United States Department of the Interior

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

IN REPLY
REFER TO:

CVO-100
WTR-2.00

MAY 11 2018

VIA ELECTRONIC MAIL AND U.S. MAIL

Ms. Maria Rea
Assistant Regional Administrator
California Central Valley Area Office
National Marine Fisheries Service
650 Capitol Mall, Suite 5-100
Sacramento, CA 95814

Subject: Transmittal of 2018 Sacramento River Temperature Management Plan per Reasonable and Prudent Alternative (RPA) I.2.4 of the National Marine Fisheries Service 2009 Coordinated Long-term Operation of the Central Valley Project (CVP) and State Water Project (SWP) Biological Opinion (NMFS 2009 BiOp)

Dear Ms. Rea:

This letter transmits the Sacramento River Temperature Management Plan (SRTMP) for Water Year 2018. The Bureau of Reclamation (Reclamation) is requesting concurrence from the National Marine Fisheries Service (NMFS) on the SRTMP as required by NMFS 2009 BiOp RPA Action I.2.4.

NMFS 2009 BiOp RPA Action I.2.4 requires Reclamation to submit a series of forecasts of CVP operations and corresponding Sacramento River temperature modeling runs to NMFS for review and concurrence. In accordance with this requirement, Reclamation has provided several sets of forecasts and temperature model runs and worked with NMFS during the spring of 2018 to develop a SRTMP to protect the cold water pool in Shasta Reservoir.

The SRTMP represents a balanced approach to management of the cold water pool in Shasta Reservoir during the spring, summer, and fall of 2018. Reclamation is recommending a plan that includes input and recommendations from the Sacramento River Temperature Task Group (SRTTG) meetings on April 26, 2018 and May 9, 2018, as well as a public stakeholder meeting held on April 25, 2018. The approach focuses on utilizing the cold water pool resource available this year, leveraging the Shasta Temperature Control Device capabilities, and maintaining reasonable temperature targets that will maximize protection of the species, while ensuring cold water will be able to be fully utilized through the season. This approach will also help Reclamation meet other obligations and maintain commitments for operation of the CVP and SWP.

Preliminary temperature operation modeling results were distributed to the SRTTG this year on February 22, March 22, April 25, April 26, and May 9. In addition, Reclamation has provided additional modeling results and model output files throughout the spring to NMFS as part of the processes outlined under Action I.2.3, including our most recent transmittals on April 18 and April 20, 2018. Historical information shows this year's cold-water-pool volume of water cooler than 49°F is less than average. In light of this and other conditions, Reclamation solicited feedback from SRTTG members on the proposed operation/simulation results. Reclamation has developed the following plan based on recommendations from SRTTG members. Preliminary discussion during the recent SRTTG meeting (April 26, 2018), included suggestions for a compliance point at the existing gaging station located on the Sacramento River above the confluence with Clear Creek (CCR California Data Exchange Center gaging station), using 53°F daily average temperature (DAT) metric from present through May 31 followed by a compliance point at Balls Ferry, using 56°F DAT metric from June 1 through October 31. This calendar-based trigger was preferred over a spawning trigger to implement the switch from 53°F at the Sacramento River above Clear Creek to 56°F at Balls Ferry, as a spawning trigger increases operational/implementation complexity and monitoring. Other more recent suggestions from NMFS included a temperature target at the CCR Gage Station, using a 53.5°F daily average temperature (DAT) metric for the entire management season.

During the May 9, 2018 SRTTG meeting members discussed options and reconciled concerns. The proposed SRTMP consists of a compliance point at Balls Ferry, using a 56°F DAT metric from May 15 through October 31. The proposed temperature management operation also includes an evaluation study targeting 53.5°F DAT at the CCR gaging station during the same time frame. Use of this location provides for targeting consistent temperatures closer to the location of actual anticipated spawning, as our agencies have discussed over the past several years. Based on recent modeling (provided May 9, 2018), the evaluation study of 53.5°F DAT target requires additional cold-water-pool utilization during later periods of the temperature management season. As a result, managing for cooler temperatures at CCR between May and October produces a tradeoff for increased risk to temperature performance confidence in the fall. Reclamation will monitor the cold-water-pool projections and compare to actual performance. The primary "off-ramp" criterion is defined as a deficient cold-water-pool volume less than 49°F which deviates more than 10% from the projected volume. In addition, ongoing modeling results will be completed for each monthly SRTTG meeting and more often as necessary (potentially as frequently as every two weeks). These results will be considered should those results indicate increased (or decreased) risk to fall temperature performance. In the event that actual cold-water-pool conditions vary from what is projected, and the fall temperature performance appears at risk, Reclamation will reconvene the SRTTG in preparation for an "off-ramp" of the evaluation study. If the "off-ramp" conditions are met and/or other indicators warrant as discussed by the SRTTG, then the evaluation study will conclude and operations will revert to the compliance location at Balls Ferry using 56°F DAT metric for the remainder of the season to protect fall temperatures. As in past years, Reclamation will work with NMFS and the other members of the SRTTG during fall operations to address the potential for redd dewatering.

Please find enclosed the latest temperature modeling results targeting 53.5°F DAT at the Sacramento River-Clear Creek (CCR) gaging station May 15 through October 31. The runs include both the April 50% and 90% exceedance hydrology forecasts and operational outlooks, modified to accommodate a monthly average Keswick release in May of 8,500 cubic feet per second, with the conservative historical meteorological forecasts at 50% and 10% exceedances.

Operational release performance was based on the two probabilistic hydrologic assumptions rather than fixed flowrates; actual release operations are expected to be within the specified ranges on an average monthly basis based on the hydrologic and operational considerations at that time. For this reason, daily operations may vary higher or lower from the projected monthly averages. Conservative results using the 90% exceedance hydrology forecast show end of September storage in Shasta Reservoir of approximately 2.3 million acre-feet. The simulation results indicated confidence in accomplishing temperature management, as proposed, with an end of September cold-water-pool less than 56°F of at least 587,000 acre-feet, and that the first side gate use of the Shasta Reservoir Temperature Control Device would begin between late August and early September, and full side gate use in early October.

RPA Action I.2.4 requires Reclamation achieve DATs between May 15 and October 31 "[n]ot in excess of 56°F at compliance locations between Balls Ferry and Bend Bridge". It also requires Reclamation to manage Shasta Reservoir in a way that provides "cold water releases from Shasta Reservoir to provide suitable habitat temperatures . . . in the Sacramento River between Keswick Dam and Bend Bridge, while retaining sufficient carryover storage to manage for next year's cohorts." Given the terms of RPA Action I.2.4 and the commitments above, Reclamation believes, the proposed SRTMP is fully compliant with the NMFS 2009 BiOp. We therefore request your concurrence of the SRTMP as required under RPA Action I.2.4. Reclamation proposes to conduct monitoring, updated modeling, and tracking of the performance of this SRTMP through the Sacramento River Temperature Task Group (SRTTG).

We look forward to working with you and your staff as we manage water resources and temperature this water year. Should you have questions or wish to discuss further, please feel free to contact me at 916-979-2197.

Sincerely,

Jeff Rieker
Operations Manager

Enclosures –5

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Estimated CVP Operations Apr 90% Exceedance

Storages

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

		Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar
Trinity	1844	1964	1893	1782	1679	1555	1439	1409	1390	1400	1432	1518	1615
	Elev.	2338	2333	2325	2318	2308	2298	2295	2294	2295	2297	2305	2313
Whiskeytown	207	238	238	238	238	238	230	206	206	206	206	206	206
	Elev.	1209	1209	1209	1209	1209	1207	1199	1199	1199	1199	1199	1199
Shasta	3880	4132	3981	3625	3046	2600	2320	2196	2190	2321	2518	2865	3321
	Elev.	1052	1047	1034	1010	989	975	968	968	975	985	1002	1021
Folsom	817	793	904	825	591	449	402	345	296	256	306	412	576
	Elev.	449	459	452	427	410	403	395	386	379	388	405	426
New Melones	2019	1977	1946	1922	1848	1784	1740	1709	1721	1735	1747	1770	1789
	Elev.	1050	1047	1045	1038	1032	1028	1025	1026	1027	1028	1031	1033
San Luis	876	773	574	266	88	8	72	198	382	526	666	699	762
	Elev.	510	485	445	421	399	414	431	451	476	491	493	505
Total		9877	9536	8658	7491	6634	6204	6063	6185	6443	6874	7470	8268

State End of the Month Reservoir Storage (TAF)

Oroville													
San Luis Total San Luis (TAF)	1774	1622	1335	919	697	518	638	791	986	1245	1411	1422	1565

Monthly River Releases (TAF/cfs)

Trinity	TAF	36	92	47	28	53	52	23	18	18	18	17	18
	cfs	600	1,498	783	450	857	870	373	300	300	300	300	300
Clear Creek	TAF	13	13	17	9	9	9	12	12	12	12	11	12
	cfs	218	216	288	150	150	150	200	200	200	200	200	200
Sacramento	TAF	297	523	625	799	645	476	369	268	200	200	180	200
	cfs	5000	8500	10500	13000	10500	8000	6000	4500	3250	3250	3250	3250
American	TAF	506	77	167	293	204	107	92	89	92	61	56	77
	cfs	8500	1250	2811	4768	3311	1798	1500	1500	1500	1000	1005	1250
Stanislaus	TAF	83	96	56	18	18	18	49	12	12	14	13	12
	cfs	1400	1555	940	300	300	300	797	200	200	232	236	200
Feather													
	cfs												

Trinity Diversions (TAF)

	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar
Carr PP	39	67	85	80	71	62	16	21	12	3	2	15
Spring Crk. PP	10	60	70	70	60	60	30	15	12	10	20	30

Delta Summary (TAF)

		Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar
Tracy		93	61	53	225	260	262	265	250	190	190	120	200
USBR Banks		0	0	0	18	18	18	0	0	0	0	0	0
Contra Costa		12.7	12.7	9.8	11.1	12.7	14.0	16.8	18.4	18.3	14.0	14.0	12.7
Total USBR		106	74	63	254	291	294	282	268	208	204	134	213
State Export													
Total Export		182	105	110	375	355	444	433	374	394	394	261	413
COA Balance		25	25	0	0	0	87	87	87	87	87	46	46
Old/Middle River Std.													
Old/Middle R. calc.		-164	146	-1,354	-4,912	-4,693	-5,945	-5,221	-4,877	-4,978	-4,960	-3,536	-5,040
Computed DOI		30476	10004	7900	6507	4002	3009	4067	4572	6767	9728	11400	12379
Excess Outflow		19079	2098	0	0	0	0	65	67	2261	3725	0	976
% Export/Inflow		8%	11%	13%	35%	40%	54%	54%	52%	47%	41%	29%	34%
% Export/Inflow std.		35%	35%	35%	65%	65%	65%	65%	65%	65%	65%	45%	35%

Hydrology

	Trinity		Shasta		Folsom		New Melones	
Water Year Inflow (TAF)	627		3,621		2,352		972	
Year to Date + Forecasted % of mean	52%		65%		86%		92%	

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.

5/10/2018

Estimated CVP Operations Apr 50% Exceedance

Storages

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

		Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar
Trinity	1844	1878	1860	1773	1659	1514	1381	1343	1330	1360	1425	1535	1629
	Elev.	2332	2331	2325	2316	2304	2293	2290	2288	2291	2297	2306	2314
Whiskeytown	207	238	238	238	238	238	230	206	206	206	206	206	206
	Elev.	1209	1209	1209	1209	1209	1207	1199	1199	1199	1199	1199	1199
Shasta	3880	4167	4055	3739	3205	2813	2586	2491	2541	2731	3138	3622	4179
	Elev.	1054	1050	1038	1017	999	989	984	986	995	1014	1033	1054
Folsom	817	813	937	885	715	604	528	480	451	439	468	521	586
	Elev.	451	462	458	441	429	420	414	410	409	412	419	427
New Melones	2019	1996	2014	2018	1958	1894	1853	1812	1829	1852	1884	1938	1915
	Elev.	1052	1054	1054	1048	1043	1039	1035	1036	1039	1042	1047	1044
San Luis	876	816	594	341	152	54	106	224	396	604	748	865	937
	Elev.	508	471	418	387	372	409	443	469	498	491	498	503
Total		9908	9698	8994	7927	7117	6684	6556	6752	7192	7868	8687	9452

State End of the Month Reservoir Storage (TAF)

Oroville													
San Luis Total San Luis (TAF)	1774	1596	1186	676	421	317	598	904	1164	1488	1406	1487	1540

Monthly River Releases (TAF/cfs)

Trinity	TAF	36	92	47	28	53	52	23	18	18	18	17	18
	cfs	600	1,498	783	450	857	870	373	300	300	300	300	300
Clear Creek	TAF	13	13	17	9	9	9	12	12	12	15	11	12
	cfs	218	216	288	150	150	150	200	200	200	240	200	200
Sacramento	TAF	268	523	625	799	645	476	369	268	200	200	278	307
	cfs	4500	8500	10500	13000	10500	8000	6000	4500	3250	3250	5000	5000
American	TAF	535	154	188	249	184	149	123	119	123	123	208	246
	cfs	9000	2500	3158	4053	3000	2500	2000	2000	2000	2000	3750	4000
Stanislaus	TAF	86	96	56	18	18	18	49	12	12	14	13	93
	cfs	1454	1555	940	300	300	300	797	200	200	232	236	1521
Feather													

Trinity Diversions (TAF)

	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar
Carr PP	35	24	71	84	85	76	26	25	9	0	2	35
Spring Crk. PP	15	25	60	75	75	75	40	20	12	20	35	60

Delta Summary (TAF)

		Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar
Tracy		113	74	155	273	274	260	265	245	260	205	215	221
USBR Banks		0	0	0	24	24	24	0	0	0	0	0	0
Contra Costa		12.7	12.7	9.8	11.1	12.7	14.0	16.8	18.4	18.3	14.0	14.0	12.7
Total USBR		126	86	165	308	311	298	282	263	278	219	229	234
State Export													
Total Export		231	105	182	528	589	694	686	531	538	269	444	421
COA Balance		25	25	0	0	0	0	0	0	0	0	0	0
Old/Middle River Std.													
Old/Middle R. calc.		-494	281	-1,960	-6,594	-7,419	-8,991	-8,251	-6,720	-6,577	-3,086	-4,826	-3,440
Computed DOI		36611	13892	7900	6507	4018	3026	4018	4522	8085	17325	23701	25588
Excess Outflow		25214	4945	0	0	16	17	16	17	3579	11322	12301	14185
% Export/Inflow		9%	9%	21%	44%	54%	66%	65%	61%	51%	20%	25%	21%
% Export/Inflow std.		35%	35%	35%	65%	65%	65%	65%	65%	65%	65%	45%	35%

Hydrology

	Trinity		Shasta		Folsom		New Melones	
Water Year Inflow (TAF)	539		3,864		2,586		1080	
Year to Date + Forecasted % of mean	45%		70%		95%		102%	

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.

5/10/2018

May 10, 2018

Upper Sacramento River – April 2018 Preliminary Temperature Analysis

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

Location	MAY	JUN	JUL	AUG	SEP	OCT	Late Sep-Oct Uncertainty Estimation
April 90%-Exceedance Outlook – 10% Historical Meteorology 53.5°F CCR							
Keswick Dam KWK	52.8	52.9	53.0	52.9	53.1	52.9	54 - 57
Sac. R. abv Clear Creek CCR	53.5	53.5	53.5	53.4	53.5	53.0	54 - 58
Balls Ferry BSF	57.2	56.5	55.5	55.3	55.3	54.1	55 - 59
April 90%-Exceedance Outlook – 50% Historical Meteorology 53.5°F CCR							
Keswick Dam KWK	52.9	53.0	53.1	53.0	53.0	52.3	54 - 56
Sac. R. abv Clear Creek CCR	53.5	53.5	53.5	53.5	53.4	52.4	54 - 58
Balls Ferry BSF	56.8	56.3	55.3	55.3	55.1	53.5	55 - 58
April 50%-Exceedance Outlook – 10% Historical Meteorology 53.5°F CCR							
Keswick Dam KWK	52.8	52.9	53.0	52.9	53.1	52.9	54 - 57
Sac. R. abv Clear Creek CCR	53.5	53.5	53.5	53.4	53.5	52.9	54 - 58
Balls Ferry BSF	57.4	56.4	55.6	55.3	55.3	54.1	55 - 59
April 50%-Exceedance Outlook – 50% Historical Meteorology 53.5°F CCR							
Keswick Dam KWK	52.9	52.9	53.1	53.0	53.1	52.3	53 - 56
Sac. R. abv Clear Creek CCR	53.5	53.5	53.5	53.4	53.5	52.3	54 - 58
Balls Ferry BSF	56.9	56.2	55.3	55.3	55.2	53.4	55 - 58

* The HEC5Q model output is displayed above for the months April through October. 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, an uncertainty estimate is provided based on the Fall Temperature Index (graphics below). This is based on a historical relationship between end-of-September Lake Shasta Volume less than 56°F and likely downstream temperature performances for the early fall months. The range represents the 90% confidence interval based on that data. Refinement of the concepts for those estimates is underway.

Temperature Model Inputs, Assumptions, Limitations and Uncertainty:

1. The latest available profiles for Shasta, Trinity, and Whiskeytown were taken on May 1, May 3, and May 2 respectively. Model results are sensitive to initial reservoir temperature conditions and the model performs best under highly stratified conditions. The model performs well after the reservoir stratifies, typically in late spring. 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.
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 can cause significant additional warming in the upper Sacramento River during spring.
3. Operation is based on the April 2018 Operation Outlooks and DWR Bulletin 120 inflow projections (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 the 90% runoff exceedance studies. The April 2018 Operation Outlook is modified to adjust for real-time operations in early May suggesting the monthly Keswick release may average closer to 8,500 cfs.
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 95% 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, or as noted. Assumed inflow temperature remain static inputs and do not vary with the assumed meteorology.

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.
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. Model re-calibrations efforts are underway.

Model Run Date May 7-10, 2018

Temperature Analysis Results:

Modeling runs explore Sacramento River compliance performance above Clear Creek confluence and Balls Ferry locations by varying hydrology and temperature compliance target location and temperature. The temperature results for the Sacramento River between Keswick Dam and Balls Ferry are shown in Figures 1-4. The fall uncertainty estimation relationship between end-of-September lake volume below 56°F and a Balls Ferry compliance through fall is based on the Figures 5-7.

Model Run	End of September Cold Water Pool <56°F (TAF)	First Side Gate	Full Side Gates
(1) 90% Hydro, 10% Historical Met 53.5 CCR	578	8/27	10/3
(2) 90% Hydro, 50% Historical Met 53.5 CCR	625	9/1	10/4
(3) 50% Hydro, 10% Historical Met 53.5 CCR	610	8/26	10/1
(4) 50% Hydro, 50% Historical Met 53.5 CCR	649	9/1	10/4

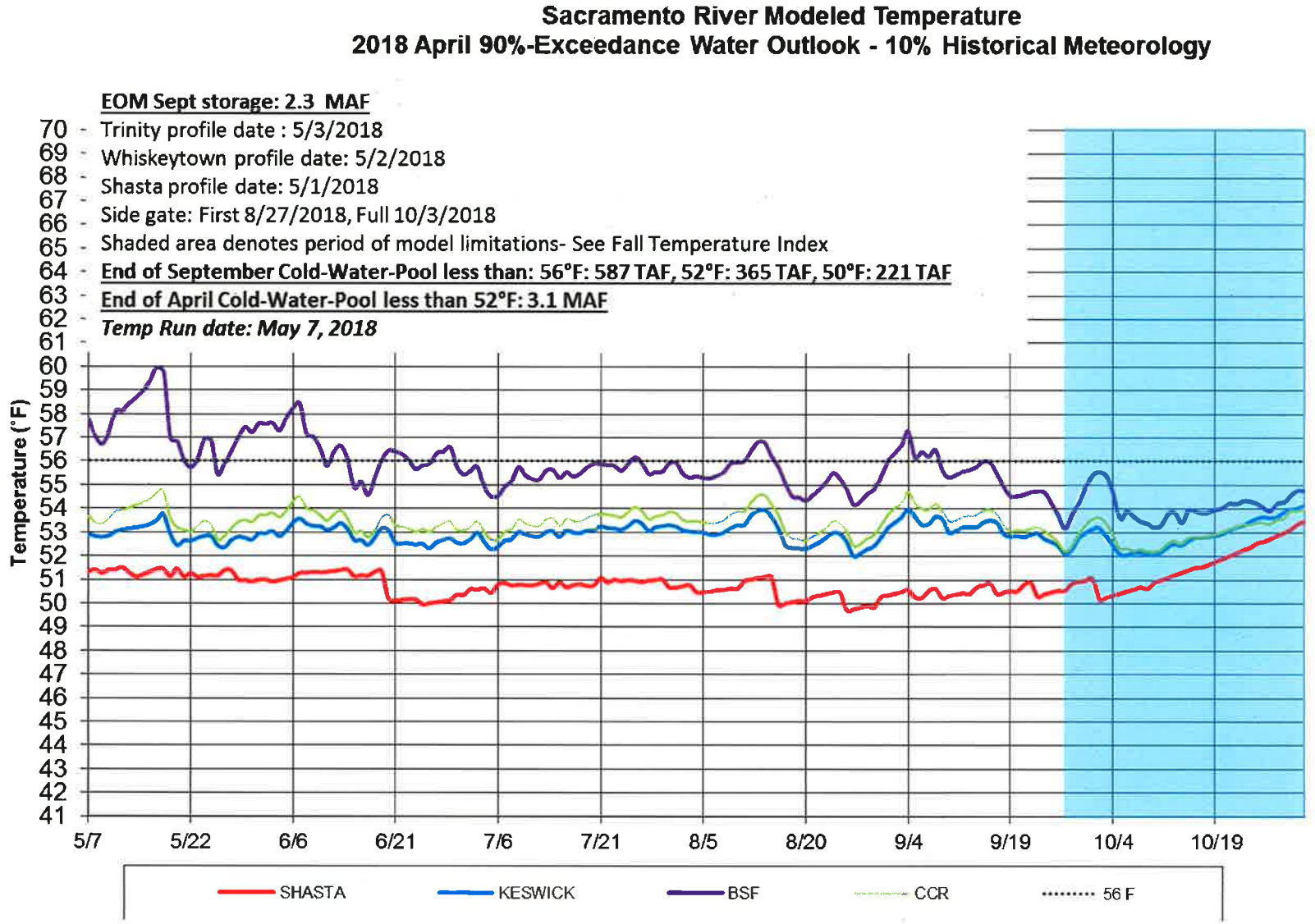
Sacramento River Modeled Temperature
2018 April 90%-Exceedance Water Outlook - 10% Historical Meteorology
EOM Sept storage: 2.3 MAF
Trinity profile date : 5/3/2018
Whiskeytown profile date: 5/2/2018
Shasta profile date: 5/1/2018
Side gate: First 8/27/2018, Full 10/3/2018
Shaded area denotes period of model limitations- See Fall Temperature Index
End of September Cold-Water-Pool less than: 56°F: 587 TAF, 52°F: 365 TAF, 50°F: 221 TAF
End of April Cold-Water-Pool less than 52°F: 3.1 MAF
Temp Run date: May 7, 2018
Temperature (°F)
70 69 68 67 66 65 64 63 62 61 60 59 58 57 56 55 54 53 52 51 50 49 48 47 46 45 44 43 42 41
5/7 5/22 6/6 6/21 7/6 7/21 8/5 8/20 9/4 9/19 10/4 10/19
SHASTA
KESWICK
BSF
CCR
56 F

Figure 1

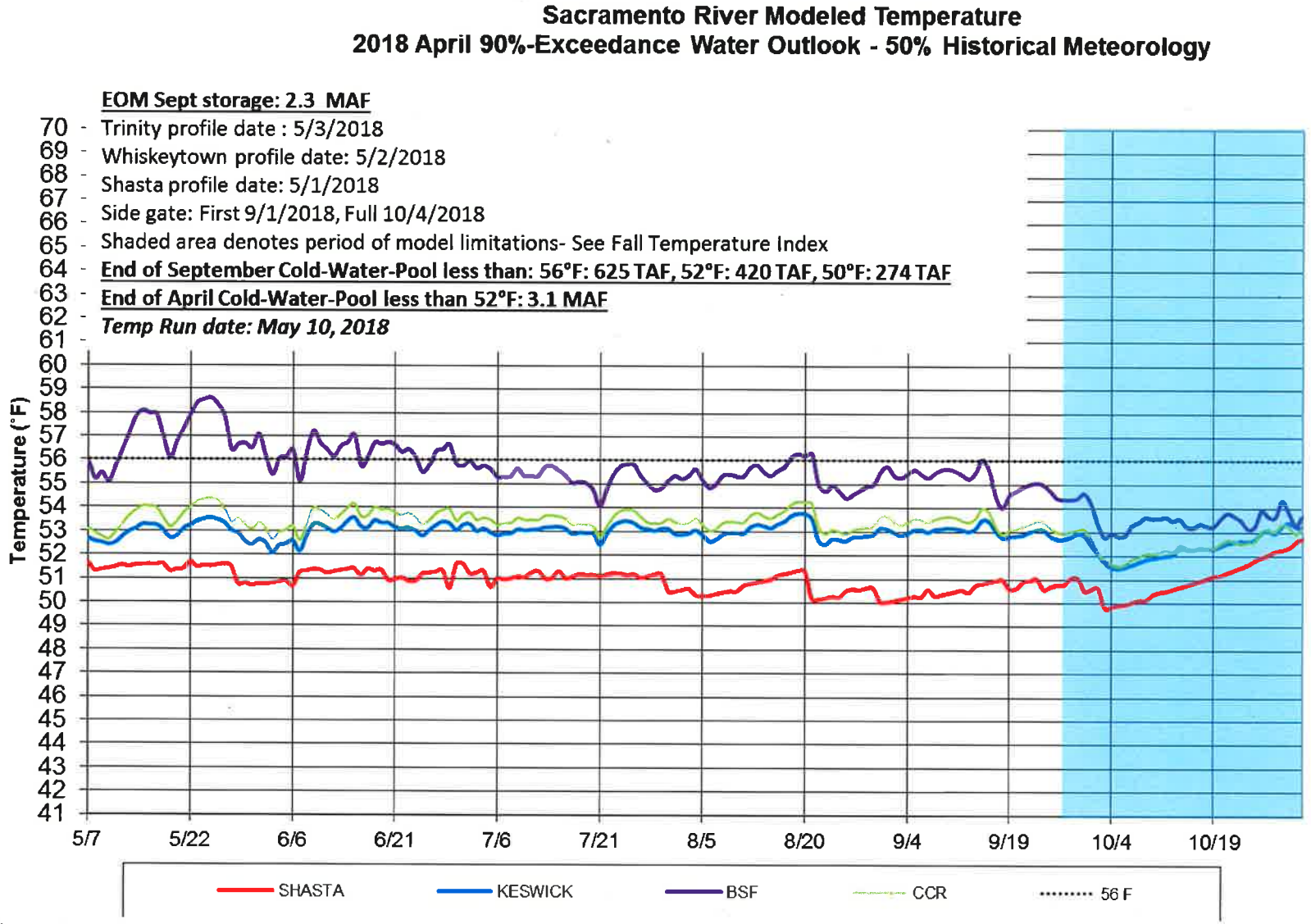
Sacramento River Modeled Temperature
2018 April 90%-Exceedance Water Outlook - 50% Historical Meteorology
EOM Sept storage: 2.3 MAF
Trinity profile date : 5/3/2018
Whiskeytown profile date: 5/2/2018
Shasta profile date: 5/1/2018
Side gate: First 9/1/2018, Full 10/4/2018
Shaded area denotes period of model limitations- See Fall Temperature Index
End of September Cold-Water-Pool less than: 56°F: 625 TAF, 52°F: 420 TAF, 50°F: 274 TAF
End of April Cold-Water-Pool less than 52°F: 3.1 MAF
Temp Run date: May 10, 2018
Temperature (°F)
70 69 68 67 66 65 64 63 62 61 60 59 58 57 56 55 54 53 52 51 50 49 48 47 46 45 44 43 42 41
5/7 5/22 6/6 6/21 7/6 7/21 8/5 8/20 9/4 9/19 10/4 10/19
SHASTA
KESWICK
BSF
CCR
56 F

Figure 2

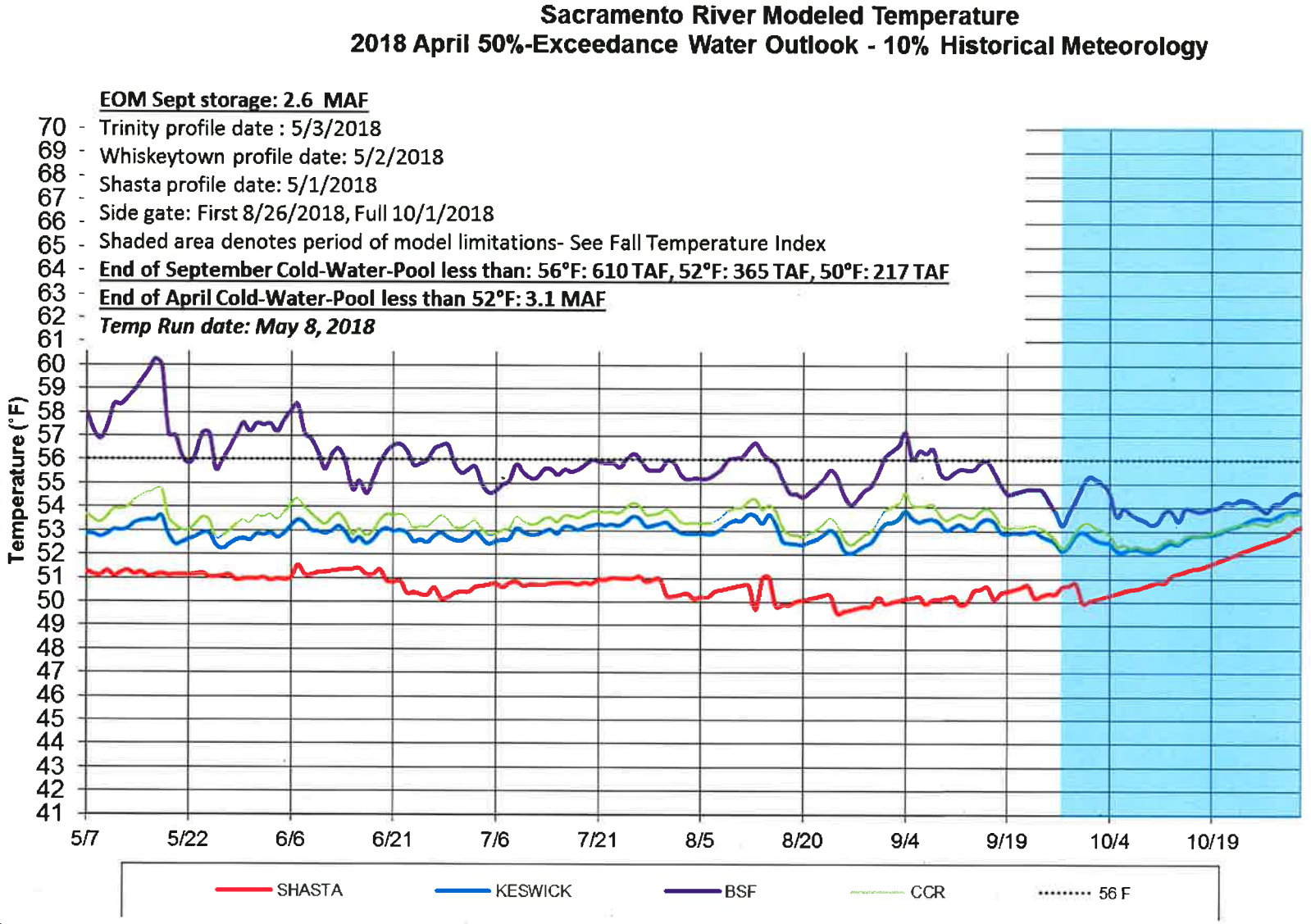
Sacramento River Modeled Temperature
2018 April 50%-Exceedance Water Outlook - 10% Historical Meteorology
EOM Sept storage: 2.6 MAF
Trinity profile date : 5/3/2018
Whiskeytown profile date: 5/2/2018
Shasta profile date: 5/1/2018
Side gate: First 8/26/2018, Full 10/1/2018
Shaded area denotes period of model limitations- See Fall Temperature Index
End of September Cold-Water-Pool less than: 56°F: 610 TAF, 52°F: 365 TAF, 50°F: 217 TAF
End of April Cold-Water-Pool less than 52°F: 3.1 MAF
Temp Run date: May 8, 2018
Temperature (°F)
70 69 68 67 66 65 64 63 62 61 60 59 58 57 56 55 54 53 52 51 50 49 48 47 46 45 44 43 42 41
5/7 5/22 6/6 6/21 7/6 7/21 8/5 8/20 9/4 9/19 10/4 10/19
SHASTA
KESWICK
BSF
CCR
56 F

Figure 3

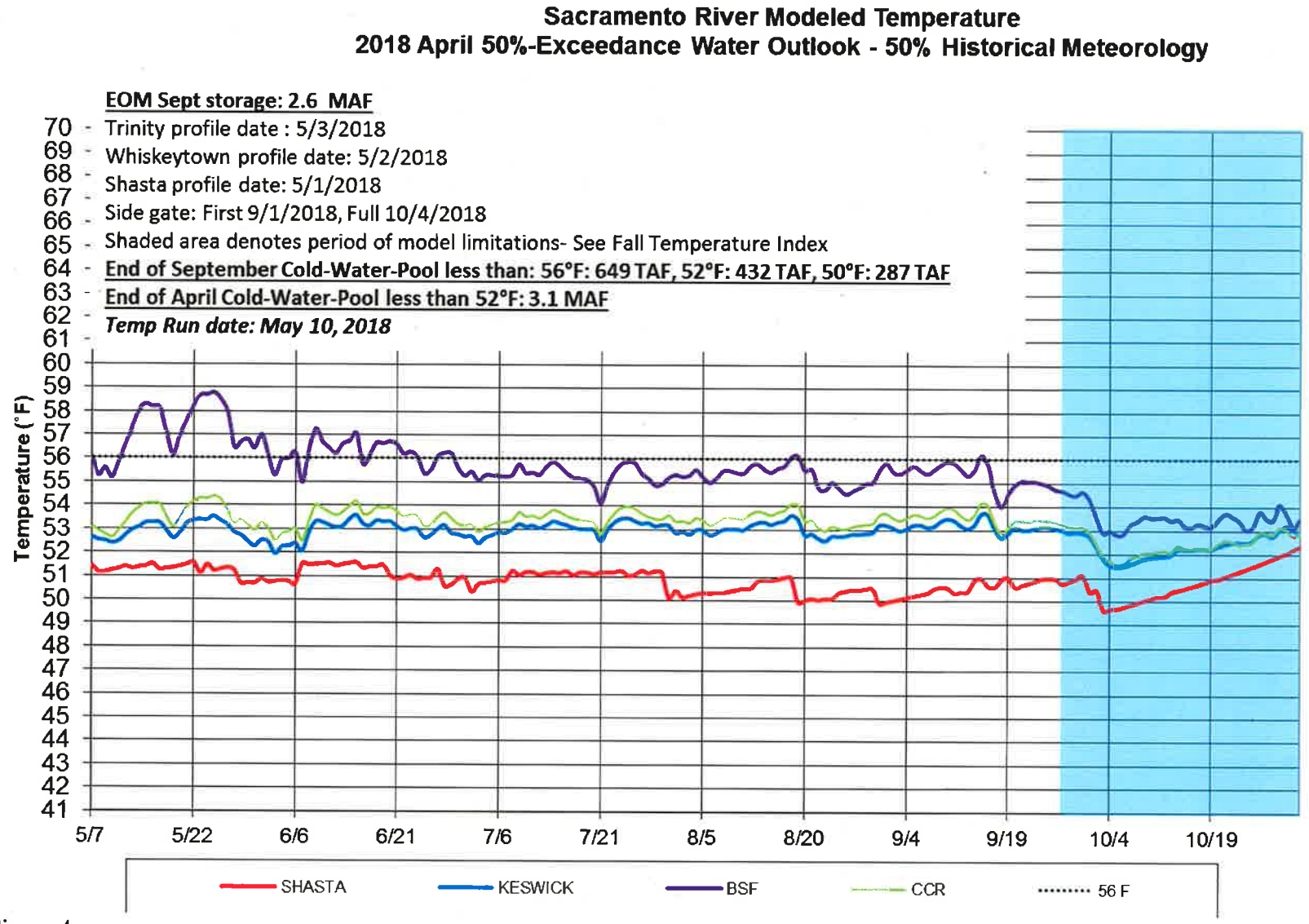
Sacramento River Modeled Temperature
2018 April 50%-Exceedance Water Outlook - 50% Historical Meteorology
EOM Sept storage: 2.6 MAF
Trinity profile date : 5/3/2018
Whiskeytown profile date: 5/2/2018
Shasta profile date: 5/1/2018
Side gate: First 9/1/2018, Full 10/4/2018
Shaded area denotes period of model limitations- See Fall Temperature Index
End of September Cold-Water-Pool less than: 56°F: 649 TAF, 52°F: 432 TAF, 50°F: 287 TAF
End of April Cold-Water-Pool less than 52°F: 3.1 MAF
Temp Run date: May 10, 2018
Temperature (°F)
70 69 68 67 66 65 64 63 62 61 60 59 58 57 56 55 54 53 52 51 50 49 48 47 46 45 44 43 42 41
5/7 5/22 6/6 6/21 7/6 7/21 8/5 8/20 9/4 9/19 10/4 10/19
SHASTA
KESWICK
BSF
CCR
56 F

Figure 4

Figures 5-7 Model Performance and Fall Temperature Index:

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 can be used as an indicator of fall water temperature in the river reach to Balls Ferry.
3. Based on these records and estimates, the index below illustrates a range of uncertainty in the ability to meet for river temperatures not to exceed 56 ˚F downstream based on the end-of-September lake volume less than 56˚F; see charts below.
4. Refinement of these estimates and concepts is currently underway.

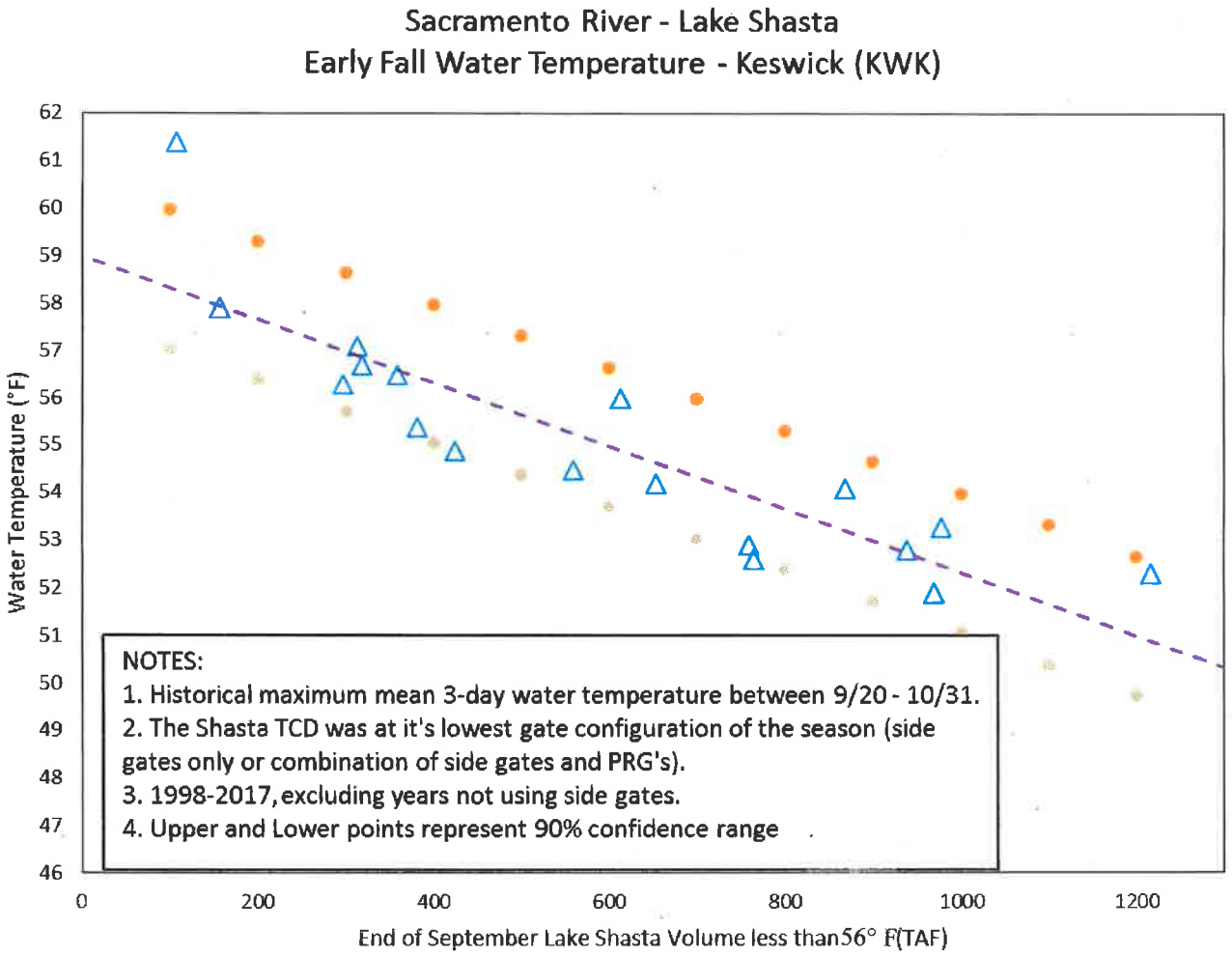
Sacramento River - Lake Shasta
Early Fall Water Temperature - Keswick (KWK)
Water Temperature (°F)
62
61
60
59
58
57
56
55
54
53
52
51
50
49
48
47
46
0
200
400
600
800
1000
1200
End of September Lake Shasta Volume less than 56° F (TAF)
NOTES:
1. Historical maximum mean 3-day water temperature between 9/20 - 10/31.
2. The Shasta TCD was at it's lowest gate configuration of the season (side gates only or combination of side gates and PRG's).
3. 1998-2017, excluding years not using side gates.
4. Upper and Lower points represent 90% confidence range

Figure 5

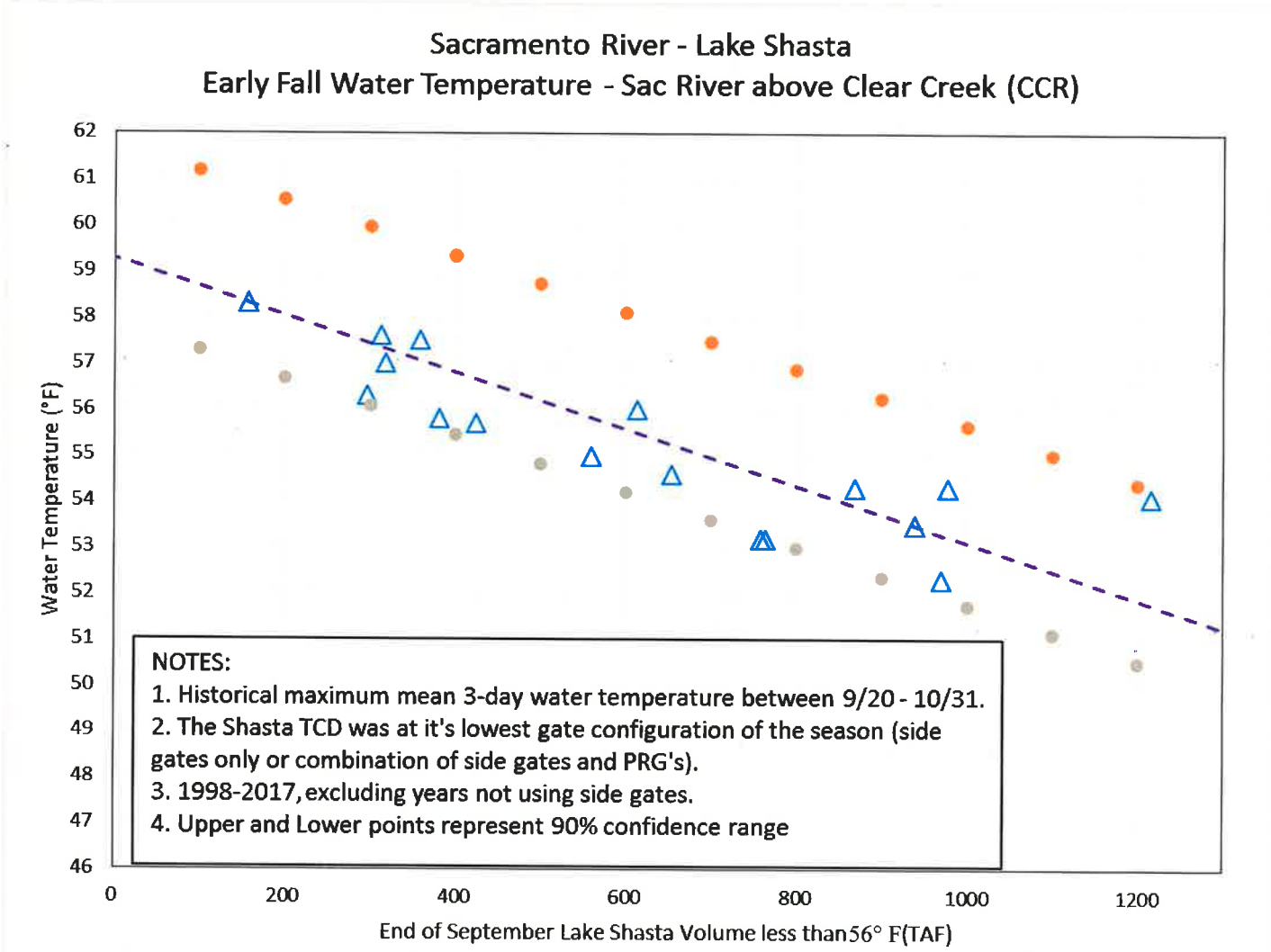
Sacramento River - Lake Shasta
Early Fall Water Temperature - Sac River above Clear Creek (CCR)
Water Temperature (°F)
62
61
60
59
58
57
56
55
54
53
52
51
50
49
48
47
46
0
200
400
600
800
1000
1200
End of September Lake Shasta Volume less than 56° F(TAF)
NOTES:
1. Historical maximum mean 3-day water temperature between 9/20 - 10/31.
2. The Shasta TCD was at it's lowest gate configuration of the season (side gates only or combination of side gates and PRG's).
3. 1998-2017, excluding years not using side gates.
4. Upper and Lower points represent 90% confidence range

Figure 6

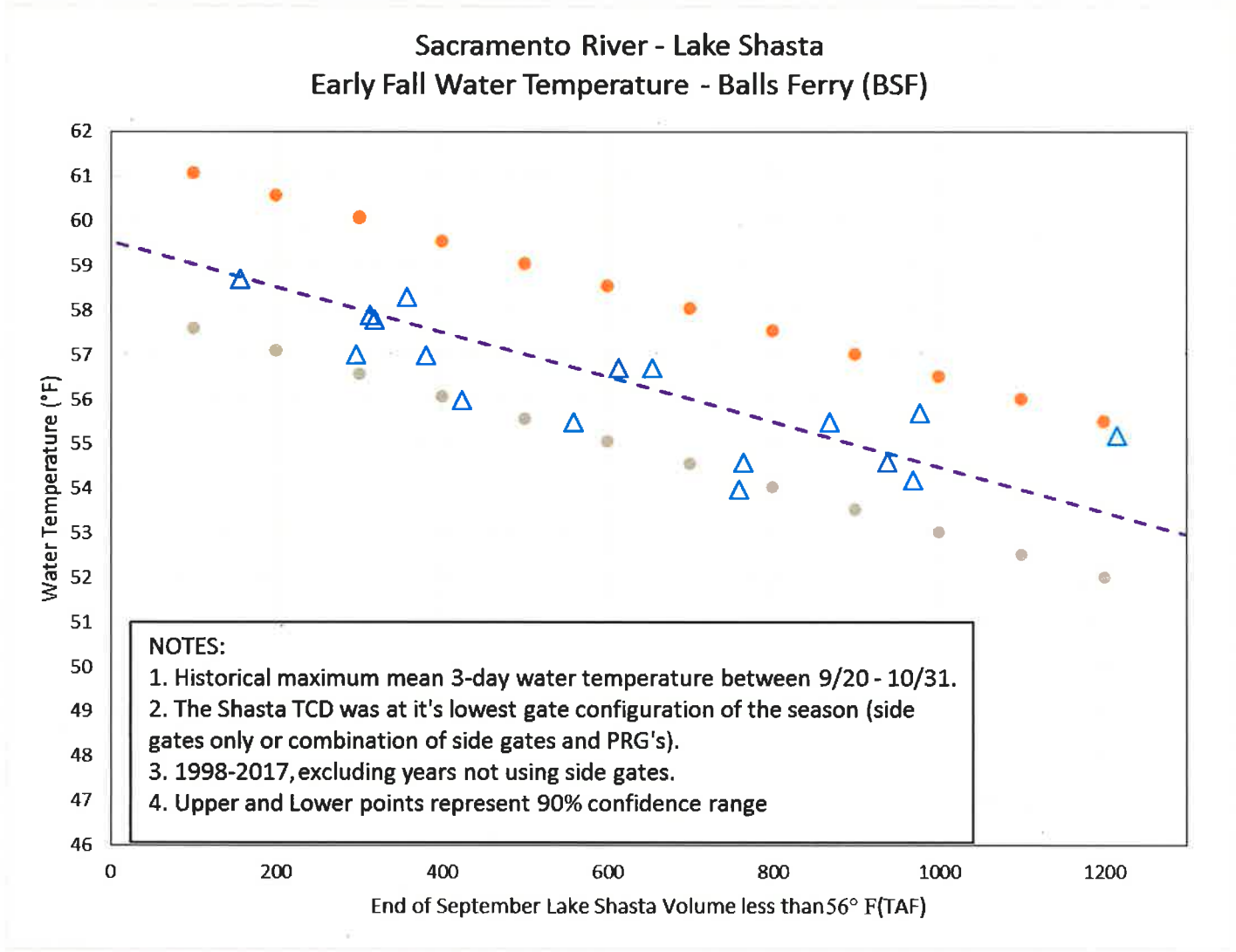
Sacramento River - Lake Shasta
Early Fall Water Temperature - Balls Ferry (BSF)
Water Temperature (°F)
62
61
60
59
58
57
56
55
54
53
52
51
50
49
48
47
46
0
200
400
600
800
1000
1200
End of September Lake Shasta Volume less than 56° F(TAF)
NOTES:
1. Historical maximum mean 3-day water temperature between 9/20 - 10/31.
2. The Shasta TCD was at it's lowest gate configuration of the season (side gates only or combination of side gates and PRG's).
3. 1998-2017, excluding years not using side gates.
4. Upper and Lower points represent 90% confidence range

Figure 7

May 10, 2018

Upper Sacramento River – April 2018 Preliminary Temperature Analysis

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

Location	MAY	JUN	JUL	AUG	SEP	OCT	Late Sep-Oct Uncertainty Estimation
April 90%-Exceedance Outlook – 10% Historical Meteorology 53°F CCR (May) 56°F BSF (Jun-Oct)							
Keswick Dam KWK	52.3	52.3	53.5	53.6	53.5	52.4	54 - 57
Sac. R. abv Clear Creek CCR	53.0	53.0	54.0	54.1	53.9	52.5	54 - 58
Balls Ferry BSF	56.8	56.0	56.0	56.0	55.6	53.7	55 - 58
April 90%-Exceedance Outlook – 50% Historical Meteorology 53°F CCR (May) 56°F BSF (Jun-Oct)							
Keswick Dam KWK	52.4	52.7	53.8	53.6	53.2	52.0	53 - 56
Sac. R. abv Clear Creek CCR	53.0	53.2	54.2	54.0	53.6	52.1	54 - 57
Balls Ferry BSF	56.4	56.0	56.0	55.9	55.3	53.2	55 - 58
April 50%-Exceedance Outlook – 10% Historical Meteorology 53°F CCR (May) 56°F BSF (Jun-Oct)							
Keswick Dam KWK	52.3	52.3	53.4	53.6	53.6	52.4	53 - 56
Sac. R. abv Clear Creek CCR	53.0	53.0	53.9	54.1	54.0	52.5	54 - 58
Balls Ferry BSF	57.0	56.0	55.9	56.0	55.8	53.7	55 - 58
April 50%-Exceedance Outlook – 50% Historical Meteorology 53°F CCR (May) 56°F BSF (Jun-Oct)							
Keswick Dam KWK	52.3	52.7	53.8	53.8	53.4	52.0	53 - 56
Sac. R. abv Clear Creek CCR	53.0	53.2	54.2	54.2	53.7	52.1	54 - 57
Balls Ferry BSF	56.5	56.0	56.0	56.0	55.4	53.2	55 - 58

* The HEC5Q model output is displayed above for the months April through October. 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, an uncertainty estimate is provided based on the Fall Temperature Index (graphics below). This is based on a historical relationship between end-of-September Lake Shasta Volume less than 56°F and likely downstream temperature performances for the early fall months. The range represents the 90% confidence interval based on that data. Refinement of the concepts for those estimates is underway.

Temperature Model Inputs, Assumptions, Limitations and Uncertainty:

1. The latest available profiles for Shasta, Trinity, and Whiskeytown were taken on May 1, May 3, and May 2 respectively. Model results are sensitive to initial reservoir temperature conditions and the model performs best under highly stratified conditions. The model performs well after the reservoir stratifies, typically in late spring. 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.
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 can cause significant additional warming in the upper Sacramento River during spring.
3. Operation is based on the April 2018 Operation Outlooks and DWR Bulletin 120 inflow projections (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 the 90% runoff exceedance studies. The April 2018 Operation Outlook is modified to adjust for real-time operations in early May suggesting the monthly Keswick release may average closer to 8,500 cfs.
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 95% 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, or as noted. Assumed inflow temperature remain static inputs and do not vary with the assumed meteorology.

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.
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. Model re-calibrations efforts are underway.

Model Run Date May 10, 2018

Temperature Analysis Results:

Modeling runs explore Sacramento River compliance performance above Clear Creek confluence and Balls Ferry locations by varying hydrology and temperature compliance target location and temperature. The temperature results for the Sacramento River between Keswick Dam and Balls Ferry are shown in Figures 1-4. The fall uncertainty estimation relationship between end-of-September lake volume below 56°F and a Balls Ferry compliance through fall is based on the Figures 5-7.

Model Run	End of September Cold Water Pool <56°F (TAF)	First Side Gate	Full Side Gates
(1) 90% Hydro, 10% Historical Met 53 CCR (May) & 56 BSF (Jun-Oct)	618	9/8	10/5
(2) 90% Hydro, 50% Historical Met 53 CCR (May) & 56 BSF (Jun-Oct)	707	9/13	10/14
(3) 50% Hydro, 10% Historical Met 53 CCR (May) & 56 BSF (Jun-Oct)	641	9/8	10/7
(4) 50% Hydro, 50% Historical Met 53 CCR (May) & 56 BSF (Jun-Oct)	707	9/18	10/14

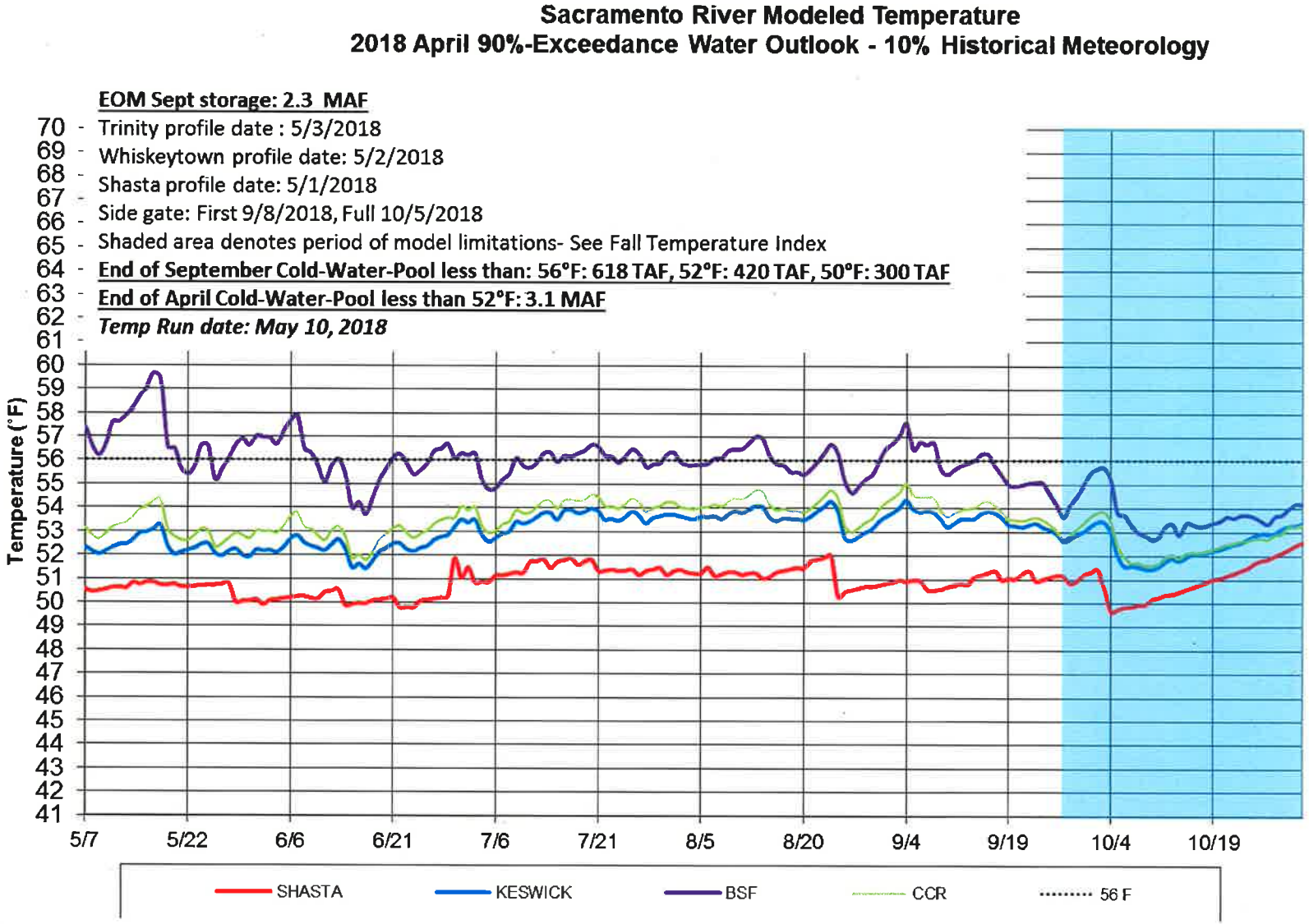
Sacramento River Modeled Temperature
2018 April 90%-Exceedance Water Outlook - 10% Historical Meteorology
EOM Sept storage: 2.3 MAF
Trinity profile date : 5/3/2018
Whiskeytown profile date: 5/2/2018
Shasta profile date: 5/1/2018
Side gate: First 9/8/2018, Full 10/5/2018
Shaded area denotes period of model limitations- See Fall Temperature Index
End of September Cold-Water-Pool less than: 56°F: 618 TAF, 52°F: 420 TAF, 50°F: 300 TAF
End of April Cold-Water-Pool less than 52°F: 3.1 MAF
Temp Run date: May 10, 2018
Temperature (°F)
70
69
68
67
66
65
64
63
62
61
60
59
58
57
56
55
54
53
52
51
50
49
48
47
46
45
44
43
42
41
5/7
5/22
6/6
6/21
7/6
7/21
8/5
8/20
9/4
9/19
10/4
10/19
SHASTA
KESWICK
BSF
CCR
56 F

Figure 1

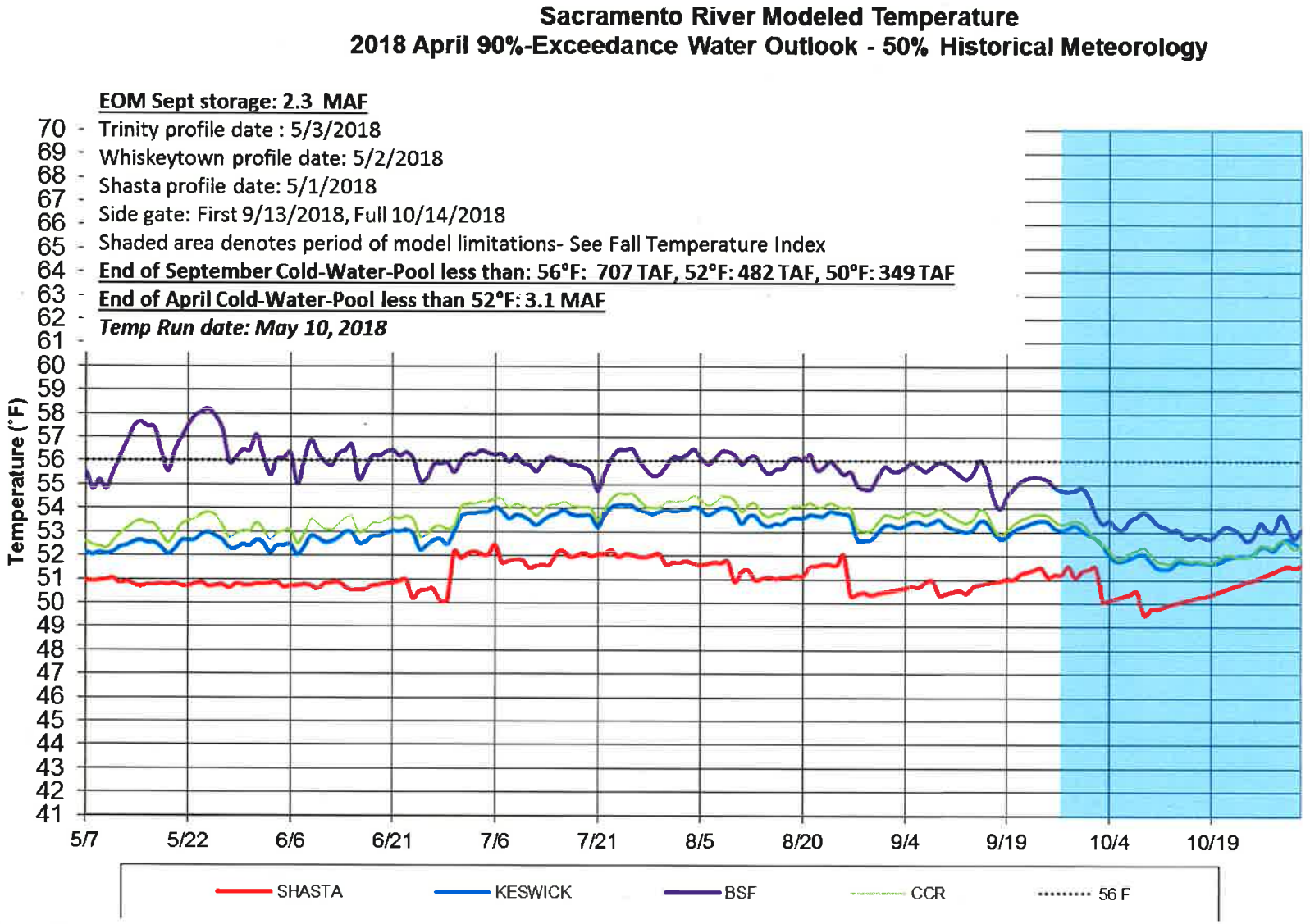
Sacramento River Modeled Temperature
2018 April 90%-Exceedance Water Outlook - 50% Historical Meteorology
EOM Sept storage: 2.3 MAF
Trinity profile date : 5/3/2018
Whiskeytown profile date: 5/2/2018
Shasta profile date: 5/1/2018
Side gate: First 9/13/2018, Full 10/14/2018
Shaded area denotes period of model limitations- See Fall Temperature Index
End of September Cold-Water-Pool less than: 56°F: 707 TAF, 52°F: 482 TAF, 50°F: 349 TAF
End of April Cold-Water-Pool less than 52°F: 3.1 MAF
Temp Run date: May 10, 2018
Temperature (°F)
70
69
68
67
66
65
64
63
62
61
60
59
58
57
56
55
54
53
52
51
50
49
48
47
46
45
44
43
42
41
5/7
5/22
6/6
6/21
7/6
7/21
8/5
8/20
9/4
9/19
10/4
10/19
SHASTA
KESWICK
BSF
CCR
56 F

Figure 2

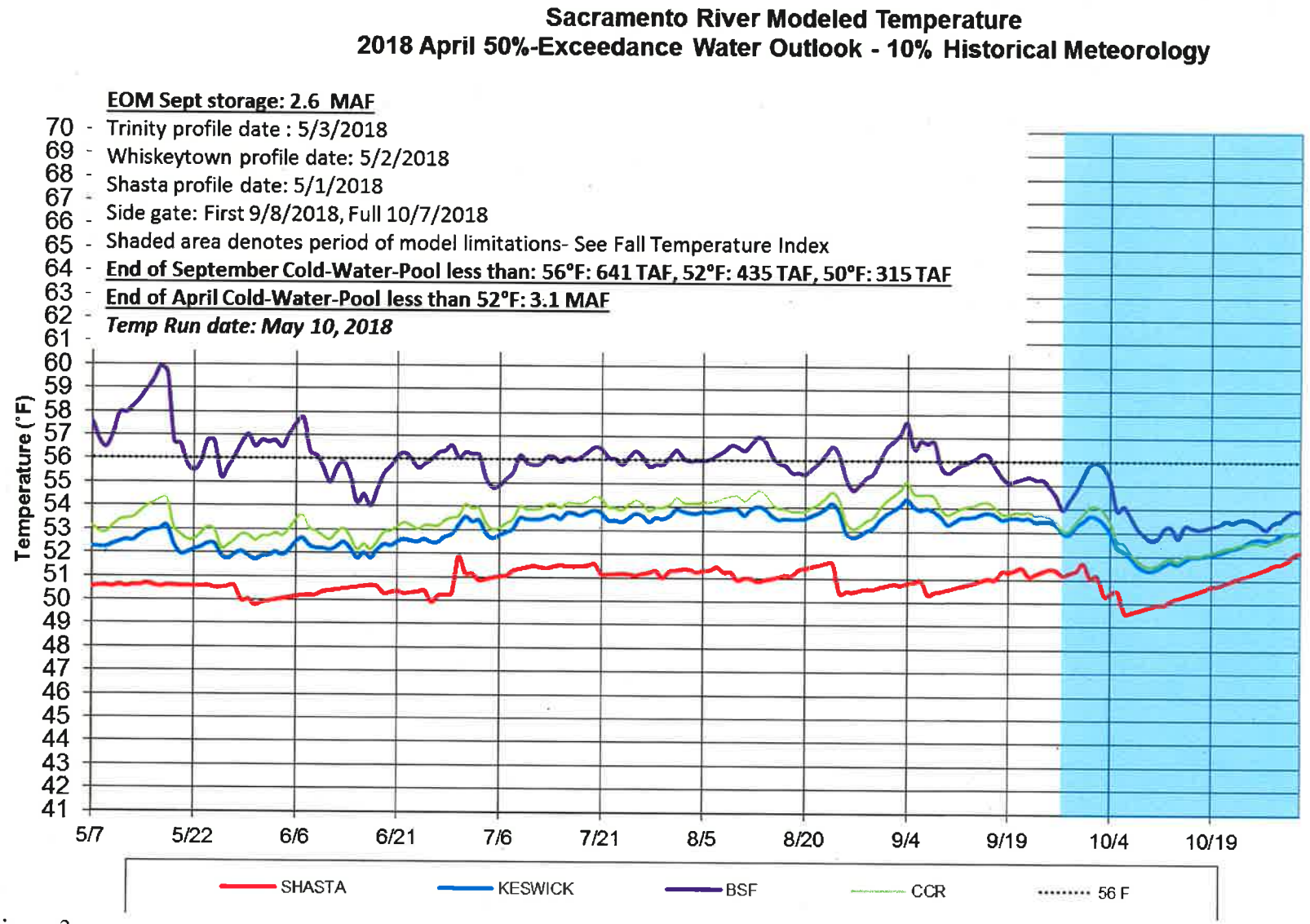
Sacramento River Modeled Temperature
2018 April 50%-Exceedance Water Outlook - 10% Historical Meteorology
EOM Sept storage: 2.6 MAF
Trinity profile date : 5/3/2018
Whiskeytown profile date: 5/2/2018
Shasta profile date: 5/1/2018
Side gate: First 9/8/2018, Full 10/7/2018
Shaded area denotes period of model limitations- See Fall Temperature Index
End of September Cold-Water-Pool less than: 56°F: 641 TAF, 52°F: 435 TAF, 50°F: 315 TAF
End of April Cold-Water-Pool less than 52°F: 3.1 MAF
Temp Run date: May 10, 2018
Temperature (°F)
70 69 68 67 66 65 64 63 62 61 60 59 58 57 56 55 54 53 52 51 50 49 48 47 46 45 44 43 42 41
5/7 5/22 6/6 6/21 7/6 7/21 8/5 8/20 9/4 9/19 10/4 10/19
SHASTA
KESWICK
BSF
CCR
56 F

Figure 3

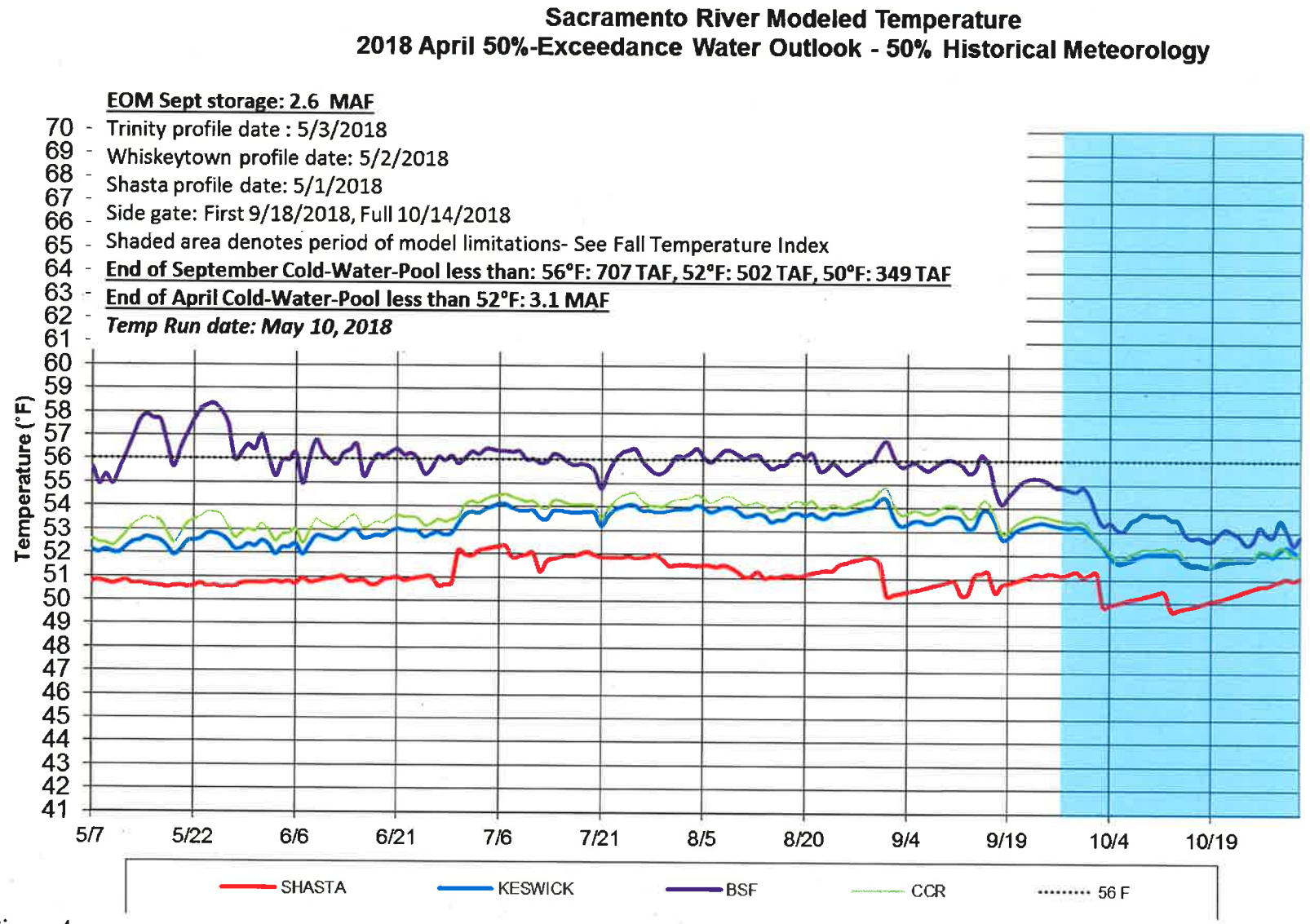
Sacramento River Modeled Temperature
2018 April 50%-Exceedance Water Outlook - 50% Historical Meteorology
EOM Sept storage: 2.6 MAF
Trinity profile date : 5/3/2018
Whiskeytown profile date: 5/2/2018
Shasta profile date: 5/1/2018
Side gate: First 9/18/2018, Full 10/14/2018
Shaded area denotes period of model limitations- See Fall Temperature Index
End of September Cold-Water-Pool less than: 56°F: 707 TAF, 52°F: 502 TAF, 50°F: 349 TAF
End of April Cold-Water-Pool less than 52°F: 3.1 MAF
Temp Run date: May 10, 2018
Temperature (°F)
70 69 68 67 66 65 64 63 62 61 60 59 58 57 56 55 54 53 52 51 50 49 48 47 46 45 44 43 42 41
5/7 5/22 6/6 6/21 7/6 7/21 8/5 8/20 9/4 9/19 10/4 10/19
SHASTA
KESWICK
BSF
CCR
56 F

Figure 4

Figures 5-7 Model Performance and Fall Temperature Index:

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 can be used as an indicator of fall water temperature in the river reach to Balls Ferry.
3. Based on these records and estimates, the index below illustrates a range of uncertainty in the ability to meet for river temperatures not to exceed 56 ˚F downstream based on the end-of-September lake volume less than 56˚F; see charts below.
4. Refinement of these estimates and concepts is currently underway.

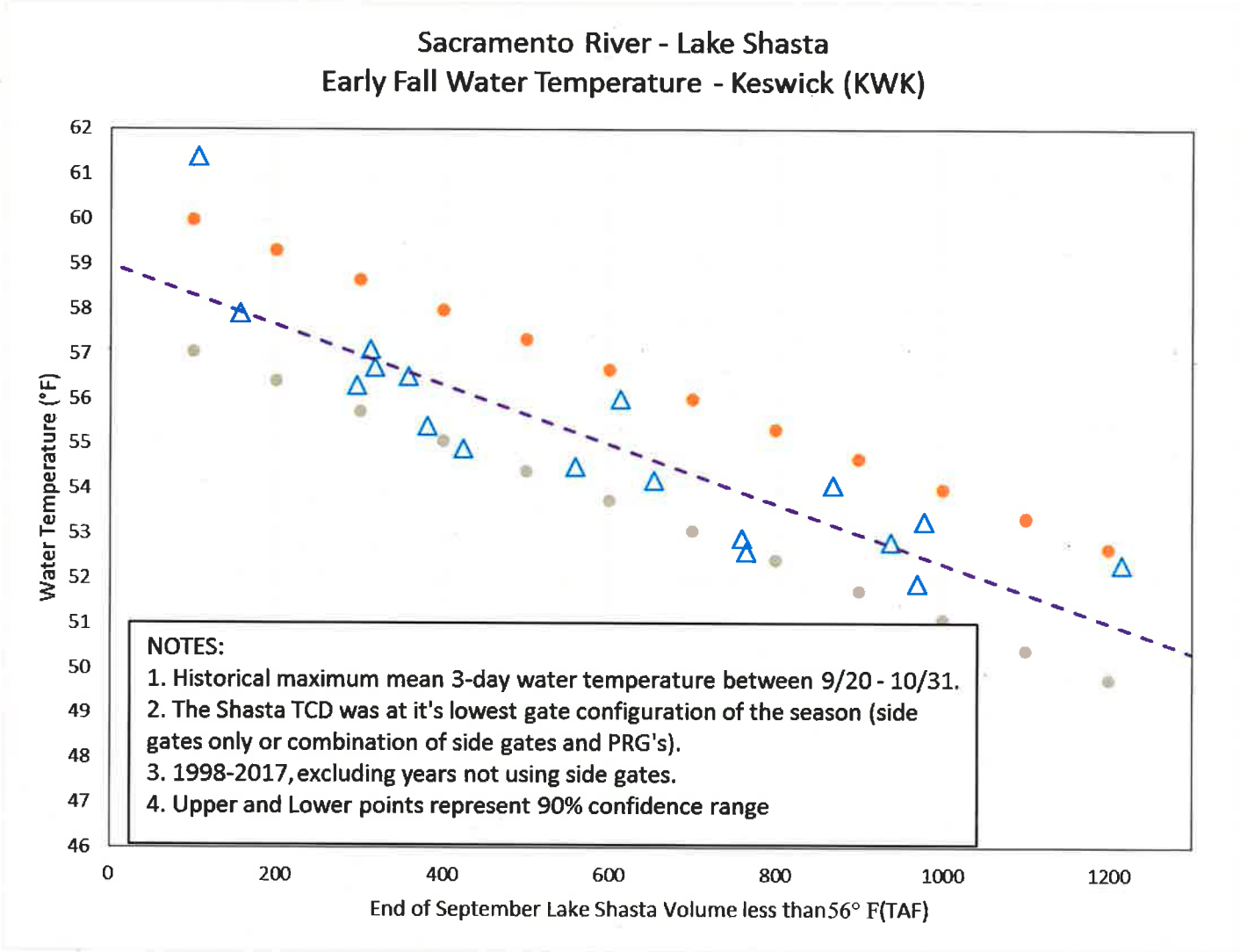
Sacramento River - Lake Shasta
Early Fall Water Temperature - Keswick (KWK)
Water Temperature (°F)
62
61
60
59
58
57
56
55
54
53
52
51
50
49
48
47
46
0
200
400
600
800
1000
1200
End of September Lake Shasta Volume less than 56° F(TAF)
NOTES:
1. Historical maximum mean 3-day water temperature between 9/20 - 10/31.
2. The Shasta TCD was at it's lowest gate configuration of the season (side gates only or combination of side gates and PRG's).
3. 1998-2017, excluding years not using side gates.
4. Upper and Lower points represent 90% confidence range

Figure 5

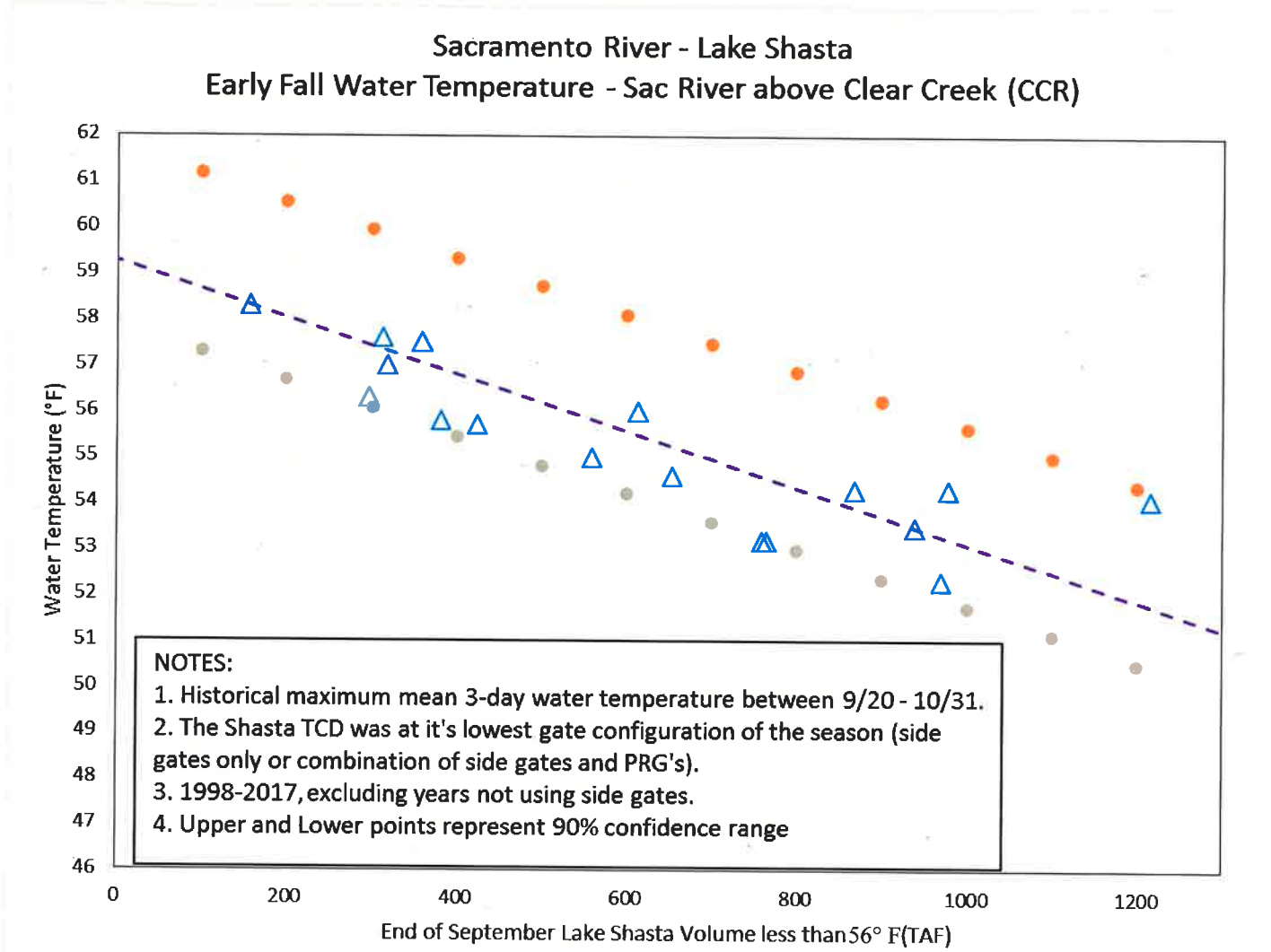
Sacramento River - Lake Shasta
Early Fall Water Temperature - Sac River above Clear Creek (CCR)
Water Temperature (°F)
62
61
60
59
58
57
56
55
54
53
52
51
50
49
48
47
46
0
200
400
600
800
1000
1200
End of September Lake Shasta Volume less than 56° F(TAF)
NOTES:
1. Historical maximum mean 3-day water temperature between 9/20 - 10/31.
2. The Shasta TCD was at it's lowest gate configuration of the season (side gates only or combination of side gates and PRG's).
3. 1998-2017, excluding years not using side gates.
4. Upper and Lower points represent 90% confidence range

Figure 6

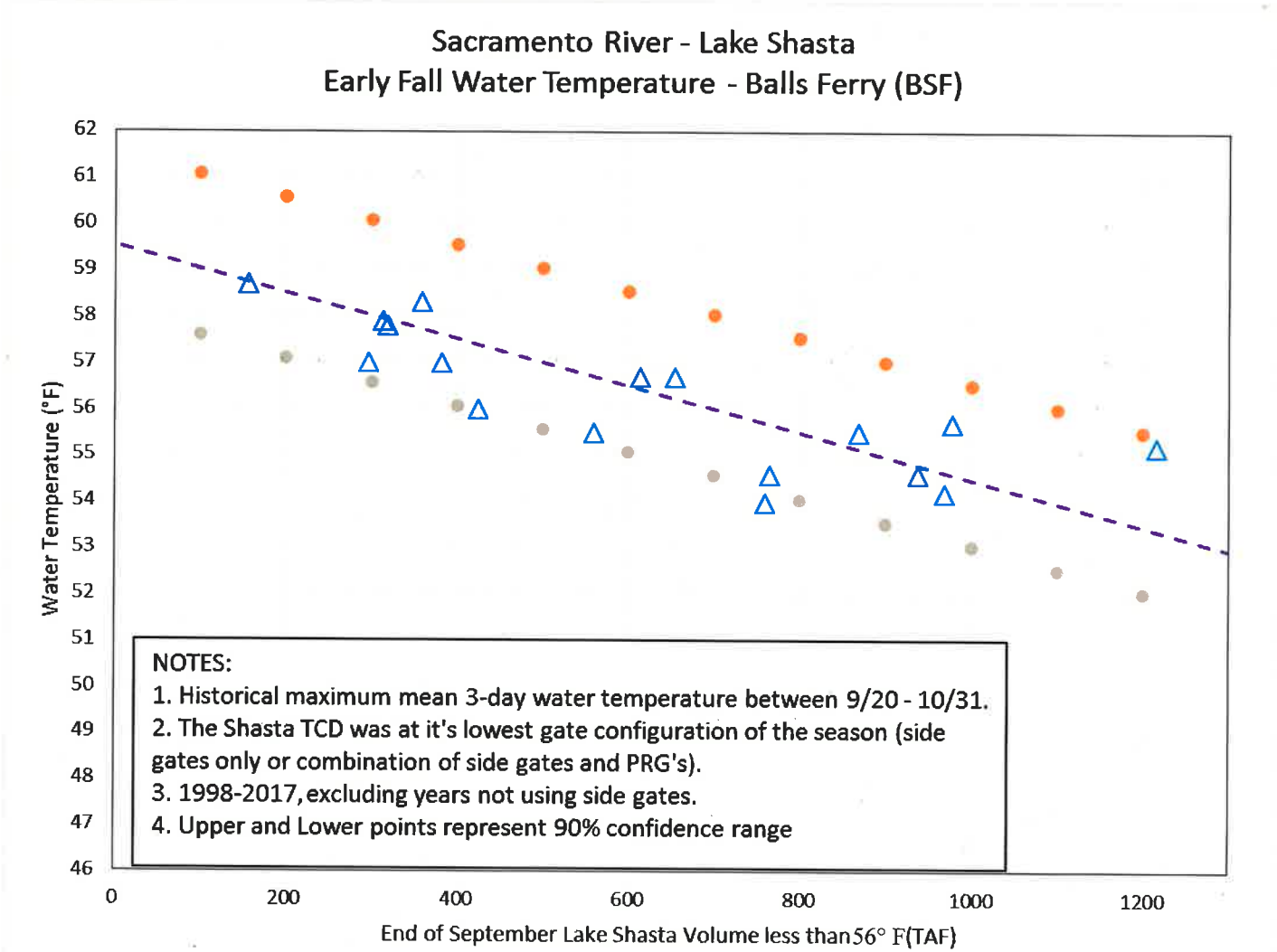
Sacramento River - Lake Shasta
Early Fall Water Temperature - Balls Ferry (BSF)
Water Temperature (°F)
62
61
60
59
58
57
56
55
54
53
52
51
50
49
48
47
46
0
200
400
600
800
1000
1200
End of September Lake Shasta Volume less than 56° F (TAF)
NOTES:
1. Historical maximum mean 3-day water temperature between 9/20 - 10/31.
2. The Shasta TCD was at it's lowest gate configuration of the season (side gates only or combination of side gates and PRG's).
3. 1998-2017, excluding years not using side gates.
4. Upper and Lower points represent 90% confidence range

Figure 7

Printed: 2018.05.11

2018 Shasta Cold Water Pool Volume ≤49°F