United States Department of the Interior

BUREAU OF RECLAMATION
Central Valley Operations Office
3310 El Camino Avenue, Suite 300
Sacramento, California 95821

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IN REPLY REFER TO:

CVO-100
2.2.1.06

VIA ELECTRONIC MAIL AND U.S. MAIL

Ms. Maria Rea
Assistant Regional Administrator
California Central Valley Area Office
650 Capital Mall, Suite 5-100
Sacramento, CA 95814

Subject: Transmittal of February 2019 Central Valley Project (CVP) Reservoir Operations Forecasts

Dear Ms. Rea:

Pursuant to Reasonable and Prudent Alternative Action I.2.3 of the 2009 National Marine Fisheries Service (NMFS) Biological Opinion (BiOp), this transmittal provides the Bureau of Reclamation's preliminary CVP operational forecasts and Sacramento River temperature model results for projected operations over the coming spring and summer. Enclosed are Reclamation's updated CVP operational projections for the coming spring and summer (Enclosure 1), and a projection of Sacramento River temperature performance for the projected operations (Enclosure 2).

The enclosed outlooks and modeling runs are based on forecasts of reservoir inflows assuming both a 90 percent exceedance hydrology, and a 50 percent exceedance hydrology using information provided by the California Department of Water Resources based on February 1 hydrologic conditions. The outlooks and modeling runs have also taken into account the runoff conditions and changes in reservoir volume that have occurred thus far in the month of February. Temperature modeling results are based on the operational forecasts, and a Shasta Lake temperature stratification profile taken February 7, 2019. It is important to note that the enclosed outlooks and projections do not suggest a certain actual future outcome, but rather the statistical likelihood of projected outcomes including, but not limited to, projected storage and releases as well as temperature performance. Thus, the outlooks do not provide exact end-of-month storages, flow rates, or anticipated water temperatures, but general projections that will likely fall within the range of uncertainty based on the different hydrologic runoff conditions between the 90 percent and 50 percent hydrology.

As illustrated in the enclosures, the results of the temperature modeling software indicate the ability to meet a 56-degree daily average temperature at a compliance location of Balls Ferry under the 90 percent exceedance hydrology. Under this same hydrology, the projected storage in

Shasta Lake at the end of September is approximately 2.5 million acre-feet. We believe these conditions are consistent with the criteria for Action I.2.3.A in the NMFS BiOp, and request that NMFS concur that it is likely the performance goals in Action I.2.3.A can be met. We have enclosed additional information discussing uncertainties associated with the modeling results, including issues surrounding the use of a 10 percent exceedance meteorology, and additional uncertainties in the modeling software results in the September and October timeframes (Enclosures 3 and 4).

Since we are within Action I.2.3.A, the Action does not require additional restrictions. With the projected operations illustrated in Enclosure 1, and other operating conditions throughout the CVP system, Reclamation anticipates the ability to support appropriately conservative initial allocations to Central Valley Project contractors, which we intend to issue on Wednesday February 20. Reclamation recognizes the potential that these allocations may need to be modified during 2019 to address ongoing temperature planning and establishment of the temperature compliance point. As such, Reclamation does not believe that issuing initial allocations would foreclose future measures for the fishery protection under the Endangered Species Act as implemented through the actions identified in the NMFS BiOp. Should NMFS have any questions or concerns, or need additional information regarding the enclosed outlooks and projections, we encourage you to contact us as soon as possible to ensure we maintain the schedule of activities necessary for the allocation notifications. In addition, Reclamation requests that NMFS take all appropriate steps to ensure that its written evaluation of these forecasts and final determination can still be provided prior to February 20 should a lapse in appropriations occur in the coming days.

We look forward to our continued coordination as we work throughout this spring on the development of the Sacramento River temperature management plan for 2019, in coordination with the Sacramento River Temperature Task Group (SRTTG). Our initial meeting for the SRTTG is currently scheduled for February 28, 2019. In addition to the development of a plan pursuant to both the NMFS BiOp and the State Water Resources Control Board's Order 90-5, we anticipate that, through this process, the agencies will be able to fully evaluate the potential for additional operational studies this year for targeting specific temperatures closer to the actual locations of redds, as in the past several years.

Please contact me at (916) 978-2197 or jrieker@usbr.gov if you have any questions regarding this transmittal.

Sincerely,

For Jeff Rieker
Operations Manager

Enclosures

Enclosure 1

Estimated CVP Operations 90% Exceedance

Storages

Federal End of the Month Storage/Elevation (TAF/Feet)

		Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan
Trinity	1587	1657	1664	1715	1756	1663	1511	1328	1225	1194	1163	1145	1144
	Elev.	2316	2316	2320	2323	2316	2304	2288	2279	2276	2273	2271	2271
Whiskeytown	207	206	206	238	238	238	238	238	238	206	206	206	206
	Elev.	1199	1199	1209	1209	1209	1209	1209	1209	1199	1199	1199	1199
Shasta	2912	3517	3996	4045	3863	3583	3199	2887	2650	2451	2398	2422	2503
	Elev.	1029	1048	1049	1043	1032	1016	1003	992	982	979	980	984
Folsom	523	609	656	798	911	917	761	669	618	542	474	415	384
	Elev.	430	435	449	460	461	446	436	430	422	413	405	401
New Melones	1871	1975	1940	1882	1821	1740	1670	1606	1558	1507	1509	1513	1515
	Elev.	1050	1047	1041	1036	1028	1021	1014	1009	1004	1004	1005	1005
San Luis	813	897	924	799	579	292	95	4	36	157	340	553	682
	Elev.	537	540	523	498	465	438	424	437	452	468	507	528
Total		8860	9386	9477	9168	8433	7474	6731	6325	6057	6090	6254	6434

Monthly River Releases (TAF/cfs)

Trinity	TAF	17	18	32	180	47	28	53	52	23	18	18	18
	cfs	300	300	540	2,924	783	450	857	870	373	300	300	300
Clear Creek	TAF	11	12	13	13	17	9	9	9	12	12	12	12
	cfs	200	200	218	216	288	150	150	150	200	200	200	200
Sacramento	TAF	180	200	447	528	625	669	591	436	428	296	246	246
	cfs	3250	3250	7517	8593	10500	10885	9610	7334	6955	4968	4000	4000
American	TAF	555	184	89	92	89	219	154	113	111	108	111	92
	cfs	10000	3000	1500	1500	1500	3570	2505	1896	1800	1807	1800	1500
Stanislaus	TAF	83	93	83	92	56	18	18	18	49	12	12	14
	cfs	1500	1521	1400	1500	940	300	300	300	797	200	200	232

Trinity Diversions (TAF)

	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan
Carr PP	8	92	72	7	135	130	131	50	14	25	21	15
Spring Crk. PP	10	99	42	0	120	120	120	40	35	15	12	10

Delta Summary (TAF)

	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan
Tracy	200	170	54	55	89	231	265	260	260	250	258	180
USBR Banks	0	0	0	0	0	18	18	18	0	0	0	0
Contra Costa	14.0	12.7	12.7	12.7	9.8	11.1	12.7	14.0	16.8	18.4	18.3	14.0
Total USBR	214	183	66	68	99	260	296	292	277	268	276	194
Total Export	396	295	102	105	159	318	377	447	391	327	534	374
COA Balance	0	0	0	0	0	0	0	82	94	0	0	0
Old/Middle River Std.												
Old/Middle R. calc.	-4,839	-2,967	-848	-790	-1,988	-4,198	-4,969	-5,983	-4,782	-4,375	-6,731	-4,709
Computed DOI	29807	21099	12355	9500	7699	4490	3156	2807	3611	4202	7499	9988
Excess Outflow	18406	10801	2252	2635	840	0	0	0	0	0	3432	4571
% Export/Inflow	19%	18%	10%	12%	19%	36%	46%	57%	53%	50%	52%	39%
% Export/Inflow std.	45%	35%	35%	35%	35%	65%	65%	65%	65%	65%	65%	65%

Hydrology

	Trinity	Shasta	Folsom	New Melones
Water Year Inflow (TAF)	948	4,460	2,281	956
Year to Date + Forecasted % of mean	78%	81%	84%	90%

CVP actual operations do not follow any forecasted operation or outlook; actual operations are based on real-time conditions.
CVP operational forecasts or outlooks represent general system-wide dynamics and do not necessarily address specific watershed/tributary details.
CVP releases or export values represent monthly averages.
CVP Operations are updated monthly as new hydrology information is made available December through May.

2/14/2019

Estimated CVP Operations 50% Exceedance

Storages

Federal End of the Month Storage/Elevation (TAF/Feet)

		Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan
Trinity	**1587**	**1703**	**1850**	**2014**	**2024**	**1929**	**1822**	**1691**	**1553**	**1528**	**1515**	**1542**	**1606**
	Elev.	2319	2330	2342	2343	2336	2328	2318	2308	2305	2304	2307	2312
Whiskeytown	**207**	**206**	**206**	**238**	**238**	**238**	**238**	**238**	**238**	**206**	**206**	**206**	**206**
	Elev.	1199	1199	1209	1209	1209	1209	1209	1209	1199	1199	1199	1199
Shasta	**2912**	**3542**	**4127**	**4404**	**4359**	**4108**	**3684**	**3336**	**3124**	**2964**	**2925**	**3011**	**3371**
	Elev.	1030	1052	1062	1060	1052	1036	1022	1013	1006	1004	1008	1023
Folsom	**523**	**609**	**676**	**788**	**932**	**877**	**745**	**665**	**618**	**569**	**540**	**529**	**526**
	Elev.	430	437	448	462	457	444	436	430	425	421	420	420
New Melones	**1871**	**1975**	**1966**	**1926**	**1893**	**1866**	**1803**	**1739**	**1695**	**1654**	**1670**	**1694**	**1726**
	Elev.	1050	1049	1046	1042	1040	1034	1028	1023	1019	1021	1023	1026
San Luis	**813**	**888**	**947**	**801**	**564**	**420**	**219**	**94**	**114**	**235**	**411**	**621**	**780**
	Elev.	535	542	519	485	458	440	438	453	467	493	527	546
Total		8923	9772	10171	10011	9437	8512	7763	7341	7156	7267	7602	8215

Monthly River Releases (TAF/cfs)

Trinity	TAF	17	18	28	258	126	68	53	52	23	18	18	18
	cfs	**300**	**300**	**477**	**4,189**	**2,120**	**1,102**	**857**	**870**	**373**	**300**	**300**	**300**
Clear Creek	TAF	11	12	13	13	17	9	9	9	12	12	12	15
	cfs	**200**	**200**	**218**	**216**	**288**	**150**	**150**	**150**	**200**	**200**	**200**	**240**
Sacramento	TAF	180	200	327	492	595	707	615	476	428	355	307	246
	cfs	**3250**	**3250**	**5500**	**8000**	**10000**	**11500**	**10000**	**8000**	**6955**	**5975**	**5000**	**4000**
American	TAF	555	307	208	184	208	222	161	126	123	119	123	154
	cfs	**10000**	**5000**	**3500**	**3000**	**3500**	**3612**	**2611**	**2113**	**2000**	**2002**	**2000**	**2500**
Stanislaus	TAF	83	93	83	96	56	18	18	18	49	12	12	14
	cfs	**1500**	**1521**	**1400**	**1555**	**940**	**300**	**300**	**300**	**797**	**200**	**200**	**232**

Trinity Diversions (TAF)

	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan
Carr PP	0	5	51	1	91	89	90	89	13	25	12	0
Spring Crk. PP	**35**	**30**	**30**	**2**	**80**	**80**	**80**	**80**	**35**	**20**	**15**	**20**

Delta Summary (TAF)

	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan
Tracy	200	208	54	55	259	270	265	265	265	246	260	215
USBR Banks	0	0	0	0	0	22	22	22	0	0	0	0
Contra Costa	14.0	12.7	12.7	12.7	9.8	11.1	12.7	14.0	16.8	18.4	18.3	14.0
Total USBR	214	221	66	68	269	303	300	301	282	264	278	229
Total Export	414	421	102	105	356	560	612	605	436	472	538	424
COA Balance	0	0	0	0	0	3	77	215	240	239	239	239
Old/Middle River Std.												
Old/Middle R. calc.	-3,841	-3,440	-46	281	-4,212	-6,995	-7,707	-7,839	-5,119	-5,956	-6,577	-5,028
Computed DOI	39623	29167	18575	16414	7833	5872	3611	2807	3611	4202	9760	29102
Excess Outflow	28222	18870	8069	6865	0	0	0	0	0	0	5694	23685
% Export/Inflow	16%	19%	7%	8%	35%	47%	56%	64%	56%	60%	46%	19%
% Export/Inflow std.	45%	35%	35%	35%	35%	65%	65%	65%	65%	65%	65%	65%

Hydrology

	Trinity	Shasta	Folsom	New Melones
Water Year Inflow (TAF)	1266	4,990	2,755	1097
Year to Date + Forecasted % of mean	105%	90%	101%	104%

CVP actual operations do not follow any forecasted operation or outlook; actual operations are based on real-time conditions.
CVP operational forecasts or outlooks represent general system-wide dynamics and do not necessarily address specific watershed/tributary details.
CVP releases or export values represent monthly averages.
CVP Operations are updated monthly as new hydrology information is made available December through May.

2/14/2019

Enclosure 2

February 14, 2019

Upper Sacramento River – February 2019 Preliminary Temperature Analysis

Location (°F DAT)	APR	MAY	JUN	JUL	AUG	SEP*	OCT*
February 90%-Exceedance Outlook – 50% Historical Meteorology							
Keswick Dam KWK	52.8	52.3	52.8	53.6	53.6	See Figures 1 and 2	See Figures 1 and 2
Sac. R. abv Clear Creek CCR	53.1	52.8	53.3	54.0	54.0	See Figures 1 and 3	See Figures 1 and 3
Balls Ferry BSF	55.3	55.7	55.5	55.8	55.8	See Figures 1 and 4	See Figures 1 and 4

Model Run	End of September Cold Water Pool <56°F (TAF)	First Side Gate	Full Side Gates
90% Hydro, 50% Met	580	8/25	9/22

Model Run Date February 14, 2019

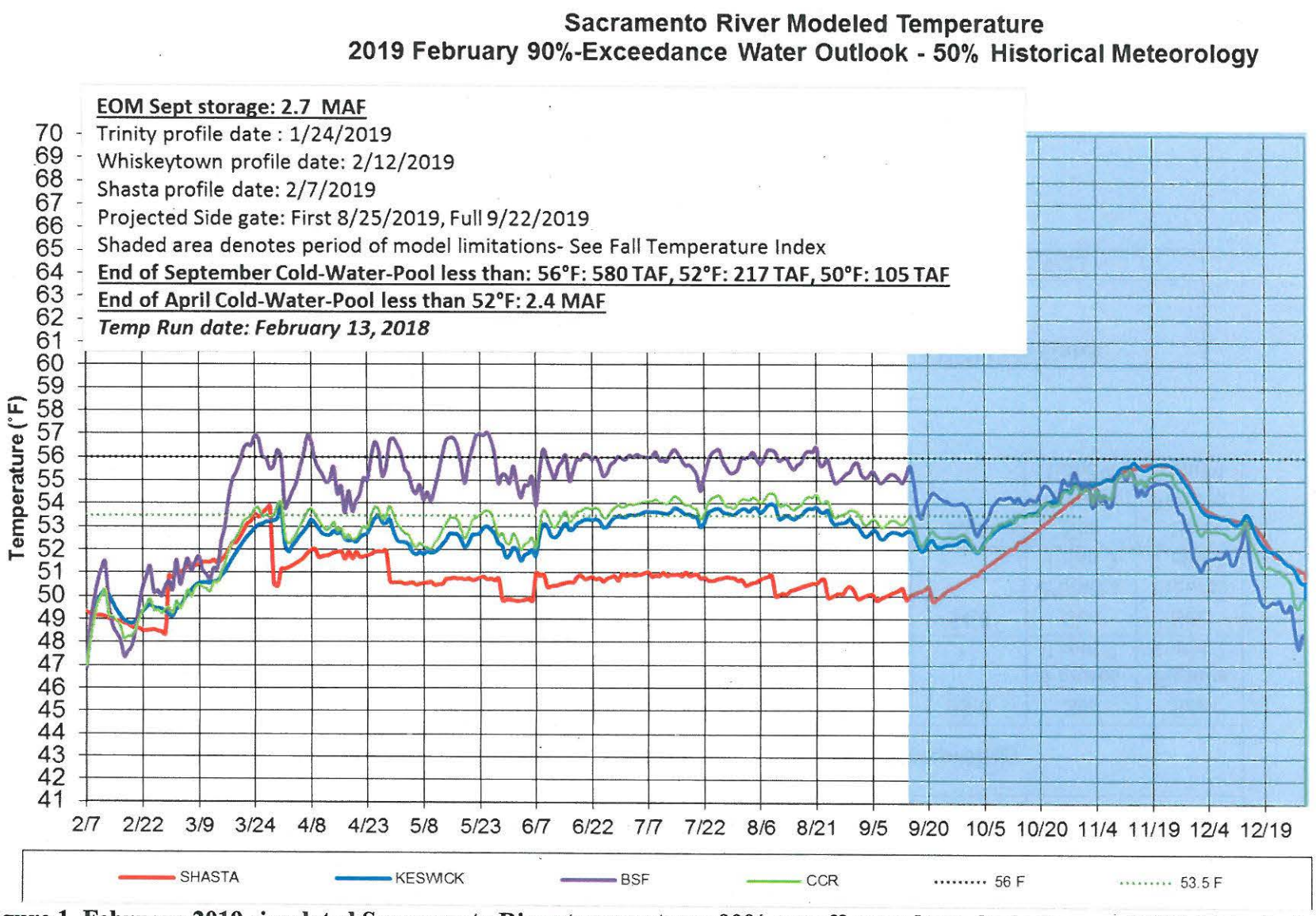

Figure 1. February 2019 simulated Sacramento River temperatures 90% runoff exceedance hydrology and 50% historical meteorology.

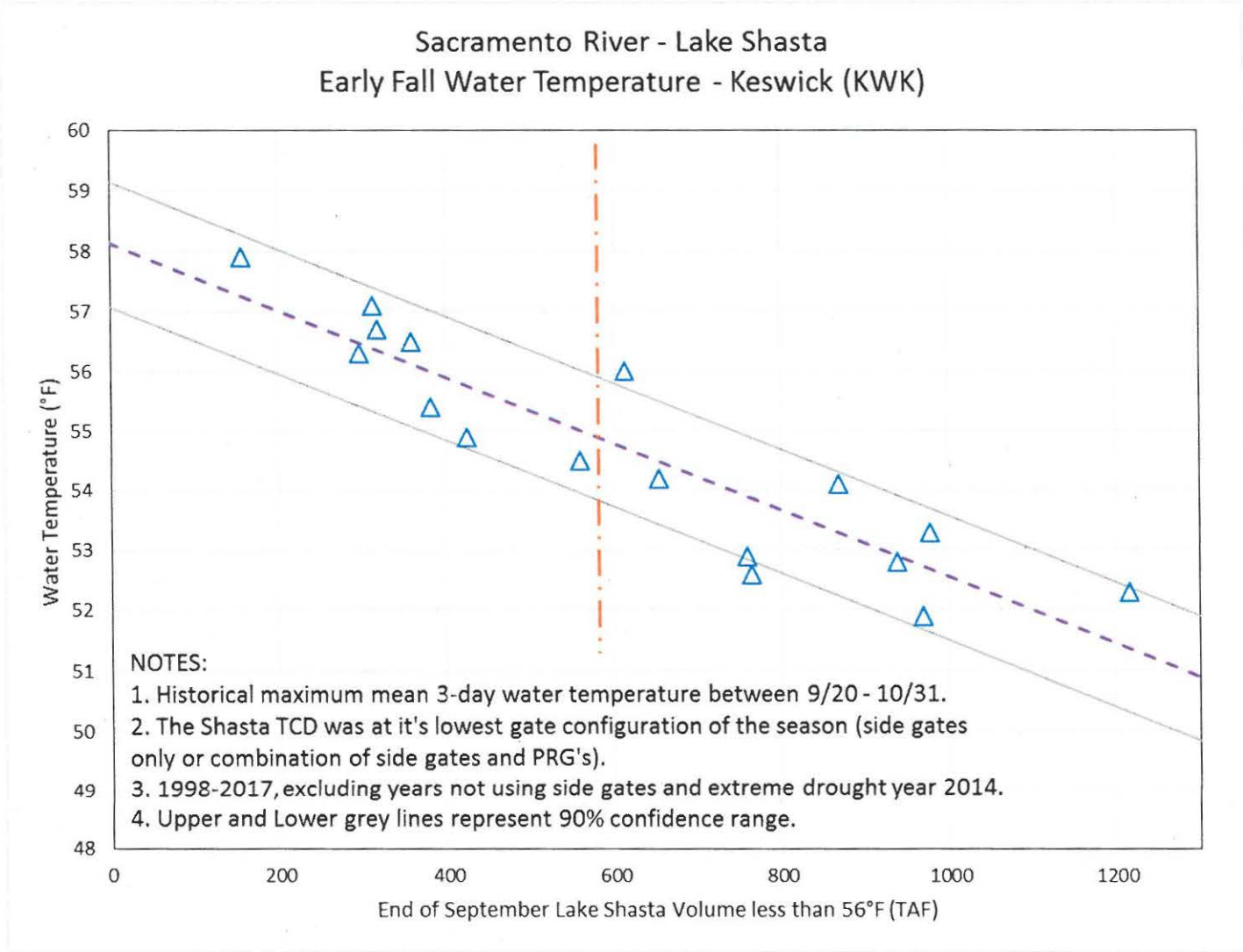

Figure 2. Historical relationship between Lake Shasta cold-water-pool characteristics and early fall Keswick water temperature and identifying relationship with 580 TAF end of September of cold-water-pool.

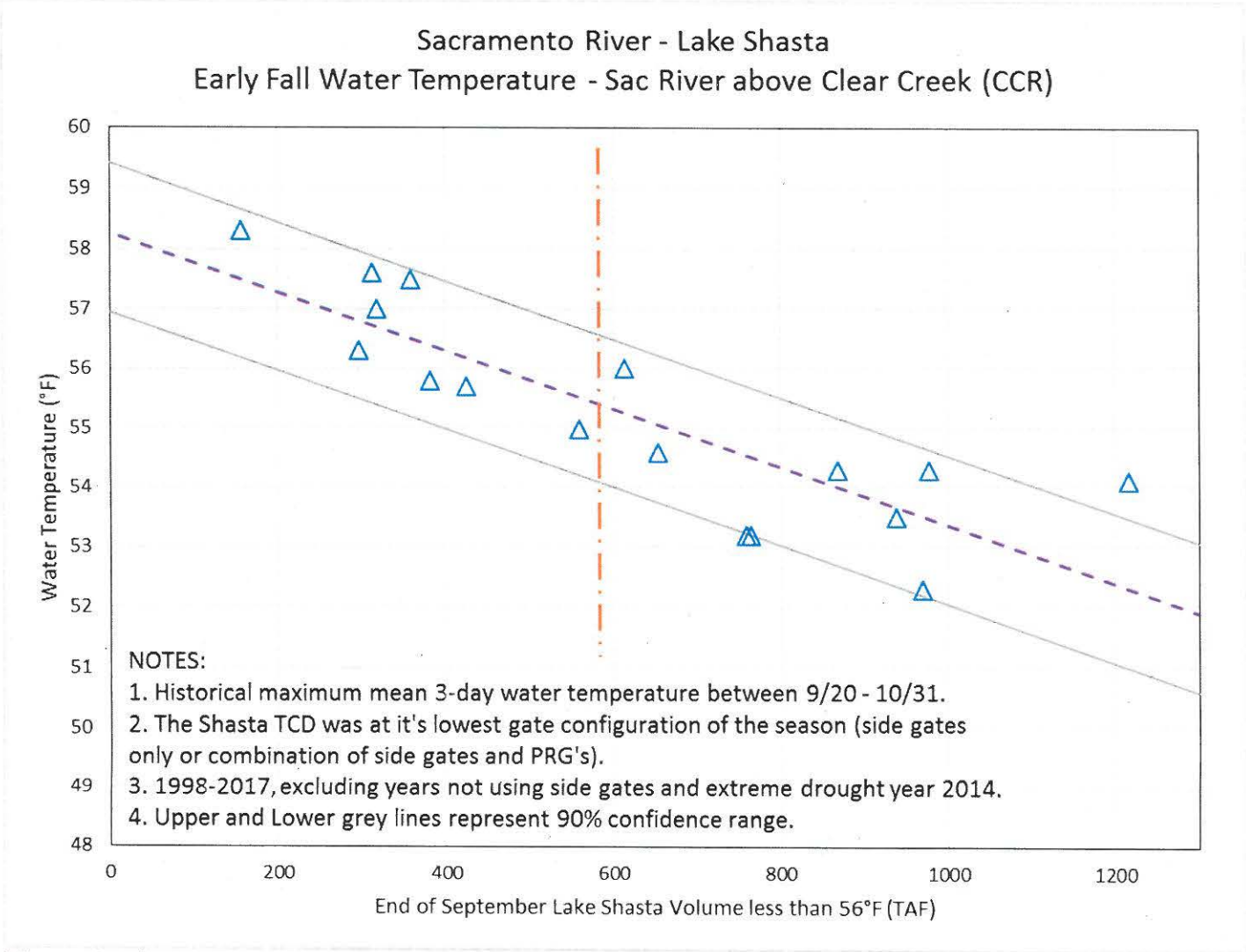

Figure 3. Historical relationship between Lake Shasta cold-water-pool characteristics and early fall Sacramento River above Clear Creek confluence water temperature and identifying relationship with 580 TAF end of September of cold-water-pool.

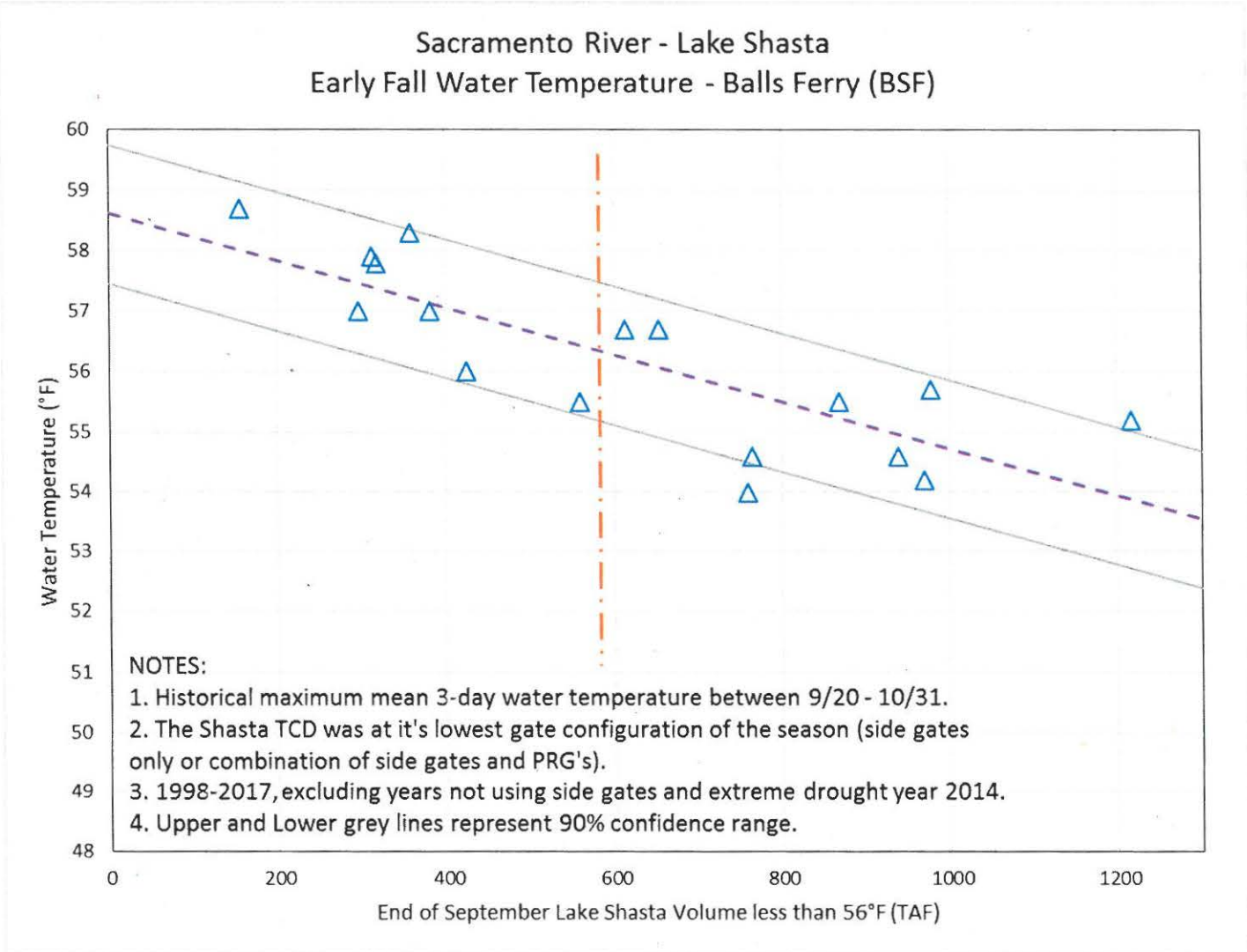

Figure 4. Historical relationship between Lake Shasta cold-water-pool characteristics and early fall Balls Ferry water temperature and identifying relationship with 580 TAF end of September of cold-water-pool.

* The HEC5Q model output is displayed above for the months April through August. Based on past analysis, the temperature model does not perform well in late September and October. One factor is that the modeled release temperatures are cooler than has historically been achieved when all release is through the side gates (lowest gates), especially when there's a large temperature gradient between the pressure relief gates (PRG) and the side gates. For the months of September and October, ranges in possible outcomes are illustrated with the Fall Temperature Index (graphics above Figures 2-4). This relationship is an end of September Lake Shasta Volume less than 56°F and likely downstream temperature performance for the early fall months.

Temperature Model Inputs, Assumptions, Limitations and Uncertainty:

1. The latest available profiles for Shasta, Trinity, and Whiskeytown were taken on February 7, January 24, and February 12, respectively. Model results are sensitive to initial reservoir temperature conditions and the model performs best under highly stratified conditions. The February 2018 temperature profile does not yet exhibit conditions for ideal model computations (still nearly isothermal conditions). The model performs well after the reservoir stratifies, typically in late spring (i.e. end of April). The concern this year is assuming over or under estimations with variable hydrologic and meteorological conditions and not capturing the stratification with sufficient detail to project into the future with confidence.
2. Guidance on forecasted flows from the creeks (e.g., Cow, Cottonwood, Battle, etc.) between Keswick Dam and Bend Bridge are not available beyond 5 days. Creek flows developed from the historical record that most closely reflects current conditions were used for all model runs. The resulting low creek flows cause significant additional warming in the upper Sacramento River during spring.
3. Operation is based on the February 2019 Operation Outlooks (monthly flows, reservoir release, and end-of-month reservoir storage) for the 90%- and 50%-exceedances. Trinity Lake inflows are updated with the CNRFC 90% runoff exceedance for both the 90% and 50% runoff exceedance studies.
4. Although mean daily flows and releases are temperature model inputs, they are based on the mean monthly values from the operation outlooks. Mean daily flow patterns are user defined and are generalized representations. It is important to note that these outlooks do not suggest a certain actual future outcome, but rather the statistical likelihood of an event occurring, including, but not limited to, projected storage and releases. Thus, the outlooks do not provide exact end of month storages or flow rates but general projections that will likely fall within the range of uncertainty based on the different hydrologic runoff conditions between the 90% and 50% runoff exceedance hydrology.
5. Cottonwood Creek flows, Keswick to Bend Bridge local flows, and ACID diversions are mean daily synthesized flows based on the available historical record for a 1922-2002 study period. Inflows were adjusted to a 50% historical exceedance for both the 90% and 50% runoff exceedance studies.
6. Meteorological inputs represent historical (1985 – 2017) monthly mean equilibrium temperature exceedance at 50% patterned after like months on a 6-hour time-step. Assumed inflows temperature remain static inputs and do not vary with the assumed meteorology. Tools to use long-term three-month-temperature outlooks, driven by the NOAA NWS Climate Prediction Center (CPC) are available beginning April, prior to April historical meteorology is used.

7. Meteorology, as well as the flow volume and pattern, significantly influences reservoir inflow temperatures and downstream tributary temperatures; and consequently, the development of the cold-water pool during winter and early spring, still uncertain prior to the end of April.
8. Modified model coefficients more closely represent actual Keswick Dam temperatures. As a result, temperature predictions downstream of Keswick Dam are likely to be warmer than actual.
9. The model is specifically being applied to generate the most accurate results at the Sacramento River above Clear Creek confluence location.

Enclosure 3

Discussion on Uncertainties in Temperature Results
February 15, 2019

Use of 10 Percent Exceedance Meteorology

Reclamation notes that our offices worked diligently in 2018 to incorporate updated meteorological data into our temperature modeling analyses, and that the analyses contained in the accompanying enclosures are based on an updated dataset that covers the years of 1985 through 2017. For this reason, we believe the data and model runs incorporate any trends in local air temperatures that may have occurred in recent years. With this incorporation, we believe that use of a 10 percent exceedance meteorology with a 90 percent exceedance hydrology in modeling runs would have a compounding effect, resulting in projected temperature performance well in excess of a 90 percent overall exceedance. We believe this extends beyond the intent of Action I.2.3, which notes that the "*90 percent forecast is a conservative approach for assessing the potential to meet both the Balls Ferry TCP and 2.2 MAF EOS performance goals.*" Further, nothing in Action 1.2.3 requires Reclamation to use a 10 percent exceedance meteorology.

In this transmittal, Reclamation has included model runs illustrating the effects of the use of a 10 percent exceedance meteorology (Enclosure 4). This inclusion is for the purposes of illustrating the compounding effect noted above, and is best exemplified by the results shown for the 50 percent exceedance hydrology (as illustrated in Enclosure 4). Under that scenario, Shasta Lake is projected to reach an essentially full state in April, is held to relatively limited releases throughout the temperature management season, and ends September with a storage of over 3.1 million acre-feet. Based on historical information, this scenario should clearly meet a 56 degree temperature performance at Balls Ferry if treated as a true 50 percent exceedance temperature performance, but when coupled with the 10 percent exceedance meteorological dataset, the run does not produce the expected result of temperature compliance.

Additional analysis of the underlying datasets would likely need to be completed to verify the actual resultant joint probability of combining the 90 percent exceedance hydrology with the 10 percent exceedance meteorology (particularly if other uncertainties, such as the those associated with reservoir stratification or model simulation are considered). However, as outlined above, we believe this combination represents an exceedance probability that far exceeds that anticipated under the current BiOp.

Evolution of Cold Water Pool

The model results shown in the accompanying enclosures are based on an early season reservoir temperature profile. There is a high degree of uncertainty in the cold water pool volume calculated by the models at this early date due to high uncertainties associated with each of the factors affecting the eventual stratification of the cold water pool. Higher confidence will come with the end of April Shasta Lake profile. In addition, it is anticipated that 2019 will carry an elevated level of this uncertainty due to the effects of recent storms during the month of February, ranging from unusually cold storms depositing snow in the watersheds surrounding Shasta Lake to warm storms bringing significant rain and melting of the snow.

September/October Temperature Performance

Based on past analysis, there is a higher degree of uncertainty in temperature modeling results in the September and October timeframe. One factor is that the modeled release temperatures are cooler than has historically been achieved when all release is through the side gates (lowest gates), especially when there exists a large temperature gradient between the pressure relief gates and the side gates. For this reason, estimated temperatures for September and October in the tables of the accompanying enclosures may fall into a range indicated within a Fall Temperature Index (graphical chart shown in the enclosures), illustrating historical performance. These indicators illustrate an added element of uncertainty in late-season temperature management. However, this range should be viewed as an element of uncertainty based on past performance, not a simulation or projection of temperature management operations or results.

Keswick Release Projections

The Keswick monthly average releases for March through May 14 are illustrated in the enclosed operational outlooks. It should be noted that actual release rates may vary throughout the month, and may require a need to operate to real-time conditions such as flood control management or higher downstream demands during certain times of the month. Ranges of projected average monthly releases for the remainder of the months of the year can be found in the enclosed tables; we anticipate these may be revised during the course of the spring through monthly hydrology updates.

Enclosure 4

Supplemental Modeling Information

Summary of Temperature Results by Month (Monthly Average Temperature °F)

Location (°F DAT)	APR	MAY	JUN	JUL	AUG	SEP*	OCT*
February 90%-Exceedance Outlook – 10% Historical Meteorology							
Keswick Dam KWK	53.1	52.3	53.1	53.9	53.8	See Figures 5 and 8	See Figures 5 and 8
Sac. R. abv Clear Creek CCR	53.5	52.9	53.7	54.4	54.3	See Figures 5 and 9	See Figures 5 and 9
Balls Ferry BSF	55.9	56.1	56.0	56.4	56.2	See Figures 5 and 10	See Figures 5 and 10
February 50%-Exceedance Outlook – 50% Historical Meteorology							
Keswick Dam KWK	52.8	52.4	52.7	53.2	53.3	See Figures 6 and 8	See Figures 6 and 8
Sac. R. abv Clear Creek CCR	53.3	53.0	53.2	53.6	53.7	See Figures 6 and 9	See Figures 6 and 9
Balls Ferry BSF	55.9	56.0	55.6	55.3	55.5	See Figures 6 and 10	See Figures 6 and 10

Location (°F DAT)	APR	MAY	JUN	JUL	AUG	SEP*	OCT*
February 50%-Exceedance Outlook – 10% Historical Meteorology							
Keswick Dam KWK	52.3	51.9	53.0	53.5	53.8	See Figures 7 and 8	See Figures 7 and 8
Sac. R. abv Clear Creek CCR	53.0	52.6	53.5	54.0	54.2	See Figures 7 and 9	See Figures 7 and 9
Balls Ferry BSF	56.1	56.0	56.0	55.9	56.0	See Figures 7 and 10	See Figures 7 and 10

Model Run	End of September Cold Water Pool <56°F (TAF)	First Side Gate	Full Side Gates
90% Hydro, 10% Met	403	7/31	9/1
50% Hydro, 50% Met	674	8/27	9/25
50% Hydro, 10% Met	444	7/30	9/1

Model Run Date February 14, 2019

* The HEC5Q model output is displayed above for the months April through August. Based on past analysis, the temperature model does not perform well in late September and October. One factor is that the modeled release temperatures are cooler than has historically been achieved when all release is through the side gates (lowest gates), especially when there's a large temperature gradient between the pressure relief gates (PRG) and the side gates. For the months of September and October, ranges in possible outcomes are illustrated with the Fall Temperature Index (graphics below Figures 8-10). This relationship is an end of September Lake Shasta Volume less than 56°F and likely downstream temperature performance for the early fall months.

Temperature Analysis Results:

Modeling runs explore Sacramento River compliance performance above Clear Creek confluence and Balls Ferry locations by varying hydrology and meteorology. The temperature results for the Sacramento River between Keswick Dam and Balls Ferry are shown in Figures 5 through 7. The relationship between end-of-September lake volume below 56°F and a Balls Ferry compliance through fall is based on the Figures 8-10.

Temperature Model Inputs, Assumptions, Limitations and Uncertainty:

1. The latest available profiles for Shasta, Trinity, and Whiskeytown were taken on February 7, January 24, and February 12, respectively. Model results are sensitive to initial reservoir temperature conditions and the model performs best under highly stratified conditions. The February 2018 temperature profile does not yet exhibit conditions for ideal model computations (still nearly isothermal conditions). The model performs well after the reservoir stratifies, typically in late spring (i.e. end of April). The concern this year is assuming over or under estimations with variable hydrologic and meteorological conditions and not capturing the stratification with sufficient detail to project into the future with confidence.
2. Guidance on forecasted flows from the creeks (e.g., Cow, Cottonwood, Battle, etc.) between Keswick Dam and Bend Bridge are not available beyond 5 days. Creek flows developed from the historical record that most closely reflects current conditions were used for all model runs. The resulting low creek flows cause significant additional warming in the upper Sacramento River during spring.
3. Operation is based on the February 2019 Operation Outlooks (monthly flows, reservoir release, and end-of-month reservoir storage) for the 90%- and 50%-exceedances. Trinity Lake inflows are updated with the CNRFC 90% runoff exceedance for both the 90% and 50% runoff exceedance studies.
4. Although mean daily flows and releases are temperature model inputs, they are based on the mean monthly values from the operation outlooks. Mean daily flow patterns are user defined and are generalized representations. It is important to note that these outlooks do not suggest a certain actual future outcome, but rather the statistical likelihood of an event occurring, including, but not limited to, projected storage and releases. Thus, the outlooks do not provide exact end of month storages or flow rates but general projections that will likely fall within the range of uncertainty based on the different hydrologic runoff conditions between the 90% and 50% runoff exceedance hydrology.
5. Cottonwood Creek flows, Keswick to Bend Bridge local flows, and ACID diversions are mean daily synthesized flows based on the available historical record for a 1922-2002 study period. Inflows were adjusted to a 50% historical exceedance for both the 90% and 50% runoff exceedance studies.
6. Meteorological inputs represent historical (1985 – 2017) monthly mean equilibrium temperature exceedance at 10% and 50% patterned after like months on a 6-hour time-step. Assumed inflows temperature remain static inputs and do not vary with the assumed meteorology. Tools to use long-term three-month-temperature outlooks, driven by the NOAA NWS Climate Prediction Center (CPC) are available beginning April, prior to April historical meteorology is used.
7. Meteorology, as well as the flow volume and pattern, significantly influences reservoir inflow temperatures and downstream

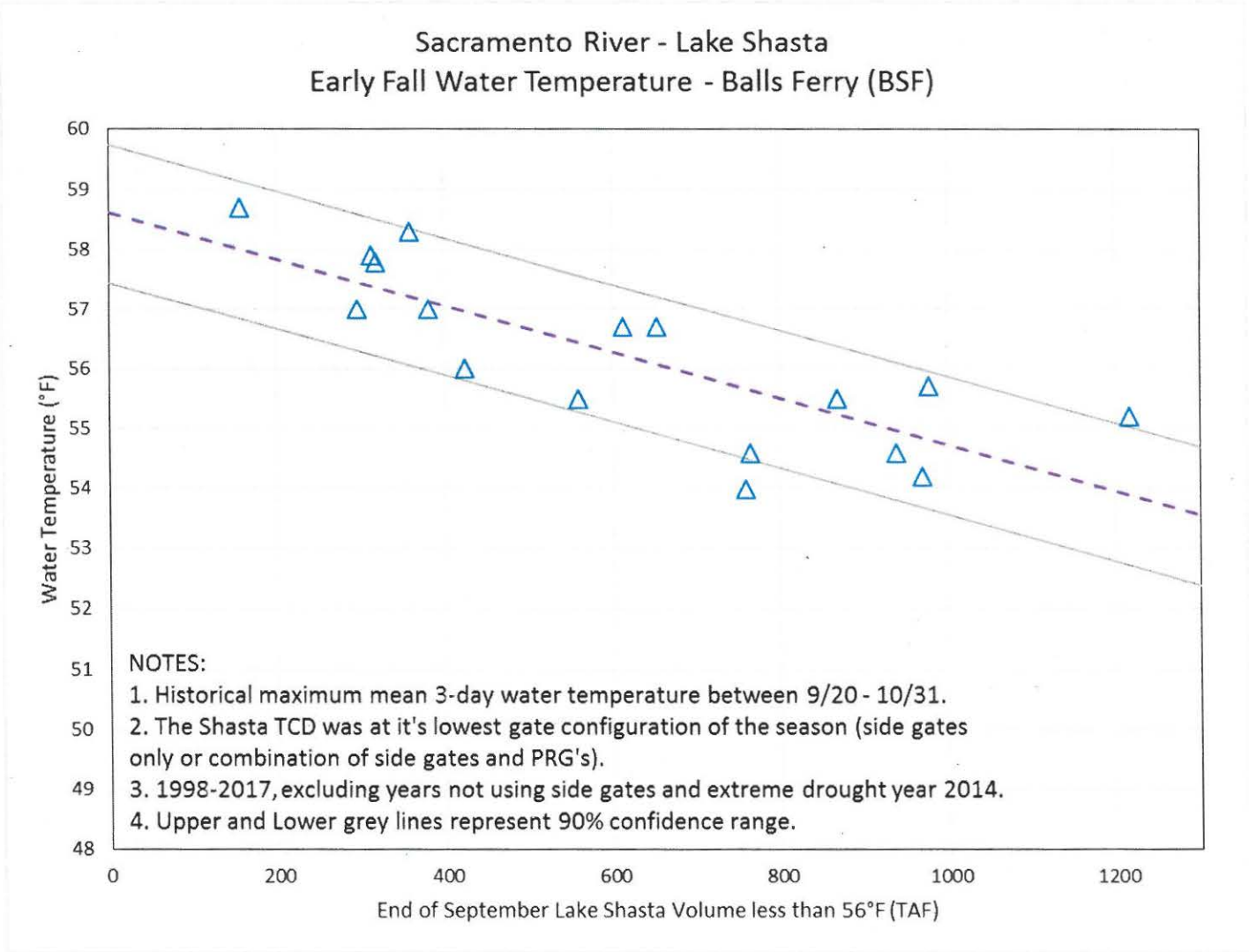

Figure 10. Historical relationship between Lake Shasta cold-water-pool characteristics and early fall Balls Ferry water temperature.

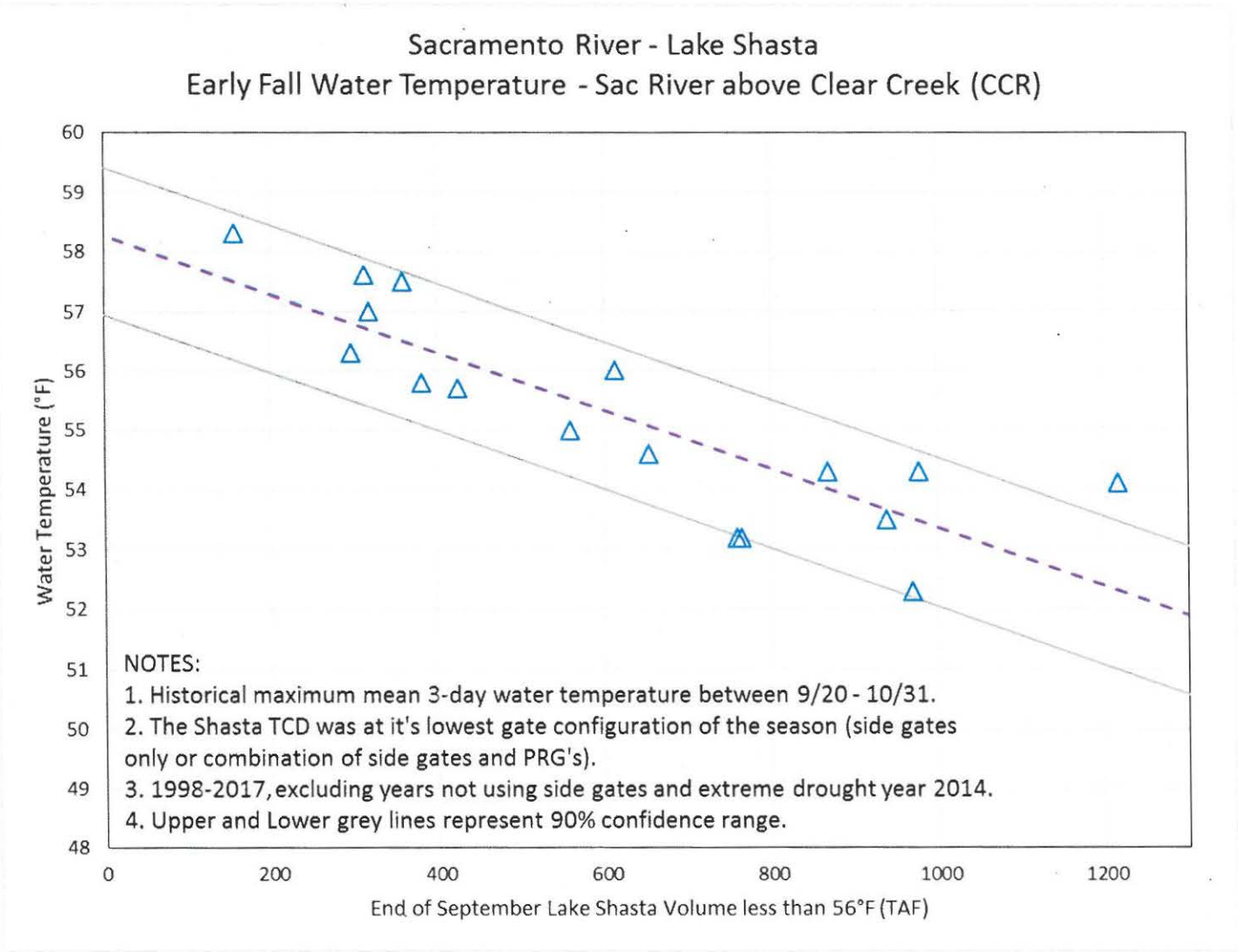

Figure 9. Historical relationship between Lake Shasta cold-water-pool characteristics and early fall Sacramento River above Clear Creek confluence water temperature.

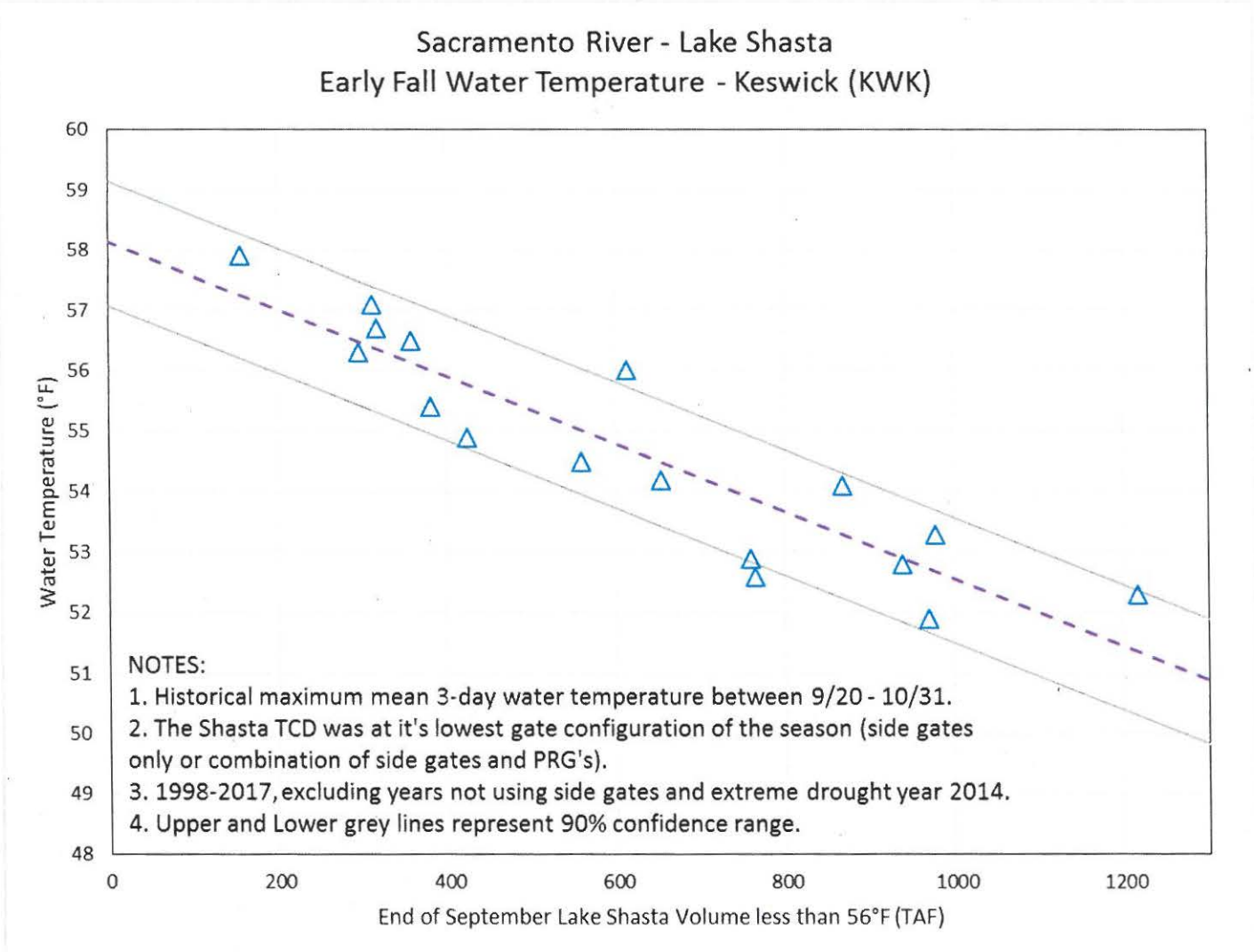

Figure 8. Historical relationship between Lake Shasta cold-water-pool characteristics and early fall Keswick water temperature.

Figure 8-10 <u>Model Performance and Fall Temperature Index</u>:

1. Based on past analyses, the temperature model does not perform well in late September and October. One factor is that the modeled release temperatures are cooler than has historically been achieved when all release is through the side gates (lowest gates), especially when there's a large temperature gradient between the pressure relief gates (PRG) and the side gates.
2. Based on historical records, the end-of-September Lake Shasta volume below 56°F is a good indicator of fall water temperature in the river reach to Balls Ferry.
3. Based on these records and estimates, the charts below illustrates a range of uncertainty in the expected river temperatures based on the end-of-September lake volume less than 56°F.

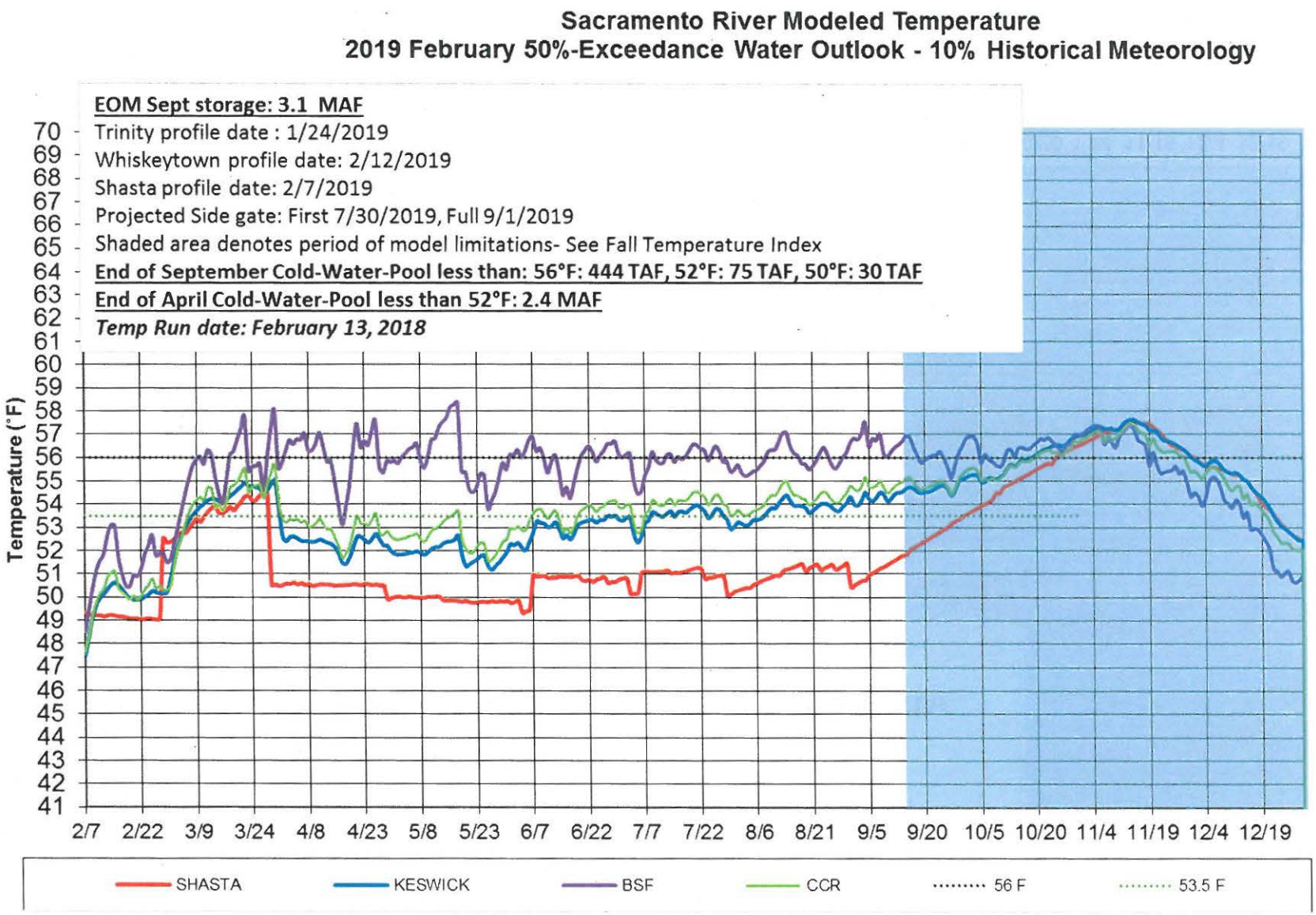

Figure 7. February 2019 simulated Sacramento River temperatures 50% runoff exceedance hydrology and 10% historical meteorology.

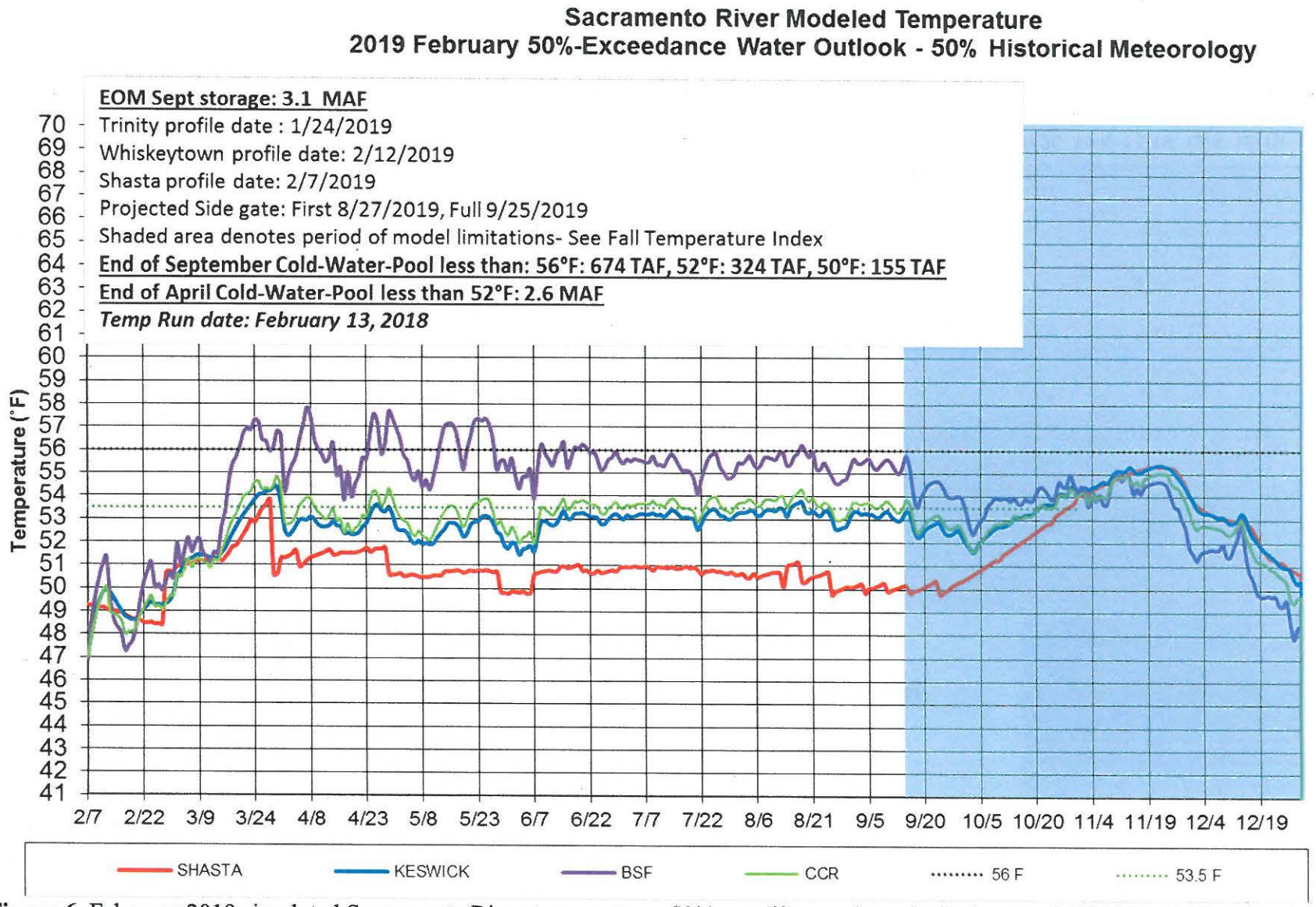

Figure 6. February 2019 simulated Sacramento River temperatures 50% runoff exceedance hydrology and 50% historical meteorology.

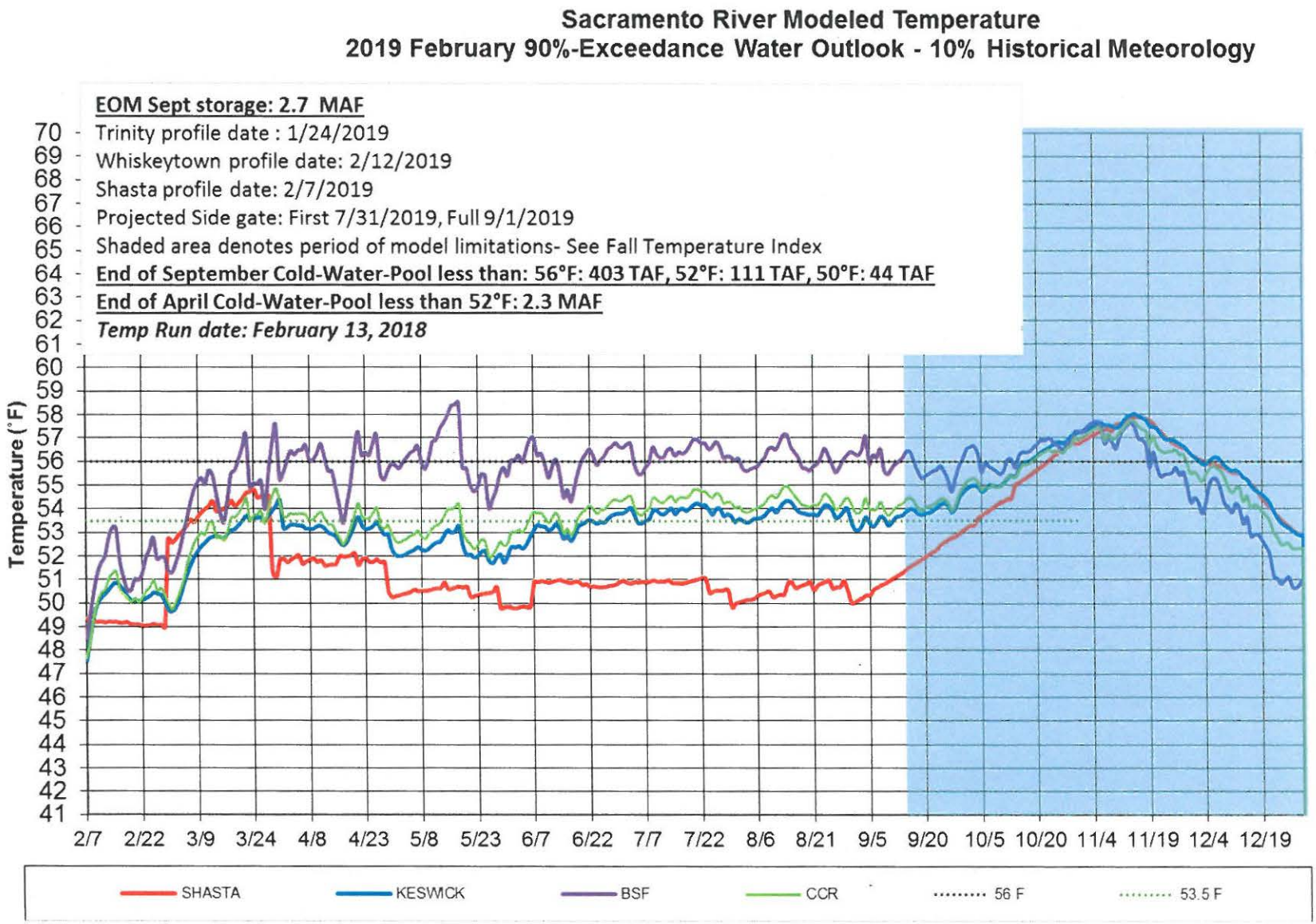

Figure 5. February 2019 simulated Sacramento River temperatures 90% runoff exceedance hydrology and 10% historical meteorology.

tributary temperatures; and consequently, the development of the cold-water pool during winter and early spring, still uncertain prior to the end of April.

8. Modified model coefficients more closely represent actual Keswick Dam temperatures. As a result, temperature predictions downstream of Keswick Dam are likely to be warmer than actual.

9. The model is specifically being applied to generate the most accurate results at the Sacramento River above Clear Creek confluence location.