UNITED STATES DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
NATIONAL MARINE FISHERIES SERVICE
West Coast Region
650 Capitol Mall, Suite 5-100
Sacramento, California 95814-4700

March 15, 2019

Mr. Jeff Rieker
Operations Manager, Central Valley Project
U.S. Bureau of Reclamation
3310 El Camino Avenue, Suite 300
Sacramento, California 95821

Re: Transmittal of March Reservoir Operations Forecast Per RPA I.2.3

Dear Mr. Rieker:

Thank you for the opportunity to review the U.S. Bureau of Reclamation's (Reclamation) March forecast water year 2019. Your March 13, 2019, letter included the results of the 90 and 50 percent exceedance Central Valley Project (CVP) reservoir operations forecasts and water temperature modeling. For purposes of compliance with NMFS' June 4, 2009, conference and biological opinion on the long-term operation of the CVP and State Water Project (SWP, CVP/SWP operations Opinion) reasonable and prudent alternative (RPA) Action I.2.3.B(3), described in NOAA's National Marine Fisheries Service's (NMFS) April 7, 2011, amendment of the 2009 RPA[1], Reclamation is required to consult with NMFS monthly on Keswick releases. Reclamation is required to submit a projected forecast, including monthly average release schedules and temperature compliance point to NMFS every month. The objective is to use a conservative forecast to protect the cold water pool in Shasta Reservoir so that suitable spawning and egg/alevin incubation habitat can be maintained in the Sacramento River during the summer and fall season for federally listed endangered Sacramento River winter-run Chinook salmon (*Oncorhynchus tshawytscha*), and threatened Central Valley spring-run Chinook salmon (*O. tshawytscha*).

The March 2019 CVP reservoir operations forecast was based on estimated runoff within the Sacramento River basin as of March 1, 2019, and was able to reflect the wetter hydrology experienced throughout February. This is in comparison to the February forecast that did not capture the wetter hydrology throughout the first part of that month.

NMFS has reviewed Reclamation's March 2019 CVP reservoir operations forecasts (Enclosure 1) and corresponding water temperature model runs for the Sacramento River (Enclosure 2). All four temperature model runs show a high likelihood of meeting a 56°F daily average temperature at the Balls Ferry temperature compliance point. As Reclamation's March

[1] http://www.westcoast.fisheries.noaa.gov/publications/Central_Valley/Water%20Operations/Operations,%20Criteria%20and%20Plan/040711_ocap_opinion_2011_amendments.pdf

13, 2019, letter noted, the temperature model runs illustrate good early-season temperature performance upstream of the CCR California Data Exchange Center gaging station, but the possibility during limited time periods in the April and May timeframe of challenges meeting a 56°F daily average temperature at the Balls Ferry. These modeling results are due to the model projecting extremely warn runoff from local creeks downstream of Clear Creek (such as Cow Creek) towards the end of spring runoff season. The Sacramento River Temperature Task Group and NMFS will be available to discuss and assist Reclamation in managing water temperatures during that time period. In addition, winter-run typically do not begin spawning in the upper Sacramento River until at least approximately mid-May. In addition, all four operational scenarios reflect full side gate operation ranging from October 24 to November 3. Delaying full side gate operation into October is preferable to be able to control water temperatures into the fall. These dates are compared to the temperature model runs in the February forecast, where full side gate operations were projected as early as September 1, granted, these full side gate operation dates utilized a 10% exceedance meteorological conditions rather than the 30% exceedance meteorological conditions in the March forecast. Finally, the 90% exceedance forecast projects an end of September Shasta Reservoir storage of 3.019 million acre-feet.

NMFS maintains that the results of the temperature-dependent egg mortality model provide valuable relative comparisons of mortality across various scenarios, and are not intended to be absolute projections/forecasts of egg mortality. Therefore, NMFS thinks that use of the temperature-dependent egg mortality model continues to be a useful tool to compare potential effects of various scenarios and forecasted operations. The NMFS-Southwest Fisheries Science Center (SWFSC) has provided temperature-dependent mortality estimates using Reclamation's HEC-5Q model and the NOAA CE-QUAL-W2 reservoir model (Enclosure 3). The following table provide the results from the temperature-dependent mortality model using outputs from the RAFT model.

March 2019 Hydrological Exceedance Forecast	**Meteorological Exceedance Forecast**	**Percent Temperature-Dependent Egg Mortality**		
		Mean	**Median**	**95% Confidence Interval**
50%	30%	16.03%	9.31%	0.08 - 61.49%
50%	50%	12.34%	4.47%	0.08 - 57.02%
90%	30%	8.29%	0.95%	0.04 – 52.25%
90%	50%	6.55%	0.46	0.01 – 47.02%

The following table provide the results from the temperature-dependent mortality model using outputs from the HEC-5Q model.

March 2019 Hydrological Exceedance Forecast	**Meteorological Exceedance Forecast**	**Percent Temperature-Dependent Egg Mortality**		
		Mean	**Median**	**95% Confidence Interval**
50%	30%	14.05%	6.55%	0.08 - 59.18%
50%	50%	10.49%	2.16%	0.08 - 54.56%
90%	30%	7.27%	0.47%	0.08 - 50.19%
90%	50%	5.6%	0.17%	0.08 - 44.93%

The above temperature-dependent mortality model results, regardless of hydrological exceedance forecast, meteorological exceedance forecast, or reservoir model, all show considerably lower temperature-dependent egg mortality compared to those in the February forecast.

The above, and enclosures, indicate that temperature management in the Sacramento River fits within RPA Action I.2.3.A., however, NMFS offers the following observations and recommendations:

- NMFS continues to be concerned about Keswick releases in the fall and their potential to dewater winter-run Chinook salmon redds prior to complete fry emergence, and also fall-run Chinook salmon redd dewatering in the late fall and into the winter. NMFS will work with Reclamation to minimize the potential for winter-run Chinook salmon redd dewatering until complete emergence, and also to stabilize flows for fall-run Chinook salmon spawning and egg incubation.
- Reclamation and NMFS staff had initial discussions regarding the use of conservative forecasted meteorological conditions in the temperature model runs. As Reclamation indicated, from those meetings, the agencies recognize the need to continue discussions and evaluations of this issue. Given the climate projections provided in NMFS' February 19, 2019, response to Reclamation's February forecast, NMFS and Reclamation agreed that a 30 percent meteorology represents a likely scenario for this summer, and therefore, not necessarily a conservative one. Therefore, until Reclamation and NMFS resolve the issue and agree on a conservative meteorology, NMFS requests including a 10 percent meteorology in addition to 30 and 50 percent.
- NMFS recommends that Reclamation continue to coordinate with NMFS staff and NMFS-SWFSC to implement a spring pulse flow from Keswick Dam, timed with the release of acoustically-tagged spring-run Chinook salmon from the tributaries.
- In the coming months, as NMFS assists Reclamation in the development of the Sacramento River Temperature Management Plan, NMFS will be seeking another operational study year to target meeting a daily average temperature of 53.5°F or less at CCR, while maintaining Balls Ferry as the temperature compliance point.

If you have any questions regarding this letter, please feel free to contact me, or have your staff contact Mr. Garwin Yip at (916) 930-3611, or via e-mail at Garwin.yip@noaa.gov.

Sincerely,

Maria Rea

Maria Rea
Assistant Regional Administrator

Enclosures:

1. 90 and 50 percent exceedance forecasts (2 pages)

2. Preliminary temperature analysis based on four scenarios cross-factoring 90 and 50 percent exceedance hydrology with 30 and 50 percent exceedance meteorology (18 pages)
3. RAFT and temperature-dependent mortality model results for the 4 forecast and meteorology scenarios (6 pages)

cc: ARN: 151422SWR2006SA00268

Enclosure 1

Estimated CVP Operations 90% Exceedance

Storages

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

		Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb
Trinity	**1739**	**1867**	**1945**	**1989**	**1959**	**1821**	**1669**	**1540**	**1508**	**1489**	**1499**	**1531**	**1616**
	Elev.	2332	2337	2340	2338	2328	2317	2306	2304	2302	2303	2306	2313
Whiskeytown	**247**	**206**	**238**	**238**	**238**	**238**	**238**	**238**	**206**	**206**	**206**	**206**	**206**
	Elev.	1199	1209	1209	1209	1209	1209	1209	1199	1199	1199	1199	1199
Shasta	**3948**	**3963**	**4350**	**4398**	**4127**	**3683**	**3378**	**3194**	**3019**	**2929**	**2982**	**3133**	**3438**
	Elev.	1046	1060	1062	1052	1036	1024	1016	1009	1005	1007	1014	1026
Folsom	**598**	**738**	**878**	**964**	**952**	**787**	**643**	**560**	**460**	**381**	**319**	**320**	**382**
	Elev.	443	457	465	464	448	433	424	411	400	390	391	400
New Melones	**2005**	**1875**	**1845**	**1873**	**1885**	**1818**	**1749**	**1709**	**1663**	**1674**	**1688**	**1700**	**1644**
	Elev.	1041	1038	1041	1042	1035	1029	1025	1020	1021	1023	1024	1018
San Luis	**921**	**966**	**823**	**587**	**425**	**225**	**75**	**86**	**210**	**287**	**504**	**664**	**796**
	Elev.	543	517	478	449	411	382	380	386	395	434	460	478
Total		9615	10080	10049	9586	8572	7750	7327	7064	6965	7198	7553	8081

Monthly River Releases (TAF/cfs)

Trinity	TAF	18	32	258	126	68	53	52	23	18	18	18	17
	cfs	**300**	**540**	**4,189**	**2,120**	**1,102**	**857**	**870**	**373**	**300**	**300**	**300**	**300**
Clear Creek	TAF	12	13	13	17	9	9	9	12	12	12	12	11
	cfs	**200**	**218**	**216**	**288**	**150**	**150**	**150**	**200**	**200**	**200**	**200**	**200**
Sacramento	TAF	1229	327	443	625	738	566	416	428	352	277	246	222
	cfs	**20000**	**5500**	**7200**	**10500**	**12000**	**9200**	**7000**	**6955**	**5909**	**4500**	**4000**	**4000**
American	TAF	430	238	314	238	258	234	169	135	119	123	111	100
	cfs	**7000**	**4000**	**5100**	**4000**	**4200**	**3811**	**2849**	**2202**	**2000**	**2000**	**1800**	**1800**
Stanislaus	TAF	277	83	92	56	18	18	18	49	12	12	14	83
	cfs	**4500**	**1400**	**1500**	**940**	**300**	**300**	**300**	**797**	**200**	**200**	**232**	**1500**

Trinity Diversions (TAF)

	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb
Carr PP	2	55	17	75	100	101	70	18	21	12	3	2
Spring Crk. PP	**50**	**25**	**10**	**60**	**90**	**90**	**60**	**40**	**15**	**12**	**10**	**20**

Delta Summary (TAF)

		Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb
Tracy		199	54	55	255	268	240	259	270	150	270	220	230
USBR Banks		0	0	0	0	24	24	24	0	0	0	0	0
Contra Costa		12.7	12.7	12.7	9.8	11.1	12.7	14.0	16.8	18.4	18.3	14.0	14.0
Total USBR		212	66	68	265	303	277	297	287	168	288	234	244
Total Export		387	102	105	445	500	511	513	413	318	528	394	404
COA Balance		0	0	0	0	0	0	0	9	9	9	9	9
Old/Middle River Std.													
Old/Middle R. calc.		-239	581	-110	-5,221	-6,207	-6,340	-6,565	-5,058	-4,258	-6,656	-4,959	-4,950
Computed DOI		80214	29030	20952	11145	8004	5694	7094	7109	7682	6849	11778	12139
Excess Outflow		66517	7531	9549	1748	0	0	0	0	588	2342	5775	738
% Export/Inflow		7%	5%	6%	34%	39%	46%	46%	42%	37%	54%	36%	38%
% Export/Inflow std.		35%	35%	35%	35%	65%	65%	65%	65%	65%	65%	65%	45%

Hydrology

	Trinity		Shasta		Folsom		New Melones	
Water Year Inflow (TAF)	1259		5,962		3,167		1264	
Year to Date + Forecasted % of mean	104%		108%		116%		120%	

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.

3/13/2019

Estimated CVP Operations 50% Exceedance

Storages

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

		Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb
Trinity	**1739**	**1904**	**2065**	**2079**	**2029**	**1891**	**1744**	**1606**	**1580**	**1567**	**1594**	**1658**	**1769**
	Elev.	2334	2345	2346	2343	2333	2322	2312	2310	2309	2311	2316	2324
Whiskeytown	**247**	**206**	**238**	**238**	**238**	**238**	**238**	**238**	**206**	**206**	**206**	**206**	**206**
	Elev.	1199	1209	1209	1209	1209	1209	1209	1199	1199	1199	1199	1199
Shasta	**3948**	**3899**	**4382**	**4542**	**4365**	**3986**	**3672**	**3397**	**3235**	**3254**	**3339**	**3638**	**3955**
	Elev.	1044	1061	1067	1061	1047	1035	1025	1018	1019	1022	1034	1046
Folsom	**598**	**725**	**875**	**964**	**961**	**855**	**748**	**605**	**496**	**466**	**455**	**483**	**495**
	Elev.	442	457	465	465	455	444	429	416	412	411	414	416
New Melones	**2005**	**1871**	**1877**	**1953**	**2026**	**2001**	**1945**	**1908**	**1864**	**1874**	**1892**	**1916**	**1962**
	Elev.	1040	1041	1048	1055	1052	1047	1044	1040	1041	1042	1045	1049
San Luis	**921**	**972**	**865**	**647**	**489**	**290**	**170**	**49**	**47**	**29**	**237**	**411**	**554**
	Elev.	544	521	486	471	463	451	426	414	407	446	472	497
Total		9576	10301	10424	10108	9263	8516	7803	7427	7396	7722	8312	8940

Monthly River Releases (TAF/cfs)

Trinity	TAF	18	28	258	126	68	53	52	23	18	18	18	17
	cfs	**300**	**477**	**4,189**	**2,120**	**1,102**	**857**	**870**	**373**	**300**	**300**	**300**	**300**
Clear Creek	TAF	12	13	13	17	9	9	9	12	12	12	15	11
	cfs	**200**	**218**	**216**	**288**	**150**	**150**	**150**	**200**	**200**	**200**	**240**	**200**
Sacramento	TAF	1414	416	492	595	707	615	565	430	297	307	307	444
	cfs	**23000**	**7000**	**8000**	**10000**	**11500**	**10000**	**9500**	**7000**	**5000**	**5000**	**5000**	**8000**
American	TAF	492	387	461	357	248	215	250	184	119	123	123	250
	cfs	**8000**	**6500**	**7500**	**6000**	**4030**	**3500**	**4200**	**3000**	**2003**	**2000**	**2000**	**4500**
Stanislaus	TAF	277	97	120	65	26	25	24	52	18	18	22	20
	cfs	**4500**	**1633**	**1958**	**1100**	**429**	**400**	**400**	**842**	**300**	**300**	**358**	**364**

Trinity Diversions (TAF)

	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb
Carr PP	4	51	1	71	99	100	89	13	25	12	0	2
Spring Crk. PP	**70**	**30**	**2**	**60**	**90**	**90**	**80**	**35**	**20**	**15**	**20**	**35**

Delta Summary (TAF)

		Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb
Tracy		200	89	74	259	270	270	128	145	55	260	235	240
USBR Banks		0	0	0	0	24	24	24	0	0	0	0	0
Contra Costa		12.7	12.7	12.7	9.8	11.1	12.7	14.0	16.8	18.4	18.3	14.0	14.0
Total USBR		213	102	86	269	305	307	166	162	73	278	249	254
Total Export		433	161	136	528	706	577	266	237	173	538	424	464
COA Balance		0	0	0	0	73	73	70	70	70	70	70	70
Old/Middle River Std.													
Old/Middle R. calc.		136	1,881	1,094	-5,996	-8,583	-6,975	-3,172	-2,606	-2,041	-6,532	-4,971	-5,045
Computed DOI		95993	48781	33982	17314	8004	6377	16019	12266	11397	10183	16918	30707
Excess Outflow		82296	23735	13388	6051	0	2375	0	862	0	5677	10915	19307
% Export/Inflow		7%	5%	5%	30%	48%	47%	18%	20%	17%	45%	29%	21%
% Export/Inflow std.		35%	35%	35%	35%	65%	65%	65%	65%	65%	65%	65%	45%

Hydrology

	Trinity		Shasta		Folsom		New Melones	
Water Year Inflow (TAF)	1317		6,592		3,741		1512	
Year to Date + Forecasted % of mean	109%		119%		137%		143%	

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.

3/13/2019

Enclosure 2

March 13, 2019

Upper Sacramento River – March 2019 Preliminary Temperature Analysis

Location (°F DAT)	APR	MAY	JUN	JUL	AUG	SEP*	OCT*
February 90%-Exceedance Outlook – 30% Historical Meteorology							
Keswick Dam KWK	53.0	52.4	52.1	52.9	52.8	See Figures 1 and 2	See Figures 1 and 2
Sac. R. abv Clear Creek CCR	53.6	53.3	52.7	53.4	53.4	See Figures 1 and 3	See Figures 1 and 3
Balls Ferry BSF	56.6	57.6	55.8	55.7	55.5	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, 30% Met	883	9/17/19	10/30/19

Model Run Date March 13, 2019

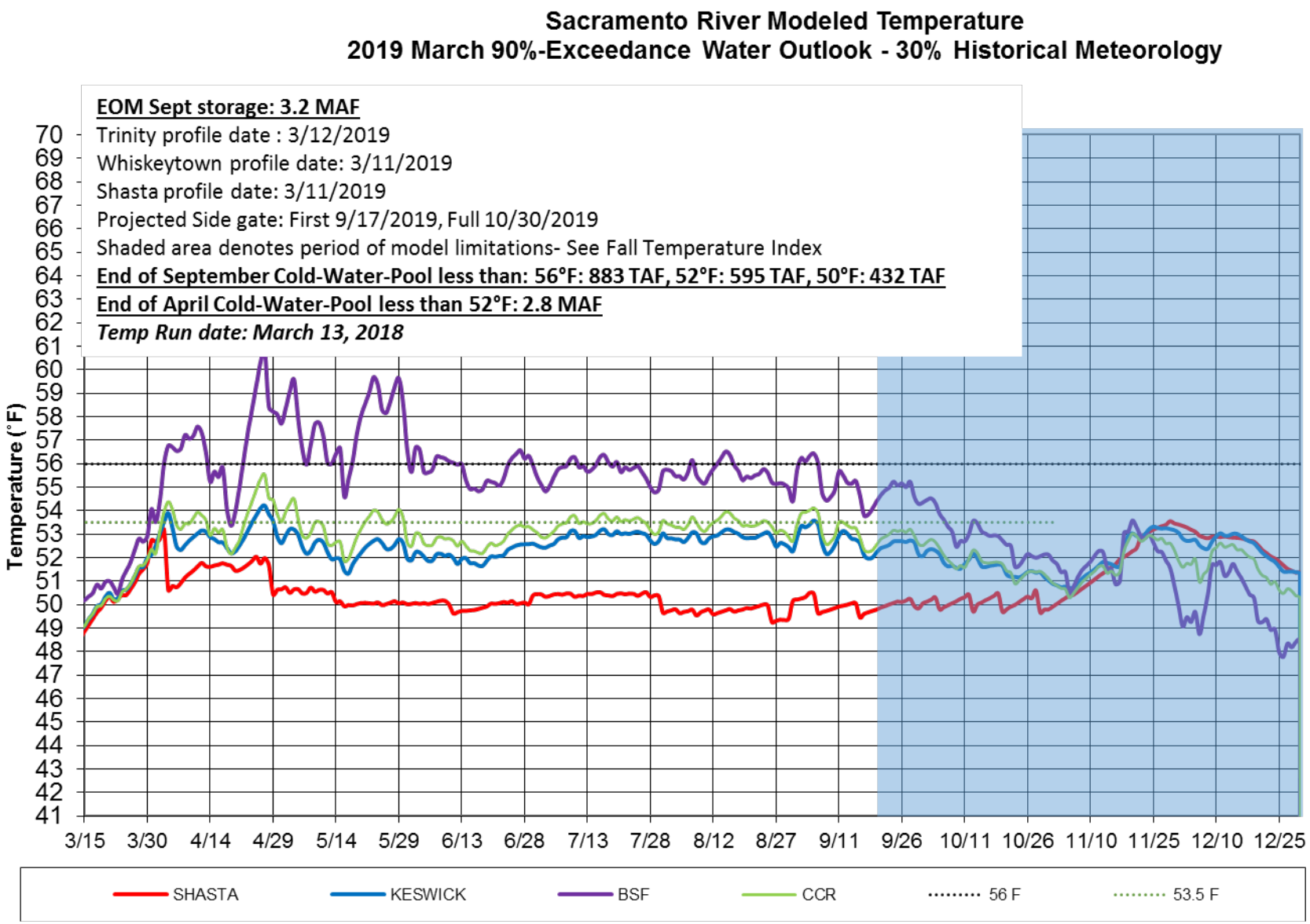

Figure 1. March 2019 simulated Sacramento River temperatures 90% runoff exceedance hydrology and 30% historical

meteorology.

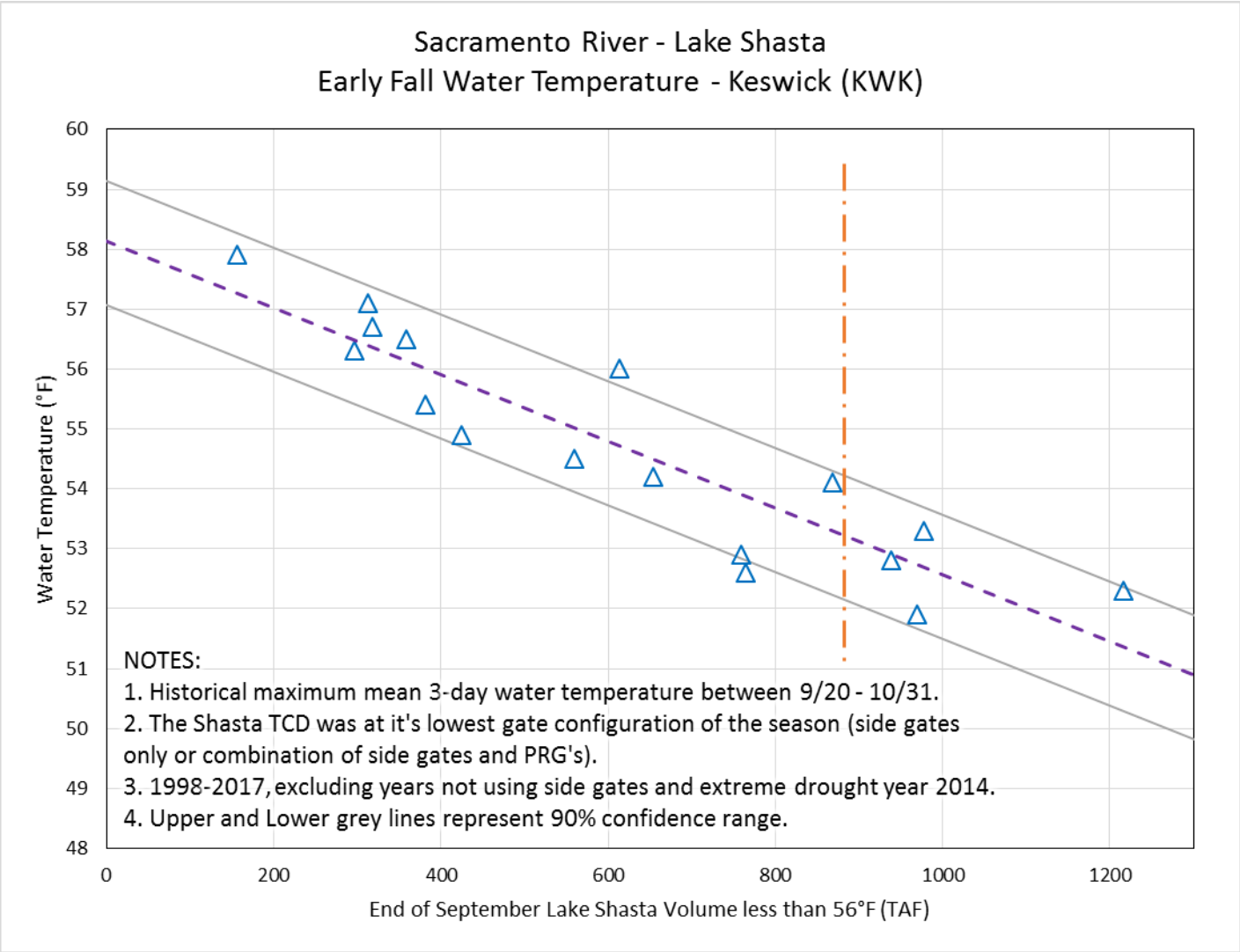

Figure 2. Historical relationship between Lake Shasta cold-water-pool characteristics and early fall Keswick water temperature and identifying relationship with 883 TAF end of September of cold-water-pool.

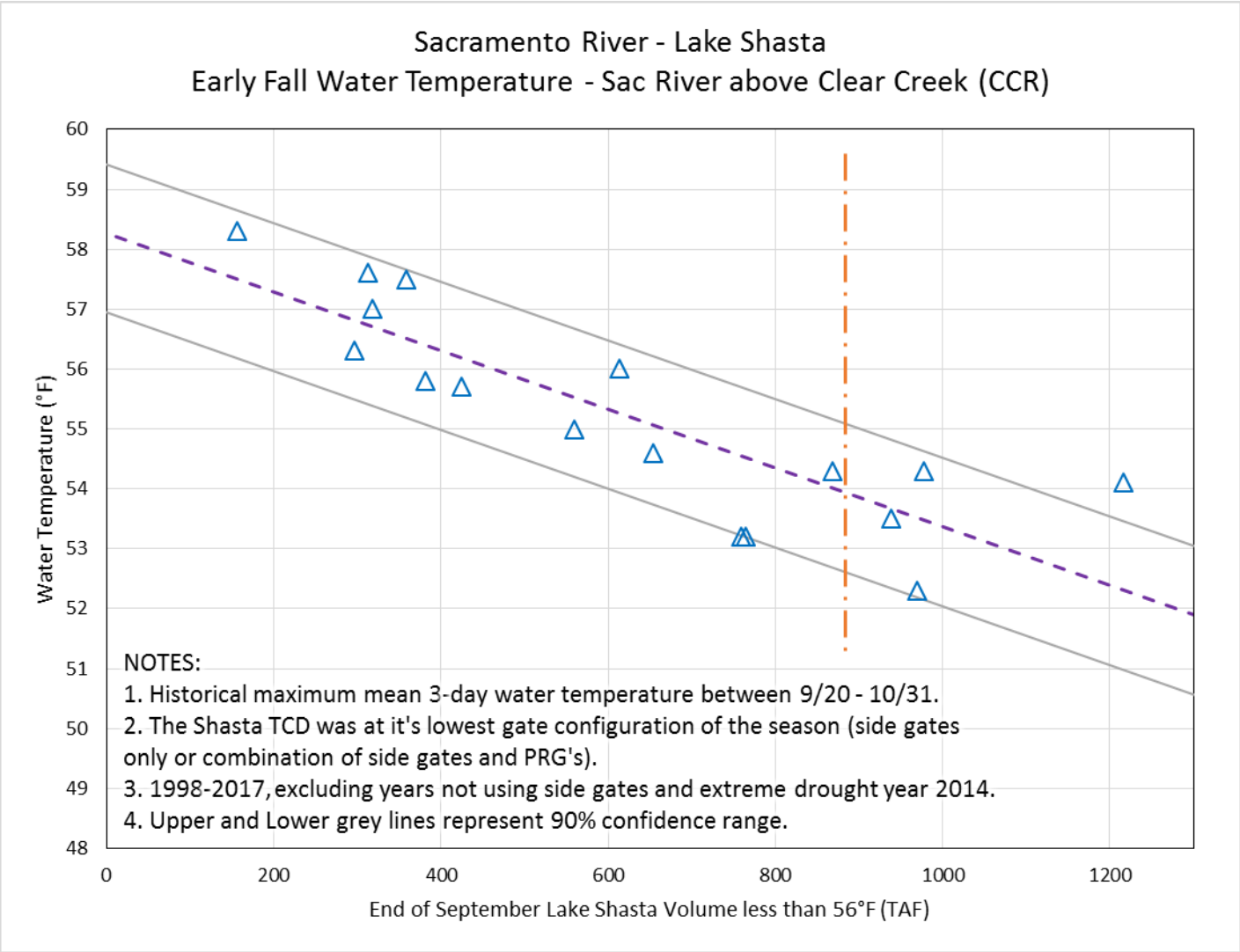

Figure 3. Historical relationship between Lake Shasta cold-water-pool characteristics and early fall Sacramento River above Clear Creek confluence water temperature and identifying relationship with 883 TAF end of September of cold-water-pool.

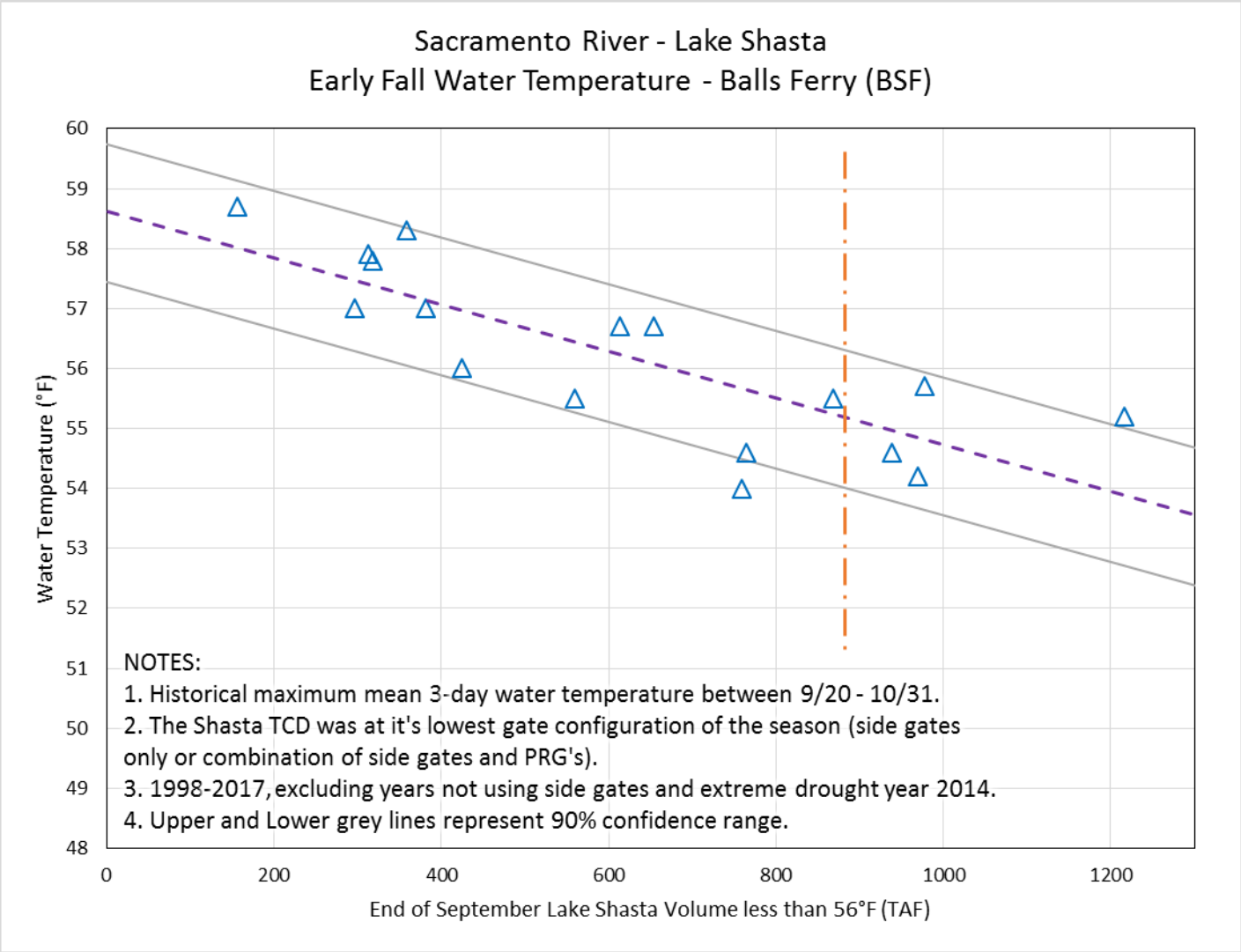

Figure 4. Historical relationship between Lake Shasta cold-water-pool characteristics and early fall Balls Ferry water temperature and identifying relationship with 883 TAF end of September of cold-water-pool.

* 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. Estimated temperatures for September and October may fall into a range indicated within the Fall Temperature Index (graphical chart), illustrating historical performance. 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.

Temperature Model Inputs, Assumptions, Limitations and Uncertainty:

1. The latest available profiles for Shasta, Trinity, and Whiskeytown were taken on March 11, March 12, and March 11, respectively. Model results are sensitive to initial reservoir temperature conditions and the model performs best under highly stratified conditions. The March 2019 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 March 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 the 90% and DWR Bulletin 120 for the 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. Side-flows were adjusted to a 25% historical exceedance for both the 90% and 50% runoff exceedance studies.

6. Meteorological inputs represent historical (1985 – 2017) monthly mean equilibrium temperature exceedance at 30% 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.

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 – 50% Historical Meteorology							
Keswick Dam KWK	53.0	52.3	51.8	52.6	52.7	See Figures 5 and 8	See Figures 5 and 8
Sac. R. abv Clear Creek CCR	53.6	53.1	52.4	53.0	53.2	See Figures 5 and 9	See Figures 5 and 9
Balls Ferry BSF	56.5	57.2	55.3	55.0	55.4	See Figures 5 and 10	See Figures 5 and 10
February 50%-Exceedance Outlook – 30% Historical Meteorology							
Keswick Dam KWK	52.8	52.2	52.1	53.1	53.6	See Figures 6 and 8	See Figures 6 and 8
Sac. R. abv Clear Creek CCR	53.3	53.0	52.8	53.6	54.0	See Figures 6 and 9	See Figures 6 and 9
Balls Ferry BSF	56.0	57.1	56.0	55.9	56.0	See Figures 6 and 10	See Figures 6 and 10

Location (°F DAT)	APR	MAY	JUN	JUL	AUG	SEP*	OCT*
February 50%-Exceedance Outlook – 50% Historical Meteorology							
Keswick Dam KWK	52.6	52.1	51.9	52.7	53.4	See Figures 7 and 8	See Figures 7 and 8
Sac. R. abv Clear Creek CCR	53.1	52.8	52.5	53.2	53.8	See Figures 7 and 9	See Figures 7 and 9
Balls Ferry BSF	55.8	56.7	55.5	55.3	55.7	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, 50% Met	912	9/19/19	11/03/19
50% Hydro, 30% Met	682	9/13/19	10/24/19
50% Hydro, 50% Met	699	9/14/19	10/26/19

Model Run Date March 13, 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 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. Estimated temperatures for September and October may fall into a range indicated within the Fall Temperature Index (graphical chart), illustrating historical performance. 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.

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 March 11, March 12, and March 11, respectively. Model results are sensitive to initial reservoir temperature conditions and the model performs best under highly stratified conditions. The March 2019 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 March 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 the 90% and DWR Bulletin 120 for the 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. Side-flows were adjusted to a 25% historical exceedance for both the 90% and 50% runoff exceedance studies.
6. Meteorological inputs represent historical (1985 – 2017) monthly mean equilibrium temperature exceedance at 30% 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 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.

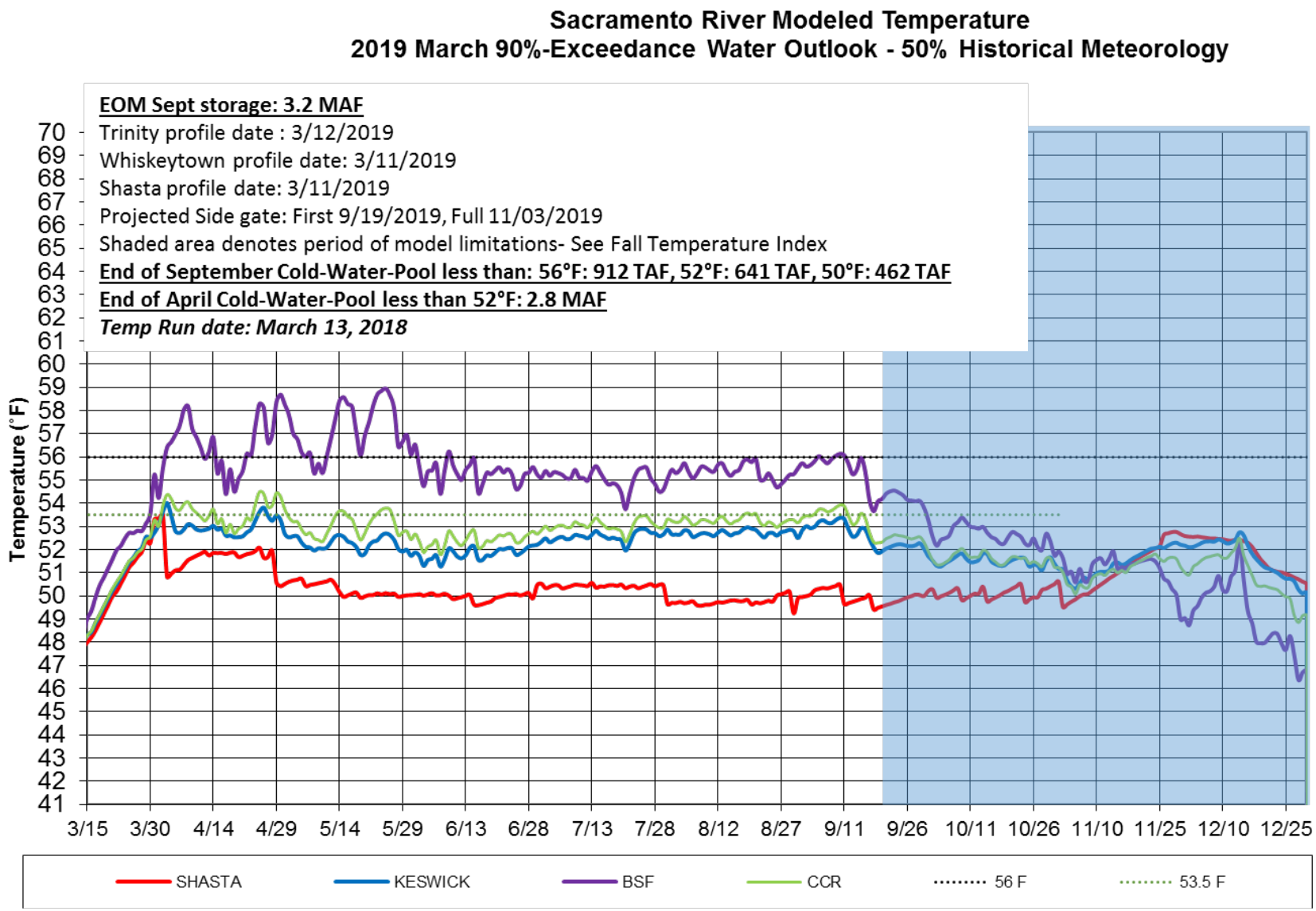

Figure 5. March 2019 simulated Sacramento River temperatures 90% runoff exceedance hydrology and 50% historical meteorology.

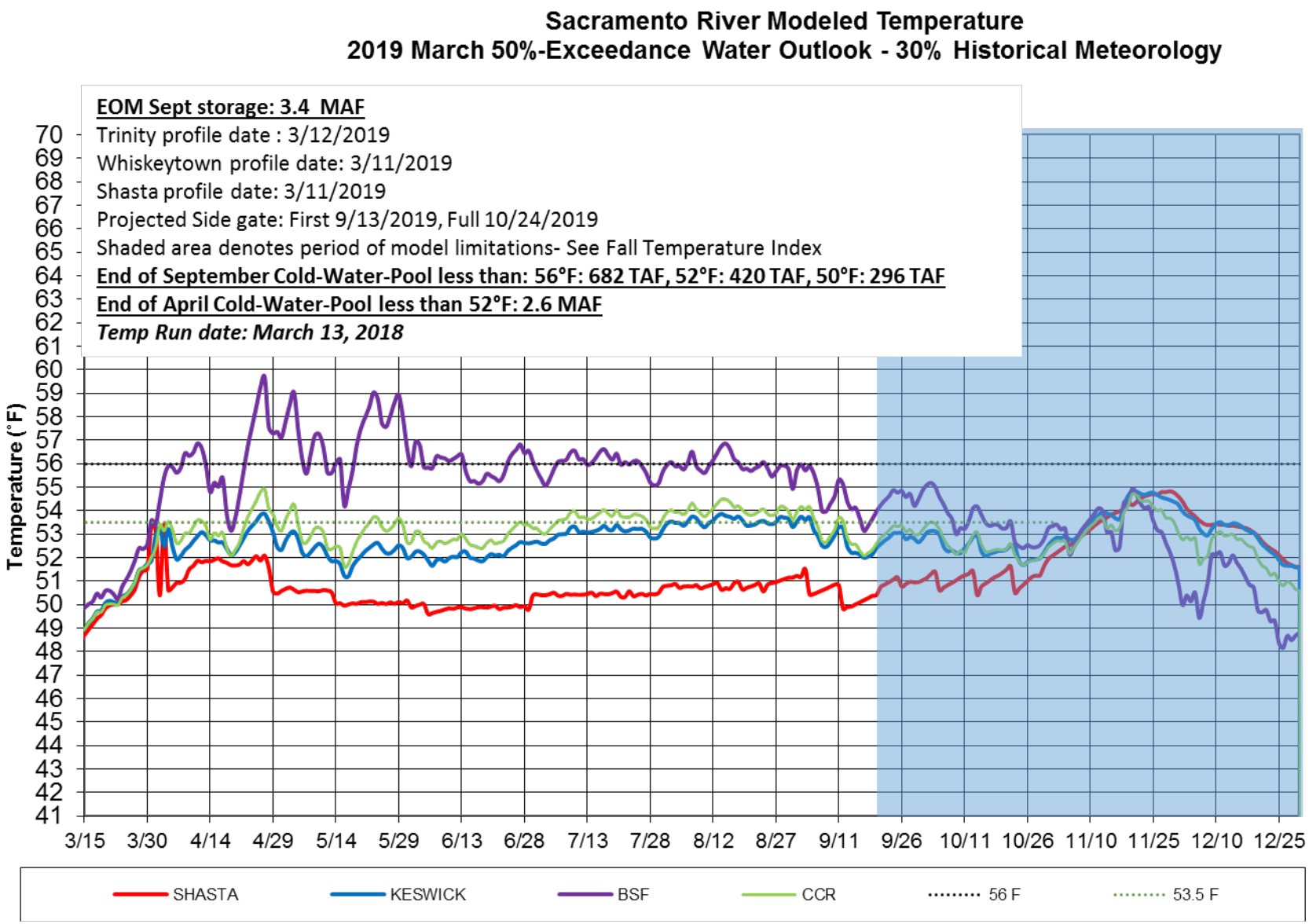

Figure 6. March 2019 simulated Sacramento River temperatures 50% runoff exceedance hydrology and 30% historical meteorology.

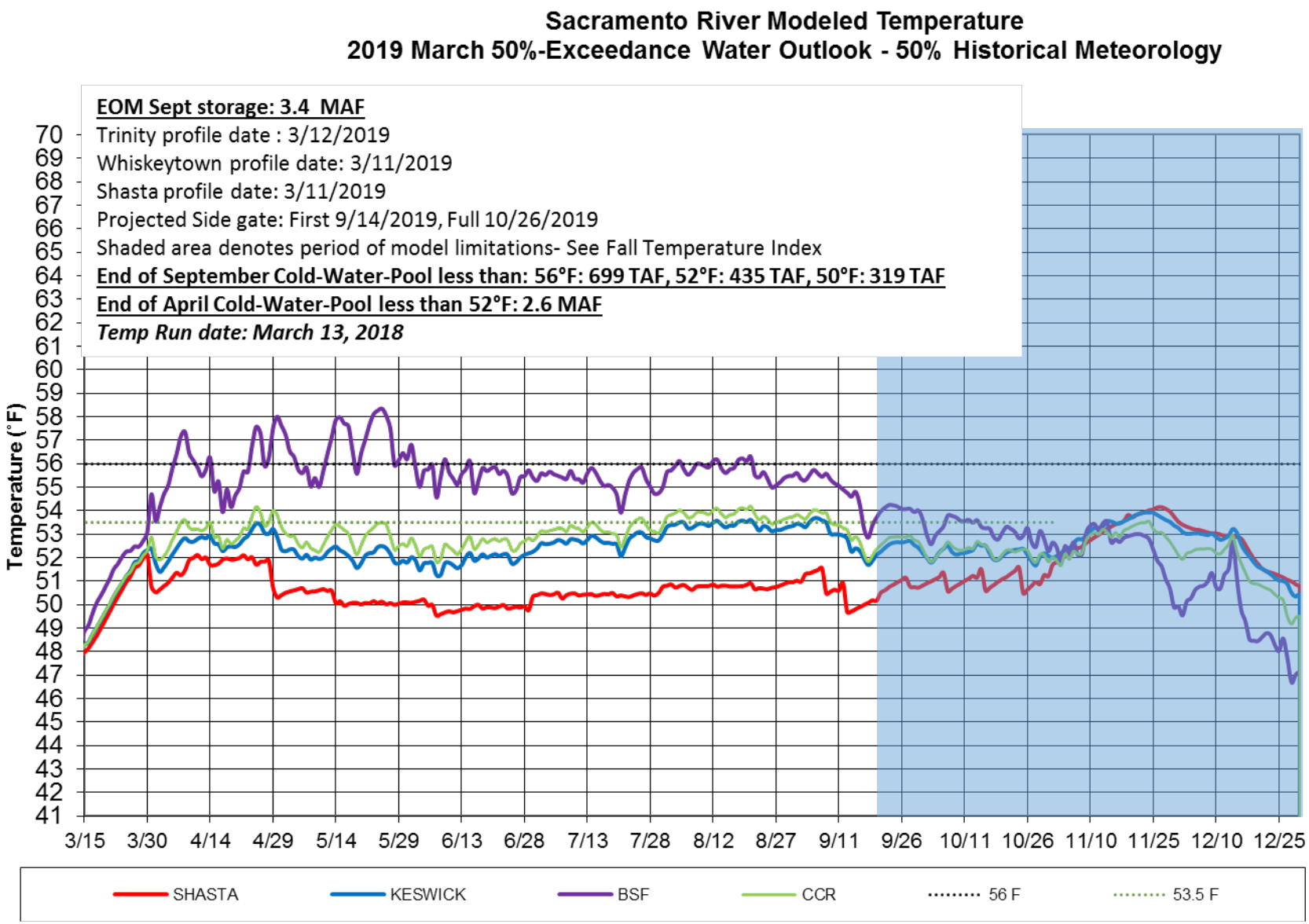

Figure 7. March 2019 simulated Sacramento River temperatures 50% runoff exceedance hydrology and 50% historical meteorology.

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.

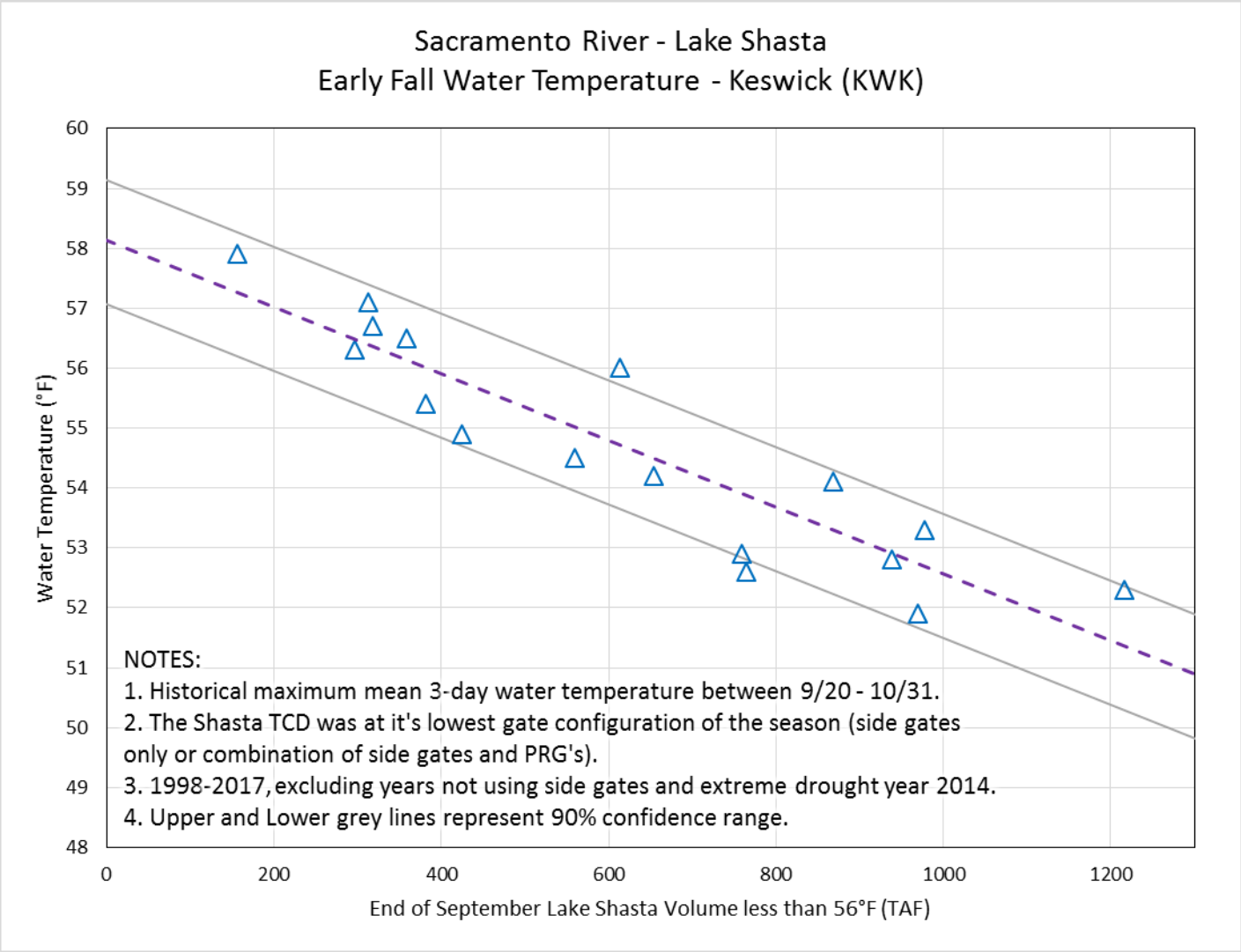

Figure 8. Historical relationship between Lake Shasta cold-water-pool characteristics and early fall Keswick water temperature.

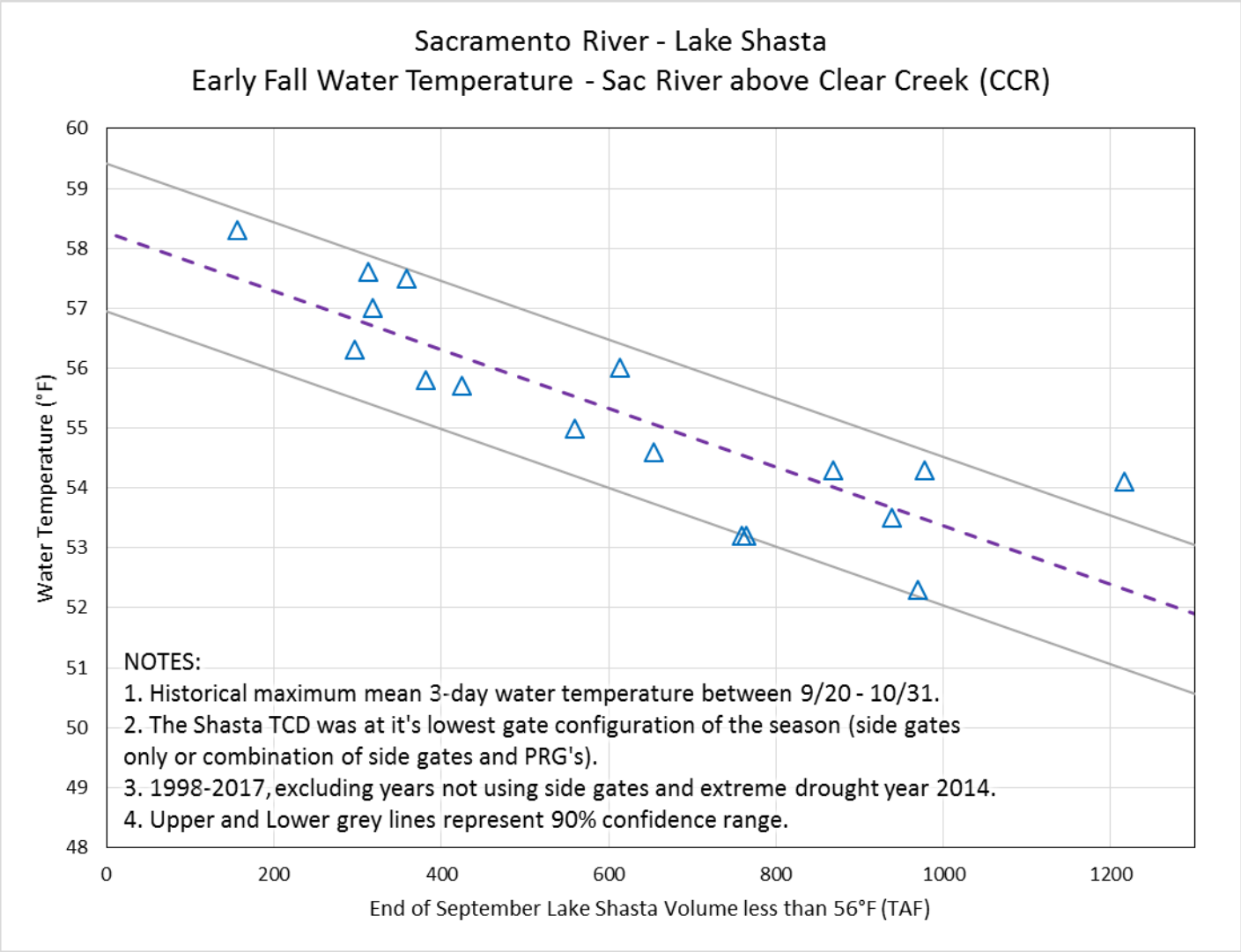

Figure 9. Historical relationship between Lake Shasta cold-water-pool characteristics and early fall Sacramento River above Clear Creek confluence water temperature.

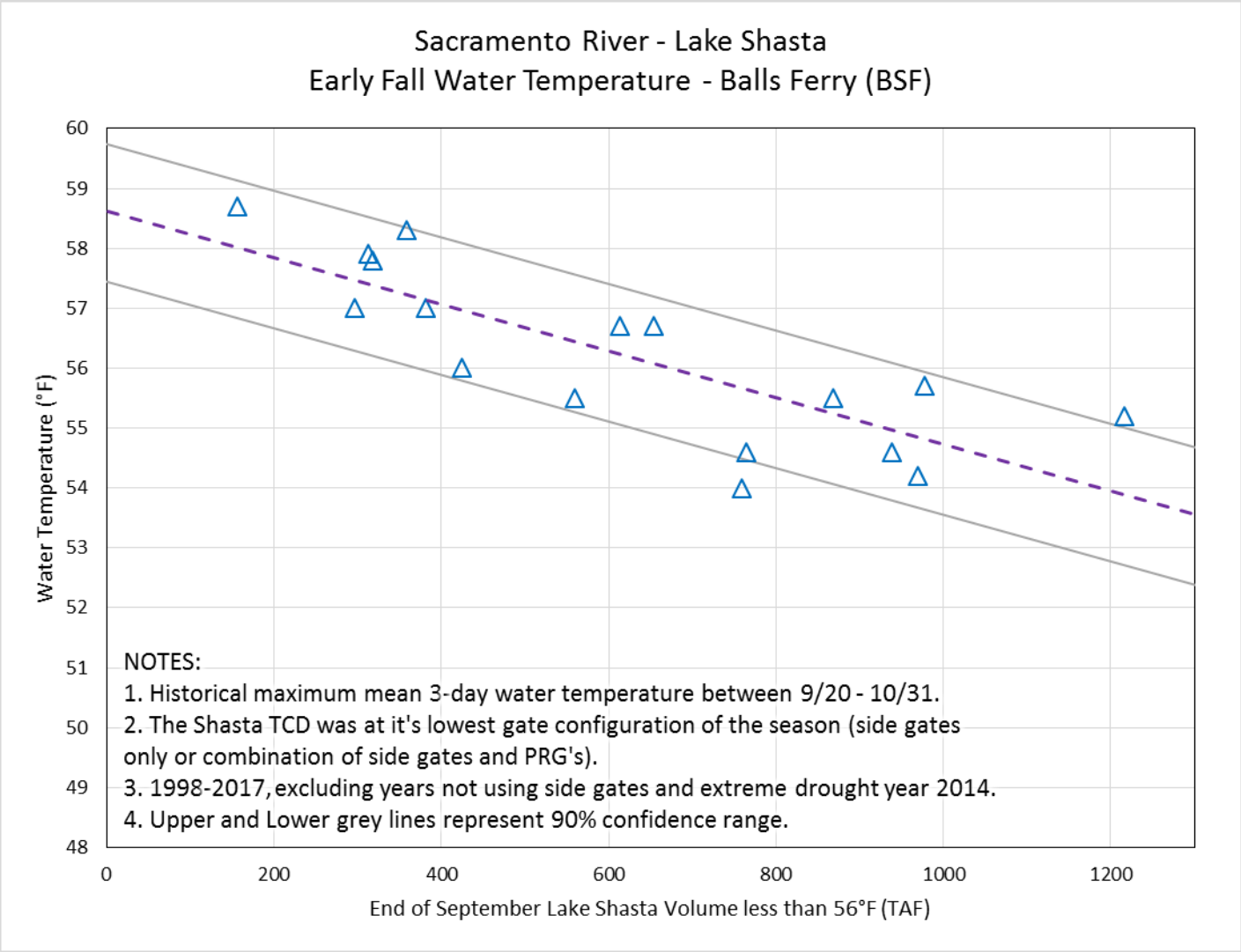

Figure 10. Historical relationship between Lake Shasta cold-water-pool characteristics and early fall Balls Ferry water temperature.

Enclosure 3

Summary Document for Shasta/Keswick Operational Scenarios
Prepared by the Southwest Fisheries Science Center on March 14th, 2019

Below are results comparing four USBR scenarios ran March 13th 2019. Scenarios differ by hydrology (Input 50 or 90 percent exceedance) and air temperature (30 or 50 exceedance of L3MTO). Inputs from scenarios are used to generate daily average Sacramento River water temperatures using the RAFT model and associated temperature-dependent egg mortality and survival estimates using the NMFS temperature mortality model (Martin et al. 2017) for the 2019 temperature management season (Table 1 and Figures 2-3). Additionally, a set of mortality model runs were generated using USBR's HEC-5Q model output (Table 2 and Figures 4-5) for comparison purposes, where the RAFT model was not used, but temperatures from the HEC-5Q nodes were linearly interpolated in space.

Further details of modeling methods are at: http://oceanview.pfeg.noaa.gov/CVTEMP/

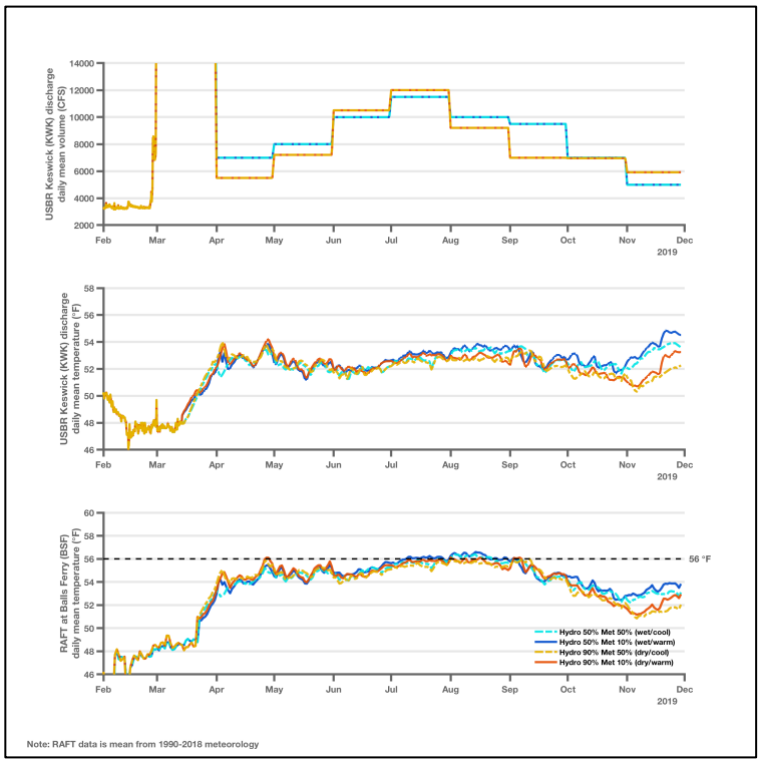

Figure 1: Summary plots showing differences in Keswick discharge volume and temperature, and Balls Ferry RAFT predicted temperature for four scenarios assessed.

Table 1: Estimated temperature-dependent egg mortality under different scenarios assuming a 2012-2017 spatial and temporal redd distribution.

Scenario	Mean (%)	Median (%)	Lower (%)	Upper (%)
MAR_13_2019_INPUT_50_OUTPUT_50_30L3MTO (Wet/Warm)	16.03	9.31	0.08	61.49
MAR_13_2019_INPUT_50_OUTPUT_50_50L3MTO (Wet/Cool)	12.34	4.47	0.08	57.02
MAR_13_2019_INPUT_90_OUTPUT_90_30L3MTO (Dry/Warm)	8.29	0.95	0.04	52.25
MAR_13_2019_INPUT_90_OUTPUT_90_50L3MTO (Dry/Cool)	6.55	0.46	0.01	47.02

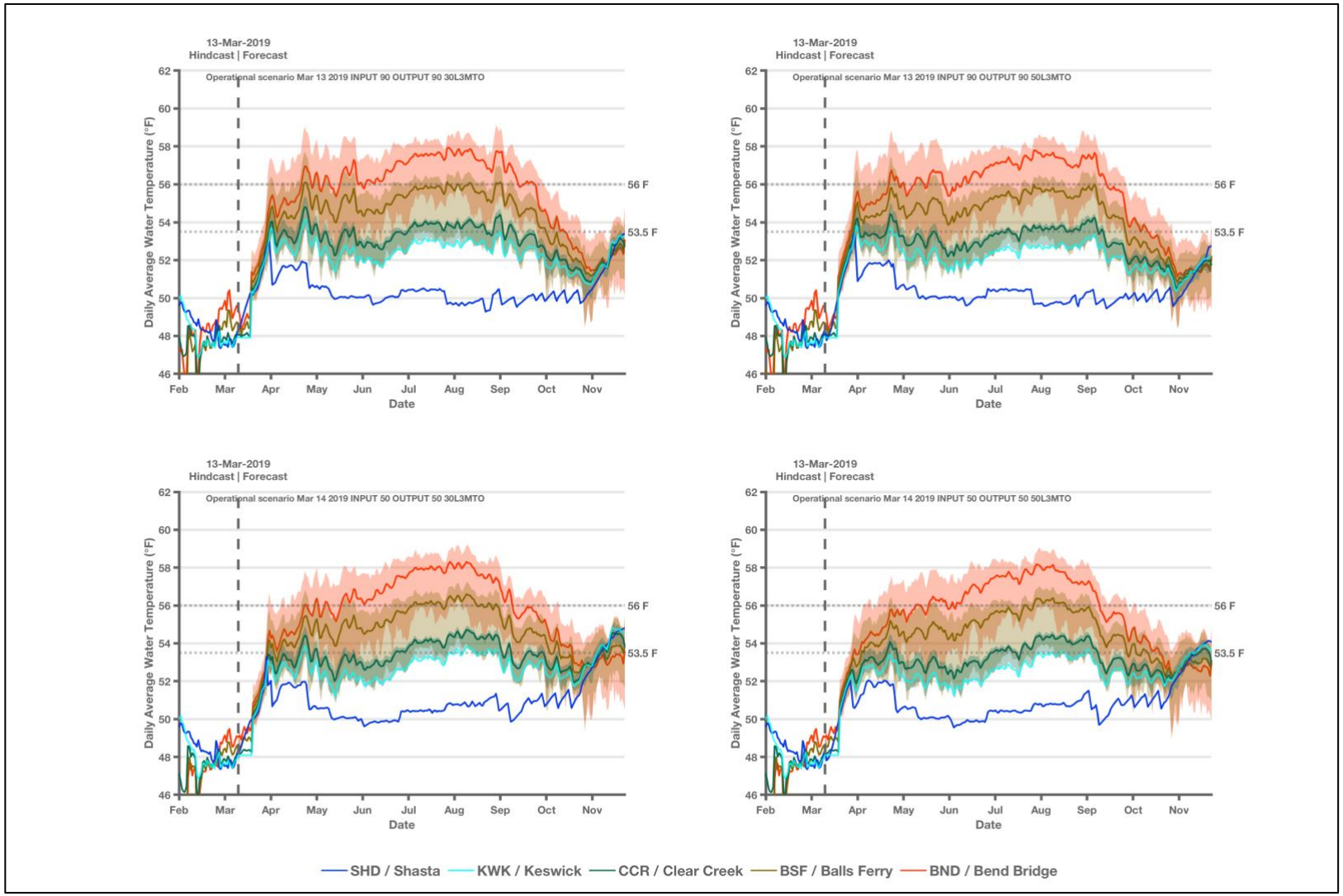

Figure 2: Estimated daily average water temperature produced by scenario input (Shasta and Keswick) and the RAFT model (Clear Creek, Balls Ferry, and Bend Bridge) under the four March 13th 2019 scenarios.

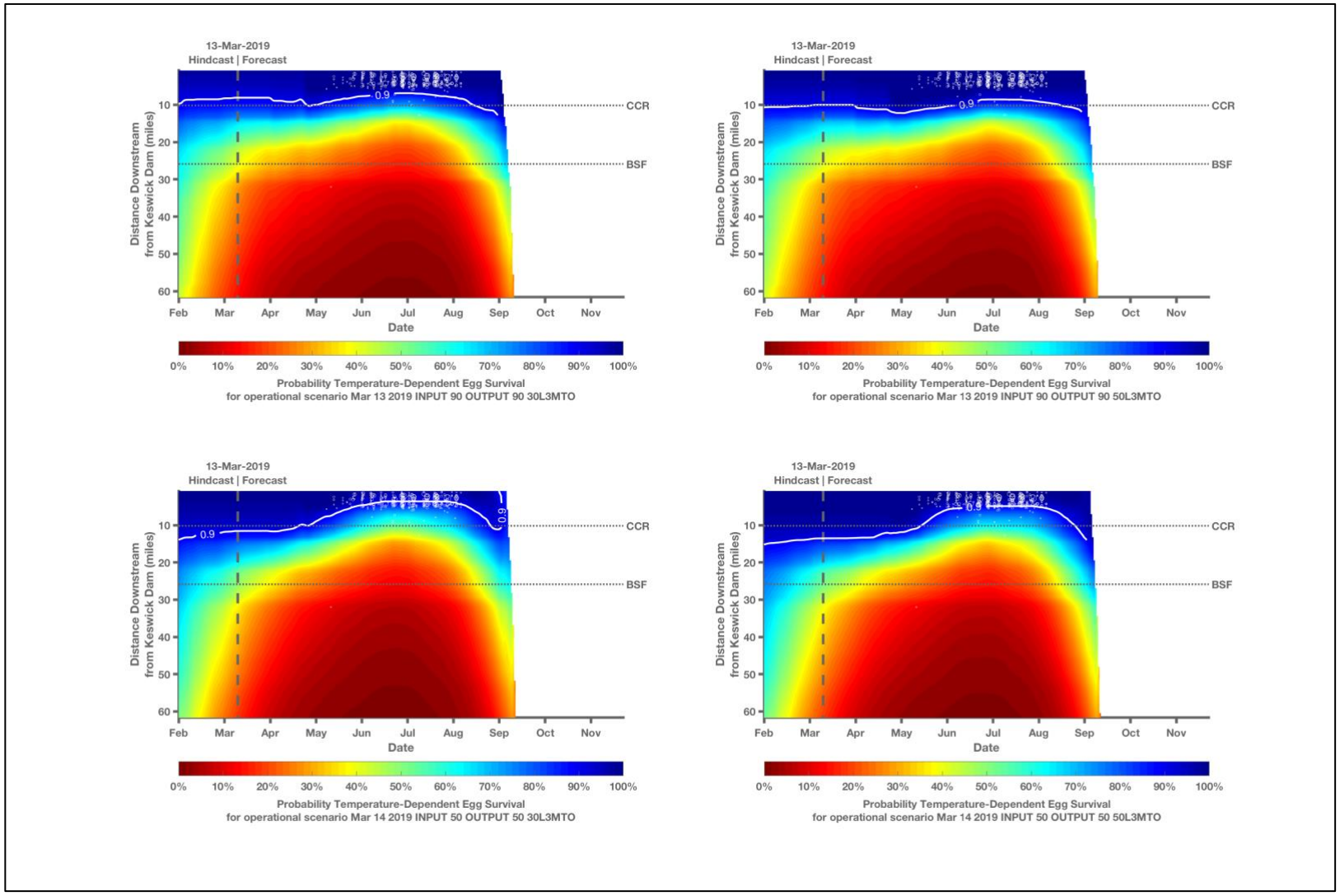

Figure 3: Estimated temperature-dependent egg survival produced by the NMFS temperature mortality model under the four March 13th 2019 scenarios

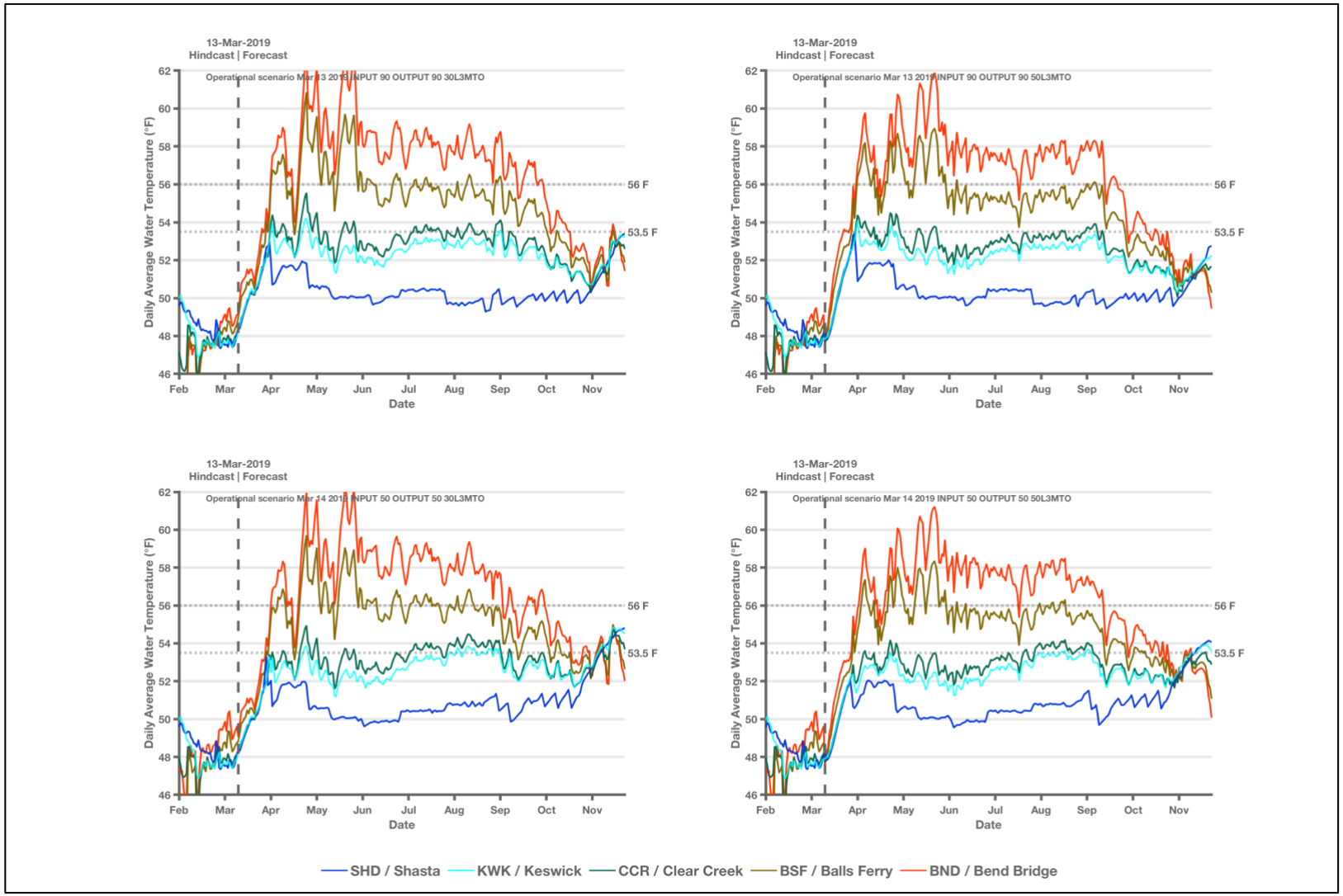

Figure 4: Estimated daily average water temperature produced by scenario input (Shasta, Keswick, Clear Creek, Balls Ferry, and Bend Bridge) under the four March 13th 2019 scenarios using HEC-5Q output.

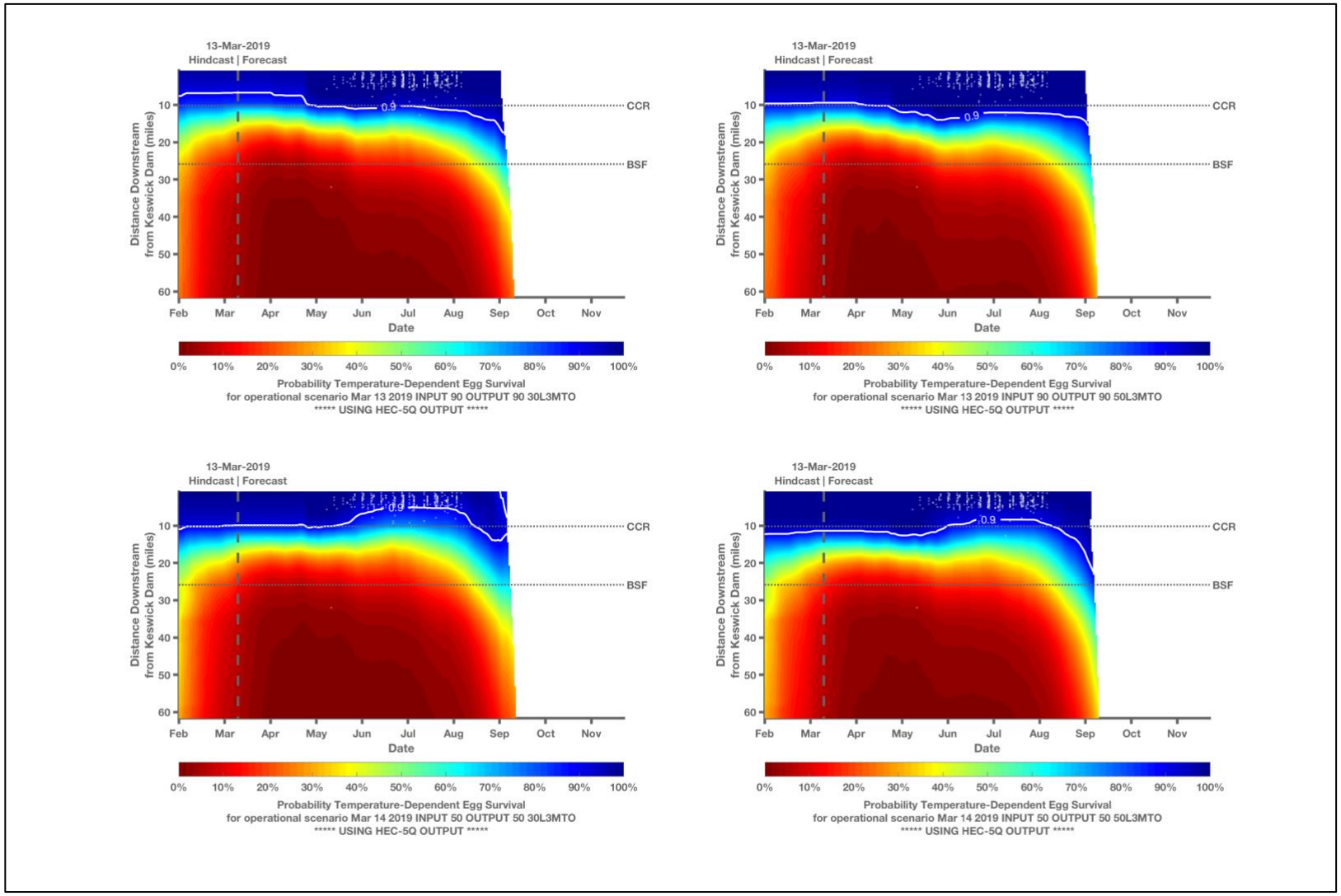

Figure 4: Estimated temperature-dependent egg survival produced by the NMFS temperature mortality model under the four March 13th 2019 scenarios using HEC-5Q output. To generate temperatures between HEC-5Q model nodes (KESWICK, CLEAR_CR, BALL_FERRY, JELLYS_FERRY, BEND_BR, and RED_BLIFF) linear interpolation was used.

Table 2: Estimated temperature-dependent egg mortality under different scenarios assuming a 2012-2017 spatial and temporal redd distribution using HEC-5Q output.

Scenario	Mean (%)	Median (%)	Lower (%)	Upper (%)
MAR_13_2019_INPUT_50_OUTPUT_50_30L3MTO (Wet/Warm)	14.05	6.55	0.08	59.18
MAR_13_2019_INPUT_50_OUTPUT_50_50L3MTO (Wet/Cool)	10.49	2.16	0.08	54.56
MAR_13_2019_INPUT_90_OUTPUT_90_30L3MTO (Dry/Warm)	7.27	0.47	0.08	50.19
MAR_13_2019_INPUT_90_OUTPUT_90_50L3MTO (Dry/Cool)	5.6	0.17	0.08	44.93

Reference:

Martin, B. T., Pike, A., John, S. N., Hamda, N., Roberts, J., Lindley, S. T. and Danner, E. M. (2017), Phenomenological vs. biophysical models of thermal stress in aquatic eggs. Ecology Letters 20: 50–59. doi:10.1111/ele.12705