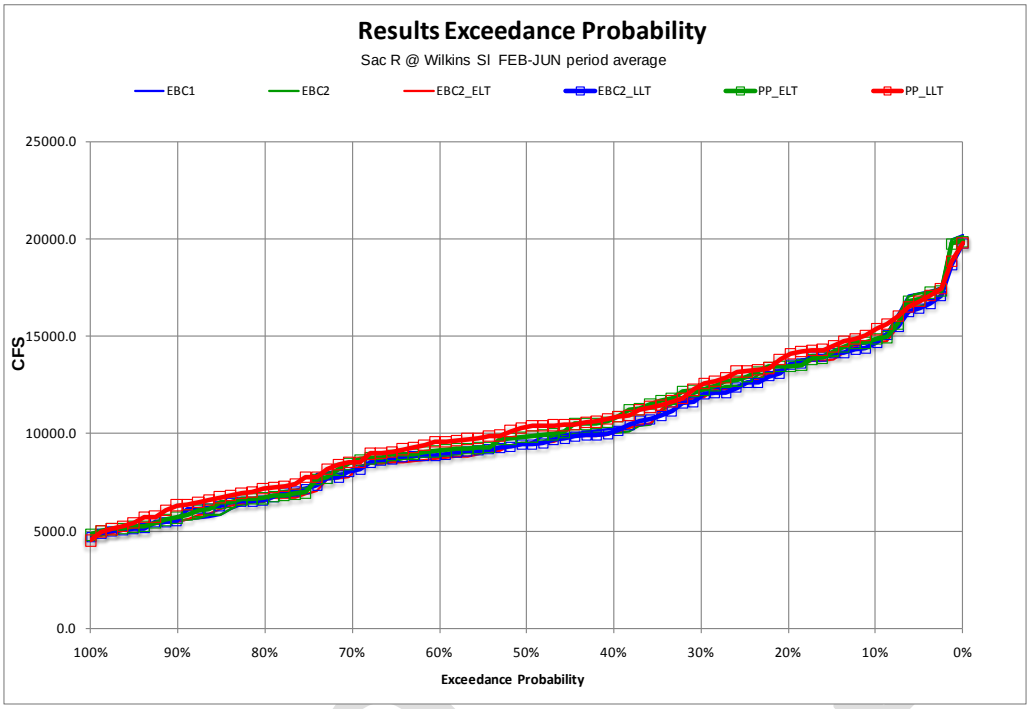

Figure C.5.2-82. Probability of Exceedance Plot for Model Scenarios of Mean Monthly Flow in the Sacramento River at Wilkins Slough, February to June

Water Temperature

Changes in flow and other factors potentially affect water temperatures in splittail upstream spawning and rearing habitat. Feyrer et al. (2005) found no evidence that temperature was an important factor in habitat selection for rearing splittail in their upstream habitats. However, if water temperatures fall outside of the tolerance range for splittail, then splittail are presumably adversely affected. Young and Cech (1996) reported a tolerance range for larval splittail of about 45°F to 90°F, with a final preferred temperature of 75°F. Based on these findings, a range of 45°F to 75°F was selected as the suitable range for rearing in the upstream habitat locations. Because no data exist regarding thermal tolerances of splittail eggs, this temperature range was also used to determine effects on eggs. Simulated daily water temperatures in the Sacramento River at Hamilton City were used to investigate the potential effects of BDCP operations on the suitability of water temperatures for splittail rearing on the mainstem Sacramento River because no SRWQM nodes are available further downstream where splittail are expected to spawn.

Table C.5.2-30 presents the percent of days from 1992–2003 during which February through June water temperatures are predicted to be below 45°F or exceed 75°F for each model scenario. Table C.5.2-31 presents the differences and percent differences between pairs of model scenarios in the percent of days predicted to be below 45°F or above 75°F. Figure C.5.2-83 presents the probability of water temperature exceedance for each model scenario. These results show that water temperatures under all scenarios would remain below 75°F in 100% of days throughout the period and above 45°F in >95% days. There are negligible (<1%) differences in the percent of days above 45°F between EBC2_ELT and PP_ELT and between EBC2_LLT and PP_LLT for any water-year type. Therefore, it is concluded that there are no temperature-related effects of the BDCP on splittail egg and larval habitat in the Sacramento River.

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Table C.5.2-30. Percent of Days during February to June[1] When Daily Average Temperatures Are Below 45°F or Exceed 75°F in the Sacramento River at Hamilton City

	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
Temperatures below 45°F						
Wet	4.6	4.7	1.8	1.1	1.8	1.1
Above Normal	4.7	4.7	1.9	0.6	1.7	0.7
Below Normal	5.1	5.1	2.6	0.8	2.4	0.8
Dry	3.0	2.9	1.6	1.0	1.6	0.9
Critical	2.1	2.2	1.0	0.4	1.0	0.5
All	4.0	4.0	1.8	0.8	1.7	0.9
Temperatures above 75°F						
Wet	0.0	0.0	0.0	0.0	0.0	0.0
Above Normal	0.0	0.0	0.0	0.0	0.0	0.0
Below Normal	0.0	0.0	0.0	0.0	0.0	0.0
Dry	0.0	0.0	0.0	0.0	0.0	0.0
Critical	0.0	0.0	0.0	0.0	0.0	0.0
All	0.0	0.0	0.0	0.0	0.0	0.0

[1] Based on the modeling period of 1922 to 2003.

Table C.5.2-31. Difference and Percent Difference in Percent of Days during February to June When Daily Average Temperature Is Below 45°F or Exceeds 75°F in the Sacramento River at Hamilton City

WY Type	Comparison[1]	EBC1 vs. PP_ELT	EBC1 vs. PP_LLT	EBC2 vs. EBC2_ELT	EBC2 vs. EBC2_LLT	EBC2 vs. PP_ELT	EBC2 vs. PP_LLT	EBC2_ELT vs. PP_ELT	EBC2_LLT vs. PP_LLT
Below 45°F									
Wet	Difference	-2.8	-3.6	-2.8	-3.6	-2.8	-3.6	-0.03	0.0
	Percent difference	-61%	-77%	-60%	-77%	-61%	-77%	-1%	0%
Above Normal	Difference	-2.9	-4.0	-2.8	-4.1	-3.0	-4.0	-0.2	0.1
	Percent difference	-63%	-86%	-60%	-87%	-64%	-86%	-9%	9%
Below Normal	Difference	-2.7	-4.3	-2.5	-4.3	-2.7	-4.3	-0.1	0.0
	Percent difference	-52%	-84%	-50%	-84%	-52%	-84%	-6%	0%
Dry	Difference	-1.3	-2.0	-1.3	-2.0	-1.3	-2.0	0.0	0.0
	Percent difference	-45%	-69%	-44%	-67%	-44%	-68%	0%	-4%
Critical	Difference	-1.1	-1.6	-1.2	-1.8	-1.2	-1.7	0.0	0.1
	Percent difference	-51%	-76%	-55%	-80%	-55%	-78%	0%	13%
All	Difference	-2.2	-3.1	-2.2	-3.2	-2.3	-3.1	-0.1	0.0
	Percent difference	-56%	-79%	-55%	-79%	-56%	-79%	-3%	1%
Above 75°F									
Wet	Difference	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Percent difference	NA	NA	NA	NA	NA	NA	NA	NA
Above Normal	Difference	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Percent difference	NA	NA	NA	NA	NA	NA	NA	NA
Below Normal	Difference	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Percent difference	NA	NA	NA	NA	NA	NA	NA	NA

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WY Type	Comparison[1]	EBC1 vs. PP_ELT	EBC1 vs. PP_LLT	EBC2 vs. EBC2_ELT	EBC2 vs. EBC2_LLT	EBC2 vs. PP_ELT	EBC2 vs. PP_LLT	EBC2_ELT vs. PP_ELT	EBC2_LLT vs. PP_LLT
Below 45°F									
Dry	Difference	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Percent difference	NA	NA	NA	NA	NA	NA	NA	NA
Critical	Difference	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Percent difference	NA	NA	NA	NA	NA	NA	NA	NA
All	Difference	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Percent difference	NA	NA	NA	NA	NA	NA	NA	NA

[1] A positive value indicates a higher value under the preliminary proposal than the EBC.
NA = Could not be calculated because dividing by 0.

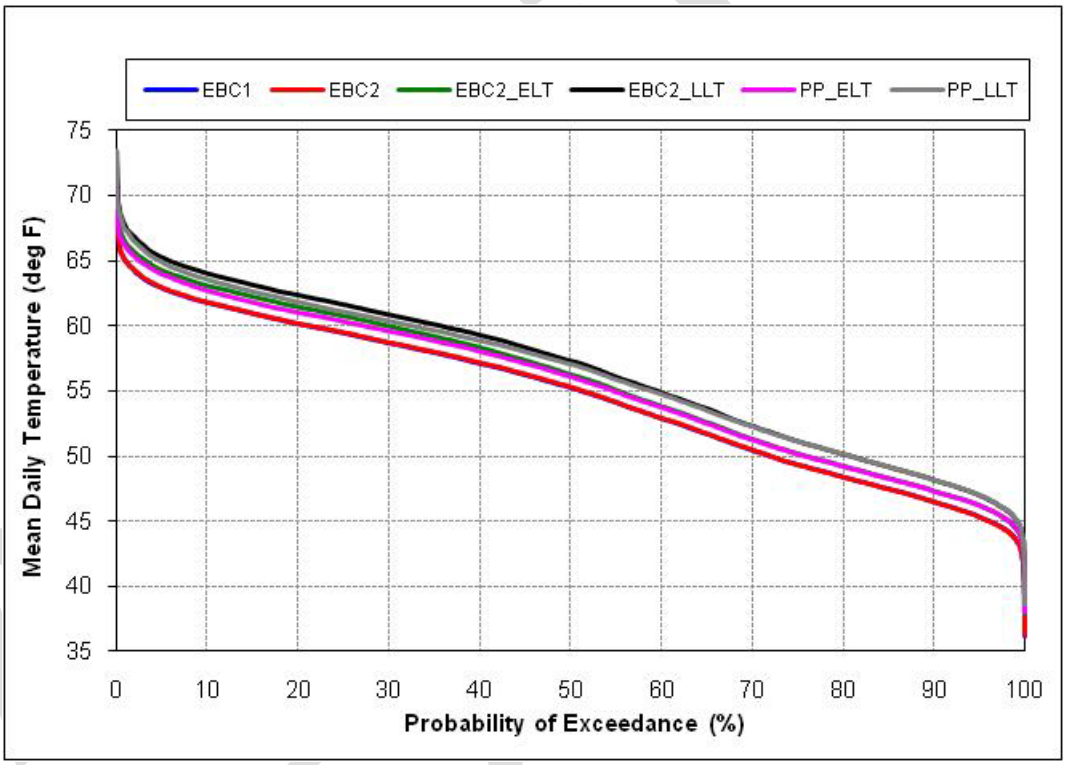

Figure C.5.2-83. Probability of Exceedance Plot for Model Scenarios of Mean Monthly Flow in the Sacramento River at Hamilton City, February through June

C.5.2.1.6 White Sturgeon

Egg/Embryo

Water Temperature

Hamilton City was selected as a surrogate for white sturgeon spawning habitat located further downstream because no SRWQM nodes are available further downstream where white sturgeon are expected to spawn. Due to variability of temperature thresholds within the literature, the analysis investigated 61°F, 68°F, and 72°F as thresholds for white sturgeon egg/embryo survival during their expanded period of potential occurrence (February through May).

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Figure C.5.2-84 to Figure C.5.2-85 display the number of days per year during which temperature thresholds would be exceeded for the thresholds of 61°F, 68°F, and 72°F for all water-year types on the Sacramento River at Hamilton City. To consider the extent of temperature variation downstream of Hamilton City, weekly average temperature from the California Department of Fish and Game Knights Landing Fish Monitoring station shows that temperatures typically remain below the 68°F threshold until late May (California Department of Fish and Game unpublished data) (Figure C.5.2-87).

Combining all water years, water temperatures at Hamilton City from February through May exceeded the 61°F threshold 8% of the time under EBC1 and EBC2, 13%–18% of the time under EBC2_ELT and EBC2_LLT, and 11%–15% of the time under PP_ELT and PP_LLT (Figure C.5.2-88 through Figure C.5.2-92, Table C.5.2-32). Among water years, the exceedance frequency ranged from 6% (wet years under EBC1 and EBC2) to 19% (below-normal years under EBC2_LLT). The higher threshold exceedances under EBC2_ELT and EBC2_LLT relative to EBC1 and EBC2 reflect the effects of climate change in the absence of BDCP implementation. BDCP implementation (scenarios PP_ELT and PP_LLT) would result in a 4%–8% increase in the frequency of water temperatures exceeding 61°F relative to EBC1 and EBC2, and a 2%–3% decrease in the frequency of water temperatures exceeding 61°F relative to EBC2_ELT and EBC2_LLT (Table C.5.2-33). The differences in threshold exceedance frequencies between PP_ELT and EBC2_ELT (-1.9%) and between PP_LLT and EBC2_LLT (-2.6%) scenarios represent project effects under similar baseline assumptions regarding climate change effects.

Combining all water years, water temperatures at Hamilton City from February through May exceeded the 68°F threshold less than 1% of the time under all modeled scenarios. Under EBC1 and EBC2, the 68°F threshold was exceeded only in wet years. Among the other scenarios, the exceedance frequency ranged from 0% in below-normal and dry years (all scenarios) to 1% in wet years (EBC2_LLT). BDCP implementation (scenarios PP_ELT and PP_LLT) would result in a <1% increase in the frequency of water temperatures exceeding 68°F relative to EBC1 and EBC2, and a <1% decrease in the frequency of water temperatures exceeding 68°F relative to EBC2_ELT and EBC2_LLT. These small differences are likely within the modeling error, indicating no detectable difference in exceedances of the 68°F threshold between the preliminary proposal and baseline conditions.

Water temperatures at Hamilton City from February through May rarely exceeded 72°F threshold under any of the modeled scenarios; this threshold was exceeded 0.1% of the time in wet and above-normal years of the EBC2_LLT scenario and in wet years of the PP_LLT scenario. These small differences are likely smaller than modeling error, suggesting that there is no detectable difference in exceedances of the 72°F threshold between EBC1, EBC2, and PP conditions.

The findings of this analysis suggest that climate change will negatively affect white sturgeon egg survival in the Sacramento River, but the preliminary proposal will have negligible effects.

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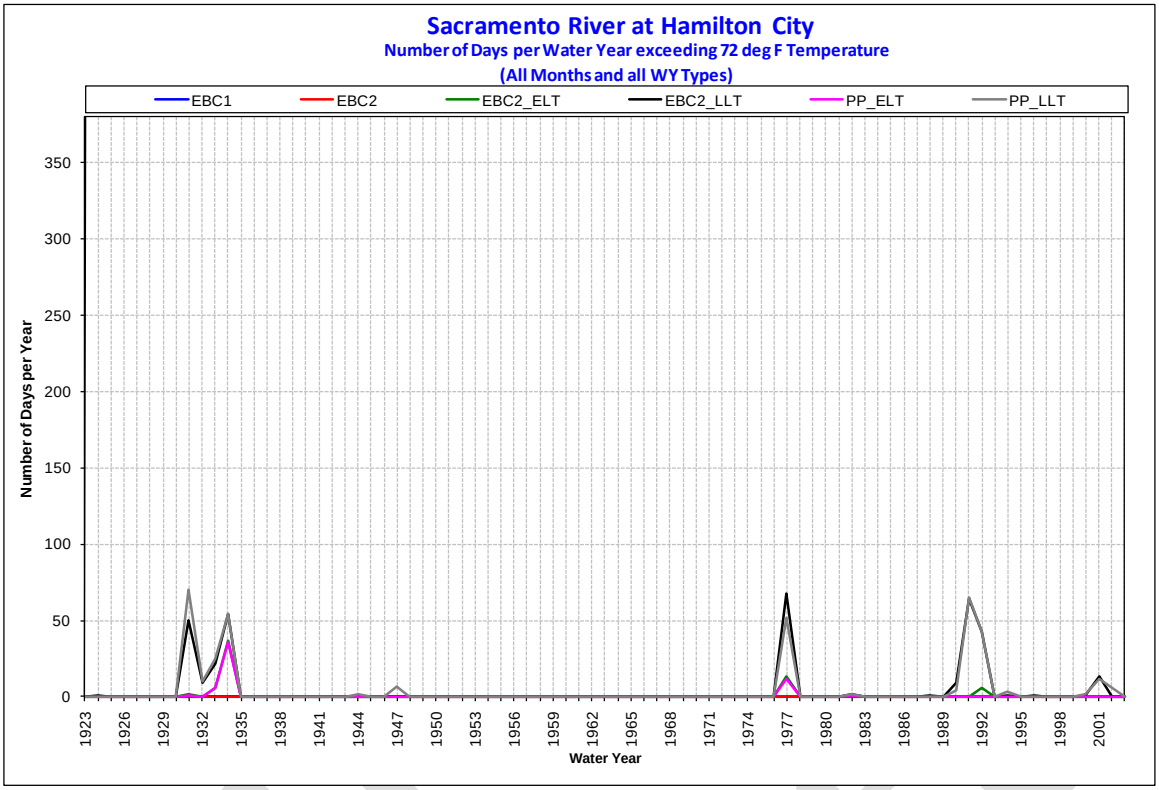

Figure C.5.2-84. Sacramento River Water Temperatures Exceeding 72°F at Hamilton City

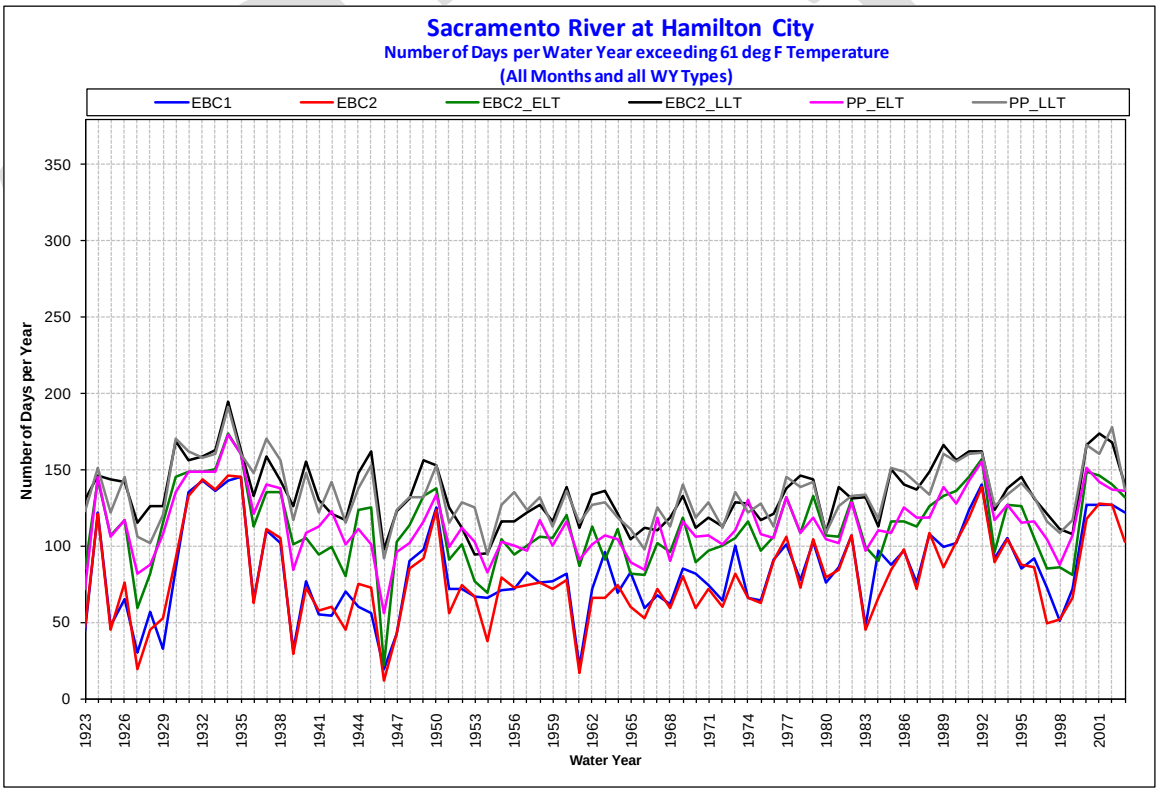

Figure C.5.2-85. Sacramento River Water Temperatures Exceeding 61°F at Hamilton City

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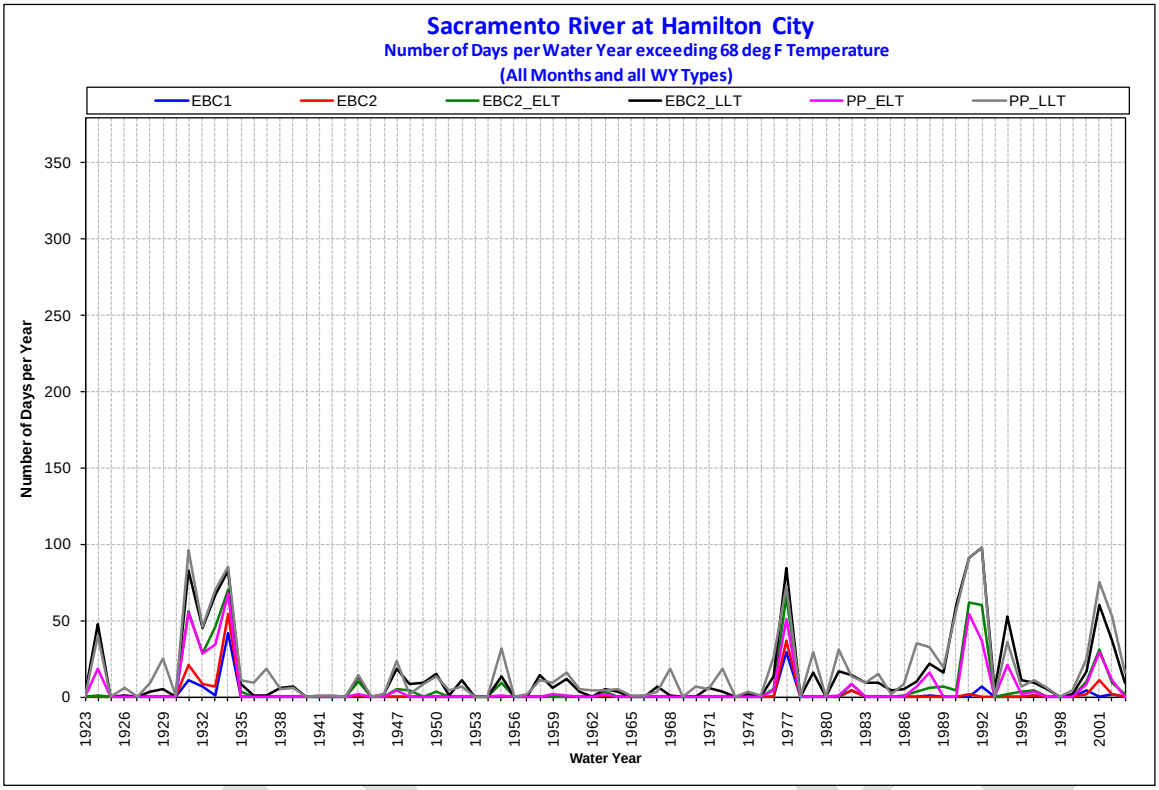
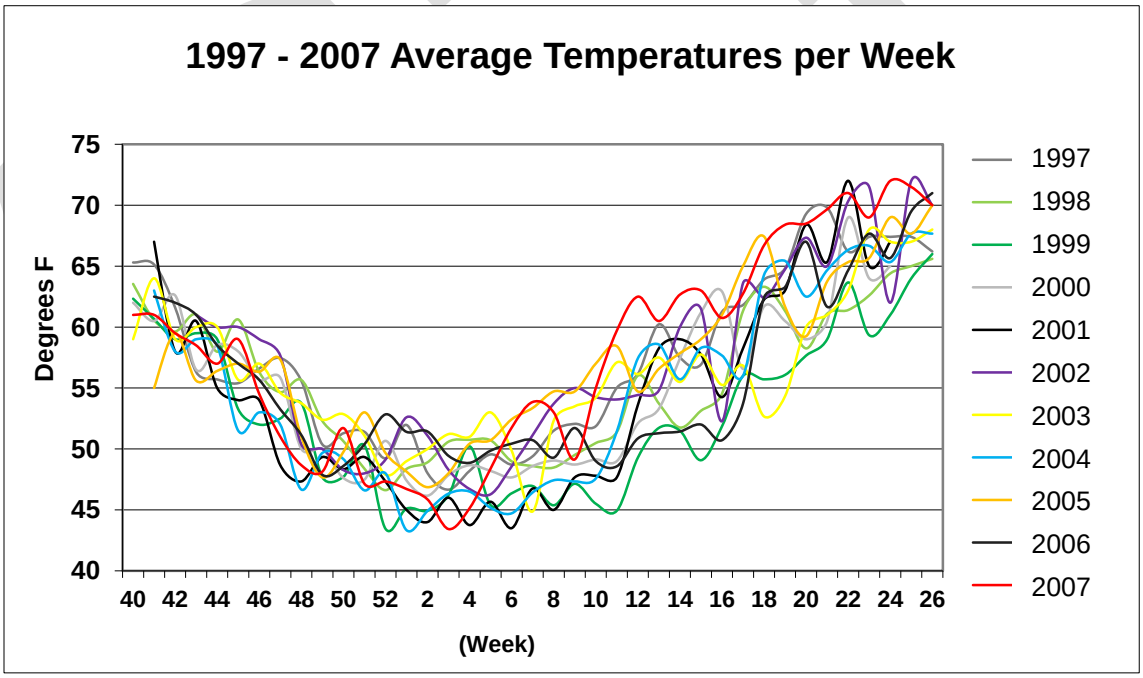


Figure C.5.2-86. Sacramento River Water Temperatures Exceeding 68°F at Hamilton City



Source: California Department of Fish and Game unpublished data.

Figure C.5.2-87. Knights Landing Fish Monitoring Station Average Weekly Temperatures, 1997–2007

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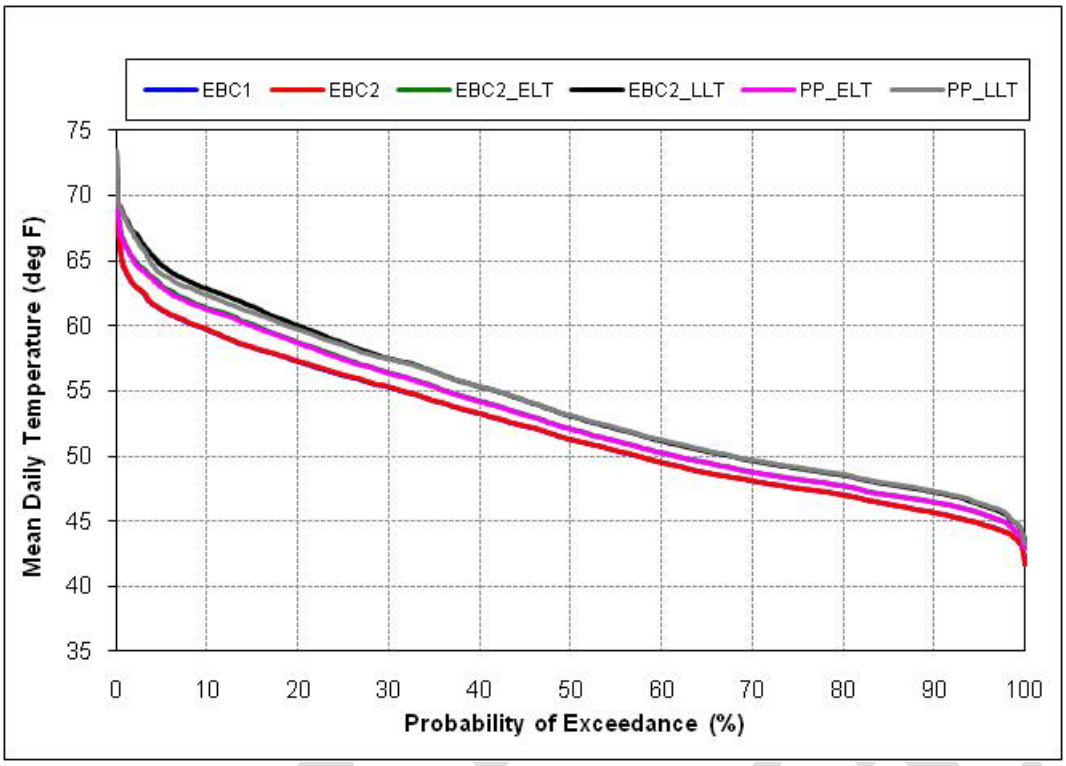

Figure C.5.2-88. Probability of Exceedance Plot for Model Scenarios of Mean Daily Temperature of the Sacramento River at Hamilton City in Wet Years, February through May

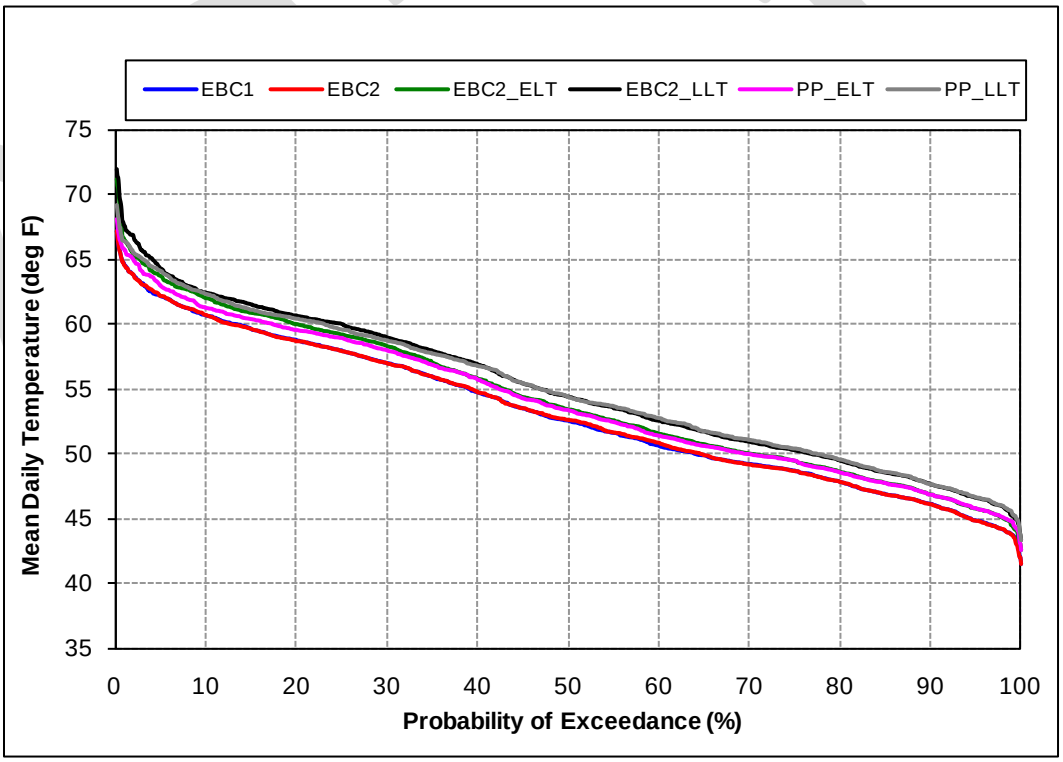

Figure C.5.2-89. Probability of Exceedance Plot for Model Scenarios of Mean Daily Temperature of the Sacramento River at Hamilton City in Above-Normal Years, February through May

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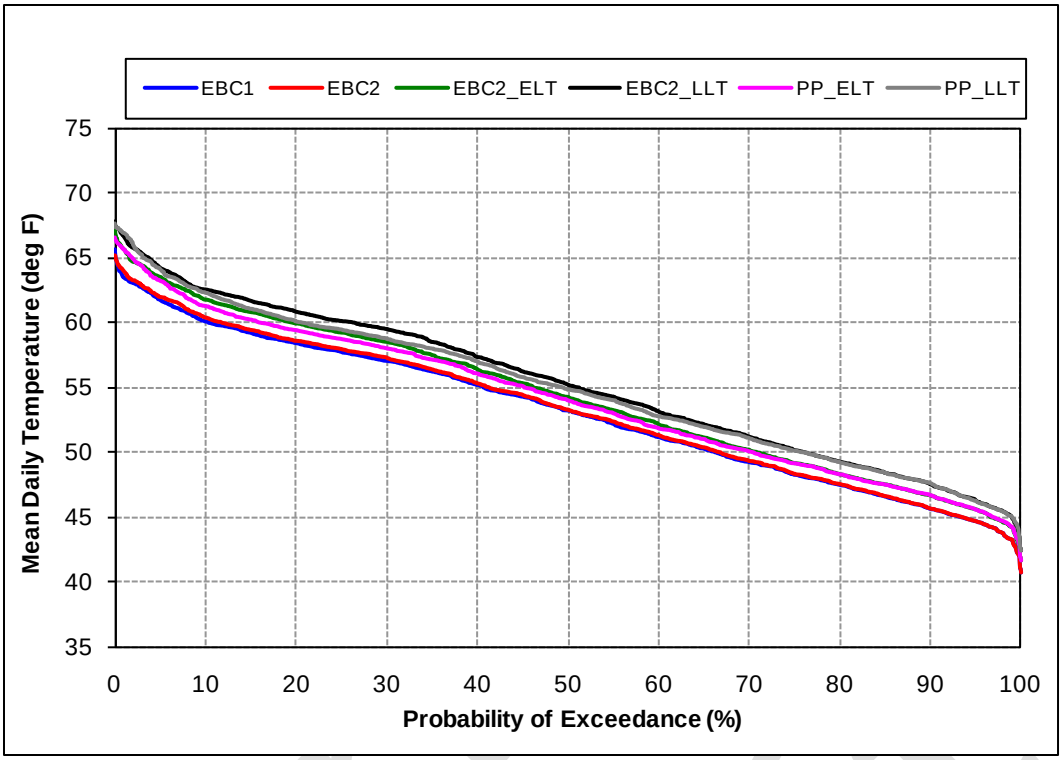

Figure C.5.2-90. Probability of Exceedance Plot for Model Scenarios of Mean Daily Temperature of the Sacramento River at Hamilton City in Below-Normal Years, February through May

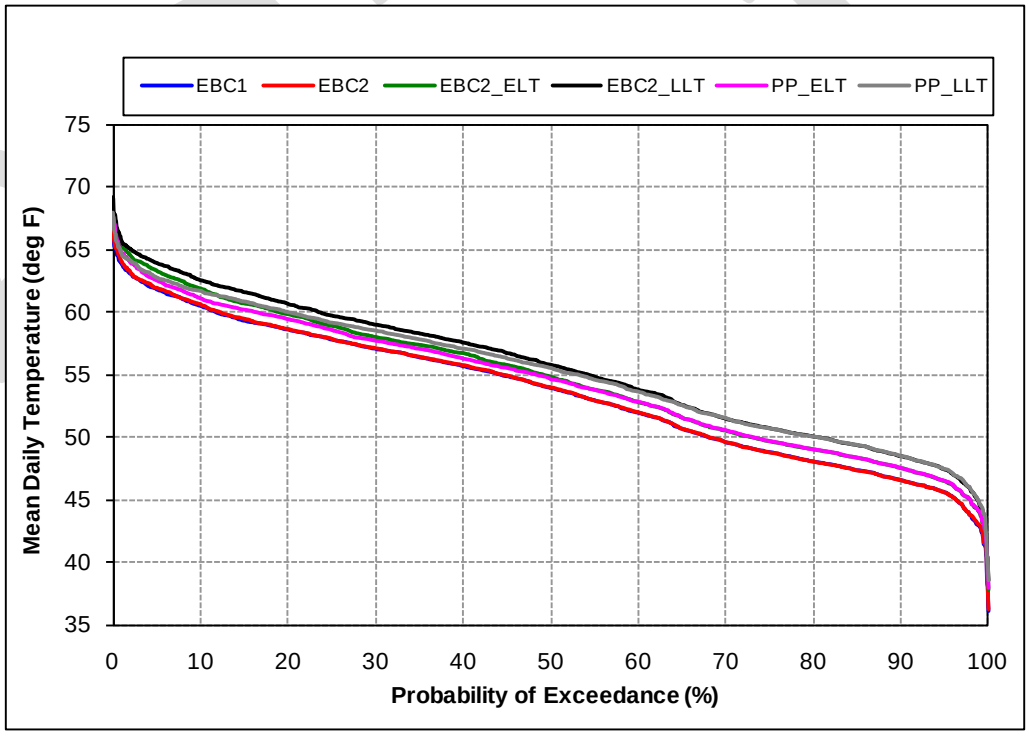

Figure C.5.2-91. Probability of Exceedance Plot for Model Scenarios of Mean Daily Temperature of the Sacramento River at Hamilton City in Dry Years, February through May

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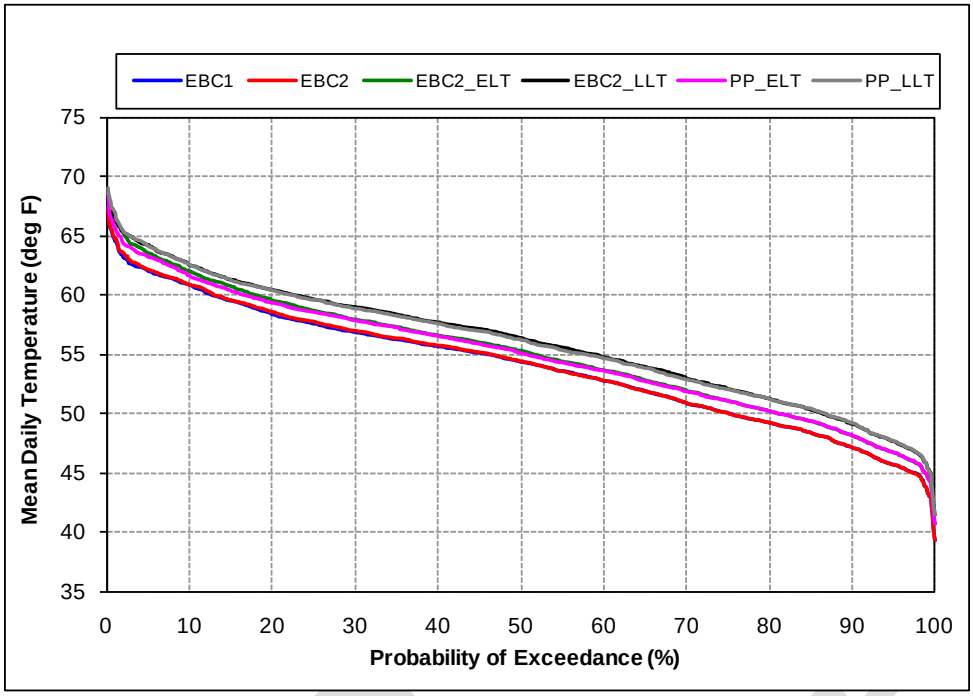

Figure C.5.2-92. Probability of Exceedance Plot for Model Scenarios of Mean Daily Temperature of the Sacramento River at Hamilton City in Critical Years, February through May

Table C.5.2-32. Percent of Days During the Months February to May[1] When Daily Average Temperature Exceeds 61°F, 68°F, and 72°F in the Sacramento River at Hamilton City

	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
Temperatures above 61°F						
Wet	5.6	5.7	12.1	16.5	11.3	14.9
Above Normal	9.0	9.3	14.2	18.2	11.9	15.3
Below Normal	7.6	8.1	13.7	19.2	11.2	15.9
Dry	8.1	8.5	13.7	18.4	10.5	14.2
Critically Dry	9.3	9.4	13.8	17.2	12.5	16.0
All	7.6	7.8	13.3	17.7	11.4	15.1
Temperatures above 68°F						
Wet	0.2	0.2	0.4	1.3	0.3	1.1
Above Normal	0.0	0.0	0.5	0.6	0.1	0.2
Below Normal	0.0	0.0	0.0	0.0	0.0	0.0
Dry	0.0	0.0	0.0	0.1	0.0	0.0
Critically Dry	0.0	0.0	0.1	0.1	0.1	0.3
All	0.1	0.1	0.2	0.5	0.1	0.4
Temperatures above 72°F						
Wet	0.0	0.0	0.0	0.1	0.0	0.1
Above Normal	0.0	0.0	0.0	0.1	0.0	0.0
Below Normal	0.0	0.0	0.0	0.0	0.0	0.0
Dry	0.0	0.0	0.0	0.0	0.0	0.0
Critically Dry	0.0	0.0	0.0	0.0	0.0	0.0
All	0.0	0.0	0.0	0.0	0.0	0.0

[1]Based on the modeling period of 1922 to 2003.

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Table C.5.2-33. Difference and Percent Difference in the Percentage of Days During the Months February through May When Daily Average Temperature Exceeds 61°F, 68°F, and 72°F in the Sacramento River at Hamilton City

WY Type	Comparison[1]	EBC1 vs. PP_ELT	EBC1 vs. PP_LLT	EBC2 vs. EBC2_ELT	EBC2 vs. EBC2_LLT	EBC2 vs. PP_ELT	EBC2 vs. PP_LLT	EBC2_ELT vs. PP_ELT	EBC2_LLT vs. PP_LLT
Temperatures above 61°F									
Wet	Difference	5.7	9.3	6.4	10.8	5.7	9.3	-0.7	-1.6
	Percent difference	101%	165%	113%	191%	100%	163%	-6%	-10%
Above Normal	Difference	2.9	6.3	4.8	8.9	2.6	6.0	-2.3	-2.9
	Percent difference	32%	70%	52%	95%	27%	64%	-16%	-16%
Below Normal	Difference	3.6	8.3	5.6	11.0	3.1	7.7	-2.5	-3.3
	Percent difference	48%	109%	69%	136%	38%	95%	-18%	-17%
Dry	Difference	2.4	6.1	5.2	9.9	2.0	5.7	-3.2	-4.2
	Percent difference	29%	74%	61%	116%	23%	67%	-24%	-23%
Critical	Difference	3.1	6.6	4.4	7.8	3.0	6.6	-1.3	-1.2
	Percent difference	33%	71%	46%	82%	32%	70%	-10%	-7%
All	Difference	3.8	7.6	5.5	9.9	3.6	7.3	-1.9	-2.6
	Percent difference	51%	100%	70%	127%	46%	94%	-14%	-15%
Temperatures above 68°F									
Wet	Difference	0.2	0.9	0.2	1.1	0.2	0.9	0.0	-0.2
	Percent difference	100%	580%	120%	700%	100%	580%	-9%	-15%
Above Normal	Difference	0.1	0.2	0.5	0.6	0.1	0.2	-0.4	-0.4
	Percent difference	NA	NA	NA	NA	NA	NA	-86%	-67%
Below Normal	Difference	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Percent difference	NA	NA	NA	NA	NA	NA	NA	NA
Dry	Difference	0.0	0.0	0.0	0.1	0.0	0.0	0.0	-0.1
	Percent difference	NA	NA	NA	NA	NA	NA	-100%	-100%
Critical	Difference	0.1	0.3	0.1	0.1	0.1	0.3	0.0	0.2
	Percent difference	NA	NA	NA	NA	NA	NA	0%	150%
All	Difference	0.1	0.4	0.2	0.5	0.1	0.4	-0.1	-0.1
	Percent difference	160%	740%	320%	980%	160%	740%	-38%	-22%
Temperatures above 72°F									
Wet	Difference	0.0	0.1	0.0	0.1	0.0	0.1	0.0	0.0
	Percent difference	NA	NA	NA	NA	NA	NA	0%	0%
Above Normal	Difference	0.0	0.0	0.0	0.1	0.0	0.0	0.0	-0.1
	Percent difference	NA	NA	NA	NA	NA	NA	NA	-100%
Below Normal	Difference	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Percent difference	NA	NA	NA	NA	NA	NA	NA	NA
Dry	Difference	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Percent difference	NA	NA	NA	NA	NA	NA	NA	NA
Critical	Difference	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Percent difference	NA	NA	NA	NA	NA	NA	NA	NA
All	Difference	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Percent difference	NA	NA	NA	NA	NA	NA	0%	-33%

[1] A positive value indicates a higher value under the preliminary proposal than the EBC.
NA = Could not be calculated because dividing by 0.

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Seasonal Flows

An analysis of the potential changes in flow was completed using CALSIM outputs for the Sacramento River at Verona and Wilkins Slough within the February through May period of egg/embryo occurrence (Israel et al. 2009).

An exceedance plot from CALSIM of flows at Verona for the February through May period is presented in Figure C.5.2-93. Monthly mean averages for each model scenario by water-year type are presented in Figure C.5.2-94 through Figure C.5.2-98. Differences between pairs of model scenarios are presented in Table C.5.2-34.

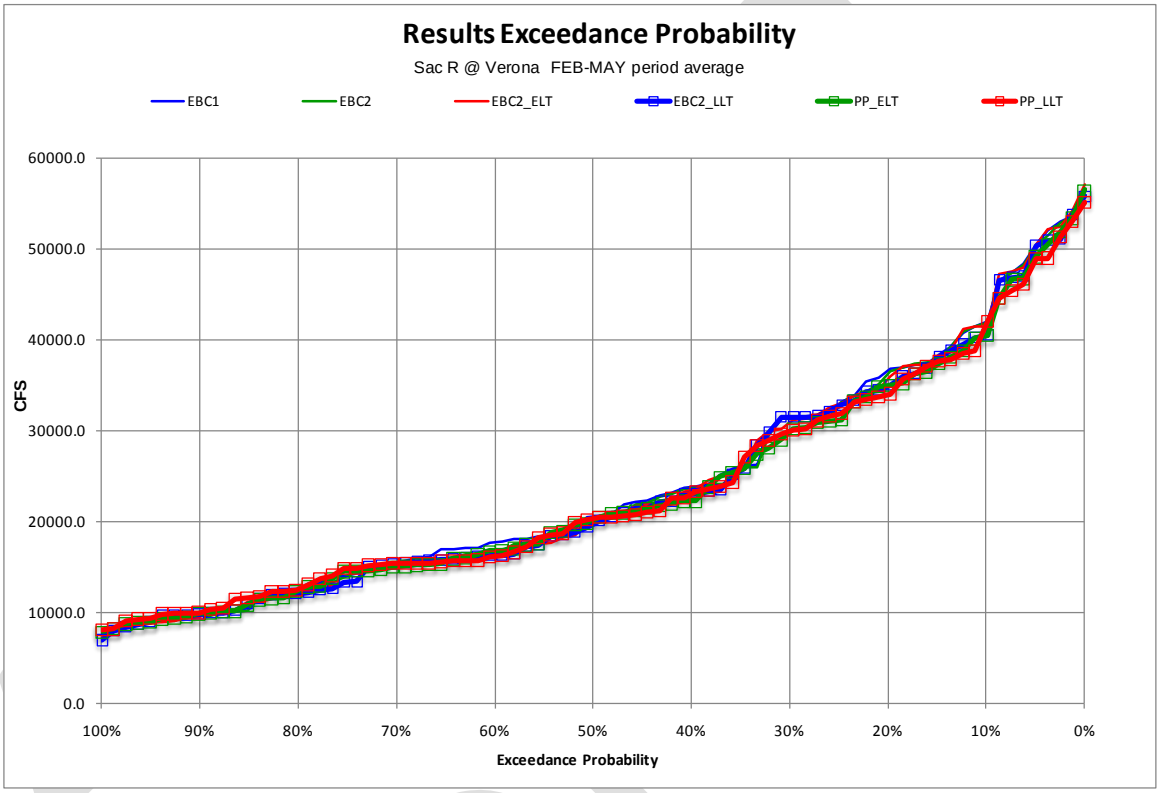

Figure C.5.2-93. Probability of Exceedance Plot for Model Scenarios of Mean Monthly Flow in the Sacramento River at Verona, February through May

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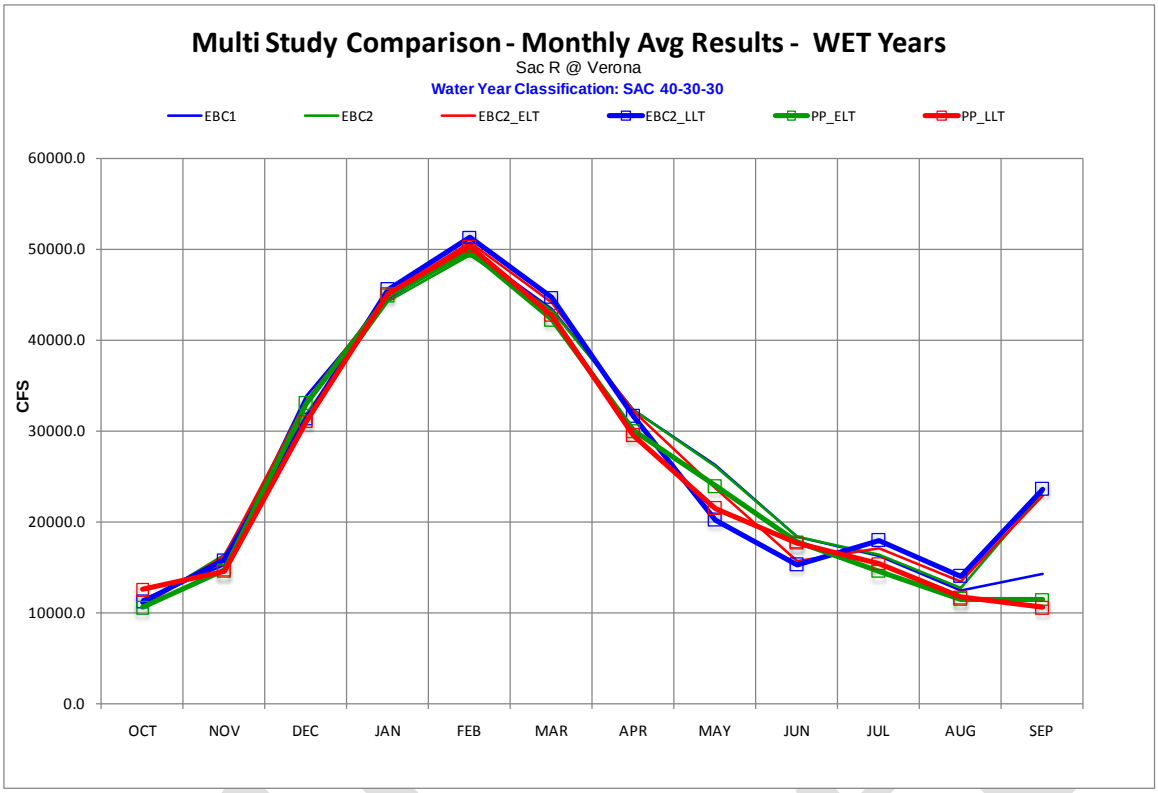

Figure C.5.2-94. Sacramento River Average Monthly Flows at Verona in Wet Years

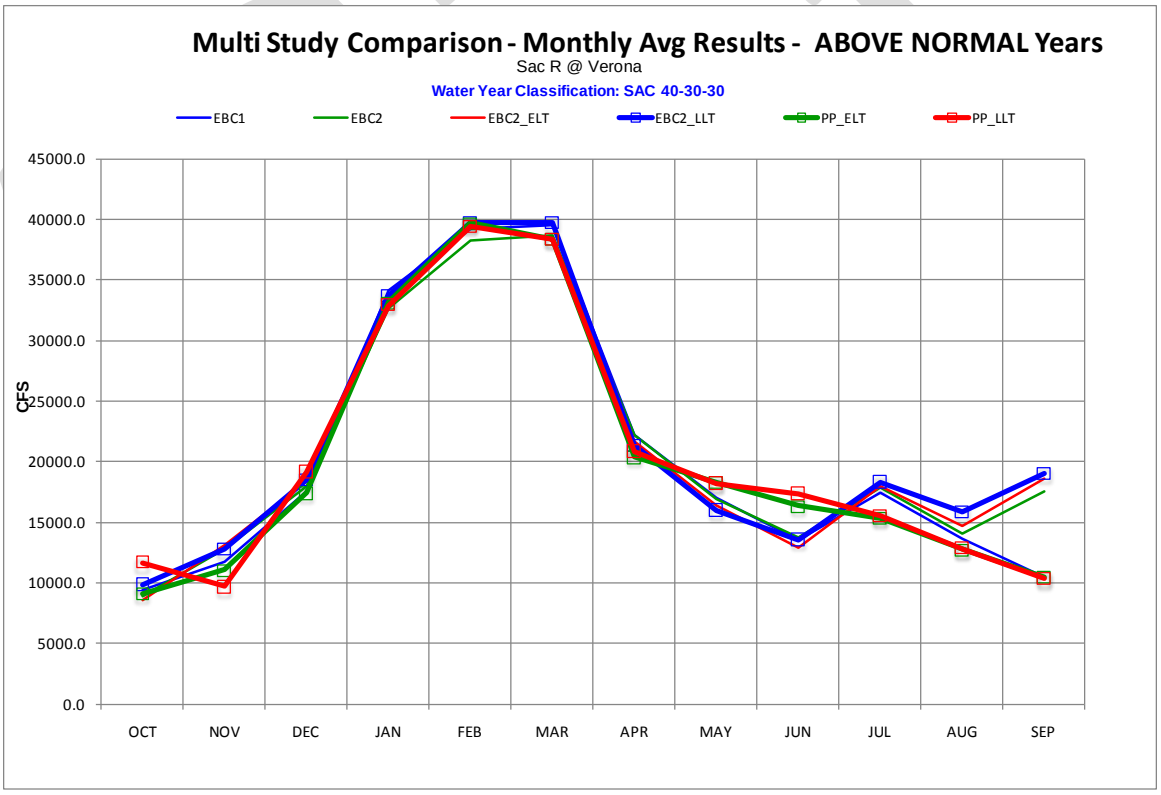

Figure C.5.2-95. Sacramento River Average Monthly Flows at Verona in Above-Normal Years

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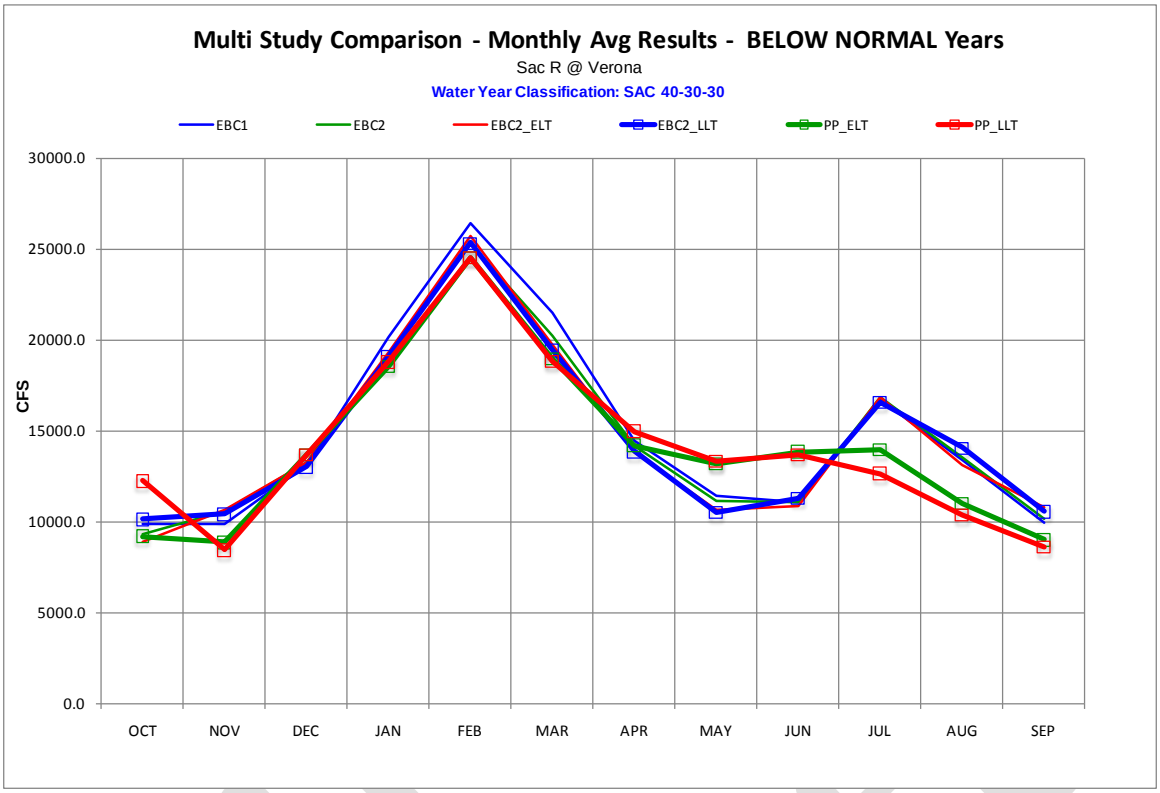

Figure C.5.2-96. Sacramento River Average Monthly Flows at Verona in Below-Normal Years

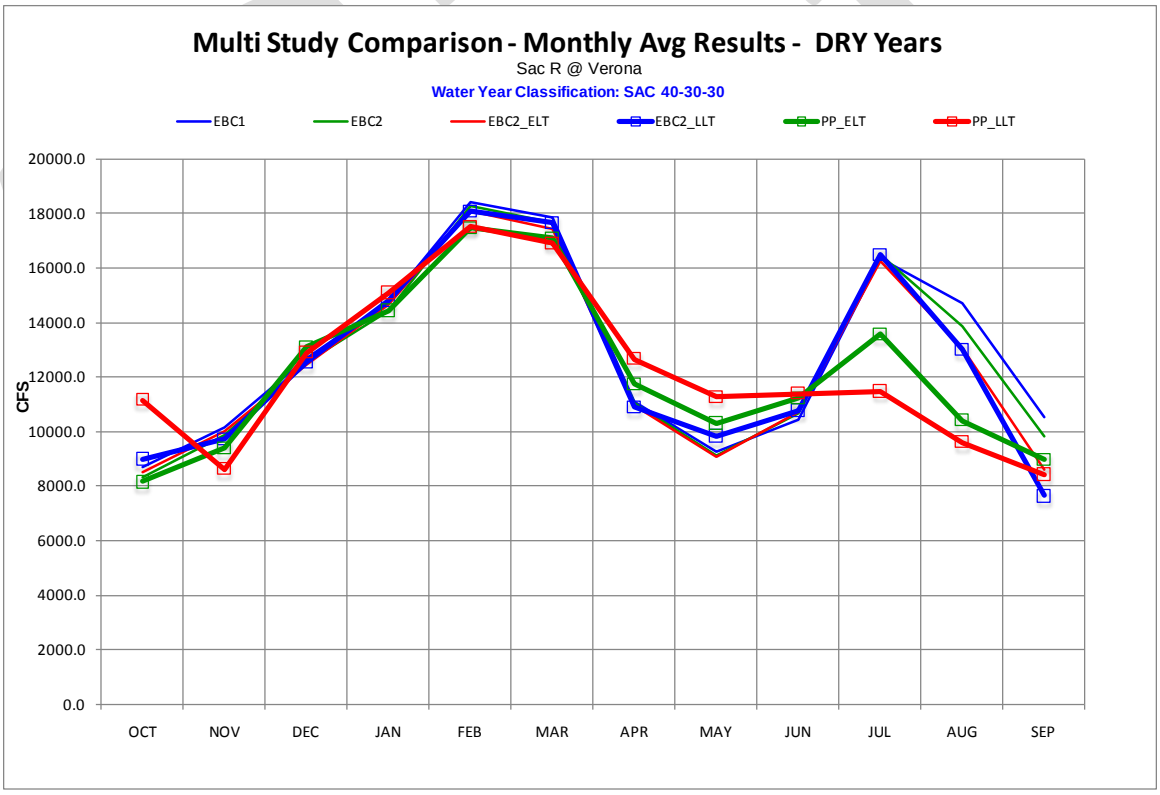

Figure C.5.2-97. Sacramento River Average Monthly Flows at Verona in Dry Years

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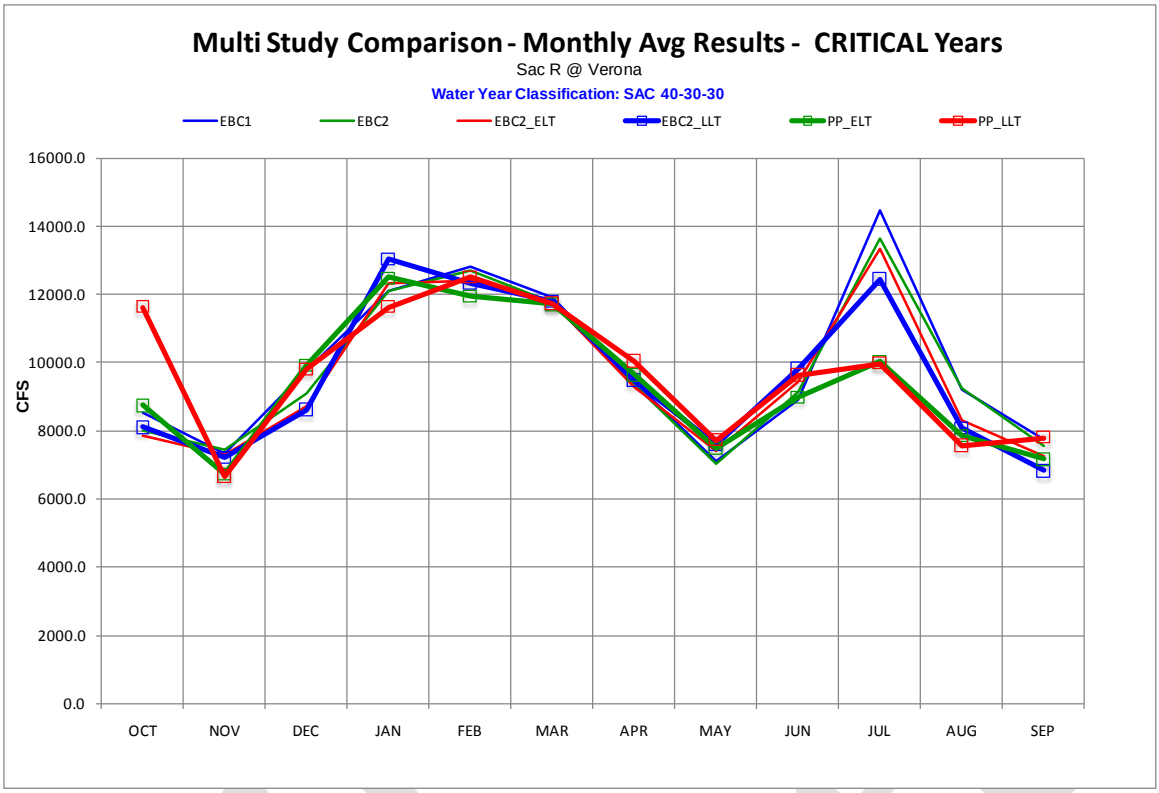

Figure C.5.2-98. Sacramento River Average Monthly Flows at Verona in Critical Years

Table C.5.2-34. Differences and Percent Differences between Pairs of Model Scenarios in the Sacramento River at Verona for All Months

Month	WY Type	EBC1 vs. PP_ELT	EBC1 vs. PP_LLT	EBC2 vs. PP_ELT	EBC2 vs. PP_LLT	EBC2_ELT vs. PP_ELT	EBC2_LLT vs. PP_LLT
Jan	W	281 (0.6%)	478 (1.1%)	647 (1.5%)	845 (1.9%)	-205 (-0.5%)	-500 (-1.1%)
	AN	-980 (-2.9%)	-1205 (-3.5%)	458 (1.4%)	233 (0.7%)	202 (0.6%)	-755 (-2.2%)
	BN	-1632 (-8.1%)	-1390 (-6.9%)	-623 (-3.2%)	-380 (-2%)	-780 (-4%)	-335 (-1.8%)
	D	-320 (-2.2%)	329 (2.2%)	27 (0.2%)	675 (4.7%)	-207 (-1.4%)	303 (2.1%)
	C	414 (3.4%)	-458 (-3.8%)	383 (3.2%)	-489 (-4%)	168 (1.4%)	-1424 (-0.9%)
	AVG	-343 (-1.2%)	-257 (-0.9%)	228 (0.8%)	314 (1.2%)	-189 (-0.7%)	-468 (-1.7%)
Feb	W	-99 (-0.2%)	460 (0.9%)	436 (0.9%)	995 (2%)	-952 (-1.9%)	-973 (-1.9%)
	AN	538 (1.4%)	255 (0.7%)	1421 (3.7%)	1139 (3%)	68 (0.2%)	-332 (-0.8%)
	BN	-1889 (-7.1%)	-1888 (-7.1%)	-787 (-3.1%)	-786 (-3.1%)	-1177 (-4.6%)	-800 (-3.2%)
	D	-924 (-5%)	-883 (-4.8%)	-793 (-4.3%)	-752 (-4.1%)	-600 (-3.3%)	-571 (-3.2%)
	C	-871 (-6.8%)	-313 (-2.4%)	-755 (-5.9%)	-197 (-1.6%)	-437 (-3.5%)	183 (1.5%)
	AVG	-605 (-1.9%)	-379 (-1.2%)	-73 (-0.2%)	154 (0.5%)	-688 (-2.1%)	-592 (-1.8%)
Mar	W	-1220 (-2.8%)	-749 (-1.7%)	-1085 (-2.5%)	-615 (-1.4%)	-1863 (-4.2%)	-1918 (-4.3%)
	AN	-1088 (-2.8%)	-1142 (-2.9%)	-332 (-0.9%)	-386 (-1%)	-1302 (-3.3%)	-1352 (-3.4%)
	BN	-2520 (-11.7%)	-2672 (-12.4%)	-1270 (-6.3%)	-1422 (-7%)	-753 (-3.8%)	-636 (-3.3%)
	D	-793 (-4.4%)	-977 (-5.5%)	-590 (-3.3%)	-774 (-4.4%)	-336 (-1.9%)	-758 (-4.3%)
	C	-181 (-1.5%)	-179 (-1.5%)	-45 (-0.4%)	-43 (-0.4%)	-42 (-0.4%)	-65 (-0.5%)
	AVG	-1177 (-4.1%)	-1101 (-3.8%)	-746 (-2.6%)	-670 (-2.4%)	-990 (-3.4%)	-1090 (-3.8%)

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Month	WY Type	EBC1 vs. PP_ELT	EBC1 vs. PP_LLT	EBC2 vs. PP_ELT	EBC2 vs. PP_LLT	EBC2_ELT vs. PP_ELT	EBC2_LLT vs. PP_LLT
Apr	W	-2242 (-7%)	-2682 (-8.3%)	-2321 (-7.2%)	-2761 (-8.5%)	-2124 (-6.6%)	-2099 (-6.6%)
	AN	-1848 (-8.3%)	-1418 (-6.4%)	-1825 (-8.2%)	-1395 (-6.3%)	-1315 (-6.1%)	-480 (-2.3%)
	BN	-256 (-1.8%)	509 (3.5%)	33 (0.2%)	798 (5.6%)	369 (2.7%)	1111 (8%)
	D	623 (5.6%)	1545 (13.9%)	685 (6.2%)	1608 (14.5%)	769 (7%)	1756 (16.1%)
	C	235 (2.5%)	622 (6.6%)	282 (3%)	669 (7.1%)	352 (3.8%)	553 (5.8%)
	AVG	-854 (-4.3%)	-541 (-2.7%)	-806 (-4.1%)	-493 (-2.5%)	-583 (-3%)	-80 (-0.4%)
May	W	-2272 (-8.7%)	-4687 (-17.9%)	-2148 (-8.2%)	-4563 (-17.5%)	208 (0.9%)	1278 (6.3%)
	AN	1227 (7.2%)	1116 (6.5%)	1388 (8.2%)	1277 (7.6%)	1879 (11.4%)	2194 (13.7%)
	BN	1746 (15.2%)	1872 (16.3%)	2023 (18.1%)	2149 (19.2%)	2544 (23.9%)	2789 (26.5%)
	D	1028 (11.1%)	1979 (21.3%)	1195 (13.1%)	2146 (23.5%)	1225 (13.5%)	1421 (14.4%)
	C	376 (5.3%)	600 (8.4%)	471 (6.7%)	695 (9.9%)	92 (1.2%)	114 (1.5%)
	AVG	38 (0.2%)	-481 (-3%)	199 (1.3%)	-320 (-2%)	1058 (7.1%)	1531 (11.1%)
Jun	W	-616 (-3.4%)	-701 (-3.8%)	-580 (-3.2%)	-665 (-3.6%)	2087 (13.3%)	2362 (15.4%)
	AN	2765 (20.3%)	3774 (27.8%)	2601 (18.9%)	3610 (26.2%)	3478 (27%)	3790 (27.9%)
	BN	2786 (25.2%)	2592 (23.4%)	2747 (24.7%)	2553 (23%)	2960 (27.2%)	2334 (20.6%)
	D	803 (7.7%)	966 (9.3%)	551 (5.2%)	714 (6.7%)	529 (4.9%)	615 (5.7%)
	C	92 (1%)	712 (8%)	-129 (-1.4%)	491 (5.4%)	-438 (-4.6%)	-204 (-2.1%)
	AVG	874 (6.6%)	1089 (8.2%)	768 (5.7%)	982 (7.3%)	1728 (13.9%)	1807 (14.4%)
Jul	W	-1734 (-10.7%)	-819 (-5%)	-1899 (-11.6%)	-983 (-6%)	-2626 (-15.3%)	-2531 (-14.1%)
	AN	-2141 (-12.2%)	-1954 (-11.2%)	-2571 (-14.3%)	-2385 (-13.3%)	-2666 (-14.8%)	-2804 (-15.3%)
	BN	-2736 (-16.4%)	-4048 (-24.2%)	-2910 (-17.2%)	-4222 (-25%)	-2861 (-17%)	-3949 (-23.8%)
	D	-2782 (-17%)	-4882 (-29.9%)	-2904 (-17.6%)	-5004 (-30.4%)	-2674 (-16.5%)	-4995 (-30.3%)
	C	-4446 (-30.7%)	-4499 (-31.1%)	-3615 (-26.5%)	-3668 (-26.9%)	-3319 (-24.9%)	-2481 (-19.9%)
	AVG	-2592 (-15.9%)	-2967 (-18.2%)	-2641 (-16.2%)	-3017 (-18.5%)	-2784 (-16.9%)	-3347 (-20.1%)
Aug	W	-962 (-7.7%)	-789 (-6.3%)	-1261 (-9.9%)	-1088 (-8.5%)	-1892 (-14.1%)	-2342 (-16.7%)
	AN	-926 (-6.8%)	-844 (-6.2%)	-1323 (-9.4%)	-1241 (-8.8%)	-1918 (-13.1%)	-2981 (-18.8%)
	BN	-2368 (-17.7%)	-3016 (-22.5%)	-2522 (-18.6%)	-3169 (-23.4%)	-2077 (-15.9%)	-3701 (-26.3%)
	D	-4279 (-29.1%)	-5084 (-34.6%)	-3456 (-24.9%)	-4261 (-30.7%)	-2648 (-20.3%)	-3414 (-26.2%)
	C	-1351 (-14.7%)	-1643 (-17.8%)	-1406 (-15.2%)	-1698 (-18.3%)	-444 (-5.3%)	-521 (-6.4%)
	AVG	-1982 (-15.5%)	-2245 (-17.5%)	-1988 (-15.5%)	-2252 (-17.6%)	-1881 (-14.8%)	-2636 (-20%)
Sep	W	-2866 (-20.1%)	-3712 (-26%)	-11869 (-51%)	-12715 (-54.6%)	-11459 (-50.1%)	-13025 (-55.2%)
	AN	-47 (-0.4%)	-173 (-1.6%)	-7043 (-40.2%)	-7169 (-40.9%)	-8177 (-43.8%)	-8680 (-45.6%)
	BN	-955 (-9.6%)	-1353 (-13.6%)	-1132 (-11.2%)	-1530 (-15.1%)	-1763 (-16.4%)	-1968 (-18.6%)
	D	-1575 (-14.9%)	-2110 (-20%)	-861 (-8.8%)	-1396 (-14.2%)	349 (4%)	768 (10%)
	C	-591 (-7.6%)	30 (0.4%)	-378 (-5%)	243 (3.2%)	-90 (-1.2%)	963 (14.1%)
	AVG	-1511 (-13.5%)	-1892 (-16.9%)	-5231 (-35%)	-5613 (-37.6%)	-5068 (-34.3%)	-5427 (-36.8%)
Oct	W	-896 (-7.8%)	1003 (8.7%)	-283 (-2.6%)	1615 (14.8%)	-73 (-0.7%)	1274 (11.3%)
	AN	-246 (-2.6%)	2318 (24.7%)	269 (3%)	2833 (32%)	518 (6%)	1809 (18.3%)
	BN	-661 (-6.7%)	2372 (24%)	-121 (-1.3%)	2912 (31.2%)	338 (3.8%)	2093 (20.6%)
	D	-502 (-5.8%)	2477 (28.5%)	-163 (-2%)	2816 (33.8%)	-336 (-3.9%)	2169 (24.1%)
	C	205 (2.4%)	3078 (36%)	752 (9.4%)	3626 (45.3%)	887 (11.3%)	3518 (43.4%)
	AVG	-513 (-5.2%)	2056 (20.9%)	3 (0%)	2573 (27.5%)	166 (1.8%)	2017 (20.4%)

Administrative Draft

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Month	WY Type	EBC1 vs. PP_ELT	EBC1 vs. PP_LLT	EBC2 vs. PP_ELT	EBC2 vs. PP_LLT	EBC2_ELT vs. PP_ELT	EBC2_LLT vs. PP_LLT
Nov	W	-629 (-4.1%)	-799 (-5.2%)	-1718 (-10.5%)	-1888 (-11.5%)	-1499 (-9.3%)	-1246 (-7.9%)
	AN	-720 (-6.1%)	-2077 (-17.6%)	-1770 (-13.8%)	-3127 (-24.3%)	-2105 (-16%)	-3102 (-24.2%)
	BN	-978 (-9.9%)	-1398 (-14.2%)	-1730 (-16.3%)	-2150 (-20.3%)	-1802 (-16.9%)	-1983 (-19%)
	D	-767 (-7.6%)	-1534 (-15.1%)	-487 (-4.9%)	-1254 (-12.7%)	-635 (-6.3%)	-1109 (-11.4%)
	C	-594 (-8.1%)	-673 (-9.2%)	-691 (-9.3%)	-770 (-10.4%)	-535 (-7.3%)	-555 (-7.7%)
	AVG	-727 (-6.3%)	-1231 (-10.6%)	-1307 (-10.8%)	-1811 (-14.9%)	-1309 (-10.8%)	-1512 (-12.8%)
Dec	W	-799 (-2.4%)	-2814 (-8.3%)	1175 (3.7%)	-841 (-2.6%)	-183 (-0.6%)	-229 (-0.7%)
	AN	-147 (-0.8%)	1588 (9%)	-597 (-3.3%)	1138 (6.3%)	-990 (-5.4%)	679 (3.7%)
	BN	575 (4.4%)	575 (4.4%)	404 (3%)	403 (3%)	418 (3.1%)	646 (5%)
	D	416 (3.3%)	205 (1.6%)	561 (4.5%)	350 (2.8%)	637 (5.1%)	358 (2.9%)
	C	153 (1.6%)	34 (0.3%)	840 (9.2%)	720 (7.9%)	1199 (13.7%)	1177 (13.6%)
	AVG	-63 (-0.3%)	-512 (-2.6%)	600 (3.1%)	151 (0.8%)	184 (0.9%)	388 (2.1%)

In February and March, differences in mean monthly flows in the Sacramento River at Verona under PP_ELT relative to EBC2_ELT are predicted to range from 68 cfs (0.2%) higher in February of above-normal water years to 1,864 cfs (4.2%) lower during March in wet years. Differences in mean monthly flows under the PP_LLT relative to the EBC2_LLT are predicted to range from 183 cfs (1.5%) higher for critical water years in February to 1,918 cfs (4.3%) lower during March in wet water years.

In April and May, greater differences between scenarios were evident than during February and March. Differences in mean monthly flows under PP_ELT relative to EBC2_ELT are predicted to range from an increase of 2,544 cfs (23.9%) in May of below-normal water years to a decrease of 2,124 cfs (6.6%) during April in wet years. Differences in mean monthly flows under the PP_LLT relative to the EBC2_LLT are predicted to range from an increase of 2,789 cfs (26.5%) for below-normal water years in May to 2,099 cfs (6.6%) lower during April in wet water years. Results of the simulation modeling for Sacramento River flows between EBC2 and BDCP operations during April and May show both increases and decreases in flows among water years. Information on the response of sturgeon to Sacramento River flows (Kohlhorst et al. 1991; Israel et al. 2009) indicates that the reproductive success of white sturgeon is greatest in wet and above-normal water years when river flows are high. As a result, changes in river flows under these high-flow conditions that would reduce river flows in areas where egg incubation and larval rearing occur have the potential to reduce survival and juvenile abundance. The potential effect of flow reductions would be expected to be greatest on egg hatching and larval growth and survival during the spring months, particularly in wetter years. The relationship between flow and juvenile production, however, has not been quantified.

Sacramento River at Wilkins Slough flows are presented in Figure C.5.2-99 through Figure C.5.2-104 and differences between pairs of model scenarios are presented in Table C.5.2-35. These results indicate that there would be little or no difference (<5%) in flows between the preliminary proposal and existing biological conditions during February and March. However, during April, flows under the preliminary proposal are predicted to be up to 763 cfs (11.6%) greater than the existing biological conditions. During May, flows under the preliminary proposal are predicted to be up to 1,208 cfs (18.8%) greater than under the existing biological conditions.

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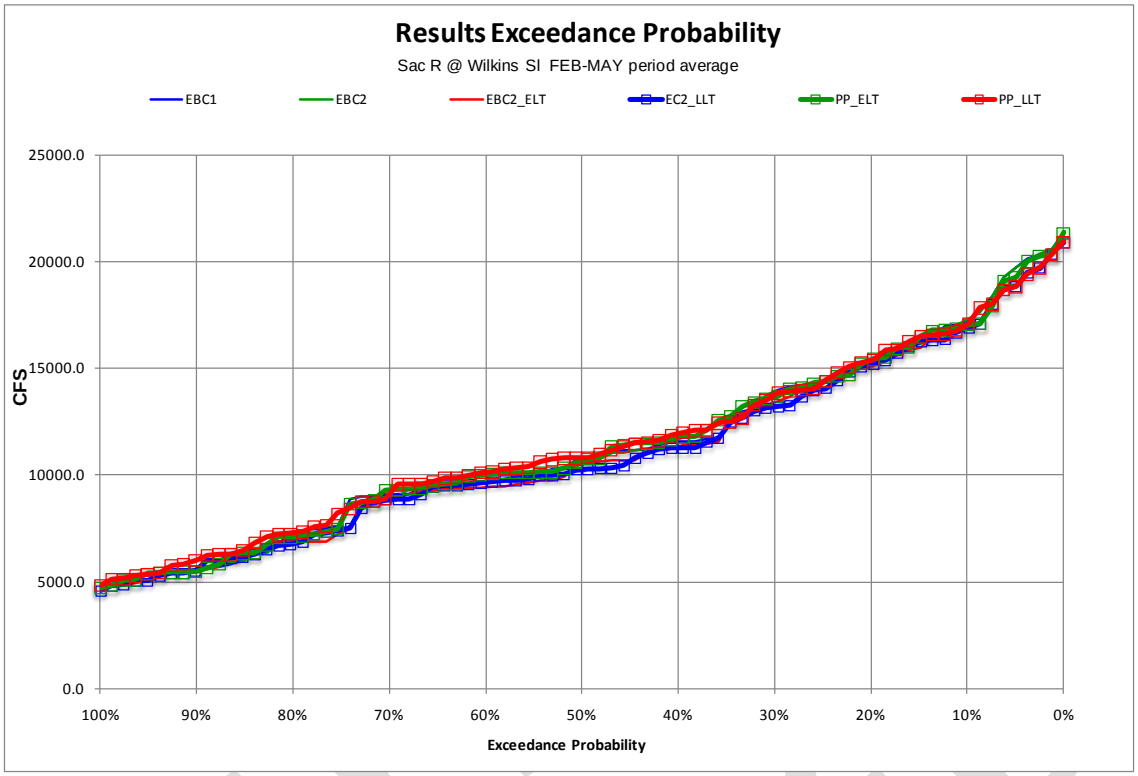

Figure C.5.2-99. Probability of Exceedance Plot for Model Scenarios of Mean Monthly Flow in the Sacramento River at Wilkins Slough, February through May

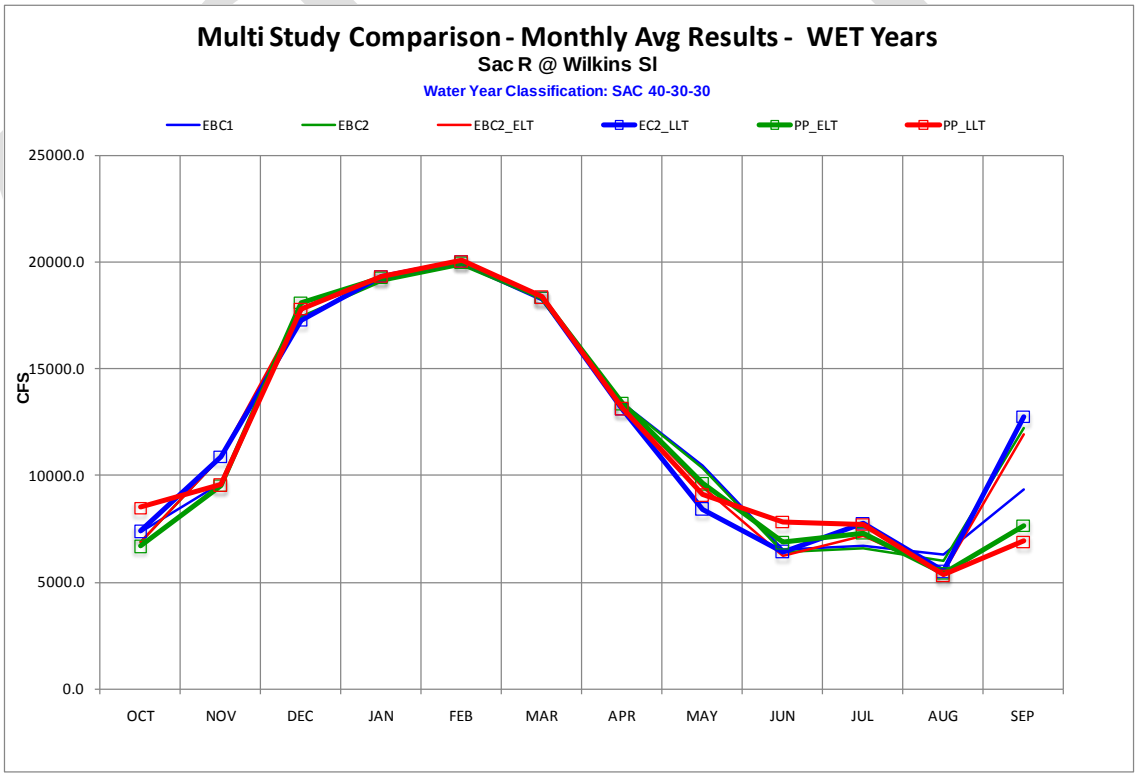

Figure C.5.2-100. Sacramento River Average Monthly Flows at Wilkins Slough in Wet Years

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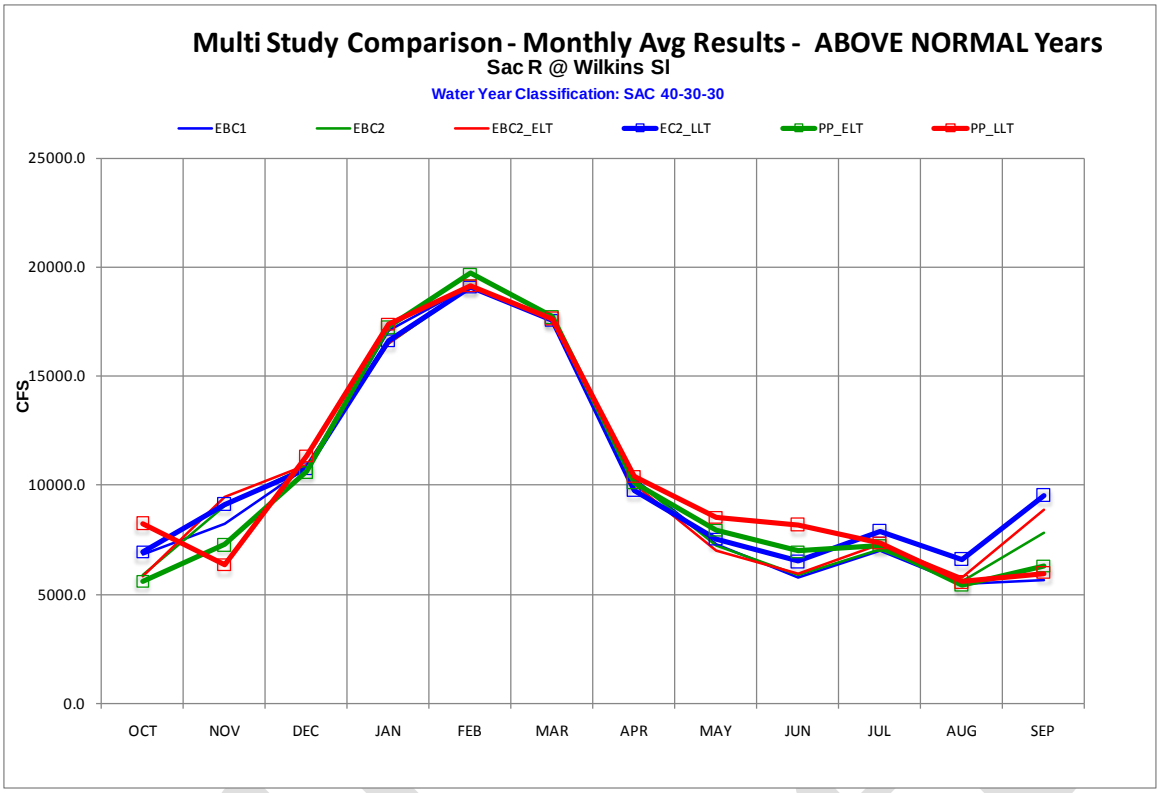

Figure C.5.2-101. Sacramento River Average Monthly Flows at Wilkins Slough in Above-Normal Years

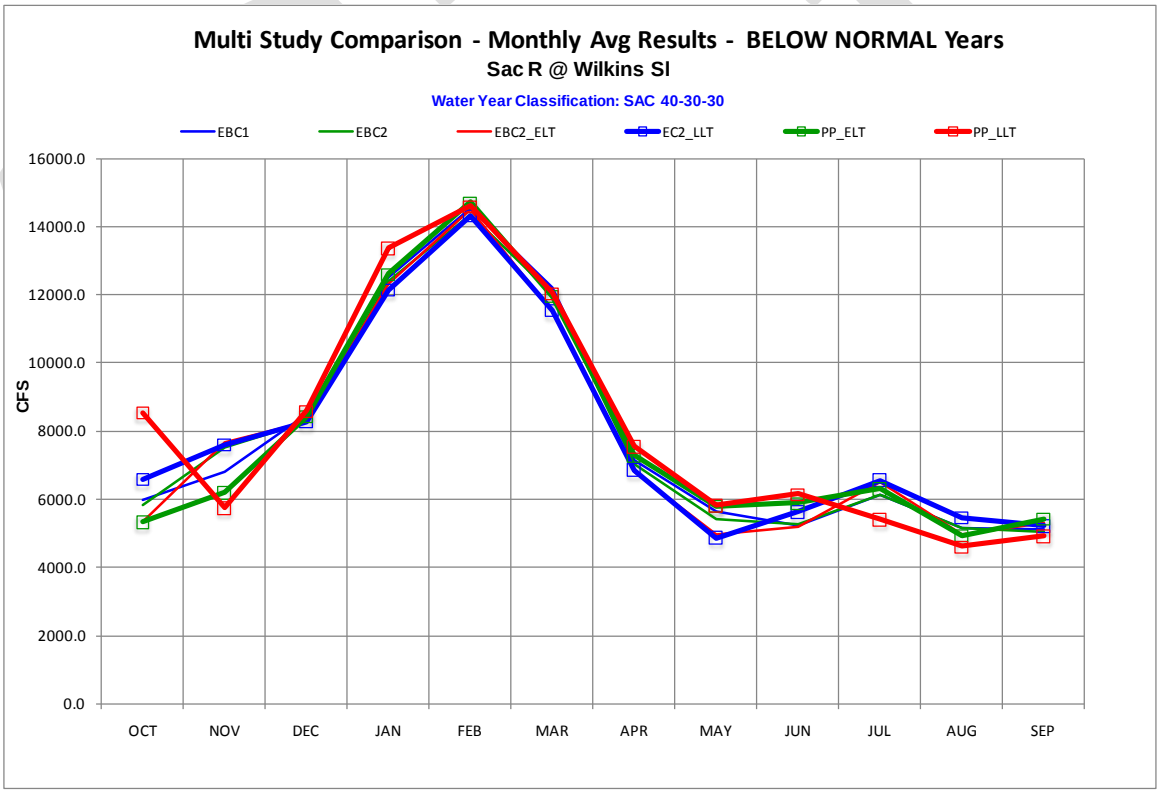

Figure C.5.2-102. Sacramento River Average Monthly Flows at Wilkins Slough in Below-Normal Years

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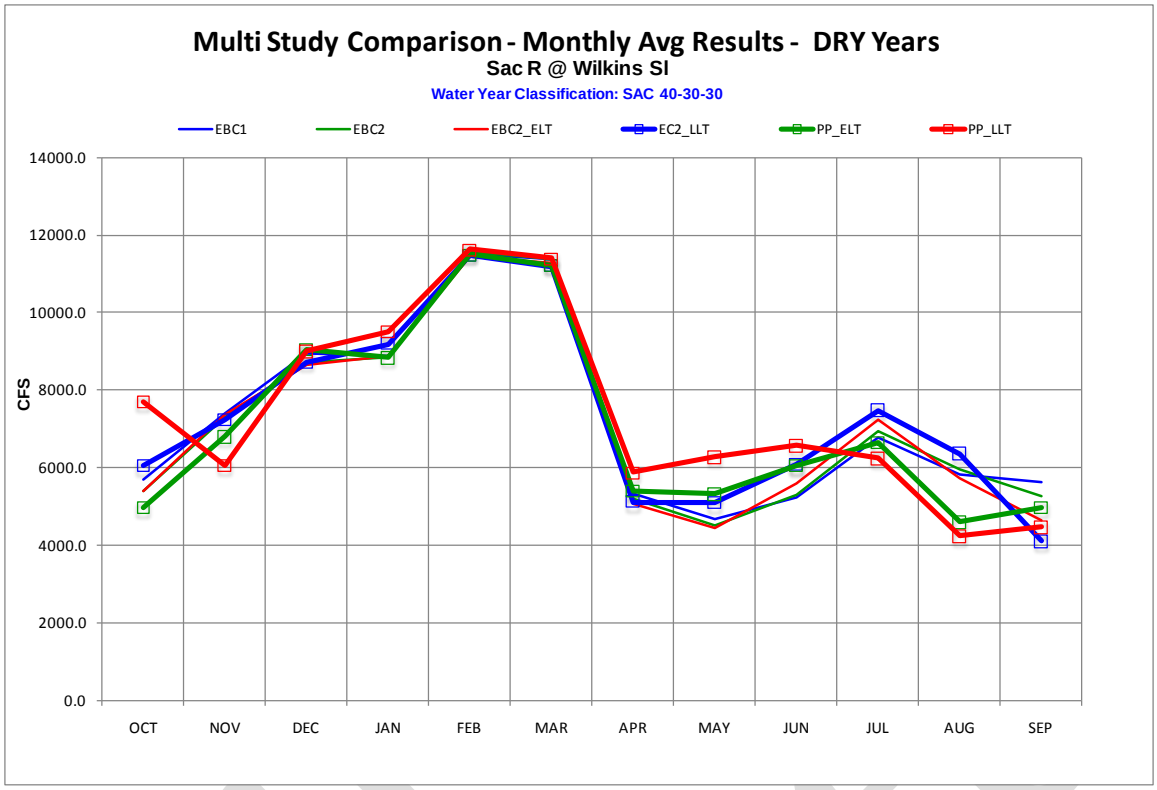

Figure C.5.2-103. Sacramento River Average Monthly Flows at Wilkins Slough in Dry Years

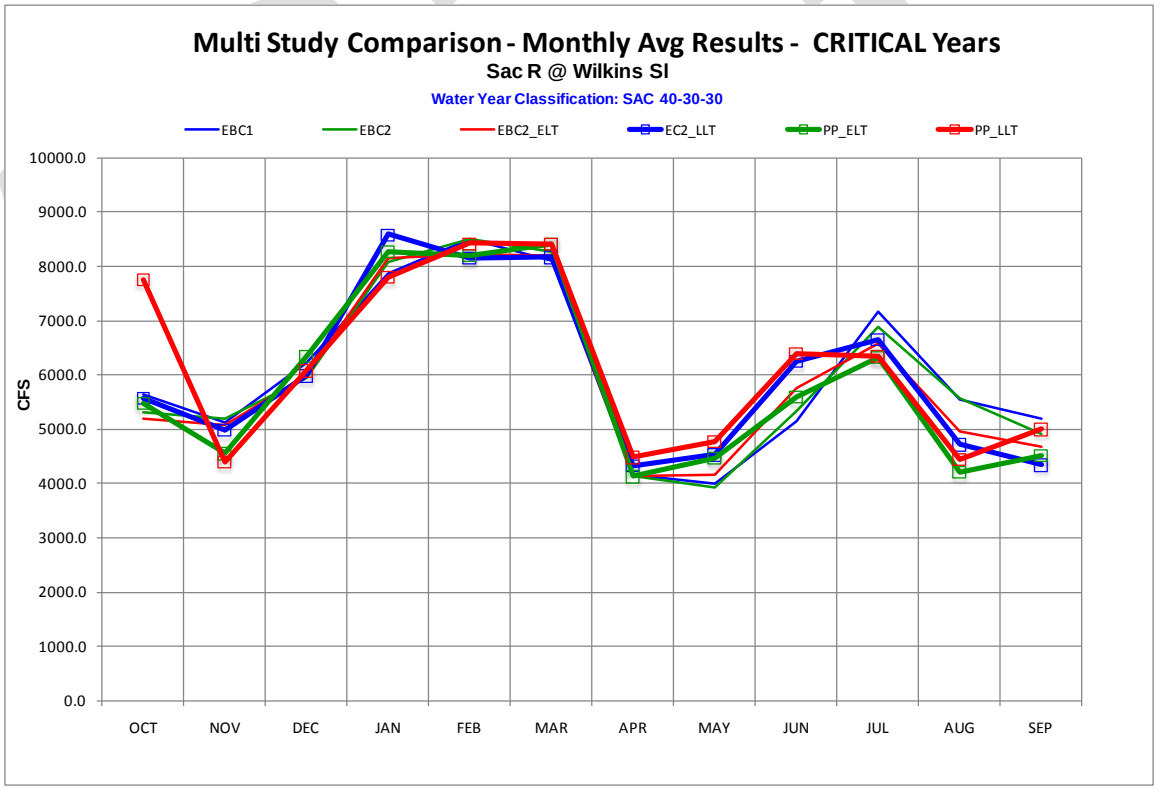

Figure C.5.2-104. Sacramento River Average Monthly Flows at Wilkins Slough in Critical Years

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Table C.5.2-35. Differences and Percent Differences between Pairs of Model Scenarios in Flows in the Sacramento River at Wilkins Slough for All Months

Month	WY Type	EBC1 vs. PP_ELT	EBC1 vs. PP_LLT	EBC2 vs. PP_ELT	EBC2 vs. PP_LLT	EBC2_ELT vs. PP_ELT	EBC2_LLT vs. PP_LLT
Jan	W	167 (0.9%)	227 (1.2%)	216 (1.1%)	277 (1.4%)	50 (0.3%)	47 (0.2%)
	AN	202 (1.2%)	339 (2%)	763 (4.6%)	900 (5.4%)	740 (4.4%)	792 (4.7%)
	BN	118 (0.9%)	894 (7.1%)	247 (2%)	1023 (8.2%)	309 (2.5%)	1267 (10.4%)
	D	-25 (-0.3%)	662 (7.4%)	18 (0.2%)	705 (7.9%)	-38 (-0.4%)	348 (3.8%)
	C	445 (5.6%)	-21 (-0.3%)	217 (2.7%)	-249 (-3.1%)	131 (1.6%)	-781 (-9%)
	AVG	162 (1.2%)	416 (3%)	258 (1.9%)	512 (3.7%)	188 (1.4%)	309 (2.2%)
Feb	W	142 (0.7%)	219 (1.1%)	188 (0.9%)	266 (1.3%)	28 (0.1%)	24 (0.1%)
	AN	611 (3.2%)	58 (0.3%)	679 (3.5%)	127 (0.7%)	601 (3.1%)	58 (0.3%)
	BN	222 (1.5%)	140 (1%)	374 (2.6%)	292 (2%)	222 (1.5%)	324 (2.2%)
	D	-3 (0%)	170 (1.5%)	-74 (-0.6%)	98 (0.8%)	41 (0.4%)	177 (1.5%)
	C	-263 (-3.1%)	-36 (-0.4%)	-284 (-3.3%)	-57 (-0.7%)	-25 (-0.3%)	234 (2.8%)
	AVG	133 (0.9%)	134 (0.9%)	165 (1.1%)	166 (1.1%)	140 (0.9%)	145 (0.9%)
Mar	W	127 (0.7%)	196 (1.1%)	78 (0.4%)	147 (0.8%)	0 (0%)	59 (0.3%)
	AN	70 (0.4%)	-23 (-0.1%)	120 (0.7%)	27 (0.1%)	100 (0.6%)	87 (0.5%)
	BN	-219 (-1.8%)	-136 (-1.1%)	-27 (-0.2%)	57 (0.5%)	466 (4%)	518 (4.4%)
	D	-116 (-1%)	58 (0.5%)	-158 (-1.4%)	16 (0.1%)	-61 (-0.5%)	205 (1.8%)
	C	320 (3.9%)	350 (4.2%)	138 (1.6%)	167 (2%)	207 (2.5%)	261 (3.1%)
	AVG	35 (0.2%)	100 (0.7%)	23 (0.2%)	88 (0.6%)	111 (0.8%)	203 (1.4%)
Apr	W	-19 (-0.1%)	-229 (-1.6%)	-20 (-0.1%)	-229 (-1.6%)	55 (0.4%)	29 (0.2%)
	AN	-137 (-1.2%)	132 (1.1%)	-60 (-0.5%)	209 (1.8%)	87 (0.8%)	596 (5.4%)
	BN	123 (1.4%)	395 (4.6%)	273 (3.2%)	545 (6.5%)	499 (6.1%)	700 (8.5%)
	D	73 (1.1%)	551 (8.2%)	205 (3.1%)	683 (10.3%)	320 (4.9%)	763 (11.6%)
	C	-24 (-0.4%)	337 (5.8%)	16 (0.3%)	377 (6.6%)	-1 (0%)	154 (2.6%)
	AVG	7 (0.1%)	185 (1.8%)	79 (0.8%)	256 (2.6%)	186 (1.9%)	406 (4.1%)
May	W	-837 (-7.1%)	-1337 (-11.4%)	-720 (-6.2%)	-1220 (-10.5%)	172 (1.6%)	676 (7%)
	AN	633 (7.4%)	1234 (14.5%)	701 (8.3%)	1303 (15.4%)	958 (11.7%)	1029 (11.8%)
	BN	186 (2.7%)	216 (3.1%)	402 (5.9%)	432 (6.4%)	838 (13.2%)	970 (15.5%)
	D	668 (11.1%)	1639 (27.3%)	830 (14.2%)	1801 (30.9%)	879 (15.2%)	1208 (18.8%)
	C	478 (8.9%)	816 (15.3%)	532 (10.1%)	870 (16.4%)	305 (5.5%)	249 (4.2%)
	AVG	76 (0.9%)	273 (3.3%)	203 (2.5%)	400 (4.9%)	575 (7.4%)	832 (10.8%)
Jun	W	371 (4.4%)	1329 (15.6%)	445 (5.3%)	1403 (16.6%)	649 (7.9%)	1414 (16.8%)
	AN	1239 (15.9%)	2469 (31.7%)	1136 (14.4%)	2366 (30%)	1045 (13.1%)	1667 (19.4%)
	BN	663 (9.2%)	939 (13%)	645 (8.9%)	921 (12.7%)	695 (9.6%)	544 (7.1%)
	D	846 (11.6%)	1396 (19.1%)	787 (10.7%)	1337 (18.2%)	490 (6.4%)	522 (6.4%)
	C	488 (6.8%)	1313 (18.4%)	269 (3.7%)	1094 (14.9%)	-156 (-2%)	145 (1.8%)
	AVG	669 (8.7%)	1441 (18.7%)	629 (8.1%)	1402 (18.1%)	562 (7.2%)	921 (11.2%)
Jul	W	655 (7.6%)	1135 (13.1%)	727 (8.5%)	1207 (14%)	140 (1.5%)	-18 (-0.2%)
	AN	349 (3.9%)	470 (5.2%)	255 (2.8%)	376 (4.1%)	-34 (-0.4%)	-526 (-5.3%)
	BN	237 (2.9%)	-649 (-7.9%)	189 (2.3%)	-697 (-8.4%)	-182 (-2.1%)	-1144 (-13.2%)
	D	-97 (-1.1%)	-489 (-5.5%)	-282 (-3.1%)	-674 (-7.4%)	-594 (-6.3%)	-1236 (-12.8%)
	C	-804 (-8.7%)	-886 (-9.6%)	-550 (-6.1%)	-632 (-7%)	-271 (-3.1%)	-289 (-3.3%)

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Month	WY Type	EBC1 vs. PP_ELT	EBC1 vs. PP_LLT	EBC2 vs. PP_ELT	EBC2 vs. PP_LLT	EBC2_ELT vs. PP_ELT	EBC2_LLT vs. PP_LLT
	AVG	160 (1.8%)	81 (0.9%)	158 (1.8%)	78 (0.9%)	-162 (-1.8%)	-592 (-6.3%)
Aug	W	-809 (-10.4%)	-888 (-11.5%)	-575 (-7.6%)	-654 (-8.7%)	-77 (-1.1%)	-233 (-3.3%)
	AN	-47 (-0.7%)	82 (1.2%)	-152 (-2.1%)	-22 (-0.3%)	-362 (-4.9%)	-1100 (-13.4%)
	BN	-167 (-2.5%)	-518 (-7.8%)	-209 (-3.1%)	-560 (-8.3%)	-65 (-1%)	-896 (-12.7%)
	D	-1217 (-16.4%)	-1606 (-21.7%)	-1365 (-18.1%)	-1754 (-23.2%)	-1152 (-15.7%)	-2180 (-27.3%)
	C	-1436 (-20.1%)	-1451 (-20.3%)	-1469 (-20.5%)	-1485 (-20.7%)	-783 (-12.1%)	-333 (-5.5%)
	AVG	-769 (-10.5%)	-923 (-12.6%)	-755 (-10.4%)	-908 (-12.5%)	-456 (-6.5%)	-915 (-12.6%)
Sep	W	-1703 (-17.7%)	-2432 (-25.3%)	-4589 (-36.7%)	-5318 (-42.5%)	-4276 (-35.1%)	-5844 (-44.8%)
	AN	675 (11.4%)	354 (6%)	-1557 (-19.1%)	-1879 (-23.1%)	-2610 (-28.4%)	-3629 (-36.7%)
	BN	305 (5.6%)	-186 (-3.4%)	360 (6.7%)	-131 (-2.4%)	119 (2.1%)	-315 (-5.7%)
	D	-673 (-11.3%)	-1194 (-20.1%)	-339 (-6.1%)	-860 (-15.3%)	313 (6.3%)	286 (6.4%)
	C	-713 (-12.9%)	-285 (-5.2%)	-448 (-8.5%)	-21 (-0.4%)	-187 (-3.7%)	610 (13.1%)
	AVG	-641 (-9.2%)	-1055 (-15.2%)	-1761 (-21.8%)	-2175 (-26.9%)	-1676 (-21%)	-2286 (-27.9%)
Oct	W	-641 (-8.5%)	1159 (15.4%)	-253 (-3.5%)	1546 (21.7%)	-239 (-3.3%)	1038 (13.6%)
	AN	-1209 (-17.3%)	1458 (20.9%)	-356 (-5.8%)	2311 (37.7%)	-264 (-4.4%)	1291 (18%)
	BN	-649 (-10.5%)	2553 (41.3%)	-535 (-8.8%)	2667 (44%)	-45 (-0.8%)	1921 (28.2%)
	D	-695 (-11.9%)	2026 (34.6%)	-442 (-7.9%)	2279 (40.7%)	-481 (-8.5%)	1621 (25.9%)
	C	-150 (-2.6%)	2111 (36.3%)	152 (2.8%)	2413 (43.8%)	269 (5%)	2170 (37.7%)
	AVG	-665 (-10.1%)	1770 (26.8%)	-298 (-4.8%)	2137 (34.3%)	-188 (-3.1%)	1519 (22.2%)
Nov	W	-95 (-1%)	23 (0.2%)	-1340 (-12.2%)	-1222 (-11.2%)	-1298 (-11.9%)	-1247 (-11.4%)
	AN	-927 (-11.2%)	-1776 (-21.4%)	-1720 (-18.9%)	-2569 (-28.2%)	-2178 (-22.8%)	-2750 (-29.6%)
	BN	-583 (-8.5%)	-915 (-13.3%)	-1328 (-17.5%)	-1660 (-21.8%)	-1475 (-19%)	-1750 (-22.7%)
	D	-604 (-8.1%)	-1259 (-16.9%)	-492 (-6.7%)	-1147 (-15.6%)	-546 (-7.4%)	-1104 (-15.1%)
	C	-542 (-10.4%)	-604 (-11.6%)	-609 (-11.6%)	-671 (-12.7%)	-519 (-10%)	-501 (-9.8%)
	AVG	-477 (-6.1%)	-774 (-9.8%)	-1100 (-13%)	-1397 (-16.5%)	-1178 (-13.8%)	-1412 (-16.6%)
Dec	W	258 (1.4%)	-49 (-0.3%)	642 (3.7%)	335 (1.9%)	257 (1.4%)	512 (2.9%)
	AN	-178 (-1.6%)	496 (4.6%)	-281 (-2.6%)	393 (3.6%)	-360 (-3.2%)	485 (4.4%)
	BN	-52 (-0.6%)	70 (0.8%)	136 (1.6%)	258 (3.1%)	110 (1.3%)	271 (3.3%)
	D	107 (1.2%)	95 (1.1%)	341 (3.9%)	329 (3.7%)	369 (4.2%)	300 (3.4%)
	C	129 (2.1%)	-148 (-2.4%)	394 (6.6%)	117 (2%)	340 (5.6%)	67 (1.1%)

In summary, CALSIM-modeled flows in the Sacramento River at Verona during periods of white sturgeon egg/embryo life stages would generally maintain existing flow conditions in February and March. In April, flows would decrease moderately under both PP_ELT and PP_LLT in wet and above-normal years, and increase in below-normal, dry, and critical years. In May, under nearly all scenarios, both PP_ELT and PP_LLT would result in substantially increased flows under nearly all scenarios. Flows in the Sacramento River at Wilkins Slough would generally maintain existing flow conditions in February and March, increase slightly in April, and increase substantially under PP_ELT and PP_LLT scenarios in May. Due to the general trend of maintaining existing mean monthly flow conditions from February through April, and an increase in flows in May, it is expected with moderate certainty that, under most water years, white sturgeon egg/embryo life stages would experience improved flow conditions during this vulnerable period. Whether the increased May flows at Verona and Wilkins Slough would result in a measurable increased survival rate at these

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young life stages is unknown, but because sturgeon spawning success is correlated to flow (Kohlhorst et al. 1991; Beamesderfer and Farr 1997), these flow increases are assumed to be a benefit for white sturgeon at this life stage. The mechanisms through which increases or decreases in Sacramento River flows occur during the February through May seasonal period of egg incubation and embryo development, hatching, and initial dispersal are unknown. Increased flows in the upper river reaches where sturgeon spawn and their eggs incubate could result in improved water circulation around developing embryos, increased turbidity contributing to reduced predation mortality, or greater larval dispersal and improved rearing conditions.

Larvae

Water Temperature

For the months of February to June, the percent difference in days that would exceed the 68°F threshold in this portion of the river would be the same for both EBC1 and EBC2 (Table C.5.2-36 and Table C.5.2-37). Therefore, the preliminary proposal would result in the same changes of future exceedances regardless of baseline condition scenario. The exceedance of the 68°F threshold under PP_ELT is predicted to be an increase of 0.1% days or 157% higher than both EBC1 and EBC2 for all water-year types combined (Table C.5.2-37). Differences in the exceedance of the 68°F threshold by water year designation are predicted to vary from 0% days (a 0% change) in dry years to 0.2% days (a 140% change) higher in wet water years under PP_ELT compared to EBC1 or EBC2. The percent of days that would exceed the 68°F threshold under PP_LLT is predicted to be 0.5% days (a 957% change) higher than under EBC1 or EBC2 for all water-year types combined. Differences ranged from 0% days (a 0% change) in dry water years to 0.9% days (a 700% change) higher in wet water years under PP_LLT compared to EBC1 and EBC2.

When isolating the effect of the preliminary proposal, the percentage of time from February to June that would exceed the 68°F threshold under PP_ELT is predicted to be reduced by 0.1% days (a 42% change) compared with EBC2_ELT for all water-year types combined. Differences in the frequency of exceedance of the 68°F threshold by water year designation are predicted to vary from a 0.1% day decrease (a 14% change) in wet water years to a 0.4% day decrease (a 70% change) in above-normal water years under PP_ELT compared to EBC2_ELT. The percentage of days that would exceed the 68°F threshold under PP_LLT is predicted to be a decrease of 0.1% days (a 17% change) compared with EBC2_LLT for all water-year types combined. Differences ranged from 0.7% day decrease (a 65% change) in above-normal water years to a 0.4% day increase (a 64% change) in critical water years under PP_LLT compared to EBC2_LLT.

Combining all water years, mean daily water temperatures in the Sacramento River at Hamilton City from February through June exceeded the 68°F threshold <1% of the time under all model scenarios. Accounting for climate change effects, BDCP implementation under early and late long-term conditions (PP_ELT and PP_LLT) is predicted to result in a <1% decrease in the frequency of temperatures exceeding 68°F relative to baseline conditions (EBC2_ELT and EBC2_LLT).

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Table C.5.2-36. Percent of Days during February to June[1] When Daily Average Temperature Exceeds 68°F in the Sacramento River at Hamilton City

	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
Temperatures above 68°F						
Wet	0.1	0.1	0.4	1.3	0.3	1.0
Above Normal	0.1	0.1	0.6	1.1	0.2	0.4
Below Normal	0.0	0.0	0.0	0.2	0.0	0.4
Dry	0.0	0.0	0.0	0.1	0.0	0.0
Critical	0.0	0.0	0.3	0.6	0.2	1.0
All	0.1	0.1	0.3	0.7	0.1	0.6

[1] Based on the modeling period of 1922 to 2003.

Table C.5.2-37. Difference and Percent Difference in Percent of Days during February to June When Daily Average Temperature Exceeds 68°F in the Sacramento River at Hamilton City

WY Type	Comparison[1]	EBC1 vs. PP_ELT	EBC1 vs. PP_LLT	EBC2 vs. EBC2_ELT	EBC2 vs. EBC2_LLT	EBC2 vs. PP_ELT	EBC2 vs. PP_LLT	EBC2_ELT vs. PP_ELT	EBC2_LLT vs. PP_LLT
Wet	Difference	0.2	0.9	0.2	1.2	0.2	0.9	-0.1	-0.3
	Percent difference	140%	700%	180%	900%	140%	700%	-14%	-20%
Above Normal	Difference	0.1	0.3	0.4	1.0	0.1	0.3	-0.4	-0.7
	Percent difference	50%	250%	400%	900%	50%	250%	-70%	-65%
Below Normal	Difference	0.0	0.4	0.0	0.2	0.0	0.4	0.0	0.2
	Percent difference	NA	NA	NA	NA	NA	NA	-100%	100%
Dry	Difference	0.0	0.0	0.0	0.1	0.0	0.0	0.0	-0.1
	Percent difference	NA	NA	NA	NA	NA	NA	-100%	-75%
Critical	Difference	0.2	1.0	0.3	0.6	0.2	1.0	-0.1	0.4
	Percent difference	NA	NA	NA	NA	NA	NA	-40%	64%
All	Difference	0.1	0.5	0.2	0.7	0.1	0.5	-0.1	-0.1
	Percent difference	157%	957%	343%	1171%	157%	957%	-42%	-17%

[1] A positive value indicates a higher value under the preliminary proposal than the EBC.
NA = Could not be calculated because dividing by 0.

Juvenile

Water Temperature

Simulated water temperatures in the Sacramento River at Hamilton City were used to evaluate potential differences in the exposure of juvenile white sturgeon to water temperatures exceeding the 68°F and 77°F thresholds on a year-round basis. Because no water temperatures exceeded 77°F in any model scenario, results here focus on water temperatures exceeding 68°F.

Combining all water years, mean daily water temperatures in the Sacramento River at Hamilton City exceeded the 68°F threshold <1% of the time under EBC1 and EBC2, 2%–4% of the time under EBC2_ELT and EBC2_LLT, and 2%–5% of the time under PP_ELT and PP_LLT (Table C.5.2-38, Table C.5.2-39). In the absence of BDCP operations, water temperatures exceeding the suitable range for juvenile rearing would be expected to increase in frequency under early and late long-term

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conditions, especially in critically dry years (EBC2_ELT and EBC2_LLT compared to EBC1 and EBC2 scenarios). Relative to these future baseline conditions (EBC2_ELT and EBC2_LLT), BDCP operations (PP_ELT and PP_LLT) would have little or no effect (<1% change over all years) on exceedance frequencies.

Table C.5.2-38. Percent of Days Year-Round When Daily Average Temperature Exceeds 68°F in the Sacramento River at Hamilton City[1]

Water-Year Type	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
Wet	0.1	0.1	0.2	1.2	0.2	1.3
Above Normal	0.1	0.0	0.3	0.8	0.2	1.3
Below Normal	0.0	0.0	0.2	1.2	0.0	2.6
Dry	0.1	0.3	1.6	4.1	1.3	5.7
Critical	2.1	2.8	8.6	16.1	8.2	16.7
All	0.4	0.5	1.7	4.0	1.6	4.7

[1] Based on the modeling period of 1922 to 2003.

Table C.5.2-39. Difference and Percent Difference in Percent of Days Year-Round When Daily Average Temperature Exceeds 68°F in the Sacramento River at Hamilton City

WY Type	Comparison[1]	EBC1 vs. PP_ELT	EBC1 vs. PP_LLT	EBC2 vs. EBC2_ELT	EBC2 vs. EBC2_LLT	EBC2 vs. PP_ELT	EBC2 vs. PP_LLT	EBC2_ELT vs. PP_ELT	EBC2_LLT vs. PP_LLT
Wet	Difference	0.1	1.2	0.1	1.1	0.1	1.2	-0.04	0.1
	Percent difference	150%	1933%	217%	1817%	150%	1933%	-21%	6%
Above Normal	Difference	0.1	1.2	0.2	0.7	0.1	1.2	-0.1	0.5
	Percent difference	100%	1300%	500%	1600%	300%	2700%	-33%	65%
Below Normal	Difference	0	2.6	0.2	1.2	0	2.6	-0.2	1.4
	Percent difference	NA	NA	NA	NA	NA	NA	-80%	113%
Dry	Difference	1.1	5.6	1.2	3.7	0.9	5.4	-0.3	1.7
	Percent difference	833%	4089%	364%	1118%	282%	1614%	-18%	41%
Critical	Difference	6.1	14.6	5.9	13.4	5.4	13.9	-0.5	0.5
	Percent difference	293%	702%	212%	484%	196%	503%	-5%	3%
All	Difference	1.2	4.4	1.2	3.5	1.1	4.2	-0.2	0.8
	Percent difference	325%	1190%	245%	686%	209%	840%	-10%	20%

[1] A positive value indicates a higher value under the preliminary proposal than the EBC.
NA = Could not be calculated because dividing by 0.

Adult

Water Temperature (Rivers)

White sturgeon spawning occurs from February through May (Kohlhorst 1976); however, pre-spawn and post-spawn adults occur near spawning areas from winter through late spring, so exceedance plots for January through May are reported. Although adult white sturgeon begin to show signs of stress at temperatures above 68°F (20°C) (Cech et al. 1984; Geist et al. 2005), Israel et al. (2009) considered temperatures above 77°F (25°C) as an upper threshold for pre-spawn,

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spawning, and post-spawn adults. For a review of the lower 68°F threshold during the spring spawning period, see the egg and embryo water temperature analysis in Section C.5.2.1.6.

There were no days between January and May in any model scenario when water temperature in the Sacramento River at Hamilton City exceeded 77°F (Figure C.5.2-105 through Figure C.5.2-110). Therefore, it is concluded with moderate certainty that there would be no temperature-related effects of the BDCP on white sturgeon migration habitat in the Sacramento River.

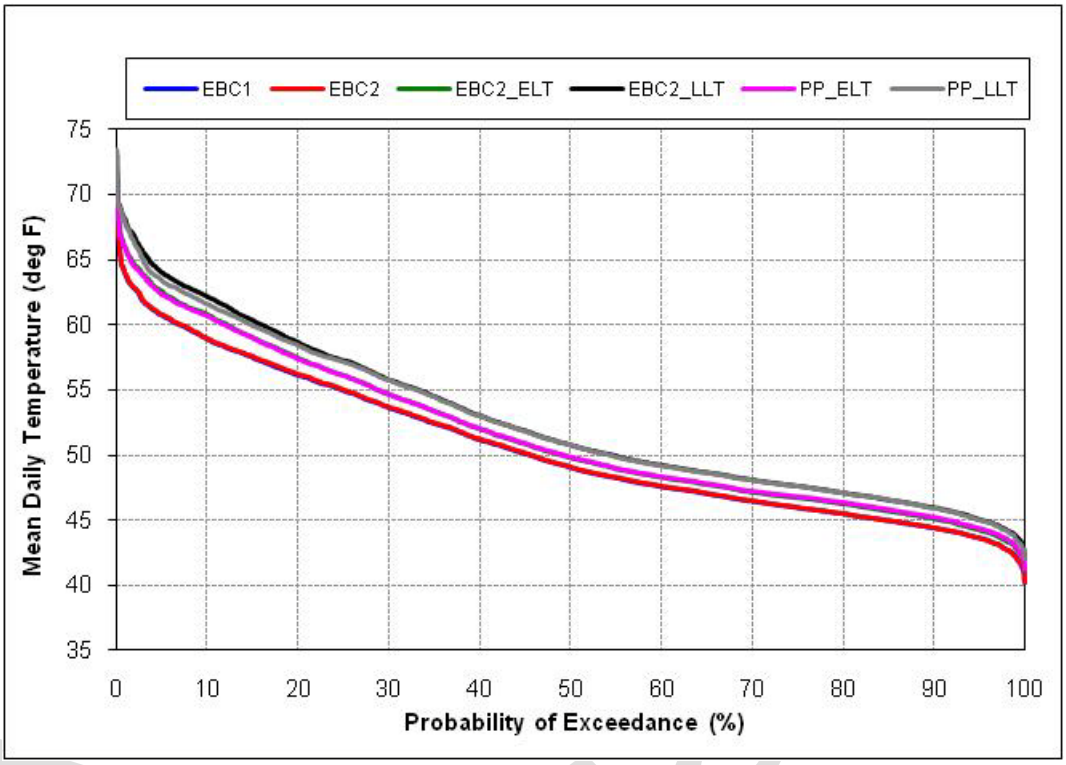

Figure C.5.2-105. Probability of Exceedance Plot for Model Scenarios of Mean Daily Temperature of the Sacramento River at Hamilton City in Wet Years, January through May

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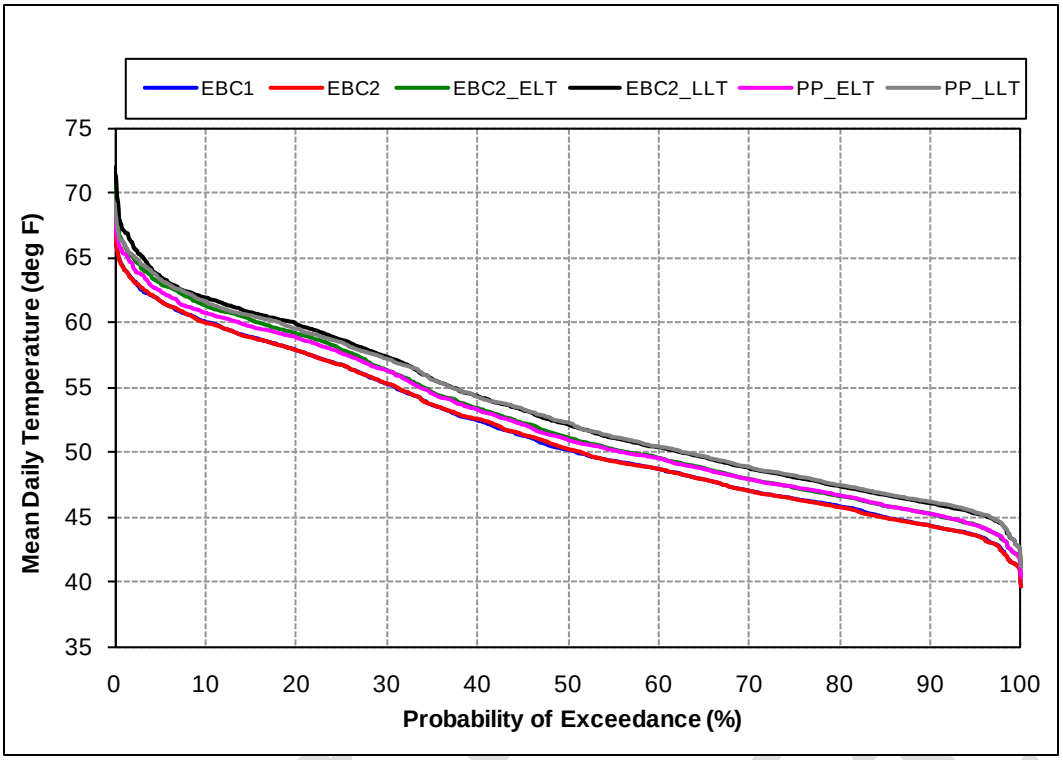

Figure C.5.2-106. Probability of Exceedance Plot for Model Scenarios of Mean Daily Temperature of the Sacramento River at Hamilton City in Above-Normal Years, January through May

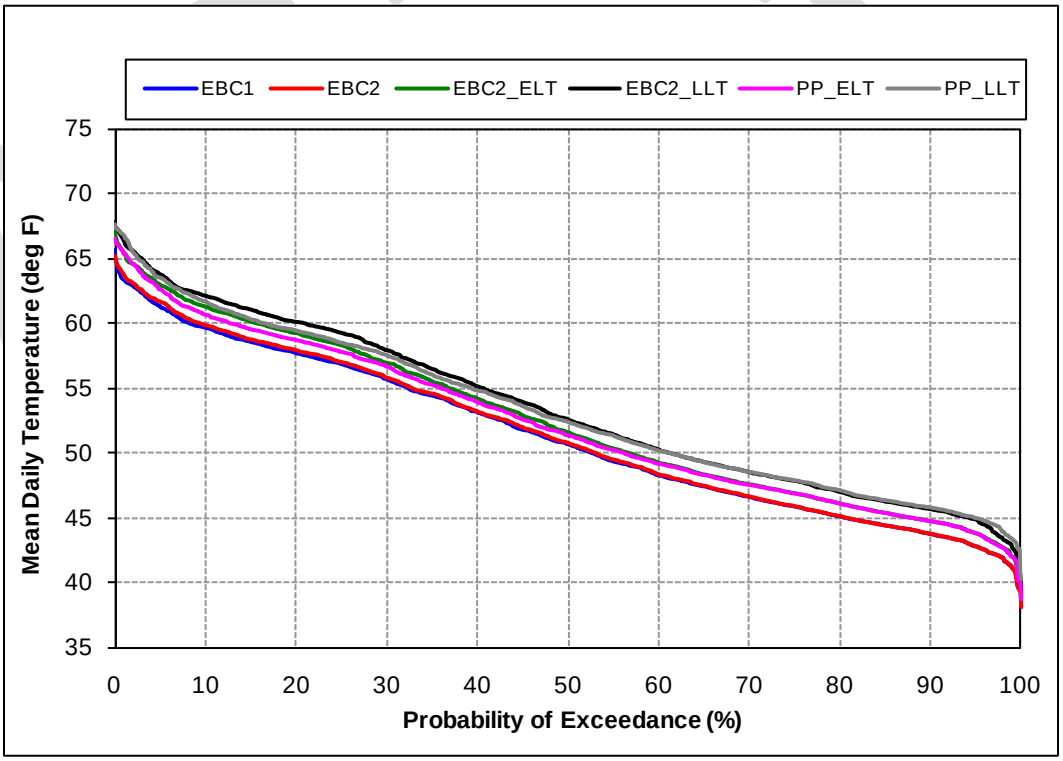

Figure C.5.2-107. Probability of Exceedance Plot for Model Scenarios of Mean Daily Temperature of the Sacramento River at Hamilton City in Below-Normal Years, January through May

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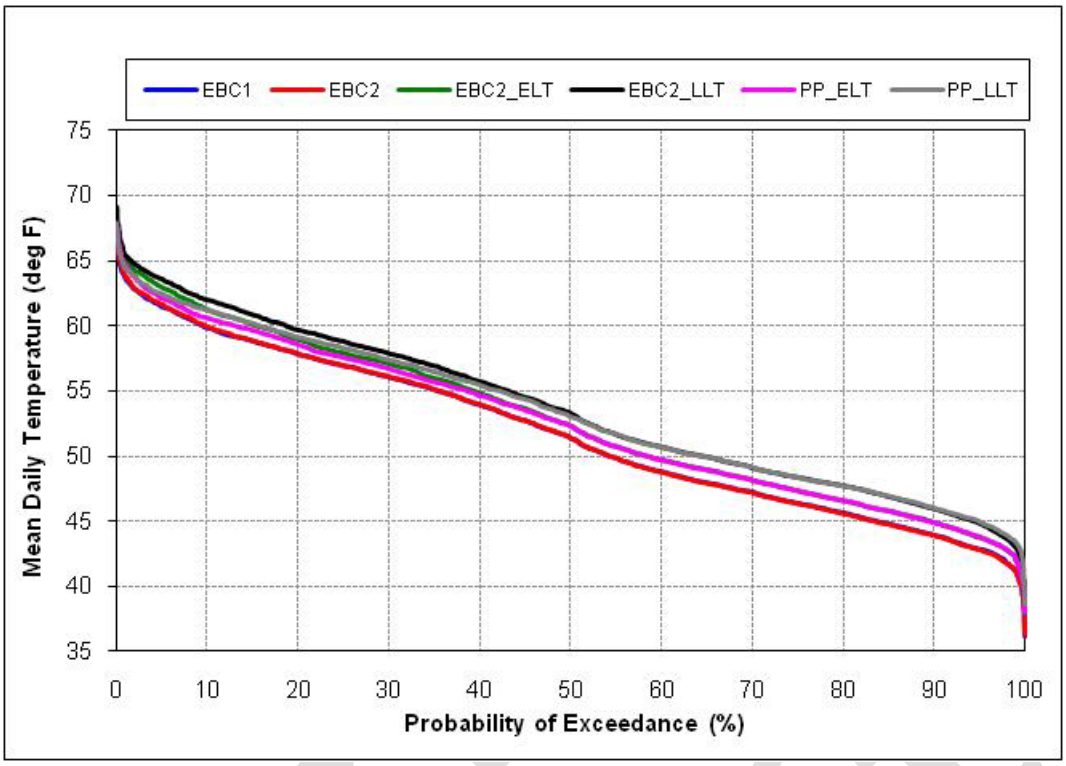

Figure C.5.2-108. Probability of Exceedance Plot for Model Scenarios of Mean Daily Temperature of the Sacramento River at Hamilton City in Dry Years, January through May

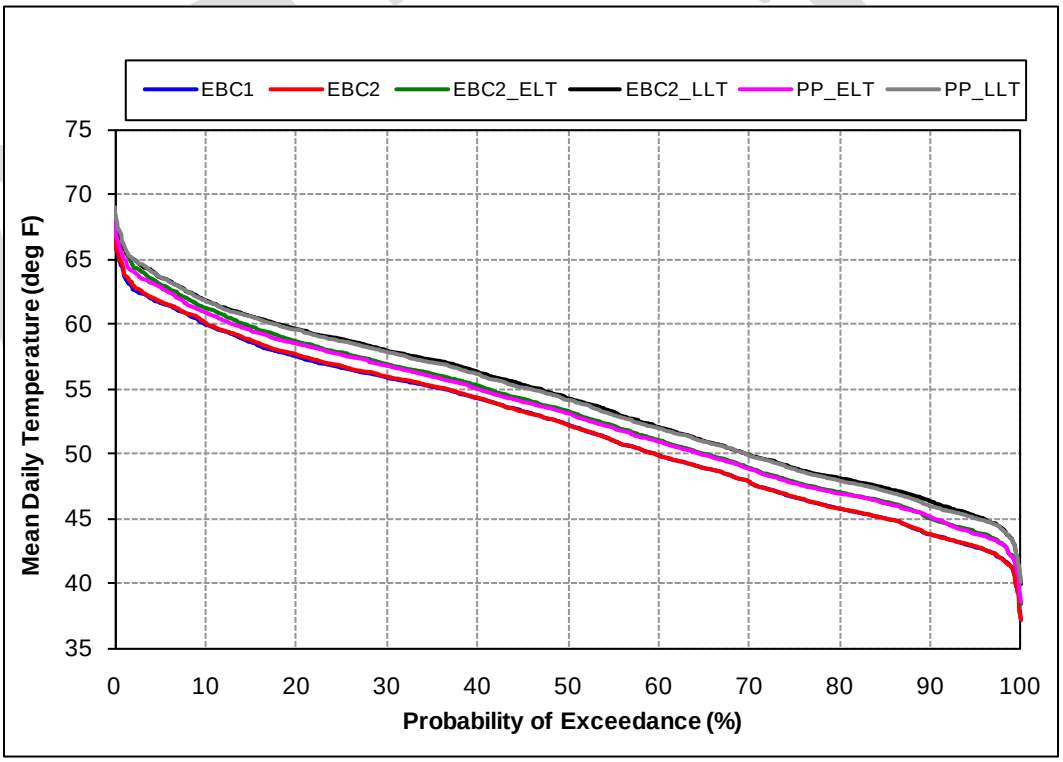

Figure C.5.2-109. Probability of Exceedance Plot for Model Scenarios of Mean Daily Temperature of the Sacramento River at Hamilton City in Critical Years, January through May

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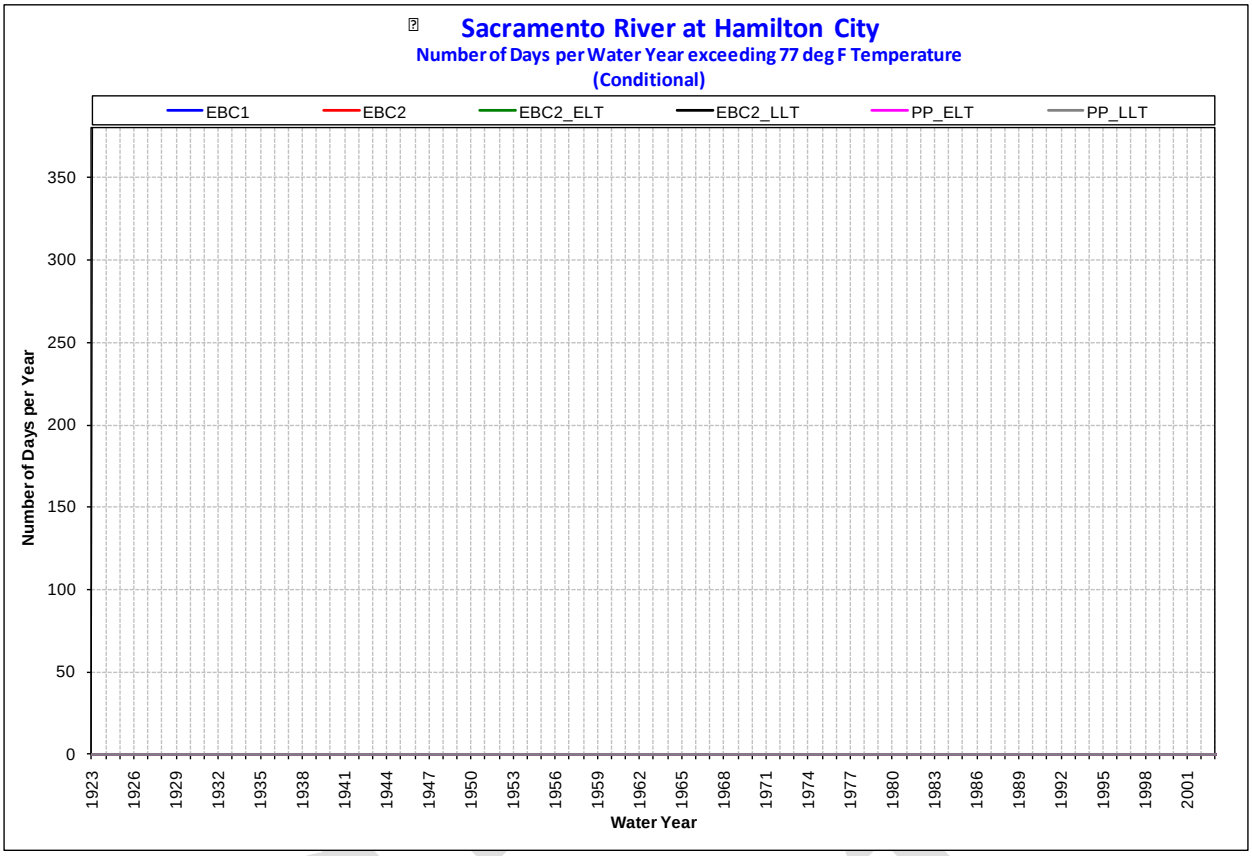

Figure C.5.2-110. Sacramento River Water Temperatures Exceeding 77°F at Hamilton City, January through May

Spawning Habitat

Gard (1996) developed a suitability index for Sacramento River white sturgeon spawning habitat. This index identified waters with velocities of 3.9–19.95 feet per second (ft/s) as suitable, with velocities of 5–12.5 ft/s as ideal. Further, water depths greater than 6 feet were identified as suitable, while those greater than 10 feet were ideal. In addition, whereas habitats with snags and gravel were considered suitable, those that included cobble, boulder, and bedrock were ideal. These criteria, combined with water temperature upper thresholds, help identify preferential spawning habitats. Although 68°F was investigated as an upper threshold for white sturgeon eggs and embryos, other criteria indicate that temperatures as low as 64°F could also be important for adult white sturgeon spawning habitat.

Water temperature at Hamilton City exceeded the 68°F threshold in <1% of days for all model scenarios and in all water-year types (Figure C.5.2-111). At the 64°F threshold, the probability of exceeding the 64°F temperature threshold is higher in EBC2_ELT and PP_ELT than EBC1 and EBC2, although the difference would be <5% (Figure C.5.2-111, Figure C.5.2-112). Likewise, the probability of exceeding the 64°F temperature threshold is higher in EBC2_LLT and PP_LLT than in EBC2_ELT and PP_ELT. Differences in exceedance above the 64°F threshold between EBC2_ETL and PP_ELT and between EBC2_LLT and PP_LLT are predicted to be smaller than difference between implementation periods.

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Due to river channel confinement in the Sacramento drainage, the upstream supply of sediment and large woody debris is limited. Consequently, the absence of large woody debris reduces in-water refuge for fish, and sediment and organic matter accumulation on the downstream side of the debris (U.S. Fish and Wildlife Service 2000) increases water velocities, depth, and substrate grain size. Sacramento River flows under PP_ELT and PP_LLT at Wilkins Slough differ only minorly relative to EBC2_ELT and EBC2_LLT, respectively (Table C.5.2-35). It was concluded with moderate certainty that few if any differences in depth, velocity, or substrate as factors influencing white sturgeon spawning habitat are anticipated between EBC2_ELT and PP_ELT or between EBC2_LLT and PP_LLT.

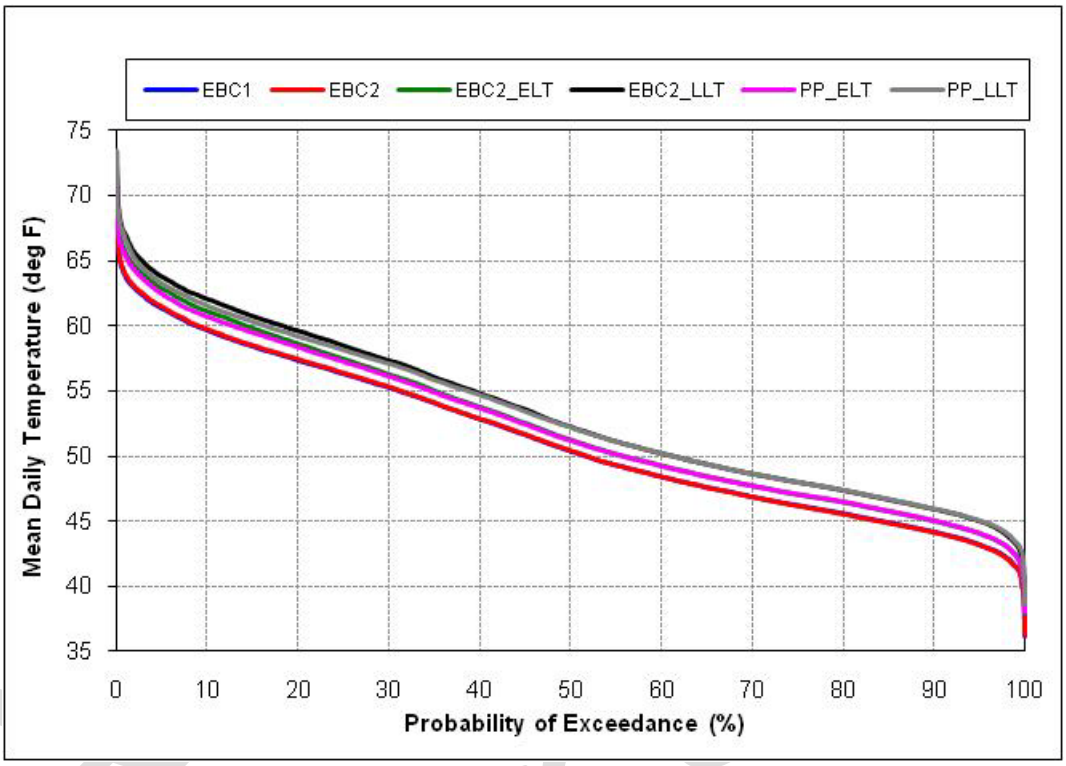

Figure C.5.2-111. Probability of Exceedance Plot for Model Scenarios of Mean Daily Temperature of the Sacramento River at Hamilton City in All Water Years, January through May

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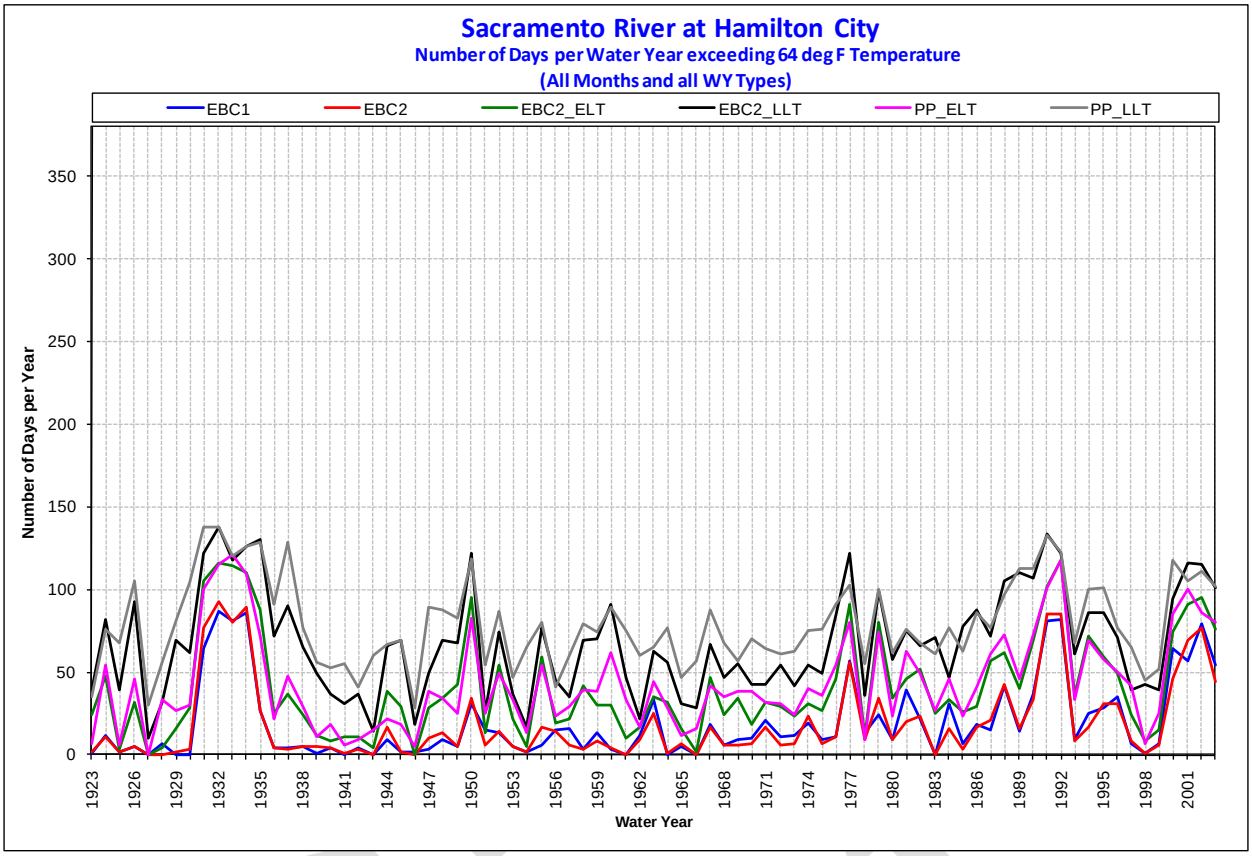

Figure C.5.2-112. Sacramento River Water Temperatures Exceeding 64°F at Hamilton City

C.5.2.1.7 Green Sturgeon

Eggs and Embryos

Water Temperature

Israel and Klimley (2008) indicates that temperature thresholds for green sturgeon eggs and embryos occur between 52°F–73°F (11°C–23°C), with optimal temperatures occurring below 63°F (17°C). In addition, Israel and Klimley (2008) indicates the period of egg/embryo occurrence occurs from April–July. The SacEFT model is based on green sturgeon egg incubation temperature tolerances observed in the laboratory. The original design of the SacEFT model assumes that green sturgeon spawning only occurs below RBDD (river mile [RM] 242). However, green sturgeon have been shown to access and utilize spawning habitats above and below RBDD (Brown 2007; Heublein et al. 2009; Poytress et al. 2009). The model also assumes a different period of occurrence (March 15–August 15) than is outlined in Israel and Klimley (2008). The model was used to investigate upper Sacramento River temperatures with respect to green sturgeon egg/embryo survival.

This effects analysis has applied the SacEFT model to assess instream temperature effects on green sturgeon eggs/embryos in the vicinity of Jelly's Ferry, a location approximately 25 river miles above the RBDD. The SacEFT model uses 63°F (17°C) as the preferential upper temperature threshold of

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green sturgeon egg survival, which is categorized as "good," and 68°F (20°C) as a maximum threshold for green sturgeon spawning periods. Cech et al. (2000) reported that temperatures above 68°F are lethal to embryos. As a result, in the approach for estimating egg/embryo lethality related to temperatures, all green sturgeon eggs exposed to temperatures exceeding 63°F (17°C) were considered to experience increased sublethal stress and incipient mortality, with exposure to temperatures of 68°F (20°C) identified as being lethal to developing embryos. The impact of water temperature on green sturgeon eggs is modeled using exceedances of average daily temperature above 63°F and 68°F during the egg development period for the green sturgeon (March 15 through August 15) at Jelly's Ferry.

Probability of exceedance plots of mean daily SRWQM temperatures for each model scenario are presented in Figure C.5.2-113. Predictions on the percent of years during which the 63°F and 68°F threshold temperatures would not be exceeded at Jelly's Ferry are presented in Table C.5.2-40 and differences between models scenarios are presented in Table C.5.2-41.

For the 63°F threshold, the percent of years under EBC1 (89%) is predicted to be 23% greater than PP_ELT (66%) and 55% greater than PP_LLT (34%). Likewise, the percent of years under EBC2 (87%) is predicted to be 21% higher than EBC2_ELT and 53% higher than PP_LLT. Isolating the effects of climate change, the percent of years under EBC2_ELT (68%) is predicted to be 2% higher than under PP_ELT and the percent of years under EBC2_LLT (3%) is predicted to be 1% higher than under PP_LLT.

For the 68°F threshold, the percent of years under EBC1 (100%) is predicted to be 2% greater than PP_ELT (98%) and 9% greater than PP_LLT (91%). Likewise, the percent of years under EBC2 (100%) is predicted to be 2% higher than EBC2_ELT and 9% higher than PP_LLT. Isolating the effects of climate change, the percent of years under EBC2_ELT (95%) is predicted to be 3% higher than under PP_ELT and the percent of years under EBC2_LLT (91%) is predicted to be identical to the percent of years under PP_LLT. These results suggest that the preliminary proposal will have little or no effect on green sturgeon egg temperature conditions. However, climate change will reduce the frequency with which temperatures at Jelly's Ferry will be under the 63°F threshold and, to some degree, under the 68°F threshold.

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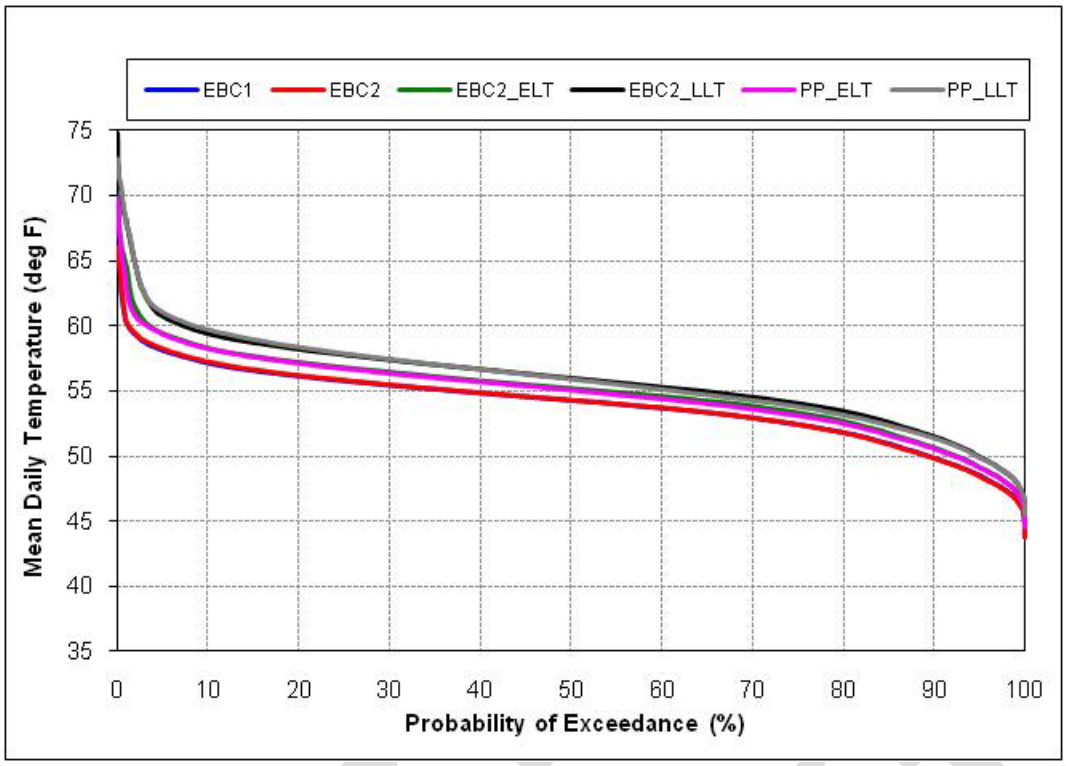

Figure C.5.2-113. Probability of Exceedance Plot for Model Scenarios of Mean Daily Temperature of the Sacramento River at Jelly's Ferry, March 15 through August 15

Table C.5.2-40. Percent of Years during Which Optimal Egg and Spawning Temperature (63°F) and Upper Tolerance Temperature (68°F) Would Not Be Exceeded between March 15 and August 15, Sacramento River at Jelly's Ferry

Temperature Threshold	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
63°F (17°C)	89	87	68	33	66	34
68°F (20°C)	100	100	95	91	98	91

Table C.5.2-41. Differences and Percent Differences between Model Scenarios in the Number of Years during Which Water Temperature Would Not Exceed Green Sturgeon Temperature Thresholds between March 15 and August 15, Sacramento River at Jelly's Ferry

Temperature Threshold	EBC1 vs. PP_ELT	EBC1 vs. PP_LLT	EBC2 vs. PP_ELT	EBC2 vs. PP_LLT	EBC2_ELT vs. PP_ELT	EBC2_LLT vs. PP_LLT
63°F (17°C) difference	-23	-55	-21	-53	-2	-1
63°F (17°C) percent difference	-26%	-62%	-24%	-61%	-3%	-3%
68°F (20°C) difference	-2	-9	-2	-9	3	0
68°F (20°C) percent difference	-2%	-9%	-2%	-9%	3%	0%
Positive values indicate more years with no exceedance under the preliminary proposal						

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Seasonal Flows

Sufficient flows are needed to oxygenate recently laid eggs and to limit disease and fungal infection (Deng et al. 2002; Parsley et al. 2002). Further, within the Sacramento River, spawning appears to be triggered by large increases in water flow during spawning (Brown 2007). Because flow relationships have been examined in more detail for white sturgeon (Kohlhorst et al. 1991) than green sturgeon (Israel and Klimley 2008), the white sturgeon analytical approach was utilized for investigating flow effects on eggs and embryo of green sturgeon. Within the March–August period of egg/embryo occurrence (Israel and Klimley 2008), an analysis of the potential alterations in flow was completed for the Sacramento River at Keswick, Red Bluff, and Wilkins Slough.

With some exceptions, Sacramento River flows at Keswick under the preliminary proposal would generally increase relative to EBC2 during the March–August egg/embryo life stage (Figure C.5.2-43, Figure C.5.2-114 to Figure C.5.2-119, Table C.5.2-42). For all water-year types combined, mean monthly flows under PP_ELT are predicted to range from 353 cfs (3.5%) lower than EBC2_ELT in August to 660 cfs (6.1%) higher than EBC2_ELT during June. In the late long-term for all water-year types combined, differences in mean monthly flows are predicted to range from 865 cfs (8.4%) lower under the PP_LLT relative to the EBC2_LLT during August to 1,035 cfs (9.3%) higher during June. Overall, these results suggest that conditions for green sturgeon eggs and embryos in the Sacramento River at Keswick would be improved under the preliminary proposal during March through June but would decline during July and August.

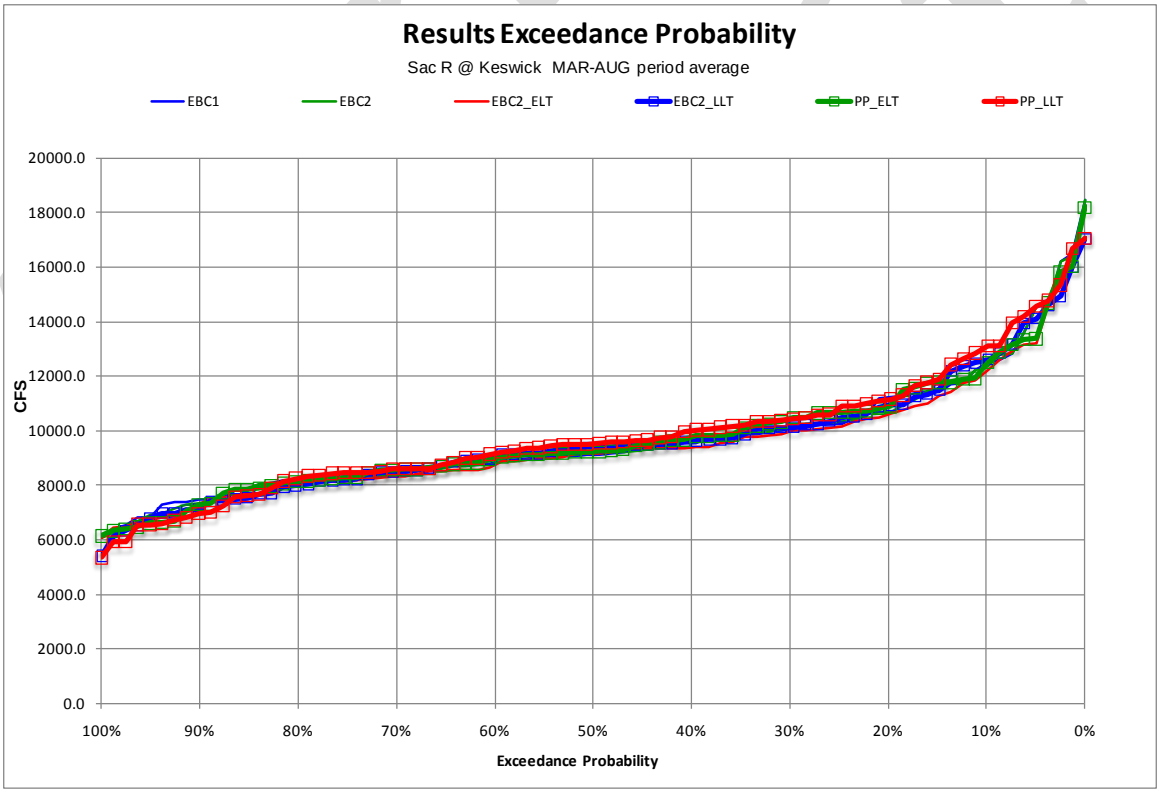

Figure C.5.2-114. Probability of Exceedance Plot for Model Scenarios of Mean Monthly Flow in the Sacramento River at Keswick, March through August

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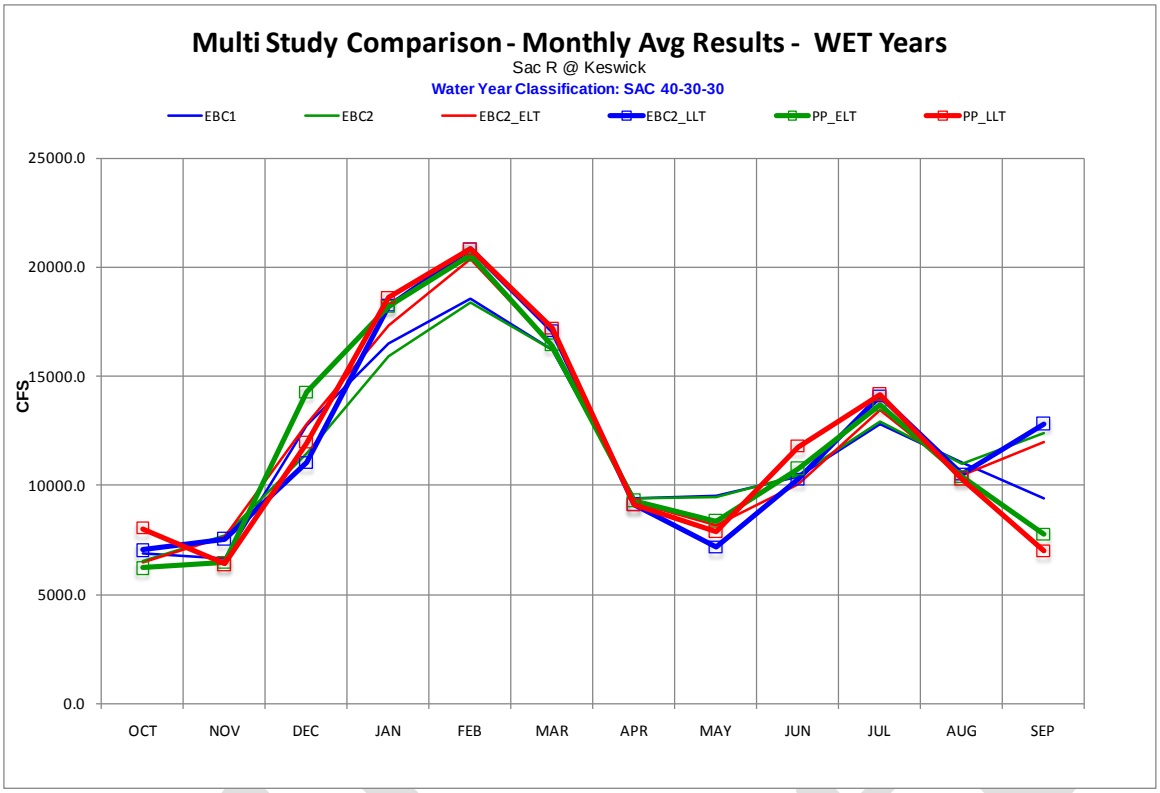

Figure C.5.2-115. Average Monthly Flows for Wet Years in the Sacramento River at Keswick

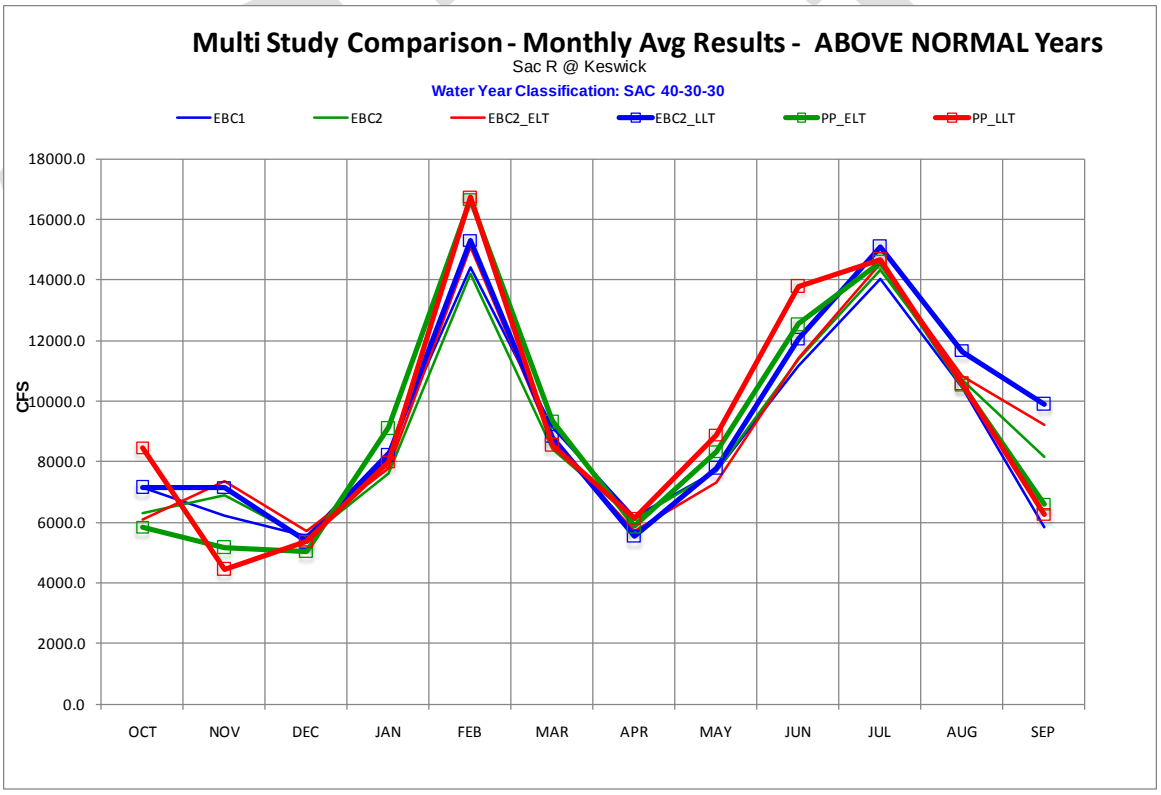

Figure C.5.2-116. Average Monthly Flows for Above-Normal Years in the Sacramento River at Keswick

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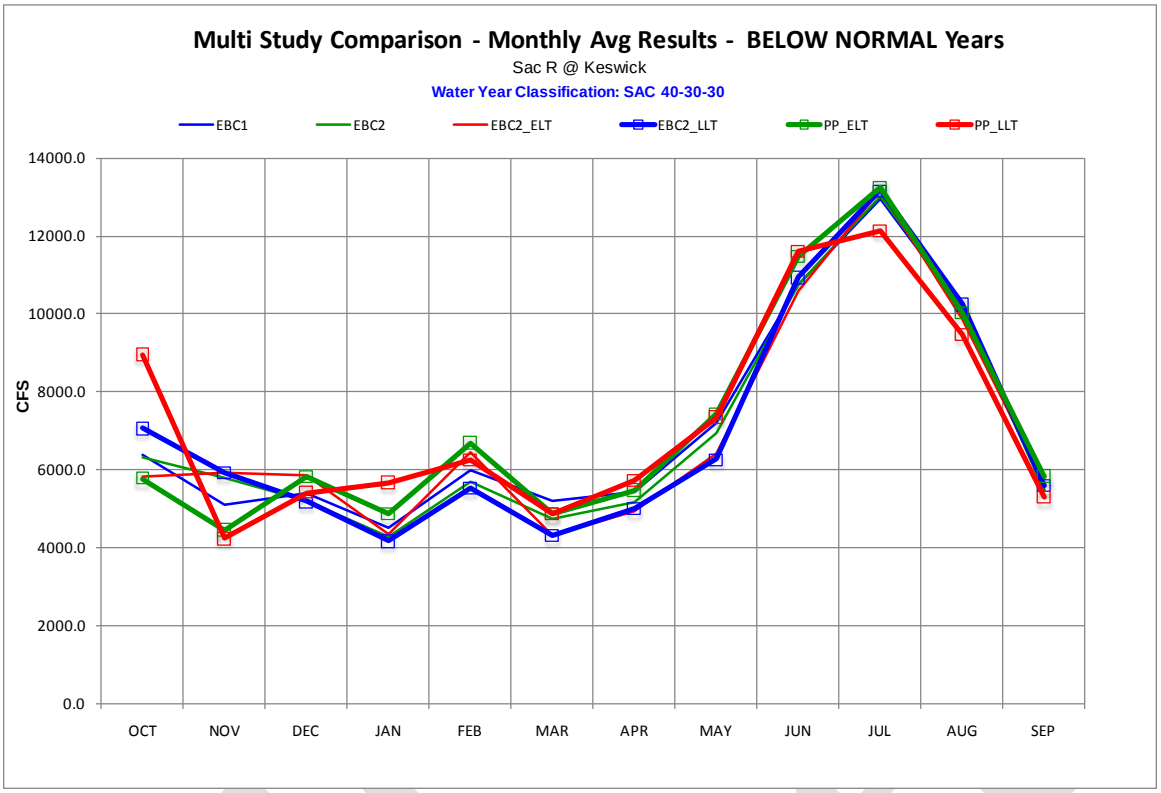

Figure C.5.2-117. Average Monthly Flows for Below-Normal Years in the Sacramento River at Keswick

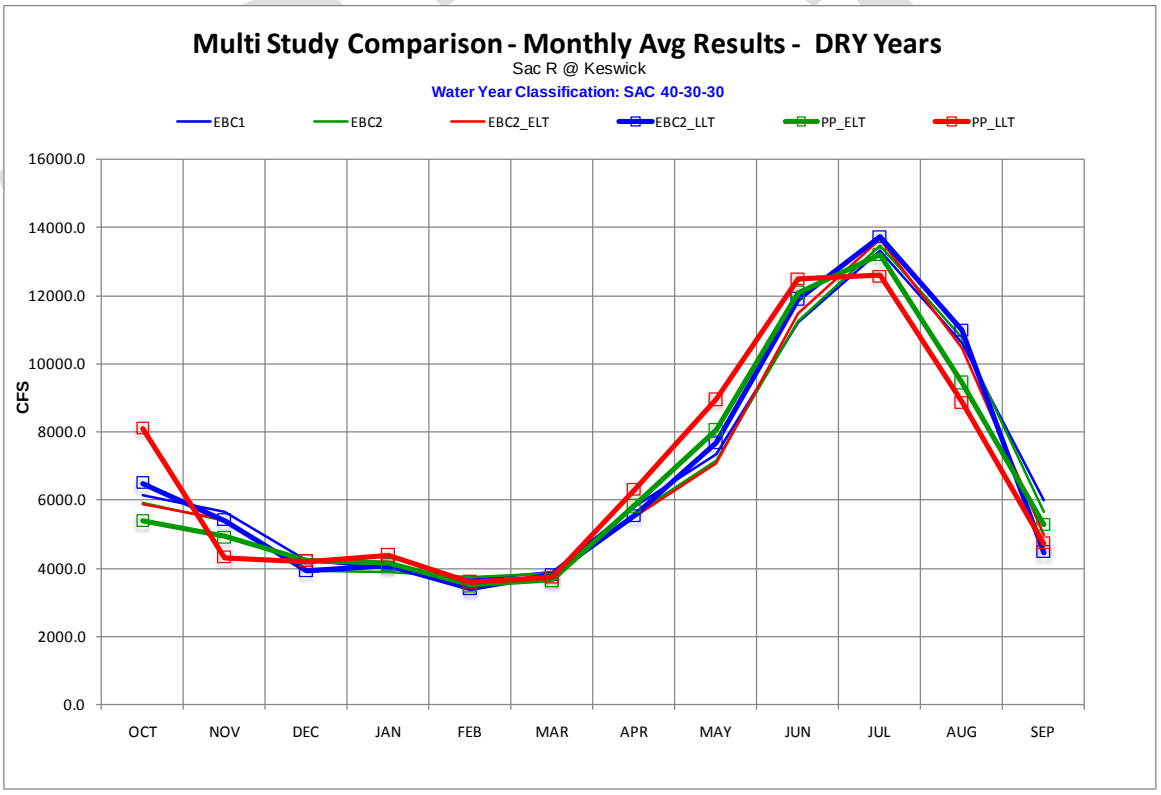

Figure C.5.2-118. Average Monthly Flows for Dry Years in the Sacramento River at Keswick

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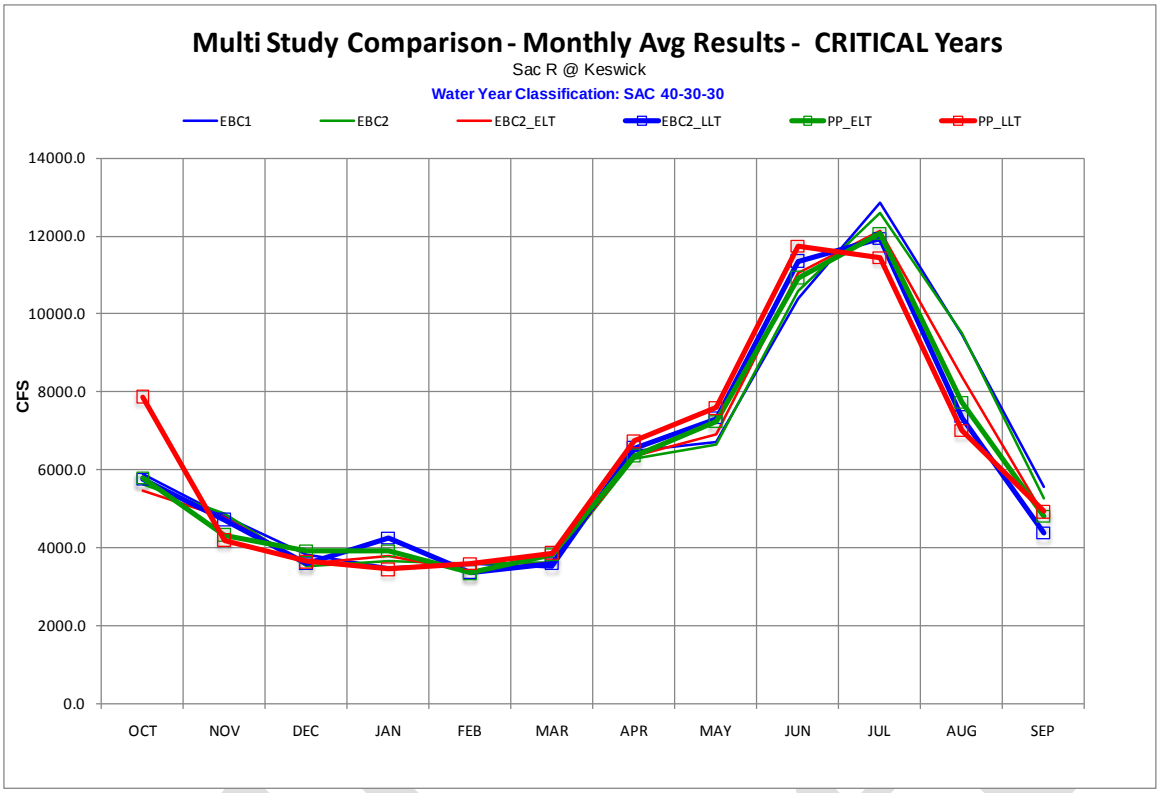

Figure C.5.2-119. Average Monthly Flows for Critical Years in the Sacramento River at Keswick

Table C.5.2-42. Differences and Percent Differences between Pairs of Model Scenarios in the Sacramento River at Keswick for all Months

Month	WY Type	EBC1 vs. PP_ELT	EBC1 vs. PP_LLT	EBC2 vs. PP_ELT	EBC2 vs. PP_LLT	EBC2_ELT vs. PP_ELT	EBC2_LLT vs. PP_LLT
Jan	W	1673 (10.1%)	2089 (12.6%)	2311 (14.5%)	2726 (17.2%)	869 (5%)	382 (2.1%)
	AN	803 (9.7%)	-330 (-4%)	1487 (19.5%)	353 (4.6%)	1345 (17.3%)	-217 (-2.6%)
	BN	358 (8%)	1164 (25.9%)	574 (13.4%)	1381 (32.2%)	519 (12%)	1483 (35.4%)
	D	141 (3.5%)	376 (9.4%)	263 (6.8%)	498 (12.9%)	38 (0.9%)	275 (6.7%)
	C	425 (12.2%)	-38 (-1.1%)	243 (6.6%)	-220 (-6%)	122 (3.2%)	-786 (-18.5%)
	AVG	802 (9.3%)	890 (10.3%)	1142 (13.8%)	1229 (14.9%)	587 (6.7%)	288 (3.1%)
Feb	W	1979 (10.7%)	2267 (12.2%)	2201 (12%)	2488 (13.6%)	208 (1%)	-9 (0%)
	AN	2263 (15.7%)	2332 (16.2%)	2488 (17.5%)	2557 (18%)	1591 (10.6%)	1444 (9.4%)
	BN	708 (11.8%)	263 (4.4%)	988 (17.3%)	544 (9.5%)	233 (3.6%)	700 (12.6%)
	D	-173 (-4.7%)	-74 (-2%)	-228 (-6.1%)	-129 (-3.5%)	63 (1.8%)	199 (5.8%)
	C	-233 (-6.5%)	-12 (-0.3%)	-234 (-6.5%)	-14 (-0.4%)	-28 (-0.8%)	214 (6.4%)
	AVG	1007 (9.7%)	1087 (10.5%)	1146 (11.2%)	1226 (12%)	348 (3.2%)	403 (3.7%)
Mar	W	212 (1.3%)	1002 (6.2%)	217 (1.3%)	1007 (6.2%)	14 (0.1%)	137 (0.8%)
	AN	202 (2.2%)	-573 (-6.3%)	904 (10.7%)	129 (1.5%)	671 (7.8%)	-260 (-2.9%)
	BN	-330 (-6.3%)	-327 (-6.3%)	113 (2.4%)	117 (2.5%)	563 (13.1%)	555 (12.9%)
	D	-233 (-6%)	-171 (-4.4%)	-202 (-5.2%)	-140 (-3.6%)	-188 (-4.9%)	-82 (-2.1%)
	C	322 (9.2%)	380 (10.9%)	192 (5.3%)	250 (6.9%)	201 (5.6%)	283 (7.9%)
	AVG	36 (0.4%)	196 (2.2%)	204 (2.4%)	364 (4.3%)	187 (2.2%)	124 (1.4%)

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Month	WY Type	EBC1 vs. PP_ELT	EBC1 vs. PP_LLT	EBC2 vs. PP_ELT	EBC2 vs. PP_LLT	EBC2_ELT vs. PP_ELT	EBC2_LLT vs. PP_LLT
Apr	W	-106 (-1.1%)	-330 (-3.5%)	-84 (-0.9%)	-308 (-3.3%)	58 (0.6%)	-43 (-0.5%)
	AN	-314 (-5.1%)	-45 (-0.7%)	-225 (-3.7%)	44 (0.7%)	156 (2.7%)	601 (10.9%)
	BN	49 (0.9%)	296 (5.5%)	308 (6%)	555 (10.7%)	541 (11%)	714 (14.2%)
	D	37 (0.6%)	505 (8.7%)	261 (4.7%)	730 (13.1%)	342 (6.2%)	775 (14%)
	C	-114 (-1.8%)	261 (4%)	59 (0.9%)	435 (6.9%)	14 (0.2%)	183 (2.8%)
	AVG	-80 (-1.1%)	88 (1.3%)	59 (0.9%)	227 (3.3%)	211 (3.1%)	393 (5.8%)
May	W	-1151 (-12.1%)	-1637 (-17.2%)	-1093 (-11.6%)	-1579 (-16.7%)	174 (2.1%)	722 (10.1%)
	AN	620 (8%)	1159 (15%)	637 (8.3%)	1176 (15.3%)	1022 (14%)	1085 (13.9%)
	BN	230 (3.2%)	153 (2.1%)	470 (6.8%)	392 (5.6%)	1012 (15.8%)	1074 (17.1%)
	D	725 (9.9%)	1608 (21.9%)	898 (12.5%)	1782 (24.8%)	998 (14.1%)	1275 (16.6%)
	C	509 (7.6%)	871 (13%)	585 (8.8%)	947 (14.3%)	324 (4.7%)	270 (3.7%)
	AVG	-1 (0%)	157 (2%)	110 (1.4%)	268 (3.4%)	644 (8.8%)	890 (12.3%)
Jun	W	386 (3.7%)	1401 (13.5%)	299 (2.9%)	1314 (12.6%)	699 (6.9%)	1502 (14.6%)
	AN	1399 (12.6%)	2642 (23.7%)	1177 (10.4%)	2421 (21.3%)	1144 (10%)	1758 (14.6%)
	BN	708 (6.6%)	840 (7.8%)	714 (6.6%)	847 (7.9%)	892 (8.4%)	651 (6%)
	D	864 (7.7%)	1274 (11.4%)	836 (7.4%)	1247 (11.1%)	624 (5.4%)	600 (5%)
	C	528 (5.1%)	1358 (13.1%)	321 (3%)	1152 (10.9%)	-121 (-1.1%)	400 (3.5%)
	AVG	715 (6.7%)	1453 (13.5%)	619 (5.7%)	1358 (12.5%)	660 (6.1%)	1035 (9.3%)
Jul	W	898 (7%)	1393 (10.9%)	730 (5.6%)	1226 (9.5%)	200 (1.5%)	75 (0.5%)
	AN	549 (3.9%)	629 (4.5%)	292 (2%)	373 (2.6%)	64 (0.4%)	-412 (-2.7%)
	BN	286 (2.2%)	-831 (-6.4%)	231 (1.8%)	-887 (-6.8%)	56 (0.4%)	-1043 (-7.9%)
	D	-104 (-0.8%)	-709 (-5.3%)	-253 (-1.9%)	-858 (-6.4%)	-452 (-3.3%)	-1133 (-8.3%)
	C	-782 (-6.1%)	-1399 (-10.9%)	-530 (-4.2%)	-1146 (-9.1%)	-57 (-0.5%)	-484 (-4.1%)
	AVG	277 (2.1%)	32 (0.2%)	181 (1.4%)	-64 (-0.5%)	-25 (-0.2%)	-534 (-3.9%)
Aug	W	-627 (-5.7%)	-727 (-6.6%)	-610 (-5.5%)	-710 (-6.5%)	-45 (-0.4%)	-189 (-1.8%)
	AN	75 (0.7%)	131 (1.3%)	-171 (-1.6%)	-116 (-1.1%)	-311 (-2.9%)	-1061 (-9.1%)
	BN	-115 (-1.1%)	-677 (-6.7%)	-177 (-1.7%)	-739 (-7.2%)	148 (1.5%)	-798 (-7.8%)
	D	-1174 (-11%)	-1754 (-16.5%)	-1322 (-12.3%)	-1902 (-17.6%)	-1011 (-9.7%)	-2112 (-19.2%)
	C	-1754 (-18.5%)	-2469 (-26.1%)	-1798 (-18.9%)	-2513 (-26.4%)	-661 (-7.9%)	-344 (-4.7%)
	AVG	-722 (-6.9%)	-1073 (-10.2%)	-802 (-7.6%)	-1154 (-10.9%)	-353 (-3.5%)	-865 (-8.4%)
Sep	W	-1629 (-17.4%)	-2387 (-25.4%)	-4618 (-37.3%)	-5377 (-43.4%)	-4256 (-35.4%)	-5835 (-45.5%)
	AN	736 (12.5%)	390 (6.7%)	-1585 (-19.4%)	-1930 (-23.6%)	-2611 (-28.4%)	-3645 (-36.8%)
	BN	339 (6.2%)	-209 (-3.8%)	360 (6.6%)	-188 (-3.4%)	155 (2.7%)	-317 (-5.7%)
	D	-687 (-11.5%)	-1263 (-21.1%)	-362 (-6.4%)	-938 (-16.6%)	316 (6.4%)	254 (5.7%)
	C	-769 (-13.8%)	-635 (-11.4%)	-482 (-9.1%)	-349 (-6.6%)	-33 (-0.7%)	559 (12.8%)
	AVG	-614 (-8.9%)	-1106 (-16%)	-1785 (-22.1%)	-2276 (-28.2%)	-1640 (-20.7%)	-2300 (-28.4%)
Oct	W	-673 (-9.8%)	1139 (16.5%)	-318 (-4.9%)	1494 (22.9%)	-279 (-4.3%)	990 (14.1%)
	AN	-1310 (-18.3%)	1317 (18.4%)	-478 (-7.6%)	2148 (34%)	-254 (-4.2%)	1310 (18.3%)
	BN	-623 (-9.7%)	2553 (39.9%)	-554 (-8.8%)	2622 (41.4%)	-61 (-1%)	1877 (26.5%)
	D	-725 (-11.8%)	1977 (32.3%)	-518 (-8.8%)	2184 (36.9%)	-496 (-8.4%)	1611 (24.8%)
	C	-126 (-2.1%)	1973 (33.4%)	164 (2.9%)	2263 (40.3%)	324 (5.9%)	2124 (36.9%)
	AVG	-689 (-10.5%)	1713 (26.2%)	-355 (-5.7%)	2046 (33%)	-197 (-3.3%)	1491 (22.1%)

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Month	WY Type	EBC1 vs. PP_ELT	EBC1 vs. PP_LLT	EBC2 vs. PP_ELT	EBC2 vs. PP_LLT	EBC2_ELT vs. PP_ELT	EBC2_LLT vs. PP_LLT
Nov	W	-227 (-3.4%)	-271 (-4.1%)	-1276 (-16.5%)	-1320 (-17.1%)	-1175 (-15.4%)	-1138 (-15.1%)
	AN	-1037 (-16.7%)	-1767 (-28.4%)	-1730 (-25%)	-2460 (-35.6%)	-2170 (-29.5%)	-2677 (-37.5%)
	BN	-629 (-12.4%)	-846 (-16.6%)	-1324 (-22.9%)	-1542 (-26.7%)	-1468 (-24.8%)	-1695 (-28.5%)
	D	-743 (-13.1%)	-1350 (-23.8%)	-483 (-8.9%)	-1089 (-20.1%)	-513 (-9.4%)	-1087 (-20.1%)
	C	-507 (-10.5%)	-627 (-13%)	-559 (-11.5%)	-678 (-13.9%)	-474 (-9.9%)	-514 (-10.9%)
	AVG	-569 (-9.7%)	-877 (-15%)	-1072 (-16.9%)	-1380 (-21.7%)	-1123 (-17.5%)	-1356 (-21.4%)
Dec	W	1495 (11.7%)	-812 (-6.4%)	2820 (24.6%)	512 (4.5%)	1453 (11.3%)	931 (8.4%)
	AN	-476 (-8.6%)	-155 (-2.8%)	-426 (-7.8%)	-106 (-1.9%)	-674 (-11.8%)	-1 (0%)
	BN	402 (7.4%)	-1 (0%)	615 (11.8%)	212 (4.1%)	-43 (-0.7%)	217 (4.2%)
	D	29 (0.7%)	-8 (-0.2%)	328 (8.4%)	292 (7.5%)	360 (9.3%)	270 (6.9%)
	C	82 (2.2%)	-183 (-4.8%)	376 (10.7%)	111 (3.1%)	318 (8.8%)	63 (1.8%)

With some very minor scalar differences, predicted flows results of CALSIM modeling in the Sacramento River flows upstream of Red Bluff are similar to those of the Sacramento River at Keswick (Figure C.5.2-4, Figure C.5.2-120 through Figure C.5.2-125, and Table C.5.2-43). Mean monthly flows upstream of Red Bluff from March through June are predicted to be higher under the preliminary proposal than EBC1, EBC2, EBC2_ELT, and EBC2_LLT. In July, mean monthly flows would vary by less than 4% for PP_ELT and PP_LLT relative to EBC2, EBC2_ELT, and EBC2_LLT scenarios. Flows in August under PP_ELT and PP_LLT are 364 cfs (3.5%) and 865 cfs (-8.3%) lower than flows under EBC2_ELT and EBC2_LLT, respectively.

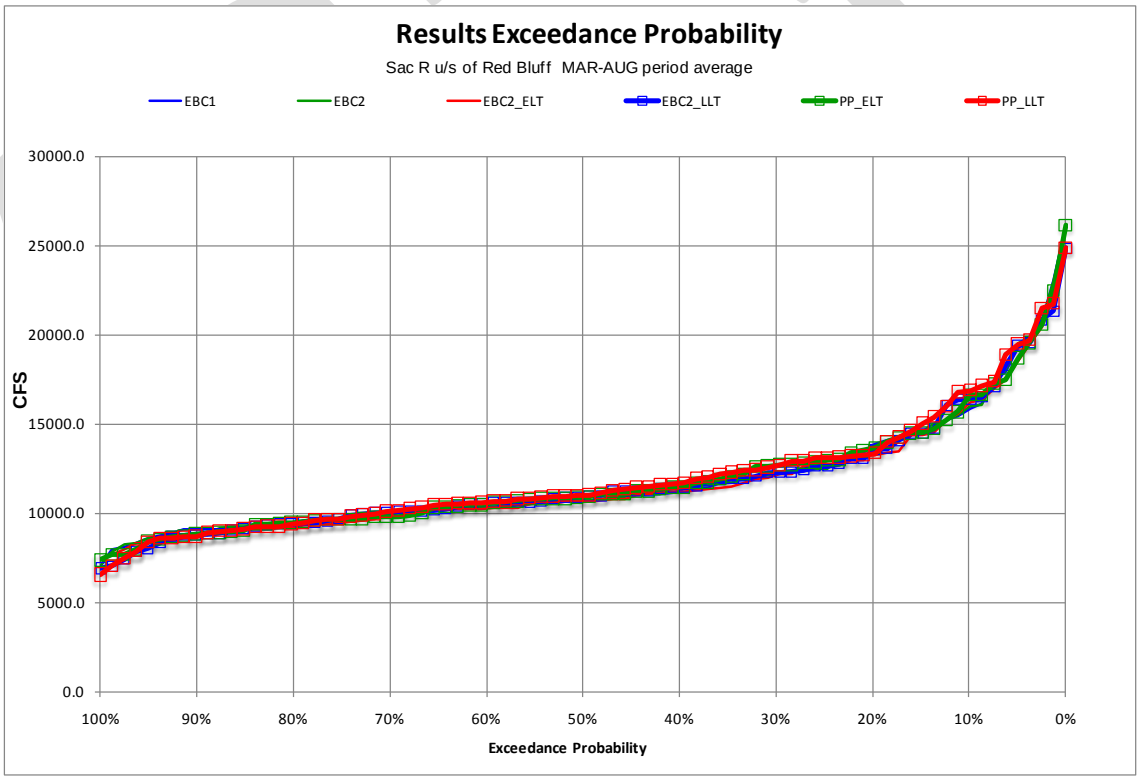

Figure C.5.2-120. Probability of Exceedance Plot for Model Scenarios of Mean Monthly Flow in the Sacramento River Upstream of Red Bluff, March through August

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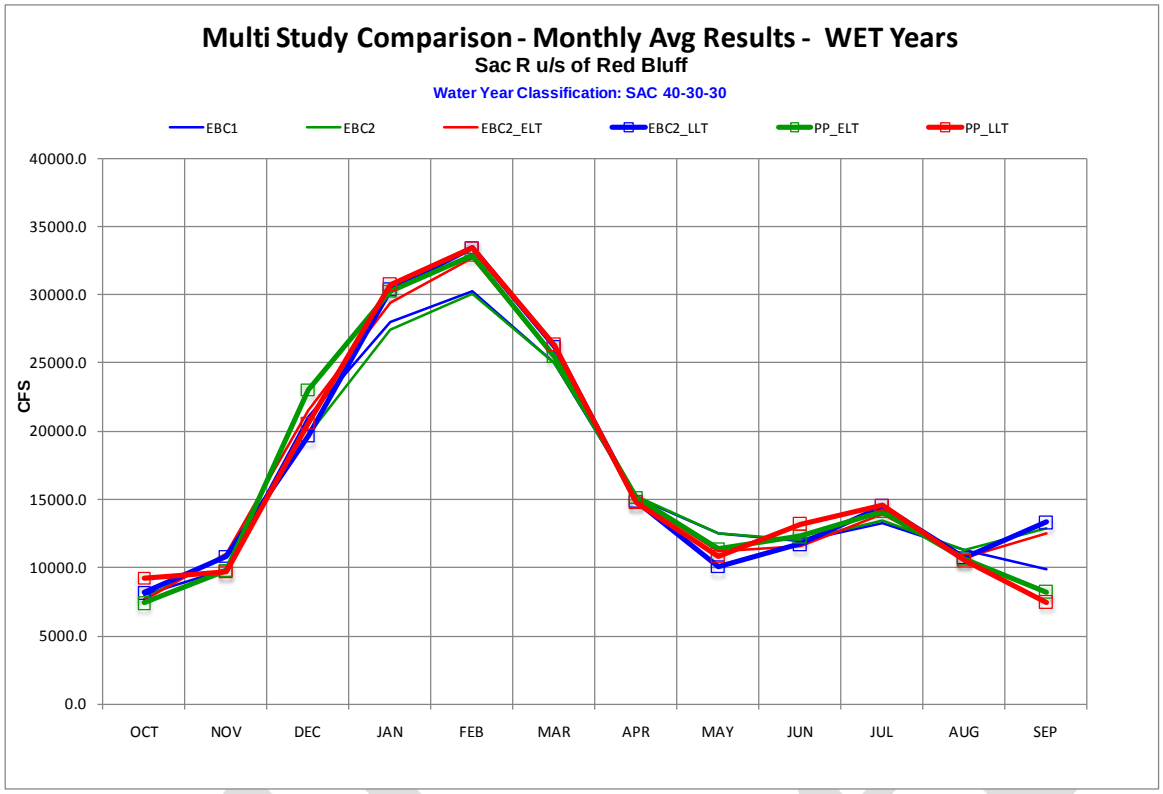

Figure C.5.2-121. Average Monthly Flows for Wet Years in the Sacramento River at Red Bluff

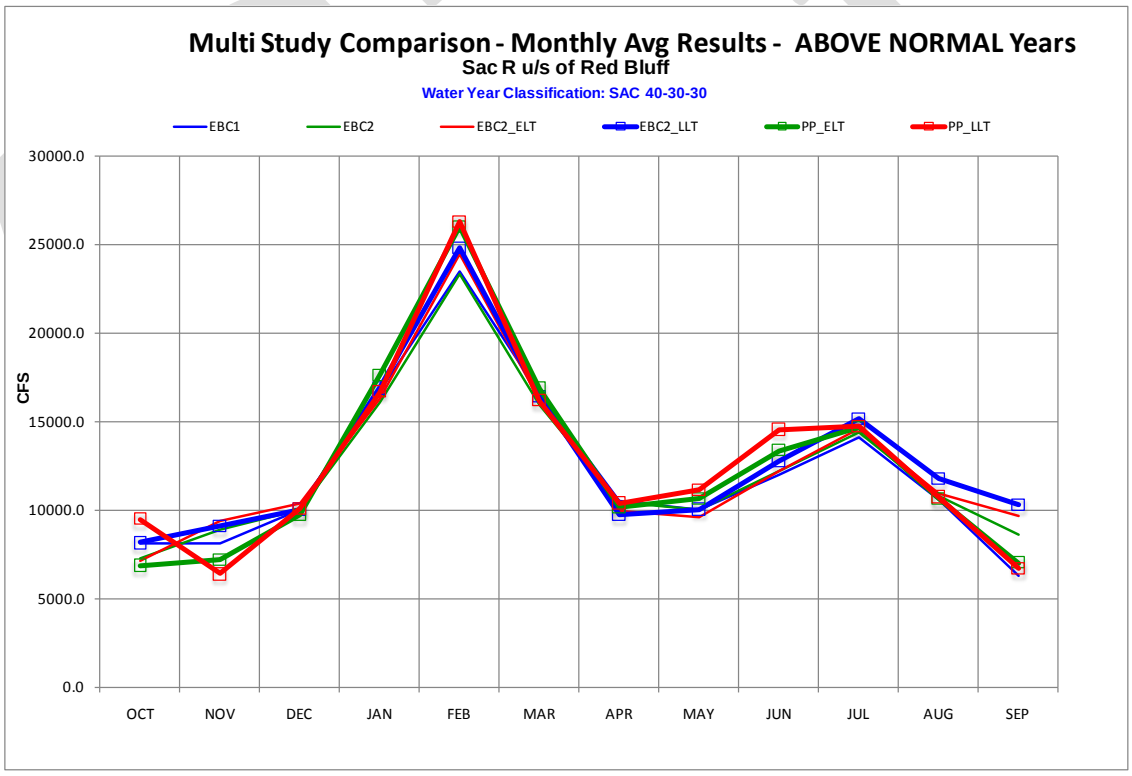

Figure C.5.2-122. Average Monthly Flows for Above-Normal Years in the Sacramento River at Red Bluff

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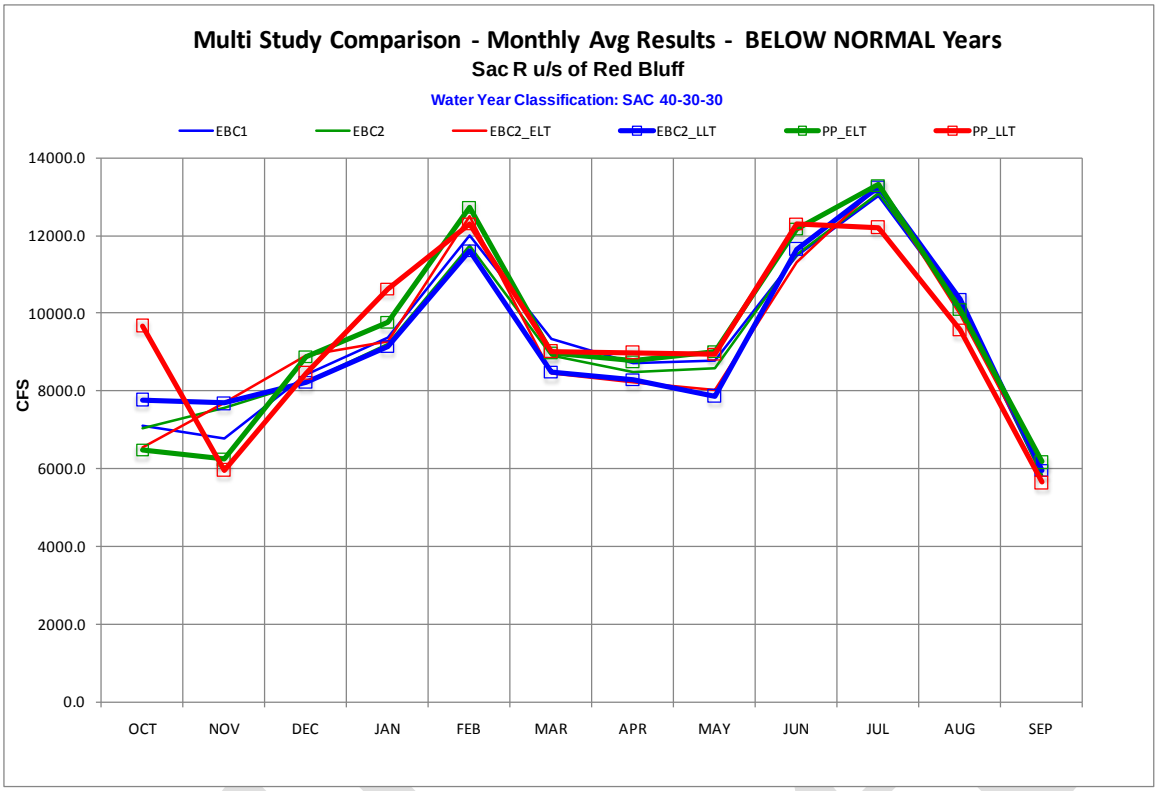

Figure C.5.2-123. Average Monthly Flows for Below-Normal Years in the Sacramento River at Red Bluff

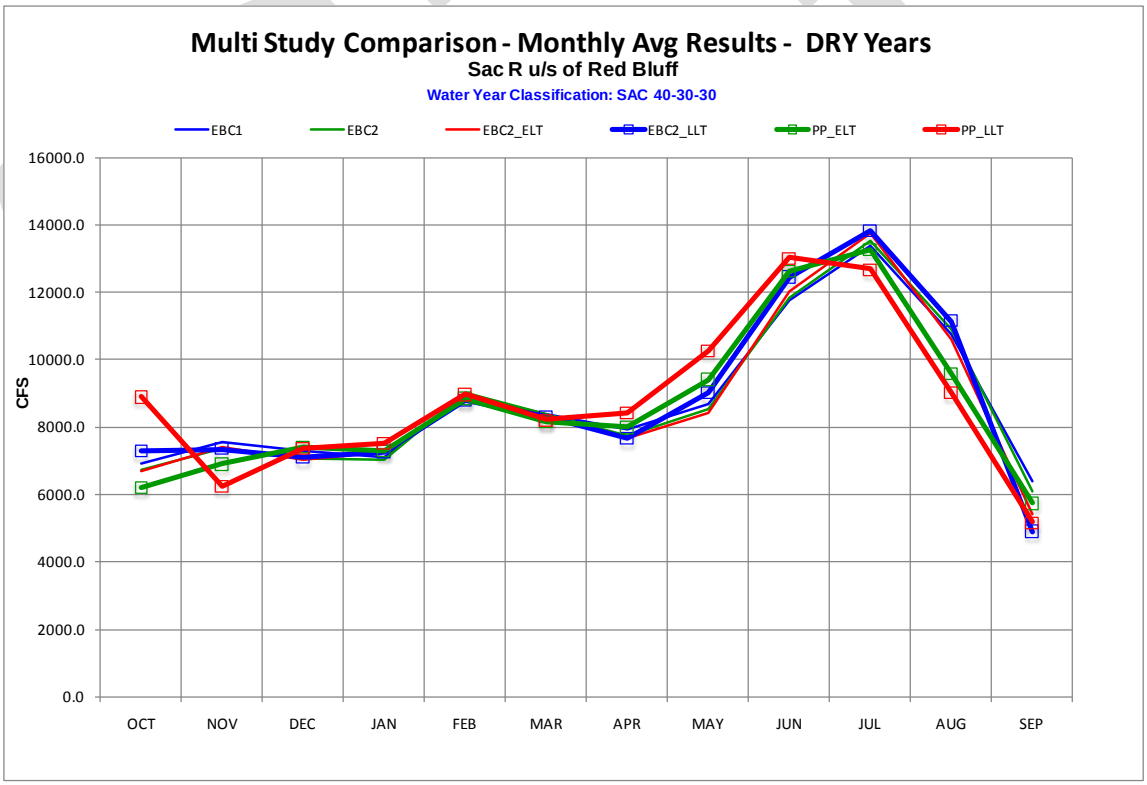

Figure C.5.2-124. Average Monthly Flows for Dry Years in the Sacramento River at Red Bluff

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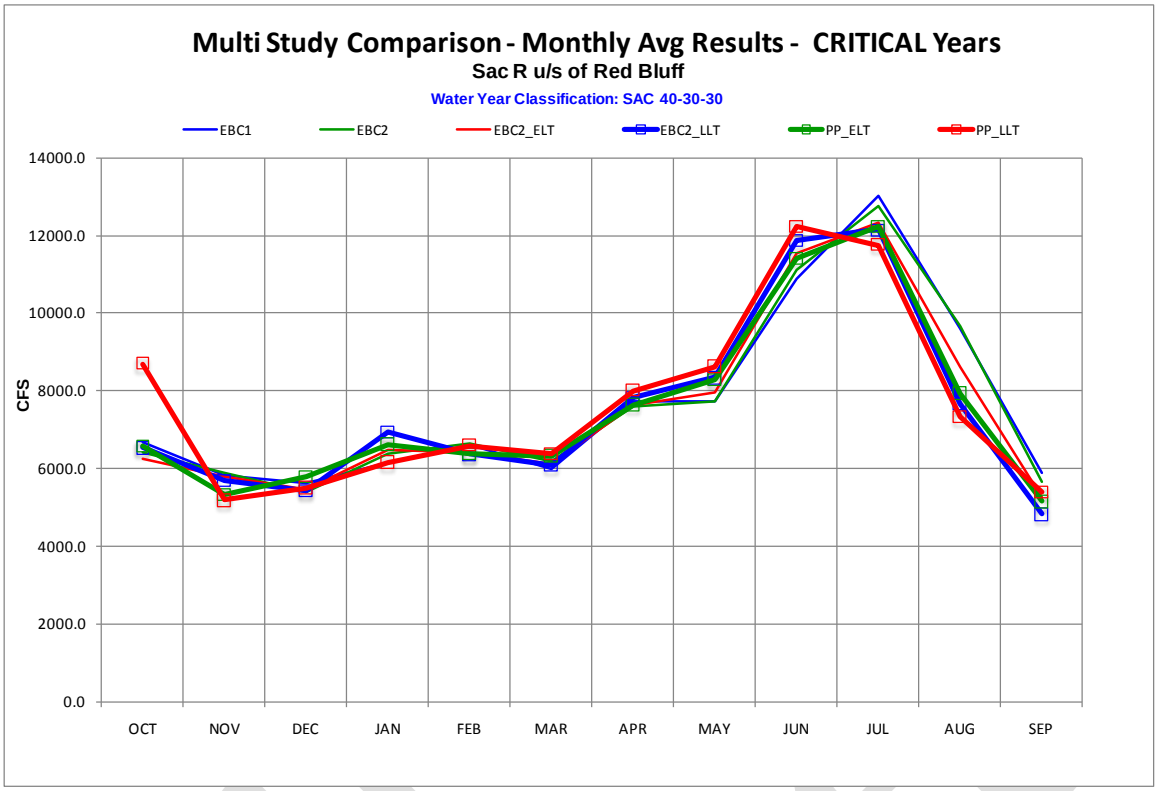

Figure C.5.2-125. Average Monthly Flows for Critical Years in the Sacramento River at Red Bluff

Table C.5.2-43. Differences and Percent Differences between Pairs of Model Scenarios in the Sacramento River Upstream of Red Bluff for All Months

Month	WY Type	EBC1 vs. PP_ELT	EBC1 vs. PP_LLT	EBC2 vs. PP_ELT	EBC2 vs. PP_LLT	EBC2_ELT vs. PP_ELT	EBC2_LLT vs. PP_LLT
Jan	W	2189 (7.8%)	2725 (9.7%)	2810 (10.3%)	3346 (12.2%)	858 (2.9%)	371 (1.2%)
	AN	887 (5.3%)	-63 (-0.4%)	1544 (9.6%)	595 (3.7%)	1345 (8.3%)	-224 (-1.3%)
	BN	402 (4.3%)	1241 (13.2%)	568 (6.2%)	1408 (15.3%)	516 (5.6%)	1476 (16.1%)
	D	196 (2.8%)	435 (6.1%)	266 (3.8%)	504 (7.2%)	32 (0.4%)	271 (3.7%)
	C	477 (7.8%)	17 (0.3%)	232 (3.6%)	-228 (-3.6%)	123 (1.9%)	-782 (-11.3%)
	AVG	1005 (6.5%)	1164 (7.6%)	1306 (8.7%)	1465 (9.7%)	582 (3.7%)	282 (1.7%)
Feb	W	2660 (8.8%)	3203 (10.6%)	2860 (9.5%)	3404 (11.3%)	203 (0.6%)	-13 (0%)
	AN	2512 (10.7%)	2777 (11.8%)	2708 (11.6%)	2973 (12.8%)	1581 (6.5%)	1441 (5.8%)
	BN	732 (6.1%)	297 (2.5%)	989 (8.4%)	553 (4.7%)	229 (1.8%)	687 (5.9%)
	D	-100 (-1.1%)	37 (0.4%)	-183 (-2%)	-46 (-0.5%)	62 (0.7%)	195 (2.2%)
	C	-218 (-3.3%)	-4 (-0.1%)	-262 (-3.9%)	-48 (-0.7%)	-24 (-0.4%)	216 (3.4%)
	AVG	1282 (7.1%)	1480 (8.2%)	1393 (7.8%)	1592 (8.9%)	345 (1.8%)	398 (2.1%)
Mar	W	484 (1.9%)	1343 (5.4%)	453 (1.8%)	1312 (5.2%)	14 (0.1%)	136 (0.5%)
	AN	279 (1.7%)	-439 (-2.6%)	935 (5.9%)	217 (1.4%)	656 (4%)	-268 (-1.6%)
	BN	-338 (-3.6%)	-314 (-3.4%)	70 (0.8%)	94 (1.1%)	557 (6.6%)	545 (6.4%)
	D	-225 (-2.7%)	-168 (-2%)	-232 (-2.8%)	-175 (-2.1%)	-189 (-2.3%)	-83 (-1%)
	C	334 (5.6%)	378 (6.3%)	158 (2.6%)	202 (3.3%)	207 (3.4%)	275 (4.5%)
	AVG	136 (0.9%)	326 (2.2%)	265 (1.8%)	455 (3.1%)	184 (1.3%)	119 (0.8%)

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Month	WY Type	EBC1 vs. PP_ELT	EBC1 vs. PP_LLT	EBC2 vs. PP_ELT	EBC2 vs. PP_LLT	EBC2_ELT vs. PP_ELT	EBC2_LLT vs. PP_LLT
Apr	W	-36 (-0.2%)	-376 (-2.5%)	-55 (-0.4%)	-395 (-2.6%)	58 (0.4%)	-46 (-0.3%)
	AN	-341 (-3.3%)	-115 (-1.1%)	-287 (-2.8%)	-61 (-0.6%)	153 (1.5%)	601 (6.2%)
	BN	56 (0.6%)	279 (3.2%)	271 (3.2%)	494 (5.8%)	528 (6.4%)	707 (8.5%)
	D	42 (0.5%)	485 (6.1%)	228 (2.9%)	671 (8.6%)	337 (4.4%)	772 (10.1%)
	C	-97 (-1.3%)	261 (3.4%)	34 (0.4%)	392 (5.1%)	17 (0.2%)	173 (2.2%)
	AVG	-57 (-0.5%)	56 (0.5%)	42 (0.4%)	155 (1.5%)	207 (2%)	389 (3.7%)
May	W	-1144 (-9.1%)	-1751 (-14%)	-1107 (-8.9%)	-1714 (-13.7%)	173 (1.5%)	717 (7.1%)
	AN	630 (6.3%)	1110 (11.1%)	625 (6.2%)	1106 (11%)	1019 (10.6%)	1076 (10.7%)
	BN	243 (2.8%)	158 (1.8%)	444 (5.2%)	359 (4.2%)	994 (12.4%)	1064 (13.5%)
	D	733 (8.5%)	1600 (18.4%)	870 (10.2%)	1737 (20.3%)	986 (11.7%)	1265 (14%)
	C	532 (6.9%)	869 (11.2%)	557 (7.2%)	894 (11.6%)	323 (4.1%)	267 (3.2%)
	AVG	10 (0.1%)	113 (1.1%)	89 (0.9%)	192 (1.9%)	637 (6.8%)	883 (9.6%)
Jun	W	381 (3.2%)	1305 (11%)	285 (2.4%)	1208 (10.1%)	696 (6%)	1490 (12.7%)
	AN	1357 (11.3%)	2533 (21.1%)	1133 (9.3%)	2309 (18.9%)	1131 (9.3%)	1744 (13.6%)
	BN	708 (6.2%)	823 (7.2%)	677 (5.9%)	791 (6.9%)	869 (7.7%)	636 (5.5%)
	D	856 (7.3%)	1250 (10.6%)	799 (6.7%)	1194 (10.1%)	605 (5%)	587 (4.7%)
	C	528 (4.9%)	1342 (12.3%)	290 (2.6%)	1104 (9.9%)	-126 (-1.1%)	346 (2.9%)
	AVG	705 (6%)	1396 (12%)	589 (5%)	1280 (10.9%)	649 (5.5%)	1016 (8.4%)
JUL	W	877 (6.6%)	1332 (10%)	713 (5.3%)	1168 (8.7%)	195 (1.4%)	61 (0.4%)
	AN	519 (3.7%)	586 (4.2%)	268 (1.9%)	335 (2.3%)	54 (0.4%)	-426 (-2.8%)
	BN	293 (2.3%)	-806 (-6.2%)	215 (1.6%)	-884 (-6.8%)	32 (0.2%)	-1053 (-7.9%)
	D	-95 (-0.7%)	-681 (-5.1%)	-267 (-2%)	-854 (-6.3%)	-467 (-3.4%)	-1139 (-8.2%)
	C	-767 (-5.9%)	-1256 (-9.7%)	-534 (-4.2%)	-1022 (-8%)	-107 (-0.9%)	-400 (-3.3%)
	AVG	271 (2%)	37 (0.3%)	165 (1.2%)	-69 (-0.5%)	-43 (-0.3%)	-531 (-3.8%)
Aug	W	-630 (-5.6%)	-741 (-6.6%)	-607 (-5.4%)	-718 (-6.4%)	-46 (-0.4%)	-192 (-1.8%)
	AN	74 (0.7%)	134 (1.3%)	-170 (-1.6%)	-110 (-1%)	-313 (-2.9%)	-1061 (-9%)
	BN	-99 (-1%)	-637 (-6.2%)	-182 (-1.8%)	-720 (-7%)	132 (1.3%)	-799 (-7.7%)
	D	-1156 (-10.8%)	-1713 (-15.9%)	-1323 (-12.1%)	-1880 (-17.2%)	-1019 (-9.6%)	-2109 (-18.9%)
	C	-1655 (-17.3%)	-2260 (-23.6%)	-1721 (-17.8%)	-2326 (-24.1%)	-697 (-8.1%)	-335 (-4.4%)
	AVG	-702 (-6.6%)	-1031 (-9.7%)	-791 (-7.4%)	-1120 (-10.4%)	-364 (-3.5%)	-865 (-8.3%)
Sep	W	-1618 (-16.4%)	-2380 (-24.2%)	-4605 (-35.9%)	-5368 (-41.8%)	-4256 (-34.1%)	-5837 (-43.8%)
	AN	744 (11.9%)	401 (6.4%)	-1582 (-18.4%)	-1926 (-22.4%)	-2610 (-27.1%)	-3640 (-35.3%)
	BN	363 (6.2%)	-172 (-2.9%)	360 (6.2%)	-175 (-3%)	146 (2.4%)	-314 (-5.3%)
	D	-649 (-10.2%)	-1213 (-19%)	-357 (-5.8%)	-920 (-15.1%)	318 (5.9%)	267 (5.4%)
	C	-725 (-12.3%)	-494 (-8.4%)	-483 (-8.6%)	-252 (-4.5%)	-118 (-2.2%)	555 (11.5%)
	AVG	-591 (-8.1%)	-1064 (-14.6%)	-1779 (-21%)	-2253 (-26.5%)	-1654 (-19.8%)	-2297 (-26.9%)
Oct	W	-620 (-7.7%)	1180 (14.7%)	-287 (-3.7%)	1514 (19.7%)	-263 (-3.4%)	1012 (12.4%)
	AN	-1248 (-15.4%)	1373 (16.9%)	-443 (-6.1%)	2178 (29.8%)	-245 (-3.4%)	1323 (16.2%)
	BN	-602 (-8.5%)	2583 (36.4%)	-546 (-7.8%)	2639 (37.5%)	-52 (-0.8%)	1899 (24.4%)
	D	-696 (-10.1%)	1999 (29%)	-510 (-7.6%)	2185 (32.5%)	-484 (-7.2%)	1615 (22.2%)
	C	-91 (-1.4%)	2020 (30.3%)	160 (2.5%)	2270 (35.4%)	326 (5.2%)	2154 (32.9%)
	AVG	-648 (-8.7%)	1751 (23.6%)	-338 (-4.7%)	2061 (28.9%)	-187 (-2.7%)	1508 (19.7%)

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Month	WY Type	EBC1 vs. PP_ELT	EBC1 vs. PP_LLT	EBC2 vs. PP_ELT	EBC2 vs. PP_LLT	EBC2_ELT vs. PP_ELT	EBC2_LLT vs. PP_LLT
Nov	W	-85 (-0.9%)	-205 (-2.1%)	-1240 (-11.2%)	-1361 (-12.3%)	-1175 (-10.7%)	-1150 (-10.6%)
	AN	-949 (-11.7%)	-1736 (-21.3%)	-1724 (-19.3%)	-2511 (-28.2%)	-2167 (-23.2%)	-2691 (-29.6%)
	BN	-548 (-8.1%)	-820 (-12.1%)	-1322 (-17.5%)	-1594 (-21.1%)	-1468 (-19%)	-1711 (-22.3%)
	D	-647 (-8.6%)	-1299 (-17.2%)	-468 (-6.4%)	-1120 (-15.2%)	-520 (-7%)	-1097 (-14.9%)
	C	-483 (-8.3%)	-626 (-10.8%)	-576 (-9.8%)	-719 (-12.2%)	-477 (-8.2%)	-518 (-9.1%)
	AVG	-472 (-5.9%)	-836 (-10.5%)	-1058 (-12.3%)	-1422 (-16.6%)	-1124 (-13%)	-1367 (-16%)
Dec	W	2000 (9.5%)	-464 (-2.2%)	3279 (16.6%)	815 (4.1%)	1460 (6.8%)	938 (4.8%)
	AN	-309 (-3.1%)	53 (0.5%)	-319 (-3.2%)	43 (0.4%)	-659 (-6.4%)	20 (0.2%)
	BN	483 (5.7%)	51 (0.6%)	655 (8%)	224 (2.7%)	-31 (-0.3%)	231 (2.8%)
	D	116 (1.6%)	80 (1.1%)	355 (5%)	319 (4.5%)	363 (5.2%)	280 (4%)
	C	164 (2.9%)	-130 (-2.3%)	399 (7.4%)	104 (1.9%)	327 (6%)	65 (1.2%)

The effects of the preliminary proposal on Sacramento River flows at Wilkins Slough (Figure C.5.2-126) would be similar to those effects described upstream for Keswick and Red Bluff during March through August (Figure C.5.2-45, Figure C.5.2-100 through Figure C.5.2-104, Table C.5.2-35). For all water years combined, predicted mean monthly flows under PP_ELT and PP_LLT are generally greater than flows under EBC2_ELT and EBC2_LLT, respectively. In only two months, July and August, are predicted mean monthly flows under PP_ELT and PP_LLT lower than EBC2_ELT and EBC2_LLT, respectively.

In total, CALSIM analysis of flows in the Sacramento River indicates that mean monthly flows during March though June under PP_ELT and PP_LLT are predicted to be 0.8% to 11.2% greater than those under EBC2_ELT and EBC2_LLT, respectively. Mean monthly flows during July and August under PPE_LT and PP_LLT are predicted to be 1.8% to 12.6% lower than EBC2_ELT and EBC2_LLT, respectively. It is concluded with low certainty, due to the lack of green sturgeon egg/embryo flow thresholds or a seasonal flow weighting metric, that green sturgeon egg/embryo benefits realized under the large increases in March through June flows under the proposed project, relative to EBC2, would at least offset the adverse effects of the small decrease in July and August flows.

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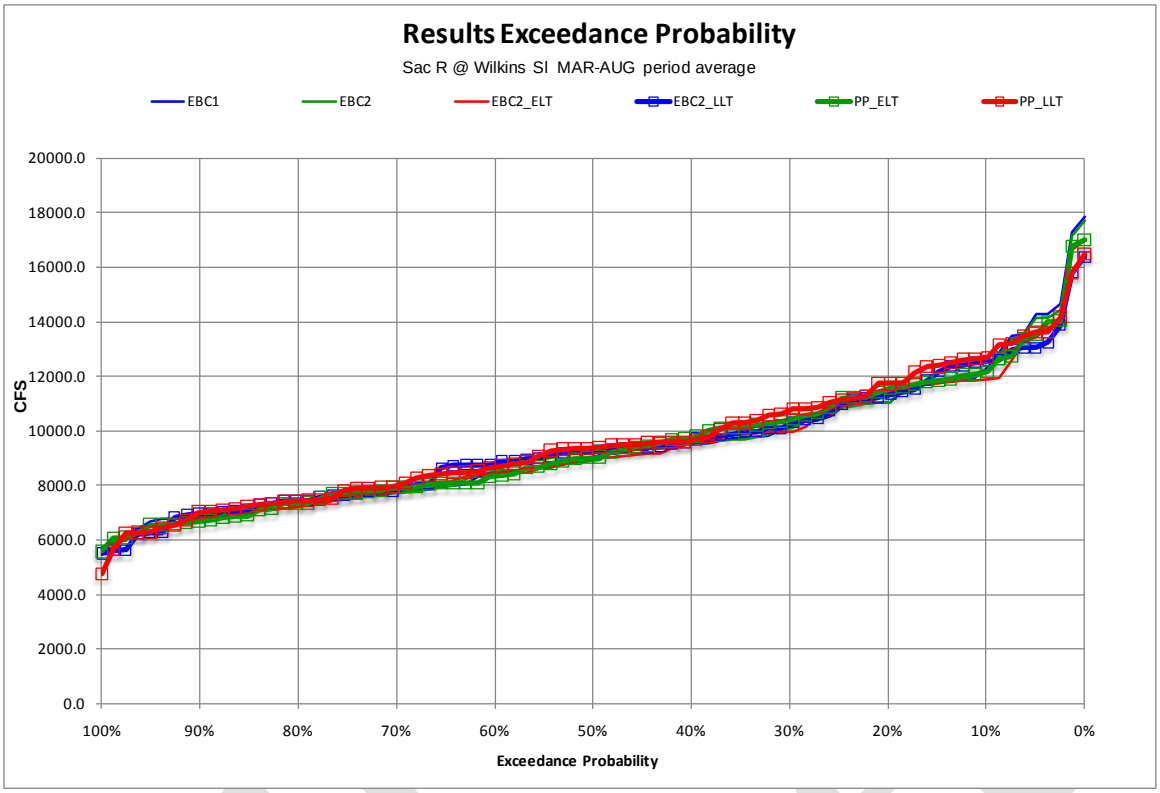

Figure C.5.2-126. Probability of Exceedance Plot for Model Scenarios of Mean Monthly Flow in the Sacramento River at Wilkins Slough, March through August

Larvae

Water Temperature

The period of larval occurrence evaluated is modified from Israel and Klimley (2008) based on a shortened larval life stage, such that the larval stage is present from April through October. Green sturgeon larvae can tolerate water temperatures ranging from 52°F–73°F (11°C–23°C) (Israel and Klimley 2008). However, Van Eenennaam et al. (2005) concluded that temperatures above 68°F (20°C) are probably detrimental to green sturgeon reproduction. While green sturgeon may survive incubation at the limits of their temperature optimum, reproductive success and young-of-year recruitment are presumably negatively impacted when larvae are subjected to prolonged water temperatures of 66°F (19°C) or above (Van Eenennaam et al. 2005). Therefore, to remain conservative, the upper threshold values for larval survival were analyzed using the SRWQM at 66°F, 68°F, and 73°F.

Larval rearing habitats for green sturgeon occur downstream of China Rapids and Iron Canyon spawning habitats (Israel and Klimley 2008). Therefore, water temperatures were analyzed at Red Bluff Diversion Dam and Hamilton City using the SRWQM in each water-year type.

Red Bluff Diversion Dam

Combining all water years, mean daily water temperatures in the Sacramento River at Red Bluff Diversion Dam from April through October exceeded the 66°F, 68°F, and 73°F thresholds <1% of the time under EBC1 and EBC2, 0%–5% of the time under EBC2_ELT and EBC2_LLT, and 0%–5% of the

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time under PP_ELT and PP_LLT (Figure C.5.2-127 through Figure C.5.2-131, Table C.5.2-44, Table C.5.2-45). Among water years, the frequency of exceedance was generally lowest in wet, above-normal, and below-normal years; intermediate in dry years; and highest in critical years. Water temperatures exceeding 73°F are predicted to occur only in critical years under EBC2_LLT and PP_LLT. The higher threshold exceedances under EBC2_ELT and EBC2_LLT relative to EBC1 and EBC2 reflect the effects of climate change in the absence of BDCP implementation. Accounting for climate change effects, BDCP implementation (PP_ELT and PP_LLT) is predicted to result in only slight differences in the frequency of threshold exceedances (<1%) relative to baseline conditions (EBC2_ELT and EBC2_LLT).

These results suggest that the effects of the preliminary proposal on the exceedance of temperature thresholds are mostly adverse, but small and variable. The effects of climate change are much larger than those of the preliminary proposal.

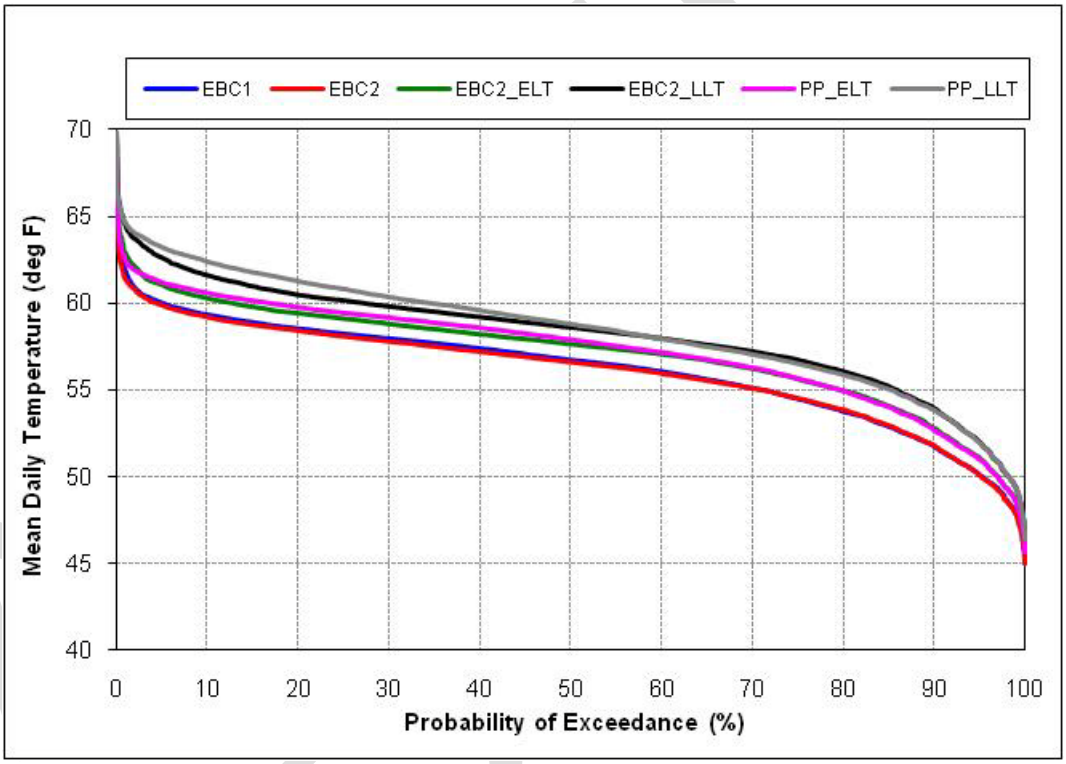

Figure C.5.2-127. Probability of Exceedance Plot for Model Scenarios of Mean Daily Temperature of the Sacramento River at the Red Bluff Diversion Dam, April through October in Wet Years

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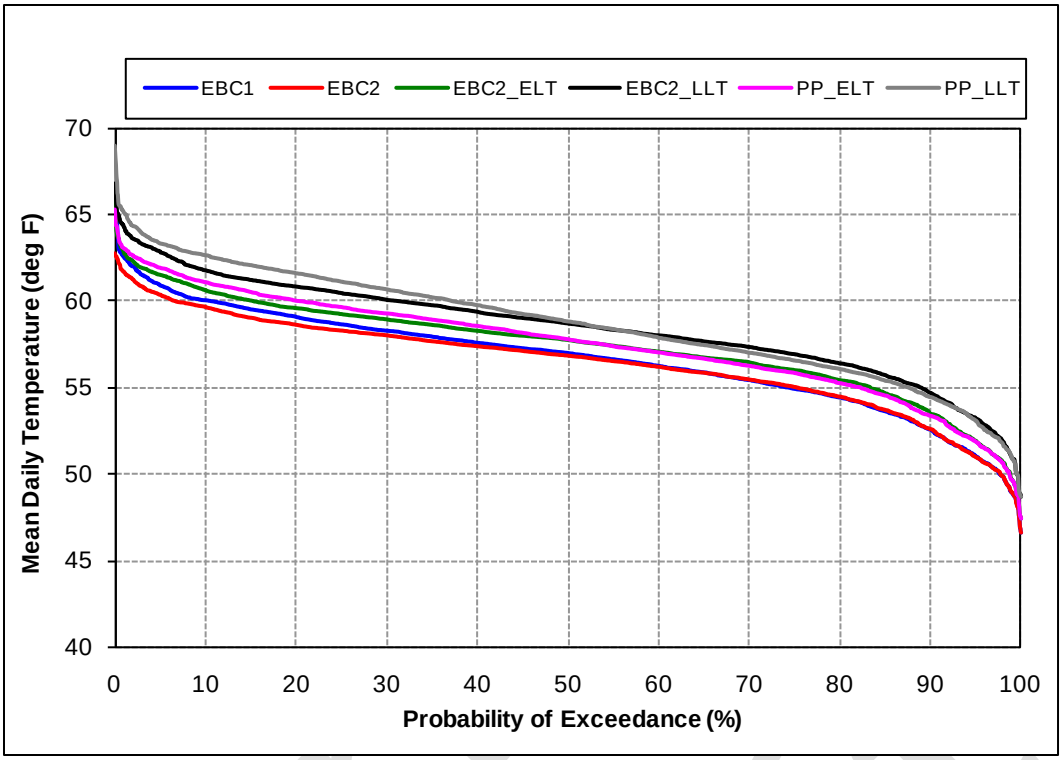

Figure C.5.2-128. Probability of Exceedance Plot for Model Scenarios of Mean Daily Temperature of the Sacramento River at the Red Bluff Diversion Dam, April through October in Above-Normal Years

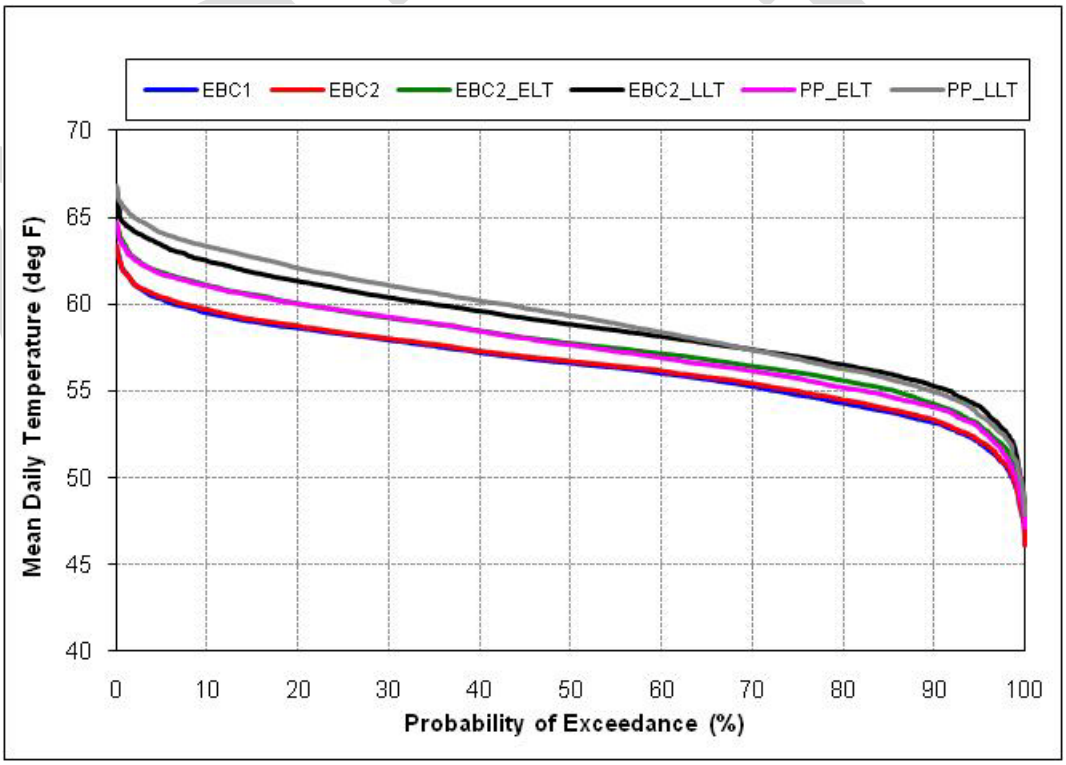

Figure C.5.2-129. Probability of Exceedance Plot for Model Scenarios of Mean Daily Temperature of the Sacramento River at the Red Bluff Diversion Dam, April through October in Below-Normal Years

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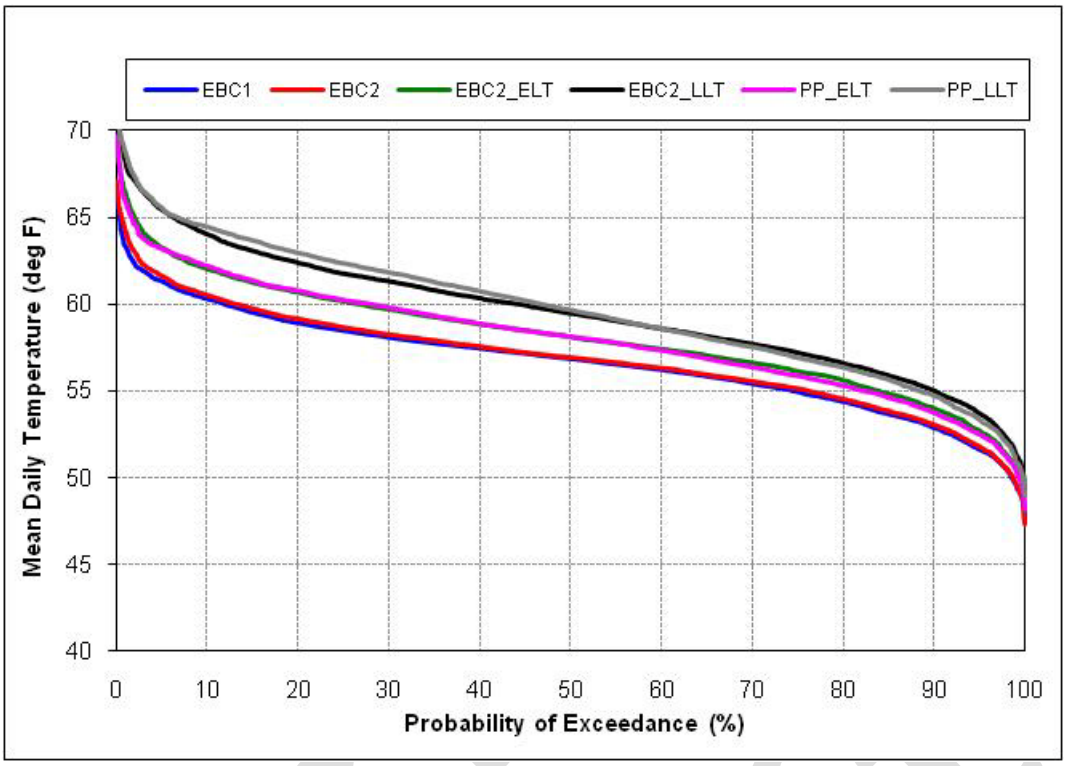

Figure C.5.2-130. Probability of Exceedance Plot for Model Scenarios of Mean Daily Temperature of the Sacramento River at the Red Bluff Diversion Dam, April through October in Dry Years

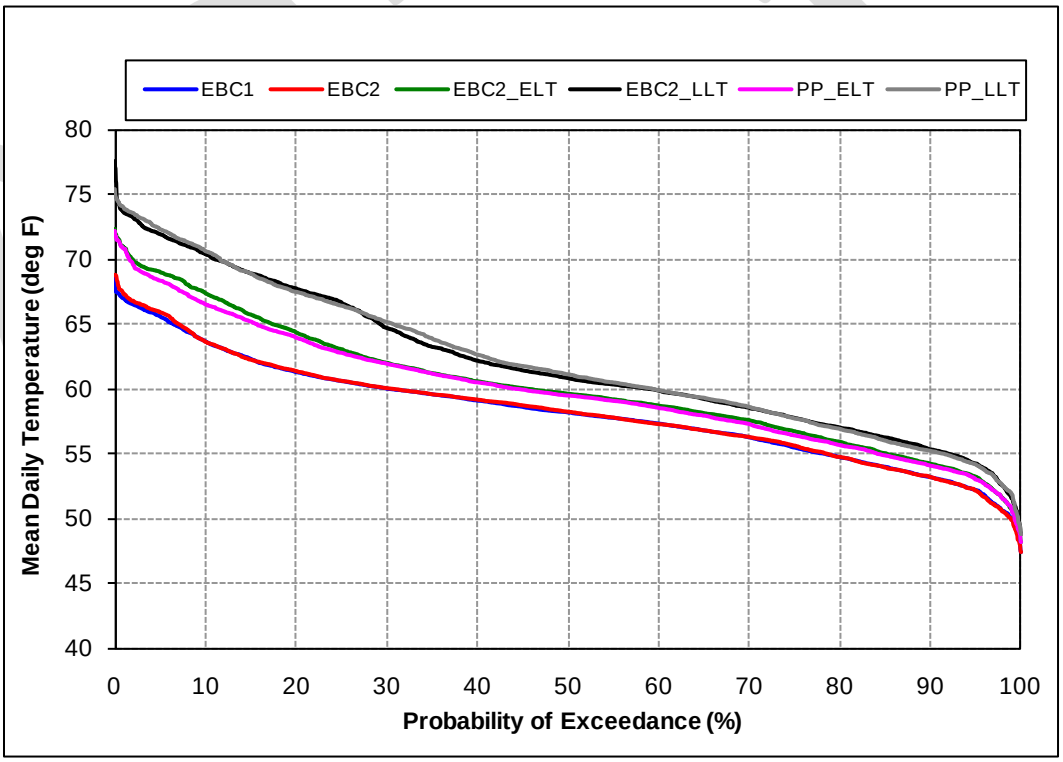

Figure C.5.2-131. Probability of Exceedance Plot for Model Scenarios of Mean Daily Temperature of the Sacramento River at the Red Bluff Diversion Dam, April through October in Critical Years

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Table C.5.2-44. Percent of Days from April through October[1] When Daily Average Temperature Exceeds 66°F, 68°F, and 73°F in the Sacramento River at Red Bluff Diversion Dam

Water-Year Type	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
Temperatures above 66°F						
Wet	0.1	0.0	0.1	0.2	0.1	0.2
Above Normal	0.0	0.0	0.0	0.1	0.0	0.4
Below Normal	0.0	0.0	0.0	0.0	0.0	0.2
Dry	0.1	0.2	1.2	3.8	0.9	4.0
Critical	3.7	4.9	14.3	27.1	12.3	26.8
All	0.6	0.8	2.4	4.9	2.0	5.0
Temperatures above 68°F						
Wet	0.0	0.0	0.0	0.1	0.0	0.1
Above Normal	0.0	0.0	0.0	0.0	0.0	0.1
Below Normal	0.0	0.0	0.0	0.0	0.0	0.0
Dry	0.0	0.0	0.3	1.1	0.3	1.4
Critical	0.1	0.4	8.3	19.0	6.3	17.7
All	0.0	0.1	1.3	3.0	1.0	2.9
Temperatures above 73°F						
Wet	0.0	0.0	0.0	0.0	0.0	0.0
Above Normal	0.0	0.0	0.0	0.0	0.0	0.0
Below Normal	0.0	0.0	0.0	0.0	0.0	0.0
Dry	0.0	0.0	0.0	0.0	0.0	0.0
Critical	0.0	0.0	0.0	2.6	0.0	3.3
All	0.0	0.0	0.0	0.4	0.0	0.5

[1] Based on the modeling period of 1922 to 2003.

Table C.5.2-45. Difference and Percent Difference in the Percentage of Days From April through October When Daily Average Temperature Exceeds 66°F, 68°F, and 73°F in the Sacramento River at Red Bluff Diversion Dam

WY Type	Comparison[1]	EBC1_ELT vs. PP_ELT	EBC1_LLT vs. PP_LLT	EBC2 vs. EBC2_ELT	EBC2 vs. EBC2_LLT	EBC2 vs. PP_ELT	EBC2 vs. PP_LLT	EBC2_ELT vs. PP_ELT	EBC2_LLT vs. PP_LLT
Temperatures above 66°F									
Wet	Difference	0.0	0.2	0.1	0.2	0.1	0.2	0.0	0.0
	Percent difference	67%	333%	250%	450%	150%	550%	-29%	18%
Above Normal	Difference	0.0	0.4	0.0	0.1	0.0	0.4	0.0	0.2
	Percent difference	NA	NA	NA	NA	NA	NA	NA	200%
Below Normal	Difference	0.0	0.2	0.0	0.0	0.0	0.2	0.0	0.2
	Percent difference	NA	NA	NA	NA	NA	NA	NA	NA
Dry	Difference	0.8	3.9	1.1	3.7	0.7	3.8	-0.4	0.1
	Percent difference	750%	3,725%	586%	2,014%	386%	2,086%	-29%	3%
Critical	Difference	8.6	23.1	9.3	22.2	7.4	21.9	-2.0	-0.3
	Percent difference	232%	624%	190%	452%	150%	446%	-14%	-1%
All	Difference	1.4	4.4	1.6	4.1	1.2	4.2	-0.4	0.1
	Percent difference	247%	753%	212%	536%	162%	544%	-16%	1%

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WY Type	Comparison[1]	EBC1_ELT vs. PP_ELT	EBC1_LLT vs. PP_LLT	EBC2 vs. EBC2_ELT	EBC2 vs. EBC2_LLT	EBC2 vs. PP_ELT	EBC2 vs. PP_LLT	EBC2_ELT vs. PP_ELT	EBC2_LLT vs. PP_LLT
Temperatures above 68°F									
Wet	Difference	0.0	0.1	0.0	0.1	0.0	0.1	0.0	0.0
	Percent difference	NA	NA	NA	NA	NA	NA	0%	-25%
Above Normal	Difference	0.0	0.1	0.0	0.0	0.0	0.1	0.0	0.1
	Percent difference	NA	NA	NA	NA	NA	NA	NA	NA
Below Normal	Difference	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Percent difference	NA	NA	NA	NA	NA	NA	NA	NA
Dry	Difference	0.3	1.4	0.3	1.1	0.3	1.4	0.0	0.3
	Percent difference	NA	NA	NA	NA	NA	NA	0%	32%
Critical	Difference	6.3	17.6	7.9	18.6	6.0	17.3	-1.9	-1.3
	Percent difference	8,050%	22,600%	2,020%	4,770%	1,530%	4,440%	-23%	-7%
All	Difference	1.0	2.9	1.2	3.0	1.0	2.9	-0.3	-0.1
	Percent difference	8,800%	25,600%	2,170%	5,220%	1,680%	5,040%	-22%	-3%
Temperatures above 73°F									
Wet	Difference	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Percent Difference	NA	NA	NA	NA	NA	NA	NA	NA
Above Normal	Difference	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Percent Difference	NA	NA	NA	NA	NA	NA	NA	NA
Below Normal	Difference	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Percent Difference	NA	NA	NA	NA	NA	NA	NA	NA
Dry	Difference	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Percent Difference	NA	NA	NA	NA	NA	NA	NA	NA
Critical	Difference	0.0	3.3	0.0	2.6	0.0	3.3	0.0	0.8
	Percent Difference	NA	NA	NA	NA	NA	NA	NA	30%
All	Difference	0.0	0.5	0.0	0.4	0.0	0.5	0.0	0.1
	Percent Difference	NA	NA	NA	NA	NA	NA	NA	30%

[1] A positive value indicates a higher value under the proposed project than the EBC.
NA = Could not be calculated because dividing by 0.

Hamilton City

At Hamilton City, mean daily water temperatures from April through October exceeded the 66°F, 68°F, and 73°F thresholds 0%–3% of the time under EBC1 and EBC2, <1%–15% of the time under EBC2_ELT and EBC2_LLT, and <1%–20% of the time under PP_ELT and PP_LLT (Figure C.5.2-132 through Figure C.5.2-136, Table C.5.2-46, Table C.5.2-47). Among water years, the frequency of exceedance was generally lowest in wet, above-normal, and below-normal years; intermediate in dry years; and highest in critical years. Water temperatures exceeding 73°F are predicted to occur only in dry and critical years of the early long-term and late long-term scenarios. Again, the higher threshold exceedances under EBC2_ELT and EBC2_LLT relative to EBC1 and EBC2 reflect the effects of climate change in the absence of BDCP implementation. Accounting for climate change effects, BDCP implementation under early long-term conditions (PP_ELT) is predicted to result in slight differences in the frequency of threshold exceedances (<1%) relative to baseline conditions (EBC2_ELT). BDCP implementation under late long-term conditions (PP_LLT) is predicted to result

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in small increases in the frequency of threshold exceedances (<1% to 4.5%) relative to baseline conditions (EBC2_LLT).

These results suggest that the effects of the preliminary proposal on the exceedance of temperature thresholds are mostly adverse, but small and variable. The effects of climate change are much larger than those of the preliminary proposal.

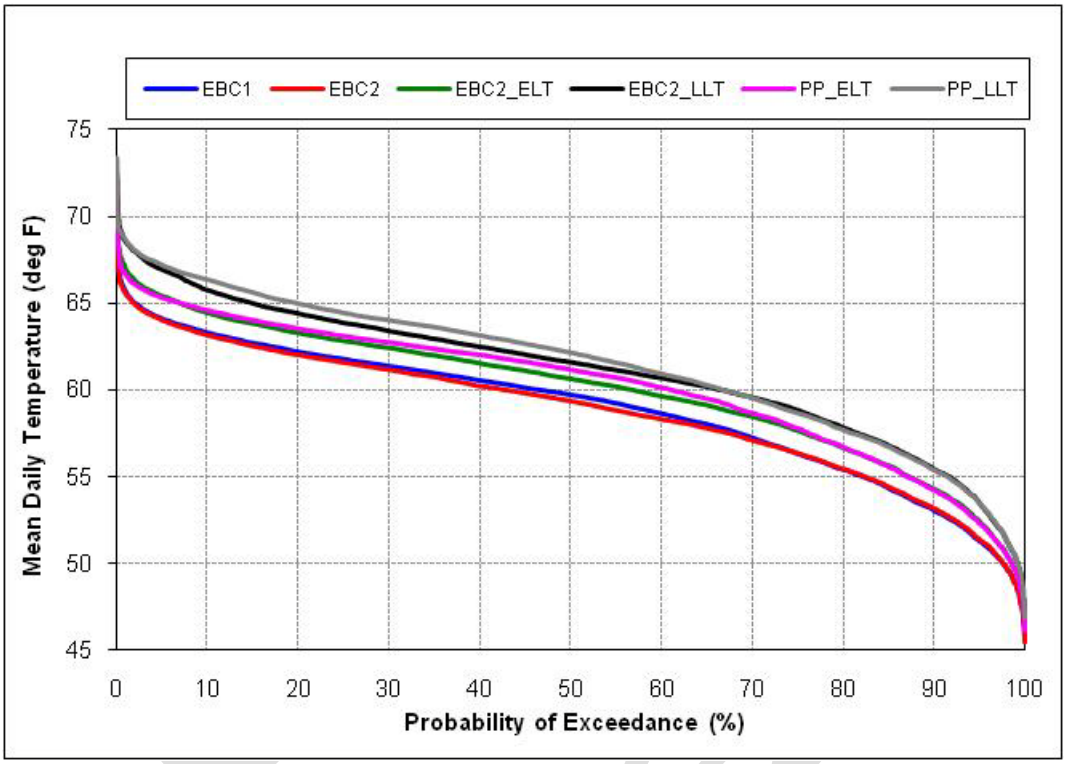

Figure C.5.2-132. Probability of Exceedance Plot for Model Scenarios of Mean Daily Temperature in the Sacramento River at Hamilton City, April through October in Wet Years

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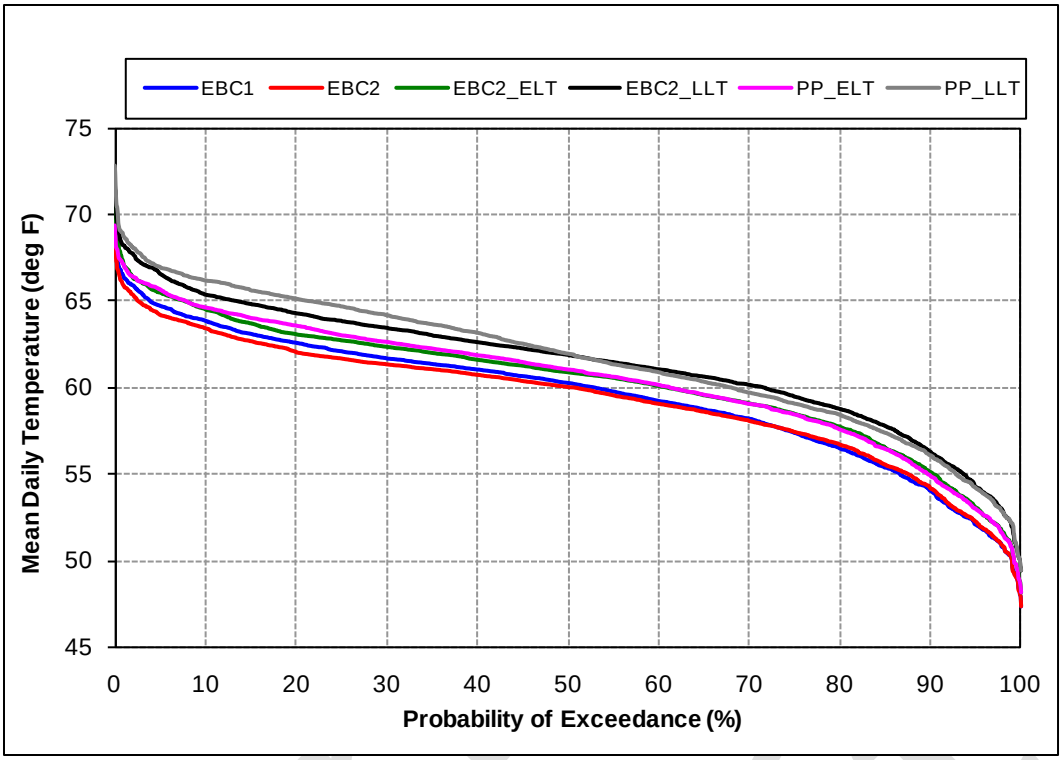

Figure C.5.2-133. Probability of Exceedance Plot for Model Scenarios of Mean Daily Temperature in the Sacramento River at Hamilton City, April through October in Above-Normal Years

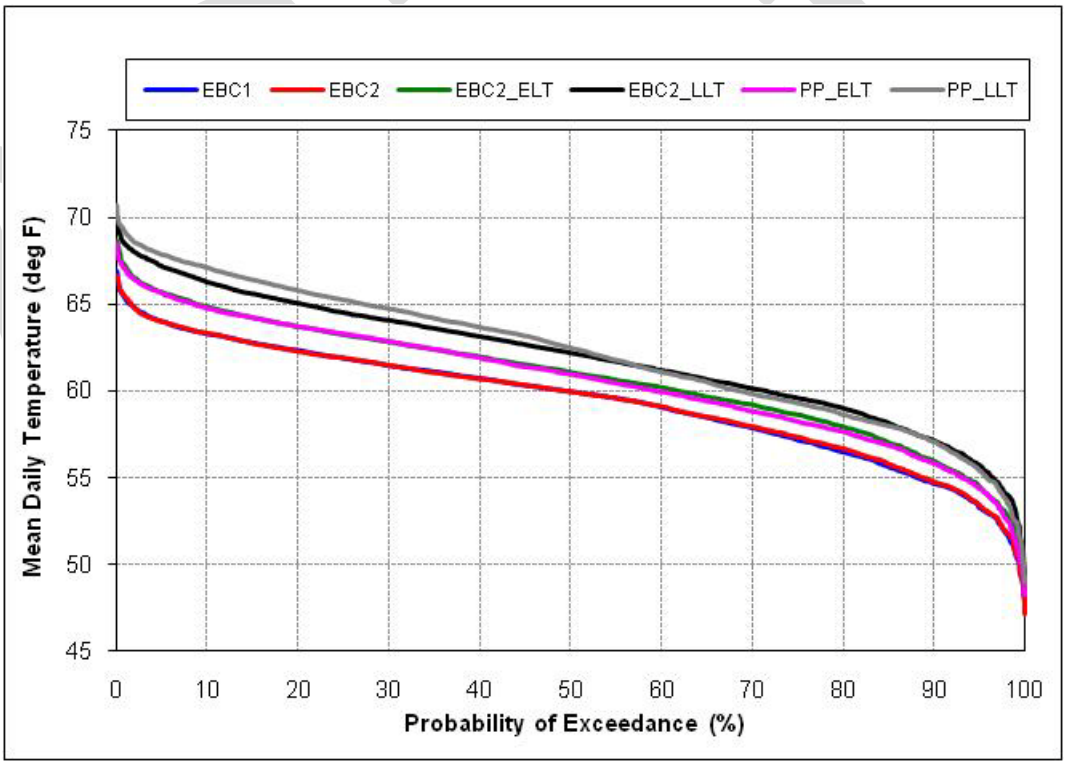

Figure C.5.2-134. Probability of Exceedance Plot for Model Scenarios of Mean Daily Temperature in the Sacramento River at Hamilton City, April through October in Below-Normal Years

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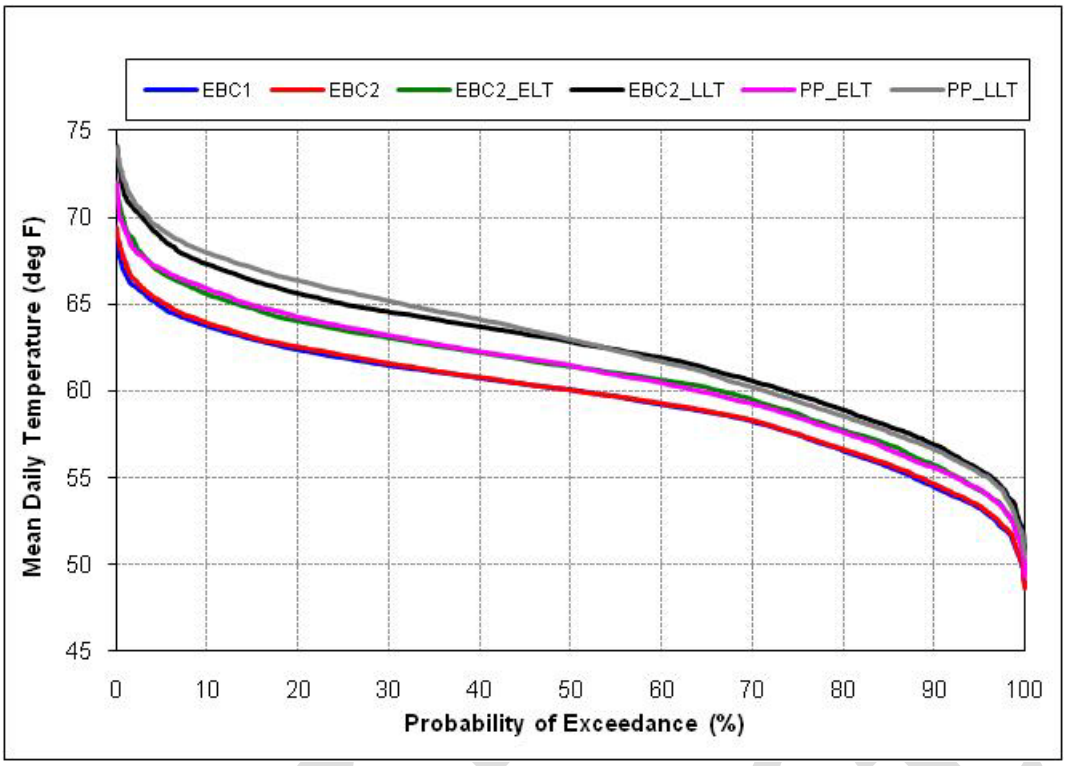

Figure C.5.2-135. Probability of Exceedance Plot for Model Scenarios of Mean Daily Temperature in the Sacramento River at Hamilton City, April through October in Dry Years

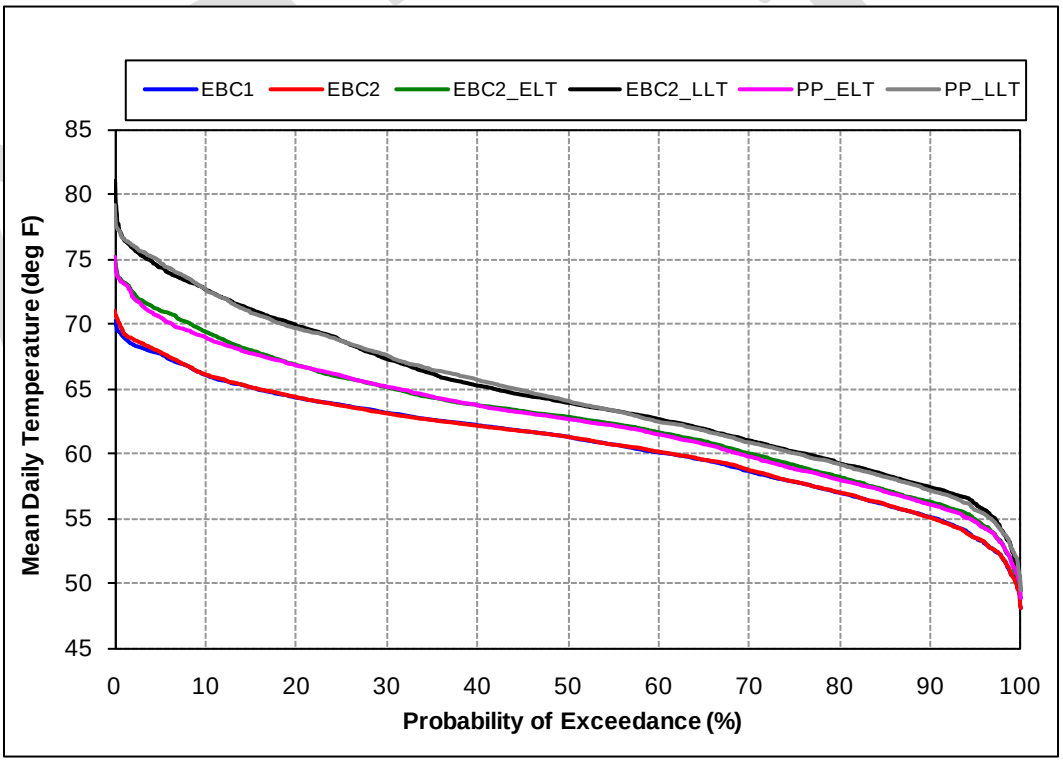

Figure C.5.2-136. Probability of Exceedance Plot for Model Scenarios of Mean Daily Temperature in the Sacramento River at Hamilton City, April through October in Critical Years

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Table C.5.2-46. Percentage of Days from April through October[1] When Daily Average Temperature Exceeds 66°F, 68°F, and 73°F in the Sacramento River at Hamilton City

Water-Year Type	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
Temperatures above 66°F						
Wet	0.7	0.6	2.8	9.1	2.2	12.5
Above Normal	1.6	0.8	3.2	6.6	3.5	12.1
Below Normal	0.2	0.3	3.6	12.2	3.2	18.5
Dry	2.1	2.7	8.2	17.5	9.4	22.7
Critical	10.3	10.6	24.0	35.9	25.2	38.7
All	2.5	2.5	7.3	15.0	7.5	19.5
Temperatures above 68°F						
Wet	0.1	0.1	0.3	2.1	0.3	2.2
Above Normal	0.2	0.1	0.5	1.3	0.3	2.2
Below Normal	0.0	0.0	0.3	2.1	0.1	4.5
Dry	0.2	0.6	2.6	7.0	2.2	9.8
Critical	3.5	4.7	14.7	27.5	13.9	28.4
All	0.6	0.9	3.0	6.8	2.7	8.1
Temperatures above 73°F						
Wet	0.0	0.0	0.0	0.0	0.0	0.0
Above Normal	0.0	0.0	0.0	0.0	0.0	0.0
Below Normal	0.0	0.0	0.0	0.0	0.0	0.0
Dry	0.0	0.0	0.0	0.2	0.0	0.3
Critical	0.0	0.0	1.4	9.2	1.3	9.4
All	0.0	0.0	0.2	1.4	0.2	1.5

[1] Based on the modeling period of 1922 to 2003

Table C.5.2-47. Difference and Percent Difference in Percent of Days from April through October When Daily Average Temperature Exceeds 66°F, 68°F, and 73°F in the Sacramento River at Hamilton City

WY Type	Comparison[1]	EBC1_ELT vs. PP_ELT	EBC1_LLT vs. PP_LLT	EBC2 vs. EBC2_ELT	EBC2 vs. EBC2_LLT	EBC2 vs. PP_ELT	EBC2 vs. PP_LLT	EBC2_ELT vs. PP_ELT	EBC2_LLT vs. PP_LLT
Temperatures above 66°F									
Wet	Difference	1.5	11.8	2.2	8.5	1.6	11.9	-0.6	3.4
	Percent difference	205%	1,638%	381%	1,475%	281%	2,072%	-21%	38%
Above Normal	Difference	1.8	10.5	2.5	5.8	2.7	11.3	0.2	5.5
	Percent difference	112%	640%	315%	745%	345%	1,455%	7%	84%
Below Normal	Difference	3.0	18.3	3.3	11.9	2.9	18.2	-0.4	6.3
	Percent difference	1,271%	7,814%	990%	3,560%	860%	5,440%	-12%	51%
Dry	Difference	7.3	20.6	5.5	14.9	6.8	20.0	1.3	5.1
	Percent difference	349%	979%	205%	556%	253%	749%	16%	29%
Critical	Difference	15.0	28.4	13.4	25.3	14.6	28.1	1.2	2.8
	Percent difference	145%	277%	126%	239%	138%	265%	5%	8%
All	Difference	5.0	17.1	4.8	12.5	5.0	17.0	0.2	4.5
	Percent difference	204%	690%	192%	503%	202%	684%	3%	30%

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WY Type	Comparison[1]	EBC1_ELT vs. PP_ELT	EBC1_LLT vs. PP_LLT	EBC2 vs. EBC2_ELT	EBC2 vs. EBC2_LLT	EBC2 vs. PP_ELT	EBC2 vs. PP_LLT	EBC2_ELT vs. PP_ELT	EBC2_LLT vs. PP_LLT
Temperatures above 68°F									
Wet	Difference	0.2	2.1	0.2	2.0	0.2	2.1	-0.1	0.1
	Percent difference	150%	1,933%	217%	1,817%	150%	1,933%	-21%	6%
Above Normal	Difference	0.2	2.0	0.4	1.2	0.2	2.1	-0.2	0.9
	Percent difference	100%	1,300%	500%	1,600%	300%	2,700%	-33%	65%
Below Normal	Difference	0.1	4.5	0.3	2.1	0.1	4.5	-0.3	2.4
	Percent difference	NA	NA	NA	NA	NA	NA	-80%	113%
Dry	Difference	1.9	9.6	2.1	6.4	1.6	9.2	-0.5	2.8
	Percent difference	833%	4,089%	364%	1,118%	282%	1,614%	-18%	41%
Critical	Difference	10.4	24.9	10.0	22.8	9.2	23.7	-0.8	0.9
	Percent difference	293%	702%	212%	484%	196%	503%	-5%	3%
All	Difference	2.0	7.5	2.1	5.9	1.8	7.2	-0.3	1.3
	Percent difference	325%	1190%	245%	686%	209%	840%	-10%	20%
Temperatures above 73°F									
Wet	Difference	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Percent difference	NA	NA	NA	NA	NA	NA	NA	0%
Above Normal	Difference	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Percent difference	NA	NA	NA	NA	NA	NA	NA	NA
Below Normal	Difference	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Percent difference	NA	NA	NA	NA	NA	NA	NA	NA
Dry	Difference	0.0	0.3	0.0	0.2	0.0	0.3	0.0	0.1
	Percent difference	NA	NA	NA	NA	NA	NA	NA	50%
Critical	Difference	1.3	9.4	1.4	9.2	1.3	9.4	-0.1	0.2
	Percent difference	NA	NA	NA	NA	NA	NA	-6%	2%
All	Difference	0.2	1.5	0.2	1.4	0.2	1.5	0.0	0.1
	Percent difference	NA	NA	NA	NA	NA	NA	-6%	4%

[1] A positive value indicates a higher value under the proposed project than the EBC.
NA = Could not be calculated because dividing by 0.

Juveniles

Water Temperature

Young of the year juvenile green sturgeon occur within the middle to lower Sacramento River from August to March (Israel and Klimley 2008). Therefore, water temperatures were analyzed at the Hamilton City using SRWQM outputs for all water-year types. Optimal juvenile green sturgeon temperatures range from 59°F–66°F (15°C–19°C); while those occurring at 81°F (<27°C) are considered lethal (Israel and Klimley 2008). NMFS (74 FR 52300) indicated an upper temperature threshold of 75°F (24°C). While green sturgeon juveniles may survive for short periods at the limits of their maximum temperature thresholds, optimal rearing temperatures are expected to maximize survival. Therefore, upper temperature threshold values for juvenile survival and optimal rearing were analyzed using the SRWQM at 66°F, 75°F, and 81°F.

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Combining all water years, mean daily water temperatures in the Sacramento River at Hamilton City from August through March exceeded the 66°F threshold 2% of the time under EBC1 and EBC2, 5%–9% of the time under EBC2_ELT and EBC2_LLT, and 5%–13% of the time under PP_ELT and PP_LLT (Figure C.5.2-137 through Figure C.5.2-141, Table C.5.2-48, Table C.5.2-49). Accounting for climate change effects, BDCP implementation under early and late long-term conditions (PP_ELT and PP_LLT) is predicted to result in a <1%–4% increase in the frequency of temperatures exceeding 66°F relative to EBC2_ELT and EBC2_LLT.

Combining all water years, mean daily water temperatures in the Sacramento River at Hamilton City from August through March exceeded the 75°F threshold <1% of the time under EBC1 and EBC2, 2%–5% of the time under EBC2_ELT and EBC2_LLT, and 2%–6% of the time under PP_ELT and PP_LLT (Figure C.5.2-137 through Figure C.5.2-141, Table C.5.2-48, Table C.5.2-49). Accounting for climate change effects, BDCP implementation under early and late long-term conditions (PP_ELT and PP_LLT) is predicted to result in little change (-0.1 to +1.0%) in the frequency of temperatures exceeding 75°F relative to baseline conditions (EBC2_ELT and EBC2_LLT).

Combining all water years, mean daily water temperatures in the Sacramento River at Hamilton City from August through March exceeded the 81°F threshold only in critical water years of the early long-term scenarios (<1% of the time under EBC2_ELT and PP_ELT) and dry and critical water years of the late long-term scenarios (1% of the time under EBC2_LLT and PP_LLT) (Figure C.5.2-137 through Figure C.5.2-141, Table C.5.2-48, Table C.5.2-49). Accounting for climate change effects, BDCP implementation under early and late long-term conditions (PP_ELT and PP_LLT) would result in no change in the frequency of temperatures exceeding 81°F relative to baseline conditions (EBC2_ELT and EBC2_LLT).

Based on this analysis, it is concluded with high certainty that juvenile green sturgeon occurring in the Sacramento River in the vicinity of Hamilton City would be unlikely to experience water temperatures sufficiently high to result in mortality in any water year for either the preliminary proposal or existing biological conditions. However, compared to existing biological conditions, these fish would experience some reduction in optimal temperature conditions (at 66°F only) for nearly all water years due to climate change. Under the late long-term period the preliminary proposal would result in a greater reduction optimal temperature conditions (at 66°F only) than would occur under existing biological conditions. Whether these differences would be sufficient to affect juvenile green sturgeon occurrence and habitat use in the vicinity of Hamilton City is currently unknown.

Draft

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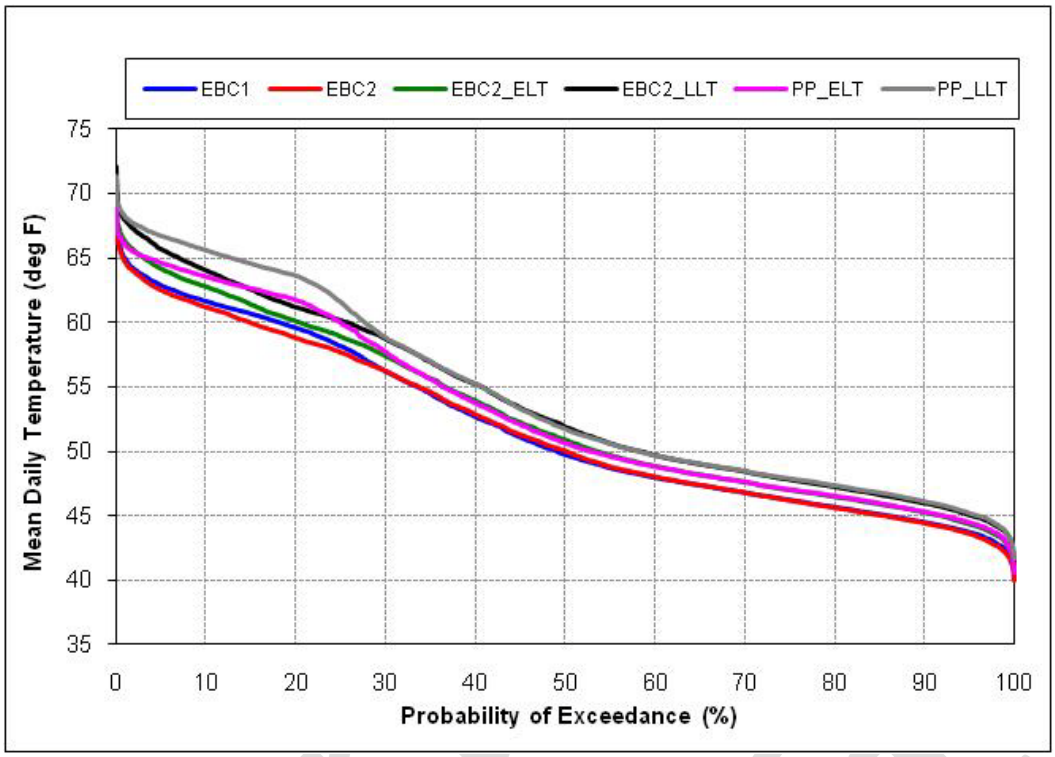

Figure C.5.2-137. Probability of Exceedance Plot for Model Scenarios of Mean Daily Temperature in the Sacramento River at Hamilton City, August through March in Wet Years

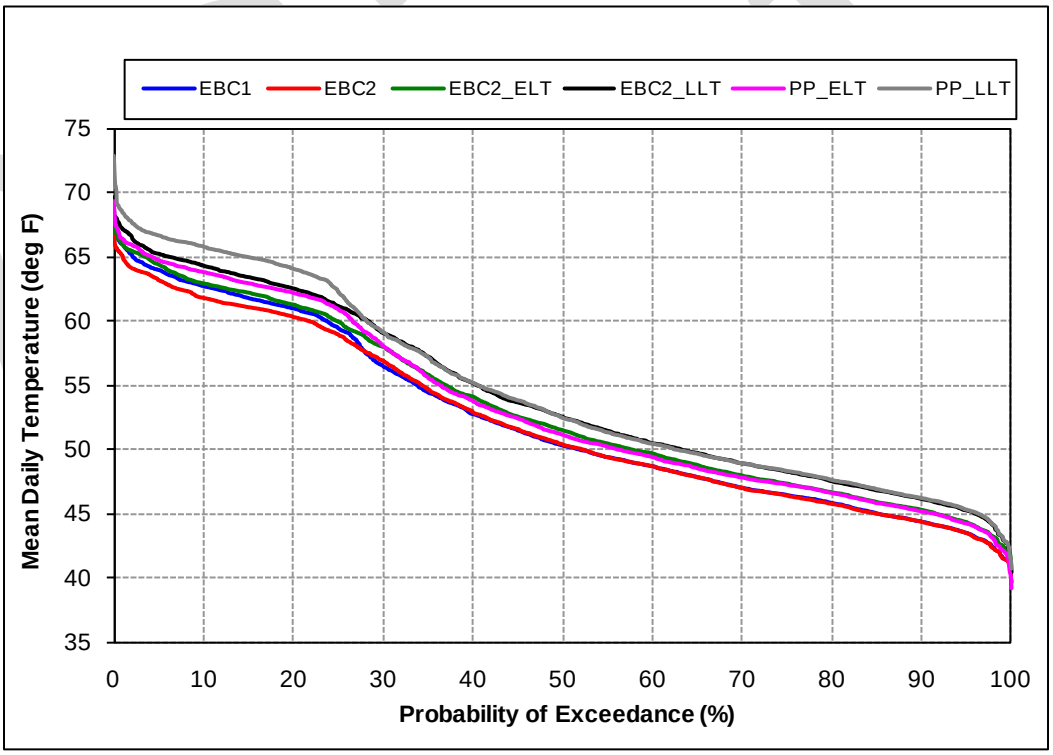

Figure C.5.2-138. Probability of Exceedance Plot for Model Scenarios of Mean Daily Temperature in the Sacramento River at Hamilton City, August through March in Above-Normal Years

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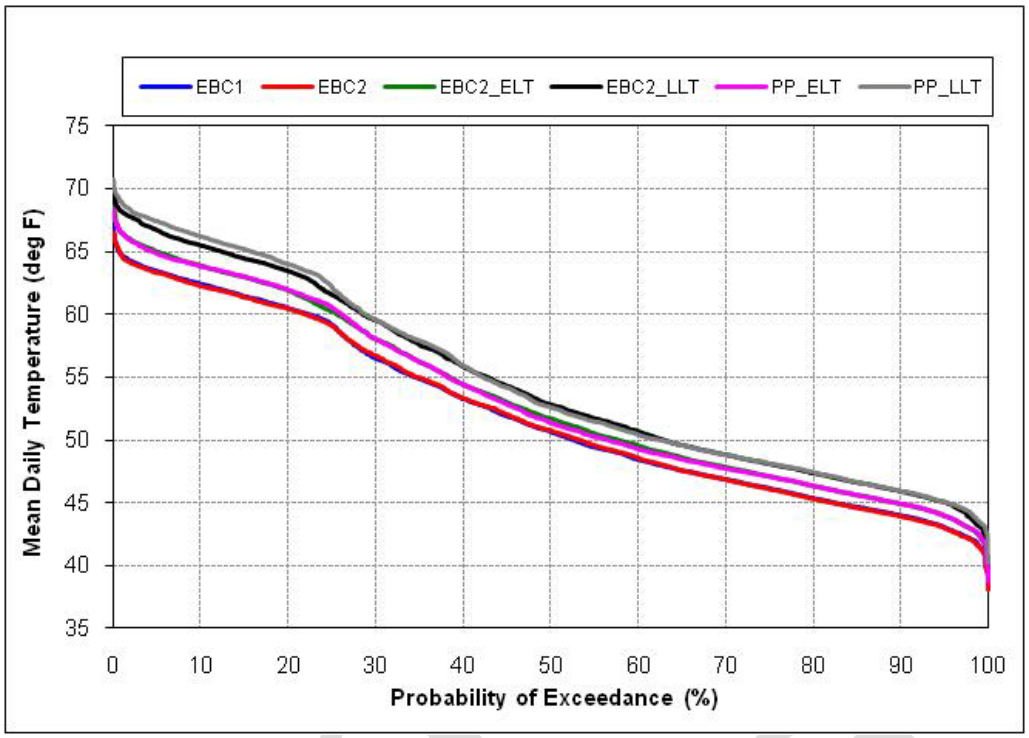

Figure C.5.2-139. Probability of Exceedance Plot for Model Scenarios of Mean Daily Temperature in the Sacramento River at Hamilton City, August through March in Below-Normal Years

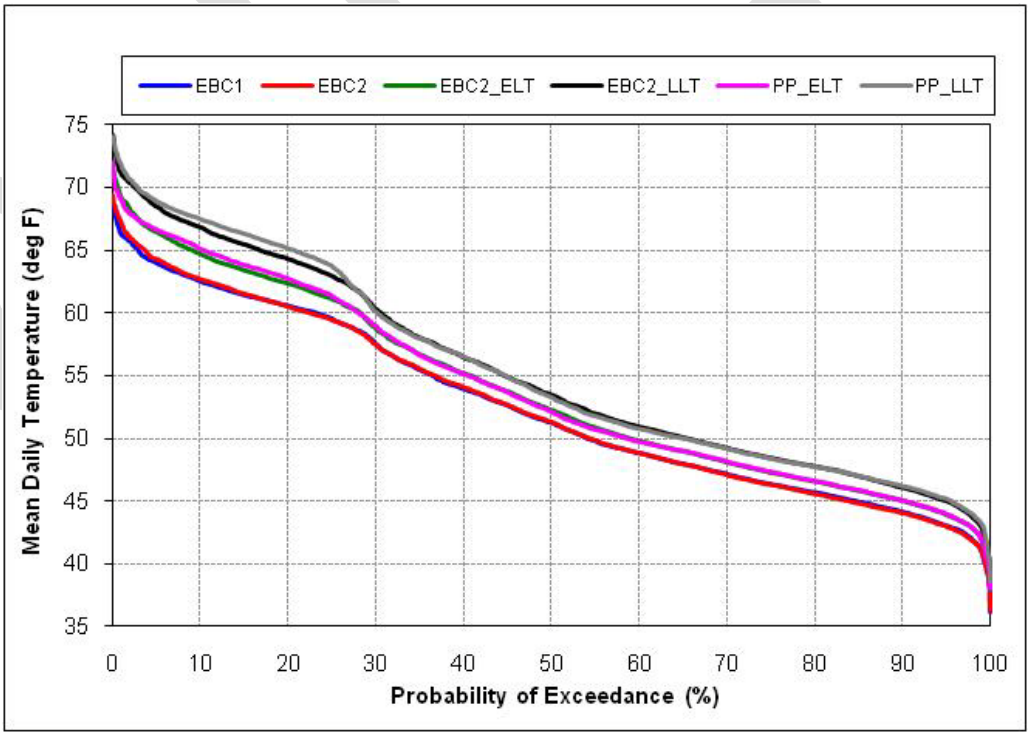

Figure C.5.2-140. Probability of Exceedance Plot for Model Scenarios of Mean Daily Temperature in the Sacramento River at Hamilton City, August through March in Dry Years

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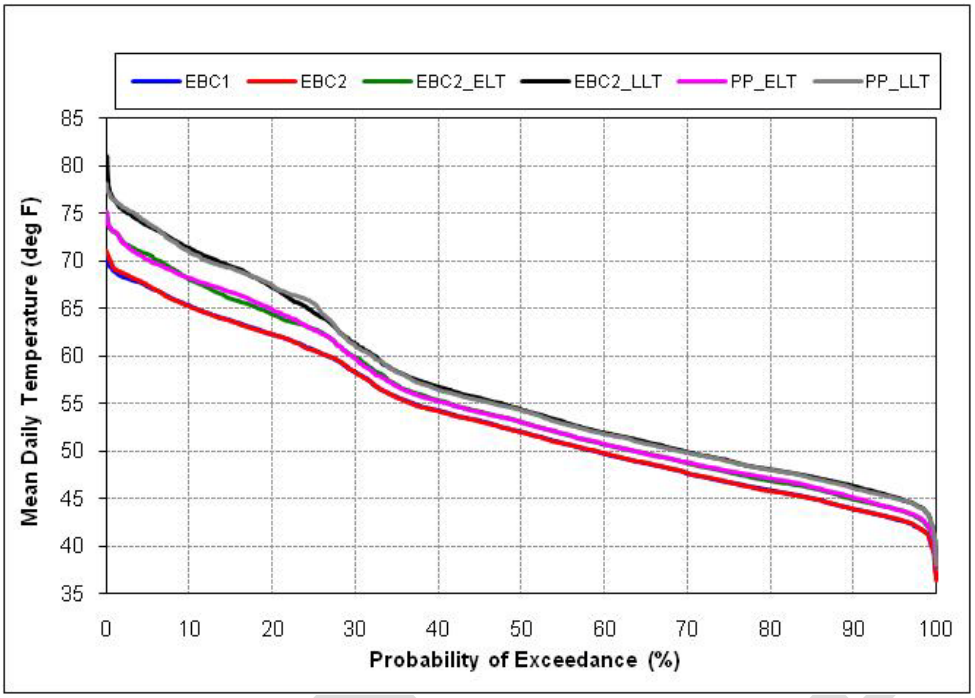

Figure C.5.2-141. Probability of Exceedance Plot for Model Scenarios of Mean Daily Temperature in the Sacramento River at Hamilton City, August through March in Critical Years

Table C.5.2-48. Percent of Days during the Months August through March[1] When Daily Average Temperature Exceeds 66°F, 75°F, and 81°F in the Sacramento River at Hamilton City

Water-Year Type	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
Temperatures above 66°F						
Wet	0.4	0.2	1.3	4.4	1.1	8.1
Above Normal	0.8	0.1	0.9	2.7	1.9	8.7
Below Normal	0.2	0.2	2.0	7.6	1.9	11.0
Dry	1.4	2.0	6.2	12.7	7.4	16.3
Critically Dry	8.0	7.9	15.4	22.2	17.2	24.1
All	1.8	1.7	4.5	9.1	5.1	12.8
Temperatures above 75°F						
Wet	0.0	0.0	0.0	0.0	0.0	0.0
Above Normal	0.0	0.0	0.0	0.0	0.0	0.0
Below Normal	0.0	0.0	0.0	0.0	0.0	0.0
Dry	0.0	0.0	0.0	0.0	0.0	0.0
Critically Dry	0.0	0.0	0.0	2.7	0.0	3.5
All	0.0	0.0	0.0	0.4	0.0	0.5
Temperatures above 81°F						
Wet	0.0	0.0	0.0	0.0	0.0	0.0
Above Normal	0.0	0.0	0.0	0.0	0.0	0.0
Below Normal	0.0	0.0	0.0	0.0	0.0	0.0
Dry	0.0	0.0	0.0	0.0	0.0	0.0
Critically Dry	0.0	0.0	0.0	0.0	0.0	0.0
All	0.0	0.0	0.0	0.0	0.0	0.0

[1] Based on the modeling period of 1922 to 2003.

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Table C.5.2-49. Comparison of the Percentage of Months from August through March When Monthly Average Temperature Exceeds 66°F, 75°F, and 81°F in the Sacramento River at Hamilton City

WY Type	Comparison[1]	EBC1_ELT vs. PP_ELT	EBC1_LLT vs. PP_LLT	EBC2 vs. EBC2_ELT	EBC2 vs. EBC2_LLT	EBC2 vs. PP_ELT	EBC2 vs. PP_LLT	EBC2_ELT vs. PP_ELT	EBC2_LLT vs. PP_LLT
Temperatures above 66°F									
Wet	Difference	0.7	7.8	1.1	4.2	0.8	7.9	-0.2	3.7
	Percent difference	191%	2,135%	447%	1,760%	347%	3,327%	-18%	84%
Above Normal	Difference	1.1	7.8	0.8	2.5	1.7	8.5	1.0	6.0
	Percent difference	129%	954%	550%	1,850%	1,275%	6,225%	112%	224%
Below Normal	Difference	1.7	10.8	1.8	7.4	1.7	10.8	-0.1	3.3
	Percent difference	967%	6,117%	1,033%	4,217%	967%	6,117%	-6%	44%
Dry	Difference	5.9	14.8	4.2	10.7	5.4	14.3	1.2	3.6
	Percent difference	413%	1,032%	213%	540%	271%	720%	19%	28%
Critical	Difference	9.2	16.1	7.5	14.3	9.3	16.3	1.8	1.9
	Percent difference	115%	201%	95%	182%	118%	207%	12%	9%
All	Difference	3.3	11.1	2.8	7.4	3.4	11.1	0.6	3.7
	Percent difference	189%	631%	162%	433%	196%	648%	13%	40%
Temperatures above 75°F									
Wet	Difference	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Percent difference	NA	NA	NA	NA	NA	NA	NA	NA
Above Normal	Difference	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Percent difference	NA	NA	NA	NA	NA	NA	NA	NA
Below Normal	Difference	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Percent difference	NA	NA	NA	NA	NA	NA	NA	NA
Dry	Difference	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Percent difference	NA	NA	NA	NA	NA	NA	NA	NA
Critical	Difference	0.0	3.5	0.0	2.7	0.0	3.5	0.0	0.8
	Percent difference	NA	NA	NA	NA	NA	NA	0%	29%
All	Difference	0.0	0.5	0.0	0.4	0.0	0.5	0.0	0.1
	Percent difference	NA	NA	NA	NA	NA	NA	0%	29%
Temperatures above 81°F									
Wet	Difference	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Percent difference	NA	NA	NA	NA	NA	NA	NA	NA
Above Normal	Difference	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Percent difference	NA	NA	NA	NA	NA	NA	NA	NA
Below Normal	Difference	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Percent difference	NA	NA	NA	NA	NA	NA	NA	NA
Dry	Difference	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Percent difference	NA	NA	NA	NA	NA	NA	NA	NA
Critical	Difference	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Percent difference	NA	NA	NA	NA	NA	NA	NA	-100%
All	Difference	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Percent difference	NA	NA	NA	NA	NA	NA	NA	-100%

[1] A positive value indicates a higher value under the proposed project than the EBC.
NA = Could not be calculated because dividing by 0.

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Dissolved Oxygen

The effects of BDCP actions on dissolved oxygen levels potentially affecting green sturgeon juveniles would be the same as described for white sturgeon juveniles. In the absence of known dissolved oxygen thresholds for green sturgeon, the threshold for white sturgeon of 56% saturation (Israel and Klimley 2008) was used as a surrogate.

Turbidity

Turbidity effects of BDCP actions on green sturgeon juveniles would be the same as described for white sturgeon juveniles.

Adults

Water Temperature (Rivers)

Adult green sturgeon have greater temperature tolerances than juveniles (for which oxygen binding ability appears to be sensitive to low temperature), which permits adult fishes to bind sufficient oxygen even at elevated water temperatures (Kaufman et al. 2006). These oxygen binding and uploading responses occurred across a range of temperatures between 52°F and 75°F (11°C–24°C). However, the critical temperature for adult mortality is 81°F (27°C) (Erickson et al. 2002; Heublein et al. 2009; Federal Register CRHB). Green sturgeon spawning occurs from March through July (Adams et al. 2007; Mora et al. 2009; Fed Register CRHB). In the absence of adult temperature threshold criteria identified in Israel and Klimley (2008), 52°F was used as the lower threshold and 75°F and 81°F were used as upper thresholds for adult survival. Within the Sacramento River, these values were investigated at Keswick, Ball's Ferry and Jelly's Ferry.

For all water-year types combined, water temperatures during March through July never exceeded the 75°F or 81°F thresholds under any model scenario at Keswick (Figure C.5.2-142), Ball's Ferry (Figure C.5.2-143), or Jelly's Ferry (Figure C.5.2-144). A review of dry and critical water years indicate similar findings, that under no scenario would the 75°F or 81°F upper threshold be exceeded for any scenario at these locations.

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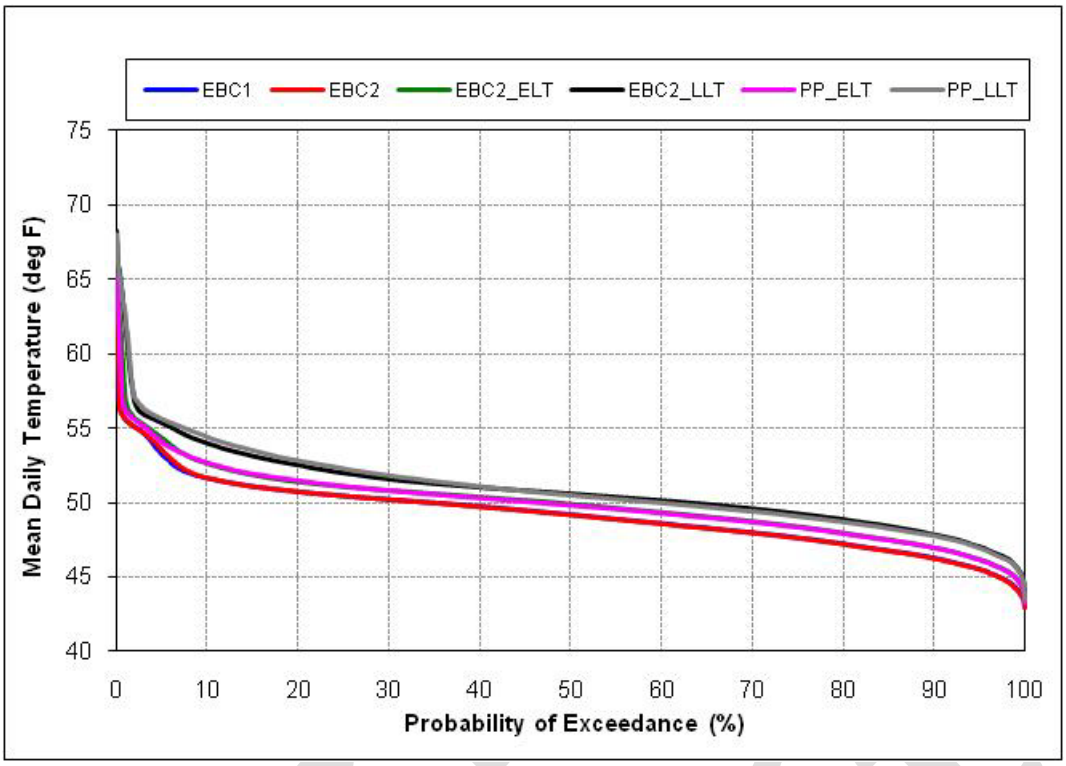

Figure C.5.2-142. Probability of Exceedance Plot for Model Scenarios of Mean Daily Temperature in the Sacramento River at Keswick, March through July for All Water-Year Types Combined

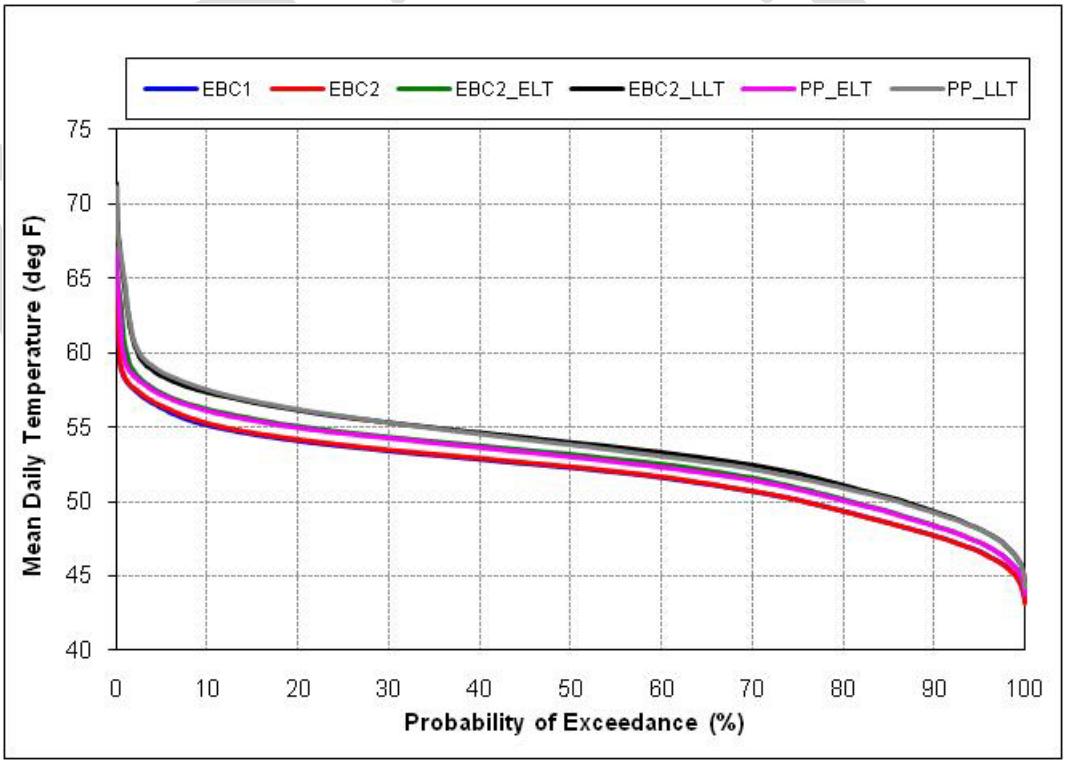

Figure C.5.2-143. Probability of Exceedance Plot for Model Scenarios of Mean Daily Temperature in the Sacramento River at Ball's Ferry, March through July for All Water-Year Types Combined

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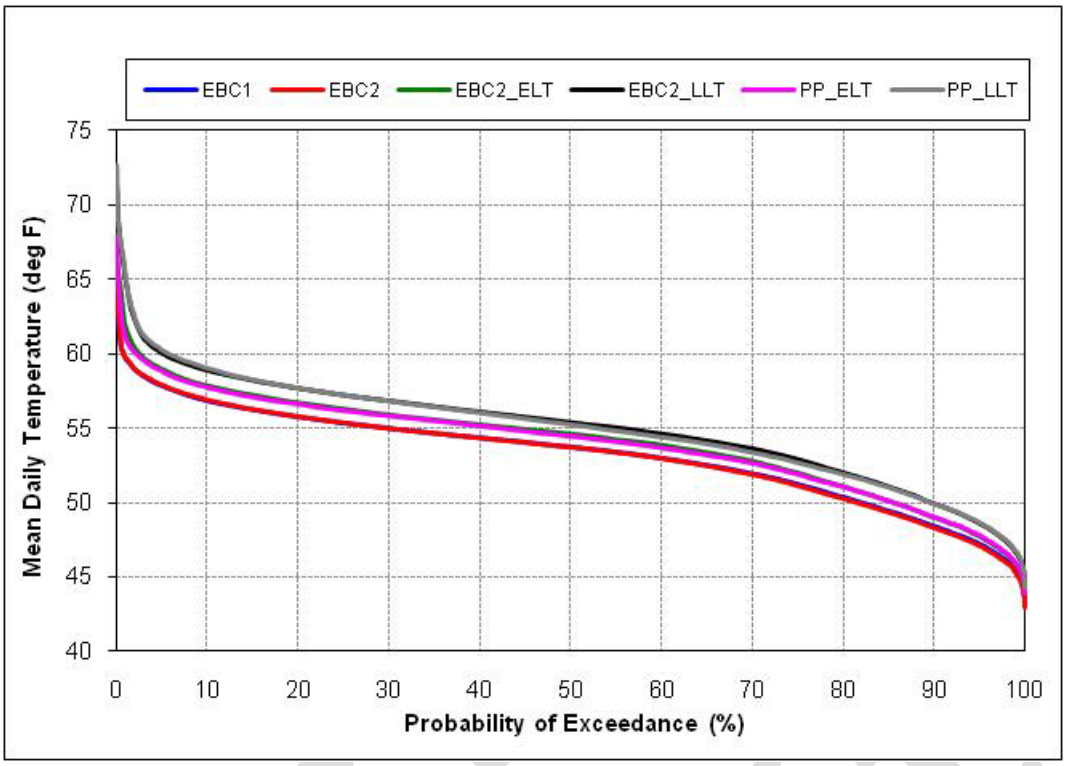

Figure C.5.2-144. Probability of Exceedance Plot for Model Scenarios of Mean Daily Temperature in the Sacramento River at Jelly's Ferry, March through July for All Water-Year Types Combined

Water temperatures in the Sacramento River at Keswick, Ball's Ferry, and Jelly's Ferry were evaluated for the percentage of daily temperatures that would drop below the 52°F lower threshold for water temperature suitability for adult green sturgeon. A review of March through July temperatures for each water year designation separately, as well as for all water years combined, indicates that the incidence of water temperatures below the 52°F threshold would be comparable (<5% difference) between EBC_ELT and PP_ELT and between EBC_LLT and PP_LLT at all locations (Table C.5.2-50, Table C.5.2-51).

Table C.5.2-50. Percentage of Days between March and July[1] When Daily Average Temperature Falls Below 52°F in the Sacramento River at Keswick, Ball's Ferry, and Jelly's Ferry

Location	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
Keswick						
Wet	76.3	75.8	68.2	60.7	67.7	59.4
Above Normal	76.0	75.7	66.8	57.4	66.1	57.4
Below Normal	72.9	71.5	63.7	55.6	63.0	52.1
Dry	69.4	68.5	59.9	51.0	59.7	49.3
Critical	54.7	54.8	45.0	36.5	45.6	36.7
All	71.0	70.4	62.0	53.7	61.7	52.3
Ball's Ferry						
Wet	51.5	50.5	44.5	40.3	45.5	41.4
Above Normal	50.7	50.9	42.7	37.7	44.8	39.4
Below Normal	50.4	49.4	41.5	35.7	44.3	38.1

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Location	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
Keswick						
Dry	48.6	47.9	40.8	34.8	42.1	36.9
Critical	45.9	45.0	38.4	31.7	38.9	32.3
All	49.8	49.0	42.0	36.7	43.5	38.2
Jelly's Ferry						
Wet	46.7	45.9	42.1	38.5	42.9	39.3
Above Normal	44.7	44.4	39.6	35.2	40.7	36.6
Below Normal	43.1	42.3	37.9	33.8	39.3	35.5
Dry	42.4	41.9	37.2	32.8	38.5	33.9
Critical	41.1	40.7	35.6	30.5	35.9	31.3
All	44.0	43.4	39.0	34.8	40.0	35.9
[1] Based on the modeling period of 1922 to 2003						

Table C.5.2-51. Comparison of the Percentage of Days from March through July When Average Temperature Falls Below 52°F in the Sacramento River at Keswick, Ball's Ferry, and Jelly's Ferry

WY Type	Comparison[1]	EBC1_ELT vs. PP_ELT	EBC1_LLT vs. PP_LLT	EBC2 vs. EBC2_ELT	EBC2 vs. EBC2_LLT	EBC2 vs. PP_ELT	EBC2 vs. PP_LLT	EBC2_ELT vs. PP_ELT	EBC2_LLT vs. PP_LLT
Keswick									
Wet	Difference	-8.6	-16.9	-7.6	-15.1	-8.1	-16.5	-0.5	-1.3
	Percent difference	-11%	-22%	-10%	-20%	-11%	-22%	-1%	-2%
Above Normal	Difference	-9.9	-18.7	-8.9	-18.4	-9.6	-18.3	-0.7	0.0
	Percent difference	-13%	-25%	-12%	-24%	-13%	-24%	-1%	0%
Below Normal	Difference	-9.9	-20.8	-7.8	-15.9	-8.5	-19.5	-0.7	-3.6
	Percent difference	-14%	-29%	-11%	-22%	-12%	-27%	-1%	-6%
Dry	Difference	-9.7	-20.0	-8.7	-17.5	-8.8	-19.2	-0.1	-1.7
	Percent difference	-14%	-29%	-13%	-26%	-13%	-28%	0%	-3%
Critical	Difference	-9.1	-17.9	-9.8	-18.4	-9.2	-18.1	0.6	0.3
	Percent difference	-17%	-33%	-18%	-34%	-17%	-33%	1%	1%
All	Difference	-9.3	-18.7	-8.4	-16.7	-8.7	-18.1	-0.3	-1.4
	Percent difference	-13%	-26%	-12%	-24%	-12%	-26%	-1%	-3%
Ball's Ferry									
Wet	Difference	-6.0	-10.1	-6.0	-10.2	-5.0	-9.1	1.0	1.1
	Percent difference	-12%	-20%	-12%	-20%	-10%	-18%	2%	3%
Above Normal	Difference	-5.9	-11.3	-8.2	-13.2	-6.2	-11.6	2.1	1.6
	Percent difference	-12%	-22%	-16%	-26%	-12%	-23%	5%	4%
Below Normal	Difference	-6.2	-12.3	-7.9	-13.6	-5.1	-11.3	2.8	2.4
	Percent difference	-12%	-24%	-16%	-28%	-10%	-23%	7%	7%
Dry	Difference	-6.4	-11.7	-7.0	-13.0	-5.7	-11.0	1.3	2.0
	Percent difference	-13%	-24%	-15%	-27%	-12%	-23%	3%	6%
Critical	Difference	-7.0	-13.6	-6.6	-13.3	-6.0	-12.7	0.5	0.6
	Percent difference	-15%	-30%	-15%	-30%	-13%	-28%	1%	2%
All	Difference	-6.3	-11.5	-7.0	-12.3	-5.5	-10.8	1.5	1.5
	Percent difference	-13%	-23%	-14%	-25%	-11%	-22%	3%	4%

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WY Type	Comparison[1]	EBC1_ELT vs. PP_ELT	EBC1_LLT vs. PP_LLT	EBC2 vs. EBC2_ELT	EBC2 vs. EBC2_LLT	EBC2 vs. PP_ELT	EBC2 vs. PP_LLT	EBC2_ELT vs. PP_ELT	EBC2_LLT vs. PP_LLT
Jelly's Ferry									
Wet	Difference	-3.8	-7.4	-3.8	-7.4	-3.0	-6.6	0.8	0.8
	Percent difference	-8%	-16%	-8%	-16%	-6%	-14%	2%	2%
Above Normal	Difference	-4.0	-8.1	-4.9	-9.2	-3.7	-7.9	1.1	1.3
	Percent difference	-9%	-18%	-11%	-21%	-8%	-18%	3%	4%
Below Normal	Difference	-3.7	-7.5	-4.4	-8.5	-3.0	-6.8	1.4	1.7
	Percent difference	-9%	-18%	-10%	-20%	-7%	-16%	4%	5%
Dry	Difference	-3.9	-8.4	-4.7	-9.1	-3.4	-7.9	1.3	1.1
	Percent difference	-9%	-20%	-11%	-22%	-8%	-19%	4%	3%
Critical	Difference	-5.1	-9.8	-5.1	-10.2	-4.8	-9.5	0.3	0.8
	Percent difference	-13%	-24%	-13%	-25%	-12%	-23%	1%	3%
All	Difference	-4.0	-8.1	-4.4	-8.7	-3.5	-7.5	1.0	1.1
	Percent difference	-9%	-18%	-10%	-20%	-8%	-17%	3%	3%
[1] A positive value indicates a higher value under the proposed project than the EBC.									

Keswick

Combining all water years, mean daily water temperatures in the Sacramento River at Keswick from March through July were lower than the 52°F threshold 70%–71% of the time under EBC1 and EBC2, 54%–62% of the time under EBC2_ELT and EBC2_LLT, and 52%–62% of the time under PP_ELT and PP_LLT (Figure C.5.2-142, Table C.5.2-50). Accounting for climate change effects, BDCP implementation under early and late long-term conditions (PP_ELT and PP_LLT) is predicted to result in a <1%–3% decrease in the frequency of temperatures below 52°F relative to baseline conditions (EBC2_ELT and EBC2_LLT) (Table C.5.2-51).

Ball's Ferry

Combining all water years, mean daily water temperatures in the Sacramento River at Ball's Ferry from March through July were lower than the 52°F threshold 49%–50% of the time under EBC1 and EBC2, 37%–42% of the time under EBC2_ELT and EBC2_LLT, and 38%–44% of the time under PP_ELT and PP_LLT (Figure C.5.2-143, Table C.5.2-50). Accounting for climate change effects, BDCP implementation under early and late long-term conditions (PP_ELT and PP_LLT) is predicted to result in a 3%–4% increase in the frequency of temperatures below 52°F relative to baseline conditions (EBC2_ELT and EBC2_LLT) (Table C.5.2-51).

Jelly's Ferry

Combining all water years, mean daily water temperatures in the Sacramento River at Jelly's Ferry from March through July were lower than the 52°F threshold 43%–44% of the time under EBC1 and EBC2, 35%–39% of the time under EBC2_ELT and EBC2_LLT, and 36%–40% of the time under PP_ELT and PP_LLT (Figure C.5.2-144, Table C.5.2-50). Accounting for climate change effects, BDCP implementation under early and late long-term conditions (PP_ELT and PP_LLT) is predicted to result in a 3% increase in the frequency of temperatures below 52°F relative to baseline conditions (EBC2_ELT and EBC2_LLT) (Table C.5.2-51).

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Turbidity

Turbidity effects of BDCP actions on green sturgeon adults would be the same as previously described for white sturgeon adults.

Spawning Habitat

In the absence of a green sturgeon-specific index, the Gard (1996) suitability index for Sacramento white sturgeon spawning habitat was utilized as a general guideline for green sturgeon. As mentioned above for white sturgeon, this index identified waters with velocities of 3.9–19.95 ft/s as suitable, with velocities of 5–12.5 ft/s as ideal. Further, water depths of >6 feet were suitable, while those >10 feet were ideal. In addition, whereas habitats with snags and gravel were considered suitable, those that included cobble and boulders were ideal. These criteria, combined with water temperatures upper thresholds, help identify preferential spawning habitats. Consistent with the SacEFT approach, Israel and Klimley (2008) identified 63°F (17°C) as an optimal April through July temperature range for green sturgeon eggs and embryos.

The percentage of years during which the 63°F threshold would be exceeded is expected to increase under all future scenarios (see Table C.5.2-40 and Table C.5.2-41). However, there are minimal differences between PP and EBC2 in ELT and LLT. Therefore, it was concluded with high certainty that the preliminary proposal would not have a biologically meaningful effect on green sturgeon spawning habitat temperatures in the Sacramento River.

Due to Sacramento River channel confinement, upstream supply of sediment and large woody debris is limited, which limits in-water refuge for fish, and contributes to the lack of sediment and organic matter accumulation on the downstream side of the debris (U.S. Fish and Wildlife Service 2000). The presence of upstream dams further exacerbates this problem. In addition, channelization increases water velocities, depth, and substrate grain size. No large effects of the preliminary proposal were detected on water temperatures in the Sacramento River at Red Bluff in any water years. However, over this large period of adult attraction and spawning periods (November through July), some decreases in upper Sacramento River flows would occur under the preliminary proposal relative to EBC and future EBC. Consequently, some reductions would be expected with respect to depth and velocity in this section of the Sacramento River, although whether these changes would be sufficient to alter the suitability of these habitats to green sturgeon is unknown.

C.5.2.1.8 Lamprey

Eggs

Water Temperature

Exact spawning locations of Pacific and river lamprey in the Sacramento River are not well known. Therefore, this analysis includes the farthest upstream (Sacramento River below Keswick) and farthest downstream (Sacramento River at Hamilton City) locations to provide the widest range of temperature conditions. To determine the number of daily egg cohorts that may be affected by high water temperatures, it was assumed that embryos hatch in up to 49 days (Bruno 2006). This duration is based on a water temperature of 15°C (59°F), although no attempt was made to adjust duration by temperature despite the likely influence of temperature on incubation duration (Brumo 2006).

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For Pacific lamprey eggs and ammocoetes, Meeuwig and others (2005) report that survival is reduced by approximately 50% at temperatures greater than 22°C (71.6°F). Although Moyle and others (1995) indicate that river lamprey eggs and ammocoetes presumably need temperatures that do not exceed 25°C (77°F), the effect of temperatures exceeding this threshold on river lamprey eggs is unknown. The effects on this species are likely similar to (and are assumed in this analysis to be similar to) those for Pacific lamprey of temperatures exceeding 22°C (71.6°F). For river lamprey, analyses for both 71.6°F and 77°F are presented below. The number of cohorts exposed to water temperatures above 71.6°F and 77°F is reported in Table C.5.2-52 (Pacific lamprey) and Table C.5.2-53 (river lamprey), and differences between model scenarios are reported in Table C.5.2-54 (Pacific lamprey) and Table C.5.2-55 (river lamprey).

Table C.5.2-52. Temperature Exposure of Pacific Lamprey Egg Cohorts for the Sacramento River[1,2]

Location	Metric	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
Keswick	# Cohorts	0	0	0	51	0	52
	Percent of Total	0%	0%	0%	0.3%	0%	0.3%
Hamilton City	# Cohorts	0	0	483	1,068	369	1,012
	Percent of Total	0%	0%	2.4%	5.4%	1.9%	5.1%

[1] n = 19,928 cohorts for Keswick; n = 19,929 cohorts for Hamilton City.
[2] Predicted number of and percent of total Pacific lamprey egg cohorts experiencing temperatures above 71.6°F during January to August on at least one day during a 49-day incubation period for each model scenario.

Table C.5.2-53. Temperature Exposure of River Lamprey Egg Cohorts in the Sacramento River[1,2]

Location	Metric	EBC1	EBC2	EBC2_ELT	EBC_LLT	PP_ELT	PP_LLT
Temperature above 71.6°F							
Keswick	# Cohorts	0	0	0	0	0	0
	Percent of Total	0%	0%	0%	0%	0%	0%
Hamilton City	# Cohorts	0	0	101	323	94	284
	Percent of Total	0%	0%	0.8%	2.6%	0.8%	2.3%
Temperature above 77°F							
Keswick	# Cohorts	0	0	0	0	0	0
	Percent of Total	0%	0%	0%	0%	0%	0%
Hamilton City	# Cohorts	0	0	0	36	0	61
	Percent of Total	0%	0%	0%	0.3%	0%	0.5%

[1] n =12,320 cohorts.
[2] Predicted number of and percent of total river lamprey egg cohorts experiencing temperatures above 71.6°F and 77°F during February to June on at least one day during a 49-day incubation period for each model scenario.

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Table C.5.2-54. Differences between Model Scenarios in Pacific Lamprey Egg Cohort Temperature Exposure in the Sacramento River[1]

Location	Comparison[2]	EBC1 vs. PP_ELT	EBC1 vs. PP_LLT	EBC2 vs. PP_ELT	EBC2 vs. PP_LLT	EBC2_ELT vs. PP_ELT	EBC2_LLT vs. PP_LLT
Keswick	Difference	0	52	0	52	0	1
	Percent difference	NA	NA	NA	NA	NA	2.0%
Hamilton City	Difference	369	1,012	369	1,012	-114	-56
	Percent difference	NA	NA	NA	NA	-23.6%	-5.2%

[1] Difference and percent difference between model scenarios in the number of Pacific lamprey egg cohorts experiencing water temperatures above 71.6°F during January to August on at least one day during a 49-day incubation period.
[2] Positive values indicate a higher value in the preliminary proposal than in the EBC.
NA = Cannot be calculated because dividing by 0.

Table C.5.2-55. Differences between Model Scenarios in River Lamprey Egg Cohort Temperature Exposure in the Sacramento River[1]

Location	Comparison[2]	EBC1 vs. PP_ELT	EBC1 vs. PP_LLT	EBC2 vs. PP_ELT	EBC2 vs. PP_LLT	EBC2_ELT vs. PP_ELT	EBC2_LLT vs. PP_LLT
Temperature above 71.6°F							
Keswick	Difference	0	0	0	0	0	0
	Percent difference	NA	NA	NA	NA	NA	NA
Hamilton City	Difference	94	284	94	284	-7	-39
	Percent difference	NA	NA	NA	NA	-6.9%	-12.1%
Temperature above 77°F							
Keswick	Difference	0	0	0	0	0	0
	Percent difference	NA	NA	NA	NA	NA	NA
Hamilton City	Difference	0	61	0	61	0	25
	Percent difference	NA	NA	NA	NA	NA	69.4%

[1] Difference and percent difference between model scenarios in the number of river lamprey egg cohorts experiencing water temperature above 71.6°F and 77°F during February to June on at least one day during a 49-day incubation period.
[2] Positive values indicate a higher value in the preliminary proposal than in the EBC.
NA = Cannot be calculated because dividing by 0.

Keswick

For Pacific lamprey at Keswick, the percent of daily egg cohorts experiencing water temperatures that exceed 71.6°F during January through August is predicted to range from 0% under EBC1, EBC2, EBC2_ELT, and PP_ELT to less than 1% for EBC2_LLT and PP_LLT over the 82-year simulation period (Figure C.5.2-145, Table C.5.2-52). Under late long-term conditions, implementation of the preliminary proposal (PP_LLT) would result in exposure of 52 daily cohorts to temperatures exceeding 71.6°F versus 51 daily cohorts in the absence of implementation of the preliminary proposal (EBC2_LLT) (Table C.5.2-52).

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For river lamprey, mean daily water temperatures in the Sacramento River at Keswick are predicted to be below 71.6°F and 77°F during February through June in all model scenarios (Figure C.5.2-146, Table C.5.2-53).

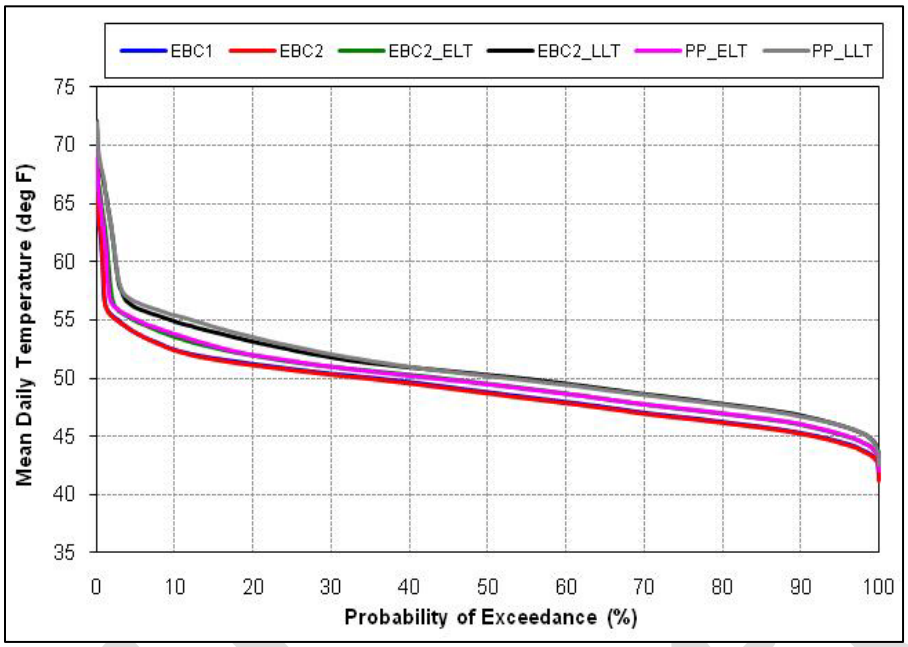

Figure C.5.2-145. Probability of Exceedance Plot for Model Scenarios of Mean Daily Water Temperature of the Sacramento River at Keswick, January through August

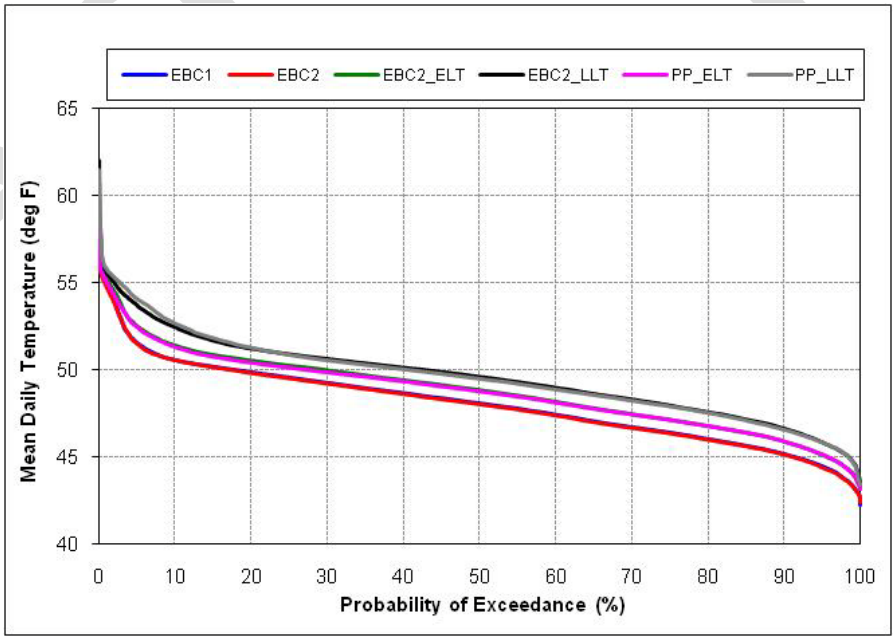

Figure C.5.2-146. Probability of Exceedance Plot for Model Scenarios of Mean Daily Water Temperature of the Sacramento River at Keswick, February through June

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Hamilton City

At Hamilton City, the percent of Pacific lamprey daily egg cohorts experiencing water temperatures that exceed 71.6°F is predicted to be 0% under EBC1 and EBC2, 2% under EBC2_ELT and PP_ELT, and 5% under EBC2_LLT and PP_LLT (Figure C.5.2-147, Table C.5.2-52). Under early long-term conditions, implementation of the preliminary proposal (PP_ELT) would result in exposure of 369 daily cohorts to temperatures exceeding 71.6°F, a 24% decrease relative to EBC2_ELT (483 cohorts) (Table C.5.2-54). Under late long-term conditions, implementation of the preliminary proposal (PP_LLT) would result in exposure of 1,012 daily cohorts to temperatures exceeding 71.6°F, a 5% decrease relative to EBC2_LLT (1,068 cohorts).

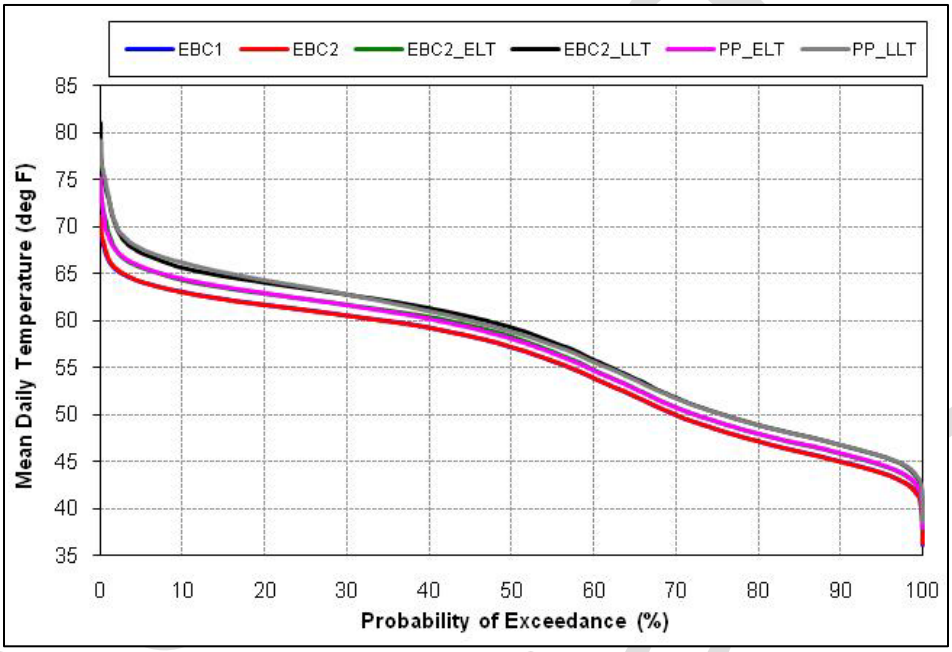

Figure C.5.2-147. Probability of Exceedance Plot for Model Scenarios of Mean Daily Water Temperature of the Sacramento River at Hamilton City, January through August

For river lamprey at Hamilton City, the proportion of daily egg cohorts experiencing water temperatures that exceed 71.6°F is predicted to be 0% under EBC1 and EBC2, 1%–3% under EBC2_ELT and EBC2_LLT, and 1%–2% under PP_ELT and PP_LLT (Figure C.5.2-148, Table C.5.2-53). Under early long-term conditions, implementation of the preliminary proposal (PP_ELT) would result in exposure of 94 daily cohorts to temperatures exceeding 71.6°F, a 7% decrease relative to EBC2_ELT (101 cohorts) (Table C.5.2-55). Under late long-term conditions, implementation of the preliminary proposal (PP_LLT) would result in exposure of 284 daily cohorts to temperatures exceeding 71.6°F, a 12% decrease relative to EBC2_LLT (323 cohorts) (Table C.5.2-55).

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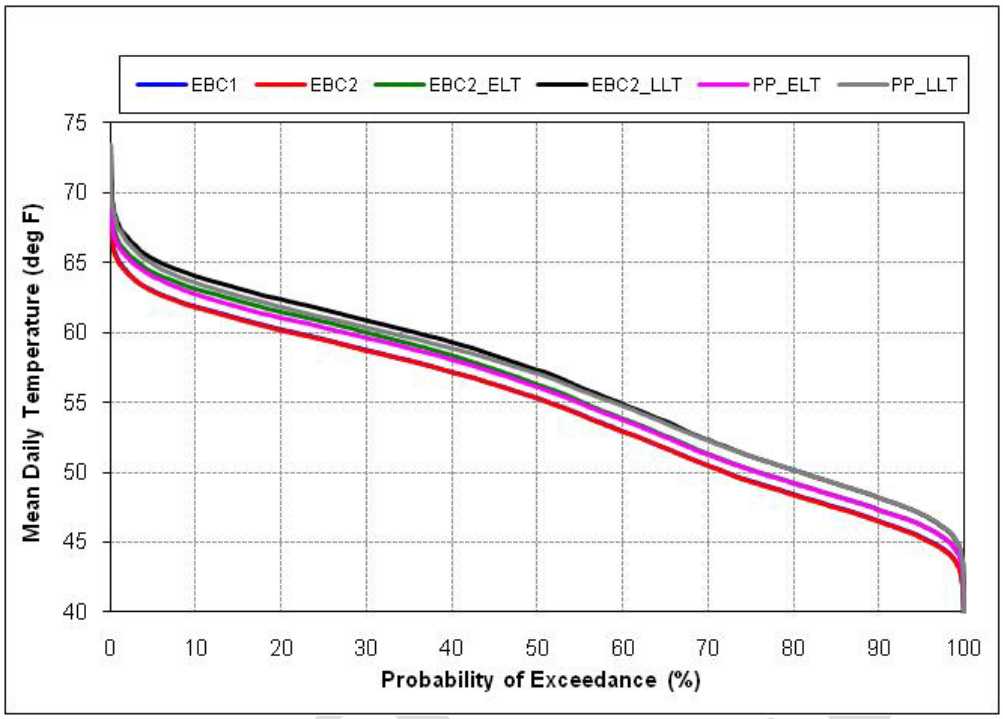

Figure C.5.2-148. Probability of Exceedance Plot for Model Scenarios of Mean Daily Water Temperature of the Sacramento River at Hamilton City, February through June

The proportion of daily river lamprey egg cohorts experiencing water temperatures that exceed 77°F is predicted to be 0% under EBC1, EBC2, EBC2_ELT, and PP_ELT and <1% under EBC2_LLT and PP_LLT (Figure C.5.2-148, Table C.5.2-53). Under late long-term conditions, implementation of the preliminary proposal (PP_LLT) would result in exposure of 61 daily cohorts to temperatures exceeding 77°F, a 69% increase relative to EBC2_LLT (36 cohorts) (Table C.5.2-55).

Collectively, modeling results for the Sacramento River suggest that climate change will increase the exposure of Pacific and river lamprey egg cohorts to temperatures exceeding 71.6°F and 77°F with potential for these species to experience declines in survival. Implementation of the preliminary proposal is predicted to provide negligible water temperature relief for Pacific lamprey and modest relief for river lamprey for 71.6°F but not for 77°F. The number of days in which water temperature exceeds these thresholds, however, is low under all scenarios (lower than 3% of all days). Thus, overall, these effects are considered minor on river lamprey. Because this analysis uses water temperature model outputs based on CALSIM outputs, error has been propagated and the level of certainty of these results is moderate.

Redd Dewatering

Keswick

For Pacific lamprey, the total predicted number of redd cohorts between January and August experiencing a month-over-month (from one month to the next) decrease in flow of greater than 50% in the Sacramento River at Keswick ranged between 54 (EBC2) and 77 cohorts (EBC_LLT) (Table C.5.2-56).

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There are zero and seven more redd cohorts (0% and 13%) predicted to experience a month-over-month change in flow of greater than 50% in PP_ELT and PP_LLT, respectively, relative to the EBC1(Table C.5.2-57). There are one and eight more redd cohorts (2% and 15%) predicted to experience a month-over-month change in flow of greater than 50% in PP_ELT and PP_LLT, respectively, relative to the EBC2 (Table C.5.2-57).

Isolating the effect of the preliminary proposal from the effects of climate change, there are 12 and 15 fewer cohorts (18% and 20%) predicted to experience a month-over-month change in flow of greater than 50% for PP_ELT and PP_LLT relative to the EBC2_ELT and EBC2_LLT, respectively.

Table C.5.2-56. Dewatering Risk of Pacific Lamprey Redd Cohorts[1]

Location	Metric	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
Sacramento River at Keswick	# Cohorts	55	54	67	77	55	62
	Percent of total[2]	8.4%	8.2%	10.2%	11.8%	8.4%	9.5%
Sacramento River at Red Bluff	# Cohorts	54	57	64	72	61	51
	Percent of total	8.2%	8.7%	9.8%	11.0%	9.3%	7.8%
Trinity River downstream of Lewiston	# Cohorts	131	129	129	131	131	129
	Percent of total	20.0%	19.7%	19.7%	20.0%	20.0%	19.7%
Feather River at Thermalito Afterbay	# Cohorts	150	109	113	108	156	153
	Percent of total	22.9%	16.6%	17.3%	16.5%	23.8%	23.4%
American River at Nimbus Dam	# Cohorts	84	92	106	121	101	111
	Percent of total	12.8%	14.0%	16.2%	18.5%	15.4%	16.9%
American River at Sacramento River confluence	# Cohorts	95	100	118	135	114	130
	Percent of total	14.5%	15.3%	18.0%	20.6%	17.4%	19.8%
Stanislaus River at San Joaquin River confluence	# Cohorts	58	61	62	60	61	61
	Percent of total	8.8%	9.3%	9.5%	9.2%	9.3%	9.3%

[1] Predicted number of and percent of total Pacific lamprey redd cohorts experiencing a month-over-month reduction in flows of greater than 50% during January to August for each model scenario.
[2] n = 655 cohorts for each location.

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Table C.5.2-57. Differences between Model Scenarios in Dewatering Risk of Pacific Lamprey Redd Cohorts[1]

Location	Comparison[2]	EBC1 vs. PP_ELT	EBC1 vs. PP_LLT	EBC2 vs. PP_ELT	EBC2 vs. PP_LLT	EBC2_ELT vs. PP_ELT	EBC2_LLT vs. PP_LLT
Sacramento River at Keswick	Difference	0	7	1	8	-12	-15
	Percent difference	0.0%	12.7%	1.9%	14.8%	-17.9%	-19.5%
Sacramento River at Red Bluff	Difference	7	-3	4	-6	-3	-21
	Percent difference	13.0%	-5.6%	7.0%	-10.5%	-4.7%	-29.2%
Trinity River downstream of Lewiston	Difference	0	-2	2	0	2	-2
	Percent difference	0.0%	-1.5%	1.6%	0.0%	1.6%	-1.5%
Feather River at Thermalito Afterbay	Difference	6	3	47	44	43	45
	Percent difference	4.0%	2.0%	43.1%	40.4%	38.1%	41.7%
American River at Nimbus Dam	Difference	17	27	9	19	-5	-10
	Percent difference	20.2%	32.1%	9.8%	20.7%	-4.7%	-8.3%
American River at Sacramento River confluence	Difference	19	35	14	30	-4	-5
	Percent difference	20.0%	36.8%	14.0%	30.0%	-3.4%	-3.7%
Stanislaus River at San Joaquin River confluence	Difference	3	3	0	0	-1	1
	Percent difference	5.2%	5.2%	0.0%	0.0%	-1.6%	1.7%

[1] Difference and percent difference between model scenarios in the number of Pacific lamprey redd cohorts experiencing a month-over-month reduction in flows of greater than 50%.
[2] Positive values indicate a higher value in the preliminary proposal than in EBC.

For river lamprey, the predicted number of redd cohorts experiencing a month-over-month decrease in flow of more than 50% in the Sacramento River at Keswick is between 32 (EBC1 and EBC2) and 35 cohorts (EBC2_ELT, EBC2_LLT, and PP_ELT) (Table C.5.2-58).

There are three and one more river lamprey redd cohorts (9% and 3%, respectively) predicted to experience a month-over-month change in flow of greater than 50% in the PP_ELT and PP_LLT, respectively, relative to the EBC1 (Table C.5.2-59). There are three and one more redd cohorts (9% and 3%, respectively) predicted to experience a month-over-month change in flow of greater than 50% in the PP_ELT and PP_LLT, respectively, relative to the EBC2.

Removing the effect of climate change, there are zero and two fewer redd cohorts (0% and 6%) predicted to experience a month-over-month change in flow of greater than 50% under the PP_ELT and PP_LLT relative to the EBC2_ELT and EBC2_LLT, respectively.

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Table C.5.2-58. Dewatering Risk of River Lamprey Redd Cohorts[1]

Location	Metric	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
Sacramento River at Keswick	Number	32	32	35	35	35	33
	Percent of total[2]	7.8%	7.8%	8.5%	8.5%	8.5%	8.0%
Sacramento River at Red Bluff	Number	37	37	40	39	41	34
	Percent of total	9.0%	9.0%	9.8%	9.5%	10.0%	8.3%
Trinity River downstream of Lewiston	Number	71	72	69	69	70	68
	Percent of total	17.3%	17.6%	16.8%	16.8%	17.1%	16.6%
Feather River below Thermalito Afterbay	Number	68	60	68	58	75	68
	Percent of total	16.6%	14.6%	16.6%	14.1%	18.3%	16.6%
American River at Nimbus	Number	55	59	64	64	59	65
	Percent of total	13.4%	14.4%	15.6%	15.6%	14.4%	15.9%
American River at Sacramento River confluence	Number	59	65	71	76	68	74
	Percent of total	14.4%	15.9%	17.3%	18.5%	16.6%	18.0%
Stanislaus River at San Joaquin River confluence	Number	56	59	59	51	58	51
	Percent of total	13.7%	14.4%	14.4%	12.4%	14.1%	12.4%

[1] Predicted number of and percent of total Pacific lamprey redd cohorts experiencing a month-over-month reduction in flows of greater than 50% during January to August for each model scenario.
[2] n = Need to correct this number cohorts for each location.

Table C.5.2-59. Differences between Model Scenarios in Dewatering Risk of River Lamprey Redd Cohorts[1]

Location	Comparison[2]	EBC1 vs. PP_ELT	EBC1 vs. PP_LLT	EBC2 vs. PP_ELT	EBC2 vs. PP_LLT	EBC2_ELT vs. PP_ELT	EBC2_LLT vs. PP_LLT
Sacramento River at Keswick	Difference	3	1	3	1	0	-2
	Percent difference	9.4%	3.1%	9.4%	3.1%	0.0%	-5.7%
Sacramento River at Red Bluff	Difference	4	-3	4	-3	1	-5
	Percent difference	10.8%	-8.1%	10.8%	-8.1%	2.5%	-12.8%
Trinity River downstream of Lewiston	Difference	-1	-3	-2	-4	1	-1
	Percent difference	-1.4%	-4.2%	-2.8%	-5.6%	1.4%	-1.4%
Feather River below Thermalito Afterbay	Difference	7	0	15	8	7	10
	Percent difference	10.3%	0%	25.0%	13.3%	10.3%	17.2%
American River at Nimbus	Difference	4	10	0	6	-5	1
	Percent difference	7.3%	18.2%	0.0%	10.2%	-7.8%	1.6%
American River at Sacramento River Confluence	Difference	9	15	3	9	-3	-2
	Percent difference	15.3%	25.4%	4.6%	13.8%	-4.2%	-2.6%
Stanislaus River at San Joaquin River Confluence	Difference	2	-5	-1	-8	-1	0
	Percent difference	3.6%	-8.9%	-1.7%	-13.6%	-1.7%	0.0%

[1] Difference and percent difference between model scenarios in the number of Pacific lamprey redd cohorts experiencing a month-over-month reduction in flows of greater than 50%.
[2] Positive values indicate a higher value in the preliminary proposal than in EBC.

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Red Bluff

For Pacific lamprey, the total predicted number of redd cohorts between January and August experiencing a month-over-month (from one month to the next) decrease in flow of greater than 50% in the Sacramento River at Red Bluff ranged from 51 (PP_LLT) to 72 cohorts (EBC2_LLT) (Table C.5.2-56).

There are seven more redd cohorts (13%) predicted to experience a month-over-month change in flow of greater than 50% for the PP_ELT relative to the EBC1 (Table C.5.2-57). There are four more redd cohorts (7%) predicted to experience a month-over-month change in flow of greater than 50% for the PP_ELT relative to the EBC2. There are three fewer cohorts (6%) predicted to experience a month-over-month change in flow of greater than 50% for the PP_LLT relative to the EBC1. There are six fewer cohorts (11%) predicted to experience a month-over-month change in flow of greater than 50% for the PP_LLT relative to the EBC2.

Isolating the effect of the preliminary proposal from the effects of climate change, there are three and 21 fewer redd cohorts (5% and 29%) predicted to experience a month-over-month change in flow of greater than 50% for PP_ELT and PP_LLT relative to the EBC2_ELT and EBC2_LLT, respectively.

For river lamprey, the predicted number of redd cohorts experiencing a month-over-month decrease in flow of more than 50% in the Sacramento River at Red Bluff is between 34 (PP_LLT) and 41 cohorts (PP_ELT) (Table C.5.2-58).

There are four more redd cohorts (11%) predicted to experience a month-over-month change in flow of greater than 50% in the PP_ELT relative to the EBC1 (Table C.5.2-59). There are three fewer redd cohorts (8%) predicted to experience a month-over-month change in flow of greater than 50% under the PP_LLT relative to the EBC1. There are four more redd cohorts (11%) predicted to experience a month-over-month change in flow of greater than 50% in the PP_ELT relative to the EBC2. There are three fewer redd cohorts (8%) predicted to experience a month-over-month change in flow of greater than 50% under the PP_LLT relative to the EBC2.

Removing the effect of climate change, there is one more redd cohort (3%) predicted to experience a month-over-month change in flow of greater than 50% under the PP_ELT relative to the EBC2_ELT. Conversely, there are five fewer redd cohorts (13%) predicted to experience a month-over-month change in flow of greater than 50% under the PP_LLT relative to the EBC2_LLT.

These results indicate that the number of Pacific lamprey redd cohorts predicted to experience a month-over-month change in flow of greater than 50% in the Sacramento River, which is assumed here to represent a redd dewatering event, would be decreased as a result of preliminary proposal effects. The preliminary proposal reduces this exposure by 5% to 29%, depending on location and time period.

Conversely, the number of river lamprey redd cohorts predicted to experience such an event varies among all model scenarios in nonsystematic ways. Therefore, collectively, there are no clear effects of the preliminary proposal on river lamprey redd dewatering in the Sacramento River.

Ammocoete

For Pacific lamprey, water temperatures above 22°C (71.6°F) may cause significant death (~50%) or deformation of eggs and ammocoetes (Meeuwig et al. 2005). Therefore, the number of Pacific

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lamprey ammocoete "cohorts" were examined that experience water temperatures greater than 71.6°F for at least 1 day in the Sacramento River (because daily water temperature data are available).

For river lamprey, the effects analysis was conducted using both 71.6°F and 77°F as thresholds. As described for Pacific lamprey, each individual day (for the Sacramento River) starts a new ammocoete cohort, corresponding to 11,569 cohorts for the Sacramento River based on daily cohorts from February 1 through June 30 for 82 years. The number of cohorts exposed to water temperatures above 71.6°F for Pacific lamprey is reported in Table C.5.2-60, and above 71.6°F and 77°F for river lamprey in Table C.5.2-62. Differences between model scenarios are reported in Table C.5.2-61 for Pacific lamprey and in Table C.5.2-63 for river lamprey.

Water Temperature

Keswick

For Pacific lamprey in the Sacramento River at Keswick, the percent of ammocoete cohorts experiencing water temperatures exceeding 71.6°F is predicted to be 0% under EBC1, EBC2, EBC2_ELT, and PP_ELT, and 9% under EBC2_LLT and PP_LLT (Figure C.5.2-149, Table C.5.2-60). Under late long-term conditions, the number of cohorts that would be exposed to temperatures exceeding 71.6°F would be nearly the same under EBC2_LLT (1,705 cohorts) and PP_LLT (1,706 cohorts). (Table C.5.2-61).

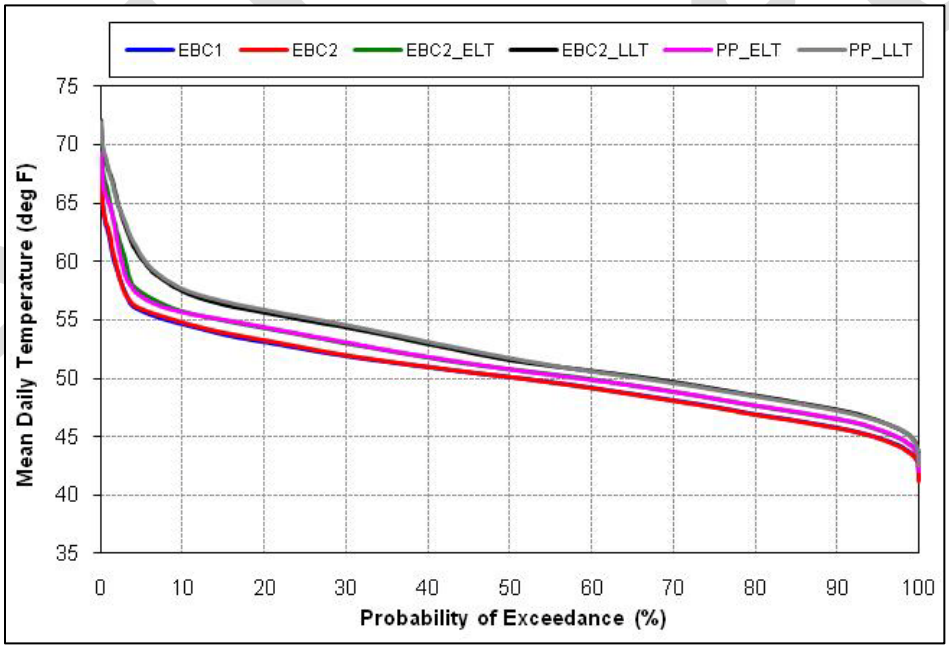

Figure C.5.2-149. Probability of Exceedance Plot for Model Scenarios of Mean Daily Temperature of the Sacramento River at Keswick for All Months

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Table C.5.2-60. Predicted Number of Pacific Lamprey Ammocoete Cohorts (Number and Percent) Exposed to Water Temperatures Greater Than 71.6°F

Location	Metric	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
Sacramento River at Keswick[1]	# Cohorts	0	0	0	1,705	0	1,706
	Percent	0.0%	0.0%	0.0%	9.3%	0.0%	9.4%
Sacramento River at Hamilton City[1]	# Cohorts	0	0	7,245	11,255	5,299	10,981
	Percent	0.0%	0.0%	39.7%	61.7%	29.0%	60.2%
Trinity River at Lewiston	# Cohorts	0	0	56	113	56	137
	Percent	0%	0%	9.4%	19.1%	9.4%	23.1%
Trinity River at North Fork	# Cohorts	0	0	65	193	65	122
	Percent	0.0%	0.0%	11.0%	32.5%	11.0%	20.6%
Feather River at Fish Barrier Dam	# Cohorts	0	0	0	56	0	0
	Percent	0.0%	0.0%	0.0%	9.4%	0.0%	0.0%
Feather River below Thermalito Afterbay	# Cohorts	382	438	476	521	570	593
	Percent	64.4%	73.9%	80.3%	87.9%	96.1%	100.0%
American River at Nimbus Dam	# Cohorts	194	333	473	561	452	547
	Percent	32.7%	56.2%	79.8%	94.6%	76.2%	92.2%
American River at Sacramento River	# Cohorts	434	498	576	593	585	593
	Percent	73.2%	84.0%	97.1%	100.0%	98.7%	100.0%
Stanislaus River at Knights Ferry	# Cohorts	0	0	0	56	0	56
	Percent	0.0%	0.0%	0.0%	9.4%	0.0%	9.4%
Stanislaus River at Riverbank	# Cohorts	56	56	339	586	338	586
	Percent	9.4%	9.4%	57.2%	98.8%	57.0%	98.8%

[1] Based on daily (not monthly) data.

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Table C.5.2-61. Difference and Percent Difference between Model Scenarios in Pacific Lamprey Ammocoete Cohorts Exposed to Temperatures Greater than 71.6°F in at Least One Month

Location	Comparison[1]	EBC1 vs. PP_ELT	EBC1 vs. PP_LLT	EBC2 vs. PP_ELT	EBC2 vs. PP_LLT	EBC2_ELT vs. PP_ELT	EB2_LLT vs. PP_LLT
Sacramento River at Keswick[2]	Difference	0	1,706	0	1,706	0	1
	Percent difference	NA	NA	NA	NA	NA	0.1%
Sacramento River at Hamilton City[2]	Difference	5,299	10,981	5,299	10,981	-1,946	-274
	Percent difference	NA	NA	NA	NA	-26.9%	-2.4%
Trinity River at Lewiston	Difference	56	137	56	137	0	24
	Percent difference	NA	NA	NA	NA	0%	21.2%
Trinity River at North Fork	Difference	65	122	65	122	0	-71
	Percent difference	NA	NA	NA	NA	0.0%	-36.8%
Feather River at Fish Barrier Dam	Difference	0	0	0	0	0	-56
	Percent difference	NA	NA	NA	NA	NA	-100%
Feather River below Thermalito Afterbay	Difference	188	211	132	155	94	72
	Percent difference	49.2%	55.2%	30.1%	35.4%	19.7%	13.8%
American River at Nimbus Dam	Difference	258	353	119	214	-21	-14
	Percent difference	133.0%	182.0%	35.7%	64.3%	-4.4%	-2.5%
American River at Sacramento River	Difference	151	159	87	95	9	0
	Percent difference	34.8%	36.6%	17.5%	19.1%	1.6%	0.%
Stanislaus River at Knights Ferry	Difference	0	56	0	56	0	0
	Percent difference	NA	NA	NA	NA	NA	0%
Stanislaus River at Riverbank	Difference	282	530	282	530	-1	0
	Percent difference	503.6%	946.4%	503.6%	946.4%	-0.3	0%

[1] Positive values indicate a higher value in the preliminary proposal than in EBC.
[2] Based on daily (not monthly) data.
NA = cannot be calculated because dividing by zero.

For river lamprey, the percent of ammocoete cohorts experiencing water temperatures that exceed 71.6°F is predicted to be 0% under EBC1, EBC2, EBC2_ELT, and PP_ELT and approximately 7% under EBC2_LLT and PP_LLT (Figure C.5.2-149, Table C.5.2-62). The number of cohorts exposed to temperatures exceeding 71.6°F was nearly identical under EBC2_LLT and PP_LLT (1,218 versus 1,219 cohorts) (Table C.5.2-63). Water temperatures are predicted to be below 77°F under all model scenarios over the 82-year period.

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Table C.5.2-62. Number and Percent of Total River Lamprey Ammocoete Cohorts Exposed to Temperatures above 71.6°F and 77°F

Location	Metric	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
Temperature above 71.6°F							
Sacramento River at Keswick[1]	Number	0	0	0	1,218	0	1,219
	Percent of Total	0.0%	0.0%	0.0%	6.5%	0.0%	6.5%
Sacramento River at Hamilton City[1]	Number	0	0	5,786	9,495	4,326	8,780
	Percent of Total	0.0%	0.0%	30.9%	50.7%	23.1%	46.9%
Trinity River at Lewiston	Number	0	0	25	50	25	65
	Percent of Total	0%	0%	6.6%	13.2%	6.6%	17.1%
Trinity River at North Fork	Number	0	0	30	90	30	56
	Percent of Total	0.0%	0.0%	7.9%	23.7%	7.9%	14.7%
Feather River at Fish Barrier Dam	Number	0	0	0	25	0	0
	Percent of Total	0.0%	0.0%	0.0%	6.6%	0.0%	0.0%
Feather River below Thermalito Afterbay	Number	190	215	260	320	355	380
	Percent of Total	50.0%	56.6%	68.4%	84.2%	93.4%	100.0%
American River at Nimbus Dam	Number	90	176	270	335	265	320
	Percent of Total	23.7%	46.3%	71.1%	88.2%	69.7%	84.2%
American River at Sacramento River	Number	245	300	360	380	365	380
	Percent of Total	64.5%	78.9%	94.7%	100.0%	96.1%	100.0%
Stanislaus River at Knights Ferry	Number	0	0	0	25	0	25
	Percent of Total	0.0%	0.0%	0.0%	6.6%	0.0%	6.6%
Stanislaus River at Riverbank	Number	25	25	180	360	180	360
	Percent of Total	6.6%	6.6%	47.4%	94.7%	47.4%	94.7%
Temperature above 77°F							
Sacramento River at Keswick[1]	Number	0	0	0	0	0	0
	Percent of Total	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Sacramento River at Hamilton City[1]	Number	0	0	0	1,502	0	2,704
	Percent of Total	0.0%	0.0%	0.0%	13.0%	0.0%	23.4%
Trinity River at Lewiston	Number	0	0	0	0	0	0
	Percent of Total	0%	0%	0%	0%	0%	0%
Trinity River at North Fork	Number	0	0	25	55	25	30
	Percent of Total	0.0%	0.0%	6.6%	14.5%	6.6%	7.9%
Feather River at Fish Barrier Dam	Number	0	0	0	0	0	0
	Percent of Total	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Feather River below Thermalito Afterbay	Number	0	0	25	40	50	100
	Percent of Total	0.0%	0.0%	6.6%	10.5%	13.2%	26.3%
American River at Nimbus Dam	Number	0	0	50	220	90	195
	Percent of Total	0.0%	0.0%	13.2%	57.9%	23.7%	51.3%
American River at Sacramento River	Number	0	50	105	230	130	275
	Percent of Total	0.0%	13.2%	27.6%	60.5%	34.2%	72.4%
Stanislaus River at Knights Ferry	Number	0	0	0	0	0	0
	Percent of Total	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Stanislaus River at Riverbank	Number	0	0	0	0	0	0
	Percent of Total	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%

[1] Based on daily (not monthly) data; 1922–2003.

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Table C.5.2-63. Difference and Percent Difference between Model Scenarios in River Lamprey Ammocoete Cohorts Exposed to Temperatures Greater than 71.6°F and 77°F in at Least One Month

Location	Comparison[1]	EBC1 vs. PP_ELT	EBC1 vs. PP_LLT	EBC vs. PP_ELT	EBC vs. PP_LLT	EBC_ELT vs. PP_ELT	EBC_LLT vs. PP_LLT
Temperature above 71.6°F							
Sacramento River at Keswick[2]	Difference	0	1,219	0	1,219	0	1
	Percent Difference	NA	NA	NA	NA	NA	0.10%
Sacramento River at Hamilton City[2]	Difference	4,326	8,780	4,326	8,780	-1,460	-715
	Percent Difference	NA	NA	NA	NA	-25.20%	7.50%
Trinity River at Lewiston	Difference	25	65	25	65	0	15
	Percent Difference	NA	NA	NA	NA	0%	30.0%
Trinity River at North Fork	Difference	30	56	30	56	0	-34
	Percent Difference	NA	NA	NA	NA	0%	-37.8%
Feather River at Fish Barrier Dam	Difference	0	0	0	0	0	-25
	Percent Difference	NA	NA	NA	NA	NA	-100%
Feather River below Thermalito Afterbay	Difference	165	190	140	165	95	60
	Percent Difference	86.8%	100%	65.1%	76.7%	36.5%	18.8%
American River at Nimbus Dam	Difference	175	230	89	144	-5	-15
	Percent Difference	194.4%	255.6%	50.6%	81.8%	-1.9%	-4.5%
American River at Sacramento River	Difference	120	135	65	80	5	0
	Percent Difference	49.0%	55.1%	21.7%	26.7%	1.4%	0%
Stanislaus River at Knights Ferry	Difference	0	25	0	25	0	0
	Percent Difference	NA	NA	NA	NA	NA	0%
Stanislaus River at Riverbank	Difference	155	335	155	335	0	0
	Percent Difference	620%	1,340%	620%	1,340%	0%	0%
Temperature above 77°F							
Sacramento River at Keswick[2]	Difference	0	0	0	0	0	0
	Percent Difference	NA	NA	NA	NA	NA	NA
Sacramento River at Hamilton City[2]	Difference	0.0	1,502	0.0	2,704	0.0	1,202
	Percent Difference	NA	NA	NA	NA	NA	80.0%
Trinity River at Lewiston	Difference	0	0	0	0	0	0
	Percent Difference	NA	NA	NA	NA	NA	NA
Trinity River at North Fork	Difference	25	30	25	30	0	-25
	Percent Difference	NA	NA	NA	NA	0.0%	-45.5%
Feather River at Fish Barrier Dam	Difference	0.0	0.0	0.0	0.0	0.0	0.0
	Percent Difference	NA	NA	NA	NA	NA	NA
Feather River below Thermalito Afterbay	Difference	50	100	50	100	25	60
	Percent Difference	NA	NA	NA	NA	100.0%	150.0%
American River at Nimbus Dam	Difference	90	195	90	195	40	-25
	Percent Difference	NA	NA	NA	NA	80.0%	-11.4%
American River at Sacramento River	Difference	130	275	80	225	25	45
	Percent Difference	NA	NA	160.0%	450.0%	23.8%	19.6%
Stanislaus River at Knights Ferry	Difference	0	0	0	0	0	0
	Percent Difference	NA	NA	NA	NA	NA	NA
Stanislaus River at Riverbank	Difference	0	0	0	0	0	0
	Percent Difference	NA	NA	NA	NA	NA	NA

[1] Positive values indicate a higher value in the preliminary proposal than in the EBC.
[2] Based on daily (not monthly) data; 1922–2003.
NA = cannot be calculated because dividing by zero.

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These results indicate that temperature-related effects of the preliminary proposal on Pacific and river lamprey ammocoetes are negligible, with effects predominantly attributable to climate change.

Hamilton City

For Pacific lamprey at Hamilton City, the proportion of ammocoete cohorts experiencing water temperatures exceeding 71.6°F is predicted to be 0% under EBC1 and EBC2, 40%–62% under EBC2_ELT and EBC2_LLT, and 29%–60% under PP_ELT and PP_LLT (Figure C.5.2-150, Table C.5.2-60). Under early long-term conditions, implementation of the preliminary proposal (PP_ELT) would result in exposure of 5,299 cohorts to temperatures exceeding 71.6°F, a 27% decrease relative to EBC2_ELT (7,245 cohorts) (Table C.5.2-61). Under late long-term conditions, implementation of the preliminary proposal (PP_LLT) would result in exposure of 10,981 cohorts to temperatures exceeding 71.6°F, a 2% decrease relative to EBC2_LLT (11,255 cohorts).

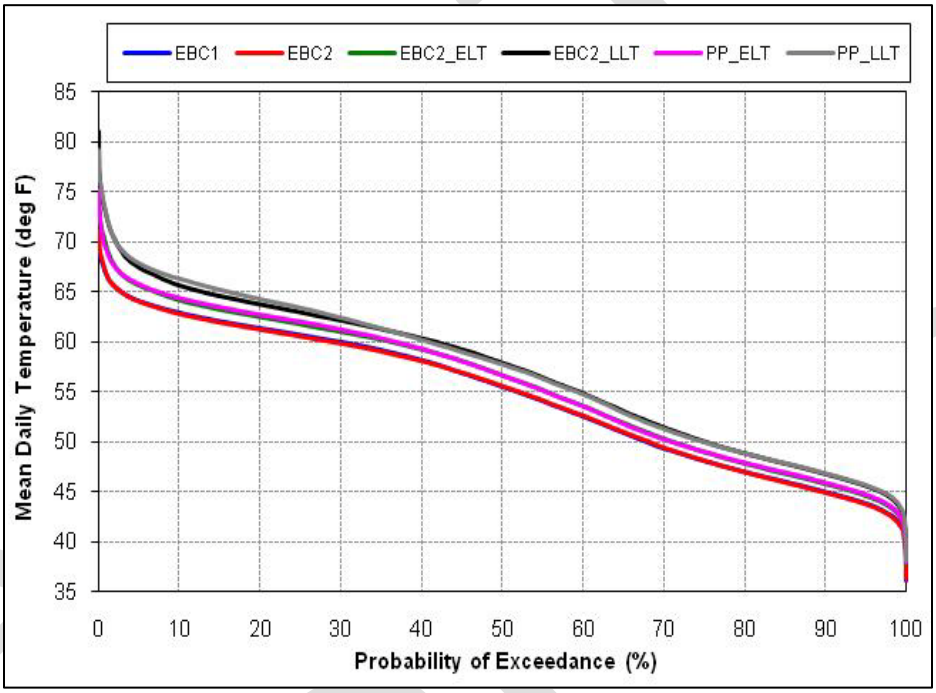

Figure C.5.2-150. Probability of Exceedance Plot for Model Scenarios of Mean Daily Temperature of the Sacramento River at Hamilton City for All Months

For river lamprey, the percent of ammocoete cohorts experiencing water temperatures that exceed 71.6°F is predicted to be 0% under EBC1 and EBC2, 31%–51% under EBC2_ELT and EBC2_LLT, and 23%–47% under PP_ELT and PP_LLT (Figure C.5.2-150, Table C.5.2-62). Under early long-term conditions, implementation of the preliminary proposal (PP_ELT) would result in exposure of 4,326 daily cohorts to temperatures exceeding 77°F, a 25% decrease relative to EBC2_ELT (5,786 cohorts) (Table C.5.2-63). Under late long-term conditions, implementation of the preliminary proposal (PP_LLT) would result in exposure of 8,780 daily cohorts to temperatures exceeding 71.6°F, an 8% decrease relative to EBC2_LLT (9,495 cohorts).

The percent of river lamprey ammocoete cohorts experiencing water temperatures that exceed 77°F is predicted to be 0% under EBC1, EBC2, EBC2_ELT, and PP_ELT and 13%–23% under EBC2_LLT and PP_LLT (Figure C.5.2-150, Table C.5.2-62). Under late long-term conditions, implementation of

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the preliminary proposal (PP_LLT) would result in exposure of 2,704 daily cohorts to temperatures exceeding 77°F, an 80% increase relative to EBC2_LLT (1,502 cohorts) (Table C.5.2-63).

These results indicate that large, temperature-related effects of climate change are predicted on Pacific lamprey ammocoetes in the Sacramento River, particularly at Hamilton City (Table C.5.2-61). However, the preliminary proposal has either no effect (Keswick) or a small to moderate positive effect on temperature and therefore on Pacific lamprey ammocoetes (Table C.5.2-63). There are both beneficial and adverse effects of the preliminary proposal predicted with respect to river lamprey, indicating that there would be fewer ammocoete cohorts exposed to 71.6°F under the preliminary proposal but more cohorts exposed to 77°F in the late long-term.

Stranding

Sacramento River at Keswick

For Pacific lamprey, the number of ammocoete cohorts that may be affected by month-over-month flow reductions in the Sacramento River at Keswick is presented in Figure C.5.2-151, and differences between model scenarios are presented in Table C.5.2-64. As the severity of flow reductions approaches 90%, the number of exposed ammocoetes cohorts is predicted to decline because of the decreasing frequency of these severe dewatering events.

The number of Pacific lamprey ammocoetes exposed to a given flow reduction is predicted to be between 2% lower to 2% higher under the PP_ELT compared to the EBC1, depending on the flow reduction (Table C.5.2-64). The number of ammocoetes exposed to a given flow reduction is predicted to be 0% to 9% higher under the PP_LLT compared to the EBC1, depending on the flow reduction. The number of ammocoetes exposed to a given flow reduction is predicted to be 3% lower to 107% higher under the PP_ELT compared to the EBC2, depending on the flow reduction. The number of ammocoetes exposed to a given flow reduction is predicted to be between 1% lower to 48% higher under the PP_LLT compared to the EBC2, depending on the flow reduction.

Isolating the effect of the preliminary proposal from the effects of climate change in the early long-term, the number of Pacific lamprey ammocoetes exposed to a given flow reduction is predicted to be 3% lower to 2% higher under the PP_ELT compared to the EBC2_ELT, depending on the flow reduction. In the late long-term, the number of ammocoetes exposed to a given flow reduction is predicted to be 0% to 7% higher under the PP_LLT compared to the EBC2_LLT, depending on the flow reduction.

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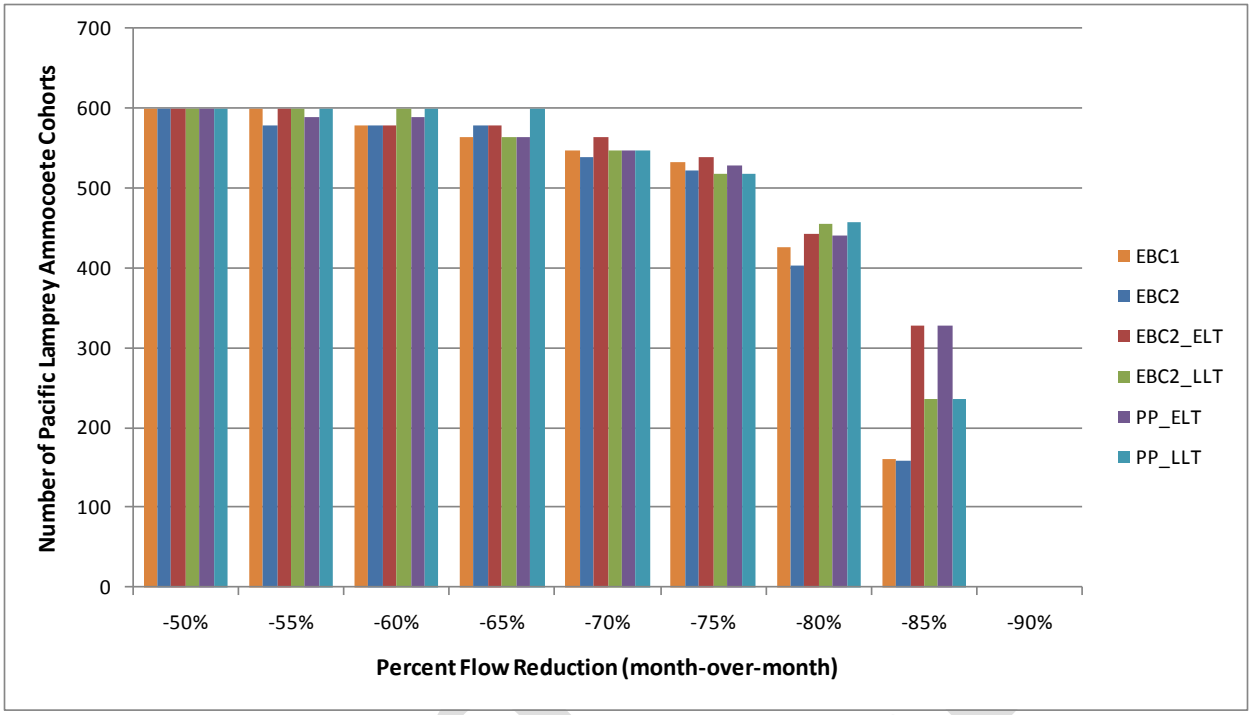

Figure C.5.2-151. Number of Pacific Lamprey Ammocoete Cohorts That Were Exposed to Month-over-Month Flow Reductions of 50% to 90%, Sacramento River at Keswick

Table C.5.2-64. Percent Difference between Model Scenarios in the Number of Pacific Lamprey Ammocoete Cohorts Exposed to Month-over-Month Flow Reductions, Sacramento River at Keswick

Percent Flow Reduction	Percent Difference[1]					
	EBC1 vs. PP_ELT	EBC1 vs. PP_LLT	EBC2 vs. PP_ELT	EBC2 vs. PP_LLT	EBC_ELT2 vs. PP_ELT	EBC_LLT2 vs. PP_LLT
-50%	0.0	0.0	0.0	0.0	0.0	0.0
-55%	0.0	0.0	1.6	3.6	-2.0	0.0
-60%	-2.1	0.0	1.6	3.6	1.6	0.2
-65%	-0.4	0.0	-2.8	3.6	-2.8	6.6
-70%	1.6	3.8	1.7	1.9	-2.8	0.2
-75%	0.3	0.7	1.0	-1.1	-1.9	0.0
-80%	0.0	8.7	9.5	13.9	-0.5	0.7
-85%	0.0	3.8	106.3	48.4	0.0	0.0
-90%	NA	NA	NA	NA	NA	NA

[1] Negative values indicate reduced cohort exposure, a benefit of the preliminary proposal.
NA = all values were 0.

For river lamprey, the number of ammocoete cohorts that may be affected by month-over-month flow reductions in the Sacramento River at Keswick is presented in Figure C.5.2-152 and differences between model scenarios are presented in Table C.5.2-65. As the severity of flow reductions approaches 90%, the number of exposed ammocoetes cohorts is predicted to decline because of the decreasing frequency of these severe dewatering events.

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The number of river lamprey ammocoetes exposed to a given flow reduction is predicted to be 0%to 6% lower under the PP_ELT compared to the EBC1, depending on the flow reduction (Table C.5.2-65). The number of ammocoetes exposed to a given flow reduction is predicted to be 0% to 19% higher under the PP_LLT compared to the EBC1, depending on the flow reduction. The number of ammocoetes exposed to a given flow reduction is predicted to be between 5% lower and 111% higher under the PP_ELT compared to the EBC2, depending on the flow reduction. The number of ammocoetes exposed to a given flow reduction is predicted to be 4% lower to 44% higher under the PP_LLT compared to the EBC2, depending on the flow reduction.

Isolating the effects of climate change, the number of river lamprey ammocoetes exposed to a given flow reduction is predicted to be 0% to 7% lower under the PP_ELT compared to the EBC2_ELT, depending on the flow reduction. The number of ammocoetes exposed to a given flow reduction is predicted to be 0% to 12% higher under the PP_LLT compared to the EBC2_LLT, depending on the flow reduction.

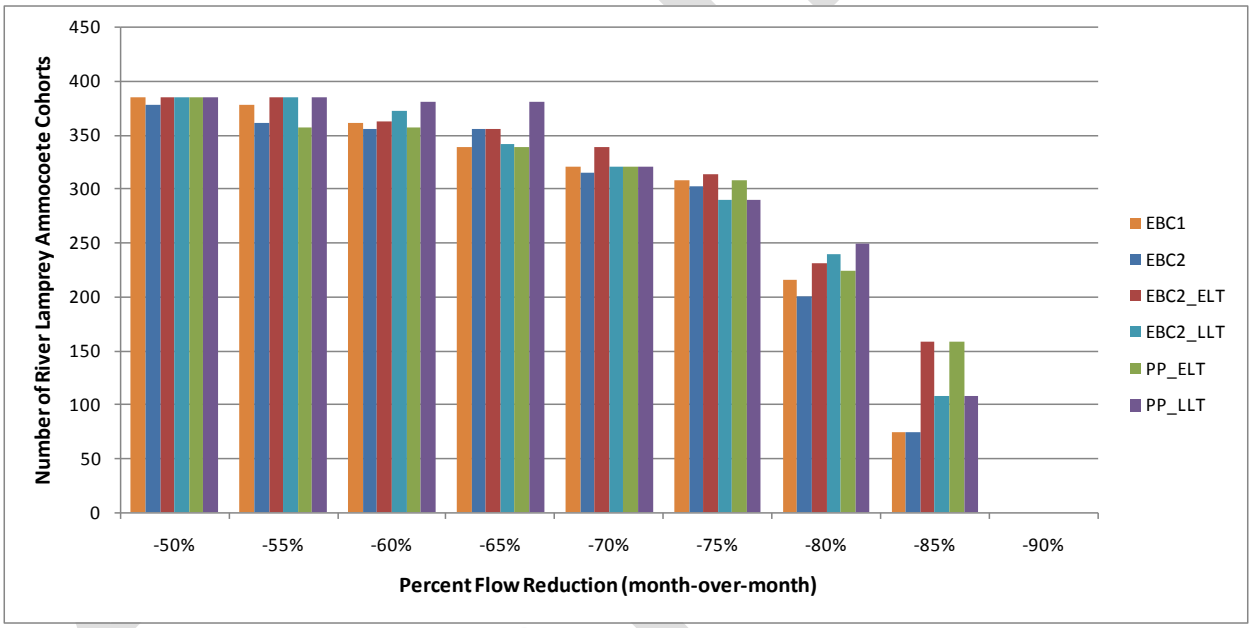

Figure C.5.2-152. Number of River Lamprey Ammocoete Cohorts Exposed to Month-over-Month Flow Reductions of 50% to 90%, Sacramento River at Keswick

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Table C.5.2-65. Percent Difference between Model Scenarios in the Number of River Lamprey Ammocoete Cohorts Exposed to Month-over-Month Flow Reductions, Sacramento River at Keswick

Percent Flow Reduction	Percent Difference[1]					
	EBC1 vs. PP_ELT	EBC1 vs. PP_LLT	EBC2 vs. PP_ELT	EBC2 vs. PP_LLT	EBC2_ELT vs. PP_ELT	EBC2_LLT vs. PP_LLT
-50%	0.0	0.0	1.9	1.9	0.0	0.0
-55%	0.0	0.0	-1.1	6.6	-7.3	0.0
-60%	-5.8	1.9	0.3	7.0	-1.7	2.1
-65%	-1.6	0.5	-4.8	7.0	-4.8	11.7
-70%	-1.2	6.2	1.9	1.6	-5.3	0.0
-75%	-0.3	1.7	2.0	-4.0	-1.6	0.0
-80%	0.0	19.4	11.4	23.9	-3.0	3.8
-85%	0.0	14.5	110.7	44.0	0.0	0.0
-90%	NA	NA	NA	NA	NA	NA

[1] Negative values indicate reduced cohort exposure, a benefit of the preliminary proposal.
NA = could not be calculated because dividing by 0.

These results indicate that, regardless of the flow reduction, preliminary proposal-related effects on the exposure of ammocoete cohorts to flow reductions are expected to be mostly small (<10% difference) in both the early long-term and late long-term for both Pacific lamprey and river lamprey at Keswick. One exception is in the 65% flow reduction scenario for river lamprey in the LLT, in which the number of cohorts exposed under the PP_LLT is expected to be 12% higher than the number of cohorts exposed under EBC2_LLT. The vast proportion of differences between model scenarios is due to climate change.

Sacramento River Upstream of Red Bluff

The number of Pacific lamprey ammocoete cohorts that may be affected by month-over-month flow reductions in the Sacramento River upstream of Red Bluff is presented in Figure C.5.2-153, and differences between model scenarios are presented in Table C.5.2-66.

The number of Pacific lamprey ammocoetes exposed to a given flow reduction is predicted to be between 2% lower and 10% higher under the PP_ELT compared to the EBC1 depending on the flow reduction. The number of ammocoetes exposed to a given flow reduction is predicted to be between 2% lower and 100% higher under the PP_LLT compared to the EBC1, depending on the flow reduction. The number of ammocoetes exposed to a given flow reduction is predicted to be between 3% lower and 16% higher under the PP_ELT compared to the EBC2, depending on the flow reduction. The number of ammocoetes exposed to a given flow reduction is predicted to be between 3% lower and 16% higher under the PP_LLT compared to the EBC2, depending on the flow reduction.

Isolating the effect of the preliminary proposal from the effects of climate change in the early long-term, the number of Pacific lamprey ammocoetes exposed to a given flow reduction is predicted to be 15% lower to 4% higher under the PP_ELT compared to the EBC2_ELT, depending on the flow reduction. In the late long-term, the number of ammocoetes exposed to a given flow reduction is predicted to be 9% lower to <1% higher under the PP_LLT compared to the EBC2_LLT, depending on the flow reduction.

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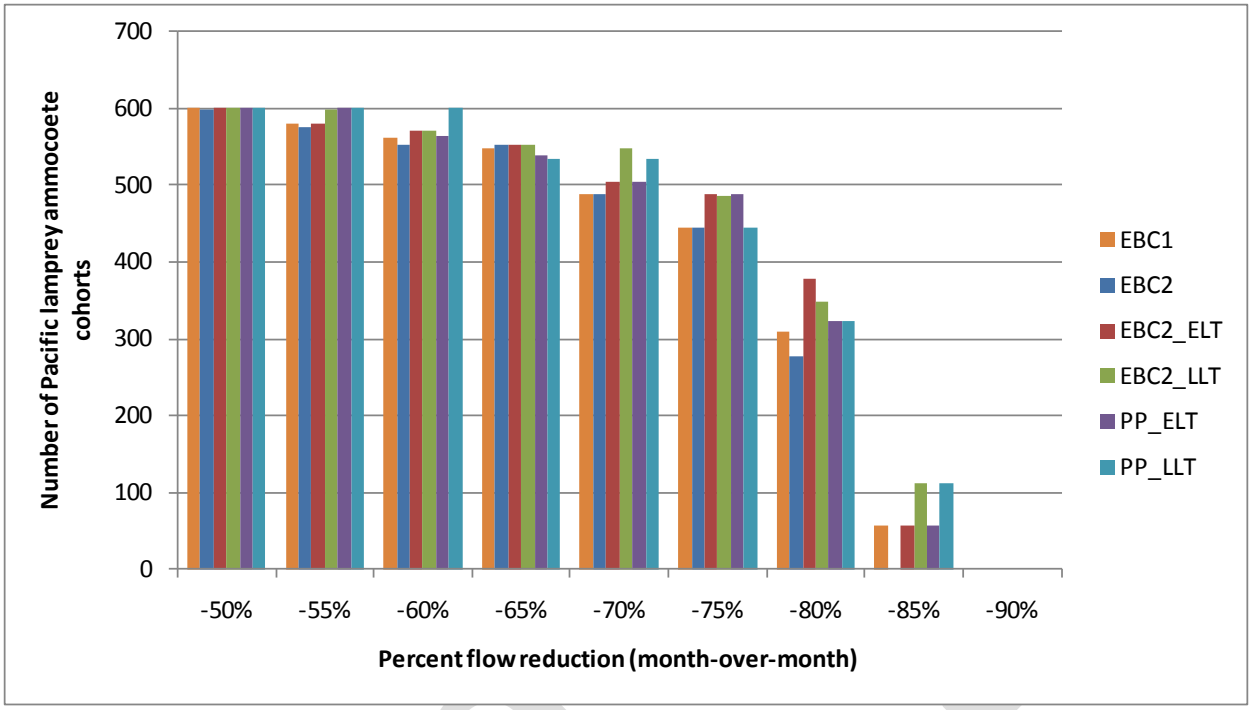

Figure C.5.2-153. Number of Pacific Lamprey Ammocoete Cohorts That Were Exposed to Month-over-Month Flow Reductions of 50% to 90%, Sacramento River Upstream of Red Bluff

Table C.5.2-66. Percent Difference between Model Scenarios in the Number of Pacific Lamprey Ammocoete Cohorts Exposed to Month-over-Month Flow Reductions, Sacramento River Upstream of Red Bluff

Percent Flow Reduction	Percent Difference[1]					
	EBC1 vs. PP_ELT	EBC1 vs. PP_LLT	EBC2 vs. PP_ELT	EBC2 vs. PP_LLT	EBC2_ELT vs. PP_ELT	EBC2_LLT vs. PP_LLT
-50%	0.0	0.0	0.2	0.2	0.0	0.0
-55%	3.6	3.6	4.3	4.3	3.6	0.2
-60%	0.2	6.8	1.8	8.5	-1.2	5.3
-65%	-1.6	-2.2	-2.7	-3.3	-2.7	-3.3
-70%	3.1	9.4	3.1	9.4	0.0	-2.4
-75%	9.7	-0.2	9.7	-0.2	0.0	-8.8
-80%	4.5	4.5	16.2	16.2	-14.8	-7.2
-85%	0.0	100.0	NA	NA	0.0	0.0
-90%	NA	NA	NA	NA	NA	NA

[1] Negative values indicate reduced cohort exposure, a benefit of the preliminary proposal.
NA = could not be calculated because dividing by 0.

The number of river lamprey ammocoete cohorts that may be affected by month-over-month flow reductions in the Sacramento River upstream of Red Bluff is presented in Figure C.5.2-154 and differences between model scenarios are presented in Table C.5.2-67.

The number of river lamprey ammocoetes exposed to a given flow reduction is predicted to be between 4% lower and 4% higher under the PP_ELT compared to the EBC1, depending on the flow

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reduction (Table C.5.2-67). The number of ammocoetes exposed to a given flow reduction is predicted to be between 10% lower and 15% higher under the PP_LLT compared to the EBC1, depending on the flow reduction. The number of ammocoetes exposed to a given flow reduction is predicted to be between 1% lower and 22% higher under the PP_ELT compared to the EBC2, depending on the flow reduction. The number of ammocoetes exposed to a given flow reduction is predicted to be between 2% lower and 22% higher under the PP_LLT compared to the EBC2, depending on the flow reduction.

Isolating the effects of climate change, the number of river lamprey ammocoetes exposed to a given flow reduction is predicted to be 14% lower to 4% higher under the PP_ELT compared to the EBC2_ELT, depending on the flow reduction. The number of ammocoetes exposed to a given flow reduction is predicted to be 10% lower to 5% higher under the PP_LLT compared to the EBC2_LLT, depending on the flow reduction.

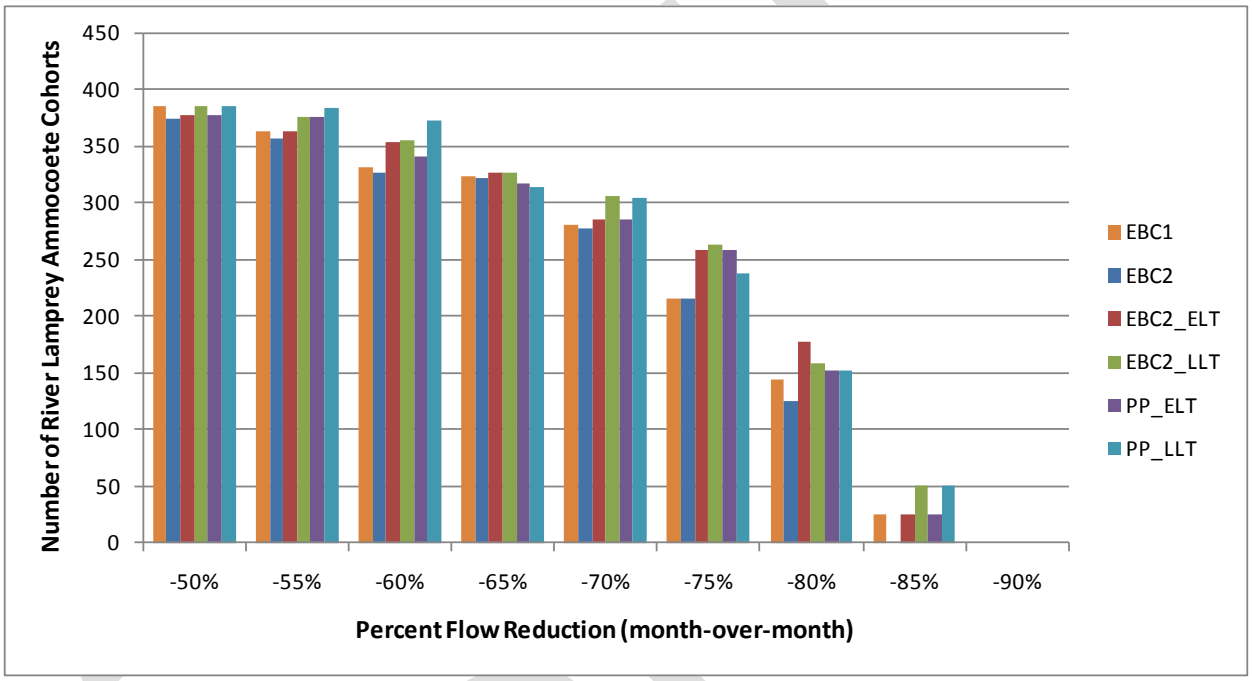

Figure C.5.2-154. Number of River Lamprey Ammocoete Cohorts Exposed to Month-over-Month Flow Reductions of 50% to 90%, Sacramento River Upstream of Red Bluff

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Table C.5.2-67. Percent Difference between Model Scenarios in the Number of River Lamprey Ammocoete Cohorts Exposed to Month-over-Month Flow Reductions, Sacramento River Upstream of Red Bluff

Percent Flow Reduction	Percent Difference					
	EBC1 vs. PP_ELT	EBC1 vs. PP_LLT	EBC2 vs. PP_ELT	EBC2 vs. PP_LLT	EBC2_ELT vs. PP_ELT	EBC2_LLT vs. PP_LLT
-50%	-1.8	0.0	1.1	2.9	0.0	0.0
-55%	-0.5	0.0	5.0	7.3	3.3	2.1
-60%	3.6	6.0	4.6	14.4	-3.7	5.1
-65%	1.0	1.6	-1.2	-2.2	-2.8	-3.7
-70%	3.2	14.6	3.2	10.1	0.0	-0.3
-75%	1.1	4.9	19.4	10.2	0.0	-9.5
-80%	-4.2	-6.3	21.6	21.6	-14.1	-3.8
-85%	0.0	-9.4	NA	NA	0.0	0.0
-90%	NA	NA	NA	NA	NA	NA

[1] Negative values indicate reduced cohort exposure, a benefit of the preliminary proposal.
NA = could not be calculated because dividing by 0.

These results indicate that, overall, in both the early long-term and late long-term, Pacific and river lamprey ammocoetes are predicted to be exposed to flow reductions less often under the preliminary proposal than under existing biological conditions, although these benefits are generally small (less than a 10% difference). One exception is the 80% flow reduction scenario during the ELT in which 14-15% fewer cohorts of both Pacific and river lamprey would experience flow reductions under the PP_ELT relative to the EBC2_ELT. The vast proportion of differences between model scenarios is due to climate change.

C.5.2.2 Trinity River

C.5.2.2.1 Steelhead

Eggs and Alevins

Upstream Spawning Habitat

The primary spawning and egg incubation period for steelhead in the Trinity River is January through April, although there are also summer-run steelhead that migrate into the river in the spring and spawn in the Trinity River in the winter (peak January) (Israel 2003).

Table C.5.2-68 presents mean monthly flows in the Trinity River at Lewiston for each month. Figure C.5.2-155 through Figure C.5.2-166 present exceedance plots for each month in the Trinity River at Lewiston. Instream flows in the Trinity River at Lewiston Dam during the steelhead spawning and egg incubation period (January through April) under EBC2_ELT and EBC2_LLT are expected to be comparable to flows that would occur under EBC1 and EBC2 (Table C.5.2-68, Figure C.5.2-155 through Figure C.5.2-158). PP_ELT and PP_LLT are predicted to differ very little in the frequency and magnitude of flows from EBC2_ELT and EBC2_LLT, respectively.

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Table C.5.2-68. Mean Monthly Flows (Cubic Feet per Second) in the Trinity River Below Lewiston Year-Round

Month	WY Type	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
Jan	W	1,440	1,396	1,570	1,518	1,638	1,457
	AN	300	316	300	300	381	483
	BN	358	300	300	300	459	464
	D	300	300	300	300	300	300
	C	300	300	300	287	300	278
	AVG	671	650	703	684	763	718
Feb	W	1,056	1,026	1,209	1,495	1,352	1,400
	AN	689	813	773	784	843	1,043
	BN	517	517	559	568	559	641
	D	300	300	300	300	300	300
	C	300	300	300	300	300	300
	AVG	634	642	702	795	757	816
Mar	W	1,209	1,141	1,335	1,385	1,449	1,347
	AN	436	436	475	519	475	519
	BN	319	319	302	300	302	300
	D	300	300	300	300	300	300
	C	300	300	300	300	300	300
	AVG	611	590	654	676	690	664
Apr	W	721	721	740	844	743	844
	AN	469	469	561	513	467	458
	BN	507	507	508	504	508	504
	D	529	529	529	529	529	529
	C	575	575	580	580	580	580
	AVG	584	584	605	630	592	622
May	W	4,636	4,636	4,620	4,620	4,620	4,620
	AN	4,462	4,462	4,450	4,416	4,450	4,416
	BN	3,774	3,774	3,763	3,865	3,763	3,865
	D	3,216	3,216	3,216	3,216	3,216	3,216
	C	2,092	2,092	1,973	1,973	1,973	1,973
	AVG	3,779	3,779	3,753	3,766	3,753	3,766
Jun	W	3,371	3,371	3,613	3,560	3,613	3,560
	AN	2,488	2,488	2,663	3,188	2,663	3,188
	BN	1,672	1,672	1,767	1,767	1,767	1,767
	D	1,251	1,251	1,251	1,251	1,251	1,251
	C	783	783	783	783	783	783
	AVG	2,108	2,108	2,226	2,286	2,226	2,286
Jul	W	1,289	1,289	1,161	1,103	1,161	1,103
	AN	1,048	1,048	1,048	1,048	1,048	1,048
	BN	869	869	916	916	916	916
	D	667	667	667	667	667	667
	C	450	450	450	413	450	413
	AVG	923	923	890	866	890	866

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Month	WY Type	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
Aug	W	450	450	450	450	450	450
	AN	450	450	450	450	450	450
	BN	450	450	450	450	450	450
	D	450	450	450	450	450	450
	C	450	450	413	338	413	337
	AVG	450	450	445	434	445	434
Sep	W	450	450	450	450	450	450
	AN	450	450	450	450	450	450
	BN	450	450	450	450	450	450
	D	450	450	450	450	450	450
	C	450	450	356	265	413	259
	AVG	450	450	436	423	445	422
Oct	W	373	373	373	373	373	373
	AN	373	373	337	311	342	323
	BN	346	346	346	346	346	346
	D	373	373	352	346	373	352
	C	373	373	342	311	373	290
	AVG	368	368	354	344	364	344
Nov	W	489	491	510	414	424	385
	AN	300	275	275	275	275	275
	BN	300	300	300	300	300	300
	D	300	300	283	283	283	283
	C	300	300	263	225	275	225
	AVG	360	357	354	318	328	309
Dec	W	1,072	1,022	1,281	837	1,393	1,011
	AN	300	300	300	300	300	300
	BN	300	300	300	300	300	300
	D	300	300	300	300	300	283
	C	300	300	300	275	300	250
	AVG	545	529	611	466	647	514

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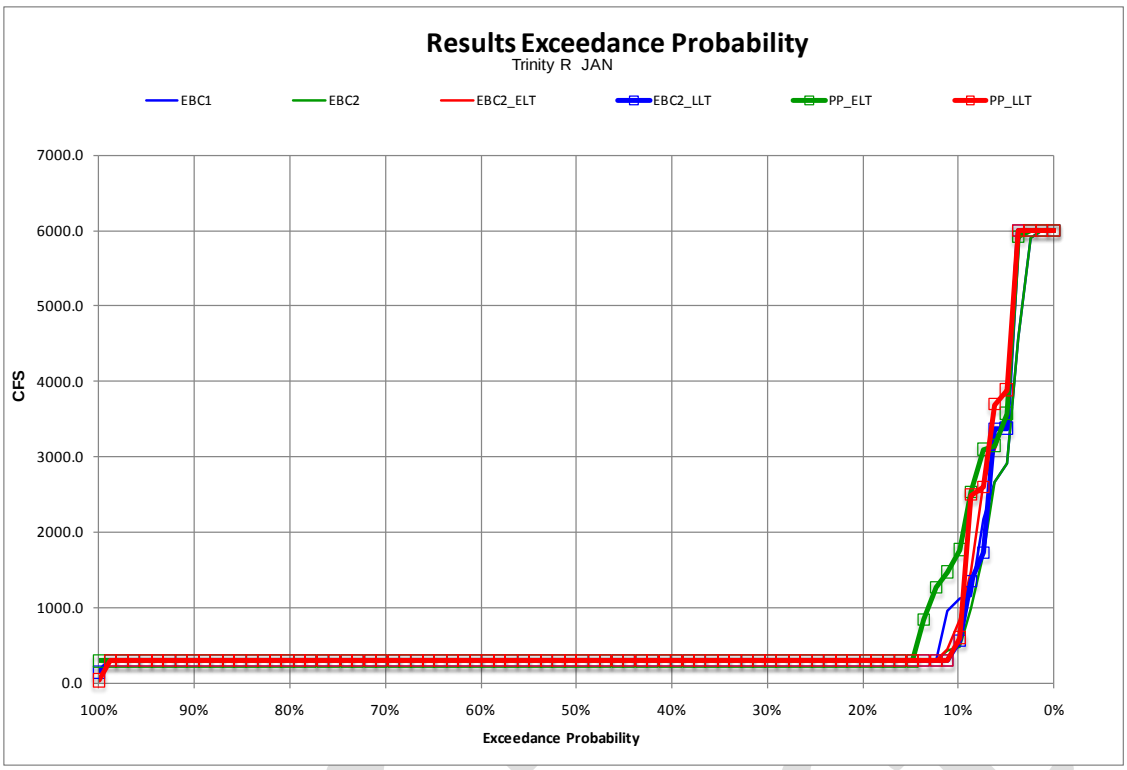

Figure C.5.2-155. Probability of Exceedance Plot for Model Scenarios of Mean Monthly Flow in the Trinity River, January

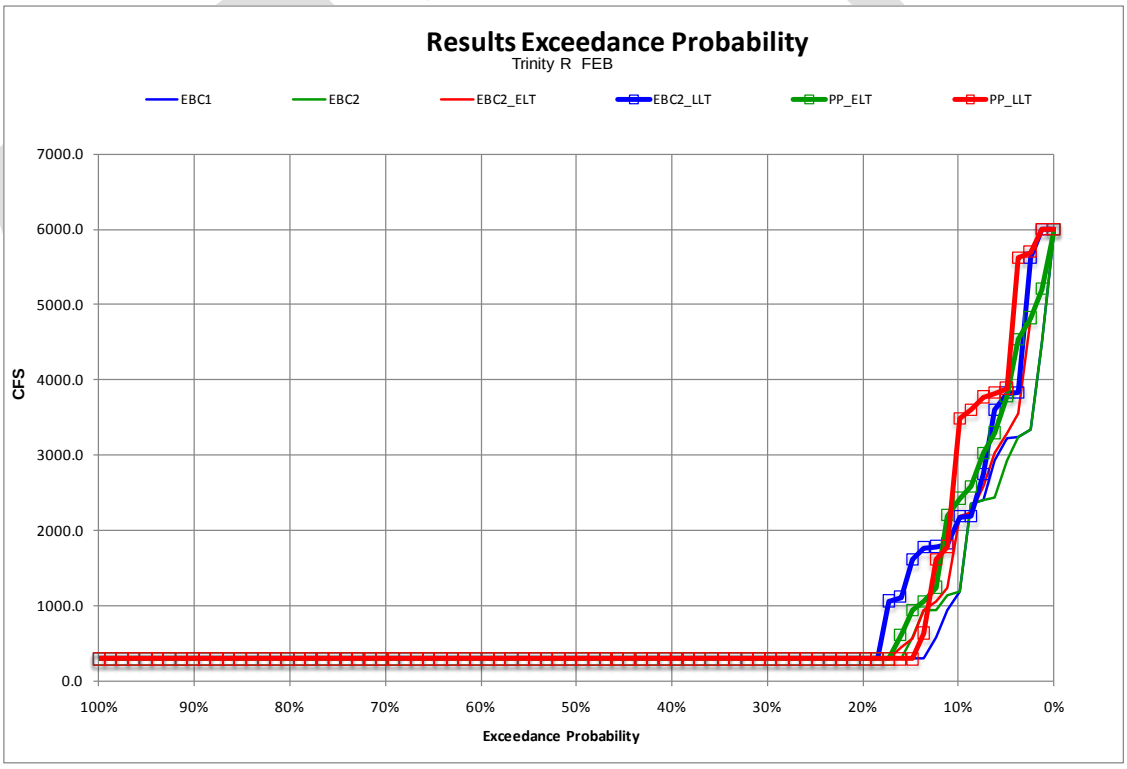

Figure C.5.2-156. Probability of Exceedance Plot for Model Scenarios of Mean Monthly Flow in the Trinity River, February

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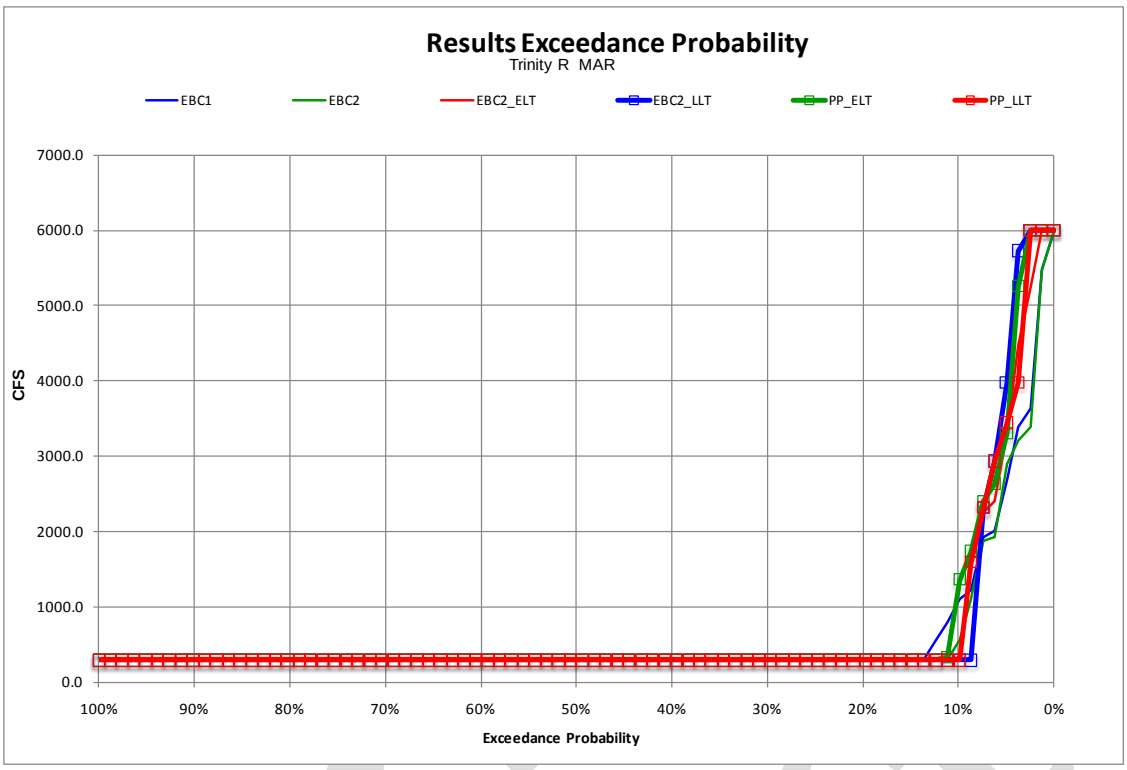

Figure C.5.2-157. Probability of Exceedance Plot for Model Scenarios of Mean Monthly Flow in the Trinity River, March

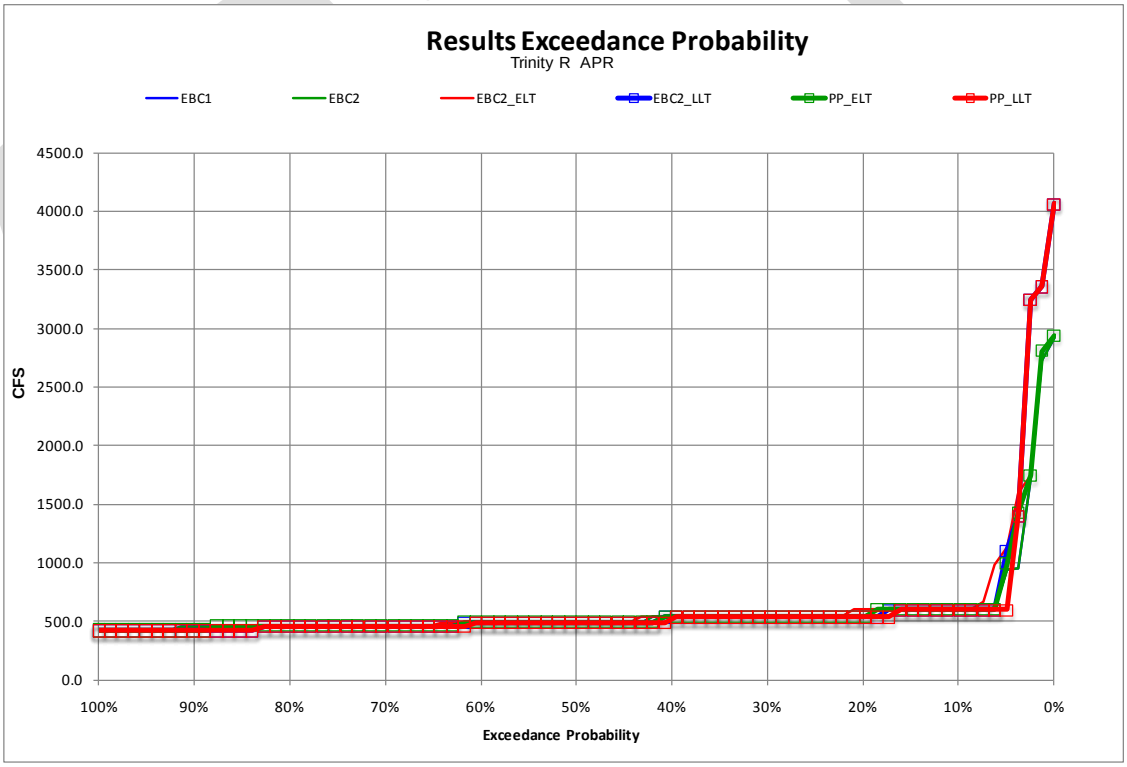

Figure C.5.2-158. Probability of Exceedance Plot for Model Scenarios of Mean Monthly Flow in the Trinity River, April

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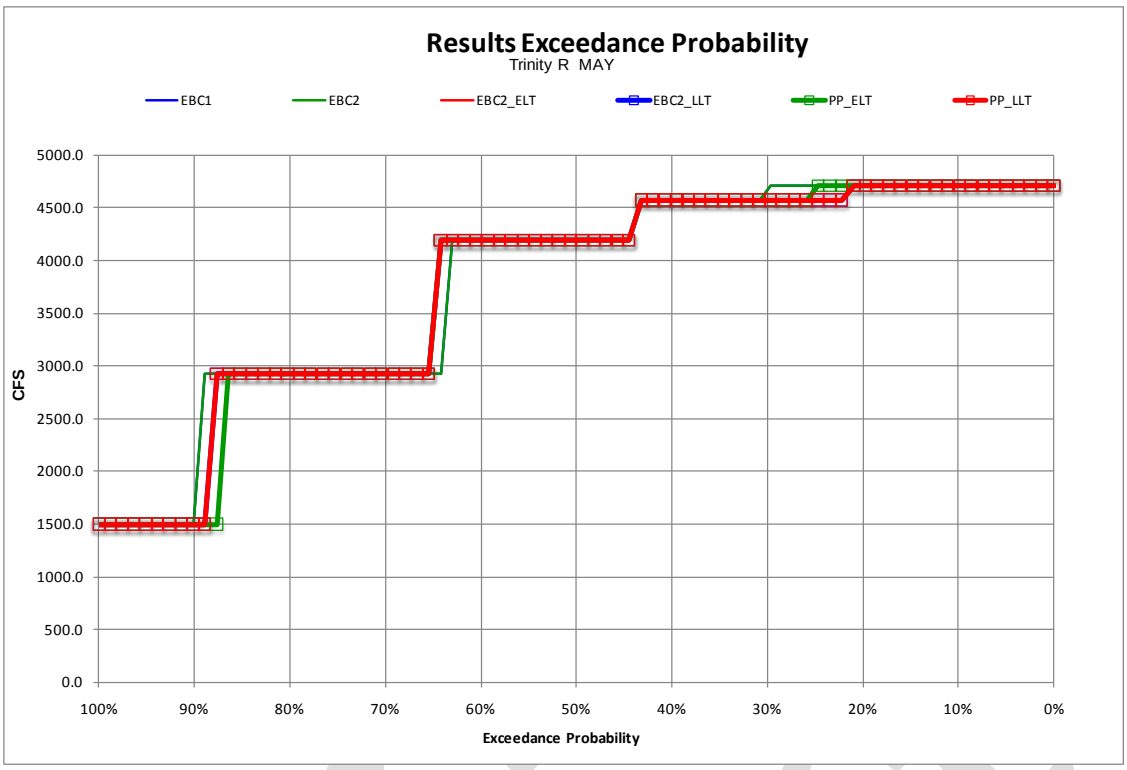

Figure C.5.2-159. Probability of Exceedance Plot for Model Scenarios of Mean Monthly Flow in the Trinity River, May

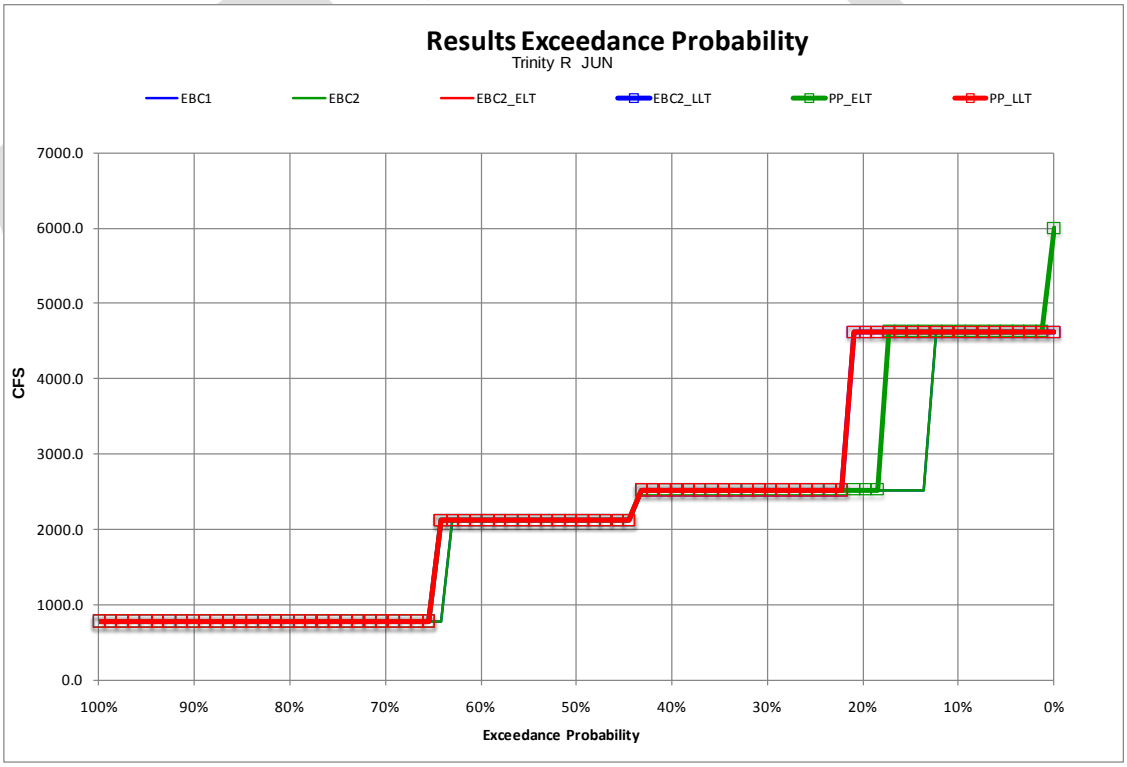

Figure C.5.2-160. Probability of Exceedance Plot for Model Scenarios of Mean Monthly Flow in the Trinity River, June

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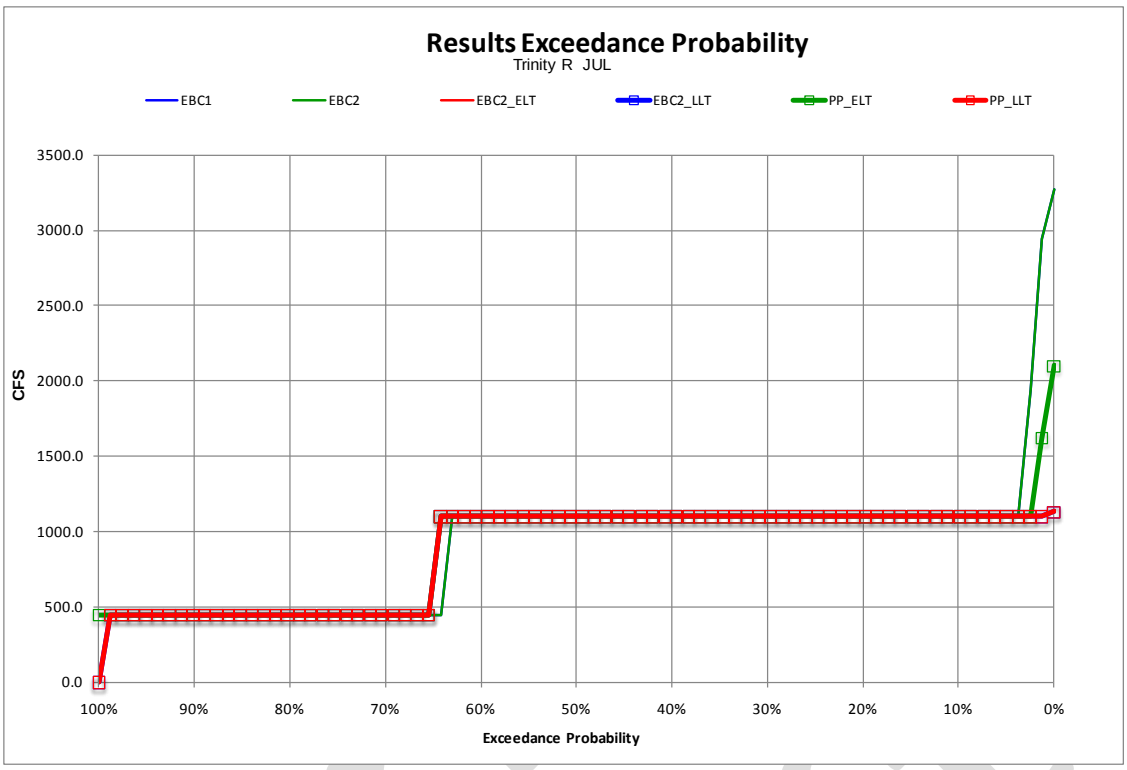

Figure C.5.2-161. Probability of Exceedance Plot for Model Scenarios of Mean Monthly Flow in the Trinity River, July

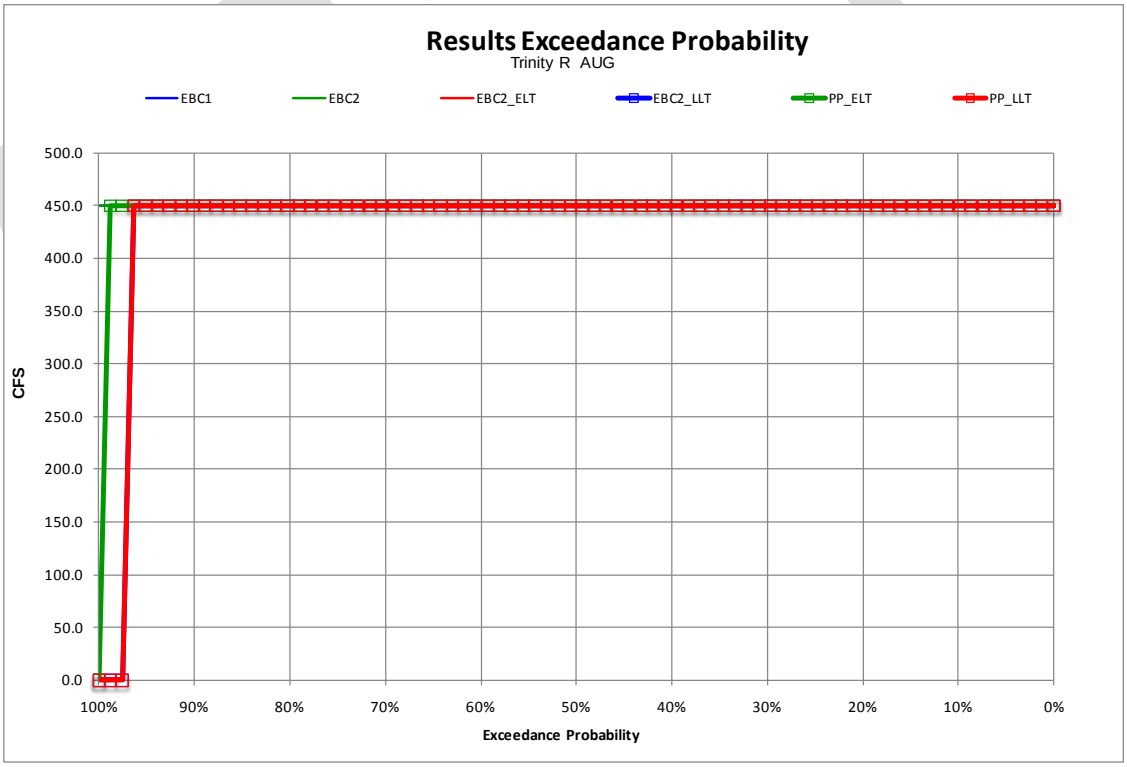

Figure C.5.2-162. Probability of Exceedance Plot for Model Scenarios of Mean Monthly Flow in the Trinity River, August

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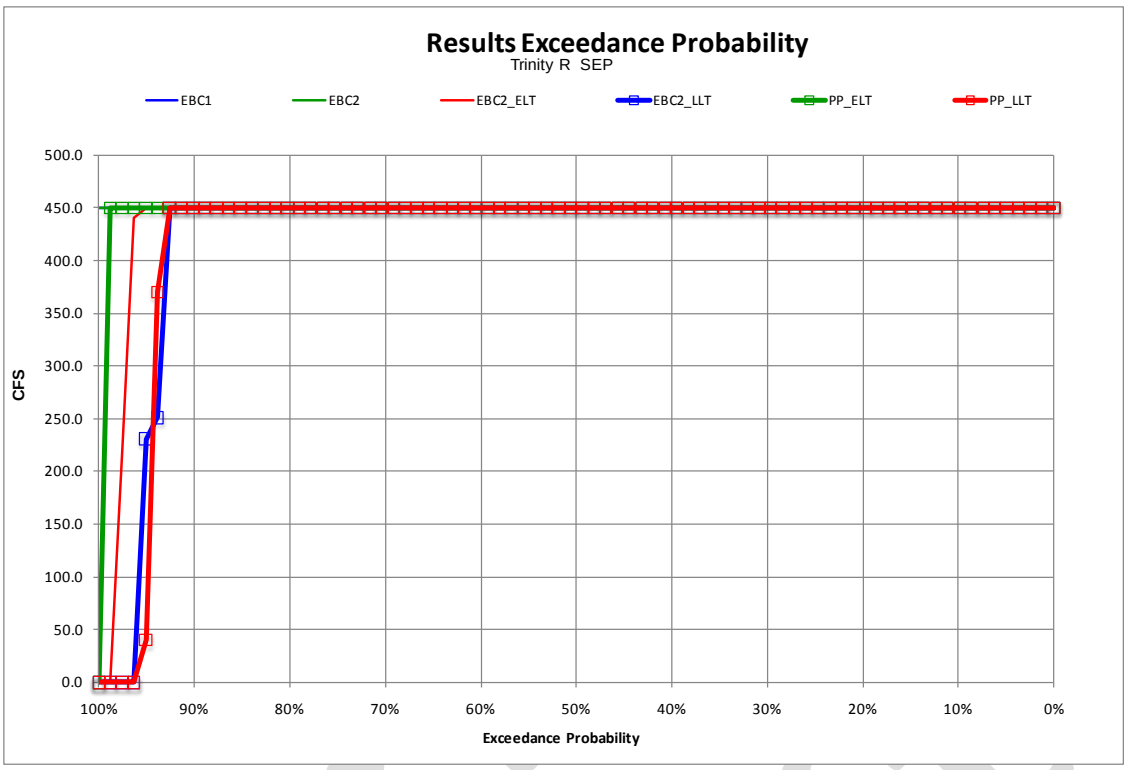

Figure C.5.2-163. Probability of Exceedance Plot for Model Scenarios of Mean Monthly Flow in the Trinity River, September

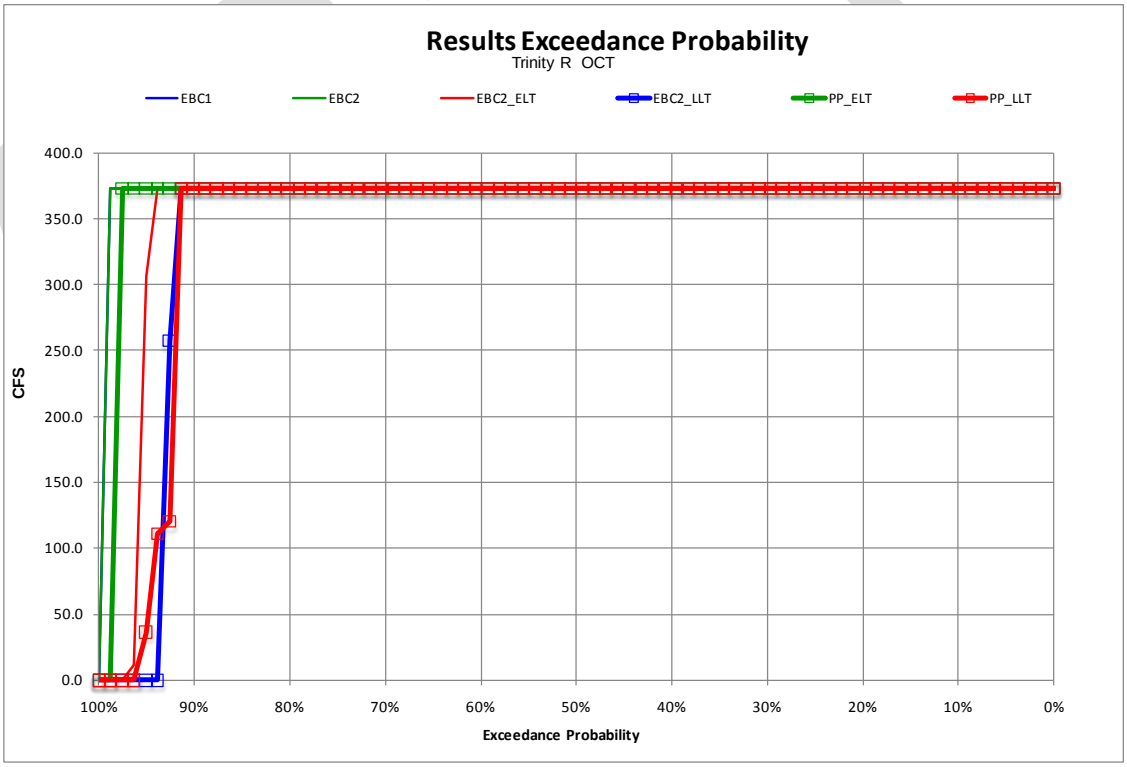

Figure C.5.2-164. Probability of Exceedance Plot for Model Scenarios of Mean Monthly Flow in the Trinity River, October

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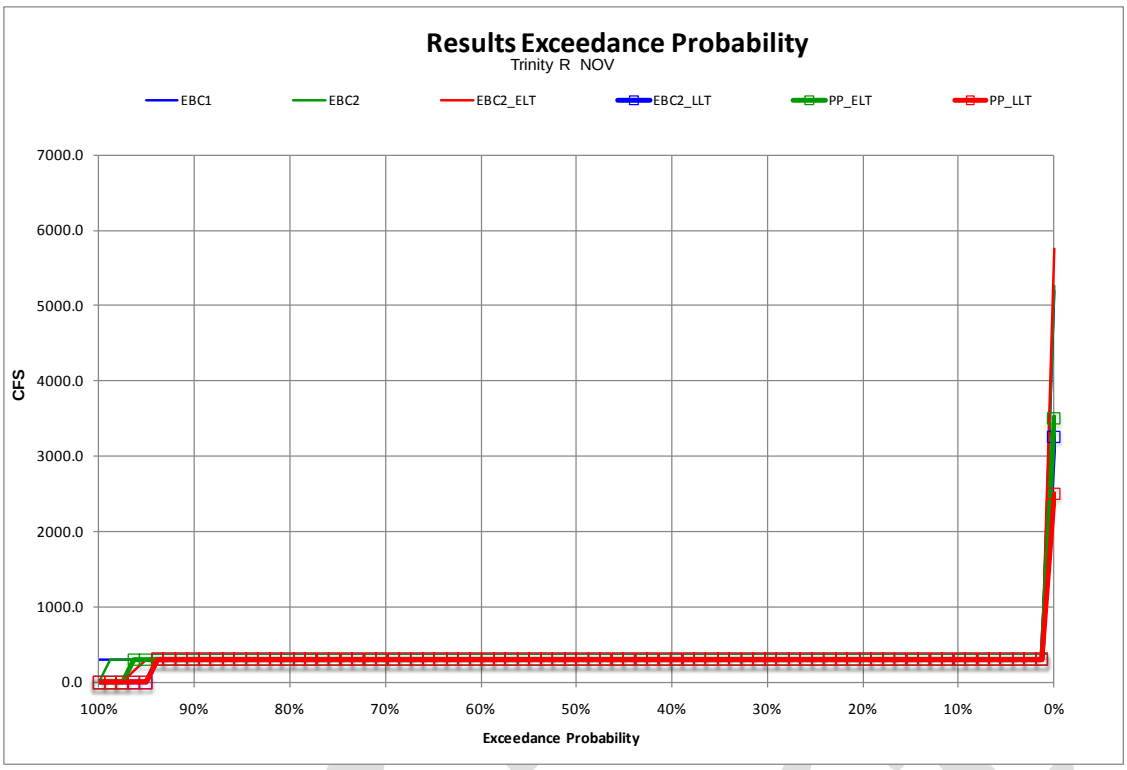

Figure C.5.2-165. Probability of Exceedance Plot for Model Scenarios of Mean Monthly Flow in the Trinity River, November

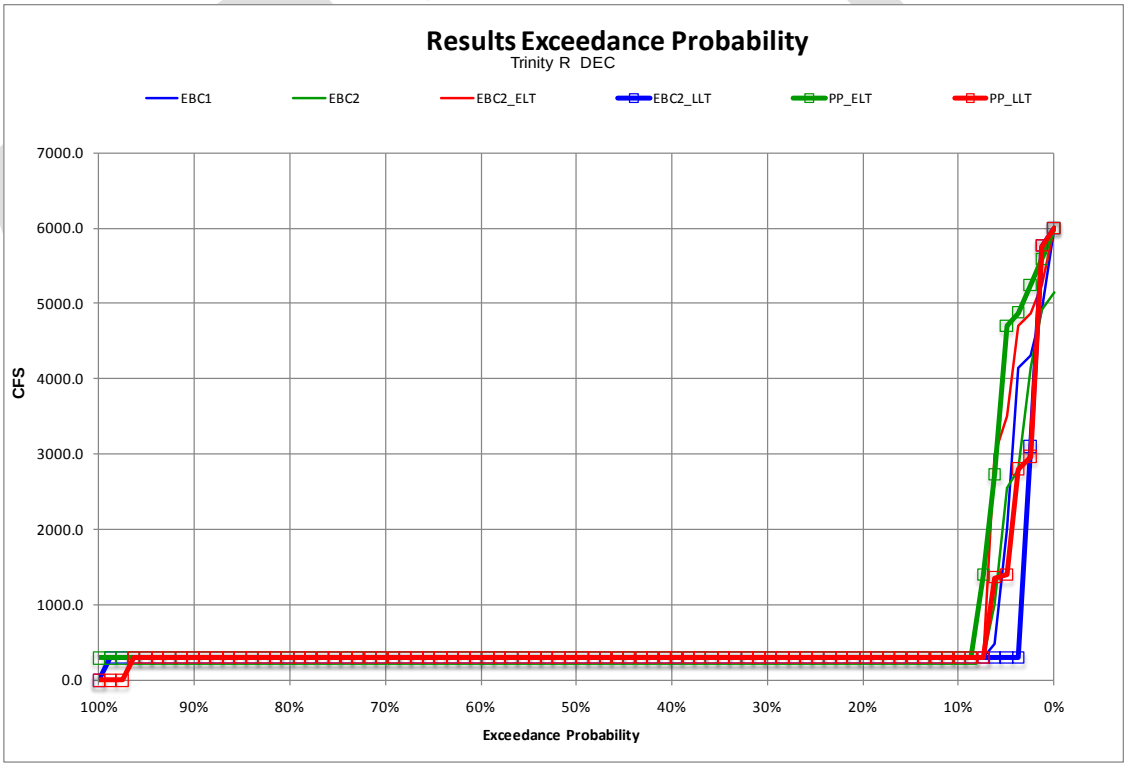

Figure C.5.2-166. Probability of Exceedance Plot for Model Scenarios of Mean Monthly Flow in the Trinity River, December

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Water Temperature

Simulated water temperatures in the Trinity River at Douglas City are generally within the suitable range for steelhead spawning and egg incubation period (<56°F) during January through April under all modeled scenarios (Figure C.5.2-167). Therefore, BDCP operations are not expected to affect the suitability of habitat conditions for steelhead spawning and egg incubation in the Trinity River.

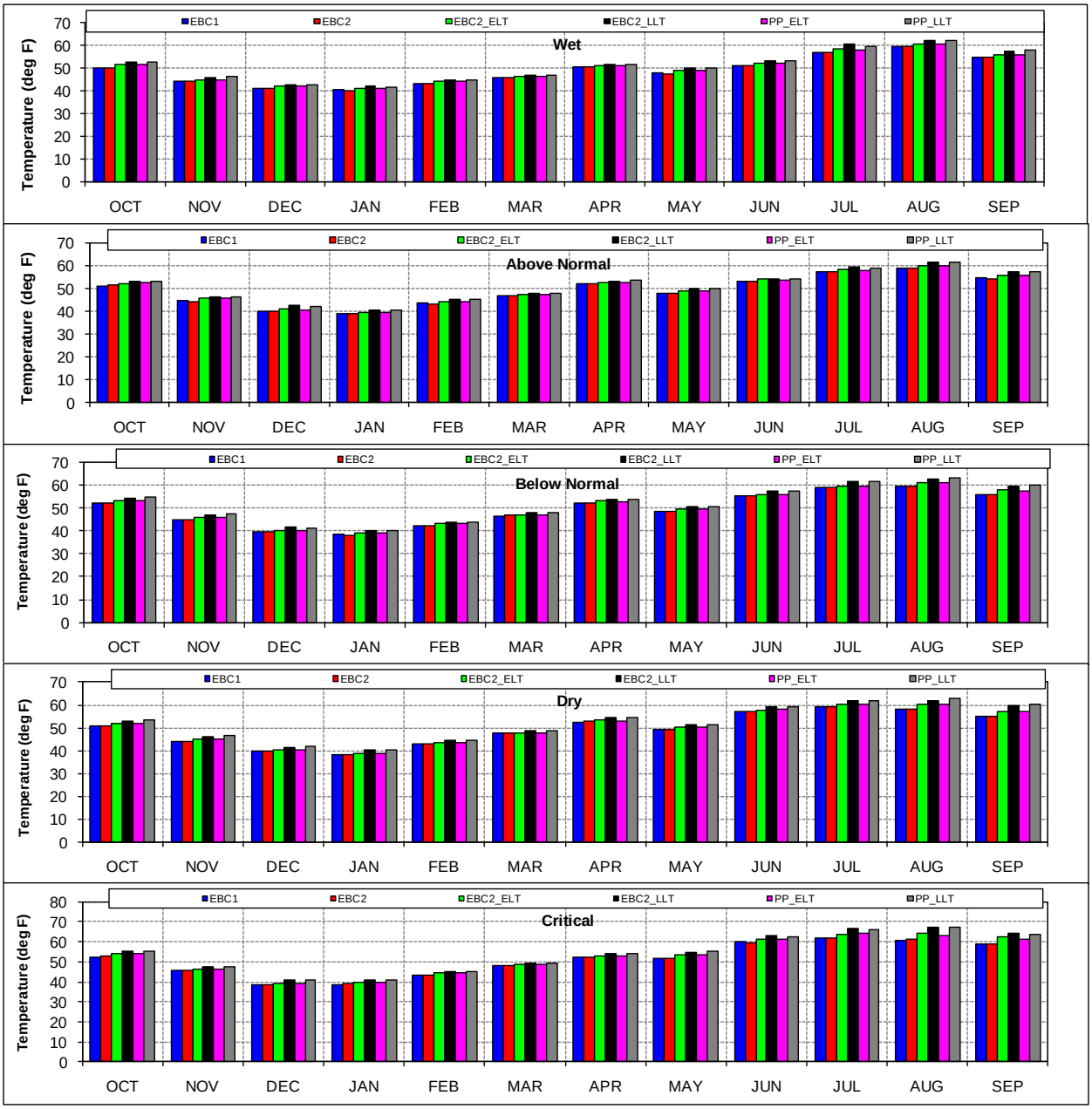

Figure C.5.2-167. Average Water Temperature in the Trinity River at Douglas City by Water-Year Type under Each Model Scenario

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Redd Dewatering

To evaluate the potential risk of redd dewatering for steelhead within the Trinity River, it was assumed that steelhead spawn in January and that the eggs and alevins incubate through April. Results of monthly simulation flows were used to determine the magnitude of flow reduction that would occur each month during the incubation period compared to the flow in January when spawning occurred. The index of risk for redd dewatering is based on the greatest percentage change (reduction) in flows in any month during the egg incubation period when compared to the flows during the month spawning was assumed to occur. Results of the flow analyses for the risk of redd dewatering are summarized in Table C.5.2-69.

Under simulated early and late long-term conditions, BDCP operations would have a negligible effect on the risk of redd dewatering in the Trinity River relative to existing biological conditions. Climate change caused a large change in instream flows in wet, above-normal, and below-normal water years.

Table C.5.2-69. Greatest Monthly Reduction (Percentage Change) in Instream Flow under Model Scenarios in the Trinity River during the January through April Steelhead Spawning and Egg Incubation Period[1]

Water-Year Type	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
Wet	-95	-95	-95	-95	-95	-95
Above Normal	0	0	0	-88	0	-92
Below Normal	-73	0	0	-68	0	-81
Dry	0	0	0	0	0	0
Critical	0	0	0	0	0	0

[1] Redd dewatering risk not applicable for months when flows during the egg incubation period were at or greater than flows in the month when spawning is assumed to occur.

Fry and Juvenile Rearing

Rearing Habitat

The Trinity River supports young steelhead rearing in the mainstem year-round. Nearly all steelhead rearing during the summer occurs upstream of Douglas City, in the vicinity of the high-density spawning. A critical seasonal period for juvenile steelhead rearing in California is generally June through September of dry years when water temperatures are at the high end of what is considered to be the optimal range for rearing. Water temperatures in the Trinity River between Lewiston and Douglas City are cooler than most steelhead streams in summer. Water temperatures during the late fall, winter, and early spring are seasonally cool. During the late spring, summer, and early fall months, however, water temperatures typically increase in response to seasonal increases in air temperatures and other factors (Figure C.5.2-167). Results of water temperature simulations (average monthly temperatures) for the Trinity River at Douglas City during the months of April through October are shown in Figure C.5.2-168 through Figure C.5.2-174. For this analysis, average monthly water temperatures of less than 62°F are assumed to support suitable juvenile steelhead rearing.

Temperatures at Douglas City in August would be below 62°F (monthly average) in over 95% of years under EBC1 and EBC2, 90% of years under EBC2_ELT and PP_ELT, and approximately 80% of

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years under EBC2_LLT and PP_LLT. Temperatures would be slightly reduced (<0.5°F) in the drier years for PP_ELT relative to EBC2_ELT. There is not much difference (<0.5°F) for PP_ LLT relative to EBC2_LLT. Results of this analysis show that water temperature conditions are not different between EBC2_ELT and PP_ ELT or between EBC2_LLT and PP_LLT. Based on these results, we conclude that the preliminary proposal is not likely to adversely affect steelhead rearing or critical habitat in the Trinity River.

Results of CALSIM modeling of instream flows in the Trinity River under each scenario are summarized by month and water-year type in Table C.5.2-68. Trinity River flows would be a minimum of 300 cfs year-round. Exceedance probabilities for Trinity River instream flows by month are presented in Figure C.5.2-155 through Figure C.5.2-166. Results of these analyses showed that instream flows would be comparable in the Trinity River for PP and EBC scenarios. Therefore, it was concluded that the preliminary proposal would not affect juvenile rearing habitat conditions within the river when compared to EBC.

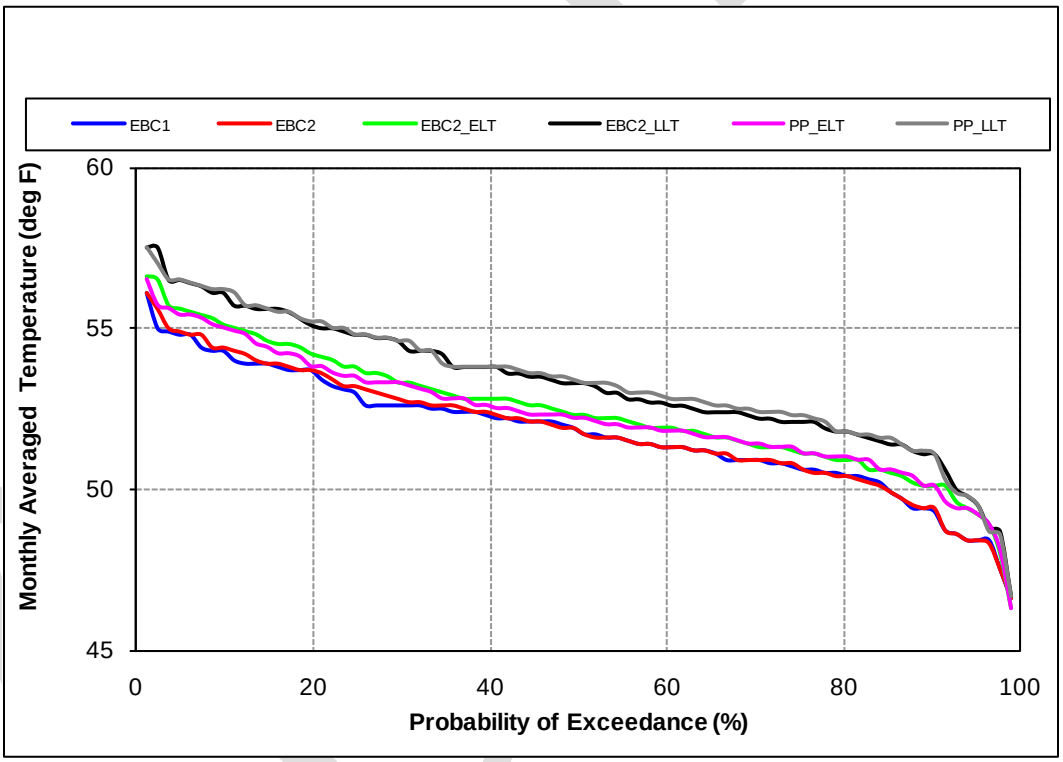

Figure C.5.2-168. Probability of Exceedance Plot for Model Scenarios of Mean Monthly Water Temperature of Trinity River at Douglas City, April

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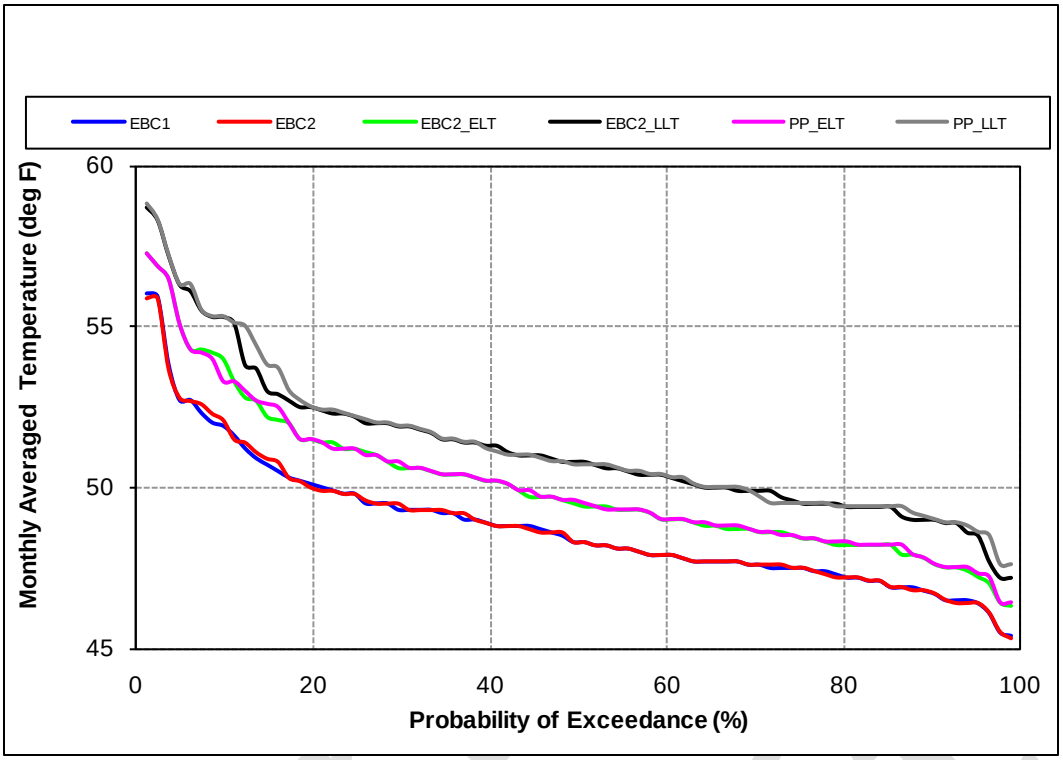

Figure C.5.2-169. Probability of Exceedance Plot for Model Scenarios of Mean Monthly Water Temperature of Trinity River at Douglas City, May

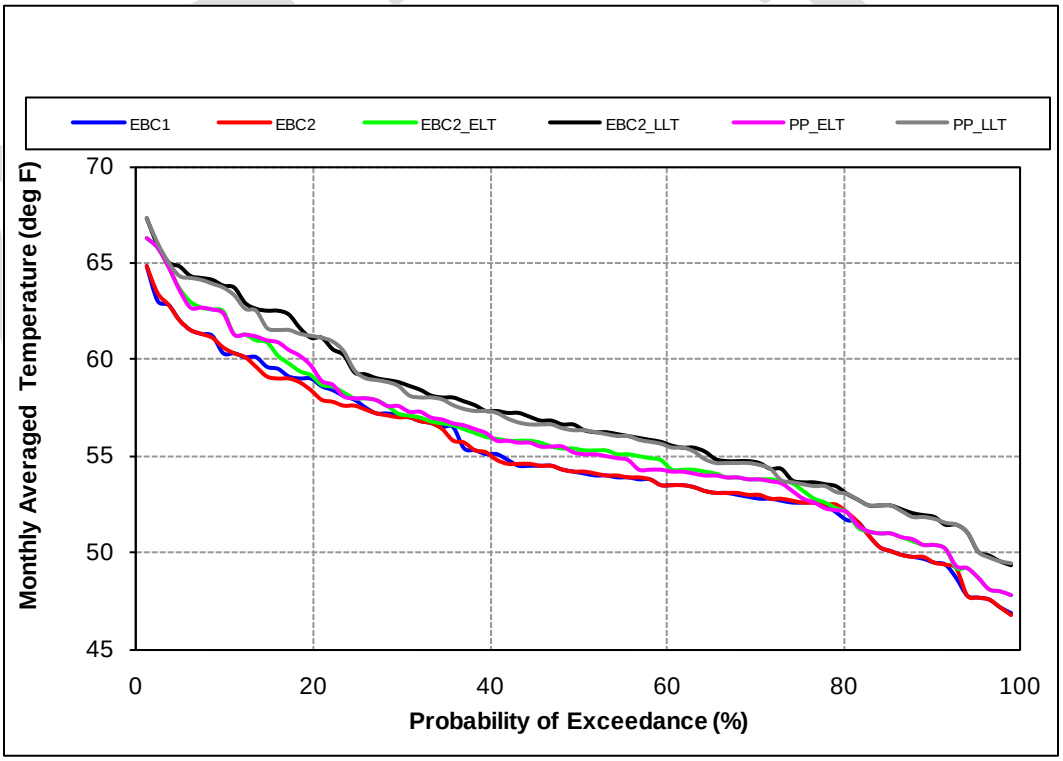

Figure C.5.2-170. Probability of Exceedance Plot for Model Scenarios of Mean Monthly Water Temperature of Trinity River at Douglas City, June

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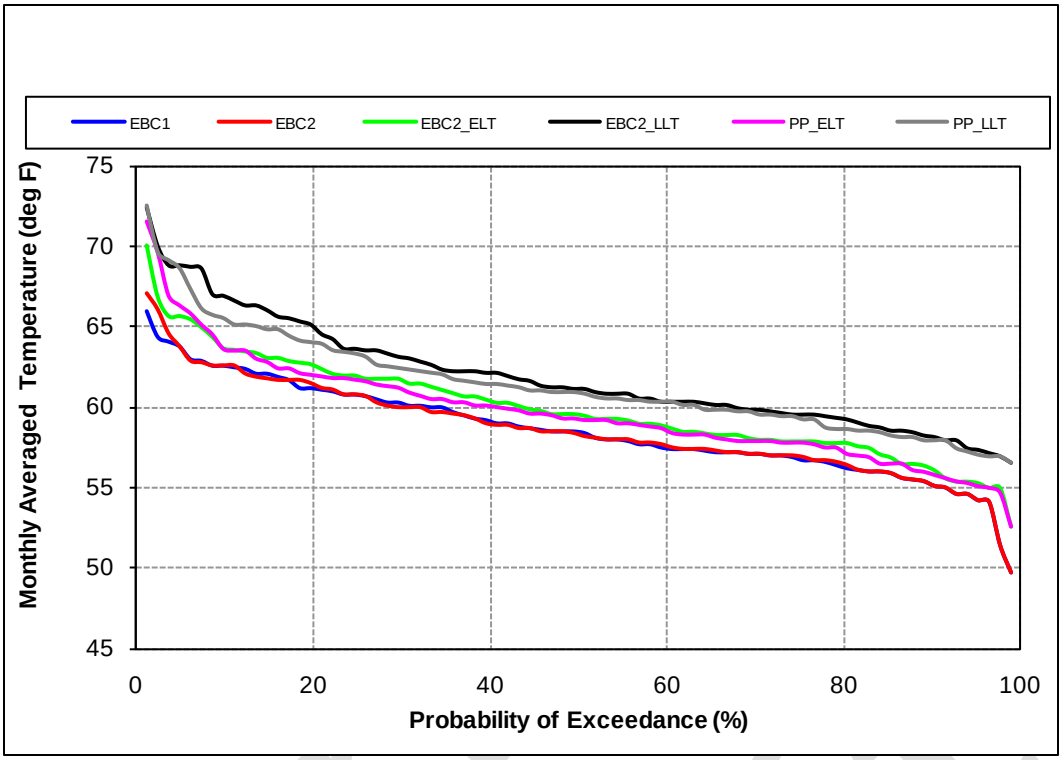

Figure C.5.2-171. Probability of Exceedance Plot for Model Scenarios of Mean Monthly Water Temperature of Trinity River at Douglas City, July

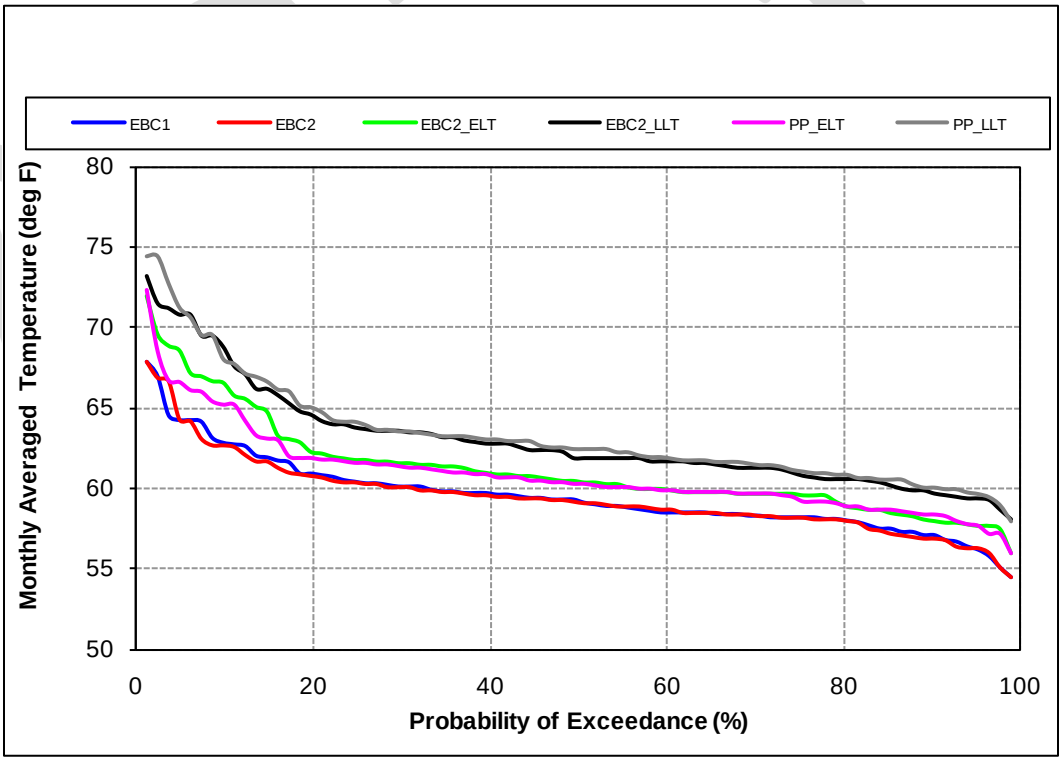

Figure C.5.2-172. Probability of Exceedance Plot for Model Scenarios of Mean Monthly Water Temperature of Trinity River at Douglas City, August

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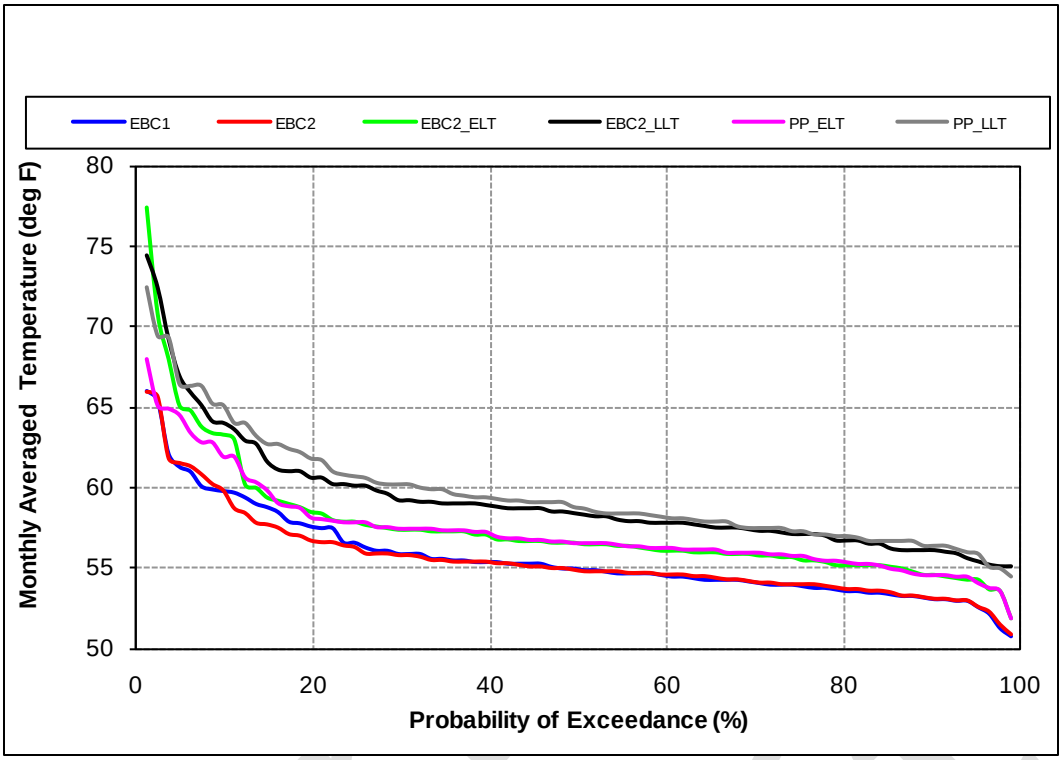

Figure C.5.2-173. Probability of Exceedance Plot for Model Scenarios of Mean Monthly Water Temperature of Trinity River at Douglas City, September

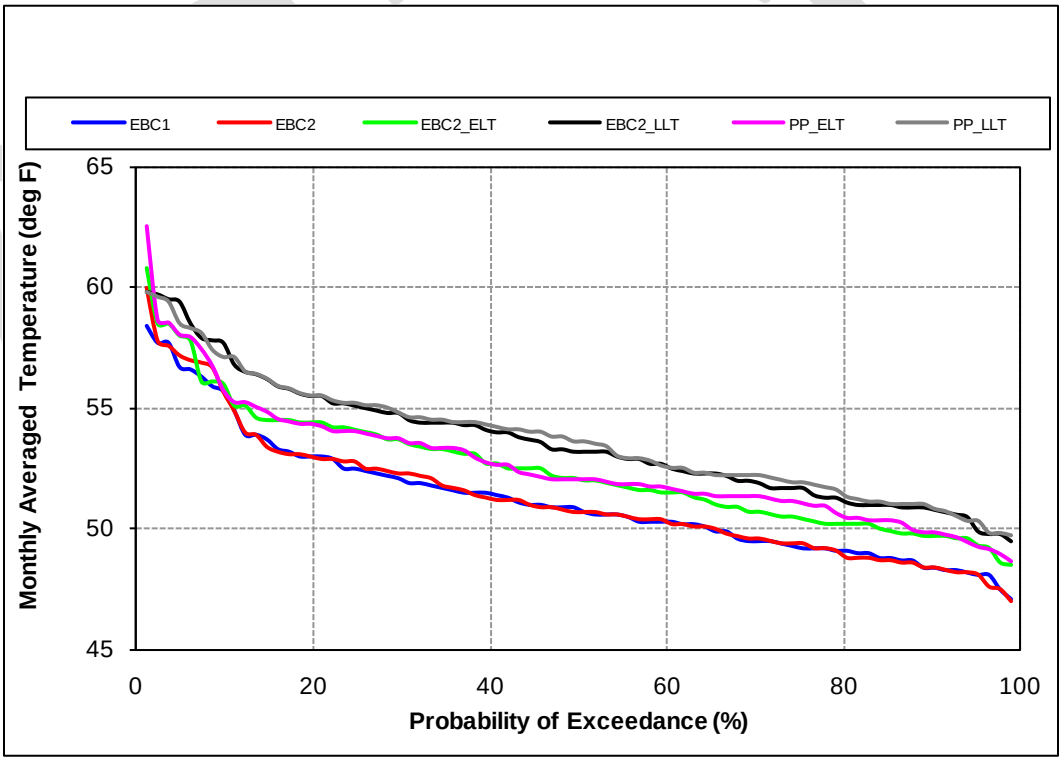

Figure C.5.2-174. Probability of Exceedance Plot for Model Scenarios of Mean Monthly Water Temperature of Trinity River at Douglas City, October

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Trinity River Restoration Program provides recommended flow releases from Lewiston Dam to the Trinity River to protect desired habitat conditions (Figure C.5.2-175). The flow schedule each year is determined through deliberations conducted by the Trinity River Restoration Program. Spring high-flows are provided to mimic the natural hydrograph during the snowmelt period (Figure C.5.2-175). These flows should increase survival of out-migrating steelhead smolts. The higher flows are intended to return more natural geomorphic processes to the Trinity River (U.S. Department of the Interior 2000). These flows should benefit steelhead through the long-term habitat values provided. The flows are designed to discourage riparian vegetation establishment down to the edge of the lower flow channel margins and to scour the bed to maintain spawning and rearing habitat. Off-channel habitats out of the main river flow are important for sustaining juvenile steelhead through the winter months when water is cooler. Off-channel habitats may potentially be created by the higher flows and are being created mechanically by the restoration program. Stranding of young steelhead can occur when the flows are lowered following the restoration program prescribed flows (Chamberlain 2003). As shown in Table C.5.2-68 and Figure C.5.2-168 through Figure C.5.2-174 as discussed above, Trinity River flows are unchanged between the EBC and PP scenarios. These flows, along with physical habitat restoration projects, are intended to increase the amount of fish habitat and increase fish production. The flows designed for the restoration program would be protective of steelhead under all scenarios.

High-flows down the Trinity will occur during safety of dam releases during high runoff events, generally between December and May, to prevent overtopping of the dam. Depending on timing of these releases, they can help or hurt juvenile steelhead. Additional rearing habitat is available during the higher releases, but when the releases are subsequently lowered some stranding can occur where off-channel areas are isolated from the river. Yearly stranding of salmonids in off-channel pools has been documented in Lewiston. Survival of juvenile steelhead through the year in the main channel is thought to be low. The higher releases make it easier for smolts to outmigrate from the river when the timing of the flows coincides with a period when fish are ready to out-migrate. Stranded fish tend to receive a lot of attention because they are visible and easy to count while benefits of the pulsed higher flows to the fish population are not as easily quantified.

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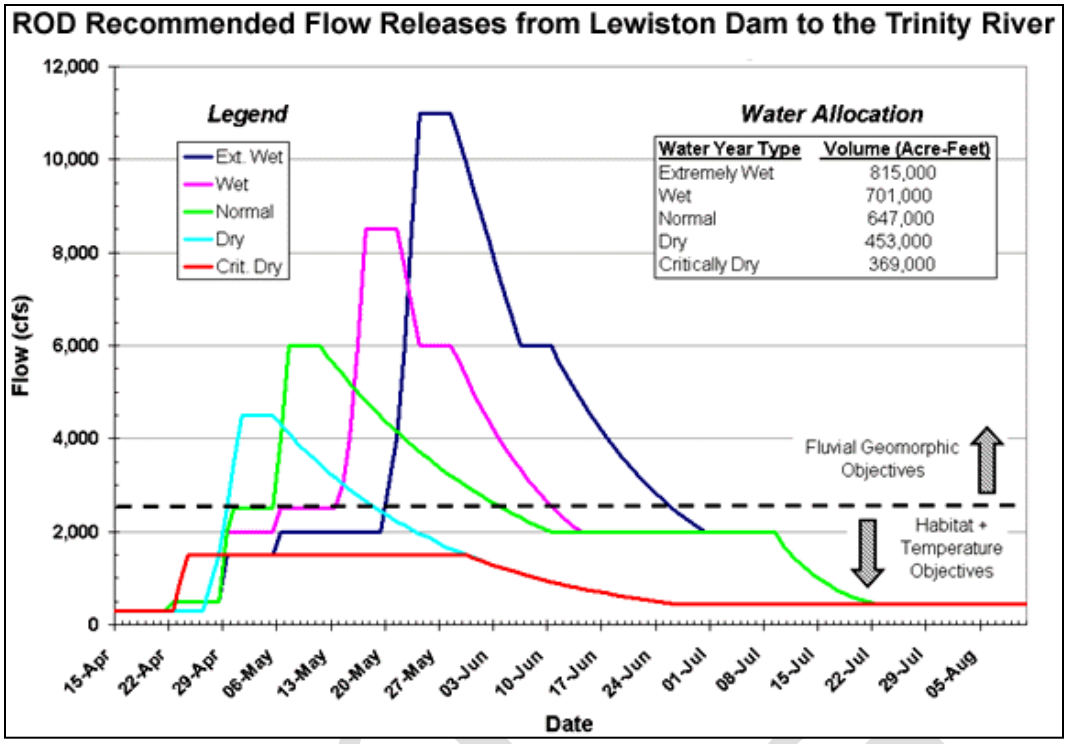

Figure C.5.2-175. Trinity River Restoration Program Recommended Flow Releases from Lewiston Dam to the Trinity River, Including Functional Performance Ranges

Juvenile steelhead rear within the Trinity River year-round. Instream flows estimated from the modeling each month were used to compare habitat conditions for PP model scenarios relative to EBC scenarios. It was assumed that habitat for juvenile steelhead rearing would be constrained by the month having the lowest instream flows. Juvenile rearing habitat increases in Trinity River as instream flows increase above the minimum levels, and therefore the use of the lowest monthly instream flow as an index of habitat constraints for juvenile rearing was selected for use in this analysis. Results of the analysis of minimum monthly instream flows affecting juvenile rearing habitat are shown in Table C.5.2-70.

Results of this analysis showed that juvenile steelhead rearing habitat, based on instream flows, was comparable for PP_ELT and PP_LLT relative to EBC2_ELT and EBC2_LLT, respectively. Based on results of these analyses it was concluded that there was no difference in the juvenile steelhead rearing habitat (as constrained by the lowest monthly instream flow) for steelhead within the Trinity River under existing biological conditions and BDCP operations.

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Table C.5.2-70. Minimum Monthly Instream Flow (Cubic Feet per Second) for Model Scenarios in the Trinity River during the Year-Round Juvenile Steelhead Rearing Period

Water-Year Type	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
Wet	373	373	373	373	373	373
Above Normal	300	275	275	275	275	275
Below Normal	300	300	300	300	300	300
Dry	300	300	283	283	283	283
Critical	300	300	263	225	275	225
Minimum flows occurred between October and March.						

Adult

Water Temperature

Water temperatures for adult steelhead during January through April in the Trinity River at Lewiston (Figure C.5.2-176) and North Fork (Figure C.5.2-177) are predicted to be always below 65°F for all model scenarios. Therefore, there are no temperature-related effects of the preliminary proposal predicted on steelhead migration habitat.

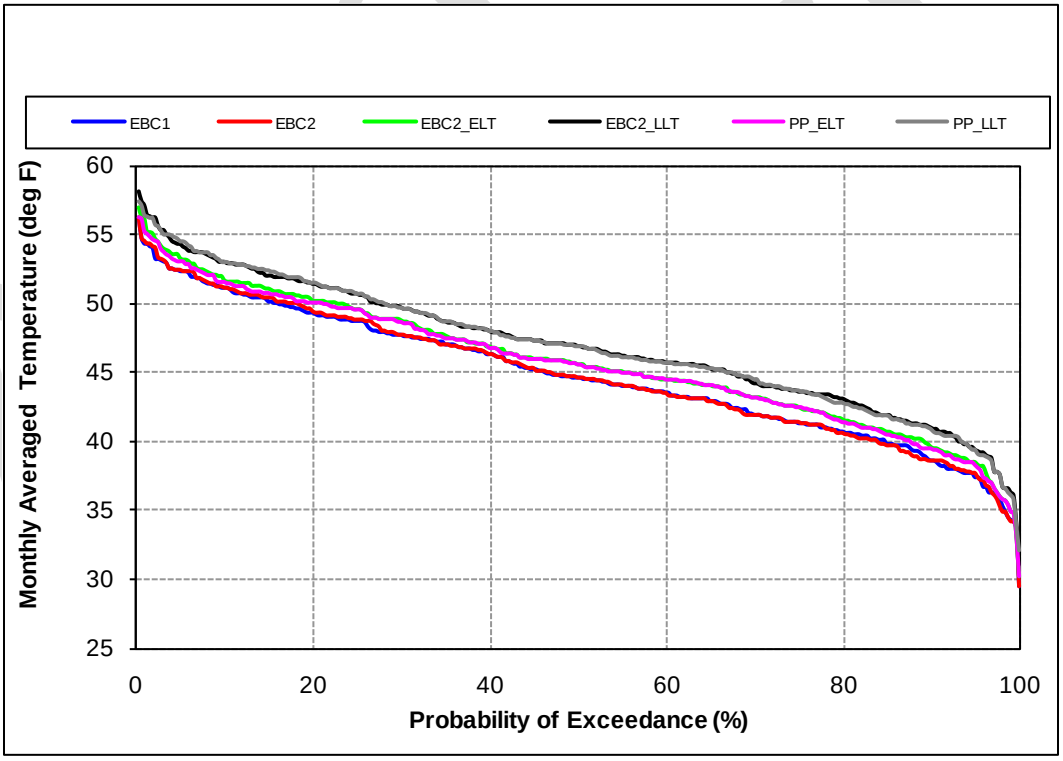

Figure C.5.2-176. Monthly Average Water Temperatures in the Trinity River at Lewiston, January through April

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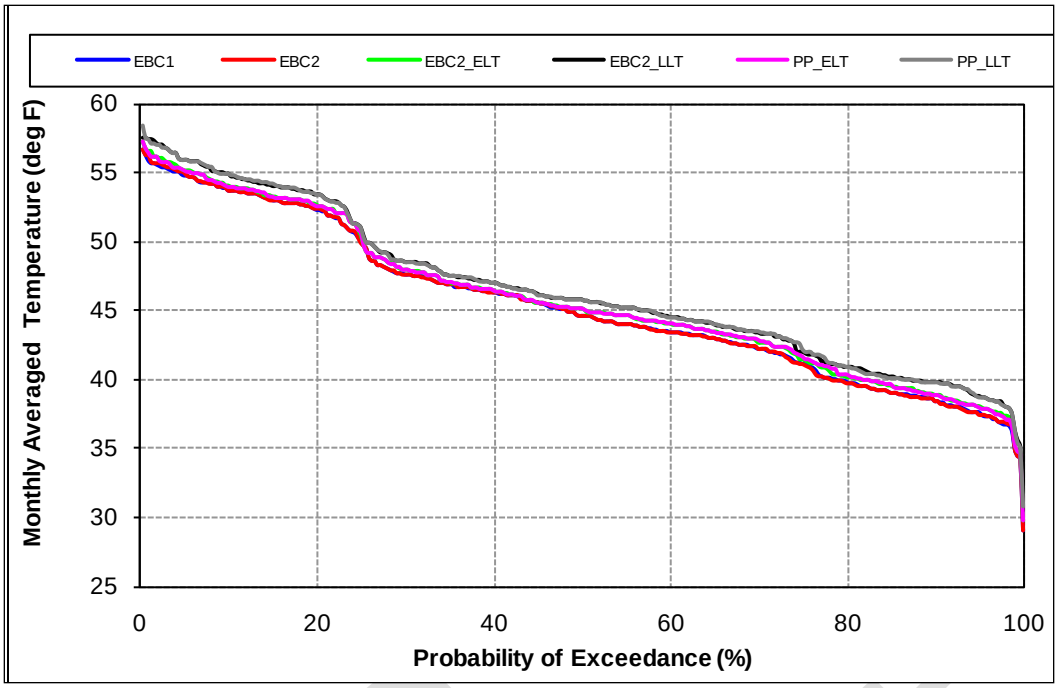

Figure C.5.2-177. Monthly Average Water Temperatures in the Trinity River at North Fork, January through April

C.5.2.2.2 Spring-Run

Eggs and Alevins

Upstream Spawning Habitat

Spring-run Chinook salmon use the lower Trinity River, downstream of Lewiston Dam, as adult holding habitat, for spawning and egg incubation, juvenile rearing, and as habitat for upstream and downstream migration by adults and juveniles. Spring-run Chinook salmon also return to the Trinity River Fish Hatchery where they are spawned, incubated, and reared. The instream flow schedule established through the Trinity River Fishery Restoration Program and associated Record of Decision would be met under all model scenarios.

Trinity River instream flows during the spring-run Chinook salmon spawning and egg incubation period (September through January) are shown in Table C.5.2-68 and Figure C.5.2-155 and Figure C.5.2-163 through Figure C.5.2-166. There are no meaningful differences in instream flow and, therefore, physical habitat predicted between EBC and PP scenarios.

Water Temperature

Spring-run Chinook salmon spawning and egg incubation occur in the reach of the Trinity River downstream of Lewiston Dam. The geographic distribution of spawning and egg incubation varies depending on a variety of factors, including the availability of physical habitat having suitable water depths, velocities, substrate for spawning, and seasonal water temperature regimes. It was assumed that egg exposure to water temperatures in excess of 56°F during the incubation period would result in adverse impacts on reproductive success, including egg mortality. Water temperatures in the Trinity River are presented by month and water-year type in Figure C.5.2-167.

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Spring-run Chinook salmon spawn in the late summer and early fall (September through October), when seasonal air temperatures are high and, therefore, the Trinity River is subject to warming. Spring-run salmon eggs continue to incubate through January, however, seasonal air temperatures and water temperatures during the late fall and winter months are naturally cool and provide suitable habitat conditions for incubation. Management of coldwater reservoir pool storage volumes is an important factor in determining habitat suitability and egg mortality for spring-run salmon. The area of the river where suitable water temperatures occur for successful egg incubation depends on the temperature of water released to the river from Lewiston Dam, the rate of instream flow, and atmospheric conditions that result in river warming as the water travels downstream from the dam. When coldwater storage in Lewiston Reservoir is reduced, the amount of cold water available to be released is reduced, and the temperature of the water at the point of release to the river is increased. Under these conditions, the length of river downstream of Lewiston Dam that maintains suitable water temperatures for spring-run Chinook salmon egg incubation and hatching is reduced and those eggs that were spawned in the downstream areas are exposed to increased water temperature and increased mortality.

September water storage in Lewiston Reservoir has been used as an indicator of coldwater pool availability. September and May storage under each model scenario by water-year type are summarized in Table C.5.2-71 and Table C.5.2-72. Results of an exceedance frequency analysis for Lewiston Reservoir storage during September and May is shown in Figure C.5.2-178 and Figure C.5.2-179.

CALSIM predicts that instream flows in the Trinity River, water temperatures at Douglas City, and storage in Lewiston Reservoir would not be substantially different between EBC and PP model scenarios during the ELT and LLT implementation periods. Based on these results, it was concluded that habitat conditions for spring-run Chinook salmon egg incubation in the Trinity River would be comparable between existing biological proposed project conditions.

Table C.5.2-71. Lewiston Reservoir Water Storage in September (Thousand Acre-Feet)

Water-Year Type	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
Wet	1,856	1,845	1,783	1,657	1,771	1,633
Above Normal	1,617	1,587	1,508	1,388	1,473	1,362
Below Normal	1,259	1,238	1,136	1,068	1,141	1,000
Dry	1,152	1,126	988	855	1,024	798
Critical	687	656	530	440	573	420

Table C.5.2-72. Lewiston Reservoir Water Storage in May (Thousand Acre-Feet)

Water-Year Type	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
Wet	2,266	2,263	2,247	2,196	2,239	2,177
Above Normal	2,030	2,014	2,005	1,988	1,998	1,971
Below Normal	1,674	1,653	1,588	1,544	1,619	1,483
Dry	1,696	1,624	1,533	1,406	1,554	1,347
Critical	1,090	1,070	944	862	985	878

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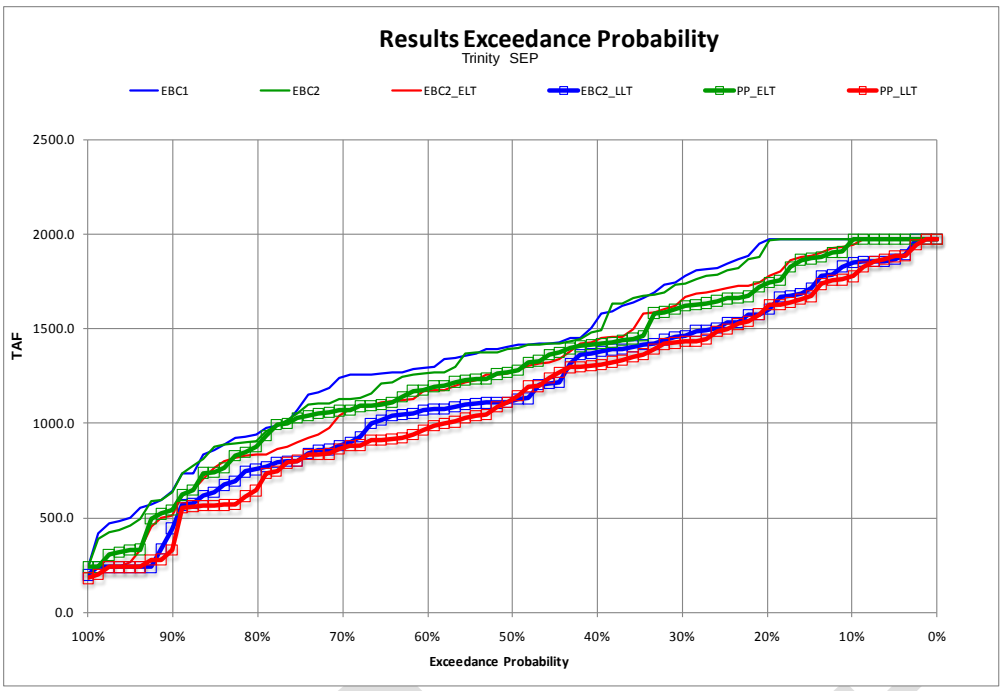

Figure C.5.2-178. Probability of Exceedance Plot for Model Scenarios of Lewiston Reservoir Storage, September

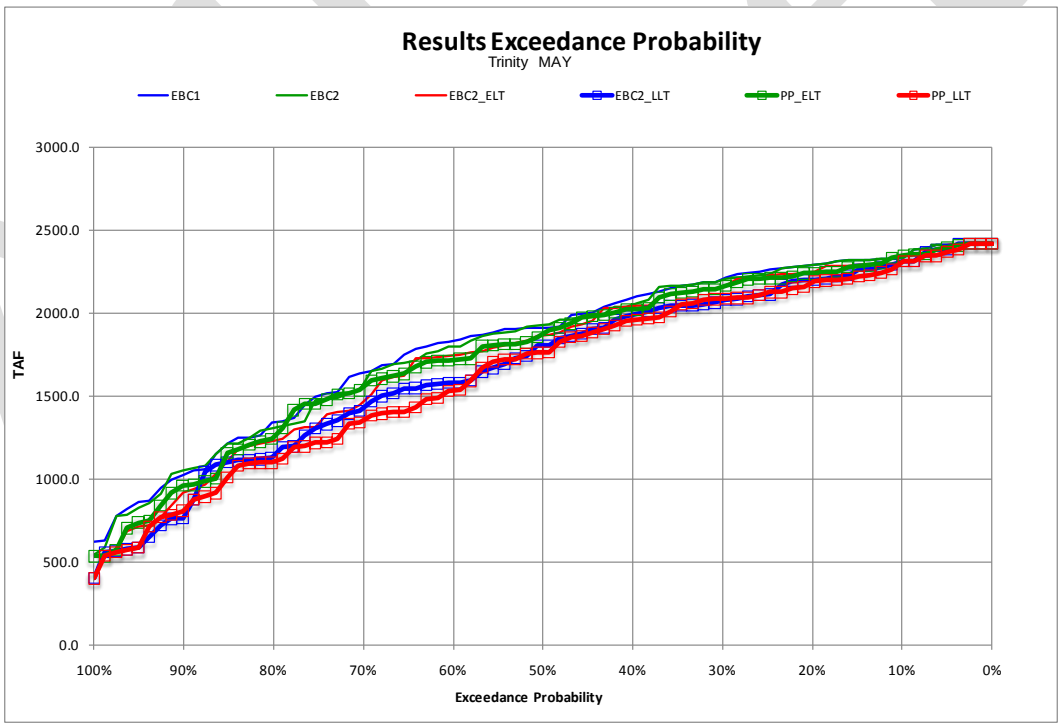

Figure C.5.2-179. Probability of Exceedance Plot for Model Scenarios of Lewiston Reservoir Storage, May

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Redd Dewatering

Water operations and instream flow management in the Trinity River are largely controlled by reservoir releases. Ramping rate schedules have been established as part of the fishery restoration program. It is expected that water operations designed to minimize and avoid the risk of redd dewatering would continue under all model scenarios. Therefore, there are no predicted effects of the preliminary proposal on spring-run redd dewatering.

Fry and Juvenile Rearing

Rearing Habitat

Water temperatures at Douglas City during April through October during the warm spring, summer, and early fall months are summarized in Figure C.5.2-168 through Figure C.5.2-174. Water temperatures exceed 65°F less than 10% of the time during the summer and early fall and are expected to be supportive of juvenile spring-run Chinook salmon. Water temperatures in April and May (Figure C.5.2-168 and Figure C.5.2-169) are predicted to always be suitable for rearing spring-run Chinook salmon under all model scenarios. Temperatures are predicted to be warmer during the LLT scenarios but still suitable for rearing. The length of river with suitable rearing temperatures would be reduced under both EBC_LLT and PP_LLT. Restoration program flows, with a minimum baseflow of 300 cfs and spring pulse flows, would be a continuation of the present management situation.

It was assumed that juvenile spring-run salmon rearing habitat would be constrained by the month having the lowest instream flows. Juvenile rearing habitat is assumed to increase in the Trinity River as instream flows increase. Therefore, the use of the lowest monthly instream flow as an index of habitat constraints for juvenile rearing was selected for use in this analysis. Results of the analysis of minimum monthly instream flows affecting juvenile rearing habitat are shown in Table C.5.2-73.

Results predict that juvenile rearing habitat, based on instream flows, would be comparable between all model scenarios. Minimum flows are predicted to be nearly identical between EBC2_ELT and PP_ELT and between EBC2_LLT and PP_LLT. Therefore, these results suggest that there will be no effect of the preliminary proposal on juvenile spring-run Chinook salmon rearing habitat (as constrained by the lowest monthly instream flows) within the Trinity River.

CALSIM modeling results showed that Trinity River instream flows, water temperatures, and storage in Lewiston Reservoir were comparable between EBC1, EBC2 and BDCP operations. Most of the few significant differences between scenarios occur during above-normal water years. Proposed project conditions result in significantly less flows compared to EBC2 conditions in April in both the early and late long-term, but result in higher flows in February in the late long-term. EBC2 flows are significantly greater than EBC flows in February in above-normal water years. Based on these results it was concluded that BDCP operations would not result in adverse effects to juvenile rearing habitat under BDCP operations when compared to EBC1 and EBC2.

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Table C.5.2-73. Minimum Monthly Mean Instream Flow (Cubic Feet per Second) in the Trinity River for Model Scenarios, by Water-Year Type, during the Year-Round Juvenile Spring-Run Chinook Salmon Rearing Period

Water-Year Type	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
Wet	373	373	373	373	373	373
Above Normal	300	275	275	275	275	275
Below Normal	300	300	300	300	300	300
Dry	300	300	283	283	283	283
Critical	300	300	263	225	275	225

Adult

Water Temperature

Adult spring-run Chinook salmon migrate upstream in the mainstem Trinity River during the spring and early summer months (March through July, with a peak in migration during April through May) and hold in the upper river reaches through the spring and early summer months prior to spawning and embryo incubation (September through January). Therefore, this analysis examined water temperatures in the Trinity River from March through August.

Water temperatures for adult spring-run Chinook salmon during March through August in the Trinity River at Lewiston are predicted to be nearly always (<5%) below 65°F for all model scenarios (Figure C.5.2-180). At North Fork, there is a ~10% higher exceedance above 65°F predicted under EBC2_ELT and PP_ELT relative to EBC1 and EBC2, although the exceedance probability does not differ between EBC2_ELT and PP_ELT (Figure C.5.2-181). Further, there is a ~20% higher exceedance above 65°F predicted under EBC2_LLT and PP_LLT relative to EBC1 and EBC2, although the exceedance probability does not differ between EBC2_LLT and PP_LLT. It is concluded that there will be temperature-related effects due to future climate change on upstream migration and rearing habitat for spring-run in the Trinity River, but the preliminary proposal will not affect temperatures.

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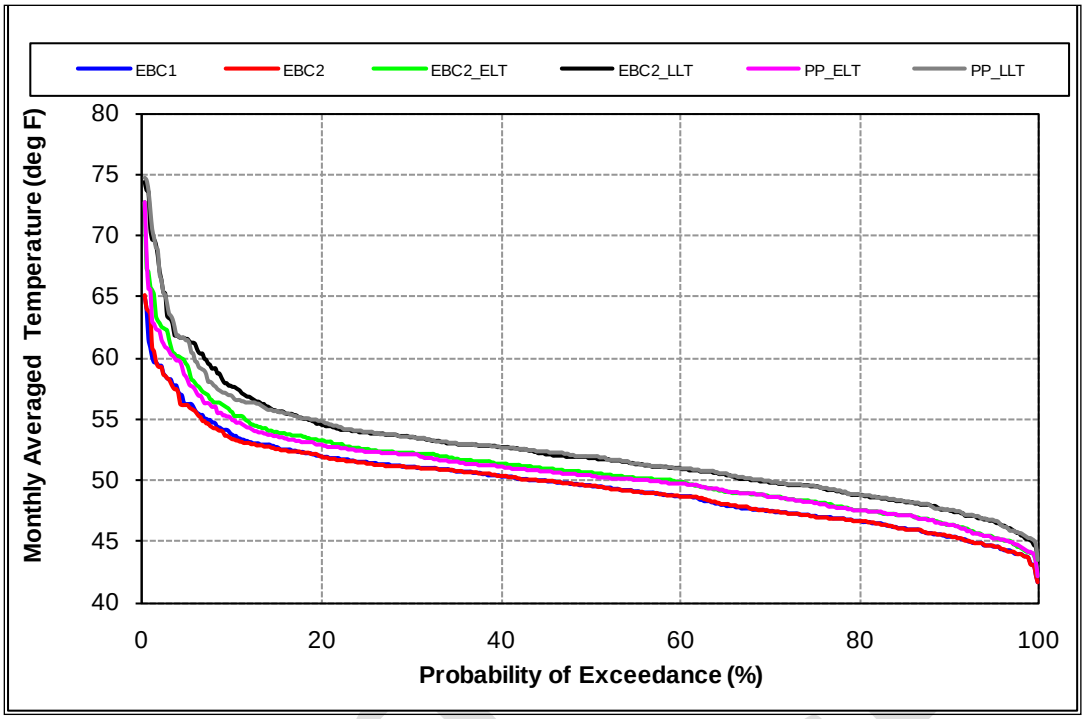

Figure C.5.2-180. Monthly Average Water Temperatures in the Trinity River at Lewiston, March through August

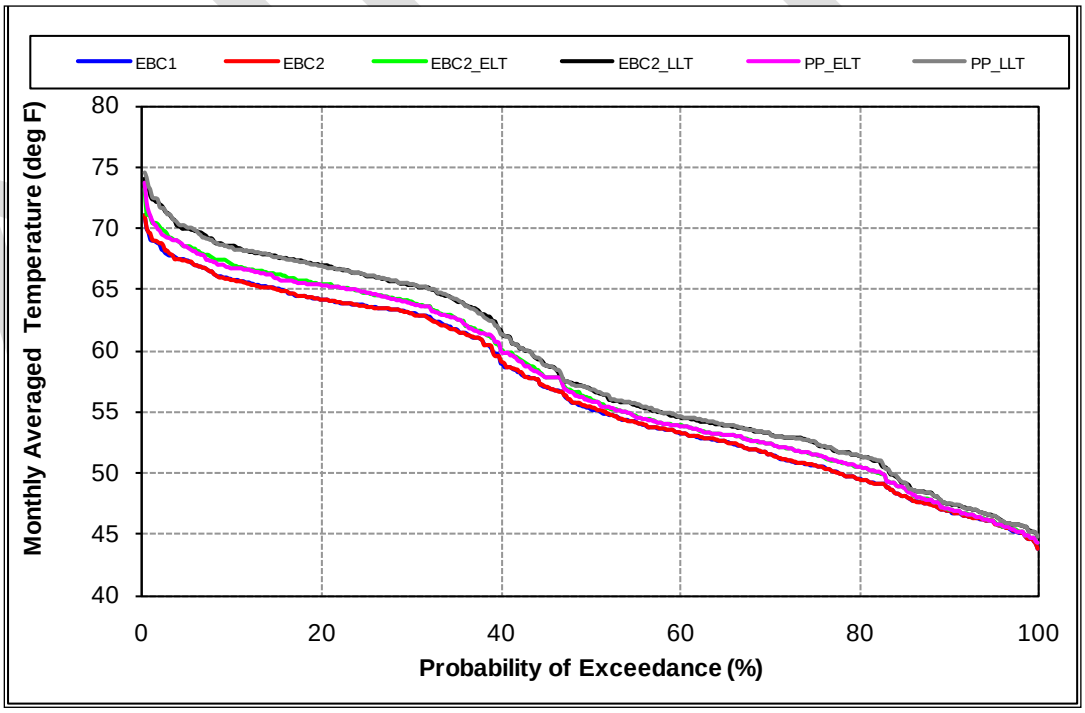

Figure C.5.2-181. Monthly Average Water Temperatures in the Trinity River at North Fork, March through August

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C.5.2.2.3 Fall-/Late Fall–Run

Eggs and Alevins

Upstream Spawning Habitat

The Reclamation egg mortality model was used to estimate the change in egg survival under different water management strategies over a wide range of hydrologic and environmental conditions. Egg mortality model results provide an important indicator regarding changes in habitat suitability for fall-run Chinook salmon spawning and successful egg incubation. Results of the fall-run Chinook salmon egg mortality estimates are summarized in Figure C.5.2-182 and Table C.5.2-74.

Predictions for fall-run Chinook salmon egg mortality in the Trinity River include the following: (1) egg mortality increases substantially during critically dry water years in all model scenarios, as a result of depleted coldwater pool storage in Lewiston Reservoir and increased temperatures of water released to the mainstem Trinity River during the fall-run salmon egg incubation period, and (2) egg mortality is comparable between EBC2_ELT and PP_ELT and between EBC2_LLT and PP_LLT.

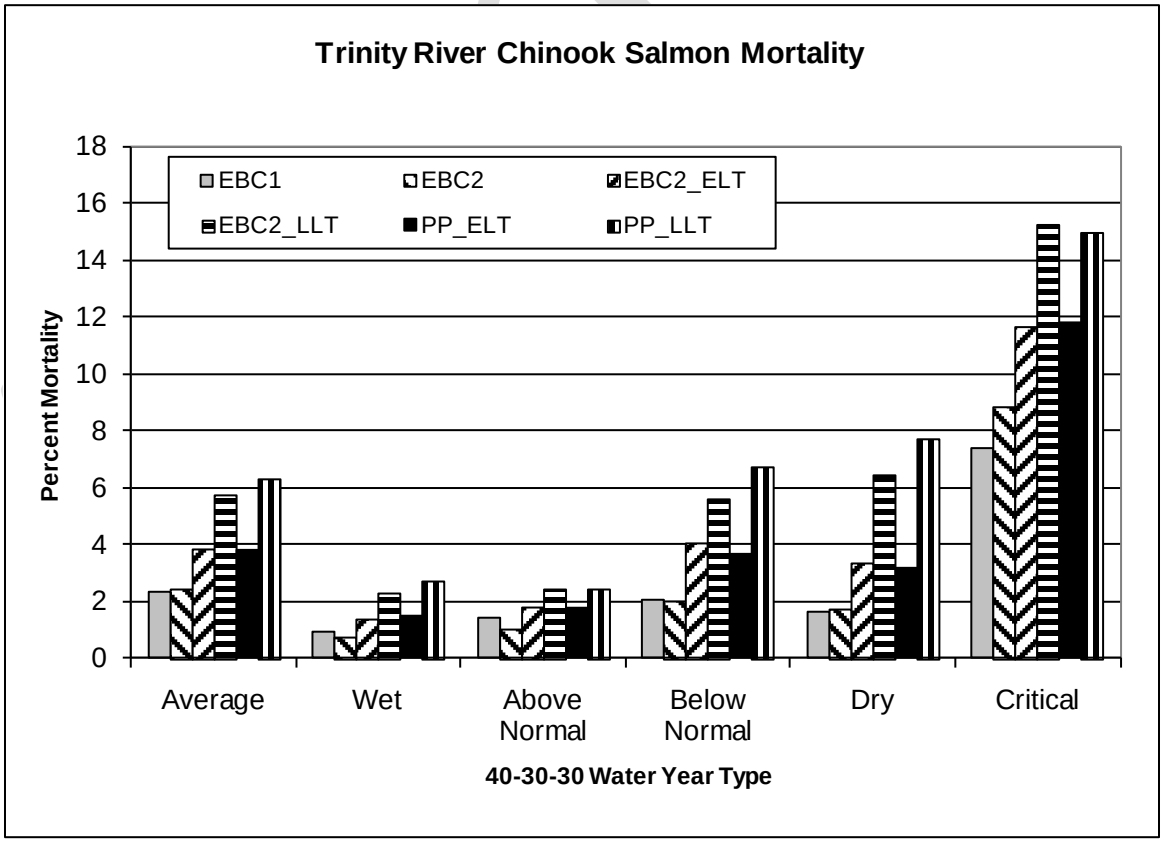

Figure C.5.2-182. Trinity River Fall-Run Chinook Average Egg Mortality under Each Model Scenario for Each Water-Year Type and for all Years from the Reclamation Egg Mortality Model

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Table C.5.2-74. Egg Mortality Percentages for Fall-Run Chinook in the Trinity River (Reclamation Egg Mortality Model)

Water-Year Type	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
Wet	0.9	0.8	1.4	2.3	1.5	2.7
Above Normal	1.4	1.0	1.8	2.5	1.8	2.5
Below Normal	2.0	2.1	4.1	5.6	3.7	6.8
Dry	1.7	1.8	3.3	6.5	3.1	7.7
Critical	7.4	8.8	11.6	15.2	11.8	15.0
Average	2.3	2.5	3.9	5.7	3.8	6.3

Fry and Juvenile Rearing

Rearing Habitat

The Trinity River supports fall-run Chinook salmon rearing from approximately January to June. Nearly all salmon rearing occurs upstream of Douglas City, in the vicinity of the high-density spawning. Water temperatures in the Trinity River between Lewiston and Douglas City are cooler during the spring than conditions further downstream. Temperatures at Douglas City are predicted to be below 62°F (monthly average) in over 95% of years in under EBC1 and EBC2, 90% of years under EBC2_ELT and PP_ELT, and about 85% of years under EBC2_LLT and PP_LLT (Figure C.5.2-167). Temperatures are predicted to be slightly reduced in the drier years in the PP_ELT compared to EBC_ELT. There are few differences predicted in flows between EBC2_LL T and PP_LLT. Based on these results, it was concluded that the preliminary proposal is not likely to affect fall-run salmon rearing habitat in the Trinity River.

Trinity River flows would be a minimum of 300 cfs year-round, except during January of critical water years under the EBC2_LLT and PP_LLT. Average flows in the Trinity River during the juvenile fall-run Chinook salmon rearing period (January through May) are summarized in Table C.5.2-68 and Figure C.5.2-155 through Figure C.5.2-159. Results of these analyses predict that instream flows in the Trinity River during the juvenile fall-run Chinook salmon rearing period would be comparable between EBC2_ELT and PP_ELT and between EBC2_LLT and PP_LLT. Based on this information, it was concluded that proposed project operations would not generally affect habitat conditions for juvenile salmon rearing within the Trinity River.

Spring high flows are provided to mimic the natural hydrograph during the snowmelt period. The flow schedule each year is determined by the Trinity River Restoration Program. These flows should increase survival of out-migrating fall-run salmon smolts. The higher flows are intended to return more natural geomorphic processes to the Trinity River (U.S. Department of the Interior 2000). These flows should benefit fall-run Chinook salmon through the long-term habitat values provided. The flows are designed to discourage riparian vegetation establishment down to the edge of the lower flow channel margins and to scour the bed to maintain spawning and rearing habitat (U.S. Department of the Interior 2000). Off-channel habitats out of the main river flow are important for fall-run salmon fry during the late winter and early spring. Off-channel habitats may potentially be created by higher flows and are being created mechanically by the restoration program. Stranding of salmon fry can occur when the flows are lowered following the restoration program-prescribed flows (Chamberlain 2003). These flows, along with physical habitat restoration projects, are intended to increase the amount of fish habitat and fish production.

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High flows within the Trinity River will occur during safety-of-dam releases following high runoff events, generally between December and May, to prevent overtopping of the dam. Depending on timing of these releases, they can help or hurt juvenile fall-run salmon. Additional rearing habitat is available during the higher releases, but when the releases are subsequently lowered some stranding can occur where off-channel areas are isolated from the river. The higher releases in the spring make it easier for smolts to out-migrate from the river when the timing of the flows coincides with a period when fall-run salmon smolts are ready to out-migrate.

Adult

Water Temperature

Adult fall-run Chinook salmon migrate upstream in the mainstem Trinity River during the fall months (August through December, with a peak in migration during September through October) prior to spawning in October through December.

Water temperatures for adult fall-run Chinook salmon during August through December in the Trinity River at Lewiston are predicted to be mostly below 65°F for all model scenarios (Figure C.5.2-183). There is a ~2% higher exceedance under both EBC2_LLT and PP_LLT scenarios relative to EBC2_ELT and PP_ELT and a ~5% under both EBC2_LLT and PP_LLT scenarios relative to EBC1 and EBC2.

At North Fork, ~5% more months are predicted to exceed 65°F under EBC2_ELT and PP_ELT relative to EBC1 and EBC2, although exceedances are not predicted to differ between EBC2_ELT and PP_ELT (Figure C.5.2-184). Further, ~15% more months are predicted to exceed 65°F under EBC2_LLT and PP_LLT relative to EBC1 and EBC2, although exceedances are not predicted to differ between EBC2_LLT and PP_LLT.

It is concluded that there will be temperature-related effects due to future climate change on upstream migration and rearing habitat for spring-run Chinook salmon in the Trinity River, but the preliminary proposal will not affect temperatures.

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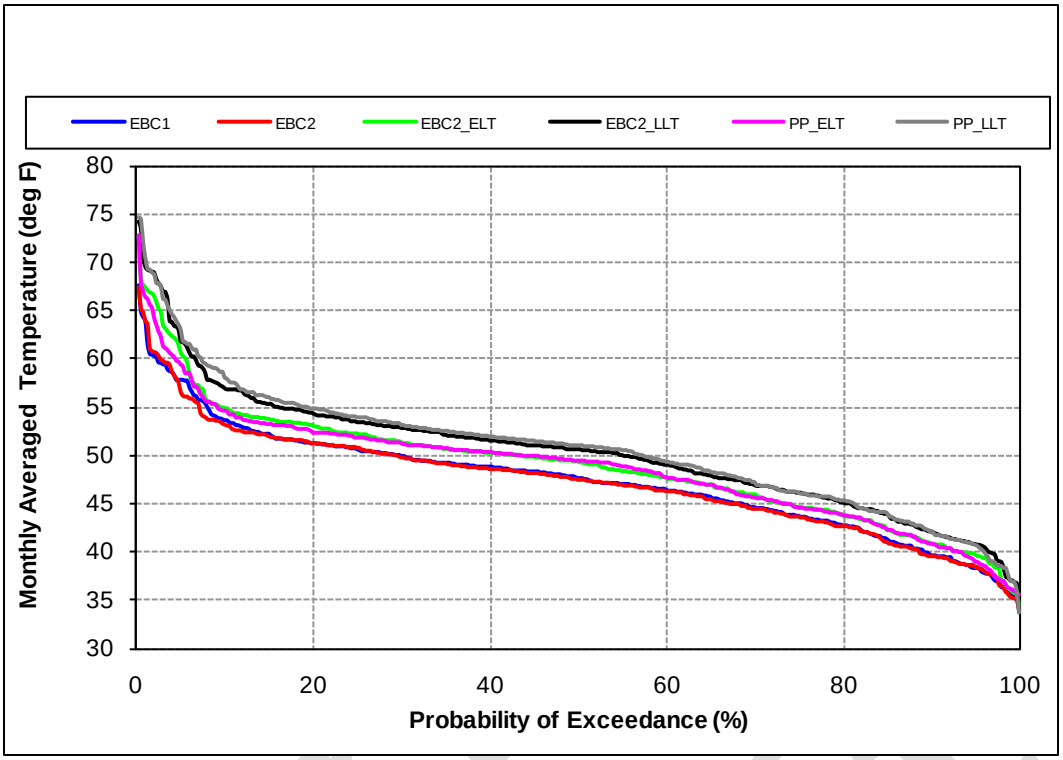

Figure C.5.2-183. Monthly Average Water Temperatures in the Trinity River at Lewiston, August through December

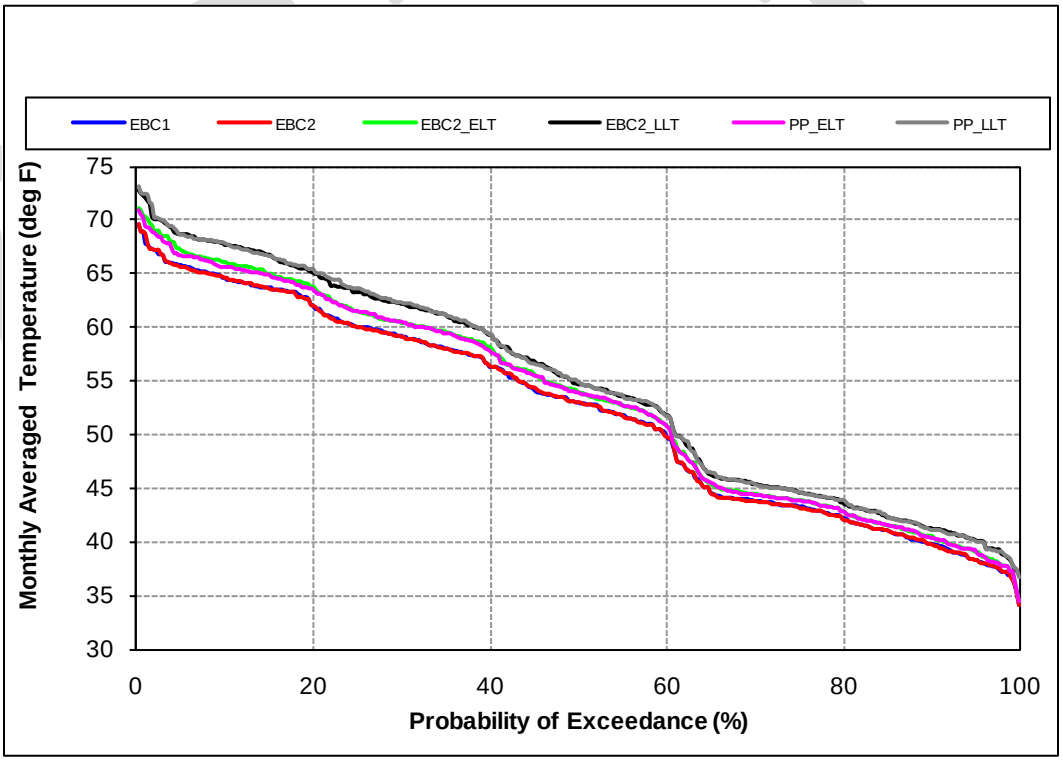

Figure C.5.2-184. Monthly Average Water Temperatures in the Trinity River at North Fork, August through December

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C.5.2.2.4 Lamprey

Eggs

Water Temperature

Exact spawning locations of Pacific and river lamprey in the Trinity River are not well known. Therefore, this analysis includes upstream (Lewiston) and downstream (North Fork) locations that encompass the spatial range of Reclamation's Temperature Model. As with the Feather River, a 2-month period was used to represent the duration of each egg cohort. The number of Pacific lamprey cohorts exposed to water temperatures above 71.6°F is reported in Table C.5.2-75, and the numbers of river lamprey cohorts exposed to water temperatures above 71.6°F and 77°F are reported in Table C.5.2-76; differences between model scenarios are reported in Table C.5.2-77 for Pacific lamprey and Table C.5.2-78 for river lamprey.

Table C.5.2-75. Temperature Exposure of Pacific Lamprey Egg Cohorts in the Trinity, Feather, American, and Stanislaus Rivers[1]

Location	Comparison[2]	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
Trinity River							
Lewiston	# Cohorts	0	0	2	5	2	7
	Percent of Total	0%	0%	0.3%	0.8%	0.3%	1.1%
North Fork	# Cohorts	0	0	2	17	4	12
	Percent of Total	0%	0%	0.3%	2.6%	0.6%	1.9%
Feather River							
Fish Barrier Dam	# Cohorts	0	0	0	1	0	0
	Percent of Total	0%	0%	0%	0.2%	0%	0%
Below Thermalito Afterbay	# Cohorts	24	26	40	92	113	176
	Percent of Total	3.7%	4.0%	6.2%	14.2%	17.4%	27.2%
American River							
Nimbus Dam	# Cohorts	11	25	51	85	44	87
	Percent of Total	1.7%	3.9%	7.9%	13.1%	6.8%	13.4%
at Sacramento River	# Cohorts	56	88	150	216	143	213
	Percent of Total	8.6%	13.6%	23.1%	33.3%	22.1%	32.9%
Stanislaus River							
Knights Ferry	# Cohorts	0	0	0	2	0	2
	Percent of Total	0%	0%	0%	0.3%	0%	0.3%
Riverbank	# Cohorts	2	2	25	89	24	89
	Percent of Total	0.3%	0.3%	3.9%	13.7%	3.7%	13.7%

[1] Predicted number of and percent of total Pacific lamprey egg cohorts experiencing water temperatures above 71.6°F during January to August for at least 1 month during a 2-month incubation period for each model scenario.
[2] n=643 to 648 because of some months not being sampled over the 82-year period at some locations.

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Table C.5.2-76. Temperature Exposure of River Lamprey Egg Cohorts in the Trinity, Feather, American, and Stanislaus Rivers[1,2]

Location	Metric	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
Temperature above 71.6°F							
Trinity River							
Lewiston	# Cohorts	0	0	0	1	0	1
	Percent of Total	0%	0%	0%	0.2%	0%	0.2%
North Fork	# Cohorts	0	0	1	5	2	3
	Percent of Total	0%	0%	0.2%	1.2%	0.5%	0.7%
Feather River							
Fish Barrier Dam	# Cohorts	0	0	0	0	0	0
	Percent of Total	0%	0%	0%	0%	0%	0%
Below Thermalito Afterbay	# Cohorts	9	9	13	38	42	61
	Percent of Total	2.2%	2.2%	3.2%	9.4%	10.4%	15.1%
American River							
Nimbus Dam	# Cohorts	5	14	19	30	16	29
	Percent of Total	1.2%	3.5%	4.7%	7.4%	3.9%	7.2%
at Sacramento River	# Cohorts	28	38	57	82	44	70
	Percent of Total	6.9%	9.4%	14.1%	20.2%	10.9%	17.3%
Stanislaus River							
Knights Ferry	# Cohorts	0	0	0	0	0	0
	Percent of Total	0%	0%	0%	0%	0%	0%
Riverbank	# Cohorts	1	1	12	35	12	35
	Percent of Total	0.2%	0.2%	3.0%	8.6%	3.0%	8.6%
Temperature above 77°F							
Trinity River							
Lewiston	# Cohorts	0	0	0	0	0	0
	Percent of Total	0%	0%	0%	0%	0%	0%
North Fork	# Cohorts	0	0	0	0	0	2
	Percent of Total	0%	0%	0%	0%	0%	0.5%
Feather River							
Fish Barrier Dam	# Cohorts	0	0	0	0	0	0
	Percent of Total	0%	0%	0%	0%	0%	0%
Below Thermalito Afterbay	# Cohorts	0	0	0	2	2	4
	Percent of Total	0%	0%	0%	0.4%	0.4%	1.0%
American River							
Nimbus Dam	# Cohorts	0	0	1	4	1	5
	Percent of Total	0%	0%	0.3%	1.0%	0.3%	1.2%
at Sacramento River	# Cohorts	0	2	3	6	4	9
	Percent of Total	0%	0.5%	0.7%	1.5%	1.0%	2.2%
Stanislaus River							
Knights Ferry	# Cohorts	0	0	0	0	0	0
	Percent of Total	0%	0%	0%	0%	0%	0%
Riverbank	# Cohorts	0	0	0	0	0	0
	Percent of Total	0%	0%	0%	0%	0%	0%

[1] n=405 over the 82-year period.
[2] River lamprey egg cohorts experiencing water temperature above 71.6°F and 77°F during February through June for at least 1 month during a 2-month incubation period for each model scenario.

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Table C.5.2-77. Differences between Model Scenarios in Pacific Lamprey Egg Cohort Temperature Exposure in the Trinity, Feather, American, and Stanislaus Rivers[1]

Location	Comparison[2]	EBC1 vs. PP_ELT	EBC1 vs. PP_LLT	EBC2 vs. PP_ELT	EBC2 vs. PP_LLT	EBC2_ELT vs. PP_ELT	EBC2_LLT vs. PP_LLT
Trinity River							
Lewiston	Difference	-2	12	4	12	2	-5
	Percent Difference	NA	NA	NA	NA	100.0%	-29.4%
North Fork	Difference	2	7	2	7	0	2
	Percent Difference	NA	NA	NA	NA	0%	40.0%
Feather River							
Fish Barrier Dam	Difference	0	0	0	0	0	-1
	Percent Difference	NA	NA	NA	NA	NA	-100%
Below Thermalito Afterbay	Difference	89	152	87	150	73	84
	Percent Difference	370.8%	633.3%	334.6%	576.9%	182.5%	91.3%
American River							
Nimbus Dam	Difference	33	76	19	62	-7	2
	Percent Difference	300%	690.9%	76%	248%	-13.7%	2.4%
Sacramento River	Difference	87	157	55	125	-7	-3
	Percent Difference	155.4%	280.4%	62.5%	142.0%	-4.7%	-1.4%
Stanislaus River							
Knights Ferry	Difference	0	2	0	2	0	0
	Percent Difference	NA	NA	NA	NA	NA	0%
Riverbank	Difference	22	86	22	86	-1	0
	Percent Difference	1100%	4300%	1100%	4300%	-4.0%	0%

[1] Difference and percent difference between model scenarios in the number of Pacific lamprey cohorts experiencing water temperatures above 71.6°F during January to August for at least 1 month during a 2-month incubation period.
[2] Positive values indicate a higher value in the preliminary proposal than in the EBC.
NA = cannot be calculated because dividing by zero.

Table C.5.2-78. Differences between Model Scenarios in River Lamprey Egg Cohort Temperature Exposure in the Trinity, Feather, American, and Stanislaus Rivers[1]

Location	Comparison[2]	EBC1 vs. PP_TLT	EBC1 vs. PP_LLT	EBC2 vs. PP_ELT	EBC2 vs. PP_LLT	EBC2_ELT vs. PP_ELT	EBC2_LLT vs. PP_LLT
Temperature above 71.6°F							
Trinity River							
Lewiston	Difference	0	1	0	1	0	0
	Percent Difference	NA	NA	NA	NA	NA	0%
North Fork	Difference	2	3	2	3	1	-2
	Percent Difference	NA	NA	NA	NA	100.0%	-40.0%
Feather River							
Fish Barrier Dam	Difference	0	0	0	0	0	0
	Percent Difference	NA	NA	NA	NA	NA	NA
Below Thermalito Afterbay	Difference	33	52	33	52	29	23
	Percent Difference	367%	578%	367%	578%	223%	60.5%

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Location	Comparison[2]	EBC1 vs. PP_TLT	EBC1 vs. PP_LLT	EBC2 vs. PP_ELT	EBC2 vs. PP_LLT	EBC2_ELT vs. PP_ELT	EBC2_LLT vs. PP_LLT
American River							
Nimbus Dam	Difference	11	24	2	15	-3	-1
	Percent Difference	220%	480%	14.3%	107%	-15.8%	-3.3%
At Sacramento River	Difference	16	42	6	32	-13	-12
	Percent Difference	57.1%	150%	15.8%	84.2%	-22.8%	-14.6%
Stanislaus River							
Knights Ferry	Difference	0	0	0	0	0	0
	Percent Difference	NA	NA	NA	NA	NA	NA
Riverbank	Difference	11	34	11	34	0	0
	Percent Difference	1,100%	3,400%	1,100%	3,400%	0%	0%
Temperature above 77°F							
Trinity River							
Lewiston	Difference	0	0	0	0	0	0
	Percent Difference	NA	NA	NA	NA	NA	NA
North Fork	Difference	0	2	0	2	0	2
	Percent Difference	NA	NA	NA	NA	NA	NA
Feather River							
Fish Barrier Dam	Difference	0	0	0	0	0	0
	Percent Difference	NA	NA	NA	NA	NA	NA
Below Thermalito Afterbay	Difference	2	4	2	4	2	2
	Percent Difference	NA	NA	NA	NA	NA	100%
American River							
Nimbus Dam	Difference	1	5	1	5	0	1
	Percent Difference	NA	NA	NA	NA	0%	25%
At Sacramento River	Difference	4	9	2	7	1	3
	Percent Difference	NA	NA	100%	350%	33.3%	50.0%
Stanislaus River							
Knights Ferry	Difference	0	0	0	0	0	0
	Percent Difference	NA	NA	NA	NA	NA	NA
Riverbank	Difference	0	0	0	0	0	0
	Percent Difference	NA	NA	NA	NA	NA	NA

[1] Difference and percent difference between model scenarios in the number of river lamprey cohorts experiencing water temperature above 71.6°F and 77°F during February to June for at least 1 month during a 2-month incubation period.
[2] Positive values indicate a higher value in preliminary proposal than in the EBC.
NA = cannot be calculated because dividing by zero.

Lewiston

For Pacific lamprey at Lewiston, the percent of egg cohorts experiencing water temperatures that exceed 71.6°F is predicted to be 0%–1% under all model scenarios (Figure C.5.2-185, Table C.5.2-75). The percent of egg cohorts experiencing water temperatures that exceed 71.6°F is predicted to range from 0% under EBC1 and EBC2 to 1% under PP_LLT. Implementation of the

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preliminary proposal (PP_ELT and PP_LLT) would have little effect on the number of cohorts exposed to temperatures exceeding 71.6°F relative to the baseline scenarios (Table C.5.2-77).

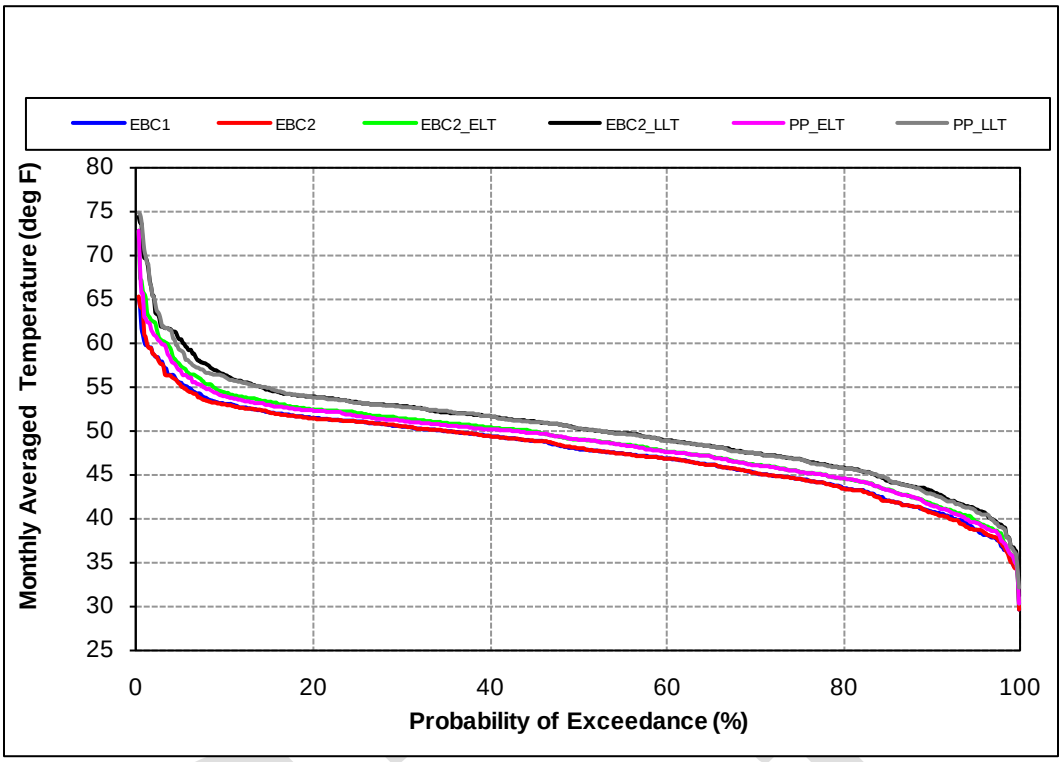

Figure C.5.2-185. Probability of Exceedance Plot for Model Scenarios of Mean Monthly Temperature of the Trinity River at Lewiston, January to August

For consideration of river lamprey effects, mean monthly water temperatures in the Trinity River at Lewiston are predicted to be below 71.6°F and 77°F between February and June all of the time under all model scenarios with two exceptions (Figure C.5.2-185, Table C.5.2-76, Table C.5.2-78). There is a single cohort predicted to be exposed to temperatures greater than 71.6°F in both the EBC2_LLT and PP_LLT.

North Fork

For Pacific lamprey in the North Fork of the Trinity River, the percent of egg cohorts experiencing water temperatures that exceed 71.6°F is predicted to be 0% under EBC1 and EBC2 and less than 2% under EBC2_ELT, EBC2_LLT, PP_ELT, and PP_LLT (Figure C.5.2-186, Table C.5.2-75). Under early long-term conditions, implementation of the preliminary proposal (PP_ELT) would result in exposure of two cohorts to temperatures exceeding 71.6°F versus one cohort in the absence of implementation of the preliminary proposal (EBC2_ELT) (Table C.5.2-77). Under late long-term conditions, implementation of the preliminary proposal (PP_LLT) would result in exposure of three cohorts to temperatures exceeding 71.6°F versus five cohorts in the absence of implementation of the preliminary proposal.

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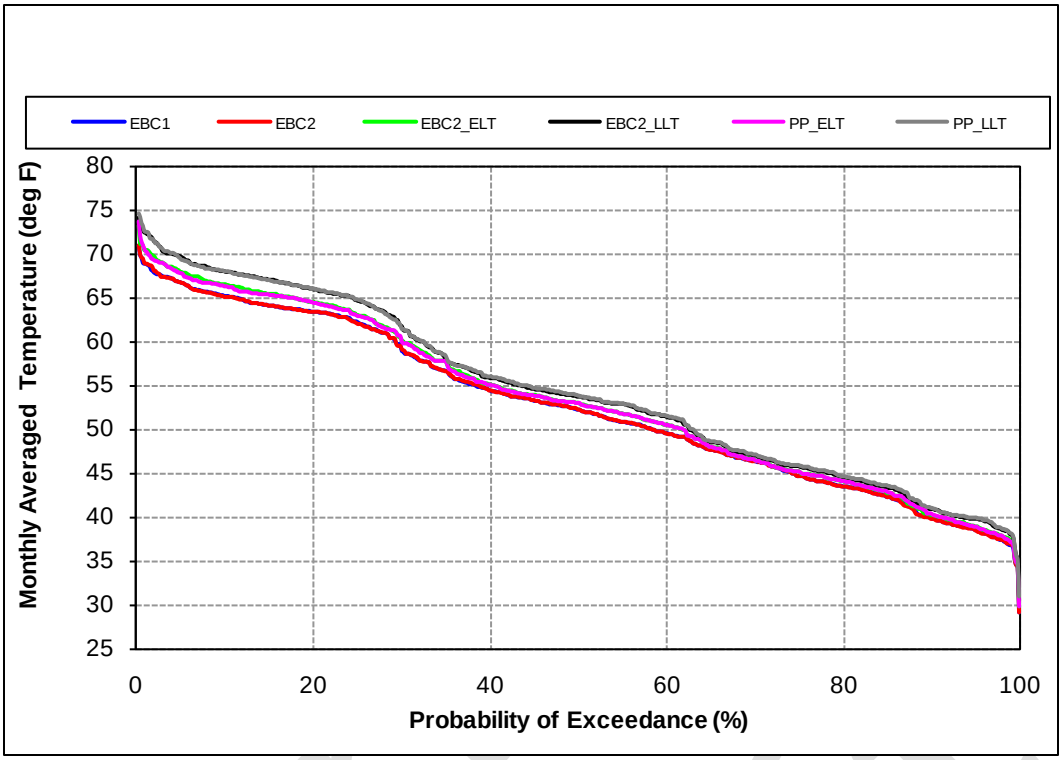

Figure C.5.2-186. Probability of Exceedance Plot for Model Scenarios of Mean Monthly Temperature of the Trinity River at North Fork, January through August

For river lamprey, the percent of egg cohorts experiencing water temperatures that exceed 71.6°F is predicted to be 0% under EBC1 and EBC2, <1% under EBC2_ELT, PP_ELT, and PP_LLT, and <2% under EBC2_LLT (Figure C.5.2-186, Table C.5.2-76). Under early long-term conditions, implementation of the preliminary proposal (PP_ELT) would result in one more cohort exposed to temperatures exceeding 71.6°F, a 100% increase relative to EBC2_ELT (1 cohort) (Table C.5.2-78). Under late long-term conditions, implementation of the preliminary proposal (PP_LLT) would result in exposure of two fewer cohorts to temperatures exceeding 71.6°F, a 40% decrease relative to EBC2_LLT (three cohorts). Mean monthly water temperatures in the North Fork of the Trinity River are predicted to be below 77°F between February and June under all model scenarios except PP_LLT, which would result in exposure of two cohorts.

These results indicate that there would be slight changes in the numbers of Pacific and river lamprey egg cohorts exposed to temperatures greater than 71.6°F and 77°F in the North Fork of the Trinity River due to effects of climate change. Preliminary proposal effects are minimal, particularly in comparison to climate change effects. Because this analysis uses water temperature model outputs based on CALSIM outputs, error has been propagated and the level of certainty of these results is moderate.

Redd Dewatering

Downstream of Lewiston

For Pacific lamprey, the total predicted number of redd cohorts between January and August experiencing a month-over-month decrease in flow of greater than 50% in the Trinity River

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downstream of Lewiston ranged between 129 (EBC2, EBC2_ELT, and PP_LLT) and 131 cohorts (EBC1, EBC2_LLT and PP_ELT) (Table C.5.2-56).

There are zero and two fewer Pacific lamprey redd cohorts (0% and 2%, respectively) predicted to experience a month-over-month change in flow of greater than 50% in the Stanislaus River at the confluence of the San Joaquin River for PP_ELT and PP_LLT, respectively, relative to the EBC1 (Table C.5.2-57). There are two and zero more redd cohorts (2% and 0%, respectively) predicted to experience a month-over-month change in flow of greater than 50% in the Stanislaus River at the confluence of the San Joaquin River for PP_ELT and PP_LLT, respectively, relative to the EBC2.

Isolating the effect of the preliminary proposal from the effects of climate change, there are two more redd cohorts (2%) predicted to experience a month-over-month change in flow of greater than 50% for PP_ELT relative to EBC2_ELT. Alternatively, there are two fewer redd cohorts (2%) predicted to experience a month-over-month change in flow of greater than 50 for PP_LLT relative to EBC2_LLT.

For river lamprey, the predicted number of redd cohorts experiencing a month-over-month decrease in flow of more than 50% in the Stanislaus River at the confluence with the San Joaquin River is between 68 (PP_LLT) and 72 cohorts (EBC2) (Table C.5.2-58).

There are one and three fewer redd cohorts (1% and 4%, respectively) predicted to experience a month-over-month change in flow of greater than 50% in the Trinity River downstream of Lewiston under the PP_ELT and PP_LLT, respectively, relative to the EBC1 (Table C.5.2-59). There are two and four fewer redd cohorts (3% and 6%, respectively) predicted to experience a month-over-month change in flow of greater than 50% in the Stanislaus River at the confluence of the San Joaquin River under the PP_ELT and PP_LLT, respectively, relative to the EBC2).

Removing the effect of climate change, there is one more redd cohort (1%) predicted to experience a month-over-month change in flow of greater than 50 in the PP_ELT relative to the EBC2_ELT. Alternatively, there is one fewer redd cohort (1%) predicted to experience a month-over-month change in flow of greater than 50 under the PP_LLT relative to the EBC2_LLT.

These results indicate that the numbers of Pacific and river lamprey redd cohorts predicted to experience a month-over-month change in flow of greater than 50% in the Trinity River, which is assumed here to represent a redd dewatering event, vary only slightly among all model scenarios. Therefore, collectively, there are no clear effects of the preliminary proposal on redd dewatering in the Trinity River for either species.

Ammocoete

Water Temperature

For Pacific lamprey, water temperatures above 22°C (71.6°F) may cause significant death (~50%) or deformation of eggs and ammocoetes (Meeuwig et al. 2005). Therefore, the number of Pacific lamprey ammocoete "cohorts" were examined that experience water temperatures greater than 71.6°F for at least 1 month in the Trinity, Feather, American, and Stanislaus rivers (using the Reclamation Water Temperature Model) over a 7-year period, the maximum likely duration of the ammocoete life stage (Moyle 2002).

For river lamprey, the effects analysis was conducted using both 71.6°F and 77°F as thresholds over a 5-year period, the maximum likely duration of the ammocoete life stage (Moyle 2002). As

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described for Pacific lamprey, each individual month starts a new ammocoete cohort, corresponding to 380 cohorts from February through June for 82 years for the Trinity, Feather, American, and Stanislaus rivers.

The number of cohorts exposed to water temperatures above 71.6°F for Pacific lamprey is reported in Table C.5.2-60, and above 71.6°F and 77°F for river lamprey in Table C.5.2-62; differences between model scenarios are reported in Table C.5.2-61 for Pacific lamprey and in Table C.5.2-63 for river lamprey. Mean monthly water temperatures in the Trinity River at Lewiston and at North Fork are presented in Figure C.5.2-187 and Figure C.5.2-188, respectively.

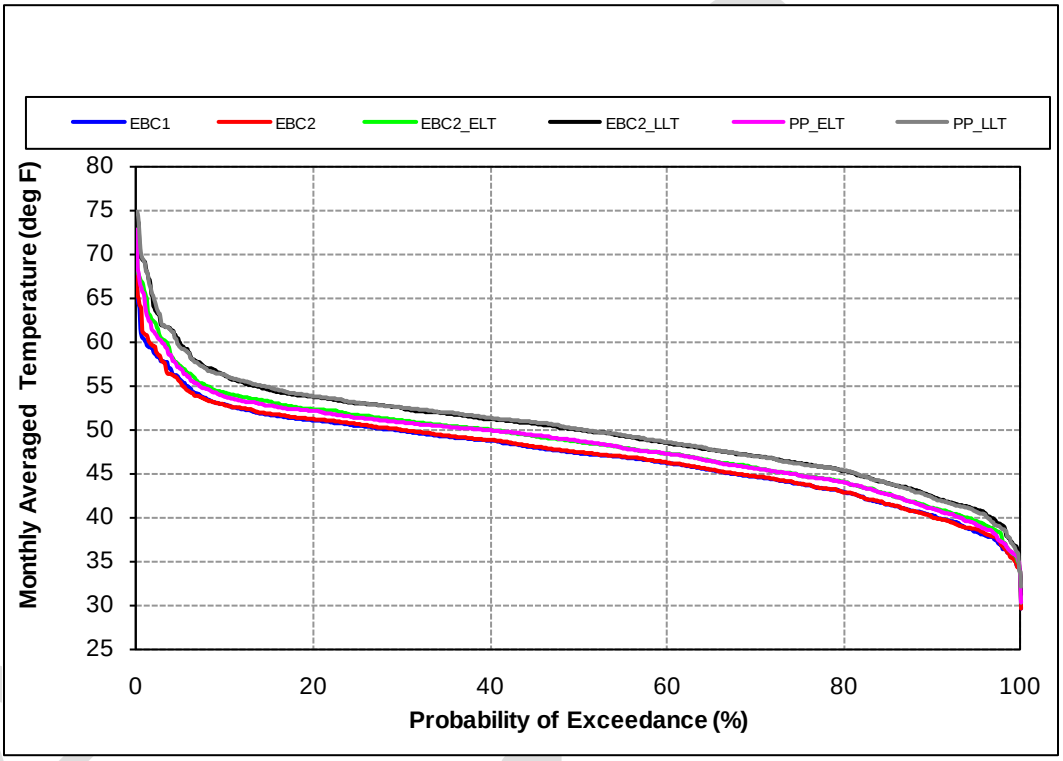

Figure C.5.2-187. Probability of Exceedance Plot for Model Scenarios of Mean Monthly Temperature of the Trinity River at Lewiston in All Months

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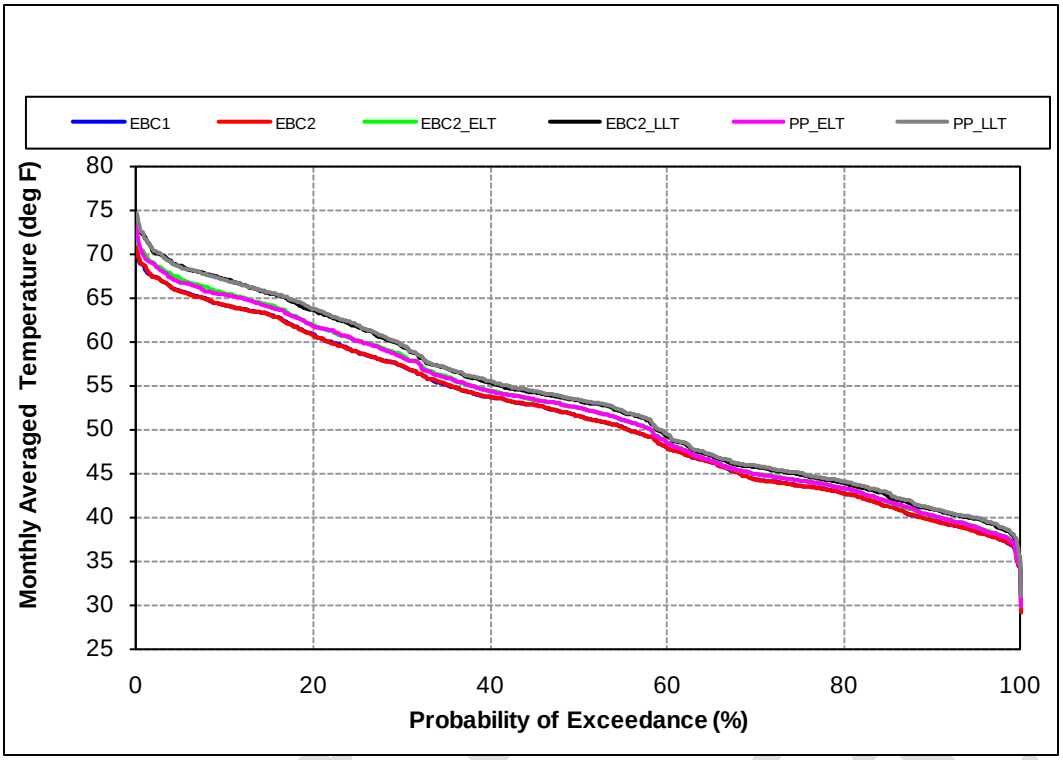

Figure C.5.2-188. Probability of Exceedance Plot for Model Scenarios of Mean Monthly Temperature of the Trinity River at North Fork in All Months

Lewiston

For Pacific lamprey in the Trinity River at Lewiston, the percent of ammocoete cohorts experiencing water temperatures exceeding 71.6°F is predicted to be 0% under EBC1 and EBC2, 0% under EBC2_ELT, 32% under EBC2_LLT, 9% under PP_ELT, and 23% under PP_LLT (Table C.5.2-60). Under early long-term conditions, implementation of the preliminary proposal (PP_ELT) would result in exposure of 56 cohorts to temperatures exceeding 71.6°F versus 56 cohorts in the absence of implementation of the preliminary proposal (EBC2_ELT). Under late long-term conditions, implementation of the preliminary proposal (PP_LLT) would result in exposure of 137 cohorts to temperatures exceeding 71.6°F, a 21% increase relative to EBC2_LLT (113 cohorts) (Table C.5.2-61).

For river lamprey, the percent of ammocoete cohorts experiencing water temperatures that exceed 71.6°F is predicted to be 0% under EBC1 and EBC2, 7% under EBC2_ELT; 13% under EBC2_LLT; 7% under PP_ELT; and 17% under PP_LLT (Table C.5.2-62). Under early long-term conditions, implementation of the preliminary proposal (PP_ELT) would result in exposure of 25 cohorts to temperatures exceeding 71.6°F versus 25 cohorts in the absence of implementation of the preliminary proposal (EBC2_ELT). Under late long-term conditions, implementation of the preliminary proposal (PP_LLT) would result in exposure of 65 cohorts to temperatures exceeding 71.6°F, a 30% increase relative to EBC2_LLT (50 cohorts) (Table C.5.2-63).

The percent of river lamprey ammocoete cohorts experiencing water temperatures that exceed 77°F is predicted to be 0% under all model scenarios (Table C.5.2-62) resulting in no differences between pairs of model scenarios (50 cohorts) (Table C.5.2-63).

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These results indicate no effects of the preliminary proposal on Pacific lamprey ammocoetes in the Trinity River at Lewiston under early long-term conditions, and a moderate adverse effect under late long-term conditions. Results also indicate that, with respect to the 71.6°F threshold, there are no effects of the preliminary proposal on river lamprey ammocoetes in the Trinity River at Lewiston in the ELT and moderate adverse effect under late long-term conditions. There are negligible effects of the preliminary proposal using the 77°F threshold.

North Fork

For Pacific lamprey at North Fork, the proportion of ammocoete cohorts experiencing water temperatures exceeding 71.6°F is predicted to be 0% under EBC1 and EBC2, 11%–33% under EBC2_ELT and EBC_LLT, and 11%–21% under PP_ELT and PP_LLT (Table C.5.2-60). Under early long-term conditions, implementation of the preliminary proposal (PP_ELT) would result in no change in the number of cohorts exposed to temperatures exceeding 71.6°F relative to EBC2_ELT (65 cohorts). Under late long-term conditions, implementation of the preliminary proposal (PP_LLT) would result in exposure of 122 cohorts to temperatures exceeding this threshold, a 37% decrease relative to EBC2_LLT (193 cohorts) (Table C.5.2-61).

For river lamprey at North Fork, the percent of ammocoete cohorts experiencing water temperatures that exceed 71.6°F is predicted to be 0% under EBC1 and EBC2, 8%–24% under EBC2_ELT and EBC2_LLT, and 8%–15% under PP_ELT and PP_LLT (Table C.5.2-62). Under early long-term conditions, implementation of the preliminary proposal (PP_ELT) would result in no change in the number of cohorts exposed to temperatures exceeding 71.6°F relative to EBC2_ELT (30 cohorts). Under late long-term conditions, implementation of the preliminary proposal (PP_LLT) would result in exposure of 56 cohorts to temperatures exceeding 71.6°F, a 38% decrease relative to EBC2_LLT (90 cohorts) (Table C.5.2-63).

The percent of ammocoete cohorts experiencing water temperatures that exceed 77°F is predicted to be 0% under EBC1 and EBC2, 7%–15% under EBC2_ELT and EBC2_LLT, and 7%–8% under PP_ELT and PP_LLT (Table C.5.2-62). Under early long-term conditions, implementation of the preliminary proposal (PP_ELT) would result in no change in the number of cohorts exposed to temperatures exceeding 77°F relative to EBC2_ELT (25 cohorts). Under late long-term conditions, implementation of the preliminary proposal (PP_LLT) would result in exposure of 30 cohorts to temperatures exceeding 77°F, a 46% decrease relative to EBC2_LLT (55 cohorts) (Table C.5.2-63).

These results indicate that climate change will cause temperature-related effects on Pacific lamprey ammocoetes that the preliminary proposal can offset partially in both the early long-term and late long-term at North Fork. The preliminary proposal would add to the negative effect at Lewiston but offset climate change effects in the late long-term. Overall, the preliminary proposal would have both small benefits to and adverse effects on Pacific lamprey survival in the early long-term, depending on location in the Trinity River, and consistent small benefits in the late long-term.

Results indicate that the effects of the preliminary proposal on river lamprey ammocoetes in the Trinity River at North Fork are moderately beneficial in the early long-term and that there is no effect in the late long-term at both the 71.6°F and 77°F thresholds.

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Stranding

Trinity River at Lewiston

The number of Pacific lamprey ammocoete cohorts that may be affected by month-over-month flow reductions in the Trinity River at Lewiston is presented in Figure C.5.2-189, and differences between model scenarios are presented in Table C.5.2-79.

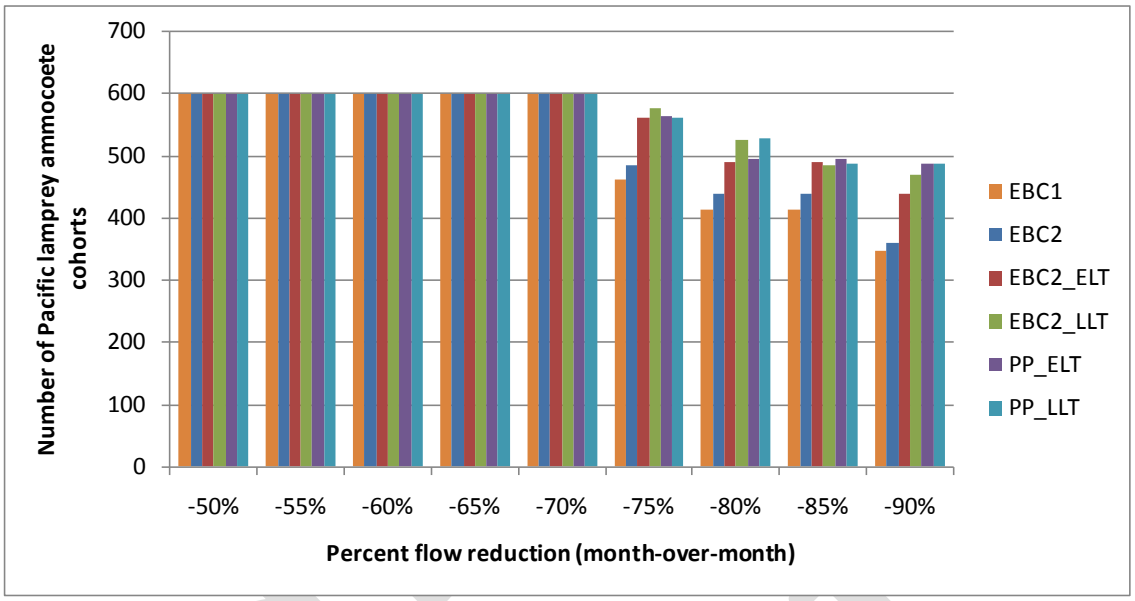

Figure C.5.2-189. Number of Pacific Lamprey Ammocoete Cohorts Exposed to Month-over-Month Flow Reductions of 50% to 90%, Trinity River at Lewiston

Table C.5.2-79. Percent Difference between Model Scenarios in the Number of Pacific Lamprey Ammocoete Cohorts Exposed to Month-over-Month Flow Reductions, Trinity River at Lewiston

Percent Flow Reduction	Percent Difference[1]					
	EBC1 vs. PP_ELT	EBC1 vs. PP_LLT	EBC2 vs. PP_ELT	EBC2 vs. PP_LLT	EBC2_ELT vs. PP_ELT	EBC2_LLT vs. PP_LLT
-50%	0.0	0.0	0.0	0.0	0.0	0.0
-55%	0.0	0.0	0.0	0.0	0.0	0.0
-60%	0.0	0.0	0.0	0.0	0.0	0.0
-65%	0.0	0.0	0.0	0.0	0.0	0.0
-70%	0.0	0.0	0.0	0.0	0.0	0.0
-75%	21.8	21.0	16.0	15.2	0.5	-2.8
-80%	20.1	27.6	12.7	19.8	1.4	0.2
-85%	20.1	17.9	12.7	10.7	1.4	0.2
-90%	40.8	40.8	35.7	35.7	10.9	3.6

[1]Negative values indicate reduced cohort exposure, a benefit of the preliminary proposal.

The number of Pacific lamprey ammocoetes exposed to a given flow reduction is predicted to be 0% to 41% higher under the PP_ELT compared to the EBC1, depending on the flow reduction (Table C.5.2-79). The number of ammocoetes exposed to a given flow reduction is predicted to be 0% to 41% higher under the PP_LLT compared to the EBC1, depending on the flow reduction. The number

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of ammocoetes exposed to a given flow reduction is predicted to be 0% to 36% higher under the PP_ELT compared to the EBC2, depending on the flow reduction. The number of ammocoetes exposed to a given flow reduction is predicted to be 0% to 36% higher under the PP_LLT compared to the EBC2, depending on the flow reduction.

Isolating the effect of the preliminary proposal from the effects of climate change in the early long-term, the number of Pacific lamprey ammocoetes exposed to a given flow reduction is predicted to be 0% to 11% higher under the PP_ELT compared to the EBC2_ELT, depending on the flow reduction. Isolating the effect of the preliminary proposal from the effects of climate change in the late long-term, the number of ammocoetes exposed to a given flow reduction is predicted to be 3% lower to 4% higher under the PP_LLT compared to the EBC2_LLT, depending on the flow reduction.

The number of river lamprey ammocoete cohorts that may be affected by month-over-month flow reductions in the Trinity River at Lewiston is presented in Figure C.5.2-190, and differences between model scenarios are presented in Table C.5.2-80.

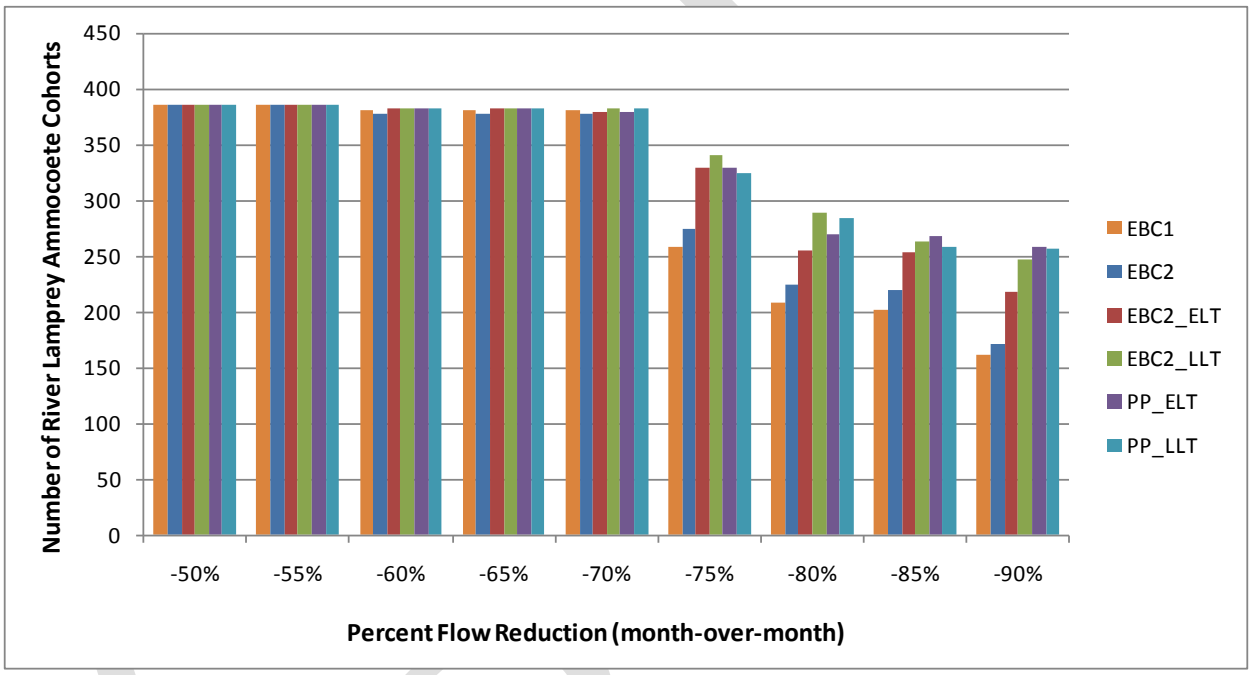

Figure C.5.2-190. Number of River Lamprey Ammocoete Cohorts Exposed to Month-over-Month Flow Reductions of 50% to 90%, Trinity River at Lewiston

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Table C.5.2-80. Percent Difference between Model Scenarios in the Number of River Lamprey Ammocoete Cohorts Exposed to Month-over-Month Flow Reductions, Trinity River at Lewiston

Percent Flow Reduction	Percent Difference[1]					
	EBC1 vs. PP_ELT	EBC1 vs. PP_LLT	EBC vs. PP_ELT	EBC vs. PP_LLT	EBC_ELT vs. PP_ELT	EBC_LLT vs. PP_LLT
-50%	0.0	0.0	0.0	0.0	0.0	0.0
-55%	0.0	0.0	0.0	0.0	0.0	0.0
-60%	0.0	0.0	1.3	1.3	0.0	0.0
-65%	0.0	0.0	1.3	1.3	0.0	0.0
-70%	0.3	0.3	0.8	1.3	0.0	0.0
-75%	0.1	0.1	20.4	18.6	0.3	-4.7
-80%	0.5	0.5	20.0	26.2	5.5	-1.7
-85%	0.0	0.1	22.4	18.3	5.5	-1.9
-90%	-0.6	0.6	50.9	50.3	18.3	4.0

[1] Negative values indicate reduced cohort exposure, a benefit of the preliminary proposal.

The number of river lamprey ammocoetes exposed to a given flow reduction is predicted to be <1% lower to <1% higher under the PP_ELT compared to the EBC1, depending on the flow reduction (Table C.5.2-80). The number of ammocoetes exposed to a given flow reduction is predicted to be 0% to 1% higher under the PP_LLT compared to the EBC1, depending on the flow reduction. The number of ammocoetes exposed to a given flow reduction is predicted to be 0% to 51% higher under the PP_ELT compared to the EBC2, depending on the flow reduction. The number of ammocoetes exposed to a given flow reduction is predicted to be 0% to 50% higher under the PP_LLT compared to the EBC2, depending on the flow reduction.

Isolating the effects of climate change, the number of river lamprey ammocoetes exposed to a given flow reduction is predicted to be 0% to 18% higher under the PP_ELT compared to the EBC2_ELT, depending on the flow reduction. The number of ammocoetes exposed to a given flow reduction is predicted to be between 5% lower and 4% higher under the PP_LLT compared to the EBC2_LLT, depending on the flow reduction.

These results indicate that for both species there are generally small (lower than 10%) effects of the preliminary proposal under both the early and late long-term scenarios, although there is a moderate (11 to 18% higher exposure) adverse effect of the preliminary proposal for the 90% flow reduction scenario in the ELT. The vast proportion of differences between model scenarios is due to climate change.

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C.5.2.3 Clear Creek

C.5.2.3.1 Steelhead

Eggs and Alevins

Upstream Spawning Habitat

The primary spawning and egg incubation period is January through April. Results of these instream flow summaries are presented in Table C.5.2-81. Monthly frequency of exceedance plots for Clear Creek flows are presented in Figure C.5.2-191 through Figure C.5.2-202.

Table C.5.2-81. Mean Monthly Flows (Cubic Feet per Second) in Clear Creek below Whiskeytown during the Year-Round Juvenile Steelhead Rearing Period

Month	WY Type	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
Jan	W	220	220	309	339	309	339
	AN	192	192	192	192	192	192
	BN	189	189	189	189	189	189
	D	184	192	192	192	192	192
	C	155	168	166	159	171	163
	AVG	193	197	225	233	225	234
Feb	W	220	220	249	257	249	257
	AN	197	196	196	196	196	196
	BN	189	189	189	189	189	189
	D	184	192	192	192	192	192
	C	155	168	166	168	171	163
	AVG	194	197	206	209	207	208
Mar	W	200	200	207	259	207	258
	AN	197	205	203	196	196	196
	BN	189	189	192	202	189	196
	D	186	192	192	192	192	192
	C	155	168	166	168	171	163
	AVG	188	193	194	212	194	210
Apr	W	200	200	200	200	200	200
	AN	197	196	196	196	196	196
	BN	189	189	192	189	189	189
	D	188	192	192	192	192	192
	C	155	168	166	168	171	163
	AVG	189	191	191	191	191	190
May	W	277	277	277	277	277	277
	AN	277	277	277	277	277	277
	BN	263	269	269	269	269	269
	D	264	264	264	264	264	264
	C	211	224	224	224	224	224
	AVG	262	265	265	265	265	265

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Month	WY Type	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
Jun	W	200	200	200	200	200	200
	AN	200	200	200	200	200	200
	BN	181	186	186	186	186	186
	D	180	180	180	180	180	180
	C	115	120	120	131	120	120
	AVG	180	181	181	183	181	181
Jul	W	85	85	85	85	85	85
	AN	85	85	85	85	85	85
	BN	85	85	85	85	85	85
	D	85	85	85	85	85	85
	C	85	85	99	85	94	98
	AVG	85	85	87	85	86	87
Aug	W	85	85	85	85	85	85
	AN	85	85	85	85	85	85
	BN	85	85	85	85	85	85
	D	85	85	85	85	85	85
	C	94	94	85	71	94	78
	AVG	86	86	85	83	86	84
Sep	W	150	150	150	150	150	150
	AN	150	150	150	150	150	150
	BN	150	150	150	150	150	150
	D	144	150	150	150	150	150
	C	133	133	121	96	121	83
	AVG	146	148	146	142	146	140
Oct	W	198	198	198	198	198	198
	AN	183	183	183	183	183	183
	BN	189	179	179	182	179	189
	D	175	183	183	183	183	178
	C	150	167	165	142	167	154
	AVG	182	185	185	182	185	184
Nov	W	198	198	198	198	198	198
	AN	185	185	180	182	180	182
	BN	184	189	189	189	189	189
	D	177	184	184	177	176	180
	C	155	168	158	145	158	158
	AVG	183	187	185	182	183	184
Dec	W	198	198	198	198	198	198
	AN	185	192	192	192	192	192
	BN	189	189	189	189	189	189
	D	177	189	189	189	189	189
	C	155	168	166	156	171	150
	AVG	184	189	189	187	190	187

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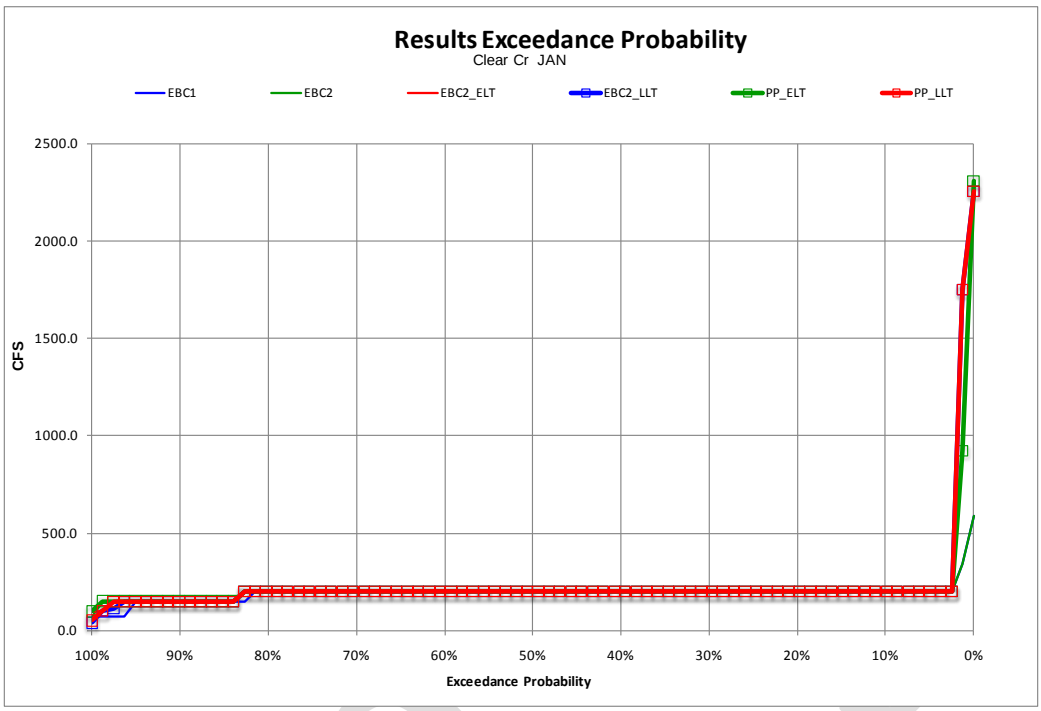

Figure C.5.2-191. Probability of Exceedance Plot for Model Scenarios of Mean Monthly Flow Rate of Clear Creek, January

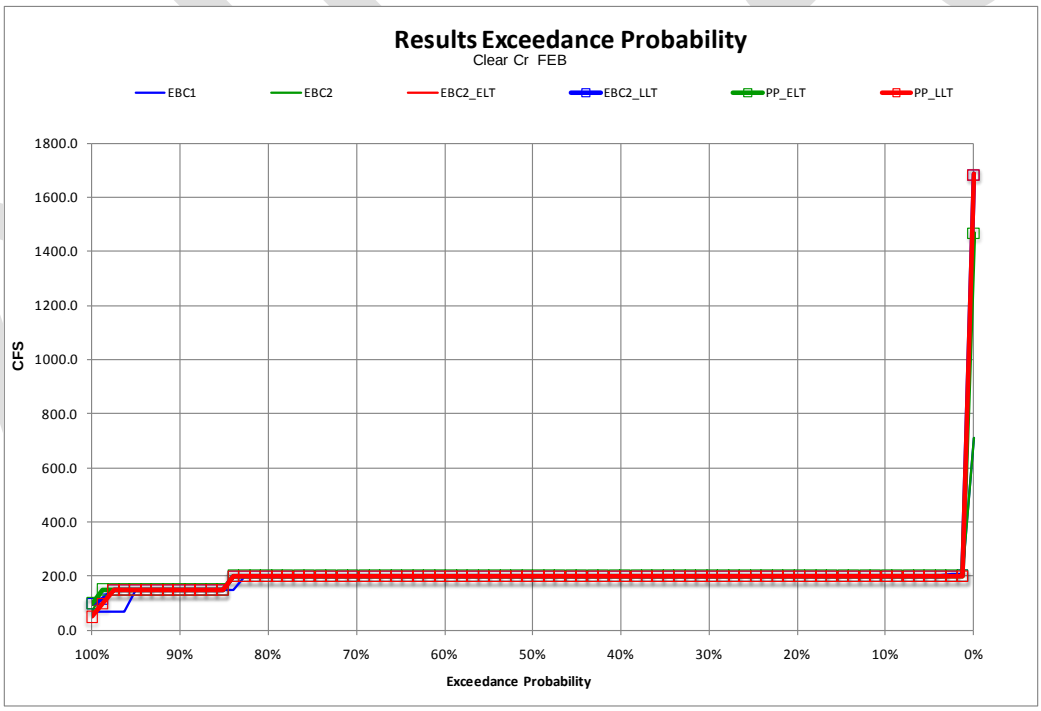

Figure C.5.2-192. Probability of Exceedance Plot for Model Scenarios of Mean Monthly Flow Rate of Clear Creek, February

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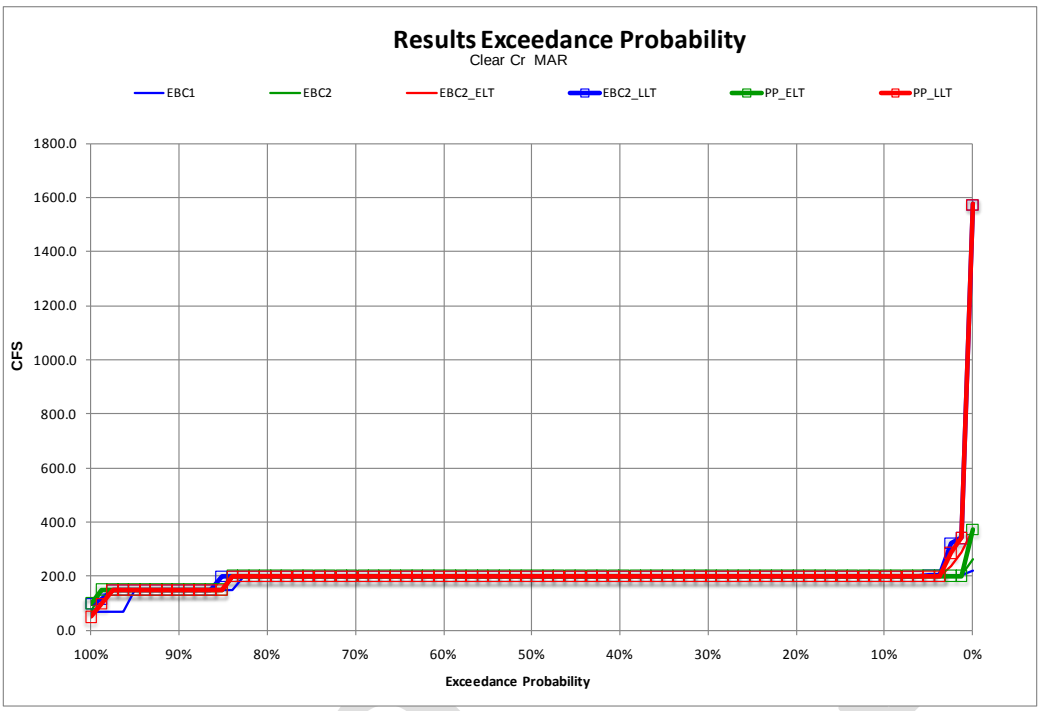

Figure C.5.2-193. Probability of Exceedance Plot for Model Scenarios of Mean Monthly Flow Rate of Clear Creek, March

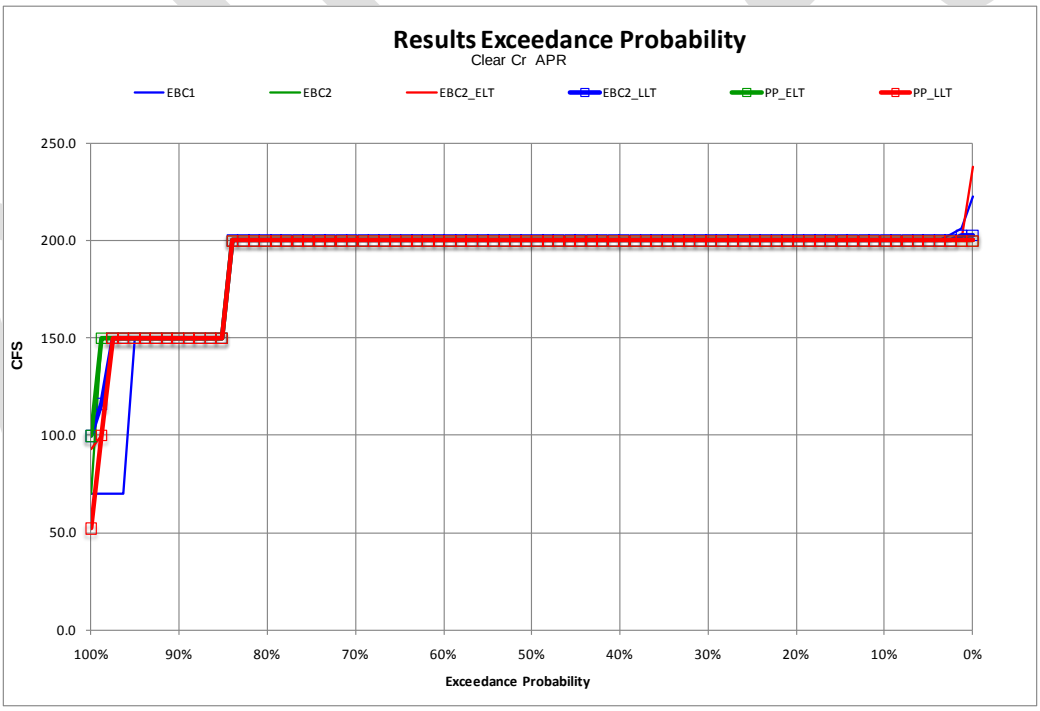

Figure C.5.2-194. Probability of Exceedance Plot for Model Scenarios of Mean Monthly Flow Rate of Clear Creek, April

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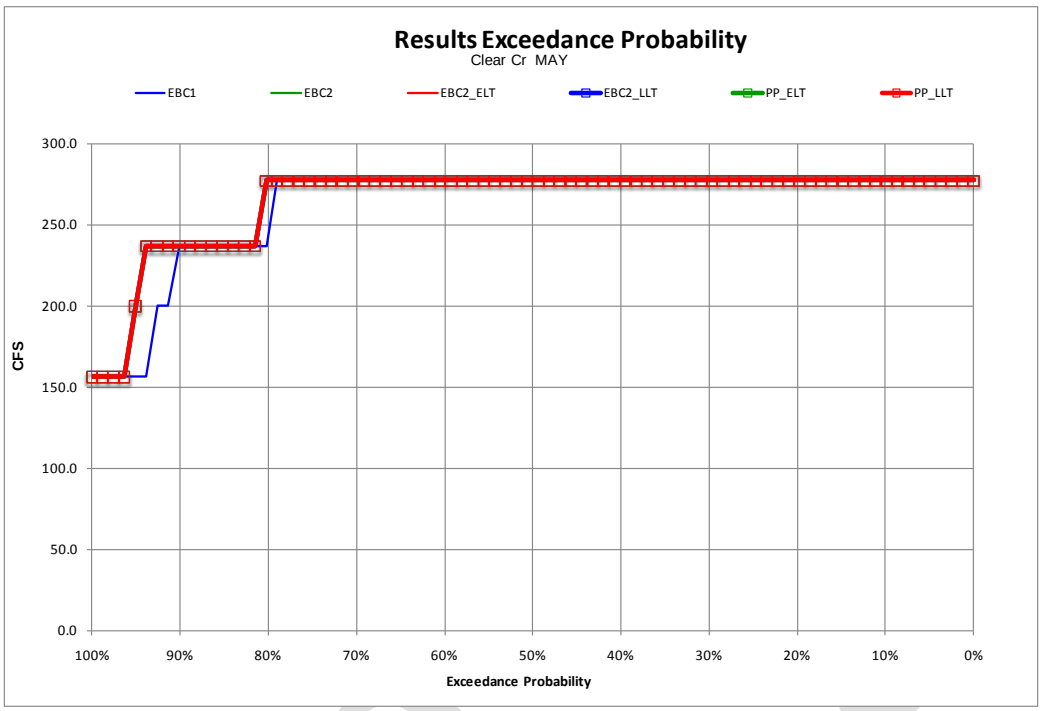

Figure C.5.2-195. Probability of Exceedance Plot for Model Scenarios of Mean Monthly Flow Rate of Clear Creek, May

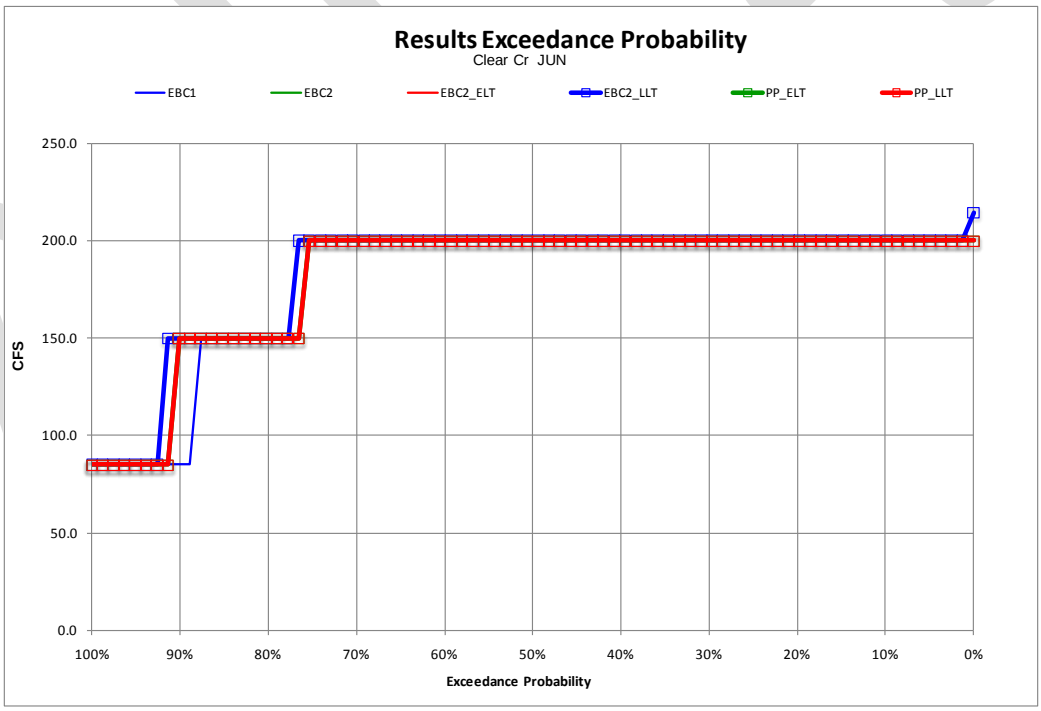

Figure C.5.2-196. Probability of Exceedance Plot for Model Scenarios of Mean Monthly Flow Rate of Clear Creek, June

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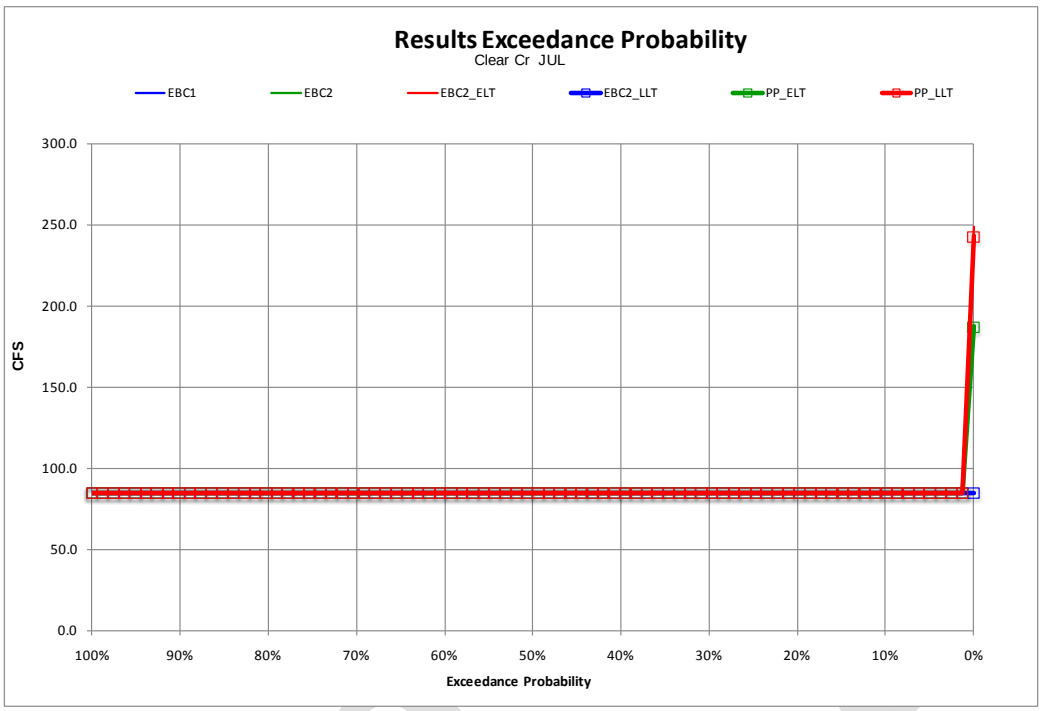

Figure C.5.2-197. Probability of Exceedance Plot for Model Scenarios of Mean Monthly Flow Rate of Clear Creek, July

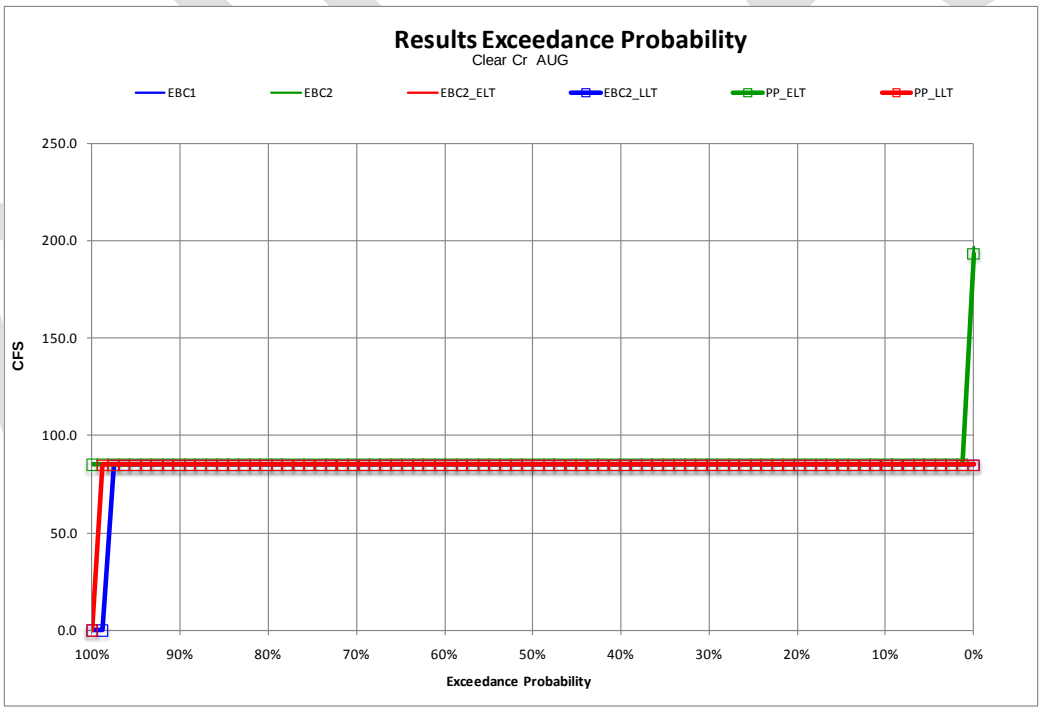

Figure C.5.2-198. Probability of Exceedance Plot for Model Scenarios of Mean Monthly Flow Rate of Clear Creek, August

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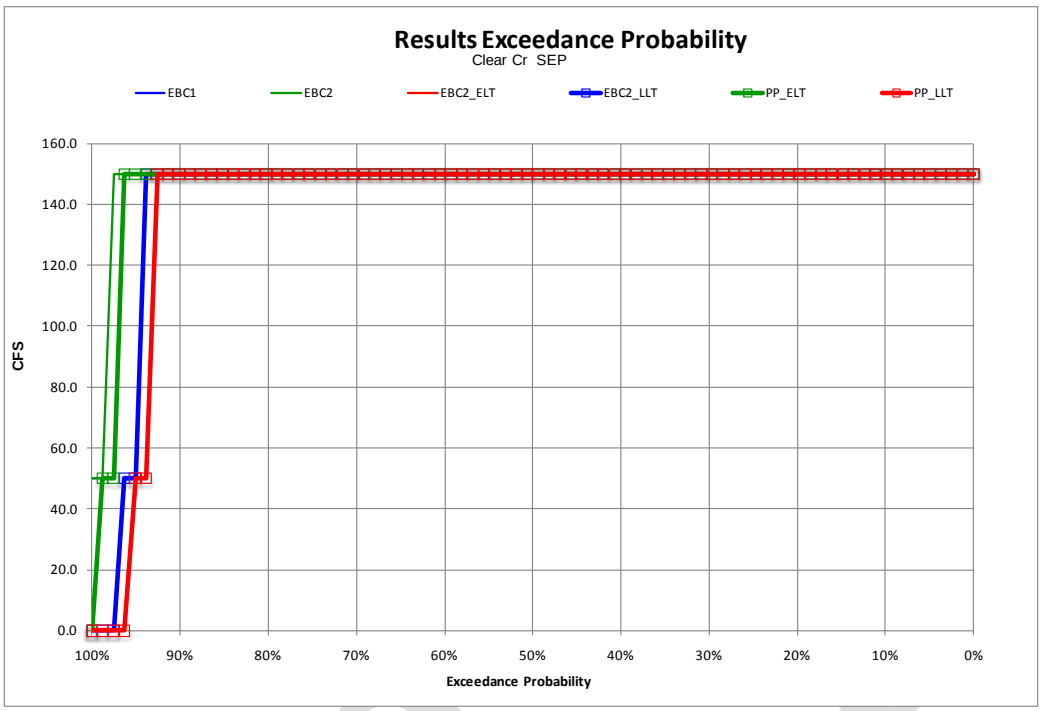

Figure C.5.2-199. Probability of Exceedance Plot for Model Scenarios of Mean Monthly Flow Rate of Clear Creek, September

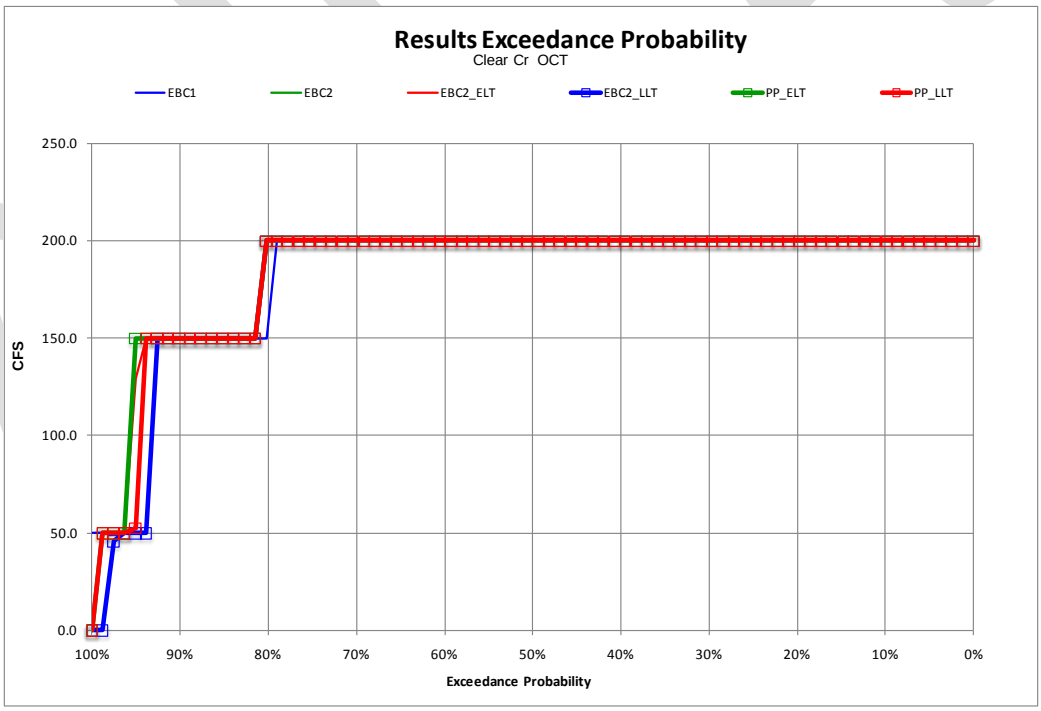

Figure C.5.2-200. Probability of Exceedance Plot for Model Scenarios of Mean Monthly Flow Rate of Clear Creek, October

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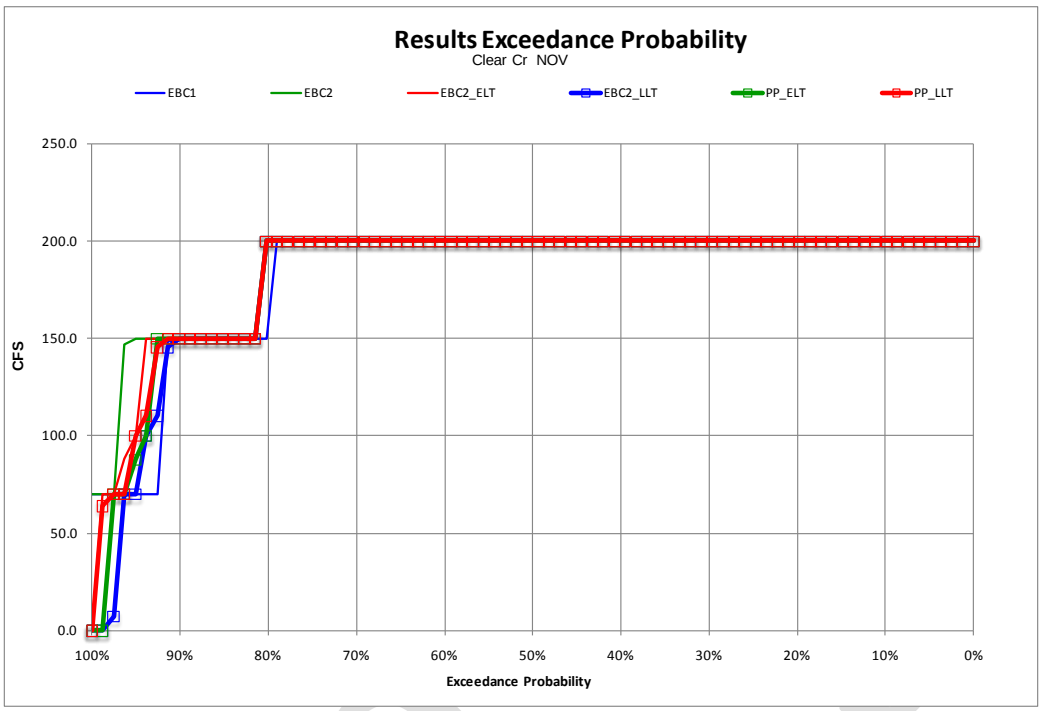

Figure C.5.2-201. Probability of Exceedance Plot for Model Scenarios of Mean Monthly Flow Rate of Clear Creek, November

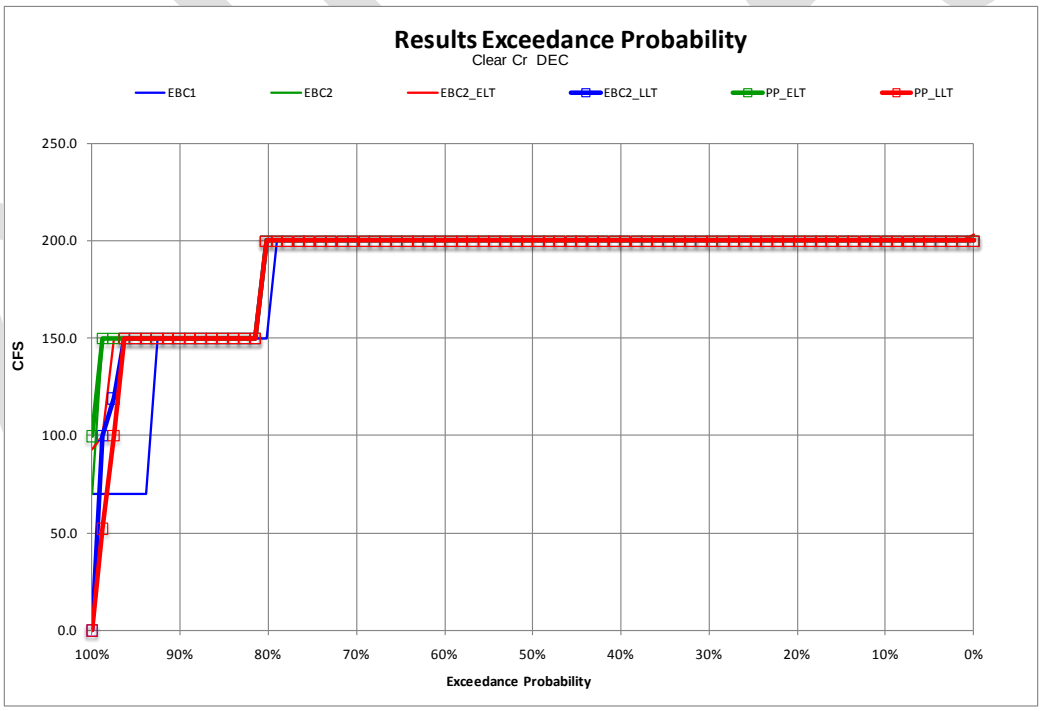

Figure C.5.2-202. Probability of Exceedance Plot for Model Scenarios of Mean Monthly Flow Rate of Clear Creek, December

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Instream flows in Clear Creek during the steelhead spawning and egg incubation period (January through April) are predicted to be similar among all model scenarios. Implementation of the BDCP, therefore, is predicted to have little to no effect on flow in Clear Creek. Climate change effects, although small, are the predominant variable affecting Clear Creek flows.

Water Temperature

Steelhead spawning and egg incubation occur primarily during the winter months when seasonal water temperatures are low and typically within the suitable range for these life stages. No simulation model exists for use in predicting water temperatures in Clear Creek. In the absence of model predictions, based on similarities in simulated flows, it was concluded that water temperatures under PP_ELT and PP_LLT would not differ from EBC2_ELT and EBC2_LLT, respectively, (Table C.5.2-81, Figure C.5.2-191 through Figure C.5.2-202).

Redd Dewatering

To evaluate the potential risk of redd dewatering for steelhead within Clear Creek, it was assumed that steelhead spawn in January and that the eggs and alevins incubate through April. Results of monthly simulation flows were used to determine the magnitude of flow reduction that occurred each month over the incubation period compared to the flow in January when spawning occurred. In the absence of quantitative information on the relationship between instream flows and spawning habitat for steelhead within Clear Creek, an index of the risk of redd dewatering was derived from results of the CALSIM hydrologic simulation modeling. The index of risk for redd dewatering is based on the greatest percentage change (reduction) in flows in any month during the egg incubation period when compared to the flows during the previous month when spawning was assumed to occur. Results of the flow analyses for the risk of redd dewatering are summarized in Table C.5.2-82. These results indicate that preliminary proposal operations would not affect the risk of redd dewatering in Clear Creek.

Table C.5.2-82. Greatest Monthly Reduction (Percent Change) in Instream Flow in Clear Creek during the January through April Steelhead Spawning and Egg Incubation Period[1]

Water-Year Type	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
Wet	-66	-66	-91	-91	-91	-91
Above Normal	0	0	0	0	0	0
Below Normal	0	0	0	0	0	0
Dry	0	0	0	0	0	0
Critical	0	0	0	0	0	0

[1] Redd dewatering risk not applicable for months when flows during the egg incubation period were at or greater than flows in the month when spawning is assumed to occur.

Fry and Juvenile Rearing

Rearing Habitat

Steelhead rear in Clear Creek throughout the year. Instream flows estimated from the modeling each month and water-year type were used to compare among model scenarios (Table C.5.2-81, Figure C.5.2-191 through Figure C.5.2-202). It was assumed that habitat for juvenile steelhead rearing would be constrained by the month having the lowest instream flows. Juvenile rearing habitat is

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assumed to increase in Clear Creek as instream flows increase, and therefore the use of the lowest monthly instream flow as an index of habitat constraints for juvenile rearing was selected for use in this analysis. Results of the analysis of minimum monthly instream flows affecting juvenile rearing habitat are shown in Table C.5.2-81.

Results predict that juvenile rearing habitat, based on instream flows, was comparable for EBC and PP scenarios. Therefore, it was concluded that there was no difference in juvenile steelhead rearing habitat conditions (as constrained by the lowest monthly instream flow) for steelhead within Clear Creek between EBC2_ELT and PP_ELT and between EBC2_LLT and PP_LLT.

Flows in Clear Creek are unchanged between the scenarios (Table C.5.2-81, Figure C.5.2-191 through Figure C.5.2-202). The only changes occur during the winter as a result of uncontrolled tributary runoff, which changes slightly with the climate change scenarios. Denton (1986) developed flow recommendations for steelhead in Clear Creek using IFIM (Figure C.5.2-203). The current Clear Creek management regime uses flows slightly lower than those recommended by Denton. Results from a new IFIM study on Clear Creek are currently being analyzed. Depending on results of this study the flow regime could be adjusted in the future. We expect that the modeled flows will be suitable for the existing steelhead populations in Clear Creek. No change in effect on steelhead in Clear Creek is anticipated.

Based on results of the flow and temperature analysis for juvenile steelhead rearing in Clear Creek, we conclude that, because instream flows will be unchanged between EBC2_ELT and PP_ELT and between EBC2_LLT and PP_LLT, there will not be effects of the preliminary proposal on steelhead habitat in Clear Creek.

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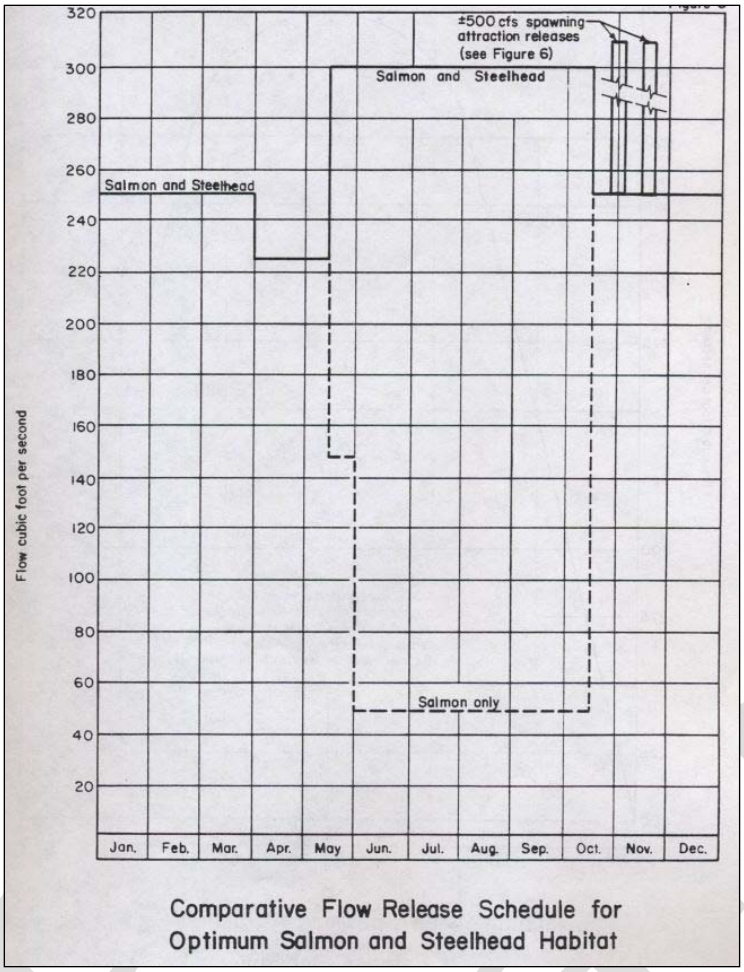

Figure C.5.2-203. Clear Creek Flow Recommendations from Denton (1986) Instream Flow Incremental Methodology Study

Adult

Water Temperature

Water temperatures in Clear Creek are not modeled in the Reclamation Temperature Model. Therefore, effects to water temperature relied on Clear Creek flows as a surrogate. CALSIM flow outputs are presented in Table C.5.2-81. For all months and all water-year types, there is no difference between EBC2_ELT and PP_ELT or between EBC2_LLT and PP_LLT. Flows are higher under EBC2_LLT than under EBC2_ELT and higher under EBC2_ELT than under EBC2. These results indicate that, although future climate change will increase flows, and, therefore, lower water temperatures in Clear Creek, the BDCP is not expected to affect flows or temperature.

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C.5.2.3.2 Spring-Run

Eggs and Alevins

Upstream Spawning Habitat

Spring-run Chinook salmon use Clear Creek downstream of the water delivery point from Whiskeytown Reservoir as adult holding habitat, and for spawning and egg incubation, juvenile rearing, and upstream and downstream migration by adults and juveniles. Clear Creek currently supports a population of adult spring-run Chinook salmon of approximately 200 individuals.

Instream flows in Clear Creek during the spring-run Chinook salmon spawning and egg incubation period (September through January) are presented in Table C.5.2-81, Figure C.5.2-191, and Figure C.5.2-199 through Figure C.5.2-202. There is no biologically meaningful difference in instream flows and, therefore, spring-run spawning habitat between EBC2_ELT and PP_ELT or between EBC2_LLT and PP_LLT.

Water Temperature

Spring-run Chinook salmon spawning and egg incubation occur in Clear Creek, which is supplied with water exported from the Trinity River system and Whiskeytown Reservoir. It was assumed that exposure of eggs to water temperatures in excess of 56°F during the incubation period would result in adverse impacts on reproductive success, including egg mortality. Spring-run salmon spawn in the late summer and early fall (i.e., September and October), when seasonal air temperatures in the Redding area are high and, therefore, the water temperatures in Clear Creek are subject to warming. Currently, no water temperature model exists for evaluating Clear Creek temperatures. No simulation model exists for use in predicting water temperatures in Clear Creek. In the absence of model predictions, it was assumed that water temperatures would be negatively correlated with instream flows. Instream flows within Clear Creek (Table C.5.2-81 and Figure C.5.2-191 through Figure C.5.2-202) were assessed based on results of CALSIM modeling. Based on the similarity in flows, no biologically meaningful differences in water temperatures are predicted between EBC2_ELT and PP_ELT and between EBC2_LLT and PP_LLT.

Redd Dewatering

In the absence of analytic tools for quantitatively assessing the effects of flow reduction on Clear Creek that would result in a risk of redd dewatering during egg incubation, it was assumed that spring-run Chinook salmon spawn in September, and that a reduction in instream flows during the following October through January of greater than 5% would result in an increased risk of redd dewatering. Predicted CALSIM flows in Clear Creek below Whiskeytown during October through January are always equal to or greater than the spawning flows during September (Table C.5.2-81, Figure C.5.2-191, and Figure C.5.2-199 through Figure C.5.2-202). Based on these results, it was concluded that there would be no risk of redd dewatering between EBC2_ELT and PP_ELT and between EBC2_LLT and PP_LLT.

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Fry and Juvenile Rearing

Rearing Habitat

Examination of predicted Clear Creek instream flows by month and water-year type during the year-round spring-run Chinook salmon rearing period showed that instream flows and physical habitat conditions (e.g., water depths, velocities, wetted cross section) are predicted to be similar between EBC2_ELT and PP_ELT and between EBC2_LLT and PP_LLT (Table C.5.2-81). The only months with differences between scenarios are during critical water years: July flows are greater under PP_LLT than EBC2_LLT and September flows are lower under PP_LLT than EBC2_LLT. Based on these results, it was concluded that the preliminary proposal would not affect spring-run juvenile rearing habitat conditions in Clear Creek.

Adult

Water Temperature

Due to a lack of quantitative modeling, the evaluation of effects to water temperature employed Clear Creek flows as a surrogate. CALSIM flow outputs are presented in Table C.5.2-81. For all months and all water-year types, there is no difference between EBC2_ELT and PP_ELT or between EBC2_LLT and PP_LLT. Flows are higher under EBC2_LLT than under EBC2_ELT and under EBC2_ELT than under EBC2. These model scenarios (EBC2, EBC2_ELT, and EBC2_LLT) differ only in climate change assumptions. These results indicate that, although future climate change will increase flows, and, therefore, lower water temperatures in Clear Creek, the BDCP is not expected to affect flows or temperature.

C.5.2.3.3 Fall-/Late Fall–Run

Eggs and Alevins

Upstream Spawning Habitat

Fall-run Chinook salmon use Clear Creek downstream of the water delivery point from Whiskeytown Reservoir as adult holding habitat, for spawning and egg incubation, juvenile rearing, and as habitat for upstream and downstream migration by adult and juvenile salmon.

Fall-run Chinook salmon eggs are subject to potential effects of BDCP operations on habitat conditions affecting incubation success through (1) changes in seasonal water temperatures that result in increased or decreased egg mortality, and (2) flow reductions after the redd construction, which exposes incubating eggs to dewatering and increased mortality. Instream flows in Clear Creek during the fall-run Chinook salmon spawning and egg incubation period (October through January) are presented in Table C.5.2-81, Figure C.5.2-191 and Figure C.5.2-200 through Figure C.5.2-202. Results of these analyses predict that there would be no difference in instream flows and, therefore, physical habitat between EBC2_ELT and PP_ELT and between EBC2_LLT and PP_LLT.

Water Temperature

Fall-run Chinook salmon spawning and egg incubation occurs in Clear Creek during the early fall (i.e., October through December) when seasonal air temperatures in the Redding area are declining seasonally. No simulation model exists for use in predicting water temperatures in Clear Creek. In

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the absence of model predictions, based on similarities in simulated flows, it was concluded that water temperatures under PP_ELT and PP_LLT would differ from EBC2_ELT and EBC2_LLT, respectively (Table C.5.2-81, Figure C.5.2-191 and Figure C.5.2-200 through Figure C.5.2-202).

Redd Dewatering

No analytical tools exist for quantitatively assessing the effects of flow reduction on Clear Creek following fall-run Chinook salmon spawning that would result in an estimate of the risk of redd dewatering during egg incubation. Therefore it was assumed that fall-run Chinook salmon spawn in Clear Creek in November and that a reduction in instream flows during the following December and January (representing the egg incubation period) of greater than 5% would result in an increased risk of redd dewatering. Predicted CALSIM flows in Clear Creek below Whiskeytown during December and January are always equal to, or greater than, the spawning flows during November (Table C.5.2-81, Figure C.5.2-191, Figure C.5.2-201, and Figure C.5.2-202). Based on these results, it was concluded that there would be no risk of redd dewatering under any model scenario.

Fry and Juvenile Rearing

Rearing Habitat

CALSIM modeling of instream flows in Clear Creek (Table C.5.2-81) during the juvenile fall-run Chinook salmon rearing period (January through May) predict that instream flows and physical habitat conditions (e.g., water depths, velocities, wetted cross-sections) were similar between EBC2_ELT and PP_ELT and between EBC2_LLT and PP_LLT. Based on these results, it was concluded that the preliminary proposal would not affect instream habitat conditions for juvenile fall-run Chinook salmon rearing within Clear Creek.

Adult

Water Temperature

Due to a lack of quantitative modeling, the evaluation of effects to water temperature employed Clear Creek flows as a surrogate. CALSIM flow outputs are presented in Table C.5.2-81. For all months and all water-year types, there is no difference between EBC2_ELT and PP_ELT or between EBC2_LLT and PP_LLT. Flows are higher under EBC2_LLT than under EBC2_ELT and under EBC2_ELT than under EBC2. These model scenarios (EBC2, EBC2_ELT, and EBC2_LLT) differ only in climate change assumptions. These results indicate that, although future climate change will increase flows, and, therefore, lower water temperatures in Clear Creek, the BDCP is not expected to affect flows or temperature.

C.5.2.4 Feather River

C.5.2.4.1 Steelhead

Eggs and Alevins

Upstream Spawning Habitat

The two primary potential effects of BDCP operations on habitat conditions for steelhead spawning and egg incubation in the mainstem Feather River relate to changes in either instream flows or

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seasonal water temperatures released from Oroville Dam or Thermalito Afterbay. The primary seasonal period for spawning and egg incubation extends from January through April. Results of the CALSIM analyses of instream flows within the reach where the majority of steelhead spawning occurs (low-flow channel) were summarized by month and water-year type based on estimated flows above Thermalito Afterbay. Flows during the spawning and egg incubation period in the high-flow channel were characterized based on information in the Feather River at Thermalito Afterbay. Results of these instream flow summaries are presented in Table C.5.2-83 for the low-flow channel (above Thermalito Afterbay) and Table C.5.2-84 for the high-flow channel (at Thermalito Afterbay). Monthly frequency of exceedance plots for Feather River flows during the steelhead spawning and egg incubation period are presented in Figure C.5.2-204 through Figure C.5.2-207 for the low-flow channel and Figure C.5.2-208 through Figure C.5.2-211 for the high-flow channel.

Table C.5.2-83. Mean Monthly Flows (Cubic Feet per Second) in the Feather River Low-Flow Channel (above Thermalito Afterbay)

Month	WY Type	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
Jan	W	800	800	800	800	800	800
	AN	800	800	800	800	800	800
	BN	800	800	800	800	800	800
	D	800	800	800	800	800	800
	C	800	800	800	800	800	800
	AVG	800	800	800	800	800	800
Feb	W	800	800	800	800	800	800
	AN	800	800	800	800	800	800
	BN	800	800	800	800	800	800
	D	800	800	800	800	800	800
	C	800	800	800	800	800	800
	AVG	800	800	800	800	800	800
Mar	W	800	800	800	800	800	800
	AN	800	800	800	800	800	800
	BN	800	800	800	800	800	800
	D	800	800	800	800	800	800
	C	800	800	800	800	800	800
	AVG	800	800	800	800	800	800
Apr	W	700	700	700	700	700	700
	AN	700	700	700	700	700	700
	BN	700	700	700	700	700	700
	D	700	700	700	700	700	700
	C	700	700	700	700	700	700
	AVG	700	700	700	700	700	700
May	W	700	700	700	700	700	700
	AN	700	700	700	700	700	700
	BN	700	700	700	700	700	700
	D	700	700	700	700	700	700
	C	700	700	700	700	700	700
	AVG	700	700	700	700	700	700

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Month	WY Type	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
Jun	W	700	700	700	700	700	700
	AN	700	700	700	700	700	700
	BN	700	700	700	700	700	700
	D	700	700	700	700	700	700
	C	700	700	700	700	700	700
	AVG	700	700	700	700	700	700
Jul	W	700	700	700	700	700	700
	AN	700	700	700	700	700	700
	BN	700	700	700	700	700	700
	D	700	700	700	700	700	700
	C	700	700	700	700	700	700
	AVG	700	700	700	700	700	700
Aug	W	700	700	700	700	700	700
	AN	700	700	700	700	700	700
	BN	700	700	700	700	700	700
	D	700	700	700	700	700	700
	C	700	700	700	700	700	700
	AVG	700	700	700	700	700	700
Sep	W	773	773	773	773	773	773
	AN	773	773	773	773	773	773
	BN	773	773	773	773	773	773
	D	773	773	773	773	773	773
	C	773	773	773	773	773	773
	AVG	773	773	773	773	773	773
Oct	W	800	800	800	800	800	800
	AN	800	800	800	800	800	800
	BN	800	800	800	800	800	800
	D	800	800	800	800	800	800
	C	800	800	800	800	800	800
	AVG	800	800	800	800	800	800
Nov	W	800	800	800	800	800	800
	AN	800	800	800	800	800	800
	BN	800	800	800	800	800	800
	D	800	800	800	800	800	800
	C	800	800	800	800	800	800
	AVG	800	800	800	800	800	800
Dec	W	800	800	800	800	800	800
	AN	800	800	800	800	800	800
	BN	800	800	800	800	800	800
	D	800	800	800	800	800	800
	C	800	800	800	800	800	800
	AVG	800	800	800	800	800	800

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Table C.5.2-84. Mean Monthly Flows (Cubic Feet per Second) in the Feather River High-Flow Channel (at Thermalito)

Month	WY Type	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
Jan	W	11,257	10,642	11,528	11,896	14,103	14,399
	AN	4,434	3,470	3,419	2,838	5,255	4,107
	BN	2,640	1,703	1,692	1,441	2,462	1,584
	D	1,798	1,448	1,477	1,459	1,918	2,168
	C	1,459	1,222	1,378	1,648	1,840	1,403
	AVG	5,277	4,669	4,970	4,995	6,351	6,118
Feb	W	12,466	11,548	13,732	14,787	15,171	16,622
	AN	7,411	5,403	5,793	5,809	8,987	8,138
	BN	3,916	2,797	2,280	1,897	3,202	3,281
	D	1,817	1,620	1,642	1,659	1,964	1,866
	C	1,610	1,477	1,467	1,482	1,483	1,829
	AVG	6,340	5,502	6,166	6,444	7,320	7,699
Mar	W	12,895	12,392	13,977	14,772	14,314	14,988
	AN	7,733	6,950	8,568	8,568	9,517	10,417
	BN	3,373	2,441	2,347	1,985	2,672	2,333
	D	2,017	1,701	1,521	1,762	2,481	2,172
	C	1,697	1,478	1,590	1,634	1,670	1,667
	AVG	6,487	5,953	6,653	6,902	7,176	7,396
Apr	W	6,472	6,510	6,652	6,408	6,770	6,389
	AN	2,251	2,257	2,240	2,170	2,233	2,504
	BN	1,205	1,119	1,132	1,203	1,533	2,152
	D	1,286	1,328	1,448	1,470	2,103	2,681
	C	1,389	1,375	1,384	1,407	1,827	1,903
	AVG	3,073	3,078	3,150	3,084	3,464	3,627
May	W	7,528	7,539	6,380	4,740	6,492	5,415
	AN	3,340	3,262	3,342	3,101	4,322	4,350
	BN	1,205	1,149	1,316	1,749	3,128	3,667
	D	1,591	1,586	1,862	2,223	2,297	2,552
	C	1,574	1,520	1,877	1,790	1,748	1,762
	AVG	3,661	3,635	3,420	3,005	3,985	3,798
Jun	W	5,062	5,139	3,659	4,211	5,181	5,281
	AN	3,301	3,385	3,107	3,930	5,722	6,278
	BN	2,707	2,752	3,153	3,552	5,533	5,456
	D	3,134	3,352	3,432	3,284	3,593	3,496
	C	2,695	2,700	2,812	2,666	2,646	2,563
	AVG	3,632	3,725	3,318	3,628	4,601	4,667
Jul	W	6,490	6,748	7,835	8,577	5,365	6,392
	AN	8,757	9,113	9,434	9,488	7,157	7,576
	BN	8,981	9,094	8,936	8,833	6,475	6,216
	D	8,294	8,266	7,980	8,099	5,997	4,420
	C	6,703	6,040	6,144	5,217	3,224	2,936
	AVG	7,674	7,724	8,041	8,157	5,642	5,597

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Month	WY Type	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
Aug	W	3,308	3,906	5,462	6,228	4,088	4,584
	AN	6,042	6,384	6,948	7,346	5,636	5,708
	BN	6,295	6,448	6,348	6,868	4,502	4,251
	D	7,036	6,106	5,633	4,990	4,265	3,859
	C	2,613	2,625	2,236	2,163	2,652	2,034
	AVG	4,935	4,998	5,396	5,634	4,214	4,159
Sep	W	2,280	8,458	8,400	8,327	1,263	1,172
	AN	2,253	7,021	7,172	6,899	1,680	1,902
	BN	2,466	2,710	3,161	3,068	1,353	1,455
	D	2,366	1,999	1,473	1,052	1,668	1,658
	C	1,421	1,529	1,451	1,345	1,715	1,744
	AVG	2,201	4,835	4,788	4,601	1,494	1,518
Oct	W	3,456	3,204	3,025	3,051	3,153	3,260
	AN	2,386	2,770	2,577	2,741	3,361	3,303
	BN	3,183	2,801	2,820	2,862	3,211	3,043
	D	2,688	2,667	2,786	2,652	2,958	3,220
	C	2,472	2,267	2,233	2,102	2,924	3,506
	AVG	2,940	2,817	2,756	2,747	3,117	3,256
Nov	W	3,292	2,992	2,812	2,470	2,860	2,747
	AN	1,824	2,003	1,915	2,119	2,114	1,915
	BN	2,101	2,043	1,950	1,900	1,762	1,854
	D	1,859	1,733	1,729	1,664	1,801	1,811
	C	1,854	1,860	1,803	1,876	1,901	2,016
	AVG	2,349	2,243	2,148	2,058	2,191	2,160
Dec	W	7,157	5,414	5,543	3,948	7,691	5,927
	AN	2,951	3,328	3,344	3,344	3,382	4,443
	BN	2,176	2,515	2,096	2,102	2,732	2,748
	D	2,364	2,343	2,202	2,229	2,865	2,690
	C	2,609	2,152	1,781	1,694	2,759	2,889
	AVG	3,973	3,462	3,349	2,837	4,433	4,012

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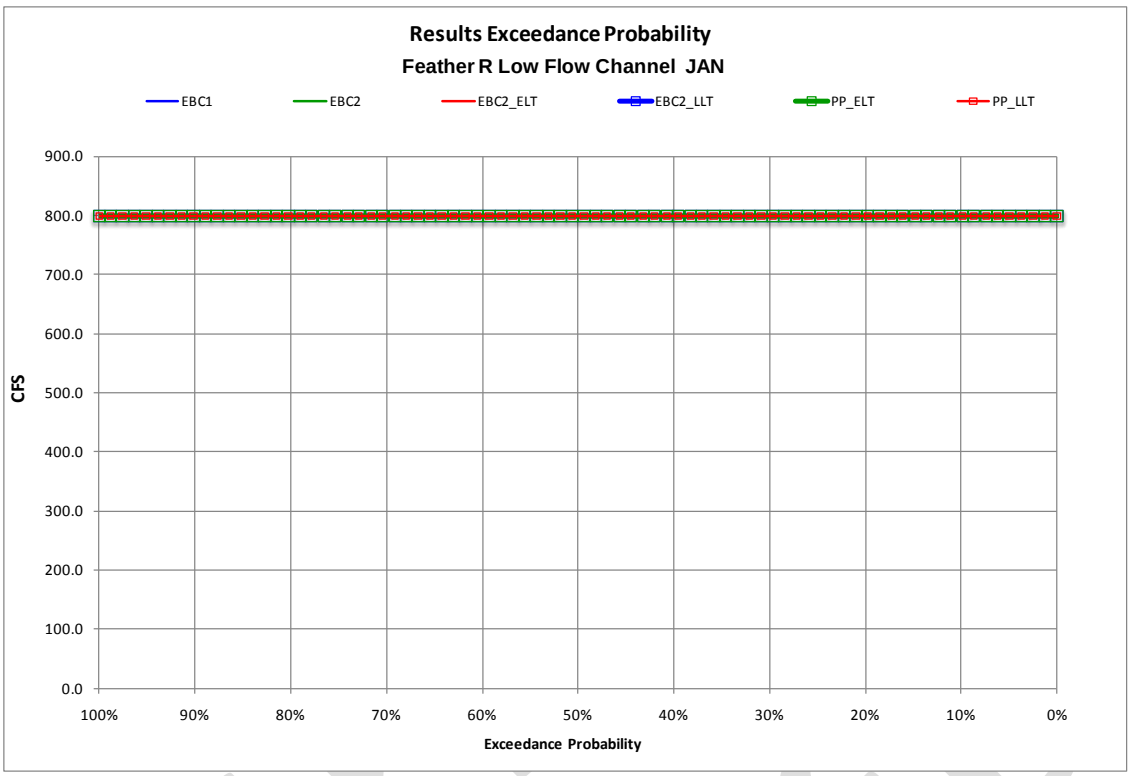

Figure C.5.2-204. Probability of Exceedance Plot for Model Scenarios of Mean Monthly Flow in the Feather River Low-Flow Channel (above Thermalito Afterbay), January

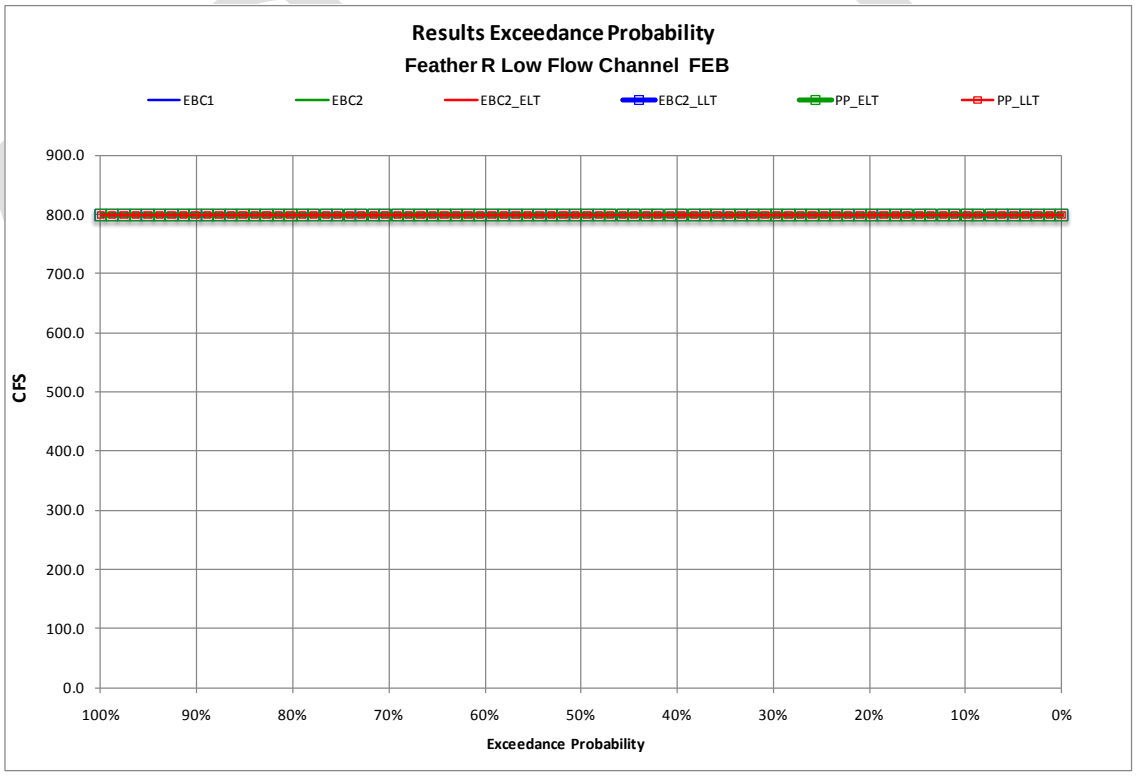

Figure C.5.2-205. Probability of Exceedance Plot for Model Scenarios of Mean Monthly Flow in the Feather River Low-Flow Channel (above Thermalito Afterbay), February

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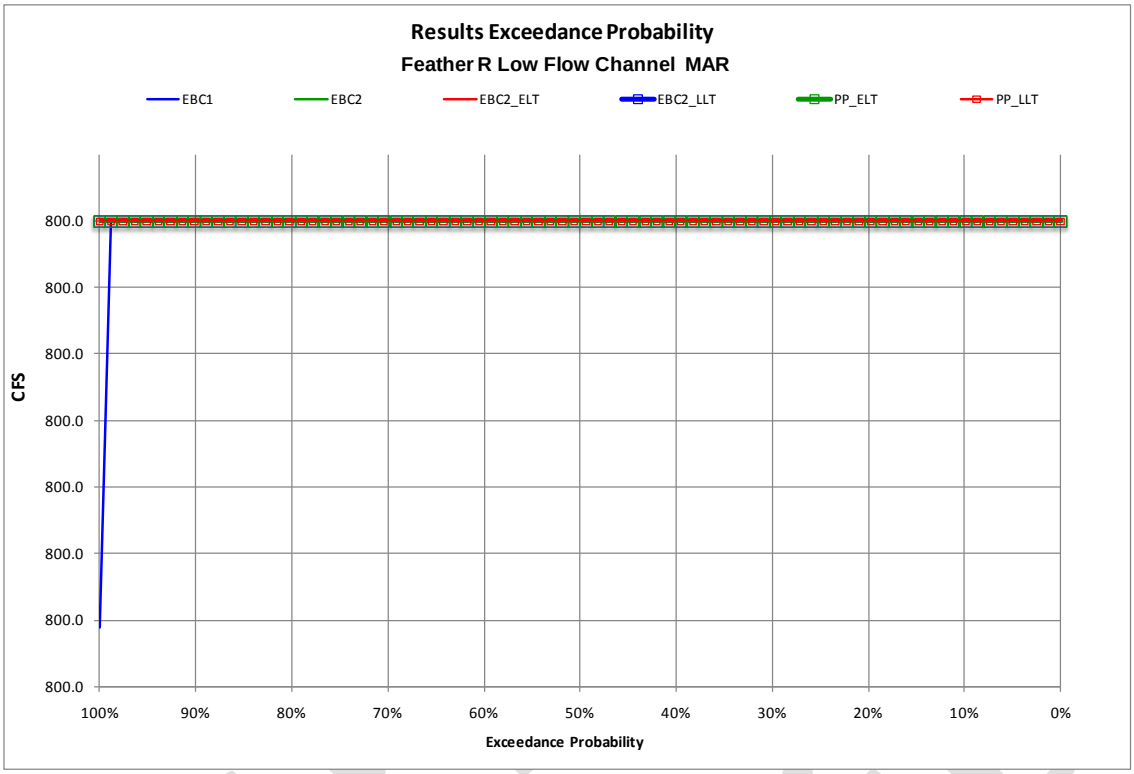

Figure C.5.2-206. Probability of Exceedance Plot for Model Scenarios of Mean Monthly Flow in the Feather River Low-Flow Channel (above Thermalito Afterbay), March

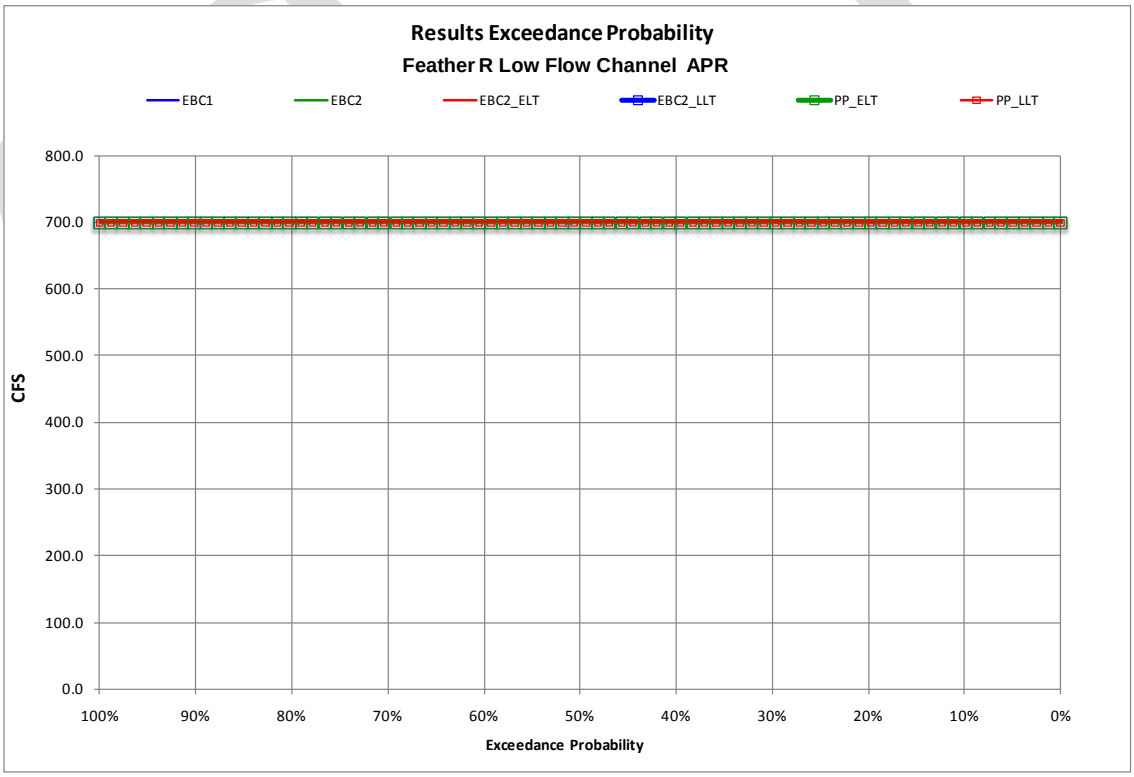

Figure C.5.2-207. Probability of Exceedance Plot for Model Scenarios of Mean Monthly Flow in the Feather River Low-Flow Channel (above Thermalito Afterbay), April

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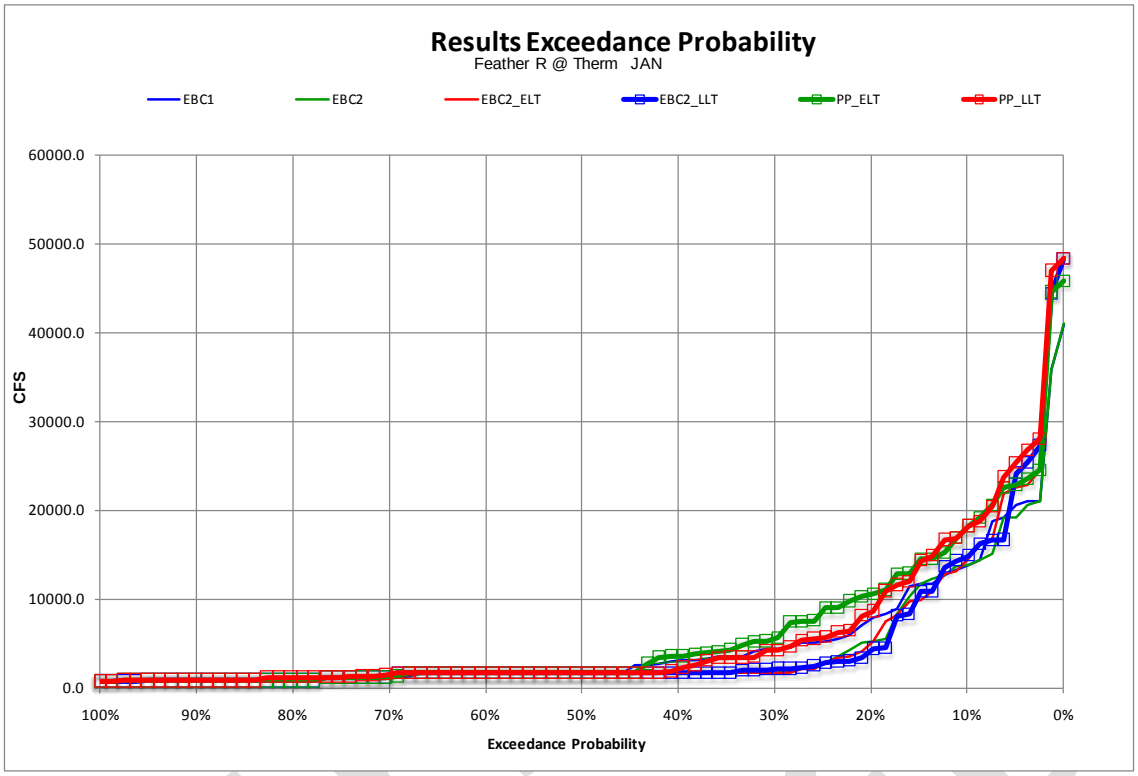

Figure C.5.2-208. Probability of Exceedance Plot for Model Scenarios of Mean Monthly Flow in the Feather River High-Flow Channel (at Thermalito Afterbay), January

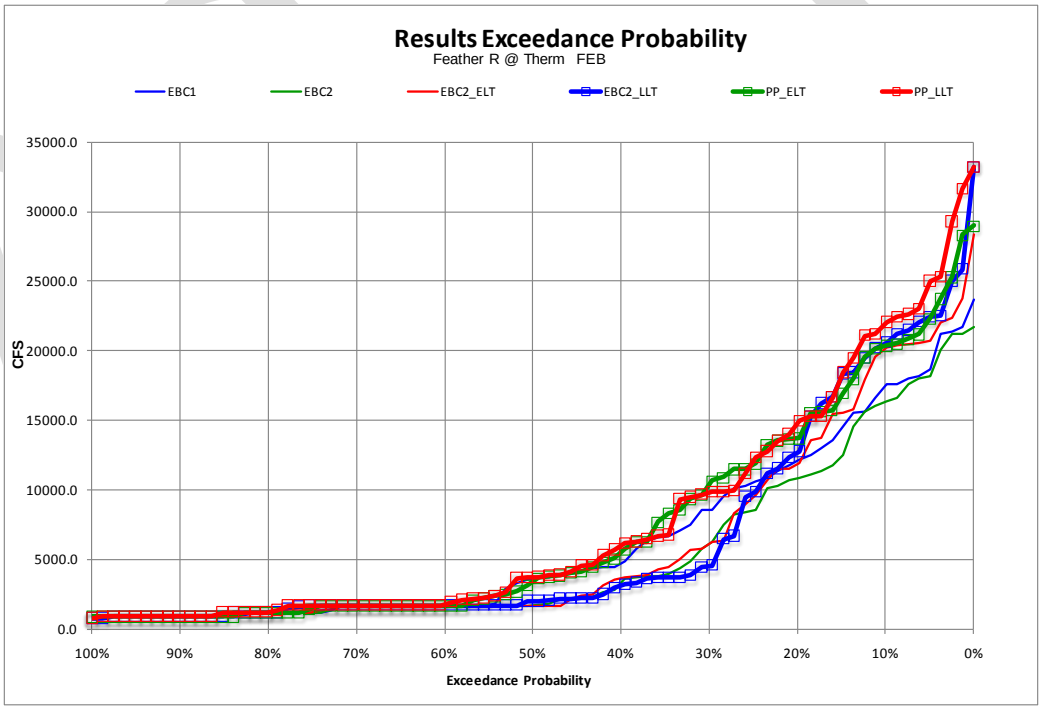

Figure C.5.2-209. Probability of Exceedance Plot for Model Scenarios of Mean Monthly Flow in the Feather River High-Flow Channel (at Thermalito Afterbay), February

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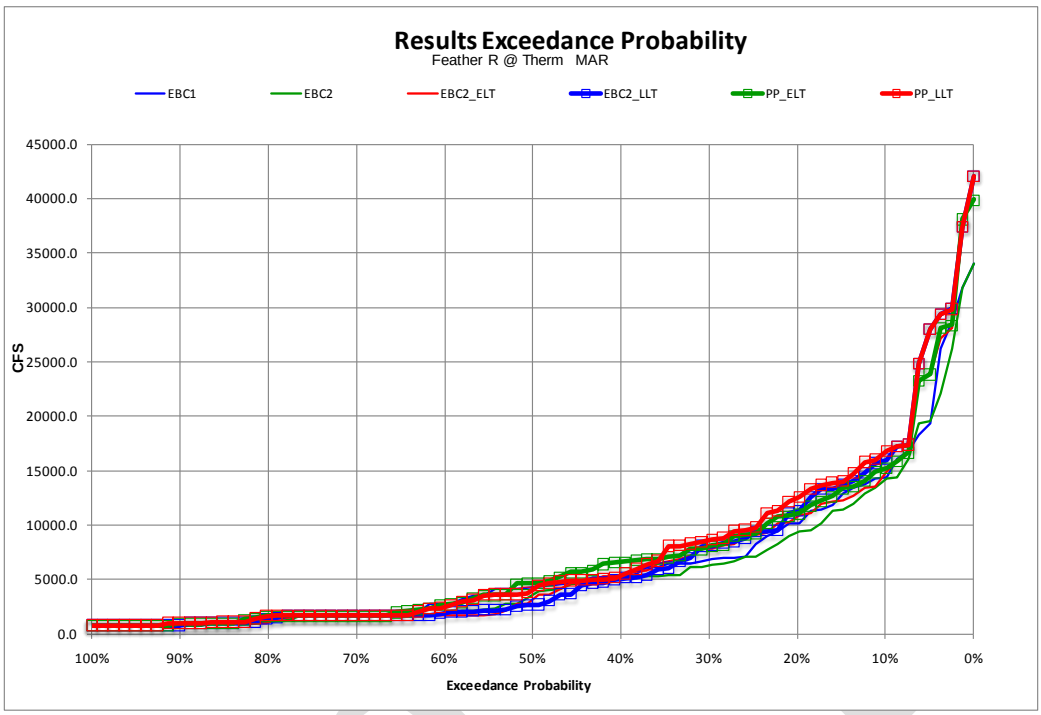

Figure C.5.2-210. Probability of Exceedance Plot for Model Scenarios of Mean Monthly Flow in the Feather River High-Flow Channel (at Thermalito Afterbay), March

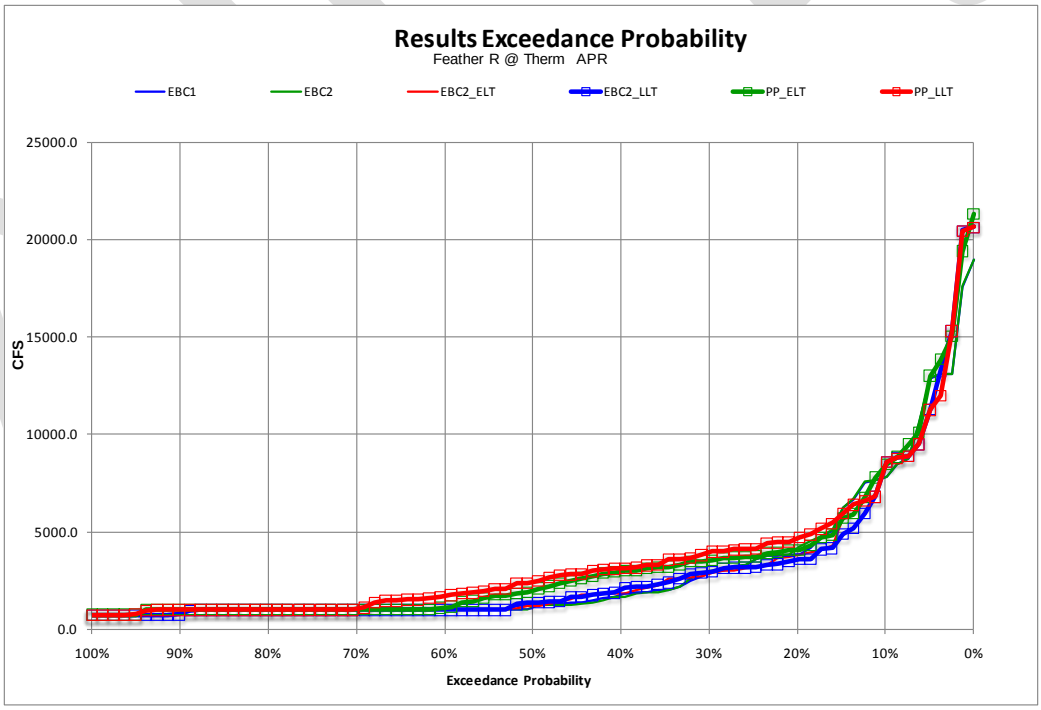

Figure C.5.2-211. Probability of Exceedance Plot for Model Scenarios of Mean Monthly Flow in the Feather River High-Flow Channel (at Thermalito Afterbay), April

Steelhead spawning and egg incubation on the Feather River occurs primarily in Hatchery Ditch and the low-flow channel in the general vicinity of the Feather River Hatchery. Instream flows affect

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physical habitat quality and availability through changes in wetted channel width, water depth, and water velocities. Results of IFIM studies (WUA versus flow relationships) provide information on the spawning habitat conditions in the low-flow channel. Results of CALSIM modeling show that instream flows in the Feather River low-flow channel were the same for all modeled scenarios and water-year types. Flows are predicted to range from 700 to 800 cfs under all conditions (Table C.5.2-83; Figure C.5.2-204 through Figure C.5.2-207). Therefore, BDCP implementation is not expected to affect physical habitat conditions for steelhead spawning and egg incubation within the Feather River low-flow channel.

Water Temperature

Results of water temperature simulation analyses for the Feather River low-flow and high-flow channels were used as an indicator of changes in water temperatures that would potentially affect steelhead egg incubation. The model results were compiled monthly over the 82-year period included in the CALSIM simulations. Average monthly water temperatures were then evaluated to determine the months during the steelhead egg incubation period (January through April) when temperatures exceeded 56°F.

Low-Flow Channel (above Thermalito Afterbay)

During the 82-year simulation period, one or more occurrences of temperatures exceeding 56°F in the low-flow channel are predicted to occur in 11–12 years under EBC1 and EBC2, 23–25 years under EBC2_ELT and PP_ELT, and 48–52 years under EBC2_LLT and PP_LLT (Table C.5.2-85). The number of consecutive years with temperatures exceeding 56°F is predicted to be 0 years under EBC1 and EBC2, 6–11 years under EBC2_ELT and PP_ELT, and 38–45 years under EBC2_LLT and PP_LLT. Thus, the frequency of stressful water temperatures for steelhead egg incubation in the low-flow channel would be expected to increase substantially under future EBC2 scenarios (EBC2_ELT and EBC2_LLT). BDCP operations would be expected to further increase the frequency of stressful water temperatures during the January through April steelhead spawning and egg incubation period. Under early long-term conditions, the number of years with water temperature exceeding 56°F in one or months is predicted to be 2% greater under PP_ELT than EBC2_ELT, and the number of years with water temperature exceeding 56°F in consecutive months is predicted to be 6% greater under PP_ELT than EBC2_ELT. Under late long-term conditions, the number of years with water temperature exceeding 56°F in one or months is predicted to be 4% greater under PP_LLT than EBC2_LLT, and the number of years with water temperature exceeding 56°F in consecutive months is predicted to be 9% greater under PP_LLT than EBC2_LLT.

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Table C.5.2-85. Results of the Analysis of the 82-Year Simulation of Water Temperature in the Feather River during the January through April Steelhead Egg Incubation Period[1]

	EBC1	EBC2	EBC2_ELT	EBC2_ELT	PP_ELT	PP_LLT
Feather River Low-Flow Channel (above Thermalito Afterbay)						
Number of years with one or more exceedances	12	11	25	48	23	49
Number of years with two exceedances	0	0	3	10	3	11
Number of years with three exceedances	0	0	0	0	0	0
Number of years with four exceedances	0	0	0	0	0	0
Number of years with five or more exceedances	0	0	0	0	0	0
Number of consecutive years with one or more exceedances	0	0	11	38	6	40
Feather River High-Flow Channel (below Thermalito Afterbay)						
Number of years with one or more exceedances	53	51	62	70	63	70
Number of years with two exceedances	4	6	15	31	16	31
Number of years with three exceedances	0	0	0	4	0	3
Number of years with four exceedances	0	0	0	0	0	0
Number of years with five or more exceedances	0	0	0	0	0	0
Number of consecutive years with one or more exceedances	46	42	59	70	60	70

[1] Time period analyzed: January 1922 to April 2003. Analysis counted monthly exceedances above 56°F.

Water temperatures in the low-flow channel of the Feather River during the winter months are frequently within the range considered to be suitable for steelhead spawning and egg incubation (Figure C.5.2-212). Increasing water temperatures through the late winter and spring increase the frequency and magnitude of water temperatures above this range. Thus, April is a key month for evaluating the effects of water temperature on these life stages. Water temperature simulation results for the low-flow channel in April indicate that temperatures under PP_ELT and PP_LLT would be similar to those under their respective baselines (EBC2_ELT and EBC2_LLT) (Figure C.5.2-213). Based on these results, the preliminary proposal is not likely to affect the suitability of water temperatures for steelhead spawning and egg incubation relative to existing biological conditions.

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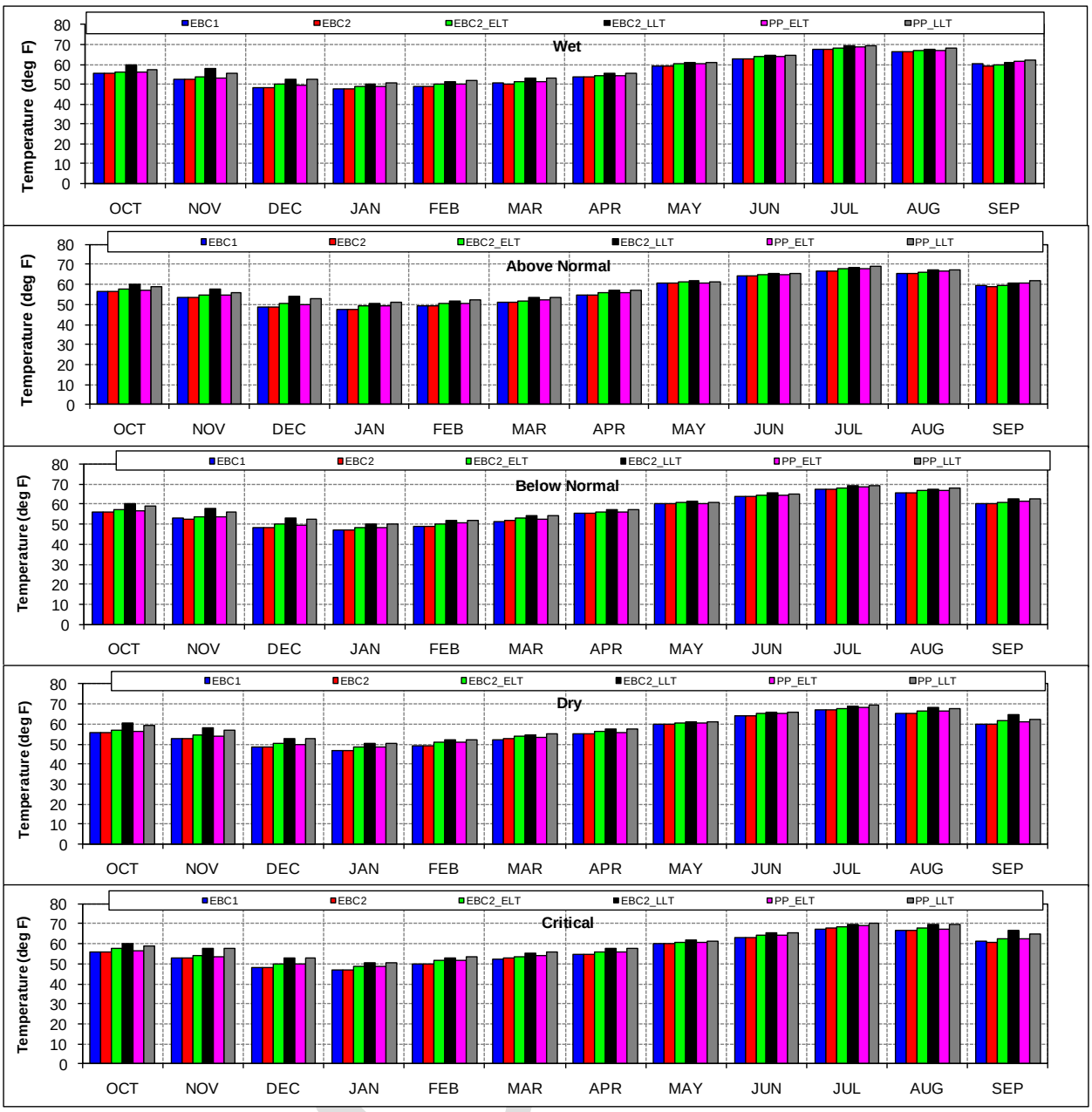

Figure C.5.2-212. Average Water Temperature of Feather River Low-Flow Channel (above Thermalito Afterbay) under Each Model Scenario

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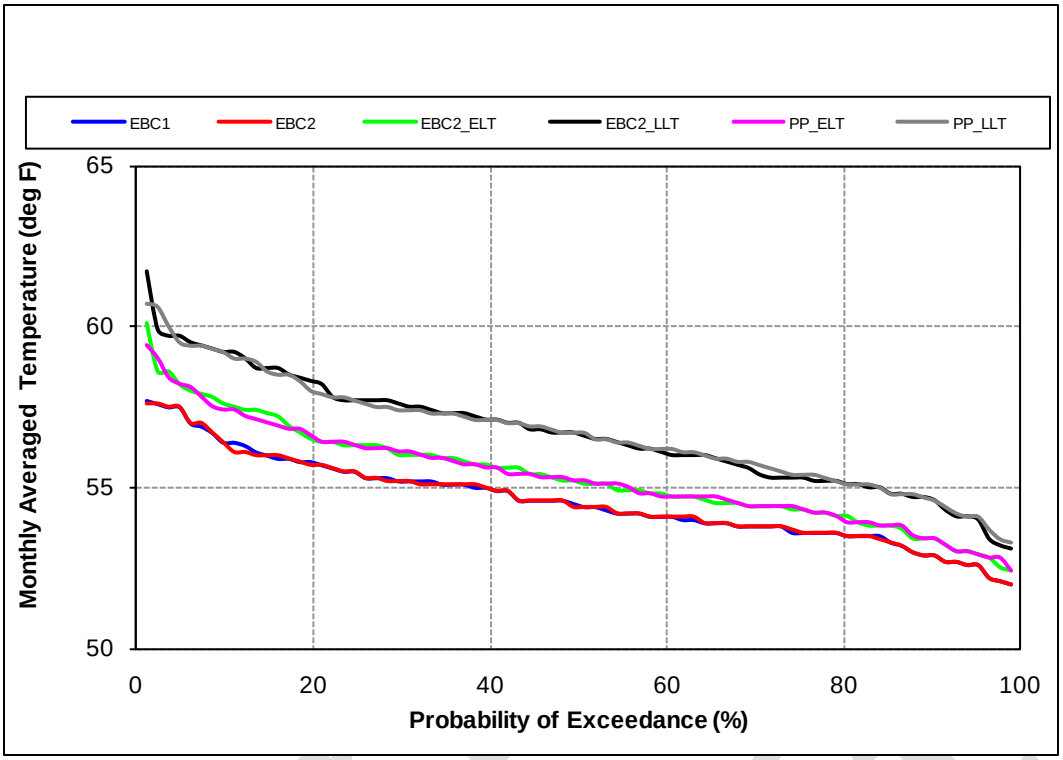

Figure C.5.2-213. Probability of Exceedance Plot for Model Scenarios of Mean Monthly Water Temperature in the Feather River Low-Flow Channel (above Thermalito Afterbay), April

High-Flow Channel (below Thermalito Afterbay)

During the 82-year simulation period, one or more occurrences of temperatures exceeding 56°F in the high-flow channel are predicted to occur in 51 to 53 years under EBC1 and EBC2, 62 to 63 years under EBC2_ELT and PP_ELT, and 70 years under EBC2_LLT and PP_LLT (Table C.5.2-85). The number of consecutive years with temperature exceeding 56°F is predicted to be 42–46 years under EBC1 and EBC2, 59–60 years under EBC2_ELT and PP_ELT, and 70 years under EBC2_LLT and PP_LLT. Similar to the low-flow channel, substantial increases in the frequency of temperatures exceeding 56°F are expected to occur in the high-flow channel under future baseline conditions in the absence of BDCP implementation (EBC2_ELT and EBC2_LLT). However, the results indicate that the incremental effect of BDCP implementation would be negligible.

Water temperatures in the low-flow channel of the Feather River are determined largely by coldwater pool storage in Oroville Reservoir and instream flow releases. Because instream flows in the low-flow channel would be the same under EBC2 and preliminary project conditions, any simulated changes in water temperatures under BDCP operations would be attributed to changes in reservoir storage. Reservoir storage in May and September provides an indicator of coldwater pool availability. Results of CALSIM modeling of Oroville Reservoir storage in May are shown in Table C.5.2-86 with the corresponding frequency of exceedance analysis for May storage shown in Figure C.5.2-214. September storage in Oroville Reservoir is shown in Table C.5.2-87 with the corresponding frequency of exceedance analysis for September in Figure C.5.2-215.

CALSIM results indicate that May and September storage in Oroville Reservoir under early and late long-term conditions in the absence of BDCP operations (EBC2_ELT and EBC2_LLT) would be reduced relative to current conditions (EBC1 and EBC2) (Table C.5.2-86 and Table C.5.2-87, Figure

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C.5.2-214 and Figure C.5.2-215). The effects of BDCP operations under early and late long-term conditions (PP_ELT and PP_LLT) would range from little or no effect to relatively large increases in reservoir storage relative to existing biological conditions (EBC2_ELT and EBC2_LLT).

Table C.5.2-86. May Water Storage Volume (Thousand Acre-Feet) in Oroville Reservoir for Model Scenarios

Water-Year Type	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
Wet	3,507	3,508	3,488	3,461	3,473	3,416
Above Normal	3,497	3,498	3,438	3,341	3,378	3,260
Below Normal	3,264	3,402	3,099	2,911	3,077	2,885
Dry	2,756	2,625	2,406	2,236	2,622	2,346
Critical	1,824	1,764	1,685	1,508	1,802	1,564

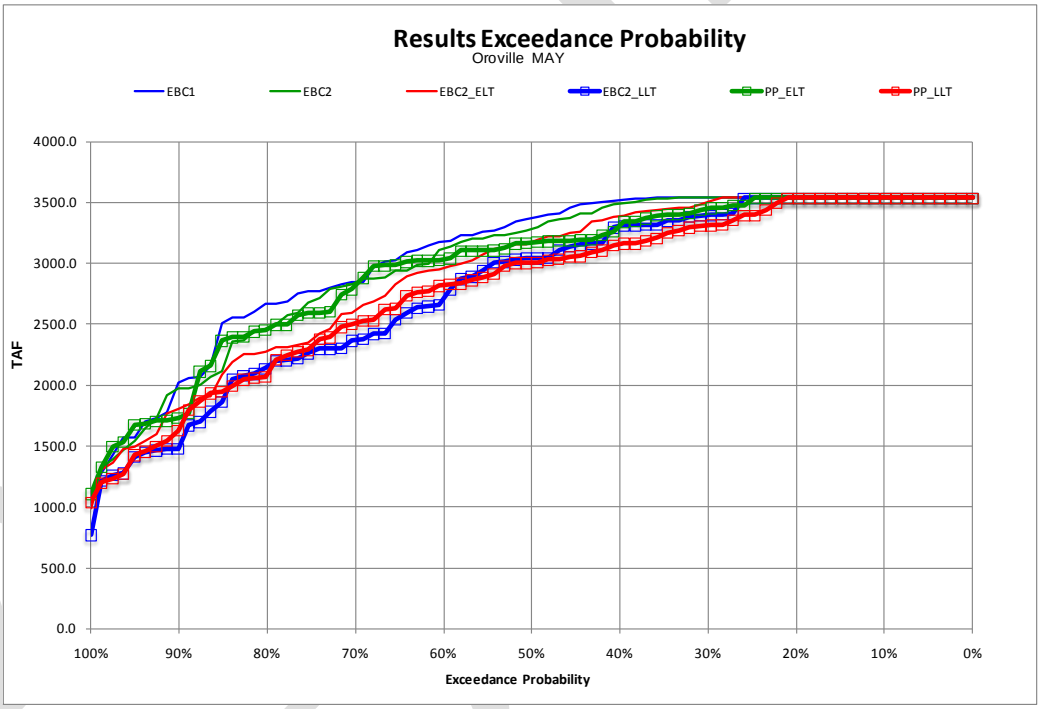

Figure C.5.2-214. Probability of Exceedance Plot for Model Scenarios of Oroville Reservoir, Water Storage Volume, May

Table C.5.2-87. September Water Storage Volume (Thousand Acre-Feet) in Oroville Reservoir for Model Scenarios

Water-Year Type	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
Wet	2,899	2,474	2,177	1,885	2,727	2,432
Above Normal	2,374	2,043	1,818	1,583	2,141	1,870
Below Normal	2,018	1,922	1,693	1,409	1,894	1,678
Dry	1,361	1,303	1,124	1,008	1,496	1,319
Critical	984	956	902	796	1,131	964

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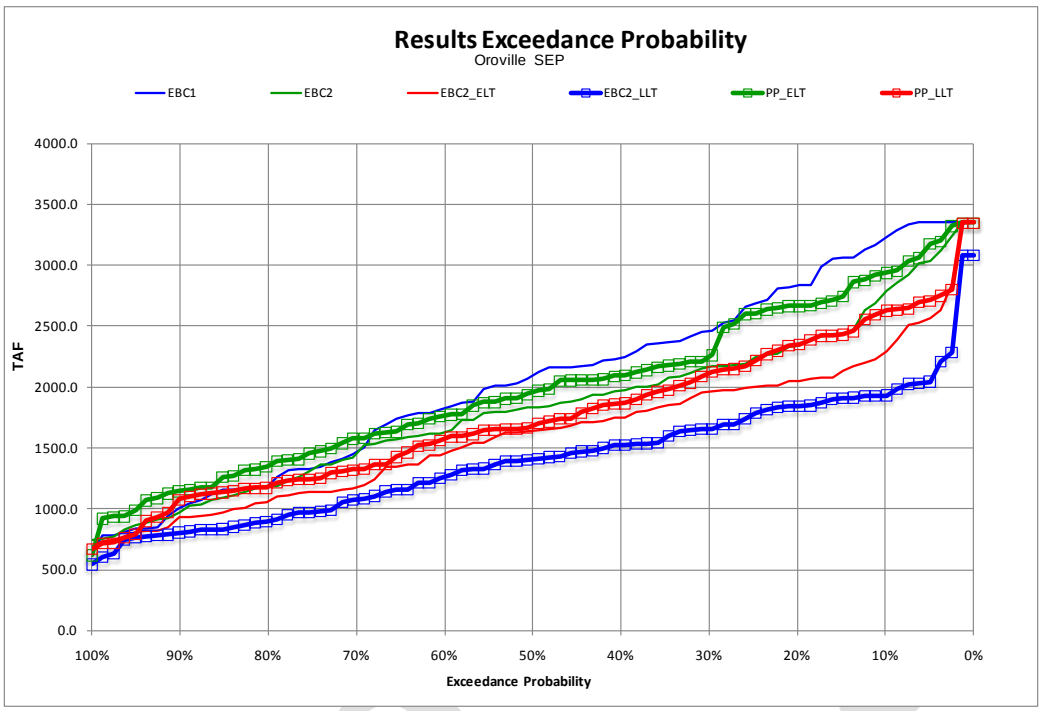

Figure C.5.2-215. Probability of Exceedance Plot for Model Scenarios of Oroville Reservoir Water Storage Volume, September

Redd Dewatering

Ramping rates for releases on the Feather River are included as part of routine operations and would be expected to remain the same in the future under BDCP. Flows in the low-flow channel are maintained to avoid redd dewatering. Monthly CALSIM modeling predicts that flows between January and April encompassing the steelhead spawning period would be maintained at levels that would minimize and avoid the risk of dewatering steelhead redds in the low-flow channel under all model scenarios (Table C.5.2-83).

Fry and Juvenile Rearing

Rearing Habitat

The low-flow channel is the primary reach of the Feather River utilized by steelhead spawning and rearing. Although there is relatively little natural steelhead production in the river, most steelhead spawning and rearing appears to occur in the low-flow channel in habitats associated with well-vegetated side channels (Cavallo et al. 2003; California Department of Water Resources 2004). Because these habitats are relatively uncommon they could limit natural steelhead production. Flow in the low-flow channel is projected to remain between 700 and 800 cfs except during occasional flood control releases. This flow is less than pre-dam levels during all months of the year as a result of water diversions through the Thermalito Afterbay. The significance of these flow conditions for steelhead spawning and rearing is uncertain. Feather River screw trap data suggest that Chinook salmon initiate emigration regardless of flow regime (i.e., they do not wait for a high-flow pulse). This is likely true for steelhead as well.

Habitat also exists on the Feather River high-flow channel downstream of Thermalito Afterbay for steelhead spawning and rearing. Flows in the high-flow channel are greater and substantially more

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variable than those in the low-flow channel, which contributes to greater habitat diversity and complexity. Seasonal water temperatures in the high-flow channel are elevated under some conditions that reduce habitat quality for egg incubation and extended juvenile rearing.

Results of water temperature simulation analyses for the Feather River low-flow and high-flow channels were used as an indicator of changes in water temperatures that would potentially affect steelhead rearing conditions. The model results were compiled monthly over the 82-year period included in the CALSIM simulations. Average monthly water temperatures were then evaluated to determine the months during the steelhead rearing period (year-round) when temperatures exceeded 65°F. Results of the frequency of years in which monthly average temperatures exceeded the criterion are summarized in Table C.5.2-88.

Table C.5.2-88. Results of the Analysis of the 82-Year Simulation of Water Temperature in the Feather River during the Year-Round Juvenile Steelhead Rearing Period[1]

	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
Feather River at the Low-Flow Channel (above Thermalito Afterbay)						
Number of years with one or more exceedances	81	81	81	81	81	81
Number of years with two exceedances	52	50	45	31	48	32
Number of years with three exceedances	8	8	29	37	27	41
Number of years with four exceedances	0	0	2	6	1	2
Number of years with five or more exceedances	0	0	0	7	1	6
Number of consecutive years with one or more exceedances	81	81	81	81	81	81
Feather River High-Flow Channel (below Thermalito Afterbay)						
Number of years with one or more exceedances	81	81	81	81	81	81
Number of years with two exceedances	10	12	4	2	6	3
Number of years with three exceedances	43	47	46	28	42	14
Number of years with four exceedances	24	20	20	24	23	39
Number of years with five or more exceedances	4	2	11	27	10	25
Number of consecutive years with one or more exceedances	81	81	81	81	81	81

[1] Time period analyzed: January 1922 to December 2002. Analysis counted monthly exceedances above 65°F.

In both the low and high-flow channels, one or more occurrences of temperatures exceeding 65°F are predicted to occur in most years under all scenarios. Under early and late long-term conditions, BDCP operations are predicted to result in no change in the number of years with one or more occurrences of temperatures exceeding 65°F. Small increases or decreases in the number of years with two, three, four, and five or more occurrences of temperatures exceeding 65°F are predicted to occur in the low-flow channel. The magnitude of these increases and decreases is predicted to increase under late long-term conditions, especially in the high-flow channel. Thus, the risk of exposure to stressful rearing temperatures is expected to increase in response to future climate change. Operations under the preliminary proposal will have variable incremental effects on water temperatures from year to year but are not expected to substantially affect the quality of juvenile rearing habitat relative to baseline conditions.

As part of the FERC Settlement Agreement, DWR is investigating alternative methods of releasing cold water into the Feather River to improve habitat conditions for steelhead rearing as well as for

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other salmonids. Results of this analysis indicate that habitat conditions for steelhead rearing will be stressful within the Feather River with rearing habitat conditions more suitable in the low-flow channel under both ELT and LLT conditions. The risk of exposure to potentially stressful temperature conditions increases as a function of distance downstream of the dam and in response to future climate change. These changes in habitat conditions, however, are independent of the preliminary proposal.

Predicted water temperatures on the Feather River in the low-flow channel under each model scenario between April and October are shown in Figure C.5.2-213 and Figure C.5.2-216 through Figure C.5.2-221. Steelhead rear successfully at the downstream extent of the low-flow channel where summer temperatures reach or occasionally exceed 65°F (Figure C.5.2-222 and Figure C.5.2-223) as reflected in water temperatures at the fish barrier fence. A laboratory study found that Feather River steelhead have a relatively high thermal preference (Myrick and Cech 2000). This study also found that in-channel-produced steelhead displayed a higher thermal tolerance than juvenile steelhead produced in the Feather River hatchery. Water temperatures in the Feather River at the fish hatchery barrier dam (upstream boundary of anadromous access) could exceed 65°F during September and October in the LLT scenarios (Figure C.5.2-222 and Figure C.5.2-223). Temperatures are improved for PP_LLT, so this should benefit steelhead rearing. Temperatures downstream above the Thermalito Afterbay (7¾ miles downstream) would exceed 65°F in 50% to 60% of months between July and October and would increase in the future in response to climate change (Figure C.5.2-218 through Figure C.5.2-221). Differences between EBC and PP scenarios do not appear to be biologically significant at that point in the river. Temperatures during the rest of the year (November through May) remain below 65°F under all model scenarios and would be adequately protective for steelhead rearing within the low-flow channel. The length of river with suitable rearing temperatures would be reduced in the future with the climate change scenarios for both EBC_LLT and PP_LLT conditions. Although young-of-the-year steelhead are occasionally observed downstream of Thermalito, the high-flow channel is used to only a limited extent by steelhead spawning or rearing downstream of the Thermalito Afterbay outlet. The high-flow channel primarily serves as the migratory corridor for steelhead passage.

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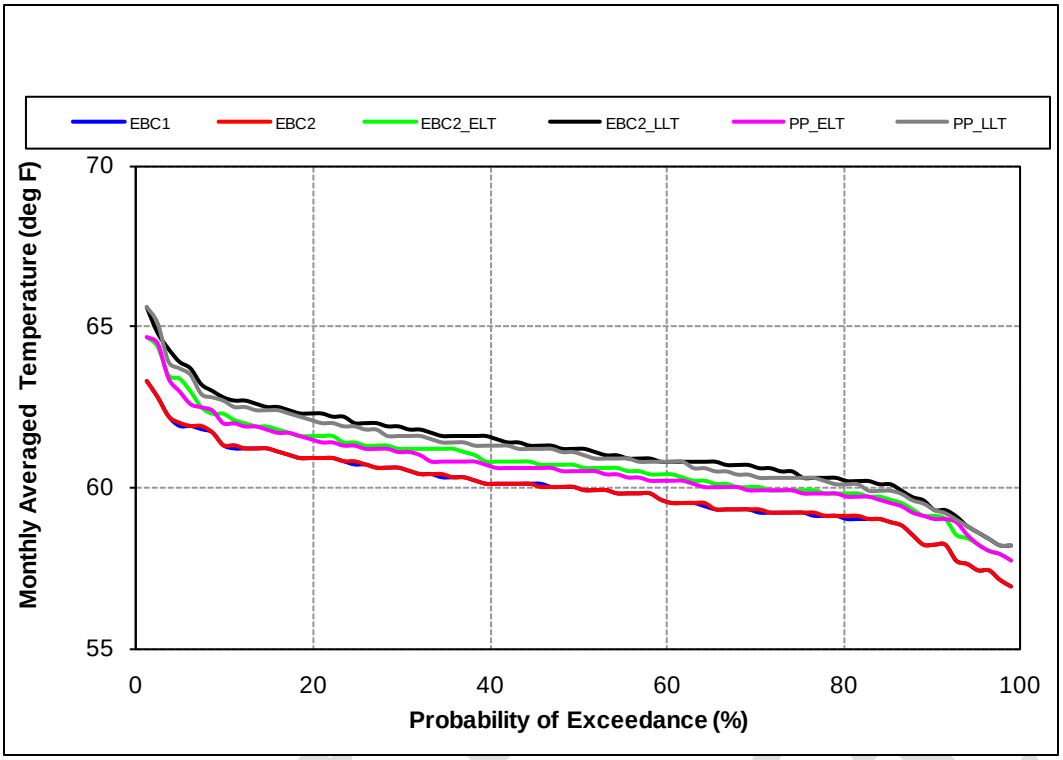

Figure C.5.2-216. Probability of Exceedance Plot for Model Scenarios of Mean Monthly Water Temperature in the Feather River Low-Flow Channel (above Thermalito Afterbay), May

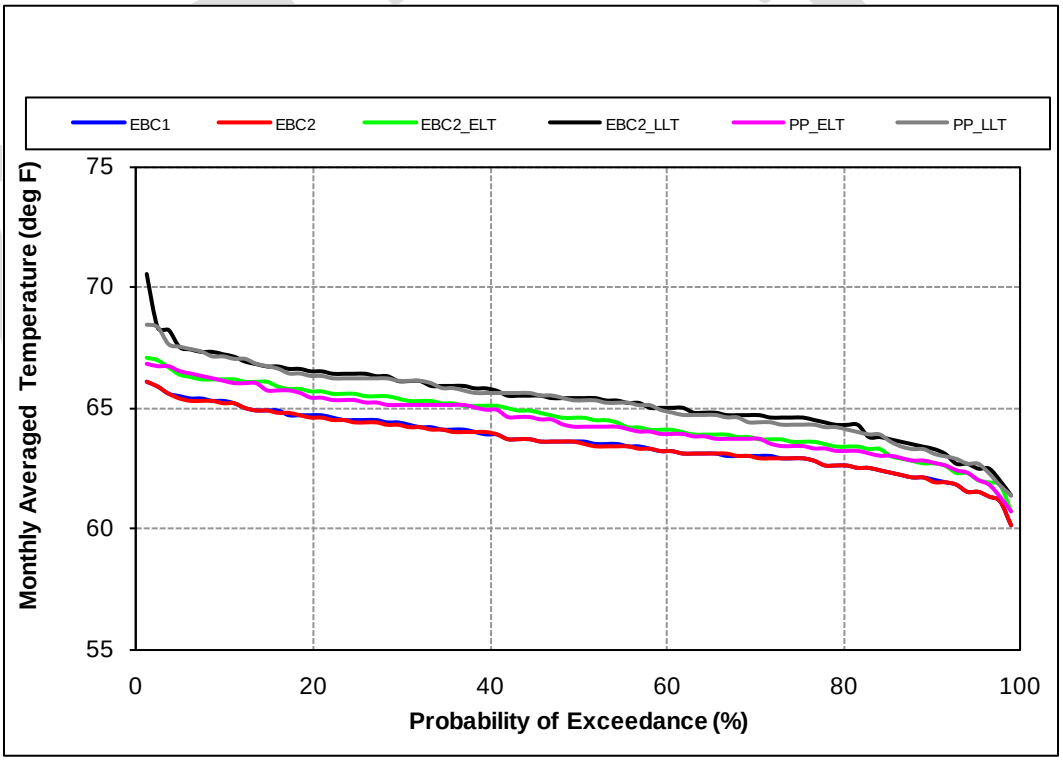

Figure C.5.2-217. Probability of Exceedance Plot for Model Scenarios of Mean Monthly Water Temperature in the Feather River Low-Flow Channel (above Thermalito Afterbay), June

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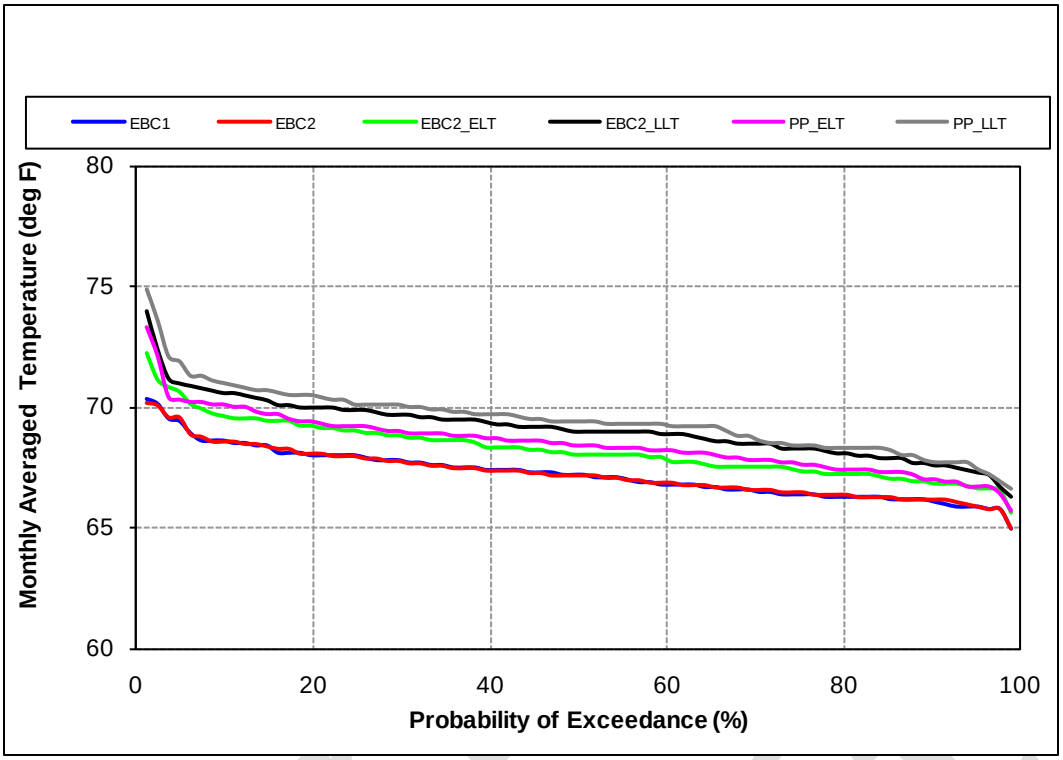

Figure C.5.2-218. Probability of Exceedance Plot for Model Scenarios of Mean Monthly Water Temperature in the Feather River Low-Flow Channel (above Thermalito Afterbay), July

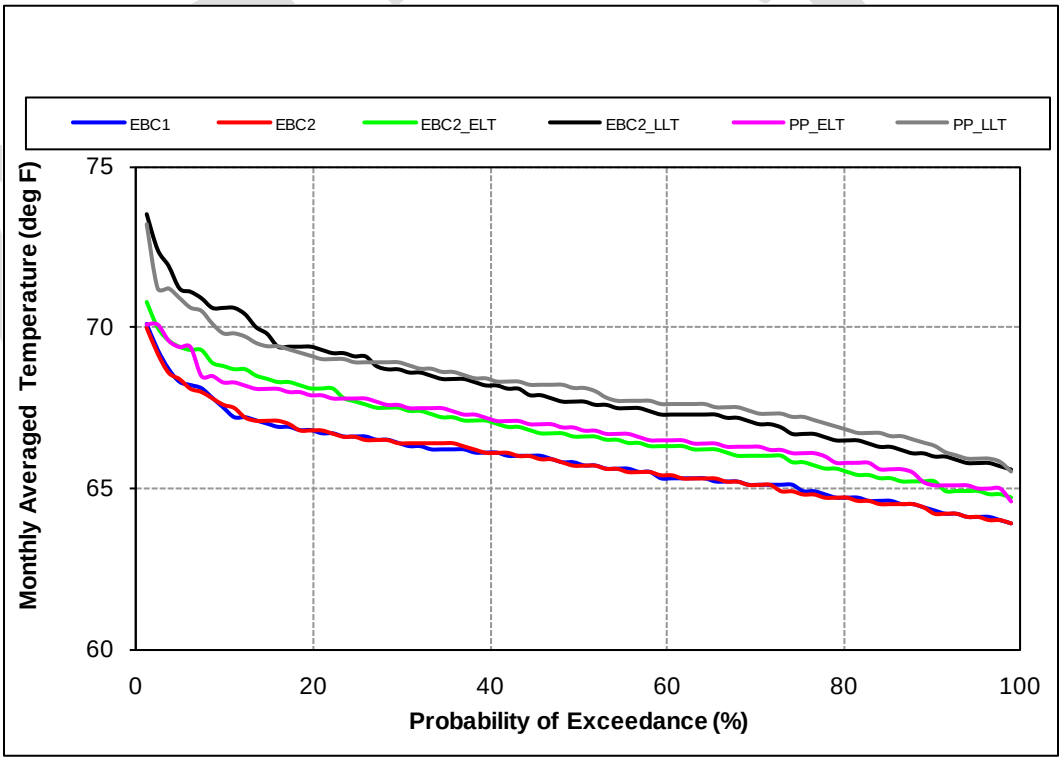

Figure C.5.2-219. Probability of Exceedance Plot for Model Scenarios of Mean Monthly Water Temperature in the Feather River Low-Flow Channel (above Thermalito Afterbay), August

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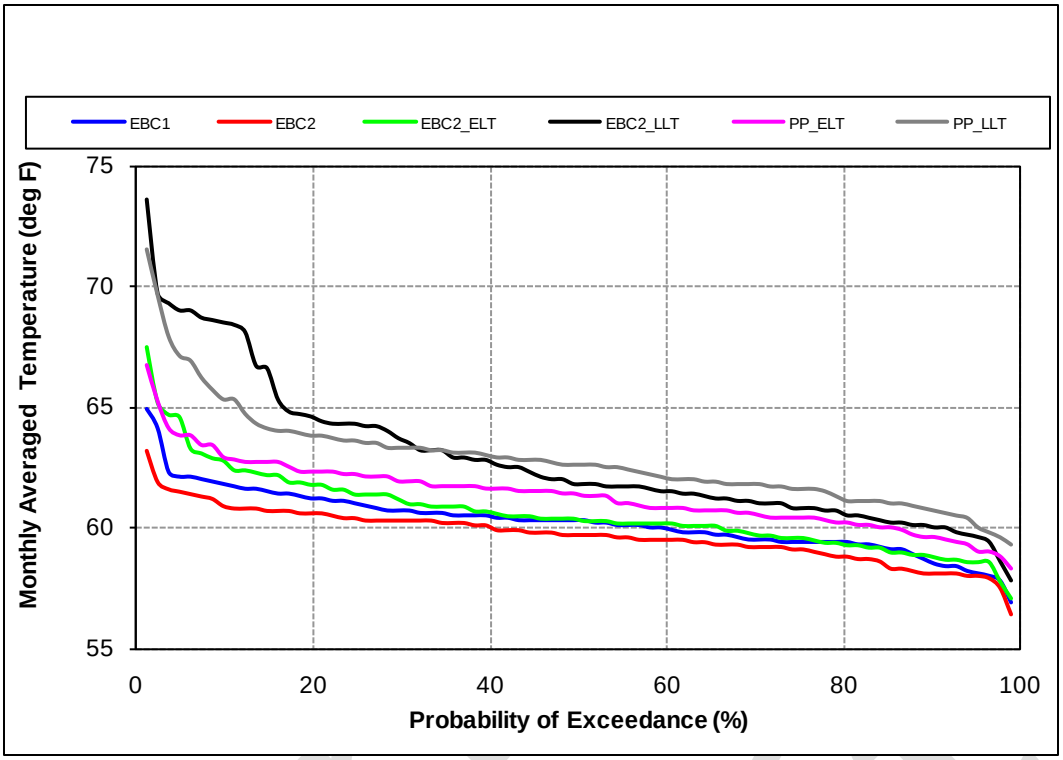

Figure C.5.2-220. Probability of Exceedance Plot for Model Scenarios of Mean Monthly Water Temperature in the Feather River Low-Flow Channel (above Thermalito Afterbay), September

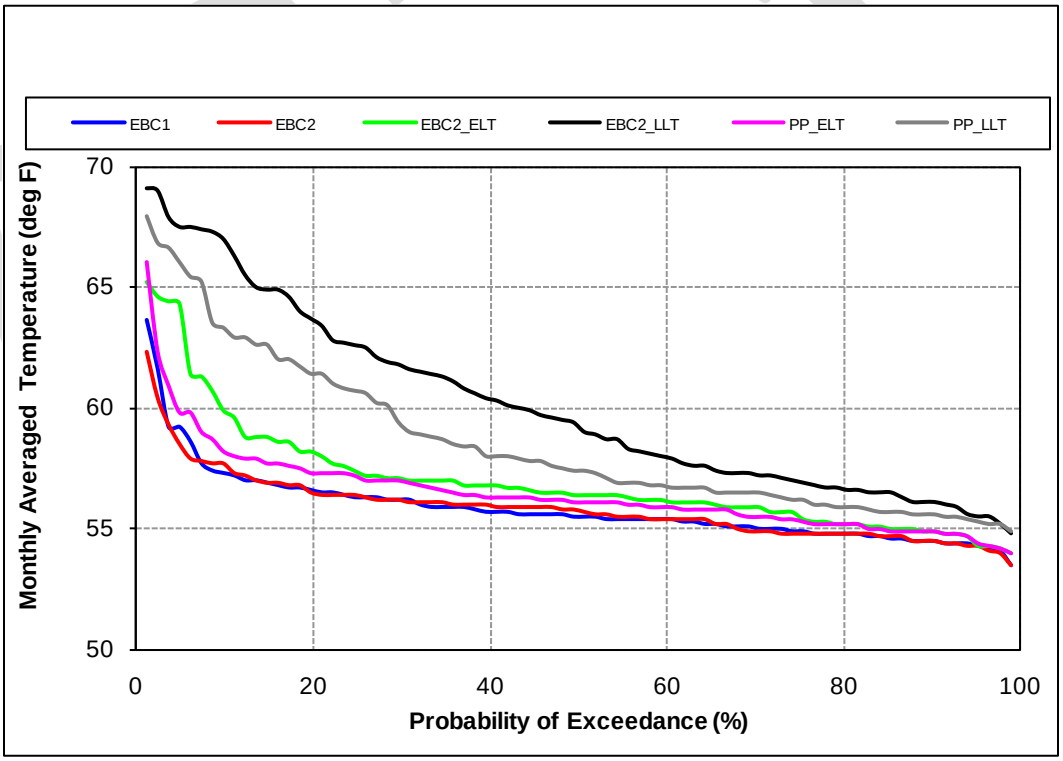

Figure C.5.2-221. Probability of Exceedance Plot for Model Scenarios of Mean Monthly Water Temperature in the Feather River Low-Flow Channel (above Thermalito Afterbay), October

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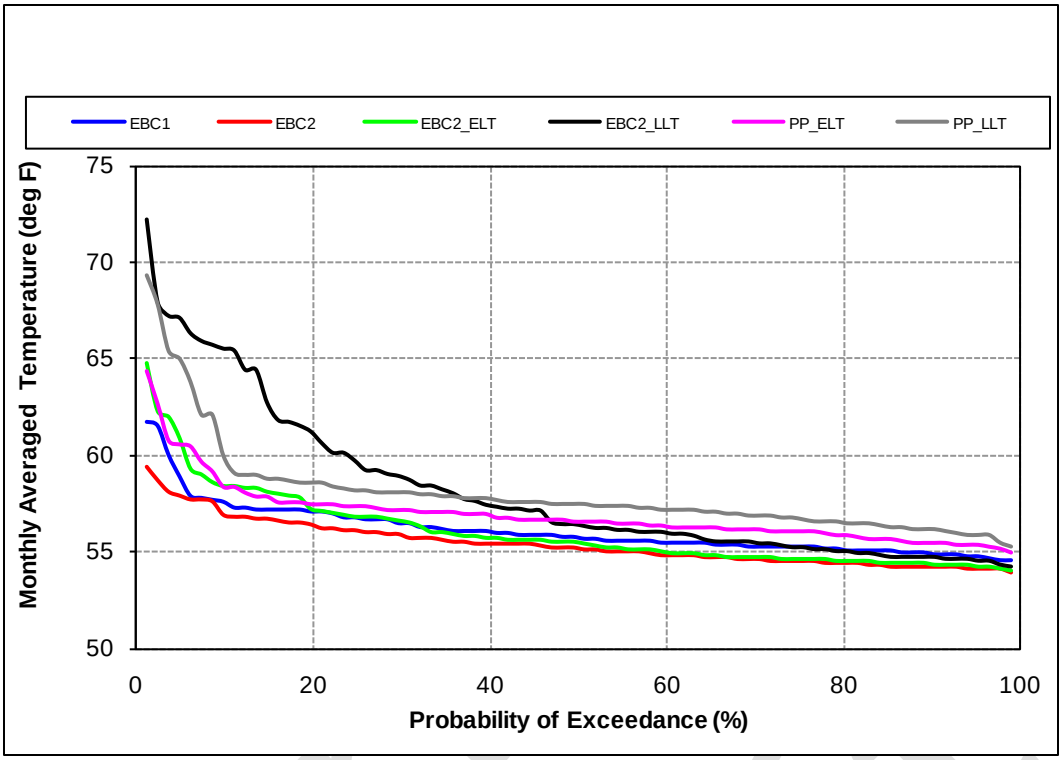

Figure C.5.2-222. Probability of Exceedance Plot for Model Scenarios of Mean Monthly Water Temperature in the Feather River at Fish Barrier Dam, September

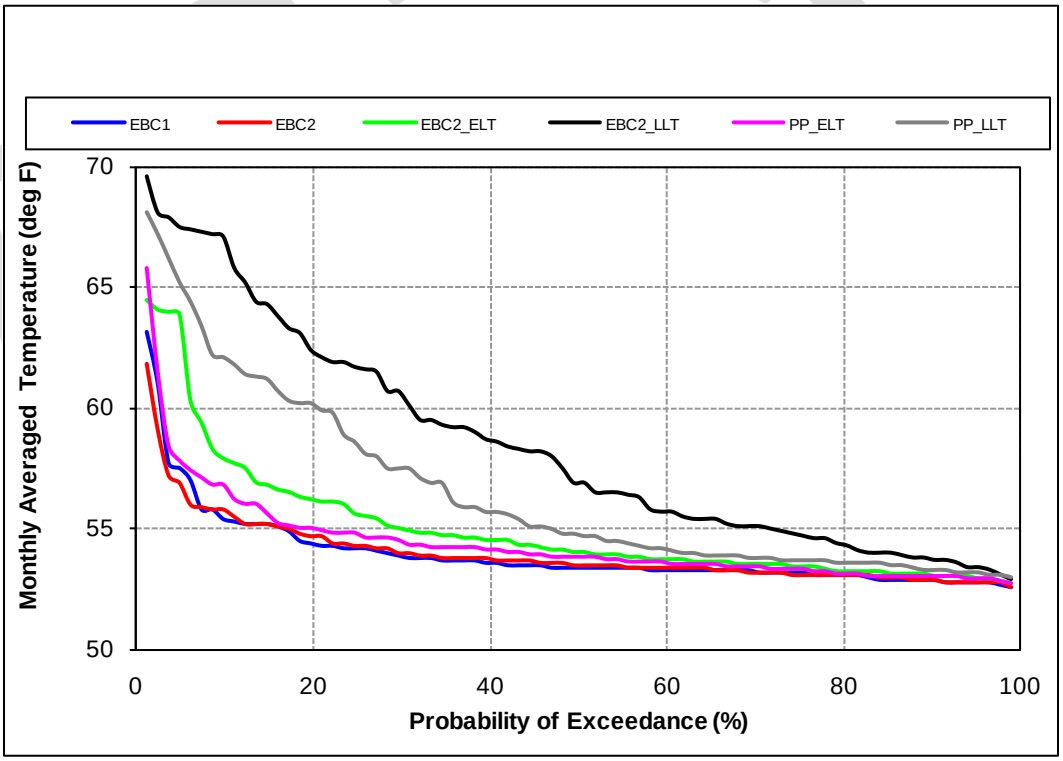

Figure C.5.2-223. Probability of Exceedance Plot for Model Scenarios of Mean Monthly Water Temperature in the Feather River at Fish Barrier Dam, October

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The river channel downstream of Thermalito (high-flow channel) offers few of the habitat types upon which steelhead appear to rely in the low-flow channel. Experiments and fish observations also suggest that predation risk for juvenile steelhead is higher downstream of the Thermalito outlet (California Department of Water Resources 2004). Increased predation risk is likely a function of water temperature, where warm water exotic species such as striped bass, largemouth bass, and smallmouth bass are more prevalent, and in general, predators have greater metabolic requirements. Thus, summer temperatures that exceed 65°F and the absence of preferred steelhead habitat appears to limit steelhead rearing in the river downstream of the Thermalito outlet. The relative importance of these two factors is unknown. For example, it is unclear whether a reduction in summer water temperatures below Thermalito would be enough to induce or allow successful steelhead rearing and spawning.

Juvenile steelhead rear within the Feather River year-round. Instream flows in the low-flow channel estimated from the modeling each month were used to compare habitat conditions for PP relative to EBC by month and water-year type (Table C.5.2-83). It was assumed that habitat for juvenile steelhead rearing would be constrained by the month having the lowest instream flows. This is because juvenile rearing habitat increases in the Feather River as instream flows increase above the minimum levels. Results of the analysis of minimum monthly instream flows affecting juvenile rearing habitat showed that the lowest average monthly instream flow in the low-flow channel was 700 cfs for EBC2_ELT, PP_ELT, EBC2_LLT, and PP_LLT. Based on these results, it was concluded that juvenile steelhead rearing habitat as measured by minimum instream flows would not be affected by the preliminary proposal.

Adult

Water Temperature

Predicted monthly water temperatures from the Reclamation Temperature Model for the Feather River at Honcut Creek between January through April are presented in Figure C.5.2-224. Results indicate that water temperatures are nearly always below 65°F for all model scenarios. There are negligible differences in the number of exceedances above 65°F among all model scenarios (Table C.5.2-89). Therefore, the preliminary proposal is not expected to affect water temperature in the Feather River at Honcut Creek during the steelhead adult migration period.

Table C.5.2-89. Results of the Analysis of the 82-Year Simulation of Water Temperature in the Feather River during the September through March Steelhead Adult Migration Incubation Period[1]

	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
Low-Flow Channel (above Thermalito Afterbay)						
Number of years with one or more exceedances	0	0	3	14	2	9
Number of years with two exceedances	0	0	0	9	1	6
Number of years with three exceedances	0	0	0	0	0	0
Number of years with four exceedances	0	0	0	0	0	0
Number of years with five or more exceedances	0	0	0	0	0	0
Number of consecutive years with one or more exceedances	0	0	0	4	0	2

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	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
High-Flow Channel (below Thermalito Afterbay)						
Number of years with one or more exceedances	27	17	25	44	35	62
Number of years with two exceedances	0	0	2	14	2	13
Number of years with three exceedances	0	0	0	0	0	0
Number of years with four exceedances	0	0	0	0	0	0
Number of years with five or more exceedances	0	0	0	0	0	0
Number of consecutive years with one or more exceedances	15	4	16	34	28	60
[1] Time period analyzed: September 1922 to March 2002. Analysis counted monthly exceedances above 56°F.						

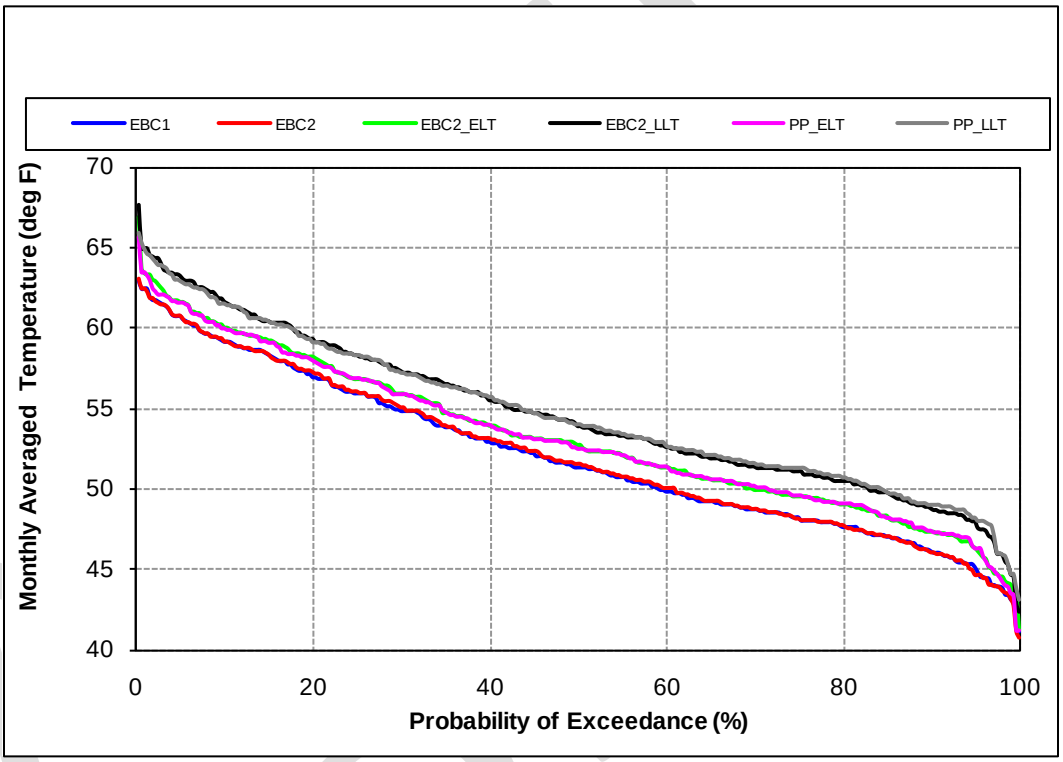

Figure C.5.2-224. Probability of Exceedance Plot for Model Scenarios of Mean Monthly Water Temperature of Feather River at Honcut Creek during the Steelhead Adult Migration Period, January through April

C.5.2.4.2 Spring-Run

Eggs and Alevins

Upstream Spawning Habitat

The primary habitat for spring-run Chinook salmon in the Feather River is in the low-flow channel upstream of Thermalito Afterbay. Spring-run Chinook salmon also return to the Feather River Fish Hatchery where they are spawned, incubated and reared. As part of various fishery investigations, and as part of Federal Energy Regulatory Commission (FERC) hydroelectric relicensing for the Feather River Oroville Dam (FERC Project No. 2100), DWR has compiled an extensive body of

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information on Feather River fishery habitat. For example, DWR (2004) presents an IFIM investigation of the relationship between instream flows and habitat in the lower Feather River. Results of these investigations have been used as part of the technical foundation for this effects assessment.

Minimum Feather River instream flows are included in the FERC settlement agreement and would be met for all model scenarios. Results of CALSIM modeling of flows, by month and water-year type, in the low-flow channel are summarized in Table C.5.2-83 for the spring-run spawning and egg incubation period. Instream flows in the low-flow channel are managed by releases from Oroville Dam and remain relatively stable among months and water years to meet habitat requirements for salmon spawning and rearing. The FERC settlement agreement includes other nonflow actions (e.g., spawning gravel augmentation) that, although not part of BDCP-covered activities or conservation measures, would benefit habitat for steelhead, spring-run and fall-run Chinook salmon, and other aquatic resources inhabiting the Feather River.

Spring-run Chinook salmon eggs are subject to potential effects of preliminary proposal operations on habitat conditions affecting incubation success through (1) changes in seasonal water temperatures or instream flows within the low-flow channel that result in increased or decreased egg mortality; and (2) redd dewatering as a result of flow reductions after the redd has been constructed and the eggs are incubating, which exposes the eggs to dewatering and increased mortality.

Instream flows in the Feather River low-flow channel during the spring-run salmon spawning and egg incubation period are predicted to be 773 cfs in September and 800 cfs from October through March for all model scenarios (Table C.5.2-83). Instream flows are not predicted to vary by water-year type. Results of IFIM studies conducted on the Feather River showed that spawning habitat was maximized at flows of approximately 700 to 800 cfs. Based on the CALSIM modeling results, it was concluded that physical habitat for spawning and egg incubation would not differ between EBC2_ELT and PP_ELT or between EBC2_LLT and PP_LLT.

Water Temperature

Spring-run Chinook salmon spawning and egg incubation occurs in the reach of the Feather River low-flow channel downstream from Oroville Dam to approximately the Thermalito Afterbay. The geographic distribution of spawning and egg incubation varies depending on a variety of factors, including suitable water depths, velocities, spawning substrate, and seasonal water temperature regimes. For purposes of this assessment, it was assumed that exposure of eggs to water temperatures in excess of 56°F during the incubation period would result in adverse impacts on reproductive success, including egg mortality. Average monthly water temperatures in the Feather River low-flow channel (above Thermalito Afterbay)are summarized in Figure C.5.2-212. Results of monthly water temperature simulation analyses in the low-flow channel were compiled by month over the 82-year simulation period. Months during the spring-run Chinook salmon incubation period (September through January) were identified in which average monthly temperature exceeded 56°F. Results of the analysis are summarized in Table C.5.2-90. Results of these analyses show that the frequency of years with water temperatures exceeding a 56°F criterion was comparable between EBC1, EBC2 and BDCP operations. The frequency of years with water temperatures greater than 56°F in two or more months increased in response to future climate change as reflected in the number of years with two or more months of elevated water temperatures in ELT and LLT conditions. The frequency of years with predicted water temperatures greater than

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the 56°F criterion in two, three, and four consecutive months decreased between EBC2 and BDCP operations with the exception of the two month exceedance between EBC2_LLT and PP_LLT operations. The increase in release temperatures in the future under climate change, with and without BDCP operations, would be expected to contribute to increased egg mortality for spring-run Chinook salmon.

Table C.5.2-90. Results of Monthly Analysis of Water Temperature Simulations in the Feather River Low-Flow Channel (above Thermalito Afterbay) during the September through January Spring-Run Salmon Egg Incubation Period[1]

	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
Number of years with one or more exceedances	80	80	80	80	80	80
Number of years with two exceedances	23	24	44	20	37	26
Number of years with three exceedances	2	4	9	48	7	34
Number of years with four exceedances	0	0	0	7	0	1
Number of years with five or more exceedances	0	0	0	0	0	0
Number of consecutive years with one or more exceedances	80	80	80	80	80	80

[1] Time period analyzed: September 1922 to January 2002. Analysis counted monthly exceedances over 56°F.

Spring-run salmon spawn and eggs incubate in the late summer, fall, and winter (September through January). During September and October air temperatures in the Oroville area are high and, therefore, the Feather River is subject to warming. Later in the winter air and water temperatures are relatively cool. The area of the river where suitable water temperatures occur for successful egg incubation depends on the temperature of water released to the river from Oroville Dam, the rate of instream flow, atmospheric conditions that result in river warming as the water travels downstream from the dam, and the ability to access cold water within the reservoir.

When Oroville Reservoir coldwater storage that is accessible for release is reduced, the amount of cold water available to be released is reduced, creating warmer water temperatures at the point of release to the lower river. Oroville Dam has limited ability to control access to the coldwater pool. Under most conditions, coldwater is accessed using an intake structure equipped with a series of stop-log gates that can be inserted or removed to adjust the location within the water column where coldwater is withdrawn for downstream release. As part of the FERC Settlement and SWRCB 401 certification process, DWR is investigating various physical modifications to the dam outlet works to improve operational control and access the coldwater pool. Depending on reservoir storage and access to cold water, the release temperatures from Oroville Dam to the low-flow channel may increase. Under these conditions, the length of river that maintains suitable water temperatures available for spring-run Chinook salmon incubation and hatching is reduced and therefore incubating eggs in the downstream areas are exposed to increased mortality. CALSIM modeling was used to predict changes in Oroville Reservoir storage during September, as summarized in Table C.5.2-105. Results of an exceedance frequency analysis for Oroville Reservoir storage during September are shown in Figure C.5.2-215. As part of Oroville Dam operations, management of coldwater reservoir pool storage volumes is an important factor in determining habitat suitability and mortality for spring-run Chinook salmon eggs. Management of coldwater releases in the future that comply with the FERC Settlement and 401 certification are expected to consistently support salmon habitat in the low-flow channel.

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CALSIM modeling indicates that Oroville Reservoir storage levels in September under PP_ELT and PP_LLT would be greater than under EBC2_ELT and EBC2_LLT, respectively (Table C.5.2-87, Figure C.5.2-215). Based on these results, it was concluded that coldwater pool availability in Oroville Reservoir and the ability to maintain suitable water temperatures for spring-run Chinook salmon spawning and incubation would be potentially improved relative to future baseline conditions.

Redd Dewatering

No analytical tools exist for quantitatively assessing the effects of flow reduction in the Feather River following spring-run Chinook salmon spawning that would result in a risk of redd dewatering during egg incubation. It was assumed that spring-run Chinook salmon spawn in the Feather River in September and that a reduction in instream flows of greater than 5% during the following October and November (representing the egg incubation period) would result in an increased risk of redd dewatering. Results of the 82-year monthly CALSIM model were used as the basis for the analysis (Table C.5.2-83). Results predict that instream flows in October through January (800 cfs) are equal to or greater than the spawning flows in September (773 cfs). Thus, it was concluded that there would be no difference in the risk of redd dewatering between EBC2_ELT and PP_ELT and between EBC2_LLT and PP_LLT.

Fry and Juvenile Rearing

Rearing Habitat

Spring-run Chinook salmon juveniles are present in the Feather River both above (low-flow channel) and below Thermalito Afterbay (high-flow channel) from November through June. Temperatures throughout the low-flow channel should be suitable for rearing (less than 65°F) through this period under all scenarios. Feather River low-flow channel water temperatures may be elevated during the late spring (April through June). Predicted water temperatures are shown in Figure C.5.2-213 and Figure C.5.2-216 through Figure C.5.2-217. In addition, results of monthly water temperature model simulations were compiled for the Feather River low-flow channel over the 82-year period of CALSIM modeling. Results of monthly temperatures were then evaluated to identify those months during the juvenile spring-run salmon rearing period when temperatures exceeded 65°F (Table C.5.2-91). Results of this analysis show that the frequency of years in which the average monthly temperature exceeded 65°F was greater in the high-flow channel when compared to the low-flow channel. Within the low-flow channel the frequency of years with one month of exceedance was comparable under EBC2 and BDCP operations in the early long-term (33 years under EBC2_ELT and 30 years under PP_ELT) as well as during the late long-term (46 years under EBC2_LLT and 47 years under PP_LLT). As expected, the frequency of years with high temperatures increased in the low-flow channel under late long-term operations in response to future climate change. In the high-flow channel, the frequency of years in which one, two, and three consecutive months exceeded the 65°F criterion increased when compared to the low-flow channel under EBC1, EBC2 and BDCP operations. The number of consecutive years with one or months of exceedance increased substantially in the high-flow channel. Results of these analyses indicate that habitat conditions for juvenile rearing are more suitable in the low-flow channel than in the high-flow channel, however the differences are independent of BDCP operations.

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Table C.5.2-91. Results of the Analysis of Water Temperature Simulation in the Feather River during the November through June Spring-Run Juvenile Chinook Salmon Rearing Period[1]

	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
Low-Flow Channel (above Thermalito Afterbay)						
Number of years with one or more exceedances	9	9	33	46	30	47
Number of years with two exceedances	0	0	0	1	0	2
Number of years with three exceedances	0	0	0	0	0	0
Number of years with four exceedances	0	0	0	0	0	0
Number of years with five or more exceedances	0	0	0	0	0	0
Number of consecutive years with one or more exceedances	2	2	22	36	18	32
High-Flow Channel (below Thermalito Afterbay)						
Number of years with one or more exceedances	67	67	74	78	68	72
Number of years with two exceedances	8	8	16	24	13	23
Number of years with three exceedances	0	0	1	1	0	0
Number of years with four exceedances	0	0	0	0	0	0
Number of years with five or more exceedances	0	0	0	0	0	0
Number of consecutive years with one or more exceedances	66	66	74	78	68	72

[1] Time period analyzed: November 1922 to June 2002. Analysis counted monthly exceedances above 65°F.

Constant flows in the low-flow channel would be unchanged for the preliminary proposal, with no measureable effect in that reach of the river (Table C.5.2-83) during the November through June juvenile rearing period. Flows in the high-flow channel at Thermalito Afterbay under the preliminary proposal during October through June would be greater than flows under existing biological conditions in the early and late long-term periods (Table C.5.2-84, Figure C.5.2-225). Flows in July, August, and September would be substantially reduced under the preliminary proposal in the early and late long-term. These reduced-flow months are at the time of year (warm months) when juvenile spring-run Chinook salmon are not rearing in the lower Feather River. This change in flow timing is closer to a natural hydrograph and should benefit spring-run Chinook salmon.

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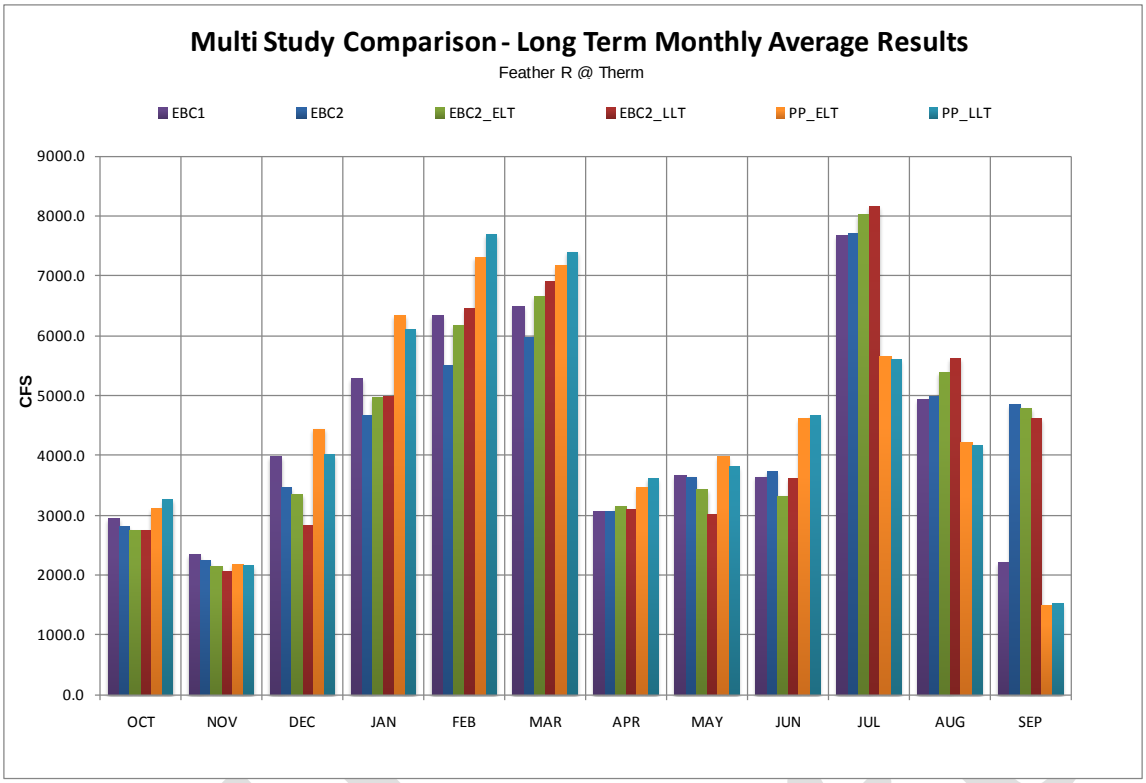

Figure C.5.2-225. Mean Monthly Flows (Cubic Feet per Second) for Model Scenarios in the Feather River High-Flow Channel (at Thermalito Afterbay)

Water temperatures for juvenile Chinook salmon rearing and migrating downstream of Thermalito to the Sacramento River would be suitable under all scenarios in November through March. This encompasses the majority of the spring-run Chinook salmon rearing and emigration period. April temperatures at the Feather River's confluence with the Sacramento River could exceed 65°F in 5% to 20% of years, depending on the climate scenario. May temperatures at the confluence could exceed 65°F in over 60% of years (Figure C.5.2-226). Differences in May mean water temperatures between EBC2_ELT and PP_ELT and between EBC2_LLT and PP_LLT are predicted to be typically less than 0.5°F.

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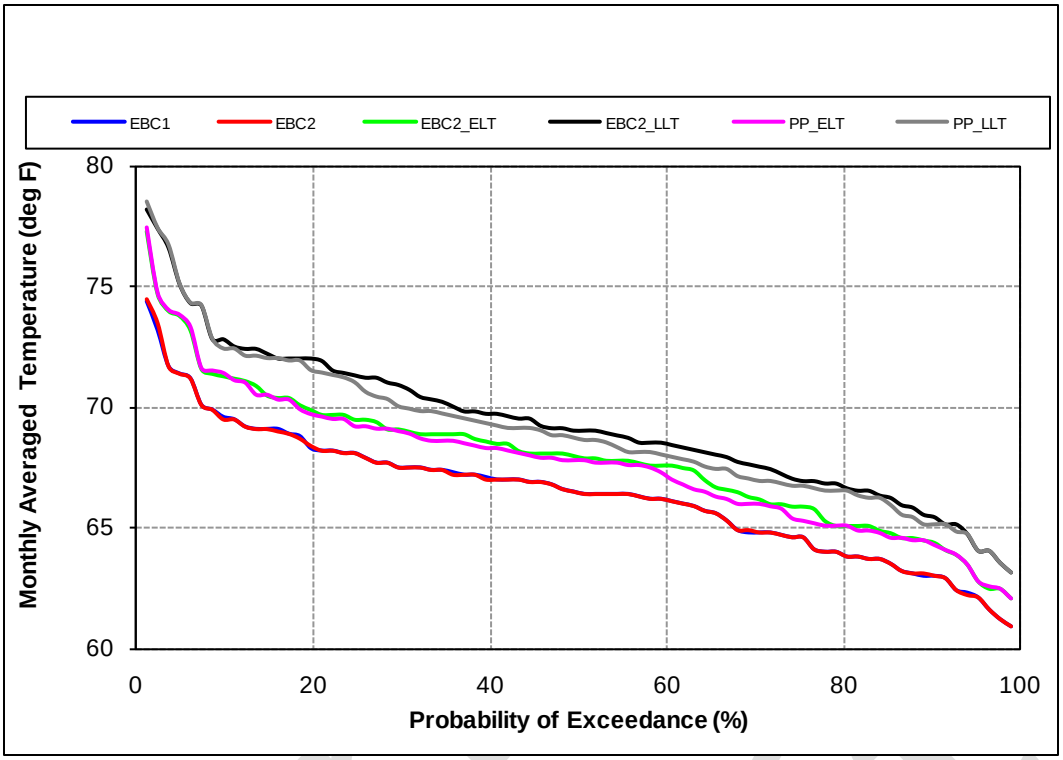

Figure C.5.2-226. Probability of Exceedance Plot for Model Scenarios of Mean Monthly Water Temperature of the Feather River at the Confluence with the Sacramento River, May

Instream flows in the Feather River low-flow channel are predicted to be 700 cfs from April through August, increasing to 773 cfs in September, and 800 cfs from October through March for all model scenarios (Table C.5.2-83). Instream flows in the low-flow channel did not vary among water-year types. Therefore, effects of the preliminary proposal flow-related rearing conditions for juvenile spring-run Chinook salmon are not expected to occur.

Adult

Water Temperature

The effects of the preliminary proposal on water temperature-related habitat of spring-run Chinook salmon were assessed by compiling water temperature outputs from the Reclamation Temperature Model for the 82-year CALSIM period. Water temperatures each month between April and August were assessed to determine the frequency of months when average temperatures exceeded 65°F. Results of the analysis are summarized in Table C.5.2-92. Results of these analyses show that water temperatures in the low-flow channel would be stressful for pre-spawning holding adult spring-run Chinook salmon under all model scenarios. The frequency of years exceeding the criterion one month was 81 years under all model scenarios. The criterion was exceeded in two consecutive months in 46 years under EBC2_ELT, 48 years under PP_ELT, 34 under EBC2_LLT, and 33 years under PP_LLT conditions. The criterion was exceeded in three consecutive months in 30 years under EBC2_ELT, 29 years under PP_ELT, and 46 under both EBC2_LLT and PP_LLT conditions. The increase in the late long-term reflects the effects of future climate change. As part of the FERC Settlement Agreement, DWR is investigating alternative methods to release cold water and to manage coldwater pool on the Feather River to improve habitat conditions for all life stages of

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spring-run Chinook salmon and other salmonids. Results of this analysis indicate that habitat conditions for spring-run adult holding will be highly stressful in the Feather River low-flow channel under all models scenarios. These changes in habitat conditions, however, are independent of BDCP operations.

Table C.5.2-92. Results of Monthly Analysis of Water Temperature Simulations in the Feather River Low-Flow Channel (above Thermalito Afterbay) during the April through August Spring-Run Chinook Salmon Adult Migration Period[1]

	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
Number of years with one or more exceedances	81	81	81	81	81	81
Number of years with two exceedances	52	50	46	34	48	33
Number of years with three exceedances	8	8	30	46	29	46
Number of years with four exceedances	0	0	0	1	0	2
Number of years with five or more exceedances	0	0	0	0	0	0
Number of consecutive years with one or more exceedances	81	81	81	81	81	81

[1] Time period analyzed: April 1922 to August 2002. Analysis counted monthly exceedances above 65°F.

C.5.2.4.3 Fall-/Late Fall–Run

Eggs and Alevins

Upstream Spawning Habitat

The Feather River supports a population of naturally reproducing fall-run Chinook salmon that use the low-flow and high-flow channel reaches of the river for spawning, egg incubation, juvenile rearing, and upstream and downstream migration habitat. Fall-run Chinook salmon also return to the Feather River Fish Hatchery where they are spawned and mature.

Fall-run Chinook salmon spawning and egg incubation occurs in the reach of the Feather River low-flow channel downstream from Oroville Dam to the vicinity of Thermalito Afterbay. Spawning also occurs in the high-flow channel starting typically in November. The geographic distribution of spawning and incubation varies depending on a variety of factors, including the availability of suitable water depths, velocities, and substrate for spawning, and seasonal water temperature regimes. It was assumed that egg exposure to water temperatures in excess of 56°F during the incubation period would result in adverse impacts on reproductive success, including egg mortality.

Fall-run salmon spawn in the late fall (October through December), when seasonal air temperatures in the Oroville area are declining and habitat conditions for fall-run salmon spawning are generally improving. Suitable water temperatures for successful egg incubation depend on the temperature of water released to the river from Oroville Dam, the rate of instream flow, and atmospheric conditions that result in river warming as the water travels downstream from the dam.

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Water Temperature

Reservoir storage volumes in Lake Oroville in May and September under each model scenario are presented in Table C.5.2-86 and Table C.5.2-87, respectively. Monthly simulation estimates of water temperatures in the low-flow and high-flow channels were compiled from the 82-year CALSIM studies. The frequency of months in which the average temperature exceeded 56°F was used to compare egg incubation conditions among scenarios (Table C.5.2-93). Results of these analyses show the frequency of months in which average temperature exceeded 56°F was greater for the high-flow channel than in the low-flow channel. In the low-flow channel, the frequency of months exceeding 56°F was lower under PP_ELT (54 years with at least one month exceeding 56°F and 10 years with two consecutive months exceeding 56°F under EBC2_ELT) and PP_LLT (76 years with at least one month exceeding 56°F and 49 years with two consecutive months exceeding 56°F under EBC2_LLT) compared to EBC2_ELT (44 years with at least one month exceeding 56°F and 7 years with two consecutive months exceeding 56°) and EBC2_LLT (62 years with at least one month exceeding 56°F and 35 years with two consecutive months exceeding 56°F), respectively. The frequency of years with higher temperatures increased in the late long-term with and without the preliminary proposal in response to future climate change. Results of the analysis for the high-flow channel showed at least one month of temperature exceedance in 81 years for both EBC2 and PP operations in the early and late long-term. The number of years having two consecutive months of temperature exceedance decreased under the preliminary proposal from 19 years under EBC2_ELT to 16 years under PP_ELT and from 61 years under EBC2_LLT to 42 years under PP_LLT operations. EBC1 results are comparable (<5% difference) to EBC2 results. These results show that exposure to elevated water temperature will affect egg incubation in both the high-flow and low-flow channels of the Feather River but the number of years having elevated temperatures is predicted to be lower under the preliminary proposal in both channels.

Table C.5.2-93. Summary of the Frequency of Water Temperatures in the Feather River that Exceeded 56°F during the October through January Fall-Run Chinook Salmon Incubation Period[1]

	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
Low-Flow Channel (above Thermalito Afterbay)						
Number of years with one or more exceedances	25	28	53	75	44	61
Number of years with two exceedances	2	4	9	48	7	34
Number of years with three exceedances	0	0	0	7	0	1
Number of years with four exceedances	0	0	0	0	0	0
Number of years with five or more exceedances	0	0	0	0	0	0
Number of consecutive years with one or more exceedances	19	18	47	74	35	55
High-Flow Channel (below Thermalito Afterbay)						
Number of years with one or more exceedances	78	78	80	80	80	80
Number of years with two exceedances	3	4	18	60	16	41
Number of years with three exceedances	0	0	0	1	0	0
Number of years with four exceedances	0	0	0	0	0	0
Number of years with five or more exceedances	0	0	0	0	0	0
Number of consecutive years with one or more exceedances	78	78	80	80	80	80

[1] Time period analyzed: October 1922 to January 2002. Analysis counted monthly exceedances above 56°F.

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The Reclamation egg mortality model for the Feather River has been developed for fall-run Chinook seasonal timing and spawning distribution. The actual geographic distribution of spawning varies among years and can affect egg mortality. Depending on the abundance of spawning adults and other factors, a substantial portion of the spawning and rearing by fall-run Chinook salmon may take place in the high-flow channel. Results of the fall-run Chinook salmon egg mortality estimates are summarized in Table C.5.2-94 and Figure C.5.2-227. Egg mortality in the Feather River was relatively low under existing biological conditions and during the early long-term period under all conditions, but showed a large increase of more than double in the late long-term period. Egg mortality decreased under proposed project operations when compared to existing biological condition scenarios in all water-year types. Egg mortality estimates for fall-run Chinook salmon in the Feather River are comparable between existing biological conditions and proposed project operations during the early long-term period. During the late long-term period, there is a marked increase in egg mortality predicted under existing biological conditions when compared to proposed project operations. Although the predicted egg mortality in the late long-term was less under BDCP operations in all water-year types, the greatest differences occurred in wet (13.8% reduction), above-normal (9.2% reduction), and dry years (5.6% reduction). The predicted differences in egg mortality were unexpected since most of the spawning occurs in the low-flow channel where river flows are stable and identical between existing biological conditions and BDCP operations and water temperatures were also comparable.

Table C.5.2-94. Egg Mortality Percentages for Fall-Run Chinook in the Feather River

Water-Year Type	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
Wet	1.4	1.4	2.7	20.5	2.4	6.7
Above Normal	1.1	1.1	2.3	13.6	1.6	7.4
Below Normal	1.8	1.9	3.1	14.9	3.3	13.4
Dry	2.2	2.4	6.4	21.0	4.6	15.4
Critical	4.9	4.7	10.8	28.3	8.9	25.8
Average	2.1	2.2	4.7	19.9	3.9	12.7

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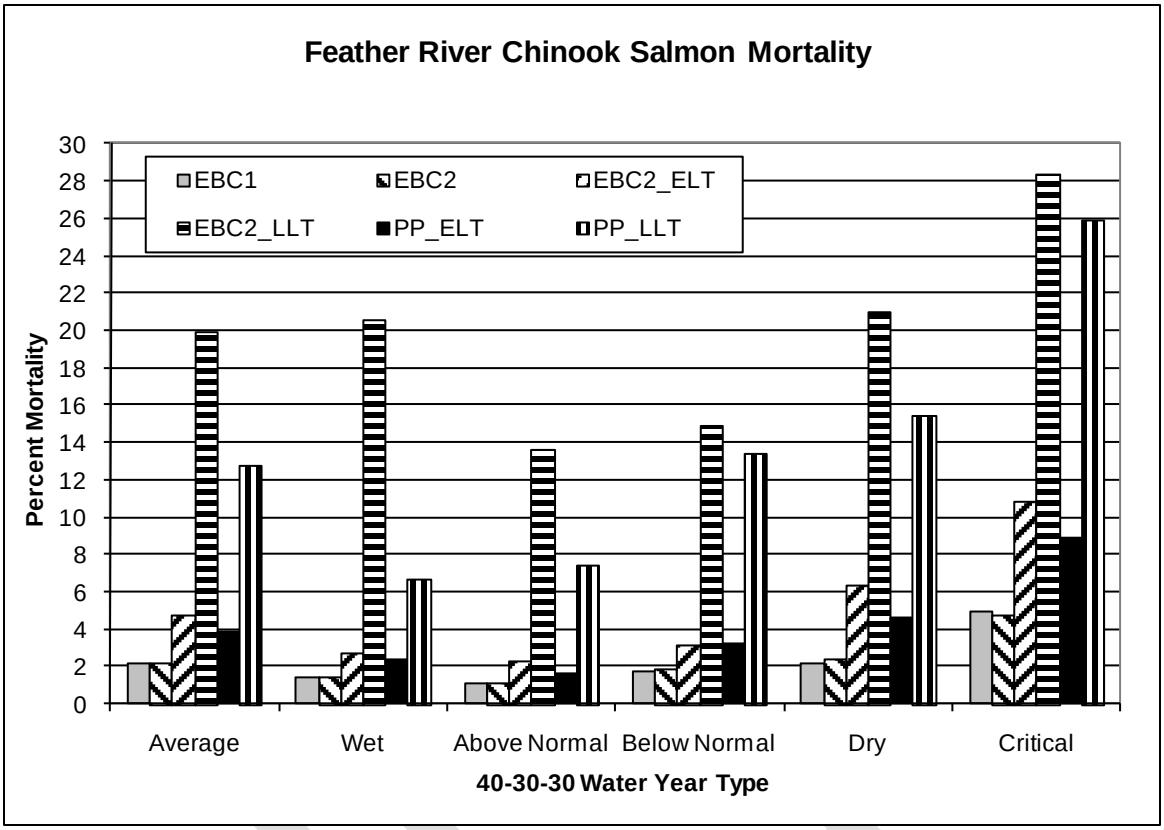

Figure C.5.2-227. Feather River Fall-Run Chinook Average Egg Mortality under Each Model Scenario for Each Water-Year Type and for All Years from the Reclamation Egg Mortality Model

Redd Dewatering

Instream flows in the Feather River low-flow channel are maintained at 800 cfs under all model scenarios (Table C.5.2-83). Ramping rates are part of routine operations. The stability of these flows is expected to minimize or avoid the risk of redd dewatering under both existing biological conditions and proposed project operations.

Flow fluctuations do occur in the high-flow channel during fall-run salmon egg incubation. Results of CALSIM modeling show a reduction in flows between October and November under all model scenarios that would pose an increased risk of redd dewatering under all conditions (Table C.5.2-84). Flows increased under all scenarios between November and March, which would reduce the risk of redd dewatering later in the incubation period. The risk of redd dewatering within the high-flow channel is not expected to differ between EBC2 and BDCP conditions.

Fry and Juvenile Rearing

Rearing Habitat

Fall-run Chinook juveniles are present in the Feather River in December through June, with peak rearing occurring between January and May. Instream flows in the Feather River low-flow channel during the juvenile fall-run Chinook salmon rearing period are predicted to be identical (700 to 800 cfs) for all model scenarios (Table C.5.2-83). Therefore, it was concluded that there would be no

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effects of the preliminary proposal on physical habitat characteristics (e.g., water depth, velocity, wetted cross sectional area) within the low-flow channel.

Mean monthly water temperatures throughout the low-flow channel would also be suitable for rearing (lower than 65°F) through this period under all scenarios (Figure C.5.2-213, Figure C.5.2-216, Figure C.5.2-228, Figure C.5.2-229, Figure C.5.2-230). The constant flows in the low-flow channel would be unchanged among all model scenarios and would therefore not be higher under the preliminary proposal relative to existing biological conditions in nearly all months and water-year types between December and June (Table C.5.2-84). This change in flow timing is closer to a natural hydrograph and should benefit fall-run Chinook salmon.

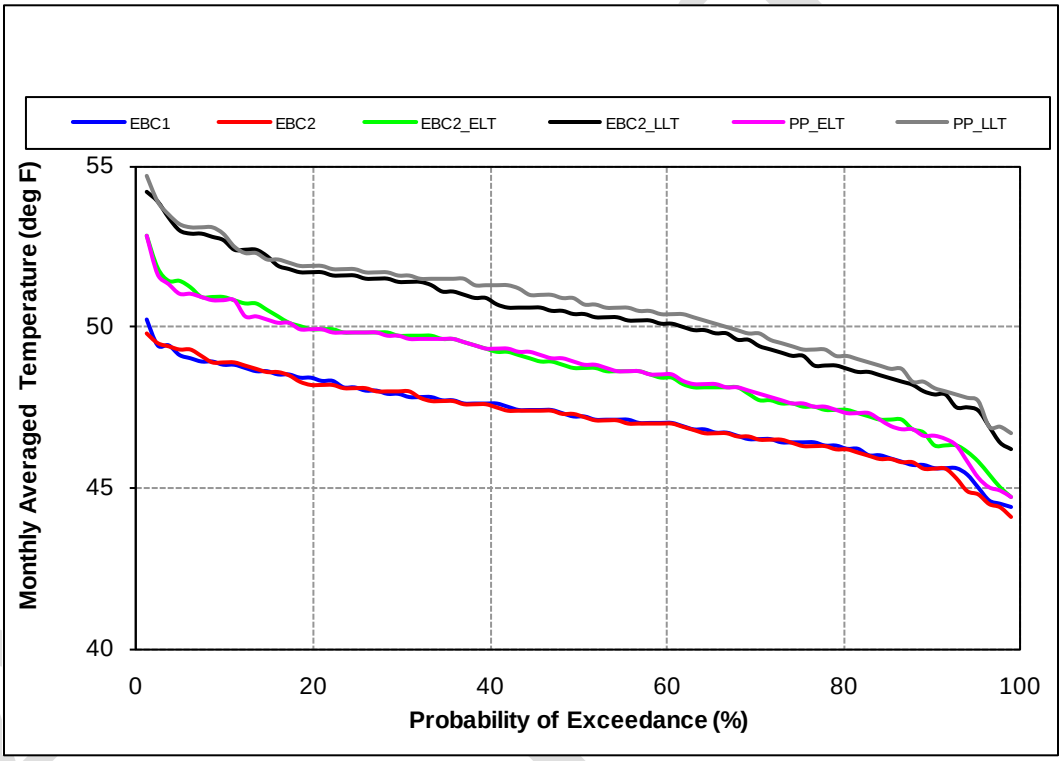

Figure C.5.2-228. Probability of Exceedance Plot for Model Scenarios of Mean Monthly Water Temperature in the Feather River Low-Flow Channel (above Thermalito Afterbay), January

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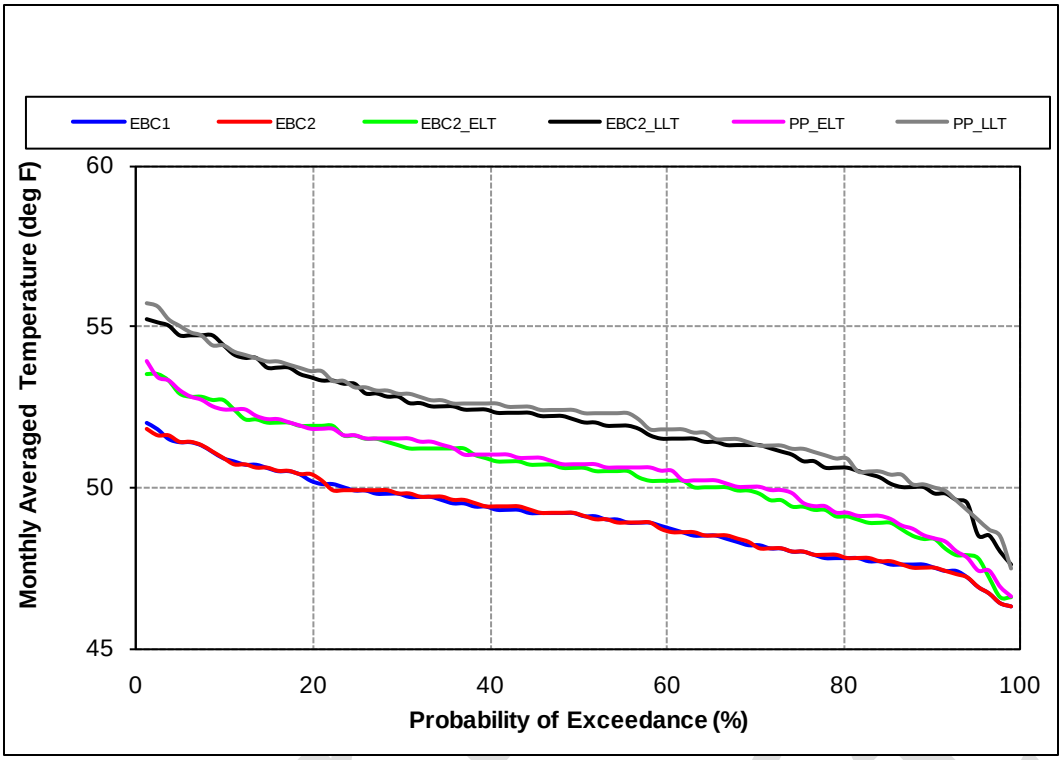

Figure C.5.2-229. Probability of Exceedance Plot for Model Scenarios of Mean Monthly Water Temperature in the Feather River Low-Flow Channel (above Thermalito Afterbay), February

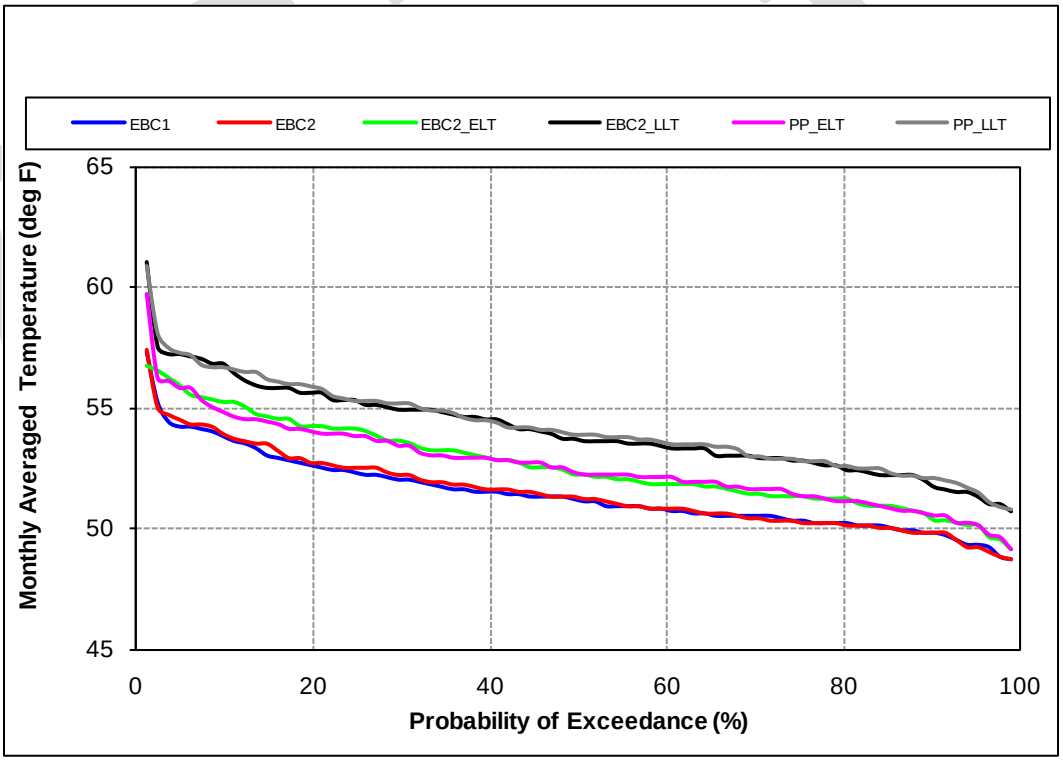

Figure C.5.2-230. Probability of Exceedance Plot for Model Scenarios of Mean Monthly Water Temperature in the Feather River Low-Flow Channel (above Thermalito Afterbay), March

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Water temperatures for rearing juvenile Chinook salmon downstream of Thermalito Afterbay to the Sacramento River confluence would be suitable under all scenarios for the months of December through March (Figure C.5.2-231 through Figure C.5.2-234). Water temperatures in April under EBC1 and EBC2 are not predicted to exceed 65°F. Temperatures in April are predicted to exceed 65°F in ~2%–3% of years in EBC2_ELT, EBC2_LLT, PP_ELT, and PP_LLT (Figure C.5.2-235). May temperatures under EBC2_ELT and PP_ELT are predicted to exceed 65°F in 10% more years than EBC1 and EBC2 (Figure C.5.2-236). May temperatures under EBC2_LLT and PP_LLT are predicted to exceed 65°F in approximately 25% more years than EBC1 and EBC2. Some fall-run juveniles remain in the river into June in some years. June temperatures at the confluence are predicted to exceed 65°F in over 80% of years (Figure C.5.2-237). Temperatures in May and June are predicted to be slightly reduced under PP_ELT and PP_LLT compared to the EBC2_ELT and EBC2_LLT, respectively, which should benefit fall-run Chinook salmon rearing habitat.

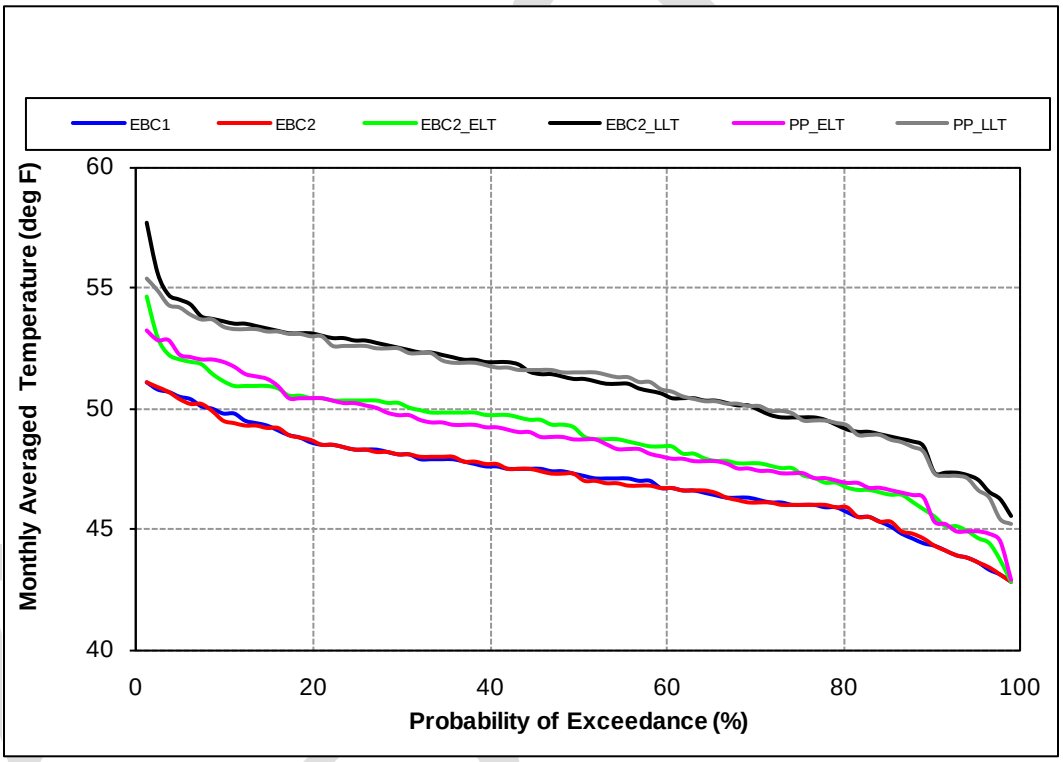

Figure C.5.2-231. Probability of Exceedance Plot for Model Scenarios of Monthly Temperatures in the Feather River High-Flow Channel (below Thermalito Afterbay), December

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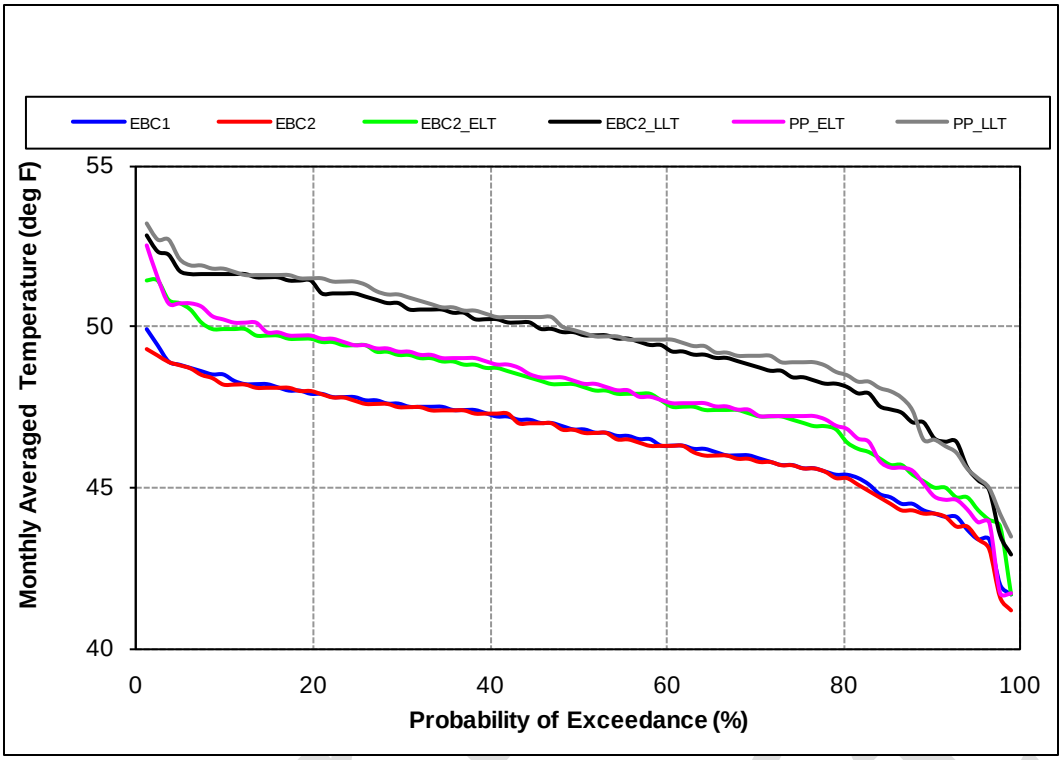

Figure C.5.2-232. Probability of Exceedance Plot for Model Scenarios of Monthly Temperatures in the Feather River High-Flow Channel (below Thermalito Afterbay), January

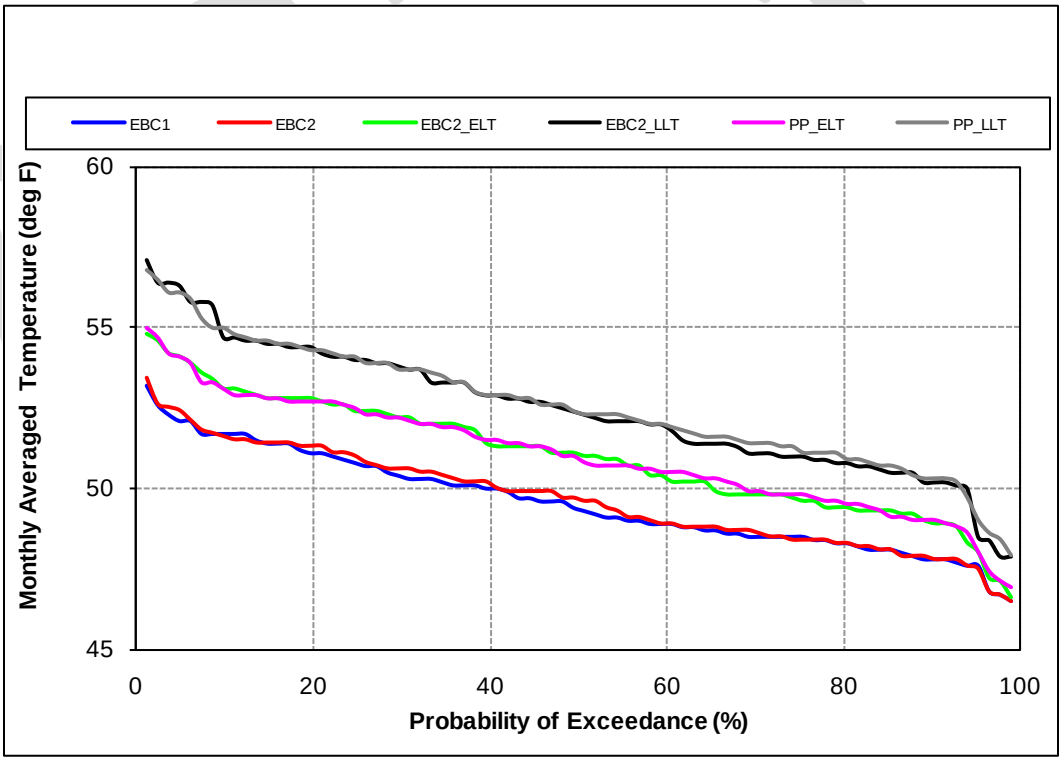

Figure C.5.2-233. Probability of Exceedance Plot for Model Scenarios of Monthly Temperatures in the Feather River High-Flow Channel (below Thermalito Afterbay), February

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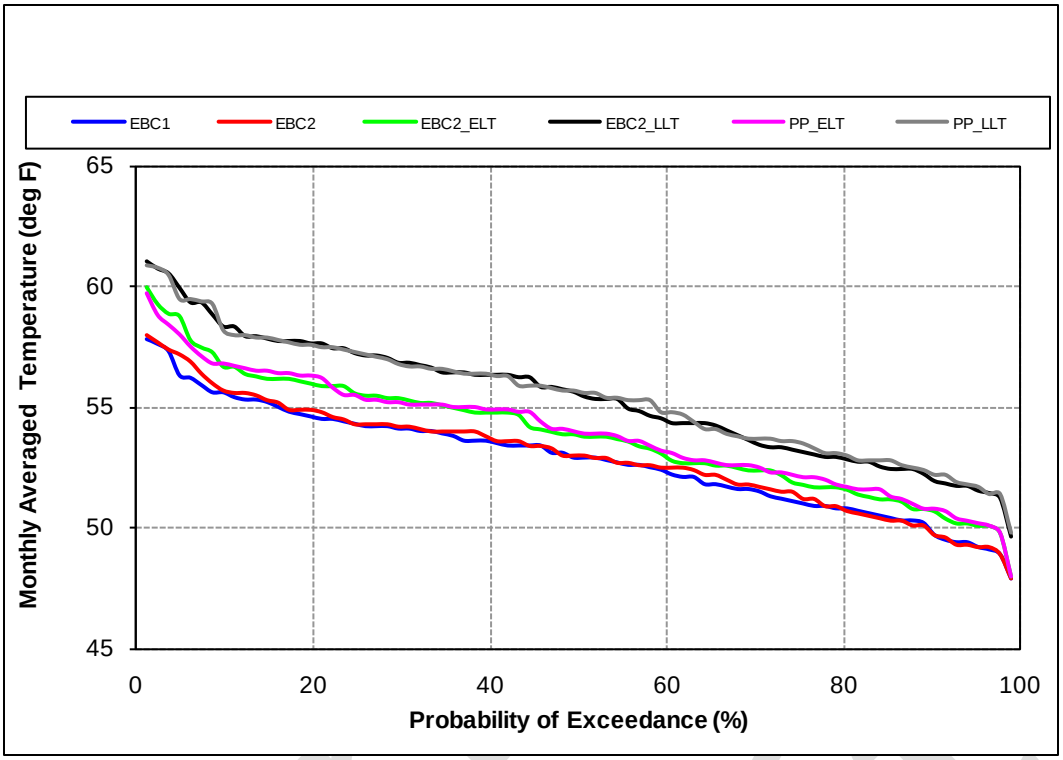

Figure C.5.2-234. Probability of Exceedance Plot for Model Scenarios of Monthly Temperatures in the Feather River High-Flow Channel (below Thermalito Afterbay), March

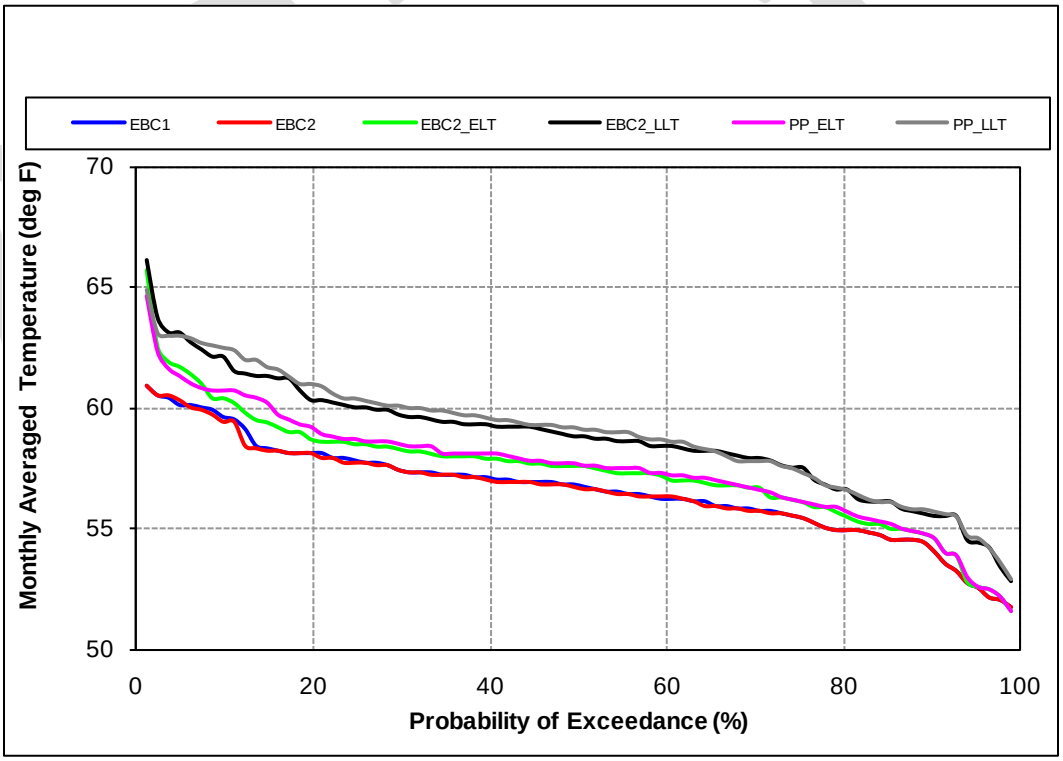

Figure C.5.2-235. Probability of Exceedance Plot for Model Scenarios of Monthly Temperatures in the Feather River High-Flow Channel (below Thermalito Afterbay), April

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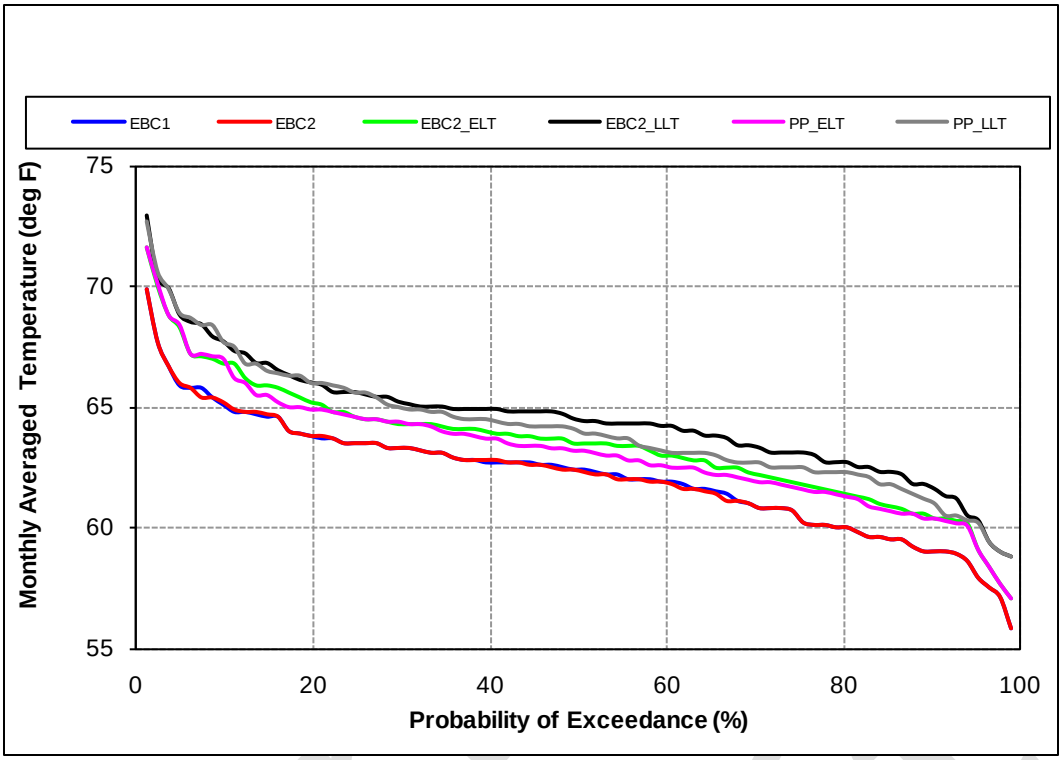

Figure C.5.2-236. Probability of Exceedance Plot for Model Scenarios of Monthly Temperatures in the Feather River High-Flow Channel (below Thermalito Afterbay), May

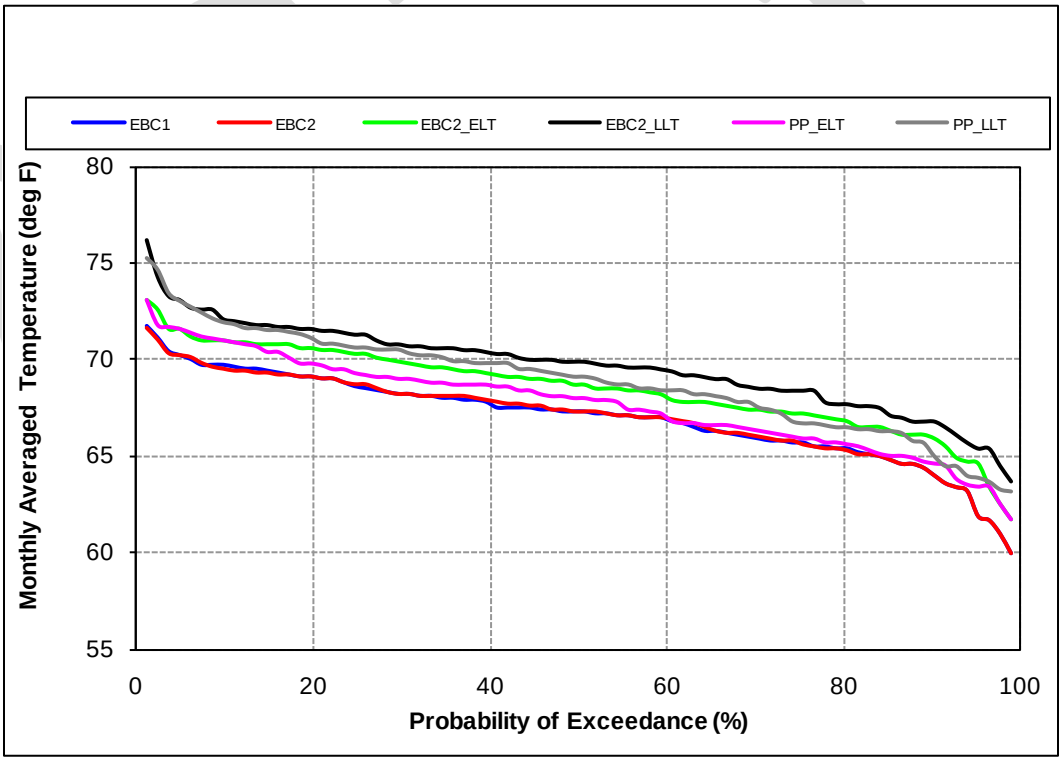

Figure C.5.2-237. Probability of Exceedance Plot for Model Scenarios of Monthly Temperatures in the Feather River High-Flow Channel (below Thermalito Afterbay), June

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Adult

Water Temperature

Predicted monthly water temperatures from the Reclamation Temperature Model for the Feather River at Honcut Creek from August through December are presented in Figure C.5.2-238. Exceedance above the 65°F threshold is predicted to occur 7% more often under PP_ELT compared to EBC2_ELT and 4% more often under PP_LLT compared to EBC2_LLT. These differences are expected to have a minor negative effect on the migration habitat of fall-run Chinook salmon.

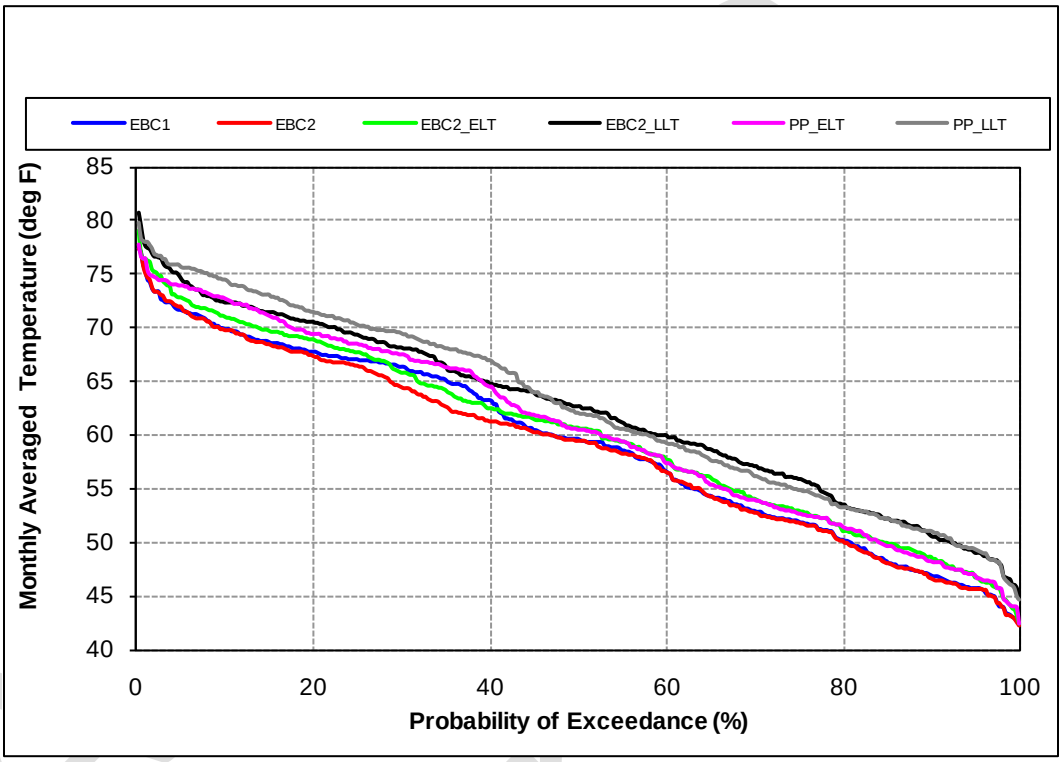

Figure C.5.2-238. Probability of Exceedance Plot for Model Scenarios of Mean Monthly Water Temperature of Feather River at Honcut Creek during the Fall-Run Chinook Salmon Adult Migration Period, August through December

C.5.2.4.4 Splittail

Larvae

As described for the Sacramento River (Section C.5.2.1.5), splittail spawning and rearing of larvae and young juveniles in channel margin and side-channel habitat upstream of the Delta is likely to be especially important during dry years, when flows are too low to inundate the floodplains. Splittail have been found upstream in the Feather River almost to the Thermalito Afterbay outlet (Sommer et al. 2007).

Spawning and Rearing Habitat

The upstream side-channel habitats used by splittail for spawning and rearing are, as previously indicated, affected by changes in flow because greater flows cause more flooding, thereby increasing

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availability of such habitat, and because rapid reductions in flow dewater the habitats, potentially stranding splittail eggs and rearing larvae. The changes in flows are expected to be especially important in years with low-flows. Simulated flows in the Feather River at its confluence with the Sacramento River were used to investigate the potential effects of BDCP operations on side-channel habitat availability on the mainstem Feather River. This analysis was limited to flows during February through June because these are the most important months for splittail spawning and larval and juvenile rearing and the months in which splittail are most likely to be in the Feather River.

Monthly average flows during February through June by water-year type are presented in Table C.5.2-95 and differences between pairs of model scenarios are presented in Table C.5.2-96. A probability of exceedance plot is presented in Figure C.5.2-239. Results show that, in the drier water-year types (below-normal, dry, and critical) when splittail are most likely to use side channel habitat in the Feather River, there are substantial differences (>10%) in flows between EBC2_ELT and PP_ELT and between EBC2_LLT and PP_LLT in some months. Differences are particularly high for below-normal years in May and June, ranging from 40%–54% percent higher under PP_ELT and PP_LLT relative to EBC2_ELT and EBC2_LLT, respectively, due to increased releases at Oroville. Differences in dry and critical years are greatest in April, with flows 14%–29% higher under PP_ELT and PP_LLT relative to EBC2_ELT and EBC2_LLT, respectively. For all differences in flow >5%, the flows are higher under PP_ELT and PP_LLT relative to EBC2_ELT and EBC2_LLT, respectively, except during June in critical years when the flows under PP_ELT and PP_LLT are 6%–8% lower. These results indicate that greater amounts of side channel habitat are available for splittail spawning and rearing in the Feather River under the preliminary proposal relative to existing biological conditions, especially during April through June, with the exception of June in critical years, when side channel habitat is less available under the preliminary proposal.

Table C.5.2-95. Mean Monthly Flows (Cubic Feet per Second) in the Feather River at the Confluence with the Sacramento River, February to June

Month	WY Type	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
Feb	W	27,039	26,129	29,508	31,065	30,944	32,896
	AN	14,818	12,840	14,119	14,599	17,311	16,932
	BN	9,153	8,053	8,081	7,892	9,009	9,278
	D	4,402	4,223	4,365	4,436	4,689	4,645
	C	3,237	3,118	3,086	3,096	3,109	3,452
	AVG	13,744	12,922	14,212	14,761	15,367	16,017
Mar	W	24,172	23,698	25,585	26,784	25,931	27,009
	AN	19,990	19,240	21,173	21,490	22,118	23,340
	BN	8,136	7,237	7,175	6,882	7,547	7,254
	D	5,073	4,794	4,626	4,940	5,599	5,336
	C	2,933	2,620	2,695	2,756	2,847	2,844
	AVG	13,521	13,001	13,846	14,300	14,393	14,806
Apr	W	15,897	15,955	16,056	15,852	16,188	15,845
	AN	9,832	9,848	9,733	9,585	9,734	9,924
	BN	5,401	5,328	5,232	5,189	5,644	6,147
	D	4,152	4,198	4,233	4,137	4,890	5,354
	C	3,298	3,280	3,195	3,185	3,650	3,692
	AVG	8,796	8,811	8,805	8,689	9,129	9,242

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Month	WY Type	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
May	W	14,387	14,390	12,987	10,385	13,112	11,072
	AN	8,068	7,986	7,777	6,884	8,770	8,143
	BN	4,704	4,642	4,534	4,509	6,357	6,432
	D	3,652	3,642	3,660	3,767	4,100	4,094
	C	2,389	2,332	2,492	2,321	2,367	2,284
	AVG	7,697	7,665	7,198	6,237	7,773	7,034
Jun	W	10,222	10,273	7,790	7,199	9,308	8,247
	AN	6,391	6,454	5,485	5,598	8,032	7,792
	BN	4,495	4,524	4,346	4,342	6,711	6,243
	D	3,853	4,055	3,776	3,367	3,928	3,582
	C	2,782	2,778	2,678	2,522	2,496	2,316
	AVG	6,197	6,271	5,236	4,951	6,500	5,946

Table C.5.2-96. Difference (Percent Difference) between Pairs of Model Scenarios in Mean Monthly Flows in the Feather River at the Confluence with the Sacramento River, February through June

Month	WY Type	EBC1 vs. PP_ELT	EBC1 vs. PP_LLT	EBC2 vs. PP_ELT	EBC2 vs. PP_LLT	EBC2_ELT vs. PP_ELT	EBC2_LLT vs. PP_LLT
Feb	W	3905 (14.4%)	5857 (21.7%)	4815 (18.4%)	6767 (25.9%)	1436 (4.9%)	1831 (5.9%)
	AN	2492 (16.8%)	2113 (14.3%)	4471 (34.8%)	4092 (31.9%)	3192 (22.6%)	2332 (16%)
	BN	-143 (-1.6%)	125 (1.4%)	956 (11.9%)	1225 (15.2%)	928 (11.5%)	1386 (17.6%)
	D	287 (6.5%)	243 (5.5%)	466 (11%)	422 (10%)	324 (7.4%)	209 (4.7%)
	C	-128 (-4%)	215 (6.6%)	-9 (-0.3%)	334 (10.7%)	23 (0.7%)	356 (11.5%)
	AVG	1623 (11.8%)	2273 (16.5%)	2445 (18.9%)	3095 (24%)	1155 (8.1%)	1256 (8.5%)
Mar	W	1760 (7.3%)	2838 (11.7%)	2234 (9.4%)	3312 (14%)	346 (1.4%)	226 (0.8%)
	AN	2128 (10.6%)	3350 (16.8%)	2878 (15%)	4100 (21.3%)	945 (4.5%)	1850 (8.6%)
	BN	-589 (-7.2%)	-882 (-10.8%)	310 (4.3%)	17 (0.2%)	372 (5.2%)	372 (5.4%)
	D	526 (10.4%)	264 (5.2%)	805 (16.8%)	542 (11.3%)	973 (21%)	397 (8%)
	C	-86 (-2.9%)	-89 (-3%)	226 (8.6%)	223 (8.5%)	151 (5.6%)	87 (3.2%)
	AVG	872 (6.4%)	1284 (9.5%)	1392 (10.7%)	1805 (13.9%)	547 (4%)	506 (3.5%)
Apr	W	291 (1.8%)	-52 (-0.3%)	233 (1.5%)	-110 (-0.7%)	132 (0.8%)	-7 (0%)
	AN	-98 (-1%)	92 (0.9%)	-114 (-1.2%)	76 (0.8%)	1 (0%)	339 (3.5%)
	BN	244 (4.5%)	747 (13.8%)	317 (5.9%)	820 (15.4%)	413 (7.9%)	959 (18.5%)
	D	739 (17.8%)	1203 (29%)	692 (16.5%)	1157 (27.6%)	657 (15.5%)	1218 (29.4%)
	C	352 (10.7%)	394 (11.9%)	370 (11.3%)	412 (12.6%)	455 (14.2%)	507 (15.9%)
	AVG	333 (3.8%)	446 (5.1%)	318 (3.6%)	430 (4.9%)	323 (3.7%)	553 (6.4%)
May	W	-1275 (-8.9%)	-3314 (-23%)	-1279 (-8.9%)	-3318 (-23.1%)	125 (1%)	687 (6.6%)
	AN	702 (8.7%)	75 (0.9%)	784 (9.8%)	156 (2%)	993 (12.8%)	1259 (18.3%)
	BN	1653 (35.1%)	1728 (36.7%)	1716 (37%)	1791 (38.6%)	1823 (40.2%)	1924 (42.7%)
	D	448 (12.3%)	442 (12.1%)	458 (12.6%)	452 (12.4%)	440 (12%)	327 (8.7%)
	C	-21 (-0.9%)	-104 (-4.4%)	36 (1.5%)	-47 (-2%)	-124 (-5%)	-36 (-1.6%)
	AVG	76 (1%)	-663 (-8.6%)	108 (1.4%)	-631 (-8.2%)	575 (8%)	797 (12.8%)

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Month	WY Type	EBC1 vs. PP_ELT	EBC1 vs. PP_LLT	EBC2 vs. PP_ELT	EBC2 vs. PP_LLT	EBC2_ELT vs. PP_ELT	EBC2_LLT vs. PP_LLT
Jun	W	-914 (-8.9%)	-1975 (-19.3%)	-965 (-9.4%)	-2026 (-19.7%)	1517 (19.5%)	1048 (14.6%)
	AN	1640 (25.7%)	1401 (21.9%)	1577 (24.4%)	1338 (20.7%)	2546 (46.4%)	2195 (39.2%)
	BN	2216 (49.3%)	1748 (38.9%)	2187 (48.3%)	1719 (38%)	2365 (54.4%)	1901 (43.8%)
	D	75 (2%)	-271 (-7%)	-127 (-3.1%)	-473 (-11.7%)	152 (4%)	215 (6.4%)
	C	-286 (-10.3%)	-467 (-16.8%)	-282 (-10.2%)	-462 (-16.6%)	-182 (-6.8%)	-206 (-8.2%)
	AVG	303 (4.9%)	-250 (-4%)	229 (3.7%)	-325 (-5.2%)	1264 (24.1%)	995 (20.1%)

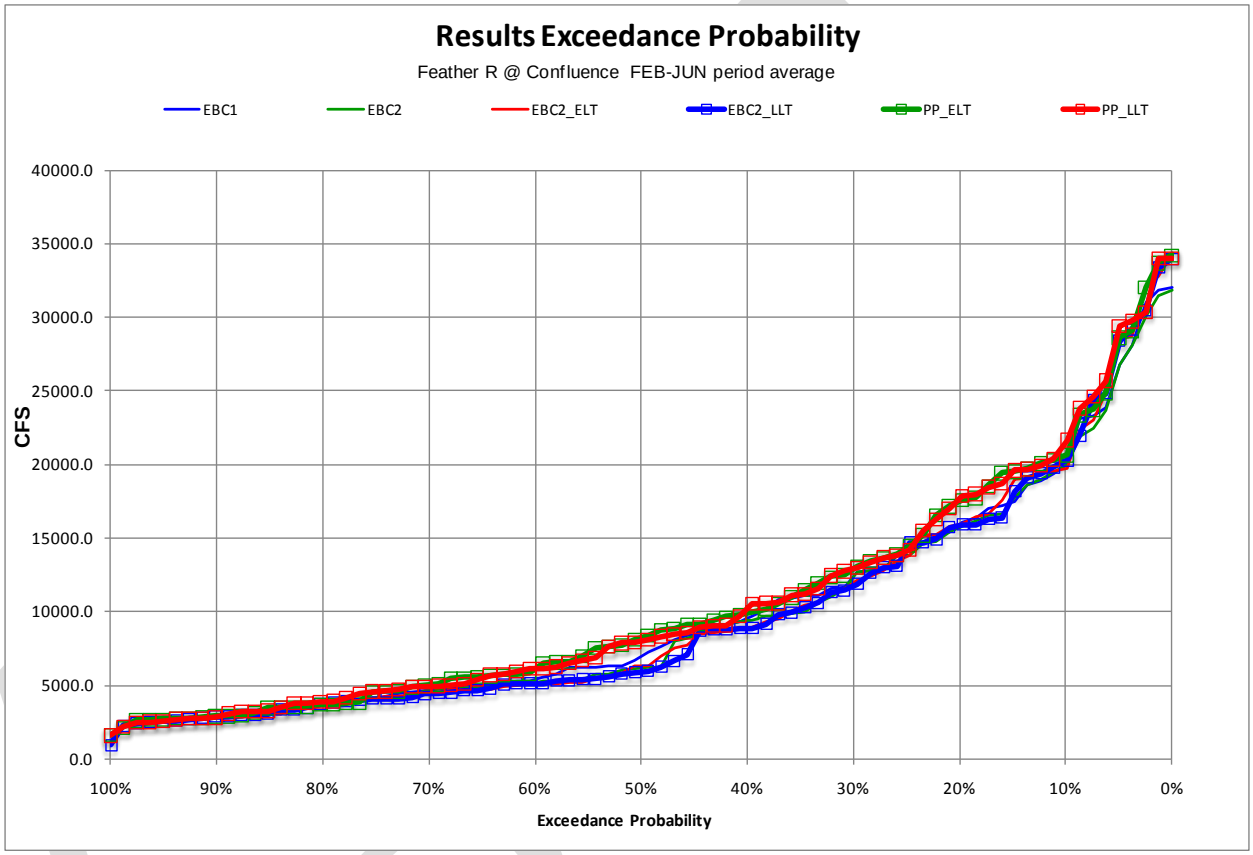

Figure C.5.2-239. Probability of Exceedance Plot for Model Scenarios of Mean Monthly Flow in the Feather River at the Confluence with the Sacramento River, February through June

Water Temperature

Simulated daily water temperatures in the Feather River at its confluence with the Sacramento River City were used to investigate the potential effects of BDCP operations on the suitability of water temperatures for splittail rearing on the mainstem Feather River. As previously indicated (Section C.6.2.1.1), a range of 45°F to 75°F was selected as the suitable range for splittail egg incubation and larval rearing in the upstream habitat locations.

Table C.5.2-97 presents the percent of days from 1992-2003 during which February through June temperatures are below 45°F or exceed 75°F for each model scenario. Table C.5.2-98 presents the differences and percent differences between pairs of model scenarios in the percent of days below 45°F or above 75°F. Figure C.5.2-240 presents the probability of water temperature exceedance for

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each model scenario. These results show that water temperatures under all scenarios would remain above 45°F in 100% of days throughout the period, but would rise above 75°F on many days, especially under late long-term climate conditions during drier water-year types (i.e., EBC2_LLT and PP_LLT with below-normal, dry and critical water-year types). There is little difference (<5%) in the percent of days above 75°F between EBC2_ELT and PP_ELT and between EBC2_LLT and PP_LLT in the drier water-year types (below-normal, dry and critical). Therefore, it is concluded that there are no biologically meaningful temperature-related effects of the BDCP on splittail egg and larval habitat in the Feather River.

Table C.5.2-97. Percent of Months during February to June[1] When Daily Average Temperatures Are Below 45°F or 75°F in the Feather River at the Confluence with the Sacramento River

	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
Temperatures below 45°F						
Wet	0.0	0.0	0.0	0.0	0.0	0.0
Above Normal	0.0	0.0	0.0	0.0	0.0	0.0
Below Normal	0.0	0.0	0.0	0.0	0.0	0.0
Dry	0.0	0.0	0.0	0.0	0.0	0.0
Critical	0.0	0.0	0.0	0.0	0.0	0.0
All	0.0	0.0	0.0	0.0	0.0	0.0
Temperatures above 75°F						
Wet	0.0	0.0	2.3	5.4	2.3	6.2
Above Normal	0.0	0.0	7.3	9.1	1.8	7.3
Below Normal	0.0	0.0	5.7	11.4	1.4	7.1
Dry	4.4	3.3	10.0	17.8	10.0	17.8
Critical	1.7	1.7	8.3	15.0	6.7	16.7
All	1.2	1.0	6.2	11.1	4.4	10.6

[1] Based on the modeling period of 1922 to 2003.

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Table C.5.2-98. Difference and Percent Difference in Percentage of Months during February to June When Daily Average Temperature Is Below 45°F or Exceeds 75°F in the Feather River at the Confluence with the Sacramento River

Water-Year Type	Comparison[1]	EBC1 vs. PP_ELT	EBC1 vs. PP_LLT	EBC2 vs. EBC2_ELT	EBC2 vs. EBC2_LLT	EBC2 vs. PP_ELT	EBC2 vs. PP_LLT	EBC2_ELT vs. PP_ELT	EBC2_LLT vs. PP_LLT
Below 45°F									
Wet	Difference	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Percent Difference	NA	NA	NA	NA	NA	NA	NA	NA
Above Normal	Difference	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Percent Difference	NA	NA	NA	NA	NA	NA	NA	NA
Below Normal	Difference	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Percent Difference	NA	NA	NA	NA	NA	NA	NA	NA
Dry	Difference	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Percent Difference	NA	NA	NA	NA	NA	NA	NA	NA
Critical	Difference	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Percent Difference	NA	NA	NA	NA	NA	NA	NA	NA
All	Difference	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Percent Difference	NA	NA	NA	NA	NA	NA	NA	NA
Above 75°F									
Wet	Difference	2.3	6.2	2.3	5.4	2.3	6.2	0.0	0.8
	Percent Difference	NA	NA	NA	NA	NA	NA	0%	14%
Above Normal	Difference	1.8	7.3	7.3	9.1	1.8	7.3	-5.5	-1.8
	Percent Difference	NA	NA	NA	NA	NA	NA	-75%	-20%
Below Normal	Difference	1.4	7.1	5.7	11.4	1.4	7.1	-4.3	-4.3
	Percent Difference	NA	NA	NA	NA	NA	NA	-75%	-38%
Dry	Difference	5.6	13.3	6.7	14.4	6.7	14.4	0.0	0.0
	Percent Difference	125%	300%	200%	433%	200%	433%	0%	0%
Critical	Difference	5.0	15.0	6.7	13.3	5.0	15.0	-1.7	1.7
	Percent Difference	300%	900%	400%	800%	300%	900%	-20%	11%
All	Difference	3.2	9.4	5.2	10.1	3.5	9.6	-1.7	-0.5
	Percent Difference	260%	760%	525%	1025%	350%	975%	-28%	-4%

[1] A positive value indicates a higher value under the preliminary proposal than the EBC.
NA = Could not be calculated because dividing by 0.

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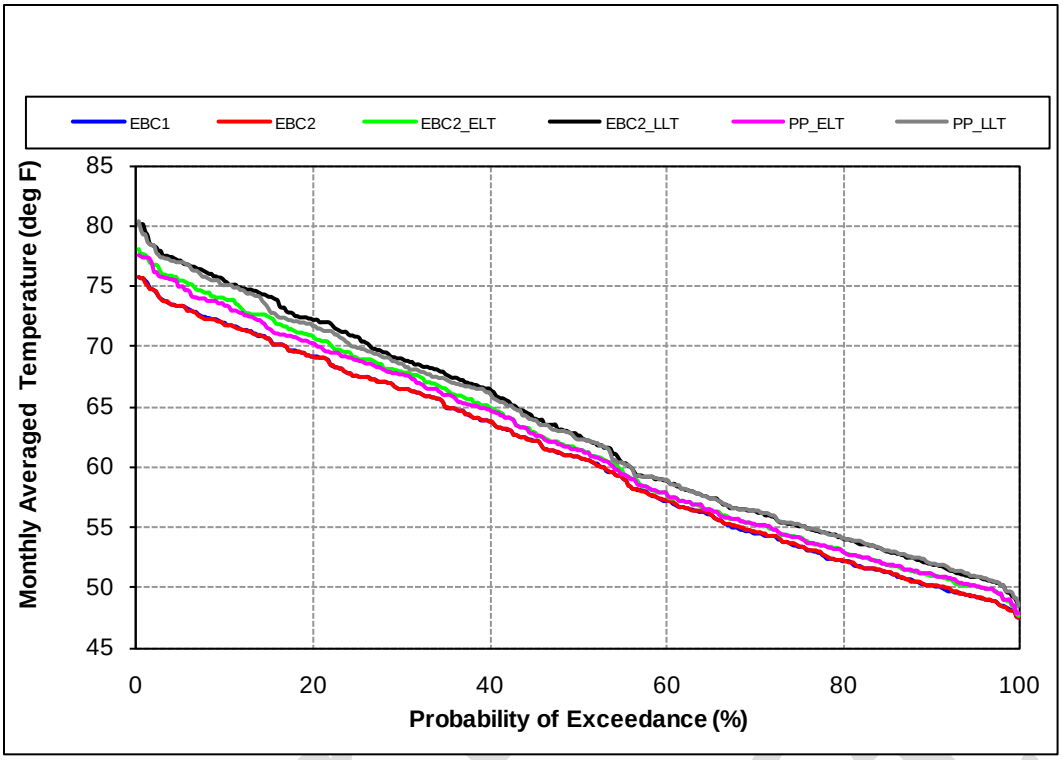

Figure C.5.2-240. Probability of Exceedance Plot for Model Scenarios of Mean Monthly Temperature in the Feather River at the Confluence with the Sacramento River, February through June

C.5.2.4.5 White Sturgeon

Egg/Embryo

Water Temperature

Below Thermalito Afterbay

Reclamation Water Temperature Model results for the Feather River below Thermalito Afterbay during the white sturgeon spawning period (February through May) are presented in Figure C.5.2-241 to Figure C.5.2-245. The percentage of months in which average temperature exceeded 61°F, 68°F, and 72°F is presented in Table C.5.2-99 and differences between pairs of model scenarios are presented in Table C.5.2-100.

Combining all water years, water temperatures in the Feather River below Thermalito Afterbay are predicted to exceed the 61°F threshold in17% of months under EBC1 and EBC2, 22%–28% of months under EBC2_ELT and EBC2_LLT, and 22%–27% of months under PP_ELT and PP_LLT. Among water years, the predicted exceedance frequency ranges from 10% (wet years under EBC1 and EBC2) to 32% (dry years under EBC2_LLT and PP_LLT). The higher threshold exceedances under EBC2_ELT and EBC2_LLT relative to EBC1 and EBC2 reflect the effects of climate change. The frequency of water temperatures exceeding 61°F is predicted to be higher under BDCP implementation (scenarios PP_ELT and PP_LLT) by 5%–10% relative to EBC1 and EBC2, and <1% relative to EBC2_ELT and EBC2_LLT. The differences in threshold exceedance frequencies between PP_ELT and EBC2_ELT and between PP_LLT and EBC2_LLT represent negligible preliminary project effects.

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Combining all water years, water temperatures in the Feather River below Thermalito Afterbay from February through May exceeded the 68°F threshold in <1% of months under EBC1 and EBC2, 1%–2% of months under EBC2_ELT and EBC2_LLT, and 1%–2% of months under PP_ELT and PP_LLT. Among water years, the 68°F threshold was exceeded only in dry and critically dry years, ranging from 0%–2% of months under EBC1 and EBC2, 3%–4% of months under EBC2_ELT and PP_ELT, and 3%–8% of months under EBC2_LLT and PP_LLT. BDCP implementation (PP_ELT and PP_LLT) would result in a 1%–2% increase in the frequency of water temperatures exceeding 68°F relative to EBC1 and EBC2, and <1% increase in the frequency of water temperatures exceeding 68°F relative to EBC2_ELT and EBC2_LLT. The differences between PP_ELT and EBC2_ELT (0%) and between PP_LLT and EBC2_LLT (+0.3%) are likely within the modeling error, indicating no detectable effects of the preliminary proposal on the 68°F threshold exceedance.

Water temperatures in the Feather River below Thermalito Afterbay from February through May exceeded the 72°F threshold only in critically dry years of EBC2_LLT and PP_LLT; this threshold was exceeded in 2% of months under both scenarios.

These results suggest with moderate certainty that there is little or no effect of the preliminary proposal on water temperature-related white sturgeon egg habitat. There are adverse effects of climate change, however, as evidenced by the increase in exceedances above temperature thresholds from EBC2 to EBC2_ELT to EBC2_LLT.

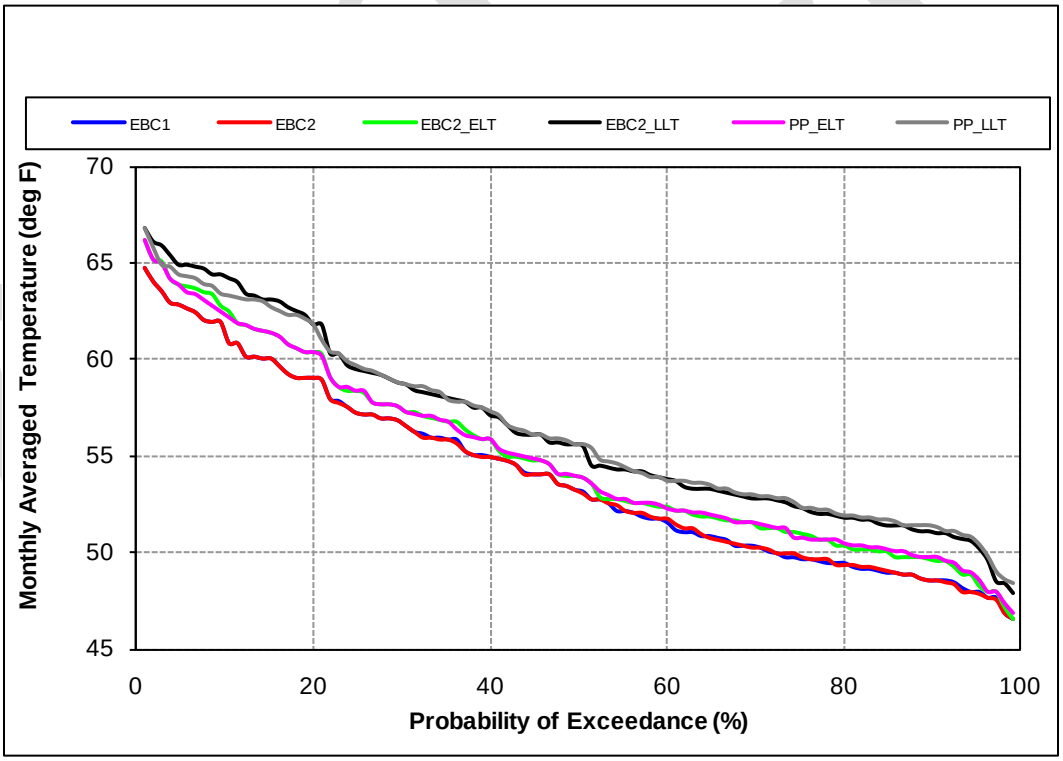

Figure C.5.2-241. Probability of Exceedance Plot for Model Scenarios of Mean Monthly Temperature of the Feather River below Thermalito Afterbay in Wet Years, February through May

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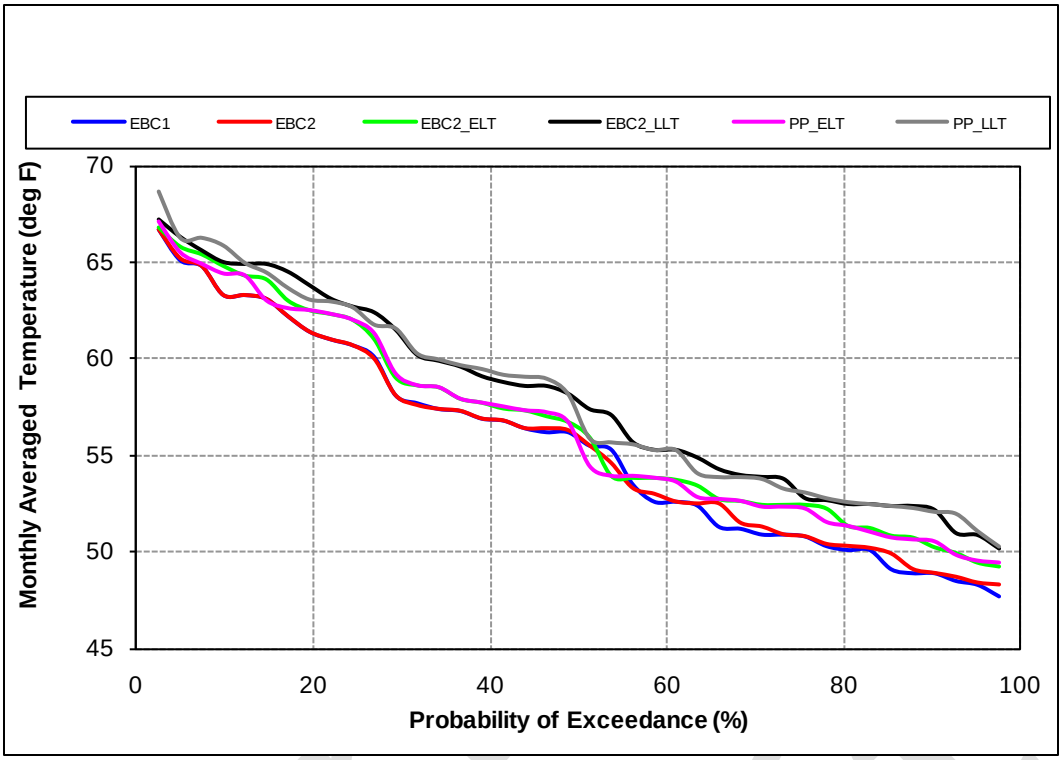

Figure C.5.2-242. Probability of Exceedance Plot for Model Scenarios of Mean Monthly Temperature of the Feather River below Thermalito Afterbay in Above-Normal Years, February through May

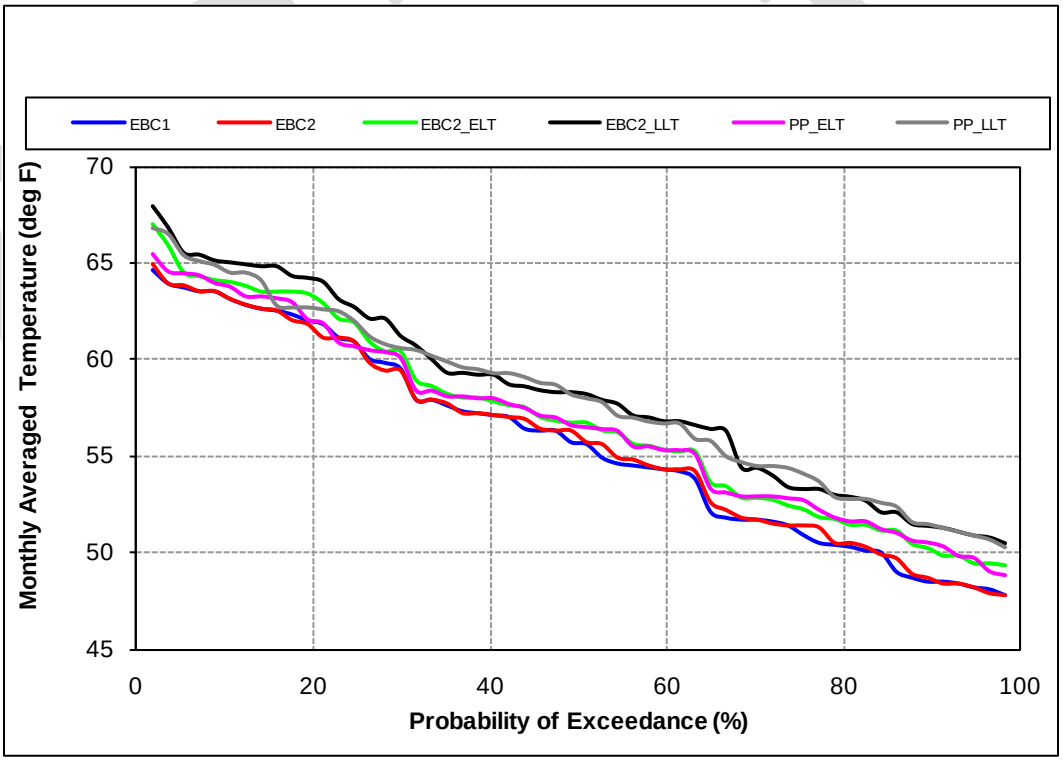

Figure C.5.2-243. Probability of Exceedance Plot for Model Scenarios of Mean Monthly Temperature of the Feather River below Thermalito Afterbay in Below Normal Years, February through May

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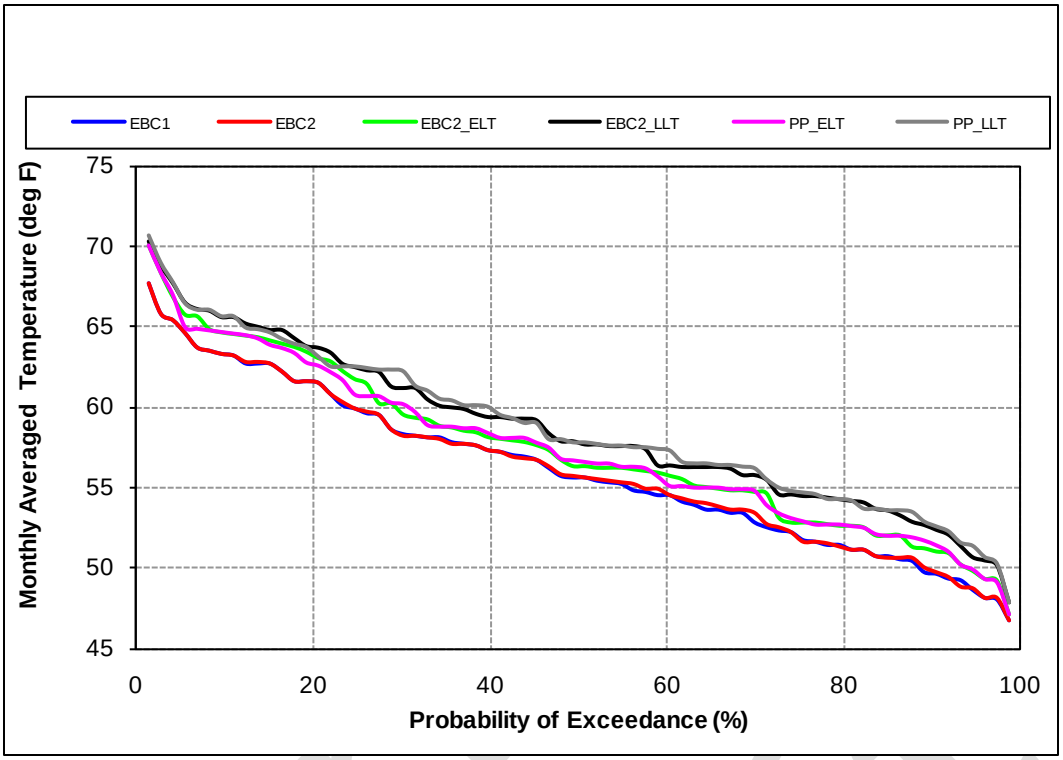

Figure C.5.2-244. Probability of Exceedance Plot for Model Scenarios of Mean Monthly Temperature of the Feather River below Thermalito Afterbay in Dry Years, February through May

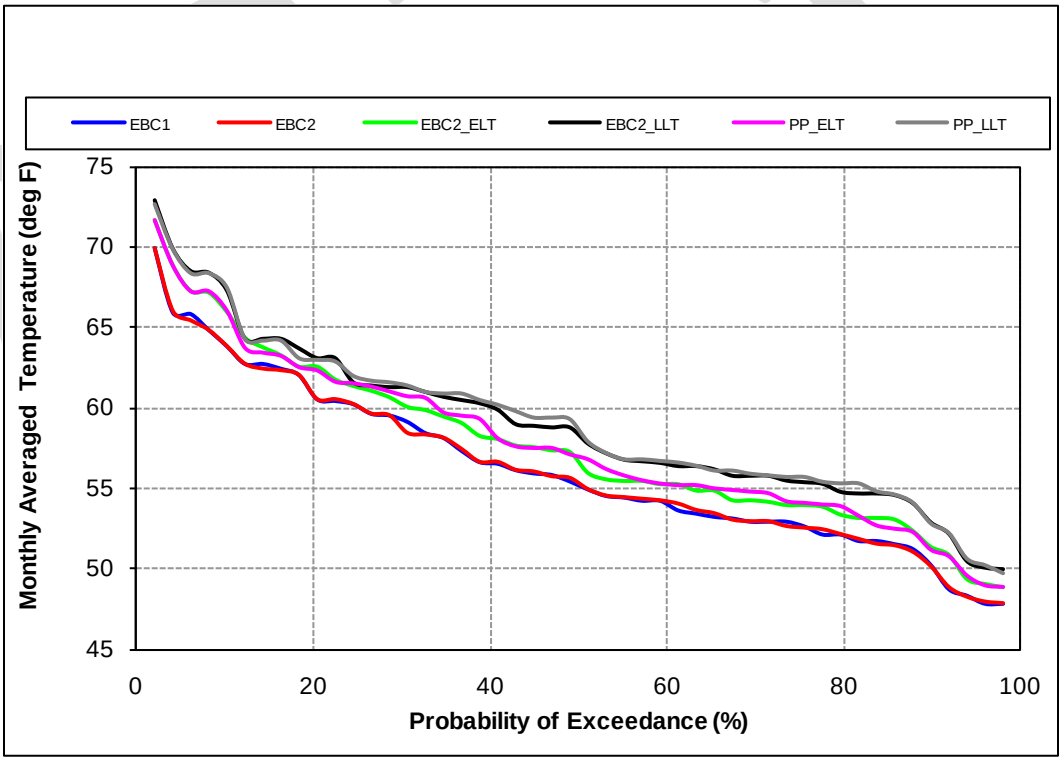

Figure C.5.2-245. Probability of Exceedance Plot for Model Scenarios of Mean Monthly Temperature of the Feather River below Thermalito Afterbay in Critical Years, February through May

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Table C.5.2-99. Percent of Months during February through May[1] When Average Temperature Exceeds 61°F, 68°F, 72°F, and 77°F in the Feather River below Thermalito Afterbay

	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
Temperatures above 61°F						
Wet	9.6	9.6	16.3	21.2	16.3	20.2
Above Normal	18.2	18.2	22.7	27.3	25.0	27.3
Below Normal	23.2	23.2	25.0	30.4	21.4	26.8
Dry	20.8	20.8	26.4	31.9	23.6	31.9
Critically Dry	18.8	18.8	25.0	31.3	27.1	31.3
All	17.0	17.0	22.2	27.5	21.6	26.5
Temperatures above 68°F						
Wet	0.0	0.0	0.0	0.0	0.0	0.0
Above Normal	0.0	0.0	0.0	0.0	0.0	2.3
Below Normal	0.0	0.0	0.0	0.0	0.0	0.0
Dry	0.0	0.0	2.8	2.8	2.8	2.8
Critically Dry	2.1	2.1	4.2	8.3	4.2	8.3
All	0.3	0.3	1.2	1.9	1.2	2.2
Temperatures above 72°F						
Wet	0.0	0.0	0.0	0.0	0.0	0.0
Above Normal	0.0	0.0	0.0	0.0	0.0	0.0
Below Normal	0.0	0.0	0.0	0.0	0.0	0.0
Dry	0.0	0.0	0.0	0.0	0.0	0.0
Critically Dry	0.0	0.0	0.0	2.1	0.0	2.1
All	0.0	0.0	0.0	0.3	0.0	0.3
Temperatures above 77°F						
Wet	0.0	0.0	0.0	0.0	0.0	0.0
Above Normal	0.0	0.0	0.0	0.0	0.0	0.0
Below Normal	0.0	0.0	0.0	0.0	0.0	0.0
Dry	0.0	0.0	0.0	0.0	0.0	0.0
Critically Dry	0.0	0.0	0.0	0.0	0.0	0.0
All	0.0	0.0	0.0	0.0	0.0	0.0

[1] Based on the modeling period of 1922 to 2003.

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Table C.5.2-100. Difference and Percent Difference in Percentage of Months during February through May When Daily Average Temperature Exceeds 61°F, 68°F, 72°F, and 77°F in the Feather River below Thermalito Afterbay

WY Type	Comparison[1]	EBC1 vs. PP_ELT	EBC1 vs. PP_ELT	EBC2 vs. EBC2_ELT	EBC2 vs. EBC2_LLT	EBC2 vs. PP_ELT	EBC2 vs. PP_LLT	EBC2_ELT vs. PP_ELT	EBC2_LLT vs. PP_LLT
Temperatures above 61°F									
Wet	Difference	6.7	10.6	6.7	11.5	6.7	10.6	0.0	-1.0
	Percent difference	70%	110%	70%	120%	70%	110%	0%	-5%
Above Normal	Difference	6.8	9.1	4.5	9.1	6.8	9.1	2.3	0.0
	Percent difference	38%	50%	25%	50%	38%	50%	10%	0%
Below Normal	Difference	-1.8	3.6	1.8	7.1	-1.8	3.6	-3.6	-3.6
	Percent difference	-8%	15%	8%	31%	-8%	15%	-14%	-12%
Dry	Difference	2.8	11.1	5.6	11.1	2.8	11.1	-2.8	0.0
	Percent difference	13%	53%	27%	53%	13%	53%	-11%	0%
Critical	Difference	8.3	12.5	6.3	12.5	8.3	12.5	2.1	0.0
	Percent difference	44%	67%	33%	67%	44%	67%	8%	0%
All	Difference	4.6	9.6	5.2	10.5	4.6	9.6	-0.6	-0.9
	Percent difference	27%	56%	31%	62%	27%	56%	-3%	-3%
Temperatures above 68°F									
Wet	Difference	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Percent difference	NA	NA	NA	NA	NA	NA	NA	NA
Above Normal	Difference	0.0	2.3	0.0	0.0	0.0	2.3	0.0	2.3
	Percent difference	NA	NA	NA	NA	NA	NA	NA	NA
Below Normal	Difference	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Percent difference	NA	NA	NA	NA	NA	NA	NA	NA
Dry	Difference	2.8	2.8	2.8	2.8	2.8	2.8	0.0	0.0
	Percent difference	NA	NA	NA	NA	NA	NA	0%	0%
Critical	Difference	2.1	6.3	2.1	6.3	2.1	6.3	0.0	0.0
	Percent difference	100%	300%	100%	300%	100%	300%	0%	0%
All	Difference	0.9	1.9	0.9	1.5	0.9	1.9	0.0	0.3
	Percent difference	300%	600%	300%	500%	300%	600%	0%	17%
Temperatures above 72°F									
Wet	Difference	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Percent difference	NA	NA	NA	NA	NA	NA	NA	NA
Above Normal	Difference	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Percent difference	NA	NA	NA	NA	NA	NA	NA	NA
Below Normal	Difference	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Percent difference	NA	NA	NA	NA	NA	NA	NA	NA
Dry	Difference	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Percent difference	NA	NA	NA	NA	NA	NA	NA	NA
Critical	Difference	0.0	2.1	0.0	2.1	0.0	2.1	0.0	0.0
	Percent difference	NA	NA	NA	NA	NA	NA	NA	0%
All	Difference	0.0	0.3	0.0	0.3	0.0	0.3	0.0	0.0
	Percent difference	NA	NA	NA	NA	NA	NA	NA	0%

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WY Type	Comparison[1]	EBC1 vs. PP_ELT	EBC1 vs. PP_ELT	EBC2 vs. EBC2_ELT	EBC2 vs. EBC2_LLT	EBC2 vs. PP_ELT	EBC2 vs. PP_LLT	EBC2_ELT vs. PP_ELT	EBC2_LLT vs. PP_LLT
Temperatures above 77°F									
Wet	Difference	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Percent difference	NA	NA	NA	NA	NA	NA	NA	NA
Above Normal	Difference	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Percent difference	NA	NA	NA	NA	NA	NA	NA	NA
Below Normal	Difference	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Percent difference	NA	NA	NA	NA	NA	NA	NA	NA
Dry	Difference	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Percent difference	NA	NA	NA	NA	NA	NA	NA	NA
Critical	Difference	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Percent difference	NA	NA	NA	NA	NA	NA	NA	NA
All	Difference	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Percent difference	NA	NA	NA	NA	NA	NA	NA	NA

[1] A positive value indicates a higher value under the second model scenario listed in the column title.
NA = Could not be calculated because dividing by 0.

Sacramento River Confluence

Reclamation Water Temperature Model results for the Feather River at the confluence with the Sacramento River during the white sturgeon spawning period (February through May) are presented in Figure C.5.2-246 through Figure C.5.2-250. The percent of months in which average temperature exceeded 61°F, 68°F, and 72°F in the Feather River below Thermalito Afterbay is presented in Table C.5.2-101 and differences between pairs of model scenarios are presented in Table C.5.2-105.

Combining all water years, water temperatures in the Feather River at its confluence with the Sacramento River from February through May are predicted to exceed the 61°F threshold in 35% of months under EBC1 and EBC2, 39%–43% of months under EBC2_ELT and EBC2_LLT, and 39%–42% of months under PP_ELT and PP_LLT. Among water years, the exceedance frequency is predicted to range from 26% (wet years under EBC1 and EBC2) to 50% (critical years under EBC2_LLT and PP_LLT). The higher threshold exceedances under EBC2_ELT and EBC2_LLT relative to EBC1 and EBC2 reflect the effects of climate change in the absence of BDCP implementation. BDCP implementation (scenarios PP_ELT and PP_LLT) is predicted to result in a 4%–7% increase in the frequency of water temperatures exceeding 61°F relative to EBC1 and EBC2 and a 0%–1% decrease in the frequency of water temperatures exceeding 61°F relative to EBC2_ELT and EBC2_LLT. Differences in threshold exceedance frequencies between PP_ELT and EBC2_ELT and between PP_LLT and EBC2_LLT are predicted to be negligible (<1%).

Combining all water years, water temperatures in the Feather River at its confluence with the Sacramento River from February through May are predicted to exceed the 68°F threshold in 6% of months under EBC1 and EBC2, 12%–17% of months under EBC2_ELT and EBC2_LLT, and 11%–15% of months under PP_ELT and PP_LLT. Among water years, the exceedance frequency is predicted to range from 3% (wet years under EBC1 and EBC2) to 27% (critical years under EBC2_LLT). BDCP implementation (PP_ELT and PP_LLT) is predicted to result in a 5%–9% increase in the frequency of water temperatures exceeding 68°F relative to EBC1 and EBC2 and a 1%–3% decrease in the

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frequency of water temperatures exceeding 68°F relative to EBC2_ELT and EBC2_LLT. Differences in threshold exceedance frequencies between PP_ELT and EBC2_ELT and between PP_LLT and EBC2_LLT are predicted to be negligible (<3%).

Water temperatures in the Feather River at its confluence with the Sacramento River from February through May are predicted to exceed the 72°F threshold in less than 1% of months under EBC1 and EBC2, 2%–4% of months under EBC2_ELT and EBC2_LLT, and 2%–3% of months under PP_ELT and PP_LLT. Among water years, the exceedance frequency is predicted to range from 0% (e.g., below-normal years under all scenarios except EBC2_LLT) to 7% (dry years under EBC2_LLT and PP_LLT). BDCP implementation (PP_ELT and PP_LLT) is predicted to result in a 1%–3% increase in the frequency of water temperatures exceeding 72°F relative to EBC1 and EBC2 and a <1% decrease in the frequency of water temperatures exceeding 72°F relative to EBC2_ELT and EBC2_LLT. Differences in threshold exceedance frequencies between PP_ELT and EBC2_ELT and between PP_LLT and EBC2_LLT are predicted to be negligible (<1%).

These results suggest with moderate certainty that there is little or no effect of the preliminary proposal on water temperatures in the Feather River downstream of the Thermalito Afterbay during March through August for all water years combined. There are adverse effects of climate change, however, as evidenced by the increase in exceedances above temperature thresholds from EBC2 to EBC2_ELT to EBC2_LLT.

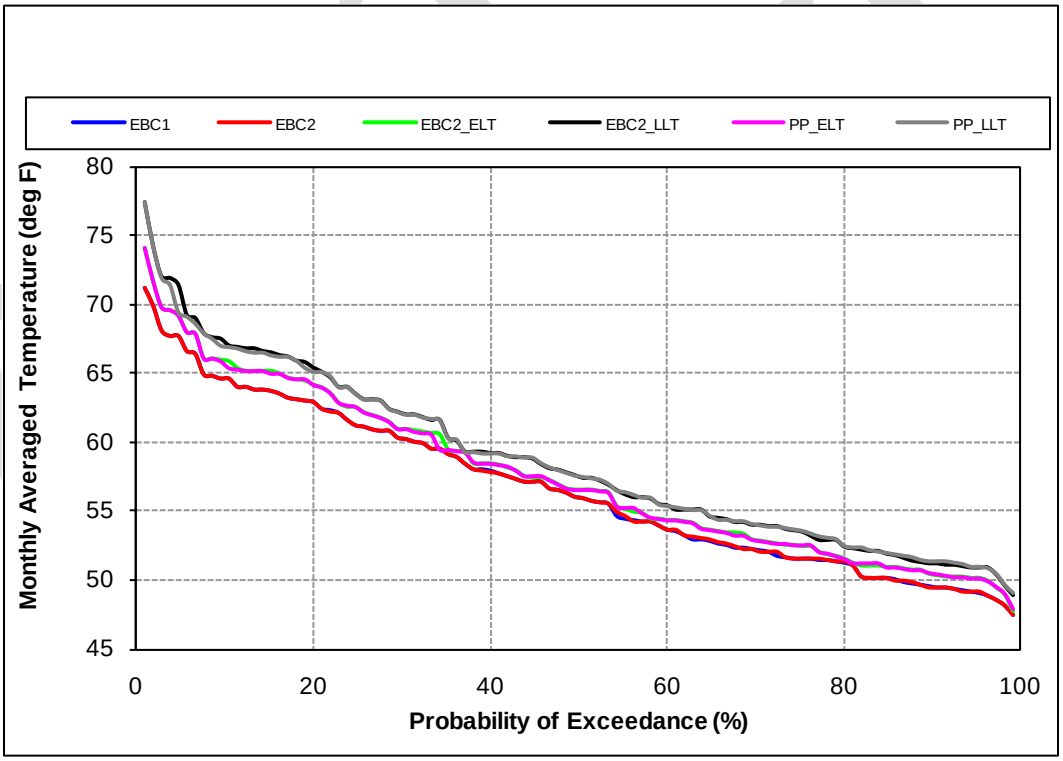

Figure C.5.2-246. Probability of Exceedance Plot for Model Scenarios of Mean Monthly Temperature of the Feather River at the Confluence with the Sacramento River in Wet Years, February through May

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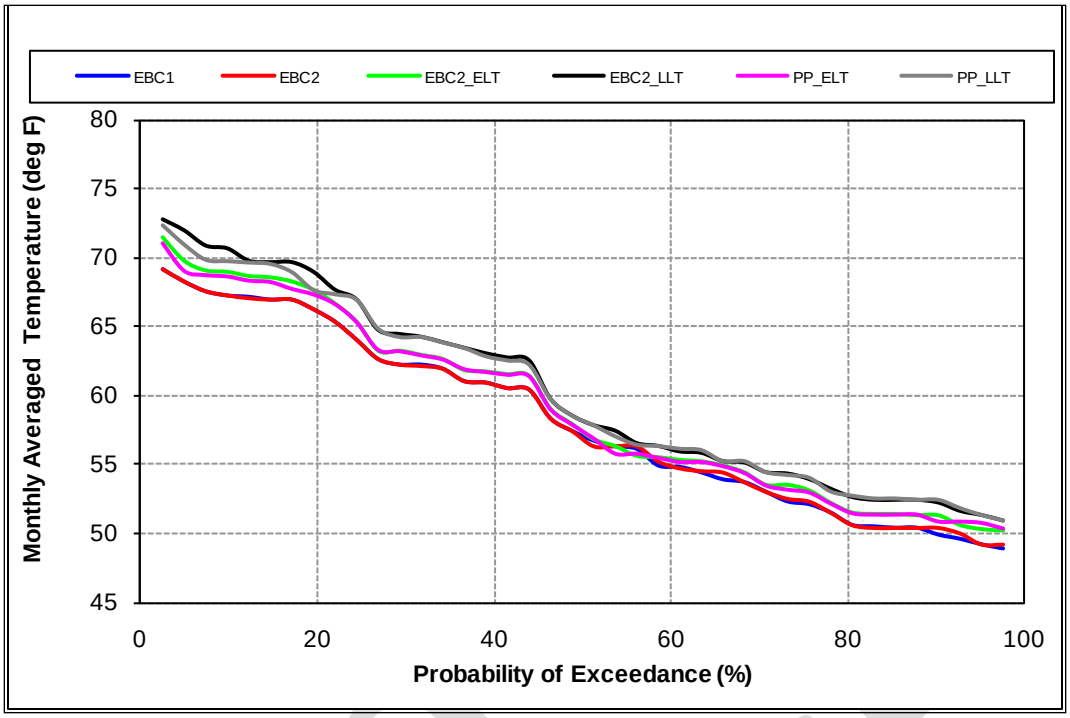

Figure C.5.2-247. Probability of Exceedance Plot for Model Scenarios of Mean Monthly Temperature of the Feather River at the Confluence with the Sacramento River in Above-Normal Years, February through May

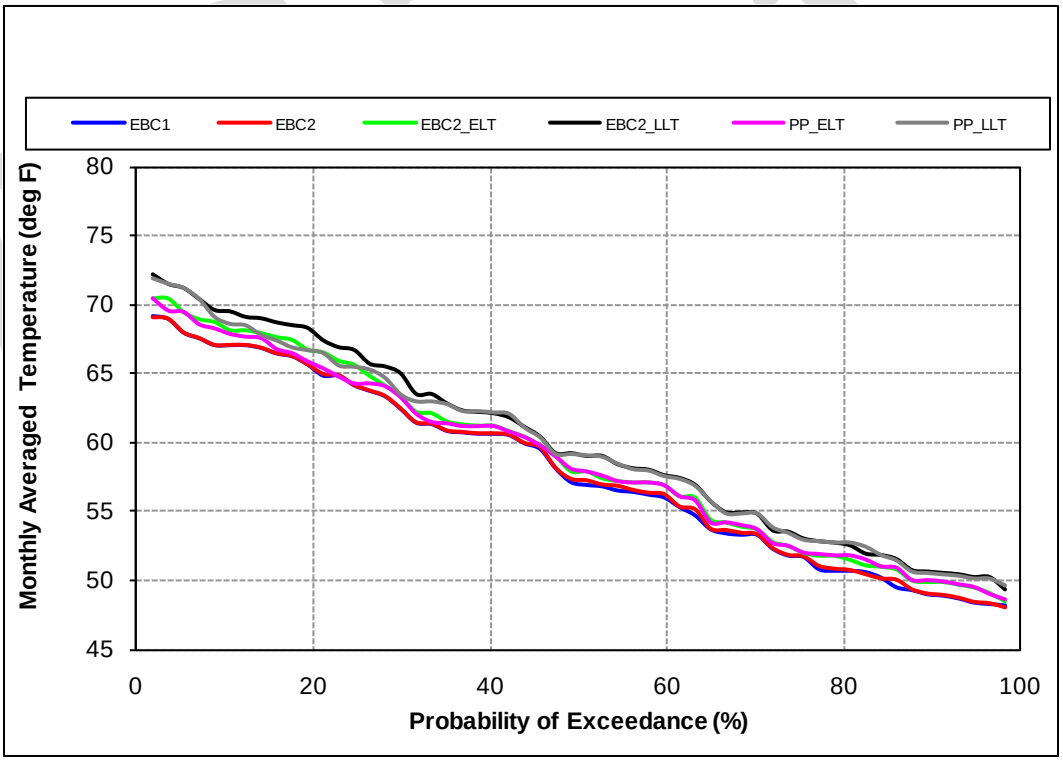

Figure C.5.2-248. Probability of Exceedance Plot for Model Scenarios of Mean Monthly Temperature of the Feather River at the Confluence with the Sacramento River in Below Normal Years, February through May

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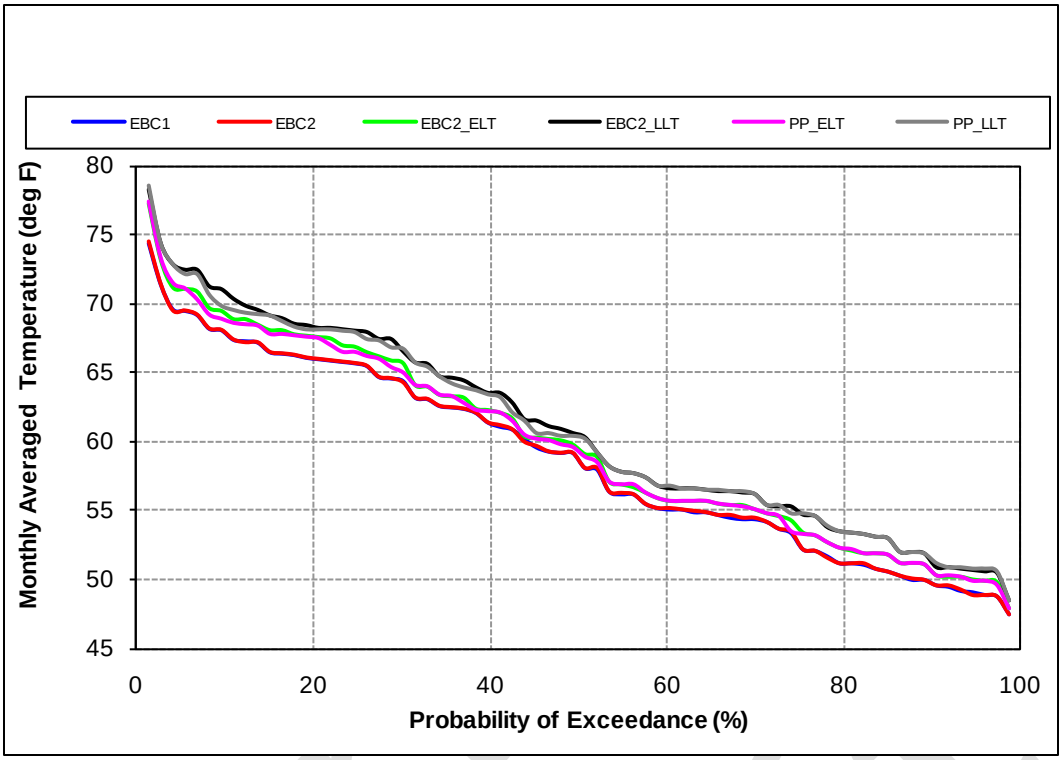

Figure C.5.2-249. Probability of Exceedance Plot for Model Scenarios of Mean Monthly Temperature of the Feather River at the Confluence with the Sacramento River in Dry Years, February through May

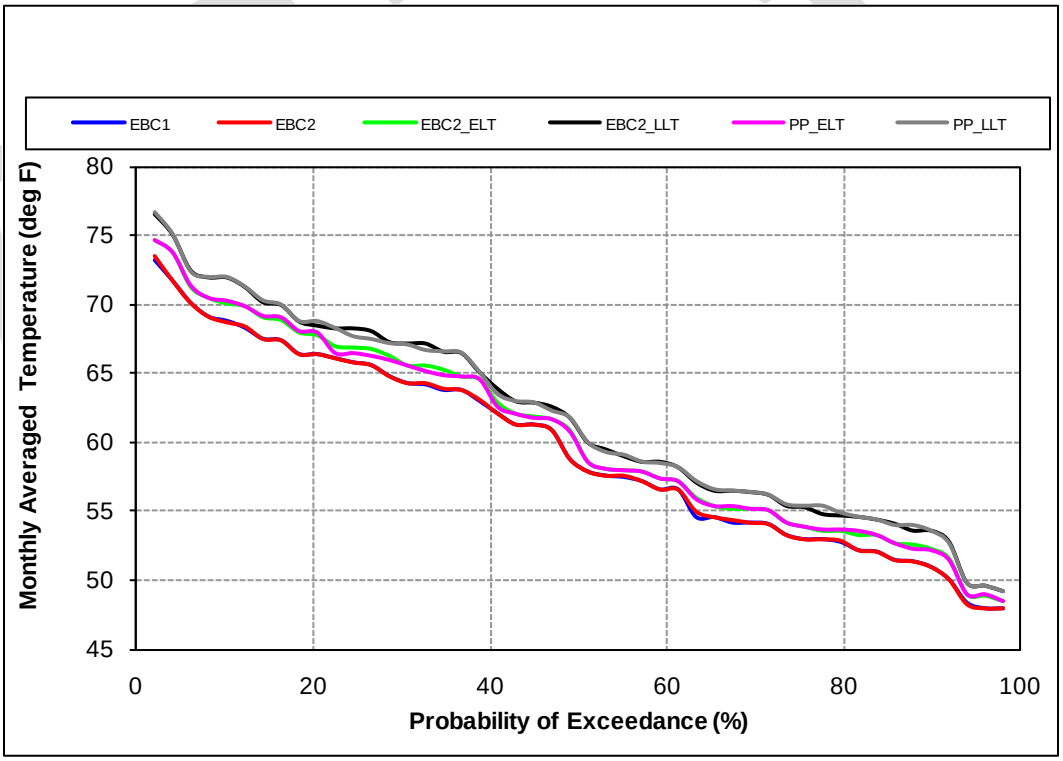

Figure C.5.2-250. Probability of Exceedance Plot for Model Scenarios of Mean Monthly Temperature of the Feather River at the Confluence with the Sacramento River in Critical Years, February through May

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Table C.5.2-101. Percentage of Months during February through May[1] When Monthly Average Temperature Exceeds 61°F, 68°F, 72°F, and 77°F in the Feather River at the Confluence with the Sacramento River

	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
Temperatures above 61°F						
Wet	26.0	26.0	28.8	34.6	28.8	34.6
Above Normal	34.1	34.1	43.2	43.2	43.2	43.2
Below Normal	33.9	33.9	41.1	44.6	41.1	44.6
Dry	41.7	41.7	43.1	47.2	43.1	44.4
Critical	45.8	45.8	47.9	50.0	47.9	50.0
All	34.9	34.9	38.9	42.6	38.9	42.0
Temperatures above 68°F						
Wet	2.9	2.9	4.8	6.7	4.8	6.7
Above Normal	4.5	4.5	15.9	18.2	13.6	15.9
Below Normal	3.6	3.6	12.5	19.6	8.9	12.5
Dry	9.7	9.7	16.7	23.6	13.9	22.2
Critical	12.5	12.5	16.7	27.1	18.8	22.9
All	6.2	6.2	12.0	17.3	10.8	14.8
Temperatures above 72°F						
Wet	0.0	0.0	1.0	1.9	1.0	1.9
Above Normal	0.0	0.0	0.0	2.3	0.0	2.3
Below Normal	0.0	0.0	0.0	1.8	0.0	0.0
Dry	1.4	1.4	2.8	6.9	2.8	6.9
Critical	2.1	2.1	4.2	6.3	4.2	6.3
All	0.6	0.6	1.5	3.7	1.5	3.4
Temperatures above 77°F						
Wet	0.0	0.0	0.0	1.0	0.0	1.0
Above Normal	0.0	0.0	0.0	0.0	0.0	0.0
Below Normal	0.0	0.0	0.0	0.0	0.0	0.0
Dry	0.0	0.0	1.4	1.4	1.4	1.4
Critical	0.0	0.0	0.0	0.0	0.0	0.0
All	0.0	0.0	0.3	0.6	0.3	0.6

[1] Based on the modeling period of 1922 to 2003.

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Table C.5.2-102. Difference and Percent Difference in Percentage of Months During February through May When Daily Average Temperature Exceeds 61°F, 68°F, 72°F, and 77°F in the Feather River at the Confluence with the Sacramento River

	Comparison[1]	EBC1 vs. PP_ELT	EBC1 vs. PP_LLT	EBC2 vs. EBC2_ELT	EBC2 vs. EBC2_LLT	EBC2 vs. PP_ELT	EBC2 vs. PP_LLT	EBC2_ELT vs. PP_ELT	EBC2_LLT vs. PP_LLT
Temperatures above 61°F									
Wet	Difference	2.9	8.7	2.9	8.7	2.9	8.7	0.0	0.0
	Percent difference	11%	33%	11%	33%	11%	33%	0%	0%
Above Normal	Difference	9.1	9.1	9.1	9.1	9.1	9.1	0.0	0.0
	Percent difference	27%	27%	27%	27%	27%	27%	0%	0%
Below Normal	Difference	7.1	10.7	7.1	10.7	7.1	10.7	0.0	0.0
	Percent difference	21%	32%	21%	32%	21%	32%	0%	0%
Dry	Difference	1.4	2.8	1.4	5.6	1.4	2.8	0.0	-2.8
	Percent difference	3%	7%	3%	13%	3%	7%	0%	-6%
Critical	Difference	2.1	4.2	2.1	4.2	2.1	4.2	0.0	0.0
	Percent difference	5%	9%	5%	9%	5%	9%	0%	0%
All	Difference	4.0	7.1	4.0	7.7	4.0	7.1	0.0	-0.6
	Percent difference	12%	20%	12%	22%	12%	20%	0%	-1%
Temperatures above 68°F									
Wet	Difference	1.9	3.8	1.9	3.8	1.9	3.8	0.0	0.0
	Percent difference	67%	133%	67%	133%	67%	133%	0%	0%
Above Normal	Difference	9.1	11.4	11.4	13.6	9.1	11.4	-2.3	-2.3
	Percent difference	200%	250%	250%	300%	200%	250%	-14%	-13%
Below Normal	Difference	5.4	8.9	8.9	16.1	5.4	8.9	-3.6	-7.1
	Percent difference	150%	250%	250%	450%	150%	250%	-29%	-36%
Dry	Difference	4.2	12.5	6.9	13.9	4.2	12.5	-2.8	-1.4
	Percent difference	43%	129%	71%	143%	43%	129%	-17%	-6%
Critical	Difference	6.3	10.4	4.2	14.6	6.3	10.4	2.1	-4.2
	Percent difference	50%	83%	33%	117%	50%	83%	13%	-15%
All	Difference	4.6	8.6	5.9	11.1	4.6	8.6	-1.2	-2.5
	Percent difference	75%	140%	95%	180%	75%	140%	-10%	-14%
Temperatures above 72°F									
Wet	Difference	1.0	1.9	1.0	1.9	1.0	1.9	0.0	0.0
	Percent difference	NA	NA	NA	NA	NA	NA	0%	0%
Above Normal	Difference	0.0	2.3	0.0	2.3	0.0	2.3	0.0	0.0
	Percent difference	NA	NA	NA	NA	NA	NA	NA	0%
Below Normal	Difference	0.0	0.0	0.0	1.8	0.0	0.0	0.0	-1.8
	Percent difference	NA	NA	NA	NA	NA	NA	NA	-100%
Dry	Difference	1.4	5.6	1.4	5.6	1.4	5.6	0.0	0.0
	Percent difference	100%	400%	100%	400%	100%	400%	0%	0%
Critical	Difference	2.1	4.2	2.1	4.2	2.1	4.2	0.0	0.0
	Percent difference	100%	200%	100%	200%	100%	200%	0%	0%
All	Difference	0.9	2.8	0.9	3.1	0.9	2.8	0.0	-0.3
	Percent difference	150%	450%	150%	500%	150%	450%	0%	-8%

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	Comparison[1]	EBC1 vs. PP_ELT	EBC1 vs. PP_LLT	EBC2 vs. EBC2_ELT	EBC2 vs. EBC2_LLT	EBC2 vs. PP_ELT	EBC2 vs. PP_LLT	EBC2_ELT vs. PP_ELT	EBC2_LLT vs. PP_LLT
Temperatures above 77°F									
Wet	Difference	0.0	1.0	0.0	1.0	0.0	1.0	0.0	0.0
	Percent difference	NA	NA	NA	NA	NA	NA	NA	0%
Above Normal	Difference	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Percent difference	NA	NA	NA	NA	NA	NA	NA	NA
Below Normal	Difference	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Percent difference	NA	NA	NA	NA	NA	NA	NA	NA
Dry	Difference	1.4	1.4	1.4	1.4	1.4	1.4	0.0	0.0
	Percent difference	NA	NA	NA	NA	NA	NA	0%	0%
Critical	Difference	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Percent difference	NA	NA	NA	NA	NA	NA	NA	NA
All	Difference	0.3	0.6	0.3	0.6	0.3	0.6	0.0	0.0
	Percent difference	NA	NA	NA	NA	NA	NA	0%	0%

[1] A positive value indicates a higher value under the second model scenario listed in the column title.
NA = Could not be calculated because dividing by 0.

Seasonal Flows

For the Feather River high-flow channel, measured at the confluence with the Sacramento River and at Thermalito Afterbay, the exceedance probability plots for February through May flows for all water years combined indicate that flows under the preliminary proposal would generally increase relative to EBC2 (Table C.5.2-103, Table C.5.2-104, Figure C.5.2-251 and Figure C.5.2-252).

Table C.5.2-103. Differences and Percent Differences between Pairs of Model Scenarios in the Feather River at the Confluence with the Sacramento River for All Months

Month	WY Type	EBC1 vs. PP_ELT	EBC1 vs. PP_LLT	EBC2 vs. PP_ELT	EBC2 vs. PP_LLT	EBC2_ELT vs. PP_ELT	EBC2_LLT vs. PP_LLT
Jan	W	3884 (16.5%)	5071 (21.6%)	4491 (19.6%)	5679 (24.8%)	2565 (10.3%)	2499 (9.6%)
	AN	1167 (9.4%)	803 (6.5%)	2112 (18.4%)	1748 (15.2%)	1842 (15.7%)	1279 (10.7%)
	BN	-66 (-1%)	-784 (-12.1%)	852 (15.3%)	134 (2.4%)	775 (13.7%)	140 (2.5%)
	D	213 (4.6%)	522 (11.3%)	543 (12.7%)	851 (19.8%)	444 (10.1%)	731 (16.6%)
	C	365 (10%)	-60 (-1.6%)	582 (17%)	158 (4.6%)	460 (12.9%)	-250 (-6.5%)
	AVG	1491 (12.5%)	1697 (14.2%)	2083 (18.4%)	2289 (20.2%)	1380 (11.5%)	1127 (9%)
Feb	W	3905 (14.4%)	5857 (21.7%)	4815 (18.4%)	6767 (25.9%)	1436 (4.9%)	1831 (5.9%)
	AN	2492 (16.8%)	2113 (14.3%)	4471 (34.8%)	4092 (31.9%)	3192 (22.6%)	2332 (16%)
	BN	-143 (-1.6%)	125 (1.4%)	956 (11.9%)	1225 (15.2%)	928 (11.5%)	1386 (17.6%)
	D	287 (6.5%)	243 (5.5%)	466 (11%)	422 (10%)	324 (7.4%)	209 (4.7%)
	C	-128 (-4%)	215 (6.6%)	-9 (-0.3%)	334 (10.7%)	23 (0.7%)	356 (11.5%)
	AVG	1623 (11.8%)	2273 (16.5%)	2445 (18.9%)	3095 (24%)	1155 (8.1%)	1256 (8.5%)
Mar	W	1760 (7.3%)	2838 (11.7%)	2234 (9.4%)	3312 (14%)	346 (1.4%)	226 (0.8%)
	AN	2128 (10.6%)	3350 (16.8%)	2878 (15%)	4100 (21.3%)	945 (4.5%)	1850 (8.6%)
	BN	-589 (-7.2%)	-882 (-10.8%)	310 (4.3%)	17 (0.2%)	372 (5.2%)	372 (5.4%)
	D	526 (10.4%)	264 (5.2%)	805 (16.8%)	542 (11.3%)	973 (21%)	397 (8%)
	C	-86 (-2.9%)	-89 (-3%)	226 (8.6%)	223 (8.5%)	151 (5.6%)	87 (3.2%)

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Month	WY Type	EBC1 vs. PP_ELT	EBC1 vs. PP_LLT	EBC2 vs. PP_ELT	EBC2 vs. PP_LLT	EBC2_ELT vs. PP_ELT	EBC2_LLT vs. PP_LLT
	AVG	872 (6.4%)	1284 (9.5%)	1392 (10.7%)	1805 (13.9%)	547 (4%)	506 (3.5%)
Apr	W	291 (1.8%)	-52 (-0.3%)	233 (1.5%)	-110 (-0.7%)	132 (0.8%)	-7 (0%)
	AN	-98 (-1%)	92 (0.9%)	-114 (-1.2%)	76 (0.8%)	1 (0%)	339 (3.5%)
	BN	244 (4.5%)	747 (13.8%)	317 (5.9%)	820 (15.4%)	413 (7.9%)	959 (18.5%)
	D	739 (17.8%)	1203 (29%)	692 (16.5%)	1157 (27.6%)	657 (15.5%)	1218 (29.4%)
	C	352 (10.7%)	394 (11.9%)	370 (11.3%)	412 (12.6%)	455 (14.2%)	507 (15.9%)
	AVG	333 (3.8%)	446 (5.1%)	318 (3.6%)	430 (4.9%)	323 (3.7%)	553 (6.4%)
May	W	-1275 (-8.9%)	-3314 (-23%)	-1279 (-8.9%)	-3318 (-23.1%)	125 (1%)	687 (6.6%)
	AN	702 (8.7%)	75 (0.9%)	784 (9.8%)	156 (2%)	993 (12.8%)	1259 (18.3%)
	BN	1653 (35.1%)	1728 (36.7%)	1716 (37%)	1791 (38.6%)	1823 (40.2%)	1924 (42.7%)
	D	448 (12.3%)	442 (12.1%)	458 (12.6%)	452 (12.4%)	440 (12%)	327 (8.7%)
	C	-21 (-0.9%)	-104 (-4.4%)	36 (1.5%)	-47 (-2%)	-124 (-5%)	-36 (-1.6%)
	AVG	76 (1%)	-663 (-8.6%)	108 (1.4%)	-631 (-8.2%)	575 (8%)	797 (12.8%)
Jun	W	-914 (-8.9%)	-1975 (-19.3%)	-965 (-9.4%)	-2026 (-19.7%)	1517 (19.5%)	1048 (14.6%)
	AN	1640 (25.7%)	1401 (21.9%)	1577 (24.4%)	1338 (20.7%)	2546 (46.4%)	2195 (39.2%)
	BN	2216 (49.3%)	1748 (38.9%)	2187 (48.3%)	1719 (38%)	2365 (54.4%)	1901 (43.8%)
	D	75 (2%)	-271 (-7%)	-127 (-3.1%)	-473 (-11.7%)	152 (4%)	215 (6.4%)
	C	-286 (-10.3%)	-467 (-16.8%)	-282 (-10.2%)	-462 (-16.6%)	-182 (-6.8%)	-206 (-8.2%)
	AVG	303 (4.9%)	-250 (-4%)	229 (3.7%)	-325 (-5.2%)	1264 (24.1%)	995 (20.1%)
Jul	W	-2340 (-28.6%)	-1870 (-22.9%)	-2586 (-30.7%)	-2115 (-25.1%)	-2699 (-31.6%)	-2427 (-27.8%)
	AN	-2354 (-25.3%)	-2291 (-24.6%)	-2689 (-27.8%)	-2626 (-27.2%)	-2474 (-26.2%)	-2191 (-23.8%)
	BN	-2969 (-31.7%)	-3382 (-36.1%)	-3080 (-32.5%)	-3493 (-36.8%)	-2574 (-28.6%)	-2727 (-31.3%)
	D	-2682 (-32.4%)	-4357 (-52.6%)	-2634 (-32%)	-4309 (-52.3%)	-2083 (-27.1%)	-3742 (-48.8%)
	C	-3639 (-56.4%)	-3887 (-60.3%)	-3066 (-52.2%)	-3314 (-56.4%)	-3020 (-51.8%)	-2328 (-47.6%)
	AVG	-2715 (-32.6%)	-3031 (-36.4%)	-2766 (-33%)	-3082 (-36.8%)	-2557 (-31.3%)	-2718 (-33.9%)
Aug	W	-96 (-2%)	169 (3.4%)	-651 (-11.9%)	-386 (-7%)	-1830 (-27.5%)	-2130 (-29.5%)
	AN	-879 (-12.4%)	-931 (-13.2%)	-1194 (-16.1%)	-1246 (-16.8%)	-1589 (-20.4%)	-1940 (-24%)
	BN	-2214 (-30.6%)	-2535 (-35%)	-2343 (-31.8%)	-2664 (-36.2%)	-2076 (-29.3%)	-2869 (-37.9%)
	D	-3061 (-39.7%)	-3496 (-45.3%)	-2110 (-31.2%)	-2544 (-37.6%)	-1535 (-24.8%)	-1272 (-23.2%)
	C	-41 (-1.4%)	-711 (-25%)	-50 (-1.8%)	-719 (-25.2%)	392 (16.3%)	-210 (-9%)
	AVG	-1215 (-20.5%)	-1387 (-23.3%)	-1252 (-20.9%)	-1423 (-23.8%)	-1447 (-23.4%)	-1759 (-27.9%)
Sep	W	-1071 (-24.6%)	-1190 (-27.3%)	-7269 (-68.9%)	-7387 (-70%)	-7146 (-68.5%)	-7168 (-69.4%)
	AN	-620 (-14.8%)	-423 (-10.1%)	-5396 (-60.2%)	-5199 (-58%)	-5496 (-60.6%)	-5002 (-57%)
	BN	-1162 (-27.3%)	-1062 (-25%)	-1419 (-31.5%)	-1318 (-29.2%)	-1807 (-36.9%)	-1596 (-33.3%)
	D	-827 (-19.8%)	-835 (-20%)	-479 (-12.5%)	-487 (-12.7%)	71 (2.2%)	496 (17.4%)
	C	187 (9.1%)	262 (12.7%)	104 (4.8%)	178 (8.3%)	189 (9.2%)	352 (17.9%)
	AVG	-783 (-19.9%)	-765 (-19.4%)	-3427 (-52.1%)	-3409 (-51.8%)	-3335 (-51.4%)	-3117 (-49.6%)
Oct	W	-280 (-6.7%)	-189 (-4.5%)	-24 (-0.6%)	68 (1.7%)	155 (4.1%)	241 (6.4%)
	AN	1012 (38.5%)	927 (35.2%)	644 (21.5%)	558 (18.6%)	803 (28.3%)	569 (19%)
	BN	50 (1.3%)	-129 (-3.4%)	442 (13.1%)	263 (7.8%)	409 (12%)	187 (5.4%)
	D	291 (9.6%)	540 (17.8%)	321 (10.7%)	570 (19%)	184 (5.9%)	585 (19.6%)
	C	450 (15.3%)	1039 (35.4%)	661 (24.2%)	1250 (45.8%)	687 (25.4%)	1412 (55%)
	AVG	197 (5.7%)	324 (9.4%)	329 (9.9%)	456 (13.8%)	378 (11.6%)	527 (16.2%)

Administrative Draft

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Month	WY Type	EBC1 vs. PP_ELT	EBC1 vs. PP_LLT	EBC2 vs. PP_ELT	EBC2 vs. PP_LLT	EBC2_ELT vs. PP_ELT	EBC2_LLT vs. PP_LLT
Nov	W	-259 (-5.5%)	-618 (-13.2%)	-29 (-0.6%)	-388 (-8.7%)	31 (0.7%)	253 (6.6%)
	AN	326 (10.6%)	-107 (-3.5%)	80 (2.4%)	-353 (-10.7%)	170 (5.3%)	-229 (-7.2%)
	BN	-299 (-11.1%)	-287 (-10.7%)	-280 (-10.5%)	-268 (-10%)	-201 (-7.8%)	-55 (-2.2%)
	D	0 (0%)	-74 (-3.2%)	89 (4%)	15 (0.7%)	58 (2.5%)	144 (6.8%)
	C	68 (3.3%)	132 (6.3%)	35 (1.6%)	99 (4.7%)	79 (3.8%)	109 (5.2%)
	AVG	-76 (-2.4%)	-258 (-8%)	-21 (-0.7%)	-203 (-6.4%)	25 (0.8%)	85 (3%)
Dec	W	1654 (13.3%)	-182 (-1.5%)	3365 (31.4%)	1529 (14.3%)	2155 (18.1%)	1982 (19.3%)
	AN	855 (16.5%)	1912 (36.8%)	447 (8%)	1503 (26.8%)	43 (0.7%)	1105 (18.4%)
	BN	907 (29.5%)	819 (26.6%)	545 (15.8%)	457 (13.3%)	645 (19.3%)	650 (20%)
	D	612 (21.6%)	435 (15.3%)	606 (21.3%)	429 (15.1%)	662 (23.8%)	461 (16.4%)
	C	160 (5.4%)	281 (9.5%)	595 (23.4%)	717 (28.2%)	983 (45.7%)	1202 (58.5%)
	AVG	3884 (16.5%)	5071 (21.6%)	4491 (19.6%)	5679 (24.8%)	2565 (10.3%)	2499 (9.6%)

Table C.5.2-104. Differences and Percent Differences between Pairs of Model Scenarios in the Feather River at Thermalito Afterbay for All Months

Month	WY Type	EBC1 vs. PP_ELT	EBC1 vs. PP_LLT	EBC2 vs. PP_ELT	EBC2 vs. PP_LLT	EBC2_ELT vs. PP_ELT	EBC2_LLT vs. PP_LLT
Jan	W	2846 (25.3%)	3141 (27.9%)	3461 (32.5%)	3757 (35.3%)	2575 (22.3%)	2503 (21%)
	AN	821 (18.5%)	-327 (-7.4%)	1785 (51.4%)	637 (18.4%)	1836 (53.7%)	1269 (44.7%)
	BN	-177 (-6.7%)	-1056 (-40%)	760 (44.6%)	-119 (-7%)	770 (45.5%)	143 (9.9%)
	D	120 (6.7%)	370 (20.6%)	470 (32.5%)	720 (49.7%)	441 (29.9%)	709 (48.6%)
	C	381 (26.1%)	-57 (-3.9%)	618 (50.6%)	181 (14.8%)	462 (33.6%)	-245 (-14.9%)
	AVG	1074 (20.4%)	841 (15.9%)	1682 (36%)	1449 (31%)	1381 (27.8%)	1124 (22.5%)
Feb	W	2705 (21.7%)	4156 (33.3%)	3623 (31.4%)	5074 (43.9%)	1439 (10.5%)	1835 (12.4%)
	AN	1576 (21.3%)	727 (9.8%)	3584 (66.3%)	2735 (50.6%)	3194 (55.1%)	2329 (40.1%)
	BN	-714 (-18.2%)	-635 (-16.2%)	405 (14.5%)	484 (17.3%)	922 (40.4%)	1384 (73%)
	D	148 (8.1%)	49 (2.7%)	344 (21.2%)	245 (15.1%)	322 (19.6%)	206 (12.4%)
	C	-128 (-7.9%)	219 (13.6%)	6 (0.4%)	352 (23.8%)	16 (1.1%)	347 (23.4%)
	AVG	980 (15.5%)	1358 (21.4%)	1819 (33.1%)	2197 (39.9%)	1154 (18.7%)	1255 (19.5%)
Mar	W	1419 (11%)	2093 (16.2%)	1922 (15.5%)	2595 (20.9%)	337 (2.4%)	216 (1.5%)
	AN	1784 (23.1%)	2684 (34.7%)	2567 (36.9%)	3467 (49.9%)	949 (11.1%)	1849 (21.6%)
	BN	-701 (-20.8%)	-1040 (-30.8%)	231 (9.5%)	-108 (-4.4%)	325 (13.8%)	348 (17.6%)
	D	464 (23%)	156 (7.7%)	780 (45.8%)	471 (27.7%)	960 (63.1%)	410 (23.3%)
	C	-27 (-1.6%)	-30 (-1.7%)	192 (13%)	190 (12.8%)	80 (5%)	34 (2.1%)
	AVG	689 (10.6%)	908 (14%)	1224 (20.6%)	1443 (24.2%)	524 (7.9%)	493 (7.1%)
Apr	W	298 (4.6%)	-84 (-1.3%)	260 (4%)	-121 (-1.9%)	119 (1.8%)	-19 (-0.3%)
	AN	-18 (-0.8%)	252 (11.2%)	-24 (-1.1%)	246 (10.9%)	-7 (-0.3%)	333 (15.4%)
	BN	328 (27.2%)	948 (78.7%)	413 (36.9%)	1033 (92.3%)	401 (35.4%)	949 (78.9%)
	D	817 (63.5%)	1395 (108.5%)	775 (58.3%)	1353 (101.9%)	654 (45.2%)	1211 (82.3%)
	C	438 (31.5%)	514 (37%)	452 (32.9%)	528 (38.4%)	443 (32.1%)	495 (35.2%)
	AVG	391 (12.7%)	554 (18%)	386 (12.5%)	548 (17.8%)	314 (10%)	543 (17.6%)

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Month	WY Type	EBC1 vs. PP_ELT	EBC1 vs. PP_LLT	EBC2 vs. PP_ELT	EBC2 vs. PP_LLT	EBC2_ELT vs. PP_ELT	EBC2_LLT vs. PP_LLT
May	W	-1036 (-13.8%)	-2113 (-28.1%)	-1048 (-13.9%)	-2124 (-28.2%)	112 (1.8%)	675 (14.2%)
	AN	982 (29.4%)	1010 (30.2%)	1060 (32.5%)	1089 (33.4%)	980 (29.3%)	1249 (40.3%)
	BN	1923 (159.5%)	2462 (204.3%)	1980 (172.4%)	2519 (219.3%)	1812 (137.6%)	1919 (109.7%)
	D	706 (44.4%)	960 (60.3%)	711 (44.8%)	965 (60.8%)	436 (23.4%)	328 (14.8%)
	C	174 (11%)	188 (11.9%)	228 (15%)	242 (15.9%)	-129 (-6.9%)	-28 (-1.5%)
	AVG	324 (8.8%)	137 (3.7%)	350 (9.6%)	163 (4.5%)	565 (16.5%)	793 (26.4%)
Jun	W	120 (2.4%)	219 (4.3%)	43 (0.8%)	142 (2.8%)	1522 (41.6%)	1070 (25.4%)
	AN	2421 (73.3%)	2977 (90.2%)	2337 (69%)	2893 (85.5%)	2615 (84.2%)	2349 (59.8%)
	BN	2826 (104.4%)	2749 (101.6%)	2781 (101.1%)	2704 (98.3%)	2379 (75.5%)	1904 (53.6%)
	D	459 (14.6%)	363 (11.6%)	241 (7.2%)	145 (4.3%)	161 (4.7%)	212 (6.5%)
	C	-49 (-1.8%)	-131 (-4.9%)	-55 (-2%)	-137 (-5.1%)	-166 (-5.9%)	-103 (-3.8%)
	AVG	968 (26.7%)	1035 (28.5%)	875 (23.5%)	942 (25.3%)	1282 (38.7%)	1040 (28.7%)
Jul	W	-1125 (-17.3%)	-98 (-1.5%)	-1383 (-20.5%)	-355 (-5.3%)	-2470 (-31.5%)	-2185 (-25.5%)
	AN	-1599 (-18.3%)	-1181 (-13.5%)	-1955 (-21.5%)	-1536 (-16.9%)	-2276 (-24.1%)	-1912 (-20.2%)
	BN	-2505 (-27.9%)	-2764 (-30.8%)	-2618 (-28.8%)	-2878 (-31.6%)	-2461 (-27.5%)	-2616 (-29.6%)
	D	-2297 (-27.7%)	-3874 (-46.7%)	-2269 (-27.5%)	-3846 (-46.5%)	-1983 (-24.8%)	-3678 (-45.4%)
	C	-3479 (-51.9%)	-3767 (-56.2%)	-2817 (-46.6%)	-3105 (-51.4%)	-2921 (-47.5%)	-2281 (-43.7%)
	AVG	-2032 (-26.5%)	-2078 (-27.1%)	-2082 (-27%)	-2127 (-27.5%)	-2399 (-29.8%)	-2561 (-31.4%)
Aug	W	780 (23.6%)	1276 (38.6%)	182 (4.7%)	678 (17.4%)	-1374 (-25.2%)	-1644 (-26.4%)
	AN	-406 (-6.7%)	-334 (-5.5%)	-747 (-11.7%)	-675 (-10.6%)	-1312 (-18.9%)	-1637 (-22.3%)
	BN	-1793 (-28.5%)	-2044 (-32.5%)	-1946 (-30.2%)	-2197 (-34.1%)	-1847 (-29.1%)	-2617 (-38.1%)
	D	-2772 (-39.4%)	-3177 (-45.2%)	-1841 (-30.2%)	-2246 (-36.8%)	-1368 (-24.3%)	-1131 (-22.7%)
	C	39 (1.5%)	-579 (-22.2%)	28 (1.1%)	-591 (-22.5%)	417 (18.6%)	-129 (-6%)
	AVG	-721 (-14.6%)	-776 (-15.7%)	-784 (-15.7%)	-839 (-16.8%)	-1182 (-21.9%)	-1475 (-26.2%)
Sep	W	-1017 (-44.6%)	-1108 (-48.6%)	-7195 (-85.1%)	-7286 (-86.1%)	-7137 (-85%)	-7155 (-85.9%)
	AN	-572 (-25.4%)	-351 (-15.6%)	-5341 (-76.1%)	-5119 (-72.9%)	-5492 (-76.6%)	-4997 (-72.4%)
	BN	-1113 (-45.1%)	-1011 (-41%)	-1357 (-50.1%)	-1255 (-46.3%)	-1808 (-57.2%)	-1613 (-52.6%)
	D	-698 (-29.5%)	-707 (-29.9%)	-331 (-16.6%)	-341 (-17.1%)	195 (13.2%)	606 (57.6%)
	C	294 (20.7%)	323 (22.8%)	186 (12.2%)	215 (14.1%)	264 (18.2%)	399 (29.7%)
	AVG	-706 (-32.1%)	-683 (-31%)	-3340 (-69.1%)	-3317 (-68.6%)	-3294 (-68.8%)	-3084 (-67%)
Oct	W	-303 (-8.8%)	-196 (-5.7%)	-50 (-1.6%)	56 (1.7%)	128 (4.2%)	209 (6.8%)
	AN	974 (40.8%)	917 (38.4%)	591 (21.3%)	533 (19.2%)	784 (30.4%)	562 (20.5%)
	BN	28 (0.9%)	-140 (-4.4%)	410 (14.6%)	242 (8.6%)	391 (13.9%)	181 (6.3%)
	D	270 (10.1%)	532 (19.8%)	292 (10.9%)	553 (20.7%)	172 (6.2%)	568 (21.4%)
	C	453 (18.3%)	1035 (41.9%)	657 (29%)	1239 (54.7%)	691 (30.9%)	1404 (66.8%)
	AVG	177 (6%)	316 (10.7%)	301 (10.7%)	440 (15.6%)	361 (13.1%)	509 (18.5%)
Nov	W	-433 (-13.1%)	-545 (-16.6%)	-132 (-4.4%)	-245 (-8.2%)	48 (1.7%)	277 (11.2%)
	AN	290 (15.9%)	91 (5%)	110 (5.5%)	-88 (-4.4%)	199 (10.4%)	-204 (-9.6%)
	BN	-339 (-16.1%)	-248 (-11.8%)	-280 (-13.7%)	-189 (-9.3%)	-188 (-9.6%)	-47 (-2.5%)
	D	-58 (-3.1%)	-48 (-2.6%)	68 (3.9%)	78 (4.5%)	72 (4.2%)	147 (8.8%)
	C	47 (2.5%)	162 (8.7%)	42 (2.2%)	156 (8.4%)	98 (5.5%)	140 (7.5%)
	AVG	-158 (-6.7%)	-189 (-8%)	-53 (-2.3%)	-83 (-3.7%)	43 (2%)	103 (5%)

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Month	WY Type	EBC1 vs. PP_ELT	EBC1 vs. PP_LLT	EBC2 vs. PP_ELT	EBC2 vs. PP_LLT	EBC2_ELT vs. PP_ELT	EBC2_LLT vs. PP_LLT
Dec	W	534 (7.5%)	-1230 (-17.2%)	2278 (42.1%)	513 (9.5%)	2149 (38.8%)	1979 (50.1%)
	AN	431 (14.6%)	1492 (50.6%)	53 (1.6%)	1115 (33.5%)	38 (1.1%)	1099 (32.9%)
	BN	556 (25.6%)	573 (26.3%)	217 (8.6%)	233 (9.3%)	636 (30.3%)	646 (30.8%)
	D	501 (21.2%)	327 (13.8%)	522 (22.3%)	347 (14.8%)	663 (30.1%)	461 (20.7%)
	C	150 (5.8%)	280 (10.7%)	606 (28.2%)	736 (34.2%)	978 (54.9%)	1195 (70.5%)
	AVG	460 (11.6%)	39 (1%)	970 (28%)	550 (15.9%)	1084 (32.4%)	1175 (41.4%)

Sacramento River Confluence

For the Feather River at the confluence with the Sacramento River for all years combined, differences in mean monthly flows during February through May under the PP_ELT compared to EBC1 are predicted to range from a decrease of 1,275 (8.9%) during May of wet years to an increase of 3,905 (14.4%) in February of wet years (Table C.5.2-103). Differences in mean monthly flows under the PP_LLT compared to EBC1 are predicted to range from a decrease of 3,314 (23%) during May of wet years to an increase of 5,857 (21.7%) in February of wet years. Differences in mean monthly flows under the PP_ELT compared to EBC2 are predicted to range from a decrease of 1,279 cfs (8.9%) during May of wet years to an increase of 4,815 cfs (18.4%) in February of wet years. Differences in mean monthly flows under the PP_LLT compared to EBC2 are predicted to range from a decrease of 3,318 cfs (23.1%) during May of wet years to an increase of 6,767 cfs (25.9%) in February of wet years.

When isolating the effect of the project, differences in mean monthly flows under PP_ELT relative to EBC2_ELT are predicted to range from a decrease of 129 cfs (6.9%) in May of critical water years to 3,194 cfs (55.1%) during February of above-normal years. Differences in mean monthly flows under the PP_LLT relative to the EBC2_LLT are predicted to range from a decrease of 28 cfs (1.5%) for critical water years in May to an increase of 2,329 cfs (40.1%) during May in dry water years.

Admin Draft

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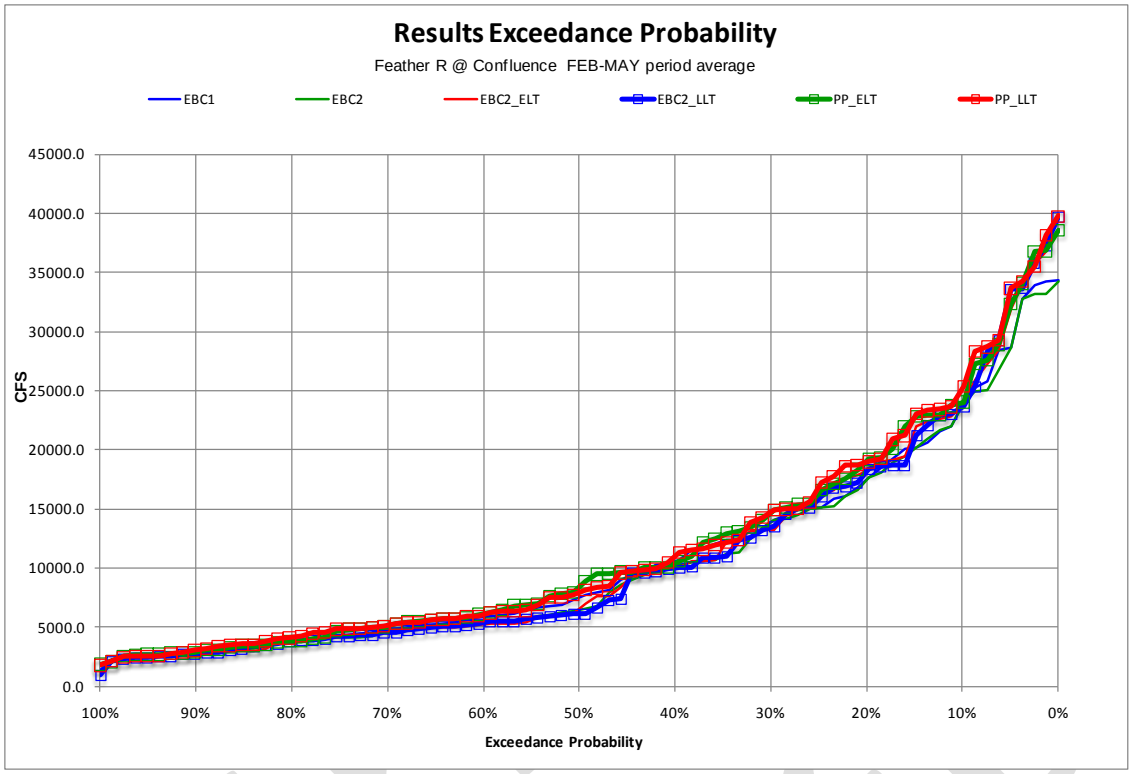

Figure C.5.2-251. Probability of Exceedance Plot for Model Scenarios of Mean Monthly Flow in the Feather River at the Confluence with the Sacramento River, February through May

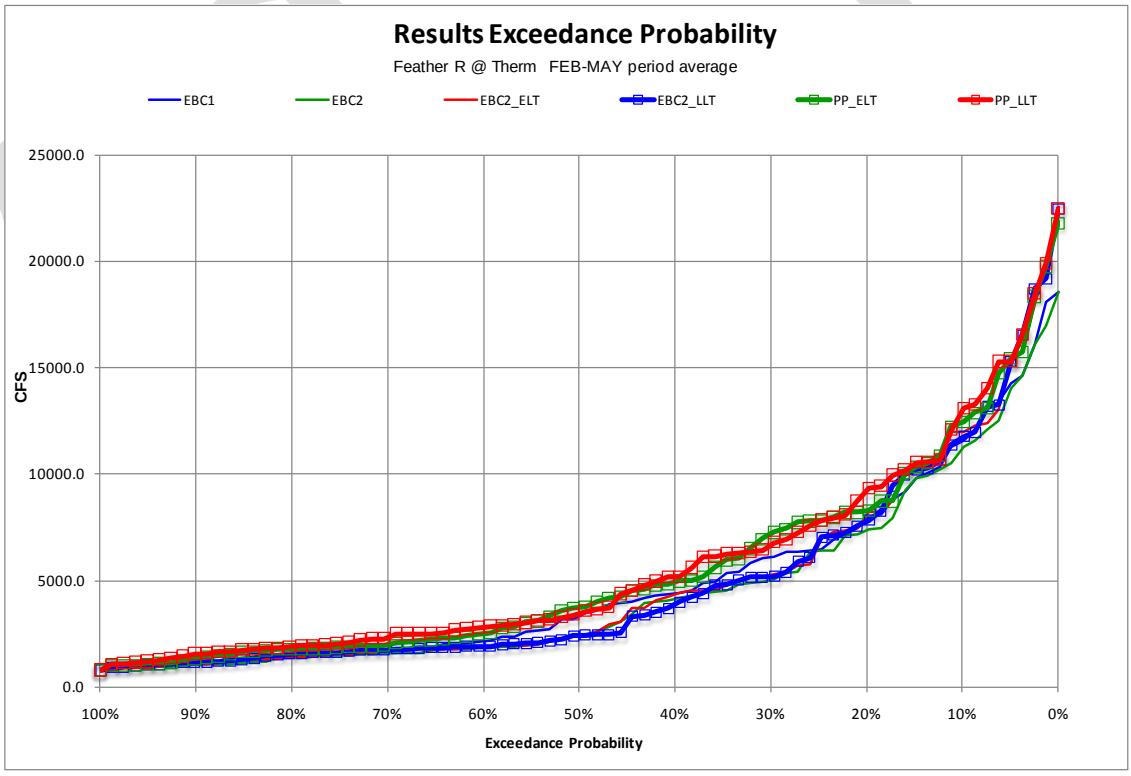

Figure C.5.2-252. Probability of Exceedance Plot for Model Scenarios of Mean Monthly Flow in the Feather River at Thermalito Afterbay, February through May

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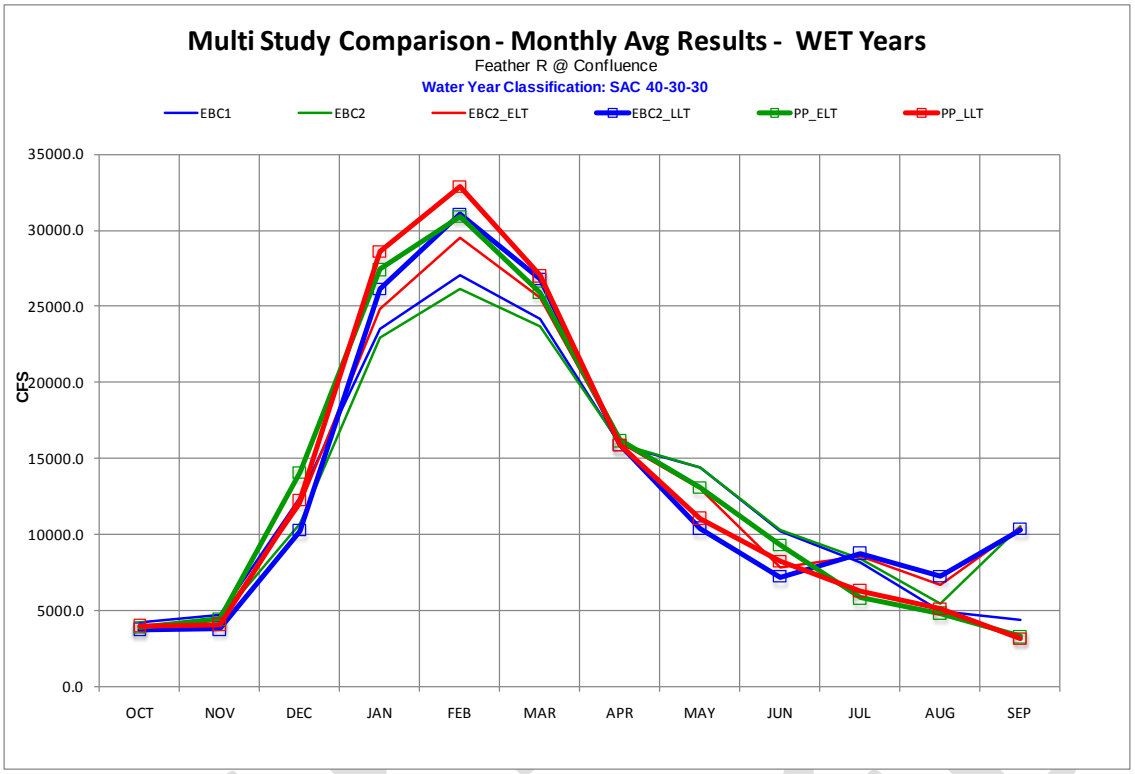

Figure C.5.2-253. Average Monthly Flows in the Feather River at the Confluence with the Sacramento River in Wet Years

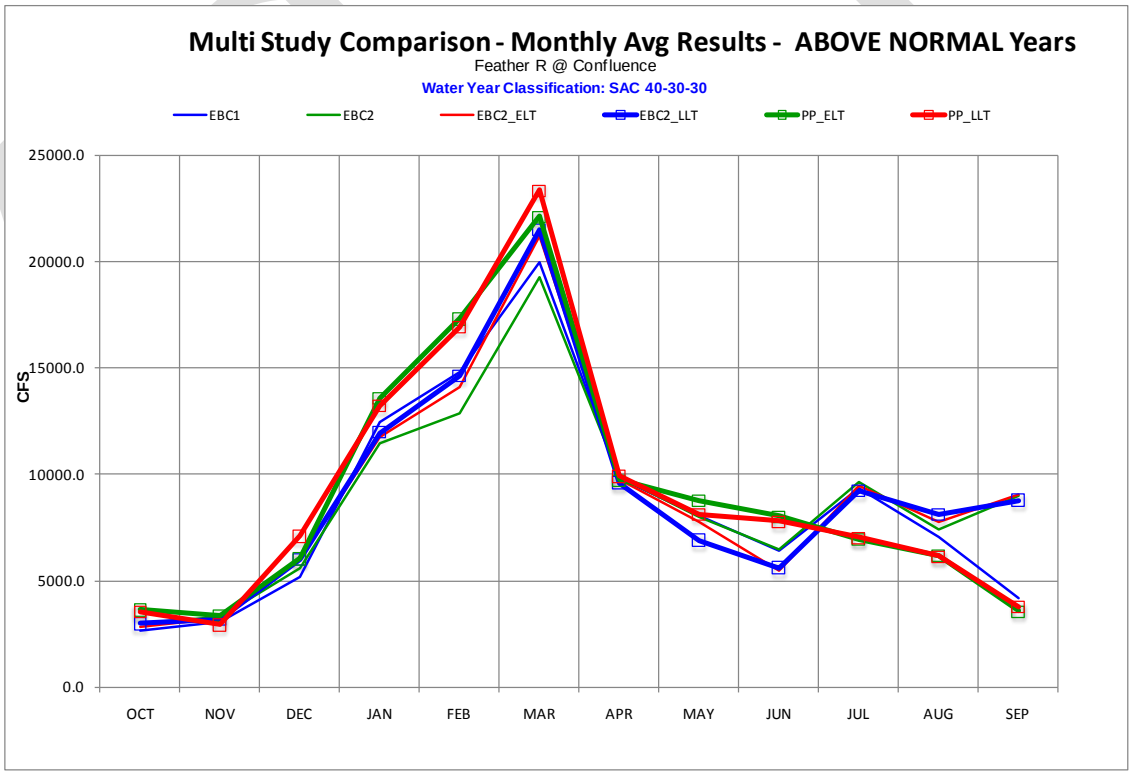

Figure C.5.2-254. Average Monthly Flows in the Feather River at the Confluence with the Sacramento River in Above-Normal Years

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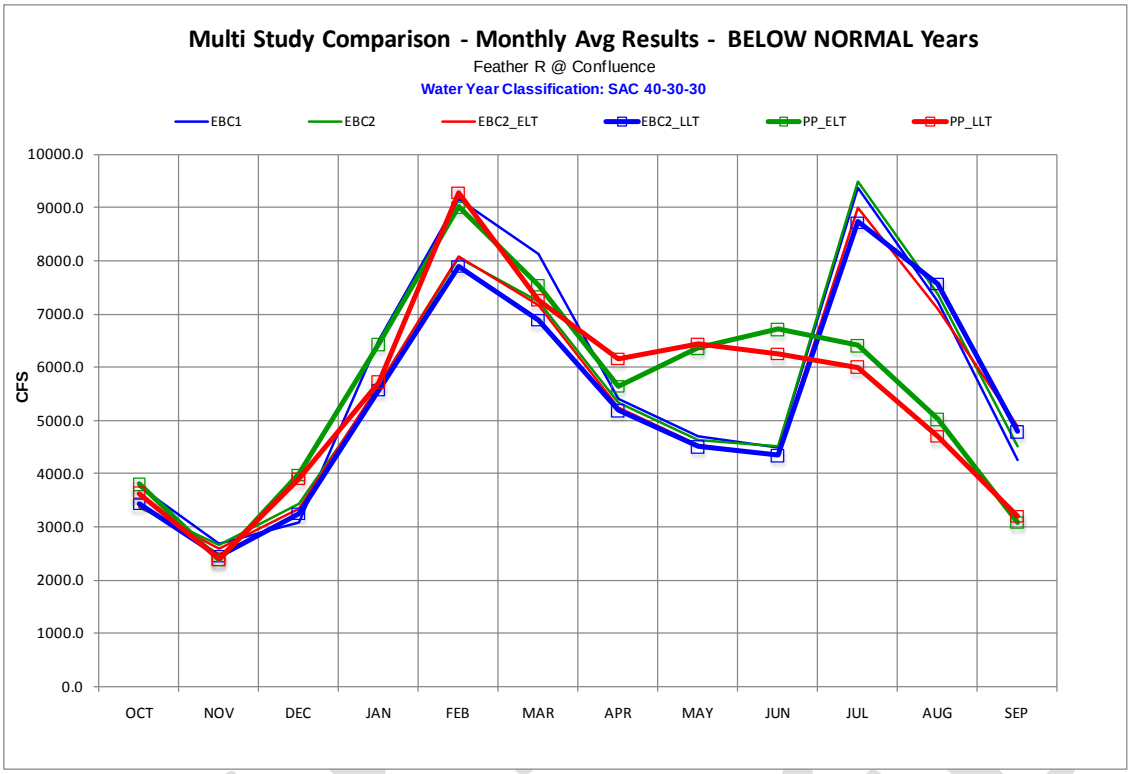

Figure C.5.2-255. Average Monthly Flows in the Feather River at the Confluence with the Sacramento River in Below-Normal Years

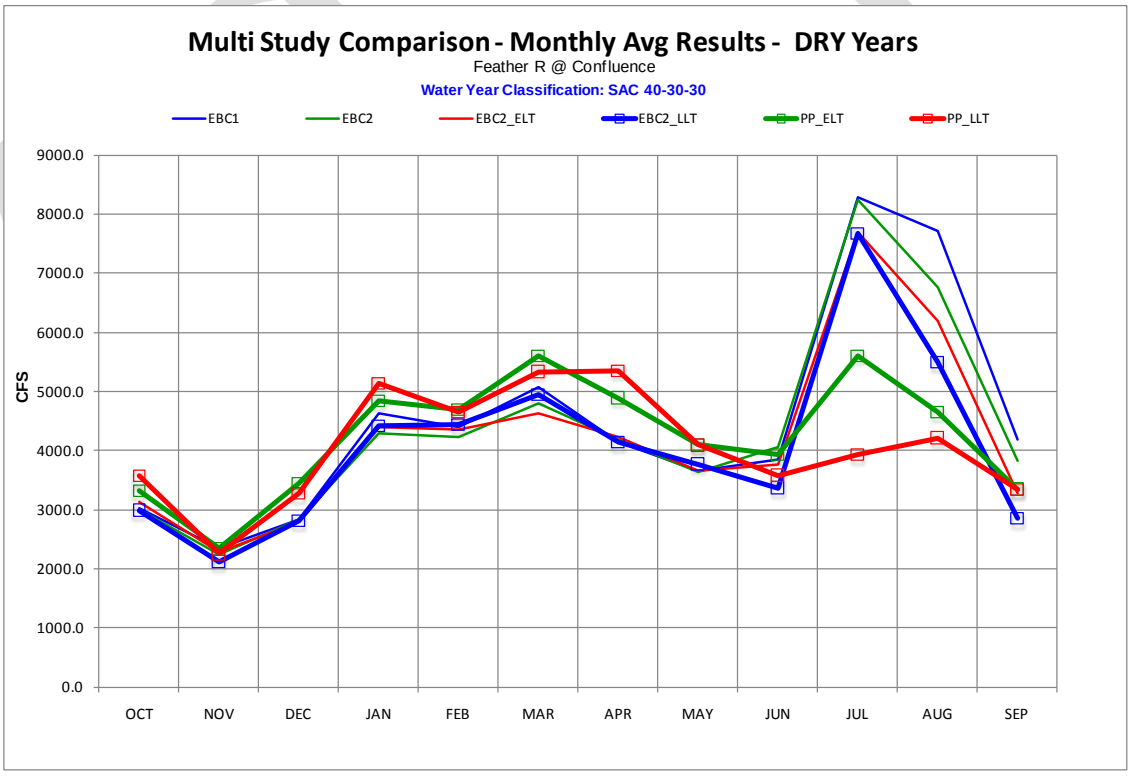

Figure C.5.2-256. Average Monthly Flows in the Feather River at the Confluence with the Sacramento River in Dry Years

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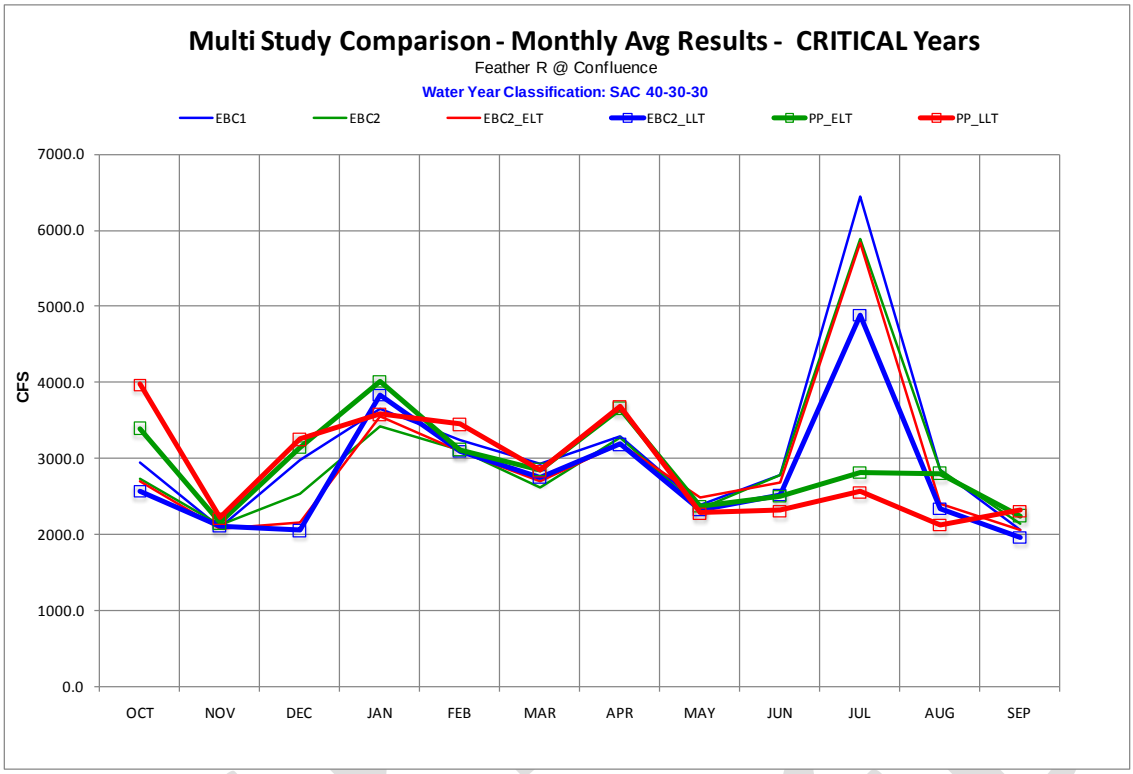

Figure C.5.2-257. Average Monthly Flows in the Feather River at the Confluence with the Sacramento River in Critical Years

At Thermalito Afterbay

With some scalar differences (far less upstream volume), the investigation of modeled scenarios for each water-year type in the Feather River at Thermalito Afterbay between February and May (Figure C.5.2-258 to Figure C.5.2-262, Table C.5.2-104) indicates a very similar distribution to the Feather River at the confluence with the Sacramento River (Figure C.5.2-253 to Figure C.5.2-257, Table C.5.2-103).

For the Feather River at Thermalito, differences in mean monthly flows under the PP_ELT compared to EBC1 are predicted to range from a decrease of 1,036 (13.8%)during May of wet years to an increase of 2,705 (21.7%) in February of wet years. Differences in mean monthly flows under the PP_LLT compared to EBC1 are predicted to range from a decrease of 2,113 (28.1%) during May of wet years to an increase of 4,156 (33.3%) in February of wet years. Differences in mean monthly flows under the PP_ELT compared to EBC2 are predicted to range from a decrease of 1,048 cfs (13.9%) during May of wet years to an increase of 3,623 cfs (31.4%) in February of wet years. Differences in mean monthly flows under the PP_LLT compared to EBC2 are predicted to range from a decrease of 2,124 cfs (28.2%) during May of wet years to an increase of 5,074 cfs (43.9%) in February of wet years.

When isolating the effect of the project, differences in mean monthly flows under PP_ELT relative to EBC2_ELT are predicted to range from a decrease of 129 cfs (6.9%) in May of critical water years to 3,194 cfs (55.1%) during February of above-normal years. Differences in mean monthly flows under the PP_LLT relative to the EBC2_LLT are predicted to range from a decrease of 28 cfs (1.5%) for critical water years in May to an increase of 2,329 cfs (40.1%) during May in dry water years.

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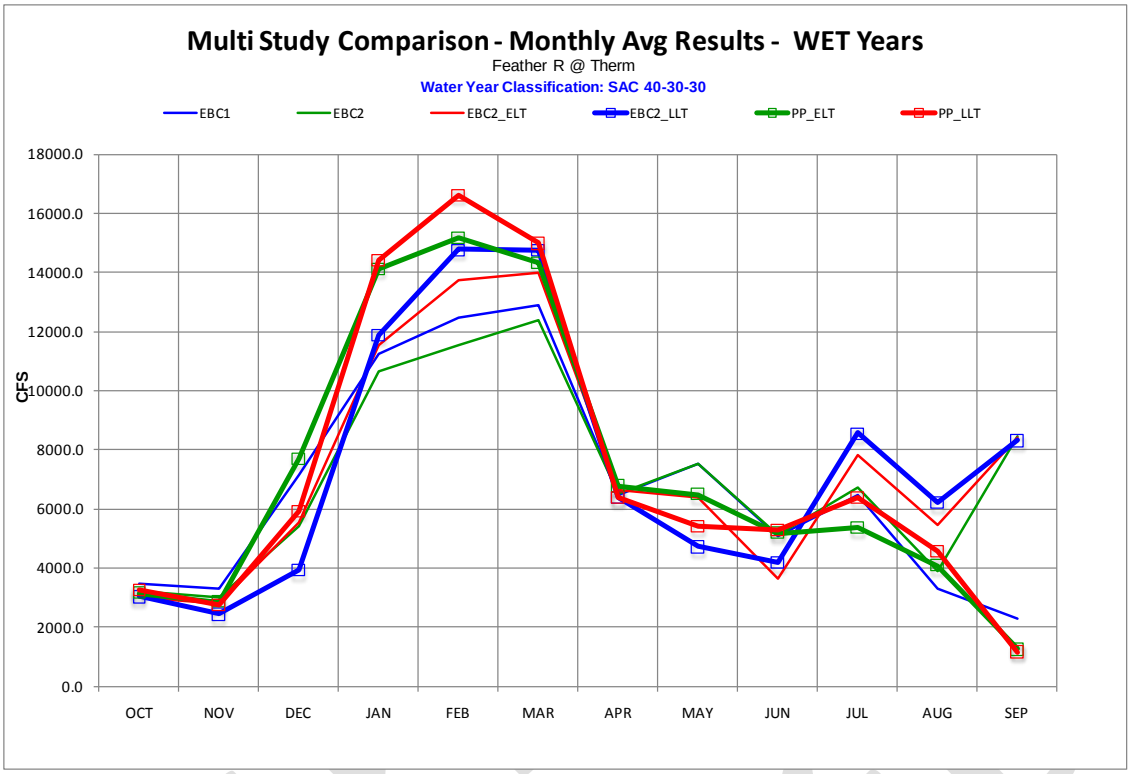

Figure C.5.2-258. Average Monthly Flows in the Feather River at Thermalito Afterbay in Wet Years

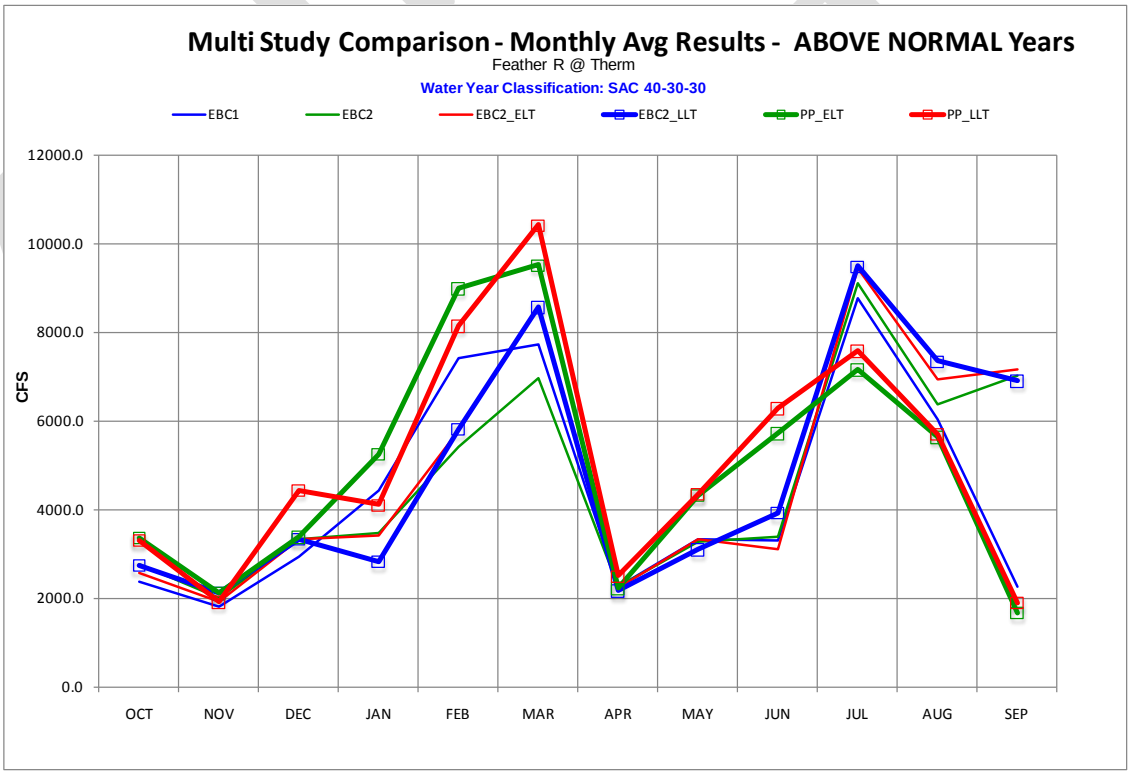

Figure C.5.2-259. Average Monthly Flows in the Feather River at Thermalito Afterbay in Above-Normal Years

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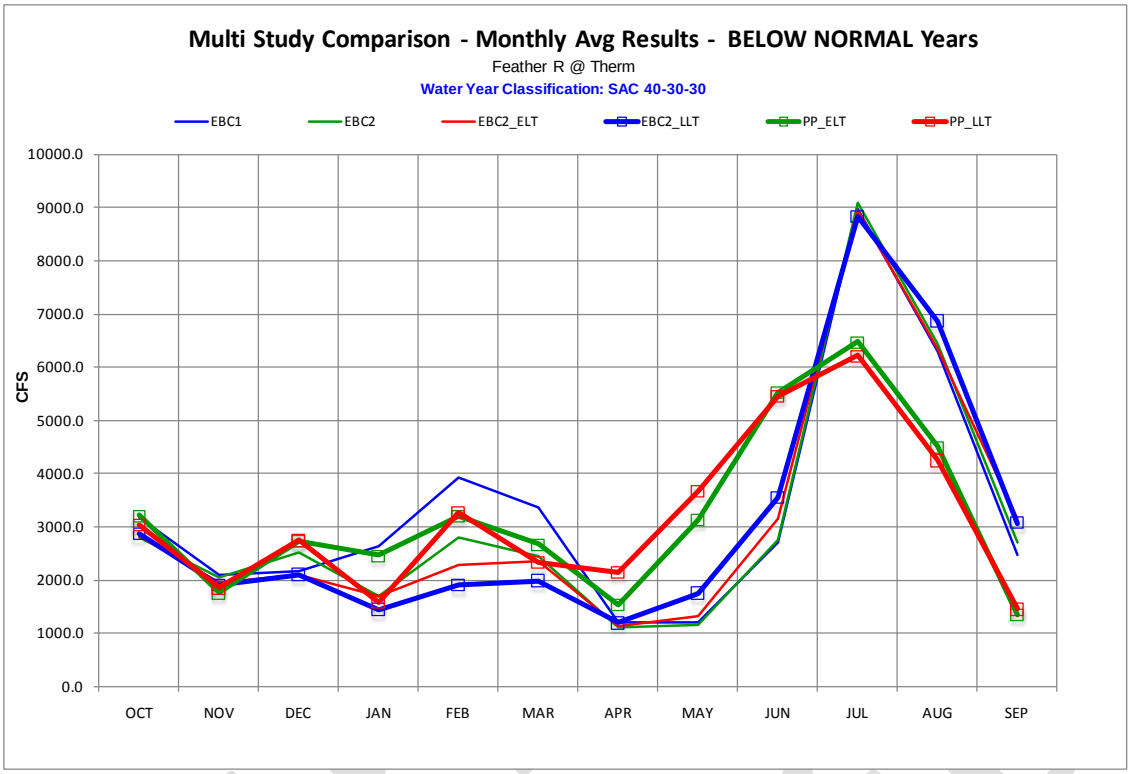

Figure C.5.2-260. Average Monthly Flows in the Feather River at Thermalito Afterbay in Below-Normal Years

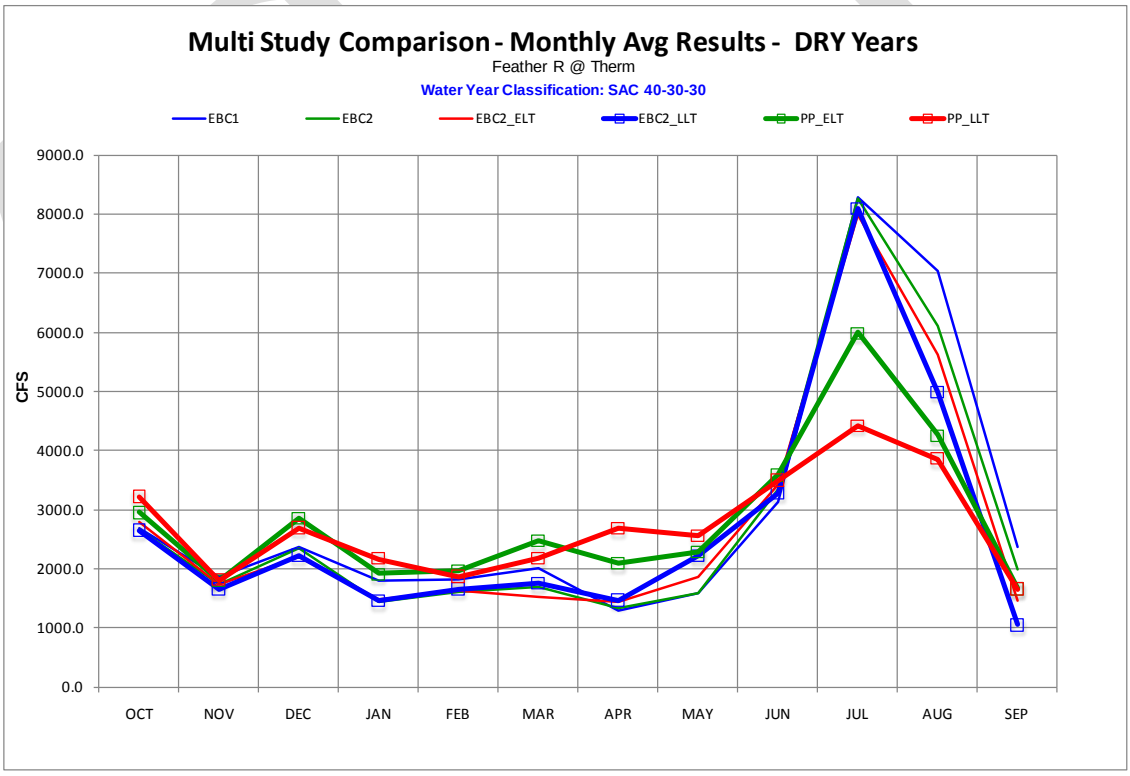

Figure C.5.2-261. Average Monthly Flows in the Feather River at Thermalito Afterbay in Dry Years

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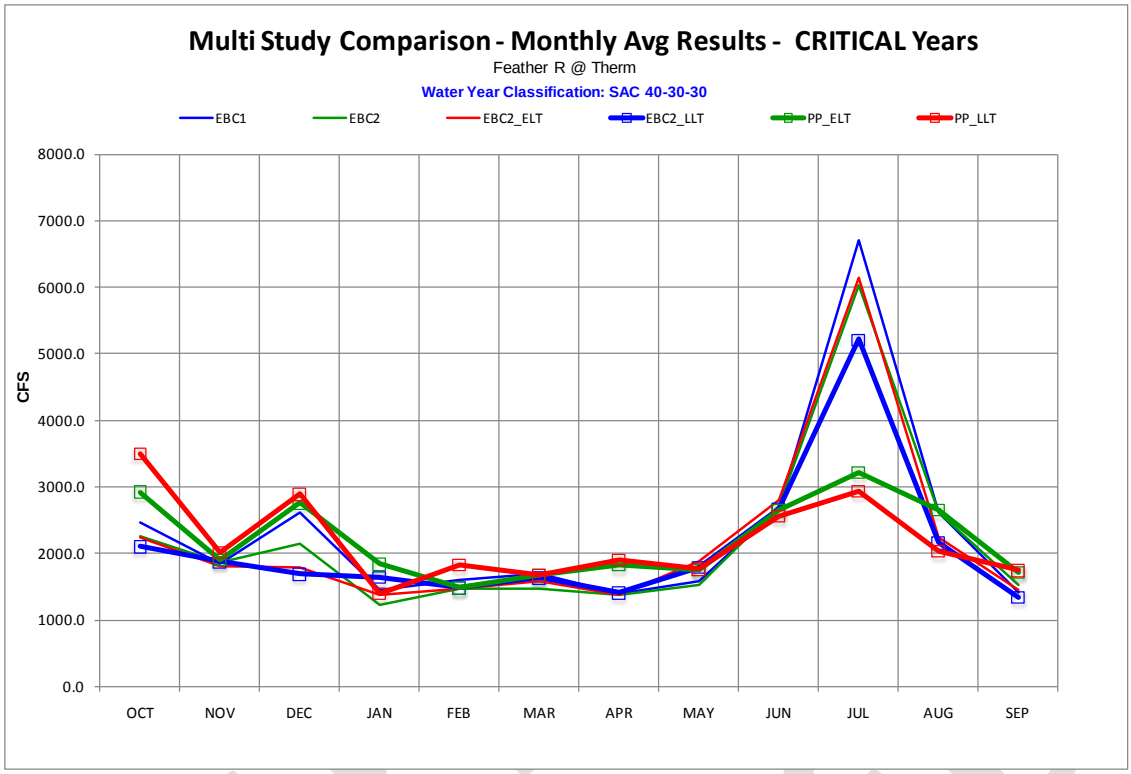

Figure C.5.2-262. Average Monthly Flows in the Feather River at Thermalito Afterbay in Critical Years

CALSIM-modeled February through May flows in the Feather River high-flow channel, both at the confluence with the Sacramento River and at Thermalito Afterbay, with very few exceptions, would substantially increase for each water-year type under PP_ELT and PP_LLT compared to EBC2_ELT and EBC2_LLT, respectively. The increased flows in the Feather River high-flow channel under BDCP operations during the seasonal period of white sturgeon egg incubation and embryo development would potentially improve habitat conditions and increase juvenile abundance. Information on the relationship between river flows and habitat quality and quantity for sturgeon spawning and development have not been developed for the Feather River. As flows increase, water depths and velocities increase, which affect habitat conditions for spawning and egg development as well as larval dispersal and rearing habitat. Results of general analyses of the relationship between Delta outflow and overall indices of juvenile white sturgeon abundance (Kohlhorst et al. 1991) suggest that, in general, higher flows within the Sacramento River system contribute to stronger juvenile year classes (increased juvenile abundance). Similar analyses, however, have not been developed for specific rivers (e.g., Feather River) or specific reaches within a river. As a result, the effects of increased flows in the Feather River high-flow channel on reproductive success and juvenile rearing are unknown. However, based on the general relationship between higher flows and increased juvenile abundance, it has been hypothesized that the increased Feather River flows would provide an incremental increase in habitat and benefits to white sturgeon that reproduce in the lower Feather River.

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Larvae

Water Temperature

To investigate temperatures further downstream in the Feather River for larval rearing, the Reclamation temperature model was used to evaluate spring (February through June) seasonal water temperature distributions at the confluence with the Sacramento River and at Honcut Creek.

Sacramento River Confluence

Water temperatures in the Feather River at the confluence with the Sacramento River from February to June exceeded the 68°F threshold for all scenarios regardless of water-year type (Figure C.5.2-263 through Figure C.5.2-267).

Combining all water years, mean monthly water temperatures in the Feather River at the confluence with the Sacramento River from February through June exceeded the 68°F threshold 23% of the time under EBC1 and EBC2, 29%–34% of the time under EBC2_ELT and EBC2_LLT, and 28%–32% of the time under PP_ELT and PP_LLT (Table C.5.2-105). Water temperatures are predicted to exceed 68°F under PP_ELT in 4.7% more months relative to both EBC1 and EBC2 (Table C.5.2-106). Temperatures are predicted to exceed 68°F under PP_LLT in 8.4% more months relative to both EBC1 and EBC2. Accounting for climate change effects, temperatures are predicted to exceed 68°F under PP_ELT and PP_LLT in 1% and 2.2% fewer months relative to EBC2_ELT and EBC2_LLT, respectively. These results indicate that the preliminary proposal would have a very minor beneficial effect on the frequency of water temperature exceedance above 68°F at the Sacramento River confluence.

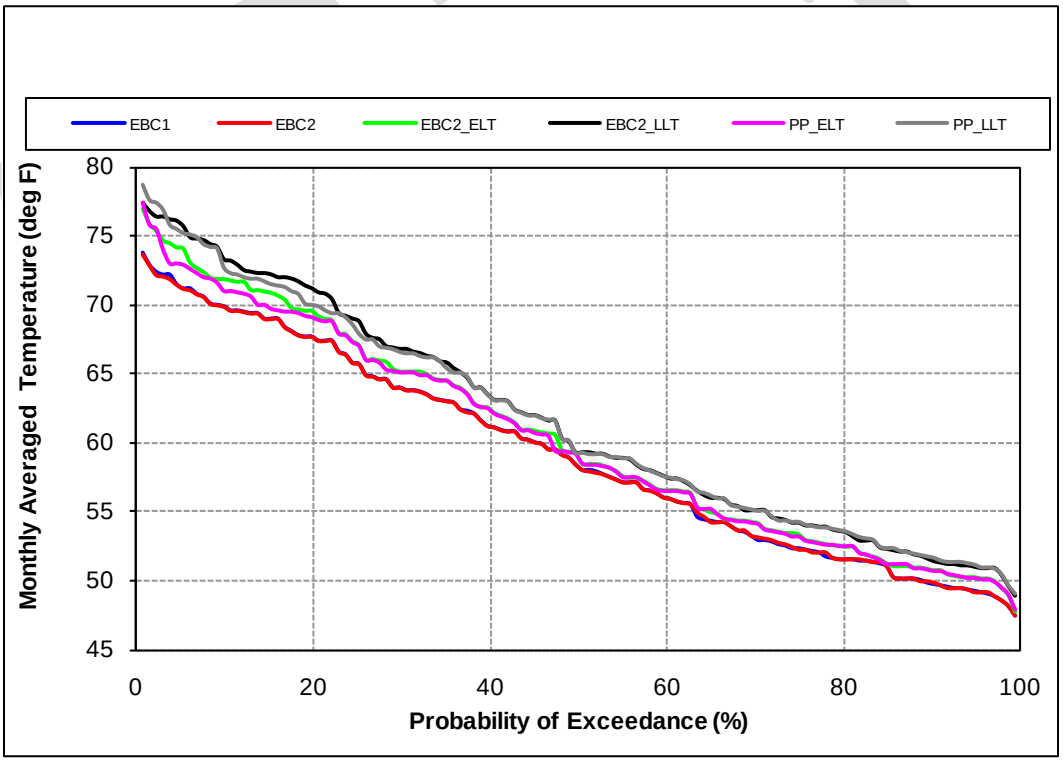

Figure C.5.2-263. Probability of Exceedance Plot for Model Scenarios of Mean Monthly Temperature of the Feather River at the Confluence with the Sacramento River in Wet Years, February through June

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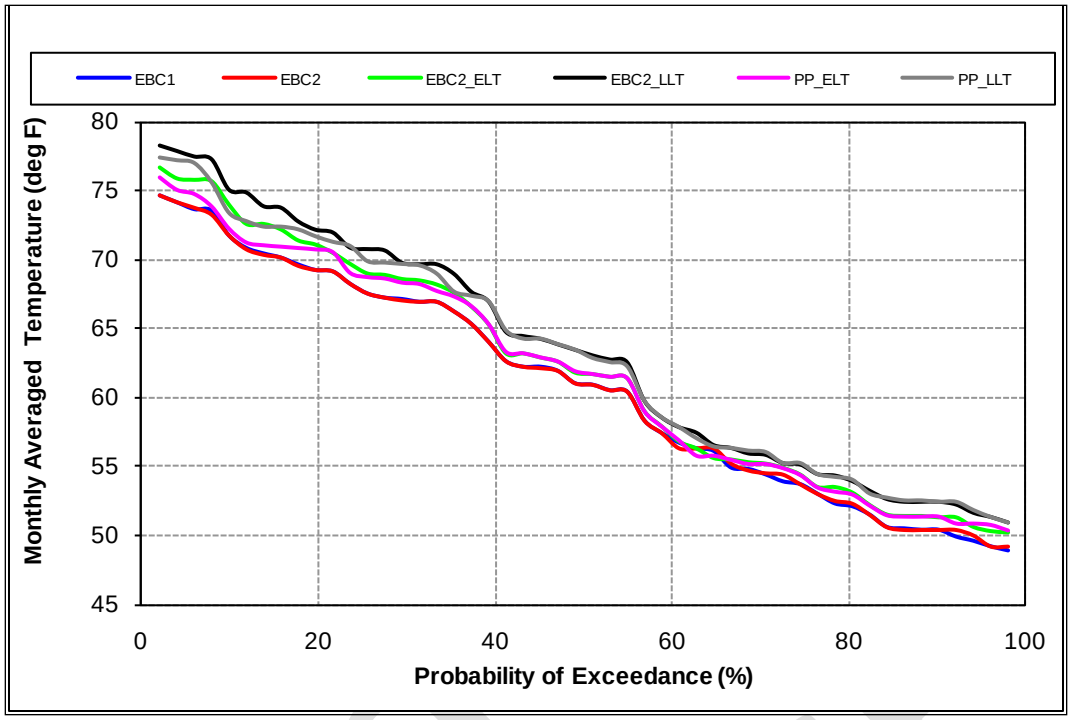

Figure C.5.2-264. Probability of Exceedance Plot for Model Scenarios of Mean Monthly Temperature of the Feather River at the Confluence with the Sacramento River in Above-Normal Years, February through June

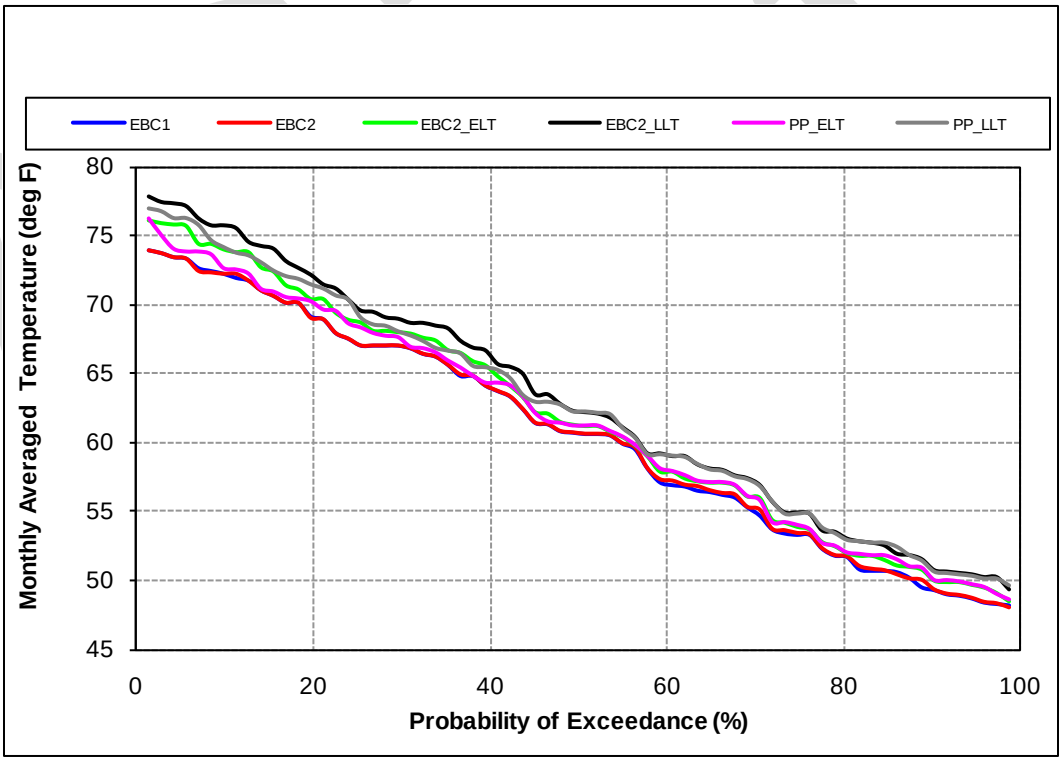

Figure C.5.2-265. Probability of Exceedance Plot for Model Scenarios of Mean Monthly Flow in the Feather River at the Confluence with the Sacramento River in Below Normal Years, February through June

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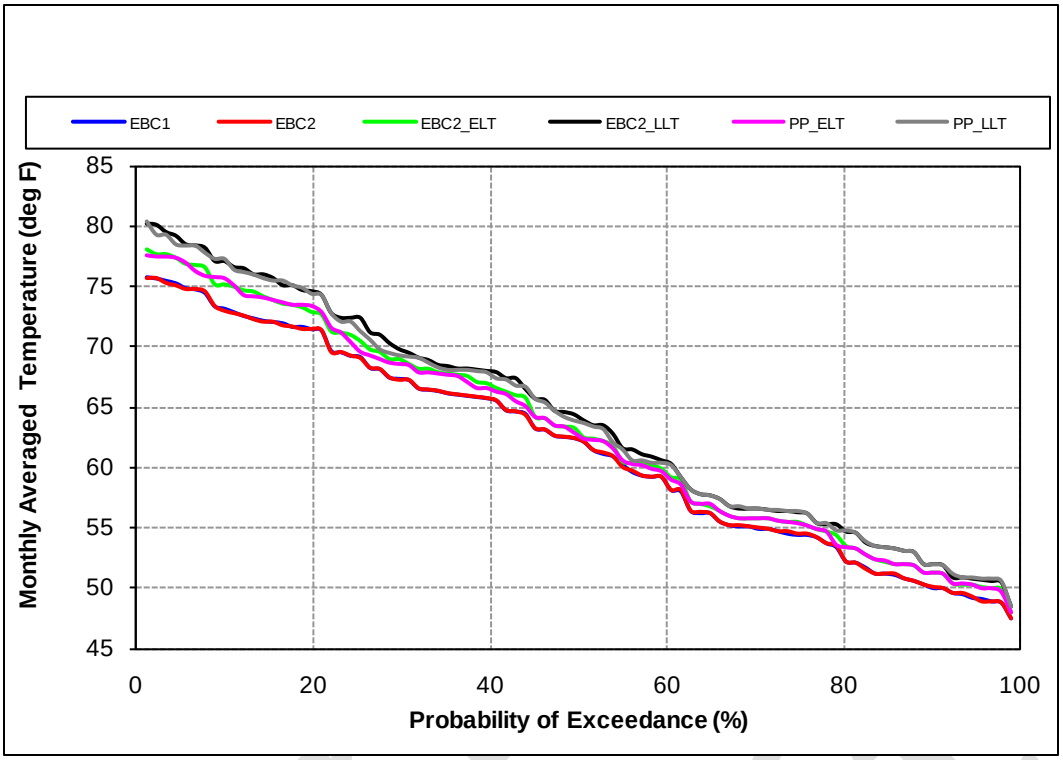

Figure C.5.2-266. Probability of Exceedance Plot for Model Scenarios of Mean Monthly Temperature of the Feather River at the Confluence with the Sacramento River in Dry Years, February through June

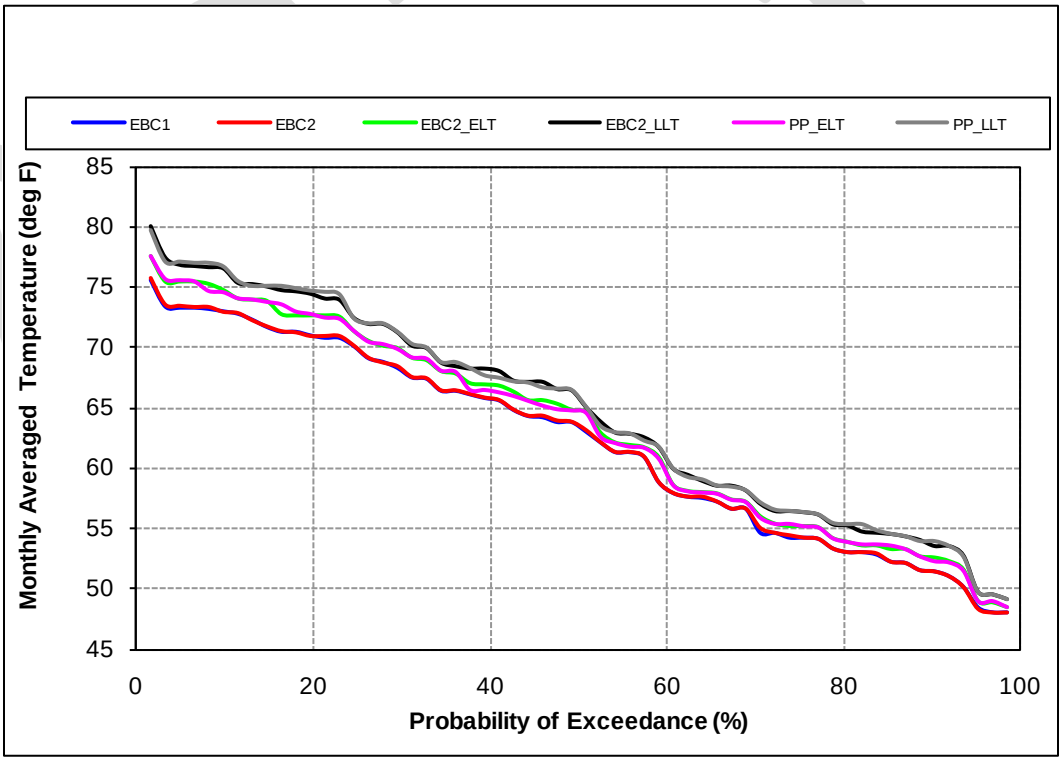

Figure C.5.2-267. Probability of Exceedance Plot for Model Scenarios of Mean Monthly Temperature of the Feather River at the Confluence with the Sacramento River in Critical Years, February through June

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Table C.5.2-105. Percent of Months during the Months February through June[1] When Monthly Average Temperature Exceeds 68°F in the Feather River at the Confluence with the Sacramento River

WY Type	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
Wet	17.7	17.7	22.3	25.4	22.3	24.6
Above Normal	23.6	23.6	32.7	34.5	30.9	32.7
Below Normal	21.4	21.4	28.6	35.7	25.7	30.0
Dry	27.8	27.8	33.3	38.9	31.1	37.8
Critically Dry	30.0	30.0	33.3	41.7	35.0	38.3
All	23.2	23.2	28.9	33.8	27.9	31.6

[1] Based on the modeling period of 1922 to 2003

Table C.5.2-106. Difference and Percent Difference in the Percent of Months during February through June When Monthly Average Temperature Exceeds 68°F in the Feather River at the Confluence with the Sacramento River

WY Type	Comparison[1]	EBC1 vs. PP_ELT	EBC1 vs. PP_LLT	EBC2 vs. EBC2_ELT	EBC2 vs. EBC2_LLT	EBC2 vs. PP_ELT	EBC2 vs. PP_LLT	EBC2_ELT vs. PP_ELT	EBC2_LLT vs. PP_LLT
Temperatures above 68°F									
Wet	Difference	4.6	6.9	4.6	7.7	4.6	6.9	0.0	-0.8
	Percent difference	26%	39%	26%	43%	26%	39%	0%	-3%
Above Normal	Difference	7.3	9.1	9.1	10.9	7.3	9.1	-1.8	-1.8
	Percent difference	31%	38%	38%	46%	31%	38%	-6%	-5%
Below Normal	Difference	4.3	8.6	7.1	14.3	4.3	8.6	-2.9	-5.7
	Percent difference	20%	40%	33%	67%	20%	40%	-10%	-16%
Dry	Difference	3.3	10.0	5.6	11.1	3.3	10.0	-2.2	-1.1
	Percent difference	12%	36%	20%	40%	12%	36%	-7%	-3%
Critical	Difference	5.0	8.3	3.3	11.7	5.0	8.3	1.7	-3.3
	Percent difference	17%	28%	11%	39%	17%	28%	5%	-8%
All	Difference	4.7	8.4	5.7	10.6	4.7	8.4	-1.0	-2.2
	Percent difference	20%	36%	24%	46%	20%	36%	-3%	-7%

[1] A positive value indicates a higher value under the second model scenario listed in the column title.

At Honcut Creek

Water temperature exceedance plots for the Feather River at Honcut Creek during the white sturgeon larval rearing period (February through June) are presented in Figure C.5.2-268 through Figure C.5.2-272.

Combining all water years, mean monthly water temperatures in the Feather River at Honcut Creek from February through June exceeded the 68°F threshold 15% of the time under EBC1 and EBC2, 20%–24% of the time under EBC2_ELT and EBC2_LLT, and 17%–20% of the time under PP_ELT and PP_LLT (Table C.5.2-107). Water temperatures are predicted to exceed 68°F under PP_ELT in 17% more months relative to both EBC1 and EBC2 (Table C.5.2-108). Temperatures are predicted to exceed 68°F under PP_LLT in 5.4% more months relative to both EBC1 and EBC2. Accounting for climate change effects, water temperatures are predicted to exceed 68°F under PP_ELT and PP_LLT in 3.7 and 3.2 fewer months than under EBC2_ELT and EBC2_LLT, respectively. These results

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indicate that the preliminary proposal would have a small beneficial effect on the frequency of water temperature exceedance above 68°F at the Sacramento River confluence.

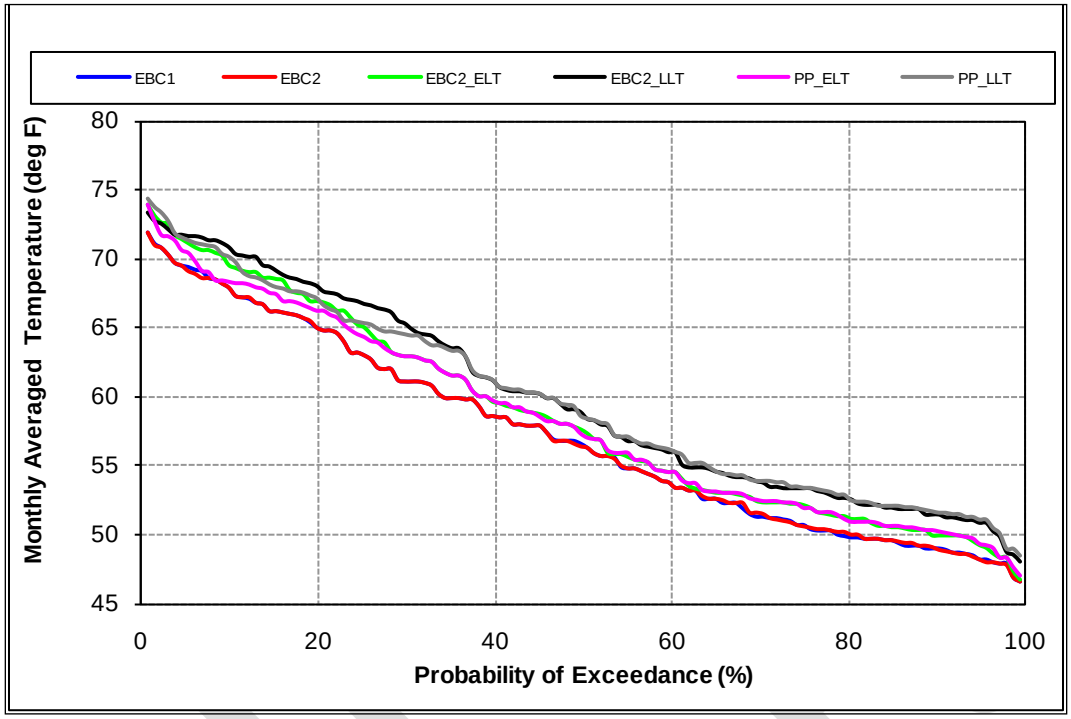

Figure C.5.2-268. Probability of Exceedance Plot for Model Scenarios of Mean Monthly Temperature of the Feather River at Honcut Creek in Wet Years, February through June

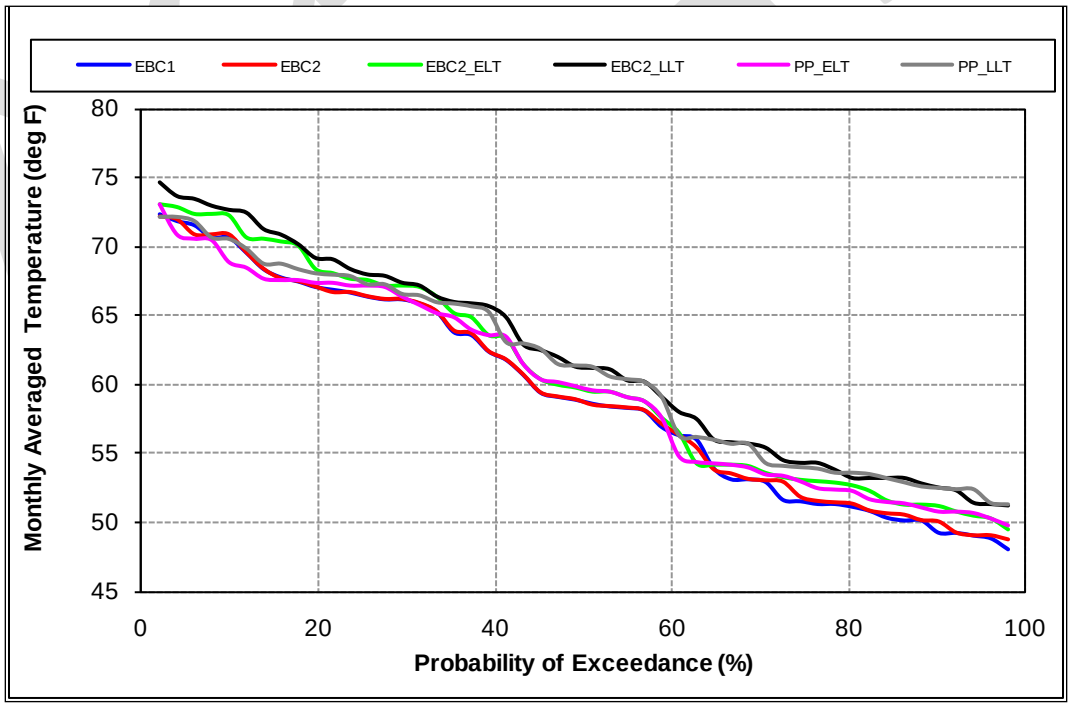

Figure C.5.2-269. Probability of Exceedance Plot for Model Scenarios of Mean Monthly Temperature of the Feather River at Honcut Creek in Above-Normal Years, February through June

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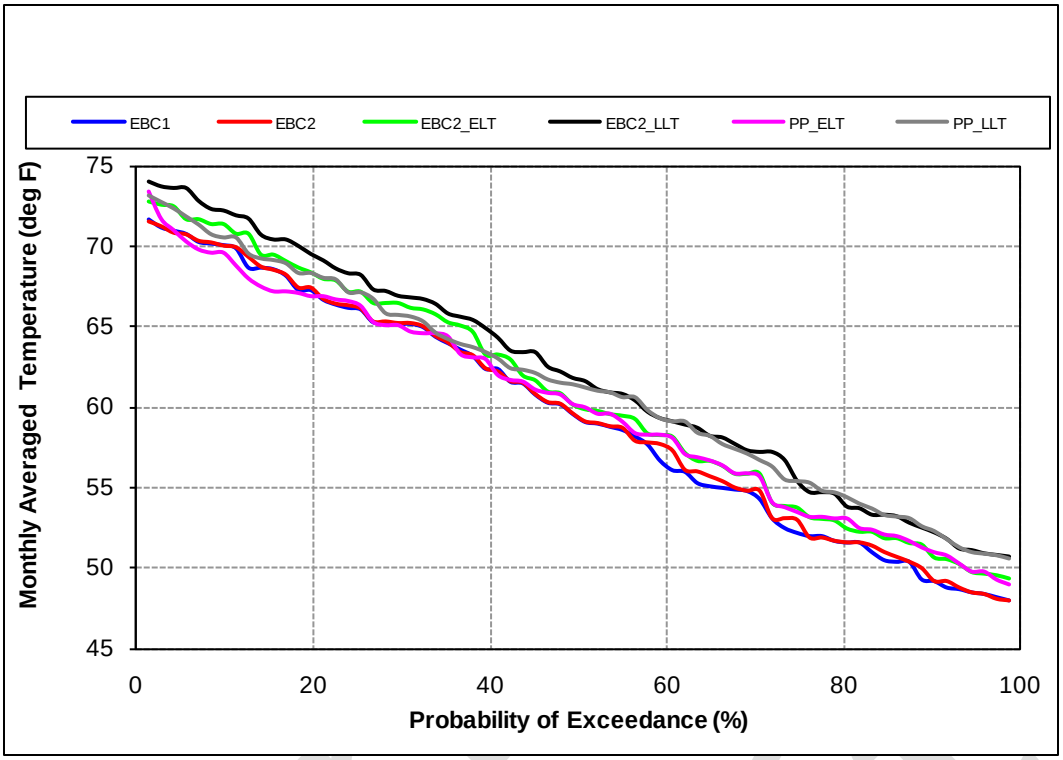

Figure C.5.2-270. Probability of Exceedance Plot for Model Scenarios of Mean Monthly Temperature of the Feather River at Honcut Creek in Below Normal Years, February through June

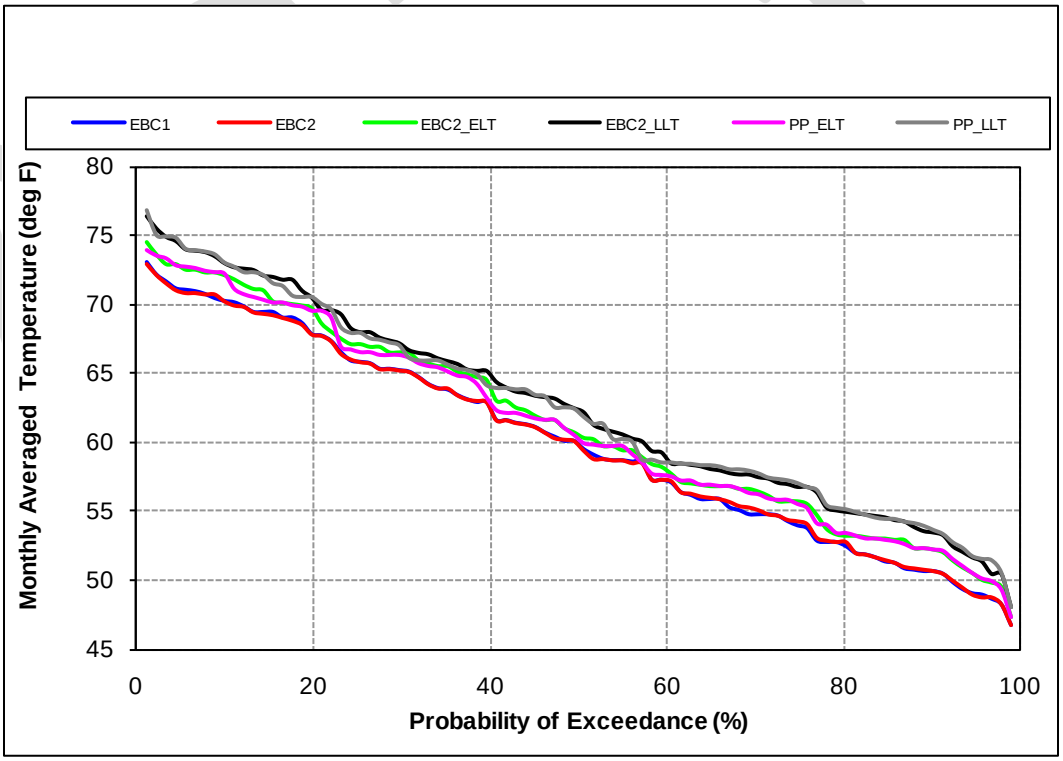

Figure C.5.2-271. Probability of Exceedance Plot for Model Scenarios of Mean Monthly Temperature of the Feather River at Honcut Creek in Dry Years, February through June

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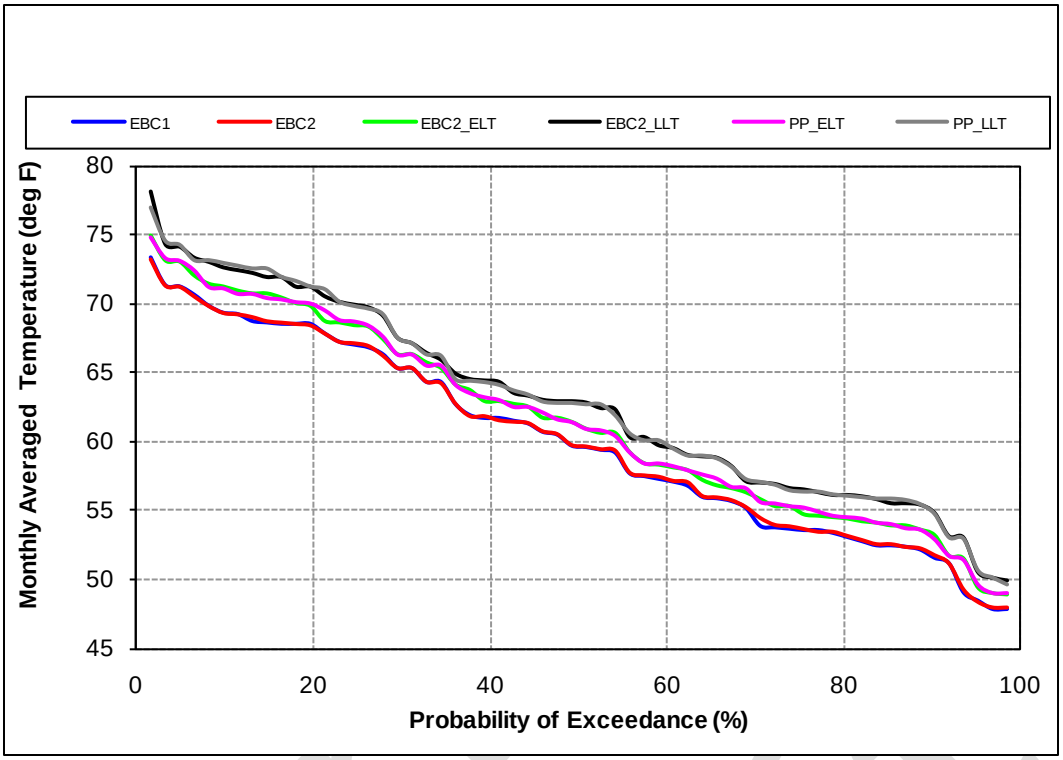

Figure C.5.2-272. Probability of Exceedance Plot for Model Scenarios of Mean Monthly Temperature of the Feather River at Honcut Creek in Critical Years, February through June

Table C.5.2-107. Percent of Months during the Months from February through June[1] When Monthly Average Temperature Exceeds 68°F in the Feather River at Honcut Creek

WY Type	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
Wet	9.2	9.2	16.2	19.2	12.3	14.6
Above Normal	12.7	12.7	21.8	23.6	12.7	20.0
Below Normal	17.1	17.1	20.0	25.7	11.4	20.0
Dry	18.9	18.9	21.1	24.4	22.2	23.3
Critically Dry	20.0	20.0	26.7	28.3	26.7	28.3
All	14.8	14.8	20.2	23.5	16.5	20.2

[1] Based on the modeling period of 1922 to 2003.

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Table C.5.2-108. Difference and Percent Difference in Percent of Months during February to June[1] When Monthly Average Temperature Exceeds 68°F in the Feather River at Honcut Creek

Month	Comparison[1]	EBC1 vs. PP_ELT	EBC1 vs. PP_LLT	EBC2 vs. EBC2_ELT	EBC2 vs. EBC2_LLT	EBC2 vs. PP_ELT	EBC2 vs. PP_LLT	EBC2_ELT vs. PP_ELT	EBC2_LLT vs. PP_LLT
Temperatures above 68°F									
Wet	Difference	3.1	5.4	6.9	10.0	3.1	5.4	-3.8	-4.6
	Percent difference	33%	58%	75%	108%	33%	58%	-24%	-24%
Above Normal	Difference	0.0	7.3	9.1	10.9	0.0	7.3	-9.1	-3.6
	Percent difference	0%	57%	71%	86%	0%	57%	-42%	-15%
Below Normal	Difference	-5.7	2.9	2.9	8.6	-5.7	2.9	-8.6	-5.7
	Percent difference	-33%	17%	17%	50%	-33%	17%	-43%	-22%
Dry	Difference	3.3	4.4	2.2	5.6	3.3	4.4	1.1	-1.1
	Percent difference	18%	24%	12%	29%	18%	24%	5%	-5%
Critical	Difference	6.7	8.3	6.7	8.3	6.7	8.3	0.0	0.0
	Percent difference	33%	42%	33%	42%	33%	42%	0%	0%
All	Difference	1.7	5.4	5.4	8.6	1.7	5.4	-3.7	-3.2
	Percent difference	12%	37%	37%	58%	12%	37%	-18%	-14%

[1] A positive value indicates a higher value under the second model scenario listed in the column title.

Juvenile

Water Temperature

Sacramento River Confluence

Year-round water temperature exceedance plots in the Feather River at its confluence with the Sacramento River are presented by water-year type in Figure C.5.2-273 through Figure C.5.2-277. The percent of months exceeding the 68°F and 77°F thresholds for each model scenario are presented in Table C.5.2-109 and differences between pairs of model scenarios are presented in Table C.5.2-110.

Combining all water years, mean monthly water temperatures in the Feather River at its confluence with the Sacramento River (year-round) exceeded the 68°F threshold in 31%–34% of months under EBC1 and EBC2, in 35%–39% of months under EBC2_ELT and EBC2_LLT, and in 37%–39% of months under PP_ELT and PP_LLT (Figure C.5.2-273 through Figure C.5.2-277, Table C.5.2-109). Accounting for climate change effects, water temperatures are predicted to exceed 68°F under PP_ELT 2% more often than under EBC2_ELT (Table C.5.2-110). Water temperatures are predicted to exceed 68°F under PP_LLT <1% less often than under EBC2_LLT.

Combining all water years, mean monthly water temperatures in the confluence of the Feather and Sacramento Rivers (year-round) exceeded the 77°F threshold <1% of the time under EBC1 and EBC2, 3%–8% of the time under EBC2_ELT and EBC2_LLT, and 5%–12% of the time under PP_ELT and PP_LLT. Accounting for climate change effects, water temperatures are predicted to exceed 77°F under PP_ELT 2% more often than under EBC2_ELT (Table C.5.2-110). Water temperatures are predicted to exceed 68°F under PP_LLT 5% more often than under EBC2_LLT. These results indicate that the preliminary proposal will have small adverse water temperature-related effects on white sturgeon juvenile rearing in the Feather River.

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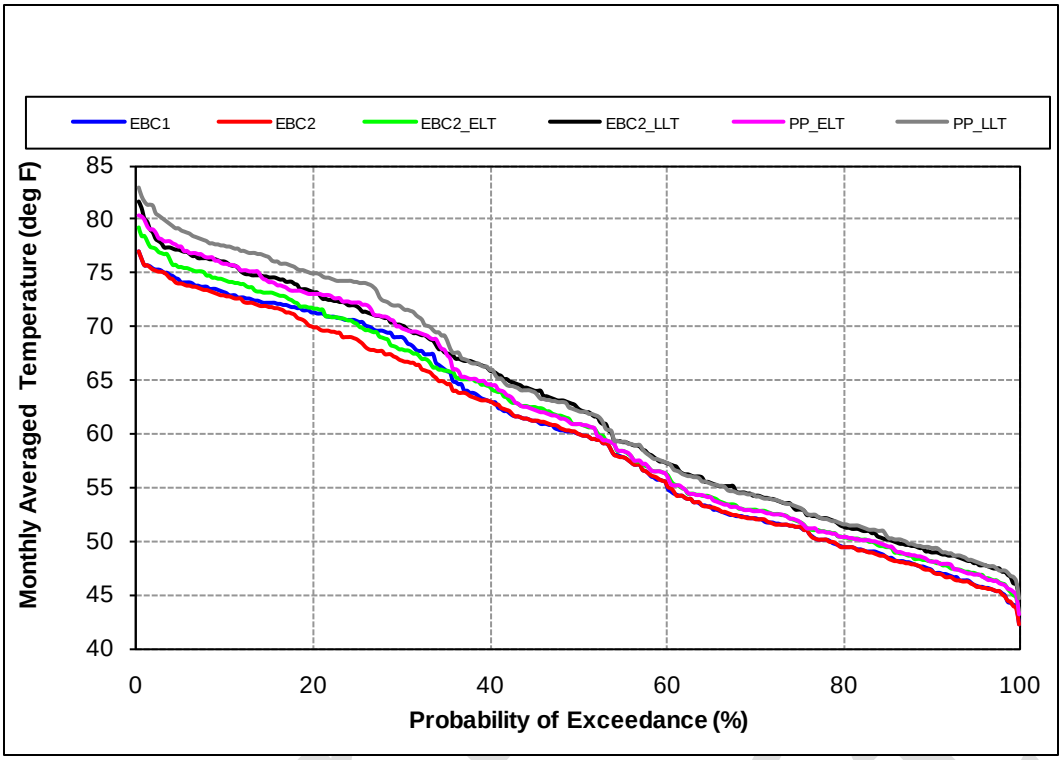

Figure C.5.2-273. Probability of Exceedance Plot for Model Scenarios of Mean Monthly Temperature of the Feather River at the Confluence with the Sacramento River in Wet Years, Year-Round

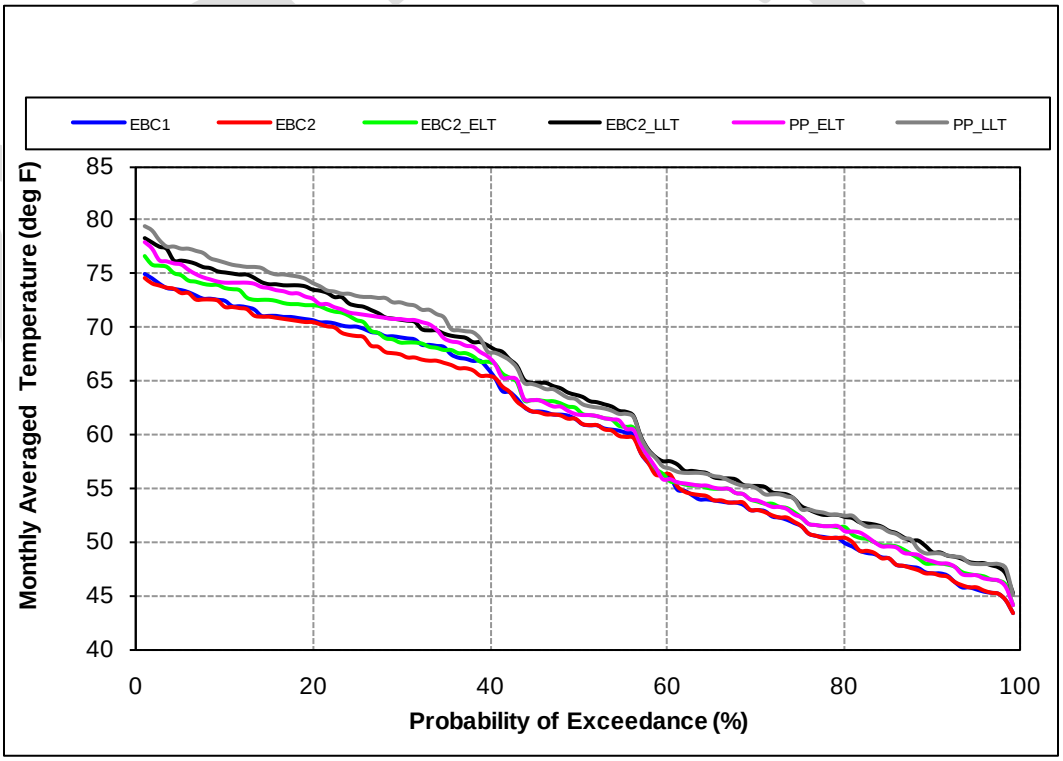

Figure C.5.2-274. Probability of Exceedance Plot for Model Scenarios of Mean Monthly Temperature of the Feather River at the Confluence with the Sacramento River in Above-Normal Years, Year-Round

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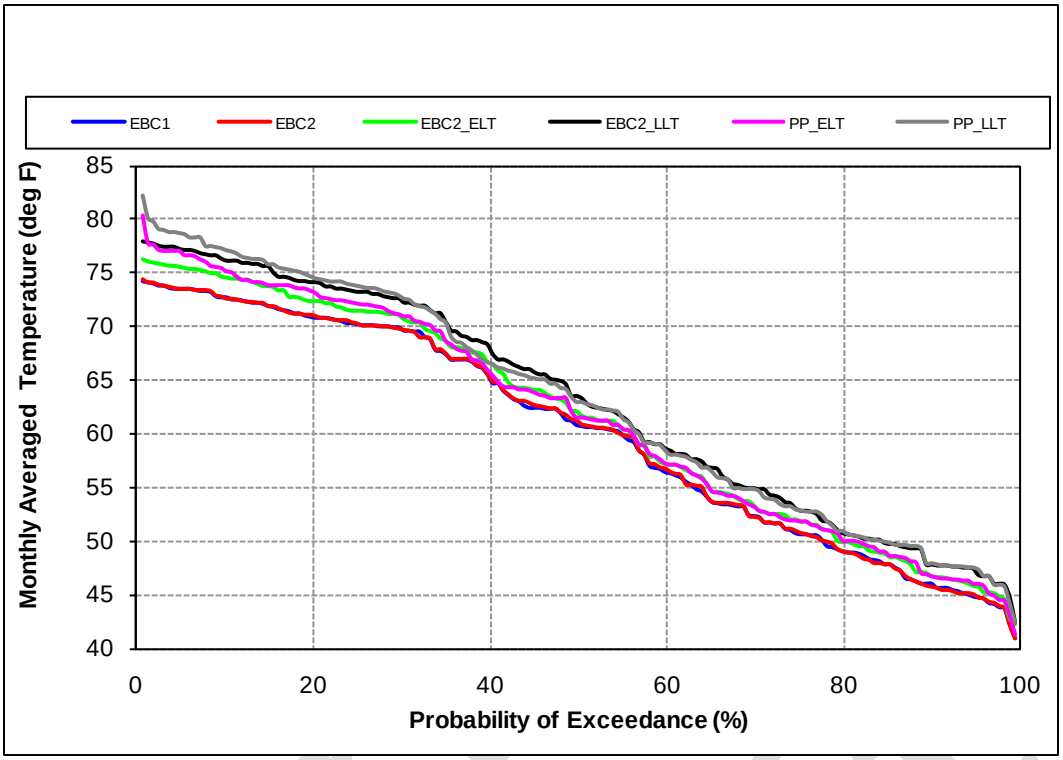

Figure C.5.2-275. Probability of Exceedance Plot for Model Scenarios of Mean Monthly Temperature of the Feather River at the Confluence with the Sacramento River in Below Normal Years, Year-Round

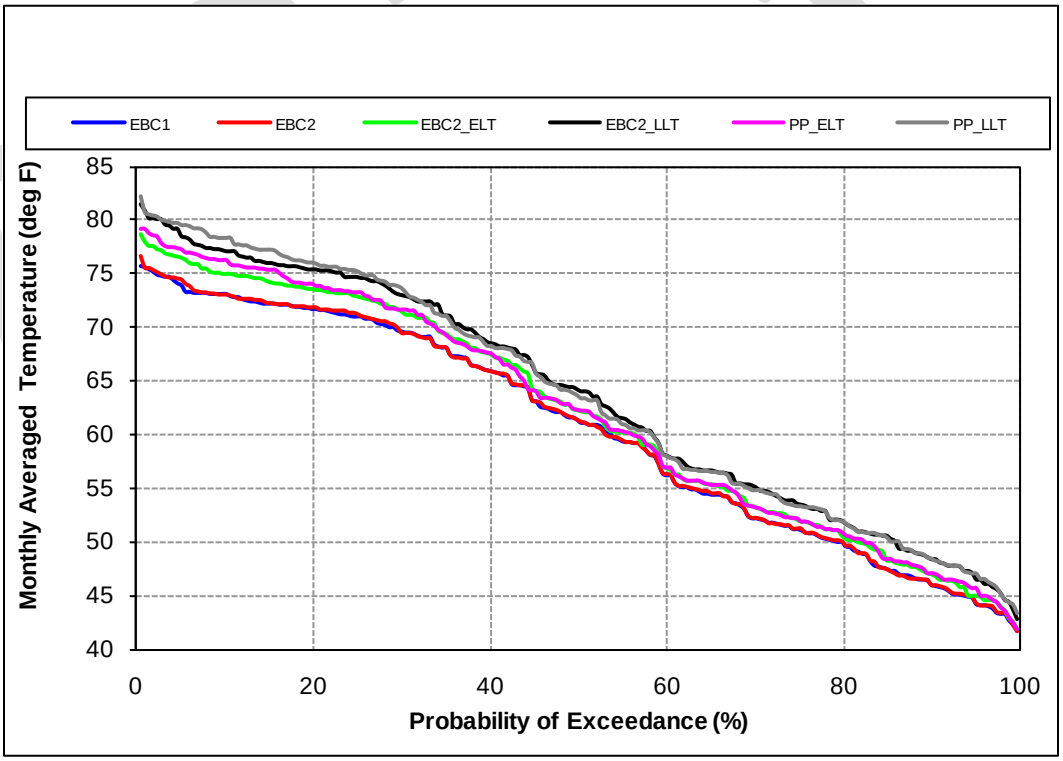

Figure C.5.2-276. Probability of Exceedance Plot for Model Scenarios of Mean Monthly Temperature of the Feather River at the Confluence with the Sacramento River in Dry Years, Year-Round

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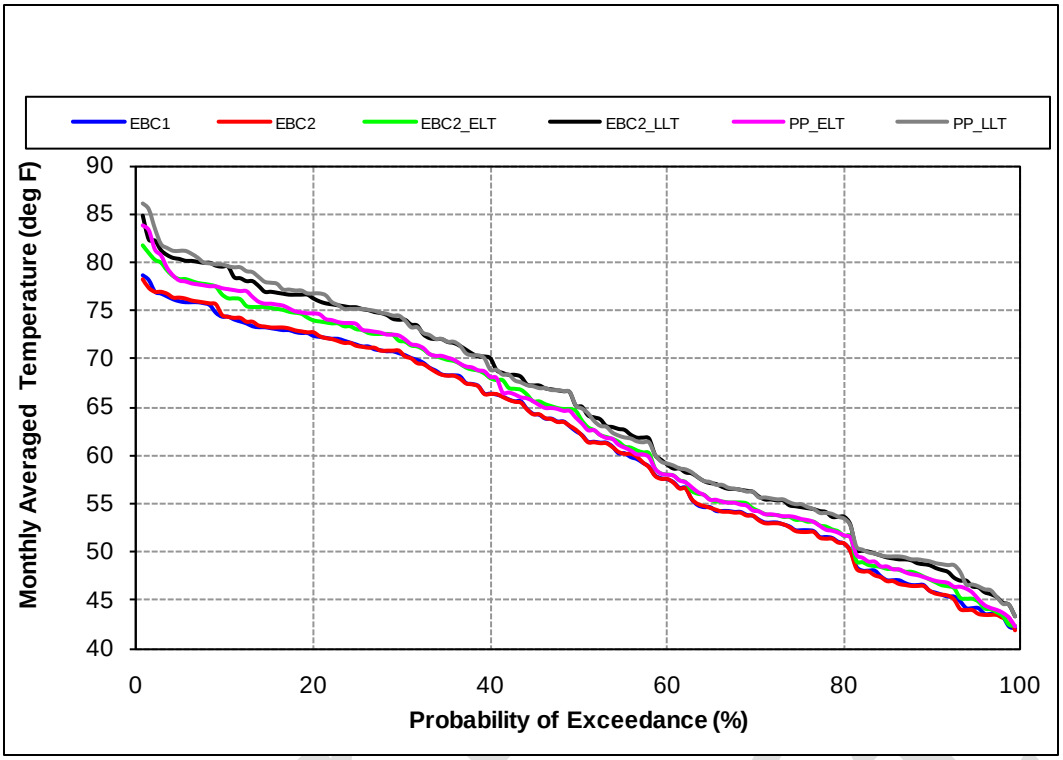

Figure C.5.2-277. Probability of Exceedance Plot for Model Scenarios of Mean Monthly Temperature of the Feather River at the Confluence with the Sacramento River in Critical Years, Year-Round

Table C.5.2-109. Percent of Months When Monthly Average Temperature Exceeds 68°F and 77°F in the Feather River at the Confluence With the Sacramento River, Year-Round[1]

Month	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
Temperatures above 68°F						
Wet	31.4	26.0	29.5	34.0	34.3	35.3
Above Normal	34.8	27.3	33.3	39.4	37.9	38.6
Below Normal	33.3	33.3	36.3	39.9	35.7	37.5
Dry	35.2	35.2	38.4	42.1	37.5	41.7
Critically Dry	36.8	36.1	39.6	43.8	40.3	42.4
All	33.8	31.0	34.7	39.0	36.6	38.6
Temperatures above 77°F						
Wet	0.0	0.0	2.2	5.1	5.1	11.5
Above Normal	0.0	0.0	0.0	3.0	1.5	6.1
Below Normal	0.0	0.0	0.0	6.0	2.4	10.1
Dry	0.0	0.0	2.8	11.1	5.1	15.7
Critically Dry	1.4	1.4	9.0	13.9	11.1	17.4
All	0.2	0.2	2.7	7.6	5.0	12.3

[1] Based on the modeling period of 1922 to 2003.

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Table C.5.2-110. Difference and Percent Difference in Percent of Days when Daily Average Temperature Exceeds 68°F and 77°F in the Feather River at the Confluence with the Sacramento River, Year-Round

Month	Comparison[1]	EBC1 vs. PP_ELT	EBC1 vs. PP_LLT	EBC2 vs. EBC2_ELT	EBC2 vs. EBC2_LLT	EBC2 vs. PP_ELT	EBC2 vs. PP_LLT	EBC2_ELT vs. PP_ELT	EBC2_LLT vs. PP_LLT
Temperatures above 68°F									
Wet	Difference	2.9	3.8	3.5	8.0	8.3	9.3	4.8	1.3
	Percent difference	9%	12%	14%	31%	32%	36%	16%	4%
Above Normal	Difference	3.0	3.8	6.1	12.1	10.6	11.4	4.5	-0.8
	Percent difference	9%	11%	22%	44%	39%	42%	14%	-2%
Below Normal	Difference	2.4	4.2	3.0	6.5	2.4	4.2	-0.6	-2.4
	Percent difference	7%	13%	9%	20%	7%	13%	-2%	-6%
Dry	Difference	2.3	6.5	3.2	6.9	2.3	6.5	-0.9	-0.5
	Percent difference	7%	18%	9%	20%	7%	18%	-2%	-1%
Critical	Difference	3.5	5.6	3.5	7.6	4.2	6.3	0.7	-1.4
	Percent difference	9%	15%	10%	21%	12%	17%	2%	-3%
All	Difference	2.8	4.7	3.7	8.0	5.7	7.6	2.0	-0.4
	Percent difference	8%	14%	12%	26%	18%	25%	6%	-1%
Temperatures above 77°F									
Wet	Difference	5.1	11.5	2.2	5.1	5.1	11.5	2.9	6.4
	Percent difference	NA	NA	NA	NA	NA	NA	129%	125%
Above Normal	Difference	1.5	6.1	0.0	3.0	1.5	6.1	1.5	3.0
	Percent difference	NA	NA	NA	NA	NA	NA	NA	100%
Below Normal	Difference	2.4	10.1	0.0	6.0	2.4	10.1	2.4	4.2
	Percent difference	NA	NA	NA	NA	NA	NA	NA	70%
Dry	Difference	5.1	15.7	2.8	11.1	5.1	15.7	2.3	4.6
	Percent difference	NA	NA	NA	NA	NA	NA	83%	42%
Critical	Difference	9.7	16.0	7.6	12.5	9.7	16.0	2.1	3.5
	Percent difference	700%	1,150%	550%	900%	700%	1,150%	23%	25%
All	Difference	4.8	12.1	2.5	7.4	4.8	12.1	2.4	4.7
	Percent difference	2,350%	5,900%	1,200%	3,600%	2,350%	5,900%	88%	62%

[1] A positive value indicates a higher value under the second model scenario listed in the column title.
NA = Could not be calculated because dividing by 0.

Adult

Water Temperature

Simulated water temperatures in the Feather River at Thermalito Afterbay and at the Sacramento River confluence were used to evaluate potential differences in exposure of adult white sturgeon to water temperatures exceeding the 68°F and 77°F thresholds during February through May when pre-spawning, spawning, and post-spawning adults are most likely to occur in the Feather River. Water temperatures above 68°F have been reported to cause stress in adults while 77°F is considered an upper tolerance threshold. The percent of months exceeding the 68°F and 77°F thresholds for each model scenario below Thermalito are presented in Table C.5.2-99 and

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differences between pairs of model scenarios are presented in Table C.5.2-100). The percent of months exceeding the 68°F and 77°F thresholds for each model scenario at the confluence with the Sacramento River are presented in Table C.5.2-101 and differences between pairs of model scenarios are presented in Table C.5.2-102.

As described for the egg/embryo life stage, water temperatures in the Feather River below Thermalito exceeding the 68°F during February through May would occur infrequently (<5%) under all model scenarios, with no measurable differences between the PP_ELT and EBC2_ELT and between the PP_LLT and EBC2_LLT (Table C.5.2-99, Table C.5.2-100). Downstream at the Sacramento River confluence, differences in threshold exceedance frequencies between PP_ELT and EBC2_ELT and between PP_LLT and EBC2_LLT are predicted to be negligible (<3%) (Table C.5.2-101, Table C.5.2-102.) Thus, while water temperatures exceeding the 68°F threshold would be expected to increase in the lower Feather River due to climate change, BDCP operations would have little or no incremental effect on the occurrence of these temperatures.

Water temperature is predicted to always be below the 77°F threshold during February through May in the Feather River below Thermalito. At the Sacramento River confluence, water temperatures are predicted to exceed the 77°F threshold very rarely (<2% of months)during February through May (Table C.5.2-101) and differences between pairs of model scenarios are negligible (Table C.5.2-102). Based on these results, it is concluded that there would be no detectable effect of the preliminary proposal on the frequency of exceedance above the 77°F threshold temperature for adults.

C.5.2.4.6 Green Sturgeon

Eggs and Embryos

Water Temperature

Green sturgeon likely spawn in the Feather River, although information on the extent of spawning is limited and the Biological Review Team (National Marine Fisheries Service 2005) concluded that a significant population of spawning green sturgeon no longer exists in this river. Green sturgeon spawning locations within the Feather River appear to be limited to reaches just downstream of the Thermalito Afterbay Outlet (RM 59) and Gridley Bridge (RM 51) (U.S. Fish and Wildlife Service 1995). Green sturgeon spawning near Thermalito Afterbay Outlet was confirmed in June 2011 (A. Seesholz pers. comm.). Predicted water temperatures from the Reclamation Temperature Model below the Thermalito Afterbay were used to represent this reach. Green sturgeon spawn between March and August. Exceedance plots for this period by water-year type are presented in Figure C.5.2-278 through Figure C.5.2-282.

Three threshold water temperatures were selected (63°F, 68°F, and 73°F) and the frequency of exceedance above these temperatures was analyzed for each model scenario.

Combining all water years, mean monthly water temperatures in the Feather River below Thermalito Afterbay from March through August are predicted to exceed the 63°F threshold in 55% of months under EBC1 and EBC2, in 60%–63% of months under EBC2_ELT and EBC2_LLT, and in 58%–61% of months under PP_ELT and PP_LLT (Table C.5.2-111). Among water years, the predicted exceedance frequency ranged from 49% of months (wet years under EBC1 and EBC2) to 65% of months (critically dry years under EBC2_LLT). The higher threshold exceedances under EBC2_ELT and EBC2_LLT relative to EBC1 and EBC2 reflect the effects of climate change in the

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absence of BDCP implementation (Table C.5.2-112). The frequency of exceedance above the 63°F threshold is predicted to be 4% and 6% greater under PP_ELT and PP_LLT, respectively, relative to EBC1. The frequency of exceedance is predicted to be 4% and 6% greater under PP_ELT and PP_LLT, respectively, relative to EBC2. Isolating the effect of the preliminary proposal from climate change, the frequency of exceedance is predicted to be 1% and 2% lower under PP_ELT and PP_LLT relative to EBC2_ELT and EBC2_LLT, respectively. These results indicate that there is a very minor predicted benefit of the preliminary proposal for this temperature threshold.

Combining all water years, mean monthly water temperatures in the Feather River below Thermalito Afterbay from March through August are predicted to exceed the 68°F threshold in 24%–26% of months under EBC1 and EBC2, in 36%–45% of months under EBC2_ELT and EBC2_LLT, and in 39%–44% of months under PP_ELT and PP_LLT (Table C.5.2-111). Among water years, the predicted exceedance frequency ranged from 18% of months (above-normal years under EBC1 and EBC2) to 54% of months (critically dry years under PP_LLT). The frequency of exceedance above the 68°F threshold is predicted to be 14% and 20% greater under PP_ELT and PP_LLT, respectively, relative to EBC1 (Table C.5.2-112). The frequency of exceedance is predicted to be 13% and 18% greater under PP_ELT and PP_LLT, respectively, relative to EBC2. Isolating the effect of the preliminary proposal from climate change, the frequency of exceedance is predicted to be 3% higher under PP_ELT relative to EBC2_ELT. The frequency of exceedance is predicted to be 1% lower under PP_LLT relative to EBC2_LLT. These results indicate that there is a very minor predicted adverse effect of the preliminary proposal in the early long-term and a very minor predicted benefit of the preliminary proposal in the late long-term implementation period.

Combining all water years, mean monthly water temperatures in the Feather River below Thermalito Afterbay from March through August are predicted to exceed the 73°F threshold in 2% of months under EBC1 and EBC2, in 3%–6% of months under EBC2_ELT and EBC2_LLT, and in 6%–14% of months under PP_ELT and PP_LLT (Table C.5.2-111). Among water years, the predicted exceedance frequency ranged from 0% of months (e.g., above and below-normal years under EBC1, EBC2, EBC2_ELT and EBC2_LLT and dry years under EBC1, EBC2, and EBC2_ELT) to 26% of months (critical years under PP_LLT). The frequency of exceedance above the 73°F threshold is predicted to be 4% and 12% greater under PP_ELT and PP_LLT, respectively, relative to EBC1 (Table C.5.2-112). The frequency of exceedance is predicted to be 4% and 12% greater under PP_ELT and PP_LLT, respectively, relative to EBC2. Isolating the effect of the preliminary proposal from climate change, the frequency of exceedance is predicted to be 3% and 8% greater under PP_ELT and PP_LLT relative to EBC2_ELT and EBC2_LLT, respectively. These results indicate that there is a small predicted adverse effect of the preliminary proposal for this temperature threshold.

These results suggest with moderate certainty that there are negligible or small effects of the preliminary proposal on water temperature-related habitat for green sturgeon spawning and egg incubation in the Feather River below Thermalito Afterbay. The effects of climate change are generally greater than those of the preliminary proposal, as evidenced by EBC2 to EBC2_ELT and EBC2 to EBC2_LLT comparisons.

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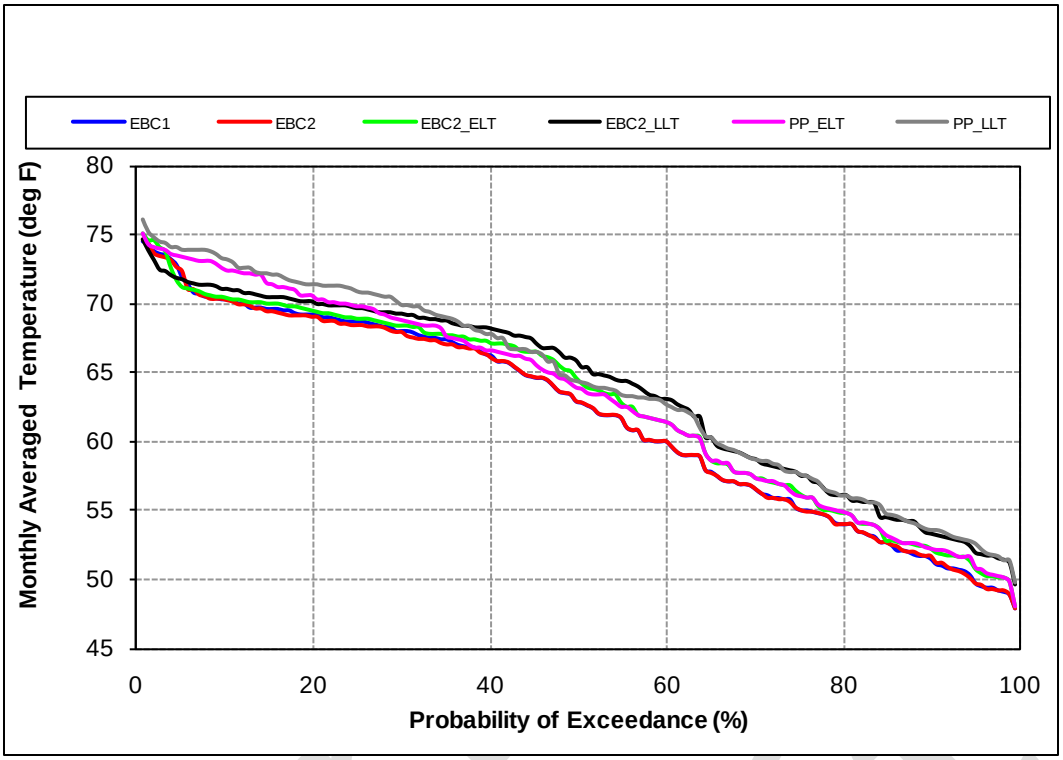

Figure C.5.2-278. Probability of Exceedance Plot for Model Scenarios of Mean Monthly Temperature of the Feather River below Thermalito Afterbay, March through August, Wet Years

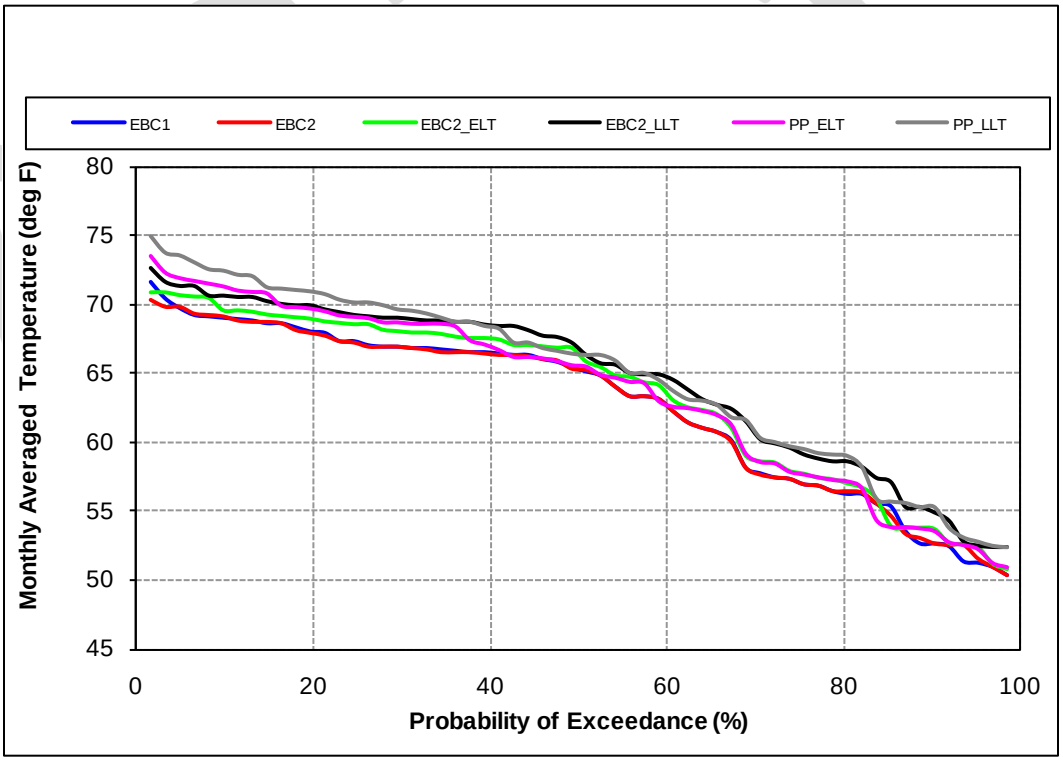

Figure C.5.2-279. Probability of Exceedance Plot for Model Scenarios of Mean Monthly Temperature of the Feather River below Thermalito Afterbay, March through August, Above-Normal Years

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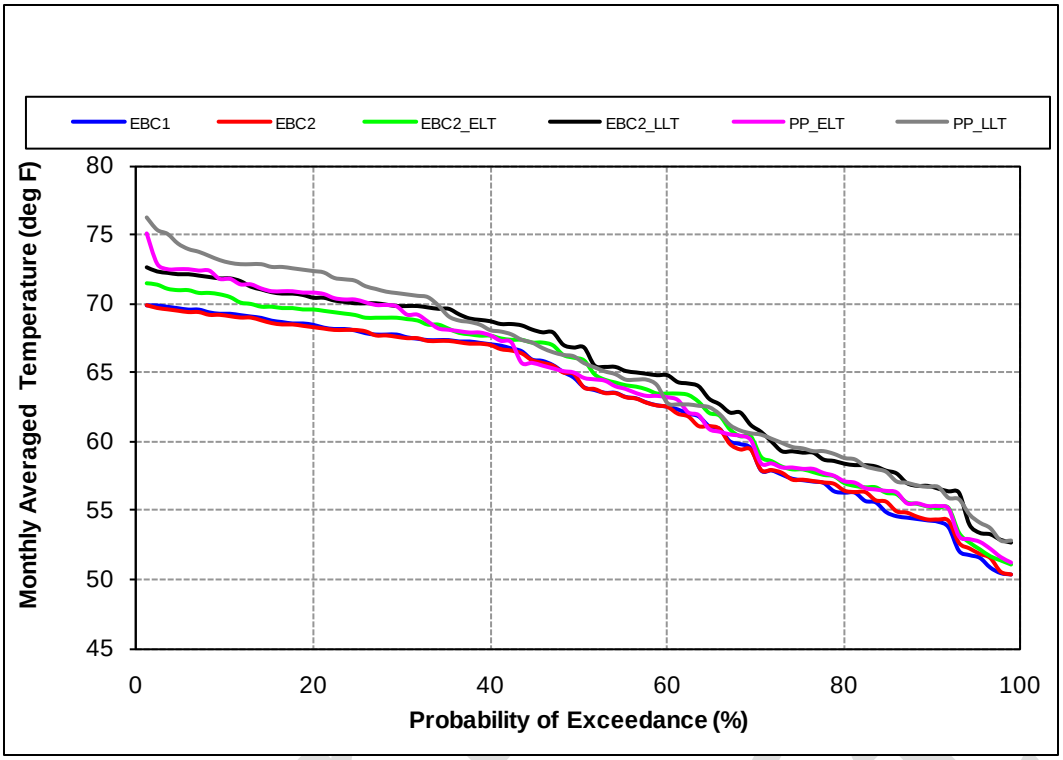

Figure C.5.2-280. Probability of Exceedance Plot for Model Scenarios of Mean Monthly Temperature of the Feather River below Thermalito Afterbay, March through August, Below-Normal Years

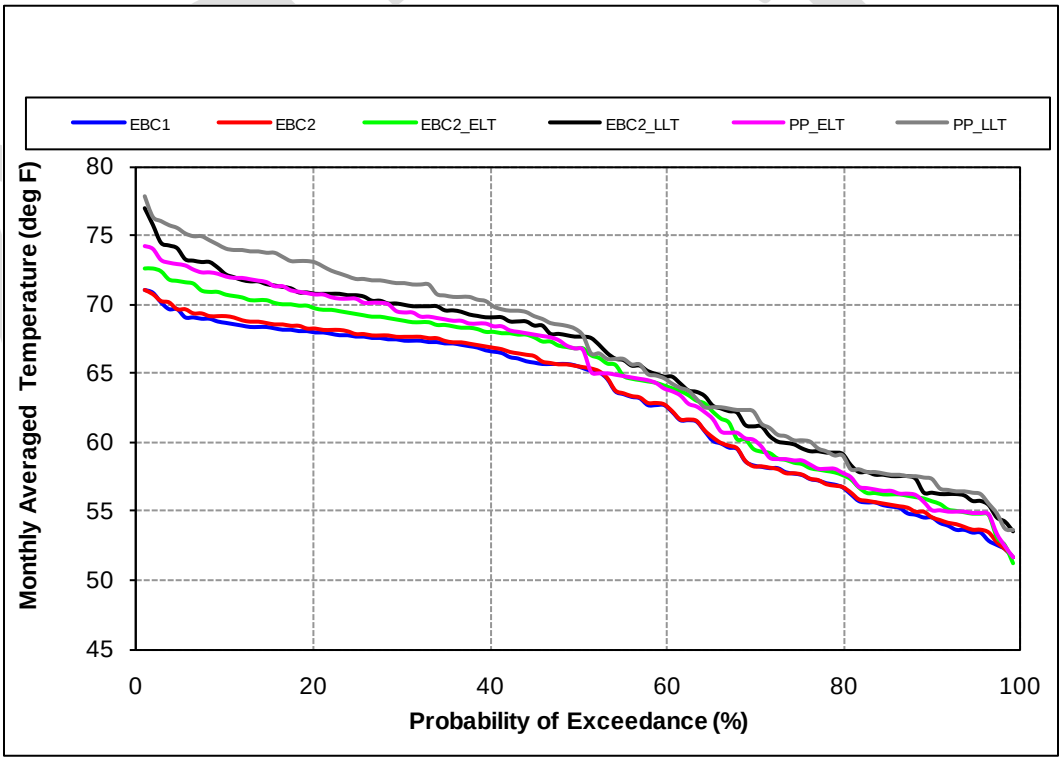

Figure C.5.2-281. Probability of Exceedance Plot for Model Scenarios of Mean Monthly Temperature of the Feather River below Thermalito Afterbay, March through August, Dry Years

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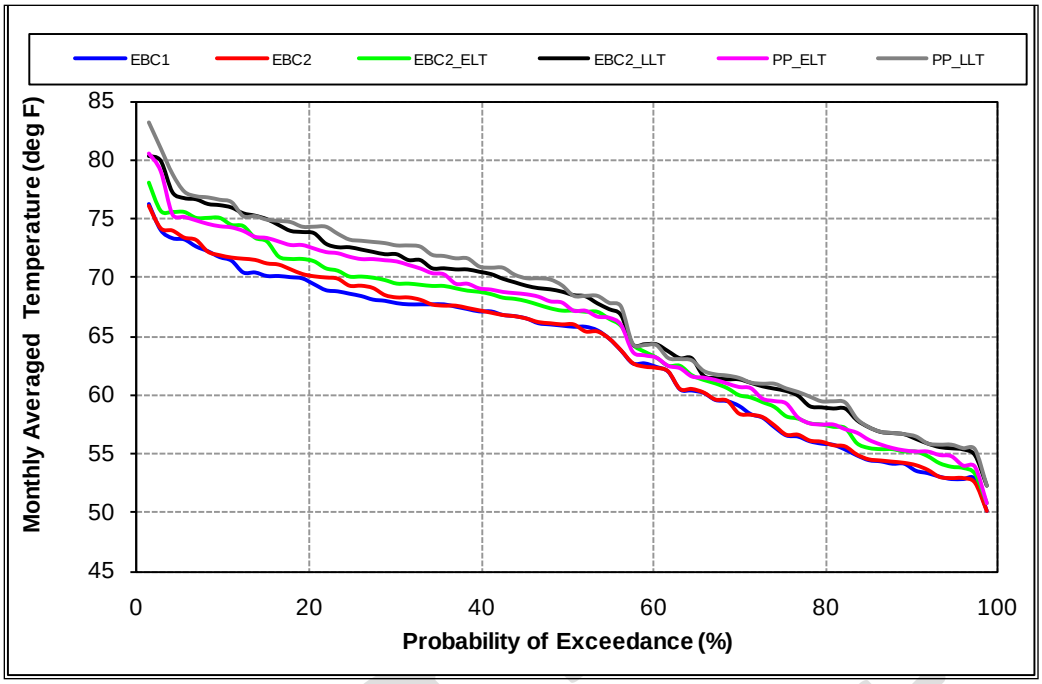

Figure C.5.2-282. Probability of Exceedance Plot for Model Scenarios of Mean Monthly Temperature of the Feather River below Thermalito Afterbay, March through August, Critical Years

Table C.5.2-111. Percentage of Months during March through August[1] When Monthly Average Temperature Exceeds 63°F, 68°F, and 73°F in the Feather River below Thermalito Afterbay

Month	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
Temperatures above 63°F						
Wet	49.4	49.4	54.5	60.3	53.8	59.0
Above Normal	59.1	59.1	59.1	63.6	57.6	62.1
Below Normal	57.1	57.1	63.1	65.5	60.7	59.5
Dry	57.4	57.4	63.0	64.8	62.0	63.9
Critical	56.9	56.9	61.1	65.3	61.1	62.5
All	54.9	54.9	59.5	63.4	58.4	61.1
Temperatures above 68°F						
Wet	28.8	28.2	32.1	41.0	34.6	38.5
Above Normal	18.2	18.2	28.8	43.9	36.4	40.9
Below Normal	23.8	25.0	35.7	45.2	35.7	40.5
Dry	19.4	23.1	38.9	46.3	42.6	50.0
Critical	27.8	33.3	44.4	52.8	47.2	54.2
All	24.3	25.9	35.6	45.1	38.7	44.0
Temperatures above 73°F						
Wet	3.8	3.8	3.2	1.9	8.3	10.3
Above Normal	0.0	0.0	0.0	0.0	1.5	4.5
Below Normal	0.0	0.0	0.0	0.0	1.2	9.5
Dry	0.0	0.0	0.0	8.3	2.8	19.4
Critical	5.6	6.9	15.3	20.8	16.7	26.4
All	2.1	2.3	3.3	5.6	6.2	13.8

[1] Based on the modeling period of 1922 to 2003.

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Table C.5.2-112. Difference and Percent Difference in Percentage of Months During the Months March Through August[1] When Monthly Average Temperature Exceeds 63°F, 68°F, and 73°F in the Feather River below Thermalito Afterbay

WY Type	Comparison[1]	EBC1 vs. PP_ELT	EBC1 vs. PP_LLT	EBC2 vs. EBC2_ELT	EBC2 vs. EBC2_LLT	EBC2 vs. PP_ELT	EBC2 vs. PP_LLT	EBC2_ELT vs. PP_ELT	EBC2_LLT vs. PP_LLT
Temperatures above 63°F									
Wet	Difference	4.5	9.6	5.1	10.9	4.5	9.6	-0.6	-1.3
	Percent difference	9%	19%	10%	22%	9%	19%	-1%	-2%
Above Normal	Difference	-1.5	3.0	0.0	4.5	-1.5	3.0	-1.5	-1.5
	Percent difference	-3%	5%	0%	8%	-3%	5%	-3%	-2%
Below Normal	Difference	3.6	2.4	6.0	8.3	3.6	2.4	-2.4	-6.0
	Percent difference	6%	4%	10%	15%	6%	4%	-4%	-9%
Dry	Difference	4.6	6.5	5.6	7.4	4.6	6.5	-0.9	-0.9
	Percent difference	8%	11%	10%	13%	8%	11%	-1%	-1%
Critical	Difference	4.2	5.6	4.2	8.3	4.2	5.6	0.0	-2.8
	Percent difference	7%	10%	7%	15%	7%	10%	0%	-4%
All	Difference	3.5	6.2	4.5	8.4	3.5	6.2	-1.0	-2.3
	Percent difference	6%	11%	8%	15%	6%	11%	-2%	-4%
Temperatures above 68°F									
Wet	Difference	5.8	9.6	3.8	12.8	6.4	10.3	2.6	-2.6
	Percent difference	20%	33%	14%	45%	23%	36%	8%	-6%
Above Normal	Difference	18.2	22.7	10.6	25.8	18.2	22.7	7.6	-3.0
	Percent difference	100%	125%	58%	142%	100%	125%	26%	-7%
Below Normal	Difference	11.9	16.7	10.7	20.2	10.7	15.5	0.0	-4.8
	Percent difference	50%	70%	43%	81%	43%	62%	0%	-11%
Dry	Difference	23.1	30.6	15.7	23.1	19.4	26.9	3.7	3.7
	Percent difference	119%	157%	68%	100%	84%	116%	10%	8%
Critical	Difference	19.4	26.4	11.1	19.4	13.9	20.8	2.8	1.4
	Percent difference	70%	95%	33%	58%	42%	63%	6%	3%
All	Difference	14.4	19.8	9.7	19.1	12.8	18.1	3.1	-1.0
	Percent difference	59%	81%	37%	74%	49%	70%	9%	-2%
Temperatures above 73°F									
Wet	Difference	4.5	6.4	-0.6	-1.9	4.5	6.4	5.1	8.3
	Percent difference	117%	167%	-17%	-50%	117%	167%	160%	433%
Above Normal	Difference	1.5	4.5	0.0	0.0	1.5	4.5	1.5	4.5
	Percent difference	NA	NA	NA	NA	NA	NA	NA	NA
Below Normal	Difference	1.2	9.5	0.0	0.0	1.2	9.5	1.2	9.5
	Percent difference	NA	NA	NA	NA	NA	NA	NA	NA
Dry	Difference	2.8	19.4	0.0	8.3	2.8	19.4	2.8	11.1
	Percent difference	NA	NA	NA	NA	NA	NA	NA	133%
Critical	Difference	11.1	20.8	8.3	13.9	9.7	19.4	1.4	5.6
	Percent difference	200%	375%	120%	200%	140%	280%	9%	27%
All	Difference	4.1	11.7	1.0	3.3	3.9	11.5	2.9	8.2
	Percent difference	200%	570%	45%	145%	173%	509%	88%	148%

[1]A positive value indicates a higher value under the second model scenario listed in the column title.
NA = Could not be calculated because dividing by 0.

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Seasonal Flows

Sacramento River Confluence

Figure C.5.2-283 reports the probability of exceedance of mean monthly flows in the Feather River at the confluence with the Sacramento River during the March through August green sturgeon spawning and egg incubation period for each of the model scenarios. Figure C.5.2-253 through Figure C.5.2-257 show predicted mean monthly flows by water-year type in the Feather River at the confluence with the Sacramento River. Table C.5.2-103 shows differences in predicted flows between pairs of model scenarios by month and water-year type. Flows under the preliminary proposal are predicted to generally be higher than those under EBC1 and EBC2 during March through June, and to be lower than EBC1 and EBC2 during July and August. Due to these differences, the following described results for the March through June period separately from those for July and August.

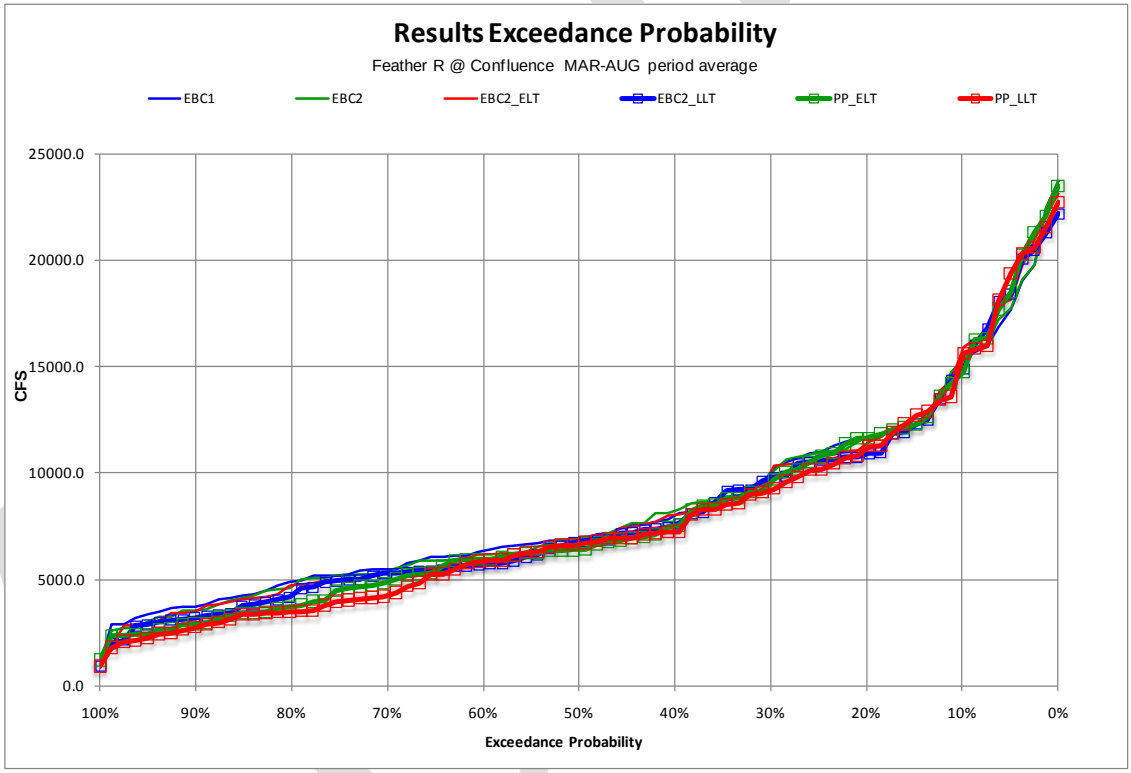

Figure C.5.2-283. Probability of Exceedance Plot for Model Scenarios of Mean Monthly Flow in the Feather River at the Confluence with the Sacramento River, March through August

Combining all water years, mean monthly flows in the Feather River at the confluence with the Sacramento River from March through June are predicted to be 76 (May) to 872 cfs (March) greater under PP_ELT than EBC1 Table C.5.2-103. Flows under PP_LLT are predicted to be 663 cfs lower (May) to 1,284 cfs greater (March) than EBC1. Flows under PP_ELT are predicted to be 108 (May) to 1,392 cfs greater (March) than EBC2. Flows under PP_LLT are predicted to be 325 cfs lower (June) to 1,805 cfs greater (March) than EBC2. Isolating the effect of the preliminary proposal from climate change, flows under PP_ELT are predicted to be 323 (April) to 1,264 cfs greater (June) than EBC2_ELT. Further, flows under PP_LLT are predicted to be 506 (March) to 995 cfs greater (June) than EBC2_LLT. These results indicate that March through June flows in the Feather River at the

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confluence with the Sacramento River generally would be better under the preliminary proposal for green sturgeon egg incubation.

Combining all water years, mean monthly flows in the Feather River at the confluence with the Sacramento River for July and August are predicted to be 2,715 (July) and 1,215 cfs (August) lower under PP_ELT than EBC1 Table C.5.2-103. Flows under PP_LLT are predicted to be 3,031 (July) and 1,387 cfs (August) lower than EBC1. Flows under PP_ELT are predicted to be 2,766 (July) and 1,252 cfs (August) lower than EBC2. Flows under PP_LLT are predicted to be 3,082 (July) and 719 cfs (August) lower than EBC2. Isolating the effect of the preliminary proposal from climate change, flows under PP_ELT are predicted to be 2,557 (July) and 1,447 cfs (August) lower than EBC2_ELT. Further, flows under PP_LLT are predicted to be 2,718 (July) and 1,759 cfs lower (August) than EBC2_LLT. These results indicate that July and August flows in the Feather River at the confluence with the Sacramento River are moderately worse under the preliminary proposal for green sturgeon egg incubation.

At Thermalito Afterbay

Figure C.5.2-284 reports the probability of exceedance of mean monthly flows in the Feather River at Thermalito Afterbay during the March through August green sturgeon spawning and egg incubation period for each of the model scenarios. Figure C.5.2-258 through Figure C.5.2-262 show predicted mean monthly flows by water-year type. Table C.5.2-104 shows differences in predicted flows between pairs of model scenarios by month and water-year type. As with model outputs for the Sacramento River confluence, flows under the preliminary proposal are predicted to generally be higher than those under EBC1 and EBC2 during March through June, and to be lower than EBC1 and EBC2 during July and August. Due to these differences, the following results are presented for the March through June period separately from those for July and August.

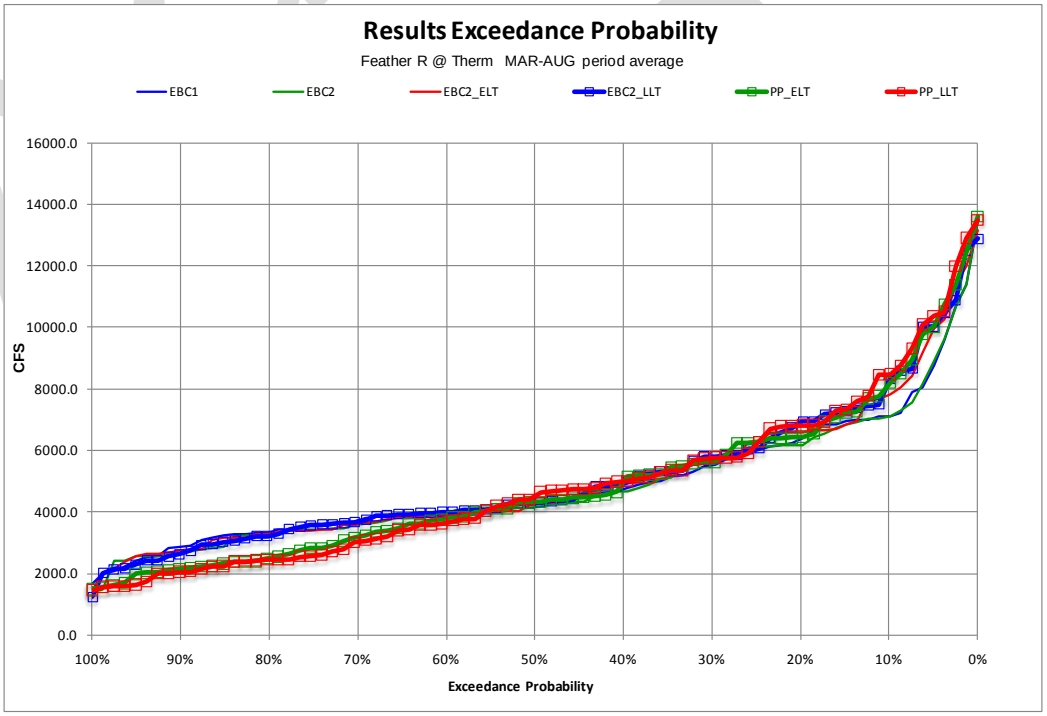

Figure C.5.2-284. Probability of Exceedance Plot for Model Scenarios of Mean Monthly Flow in the Feather River at Thermalito, March through August

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Combining all water years, mean monthly flows under PP_ELT in the Feather River at Thermalito Afterbay from March through June are predicted to be 324 (May) to 968 cfs (June) greater than EBC1 Table C.5.2-104. Flows under PP_LLT are predicted to be 137 (May) to 1,035 cfs greater (June) than EBC1. Flows under PP_ELT are predicted to be 350 (May) to 1,224 cfs greater (March) than EBC2. Flows under PP_LLT are predicted to be 163 cfs lower (May) to 1,443 cfs greater (March) than EBC2. Isolating the effect of the preliminary proposal from climate change, flows under PP_ELT are predicted to be 314 (April) to 1,282 cfs greater (June) than EBC2_ELT. Further, flows under PP_LLT are predicted to be 493 (March) to 1,040 cfs greater (June) than EBC2_LLT. These results indicate that March through June flows in the Feather River at Thermalito Afterbay generally would be moderately better under the preliminary proposal for green sturgeon egg incubation.

Combining all water years, mean monthly flows under PP_ELT in the Feather River at Thermalito Afterbay for July and August are predicted to be 2,032 (July) and 721 cfs (August) lower than EBC1 Table C.5.2-104. Flows under PP_LLT are predicted to be 2,078 (July) and 776 cfs (August) lower than EBC1. Flows under PP_ELT are predicted to be 2,082 (July) and 784 cfs (August) lower than EBC2. Flows under PP_LLT are predicted to be 2,127 (July) and 839 cfs (August) lower than EBC2. Isolating the effect of the preliminary proposal from climate change, flows under PP_ELT are predicted to be 2,399 (July) and 1,182 cfs (August) lower than EBC2_ELT. Further, flows under PP_LLT are predicted to be 2,561 (July) and 1,475 cfs lower (August) than EBC2_LLT. These results indicate that July and August flows in the Feather River at Thermalito Afterbay are moderately worse under the preliminary proposal for green sturgeon egg incubation.

In total, predicted flows in the Feather River at the confluence with the Sacramento River and upstream at Thermalito indicate with moderate certainty that March through June flows would be moderately higher under the preliminary proposal with few exceptions, but would decrease moderately in July and August. It is concluded with low certainty, due to the lack of green sturgeon egg/embryo flow thresholds or a seasonal flow weighting metric, that green sturgeon egg/embryo benefits as a results of increased March through June flows under the preliminary proposal would at least offset the adverse effects of reduced July and August flows.

Larvae

Water Temperature

At Honcut Creek

Water temperature exceedance plots are presented by water-year type for April through October, the green sturgeon larval rearing period, in the Feather River at Honcut Creek in Figure C.5.2-285 through Figure C.5.2-289. The frequencies of exceedance above three temperature thresholds, 66°F, 68°F, and 73°F, are presented in Table C.5.2-113 and differences between pairs of model scenarios in the frequency of exceedance are presented in Table C.5.2-114.

Combining all water years, mean monthly water temperatures in the Feather River at Honcut Creek from April through October exceeded the 66°F threshold in 49%–53% of months under EBC1 and EBC2, in 56%–62% of months under EBC2_ELT and EBC2_LLT, and in 60%–64% of months under PP_ELT and PP_LLT (Table C.5.2-113). Accounting for climate change effects, the frequency of temperatures exceeding 66°F under PP_ELT and PP_LLT is predicted to be 4% and 2% greater than under EBC2_ELT and EBC2_LLT, respectively (Table C.5.2-114).

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Combining all water years, mean monthly water temperatures in the Feather River at Honcut Creek from April through October exceeded the 68°F threshold in 35%–36% of months under EBC1 and EBC2, in 45%–53% of months under EBC2_ELT and EBC2_LLT, and in 45%–54% of months under PP_ELT and PP_LLT (Table C.5.2-113). Accounting for climate change effects, the frequency of temperatures exceeding 68°F under PP_ELT and PP_LLT is predicted to be 0% and 1% greater than under EBC2_ELT and EBC2_LLT, respectively (Table C.5.2-114).

Combining all water years, mean monthly water temperatures in the Feather River at Honcut Creek from April through October exceeded the 73°F threshold in 4% of months under EBC1 and EBC2, in 6%–12% of months under EBC2_ELT and EBC2_LLT, and in 15%–23% of months under PP_ELT and PP_LLT (Figure C.5.2-285 through Figure C.5.2-289, Table C.5.2-113). Accounting for climate change effects, the frequency of temperatures exceeding 73°F under PP_ELT and PP_LLT is predicted to be 9% and 11% greater than under EBC2_ELT and EBC2_LLT, respectively (Table C.5.2-114).

These results suggest that the effects of the preliminary proposal on the exceedance of water temperature thresholds are moderately beneficial to green sturgeon larvae. The effects of climate change are typically much larger than those of the preliminary proposal, except for the 73°F threshold.

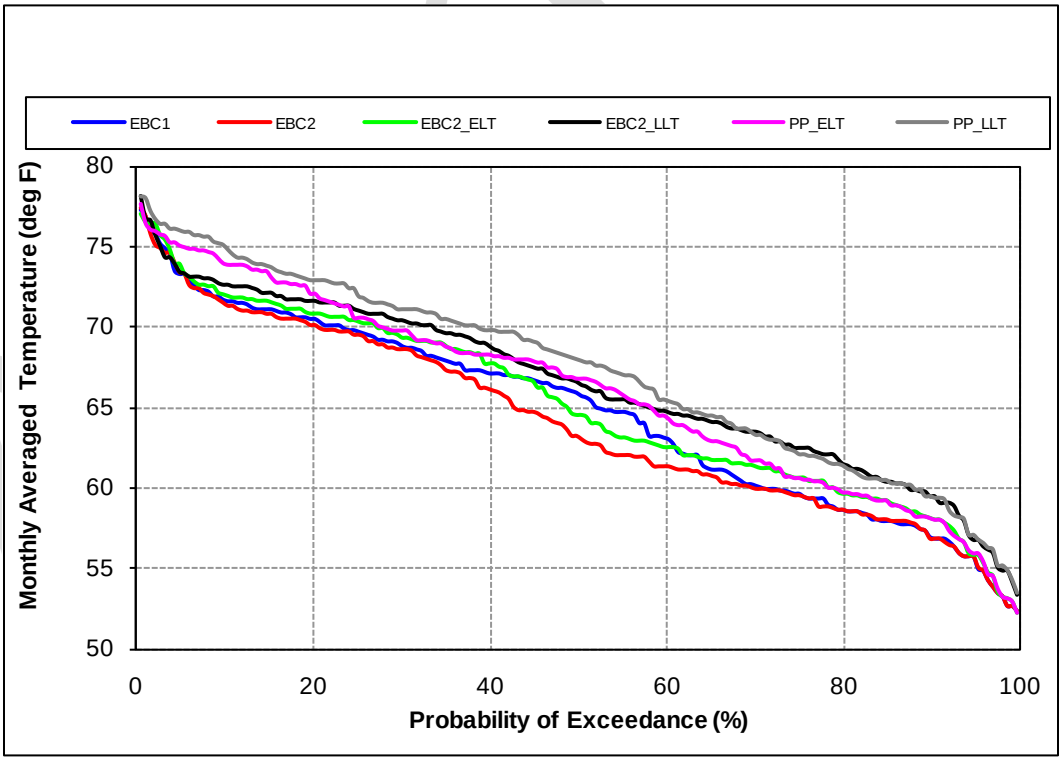

Figure C.5.2-285. Probability of Exceedance Plot for Model Scenarios of Mean Monthly Temperature in the Feather River at Honcut Creek, April through October in Wet Years

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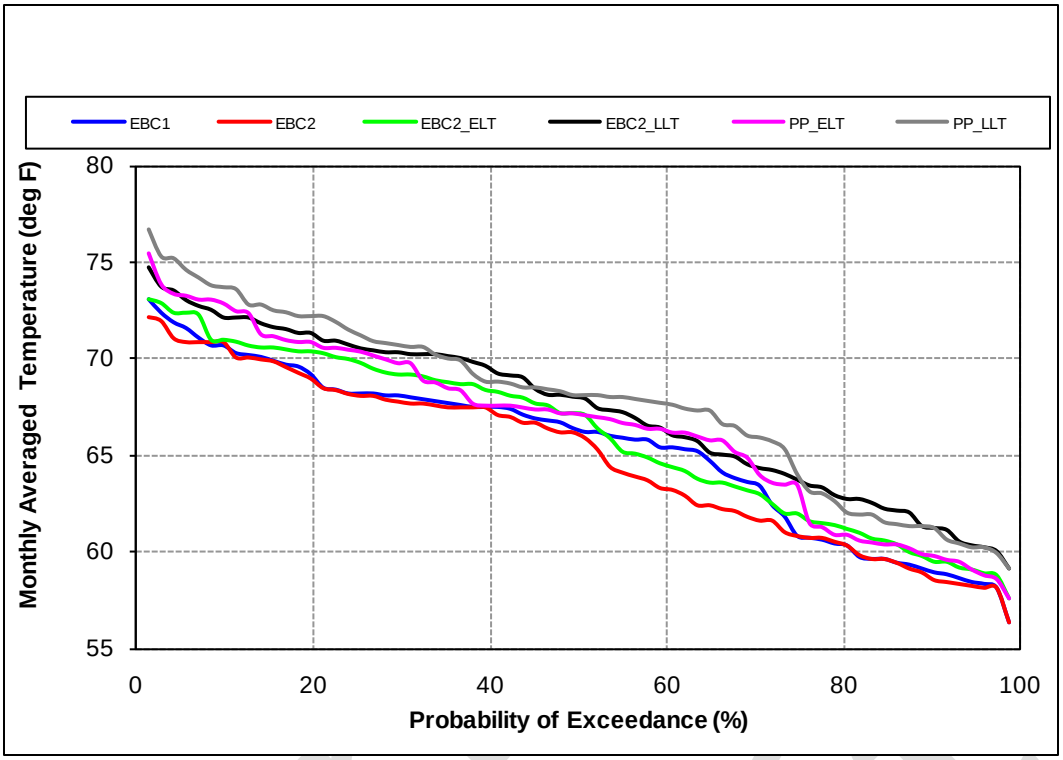

Figure C.5.2-286. Probability of Exceedance Plot for Model Scenarios of Mean Monthly Temperature in the Feather River at Honcut Creek, April through October in Above-Normal Years

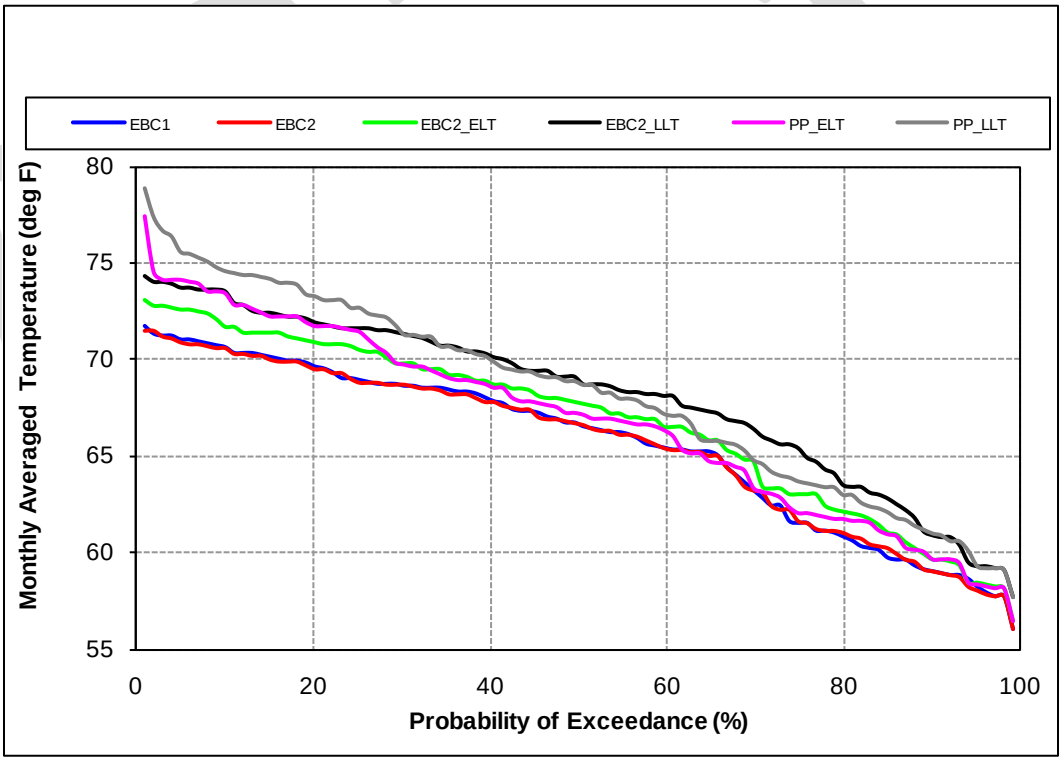

Figure C.5.2-287. Probability of Exceedance Plot for Model Scenarios of Mean Monthly Temperature in the Feather River at Honcut Creek, April through October in Below-Normal Years

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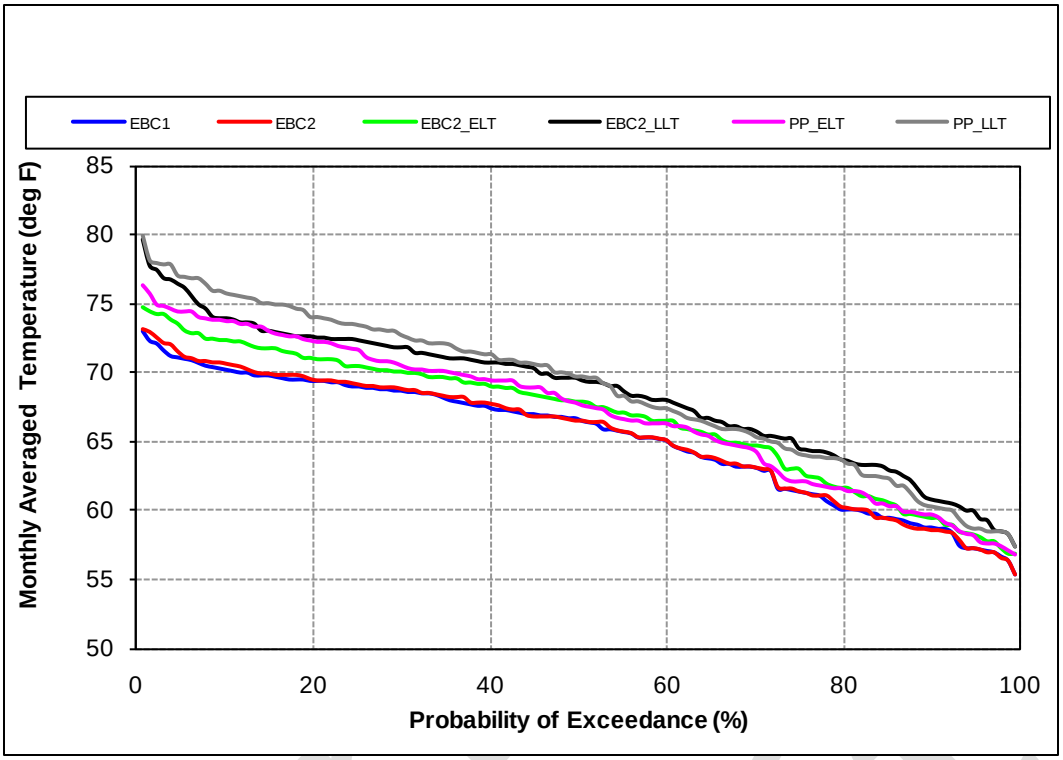

Figure C.5.2-288. Probability of Exceedance Plot for Model Scenarios of Mean Monthly Temperature in the Feather River at Honcut Creek, April through October in Dry Years

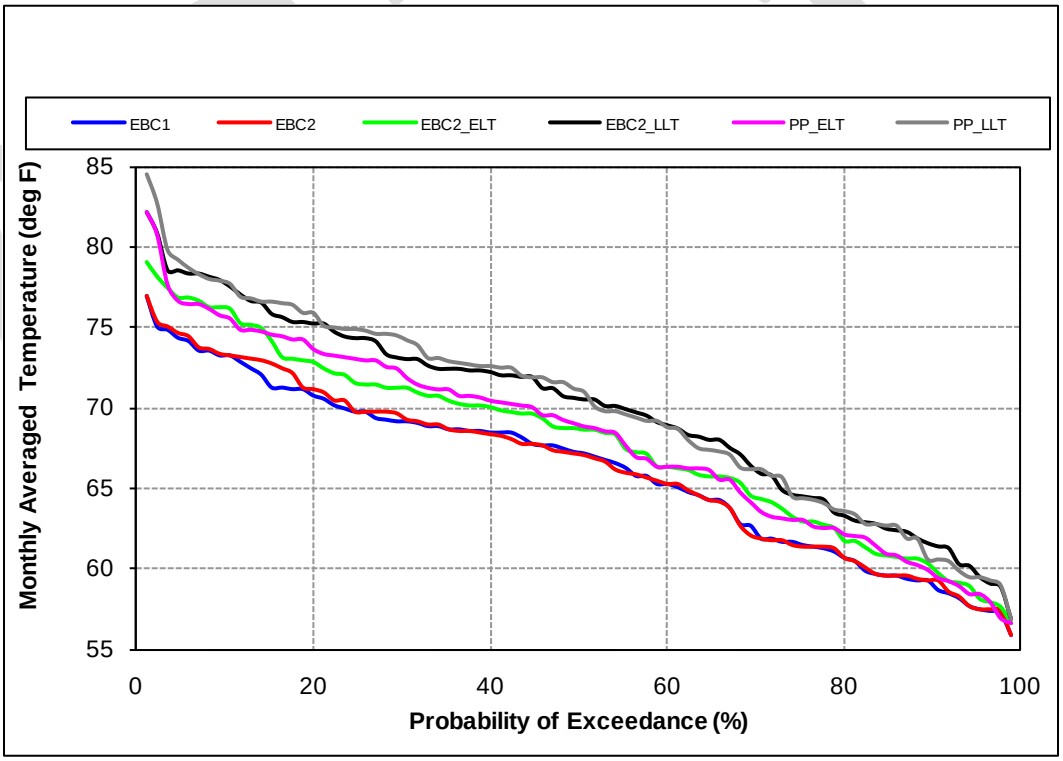

Figure C.5.2-289. Probability of Exceedance Plot for Model Scenarios of Mean Monthly Temperature in the Feather River at Honcut Creek, April through October in Critical Years

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Table C.5.2-113. Percent of Months during the Months April through October[1] When Monthly Average Temperature Exceeds 66°F, 68°F, and 73°F in the Feather River at Honcut Creek

	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
Temperatures above 66°F						
Wet	48.9	40.1	46.2	51.6	54.4	58.8
Above Normal	53.2	49.4	51.9	58.4	61.0	67.5
Below Normal	56.1	56.1	64.3	70.4	60.2	63.3
Dry	52.4	53.2	61.1	68.3	61.9	65.9
Critical	56.0	54.8	63.1	70.2	65.5	71.4
All	52.6	49.2	55.9	62.3	59.6	64.2
Temperatures above 68°F						
Wet	34.1	32.4	39.0	42.3	42.3	49.5
Above Normal	28.6	26.0	41.6	48.1	37.7	51.9
Below Normal	38.8	37.8	45.9	61.2	41.8	54.1
Dry	34.9	37.3	47.6	57.9	48.4	55.6
Critical	44.0	42.9	54.8	64.3	54.8	61.9
All	35.8	35.1	44.8	53.1	44.8	53.8
Temperatures above 73°F						
Wet	5.5	5.5	6.0	7.1	15.4	18.7
Above Normal	1.3	0.0	1.3	3.9	7.8	10.4
Below Normal	0.0	0.0	1.0	10.2	10.2	23.5
Dry	0.0	0.8	5.6	13.5	14.3	27.8
Critical	10.7	13.1	16.7	29.8	23.8	34.5
All	3.5	3.9	6.0	12.0	14.5	22.8

[1] Based on the modeling period of 1922 to 2003.

Table C.5.2-114. Difference and Percent Difference in Percentage of Months in April through October When Monthly Average Temperature Exceeds 66°F, 68°F, and 73°F in the Feather River at Honcut Creek

WY Type	Comparison[1]	EBC1_ELT vs. PP_ELT	EBC1_LLT vs. PP_LLT	EBC2 vs. EBC2_ELT	EBC2 vs. EBC2_LLT	EBC2 vs. PP_ELT	EBC2 vs. PP_LLT	EBC2_ELT vs. PP_ELT	EBC2_LLT vs. PP_LLT
Temperatures above 66°F									
Wet	Difference	5.5	9.9	6.0	11.5	14.3	18.7	8.2	7.1
	Percent difference	11%	20%	15%	29%	36%	47%	18%	14%
Above Normal	Difference	7.8	14.3	2.6	9.1	11.7	18.2	9.1	9.1
	Percent difference	15%	27%	5%	18%	24%	37%	18%	16%
Below Normal	Difference	4.1	7.1	8.2	14.3	4.1	7.1	-4.1	-7.1
	Percent difference	7%	13%	15%	25%	7%	13%	-6%	-10%
Dry	Difference	9.5	13.5	7.9	15.1	8.7	12.7	0.8	-2.4
	Percent difference	18%	26%	15%	28%	16%	24%	1%	-3%
Critical	Difference	9.5	15.5	8.3	15.5	10.7	16.7	2.4	1.2
	Percent difference	17%	28%	15%	28%	20%	30%	4%	2%
All	Difference	7.1	11.6	6.7	13.1	10.4	15.0	3.7	1.9
	Percent difference	13%	22%	14%	27%	21%	30%	7%	3%

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WY Type	Comparison[1]	EBC1_ELT vs. PP_ELT	EBC1_LLT vs. PP_LLT	EBC2 vs. EBC2_ELT	EBC2 vs. EBC2_LLT	EBC2 vs. PP_ELT	EBC2 vs. PP_LLT	EBC2_ELT vs. PP_ELT	EBC2_LLT vs. PP_LLT
Temperatures above 68°F									
Wet	Difference	8.2	15.4	6.6	9.9	9.9	17.0	3.3	7.1
	Percent difference	24%	45%	20%	31%	31%	53%	8%	17%
Above Normal	Difference	9.1	23.4	15.6	22.1	11.7	26.0	-3.9	3.9
	Percent difference	32%	82%	60%	85%	45%	100%	-9%	8%
Below Normal	Difference	3.1	15.3	8.2	23.5	4.1	16.3	-4.1	-7.1
	Percent difference	8%	39%	22%	62%	11%	43%	-9%	-12%
Dry	Difference	13.5	20.6	10.3	20.6	11.1	18.3	0.8	-2.4
	Percent difference	39%	59%	28%	55%	30%	49%	2%	-4%
Critical	Difference	10.7	17.9	11.9	21.4	11.9	19.0	0.0	-2.4
	Percent difference	24%	41%	28%	50%	28%	44%	0%	-4%
All	Difference	9.0	18.0	9.7	18.0	9.7	18.7	0.0	0.7
	Percent difference	25%	50%	28%	51%	28%	53%	0%	1%
Temperatures above 73°F									
Wet	Difference	9.9	13.2	0.5	1.6	9.9	13.2	9.3	11.5
	Percent difference	180%	240%	10%	30%	180%	240%	155%	162%
Above Normal	Difference	6.5	9.1	1.3	3.9	7.8	10.4	6.5	6.5
	Percent difference	500%	700%	NA	NA	NA	NA	500%	167%
Below Normal	Difference	10.2	23.5	1.0	10.2	10.2	23.5	9.2	13.3
	Percent difference	NA	NA	NA	AN	NA	NA	900%	130%
Dry	Difference	14.3	27.8	4.8	12.7	13.5	27.0	8.7	14.3
	Percent difference	NA	NA	600%	1,600%	1,700%	3,400%	157%	106%
Critical	Difference	13.1	23.8	3.6	16.7	10.7	21.4	7.1	4.8
	Percent difference	122%	222%	27%	127%	82%	164%	43%	16%
All	Difference	10.9	19.2	2.1	8.1	10.6	18.9	8.5	10.8
	Percent difference	310%	545%	55%	209%	273%	486%	141%	90%

[1]A positive value indicates a higher value under the second model scenario listed in the column title.
NA = Could not be calculated because dividing by 0.

Sacramento Confluence

Water temperature exceedance plots are presented by water-year type for April through October, the green sturgeon larval rearing period, in the Feather River at the confluence with the Sacramento River in Figure C.5.2-290 through Figure C.5.2-294. The frequencies of exceedance above three temperature thresholds, 66°F, 68°F, and 73°F, are presented in Table C.5.2-115 and differences between pairs of model scenarios in the frequency of exceedance are presented in Table C.5.2-116.

Combining all water years, mean monthly water temperatures in the Feather River at the confluence with the Sacramento River from April through October exceeded the 66°F threshold in 64%–65% of months under EBC1 and EBC2, in 68%–74% of months under EBC2_ELT and EBC2_LLT, and in 68%–74% of months under PP_ELT and PP_LLT (Table C.5.2-115). Accounting for climate change effects, the frequency of temperatures exceeding 66°F under PP_ELT and PP_LLT is predicted to be <1% lower than under EBC2_ELT and EBC2_LLT, respectively (Table C.5.2-116).

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Combining all water years, mean monthly water temperatures in the Feather River at the confluence with the Sacramento River from April through October exceeded the 68°F threshold in 53%-58% of months under EBC1 and EBC2, in 59%-67% of months under EBC2_ELT and EBC2_LLT, and in 63%-66% of months under PP_ELT and PP_LLT (Table C.5.2-115). Accounting for climate change effects, the frequency of temperatures exceeding 68°F under PP_ELT and PP_LLT is predicted to be 3% greater and <1% lower than under EBC2_ELT and EBC2_LLT, respectively (Table C.5.2-116).

Combining all water years, mean monthly water temperatures in the Feather River at the confluence with the Sacramento River from April through October exceeded the 73°F threshold in 17% of months under EBC1 and EBC2, in 32%-43% of months under EBC2_ELT and EBC2_LLT, and in 37%-49% of months under PP_ELT and PP_LLT (Table C.5.2-115). Accounting for climate change effects, the frequency of temperatures exceeding 73°F under PP_ELT and PP_LLT is predicted to be 5% and 6% greater than under EBC2_ELT and EBC2_LLT, respectively (Table C.5.2-116).

These results suggest that the effects of the preliminary proposal on the exceedance of temperature thresholds are mostly small (<6%) and benenficial to green sturgeon larvae. The effects of climate change are much larger than those of the preliminary proposal, as evidenced by differences in EBC2 vs. EBC2_ELT and EBC2 vs. EBC2_LLT exceedance comparisons.

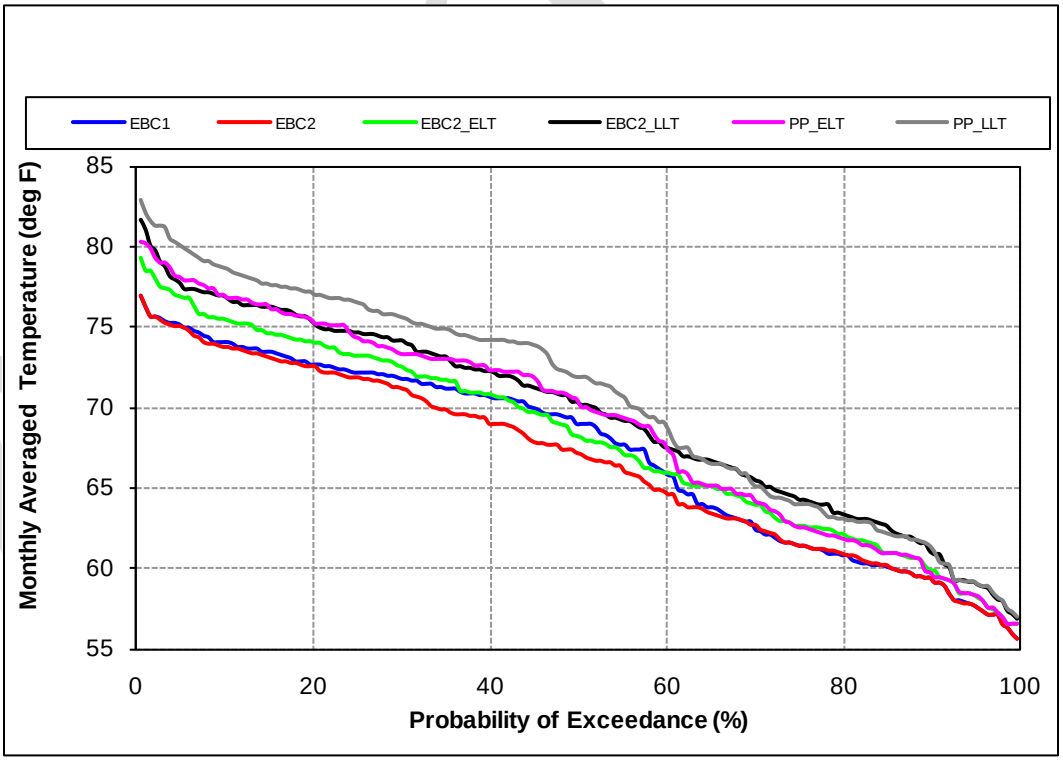

Figure C.5.2-290. Probability of Exceedance Plot for Model Scenarios of Mean Monthly Temperature in the Feather River at the Confluence with the Sacramento River, April through October in Wet Years

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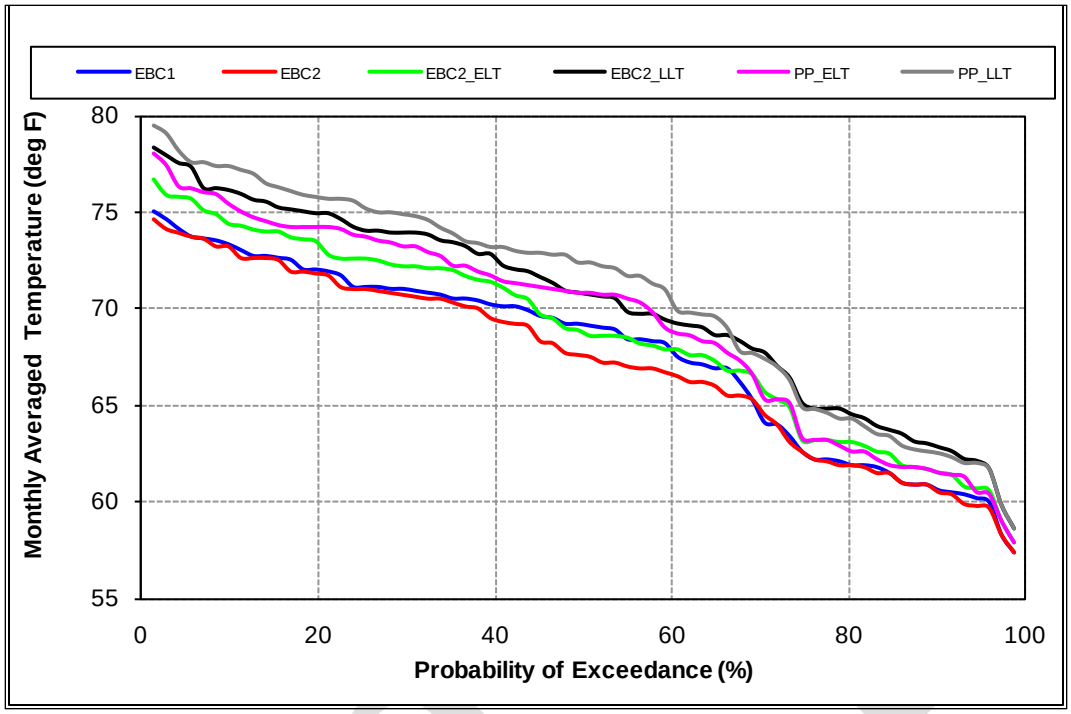

Figure C.5.2-291. Probability of Exceedance Plot for Model Scenarios of Mean Monthly Temperature in the Feather River at the Confluence with the Sacramento River, April through October in Above-Normal Years

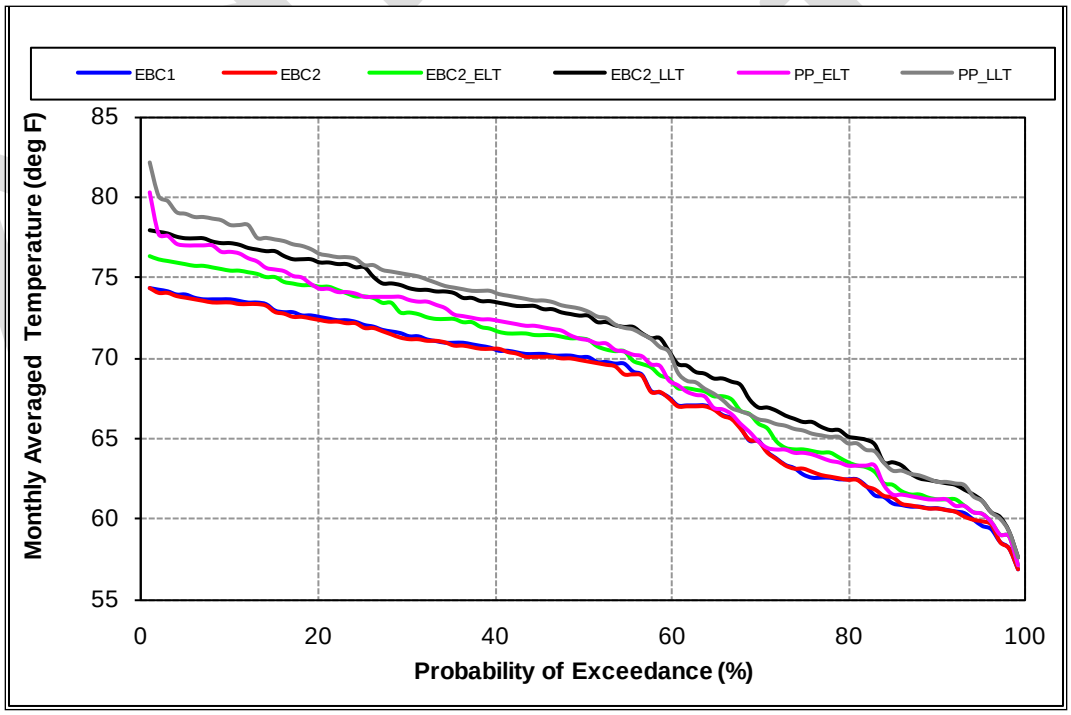

Figure C.5.2-292. Probability of Exceedance Plot for Model Scenarios of Mean Monthly Temperature in the Feather River at the Confluence with the Sacramento River, April through October in Below-Normal Years

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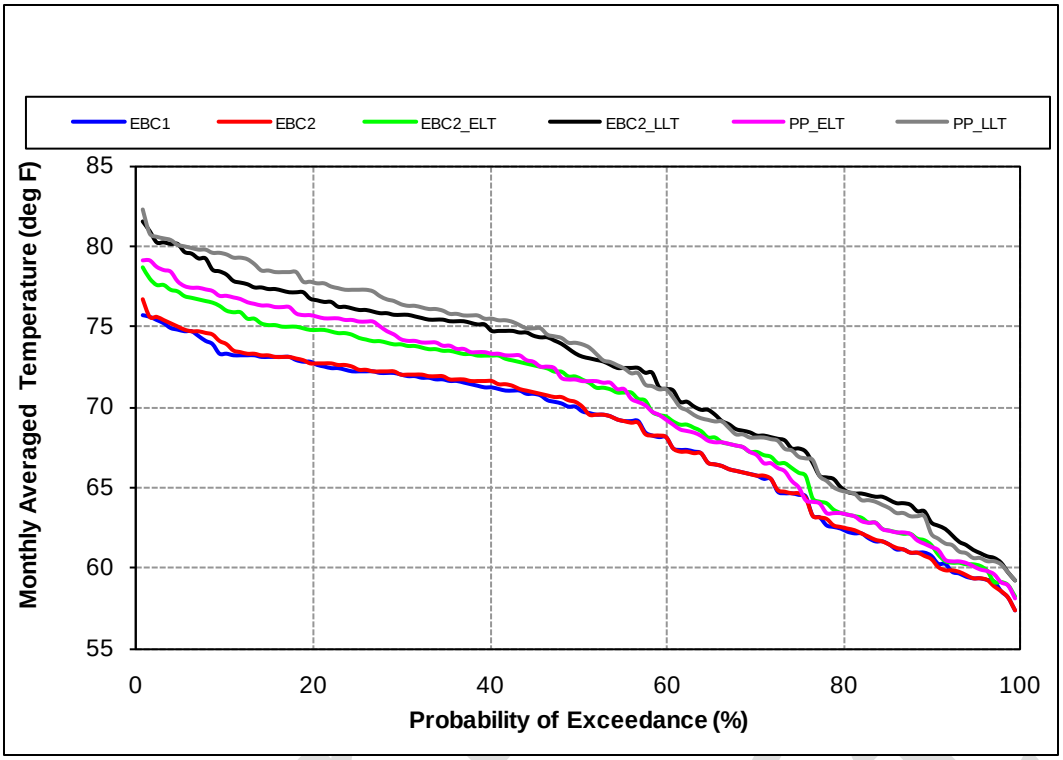

Figure C.5.2-293. Probability of Exceedance Plot for Model Scenarios of Mean Monthly Temperature in the Feather River at the Confluence with the Sacramento River, April through October in Dry Years

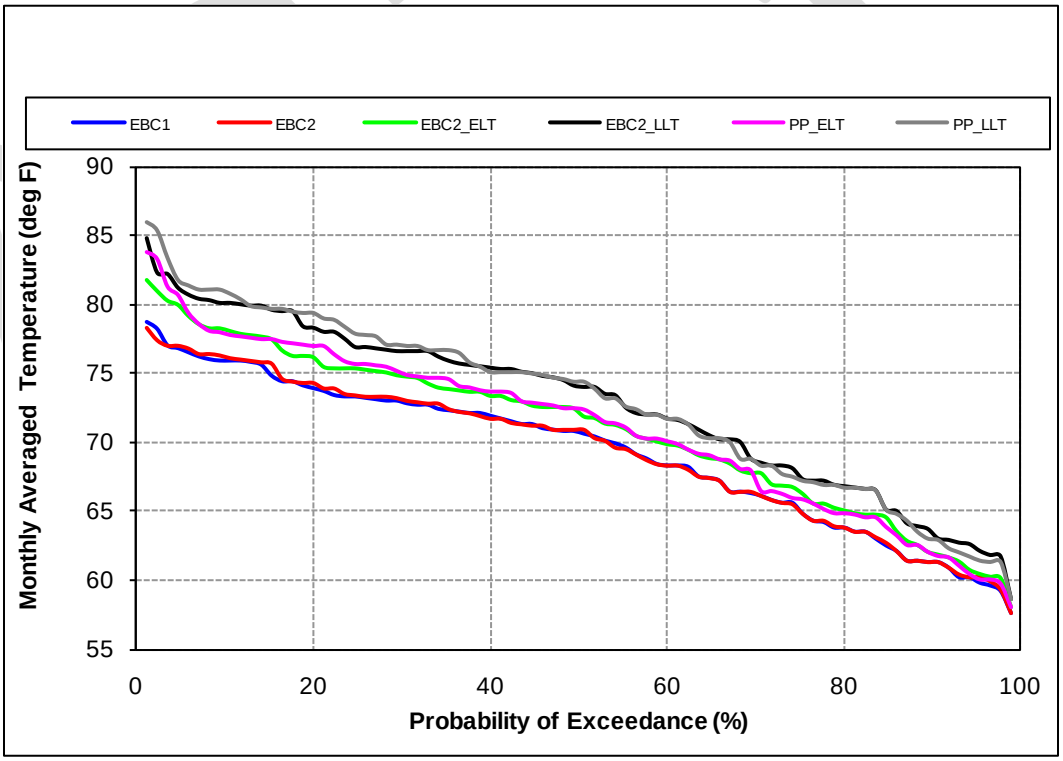

Figure C.5.2-294. Probability of Exceedance Plot for Model Scenarios of Mean Monthly Temperature in the Feather River at the Confluence with the Sacramento River, April through October in Critical Years

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Table C.5.2-115. Percentage of Months from April through October[1] When Monthly Average Temperature Exceeds 66°F, 68°F, and 73°F in the Feather River at the Confluence with the Sacramento River

	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
Temperatures above 66°F						
Wet	59.3	54.9	58.2	68.1	61.0	68.1
Above Normal	67.5	63.6	68.8	72.7	68.8	72.7
Below Normal	67.3	67.3	69.4	74.5	67.3	71.4
Dry	67.5	67.5	74.6	77.0	73.0	77.0
Critical	71.4	71.4	76.2	84.5	73.8	84.5
All	65.4	63.5	67.9	74.3	67.7	73.7
Temperatures above 68°F						
Wet	53.8	44.5	50.5	58.2	58.8	60.4
Above Normal	59.7	46.8	57.1	67.5	64.9	66.2
Below Normal	57.1	57.1	62.2	68.4	61.2	64.3
Dry	60.3	60.3	65.9	72.2	64.3	71.4
Critical	63.1	61.9	67.9	75.0	69.0	72.6
All	58.0	53.1	59.4	66.8	62.8	66.1
Temperatures above 73°F						
Wet	17.6	15.4	26.9	35.2	33.0	46.7
Above Normal	9.1	9.1	19.5	35.1	29.9	40.3
Below Normal	14.3	14.3	28.6	44.9	34.7	50.0
Dry	17.5	17.5	41.3	50.8	43.7	52.4
Critical	27.4	29.8	42.9	54.8	42.9	54.8
All	17.3	16.9	31.7	43.2	36.7	48.9

[1] Based on the modeling period of 1922 to 2003.

Table C.5.2-116. Difference and Percent Difference in Percentage of Months from April through October When Monthly Average Temperature Exceeds 66°F, 68°F, and 73°F in the Feather River at the Confluence with the Sacramento River

WY Type	Comparison[1]	EBC1_ELT vs. PP_ELT	EBC1_LLT vs. PP_LLT	EBC2 vs. EBC2_ELT	EBC2 vs. EBC2_LLT	EBC2 vs. PP_ELT	EBC2 vs. PP_LLT	EBC2_ELT vs. PP_ELT	EBC2_LLT vs. PP_LLT
Temperatures above 66°F									
Wet	Difference	1.6	8.8	3.3	13.2	6.0	13.2	2.7	0.0
	Percent difference	3%	15%	6%	24%	11%	24%	5%	0%
Above Normal	Difference	1.3	5.2	5.2	9.1	5.2	9.1	0.0	0.0
	Percent difference	2%	8%	8%	14%	8%	14%	0%	0%
Below Normal	Difference	0.0	4.1	2.0	7.1	0.0	4.1	-2.0	-3.1
	Percent difference	0%	6%	3%	11%	0%	6%	-3%	-4%
Dry	Difference	5.6	9.5	7.1	9.5	5.6	9.5	-1.6	0.0
	Percent difference	8%	14%	11%	14%	8%	14%	-2%	0%
Critical	Difference	2.4	13.1	4.8	13.1	2.4	13.1	-2.4	0.0
	Percent difference	3%	18%	7%	18%	3%	18%	-3%	0%
All	Difference	2.3	8.3	4.4	10.8	4.2	10.2	-0.2	-0.5
	Percent difference	4%	13%	7%	17%	7%	16%	0%	-1%

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WY Type	Comparison[1]	EBC1_ELT vs. PP_ELT	EBC1_LLT vs. PP_LLT	EBC2 vs. EBC2_ELT	EBC2 vs. EBC2_LLT	EBC2 vs. PP_ELT	EBC2 vs. PP_LLT	EBC2_ELT vs. PP_ELT	EBC2_LLT vs. PP_LLT
Temperatures above 68°F									
Wet	Difference	4.9	6.6	6.0	13.7	14.3	15.9	8.2	2.2
	Percent difference	9%	12%	14%	31%	32%	36%	16%	4%
Above Normal	Difference	5.2	6.5	10.4	20.8	18.2	19.5	7.8	-1.3
	Percent difference	9%	11%	22%	44%	39%	42%	14%	-2%
Below Normal	Difference	4.1	7.1	5.1	11.2	4.1	7.1	-1.0	-4.1
	Percent difference	7%	13%	9%	20%	7%	13%	-2%	-6%
Dry	Difference	4.0	11.1	5.6	11.9	4.0	11.1	-1.6	-0.8
	Percent difference	7%	18%	9%	20%	7%	18%	-2%	-1%
Critical	Difference	6.0	9.5	6.0	13.1	7.1	10.7	1.2	-2.4
	Percent difference	9%	15%	10%	21%	12%	17%	2%	-3%
All	Difference	4.8	8.1	6.3	13.8	9.7	13.1	3.4	-0.7
	Percent difference	8%	14%	12%	26%	18%	25%	6%	-1%
Temperatures above 73°F									
Wet	Difference	15.4	29.1	11.5	19.8	17.6	31.3	6.0	11.5
	Percent difference	88%	166%	75%	129%	114%	204%	22%	33%
Above Normal	Difference	20.8	31.2	10.4	26.0	20.8	31.2	10.4	5.2
	Percent difference	229%	343%	114%	286%	229%	343%	53%	15%
Below Normal	Difference	20.4	35.7	14.3	30.6	20.4	35.7	6.1	5.1
	Percent difference	143%	250%	100%	214%	143%	250%	21%	11%
Dry	Difference	26.2	34.9	23.8	33.3	26.2	34.9	2.4	1.6
	Percent difference	150%	200%	136%	191%	150%	200%	6%	3%
Critical	Difference	15.5	27.4	13.1	25.0	13.1	25.0	0.0	0.0
	Percent difference	57%	100%	44%	84%	44%	84%	0%	0%
All	Difference	19.4	31.6	14.8	26.3	19.8	31.9	4.9	5.6
	Percent difference	112%	183%	88%	155%	117%	189%	16%	13%

[1]A positive value indicates a higher value under the second model scenario listed in the column title.

Juveniles

Water Temperature

Water temperature exceedance plots are presented by water-year type for August through March, the green sturgeon juvenile rearing period, in the Feather River at the confluence with the Sacramento River in Figure C.5.2-295 through Figure C.5.2-299. The frequencies of exceedance above three temperature thresholds, 66°F, 75°F, and 81°F, are presented in Table C.5.2-117 and differences between pairs of model scenarios in the frequency of exceedance are presented in Table C.5.2-118.

Combining all water years, mean monthly water temperatures in the Feather River at the confluence with the Sacramento River from August through March exceeded the 66°F threshold in 23–25% of months under EBC1 and EBC2, in 25–27% of months under EBC2_ELT and EBC2_LLT, and in 25–27% of months under PP_ELT and PP_LLT (Table C.5.2-115). Accounting for climate change effects,

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the frequency of temperatures exceeding 66°F under PP_ELT and PP_LLT is predicted to be <1% higher and <1% lower than under EBC2_ELT and EBC2_LLT, respectively (Table C.5.2-118).

Combining all water years, mean monthly water temperatures in the Feather River at the confluence with the Sacramento River from August through March exceeded the 75°F threshold in 2% of months under EBC1 and EBC2, in 4–9% of months under EBC2_ELT and EBC2_LLT, and in 7–14% of months under PP_ELT and PP_LLT (Table C.5.2-117). Accounting for climate change effects, the frequency of temperatures exceeding 75°F under PP_ELT and PP_LLT is predicted to be 3% and 4% greater than under EBC2_ELT and EBC2_LLT, respectively (Table C.5.2-118).

Combining all water years, mean monthly water temperatures in the Feather River at the confluence with the Sacramento River from August through March exceeded the 81°F threshold in 0% of months under EBC1 and EBC2, EBC2_ELT, and PP_ELT, and in <1% of months under EBC2_LLT, and PP_LLT (Table C.5.2-117). Accounting for climate change effects, the frequency of temperatures exceeding 81°F under PP_ELT and PP_LLT is predicted to be <1% greater than under EBC2_ELT and EBC2_LLT, respectively (Table C.5.2-118).

Based on these results, it was concluded with moderate certainty that the preliminary proposal will have no or low adverse effects on temperature-related juvenile green sturgeon habitat conditions.

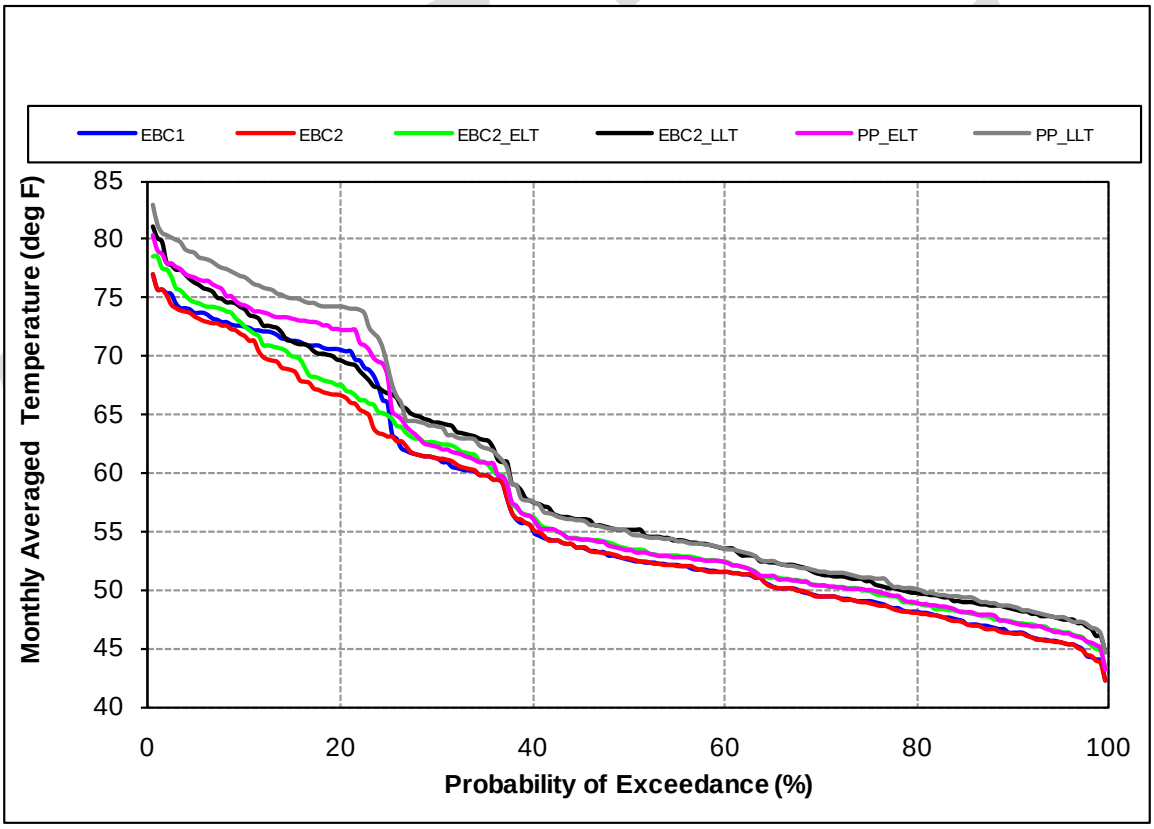

Figure C.5.2-295. Probability of Exceedance Plot for Model Scenarios of Mean Monthly Temperature in the Feather River at the Confluence with the Sacramento River, August through March in Wet Years

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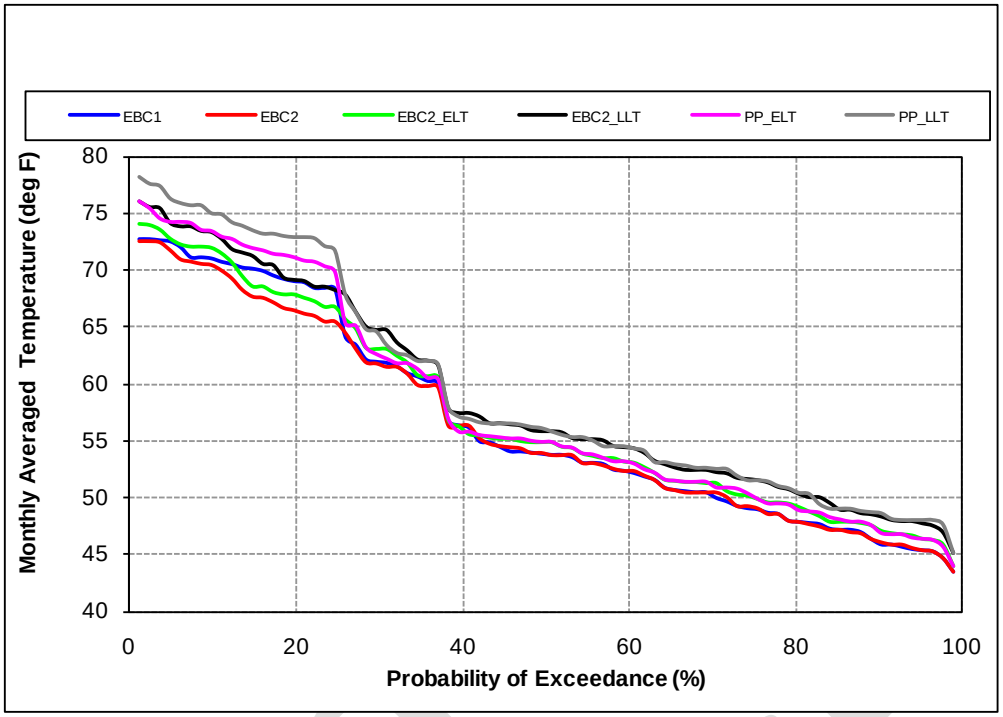

Figure C.5.2-296. Probability of Exceedance Plot for Model Scenarios of Mean Monthly Temperature in the Feather River at the Confluence with the Sacramento River, August through March in Above-Normal Years

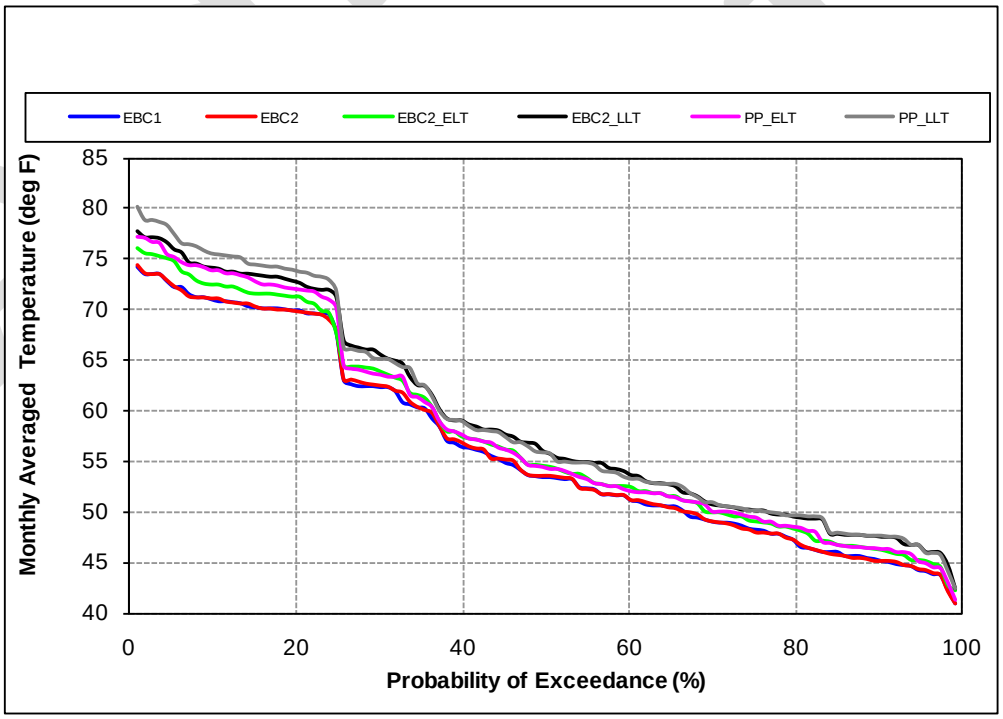

Figure C.5.2-297. Probability of Exceedance Plot for Model Scenarios of Mean Monthly Temperature in the Feather River at the Confluence with the Sacramento River, August through March in Below-Normal Years

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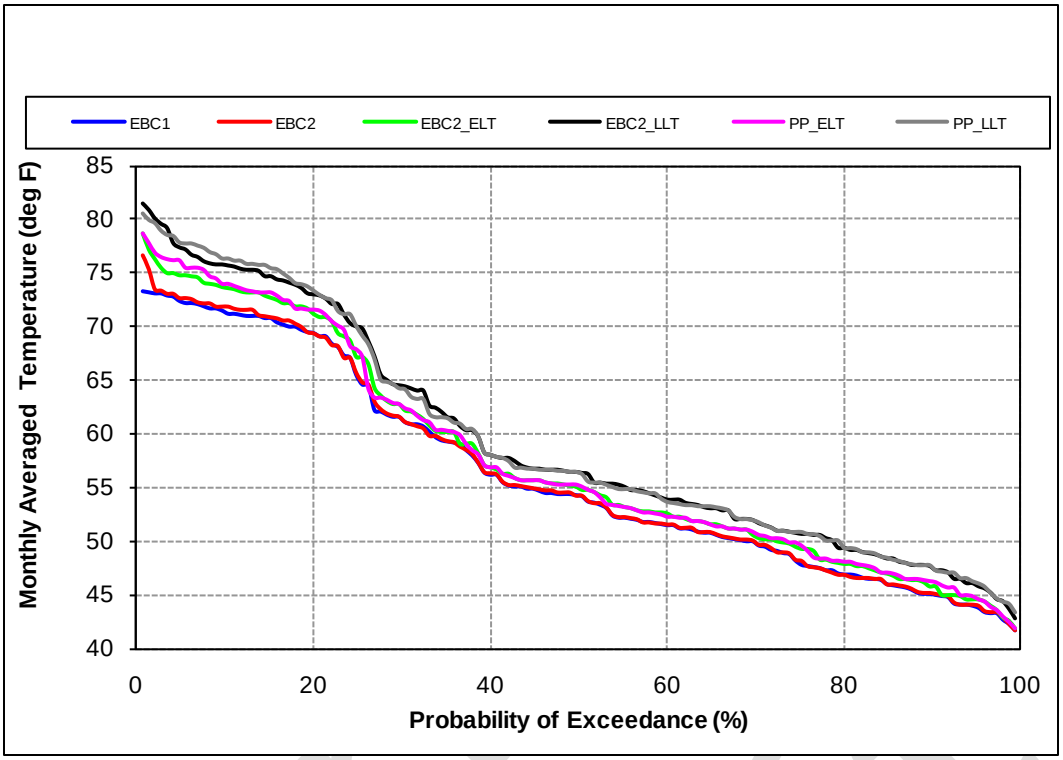

Figure C.5.2-298. Probability of Exceedance Plot for Model Scenarios of Mean Monthly Temperature in the Feather River at the Confluence with the Sacramento River, August through March in Dry Years

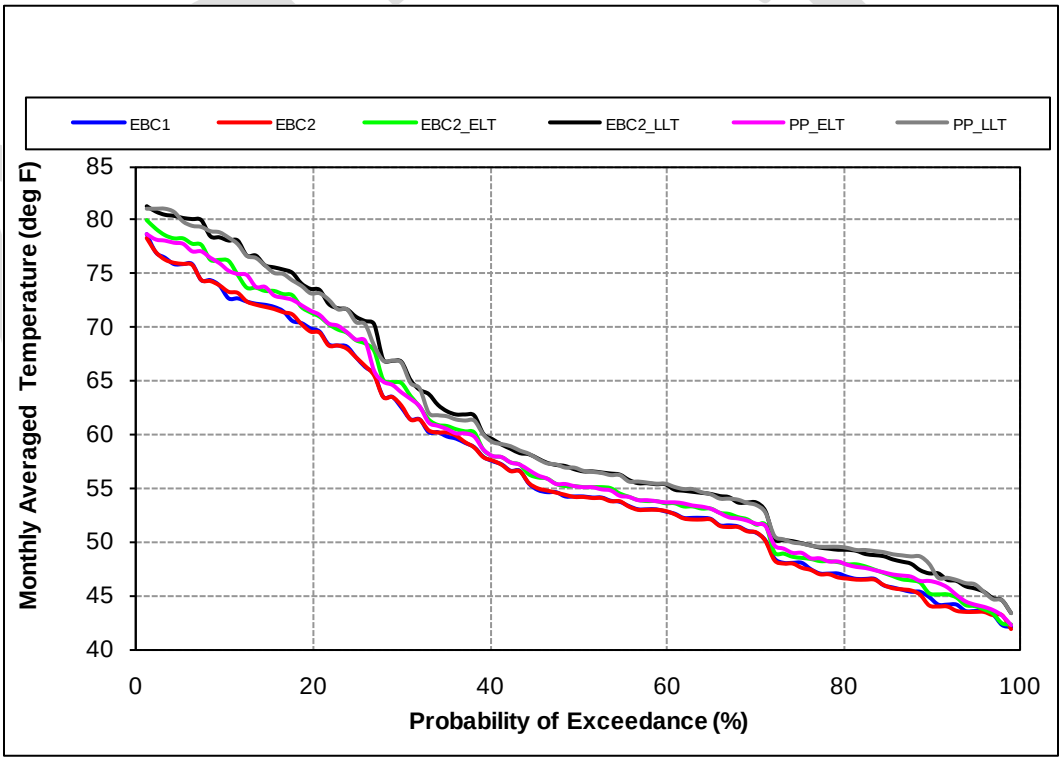

Figure C.5.2-299. Probability of Exceedance Plot for Model Scenarios of Mean Monthly Temperature in the Feather River at the Confluence with the Sacramento River, August through March in Critical Years

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Table C.5.2-117. Percentage of Months from August through March[1] When Monthly Average Temperature Exceeds 66°F, 75°F, and 81°F in the Feather River at the Confluence with the Sacramento River

Water-Year Type	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
Temperatures above 66°F						
Wet	24.5	20.7	22.6	26.0	25.0	26.0
Above Normal	25.0	21.6	25.0	27.3	25.0	27.3
Below Normal	25.0	25.0	25.0	27.7	25.0	26.8
Dry	24.3	24.3	26.4	27.1	25.7	27.1
Critically Dry	26.0	26.0	27.1	30.2	26.0	30.2
All	24.7	23.0	24.7	27.1	25.2	27.0
Temperatures above 75°F						
Wet	2.4	1.9	3.8	6.7	8.7	13.9
Above Normal	0.0	0.0	0.0	3.4	2.3	8.0
Below Normal	0.0	0.0	3.6	6.3	5.4	13.4
Dry	0.0	1.4	2.8	13.9	7.6	16.0
Critically Dry	6.3	6.3	10.4	16.7	10.4	15.6
All	1.7	1.8	4.0	9.2	7.2	13.7
Temperatures above 81°F						
Wet	0.0	0.0	0.0	0.5	0.0	1.0
Above Normal	0.0	0.0	0.0	0.0	0.0	0.0
Below Normal	0.0	0.0	0.0	0.0	0.0	0.0
Dry	0.0	0.0	0.0	0.7	0.0	0.0
Critically Dry	0.0	0.0	0.0	1.0	0.0	3.1
All	0.0	0.0	0.0	0.5	0.0	0.8

[1] Based on the modeling period of 1922 to 2003.

Table C.5.2-118. Difference and Percent Difference in Percentage of Months during August through March When Monthly Average Temperature Exceeds 66°F, 75°F, and 81°F in the Feather River at the Confluence with the Sacramento River

WY Type	Comparison[1]	EBC1 vs. PP_ELT	EBC1 vs. PP_LLT	EBC2 vs. EBC2_ELT	EBC2 vs. EBC2_LLT	EBC2 vs. PP_ELT	EBC2 vs. PP_LLT	EBC2_ELT vs. PP_ELT	EBC2_LLT vs. PP_LLT
Temperatures above 66°F									
Wet	Difference	0.5	1.4	1.9	5.3	4.3	5.3	2.4	0.0
	Percent difference	2%	6%	9%	26%	21%	26%	11%	0%
Above Normal	Difference	0.0	2.3	3.4	5.7	3.4	5.7	0.0	0.0
	Percent difference	0%	9%	16%	26%	16%	26%	0%	0%
Below Normal	Difference	0.0	1.8	0.0	2.7	0.0	1.8	0.0	-0.9
	Percent difference	0%	7%	0%	11%	0%	7%	0%	-3%
Dry	Difference	1.4	2.8	2.1	2.8	1.4	2.8	-0.7	0.0
	Percent difference	6%	11%	9%	11%	6%	11%	-3%	0%
Critical	Difference	0.0	4.2	1.0	4.2	0.0	4.2	-1.0	0.0
	Percent difference	0%	16%	4%	16%	0%	16%	-4%	0%
All	Difference	0.5	2.3	1.7	4.1	2.1	4.0	0.5	-0.2
	Percent difference	2%	9%	7%	18%	9%	17%	2%	-1%

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WY Type	Comparison[1]	EBC1 vs. PP_ELT	EBC1 vs. PP_LLT	EBC2 vs. EBC2_ELT	EBC2 vs. EBC2_LLT	EBC2 vs. PP_ELT	EBC2 vs. PP_LLT	EBC2_ELT vs. PP_ELT	EBC2_LLT vs. PP_LLT
Temperatures above 75°F									
Wet	Difference	6.3	11.5	1.9	4.8	6.7	12.0	4.8	7.2
	Percent difference	260%	480%	100%	250%	350%	625%	125%	107%
Above Normal	Difference	2.3	8.0	0.0	3.4	2.3	8.0	2.3	4.5
	Percent difference	NA	NA	NA	NA	NA	NA	NA	133%
Below Normal	Difference	5.4	13.4	3.6	6.3	5.4	13.4	1.8	7.1
	Percent difference	NA	NA	NA	NA	NA	NA	50%	114%
Dry	Difference	7.6	16.0	1.4	12.5	6.3	14.6	4.9	2.1
	Percent difference	NA	NA	100%	900%	450%	1050%	175%	15%
Critical	Difference	4.2	9.4	4.2	10.4	4.2	9.4	0.0	-1.0
	Percent difference	67%	150%	67%	167%	67%	150%	0%	-6%
All	Difference	5.5	12.0	2.1	7.4	5.4	11.8	3.2	4.4
	Percent difference	327%	709%	117%	400%	292%	642%	81%	48%
Temperatures above 81°F									
Wet	Difference	0.0	1.0	0.0	0.5	0.0	1.0	0.0	0.5
	Percent difference	NA	NA	NA	NA	NA	NA	NA	100%
Above Normal	Difference	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Percent difference	NA	NA	NA	NA	NA	NA	NA	NA
Below Normal	Difference	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Percent difference	NA	NA	NA	NA	NA	NA	NA	NA
Dry	Difference	0.0	0.0	0.0	0.7	0.0	0.0	0.0	-0.7
	Percent difference	NA	NA	NA	NA	NA	NA	NA	-100%
Critical	Difference	0.0	3.1	0.0	1.0	0.0	3.1	0.0	2.1
	Percent difference	NA	NA	NA	NA	NA	NA	NA	200%
All	Difference	0.0	0.8	0.0	0.5	0.0	0.8	0.0	0.3
	Percent difference	NA	NA	NA	NA	NA	NA	NA	67%

[1] A positive value indicates a higher value under the second model scenario listed in the column title.
NA = Could not be calculated because dividing by 0.

Dissolved Oxygen

The effects of BDCP actions on dissolved oxygen levels potentially affecting green sturgeon juveniles would be the same as described for white sturgeon juveniles. In the absence of known dissolved oxygen thresholds for green sturgeon, the threshold for white sturgeon of 56% saturation (Israel and Klimley 2008) was used as a surrogate.

Turbidity

Turbidity effects of BDCP actions on green sturgeon juveniles would be the same as described for white sturgeon juveniles.

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Adults

Water Temperature (Rivers)

Below Thermalito Afterbay

Water temperature exceedances are presented for all water-year types for March through July, the green sturgeon adult migration period, in the Feather River below Thermalito Afterbay in Figure C.5.2-300. The frequencies at which water temperatures are below 52°F and above 75°F and 81°F are presented in Table C.5.2-119 and differences between pairs of model scenarios in the frequency of exceedance are presented in Table C.5.2-120.

Combining all water years, mean monthly water temperatures in the Feather River below Thermalito Afterbay from March through July were lower than the 52°F threshold in 7–8% of months under EBC1 and EBC2, in 2–6% of months under EBC2_ELT and EBC2_LLT, and in 2–5% of months under PP_ELT and PP_LLT (Table C.5.2-119). Accounting for climate change effects, the frequency of temperatures below 52°F under PP_ELT and PP_LLT is predicted to be 1% and <1% lower than under EBC2_ELT and EBC2_LLT, respectively (Table C.5.2-120).

Combining all water years, mean monthly water temperatures in the Feather River below Thermalito Afterbay from March through July are predicted to never exceed the 75°F threshold under EBC1 and EBC2, exceed the threshold in 1–2% of months under EBC2_ELT and EBC2_LLT, and exceed the threshold in 1–3% of months under PP_ELT and PP_LLT (Table C.5.2-119). Accounting for climate change effects, the frequency of temperatures are predicted to exceed 75°F under PP_ELT and PP_LLT is predicted to be <1% lower and 2% greater than under EBC2_ELT and EBC2_LLT, respectively (Table C.5.2-120).

Mean monthly water temperatures in the Feather River below Thermalito Afterbay from March through July are predicted to exceed the 81°F threshold only in critical water years under PP_LLT (in <1% of months) (Table C.5.2-119). Accounting for climate change effects, the frequency of temperatures are predicted to exceed 81°F under PP_ELT and PP_LLT is predicted to be 0% and <1% greater than under EBC2_ELT and EBC2_LLT, respectively, for all water years combined.

Based on these results, it was concluded with moderate certainty that the preliminary proposal will have negligible effects on temperature-related adult green sturgeon migration habitat conditions in the Feather River below Thermalito Afterbay.

Admin Draft

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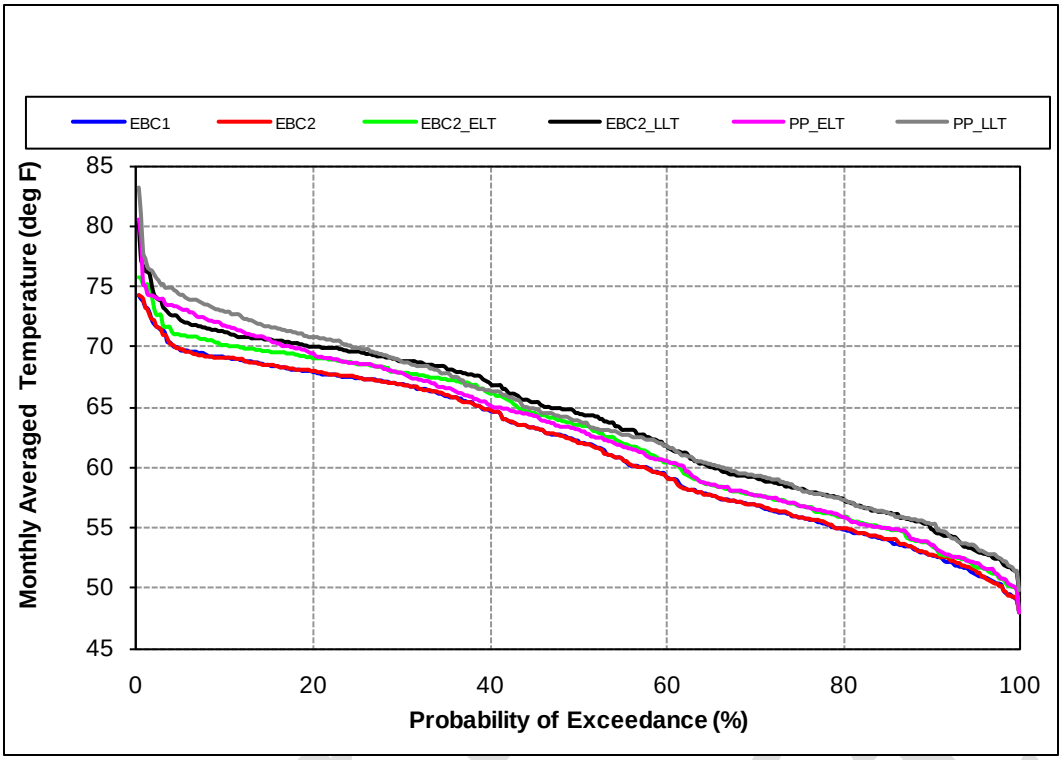

Figure C.5.2-300. Probability of Exceedance Plot for Model Scenarios of Mean Monthly Water Temperature in the Feather River below Thermalito Afterbay, March through July for All Water-Year Types Combined

Table C.5.2-119. Percent of Months between March and July[1] When Monthly Average Temperature Falls Below 52°F and Exceeds 75°F and 81°F in the Feather River below the Thermalito Afterbay

Water-Year Type	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
Temperatures below 52°F						
Wet	14.6	13.8	11.5	6.2	9.2	4.6
Above Normal	9.1	7.3	5.5	1.8	5.5	1.8
Below Normal	7.1	5.7	4.3	0.0	2.9	0.0
Dry	1.1	1.1	1.1	0.0	1.1	0.0
Critical	1.7	1.7	1.7	0.0	1.7	0.0
All	7.7	6.9	5.7	2.2	4.7	1.7
Temperatures above 75°F						
Wet	0.0	0.0	0.8	0.0	0.0	0.8
Above Normal	0.0	0.0	0.0	0.0	0.0	0.0
Below Normal	0.0	0.0	0.0	0.0	1.4	1.4
Dry	0.0	0.0	0.0	0.0	0.0	4.4
Critical	0.0	0.0	6.7	10.0	5.0	10.0
All	0.0	0.0	1.2	1.5	1.0	3.0

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Water-Year Type	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
Temperatures above 81°F						
Wet	0.0	0.0	0.0	0.0	0.0	0.0
Above Normal	0.0	0.0	0.0	0.0	0.0	0.0
Below Normal	0.0	0.0	0.0	0.0	0.0	0.0
Dry	0.0	0.0	0.0	0.0	0.0	0.0
Critical	0.0	0.0	0.0	0.0	0.0	1.7
All	0.0	0.0	0.0	0.0	0.0	0.2
[1] Based on the modeling period of 1922 to 2003.						

Table C.5.2-120. Difference and Percent Difference in the Percent of Months from March through July When Monthly Average Temperature Falls Below 52°F and Exceeds 75°F and 81°F in the Feather River below the Thermalito Afterbay

WY Type	Comparison[1]	EBC1_ELT vs. PP_ELT	EBC1_LLT vs. PP_LLT	EBC2 vs. EBC2_ELT	EBC2 vs. EBC2_LLT	EBC2 vs. PP_ELT	EBC2 vs. PP_LLT	EBC2_ELT vs. PP_ELT	EBC2_LLT vs. PP_LLT
Temperatures below 52°F									
Wet	Difference	-5.4	-10.0	-2.3	-7.7	-4.6	-9.2	-2.3	-1.5
	Percent difference	-37%	-68%	-17%	-56%	-33%	-67%	-20%	-25%
Above Normal	Difference	-3.6	-7.3	-1.8	-5.5	-1.8	-5.5	0.0	0.0
	Percent difference	-40%	-80%	-25%	-75%	-25%	-75%	0%	0%
Below Normal	Difference	-4.3	-7.1	-1.4	-5.7	-2.9	-5.7	-1.4	0.0
	Percent difference	-60%	-100%	-25%	-100%	-50%	-100%	-33%	NA
Dry	Difference	0.0	-1.1	0.0	-1.1	0.0	-1.1	0.0	0.0
	Percent difference	0%	-100%	0%	-100%	0%	-100%	0%	NA
Critical	Difference	0.0	-1.7	0.0	-1.7	0.0	-1.7	0.0	0.0
	Percent difference	0%	-100%	0%	-100%	0%	-100%	0%	NA
All	Difference	-3.0	-5.9	-1.2	-4.7	-2.2	-5.2	-1.0	-0.5
	Percent difference	-39%	-77%	-18%	-68%	-32%	-75%	-17%	-22%
Temperatures above 75°F									
Wet	Difference	0.0	0.8	0.8	0.0	0.0	0.8	-0.8	0.8
	Percent difference	NA	NA	NA	NA	NA	NA	NA	NA
Above Normal	Difference	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Percent difference	NA	NA	NA	NA	NA	NA	NA	NA
Below Normal	Difference	1.4	1.4	0.0	0.0	1.4	1.4	1.4	1.4
	Percent difference	NA	NA	NA	NA	NA	NA	NA	NA
Dry	Difference	0.0	4.4	0.0	0.0	0.0	4.4	0.0	4.4
	Percent difference	NA	NA	NA	NA	NA	NA	NA	NA
Critical	Difference	5.0	10.0	6.7	10.0	5.0	10.0	-1.7	0.0
	Percent difference	NA	NA	NA	NA	NA	NA	-25%	0%
All	Difference	1.0	3.0	1.2	1.5	1.0	3.0	-0.2	1.5
	Percent difference	NA	NA	NA	NA	NA	NA	-20%	100%

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WY Type	Comparison[1]	EBC1_ELT vs. PP_ELT	EBC1_LLT vs. PP_LLT	EBC2 vs. EBC2_ELT	EBC2 vs. EBC2_LLT	EBC2 vs. PP_ELT	EBC2 vs. PP_LLT	EBC2_ELT vs. PP_ELT	EBC2_LLT vs. PP_LLT
Temperatures above 81°F									
Wet	Difference	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Percent difference	NA	NA	NA	NA	NA	NA	NA	NA
Above Normal	Difference	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Percent difference	NA	NA	NA	NA	NA	NA	NA	NA
Below Normal	Difference	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Percent difference	NA	NA	NA	NA	NA	NA	NA	NA
Dry	Difference	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Percent difference	NA	NA	NA	NA	NA	NA	NA	NA
Critical	Difference	0.0	1.7	0.0	0.0	0.0	1.7	0.0	1.7
	Percent difference	NA	NA	NA	NA	NA	NA	NA	NA
All	Difference	0.0	0.2	0.0	0.0	0.0	0.2	0.0	0.2
	Percent difference	NA	NA	NA	NA	NA	NA	NA	NA

[1]A positive value indicates a higher value under the second model scenario listed in the column title.
NA = Could not be calculated because dividing by 0.

Gridley

Water temperature exceedances are presented for all water-year types for March through July, the green sturgeon adult migration period, in the Feather River at Gridley in Figure C.5.2-317. The frequencies at which water temperatures are below 52°F and above 75°F and 81°F are presented in Table C.5.2-119 and differences between pairs of model scenarios in the frequency of exceedance are presented in Table C.5.2-122.

Combining all water years, mean monthly water temperatures in the Feather River at Gridley from March through July were lower than the 52°F threshold in 6% of months under EBC1 and EBC2, in 2–4% of months under EBC2_ELT and EBC2_LLT, and in 2–4% of months under PP_ELT and PP_LLT (Table C.5.2-121). Accounting for climate change effects, the frequency of temperatures below 52°F under PP_ELT and PP_LLT is predicted to be <1% greater and <1% lower than under EBC2_ELT and EBC2_LLT, respectively (Table C.5.2-122).

Combining all water years, mean monthly water temperatures in the Feather River at Gridley from March through July exceeded the 75°F threshold in <1% of months under EBC1 and EBC2, in 2–3% of months under EBC2_ELT and EBC2_LLT, and in 3–6% of months under PP_ELT and PP_LLT (Table C.5.2-121). Accounting for climate change effects, the frequency of exceedance above 75°F under PP_ELT and PP_LLT is predicted to be 1% and 4% greater than under EBC2_ELT and EBC2_LLT, respectively (Table C.5.2-122).

Combining all water years, mean monthly water temperatures in the Feather River at Gridley from March through July exceeded the 81°F threshold in 0% of months under EBC1, EBC2, and EBC2_ELT, and in <1% of months under EBC2_LLT, PP_ELT, and PP_LLT (Table C.5.2-121). Accounting for climate change effects, the frequency of exceedance above 75°F under PP_ELT and PP_LLT is predicted to be <1% greater than under EBC2_ELT and EBC2_LLT, respectively (Table C.5.2-122).

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Based on these results, it was concluded with moderate certainty that the preliminary proposal will have small adverse (using the 75°F threshold) or negligible effects on temperature-related adult green sturgeon migration habitat conditions in the Feather River at Gridley.

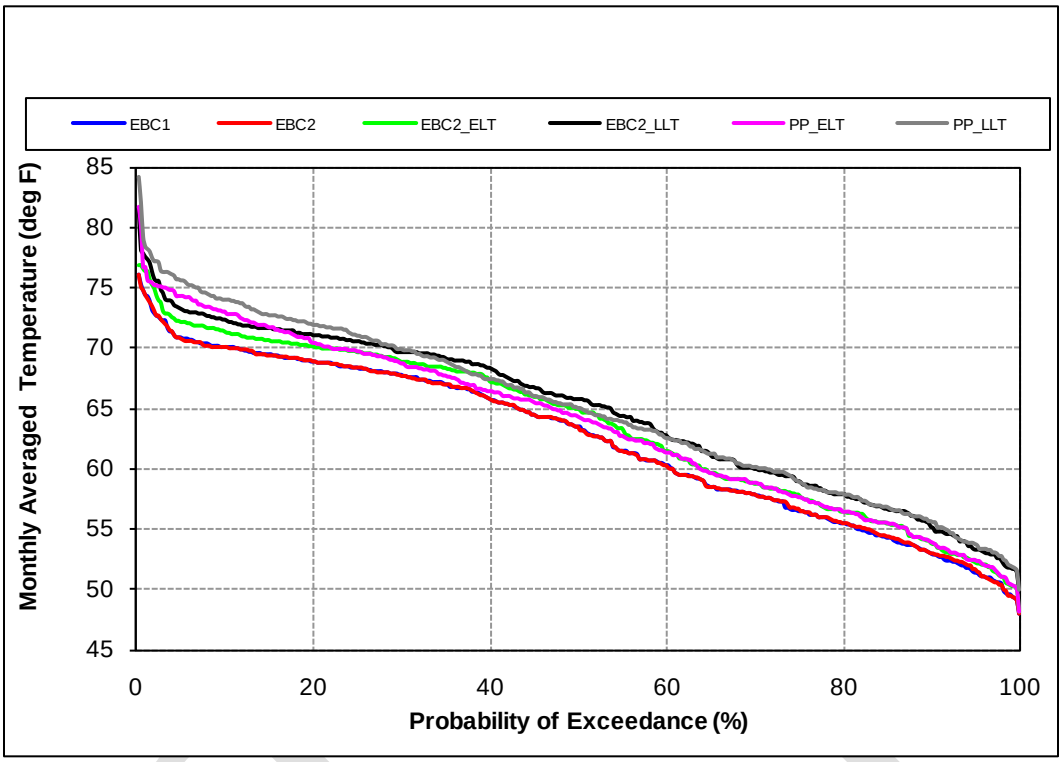

Figure C.5.2-301. Probability of Exceedance Plot for Model Scenarios of Mean Monthly Water Temperature in the Feather River at Gridley, March through July for All Water-Year Types Combined

Table C.5.2-121. Percent of Months between March and July[1] When Monthly Average Temperature Falls Below 52°F and Exceeds 75°F and 81°F in the Feather River at Gridley

	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
Temperatures below 52°F						
Wet	12.3	11.5	7.7	5.4	7.7	3.8
Above Normal	9.1	7.3	5.5	1.8	5.5	1.8
Below Normal	5.7	4.3	2.9	0.0	2.9	0.0
Dry	0.0	0.0	0.0	0.0	1.1	0.0
Critical	1.7	1.7	1.7	0.0	1.7	0.0
All	6.4	5.7	4.0	2.0	4.2	1.5
Temperatures above 75°F						
Wet	1.5	0.8	1.5	0.8	2.3	3.1
Above Normal	0.0	0.0	0.0	0.0	0.0	1.8
Below Normal	0.0	0.0	0.0	0.0	1.4	2.9
Dry	0.0	0.0	0.0	2.2	1.1	10.0
Critical	0.0	1.7	8.3	11.7	10.0	16.7
All	0.5	0.5	1.7	2.5	2.7	6.4

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	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
Temperatures above 81°F						
Wet	0.0	0.0	0.0	0.0	0.0	0.0
Above Normal	0.0	0.0	0.0	0.0	0.0	0.0
Below Normal	0.0	0.0	0.0	0.0	0.0	0.0
Dry	0.0	0.0	0.0	0.0	0.0	0.0
Critical	0.0	0.0	0.0	1.7	1.7	3.3
All	0.0	0.0	0.0	0.2	0.2	0.5
[1] Based on the modeling period of 1922 to 2003.						

Table C.5.2-122. Difference and Percent Difference in the Percentage of Months from March through July When Average Monthly Temperature Falls Below 52°F and Exceeds 75°F and 81°F in the Feather River at Gridley

WY Type	Comparison[1]	EBC1 vs. PP_ELT	EBC1 vs. PP_LLT	EBC2 vs. EBC2_ELT	EBC2 vs. EBC2_LLT	EBC2 vs. PP_ELT	EBC2 vs. PP_LLT	EBC2_ELT vs. PP_ELT	EBC2_LLT vs. PP_LLT
Temperatures below 52°F									
Wet	Difference	-4.6	-8.5	-3.8	-6.2	-3.8	-7.7	0.0	-1.5
	Percent difference	-38%	-69%	-33%	-53%	-33%	-67%	0%	-29%
Above Normal	Difference	-3.6	-7.3	-1.8	-5.5	-1.8	-5.5	0.0	0.0
	Percent difference	-40%	-80%	-25%	-75%	-25%	-75%	0%	0%
Below Normal	Difference	-2.9	-5.7	-1.4	-4.3	-1.4	-4.3	0.0	0.0
	Percent difference	-50%	-100%	-33%	-100%	-33%	-100%	0%	NA
Dry	Difference	1.1	0.0	0.0	0.0	1.1	0.0	1.1	0.0
	Percent difference	NA	NA	NA	NA	NA	NA	NA	NA
Critical	Difference	0.0	-1.7	0.0	-1.7	0.0	-1.7	0.0	0.0
	Percent difference	0%	-100%	0%	-100%	0%	-100%	0%	NA
All	Difference	-2.2	-4.9	-1.7	-3.7	-1.5	-4.2	0.2	-0.5
	Percent difference	-35%	-77%	-30%	-65%	-26%	-74%	6%	-25%
Temperatures above 75°F									
Wet	Difference	0.8	1.5	0.8	0.0	1.5	2.3	0.8	2.3
	Percent difference	50%	100%	100%	0%	200%	300%	50%	300%
Above Normal	Difference	0.0	1.8	0.0	0.0	0.0	1.8	0.0	1.8
	Percent difference	NA	NA	NA	NA	NA	NA	NA	NA
Below Normal	Difference	1.4	2.9	0.0	0.0	1.4	2.9	1.4	2.9
	Percent difference	NA	NA	NA	NA	NA	NA	NA	NA
Dry	Difference	1.1	10.0	0.0	2.2	1.1	10.0	1.1	7.8
	Percent difference	NA	NA	NA	NA	NA	NA	NA	350%
Critical	Difference	10.0	16.7	6.7	10.0	8.3	15.0	1.7	5.0
	Percent difference	NA	NA	400%	600%	500%	900%	20%	43%
All	Difference	2.2	5.9	1.2	2.0	2.2	5.9	1.0	4.0
	Percent difference	450%	1200%	250%	400%	450%	1200%	57%	160%

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WY Type	Comparison[1]	EBC1 vs. PP_ELT	EBC1 vs. PP_LLT	EBC2 vs. EBC2_ELT	EBC2 vs. EBC2_LLT	EBC2 vs. PP_ELT	EBC2 vs. PP_LLT	EBC2_ELT vs. PP_ELT	EBC2_LLT vs. PP_LLT
Temperatures above 81°F									
Wet	Difference	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Percent difference	NA	NA	NA	NA	NA	NA	NA	NA
Above Normal	Difference	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Percent difference	NA	NA	NA	NA	NA	NA	NA	NA
Below Normal	Difference	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Percent difference	NA	NA	NA	NA	NA	NA	NA	NA
Dry	Difference	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Percent difference	NA	NA	NA	NA	NA	NA	NA	NA
Critical	Difference	1.7	3.3	0.0	1.7	1.7	3.3	1.7	1.7
	Percent difference	NA	NA	NA	NA	NA	NA	NA	100%
All	Difference	0.2	0.5	0.0	0.2	0.2	0.5	0.2	0.2
	Percent difference	NA	NA	NA	NA	NA	NA	NA	100%

[1]A positive value indicates a higher value under the second model scenario listed in the column title.
NA = Could not be calculated because dividing by 0.

Honcut Creek

Water temperature exceedances are presented for all water-year types for March through July, the green sturgeon adult migration period, in the Feather River at Honcut Creek in Figure C.5.2-302. The frequencies at which water temperatures are below 52°F and above 75°F and 81°F are presented in Table C.5.2-123 and differences between pairs of model scenarios in the frequency of exceedance are presented in Table C.5.2-124.

Combining all water years, mean monthly water temperatures in the Feather River at Honcut Creek from March through July were lower than the 52°F threshold in 6% of months under EBC1 and EBC2, in 2–4% of months under EBC2_ELT and EBC2_LLT, and in 1–4% of months under PP_ELT and PP_LLT (Table C.5.2-119). Accounting for climate change effects, the frequency of temperatures below 52°F under PP_ELT and PP_LLT is predicted to be <1% greater and <1% lower than under EBC2_ELT and EBC2_LLT, respectively (Table C.5.2-124).

Combining all water years, mean monthly water temperatures in the Feather River at Honcut Creek from March through July are predicted to exceed the 75°F threshold in <1% of months under EBC1 and EBC2, in 2–3% of months under EBC2_ELT and EBC2_LLT, and in 4–8% of months under PP_ELT and PP_LLT (Table C.5.2-123). Accounting for climate change effects, the frequency of temperatures are predicted to exceed 75°F under PP_ELT and PP_LLT is predicted to be 2% and 5% greater than under EBC2_ELT and EBC2_LLT, respectively (Table C.5.2-124).

Mean monthly water temperatures in the Feather River at Honcut Creek from March through July are predicted to exceed the 81°F threshold only in critical years under EBC2_LLT, PP_ELT, and PP_LLT (Table C.5.2-123). Accounting for climate change effects, the frequency of temperatures is predicted to exceed 81°F under PP_ELT and PP_LLT is predicted to be <1% greater than under EBC2_ELT and EBC2_LLT, respectively, for all water years combined (Table C.5.2-124).

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Based on these results, it was concluded with moderate certainty that the preliminary proposal will have small adverse (using the 75°F threshold) or negligible effects on temperature-related adult green sturgeon migration habitat conditions in the Feather River at Honcut Creek.

Combining the results of all three sites in the Feather River, it was concluded that the preliminary proposal would have small or no adverse effects on temperature-related adult green sturgeon migration habitat conditions in the Feather River during March through July.

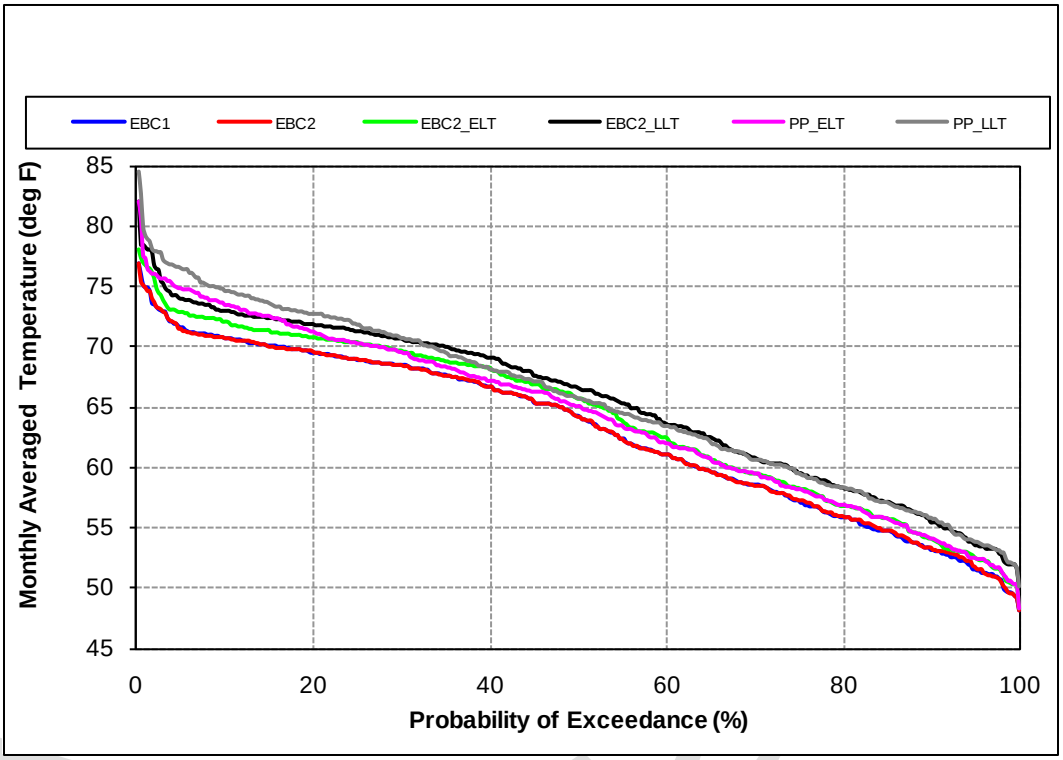

Figure C.5.2-302. Probability of Exceedance Plot for Model Scenarios of Mean Monthly Water Temperature in the Feather River at Honcut Creek, March through July for All Water-Year Types Combined

Table C.5.2-123. Percent of Months from March through July[1] When Monthly Average Temperature Falls Below 52°F and Exceeds 75°F and 81°F in the Feather River at Honcut Creek

Water-Year Type	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
Temperatures below 52°F						
Wet	12.3	11.5	7.7	4.6	7.7	2.3
Above Normal	9.1	7.3	5.5	1.8	5.5	1.8
Below Normal	2.9	4.3	1.4	0.0	1.4	0.0
Dry	0.0	0.0	0.0	0.0	0.0	0.0
Critical	1.7	1.7	1.7	0.0	1.7	0.0
All	5.9	5.7	3.7	1.7	3.7	1.0

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Water-Year Type	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
Temperatures above 75°F						
Wet	1.5	0.8	2.3	0.8	5.4	4.6
Above Normal	0.0	0.0	0.0	0.0	1.8	3.6
Below Normal	0.0	0.0	0.0	0.0	1.4	5.7
Dry	0.0	0.0	0.0	3.3	2.2	11.1
Critical	1.7	3.3	8.3	13.3	10.0	16.7
All	0.7	0.7	2.0	3.0	4.2	7.9
Temperatures above 81°F						
Wet	0.0	0.0	0.0	0.0	0.0	0.0
Above Normal	0.0	0.0	0.0	0.0	0.0	0.0
Below Normal	0.0	0.0	0.0	0.0	0.0	0.0
Dry	0.0	0.0	0.0	0.0	0.0	0.0
Critical	0.0	0.0	0.0	1.7	1.7	3.3
All	0.0	0.0	0.0	0.2	0.2	0.5
[1] Based on the modeling period of 1922 to 2003.						

Table C.5.2-124. Comparison of the Percent of Days from March through July When Average Temperature Falls Below 52°F and Exceeds 75°F and 81°F in the Feather River at Honcut Creek

WY Type	Comparison[1]	EBC1_ELT vs. PP_ELT	EBC1_LLT vs. PP_LLT	EBC2 vs. EBC2_ELT	EBC2 vs. EBC2_LLT	EBC2 vs. PP_ELT	EBC2 vs. PP_LLT	EBC2_ELT vs. PP_ELT	EBC2_LLT vs. PP_LLT
Temperatures below 52°F									
Wet	Difference	-4.6	-10.0	-3.8	-6.9	-3.8	-9.2	0.0	-2.3
	Percent difference	-38%	-81%	-33%	-60%	-33%	-80%	0%	-50%
Above Normal	Difference	-3.6	-7.3	-1.8	-5.5	-1.8	-5.5	0.0	0.0
	Percent difference	-40%	-80%	-25%	-75%	-25%	-75%	0%	0%
Below Normal	Difference	-1.4	-2.9	-2.9	-4.3	-2.9	-4.3	0.0	0.0
	Percent difference	-50%	-100%	-67%	-100%	-67%	-100%	0%	NA
Dry	Difference	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Percent difference	NA	NA	NA	NA	NA	NA	NA	NA
Critical	Difference	0.0	-1.7	0.0	-1.7	0.0	-1.7	0.0	0.0
	Percent difference	0%	-100%	0%	-100%	0%	-100%	0%	NA
All	Difference	-2.2	-4.9	-2.0	-4.0	-2.0	-4.7	0.0	-0.7
	Percent difference	-38%	-83%	-35%	-70%	-35%	-83%	0%	-43%
Temperatures above 75°F									
Wet	Difference	3.8	3.1	1.5	0.0	4.6	3.8	3.1	3.8
	Percent difference	250%	200%	200%	0%	600%	500%	133%	500%
Above Normal	Difference	1.8	3.6	0.0	0.0	1.8	3.6	1.8	3.6
	Percent difference	NA	NA	NA	NA	NA	NA	NA	NA
Below Normal	Difference	1.4	5.7	0.0	0.0	1.4	5.7	1.4	5.7
	Percent difference	NA	NA	NA	NA	NA	NA	NA	NA
Dry	Difference	2.2	11.1	0.0	3.3	2.2	11.1	2.2	7.8
	Percent difference	NA	NA	NA	NA	NA	NA	NA	233%

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WY Type	Comparison[1]	EBC1_ELT vs. PP_ELT	EBC1_LLT vs. PP_LLT	EBC2 vs. EBC2_ELT	EBC2 vs. EBC2_LLT	EBC2 vs. PP_ELT	EBC2 vs. PP_LLT	EBC2_ELT vs. PP_ELT	EBC2_LLT vs. PP_LLT
Critical	Difference	8.3	15.0	5.0	10.0	6.7	13.3	1.7	3.3
	Percent difference	500%	900%	150%	300%	200%	400%	20%	25%
All	Difference	3.5	7.2	1.2	2.2	3.5	7.2	2.2	4.9
	Percent difference	467%	967%	167%	300%	467%	967%	113%	167%
Temperatures above 81°F									
Wet	Difference	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Percent difference	NA	NA	NA	NA	NA	NA	NA	NA
Above Normal	Difference	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Percent difference	NA	NA	NA	NA	NA	NA	NA	NA
Below Normal	Difference	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Percent difference	NA	NA	NA	NA	NA	NA	NA	NA
Dry	Difference	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Percent difference	NA	NA	NA	NA	NA	NA	NA	NA
Critical	Difference	1.7	3.3	0.0	1.7	1.7	3.3	1.7	1.7
	Percent difference	NA	NA	NA	NA	NA	NA	NA	100%
All	Difference	0.2	0.5	0.0	0.2	0.2	0.5	0.2	0.2
	Percent difference	NA	NA	NA	NA	NA	NA	NA	100%

[1] A positive value indicates a higher value under the proposed project than the EBC.
NA = Could not be calculated because dividing by 0.

Turbidity

Turbidity effects of BDCP actions on green sturgeon adults would be the same as previously described for white sturgeon adults.

C.5.2.4.7 Lamprey

Eggs

Water Temperature

Exact spawning locations of Pacific and river lamprey in the Feather River are not well known. Therefore, this analysis includes upstream (Fish Barrier Dam) and downstream (below Thermalito Afterbay) locations, which encompass the range in which the species are thought to spawn (Kurth pers. comm.).

Because only monthly model outputs were available for the Feather River for this analysis, a 2-month period was used to represent the duration of each egg cohort. This duration is longer than the incubation period of 18–49 days observed by Brumo (2006) and is meant to be conservative. The number of cohorts exposed to water temperatures above 71.6°F is reported for Pacific lamprey in Table C.5.2-75, and exceedances of 71.6°F and 77°F for river lamprey are reported in Table C.5.2-76; differences between model scenarios are reported in Table C.5.2-77 for Pacific lamprey and Table C.5.2-78 for river lamprey.

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Fish Barrier Dam

For Pacific lamprey at the Fish Barrier Dam, the percent of egg cohorts experiencing water temperatures that exceed 71.6°F is predicted to be 0% under all model scenarios except EBC2_LLT, which would result in exposure of only one cohort, or less than 1% of the total number of cohorts over the 82-year CALSIM period (Figure C.5.2-303, Table C.5.2-75, Table C.5.2-77).

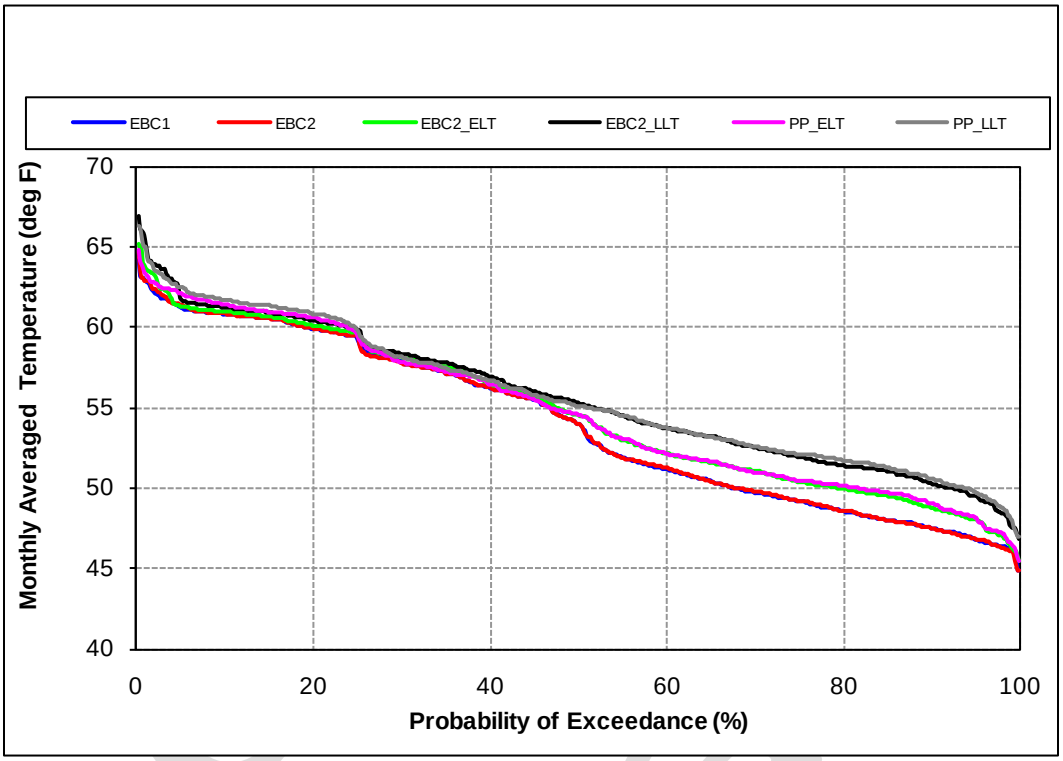

Figure C.5.2-303. Probability of Exceedance Plot for Model Scenarios of Mean Monthly Temperature of the Feather River at the Fish Barrier Dam, January through August

For river lamprey, mean monthly water temperatures in the Feather River at the Fish Barrier Dam are predicted to be below 71.6°F and 77°F between February and June all of the time under all model scenarios (Figure C.5.2-304, Table C.5.2-76, Table C.5.2-78).

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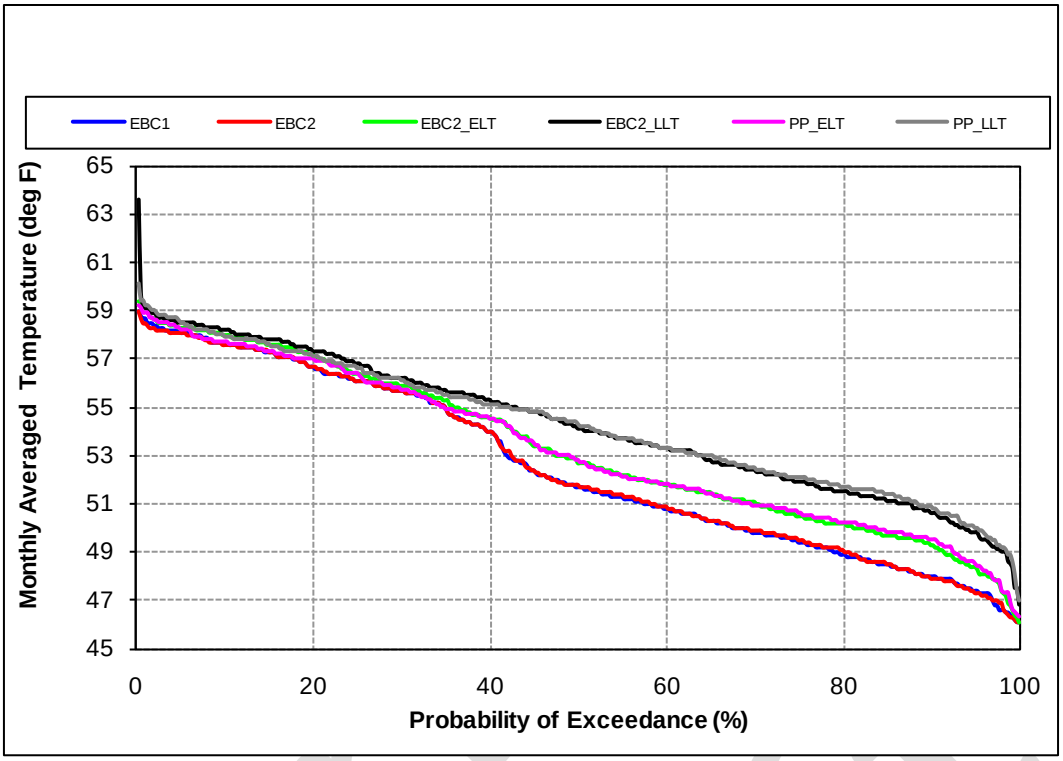

Figure C.5.2-304. Probability of Exceedance Plot for Model Scenarios of Mean Monthly Water Temperature of the Feather River at the Fish Barrier Dam, February through June

Below Thermalito Afterbay

For Pacific lamprey below Thermalito Afterbay, the percent of egg cohorts experiencing water temperatures that exceed 71.6°F is predicted to be 4% under EBC1 and EBC2, 6–14% under EBC2_ELT and EBC2_LLT and 17–27% under PP_ELT and PP_LLT (Figure C.5.2-305, Table C.5.2-75). Under early long-term conditions, implementation of the preliminary proposal (PP_ELT) would result in exposure of 113 cohorts to temperatures exceeding 71.6°F, a 183% increase relative to EBC2_ELT (40 cohorts) (Table C.5.2-77). Under late long-term conditions, implementation of the preliminary proposal (PP_LLT) would result in exposure of 176 cohorts to temperatures exceeding 71.6°F, a 91% increase relative to EBC2_LLT (92 cohorts).

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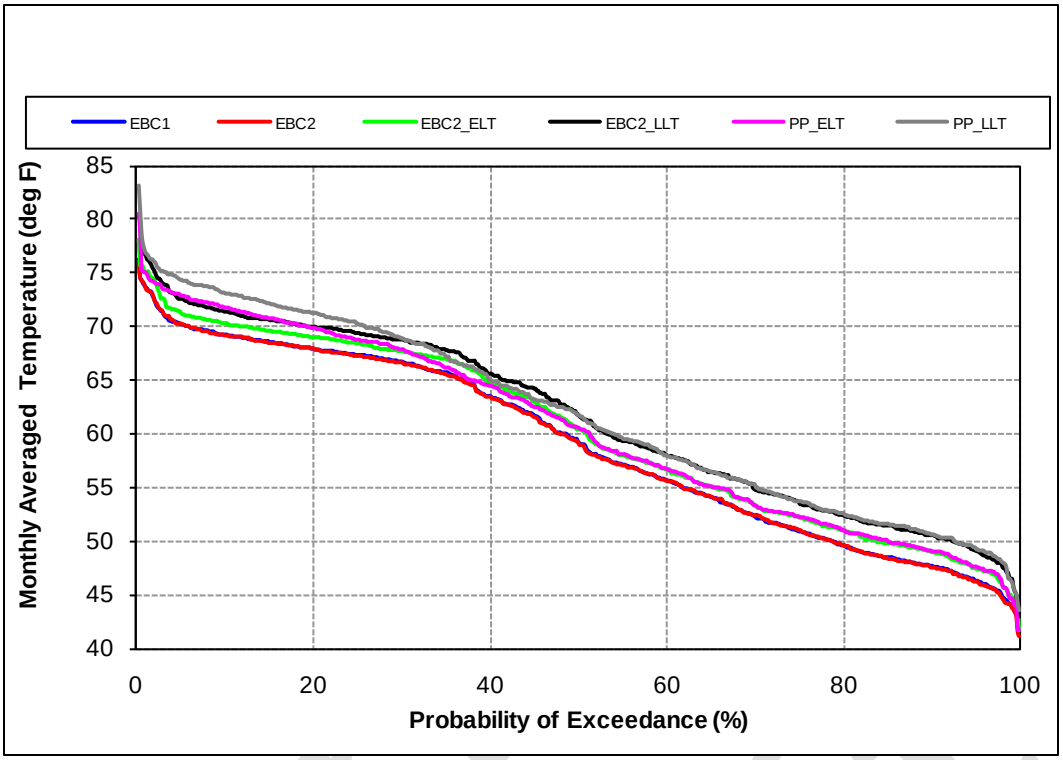

Figure C.5.2-305. Probability of Exceedance Plot for Model Scenarios of Mean Monthly Temperature of the Feather River below Thermalito Afterbay, January to August

For river lamprey below Thermalito Afterbay, the percent of egg cohorts experiencing water temperatures that exceed 71.6°F is predicted to be 2% under EBC1 and EBC2, 3–9% under EBC2_ELT and EBC2_LLT, and 10%–15% under PP_ELT and PP_LLT (Figure C.5.2-306, Table C.5.2-76). Under early long-term conditions, implementation of the preliminary proposal (PP_ELT) would result in exposure of 42 cohorts to temperatures exceeding 71.6°F, a 223% increase relative to EBC2_ELT (13 cohorts) (Table C.5.2-78). Under late long-term conditions, implementation of the preliminary proposal (PP_LLT) would result in exposure of 61 cohorts to temperatures exceeding 71.6°F, a 61% increase relative to EBC2_LLT (38 cohorts).

The percent of river lamprey egg cohorts experiencing water temperatures that exceed 77°F is predicted to be 0% under EBC1, EBC2, and EBC2_ELT and ≤1% under EBC2_LLT, PP_ELT, and PP_LLT (Figure C.5.2-306, Table C.5.2-76). Under early long-term conditions, implementation of the preliminary proposal (PP_ELT) would result in exposure of two cohorts to temperatures exceeding 77°F versus no cohorts in the absence of implementation of the preliminary proposal (EBC2_ELT) (Table C.5.2-78). Under late long-term conditions, implementation of the preliminary proposal (PP_LLT) would result in exposure of four cohorts to temperatures exceeding 77°F versus two cohorts in the absence of implementation of the preliminary proposal (EBC2_LLT).

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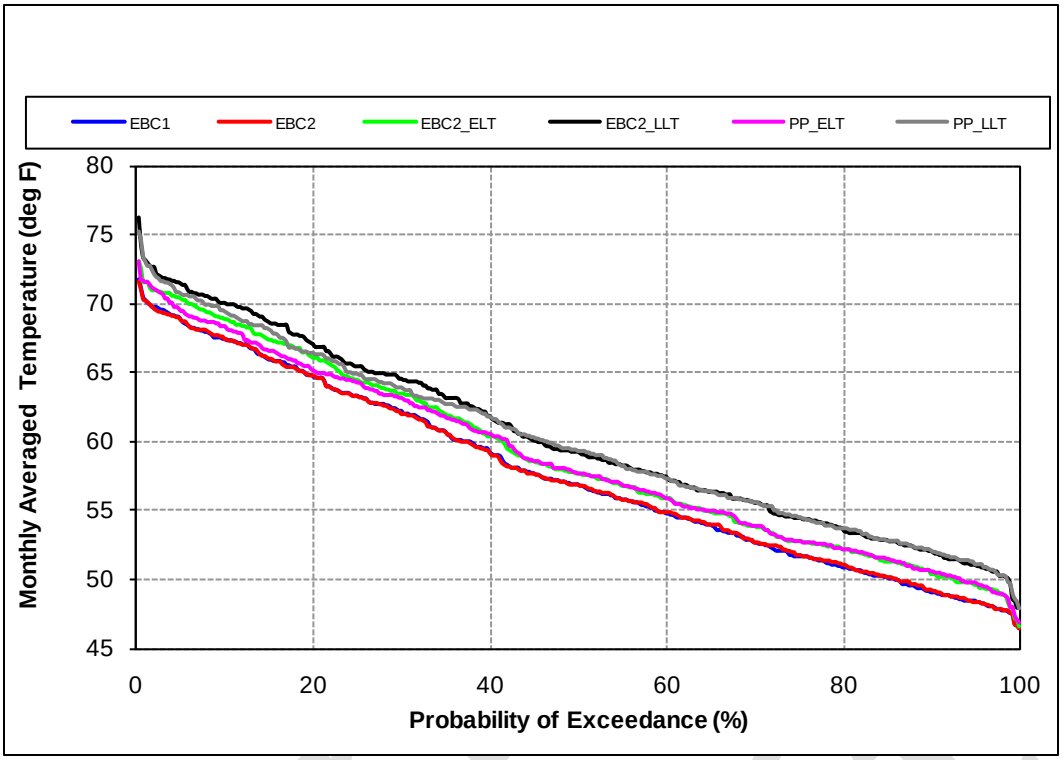

Figure C.5.2-306. Probability of Exceedance Plot for Model Scenarios of Mean Monthly Water Temperature of the Feather River below Thermalito Afterbay, February to June

These results suggest that there are moderate effects of the preliminary proposal on Pacific lamprey eggs/embryos in the Feather River, but these effects are smaller than those of future climate change.

Results also suggest moderate effects of the preliminary proposal on river lamprey eggs/embryos in the Feather River below Thermalito Afterbay based on the temperature criterion of 71.6°F. Effects for PP_ELT are greater than future climate change effects for the same timeframe; effects of PP_LLT are substantially smaller than those of future climate change. Climate change will slightly increase river lamprey eggs/embryos experiencing water temperatures greater than 77°F in the Feather River in the LLT timeframe; effects of the preliminary proposal would result in a slight increase in cohorts predicted to be exposed to temperatures greater than 77°F in the early long-term and would double the small climate change increase expected in the late long-term. Because this analysis uses water temperature model outputs based on CALSIM outputs, error has been propagated and level of certainty of these results is moderate.

Redd Dewatering

Below Thermalito Afterbay

For Pacific lamprey, the total predicted number of redd cohorts between January and August experiencing a month-over-month decrease in flow of greater than 50% in the Feather River at Thermalito Afterbay ranged between 108 (EBC2_LLT) and 156 cohorts (PP_ELT) (Table C.5.2-56).

There are six and three more redd cohorts (4% and 2%) predicted to experience a month-over-month change in flow of greater than 50% for PP_ELT and PP_LLT, respectively, relative to the EBC1 (Table C.5.2-57). There are 47 and 44 more redd cohorts (43% and 40%) predicted to experience a

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month-over-month change in flow of greater than 50% for PP_ELT and PP_LLT, respectively, relative to the EBC2.

Isolating the effect of the preliminary proposal from the effects of climate change, there are 43 and 45 more cohorts (38% and 42%) predicted to experience a month-over-month change in flow of greater than 50% for the PP_ELT and PP_LLT, respectively, relative to the EBC2_ELT and EBC2_LLT.

For river lamprey, the predicted number of redd cohorts experiencing a month-over-month decrease in flow of more than 50% in the Feather River below Thermalito Afterbay is between 58 (EBC2_LLT) and 75 cohorts (PP_ELT) (Table C.5.2-58).

There are seven and zero more redd cohorts (10% and 0%, respectively) predicted to experience a month-over-month change in flow of greater than 50% in the PP_ELT and PP_LLT, respectively, relative to the EBC1 (Table C.5.2-59). There are 15 and eight more redd cohorts (25% and 13%, respectively) predicted to experience a month-over-month change in flow of greater than 50% in the PP_ELT and PP_LLT, respectively, relative to the EBC2.

Removing the effect of climate change, there are seven and 10 fewer redd cohorts (10% and 17%, respectively) predicted to experience a month-over-month change in flow of greater than 50% in the PP_ELT and PP_LLT relative to the EBC2_ELT and EBC2_LLT, respectively.

These results indicate that the number of redd cohorts predicted to experience a month-over-month change in flow of greater than 50% in the Feather River, which is assumed here to represent a redd dewatering event, would be moderately greater under the preliminary proposal for Pacific lamprey (38% to 42%) and river lamprey (10% to 17%).

Ammocoete

Water Temperature

Predicted average monthly water temperatures in the Feather River at the Fish Barrier Dam and below Thermalito Afterbay are presented in Figure C.5.2-307 and Figure C.5.2-308, respectively.

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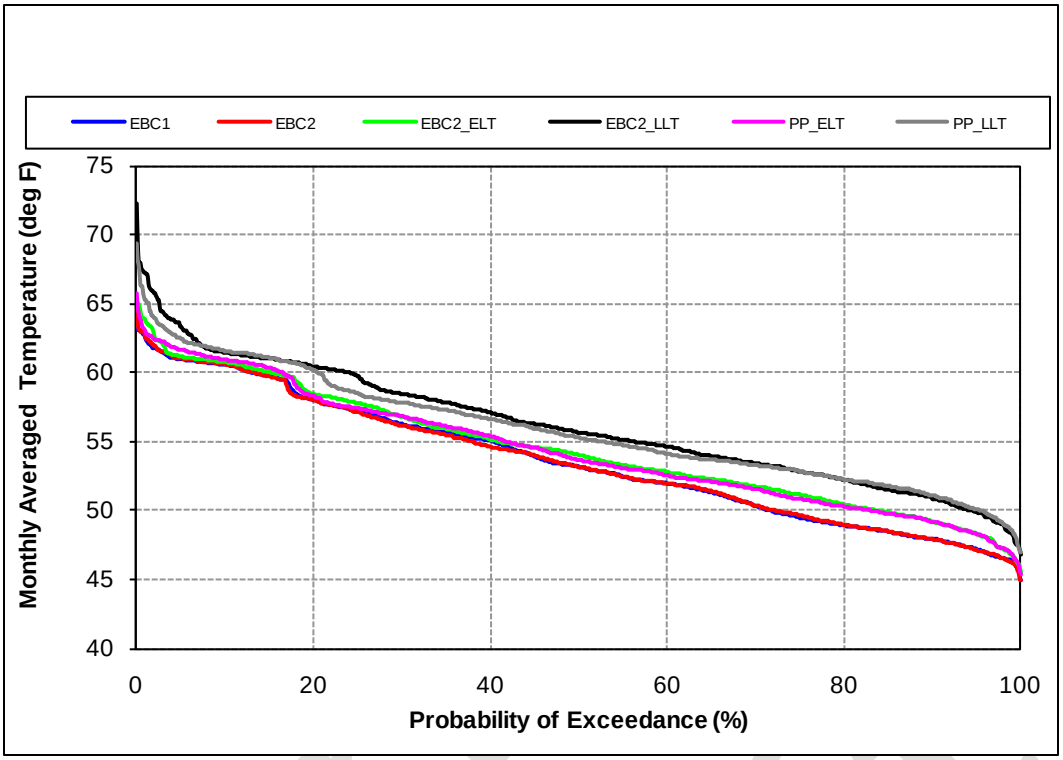

Figure C.5.2-307. Probability of Exceedance Plot for Model Scenarios of Mean Monthly Temperature of the Feather River at Fish Barrier Dam for All Months

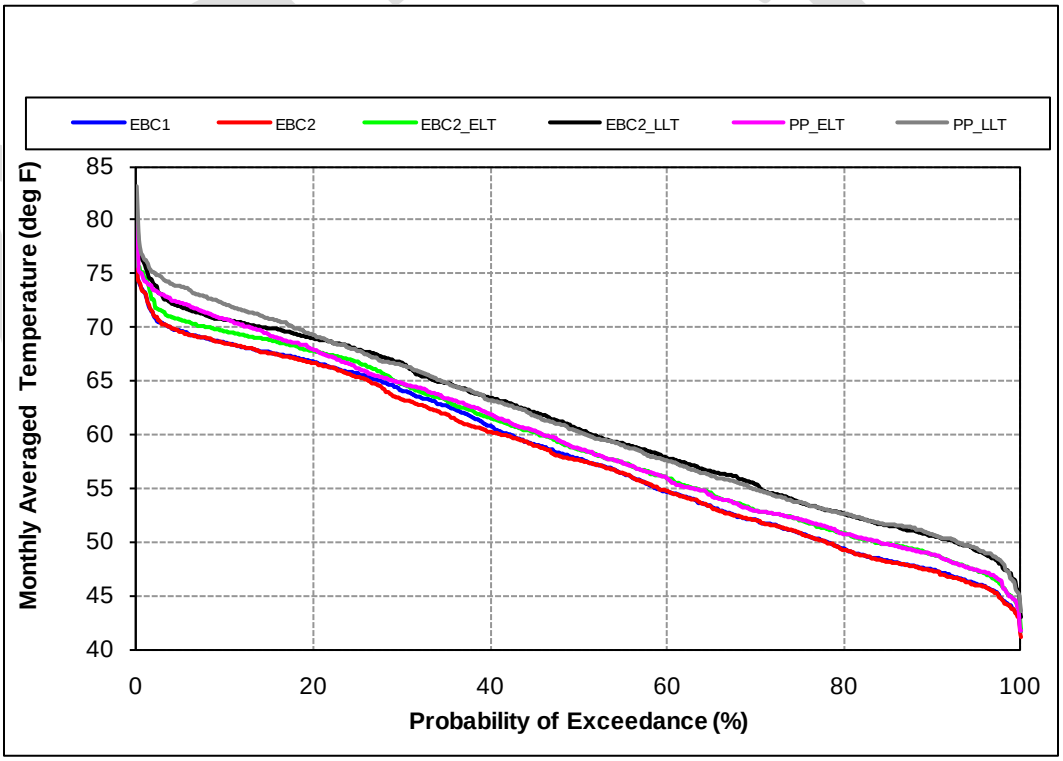

Figure C.5.2-308. Probability of Exceedance Plot for Model Scenarios of Mean Monthly Temperature of the Feather River below Thermalito Afterbay for All Months

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Fish Barrier Dam

For Pacific lamprey in the Feather River at Fish Barrier Dam, the percent of ammocoete cohorts experiencing water temperatures exceeding 71.6°F is predicted to be 0% under all model scenarios except EBC2_LLT, which would result in exposure of 9% of the total number of cohorts to temperatures exceeding this threshold (Table C.5.2-60,Table C.5.2-61). Under late long-term conditions, implementation of the preliminary proposal (PP_LLT) would result in no exposure of cohorts to temperatures exceeding 71.6°F compared to 56 cohorts under baseline conditions (EBC2_LLT).

For river lamprey, mean monthly water temperatures exceeding 71.6°F are predicted to occur only under EBC2_LLT, which would result in exposure of 25 ammocoete cohorts (7%) to temperatures exceeding this threshold during February through June of the 82-year period (Table C.5.2-62, Table C.5.2-63). Mean monthly water temperatures are predicted to be below 77°F under all model scenarios throughout the 82-year simulation period.

These results indicate that the effects of the preliminary proposal on Pacific lamprey are beneficial (reduced exposure of cohorts to temperatures exceeding threshold) and that effects on river lamprey ammocoetes are negligible, although there is a large beneficial effect of the preliminary proposal in the late long-term when examining the 77°F threshold. The vast proportion of effects on water temperature at the Fish Barrier Dam is due to climate change.

Below Thermalito Afterbay

For Pacific lamprey below Thermalito Afterbay, the percent of ammocoete cohorts experiencing water temperatures exceeding 71.6°F is predicted to be 64%–74% under EBC1 and EBC2, 80%–88% under EBC2_ELT and EBC_LLT, and 96%–100% under PP_ELT and PP_LLT (Table C.5.2-60). Under early long-term conditions, implementation of the preliminary proposal (PP_ELT) would result in exposure of 570 cohorts to temperatures exceeding 71.6°F, a 20% increase relative to EBC2_ELT (476 cohorts). Under late long-term conditions, implementation of the preliminary proposal (PP_LLT) would result in exposure of 593 cohorts to temperatures exceeding 71.6°F, a 14% decrease relative to EBC2_LLT (521 cohorts) (Table C.5.2-61).

For river lamprey, the percent of ammocoete cohorts experiencing water temperatures that exceed 71.6°F is predicted to be 50%–57% under EBC1 and EBC2, 68%–84% under EBC2_ELT and EBC2_LLT, and 93%–100% under PP_ELT and PP_LLT (Table C.5.2-62). Under early long-term conditions, implementation of the preliminary proposal (PP_ELT) would result in exposure of 355 cohorts to temperatures exceeding 71.6°F, a 37% increase relative to EBC2_ELT (260 cohorts) (Table C.5.2-63). Under late long-term conditions, implementation of the preliminary proposal (PP_LLT) would result in exposure of 380 cohorts to temperatures exceeding 71.6°F, a 19% increase relative to EBC2_LLT (320 cohorts).

The proportion of river lamprey ammocoete cohorts experiencing water temperatures that exceed 77°F is predicted to be 0% under EBC1 and EBC2, 7%–11% under EBC2_ELT and EBC2_LLT, and 13%–26% under PP_ELT and PP_LLT (Table C.5.2-62). Under early long-term conditions, implementation of the preliminary proposal (PP_ELT) would result in exposure of 50 cohorts to temperatures exceeding 77°F, a 100% increase relative to EBC2_ELT (25 cohorts) (Table C.5.2-63). Under late long-term conditions, implementation of the preliminary proposal (PP_LLT) would result in exposure of 100 cohorts to temperatures exceeding 77°F, a 150% increase relative to EBC2_LLT (40 cohorts).

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These results indicate that there are no predicted temperature-related effects on Pacific lamprey ammocoetes of the preliminary proposal at the Fish Barrier Dam in the early long-term, but a low beneficial effect in the late long-term. Farther down in the Feather River at Thermalito Afterbay, there are adverse effects of both climate change and the preliminary proposal on Pacific lamprey ammocoetes. Results for river lamprey indicate that there is a small to moderate adverse effect of the preliminary proposal on river lamprey ammocoetes. The magnitude of this effect on the river lamprey population is uncertain.

Stranding

Feather River at Thermalito Afterbay

The number of Pacific lamprey ammocoete cohorts that may be affected by month-over-month flow reductions in the Feather River at Thermalito Afterbay is presented in Figure C.5.2-309 and differences between model scenarios are presented in Table C.5.2-125. Flow reductions of 75% and lower are predicted to occur often enough in all model scenarios that 100% of ammocoete cohorts are exposed to these reductions, including under existing biological conditions. As such, no differences are observed for any of these flow reductions.

For flow rate reductions of at least 80%, the number of Pacific lamprey ammocoetes exposed to a given flow reduction is predicted to be between 2% lower and 26% higher under the PP_ELT compared to the EBC1, depending on the flow reduction (Table C.5.2-125). The number of ammocoetes exposed to a given flow reduction is predicted to be between 64% lower and 12% higher under the PP_LLT compared to the EBC1, depending on the flow reduction. The number of ammocoetes exposed to a given flow reduction is predicted to be between 2% lower and 61% higher under the PP_ELT compared to the EBC2, depending on the flow reduction. The number of ammocoetes exposed to a given flow reduction is predicted to be between 65% lower and 43% higher under the PP_LLT compared to the EBC2, depending on the flow reduction.

Isolating the effect of the preliminary proposal from the effects of climate change in the early long-term, the number of Pacific lamprey ammocoetes exposed to a given flow reduction is predicted to be 0% to 9% higher under the PP_ELT compared to the EBC2_ELT, depending on the flow reduction. In the late long-term, the number of ammocoetes exposed to a given flow reduction is predicted to be 28% lower to 1% higher under the PP_LLT compared to the EBC2_LLT, depending on the flow reduction.

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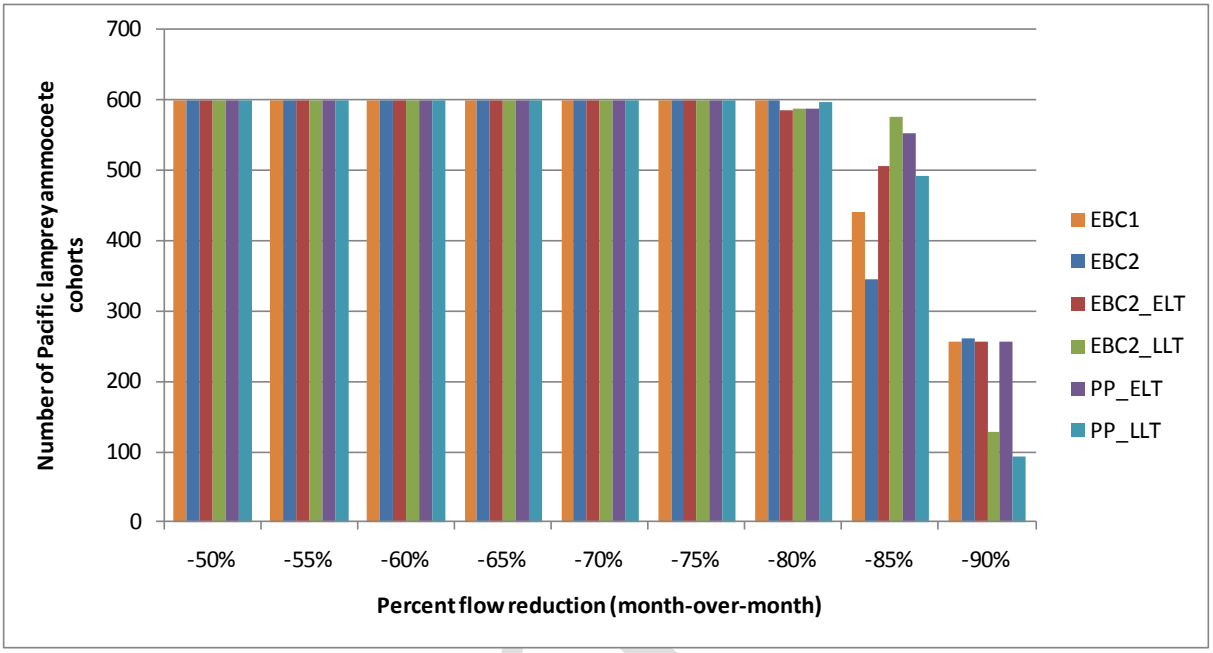

Figure C.5.2-309. Number of Pacific Lamprey Ammocoete Cohorts Exposed to Month-over-Month Flow Reductions of 50% to 90%, Feather River at Thermalito Afterbay

Table C.5.2-125. Percent Difference between Model Scenarios in the Number of Pacific Lamprey Ammocoete Cohorts Exposed to Month-over-Month Flow Reductions, Feather River at Thermalito Afterbay

Percent Flow Reduction	Percent Difference[1]					
	EBC1 vs. PP_ELT	EBC1 vs. PP_LLT	EBC2 vs. PP_ELT	EBC2 vs. PP_LLT	EBC2_ELT vs. PP_ELT	EBC2_LLT vs. PP_LLT
-50%	0.0	0.0	0.0	0.0	0.0	0.0
-55%	0.0	0.0	0.0	0.0	0.0	0.0
-60%	0.0	0.0	0.0	0.0	0.0	0.0
-65%	0.0	0.0	0.0	0.0	0.0	0.0
-70%	0.0	0.0	0.0	0.0	0.0	0.0
-75%	0.0	0.0	0.0	0.0	0.0	0.0
-80%	-2.2	-0.7	-2.2	-0.7	0.2	1.4
-85%	25.5	11.8	60.5	43.0	9.1	-14.6
-90%	0.0	-64.1	-1.5	-64.6	0.0	-28.1

[1] Negative values indicate reduced cohort exposure, a benefit of the preliminary proposal.

The number of river lamprey ammocoete cohorts that may be affected by month-over-month flow reductions in the Feather River at Thermalito Afterbay is presented in Figure C.5.2-310, and differences between model scenarios are presented in Table C.5.2-126.

Flow reductions of 70% and lower are predicted to occur often enough in all model scenarios that 100% of river lamprey ammocoete cohorts are exposed to these reductions, including under existing biological conditions (Table C.5.2-126). As such, no differences are observed for any of these flow reductions. For flow rate reductions of at least 75%, the number of ammocoetes exposed to a given flow reduction is predicted to be identical between EBC1 and PP_ELT and between EBC2 and PP_LLT. The number of ammocoetes exposed to a given flow reduction is predicted to be between

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1% lower and 82% higher under the PP_ELT compared to the EBC2, depending on the flow reduction. The number of ammocoetes exposed to a given flow reduction is predicted to be between 62% lower and 53% higher under the PP_LLT compared to the EBC2, depending on the flow reduction.

Isolating the effects of climate change, the number of river lamprey ammocoetes exposed to a given flow reduction is predicted to be 6% lower to 18% higher under the PP_ELT compared to the EBC2_ELT, depending on the flow reduction. The number of ammocoetes exposed to a given flow reduction is predicted to be 32% lower to 3% higher under the PP_LLT compared to the EBC2_LLT, depending on the flow reduction.

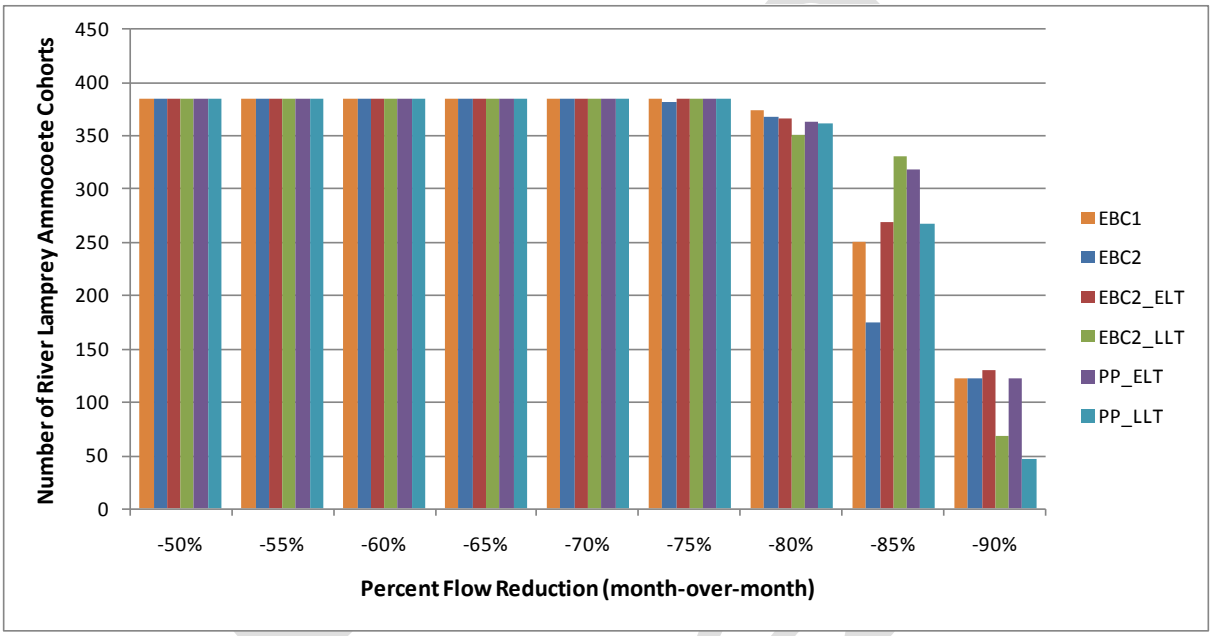

Figure C.5.2-310. Number of River Lamprey Ammocoete Cohorts Exposed to Month-over-Month Flow Reductions of 50% to 90%, Feather River at Thermalito Afterbay

Table C.5.2-126. Percent Difference between Model Scenarios in the Number of River Lamprey Ammocoete Cohorts Exposed to Month-over-Month Flow Reductions, Feather River at Thermalito Afterbay

Percent Flow Reduction	Percent Difference[1]					
	EBC1 vs. PP_ELT	EBC1 vs. PP_LLT	EBC2 vs. PP_ELT	EBC2 vs. PP_LLT	EBC2_ELT vs. PP_ELT	EBC2_LLT vs. PP_LLT
-50%	0.0	0.0	0.0	0.0	0.0	0.0
-55%	0.0	0.0	0.0	0.0	0.0	0.0
-60%	0.0	0.0	0.0	0.0	0.0	0.0
-65%	0.0	0.0	0.0	0.0	0.0	0.0
-70%	0.0	0.0	0.0	0.0	0.0	0.0
-75%	0.0	0.0	0.8	0.8	0.0	0.0
-80%	0.0	0.0	-1.4	-1.9	-0.8	3.1
-85%	0.0	0.0	81.7	53.1	18.2	-19.0
-90%	0.0	0.0	0.0	-61.5	-6.2	-31.9

[1] Negative values indicate reduced cohort exposure, a benefit of the preliminary proposal.

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These results indicate that only under extreme flow reductions are differences between model scenarios observed because existing flow fluctuations are common in the Feather River at Thermalito Afterbay. Under flow reductions in which differences are observed between model scenarios, the preliminary proposal is expected to have generally small (up to 18% increase) adverse effects or small to moderate (up to 32% reduction) beneficial effects on Pacific and river lamprey ammocoete cohorts, depending on the flow reduction. The vast proportion of differences between model scenarios is due to climate change.

C.5.2.5 American River

C.5.2.5.1 Steelhead

Eggs and Alevins

Upstream Spawning Habitat

The two primary potential effects of BDCP operations on habitat conditions for steelhead spawning and egg incubation on the lower American River relate to changes in either instream flows or seasonal water temperatures released from Folsom and Nimbus dams. The primary spawning and egg incubation period extends from January through April. Results of the CALSIM analyses of instream flows within the lower American River at the confluence with the Sacramento River were summarized by month and water-year type. Results of these instream flow summaries are presented in Table C.5.2-127. CALSIM results for each of the model scenarios were used to characterize changes in physical habitat in the river and provide input to the analysis of seasonal water temperatures and habitat conditions for steelhead spawning and egg incubation.

Under simulated future baseline conditions (EBC2_ELT and EBC2_LLT), the general trend in the lower American River during the primary steelhead spawning and egg incubation period is for flows to be lower in critically dry years and higher in wetter years compared to flows under current conditions (EBC1 and EBC2) (Table C.5.2-127, Figure C.5.2-311 through Figure C.5.2-322). Implementation of BDCP operations (PP_ELT and PP_LLT) is predicted to result in small changes (both increases and decreases) in flows relative to existing biological conditions (EBC2_ELT and EBC2_LLT).

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Table C.5.2-127. Mean Monthly Flows (Cubic Feet per Second) in the American River at the Confluence with the Sacramento River Year-Round

Month	WY Type	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
Jan	W	8,748	8,560	10,031	10,960	10,021	10,932
	AN	4,806	4,482	4,895	5,760	4,968	5,764
	BN	2,326	2,179	2,246	1,988	2,049	2,063
	D	1,654	1,565	1,535	1,424	1,551	1,458
	C	1,403	1,379	1,152	1,008	1,215	1,027
	AVG	4,443	4,287	4,786	5,118	4,773	5,132
Feb	W	9,183	8,982	10,275	10,947	10,336	10,967
	AN	6,422	6,139	7,148	8,073	7,589	8,280
	BN	4,309	4,058	4,631	4,888	4,806	5,100
	D	1,781	1,686	1,679	1,756	1,682	1,835
	C	1,119	1,074	985	921	1,057	970
	AVG	5,142	4,967	5,607	6,007	5,732	6,104
Mar	W	5,979	5,915	6,304	6,837	6,301	6,832
	AN	5,364	5,224	5,641	5,661	5,687	5,739
	BN	2,340	2,271	2,503	2,672	2,558	2,565
	D	2,121	1,968	2,095	2,224	2,163	2,022
	C	864	843	785	836	749	759
	AVG	3,672	3,583	3,826	4,063	3,851	3,999
Apr	W	5,156	4,997	5,164	5,300	5,162	5,310
	AN	3,383	3,238	3,136	3,079	3,131	3,117
	BN	2,984	2,788	2,927	2,778	2,913	2,966
	D	1,672	1,673	1,550	1,677	1,717	1,802
	C	996	985	886	1,059	1,046	1,094
	AVG	3,152	3,046	3,066	3,128	3,122	3,202
May	W	5,959	5,711	5,415	4,332	5,433	4,459
	AN	3,700	3,411	2,911	2,285	3,125	2,708
	BN	2,733	2,555	2,222	1,726	2,472	2,273
	D	1,605	1,484	1,399	1,454	1,558	1,901
	C	1,014	992	1,118	790	917	806
	AVG	3,398	3,217	2,993	2,438	3,078	2,733
Jun	W	5,743	5,456	4,206	3,388	4,743	4,261
	AN	3,103	2,973	2,562	2,736	3,463	3,566
	BN	2,631	2,358	2,274	2,603	3,282	3,483
	D	2,282	2,140	2,289	2,320	2,632	2,272
	C	1,621	1,412	1,052	793	1,382	1,026
	AVG	3,462	3,244	2,753	2,545	3,351	3,117
Jul	W	3,844	3,578	3,264	3,560	3,446	3,223
	AN	4,399	4,131	4,344	4,635	4,178	3,954
	BN	4,509	4,548	4,257	4,038	3,658	3,363
	D	3,347	2,987	2,807	2,858	2,596	2,209
	C	1,568	1,218	1,421	1,784	1,141	1,651
	AVG	3,597	3,349	3,221	3,385	3,066	2,901

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Month	WY Type	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
Aug	W	3,295	2,990	2,304	1,858	2,077	1,887
	AN	2,313	2,327	1,921	1,663	1,684	1,534
	BN	2,265	2,164	2,035	2,048	1,834	1,362
	D	2,395	2,049	1,516	1,357	1,270	1,071
	C	1,314	1,094	1,097	899	598	744
	AVG	2,488	2,268	1,852	1,612	1,585	1,400
Sep	W	3,846	4,090	3,771	3,415	2,329	1,699
	AN	2,594	2,894	2,437	1,838	1,417	1,296
	BN	2,205	1,902	1,712	1,402	1,305	1,166
	D	1,691	1,371	1,177	987	1,135	949
	C	1,011	877	591	427	981	421
	AVG	2,495	2,474	2,189	1,870	1,561	1,197
Oct	W	1,607	1,479	1,561	1,499	1,415	1,695
	AN	1,597	1,291	1,481	1,613	1,334	1,855
	BN	1,472	1,376	1,364	1,617	1,502	2,042
	D	1,344	1,190	1,333	1,114	1,156	1,579
	C	1,342	1,260	1,232	1,517	1,381	1,945
	AVG	1,486	1,338	1,418	1,454	1,356	1,789
Nov	W	3,472	3,402	3,363	2,540	3,208	2,504
	AN	3,100	3,389	3,089	2,455	2,696	2,019
	BN	1,990	2,137	1,889	1,618	2,070	1,544
	D	2,094	1,964	1,624	1,326	1,655	1,291
	C	1,897	1,849	1,590	1,489	1,823	1,540
	AVG	2,632	2,641	2,430	1,950	2,395	1,862
Dec	W	6,255	5,627	6,607	6,115	7,035	6,379
	AN	3,072	2,909	3,007	2,856	2,950	2,899
	BN	2,609	2,433	2,774	2,445	3,049	2,628
	D	1,675	1,614	1,564	1,275	1,508	1,273
	C	1,443	1,364	1,278	1,158	1,385	1,156
	AVG	3,457	3,179	3,539	3,224	3,717	3,344

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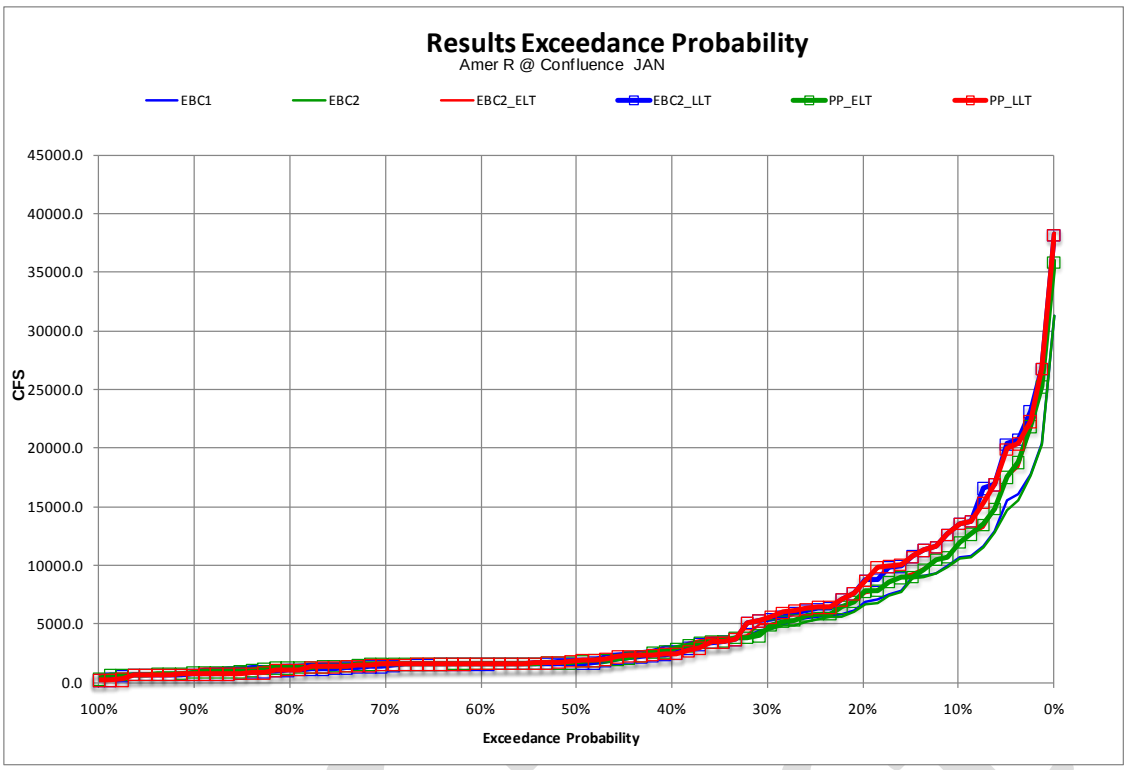

Figure C.5.2-311. Probability of Exceedance Plot for Model Scenarios of Mean Monthly Flow in the American River at the Confluence with the Sacramento River, January

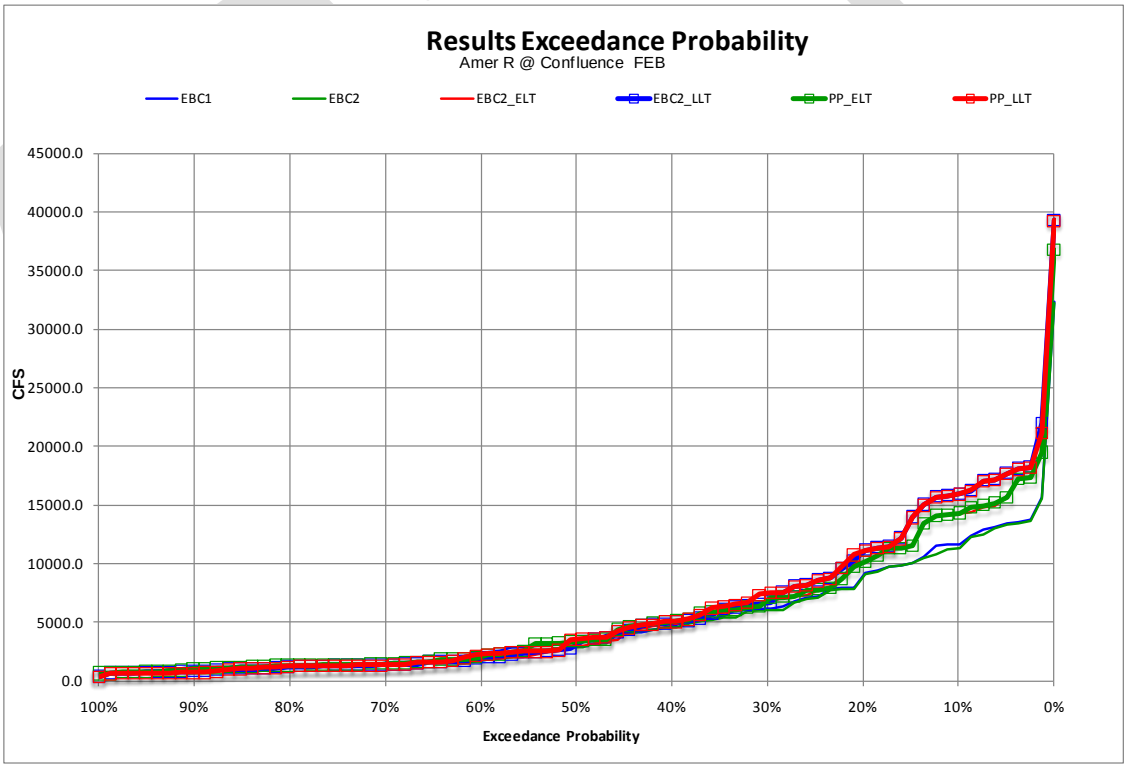

Figure C.5.2-312. Probability of Exceedance Plot for Model Scenarios of Mean Monthly Flow in the American River at the Confluence with the Sacramento River, February

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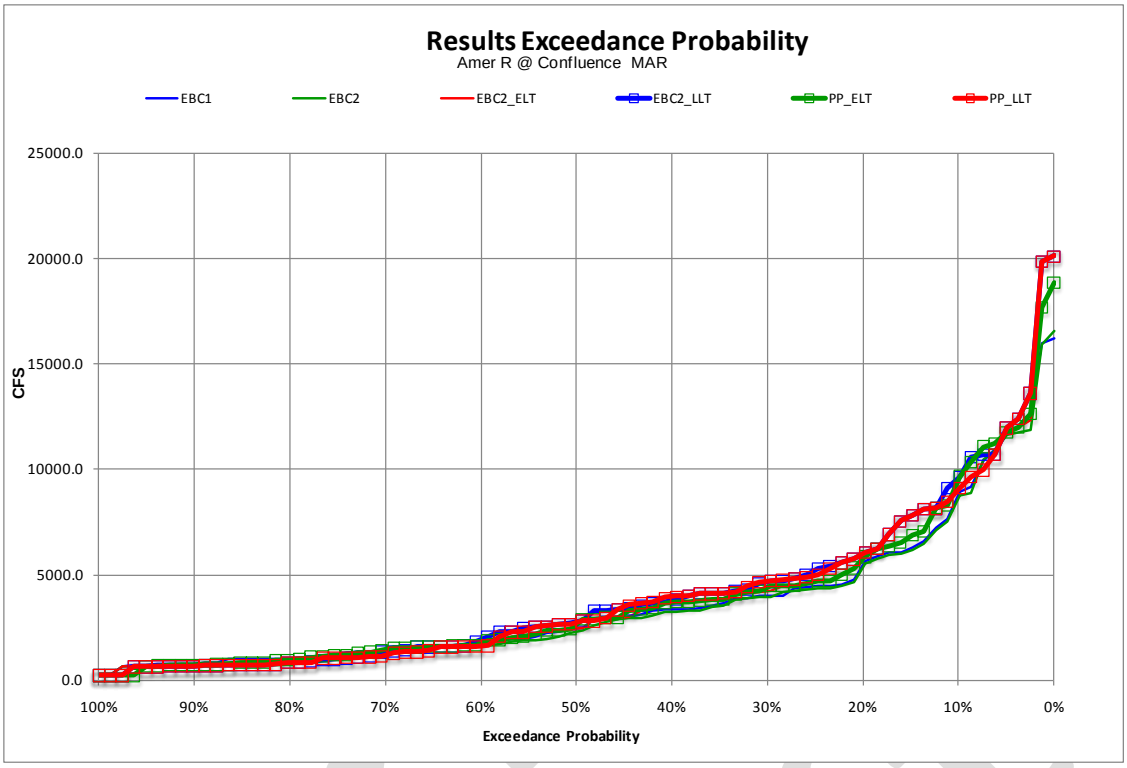

Figure C.5.2-313. Probability of Exceedance Plot for Model Scenarios of Mean Monthly Flow in the American River at the Confluence with the Sacramento River, March

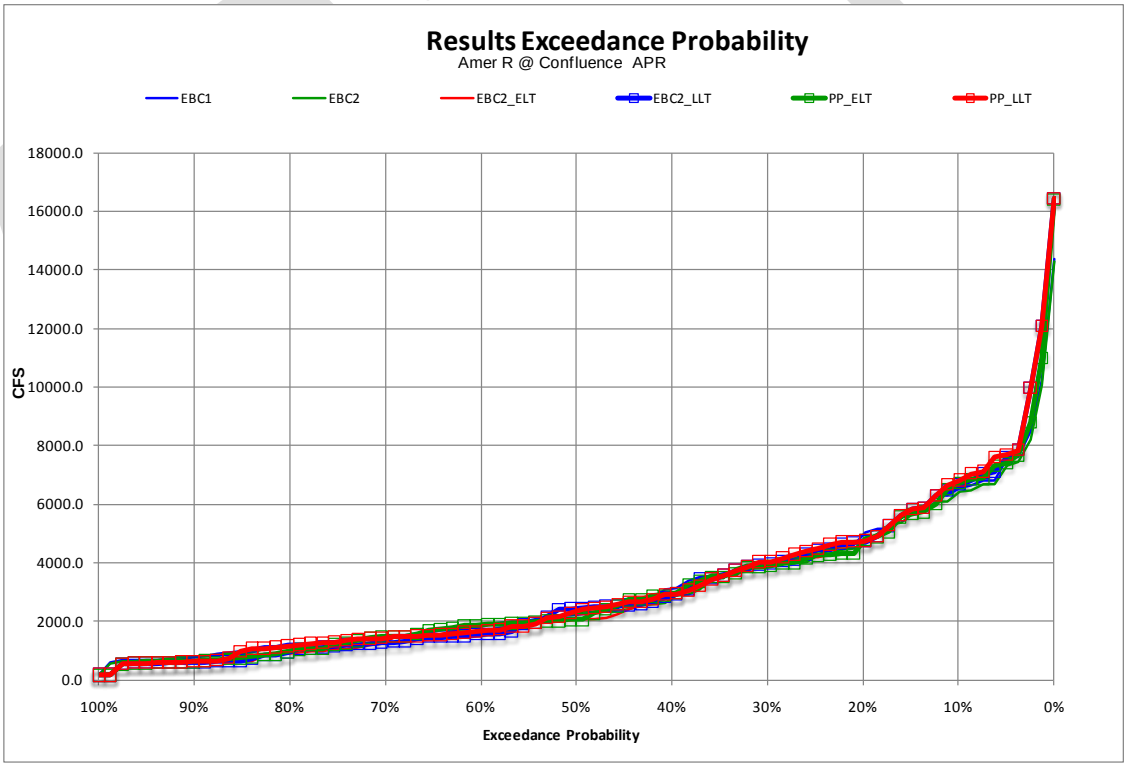

Figure C.5.2-314. Probability of Exceedance Plot for Model Scenarios of Mean Monthly Flow in the American River at the Confluence with the Sacramento River, April

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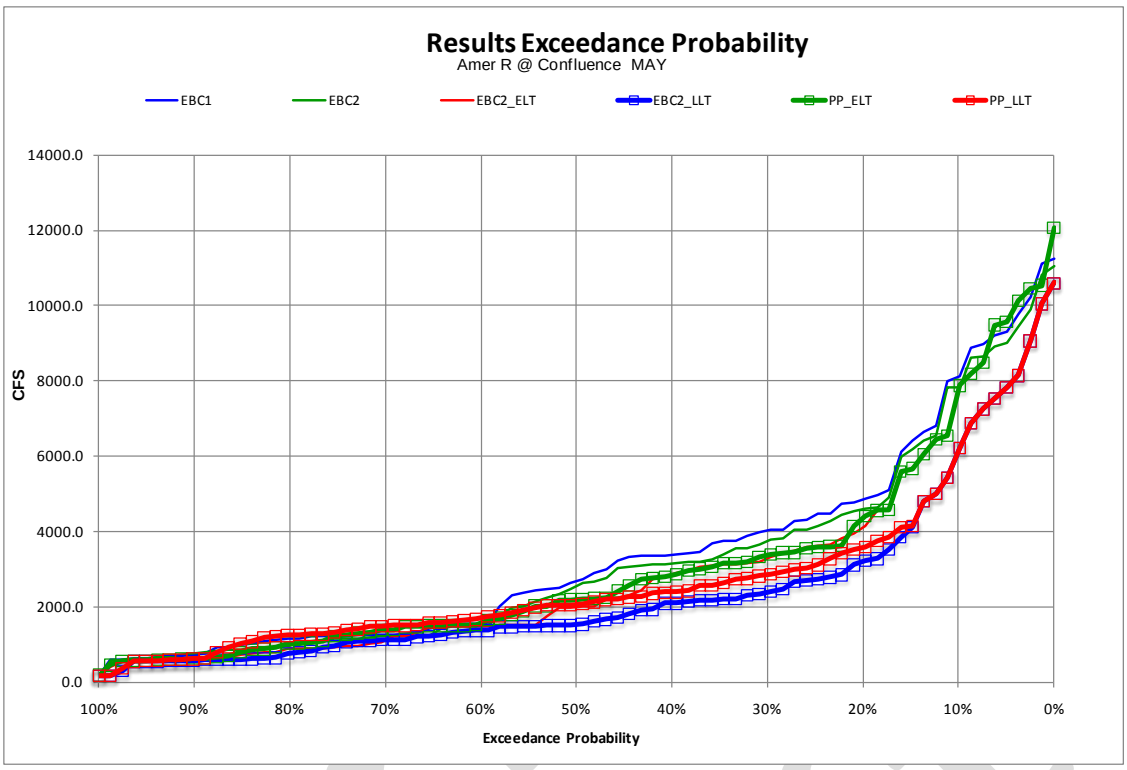

Figure C.5.2-315. Probability of Exceedance Plot for Model Scenarios of Mean Monthly Flow in the American River at the Confluence with the Sacramento River, May

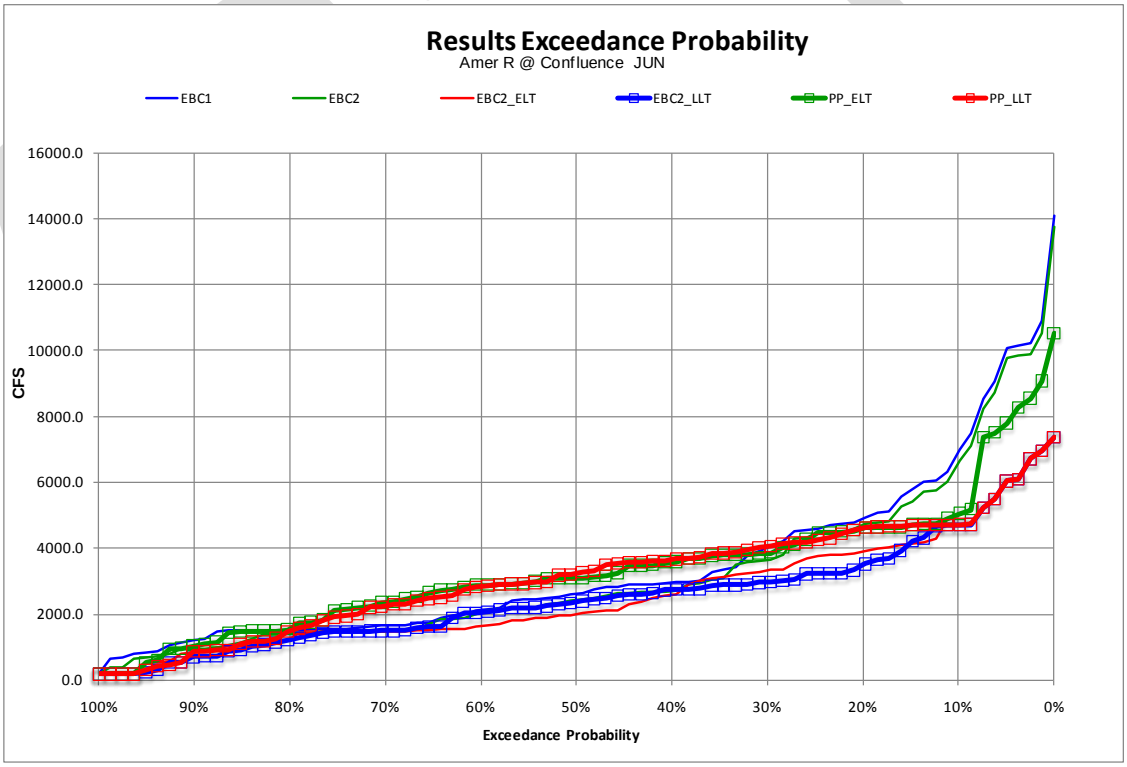

Figure C.5.2-316. Probability of Exceedance Plot for Model Scenarios of Mean Monthly Flow in the American River at the Confluence with the Sacramento River, June

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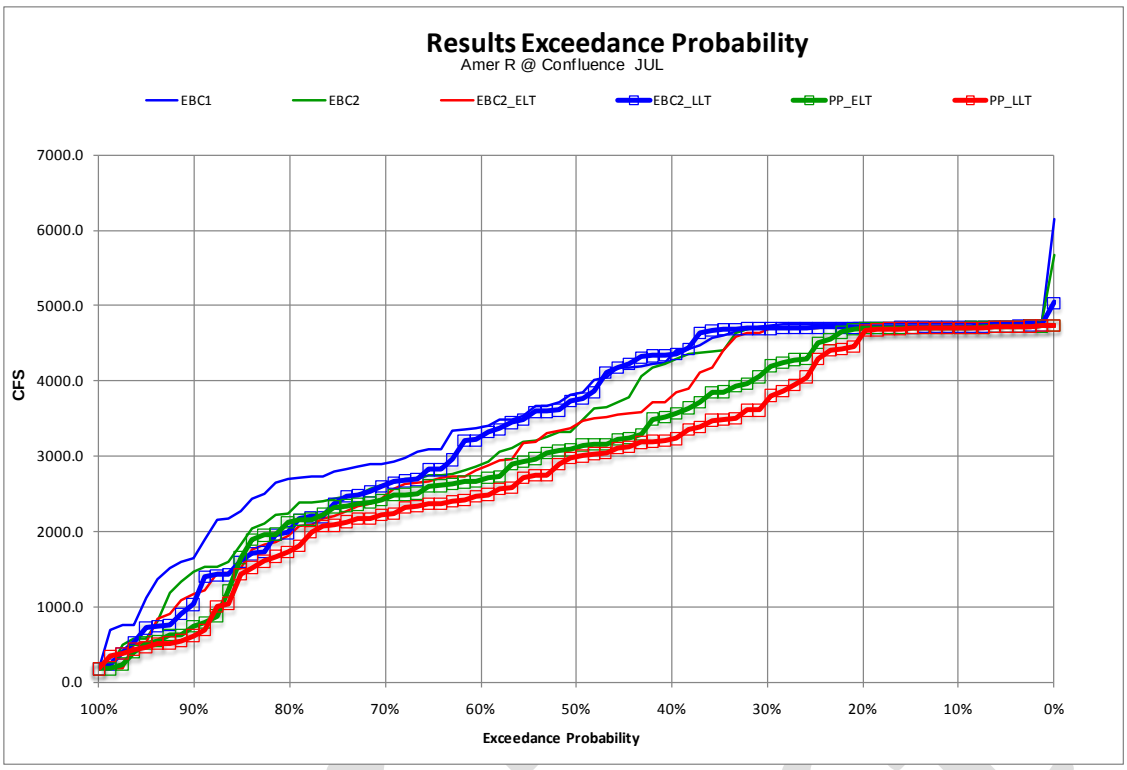

Figure C.5.2-317. Probability of Exceedance Plot for Model Scenarios of Mean Monthly Flow in the American River at the Confluence with the Sacramento River, July

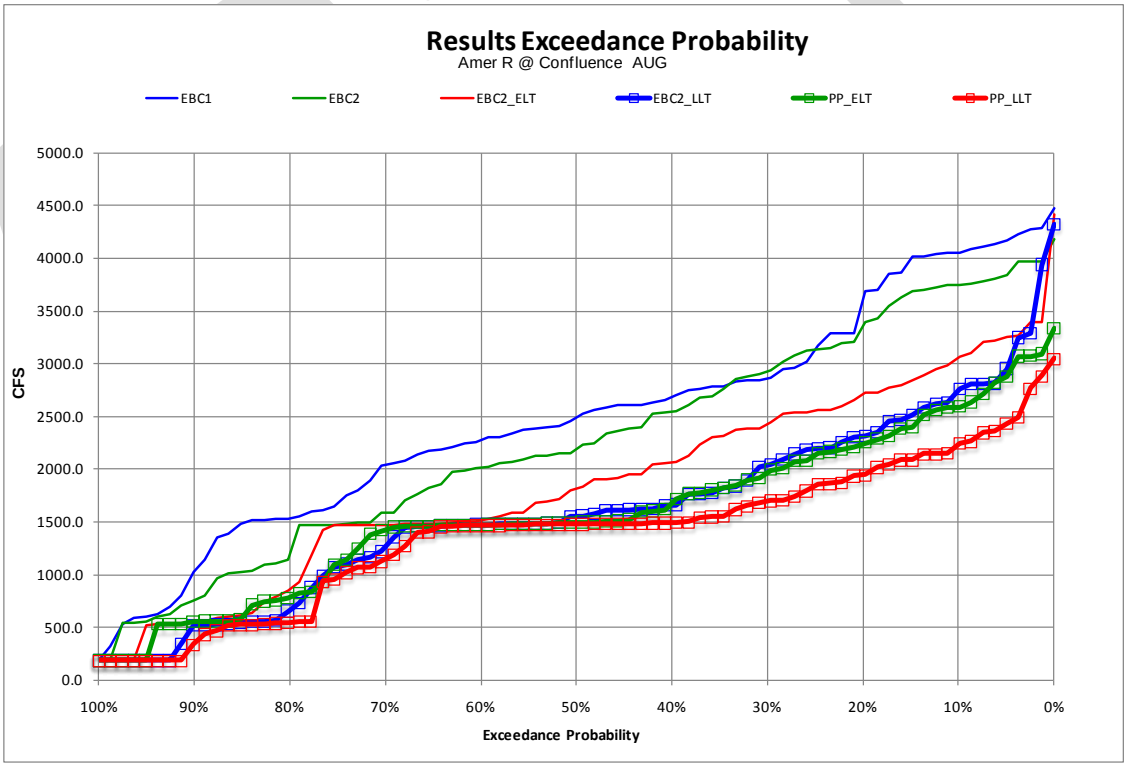

Figure C.5.2-318. Probability of Exceedance Plot for Model Scenarios of Mean Monthly Flow in the American River at the Confluence with the Sacramento River, August

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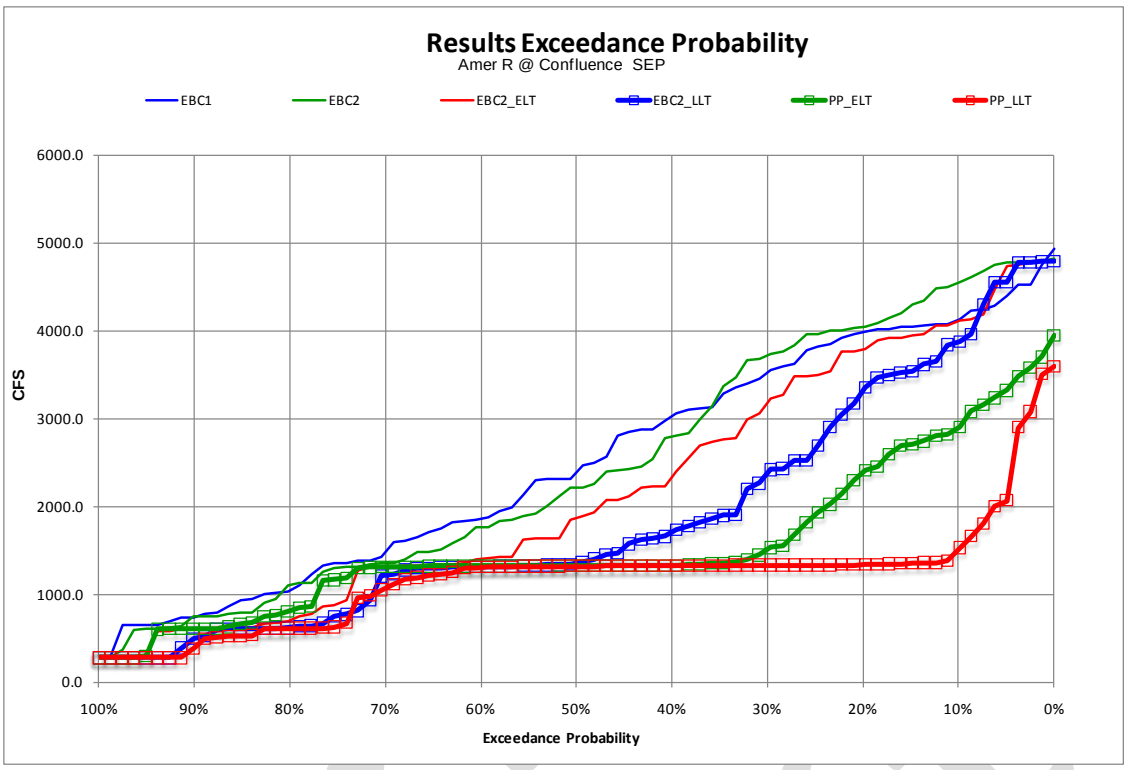

Figure C.5.2-319. Probability of Exceedance Plot for Model Scenarios of Mean Monthly Flow in the American River at the Confluence with the Sacramento River, September

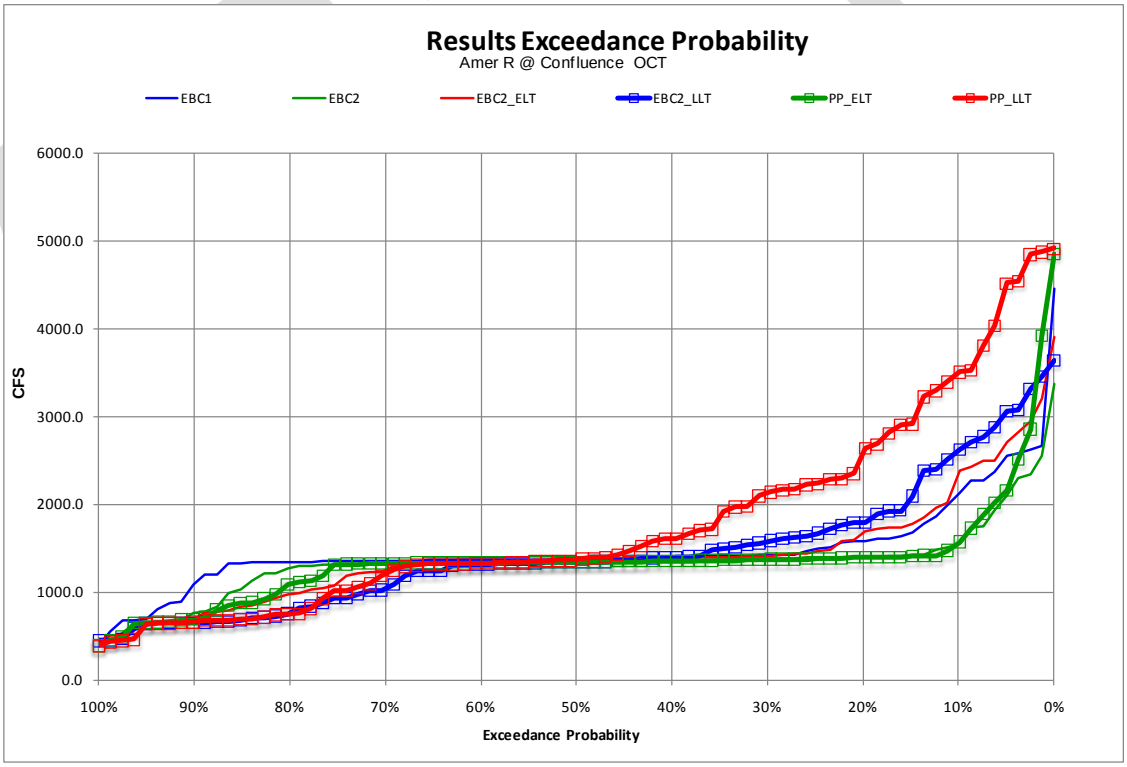

Figure C.5.2-320. Probability of Exceedance Plot for Model Scenarios of Mean Monthly Flow in the American River at the Confluence with the Sacramento River, October

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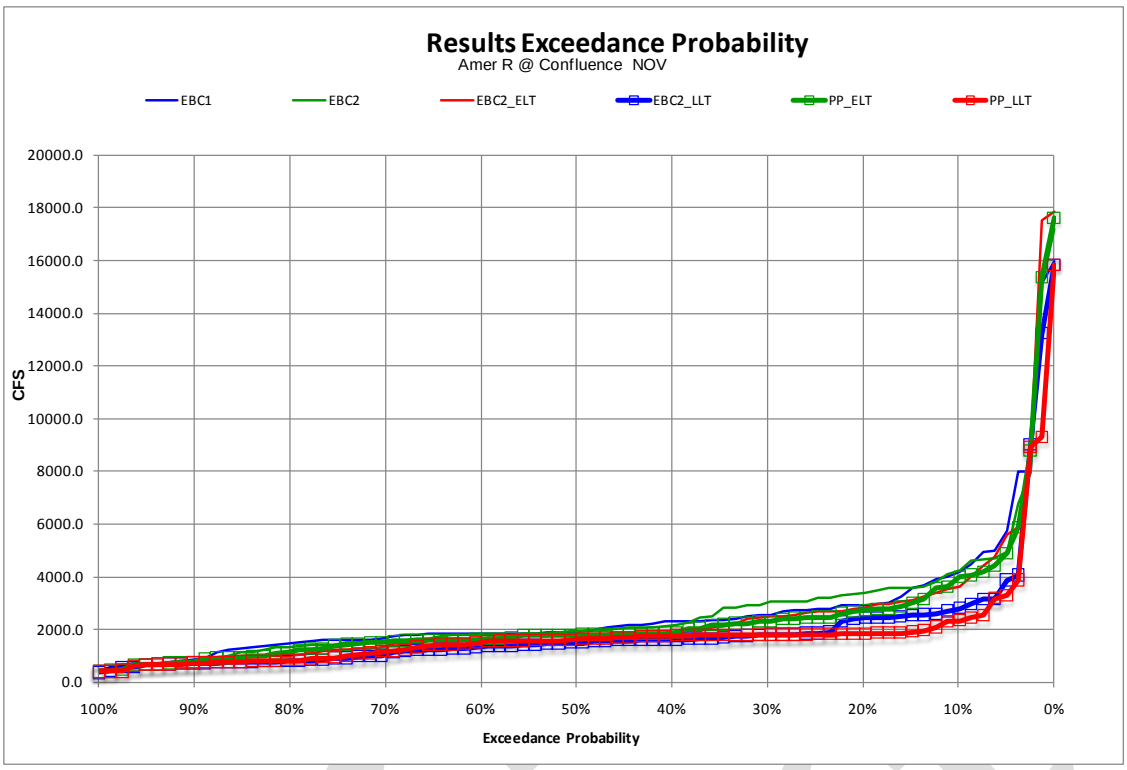

Figure C.5.2-321. Probability of Exceedance Plot for Model Scenarios of Mean Monthly Flow in the American River at the Confluence with the Sacramento River, November

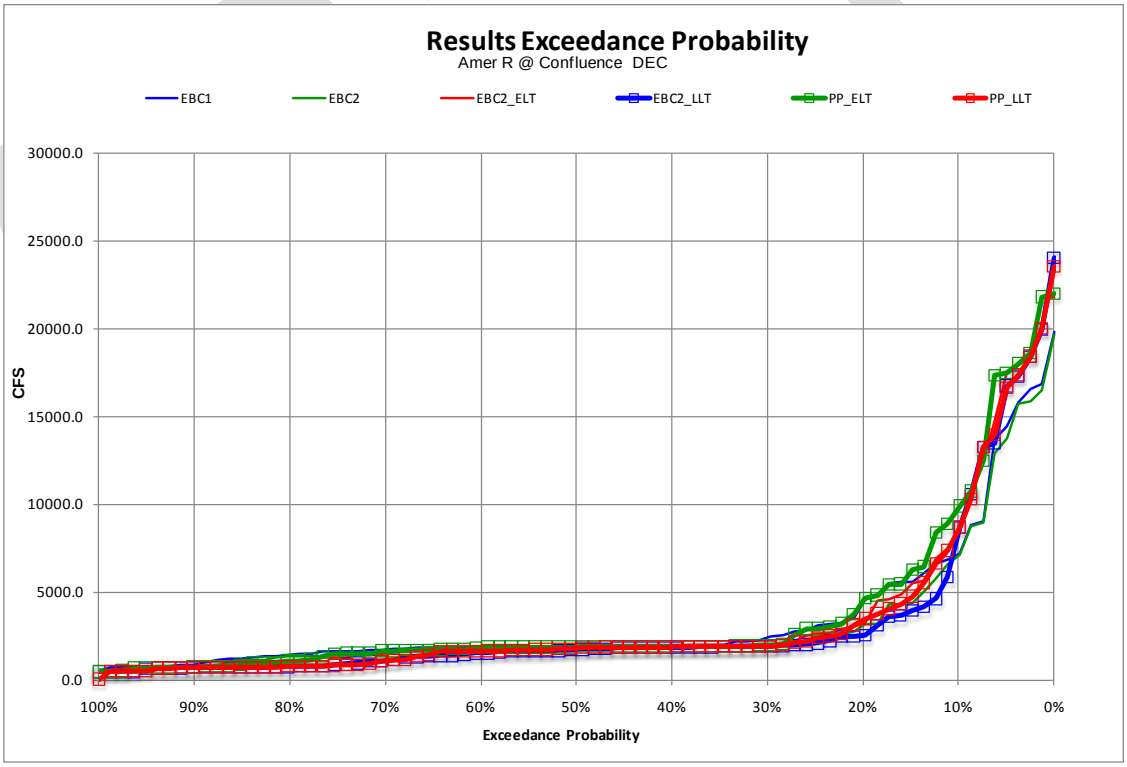

Figure C.5.2-322. Probability of Exceedance Plot for Model Scenarios of Mean Monthly Flow in the American River at the Confluence with the Sacramento River, December

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Water Temperature

Results of water temperature simulation analyses for the lower American River at Watt Avenue were used as an indicator of changes in water temperatures that would potentially affect steelhead egg incubation. The model results were compiled monthly over the 82-year period included in the CALSIM simulations. Average monthly water temperatures were then evaluated to determine the months during the steelhead egg incubation period (January through April) when temperatures exceeded 56°F. Results of the frequency of years in which monthly average temperatures exceeded the criterion are summarized in Table C.5.2-128.

During the 82-year simulation period, the number of years in which one or more occurrences of water temperatures exceeding 56°F are predicted to occur during the steelhead spawning and incubation period (January through April) is 61 to 62 years under EBC1 and EBC2, 75 years under EBC2_ELT and PP_ELT, and 79 years under EBC2_LLT and PP_LLT (Table C.5.2-128). The number of consecutive years with temperature exceeding 56°F under each scenario is predicted to be equally high. The frequency of stressful water temperatures for steelhead egg incubation is also expected to increase under early and late long-term climate conditions in the absence of the preliminary proposal (EBC2 vs. EBC2_ELT vs. EBC2_LLT). No additional increases or decreases in the frequency of these temperatures are predicted with implementation of the preliminary proposal.

Water temperatures in the American River during the winter months are frequently within the range considered to be suitable for steelhead spawning and egg incubation (Figure C.5.2-323). Increasing water temperatures through the late winter and spring increase the frequency and magnitude of water temperatures above this range. Thus, April is a key month for evaluating the effects of water temperature on these life stages. The water temperature simulation results for the American River at Watt Avenue in April indicate that temperatures under PP_ELT and PP_LLT are predicted to be similar to those under their respective baselines (EBC2_ELT and EBC2_LLT) (Figure C.5.2-324). Based on these results, it was concluded that the preliminary proposal will not affect the suitability of water temperatures for steelhead spawning and egg incubation in the American River.

Reservoir storage in May and September provides an indicator of coldwater pool availability. Results of CALSIM modeling of Folsom Reservoir storage in May is shown in Table C.5.2-129 with the corresponding frequency of exceedance analysis for May storage shown in Figure C.5.2-325. September storage in Folsom Reservoir is shown in Table C.5.2-130 with the corresponding frequency of exceedance analysis for September in Figure C.5.2-326. CALSIM results indicate that May and September storage in Folsom Reservoir under early and late long-term conditions in the absence of the preliminary proposal (EBC2_ELT and EBC2_LLT) would be reduced relative to current conditions (EBC1 and EBC2). Under early and late long-term conditions, the preliminary proposal (PP_ELT and PP_LLT) would have variable effects on storage depending on water-year type.

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Table C.5.2-128. Results of the Analysis of the 82-Year Simulation of Water Temperature in the American River at Watt Avenue during the January through April Steelhead Egg Incubation Period[1]

American River at Watt Avenue	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
Number of years with one or more exceedances	61	62	75	79	75	79
Number of years with two exceedances	10	11	21	40	23	36
Number of years with three exceedances	0	0	0	2	0	3
Number of years with four exceedances	0	0	0	0	0	0
Number of years with five or more exceedances	0	0	0	0	0	0
Number of consecutive years with one or more exceedances	58	60	75	79	75	79

[1] Time period analyzed: January 1922 to April 2002. Analysis counted monthly exceedances above 56°F.

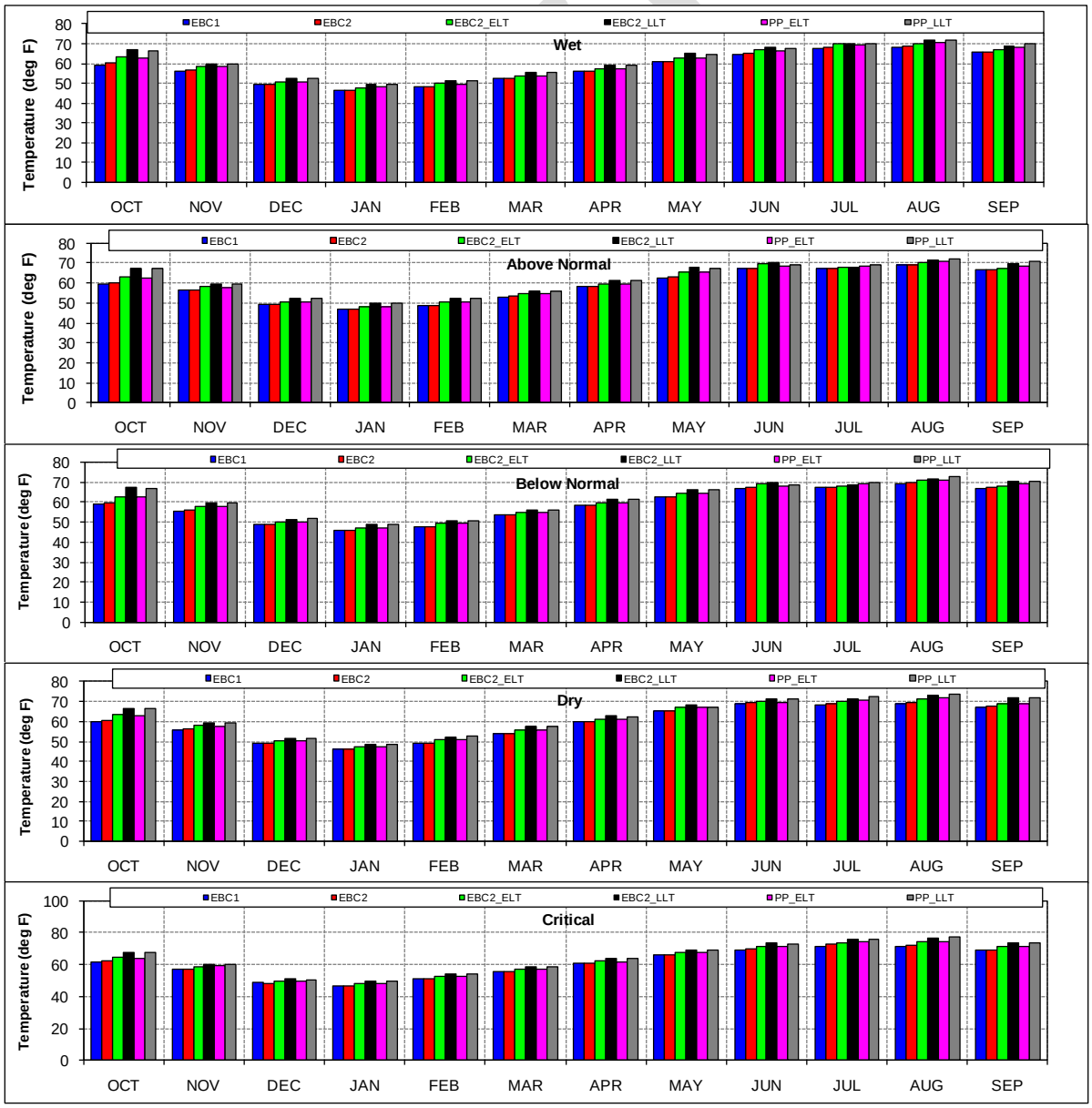

Figure C.5.2-323. Average Water Temperature of American River at Watt Avenue under Model Scenarios

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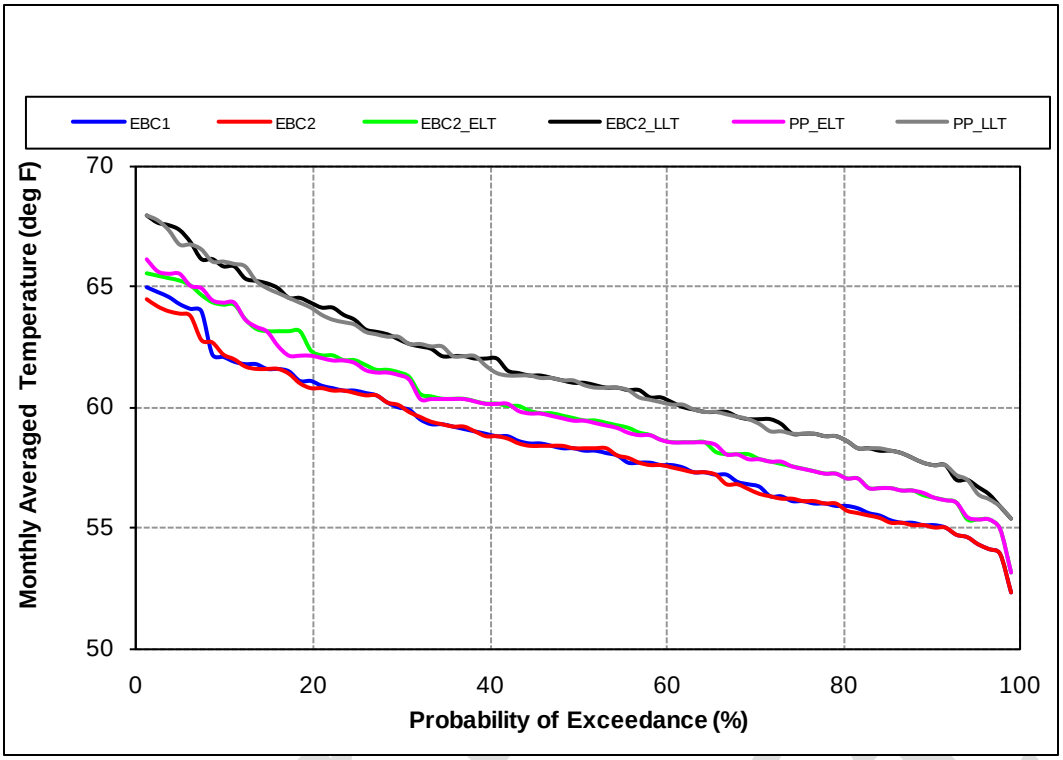

Figure C.5.2-324. Probability of Exceedance Plot for Model Scenarios of Mean Monthly Water Temperature of the American River at Watt Avenue, April

Table C.5.2-129. May Water Storage Volume (Thousand Acre-Feet) in Folsom Reservoir for Model Scenarios

Water-Year Type	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
Wet	966	964	957	943	956	934
Above Normal	968	966	955	930	941	901
Below Normal	934	928	920	891	902	851
Dry	806	777	749	691	740	643
Critical	448	430	396	360	430	342

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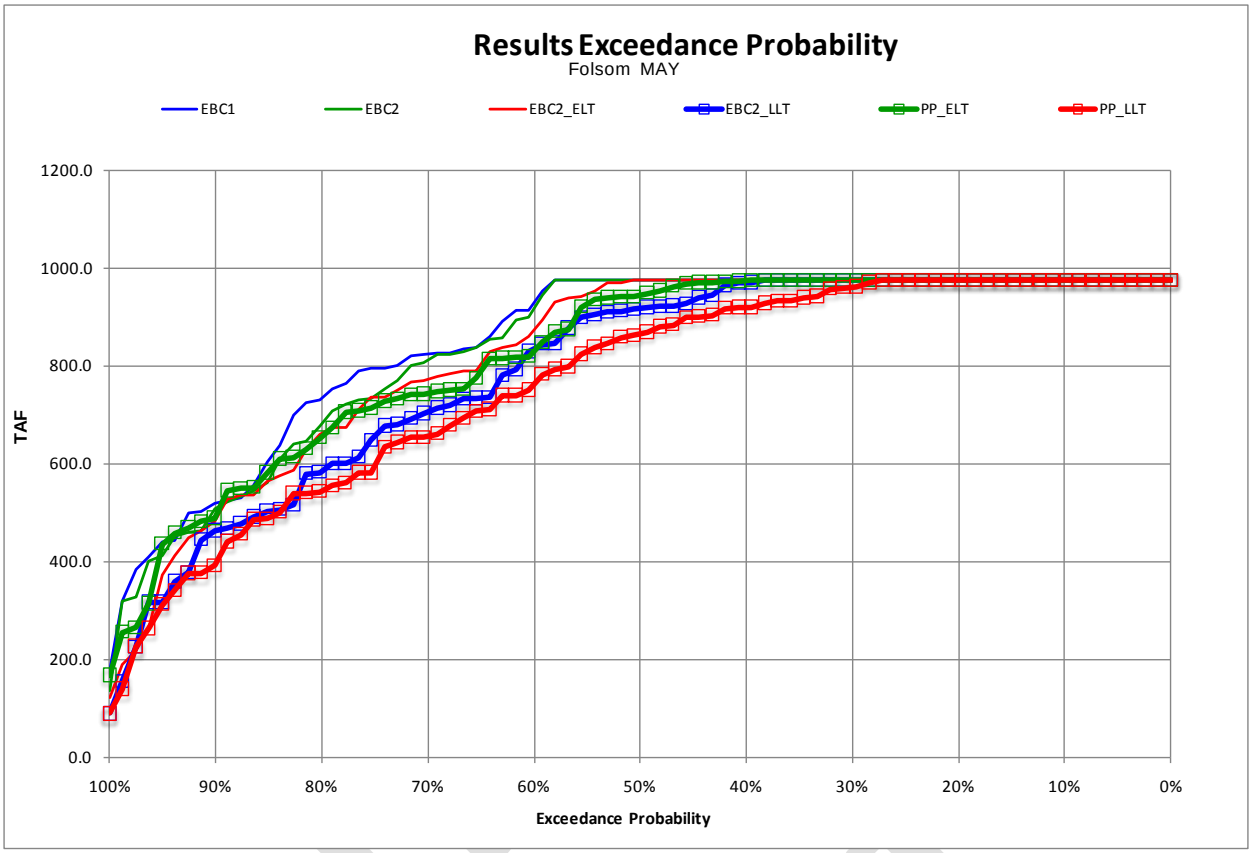

Figure C.5.2-325. Probability of Exceedance Plot for Model Scenarios of Folsom Reservoir Water Storage Volume, May

Table C.5.2-130. September Water Storage Volume (Thousand Acre-Feet) in Folsom Reservoir for Model Scenarios

Water-Year Type	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
Wet	636	600	558	485	612	543
Above Normal	623	558	504	430	521	435
Below Normal	589	558	500	423	491	428
Dry	441	418	375	306	372	316
Critical	240	228	185	159	218	147

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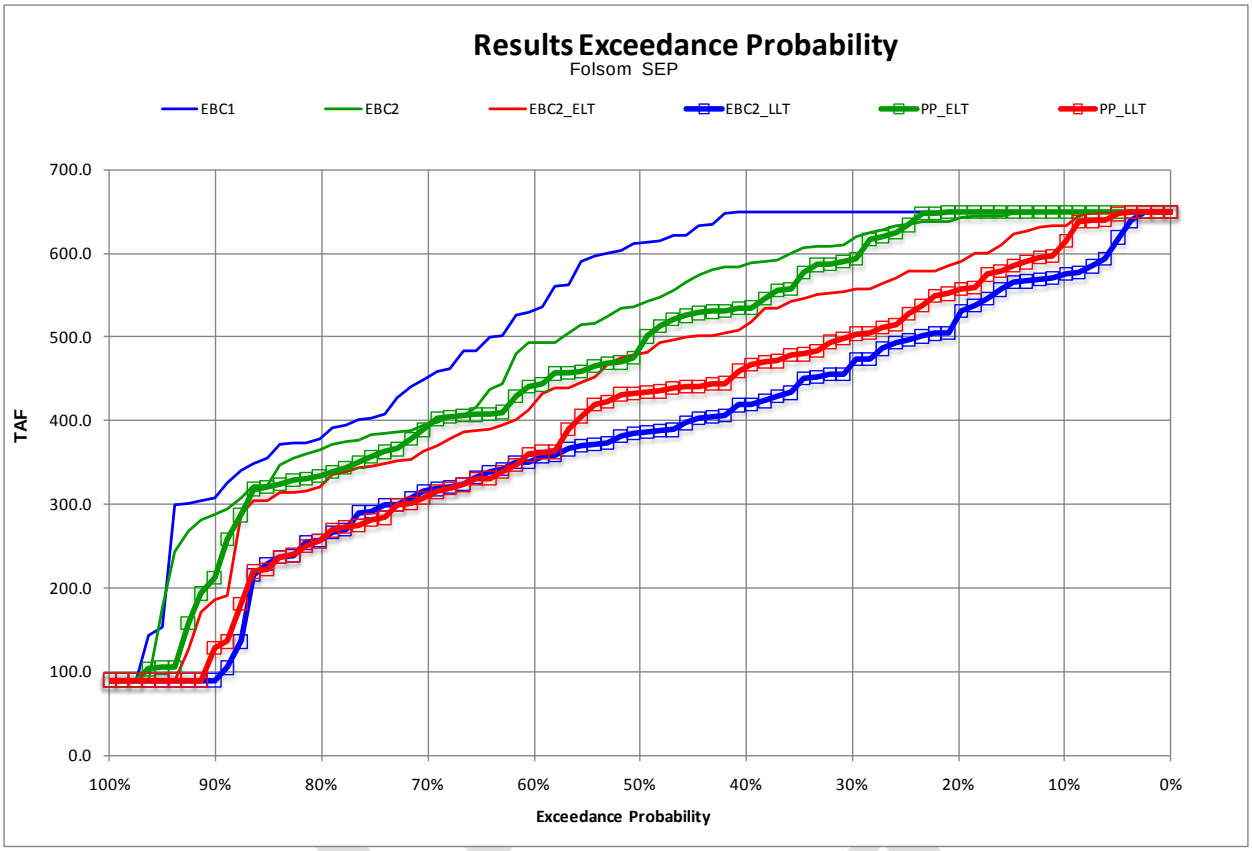

Figure C.5.2-326. Probability of Exceedance Plot for Model Scenarios of Folsom Reservoir Water Storage Volume, September

Redd Dewatering

Ramping rates for releases on the American River are included as part of routine operations and would be expected to remain the same in the future under BDCP. Flows in the river are maintained to avoid redd dewatering. Monthly CALSIM modeling (Table C.5.2-127 and Figure C.5.2-311 through Figure C.5.2-322) predicts that flows between January and April encompassing the steelhead spawning period would be maintained at levels that would minimize and avoid the risk of dewatering redds under both preliminary proposal and existing biological conditions.

A smaller run of adult steelhead spawns in the lower American River in April. It is uncertain whether these fish represent a native life history diversity group or reflect the influence of out-of-basin hatchery introductions. Instream flows during the late spring and early summer (April through July) are typically stable in drier years and exhibit a declining trend in wetter years. Reduced flows after April predicted in all model scenarios would increase the risk of redd dewatering.

Fry and Juvenile Rearing

Rearing Habitat

The freshwater life stages of steelhead occupy the American River throughout the year. Steelhead fry emerge from the gravel from March into June and grow quickly. Most juveniles that survive into the fall emigrate during their first year at an average size of about 250 millimeters (mm). Most literature has indicated that rearing fry and juvenile steelhead prefer water temperatures between

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45°F and 60°F (Reiser and Bjorn 1979, Bovee 1978, Bell 1986). However, Myrick (1998) found the preferred temperatures for Mokelumne River Hatchery steelhead placed into thermal gradients were between 62.6°F and 68°F. National Marine Fisheries Service (2009) generally uses a daily average temperature of 65°F at Watt Avenue as a temperature objective for steelhead rearing in the American River and then adjusts the temperature objective depending on Folsom coldwater pool each year. Therefore, the 65°F threshold was used for this analysis.

Results of the frequency of years in which monthly average temperatures exceeded the criterion in American River at Watt Avenue are summarized in Table C.5.2-131.

One or more occurrences of temperatures exceeding 65°F are predicted to occur in most years under model scenarios. Under PP_ELT and PP_LLT, there is no predicted difference in the number of years with one or more occurrences of temperatures exceeding 65°F relative to EBC2_ELT and EBC2_LLT, respectively. The number of years with three, four and five or more occurrences of temperatures exceeding 65°F are predicted to be higher and lower under PP_ELT and PP_LLT relative to EBC2_ELT and EBC2_LLT, respectively, depending on the exceedance value and implementation period. These results indicate that habitat conditions for steelhead rearing will continue to be stressful in the lower American River under future conditions without the preliminary proposal. The preliminary proposal is expected to have variable but small effects on water temperatures from year to year but is not expected to substantially affect the quality of juvenile rearing habitat.

Table C.5.2-131. Results of the Analysis of the 82-Year Simulation of Water Temperature in the American River at Watt Avenue during the Year-Round Juvenile Steelhead Rearing Period[1]

American River at Watt Avenue	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
Number of years with one or more exceedances	81	81	81	81	81	81
Number of years with two exceedances	3	2	0	0	0	0
Number of years with three exceedances	22	22	7	0	6	0
Number of years with four exceedances	33	33	31	4	36	10
Number of years with five or more exceedances	23	24	43	77	39	71
Number of consecutive years with one or more exceedances	81	81	81	81	81	81

[1] Time period analyzed: January 1922 to December 2002. Analysis counted monthly exceedances above 65°F.

Results of the water temperature simulations for all months at Watt Avenue are presented in Figure C.5.2-327 through Figure C.5.2-338, and specifically for the months of April through October in Figure C.5.2-331 through Figure C.5.2-337. Water temperature differences between EBC2_ELT, PP_ELT, EBC2_LLT, and PP_LLT scenarios are small. The main differences are observed between ELT and LLT results are due to climate change. During August (Figure C.5.2-335), temperatures at Watt Avenue could exceed a monthly average of 65°F 100% of the time under all model scenarios. Temperatures are modeled to be almost always higher than 65°F at Nimbus Dam in July through September (Figure C.5.2-339) with temperature differences between ELT and LLT time periods being biologically meaningful but temperatures between EBC and PP scenarios within time periods likely not. The high summer temperatures are likely to limit the naturally spawned steelhead population in the American River by limiting the length of river downstream of Nimbus Dam with suitable rearing habitat and providing conditions conducive to predatory fish. Monitoring during 2001 and 2002 indicated that steelhead did not appear to be finding water cooler than that found in

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the thalweg and they persisted below Watt Avenue in water with a daily average temperature of 72°F and daily maximum temperatures over 74°F (Reclamation and DFG, unpub. data). Average water temperature in the American River is predicted to be approximately 2°F warmer from current conditions compared to the early long-term and another 2°F warmer between the ELT and LLT conditions. The increased temperatures will put additional temperature stress on rearing steelhead during summer months. Due to the high temperatures, the steelhead run in the American River will likely require continued support by the hatchery to persist under all model scenarios.

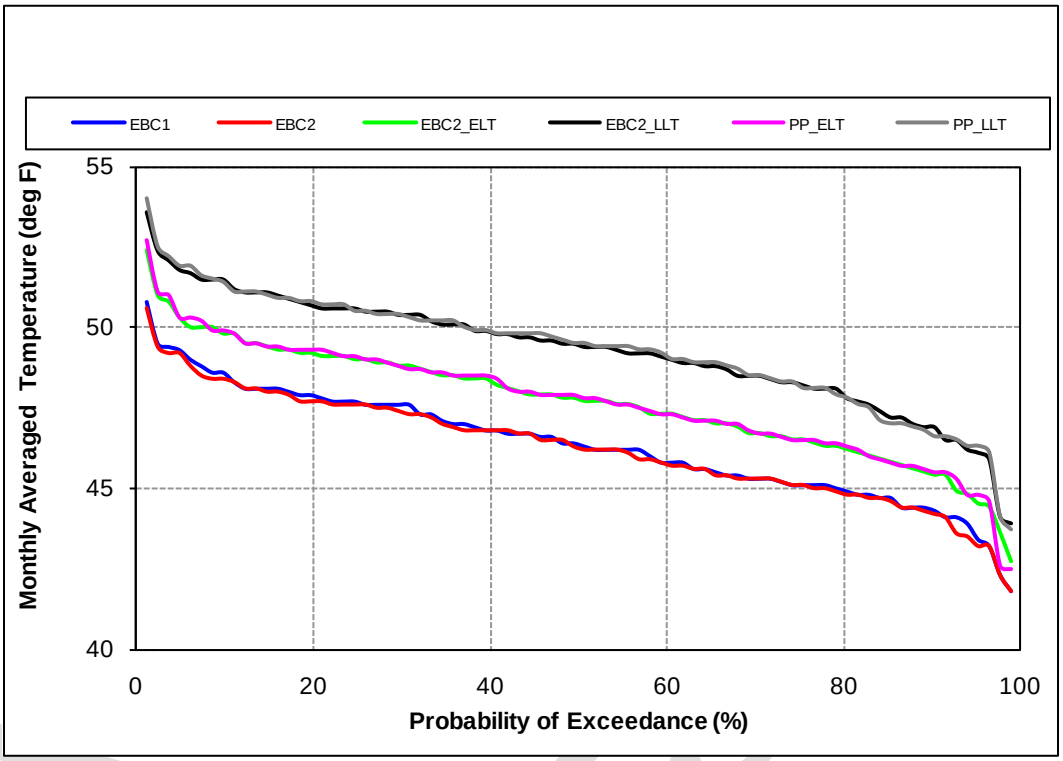

Figure C.5.2-327. Probability of Exceedance Plot for Model Scenarios of Mean Monthly Water Temperature of American River at Watt Avenue, January

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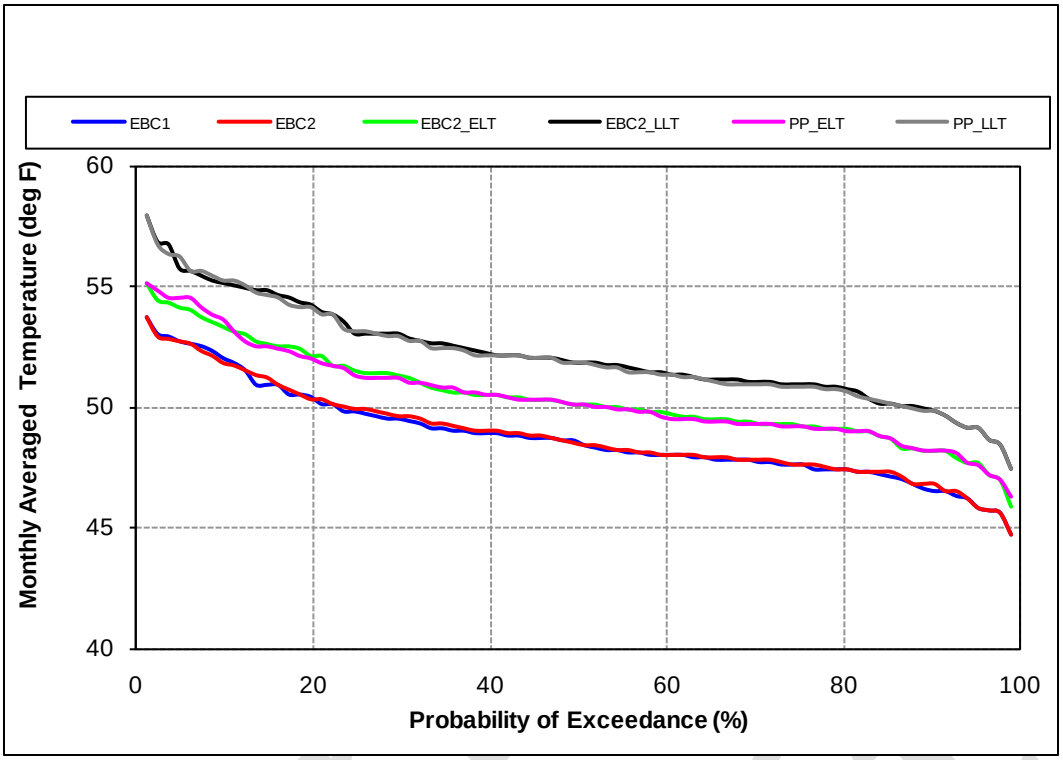

Figure C.5.2-328. Probability of Exceedance Plot for Model Scenarios of Mean Monthly Water Temperature of American River at Watt Avenue, February

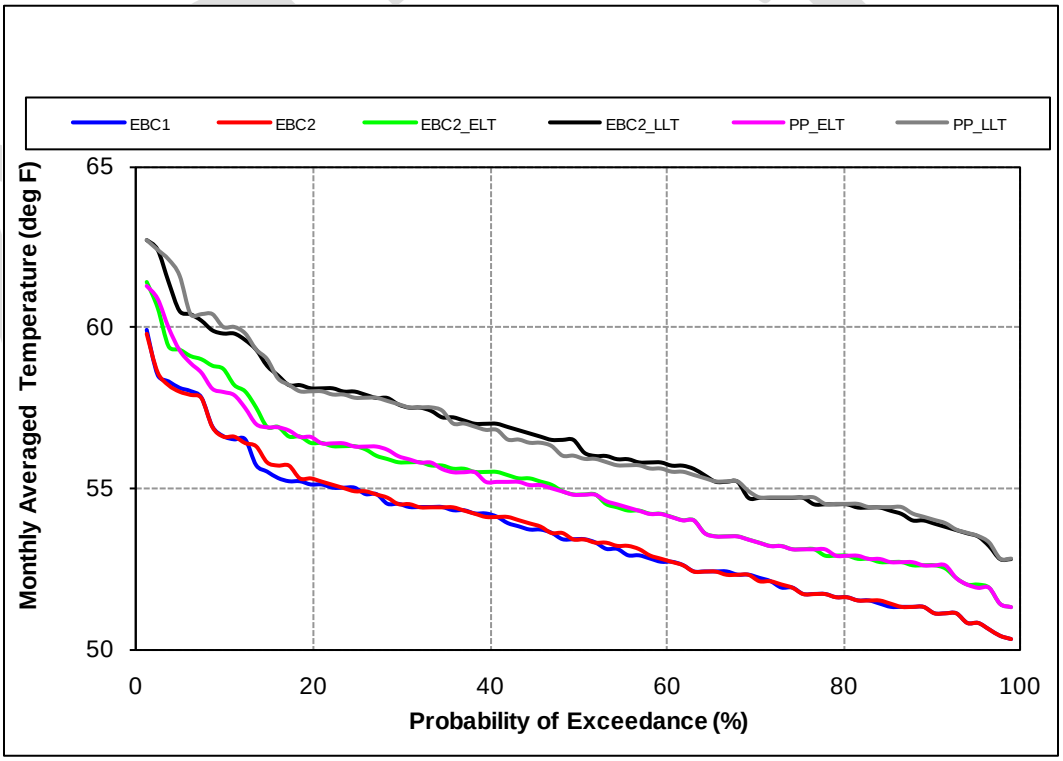

Figure C.5.2-329. Probability of Exceedance Plot for Model Scenarios of Mean Monthly Water Temperature of American River at Watt Avenue, March

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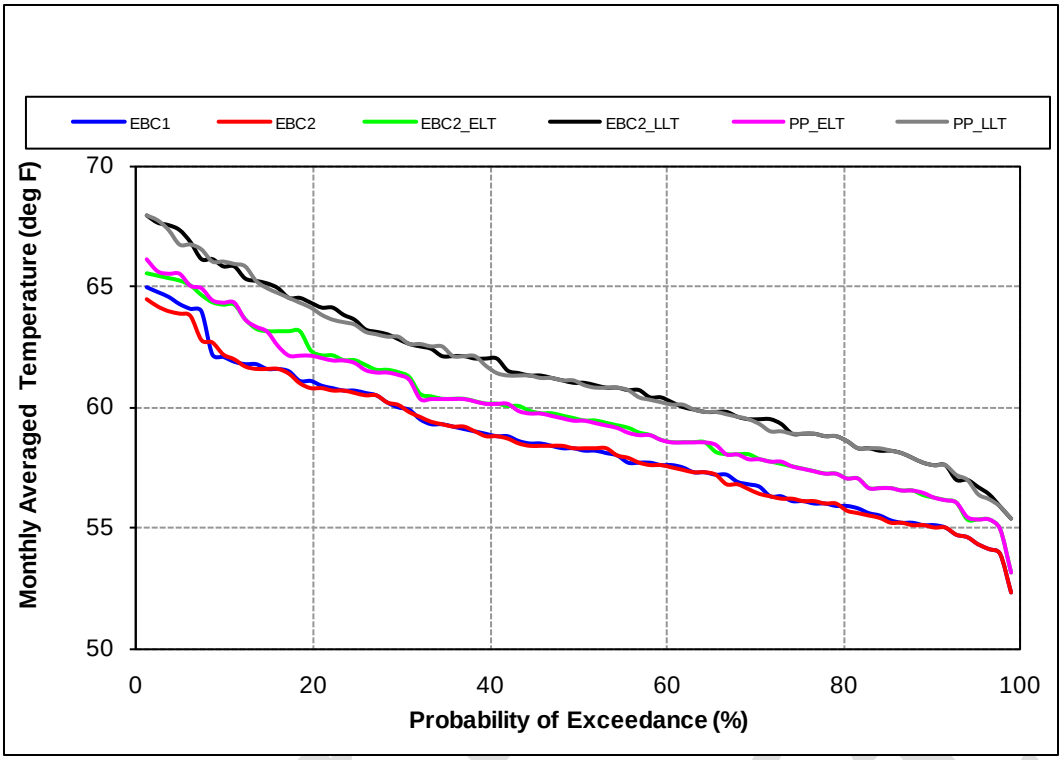

Figure C.5.2-330. Probability of Exceedance Plot for Model Scenarios of Mean Monthly Water Temperature of American River at Watt Avenue, April

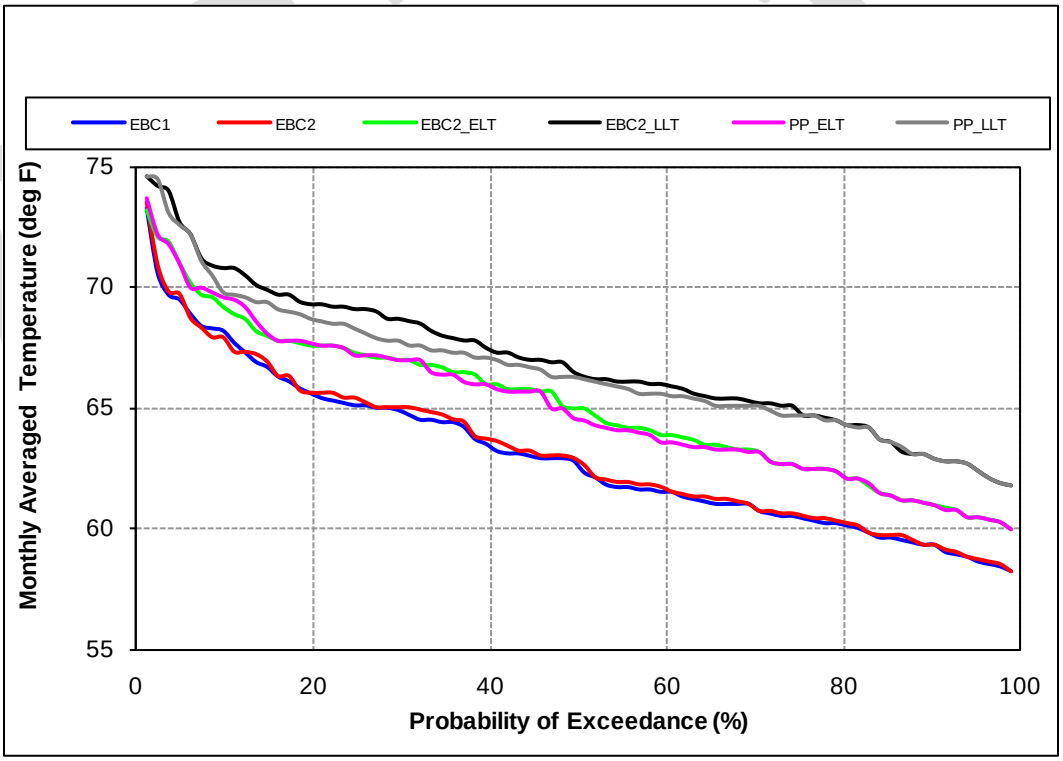

Figure C.5.2-331. Probability of Exceedance Plot for Model Scenarios of Mean Monthly Water Temperature of American River at Watt Avenue, May

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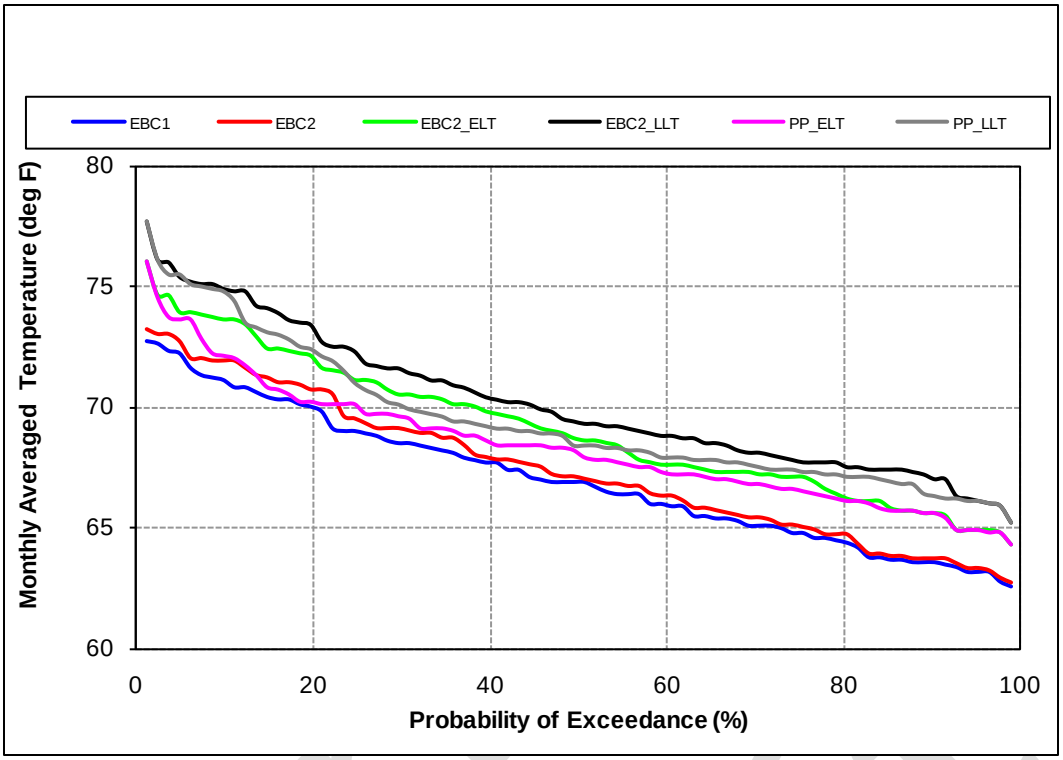

Figure C.5.2-332. Probability of Exceedance Plot for Model Scenarios of Mean Monthly Water Temperature of American River at Watt Avenue, June

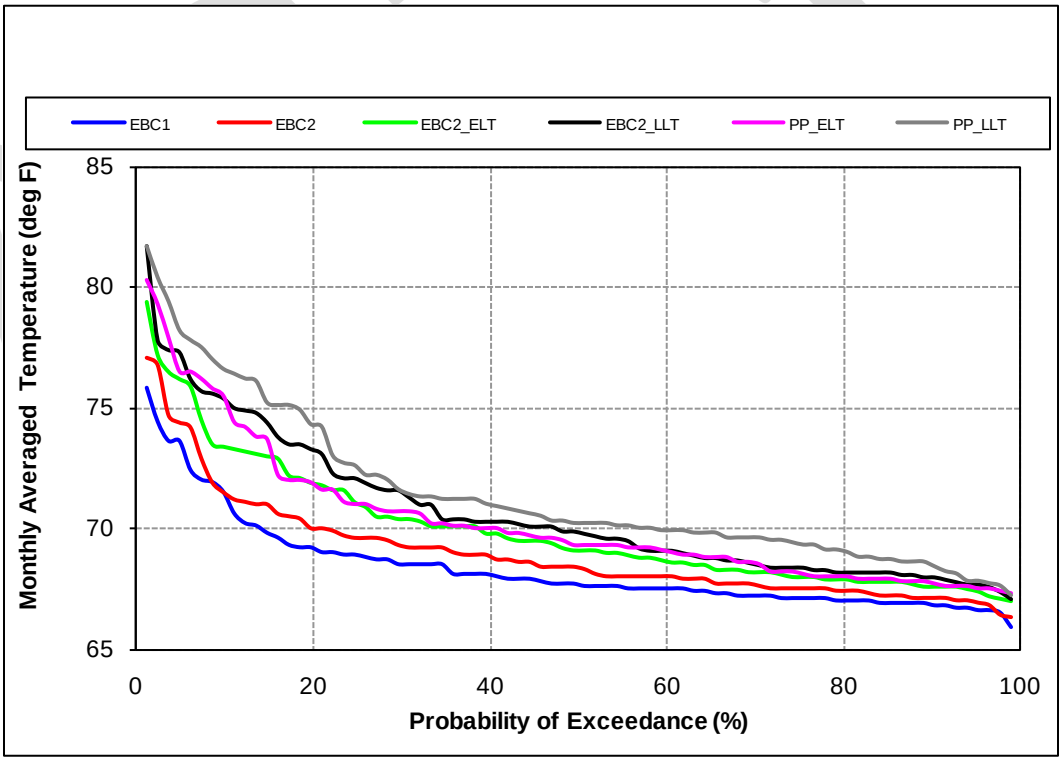

Figure C.5.2-333. Probability of Exceedance Plot for Model Scenarios of Mean Monthly Water Temperature of American River at Watt Avenue, July

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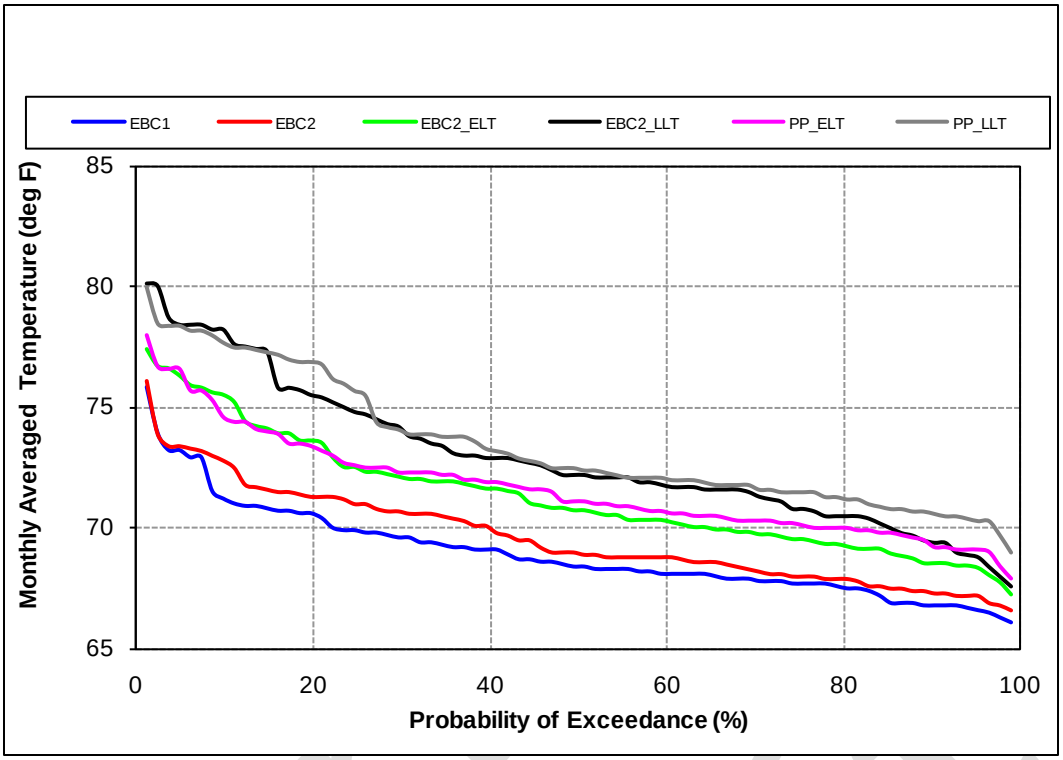

Figure C.5.2-334. Probability of Exceedance Plot for Model Scenarios of Mean Monthly Water Temperature of American River at Watt Avenue, August

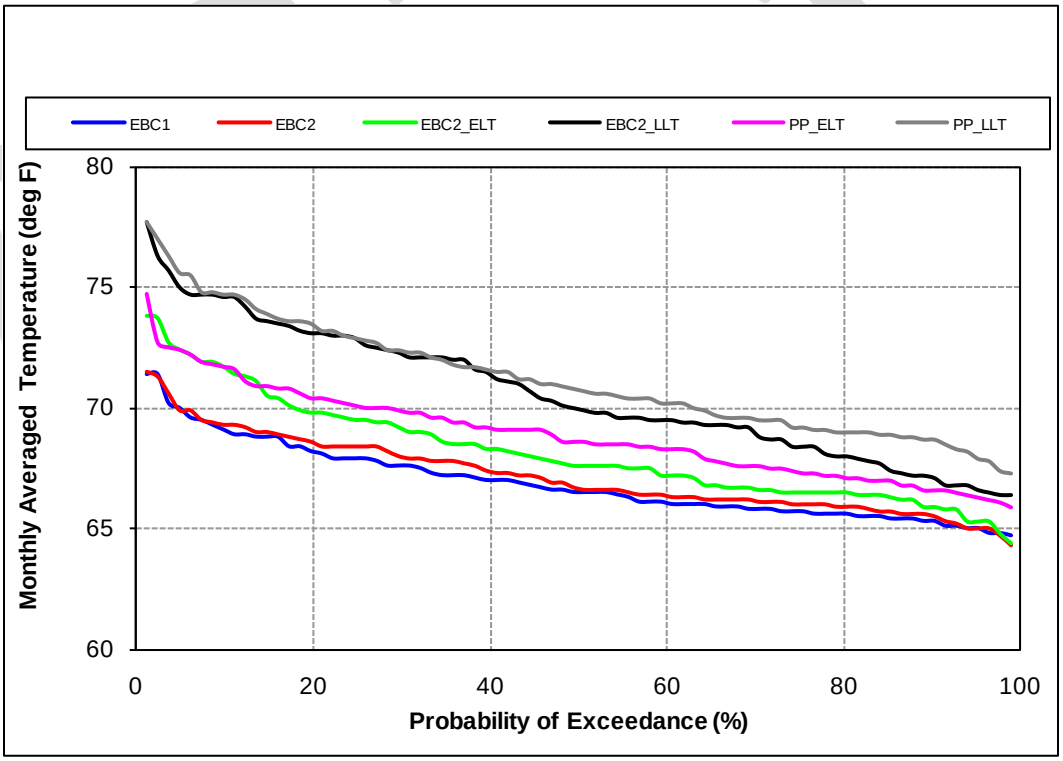

Figure C.5.2-335. Probability of Exceedance Plot for Model Scenarios of Mean Monthly Water Temperature of American River at Watt Avenue, September

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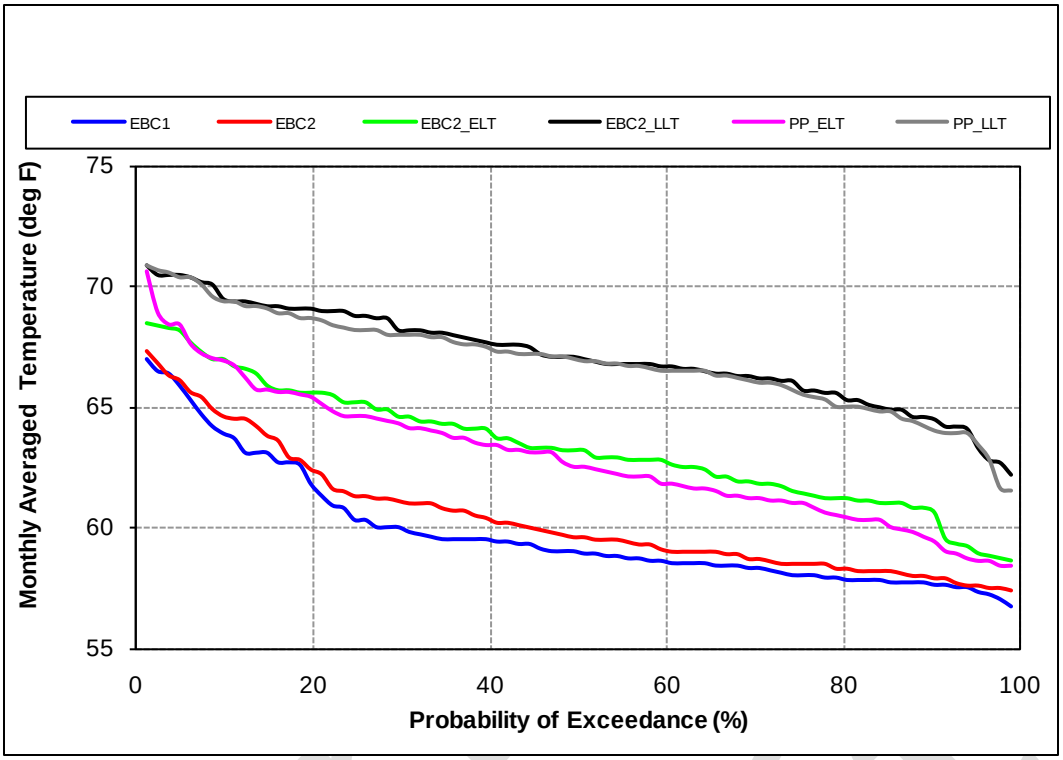

Figure C.5.2-336. Probability of Exceedance Plot for Model Scenarios of Mean Monthly Water Temperature of American River at Watt Avenue, October

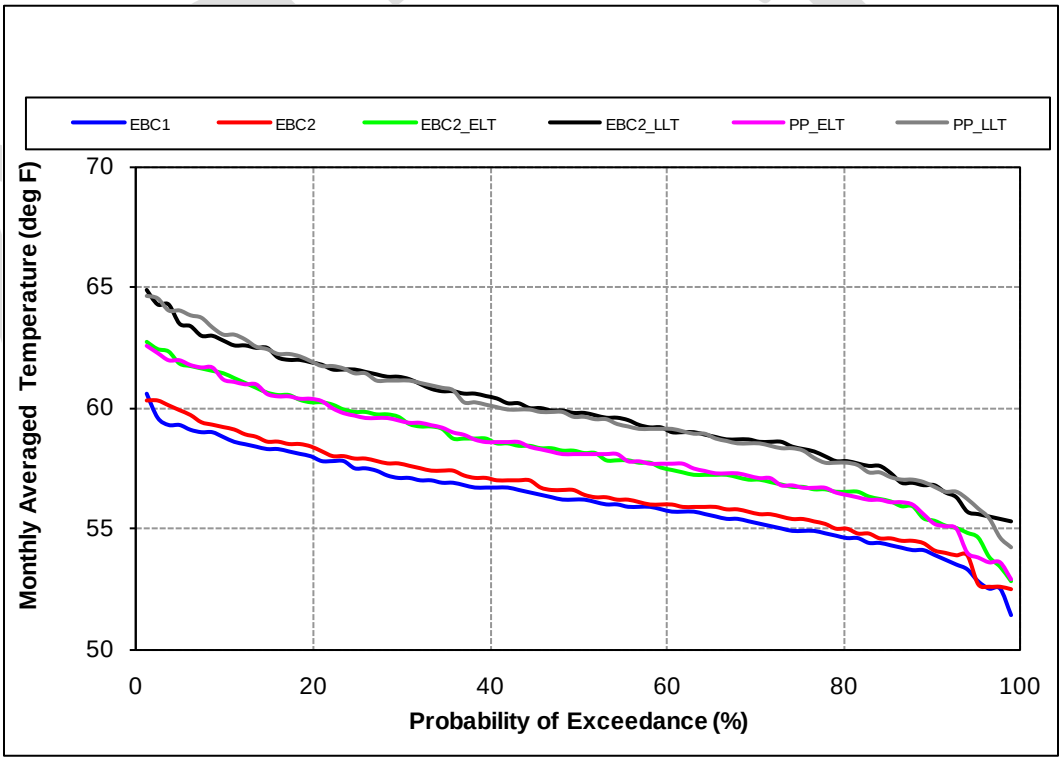

Figure C.5.2-337. Probability of Exceedance Plot for Model Scenarios of Mean Monthly Water Temperature of American River at Watt Avenue, November

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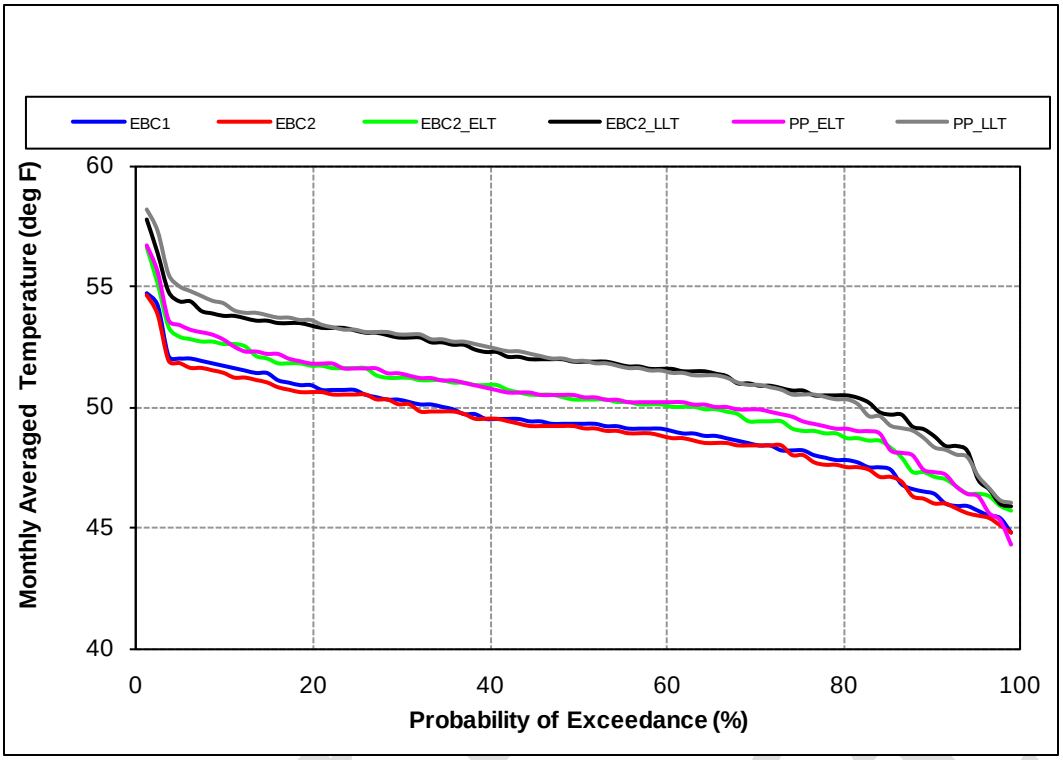

Figure C.5.2-338. Probability of Exceedance Plot for Model Scenarios of Mean Monthly Water Temperature of American River at Watt Avenue, December

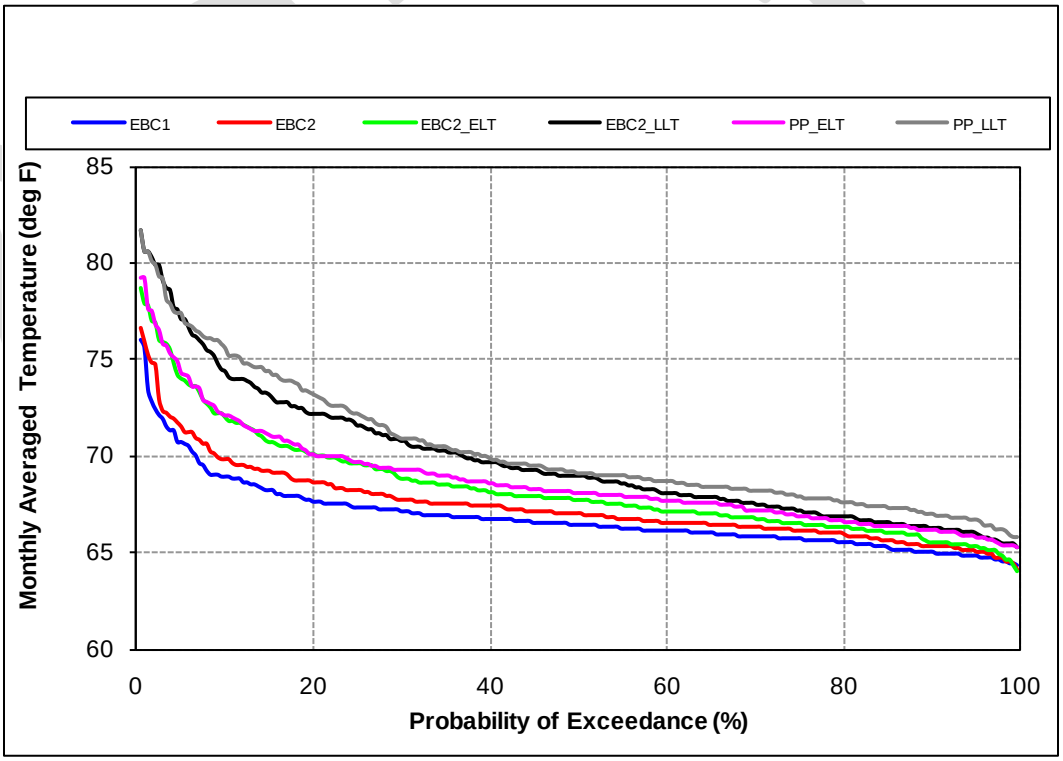

Figure C.5.2-339. Probability of Exceedance Plot for Model Scenarios of Mean Monthly Water Temperature of the American River at Nimbus Dam, July through September Combined

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Specific flow requirements for fry and juvenile steelhead rearing in the American River have not been closely studied. Flows in the lower American River that affect physical habitat conditions (e.g., water depth and velocity) are summarized by month and water-year type throughout the year in Table C.5.2-127 and shown in Figure C.5.2-311 through Figure C.5.2-322. Results of these analyses are consistent with the conclusion that instream flows and physical habitat conditions in the lower American River would not differ between EBC2_ELT and PP_ELT or between EBC2_LLT and PP_LLT. The preliminary proposal, therefore, are not expected to affect instream habitat conditions for juvenile steelhead rearing. The number of steelhead naturally spawning in the river is low and after the fry emerge from the gravel mortality is high such that rearing densities are low by midsummer. The surviving juveniles grow fast at the low densities indicating that habitat availability as related to volume of flow is not as limiting as the high water temperatures. The most limiting period, when higher water temperatures can occur, is June through September. During this time steelhead rearing occurs primarily in fast water areas on or close to riffles. Figure C.5.2-340, Figure C.5.2-341, and Figure C.5.2-342 show that, in general, flows would be lower later in the water year (July through September) under EBC2_ELT and EBC2_LLT than for EBC1 or EBC2, and PP_ELT and PP_LLT scenarios would have lower flows in the future than the EBC2_ELT and EBC2_LLT, respectively. When flows during the warm months are reduced to approximately 1,500 cfs the amount of riffle habitat becomes more limited. At existing population levels the flows would probably be adequate but this could limit any steelhead population growth in the future. Flows are increased in December through June (Figure C.5.2-340). This moves the hydrograph towards a more natural flow regime shape and could provide a benefit.

Rearing steelhead fry and juveniles can be exposed to stranding and isolation from main channel flows when high-flows are required for flood control or Delta outflow requirements results in short duration flow increases which are subsequently reduced after the requirement subsides. After high-flow events when rearing steelhead fry and juveniles issues are a concern, Reclamation coordinates flow reduction rates utilizing the CVPIA Section 3406(b)(2), *Integration Team and American River Operation Group* adaptive management processes to minimize the stranding and isolation concerns versus current hydrologic conditions and future hydrologic projections to Folsom coldwater management. Reclamation attempts to avoid flow fluctuations during non-flood control events that raise flows above 4,000 cfs and then reduce flow back below 4,000 cfs as recommended by Snider et al. (2001). Flow fluctuations are sometimes difficult to avoid with competing standards to meet in the Delta and upstream so some stranding is expected to continue to occur at about the same level as under current conditions.

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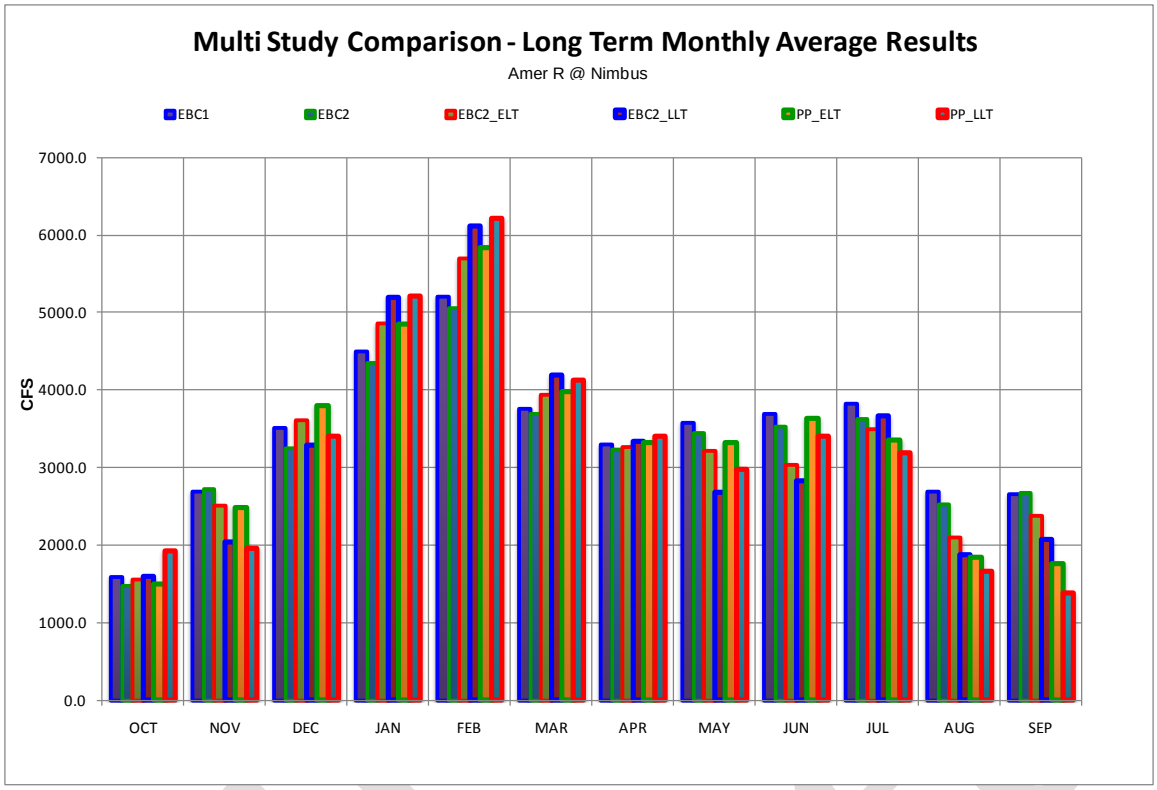

Figure C.5.2-340. American River Monthly Average Nimbus Releases for Model Scenarios

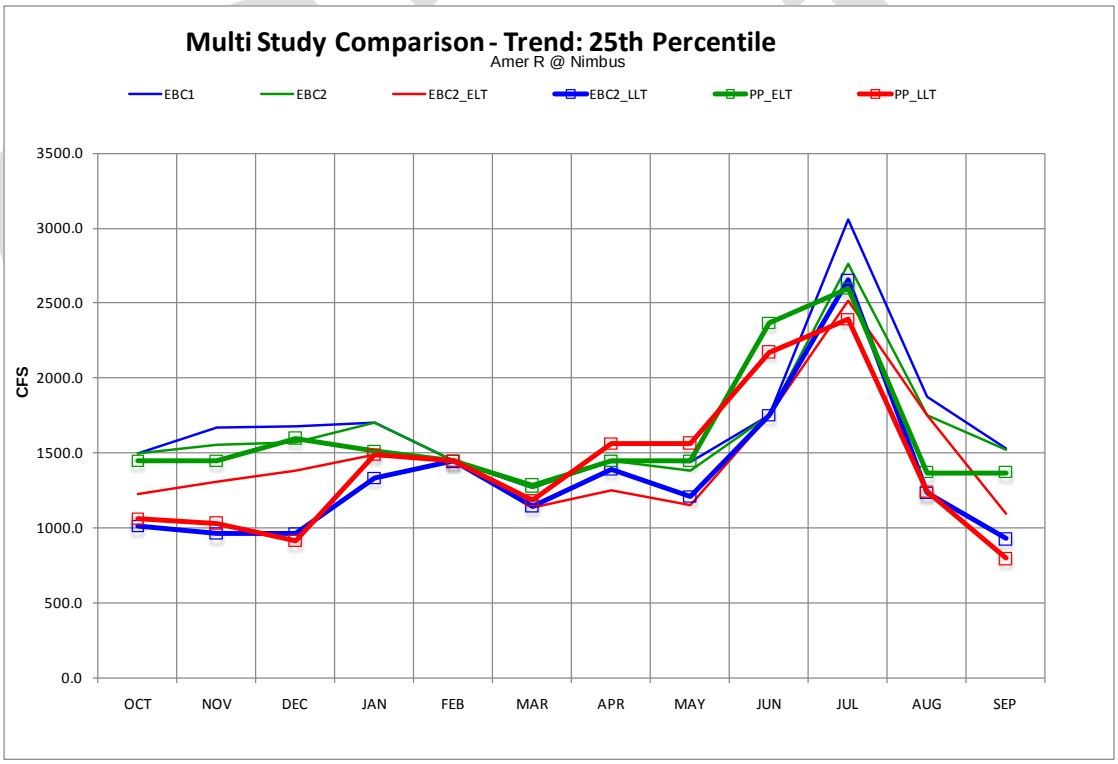

Figure C.5.2-341. American River Nimbus Releases for Model Scenarios for Dry Conditions

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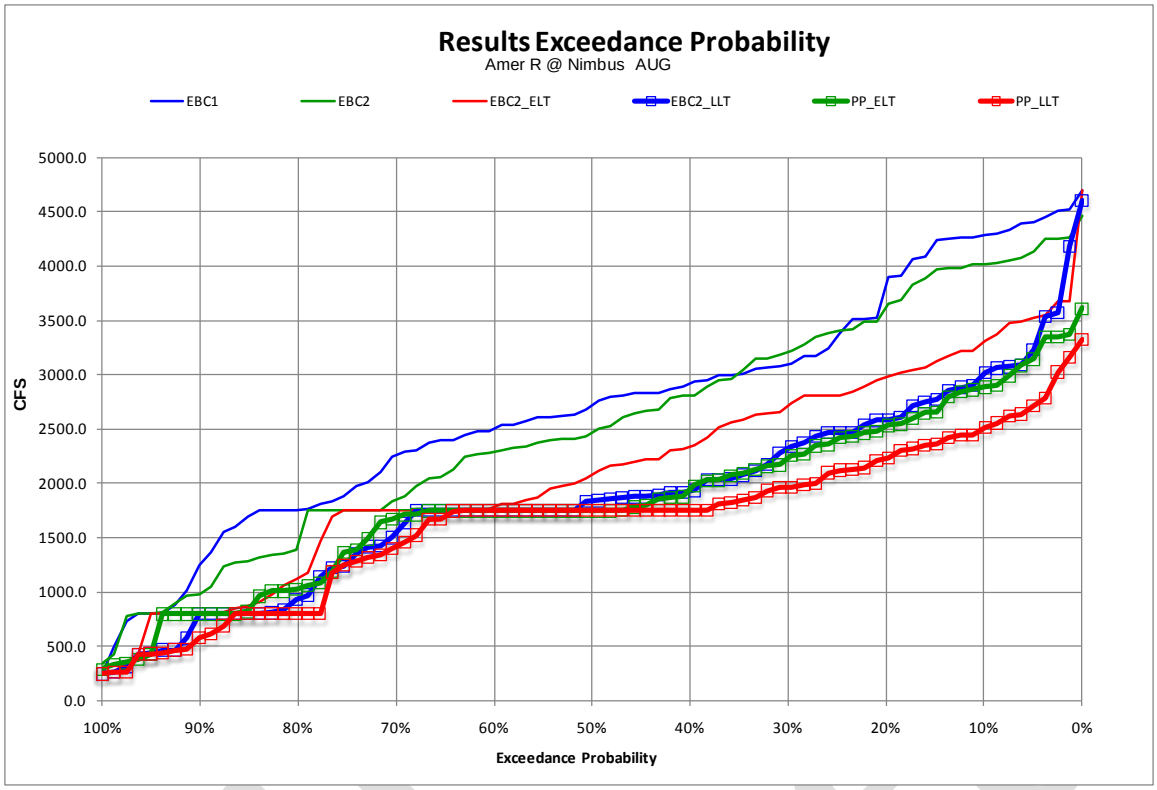

Figure C.5.2-342. Probability of Exceedance Plot for Model Scenarios of American River at Nimbus Dam Release, August

Adult

Water Temperature

It has been assumed that adult steelhead migrate upstream in the American River during September through March. Reclamation Temperature Model results for these months at Watt Avenue are presented in Figure C.5.2-327 through Figure C.5.2-329 and Figure C.5.2-335 through Figure C.5.2-338. Results of the analysis of water temperature exceedance above 65°F for each model scenario are presented in Table C.5.2-132. September is predicted to be highly stressful for adult steelhead in the American River, with temperatures exceeding 65°F in >95% of years for all model scenarios. October is predicted to be slightly better than September for all but the EBC2_LLT and PP_LLT, in which temperatures will exceed 65°F in 80% of years. Temperatures are not expected to exceed 65°F under any scenarios between December and March. These results indicate that the preliminary proposal will not affect adult steelhead migration habitat, although future climate change will have large adverse effects in September and October.

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Table C.5.2-132. Results of the Analysis of the 82-Year Simulation of Water Temperature in the American River at Watt Avenue during the September through March Steelhead Adult Migration Period[1]

American River at Watt Avenue	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
Number of years with one or more exceedances	75	75	79	80	80	80
Number of years with two exceedances	5	6	20	67	17	63
Number of years with three exceedances	0	0	0	0	0	0
Number of years with four exceedances	0	0	0	0	0	0
Number of years with five or more exceedances	0	0	0	0	0	0
Number of consecutive years with one or more exceedances	75	75	79	80	80	80

[1] Time period analyzed: September 1922 to March 2002. Analysis counted monthly exceedances above 65°F.

C.5.2.5.2 Fall-/Late Fall–Run

Eggs and Alevins

Upstream Spawning Habitat

The lower American River supports a population of naturally reproducing fall-run Chinook salmon that inhabit the river for spawning, egg incubation, juvenile rearing, and as habitat for upstream and downstream migration. Hatchery-produced fall-run Chinook salmon also return to the American River Nimbus Fish Hatchery.

Instream flows within the American River during the fall-run Chinook salmon spawning and egg incubation period (October through January) are shown in Table C.5.2-127, Figure C.5.2-311, and Figure C.5.2-320 through Figure C.5.2-322. Results predict that instream flows and, therefore, physical habitat conditions are predicted to be generally comparable among model scenarios for these months. Exceptions include flows under the PP_LLT, which are predicted to be ~300 to 1,000 cfs lower than those under the EBC2_LLT in all but critical water years and ~200 to 700 cfs higher than those under the EBC2_LLT in all but critical water years.

Water Temperature

Fall-run Chinook salmon spawning and egg incubation occurs in the American River downstream of Nimbus Dam. It was assumed that egg exposure to water temperatures >56°F during incubation would result in adverse impacts on reproductive success, including egg mortality.

Fall-run salmon spawn in the late fall (October through December), when seasonal air temperatures in the Sacramento area are declining and habitat conditions for fall-run salmon spawning are generally improving. The area of the river where suitable water temperatures occur for successful egg incubation depends on the temperature of water released to the river from Folsom and Nimbus dams, the rate of instream flow, and atmospheric conditions that result in river warming as the water travels downstream from the dam. When coldwater storage in Folsom Reservoir is reduced, the amount of cold water available for release is reduced and the temperature of the water at the point of release to the river is increased. Under these conditions, the length of river downstream of Nimbus Dam that maintains suitable water temperatures for fall-run Chinook salmon egg incubation

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and hatching is reduced and those eggs that were spawned in the downstream areas are exposed to increased water temperature and egg mortality.

Egg mortality in the American River occurs primarily early in the season (October to mid-November), after the coldwater pool in Folsom Reservoir is depleted and before natural cooling reduces temperatures to levels more conducive to egg survival. The Folsom Reservoir storage is small for the size of the watershed in comparison with other Central Valley reservoirs, so that even when the reservoir fills, it is difficult to maintain a coldwater pool that will support fall-run Chinook salmon spawning in the fall. The peak in fall-run spawning in the American River occurs in mid-November, later than in other Central Valley watersheds, likely because of the coldwater limitations early in the season. Folsom Reservoir storage during spring and late summer/early fall is presented in Table C.5.2-129 and Table C.5.2-130, respectively. Figure C.5.2-325 and Figure C.5.2-326 present exceedance frequency curves for May and September, respectively, for Folsom Reservoir storage.

The Reclamation egg mortality model was used to estimate the change in egg survival under different water management strategies over a wide range of hydrologic and environmental conditions. Egg mortality model results provide an important indicator regarding changes in habitat suitability for fall-run Chinook salmon spawning and successful egg incubation. Results of the fall-run Chinook salmon egg mortality estimates are presented in Figure C.5.2-343 and Table C.5.2-133.

There are only small differences in egg mortality predicted between EBC2_ELT and PP_ELT and between EBC2_LLT and PP_LLT. The main differences are predicted to occur between EBC2 and EBC2_ELT and between EBC2_ELT and EBC2_LLT, which reflect effects of climate change (Figure C.5.2-343 and Table C.5.2-133). There are minor differences predicted between water-year types; this is likely because Chinook salmon spawn early in the water year, Folsom Reservoir has little ability to provide carryover storage (due to flood control pool limits), and the determinants of water-year type occur after Chinook spawning has occurred. Therefore, egg mortality can be high in the American River even when the water-year type is determined to be wet.

These results indicate that the preliminary proposal will have little effect on egg mortality estimates for fall-run Chinook salmon in the lower American River. These predicted results are consistent with the observation that there are no effects of the preliminary proposal on Folsom Reservoir storage and instream flows in the American River.

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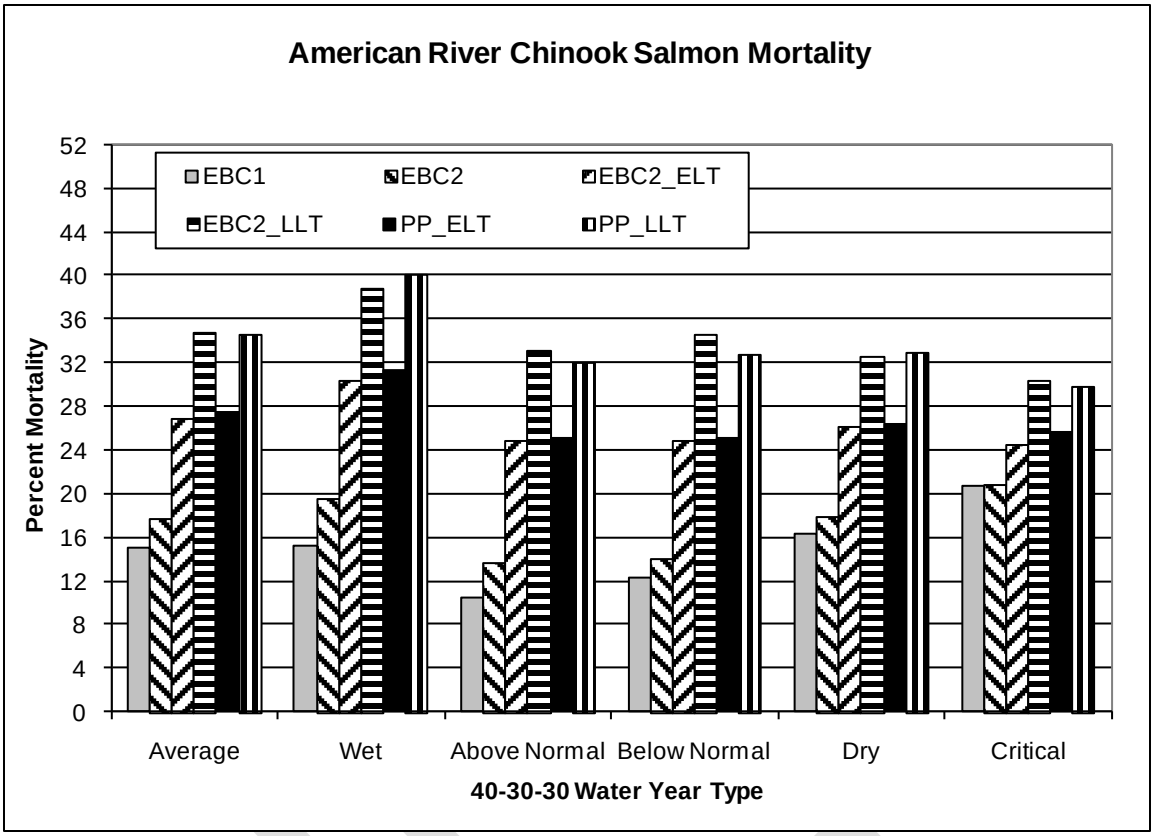

Figure C.5.2-343. American River Fall-Run Chinook Average Egg Mortality under Each Model Scenario for Each Water-Year Type and for All Years from the Reclamation Egg Mortality Model

Table C.5.2-133. Egg Mortality Percentages for Fall-Run Chinook in the Lower American River

Water-Year Type	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
Wet	15.1	19.6	30.2	38.8	31.4	40.0
Above Normal	10.5	13.7	24.8	33.0	25.0	31.9
Below Normal	12.3	14.1	24.9	34.5	25.0	32.8
Dry	16.3	17.8	26.0	32.6	26.4	32.9
Critical	20.6	20.8	24.6	30.4	25.6	29.8
Average	15.1	17.6	26.8	34.6	27.4	34.6

Redd Dewatering

Management of instream flows in the American River is largely controlled by reservoir operations and releases. Ramping schedules have been established and are expected to be applied under all model scenarios. Instream flow maintenance and ramping are designed to minimize or avoid the risk of redd dewatering. No effect is expected on the risk of redd dewatering as a result of the preliminary proposal.

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Fry and Juvenile Rearing

Rearing Habitat

Chinook emergence in the American River begins in January, peaks in February, and can continue into April. Juvenile rearing occurs from January to June, with a peak between January and May. Rearing continues later into the summer in years with higher spring flows. Water temperatures in the Feather River at Watt Avenue are predicted to be similar between EBC2_ELT and PP_ELT and between EBC2_LLT and PP_LLT during January through May (Figure C.5.2-327 through Figure C.5.2-331). June water temperatures are projected to be ~2°F–3°F lower under PP_ELT and PP_LLT than EBC2_ELT and EBC2_LLT, respectively (Figure C.5.2-332). These results suggest that water temperature conditions for fall-run Chinook salmon rearing under the preliminary proposal are expected to remain similar to or improved over existing conditions, but future climate change is predicted to result in large increases in water temperatures that would likely adversely affect juvenile fall-run Chinook salmon rearing habitat.

Flow requirements for rearing juvenile Chinook salmon in the American River have not been determined, but in years with higher spring flows, Chinook salmon tend to be present in the river later into the spring. This could be due to better survival or decreased emigration, or both. The unknown but likely high proportion of hatchery-produced fall-run Chinook salmon in the river has made correlations between populations of returning adults and flows nearly impossible, but higher flows during late winter and spring rearing were assumed to result in higher survival. CALSIM modeling predicts that flows during January through May are similar between EBC2_ELT and PP_ELT and between EBC2_LLT and PP_LLT (Table C.5.2-127 and Figure C.5.2-311 through Figure C.5.2-315).

Adult

Water Temperature

The effects of the preliminary proposal on water temperature for migrating adult fall-run Chinook salmon are expected to be similar to those for adult steelhead in Section C.5.2.5.1.

C.5.2.5.3 Splittail

Larvae

As described for the Sacramento River (Section C.5.2.1.1), splittail spawning and rearing of larvae and young juveniles in channel margin and side-channel habitat upstream of the Delta are likely to be especially important during dry years, when flows are too low to inundate the floodplains. Splittail have been found in the American River as far upstream as a couple of miles beyond the Watt Avenue Bridge (Sommer et al. 2007).

Spawning and Rearing Habitat

The upstream side-channel habitats used by splittail for spawning and rearing are, as previously indicated, affected by changes in flow because greater flows cause more flooding, thereby increasing availability of such habitat, and because rapid reductions in flow dewater the habitats, potentially stranding splittail eggs and rearing larvae. The changes in flows are expected to be especially important in years with low-flows. Simulated flows in the American River at its confluence with the

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Sacramento River were used to investigate the potential effects of BDCP operations on side channel habitat availability on the mainstem American River. This analysis was limited to flows during February through June because these are the most important months for splittail spawning and larval and juvenile rearing and the months in which splittail are most likely to be in the American River.

Monthly average flows during February through June by water-year type are presented in Table C.5.2-134 and differences between pairs of model scenarios are presented in Table C.5.2-135. A probability of exceedance plot is presented in Figure C.5.2-344. Results show that, in the drier water-year types (below-normal, dry, and critical) when splittail are most likely to use side channel habitat in the American River, there are substantial differences (>10%) in flows between EBC2_ELT and PP_ELT and between EBC2_LLT and PP_LLT in some months. Differences are particularly high in May and June; flows are up to 44% higher under PP_ELT and PP_LLT relative to EBC2_ELT and EBC2_LLT, respectively, for below-normal years, and up to 31% higher for both dry and critical years. These increases are due to increased releases at Nimbus Dam. Most differences are positive, but flow is 18% lower under PP_ELT relative to EBC2_ELT for critical years in May. These results indicate that greater amounts of side channel habitat are available for splittail spawning and rearing in the American River under the preliminary proposal relative to existing conditions, especially during May and June, with the exception of May in critical years, when side channel habitat is less available under the preliminary proposal.

Table C.5.2-134. Mean Monthly Flows (Cubic Feet per Second) in the American River at the Confluence with the Sacramento River, February through June

Month	Water-Year Type	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
Feb	W	9,183	8,982	10,275	10,947	10,336	10,967
	AN	6,422	6,139	7,148	8,073	7,589	8,280
	BN	4,309	4,058	4,631	4,888	4,806	5,100
	D	1,781	1,686	1,679	1,756	1,682	1,835
	C	1,119	1,074	985	921	1,057	970
	AVG	5,142	4,967	5,607	6,007	5,732	6,104
Mar	W	5,979	5,915	6,304	6,837	6,301	6,832
	AN	5,364	5,224	5,641	5,661	5,687	5,739
	BN	2,340	2,271	2,503	2,672	2,558	2,565
	D	2,121	1,968	2,095	2,224	2,163	2,022
	C	864	843	785	836	749	759
	AVG	3,672	3,583	3,826	4,063	3,851	3,999
Apr	W	5,156	4,997	5,164	5,300	5,162	5,310
	AN	3,383	3,238	3,136	3,079	3,131	3,117
	BN	2,984	2,788	2,927	2,778	2,913	2,966
	D	1,672	1,673	1,550	1,677	1,717	1,802
	C	996	985	886	1,059	1,046	1,094
	AVG	3,152	3,046	3,066	3,128	3,122	3,202

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Month	Water-Year Type	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
May	W	5,959	5,711	5,415	4,332	5,433	4,459
	AN	3,700	3,411	2,911	2,285	3,125	2,708
	BN	2,733	2,555	2,222	1,726	2,472	2,273
	D	1,605	1,484	1,399	1,454	1,558	1,901
	C	1,014	992	1,118	790	917	806
	AVG	3,398	3,217	2,993	2,438	3,078	2,733
Jun	W	5,743	5,456	4,206	3,388	4,743	4,261
	AN	3,103	2,973	2,562	2,736	3,463	3,566
	BN	2,631	2,358	2,274	2,603	3,282	3,483
	D	2,282	2,140	2,289	2,320	2,632	2,272
	C	1,621	1,412	1,052	793	1,382	1,026
	AVG	3,462	3,244	2,753	2,545	3,351	3,117

Table C.5.2-135. Difference (Percent Difference) between Pairs of Model Scenarios in Mean Monthly Flows in the American River at the Confluence with the Sacramento River, February through June

Month	WY Type	EBC1 vs. PP_ELT	EBC1 vs. PP_LLT	EBC2 vs. PP_ELT	EBC2 vs. PP_LLT	EBC2_ELT vs. PP_ELT	EBC2_LLT vs. PP_LLT
Feb	W	1153 (12.6%)	1784 (19.4%)	1353 (15.1%)	1984 (22.1%)	60 (0.6%)	20 (0.2%)
	AN	1167 (18.2%)	1858 (28.9%)	1450 (23.6%)	2142 (34.9%)	441 (6.2%)	208 (2.6%)
	BN	497 (11.5%)	792 (18.4%)	748 (18.4%)	1042 (25.7%)	175 (3.8%)	212 (4.3%)
	D	-98 (-5.5%)	54 (3%)	-3 (-0.2%)	149 (8.8%)	3 (0.2%)	79 (4.5%)
	C	-62 (-5.6%)	-149 (-13.3%)	-17 (-1.6%)	-104 (-9.7%)	71 (7.2%)	49 (5.3%)
	AVG	591 (11.5%)	963 (18.7%)	766 (15.4%)	1138 (22.9%)	125 (2.2%)	97 (1.6%)
Mar	W	322 (5.4%)	852 (14.3%)	387 (6.5%)	917 (15.5%)	-2 (0%)	-5 (-0.1%)
	AN	322 (6%)	374 (7%)	463 (8.9%)	515 (9.9%)	46 (0.8%)	77 (1.4%)
	BN	219 (9.3%)	225 (9.6%)	287 (12.7%)	294 (12.9%)	56 (2.2%)	-108 (-4%)
	D	42 (2%)	-99 (-4.7%)	195 (9.9%)	54 (2.7%)	68 (3.3%)	-202 (-9.1%)
	C	-115 (-13.3%)	-105 (-12.2%)	-94 (-11.1%)	-84 (-10%)	-35 (-4.5%)	-77 (-9.2%)
	AVG	179 (4.9%)	326 (8.9%)	269 (7.5%)	416 (11.6%)	25 (0.7%)	-64 (-1.6%)
Apr	W	6 (0.1%)	155 (3%)	165 (3.3%)	314 (6.3%)	-2 (0%)	11 (0.2%)
	AN	-252 (-7.4%)	-266 (-7.9%)	-107 (-3.3%)	-121 (-3.7%)	-5 (-0.2%)	38 (1.2%)
	BN	-71 (-2.4%)	-18 (-0.6%)	125 (4.5%)	177 (6.4%)	-14 (-0.5%)	188 (6.8%)
	D	45 (2.7%)	130 (7.8%)	45 (2.7%)	130 (7.8%)	168 (10.8%)	126 (7.5%)
	C	51 (5.1%)	98 (9.9%)	62 (6.3%)	110 (11.1%)	160 (18%)	35 (3.3%)
	AVG	-30 (-0.9%)	50 (1.6%)	77 (2.5%)	156 (5.1%)	56 (1.8%)	74 (2.4%)
May	W	-526 (-8.8%)	-1500 (-25.2%)	-278 (-4.9%)	-1252 (-21.9%)	18 (0.3%)	126 (2.9%)
	AN	-574 (-15.5%)	-991 (-26.8%)	-286 (-8.4%)	-703 (-20.6%)	214 (7.3%)	423 (18.5%)
	BN	-262 (-9.6%)	-461 (-16.9%)	-83 (-3.2%)	-282 (-11%)	250 (11.3%)	546 (31.6%)
	D	-47 (-2.9%)	296 (18.5%)	73 (4.9%)	416 (28.1%)	159 (11.4%)	447 (30.7%)
	C	-97 (-9.5%)	-208 (-20.5%)	-75 (-7.5%)	-185 (-18.7%)	-201 (-18%)	16 (2%)
	AVG	-320 (-9.4%)	-665 (-19.6%)	-139 (-4.3%)	-484 (-15%)	85 (2.8%)	296 (12.1%)

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Month	WY Type	EBC1 vs. PP_ELT	EBC1 vs. PP_LLT	EBC2 vs. PP_ELT	EBC2 vs. PP_LLT	EBC2_ELT vs. PP_ELT	EBC2_LLT vs. PP_LLT
Jun	W	-999 (-17.4%)	-1481 (-25.8%)	-713 (-13.1%)	-1195 (-21.9%)	538 (12.8%)	873 (25.8%)
	AN	360 (11.6%)	463 (14.9%)	491 (16.5%)	594 (20%)	901 (35.2%)	831 (30.4%)
	BN	651 (24.7%)	852 (32.4%)	923 (39.2%)	1124 (47.7%)	1008 (44.3%)	880 (33.8%)
	D	350 (15.3%)	-10 (-0.4%)	491 (23%)	131 (6.1%)	343 (15%)	-48 (-2.1%)
	C	-239 (-14.8%)	-595 (-36.7%)	-29 (-2.1%)	-385 (-27.3%)	330 (31.4%)	233 (29.4%)
	AVG	-111 (-3.2%)	-346 (-10%)	107 (3.3%)	-128 (-3.9%)	598 (21.7%)	572 (22.5%)

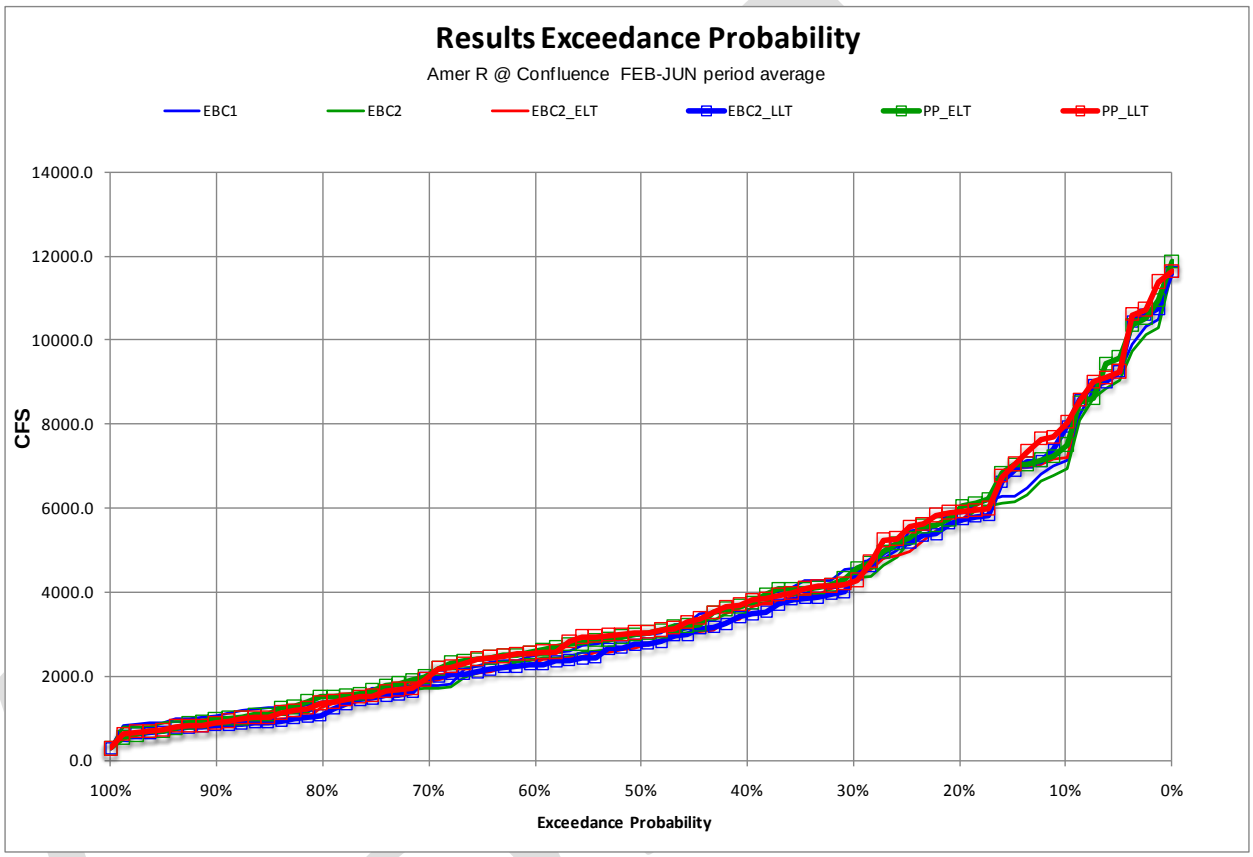

Figure C.5.2-344. Probability of Exceedance Plot for Model Scenarios of Mean Monthly Flow in the American River at the Confluence with the Sacramento River, February through June

Water Temperature

Simulated daily water temperatures in the American River at its confluence with the Sacramento River were used to investigate the potential effects of BDCP operations on the suitability of water temperatures for splittail rearing on the mainstem American River. As previously indicated (Section C.5.2.1.1), a range of 45°F to 75°F was selected as the suitable range for splittail egg incubation and larval rearing in the upstream habitat locations.

Table C.5.2-136 presents the percent of days from 1992–2003 during which February through June water temperatures are below 45°F or exceed 75°F for each model scenario. Table C.5.2-137 presents the differences and percent differences between pairs of model scenarios in the percent of days below 45°F or above 75°F. Figure C.5.2-345 presents the probability of water temperature

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exceedance for each model scenario. These results show that water temperatures under all scenarios would remain above 45°F in 100% of days throughout the period and below 75°F in >95% days. There is little difference (<5%) in the percent of days above 75°F between EBC2_ELT and PP_ELT and between EBC2_LLT and PP_LLT in all water-year types. Therefore, it is concluded that there are no biologically meaningful temperature-related effects of the BDCP on splittail egg and larval habitat in the American River.

Table C.5.2-136. Percent of Months during February to June[1] When Daily Average Temperatures Are Below 45°F or Exceed 75°F in the American River at the Confluence with the Sacramento River

	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
Temperatures below 45°F						
Wet	0.0	0.0	0.0	0.0	0.0	0.0
Above Normal	0.0	0.0	0.0	0.0	0.0	0.0
Below Normal	0.0	0.0	0.0	0.0	0.0	0.0
Dry	0.0	0.0	0.0	0.0	0.0	0.0
Critical	0.0	0.0	0.0	0.0	0.0	0.0
All	0.0	0.0	0.0	0.0	0.0	0.0
Temperatures above 75°F						
Wet	0.0	0.0	0.0	0.8	0.0	0.8
Above Normal	0.0	0.0	0.0	0.0	0.0	0.0
Below Normal	0.0	0.0	0.0	4.3	0.0	0.0
Dry	0.0	0.0	2.2	4.4	2.2	3.3
Critical	0.0	0.0	0.0	5.0	0.0	3.3
All	0.0	0.0	0.5	2.7	0.5	1.5

[1] Based on the modeling period of 1922 to 2003.

Table C.5.2-137. Difference and Percent Difference in Percentage of Months during February through June When Daily Average Temperature Is Below 45°F or Exceeds 75°F in the American River at the Confluence with the Sacramento River

Water-Year Type	Comparison[1]	EBC1 vs. PP_ELT	EBC1 vs. PP_LLT	EBC2 vs. EBC2_ELT	EBC2 vs. EBC2_LLT	EBC2 vs. PP_ELT	EBC2 vs. PP_LLT	EBC2_ELT vs. PP_ELT	EBC2_LLT vs. PP_LLT
Below 45°F									
Wet	Difference	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Percent Difference	NA	NA	NA	NA	NA	NA	NA	NA
Above Normal	Difference	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Percent Difference	NA	NA	NA	NA	NA	NA	NA	NA
Below Normal	Difference	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Percent Difference	NA	NA	NA	NA	NA	NA	NA	NA
Dry	Difference	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Percent Difference	NA	NA	NA	NA	NA	NA	NA	NA

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Water-Year Type	Comparison[1]	EBC1 vs. PP_ELT	EBC1 vs. PP_LLT	EBC2 vs. EBC2_ELT	EBC2 vs. EBC2_LLT	EBC2 vs. PP_ELT	EBC2 vs. PP_LLT	EBC2_ELT vs. PP_ELT	EBC2_LLT vs. PP_LLT
Below 45°F									
Critical	Difference	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Percent Difference	NA	NA	NA	NA	NA	NA	NA	NA
All	Difference	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Percent Difference	NA	NA	NA	NA	NA	NA	NA	NA
Above 75°F									
Wet	Difference	0.0	0.8	0.0	0.8	0.0	0.8	0.0	0.0
	Percent Difference	NA	NA	NA	NA	NA	NA	NA	0%
Above Normal	Difference	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Percent Difference	NA	NA	NA	NA	NA	NA	NA	NA
Below Normal	Difference	0.0	0.0	0.0	4.3	0.0	0.0	0.0	-4.3
	Percent Difference	NA	NA	NA	NA	NA	NA	NA	-100%
Dry	Difference	2.2	3.3	2.2	4.4	2.2	3.3	0.0	-1.1
	Percent Difference	NA	NA	NA	NA	NA	NA	0%	-25%
Critical	Difference	0.0	3.3	0.0	5.0	0.0	3.3	0.0	-1.7
	Percent Difference	NA	NA	NA	NA	NA	NA	NA	-33%
All	Difference	0.5	1.5	0.5	2.7	0.5	1.5	0.0	-1.2
	Percent Difference	NA	NA	NA	NA	NA	NA	0%	-45%

[1] A positive value indicates a higher value under the preliminary proposal than the EBC.
NA = Could not be calculated because dividing by 0.

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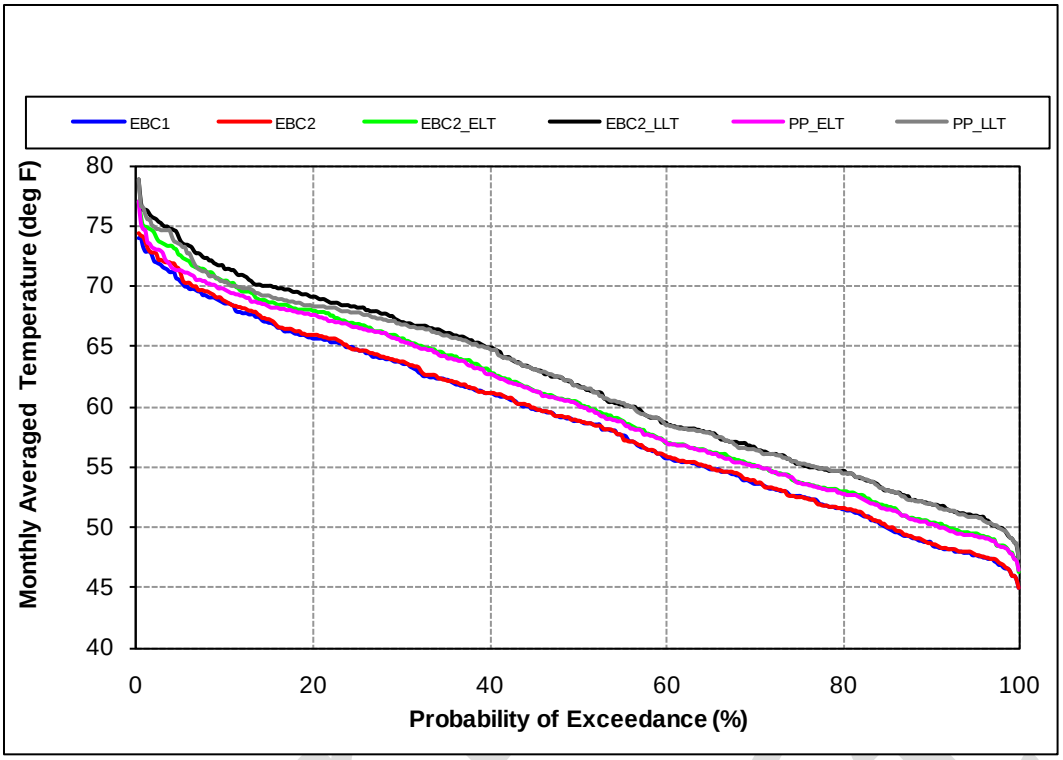

Figure C.5.2-345. Probability of Exceedance Plot for Model Scenarios of Mean Monthly Temperature in the American River at the Confluence with the Sacramento River, February through June

C.5.2.5.4 Lamprey

Eggs

Water Temperature

Exact spawning locations of Pacific and river lamprey in the American River are not well known. Therefore, this analysis includes upstream (Nimbus Dam) and downstream (confluence with the Sacramento River) locations that encompass the range in which those species are thought to spawn (Hannon pers. comm.). As with the Feather River, a 2-month period was used to represent the duration of each egg cohort. The number of cohorts exposed to water temperatures above 71.6°F for Pacific lamprey is reported in Table C.5.2-75, and number of river lamprey exposed to water temperatures above 71.6°F and 77°F are reported in Table C.5.2-76; differences between model scenarios are reported in Table C.5.2-77 (Pacific lamprey) and Table C.5.2-78 (river lamprey).

At Nimbus Dam

For Pacific lamprey at Nimbus Dam, the percent of egg cohorts experiencing water temperatures that exceed 71.6°F is predicted to be 2%–4% under EBC1 and EBC2, 8%–13% under EBC2_ELT and EBC2_LLT, and 7%–13% under PP_ELT and PP_LLT (Figure C.5.2-346, Table C.5.2-75). Under early long-term conditions, implementation of the preliminary proposal (PP_ELT) would result in exposure of 44 cohorts to temperatures exceeding 71.6°F, a 14% decrease relative to EBC2_ELT (51 cohorts) (Table C.5.2-77). Under late long-term conditions, implementation of the preliminary proposal (PP_LLT) would result in exposure of 87 cohorts to temperatures exceeding 71.6°F, a 2% increase relative to EBC2_LLT (85 cohorts).

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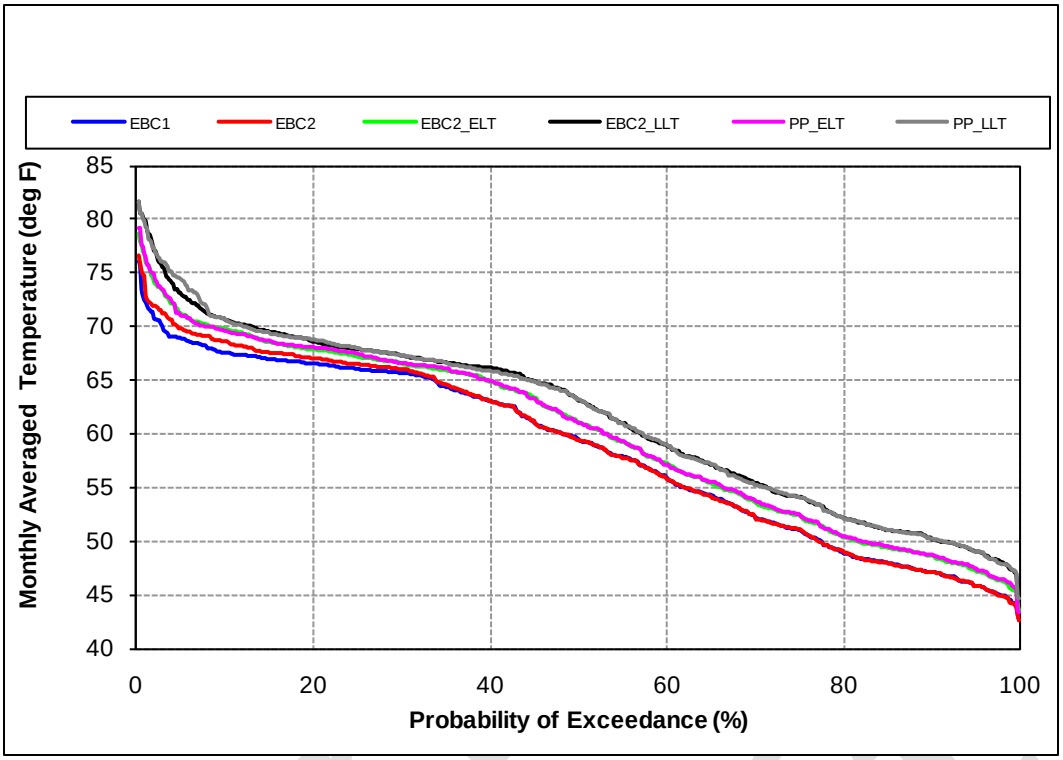

Figure C.5.2-346. Probability of Exceedance Plot for Model Scenarios of Mean Monthly Temperature of the American River at Nimbus, January through August

For river lamprey, the percent of egg cohorts experiencing water temperatures that exceed 71.6°F is predicted to be 1%–4% under EBC1 and EBC2, and 4%–7% under EBC2_ELT, EBC2_LLT, PP_ELT, and PP_LLT (Figure C.5.2-347, Table C.5.2-76). Under early long-term conditions, implementation of the preliminary proposal (PP_ELT) would result in exposure of 16 cohorts to temperatures exceeding 71.6°F, a 16% decrease relative to EBC2_ELT (19 cohorts) (Table C.5.2-78). Under late long-term conditions, implementation of the preliminary proposal (PP_LLT) would result in exposure of 29 cohorts to temperatures exceeding 71.6°F, a 3% decrease relative to EBC2_LLT (30 cohorts).

The percent of river lamprey egg cohorts experiencing water temperatures that exceed 77°F is predicted to be 0% under EBC1 and EBC2, and ≤1% under EBC2_ELT, EBC2_LLT, PP_ELT, and PP_LLT (Figure C.5.2-347, Table C.5.2-76). Under early long-term conditions, implementation of the preliminary proposal (PP_ELT) would result in no change in the number of cohorts exposed to temperatures exceeding 77°F relative to EBC2_ELT (1 cohort) (Table C.5.2-78). Under late long-term conditions, implementation of the preliminary proposal (PP_LLT) would result in exposure of five cohorts to temperatures exceeding 77°F, a 25% decrease relative to EBC2_LLT (4 cohorts).

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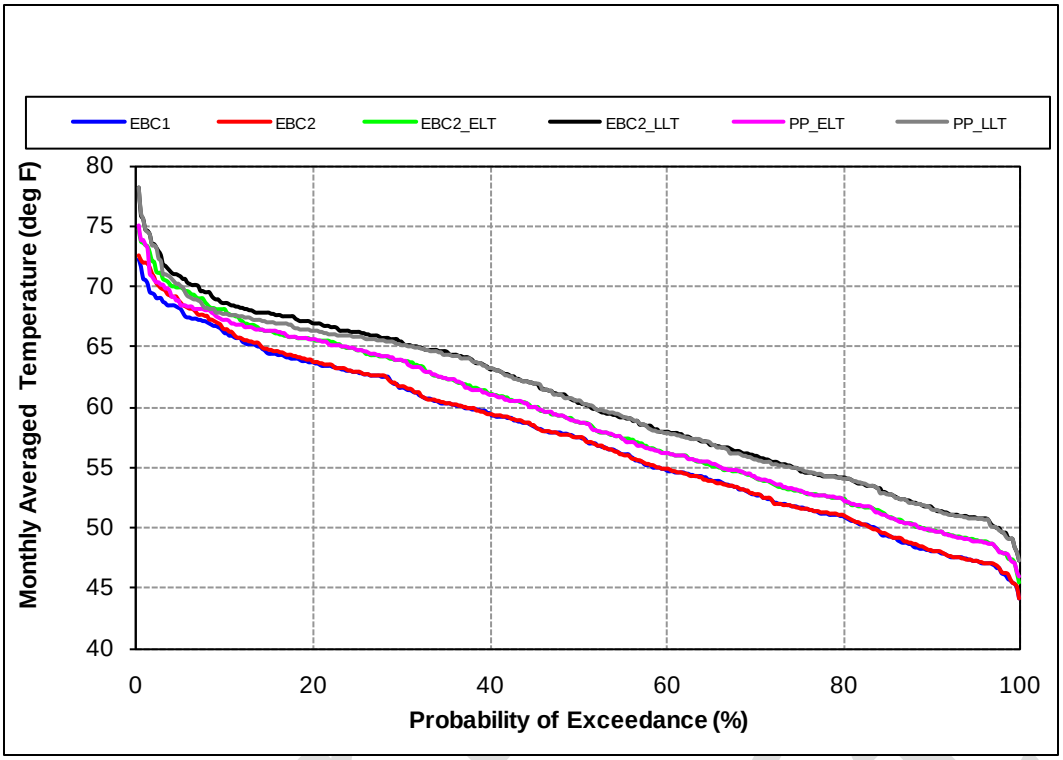

Figure C.5.2-347. Probability of Exceedance Plot for Model Scenarios of Mean Monthly Water Temperature of the American River at Nimbus Dam, February through June

At Sacramento River Confluence

For Pacific lamprey at the confluence with the Sacramento River, the proportion of egg cohorts experiencing water temperatures that exceed 71.6°F is predicted to be 9%–14% under EBC1 and EBC2, 23%–33% under EBC2_ELT and EBC2_LLT, and 22%–33% under PP_ELT and PP_LLT (Figure C.5.2-348, Table C.5.2-75). Under early long-term conditions, implementation of the preliminary proposal (PP_ELT) would result in exposure of 143 cohorts to temperatures exceeding 71.6°F, a 5% decrease relative to EBC2_ELT (150 cohorts) (Table C.5.2-77). Under late long-term conditions, implementation of the preliminary proposal (PP_LLT) would result in exposure of 213 cohorts to temperatures exceeding 71.6°F, a 1% decrease relative to EBC2_LLT (216 cohorts).

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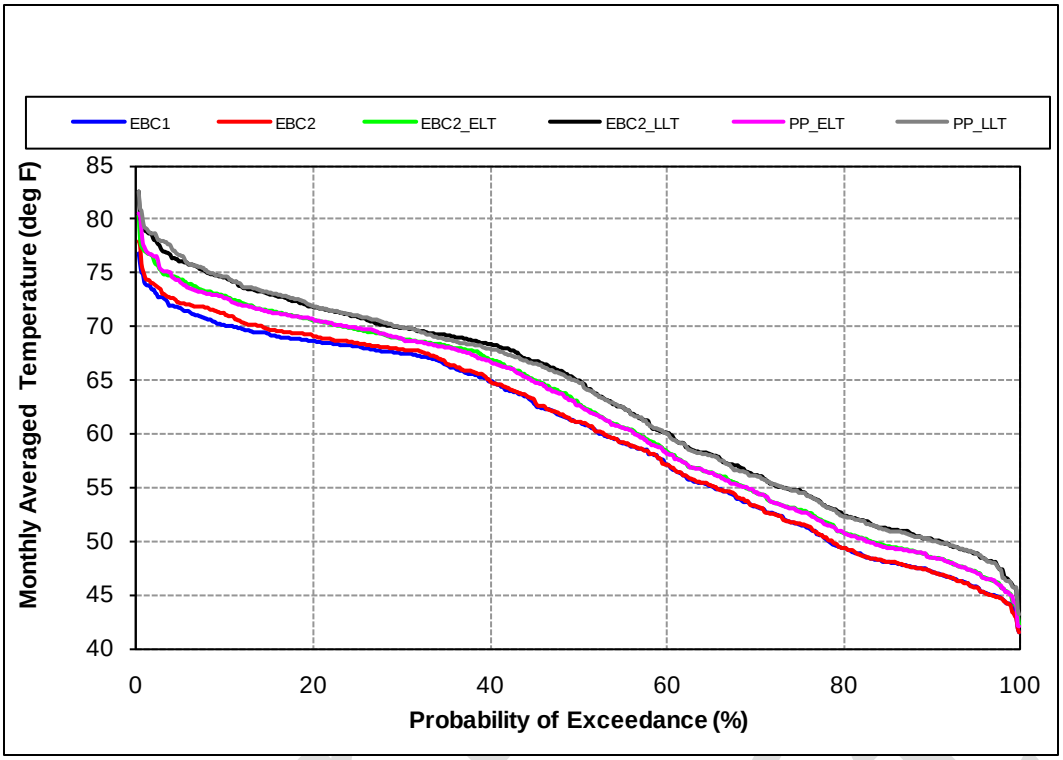

Figure C.5.2-348. Probability of Exceedance Plot for Model Scenarios of Mean Monthly Temperature of the American River at the Confluence with the Sacramento River, January through August

For river lamprey, the percent of egg cohorts experiencing water temperatures that exceed 71.6°F is predicted to be 7%–9% under EBC1 and EBC2, 14%–20% under EBC2_ELT and EBC2_LLT, and 11%–17% under PP_ELT and PP_LLT (Figure C.5.2-349, Table C.5.2-76). Under early long-term conditions, implementation of the preliminary proposal (PP_ELT) would result in exposure of 44 cohorts to temperatures exceeding 71.6°F, a 23% decrease relative to EBC2_ELT (57 cohorts) (Table C.5.2-78). Under late long-term conditions, implementation of the preliminary proposal (PP_LLT) would result in exposure of 70 cohorts to temperatures exceeding 71.6°F, a 15% decrease relative to EBC2_LLT (82 cohorts).

The percent of river lamprey egg cohorts experiencing water temperatures that exceed 77°F is predicted to be <1% under EBC1 and EBC2, <2% under EBC2_ELT and EBC2_LLT, and 1%–2% under PP_ELT and PP_LLT (Figure C.5.2-349, Table C.5.2-76). Under early long-term conditions, implementation of the preliminary proposal (PP_ELT) would result in exposure of four cohorts to temperatures exceeding 77°F versus three cohorts in the absence of implementation of the preliminary proposal (EBC2_ELT) (Table C.5.2-78). Under late long-term conditions, implementation of the preliminary proposal (PP_LLT) would result in exposure of nine cohorts to temperatures exceeding 77°F versus six cohorts in the absence of implementation of the preliminary proposal (EBC2_LLT).

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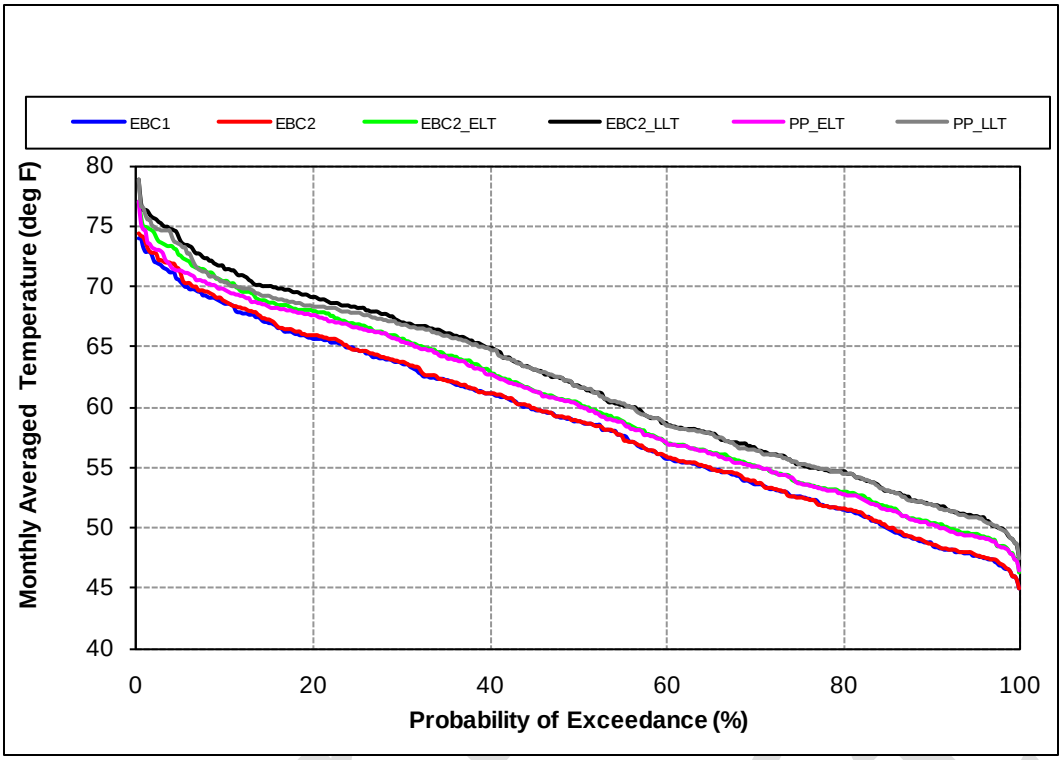

Figure C.5.2-349. Probability of Exceedance Plot for Model Scenarios of Mean Monthly Water Temperature of the American River at the Confluence with the Sacramento River, February through June

These results indicate that climate change will increase the number of Pacific lamprey and river lamprey egg cohorts exposed to temperatures greater than 71.6°F. The preliminary proposal has small benefits in the early long-term and a small variable effect in the late long-term relative to climate change effects for Pacific lamprey, and small benefits for both timeframes for river lamprey at both locations analyzed. There also would be minor increases in the number of river lamprey egg cohorts exposed to temperatures greater than 77°F, including minor increases attributable to climate change as well as to the preliminary proposal in the late long-term in the American River at Nimbus Dam and early and late long-term at the confluence with the Sacramento River. Because this analysis uses water temperature model outputs based on CALSIM outputs, error has been propagated and the level of certainty of these results is moderate.

Redd Dewatering

At Nimbus Dam

For Pacific lamprey, the total predicted number of redd cohorts between January and August experiencing a month-over-month decrease in flow of greater than 50% in the American River at Nimbus Dam ranged between 84 (EBC1) and 121 cohorts (EBC2_LLT) (Table C.5.2-56).

There are 17 and 27 more Pacific lamprey redd cohorts (20% and 32%) predicted to experience a month-over-month decrease in flow of greater than 50% for PP_ELT and PP_LLT, respectively, relative to the EBC1 (Table C.5.2-57). At Nimbus Dam, there are nine and 19 more redd cohorts (10% and 21%) predicted to experience a month-over-month decrease in flow of greater than 50% for PP_ELT and PP_LLT, respectively, relative to the EBC2.

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Isolating the effect of the preliminary proposal from the effects of climate change, there are five and 10 fewer cohorts (5% and 8%) predicted to experience a month-over-month change in flow of greater than 50% for PP_ELT and PP_LLT relative to the EBC2_ELT and EBC2_LLT, respectively.

For river lamprey, the predicted number of redd cohorts experiencing a month-over-month decrease in flow of more than 50% in the American River at Nimbus Dam is between 55 (EBC1 and PP_ELT) and 65 cohorts (PP_LLT) (Table C.5.2-58).

There are four and 10 more river lamprey redd cohorts (7% and 18%, respectively) predicted to experience a month-over-month change in flow of greater than 50% in the PP_ELT and PP_LLT, respectively, relative to the EBC1 (Table C.5.2-59). There are zero and six more redd cohorts (0% and 10%, respectively) predicted to experience a month-over-month change in flow of greater than 50% in the PP_ELT and PP_LLT, respectively, relative to the EBC2.

Removing the effect of climate change, there are five fewer redd cohorts (8%) predicted to experience a month-over-month change in flow of greater than 50% under the PP_ELT relative to the EBC2_ELT. However, there is one more redd cohort (2%) predicted to experience a month-over-month change in flow of greater than 50% under the PP_LLT relative to the EBC2_LLT.

At Sacramento River Confluence

For Pacific lamprey, the total predicted number of cohorts between January and August experiencing month-over-month flow in the American River at the confluence with the Sacramento River that decreased by more than 50% ranged between 95 (EBC1) and 135 cohorts (EBC2_LLT) (Table C.5.2-56).

There are 19 and 35 more Pacific lamprey redd cohorts (20% and 37%, respectively) predicted to experience a month-over-month change in flow of greater than 50% for PP_ELT and PP_LLT, respectively, relative to the EBC1 (Table C.5.2-57). At the confluence with the Sacramento River, there are 14 and 30 more redd cohorts (14% and 30%, respectively) predicted to experience a month-over-month change in flow of greater than 50% for PP_ELT and PP_LLT, respectively, relative to the EBC2.

Isolating the effect of the preliminary proposal from the effects of climate change, there are four and five fewer redd cohorts (3% and 4%) predicted to experience a month-over-month change in flow of greater than 50% for PP_ELT and PP_LLT relative to EBC2_ELT and EBC2_LLT, respectively.

For river lamprey, the predicted number of redd cohorts experiencing a month-over-month decrease in flow of more than 50% in the American River at the confluence with the Sacramento River is between 59 (EBC1) and 76 cohorts (EBC2_LLT) (Table C.5.2-58).

There are nine and 15 more redd cohorts (15% and 25%, respectively) predicted to experience a month-over-month change in flow of greater than 50% under the PP_ELT and PP_LLT, respectively, relative to the EBC1 (Table C.5.2-59). There are three and nine more redd cohorts (5% and 14%, respectively) predicted to experience a month-over-month change in flow of greater than 50% under the PP_ELT and PP_LLT, respectively, relative to the EBC2).

Removing the effect of climate change, there are three and two fewer redd cohorts (4% and 3%) predicted to experience a month-over-month change in flow of greater than 50% under the PP_ELT and PP_LLT relative to the EBC2_ELT and EBC2_LLT, respectively.

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These results indicate that, although climate change will increase the number of Pacific and river lamprey redd cohorts predicted to experience a month-over-month change in flow of greater than 50% in the American River (assumed here to represent a redd dewatering event), the preliminary proposal reduces this exposure by 2% to 8%, depending on time period and location.

Ammocoete

Water Temperature

Predicted monthly average water temperatures in the American River at Nimbus Dam and at the confluence with the Sacramento River are presented in Figure C.5.2-350 and Figure C.5.2-351, respectively.

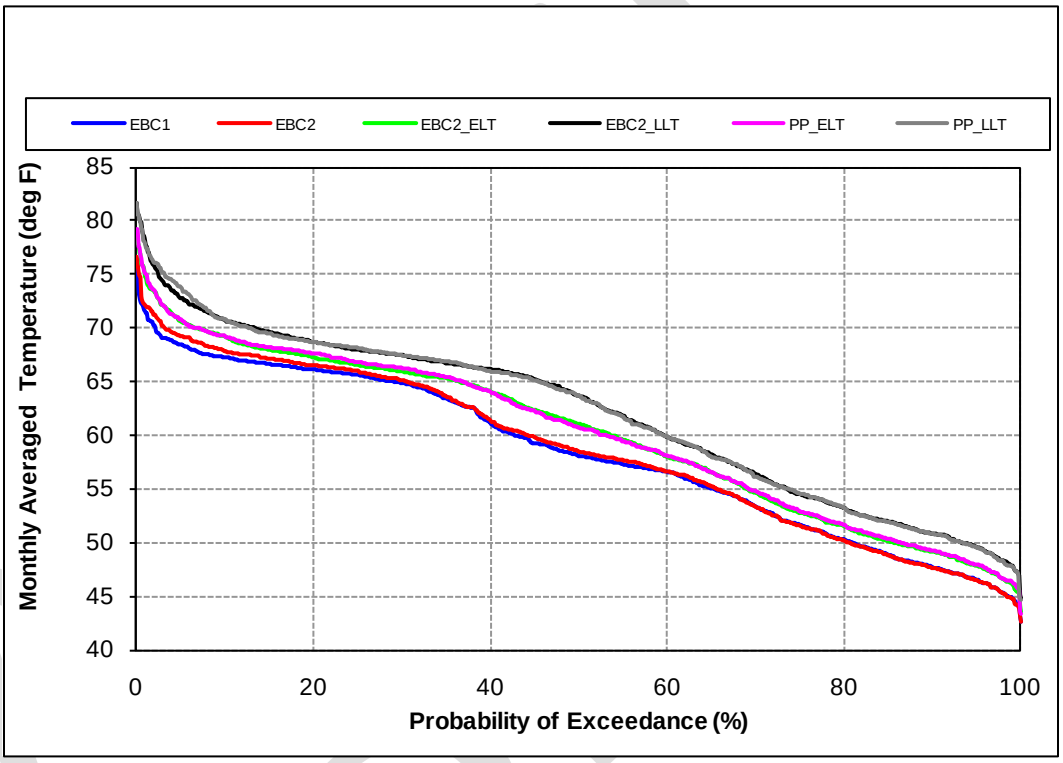

Figure C.5.2-350. Probability of Exceedance Plot for Model Scenarios of Mean Monthly Temperature of the American River at Nimbus Dam for All Months

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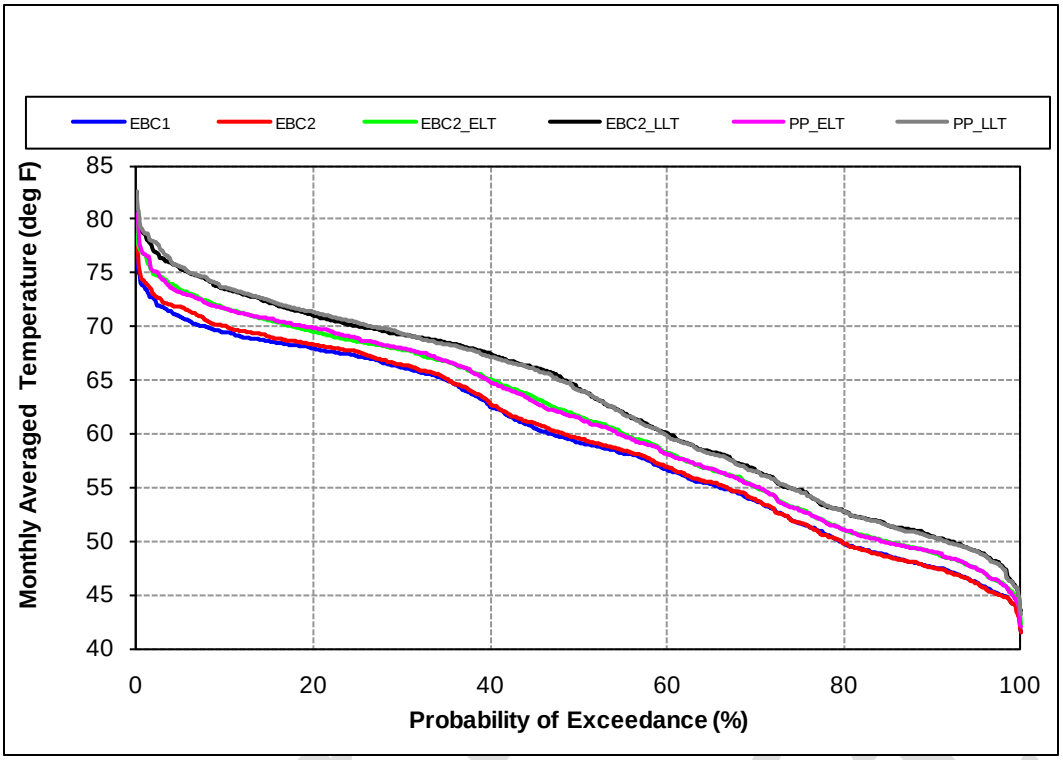

Figure C.5.2-351. Probability of Exceedance Plot for Model Scenarios of Mean Monthly Temperature of the American River at the Confluence with the Sacramento River for All Months

At Nimbus Dam

For Pacific lamprey in the American River at Nimbus Dam, the percent of ammocoete cohorts experiencing water temperatures exceeding 71.6°F is predicted to be 33%–56% under EBC1 and EBC2, 80%–95% under EBC2_ELT and EBC2_LLT, and 76%–92% under PP_ELT and PP_LLT (Table C.5.2-60). Under early long-term conditions, implementation of the preliminary proposal (PP_ELT) would result in exposure of 452 cohorts to temperatures exceeding 71.6°F, a 4% decrease relative to EBC2_ELT (473 cohorts) (Table C.5.2-61). Under late long-term conditions, implementation of the preliminary proposal (PP_LLT) would result in exposure of 547 cohorts to temperatures exceeding 71.6°F, a 3% decrease relative to EBC2_LLT (561 cohorts).

For river lamprey, the percent of ammocoete cohorts experiencing water temperatures that exceed 71.6°F is predicted to be 24%–46% under EBC1 and EBC2, 71%–88% under EBC2_ELT and EBC2_LLT, and 70%–84% under PP_ELT and PP_LLT (Table C.5.2-62). Under early long-term conditions, implementation of the preliminary proposal (PP_ELT) would result in exposure of 265 cohorts to temperatures exceeding 71.6°F, a 2% decrease relative to EBC2_LLT (270 cohorts)(Table C.5.2-63). Under late long-term conditions, implementation of the preliminary proposal (PP_LLT) would result in exposure of 320 cohorts to temperatures exceeding 71.6°F, a 5% decrease relative to EBC2_LLT (335 cohorts).

The percent of river lamprey ammocoete cohorts experiencing water temperatures that exceed 77°F is predicted to be 0% under EBC1 and EBC2, 13%–58% under EBC2_ELT and EBC2_LLT, and 24%–51% under PP_ELT and PP_LLT (Table C.5.2-62). Under early long-term conditions, implementation of the preliminary proposal (PP_ELT) would result in exposure of 90 cohorts to temperatures exceeding 77°F, an 80% increase relative to EBC2_ELT (50 cohorts) (Table C.5.2-63). Under late

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long-term conditions, implementation of the preliminary proposal (PP_LLT) would result in exposure of 195 cohorts to temperatures exceeding 77°F, an 11% decrease relative to EBC2_LLT (220 cohorts).

These results indicate that the effects of the preliminary proposal on Pacific and river lamprey ammocoetes in the American River at Nimbus Dam are negligible at the 71.6°F and 77°F thresholds.

At Sacramento River Confluence

For Pacific lamprey in the American River at the confluence with the Sacramento River, the percent of ammocoete cohorts experiencing water temperatures exceeding 71.6°F is predicted to be 73%–84% under EBC1 and EBC2, 97%–100% under EBC2_ELT and EBC2_LLT, and 99%–100% under PP_ELT and PP_LLT (Table C.5.2-60). Under early long-term conditions, implementation of the preliminary proposal (PP_ELT) would result in exposure of 585 cohorts to temperatures exceeding 71.6°F, a 2% increase relative to EBC2_ELT (576 cohorts) (Table C.5.2-61). Under late long-term conditions, implementation of the preliminary proposal (PP_LLT) would result in no change in the number of cohorts exposed to temperatures exceeding 71.6°F relative to EBC2_LLT (593 cohorts).

For river lamprey, the percent of ammocoete cohorts experiencing water temperatures that exceed 71.6°F is predicted to be 65%–79% under EBC1 and EBC2, 95%–100% under EBC2_ELT and EBC2_LLT, and 96%–100% under PP_ELT and PP_LLT (Table C.5.2-62). Under early long-term conditions, implementation of the preliminary proposal (PP_ELT) would result in exposure of 365 cohorts to temperatures exceeding 71.6°F, a 1% increase relative to EBC2_ELT (360 cohorts) (Table C.5.2-63). Under late long-term conditions, implementation of the preliminary proposal (PP_LLT) would result in no change in the number of ammocoete cohorts exposed to temperatures exceeding 71.6°F relative to the EBC2_LLT (380 cohorts, or 100% of the total number of cohorts).

The percent of river lamprey ammocoete cohorts experiencing water temperatures that exceed 77°F is predicted to be 0%–13% under EBC1 and EBC2, 28%–61% under EBC2_ELT and EBC2_LLT, and 34%–72% under PP_ELT and PP_LLT (Table C.5.2-62). Under early long-term conditions, implementation of the preliminary proposal (PP_ELT) would result in exposure of 130 cohorts to temperatures exceeding 77°F, a 24% increase relative to EBC2_ELT (105 cohorts) (Table C.5.2-63). Under late long-term conditions, implementation of the preliminary proposal (PP_LLT) would result in exposure of 275 cohorts to temperatures exceeding 77°F, a 20% increase relative to EBC2_LLT (230 cohorts).

These results indicate that Pacific lamprey ammocoetes in the American River would experience an increase in water temperature–related effects due to climate change. However, the preliminary proposal would provide a small benefit to ammocoetes by reducing water temperatures by 2.5%–4.4% upstream (at Nimbus Dam) but would have no effect downstream (at the confluence with the Sacramento River). Results indicate that the effects of the preliminary proposal on river lamprey ammocoetes in the American River at the confluence with the Sacramento River are negligible at the 71.6°F threshold and are small to moderately adverse at the 77°F threshold.

Stranding

At Nimbus Dam

The number of Pacific lamprey ammocoete cohorts that may be affected by month-over-month flow Figure C.5.2-352, and differences between model scenarios are presented in Table C.5.2-138.

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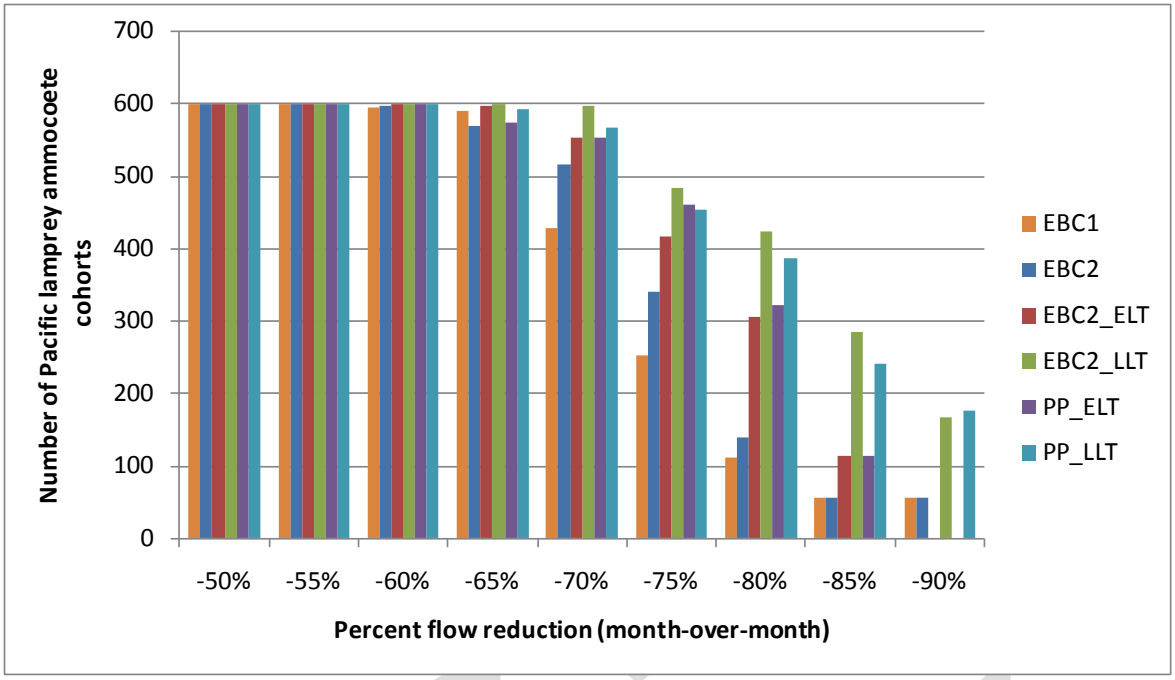

Figure C.5.2-352. Number of Pacific Lamprey Ammocoete Cohorts That Were Exposed to Month-over-Month Flow Reductions of 50% to 90%, American River at Nimbus Dam

Table C.5.2-138. Percent Difference between Model Scenarios in the Number of Pacific Lamprey Ammocoete Cohorts Exposed to Month-over-Month Flow Reductions, American River at Nimbus Dam

Percent Flow Reduction	Percent Difference[1]					
	EBC1 vs. PP_ELT	EBC1 vs. PP_LLT	EBC2 vs. PP_ELT	EBC2 vs. PP_LLT	EBC2_ELT vs. PP_ELT	EBC2_LLT vs. PP_LLT
-50%	0.0	0.0	0.0	0.0	0.0	0.0
-55%	0.0	0.0	0.0	0.0	0.0	0.0
-60%	0.8	0.8	0.7	0.7	0.0	0.0
-65%	-2.5	0.5	0.9	4.0	-3.5	-1.2
-70%	29.4	32.7	7.4	10.1	0.0	-4.9
-75%	82.5	79.8	35.3	33.2	10.6	-6.2
-80%	188.4	244.6	132.4	177.7	5.2	-9.0
-85%	103.6	332.1	103.6	332.1	0.0	-14.8
-90%	-100.0	214.3	-100.0	214.3	NA	4.8

[1] Negative values indicate reduced cohort exposure, a benefit of the preliminary proposal.
NA = could not be calculated because dividing by 0.

The number of Pacific lamprey ammocoetes exposed to a given flow reduction is predicted to be 100% lower to 188% higher under the PP_ELT compared to the EBC1, depending on the flow reduction (Table C.5.2-138). The number of ammocoetes exposed to a given flow reduction is predicted to be between 0% and 332% higher under the PP_LLT compared to EBC1, depending on the flow reduction. The number of ammocoetes exposed to a given flow reduction is predicted to be 100% lower to 132% higher under the PP_ELT compared to the EBC2, depending on the flow reduction. The number of ammocoetes exposed to a given flow reduction is predicted to be between 0% and 332% higher under the PP_LLT compared to the EBC2, depending on the flow reduction.

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Isolating the effect of the preliminary proposal from the effects of climate change in the early long-term, the number of Pacific lamprey ammocoetes exposed to a given flow reduction is predicted to be 4% lower to 11% higher under the PP_ELT compared to the EBC2_ELT, depending on the flow reduction. In the late long-term, the number of ammocoetes exposed to a given flow reduction is predicted to be 15% lower to 5% lower under the PP_LLT compared to the EBC2_LLT, depending on the flow reduction.

The number of river lamprey ammocoete cohorts that may be affected by month-over-month flow reductions in the American River at Nimbus Dam is presented in Figure C.5.2-353, and differences between model scenarios are presented in Table C.5.2-139.

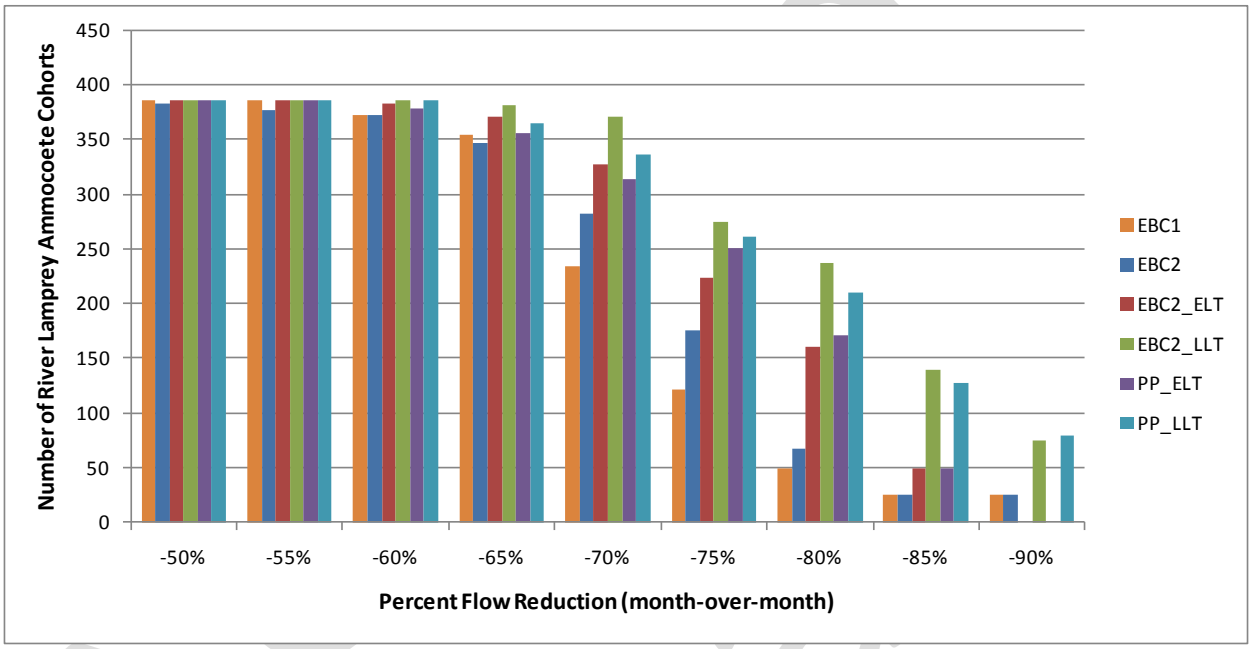

Figure C.5.2-353. Number of River Lamprey Ammocoete Cohorts Exposed to Month-over-Month Flow Reductions of 50% to 90%, American River at Nimbus Dam

Table C.5.2-139. Percent Difference between Model Scenarios in the Number of River Lamprey Ammocoete Cohorts Exposed to Month-over-Month Flow Reductions, American River at Nimbus Dam

Percent Flow Reduction	Percent Difference[1]					
	EBC1 vs. PP_ELT	EBC1 vs. PP_LLT	EBC2 vs. PP_ELT	EBC2 vs. PP_LLT	EBC2_ELT vs. PP_ELT	EBC2_LLT vs. PP_LLT
-50%	0.0	0.0	0.8	0.8	0.0	0.0
-55%	0.0	0.0	2.1	2.1	0.0	0.0
-60%	0.0	0.0	1.6	3.5	-1.0	0.0
-65%	0.0	0.0	2.9	5.5	-3.8	-4.2
-70%	2.6	5.6	11.0	19.1	-4.3	-9.2
-75%	1.3	2.8	43.4	49.1	12.6	-4.7
-80%	4.0	22.0	155.2	213.4	6.2	-11.4
-85%	0.0	11.4	100.0	412.0	0.0	-8.6
-90%	316.0	408.0	-100.0	220.0	NA	6.7

[1] Negative values indicate reduced cohort exposure, a benefit of the preliminary proposal.
NA = could not be calculated because dividing by 0.

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The number of river lamprey ammocoetes exposed to a given flow reduction is predicted to be 0% to 316% higher under the PP_ELT compared to the EBC1, depending on the flow reduction (Table C.5.2-139). The number of ammocoetes exposed to a given flow reduction is predicted to be 0% to 408% higher under the PP_LLT compared to the EBC1, depending on the flow reduction. The number of ammocoetes exposed to a given flow reduction is predicted to be 100% lower to 155% higher under the PP_ELT compared to the EBC2, depending on the flow reduction. The number of ammocoetes exposed to a given flow reduction is predicted to be 1% to 412% higher under the PP_LLT compared to the EBC2, depending on the flow reduction.

Isolating the effects of climate change, the number of river lamprey ammocoete cohorts exposed to a given flow reduction is predicted to be 4% lower to 13% higher under the PP_ELT compared to the EBC2_ELT, depending on the flow reduction. The number of ammocoetes exposed to a given flow reduction is predicted to be 0% to 11% lower under the PP_LLT compared to the EBC2_LLT, depending on the flow reduction.

These results indicate that, in the early long-term, the preliminary proposal is predicted generally to have small (less than 10%) benefits to Pacific and river lamprey ammocoetes by reducing their exposure to flow reductions. One exception is the 75% flow reduction scenario, in which the number of ammocoete cohorts exposed to this flow reduction is predicted to be 11-113% greater under PP_ELT relative to EBC2_ELT. In the late long-term, the preliminary proposal is predicted to have small to moderate benefits (up to 15% difference). The vast proportion of differences between model scenarios is due to climate change.

At Sacramento River Confluence

The number of Pacific lamprey ammocoete cohorts that may be affected by month-over-month flow reductions in the American River at the confluence with the Sacramento River is presented in Figure C.5.2-354, and differences between model scenarios are presented in Table C.5.2-140.

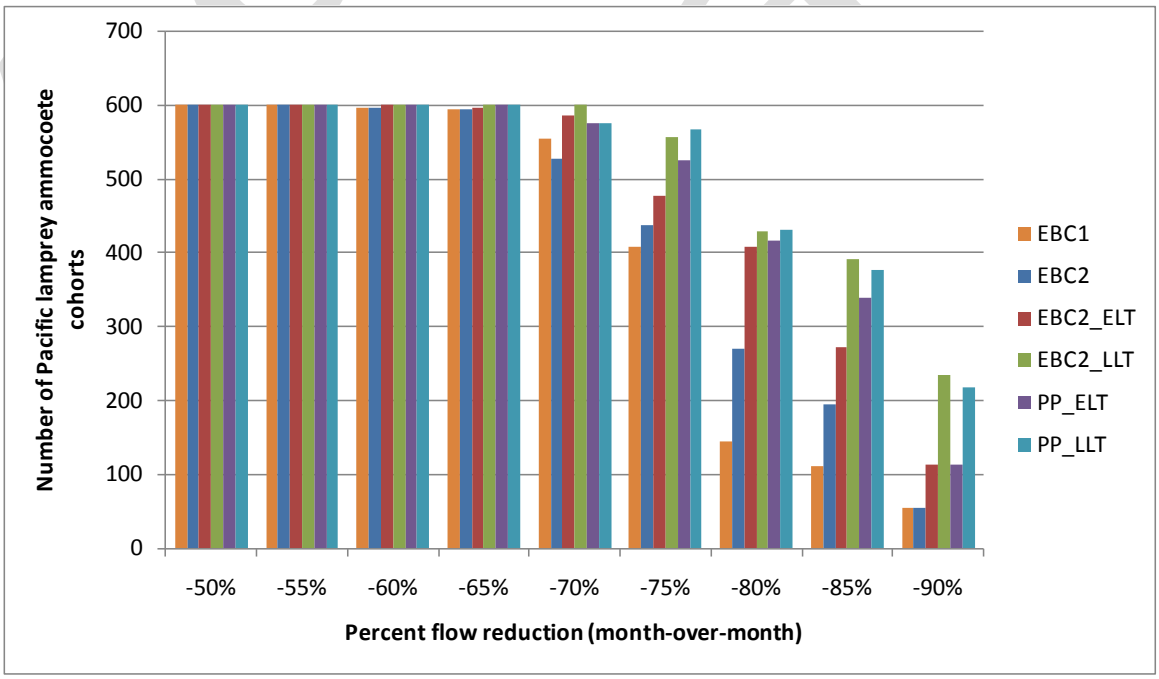

Figure C.5.2-354. Number of Pacific Lamprey Ammocoete Cohorts Exposed to Month-over-Month Flow Reductions of 50% to 90%, American River at the Confluence with the Sacramento River

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Table C.5.2-140. Percent Difference between Model Scenarios in the Number of Pacific Lamprey Ammocoete Cohorts Exposed to Month-over-Month Flow Reductions, American River at the Confluence with the Sacramento River

Percent Flow Reduction	Percent Difference[1]					
	EBC1 vs. PP_ELT	EBC1 vs. PP_LLT	EBC2 vs. PP_ELT	EBC2 vs. PP_LLT	EBC2_ELT vs. PP_ELT	EBC2_LLT vs. PP_LLT
-50%	0.0	0.0	0.0	0.0	0.0	0.0
-55%	0.0	0.0	0.0	0.0	0.0	0.0
-60%	0.7	0.7	0.7	0.7	0.0	0.0
-65%	0.8	0.8	0.8	0.8	0.7	0.0
-70%	3.8	3.8	9.1	9.1	-1.9	-4.2
-75%	28.6	38.9	20.1	29.7	10.3	2.0
-80%	187.6	197.9	54.4	60.0	2.0	0.7
-85%	202.7	235.7	73.8	92.8	24.2	-4.1
-90%	103.6	289.3	103.6	289.3	0.0	-7.2

[1] Negative values indicate reduced cohort exposure, a benefit of the preliminary proposal.

The number of Pacific lamprey ammocoetes exposed to a given flow reduction is predicted to be between 0% and 202% higher under the PP_ELT compared to the EBC1, and between 0% and 203% higher compared to the EBC2, depending on the flow reduction (Table C.5.2-140). The number of ammocoetes exposed to a given flow reduction is predicted to be between 0% and 289% higher under the PP_LLT compared to both the EBC1 and EBC2, depending on the flow reduction.

Isolating the effect of the preliminary proposal from the effects of climate change in the early long-term, the number of Pacific lamprey ammocoetes exposed to a given flow reduction is predicted to be 2% lower to 24% higher under the PP_ELT compared to the EBC2_ELT, depending on the flow reduction. In the late long-term, the number of ammocoetes exposed to a given flow reduction is predicted to be 7% lower to 2% higher under the PP_LLT compared to the EBC2_LLT, depending on the flow reduction.

The number of river lamprey ammocoete cohorts that may be affected by month-over-month flow reductions in the American River at the confluence with the Sacramento River is presented in Figure C.5.2-355, and differences between model scenarios are presented in Table C.5.2-141.

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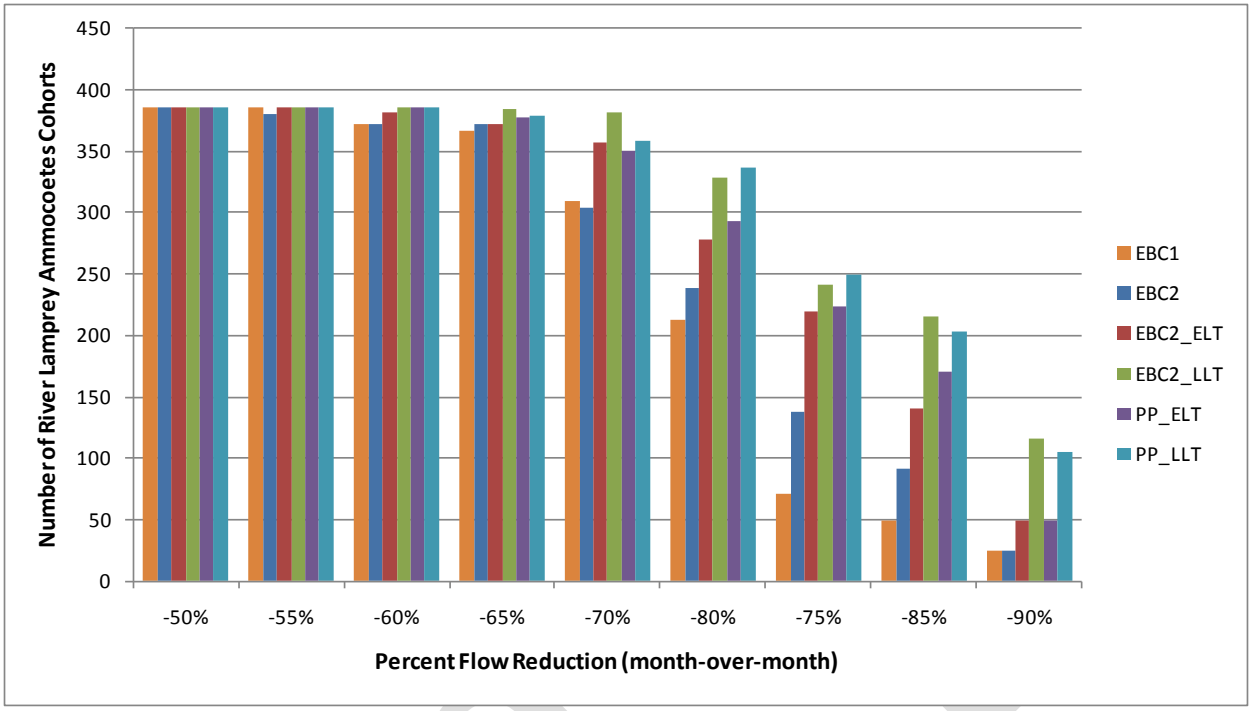

Figure C.5.2-355. Number of River Lamprey Ammocoete Cohorts Exposed to Month-over-Month Flow Reductions of 50% to 90%, American River at the Confluence with the Sacramento River

Table C.5.2-141. Relative Difference between Model Scenarios in the Number of River Lamprey Ammocoete Cohorts Exposed to Month-over-Month Flow Reductions, American River at the Confluence with the Sacramento River

Percent Flow Reduction	Percent Difference[1]					
	EBC1 vs. PP_ELT	EBC1 vs. PP_LLT	EBC2 vs. PP_ELT	EBC2 vs. PP_LLT	EBC2_ELT vs. PP_ELT	EBC2_LLT vs. PP_LLT
-50%	0.0	0.0	0.0	0.0	0.0	0.0
-55%	0.0	0.0	1.3	1.3	0.0	0.0
-60%	0.0	0.0	3.5	3.5	0.8	0.0
-65%	0.0	0.0	1.6	1.9	1.6	-1.3
-70%	4.2	4.2	15.1	17.8	-2.0	-6.0
-75%	1.6	1.6	23.1	41.2	5.4	2.4
-80%	16.9	18.3	62.3	81.2	2.3	3.7
-85%	0.0	6.8	84.8	120.7	21.4	-5.6
-90%	164.0	196.0	100.0	320.0	0.0	-9.5

[1] Negative values indicate reduced cohort exposure, a benefit of the preliminary proposal.

The number of river lamprey ammocoetes exposed to a given flow reduction is predicted to be between 0% and 164% higher under the PP_ELT compared to the EBC1, depending on the flow reduction (Table C.5.2-141). The number of ammocoetes exposed to a given flow reduction is predicted to be between 0% and 196% higher under the PP_LLT compared to the EBC1, depending on the flow reduction. The number of ammocoetes exposed to a given flow reduction is predicted to be between 0% and 100% higher under the PP_ELT compared to the EBC2, depending on the flow

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reduction. The number of ammocoetes exposed to a given flow reduction is predicted to be between 0% and 320% higher under the PP_LLT compared to the EBC2, depending on the flow reduction.

Isolating the effects of climate change, the number of ammocoetes exposed to a given flow reduction is predicted to be2% lower to 21% higher under the PP_ELT compared to the EBC2_ELT, depending on the flow reduction. The number of ammocoetes exposed to a given flow reduction is predicted to be 10% lower to 4% higher under the PP_LLT compared to the EBC2_LLT, depending on the flow reduction.

These results indicate that there are generally small beneficial and adverse effects of the preliminary proposal for both Pacific and river lamprey under the early and late long-term (less than 10% difference). However, there are moderate adverse effects (21% to 24% higher exposure) predicted for the 85% flow reduction scenario in the early long-term. The vast proportion of differences between model scenarios is due to climate change.

C.5.2.6 Mainstem San Joaquin River

C.5.2.6.1 Steelhead

Eggs and Alevins

Upstream Spawning Habitat

The mainstem San Joaquin River does not provide habitat for steelhead spawning or egg incubation. Therefore, changes in flow associated with BDCP operations on the San Joaquin River would have no effect on steelhead spawning or egg incubation.

Fry and Juvenile Rearing

Rearing Habitat

Juvenile steelhead rear and migrate through the lower San Joaquin River during the spring (primarily January through April) during their downstream movement from the tributary spawning and rearing habitat to coastal marine waters. Results of CALSIM modeling of San Joaquin River flows are summarized, by month and water-year type for all months, in Table C.5.2-142. Results of the monthly frequency of exceedance analysis for San Joaquin River flows during the juvenile steelhead migration period are shown in Figure C.5.2-356 through Figure C.5.2-360. Flows in the San Joaquin River at Vernalis are not predicted to differ in a biologically meaningful way (less than a 5% difference) between EBC2_ELT and PP_ELT and between EBC2_LLT and PP_LLT. Based on these results it was concluded that BDCP operations would not affect instream habitat conditions on the lower San Joaquin River for steelhead juvenile rearing or smolt downstream migration.

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Table C.5.2-142. Mean Monthly Flows (Cubic Feet per Second) in the San Joaquin River at Vernalis Year-Round

Month	Water-Year Type	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
Jan	W	9,260	9,162	10,074	9,922	10,143	10,000
	AN	4,286	4,217	4,400	4,770	4,427	4,889
	BN	2,974	2,912	2,992	2,850	2,994	2,871
	D	2,094	2,046	2,066	2,065	2,065	2,080
	C	1,683	1,615	1,619	1,599	1,619	1,599
	AVG	4,777	4,705	5,040	5,018	5,065	5,067
Feb	W	11,419	11,262	12,429	11,814	12,431	11,809
	AN	6,144	6,104	6,471	6,182	6,428	6,114
	BN	5,804	5,639	5,773	5,277	5,739	5,261
	D	2,580	2,453	2,456	2,384	2,468	2,409
	C	2,123	1,942	1,956	1,955	1,957	1,957
	AVG	6,388	6,250	6,699	6,361	6,690	6,352
Mar	W	12,943	12,826	13,531	13,574	13,541	13,573
	AN	6,344	6,146	6,320	6,718	6,319	6,720
	BN	4,852	4,747	4,668	4,441	4,669	4,442
	D	2,403	2,295	2,216	2,177	2,217	2,177
	C	1,775	1,640	1,640	1,638	1,640	1,638
	AVG	6,648	6,520	6,739	6,763	6,742	6,763
Apr	W	10,967	10,934	11,102	11,279	11,097	11,280
	AN	6,244	6,094	6,162	6,272	6,167	6,272
	BN	5,440	5,435	5,345	5,208	5,347	5,210
	D	3,411	3,385	3,129	2,934	3,130	2,935
	C	1,930	1,877	1,811	1,800	1,812	1,800
	AVG	6,351	6,305	6,286	6,291	6,286	6,292
May	W	11,037	10,992	11,748	11,205	11,753	11,207
	AN	5,493	5,423	5,993	5,803	5,998	5,810
	BN	5,074	5,086	4,946	4,678	4,950	4,681
	D	3,140	3,102	2,872	2,737	2,876	2,738
	C	1,974	1,901	1,843	1,827	1,844	1,829
	AVG	6,148	6,106	6,347	6,069	6,351	6,072
Jun	W	9,264	9,267	7,866	5,979	7,867	5,982
	AN	5,042	4,949	4,206	3,306	4,209	3,312
	BN	2,455	2,425	2,370	2,256	2,376	2,260
	D	1,536	1,481	1,410	1,375	1,414	1,377
	C	1,032	991	990	953	992	955
	AVG	4,583	4,547	3,969	3,206	3,971	3,209
Jul	W	6,669	6,726	5,261	3,899	5,267	3,907
	AN	2,805	2,772	2,255	2,089	2,266	2,099
	BN	1,774	1,736	1,614	1,554	1,624	1,560
	D	1,273	1,208	1,170	1,147	1,177	1,149
	C	903	886	872	853	872	856
	AVG	3,239	3,229	2,658	2,184	2,665	2,190

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Month	Water-Year Type	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
Aug	W	3,235	3,213	2,811	2,466	2,816	2,472
	AN	2,020	2,008	1,822	1,785	1,831	1,793
	BN	1,832	1,814	1,638	1,486	1,646	1,490
	D	1,336	1,306	1,265	1,244	1,269	1,246
	C	989	1,006	975	959	976	960
	AVG	2,072	2,056	1,858	1,710	1,863	1,715
Sep	W	3,325	3,283	3,126	2,962	3,128	2,965
	AN	2,328	2,307	2,221	2,193	2,225	2,196
	BN	2,099	2,078	1,998	1,895	2,001	1,897
	D	1,771	1,749	1,707	1,687	1,709	1,688
	C	1,337	1,345	1,327	1,298	1,327	1,299
	AVG	2,338	2,314	2,226	2,144	2,228	2,146
Oct	W	3,034	3,015	2,970	3,004	2,977	3,021
	AN	2,328	2,314	2,226	2,179	2,227	2,180
	BN	2,601	2,581	2,523	2,424	2,524	2,424
	D	2,600	2,594	2,517	2,482	2,519	2,483
	C	2,193	2,169	2,146	1,947	2,147	1,948
	AVG	2,639	2,622	2,565	2,515	2,568	2,521
Nov	W	3,183	3,141	3,197	3,020	3,196	3,032
	AN	2,011	1,986	2,025	2,061	2,032	2,068
	BN	2,214	2,185	2,249	2,137	2,289	2,137
	D	2,193	2,167	2,144	2,127	2,177	2,153
	C	1,944	1,920	1,893	1,888	1,894	1,888
	AVG	2,448	2,416	2,441	2,367	2,457	2,378
Dec	W	5,167	5,130	5,754	5,353	5,790	5,404
	AN	2,832	2,758	2,855	2,722	2,856	2,731
	BN	2,706	2,656	2,554	2,434	2,693	2,428
	D	2,058	2,031	2,001	2,053	2,030	2,066
	C	1,724	1,699	1,694	1,700	1,693	1,700
	AVG	3,219	3,178	3,366	3,211	3,407	3,230

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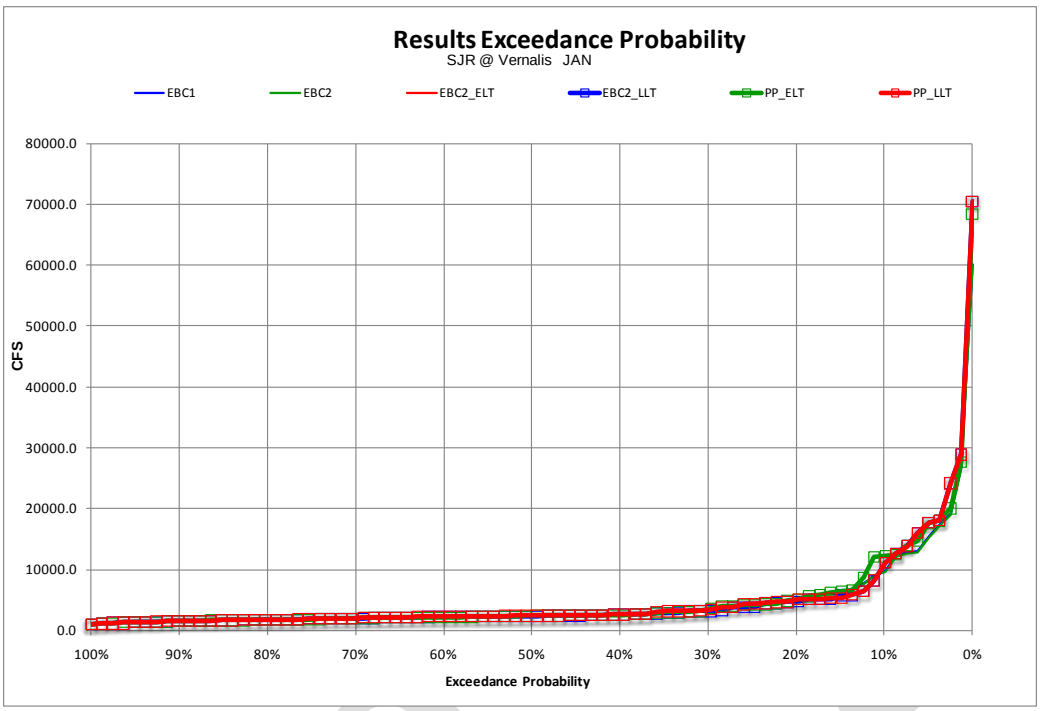

Figure C.5.2-356. Probability of Exceedance Plot for Model Scenarios of Mean Monthly Flow Rate of San Joaquin River at Vernalis, January

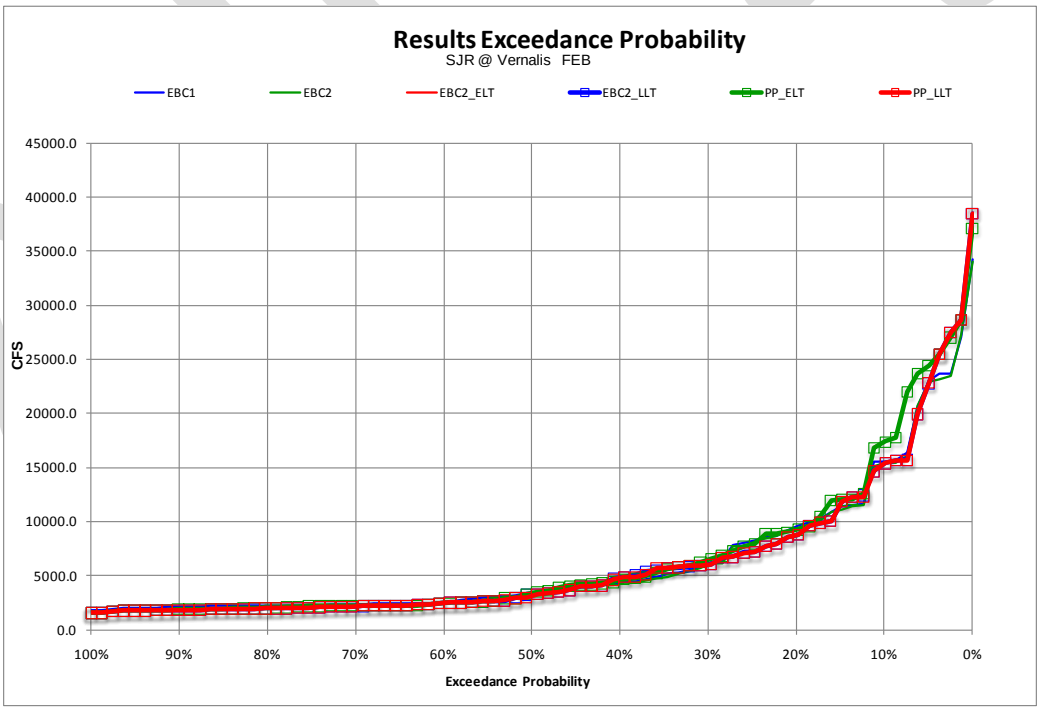

Figure C.5.2-357. Probability of Exceedance Plot for Model Scenarios of Mean Monthly Flow Rate of San Joaquin River at Vernalis, February

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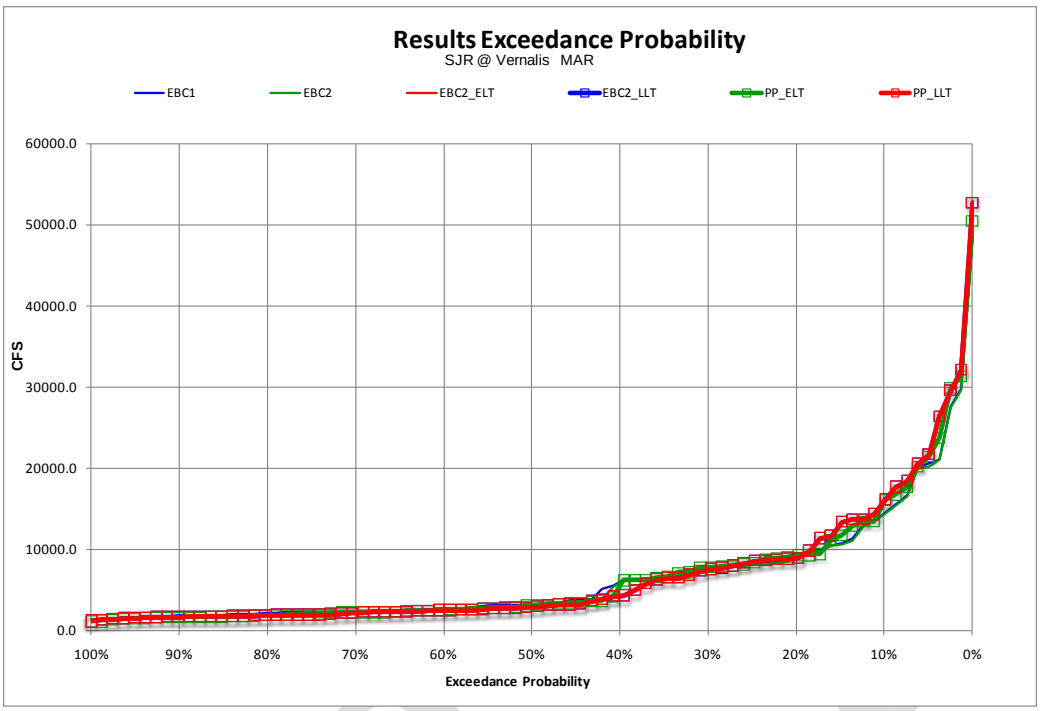

Figure C.5.2-358. Probability of Exceedance Plot for Model Scenarios of Mean Monthly Flow Rate of San Joaquin River at Vernalis, March

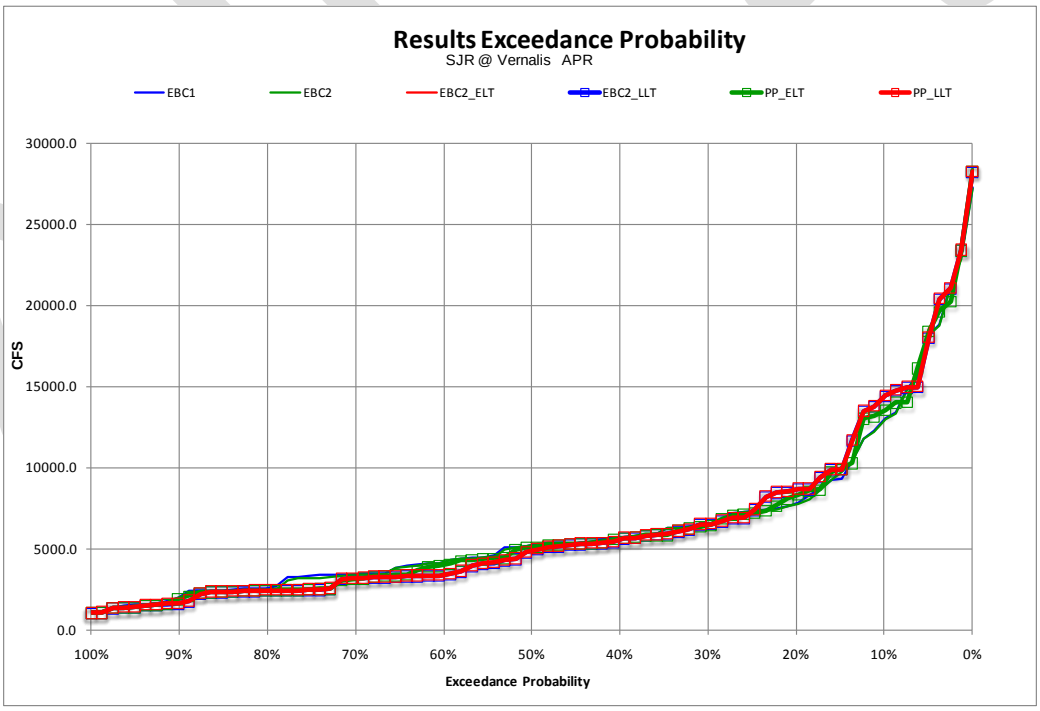

Figure C.5.2-359. Probability of Exceedance Plot for Model Scenarios of Mean Monthly Flow Rate of San Joaquin River at Vernalis, April

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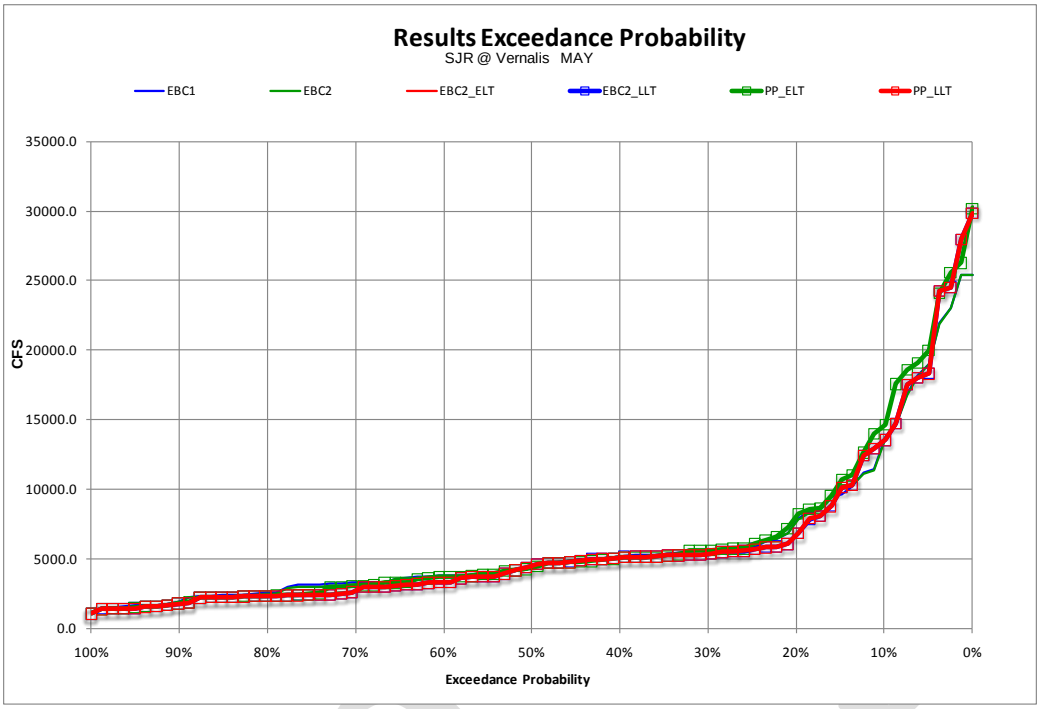

Figure C.5.2-360. Probability of Exceedance Plot for Model Scenarios of Mean Monthly Flow Rate of San Joaquin River at Vernalis, May

Adult

Water Temperature

Based on the similarity San Joaquin River instream flows between EBC2_ELT and PP_ELT and between EBC2_LLT and PP_LLT during the September through March steelhead migration period (Table C.5.2-142), it is expected that there would be no differences in seasonal water temperatures between these two pairs of model scenarios that would affect habitat conditions for adult steelhead migrating upstream in the San Joaquin River.

C.5.2.6.2 Spring-Run

Spring-run Chinook salmon do not currently inhabit the mainstem San Joaquin River or its tributaries. Although efforts are currently underway to restore a spring-run population to the upper reaches of the San Joaquin River downstream of Friant Dam, the preliminary proposal would have no effect on future instream habitat conditions in the San Joaquin River (Table C.5.2-142).

C.5.2.6.3 Fall-/Late Fall–Run

Eggs and Alevins

Upstream Spawning Habitat

Fall-run Chinook salmon do not currently spawn in the mainstem San Joaquin River. Although efforts are currently underway to restore spring-run and fall-run salmon to the upper reaches of the San Joaquin River downstream of Friant Dam, the preliminary proposal would have no effect on future instream habitat conditions in the San Joaquin River (Table C.5.2-142).

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Fry and Juvenile Rearing

Rearing Habitat

Fall-run Chinook salmon juveniles rear in the lower San Joaquin River. During the late winter and early spring, fall-run salmon fry may rear in the river prior to migrating downstream to coastal marine waters, although the majority of juvenile fall-run salmon are expected to migrate downstream as smolts later in the spring (April through May). CALSIM hydrologic modeling over the 82 simulation years for the lower San Joaquin River at Vernalis predicts little or no difference (less than a 5% difference) in instream flows EBC2_ELT and PP_ELT and between EBC2_LLT and PP_LLT during the fry (January through March) and juvenile (April through May) rearing period (Table C.5.2-142, Figure C.5.2-356 through Figure C.5.2-360). Other drivers, notably climate change, are predicted to have the greatest effect on future flows and water temperatures. Based on these results, it was concluded that the preliminary proposal would not affect instream habitat conditions in the lower San Joaquin River for fall-run fry or juvenile rearing.

Adult

Water Temperature

Based on the similarity San Joaquin River in-stream flows between EBC2_ELT and PP_ELT and between EBC2_LLT and PP_LLT (Table C.5.2-142), it is expected that there would be no differences in seasonal water temperatures between these two pairs of model scenarios that would affect habitat conditions for adult fall-run Chinook salmon migrating upstream in the San Joaquin River.

C.5.2.6.4 Splittail

As described for the Sacramento River (Section C.5.2.1.1), splittail spawning and rearing of larvae and young juveniles in channel margin and side-channel habitat upstream of the Delta is likely to be especially important during dry years, when flows are too low to inundate the floodplains. Splittail have been found in the San Joaquin River as far upstream as the confluence with the Tuolumne River (Sommer et al. 2007).

Rearing Habitat

The upstream side-channel habitats used by splittail for spawning and rearing are, as previously indicated, affected by changes in flow because greater flows cause more flooding, thereby increasing availability of such habitat, and because rapid reductions in flow dewater the habitats, potentially stranding splittail eggs and rearing larvae. The changes in flows are expected to be especially important in years with low-flows. Simulated flows in the San Joaquin River at Vernalis were used to investigate the potential effects of BDCP operations on side-channel habitat availability on the mainstem of the river. This analysis was limited to flows during February through June because these are the most important months for splittail spawning and larval and juvenile rearing and the months in which splittail are most likely to be upstream in the San Joaquin River.

Monthly average flows by water-year type are presented in Table C.5.2-142 and differences between pairs of model scenarios during February through June are presented in Table C.5.2-142. A probability of exceedance plot is presented in Figure C.5.2-361. Results show that difference in flows between EBC2_ELT and PP_ELT and between EBC2_LLT and PP_LLT were negligible (≤1%) in all months and water-year types. These results indicate that similar amounts of side channel habitat

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are available for splittail spawning and rearing in the San Joaquin River under the preliminary proposal relative to existing conditions during the entire February through June period.

Table C.5.2-143. Difference (Percent Difference) between Pairs of Model Scenarios in Mean Monthly Flows in the San Joaquin River at Vernalis, February through June

Month	WY Type	EBC1 vs. PP_ELT	EBC1 vs. PP_LLT	EBC2 vs. PP_ELT	EBC2 vs. PP_LLT	EBC2_ELT vs. PP_ELT	EBC2_LLT vs. PP_LLT
Feb	W	1012 (8.9%)	389 (3.4%)	1169 (10.4%)	547 (4.9%)	2 (0%)	-6 (0%)
	AN	283 (4.6%)	-30 (-0.5%)	324 (5.3%)	10 (0.2%)	-43 (-0.7%)	-69 (-1.1%)
	BN	-65 (-1.1%)	-544 (-9.4%)	100 (1.8%)	-378 (-6.7%)	-34 (-0.6%)	-16 (-0.3%)
	D	-112 (-4.4%)	-170 (-6.6%)	14 (0.6%)	-44 (-1.8%)	12 (0.5%)	26 (1.1%)
	C	-166 (-7.8%)	-166 (-7.8%)	15 (0.8%)	15 (0.8%)	1 (0.1%)	2 (0.1%)
	AVG	302 (4.7%)	-36 (-0.6%)	441 (7.1%)	103 (1.6%)	-9 (-0.1%)	-9 (-0.1%)
Mar	W	598 (4.6%)	630 (4.9%)	714 (5.6%)	746 (5.8%)	10 (0.1%)	-2 (0%)
	AN	-25 (-0.4%)	376 (5.9%)	174 (2.8%)	575 (9.4%)	-1 (0%)	2 (0%)
	BN	-183 (-3.8%)	-410 (-8.5%)	-78 (-1.6%)	-305 (-6.4%)	1 (0%)	0 (0%)
	D	-186 (-7.7%)	-226 (-9.4%)	-78 (-3.4%)	-118 (-5.1%)	0 (0%)	0 (0%)
	C	-134 (-7.6%)	-136 (-7.7%)	0 (0%)	-2 (-0.1%)	0 (0%)	0 (0%)
	AVG	94 (1.4%)	115 (1.7%)	221 (3.4%)	243 (3.7%)	3 (0%)	0 (0%)
Apr	W	131 (1.2%)	313 (2.9%)	163 (1.5%)	346 (3.2%)	-5 (0%)	1 (0%)
	AN	-77 (-1.2%)	28 (0.4%)	74 (1.2%)	178 (2.9%)	5 (0.1%)	0 (0%)
	BN	-93 (-1.7%)	-229 (-4.2%)	-89 (-1.6%)	-225 (-4.1%)	2 (0%)	2 (0%)
	D	-281 (-8.2%)	-477 (-14%)	-255 (-7.5%)	-451 (-13.3%)	2 (0.1%)	1 (0%)
	C	-117 (-6.1%)	-130 (-6.7%)	-65 (-3.4%)	-77 (-4.1%)	1 (0.1%)	0 (0%)
	AVG	-65 (-1%)	-59 (-0.9%)	-18 (-0.3%)	-13 (-0.2%)	0 (0%)	1 (0%)
May	W	716 (6.5%)	170 (1.5%)	761 (6.9%)	215 (2%)	5 (0%)	3 (0%)
	AN	505 (9.2%)	316 (5.8%)	575 (10.6%)	386 (7.1%)	5 (0.1%)	6 (0.1%)
	BN	-124 (-2.4%)	-393 (-7.7%)	-136 (-2.7%)	-405 (-8%)	4 (0.1%)	3 (0.1%)
	D	-264 (-8.4%)	-402 (-12.8%)	-226 (-7.3%)	-364 (-11.7%)	4 (0.1%)	1 (0%)
	C	-130 (-6.6%)	-145 (-7.4%)	-57 (-3%)	-72 (-3.8%)	1 (0.1%)	1 (0.1%)
	AVG	203 (3.3%)	-76 (-1.2%)	244 (4%)	-35 (-0.6%)	4 (0.1%)	3 (0%)
Jun	W	-1397 (-15.1%)	-3282 (-35.4%)	-1400 (-15.1%)	-3285 (-35.4%)	1 (0%)	3 (0%)
	AN	-833 (-16.5%)	-1730 (-34.3%)	-740 (-15%)	-1637 (-33.1%)	3 (0.1%)	6 (0.2%)
	BN	-80 (-3.2%)	-195 (-7.9%)	-49 (-2%)	-164 (-6.8%)	5 (0.2%)	5 (0.2%)
	D	-122 (-8%)	-160 (-10.4%)	-67 (-4.5%)	-104 (-7%)	4 (0.3%)	2 (0.1%)
	C	-40 (-3.9%)	-77 (-7.5%)	0 (0%)	-37 (-3.7%)	2 (0.2%)	1 (0.1%)
	AVG	-611 (-13.3%)	-1374 (-30%)	-575 (-12.7%)	-1337 (-29.4%)	3 (0.1%)	3 (0.1%)

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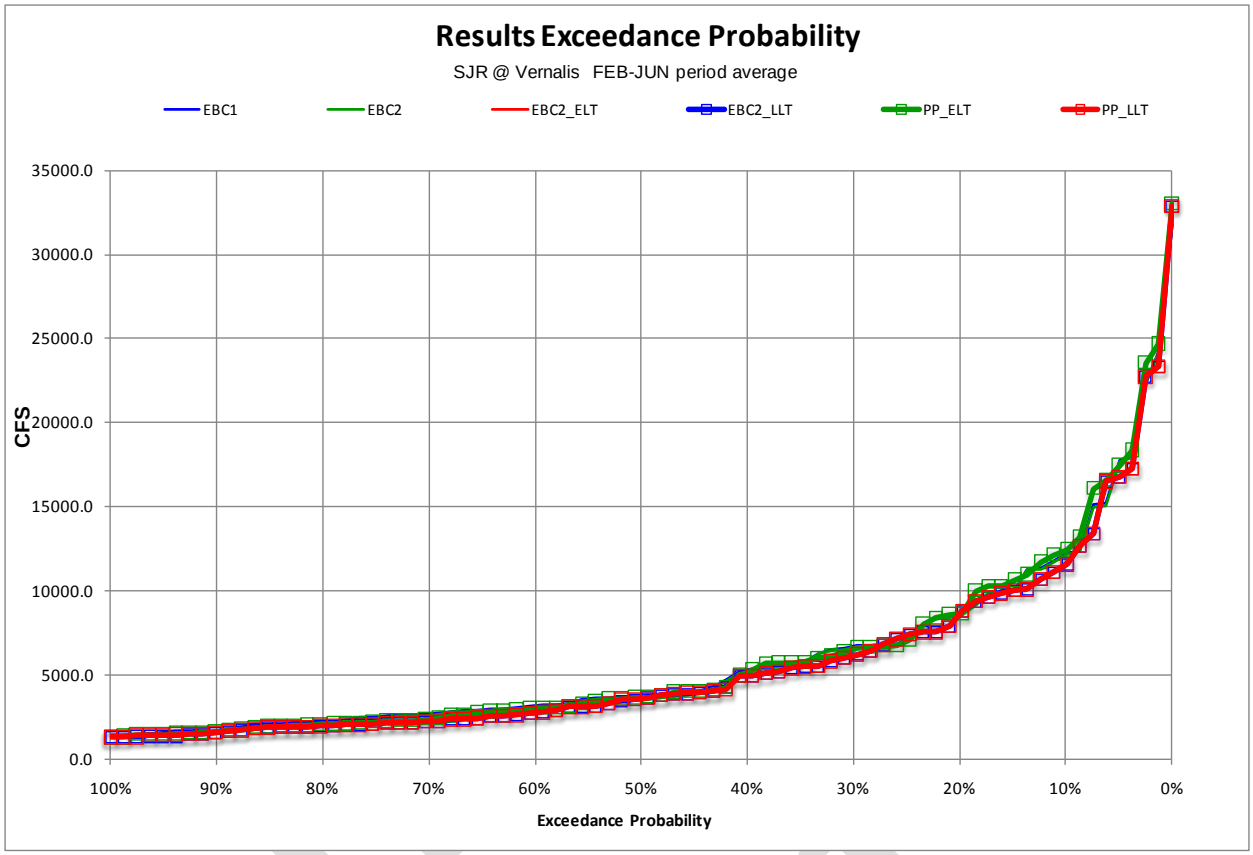

Figure C.5.2-361. Probability of Exceedance Plot for Model Scenarios of Mean Monthly Flow in the San Joaquin River at Vernalis, February through June

Water Temperature

As described above, differences in flow in the San Joaquin River at Vernalis between EBC2_ELT and PP_ELT and between EBC2_LLT and PP_LLT are negligible. The similarity in flows results because releases from Friant Dam and dams on the Stanislaus, Tuolumne and Merced rivers would not be affected by the preliminary proposal. Because of these similarities in releases, and because flows largely drive water temperatures in the San Joaquin River, no significant temperature-related effects of the BDCP on splittail egg and larval habitat in the American River are expected.

C.5.2.6.5 White Sturgeon

Due to uncertainties regarding white sturgeon presence in the San Joaquin River system, the analysis of effects on white sturgeon in the Stanislaus River was combined with the analysis in the mainstem San Joaquin River here.

Egg/Embryo

A review of the DFG sturgeon recreational fishery tag data from 2007 through 2009 did not indicate that white sturgeon immigrate into the Stanislaus River during the winter or spring to spawn. This suggests that the Stanislaus River downstream of Goodwin Dam does not provide spawning or egg incubation habitats for white sturgeon. Based on DFG recreational fishery tag data, white sturgeon are observed in the mainstem San Joaquin River upstream of the confluence with the Merced River

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during the winter and spring, so it is assumed white sturgeon are spawning somewhere within the San Joaquin River.

CALSIM hydrologic modeling over the 82-year simulation period for the lower San Joaquin River at Vernalis predicts little or no difference in instream flows (less than a 5% difference) between EBC2_ELT and PP_ELT and between EBC2_LLT and PP_LLT during the primary spawning and egg incubation period for white sturgeon (February through May) (Table C.5.2-142, Figure C.5.2-362 through Figure C.5.2-367). Other drivers, notably climate change, are predicted to have the greatest effect on future flows and water temperatures. Based on these results, it was concluded that the preliminary proposal would not affect instream habitat conditions in the lower San Joaquin River for white sturgeon.

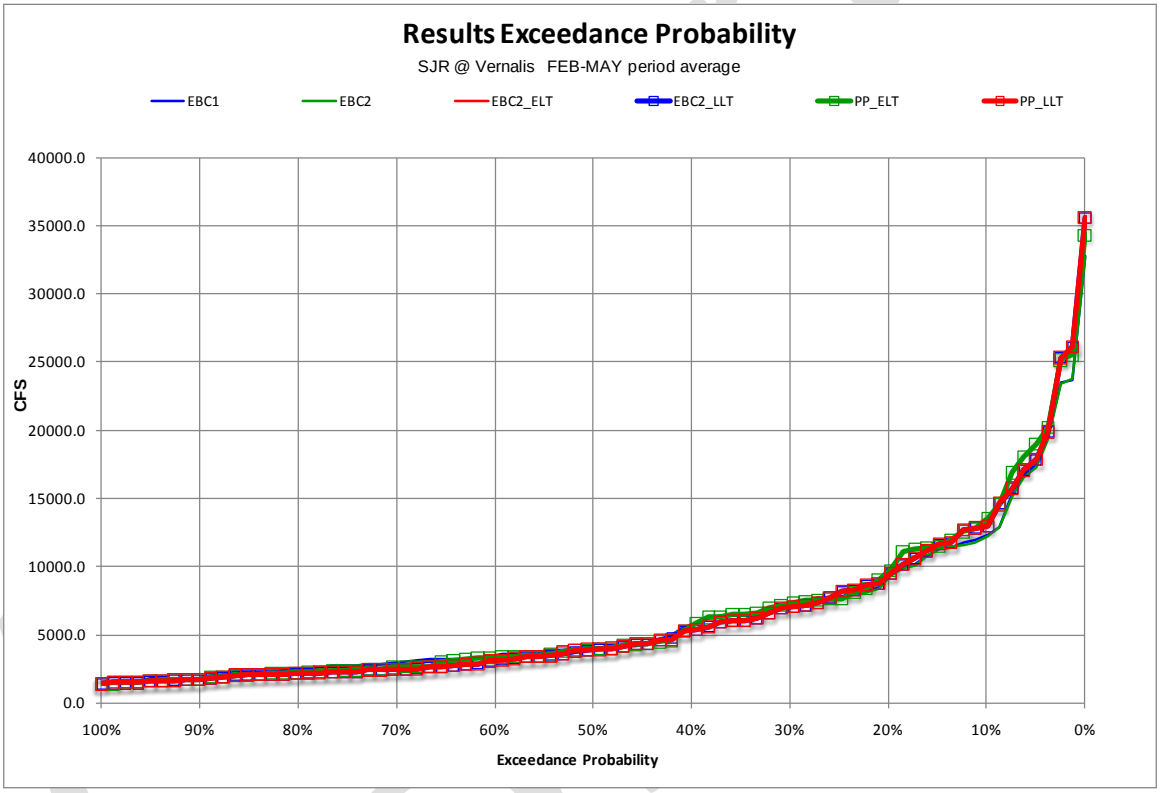

Figure C.5.2-362. Probability of Exceedance Plot for Model Scenarios of Mean Monthly Flow in the San Joaquin River at Vernalis, February through May

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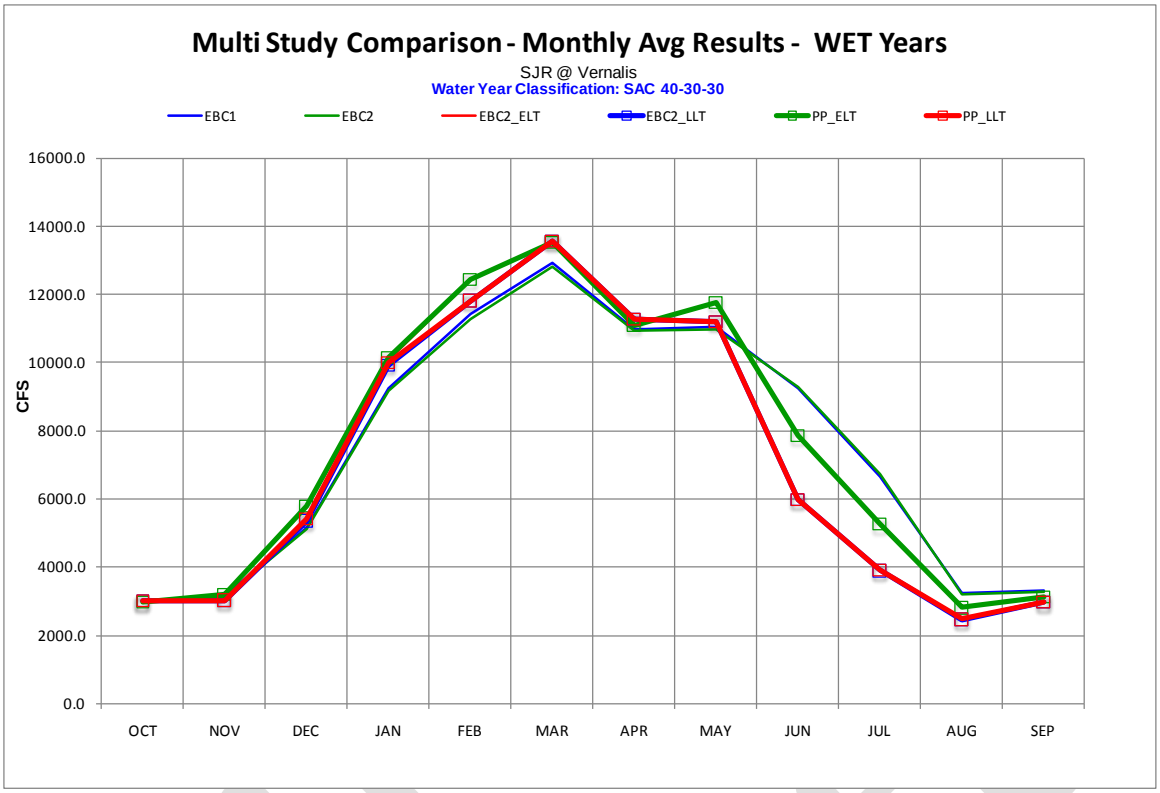

Figure C.5.2-363. San Joaquin River Average Monthly Flows at Vernalis in Wet Years

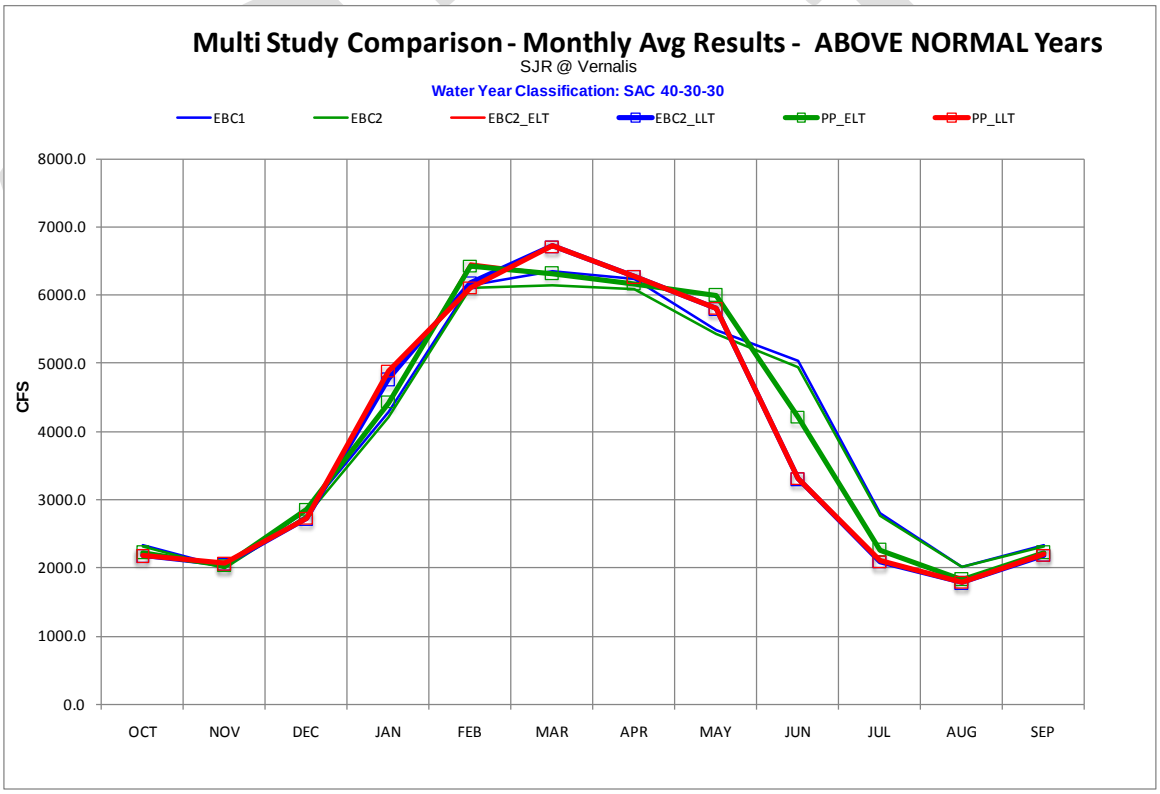

Figure C.5.2-364. San Joaquin River Average Monthly Flows at Vernalis in Above-Normal Years

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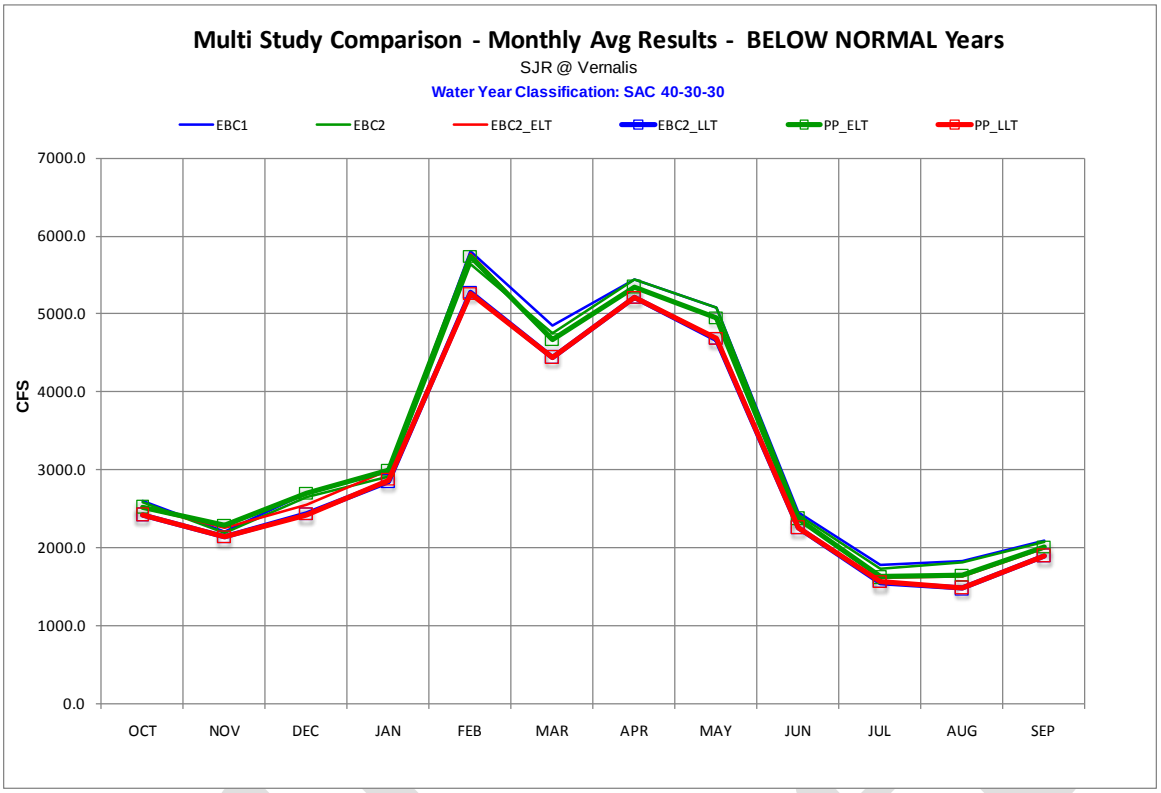

Figure C.5.2-365. San Joaquin River Average Monthly Flows at Vernalis in Below-Normal Years

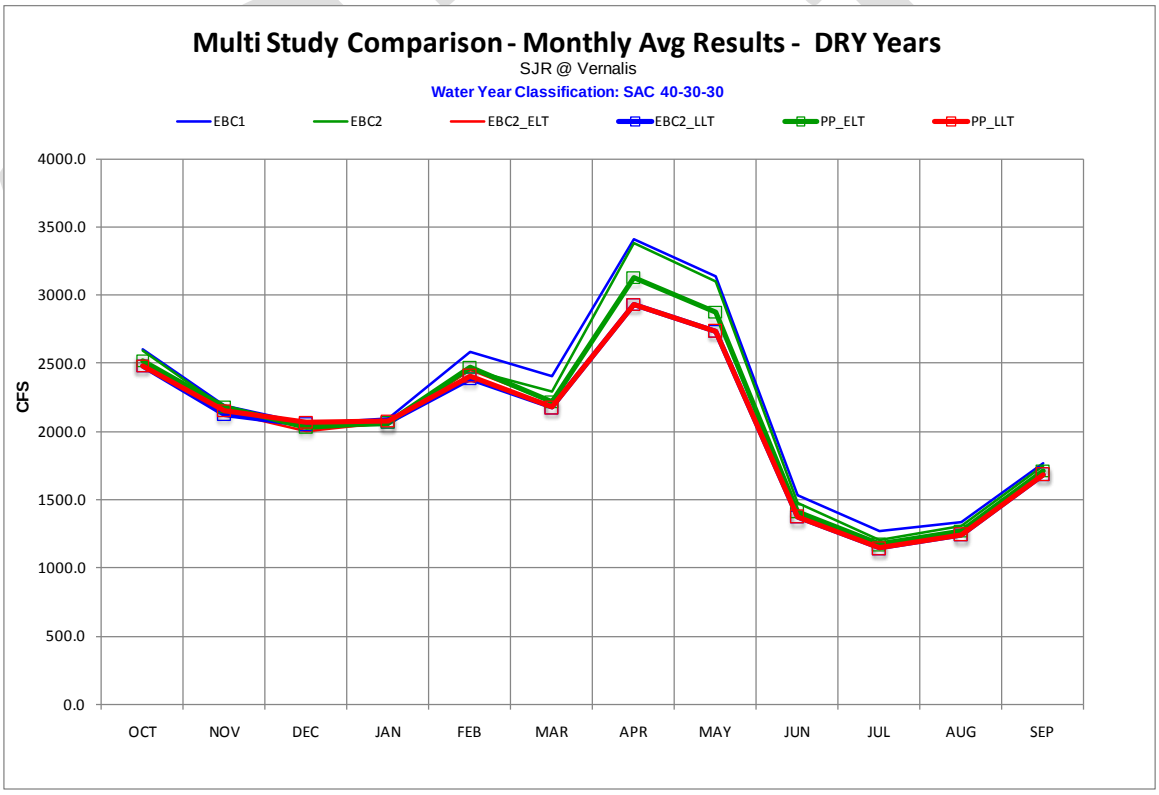

Figure C.5.2-366. San Joaquin River Average Monthly Flows at Vernalis in Dry Years

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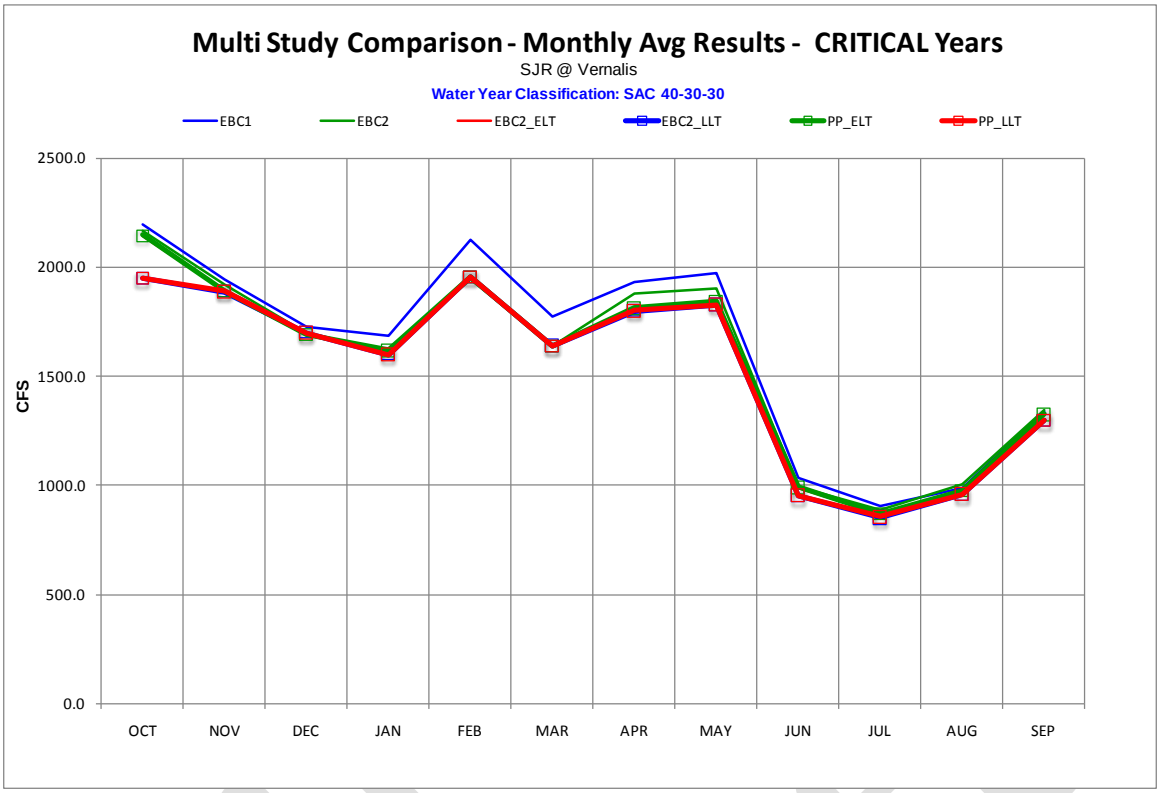

Figure C.5.2-367. San Joaquin River Average Monthly Flows at Vernalis in Critical Years

Larvae

Water Temperature

Combining all water years, mean monthly water temperatures in the Stanislaus River at its confluence with the San Joaquin River during the white sturgeon larval rearing period (February through June) are predicted to exceed the 68°F threshold in 5% of months under EBC1 and EBC2, in 9%–13% of months under EBC2_ELT and EBC2_LLT, and in 9%–13% of months under PP_ELT and PP_LLT (Figure C.5.2-368 through Figure C.5.2-372, Table C.5.2-144). Accounting for climate change effects, the frequency of temperatures exceeding 68°F under EBC2_ELT and EBC2_LLT is predicted to be nearly identical to that under PP_ELT and PP_LLT (Table C.5.2-145).

This analysis suggests that future increases in water temperatures in the Stanislaus River potentially affecting the suitability of the San Joaquin River for larval rearing of white sturgeon would occur largely in response to climate change and would not be affected by the preliminary proposal.

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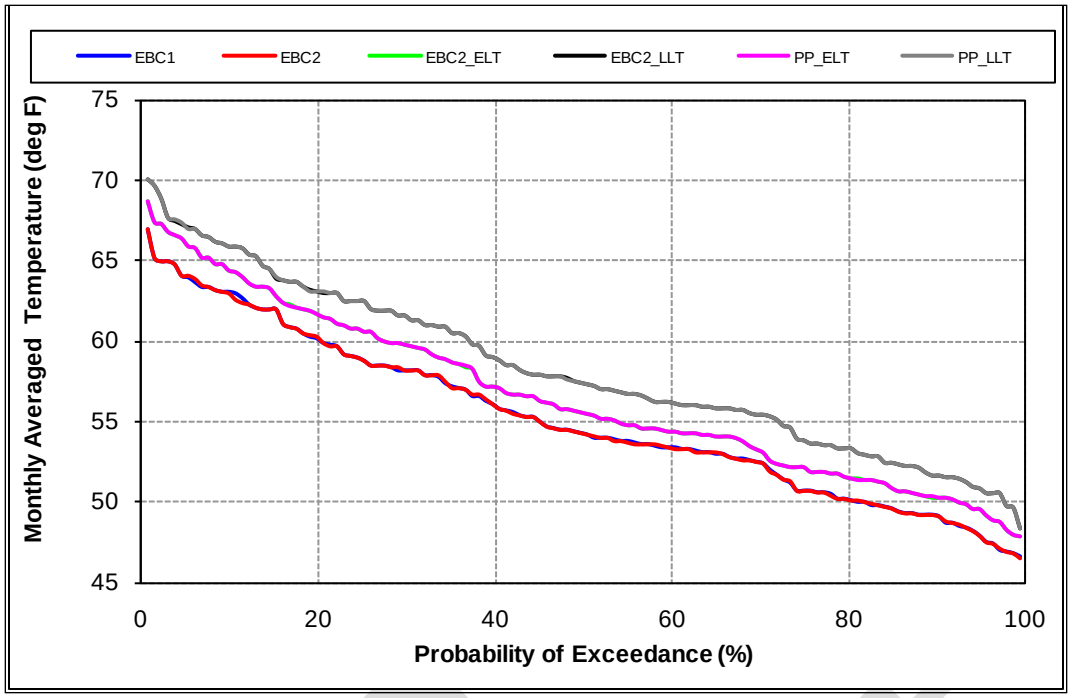

Figure C.5.2-368. Probability of Exceedance Plot for Model Scenarios of Mean Monthly Temperature of the Stanislaus River at the Confluence with the San Joaquin River in Wet Years, February through June

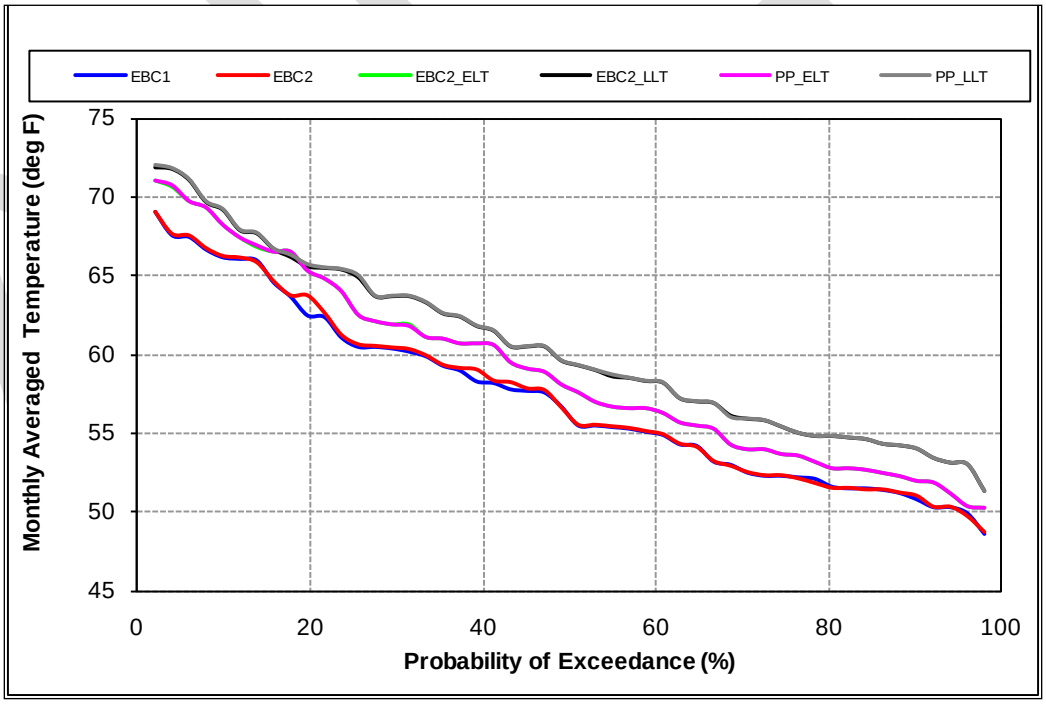

Figure C.5.2-369. Probability of Exceedance Plot for Model Scenarios of Mean Monthly Temperature of the Stanislaus River at the Confluence with the San Joaquin River in Above-Normal Years, February through June

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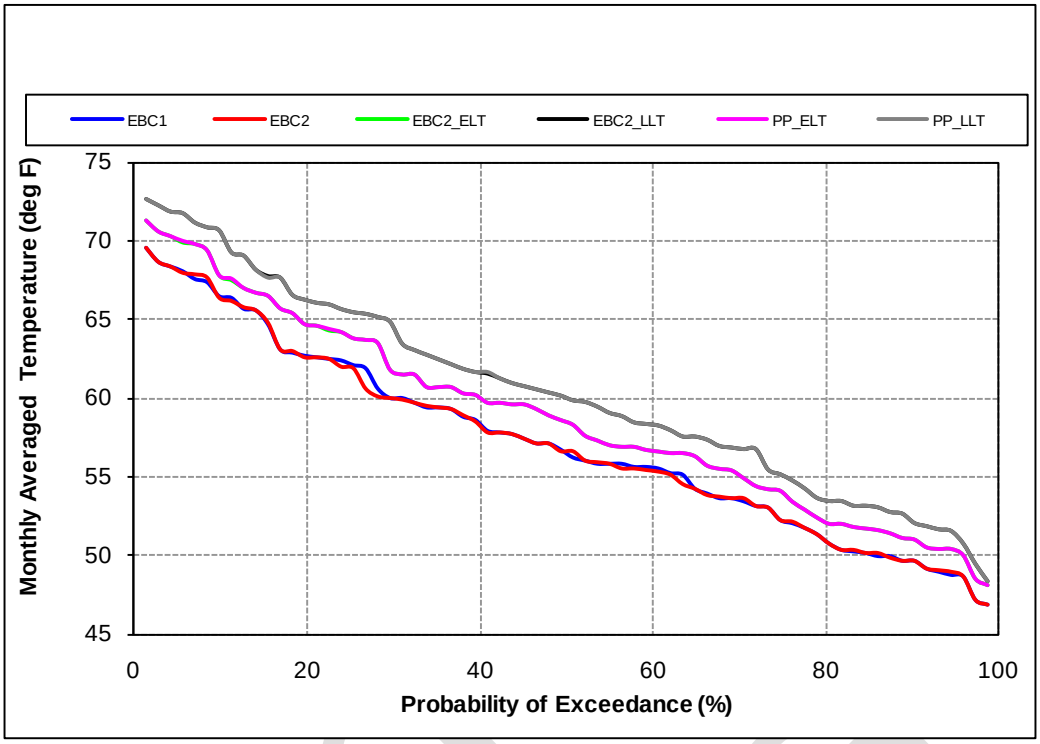

Figure C.5.2-370. Probability of Exceedance Plot for Model Scenarios of Mean Monthly Temperature of the Stanislaus River at the Confluence with the San Joaquin River in Below-Normal Years, February through June

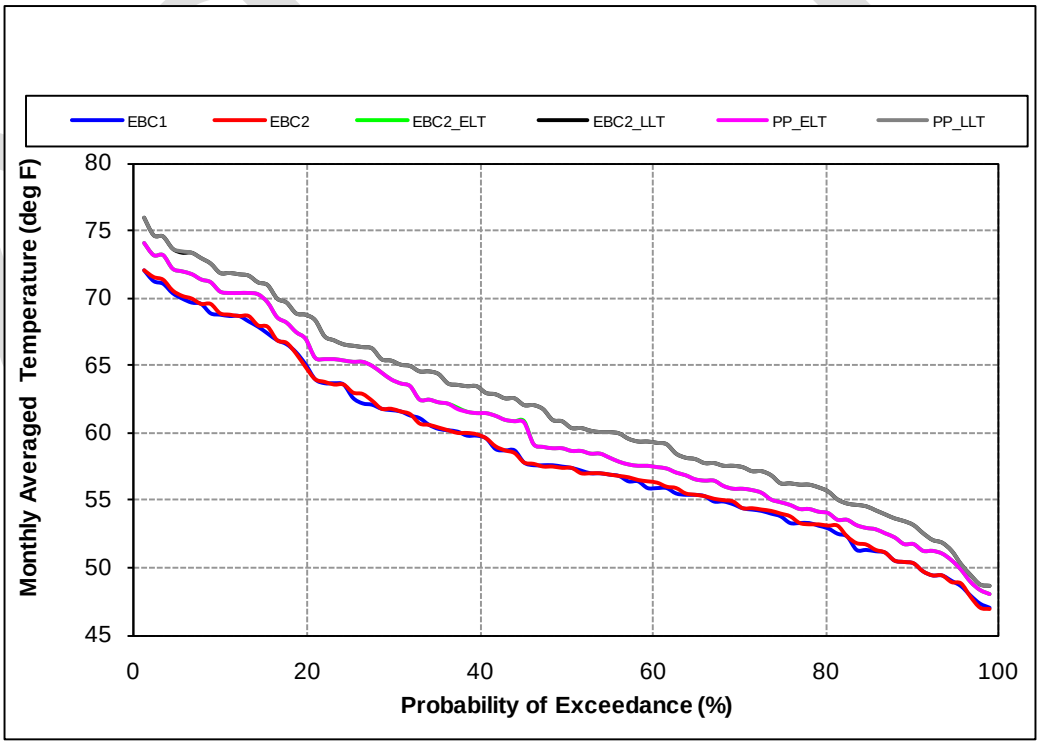

Figure C.5.2-371. Probability of Exceedance Plot for Model Scenarios of Mean Monthly Temperature of the Stanislaus River at the Confluence with the San Joaquin River in Dry Years, February through June

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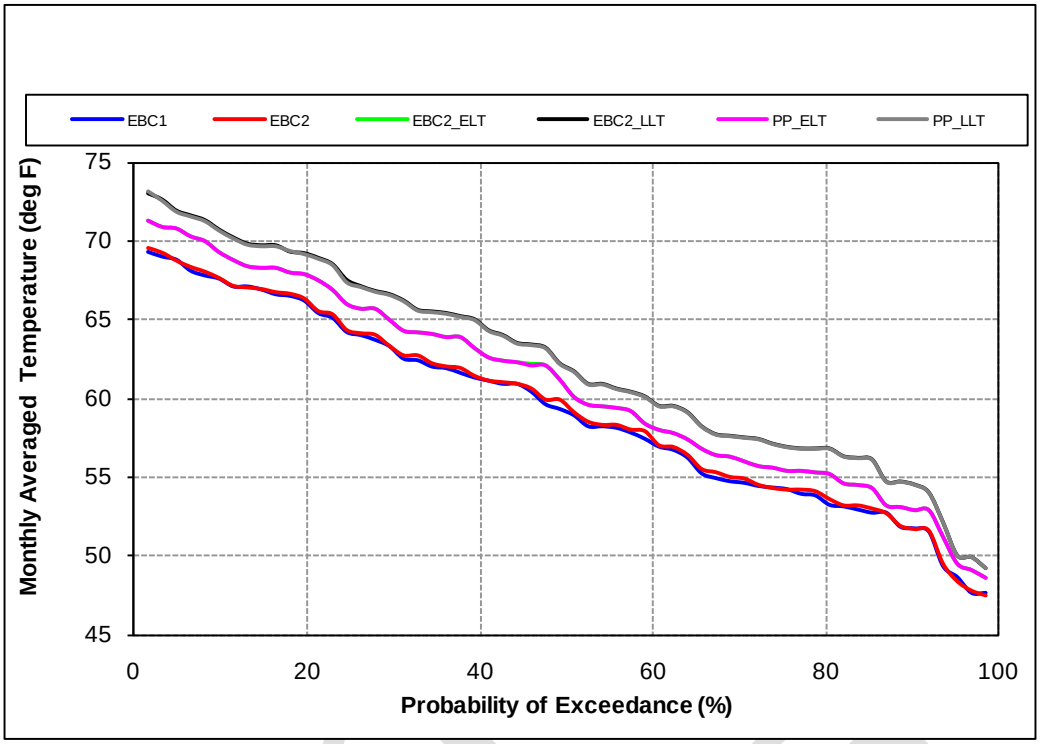

Figure C.5.2-372. Probability of Exceedance Plot for Model Scenarios of Mean Monthly Temperature of the Stanislaus River at the Confluence with the San Joaquin River in Critical Years, February through June

Table C.5.2-144. Percent of Months from February through June[1] When Monthly Average Temperature Exceeds 68°F in the Stanislaus River at the Confluence with the San Joaquin River

Water Year	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
Wet	0.0	0.0	0.8	2.3	0.8	2.3
Above Normal	1.8	1.8	9.1	9.1	9.1	9.1
Below Normal	5.7	4.3	8.6	14.3	8.6	14.3
Dry	13.3	13.3	17.8	21.1	17.8	21.1
Critically Dry	6.7	6.7	16.7	23.3	16.7	23.3
All	5.2	4.9	9.4	12.6	9.4	12.6

[1] Based on the modeling period of 1922 to 2003.

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Table C.5.2-145. Comparison of the Percent of Months during February through June When Monthly Average Temperature Exceeds 68°F in the Stanislaus River at the Confluence with the San Joaquin River

Water Year	Comparison[1]	EBC1 vs. PP_ELT	EBC1 vs. PP_LLT	EBC2 vs. EBC2_ELT	EBC2 vs. EBC2_LLT	EBC2 vs. PP_ELT	EBC2 vs. PP_LLT	EBC2_ELT vs. PP_ELT	EBC2_LLT vs. PP_LLT
Temperatures above 68°F									
Wet	Difference	0.8	2.3	0.8	2.3	0.8	2.3	0.0	0.0
	Percent Difference	NA	NA	NA	NA	NA	NA	0%	0%
Above Normal	Difference	7.3	7.3	7.3	7.3	7.3	7.3	0.0	0.0
	Percent Difference	400%	400%	400%	400%	400%	400%	0%	0%
Below Normal	Difference	2.9	8.6	4.3	10.0	4.3	10.0	0.0	0.0
	Percent Difference	50%	150%	100%	233%	100%	233%	0%	0%
Dry	Difference	4.4	7.8	4.4	7.8	4.4	7.8	0.0	0.0
	Percent Difference	33%	58%	33%	58%	33%	58%	0%	0%
Critical	Difference	10.0	16.7	10.0	16.7	10.0	16.7	0.0	0.0
	Percent Difference	150%	250%	150%	250%	150%	250%	0%	0%
All	Difference	4.2	7.4	4.4	7.7	4.4	7.7	0.0	0.0
	Percent Difference	81%	143%	90%	155%	90%	155%	0%	0%

[1] A positive value indicates a higher value under the second model scenario listed in the column title.
NA = Could not be calculated because dividing by 0.

Juvenile

Water Temperature

Water temperature exceedance plots are presented by water-year type during the white sturgeon rearing period (year-round) in the Stanislaus River at its confluence with the San Joaquin River in Figure C.5.2-373 through Figure C.5.2-377. The frequencies of exceedance above the 68°F and 71°F temperature thresholds are presented in Table C.5.2-146 and differences between pairs of model scenarios in the frequency of exceedance are presented in Table C.5.2-147.

Combining all water years, mean monthly water temperatures in the Stanislaus River at its confluence with the San Joaquin River year-round exceeded the 68°F threshold in 15% of months under EBC1 and EBC2, in 23%–28% of months under EBC2_ELT and EBC2_LLT, and in 23%–38% of months under PP_ELT and PP_LLT (Table C.5.2-146). Accounting for climate change effects, the frequency of temperatures exceeding 68°F under PP_ELT and PP_LLT is predicted to be the same under EBC2_ELT and EBC2_LLT, respectively (Table C.5.2-147).

Mean monthly water temperatures in the Stanislaus River at the confluence with the San Joaquin River (year-round) exceeded the 77°F threshold only in critical water years under the EBC2_LLT and PP_LLT scenarios. The exceedance frequency under both scenarios was <1% of the 82-year simulation period.

This analysis suggests that there were no effects of the preliminary proposal on water temperature-related habitat for juvenile white sturgeon rearing in the Stanislaus River. All predicted differences between model scenarios were a results of future climate change.

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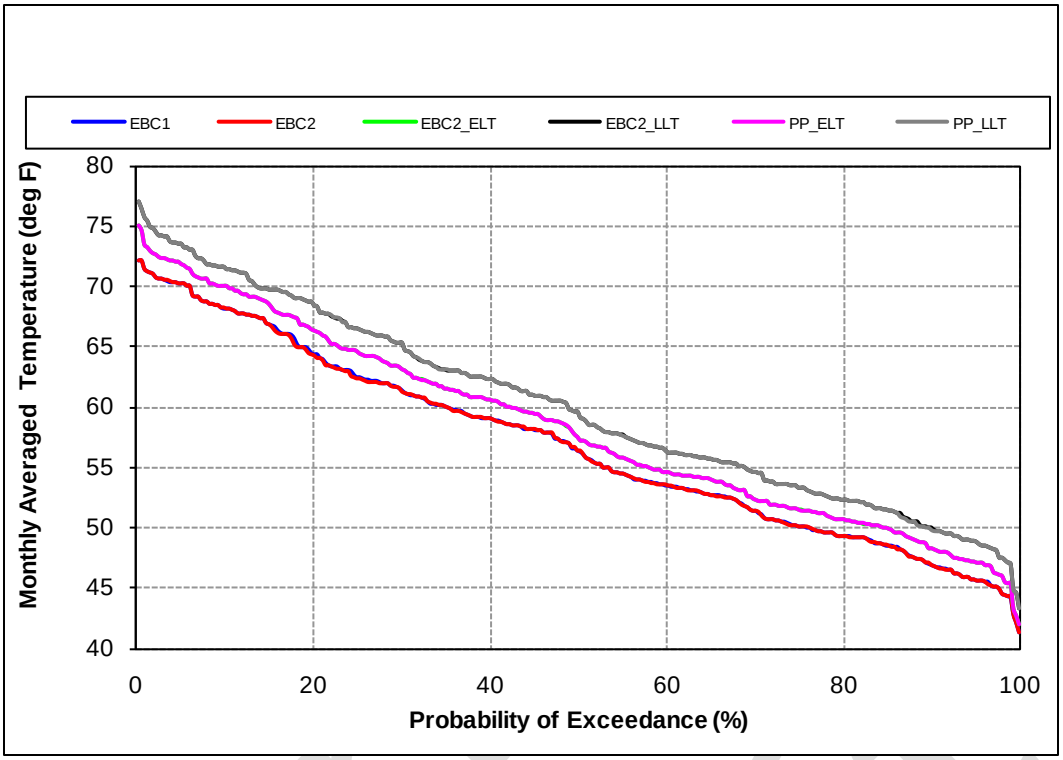

Figure C.5.2-373. Probability of Exceedance Plot for Model Scenarios of Mean Monthly Temperature of the Stanislaus River at the Confluence with the San Joaquin River in Wet Years, All Months

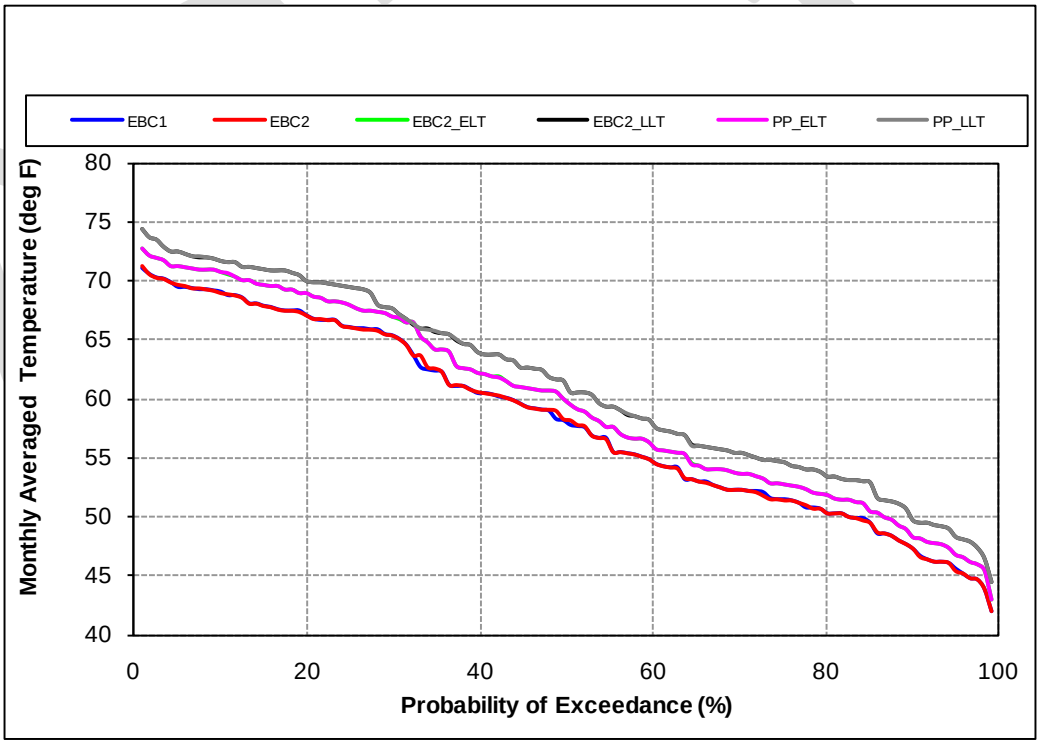

Figure C.5.2-374. Probability of Exceedance Plot for Model Scenarios of Mean Monthly Temperature of the Stanislaus River at the Confluence with the San Joaquin River in Above-Normal Years, All Months

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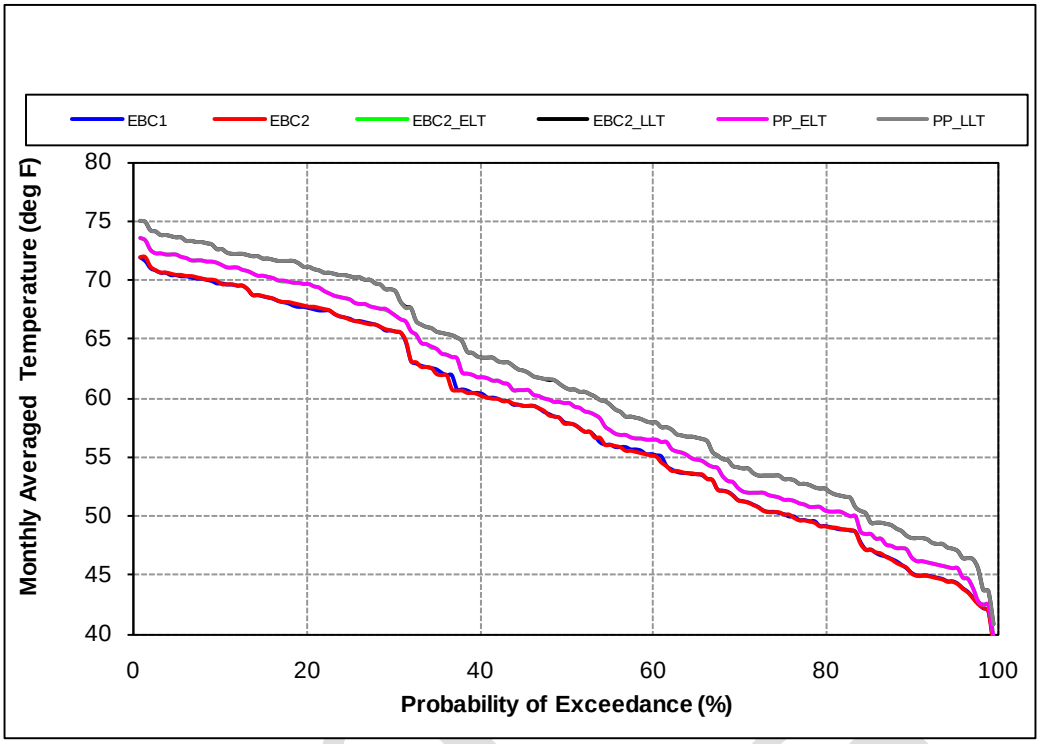

Figure C.5.2-375. Probability of Exceedance Plot for Model Scenarios of Mean Monthly Temperature of the Stanislaus River at the Confluence with the San Joaquin River in Below Normal Years, All Months

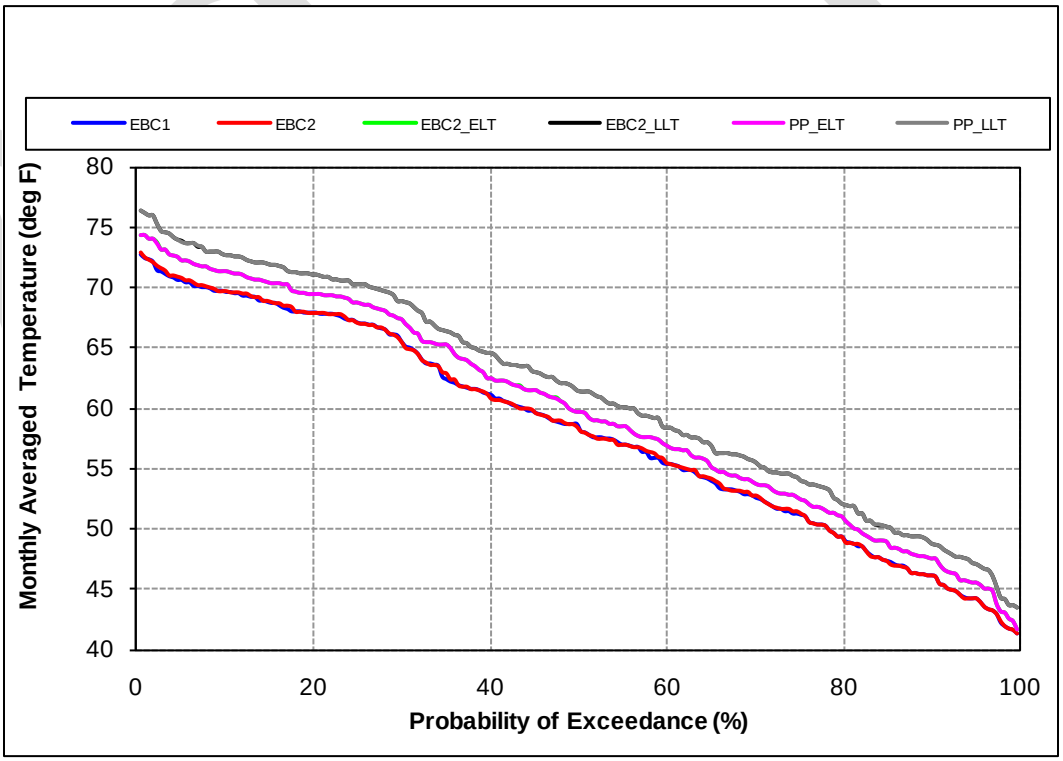

Figure C.5.2-376. Probability of Exceedance Plot for Model Scenarios of Mean Monthly Temperature of the Stanislaus River at the Confluence with the San Joaquin River in Dry Years, All Months

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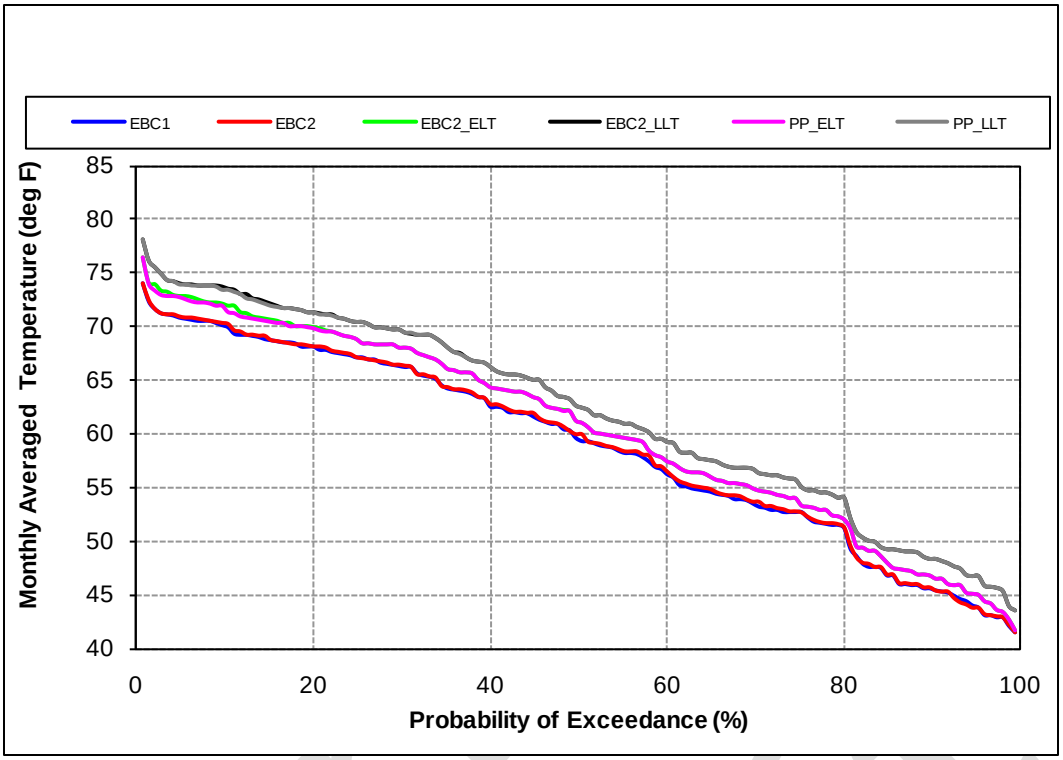

Figure C.5.2-377. Probability of Exceedance Plot for Model Scenarios of Mean Monthly Temperature of the Stanislaus River at the Confluence with the San Joaquin River in Critical Years, All Months

Table C.5.2-146. Percent of Months When Monthly Average Temperature Exceeds 68°F and 77°F in the Stanislaus River at the Confluence with the San Joaquin River, Year-Round[1]

	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
Temperatures above 68°F						
Wet	10.9	10.9	15.4	20.5	15.4	20.5
Above Normal	13.6	13.6	23.5	27.3	23.5	27.3
Below Normal	17.3	17.9	25.6	31.0	25.6	31.0
Dry	17.1	17.6	28.2	31.9	28.2	31.9
Critically Dry	19.4	20.8	29.2	34.7	29.2	34.7
All	15.0	15.4	23.1	27.9	23.1	27.9
Temperatures above 77°F						
Wet	0.0	0.0	0.0	0.0	0.0	0.0
Above Normal	0.0	0.0	0.0	0.0	0.0	0.0
Below Normal	0.0	0.0	0.0	0.0	0.0	0.0
Dry	0.0	0.0	0.0	0.0	0.0	0.0
Critically Dry	0.0	0.0	0.0	0.7	0.0	0.7
All	0.0	0.0	0.0	0.1	0.0	0.1

[1] Based on the modeling period of 1922 to 2003.

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Table C.5.2-147. Difference in Percent of Months when Monthly Average Temperature Exceeds 68°F and 77°F in the Stanislaus River at the Confluence with the San Joaquin River, Year-Round

Water Year	Comparison[1]	EBC1 vs. PP_ELT	EBC1 vs. PP_LLT	EBC2 vs. EBC2_ELT	EBC2 vs. EBC2_LLT	EBC2 vs. PP_ELT	EBC2 vs. PP_LLT	EBC2_ELT vs. PP_ELT	EBC2_LLT vs. PP_LLT
Temperatures above 68°F									
Wet	Difference	4.5	9.6	4.5	9.6	4.5	9.6	0.0	0.0
	Percent Difference	41%	88%	41%	88%	41%	88%	0%	0%
Above Normal	Difference	9.8	13.6	9.8	13.6	9.8	13.6	0.0	0.0
	Percent Difference	72%	100%	72%	100%	72%	100%	0%	0%
Below Normal	Difference	8.3	13.7	7.7	13.1	7.7	13.1	0.0	0.0
	Percent Difference	48%	79%	43%	73%	43%	73%	0%	0%
Dry	Difference	11.1	14.8	10.6	14.4	10.6	14.4	0.0	0.0
	Percent Difference	65%	86%	61%	82%	61%	82%	0%	0%
Critical	Difference	9.7	15.3	8.3	13.9	8.3	13.9	0.0	0.0
	Percent Difference	50%	79%	40%	67%	40%	67%	0%	0%
All	Difference	8.1	12.9	7.7	12.4	7.7	12.4	0.0	0.0
	Percent Difference	54%	86%	50%	81%	50%	81%	0%	0%
Temperatures above 77°F									
Wet	Difference	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Percent Difference	NA	NA	NA	NA	NA	NA	NA	NA
Above Normal	Difference	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Percent Difference	NA	NA	NA	NA	NA	NA	NA	NA
Below Normal	Difference	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Percent Difference	NA	NA	NA	NA	NA	NA	NA	NA
Dry	Difference	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Percent Difference	NA	NA	NA	NA	NA	NA	NA	NA
Critical	Difference	0.0	0.7	0.0	0.7	0.0	0.7	0.0	0.0
	Percent Difference	NA	NA	NA	NA	NA	NA	NA	0%
All	Difference	0.0	0.1	0.0	0.1	0.0	0.1	0.0	0.0
	Percent Difference	NA	NA	NA	NA	NA	NA	NA	0%

[1] A positive value indicates a higher value under the proposed project than the EBC.
NA = Could not be calculated because dividing by 0.

C.5.2.7 Stanislaus River

C.5.2.7.1 Steelhead

Eggs and Alevins

Upstream Spawning Habitat

The two primary potential effects of BDCP operations on habitat conditions for steelhead spawning and egg incubation on the Stanislaus River relate to changes in instream flows or seasonal water temperatures released from New Melones Reservoir. The primary spawning and incubation period extends from January through April. Results of these instream flow summaries are presented in

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Table C.5.2-148. Monthly frequency of exceedance plots for Stanislaus River flows for all months are presented in Figure C.5.2-378 through Figure C.5.2-389, and during the steelhead spawning and egg incubation period in Figure C.5.2-378 through Figure C.5.2-381. CALSIM results for each model scenario were used to characterize changes in physical habitat in the river and provide input to the analysis of seasonal water temperatures and other flow-related effects (e.g., redd dewatering) for steelhead spawning and egg incubation. These results indicate that instream flows in the Stanislaus River during the steelhead spawning and egg incubation period are predicted to be lower under EBC2_ELT and EBC2_LLT in most years relative to EBC1 and EBC2. Instream flows are predicted to be nearly identical between EBC2_ELT and PP_ELT and between EBC2_LLT and PP_LLT for all months and water-year types.

Table C.5.2-148. Mean Monthly Flows (Cubic Feet per Second) in the Stanislaus River at the Confluence with the San Joaquin River during the Year-Round Juvenile Steelhead Rearing Period

Month	Water-Year Type	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
Jan	W	1,240	1,218	1,284	1,250	1,284	1,250
	AN	360	358	350	328	351	328
	BN	377	378	371	341	371	341
	D	371	371	363	363	363	363
	C	298	274	251	227	251	227
	AVG	635	624	638	615	638	615
Feb	W	1,518	1,488	1,683	1,516	1,683	1,516
	AN	550	582	750	376	751	381
	BN	514	463	414	351	414	351
	D	479	417	376	353	376	353
	C	494	355	345	344	345	344
	AVG	827	780	847	723	847	724
Mar	W	2,145	2,140	2,310	2,194	2,311	2,193
	AN	1,126	1,124	962	910	961	910
	BN	797	791	640	561	640	561
	D	482	444	399	374	399	373
	C	544	440	440	439	440	439
	AVG	1,167	1,140	1,134	1,071	1,135	1,071
Apr	W	2,118	2,119	2,077	2,012	2,077	2,012
	AN	1,690	1,640	1,583	1,467	1,582	1,468
	BN	1,480	1,503	1,397	1,283	1,396	1,282
	D	1,290	1,273	1,156	1,019	1,157	1,019
	C	734	702	635	627	635	627
	AVG	1,562	1,551	1,475	1,387	1,475	1,387
May	W	1,731	1,732	1,736	1,670	1,736	1,671
	AN	1,386	1,356	1,278	1,118	1,280	1,118
	BN	1,191	1,238	1,115	1,005	1,113	1,005
	D	978	955	865	768	865	768
	C	694	647	636	624	637	624
	AVG	1,271	1,263	1,211	1,125	1,211	1,125

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Month	Water-Year Type	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
Jun	W	1,613	1,623	1,754	1,614	1,752	1,611
	AN	933	925	894	1,034	889	1,033
	BN	829	832	799	743	797	743
	D	427	404	379	366	379	366
	C	335	310	312	295	314	293
	AVG	932	926	952	914	951	912
Jul	W	1,026	1,076	1,019	934	1,019	934
	AN	461	448	443	647	443	646
	BN	466	449	439	440	439	441
	D	387	352	357	356	359	356
	C	340	333	319	312	317	315
	AVG	607	610	588	590	588	590
Aug	W	898	905	810	698	810	698
	AN	448	449	446	437	446	437
	BN	437	437	428	425	428	425
	D	389	390	388	387	388	387
	C	338	364	338	333	337	333
	AVG	560	566	530	491	530	491
Sep	W	1,003	992	926	834	926	834
	AN	474	474	466	457	466	457
	BN	438	439	427	422	427	422
	D	390	390	388	387	388	387
	C	319	340	323	308	323	322
	AVG	595	594	567	533	567	535
Oct	W	1,000	1,005	976	955	976	955
	AN	807	815	750	733	750	734
	BN	862	864	825	799	825	802
	D	874	874	867	859	867	859
	C	632	630	612	497	612	497
	AVG	867	869	840	808	840	808
Nov	W	591	584	603	549	603	549
	AN	296	297	287	276	287	276
	BN	334	336	335	312	335	312
	D	340	340	335	334	335	334
	C	325	327	307	303	307	304
	AVG	410	409	409	386	409	386
Dec	W	760	768	804	677	804	667
	AN	294	293	285	274	285	274
	BN	319	320	320	324	320	324
	D	330	330	324	324	324	324
	C	268	270	250	246	250	246
	AVG	450	453	459	417	459	414

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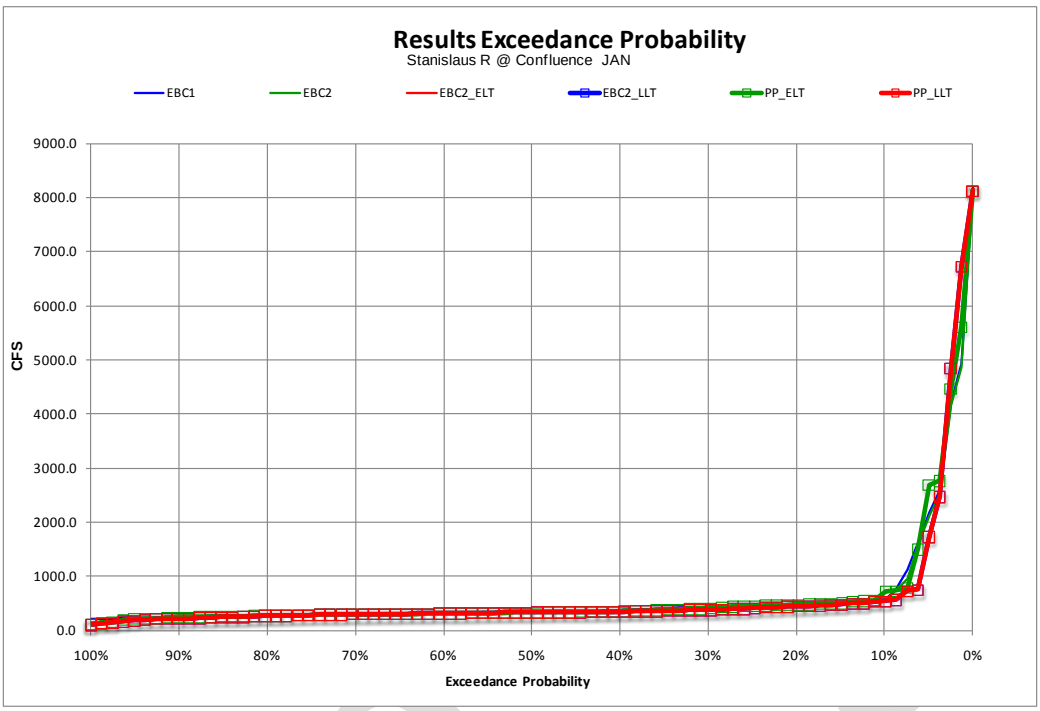

Figure C.5.2-378. Probability of Exceedance Plot for Model Scenarios of Mean Monthly Flow in the Stanislaus River at the Confluence with the San Joaquin River, January

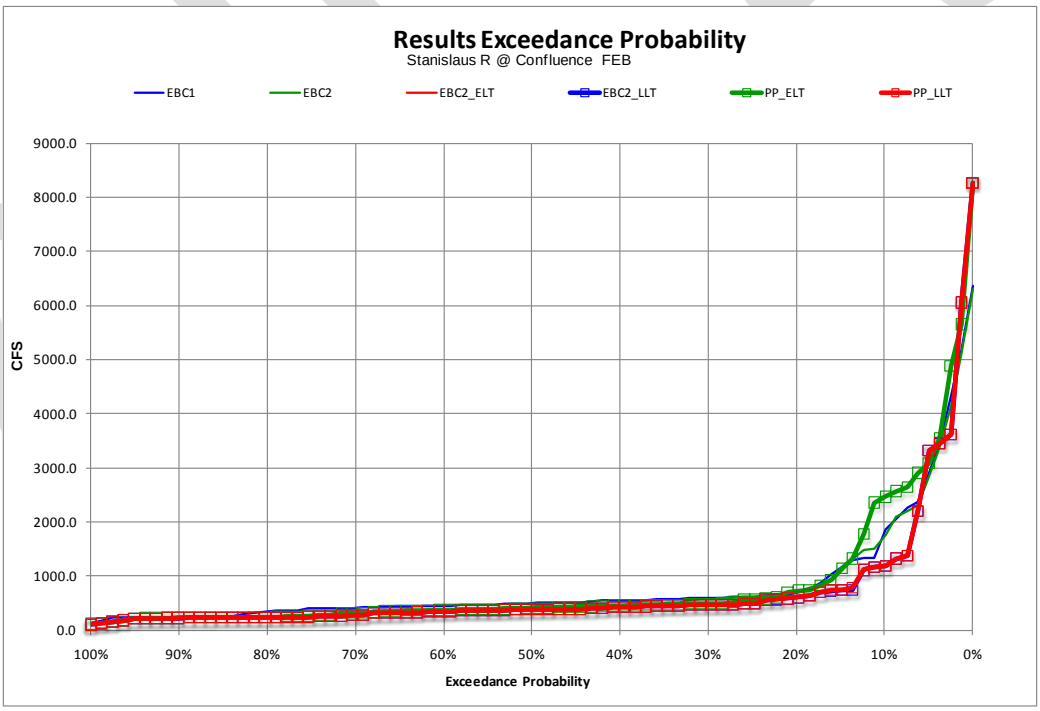

Figure C.5.2-379. Probability of Exceedance Plot for Model Scenarios of Mean Monthly Flow in the Stanislaus River at the Confluence with the San Joaquin River, February

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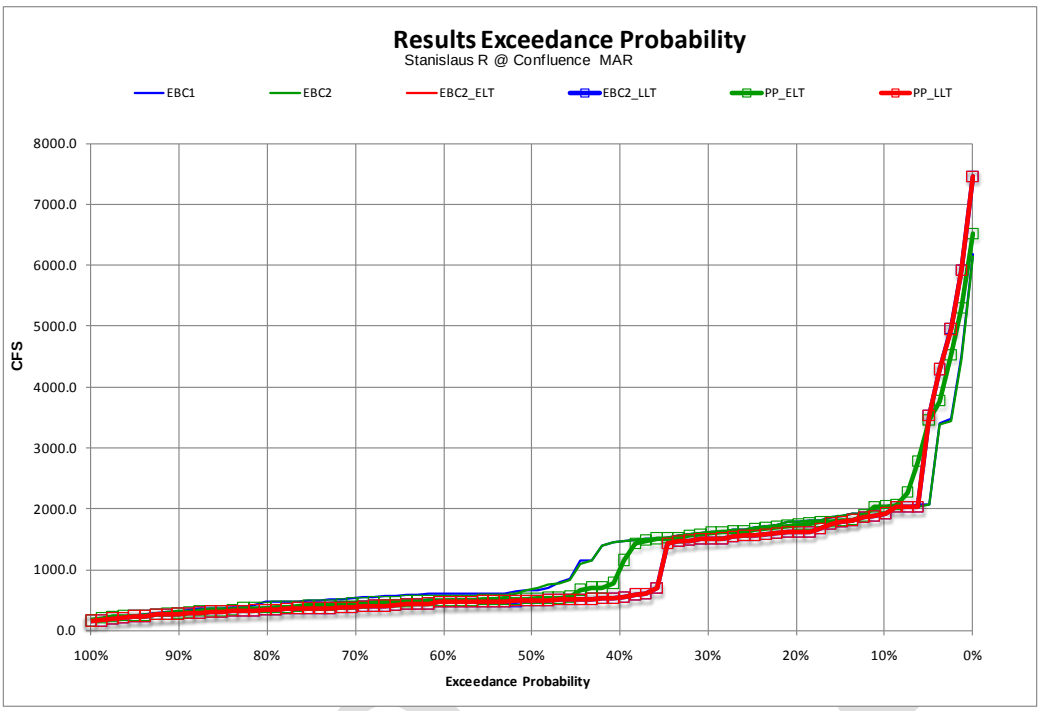

Figure C.5.2-380. Probability of Exceedance Plot for Model Scenarios of Mean Monthly Flow in the Stanislaus River at the Confluence with the San Joaquin River, March

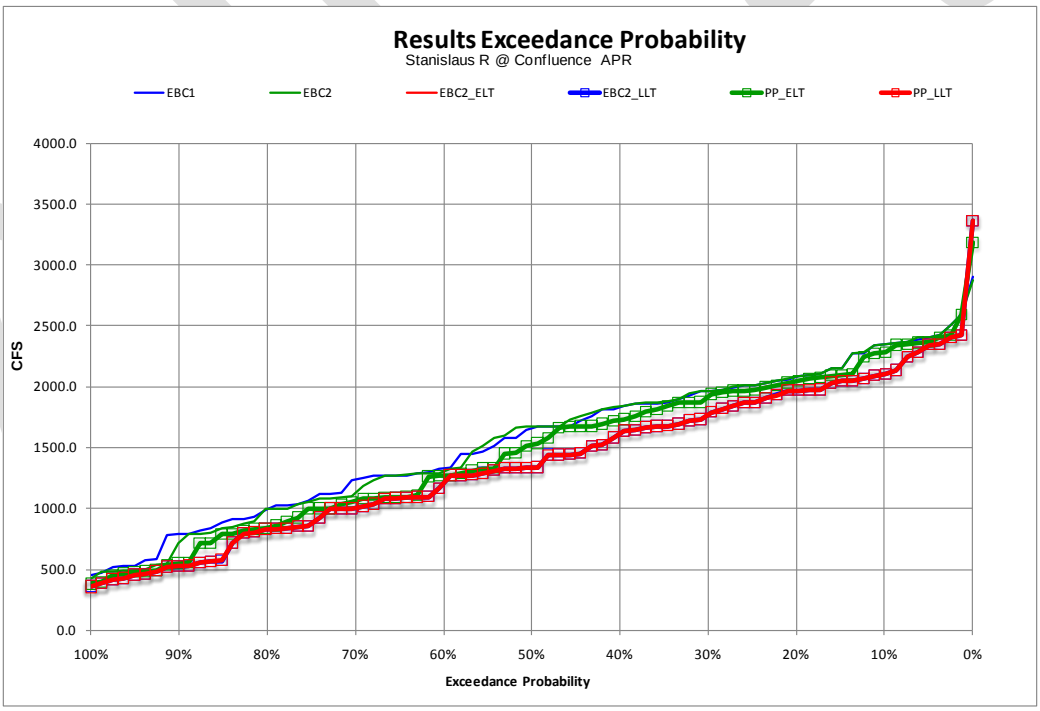

Figure C.5.2-381. Probability of Exceedance Plot for Model Scenarios of Mean Monthly Flow in the Stanislaus River at the Confluence with the San Joaquin River, April

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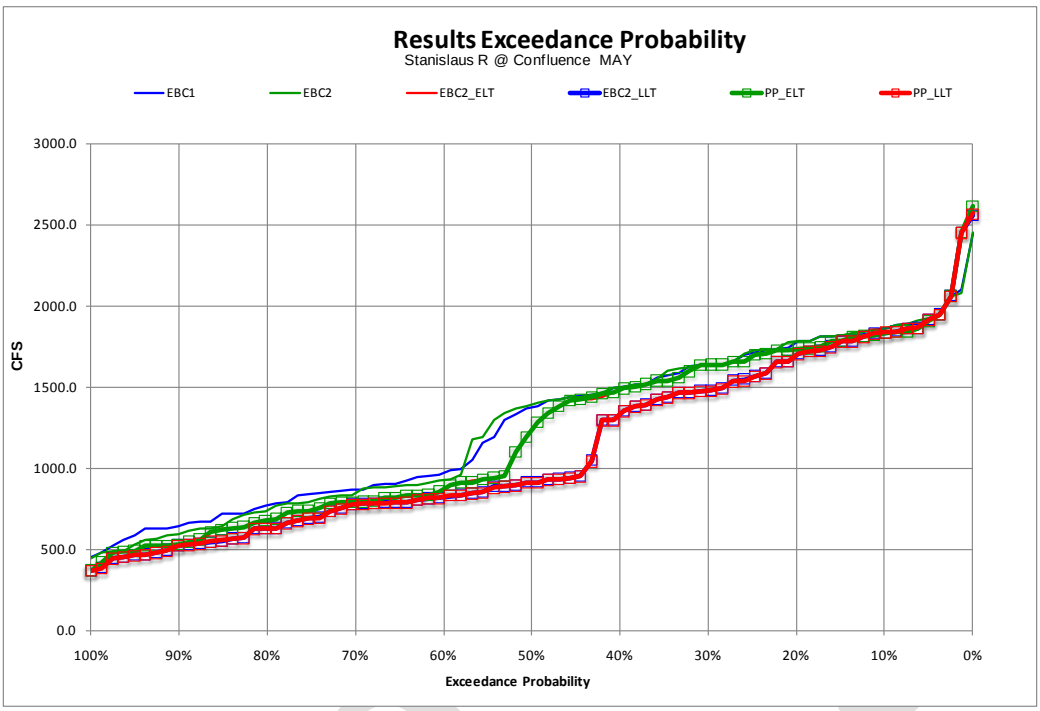

Figure C.5.2-382. Probability of Exceedance Plot for Model Scenarios of Mean Monthly Flow in the Stanislaus River at the Confluence with the San Joaquin River, May

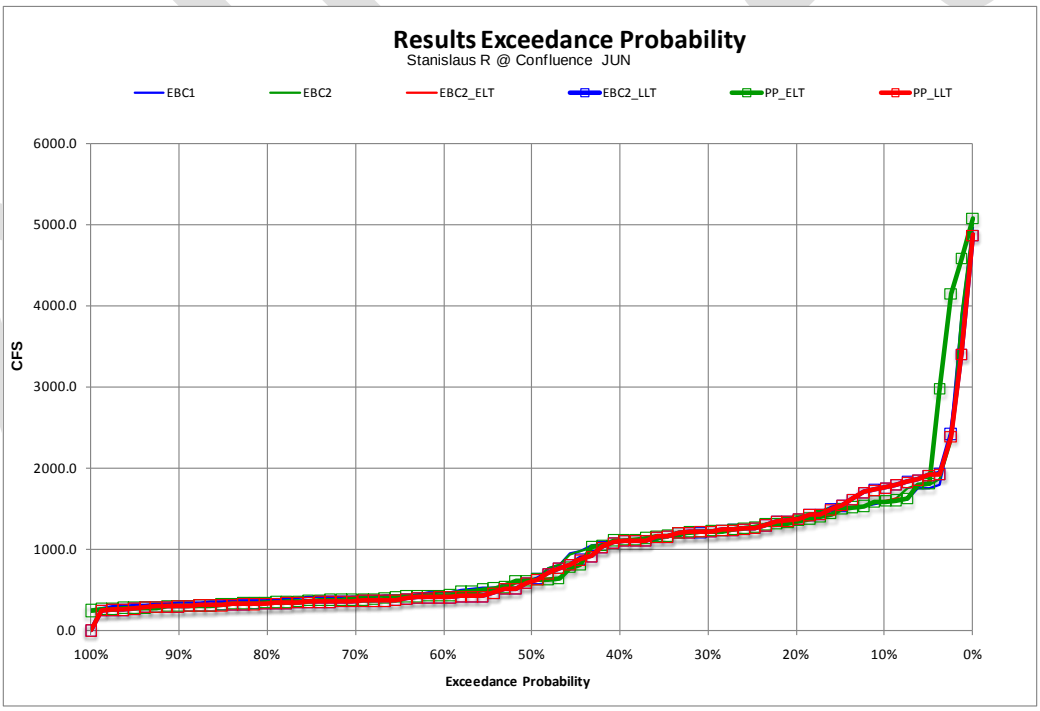

Figure C.5.2-383. Probability of Exceedance Plot for Model Scenarios of Mean Monthly Flow in the Stanislaus River at the Confluence with the San Joaquin River, June

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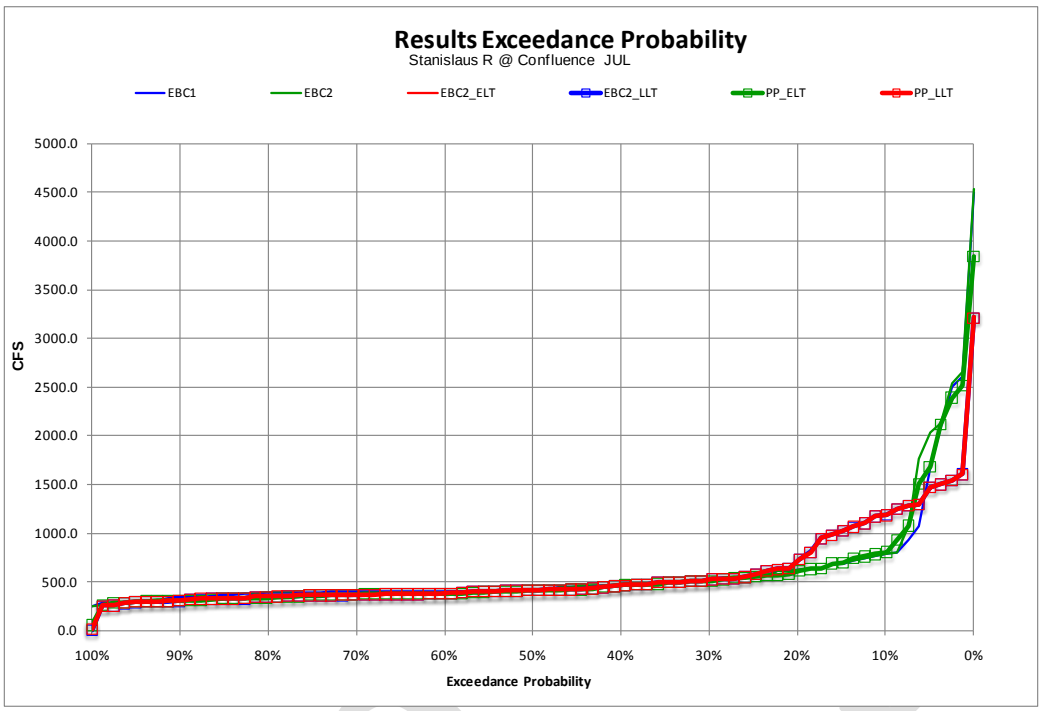

Figure C.5.2-384. Probability of Exceedance Plot for Model Scenarios of Mean Monthly Flow in the Stanislaus River at the Confluence with the San Joaquin River, July

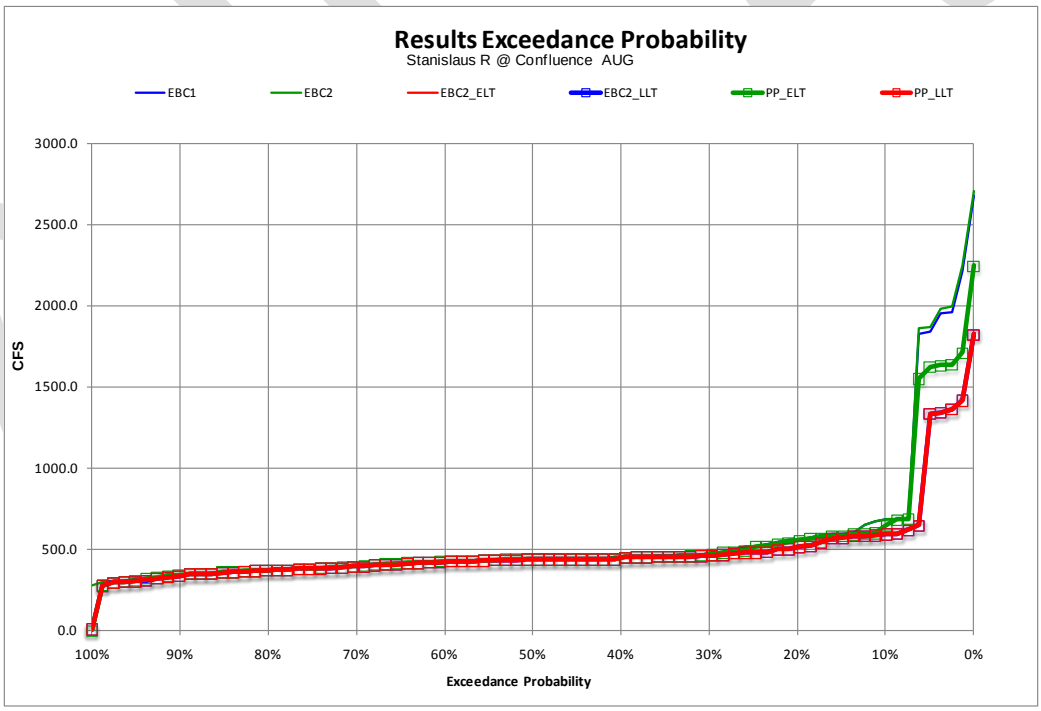

Figure C.5.2-385. Probability of Exceedance Plot for Model Scenarios of Mean Monthly Flow in the Stanislaus River at the Confluence with the San Joaquin River, August

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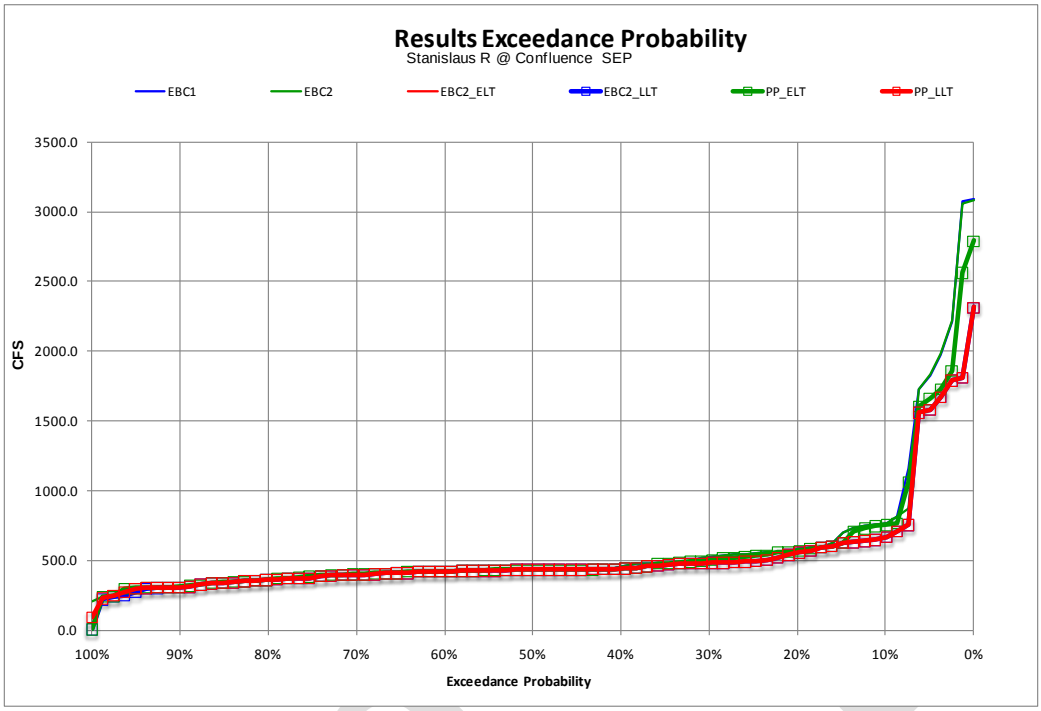

Figure C.5.2-386. Probability of Exceedance Plot for Model Scenarios of Mean Monthly Flow in the Stanislaus River at the Confluence with the San Joaquin River, September

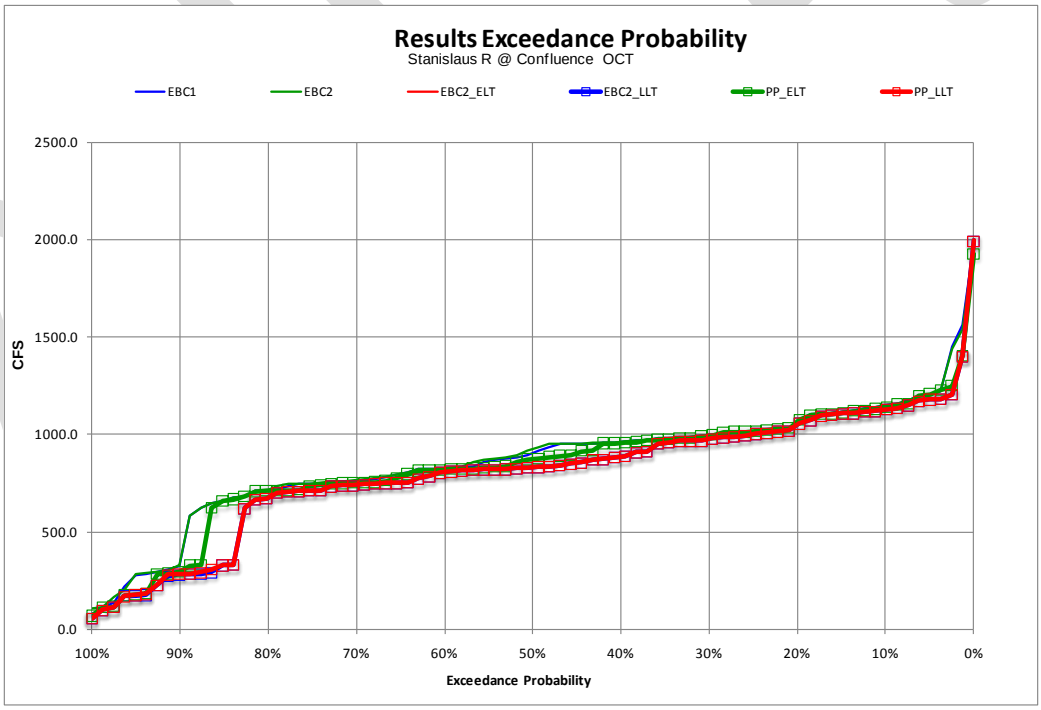

Figure C.5.2-387. Probability of Exceedance Plot for Model Scenarios of Mean Monthly Flow in the Stanislaus River at the Confluence with the San Joaquin River, October

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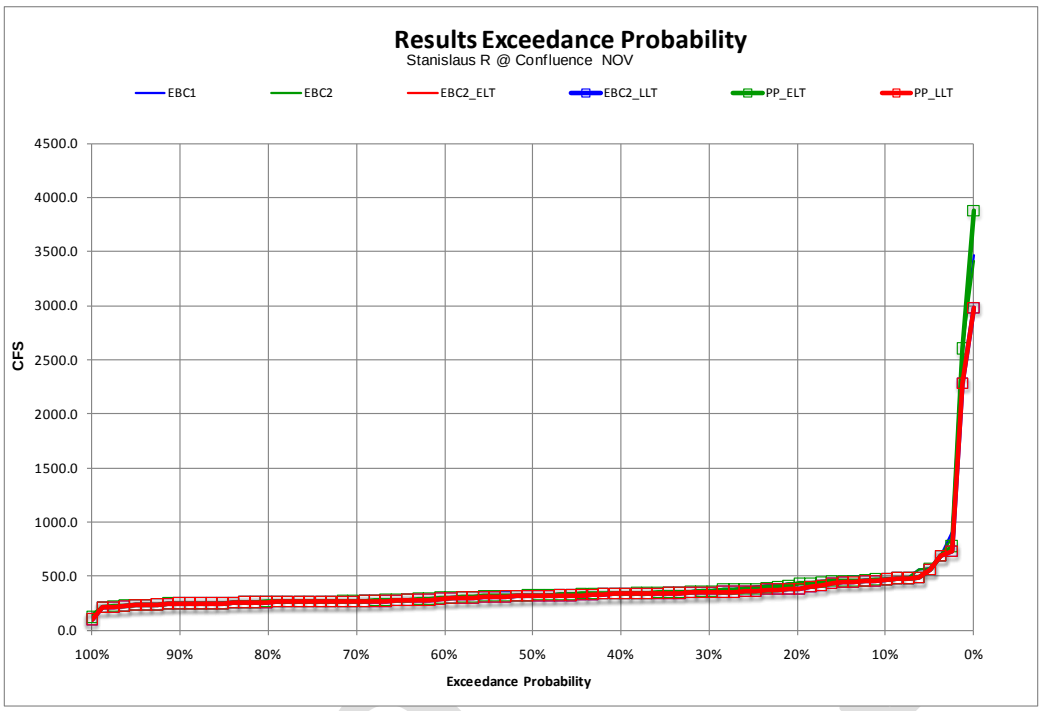

Figure C.5.2-388. Probability of Exceedance Plot for Model Scenarios of Mean Monthly Flow in the Stanislaus River at the Confluence with the San Joaquin River, November

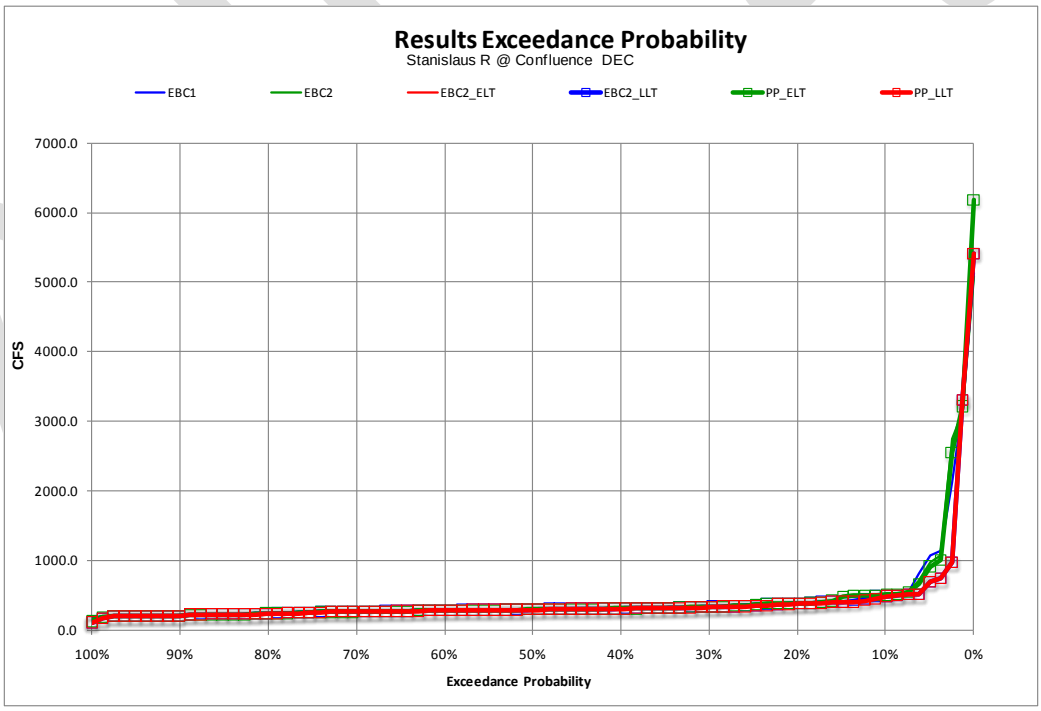

Figure C.5.2-389. Probability of Exceedance Plot for Model Scenarios of Mean Monthly Flow in the Stanislaus River at the Confluence with the San Joaquin River, December

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Water Temperature

Water temperature in the Stanislaus River during the steelhead spawning and egg incubation period is determined largely by coldwater pool storage in New Melones Reservoir and instream flow releases. Results of water temperature simulation analyses for the Stanislaus River at Orange Blossom Bridge were used as an indicator of effects of the preliminary proposal on water temperatures that would potentially affect steelhead spawning and egg incubation. The model results were compiled monthly over the 82-year period included in the CALSIM simulations. Average monthly water temperatures were then evaluated to determine the months during the steelhead egg incubation period (January through April) when temperatures exceeded 56°F. Excedance plots for each month year-round are presented in Figure C.5.2-390 through Figure C.5.2-401, and for the steelhead incubation period in Figure C.5.2-390 through Figure C.5.2-393. Results of the frequency of years in which monthly average temperatures exceeded the criterion between January and April are summarized in Table C.5.2-149.

During the 82-year simulation period, one or more occurrences of temperatures exceeding 56°F at Orange Blossom Bridge are predicted to occur in 4 years under EBC1 and EBC2, 13 years under EBC2_ELT and PP_ELT, and 34 years under EBC2_LLT and PP_LLT (Table C.5.2-149). The number of consecutive years with temperature exceeding 56°F is predicted to be 2 years under EBC1 and EBC2, 8 years under EBC2_ELT and PP_ELT, and 25 years under EBC2_LLT and PP_LLT. Thus, the frequency of stressful water temperatures for steelhead egg incubation in the Stanislaus River would be expected to increase substantially between EBC2, EBC2_ELT, and EBC2_LLT. However, the preliminary proposal is predicted to have no effect on the frequency of stressful water temperatures during the January through April steelhead spawning and egg incubation period (EBC2_ELT vs. PP_ELT and EBC2_LLT vs. PP_LLT).

Reservoir storage in May and September provides an indicator of coldwater pool availability. Results of CALSIM modeling of New Melones Reservoir storage in May is shown in Table C.5.2-150 with the corresponding frequency of exceedance analysis for May storage shown in Figure C.5.2-402. September storage in New Melones Reservoir is shown in Table C.5.2-151 with the corresponding frequency of exceedance analysis for September in Figure C.5.2-403. Results indicate that May and September storage in New Melones Reservoir under EBC2_ELT and EBC2_LLT would be lower than under EBC1 and EBC2. May and September storage under EBC2_ELT and BEC2_LLT would be nearly identical to storage under PP_ELT and PP_LLT, respectively.

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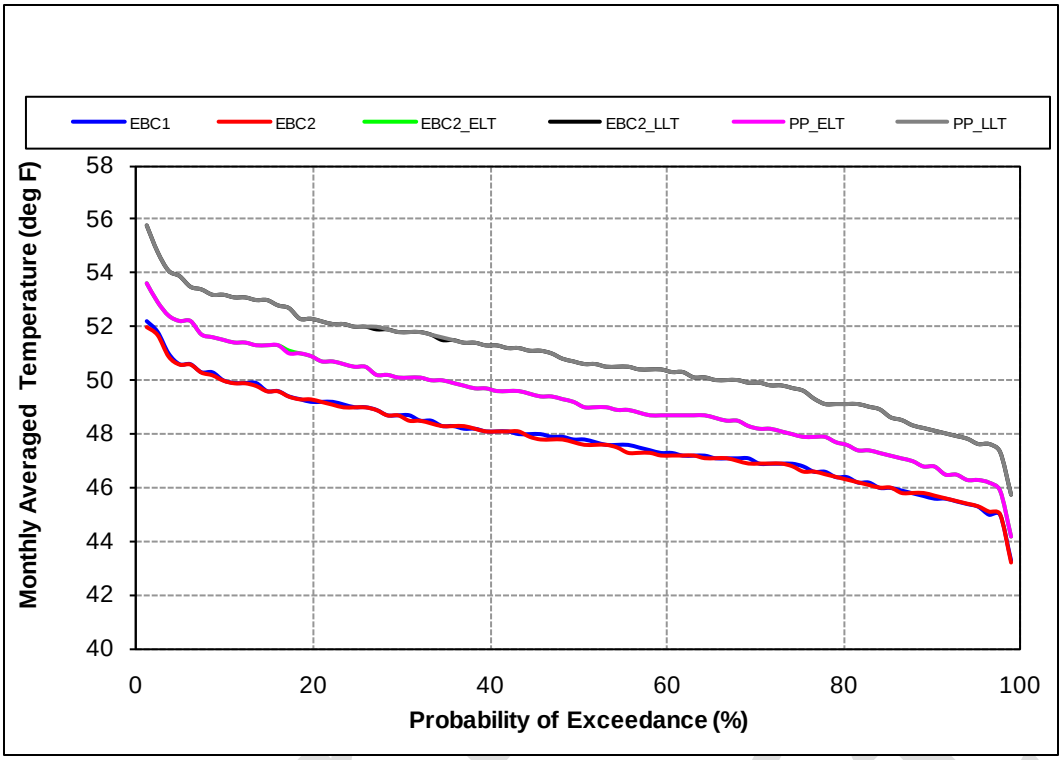

Figure C.5.2-390. Probability of Exceedance Plot for Model Scenarios of Mean Monthly Water Temperature of Stanislaus River at Orange Blossom, January

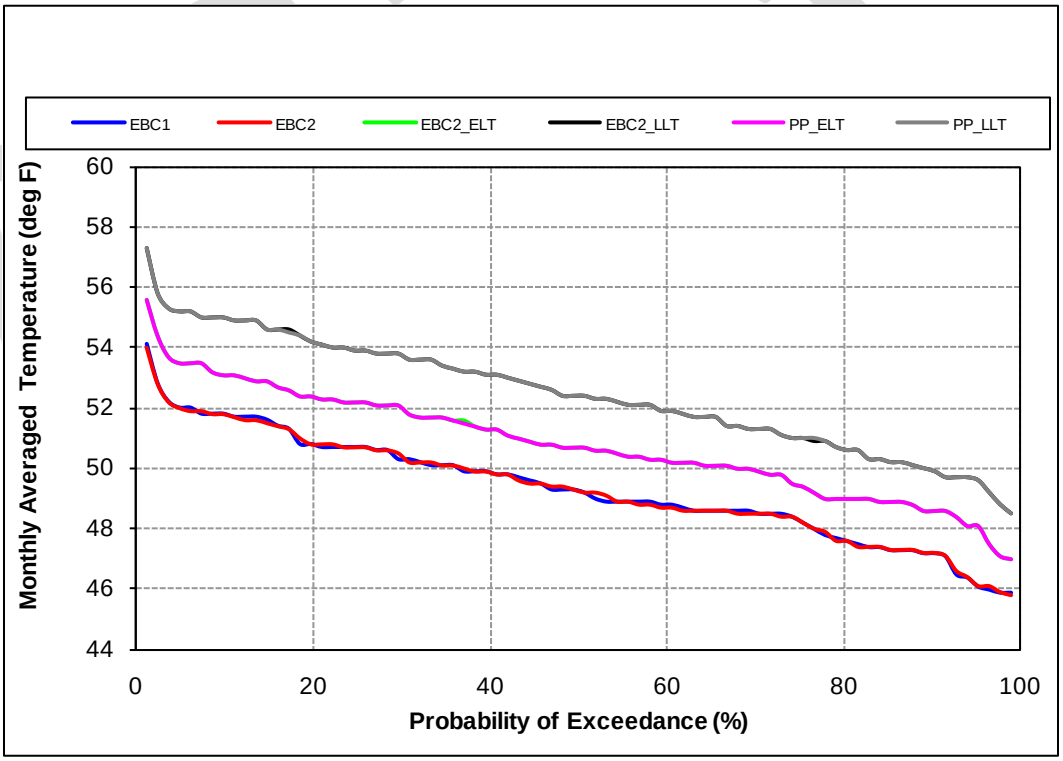

Figure C.5.2-391. Probability of Exceedance Plot for Model Scenarios of Mean Monthly Water Temperature of Stanislaus River at Orange Blossom, February

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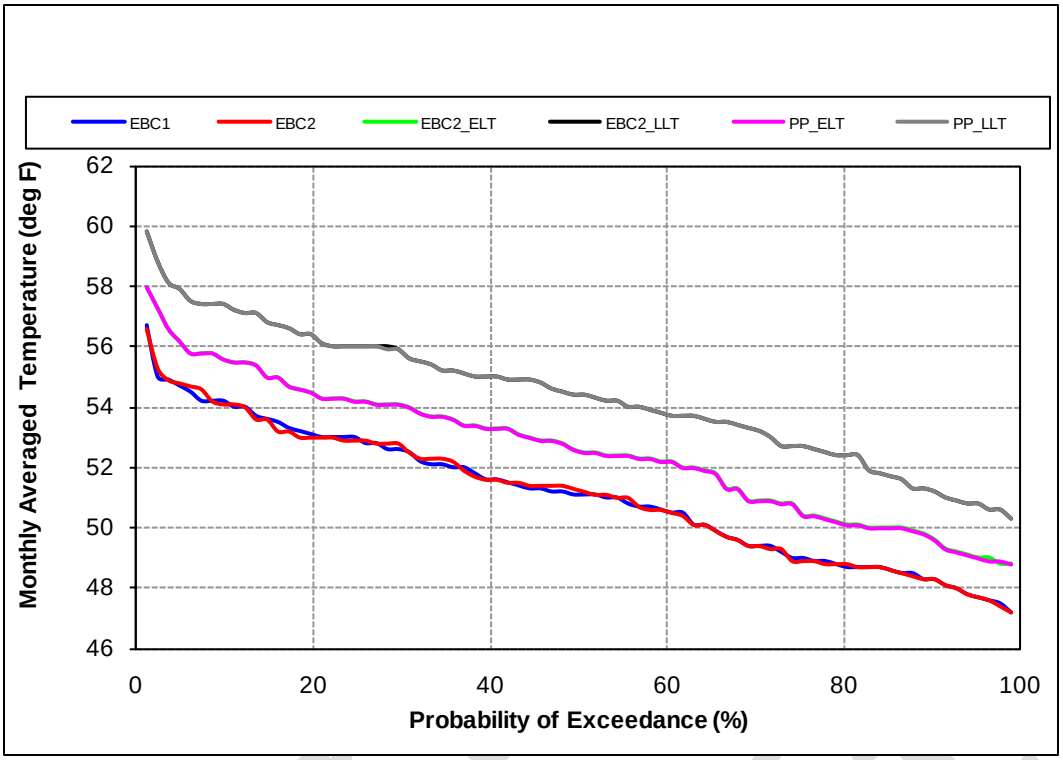

Figure C.5.2-392. Probability of Exceedance Plot for Model Scenarios of Mean Monthly Water Temperature of Stanislaus River at Orange Blossom, March

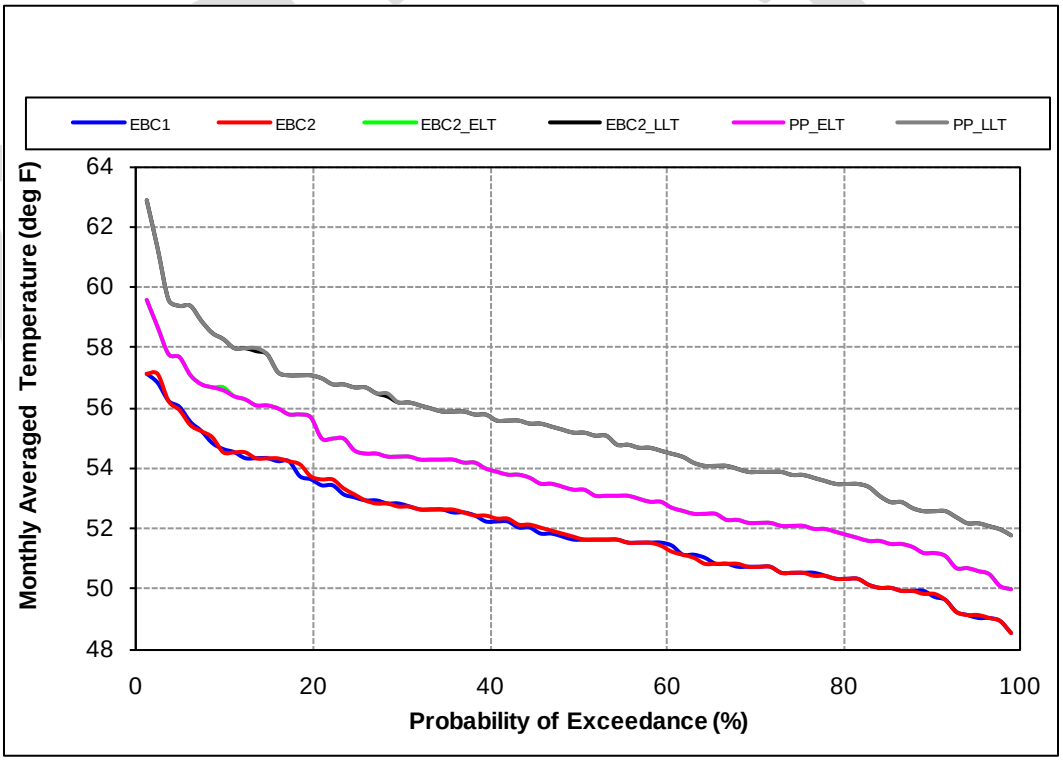

Figure C.5.2-393. Probability of Exceedance Plot for Model Scenarios of Mean Monthly Water Temperature of Stanislaus River at Orange Blossom, April

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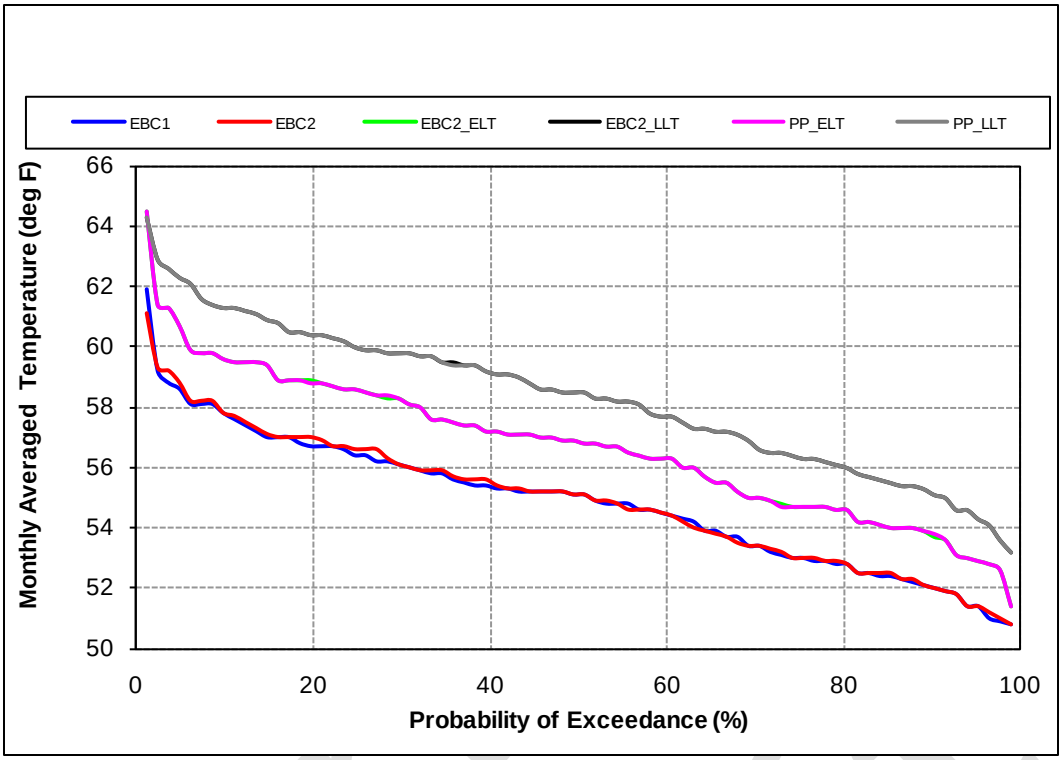

Figure C.5.2-394. Probability of Exceedance Plot for Model Scenarios of Mean Monthly Water Temperature of Stanislaus River at Orange Blossom, May

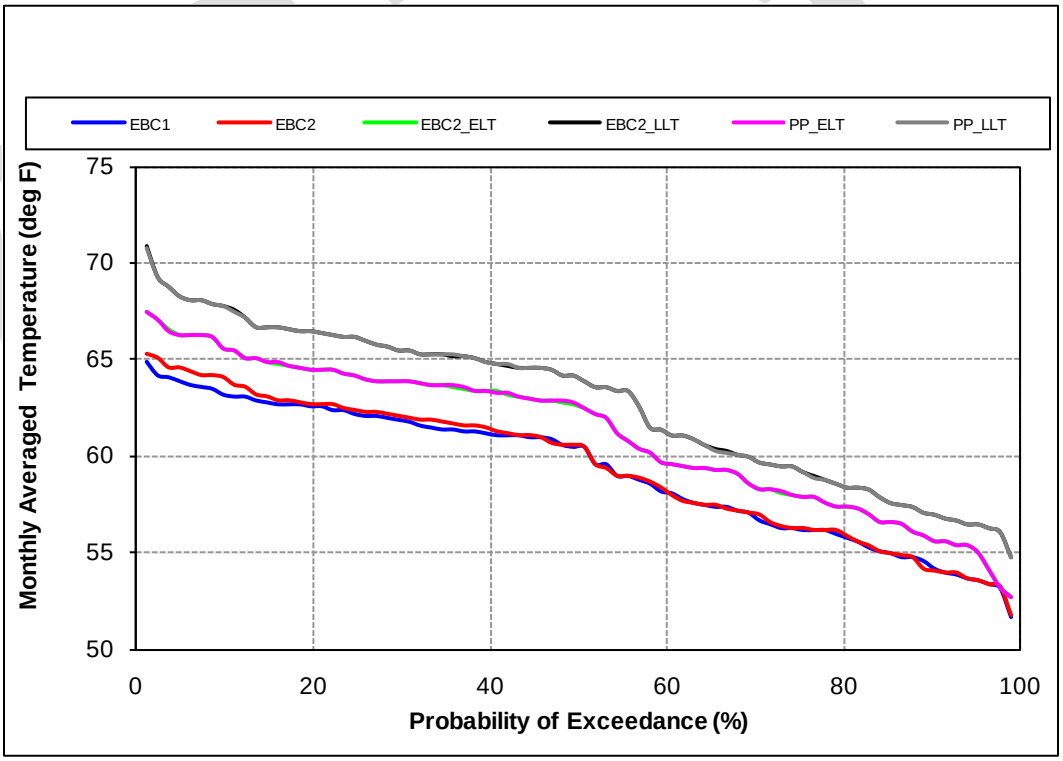

Figure C.5.2-395. Probability of Exceedance Plot for Model Scenarios of Mean Monthly Water Temperature of Stanislaus River at Orange Blossom, June

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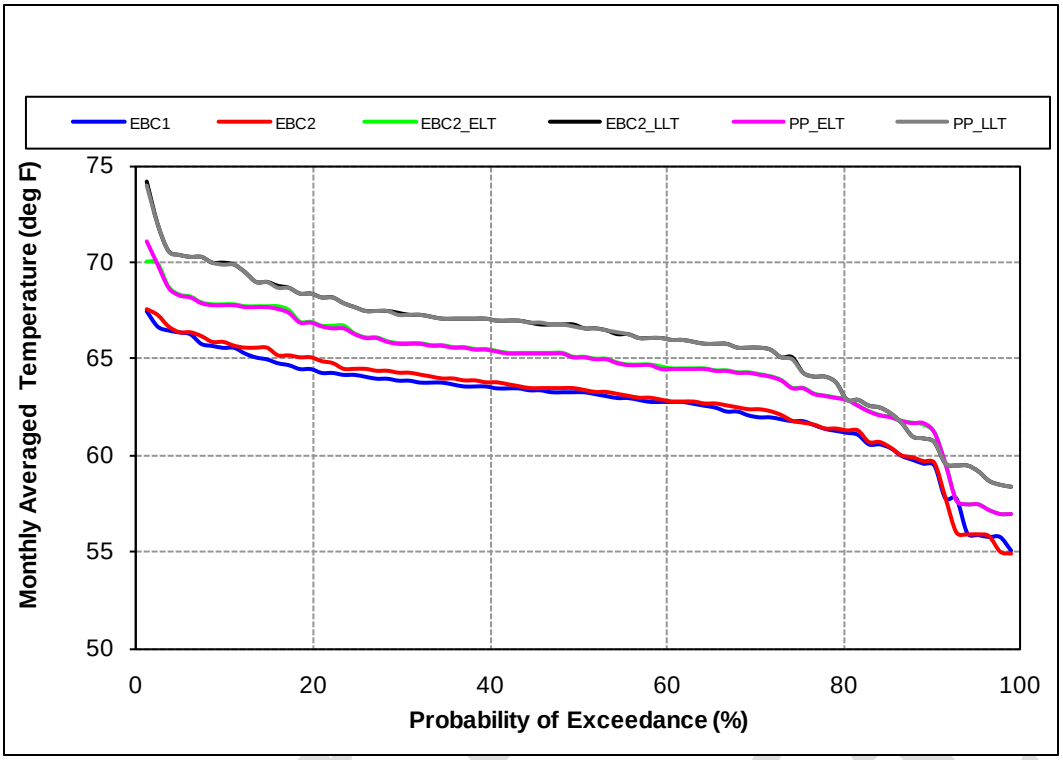

Figure C.5.2-396. Probability of Exceedance Plot for Model Scenarios of Mean Monthly Water Temperature of Stanislaus River at Orange Blossom, July

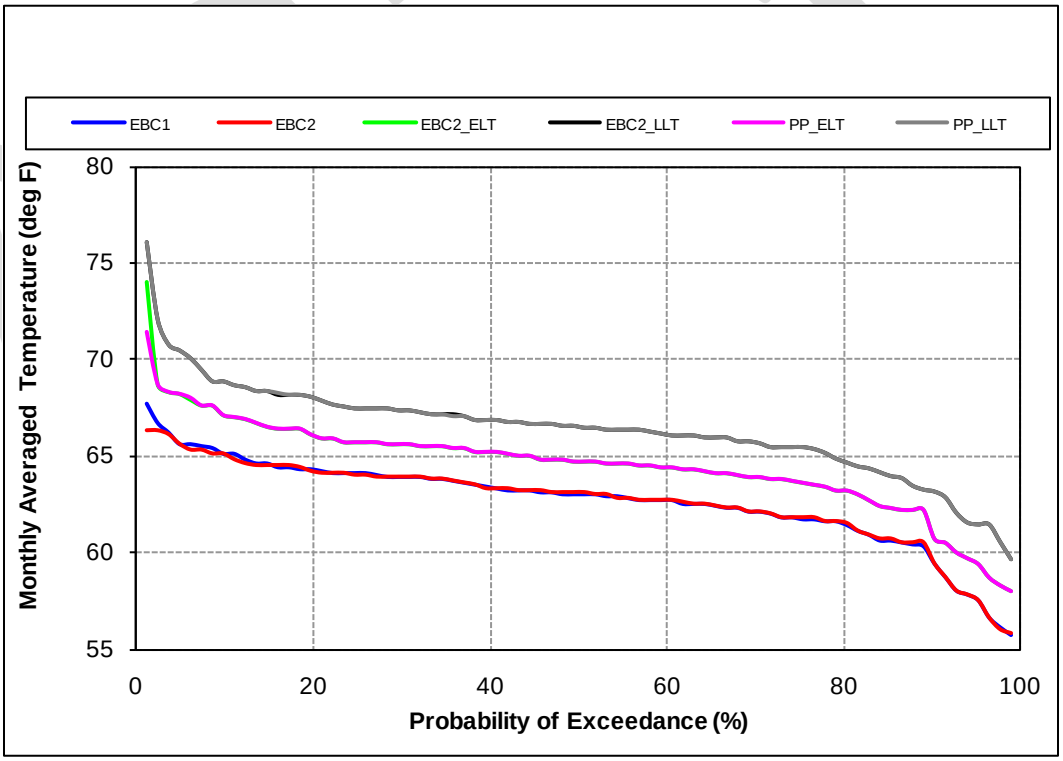

Figure C.5.2-397. Probability of Exceedance Plot for Model Scenarios of Mean Monthly Water Temperature of Stanislaus River at Orange Blossom, August

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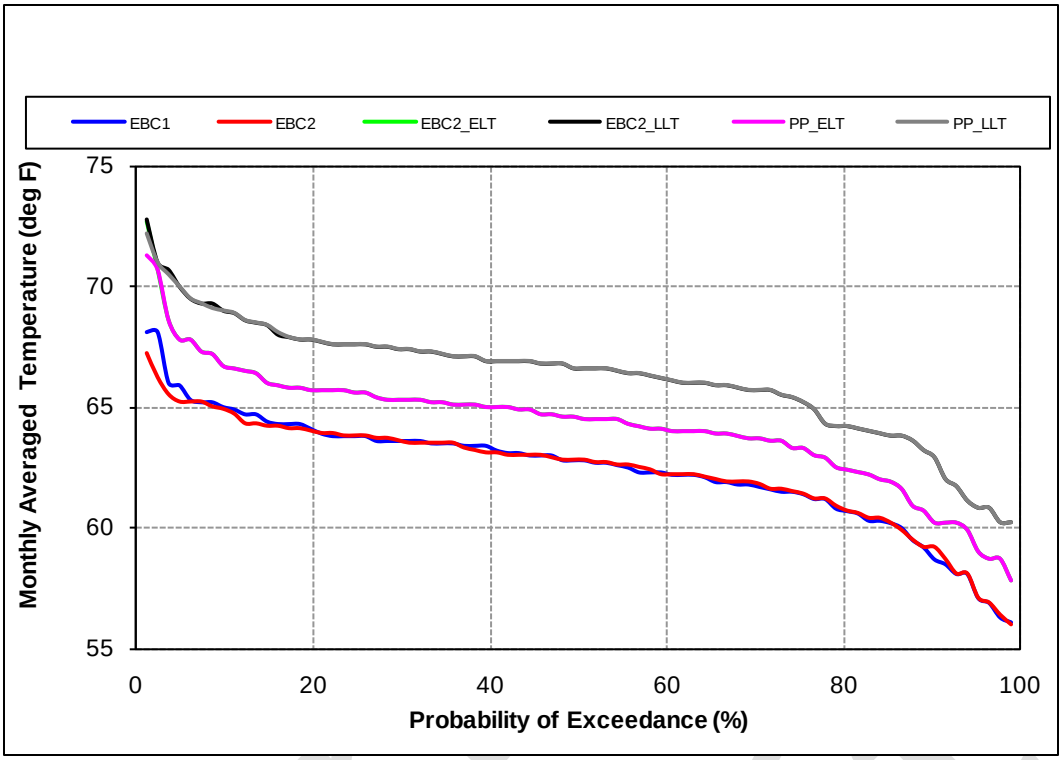

Figure C.5.2-398. Probability of Exceedance Plot for Model Scenarios of Mean Monthly Water Temperature of Stanislaus River at Orange Blossom, September

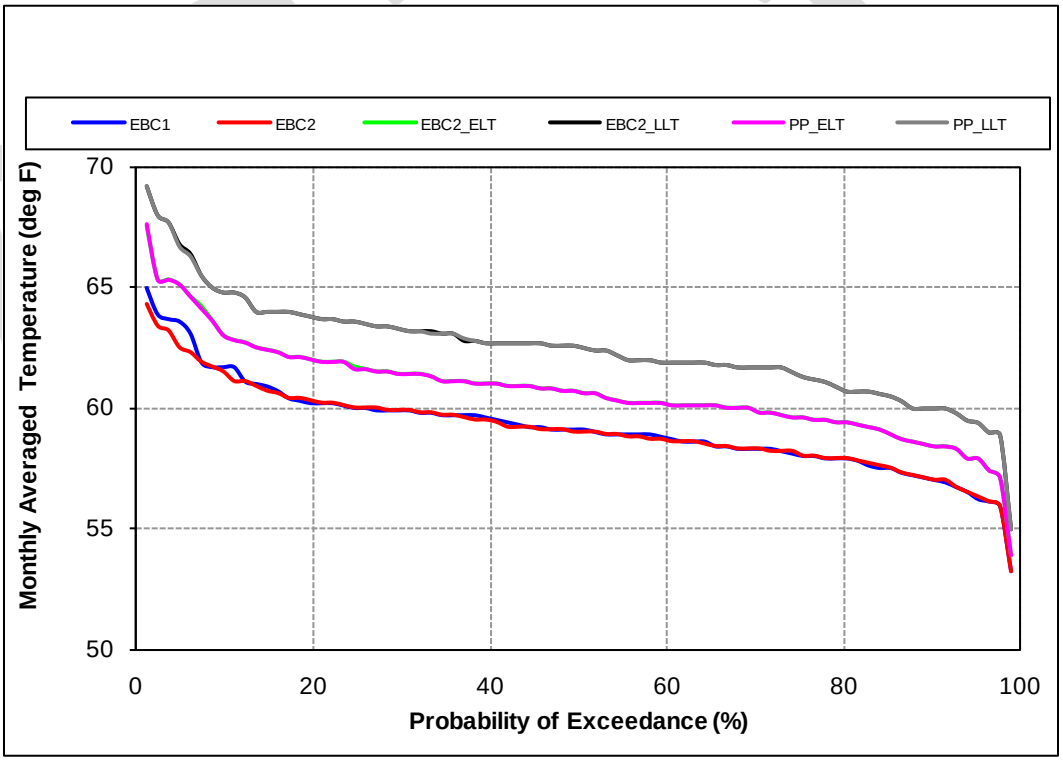

Figure C.5.2-399. Probability of Exceedance Plot for Model Scenarios of Mean Monthly Water Temperature of Stanislaus River at Orange Blossom, October

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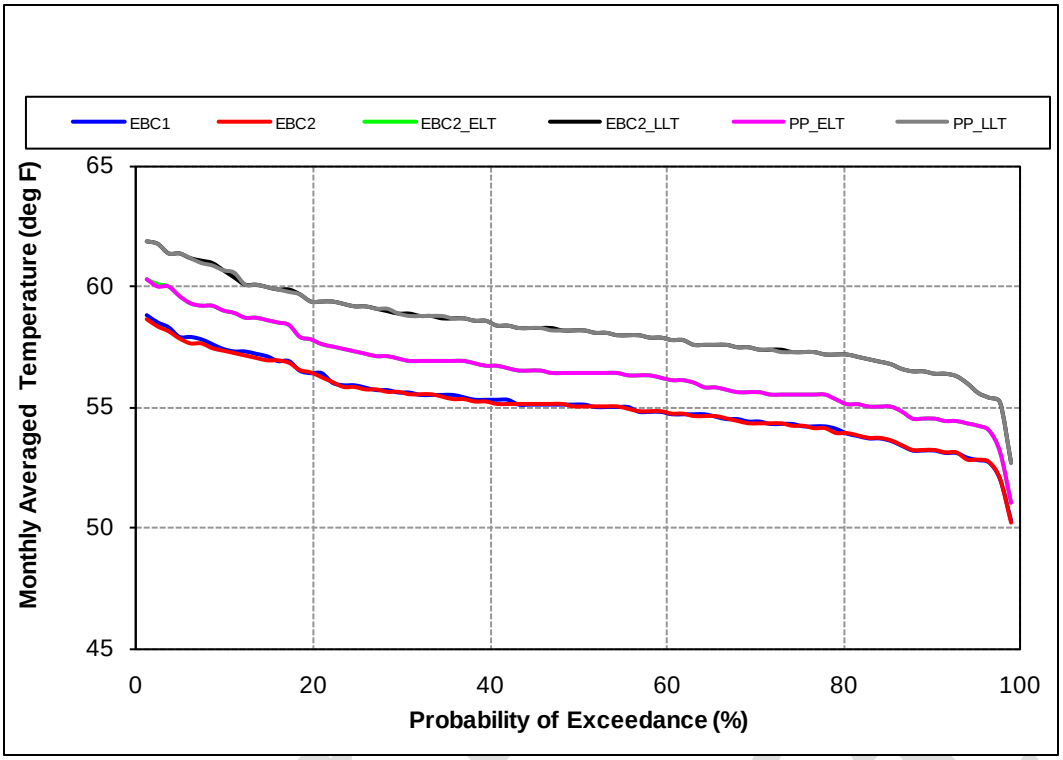

Figure C.5.2-400. Probability of Exceedance Plot for Model Scenarios of Mean Monthly Water Temperature of Stanislaus River at Orange Blossom, November

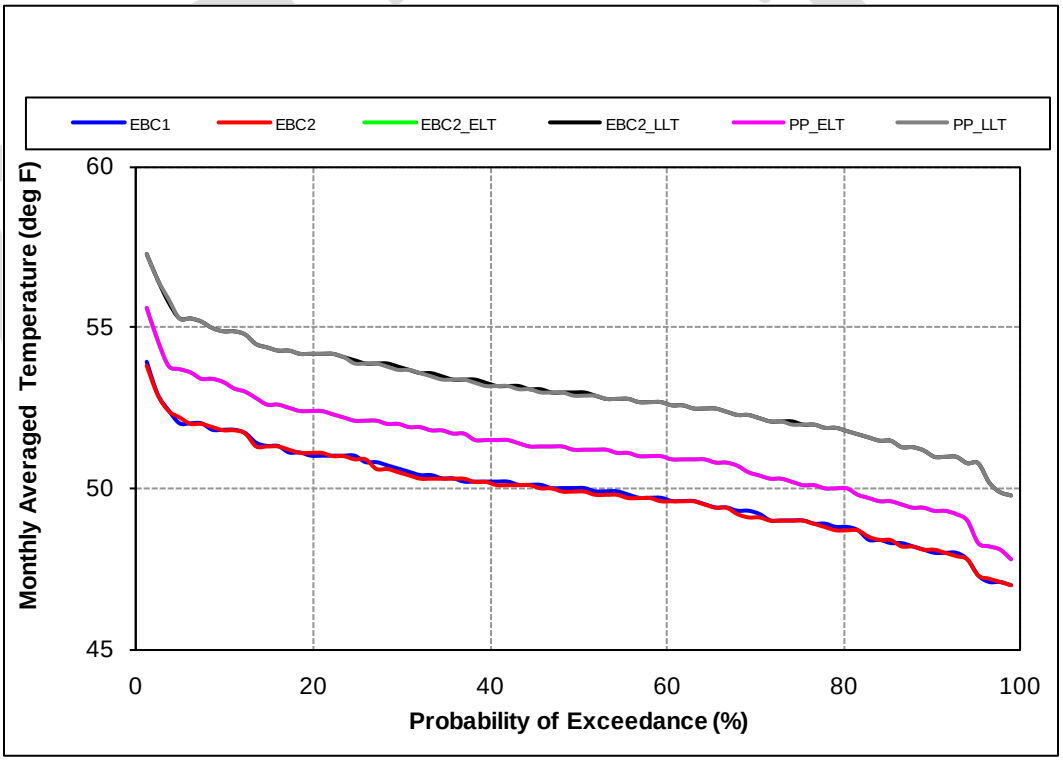

Figure C.5.2-401. Probability of Exceedance Plot for Model Scenarios of Mean Monthly Water Temperature of Stanislaus River at Orange Blossom, December

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Table C.5.2-149. Results of the Analysis of the 82-year Simulation of Water Temperature in the Stanislaus River at Orange Blossom Bridge during the January through April Steelhead Egg Incubation Period[1]

Stanislaus River at Orange Blossom Bridge	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
Number of years with one or more exceedances	4	4	13	34	13	34
Number of years with two exceedances	0	0	3	10	3	10
Number of years with three exceedances	0	0	0	0	0	0
Number of years with four exceedances	0	0	0	0	0	0
Number of years with five or more exceedances	0	0	0	0	0	0
Number of consecutive years with one or more exceedances	2	2	8	25	8	25
[1] Time period analyzed: January 1922 to April 2002. Analysis counted monthly exceedances above 56°F.						

Table C.5.2-150. May Water Storage Volume (Thousand Acre-Feet) in New Melones Reservoir for Model Scenarios

Water-Year Type	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
Wet	1,932	1,941	1,948	1,917	1,948	1,919
Above Normal	1,638	1,650	1,641	1,623	1,641	1,624
Below Normal	1,476	1,509	1,458	1,394	1,458	1,394
Dry	1,375	1,394	1,334	1,287	1,334	1,287
Critical	820	894	821	711	821	713

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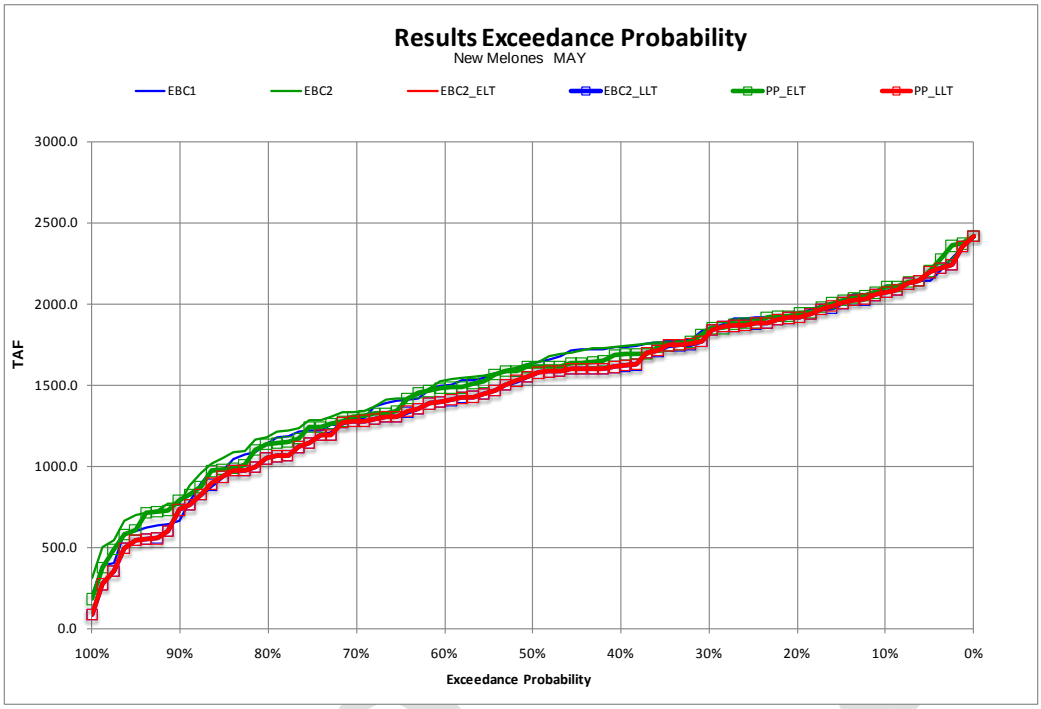

Figure C.5.2-402. Probability of Exceedance Plot for Model Scenarios of New Melones Reservoir Water Storage Volume, May

Table C.5.2-151. September Water Storage Volume (Thousand Acre-Feet) in New Melones Reservoir for Model Scenarios

Water-Year Type	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
Wet	1,787	1,797	1,749	1,677	1,750	1,678
Above Normal	1,484	1,504	1,444	1,366	1,444	1,366
Below Normal	1,314	1,354	1,272	1,180	1,273	1,180
Dry	1,190	1,219	1,130	1,066	1,130	1,066
Critical	647	718	642	537	641	539

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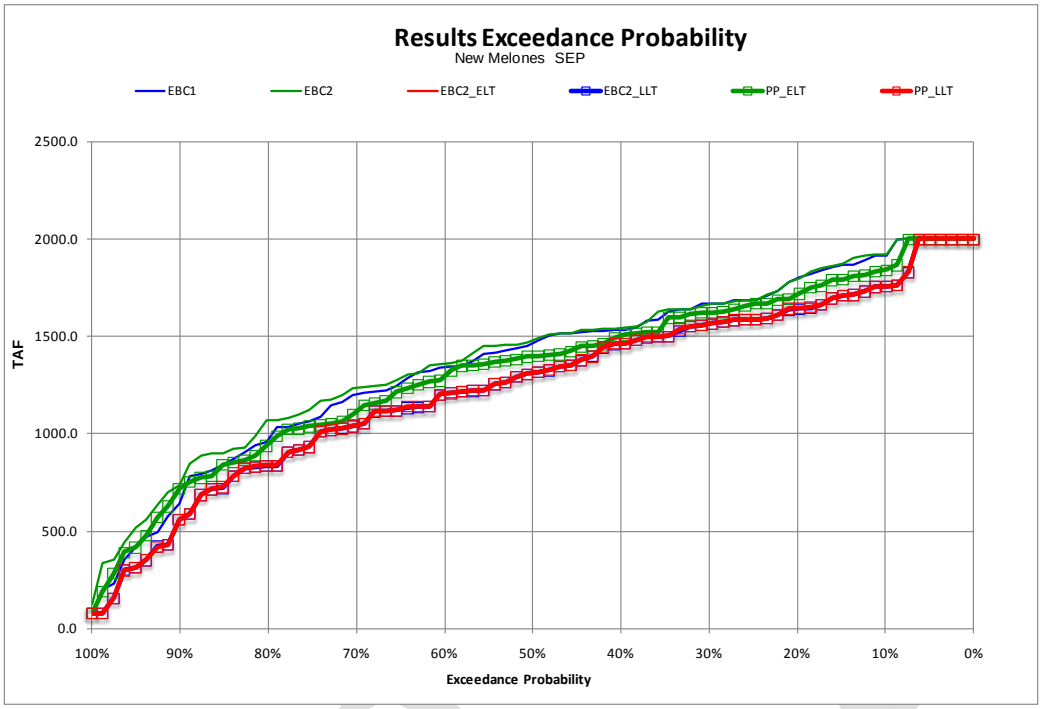

Figure C.5.2-403. Probability of Exceedance Plot for Model Scenarios of New Melones Reservoir Water Storage Volume, September

Redd Dewatering

Ramping rates for releases on the Stanislaus River are included as part of routine operations and would be expected to remain the same in the future under the preliminary proposal. Flows in the river are maintained to avoid redd dewatering. Monthly CALSIM modeling predicts that flows under EBC2_ELT and EBC2_LLT during the steelhead spawning and egg incubation period (January and April)would be similar to flows under PP_ELT and PP_LLT, indicating that the preliminary proposal would not affect the risk of redd dewatering (Figure C.5.2-378 through Figure C.5.2-381).

Fry and Juvenile Rearing

Rearing Habitat

Juvenile steelhead rear in freshwater for a year or more, therefore they are dependent on suitable freshwater rearing conditions during all months of the year. Information on steelhead abundance on the Stanislaus River is limited and has generally been collected opportunistically with existing Chinook salmon monitoring protocols. The juvenile life stage occurs throughout the entire river, with the majority of rearing occurring between Goodwin Dam and Oakdale. Resident rainbow trout are abundant from Goodwin Dam down through the Lover's Leap area. Rotary screw traps at Oakdale and Caswell catch downstream migrating steelhead with smolting characteristics each year. The Stanislaus River weir has captured a few adult steelhead. Three of these steelhead captured at the weir were positively identified as steelhead based on scale samples. The Stanislaus River receives the highest year-round flows during most years and has the coolest water of the three major San Joaquin tributaries. A large population of resident trout in the roughly 10 river miles below Goodwin Dam indicates favorable year-round habitat conditions for juvenile steelhead rearing in this reach. Snorkel surveys (Kennedy and Cannon 2002) identified trout fry starting in

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April 2000 and 2001, with the first fry observed in upstream areas each year. During 2003, a few trout fry were identified as early as January but most did not appear until April as in 2000 and 2001.

CALSIM hydrologic modeling over the 82-year simulation period for the Stanislaus River at its confluence with the San Joaquin River predicts little or no change in instream flows (less than a 5% difference) between EBC2_ELT and PP_ELT and between EBC2_LLT and PP_LLT (Table C.5.2-148, Figure C.5.2-356 through Figure C.5.2-358). Other drivers, notably climate change, are predicted to have the greatest effect on future flows. Based on these results, it was concluded that the preliminary proposal would not affect instream habitat conditions in the Stanislaus River for steelhead rearing.

Summer water temperatures (June through September) on the Stanislaus River that exceed 65°F may cause thermal stress in juvenile steelhead (National Marine Fisheries Service 2009). Results of water temperature simulation analyses for the Stanislaus River at Orange Blossom Bridge were used as an indicator of changes in water temperatures that would potentially affect steelhead rearing conditions. The model results were compiled monthly over the 82-year period included in the CALSIM simulations. Average monthly water temperatures were then evaluated to determine the months during the steelhead rearing period (year-round) when temperatures exceeded 65°F. Results of the frequency of years in which monthly average temperatures exceeded the criterion are summarized in Table C.5.2-152.

During the 82-year simulation period, one or more occurrences of temperatures exceeding 65°F are predicted to occur in 14–17 years under EBC1 and EBC2, 54 years under EBC2_ELT and PP_ELT, and 66 years under EBC2_LLT and PP_LLT (Table C.5.2-151). The number of consecutive years with temperature exceeding 65°F is predicted to be 8–12 years under EBC1 and EBC2, 48 years under EBC2_ELT and PP_ELT, and 64 years under EBC2_LLT and PP_LLT. The frequency of stressful water temperatures for juvenile rearing is predicted to be greater under EBC2_LLT than EBC2_ELT and greater under EBC2_ELT than under EBC1 and EBC2. The frequency of stressful water temperatures for juvenile rearing under EBC2_ELT and EBC2_LLT is not predicted to differ from the frequency under PP_ELT and PP_LLT.

Table C.5.2-152. Results of the Analysis of the 82-Year Simulation of Water Temperature in the Stanislaus River during the Year-Round Juvenile Steelhead Rearing Period[1]

Stanislaus River at Orange Blossom Bridge	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
Number of years with one or more exceedances	15	17	54	66	54	66
Number of years with two exceedances	4	7	13	8	13	9
Number of years with three exceedances	4	4	10	26	10	25
Number of years with four exceedances	0	0	10	25	10	25
Number of years with five or more exceedances	0	0	1	5	1	5
Number of consecutive years with one or more exceedances	9	12	48	64	48	64

[1] Time period analyzed: January 1922 to December 2002. Analysis counted monthly exceedances above 65°F.

Optimal temperature criteria reported for steelhead smoltification ranges from less than 52°F to less than 57°F (Adams et al. 1975; U.S. Environmental Protection Agency 2003). Exceedance plots of monthly water temperatures at Orange Blossom and Knights Ferry during the smoltification and emigration period (January through May) indicate that the frequency of temperatures exceeding

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these thresholds would increase under future baseline conditions (EBC2_ELT and EBC2_LLT) but would be unaffected by the preliminary proposal (Figure C.5.2-404 and Figure C.5.2-405) Thus, BDCP operations would have no effect on the suitability of water temperatures for smolting and emigrating steelhead in the Stanislaus River.

Based on the similarity of instream flow releases and water temperatures in the Stanislaus River, the similarities in flows in the lower San Joaquin River (see Section C.5.2.6.1), and the fact that BDCP operations would have no effect on either water temperatures or instream flows in the Tuolumne or Merced rivers or releases from Friant Dam, it is expected that there would be no differences in flows or seasonal water temperatures during the juvenile migration period that would affect habitat conditions for juvenile steelhead for the entire San Joaquin River basin.

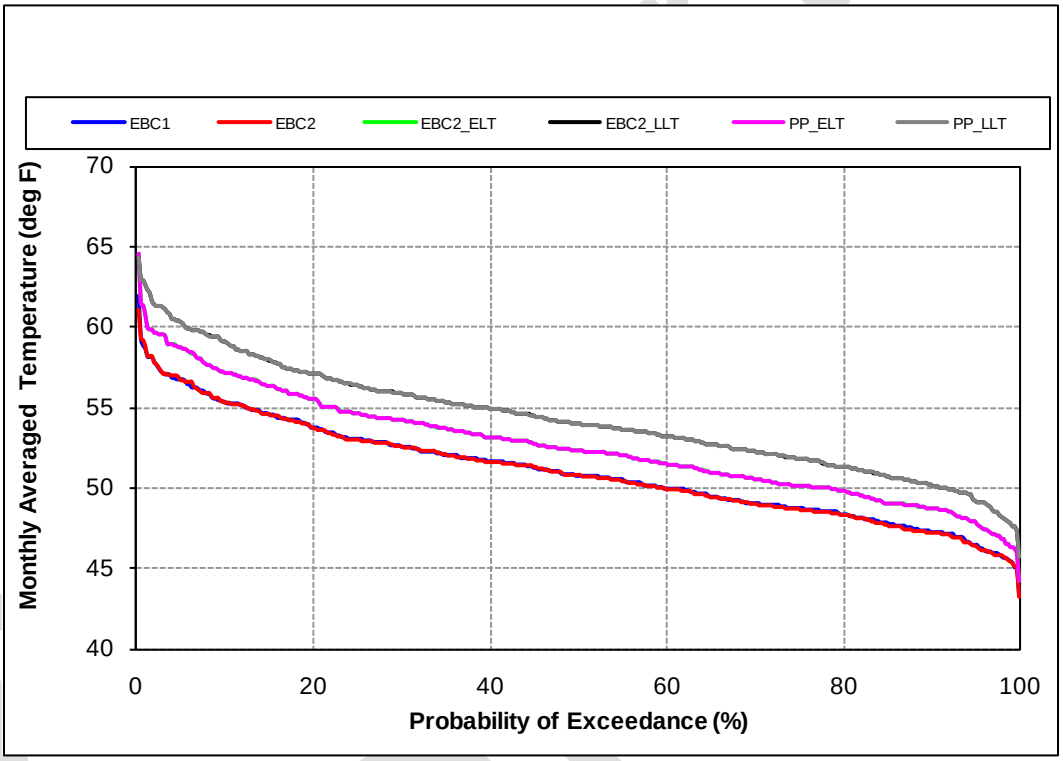

Figure C.5.2-404. Probability of Exceedance Plot for Model Scenarios of Mean Monthly Water Temperature during Steelhead Smoltification and Emigration on the Stanislaus River at Orange Blossom, January through May

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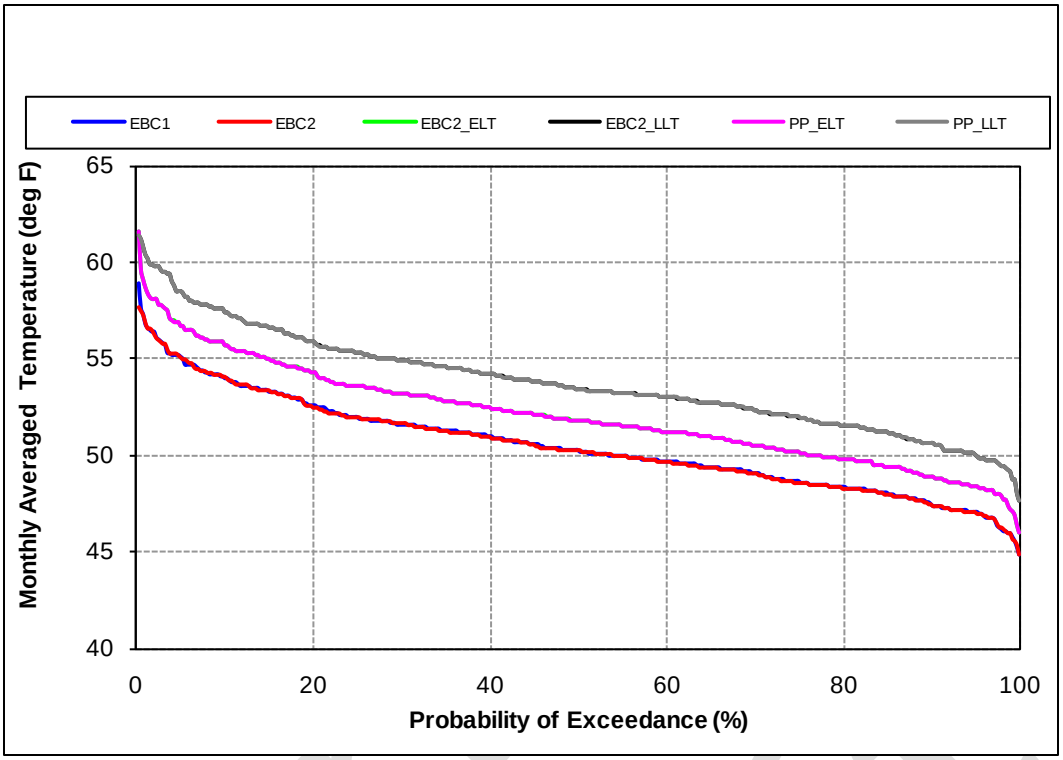

Figure C.5.2-405. Probability of Exceedance Plot for Model Scenarios of Mean Monthly Water Temperature during Steelhead Smoltification and Emigration on the Stanislaus River at Knights Ferry, January through May

Adult

Water Temperature

Results of the Reclamation Temperature Model for the steelhead migration period (September through March) in the Stanislaus River at Orange Blossom Bridge are presented in Figure C.5.2-390 through Figure C.5.2-392 and Figure C.5.2-398 through Figure C.5.2-401. There are no biologically meaningful differences between EBC2_ELT and PP_ELT or between EBC2_LLT and PP_LLT. Therefore, the preliminary proposal would have little or no effect on water temperatures in the Stanislaus River during the steelhead migration period. Other drivers, notably climate change, are predicted to have the greatest effect on future water temperatures. Based on these results, it was concluded that the preliminary proposal would not affect the suitability of instream habitat conditions for adult steelhead migration.

C.5.2.7.2 Fall-/Late Fall–Run

Eggs and Alevins

Upstream Spawning Habitat

Fall-run Chinook salmon migrate upstream from the mainstem San Joaquin River to spawn in the Stanislaus River between October and January. Habitat quality and availability for various life stages of salmon in the Stanislaus River varies in response to flow which affects water depths, velocities,

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and a number of other factors (e.g., water temperature) important in determining the suitability of habitat for spawning, egg incubation, juvenile rearing, and juvenile migration.

Changes in instream flows and/or seasonal water temperatures within the Stanislaus River are based on changes in federal Central Valley Project operations at New Melones Reservoir. Results of CALSIM hydrologic modeling over the 82 years of simulation at the confluence with the lower San Joaquin River predict no major differences (less than a 5% difference) in instream flows between EBC2_ELT and PP_ELT and between EBC2_LLT and PP_LLT during the primary Chinook salmon spawning and incubation period (October through February)(Table C.5.2-148, Figure C.5.2-378, and Figure C.5.2-387 through Figure C.5.2-389). Based on these results, it was concluded that the preliminary proposal would not affect habitat conditions for Chinook salmon spawning and incubation in the Stanislaus River.

Water Temperature

Fall-run salmon spawn in the Stanislaus River primarily during the late fall and early winter (October through December) when seasonal air temperatures are declining. For purposes of assessment, it was assumed that exposure of eggs to water temperatures in excess of 56°F during the incubation period would result in egg mortality and adverse impacts on reproductive success. The area of the river where suitable water temperatures occur for successful egg incubation depends on the temperature of water released into the river, flow magnitude, and atmospheric conditions that affect the rate of warming as the water travels downstream. When coldwater storage in New Melones Reservoir is reduced, the amount of cold water available for release is reduced, and the temperature of the water at the point of release to the river is increased. Under these conditions, the length of the Stanislaus River that maintains suitable water temperatures for fall-run Chinook salmon egg incubation and hatching is reduced, particularly in October, and eggs in the downstream areas can be exposed to increased water temperature. As seasonal temperatures naturally cool during the fall, habitat conditions in the river that are suitable for egg incubation extend further downstream.

CALSIM modeling of New Melones Reservoir storage in May (Table C.5.2-150 and Figure C.5.2-402) and September (Table C.5.2-151 and Figure C.5.2-403) predict that storage and coldwater pool volume would be comparable between EBC2_ELT and PP_ELT and between EBC2_LLT and PP_LLT. Similarly, lower Stanislaus River instream flows during the fall-run Chinook salmon egg incubation period are predicted to be comparable between EBC2_ELT and PP_ELT and between EBC2_LLT and PP_LLT. Therefore, BDCP operations are not expected to affect fall-run Chinook salmon egg mortality in the Stanislaus River relative to future baseline conditions.

The Reclamation egg mortality model was also used to predict the effect of the preliminary proposal on fall-run egg survival. Results are summarized in Figure C.5.2-406 and Table C.5.2-153. The egg mortality model predicts that (1) egg mortality increases substantially during dry and critically dry water years in all model scenarios as a result of depleted New Melones Reservoir coldwater pool storage and increased water temperatures released to the Stanislaus River during the fall-run salmon egg incubation period; (2) egg mortality would increase in the future as a result of climate change; (3) the effects of climate change on fall-run Chinook salmon egg mortality become greater as time passes under both existing biological conditions and preliminary proposal operations; and (4) egg mortality is comparable between EBC2_ELT and PP_ELT and between EBC2_LLT and PP_LLT.

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Table C.5.2-153. Egg Mortality Percentages for Fall-Run Chinook in the Stanislaus River (Egg Mortality Model)

Water-Year Type	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
Wet	4.4	4.3	7.8	14.9	7.8	14.9
Above Normal	3.3	3.2	5.8	11.4	5.8	11.3
Below Normal	5.5	5.3	9.8	18.6	9.8	18.6
Dry	6.2	6.0	10.9	20.9	10.9	20.9
Critical	11.7	10.6	18.4	28.2	18.4	28.0

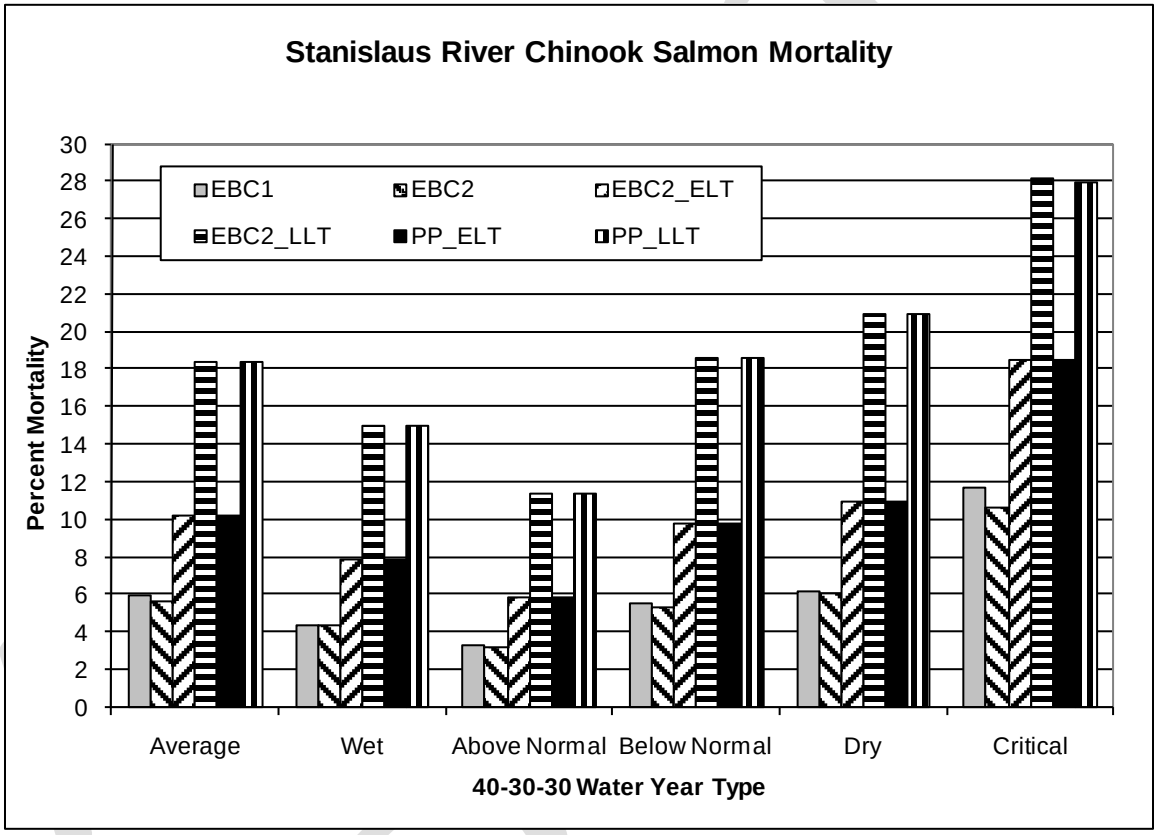

Figure C.5.2-406. Stanislaus River Fall-Run Chinook Average Egg Mortality under Each Model Scenario for Each Water-Year Type and for All Years from the Reclamation Egg Mortality Model

Redd Dewatering

No analytical tools exist for quantitatively assessing the effects of flow reduction in the Stanislaus River following fall-run Chinook salmon spawning that would result in estimates of the risk of redd dewatering during egg incubation. Operation of upstream reservoirs and management of instream flows in the Stanislaus River are performed based on ramping rate criteria and operations designed to reduce or avoid the risk of redd dewatering for fall-run Chinook salmon. It is expected that operations to reduce the risk of redd dewatering would continue in the future under both existing biological conditions and proposed project operations. It was assumed that fall-run Chinook salmon spawn in the Stanislaus River in November and that a reduction in instream flows during the following December through February (representing the egg incubation period) of greater than 5%

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would result in an increased risk of redd dewatering. Results of the 82-year monthly CALSIM model predict that instream flows in the Stanislaus River during the period from November through February are typically stable or increase and, therefore, the risk of redd dewatering is considered to be minimal under all model scenarios (Table C.5.2-148). Under all model scenarios, there is typically a reduction predicted in instream flows in the Stanislaus River between October and November. This flow reduction that is observed in all model scenarios would increase the risk of redd dewatering for fall-run Chinook salmon that spawned near the channel margin in October. The risk of redd dewatering for these earlier spawning salmon is predicted to be comparable between EBC2_ELT and PP_ELT and between EBC2_LLT and PP_LLT.

Fry and Juvenile Rearing

Rearing Habitat

Stanislaus River instream flows during the fall-run Chinook salmon rearing period (January through May) affect the quality and availability of physical habitat for juvenile development and survival. CALSIM modeling of Stanislaus River flows over the January through May period are summarized in Table C.5.2-148 and flows exceedances are plotted in Figure C.5.2-378 through Figure C.5.2-382. Results suggest that there would be no difference in instream flows between EBC2_ELT and PP_ELT and between EBC2_LLT and PP_LLT that would affect juvenile fall-run Chinook salmon rearing habitat in the Stanislaus River.

Adult

Water Temperature

Results of the Reclamation Temperature Model for the fall-run migration period (September through October) in the Stanislaus River at Orange Blossom Bridge are presented in Figure C.5.2-398 and Figure C.5.2-399. There are no biologically meaningful differences between EBC2_ELT and PP_ELT and between EBC2_LLT and PP_LLT. Therefore, it is concluded that the preliminary proposal would have no effect on water temperature-related migration habitat conditions for adult fall-run Chinook salmon in the Stanislaus River.

C.5.2.7.3 White Sturgeon

Due to uncertainties regarding white sturgeon presence in the San Joaquin River system, the analysis of effects on white sturgeon in the Stanislaus River was combined with the analysis in the mainstem San Joaquin River (Section C.5.2.6.5).

C.5.2.7.4 Lamprey

Eggs

Water Temperature

Exact spawning locations of Pacific and river lamprey in the Stanislaus River are not well known. Therefore, this analysis includes upstream (Knights Ferry) and downstream (Riverbank) locations that encompass the range in which those species are thought to spawn (Hannon pers. comm.). As with the Feather River, a 2-month period was used to represent the duration of each egg cohort. The number of Pacific lamprey cohorts exposed to water temperatures above 71.6°F is reported in Table

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C.5.2-75 and the numbers of river lamprey cohorts exposed to temperatures above 71.6°F and 77°F are reported in Table C.5.2-76; differences between model scenarios are reported in Table C.5.2-77 for Pacific lamprey and Table C.5.2-78 for river lamprey.

At Knights Ferry

For Pacific lamprey at Knights Ferry, the percent of egg cohorts experiencing water temperatures that exceed 71.6°F is predicted to be 0% under all model scenarios except EBC2_LLT and PP_LLT, which would result in exposure of only two cohorts, or less than 1% of the total number of cohorts, over the 82-year CALSIM period (Figure C.5.2-407, Table C.5.2-75, Table C.5.2-77).

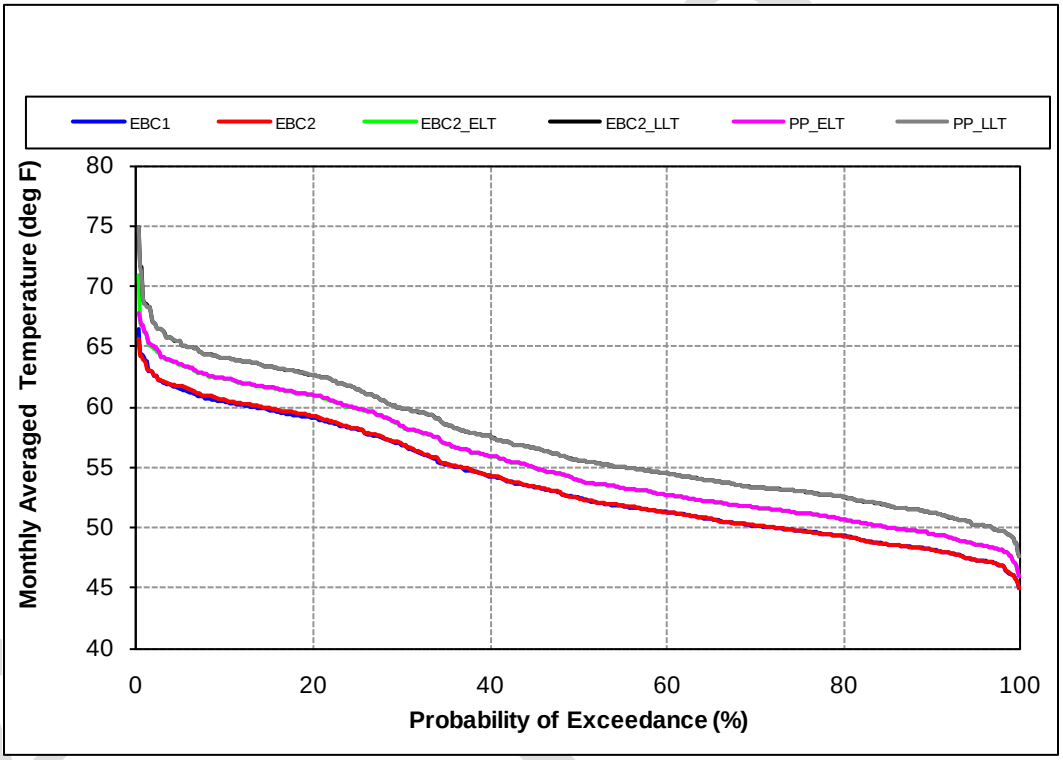

Figure C.5.2-407. Probability of Exceedance Plot for Model Scenarios of Mean Monthly Temperature of the Stanislaus River at Knights Ferry, January through August

For consideration of river lamprey effects, mean monthly water temperatures in the Stanislaus River at Knights Ferry are predicted to be below the 71.6°F and 77°F thresholds between February and June under all model scenarios (Figure C.5.2-408, Table C.5.2-76, Table C.5.2-78).

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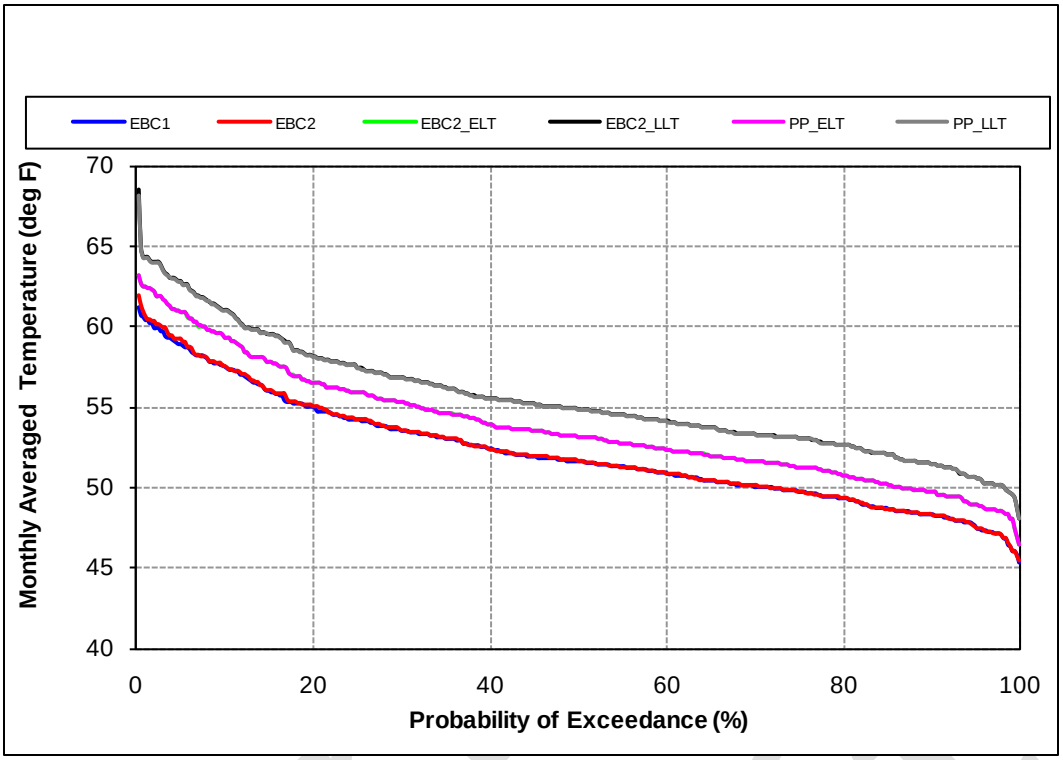

Figure C.5.2-408. Probability of Exceedance Plot for Model Scenarios of Mean Monthly Water Temperature of the Stanislaus River at Knights Ferry, February through June

At Riverbank

For Pacific lamprey at Riverbank, the percent of egg cohorts experiencing water temperatures that exceed 71.6°F is predicted to be less than 1% under EBC1 and EBC2, and 4%–14% under EBC2_ELT, EBC2_LLT, PP_ELT, and PP_LLT (Figure C.5.2-409, Table C.5.2-75). Under early long-term conditions, implementation of the preliminary proposal (PP_ELT) would result in exposure of 25 cohorts to temperatures exceeding 71.6°F, a 4% decrease relative to EBC2_ELT (25 cohorts) (Table C.5.2-77). Under late long-term conditions, implementation of the preliminary proposal (PP_LLT) would result in no change in the number of cohorts exposed to temperatures exceeding 71.6°F relative to EBC2_LLT (88 cohorts).

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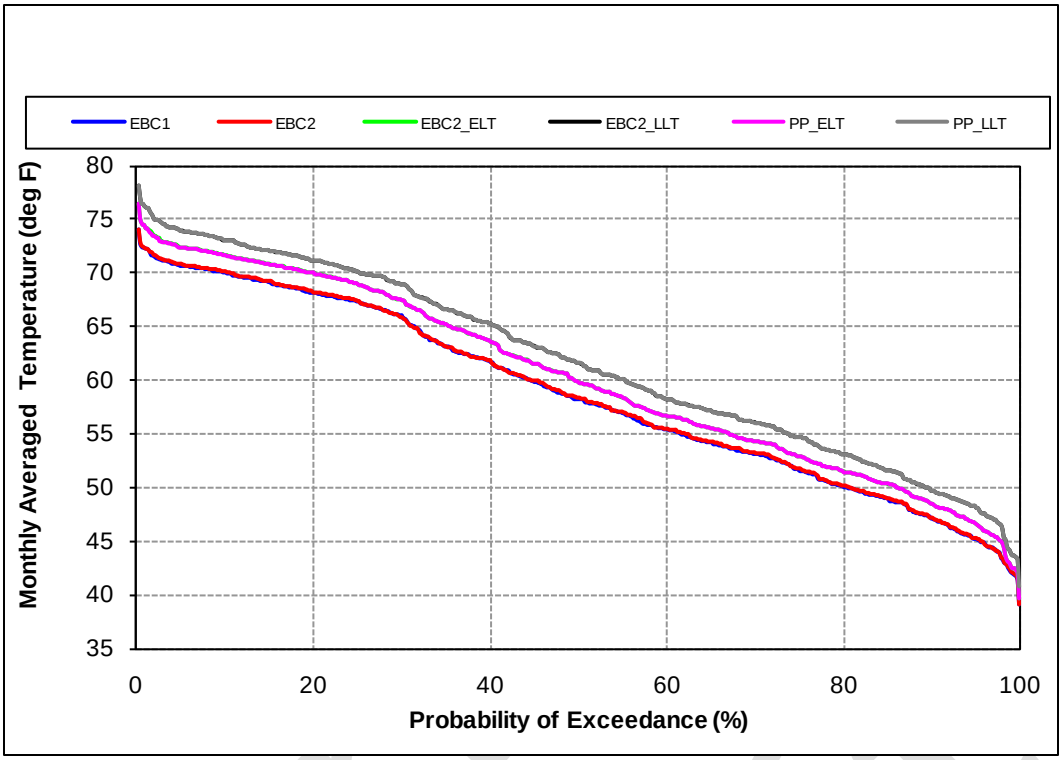

Figure C.5.2-409. Probability of Exceedance Plot for Model Scenarios of Mean Monthly Temperature of the Stanislaus River at Riverbank, January through August

For river lamprey, the percent of egg cohorts experiencing water temperatures that exceed 71.6°F is predicted to be <1% under EBC1 and EBC2 and 3%–9% under EBC2_ELT, EBC2_LLT, PP_ELT, and PP_LLT (Figure C.5.2-410, Table C.5.2-76). Implementation of the preliminary proposal in the early and late long-term periods (PP_ELT and PP_LLT, respectively) would result in no change in the number of cohorts exposed to temperatures exceeding 71.6°F relative to EBC2_ELT (12 cohorts) and EBC2_LLT (34 cohorts), respectively (Table C.5.2-78). Mean monthly water temperatures at Riverbank are predicted to be below 77°F between February and June under all model scenarios.

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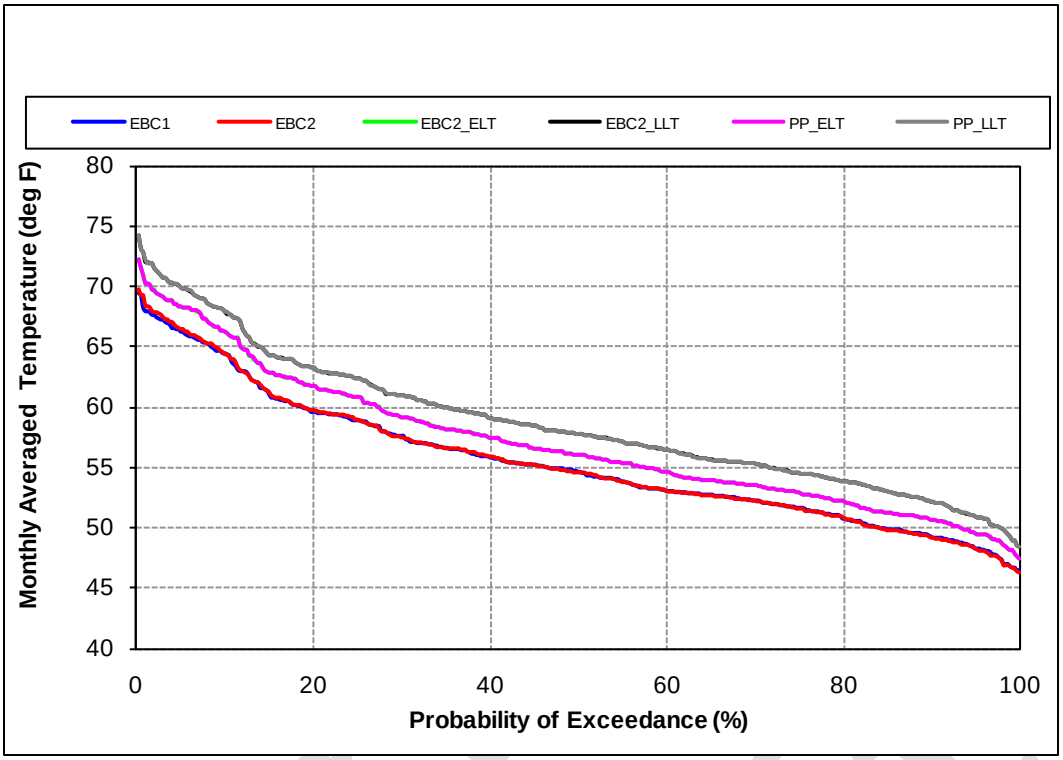

Figure C.5.2-410. Probability of Exceedance Plot for Model Scenarios of Mean Monthly Water Temperature of the Stanislaus River at Riverbank, February through June

These results suggest that the preliminary proposal would have minimal effects on water temperatures in the Stanislaus River for Pacific lamprey, and no effect for river lamprey, but that climate change would lead to increases in water temperature. Because this analysis uses water temperature model outputs based on CALSIM outputs, error has been propagated and the level of certainty of these results is moderate.

Redd Dewatering

At San Joaquin River Confluence

For Pacific lamprey, the total predicted number of redd cohorts between January and August experiencing a month-over-month decrease in flow of greater than 50% in the Stanislaus River at the confluence of the San Joaquin River ranged between 58 (EBC1_LLT) and 62 cohorts (EBC_ELT) (Table C.5.2-56).

There are three more Pacific lamprey redd cohorts (5%) predicted to experience a month-over-month change in flow of greater than 50% for both the PP_ELT and PP_LLT relative to the EBC1 (Table C.5.2-57). There are no differences in the number of cohorts experiencing a month-over-month decrease in flows of greater than 50% between PP_ELT and EBC and between PP_LLT and EBC2.

Isolating the effect of the preliminary proposal from the effects of climate change, there is one fewer redd cohort (2%) predicted to experience a month-over-month change in flow of greater than 50% for PP_ELT relative to the EBC2_ELT. Alternatively, there is one more redd cohort (2%) predicted to

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experience a month-over-month change in flow of greater than 50% for PP_LLT relative to the EBC2_LLT.

For river lamprey, the predicted number of redd cohorts experiencing a month-over-month decrease in flow of more than 50% in the Stanislaus River at the confluence with the San Joaquin River is between 51 (EBC2_LLT and PP_LLT) and 59 cohorts (EBC2 and EBC2_ELT) (Table C.5.2-58).

There are two and five fewer redd cohorts (4% and 9%, respectively) predicted to experience a month-over-month change in flow of greater than 50% in the Stanislaus River at the confluence of the San Joaquin River in the PP_ELT and PP_LLT, respectively, relative to the EBC1 (Table C.5.2-59). There are one and eight fewer redd cohorts (2% and 14%, respectively) predicted to experience a month-over-month change in flow of greater than 50% in the Stanislaus River at the confluence of the San Joaquin River in the PP_ELT and PP_LLT, respectively, relative to the EBC2.

Removing the effect of climate change, there are one and zero fewer redd cohorts (2% and 0%, respectively) predicted to experience a month-over-month change in flow of greater than 50% under the PP_ELT and PP_LLT relative to the EBC2_ELT and EBC2_LLT, respectively.

These results indicate that the numbers of Pacific and river lamprey redd cohorts predicted to experience a month-over-month change in flow of greater than 50% in the Stanislaus River, which is assumed here to represent a redd dewatering event, vary only slightly among all model scenarios. Therefore, collectively, there are no clear effects of the preliminary proposal on redd dewatering in the Stanislaus River on either species.

Ammocoete

Water Temperature

Predicted monthly average water temperatures in the Stanislaus River at Knights Ferry and Riverbank are presented in Figure C.5.2-411 and Figure C.5.2-412, respectively.

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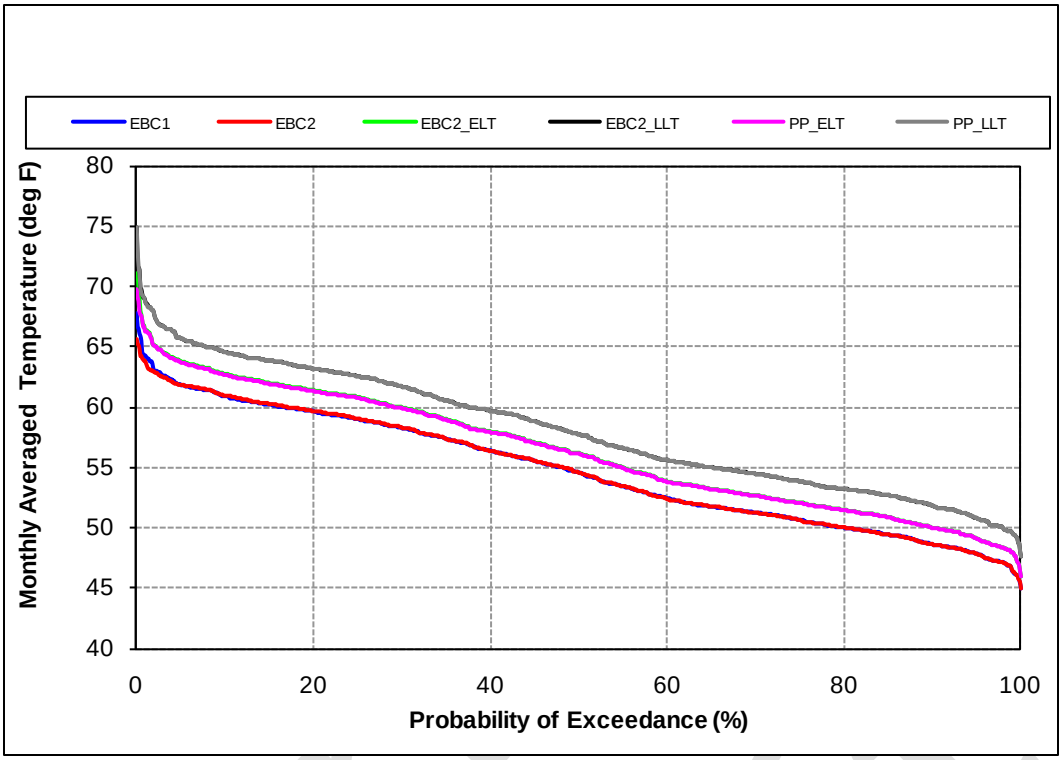

Figure C.5.2-411. Probability of Exceedance Plot for Model Scenarios of Mean Monthly Temperature of the Stanislaus River at Knights Ferry in All Months

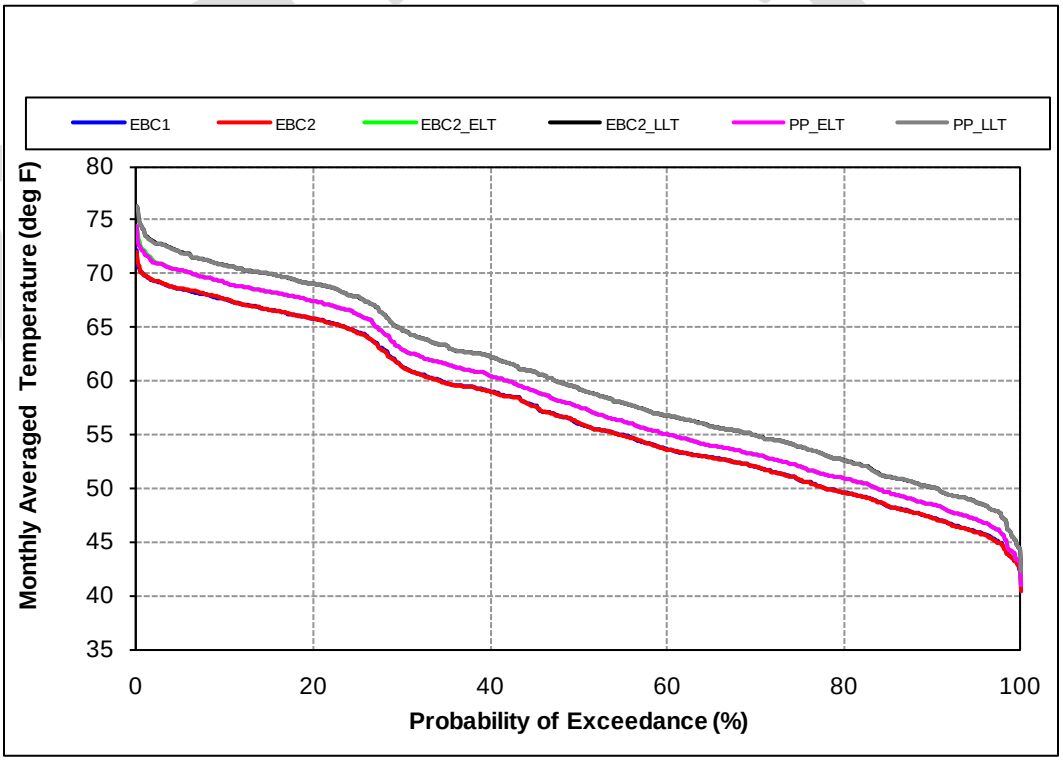

Figure C.5.2-412. Probability of Exceedance Plot for Model Scenarios of Mean Monthly Temperature of the Stanislaus River at Riverbank in All Months

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At Knights Ferry

For Pacific lamprey in the Stanislaus River at Knights Ferry, the percent of ammocoete cohorts experiencing water temperatures exceeding 71.6°F is predicted to be 0% under EBC1, EBC2, EBC2_ELT, and PP_ELT and 9% under EBC2_LLT and PP_LLT (Table C.5.2-60). Under late long-term conditions, implementation of the preliminary proposal (PP_LLT) would result in no change in the number of cohorts exposed to temperatures exceeding 71.6°F relative to EBC2_LLT (56 cohorts) (Table C.5.2-61).

For river lamprey, the percent of ammocoete cohorts experiencing water temperatures that exceed 71.6°F is predicted to be 0% under EBC1, EBC2, EBC2_ELT, and PP_ELT and 7% under EBC2_LLT and PP_LLT (Table C.5.2-62). Under late long-term conditions, implementation of the preliminary proposal (PP_LLT) would result in no change in the number of cohorts exposed to temperatures exceeding 71.6°F relative to EBC2_LLT (25 cohorts) (Table C.5.2-63). Mean monthly water temperatures in the Stanislaus River at Knights Ferry are predicted to be below 77°F at all times under all model scenarios.

These results indicate that the effects of the preliminary proposal on Pacific lamprey are negligible. Effects on river lamprey ammocoetes in the Stanislaus River at Knights Ferry are small in the early long-term and nonexistent in the late long-term at the 71.6°F threshold and are moderate in the early long-term and nonexistent in the late long-term at the 77°F threshold.

At Riverbank

For Pacific lamprey at Riverbank, the percent of ammocoete cohorts experiencing water temperatures exceeding 71.6°F is predicted to be 9% under EBC1 and EBC2, and 57%–99% under EBC2_ELT, EBC2_LLT, PP_ELT, and PP_LLT (Table C.5.2-60). Under early long-term conditions, the number of cohorts exposed to temperatures exceeding 71.6°F would be nearly identical under EBC2_ELT and PP_ELT (339 and 338 cohorts, respectively) (Table C.5.2-61). Under late long-term conditions, implementation of the preliminary proposal (PP_LLT) would result in no change in the number of cohorts exposed to temperatures exceeding this threshold relative to EBC2_LLT (586 cohorts).

For river lamprey, the proportion of ammocoete cohorts experiencing water temperatures that exceed 71.6°F is predicted to be 7% under EBC1 and EBC2, and 47%–95% under EBC2_ELT, EBC2_LLT, PP_ELT, and PP_LLT (Table C.5.2-62). Implementation of PP_ELT and PP_LLT would result in no change in the number of cohorts exposed to temperatures exceeding 71.6°F relative to EBC2_ELT (180 cohorts) and EBC2_LLT (360 cohorts), respectively (Table C.5.2-63). Mean monthly water temperatures in the Stanislaus River at Riverbank are predicted to be below 77°F under all model scenarios throughout the 82-year simulation period.

These results suggest that climate change has a large temperature-related effect on Pacific lamprey ammocoetes, and the preliminary proposal has small or no effects in both the early and late long-term for both Pacific and river lamprey at the 71.6°F threshold and the 77°F threshold.

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At San Joaquin River Confluence

The number of Pacific lamprey ammocoete cohorts that may be affected by month-over-month flow reductions in the Stanislaus River at the confluence with the San Joaquin River is presented in Figure C.5.2-413 and differences between model scenarios are presented in Table C.5.2-154.

The number of Pacific lamprey ammocoetes exposed to a given flow reduction is predicted to be 0% to 26% higher under the PP_ELT compared to the EBC1, depending on the flow reduction. The number of ammocoetes exposed to a given flow reduction is predicted to be 8% lower and 51% higher under the PP_LLT compared to the EBC1, depending on the flow reduction. The number of ammocoetes exposed to a given flow reduction is predicted to be 0% lower to 124% higher under the PP_ELT compared to the EBC2, depending on the flow reduction. The number of ammocoetes exposed to a given flow reduction is predicted to be 8% lower to 168% higher under the PP_LLT compared to the EBC2, depending on the flow reduction.

Isolating the effect of the preliminary proposal from the effects of climate change in the early long-term, the number of Pacific lamprey ammocoetes exposed to a given flow reduction is predicted to be nearly identical (0% to <1% higher) under the PP_ELT compared to the EBC2_ELT, depending on the flow reduction. In the late long-term, there are no predicted differences in the number of ammocoetes exposed to a given flow reduction between the EBC2_LLT and PP_LLT.

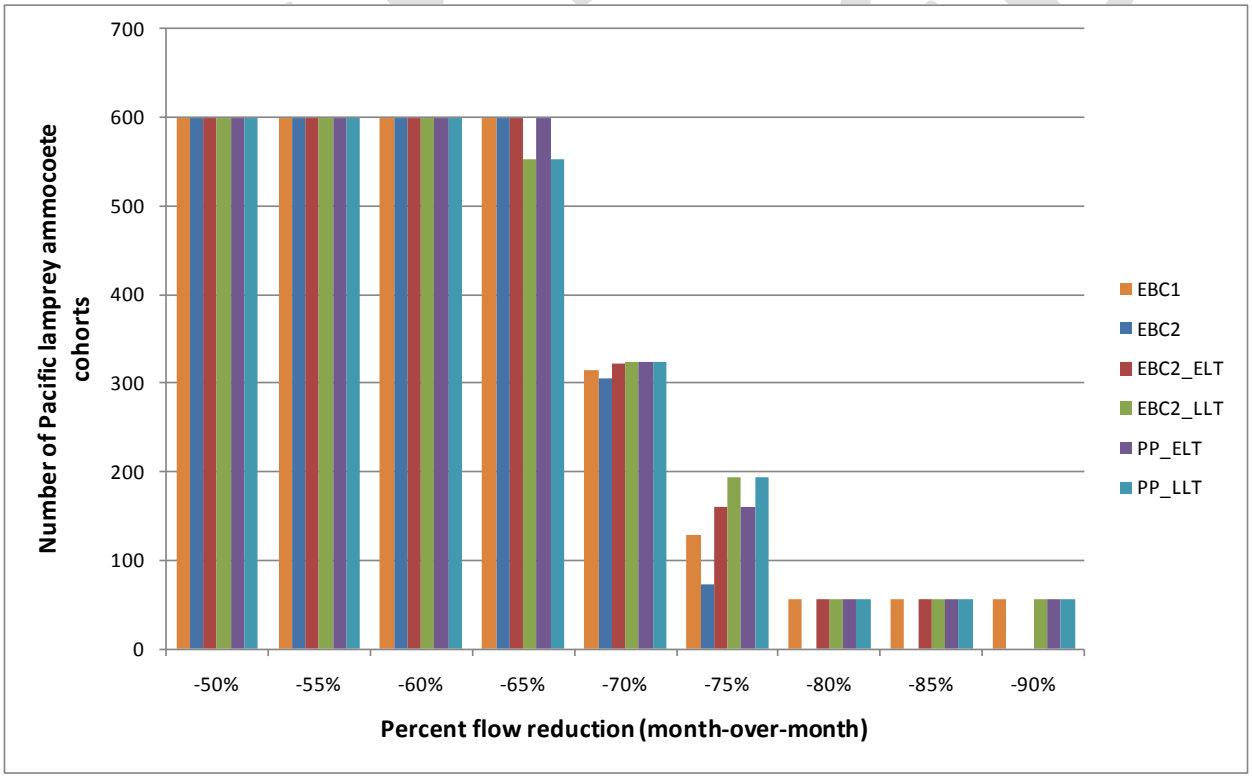

Figure C.5.2-413. Number of Pacific Lamprey Ammocoete Cohorts Exposed to Month-over-Month Flow Reductions of 50% to 90%, Stanislaus River at the Confluence with the San Joaquin River

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Table C.5.2-154. Percent Difference between Model Scenarios in the Number of Pacific Lamprey Ammocoete Cohorts Exposed to Month-over-Month Flow Reductions, Stanislaus River at the Confluence with the San Joaquin River

Percent Flow Reduction	Percent Difference[1]					
	EBC1 vs. PP_ELT	EBC1 vs. PP_LLT	EBC2 vs. PP_ELT	EBC2 vs. PP_LLT	EBC2_ELT vs. PP_ELT	EBC2_LLT vs. PP_LLT
-50%	0.0	0.0	0.0	0.0	0.0	0.0
-55%	0.0	0.0	0.0	0.0	0.0	0.0
-60%	0.0	0.0	0.0	0.0	0.0	0.0
-65%	0.0	-8.0	0.0	-8.0	0.0	0.0
-70%	2.9	3.2	5.6	5.9	0.3	0.0
-75%	25.8	50.8	123.6	168.1	0.6	0.0
-80%	0.0	0.0	NA	NA	0.0	0.0
-85%	0.0	0.0	NA	NA	0.0	0.0
-90%	0.0	0.0	NA	NA	NA	0.0

[1] Negative values indicate reduced cohort exposure, a benefit of the preliminary proposal.
NA = could not be calculated because dividing by 0.

The number of river lamprey ammocoete cohorts that may be affected by month-over-month flow reductions in the Stanislaus River at the confluence with the San Joaquin River is presented in Figure C.5.2-414, and differences between model scenarios are presented in Table C.5.2-155.

The number of river lamprey ammocoetes exposed to a given flow reduction is predicted to be identical between EBC1 and PP_ELT (Table C.5.2-155). The number of ammocoetes exposed to a given flow reduction is predicted to be 0% to 100% lower under the PP_LLT compared to the EBC1, depending on the flow reduction. The number of ammocoetes exposed to a given flow reduction is predicted to be 0% lower to 124% higher under the PP_ELT compared to the EBC2, depending on the flow reduction. The number of ammocoetes exposed to a given flow reduction is predicted to be 8% lower to 168% higher under the PP_LLT compared to the EBC2, depending on the flow reduction.

Isolating the effects of climate change, the number of river lamprey ammocoetes exposed to a given flow reduction is predicted to be <1% higher under the PP_ELT compared to the EBC2_ELT for all flow reductions. There are no predicted differences in the number of ammocoetes exposed to a given flow reduction between the EBC2_LLT and PP_LLT.

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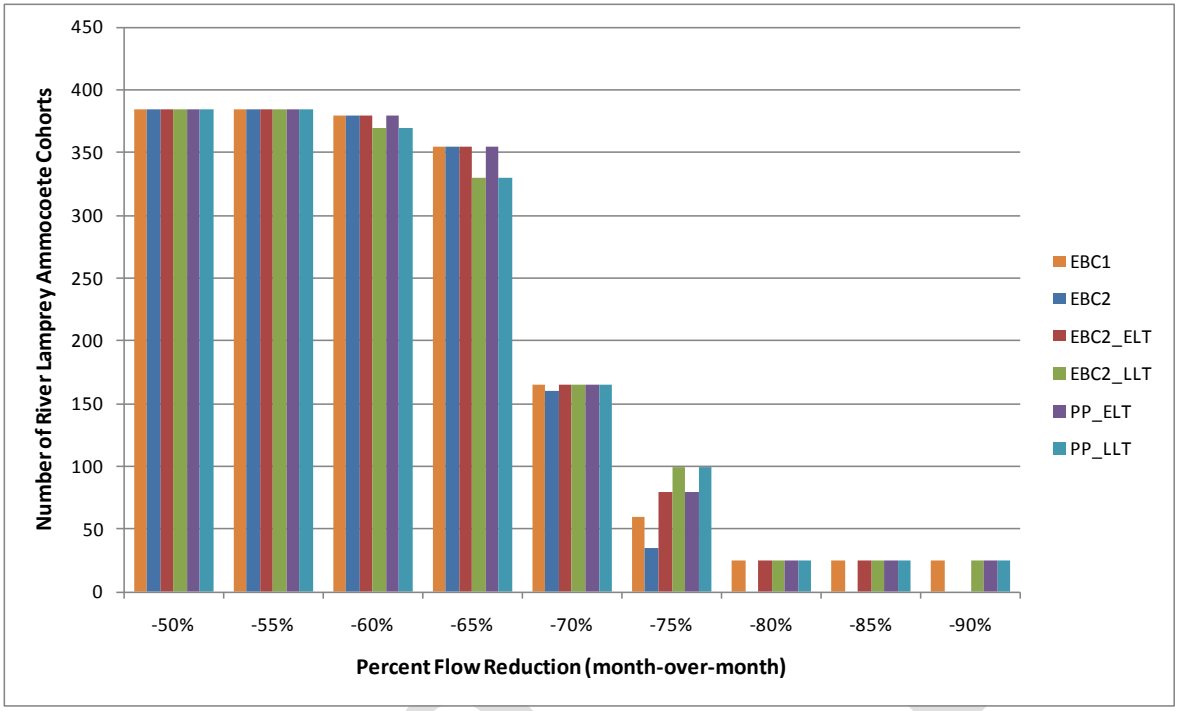

Figure C.5.2-414. Number of River Lamprey Ammocoete Cohorts Exposed to Month-over-Month Flow Reductions of 50% to 90%, Stanislaus River at the Confluence with the San Joaquin River

Table C.5.2-155. Percent Difference between Model Scenarios in the Number of River Lamprey Ammocoete Cohorts Exposed to Month-over-Month Flow Reductions, Stanislaus River at the Confluence with the Sacramento River

Percent Flow Reduction	Percent Difference[1]					
	EBC1 vs. PP_ELT	EBC1 vs. PP_LLT	EBC2 vs. PP_ELT	EBC2 vs. PP_LLT	EBC2_ELT vs. PP_ELT	EBC2_LLT vs. PP_LLT
-50%	0.0	-0.3	0.0	-0.3	0.0	0.0
-55%	0.0	-0.1	0.0	-0.3	0.0	0.0
-60%	0.0	-0.3	0.0	-2.6	0.0	0.0
-65%	0.0	-0.1	0.0	-7.0	0.0	0.0
-70%	0.0	-6.1	3.1	3.1	0.0	0.0
-75%	0.0	-4.3	128.6	185.7	0.0	0.0
-80%	0.0	-100.0	NA	NA	0.0	0.0
-85%	0.0	-26.0	NA	NA	0.0	0.0
-90%	0.0	0.0	NA	NA	NA	0.0

[1] Negative values indicate reduced cohort exposure, a benefit of the preliminary proposal.
NA = could not be calculated because dividing by 0.

These results indicate that there are negligible effects of the preliminary proposal on both species under the early and late long-term. The vast proportion of differences between model scenarios is due to climate change.