



June 07, 2023

## 2023 SACRAMENTO RIVER TEMPERATURE MANAGEMENT PLAN

### INTRODUCTION

Conditions in the Central Valley this winter season have been cold and wet and, consequently, Shasta temperature management will be much improved compared to the last three consecutive dry years. The Northern Sierra Precipitation 8-Station Index indicates that this year's hydrologic conditions are nearly 10 inches more than average. In mid-May, Shasta Reservoir's cold water pool, managed to protect winter-run Chinook salmon, was projected to be comparable to other recent wet years such as 2017 and 2019. This Water Year 2023 Sacramento River Temperature Management Plan (Plan) reflects coordination starting in February 2023 to manage operations of Shasta Reservoir for water temperatures on the Sacramento River using conservative assumptions in modeling, taking advantage of opportunities to increase the cold water pool, and managing to real-time conditions. The Plan describes how the U.S. Bureau of Reclamation (Reclamation) plans to operate Shasta Reservoir and the Temperature Control Device (TCD) on Shasta Dam consistent with the 2020 Record of Decision on the Coordinated Long-Term Operation of the Central Valley Project and State Water Project (LTO) in compliance with:

- RPM 1.a. of the 2019 National Marine Fisheries Service (NMFS) Biological Opinion to, in coordination with the Sacramento River Temperature Task Group (SRTTG), consider technical assistance from NMFS regarding the development of an annual temperature management plan and to submit a final temperature management plan to NMFS by May 20 of each year;
- Order 90-5 to consult with the California Department of Fish and Wildlife (CDFW), U.S. Fish and Wildlife Service (USFWS), NMFS, and Western Area Power Administration on the designation of a location upstream of the Red Bluff Diversion Dam where Reclamation will meet a daily average water temperature of 56 degrees F;
- Order 90-5 to provide an operation plan to the State Water Resources Control Board (SWRCB), Chief of the Division of Water Rights, on Reclamation's strategy to meet the temperature requirement at a location upstream of the Red Bluff Diversion Dam; and
- The Interim Operations Plan (IOP), ordered by the US District Court on February 28, 2023, which identified priorities and planning efforts for Shasta cold water pool management to meet operational priorities and species needs. This IOP included establishing a six-agency Shasta Planning Group (SPG) to work iteratively with the technical groups (e.g., SRTTG and USST) to solicit operational guidance and risk assessments and provide policy guidance as necessary.

The temperature management strategy provided by the Plan is based on technical review and recommendations received from Sacramento River Temperature Task Group (SRTTG). The Plan establishes temperature locations and targets through October 31, and estimates winter-run Chinook salmon egg mortality, dates for operation of the side gates on the TCD, and end of September cold water pool. Reclamation will monitor the cold water pool, compare measured conditions to actual performance during implementation, and provide regular updates through the SRTTG throughout Plan implementation.

Based on the March 90% forecast, Reclamation identified that Water Year 2023 was likely to be a Tier 1 year. In a Tier 1 year, there is more than 2.8 MAF of total storage in Shasta Reservoir at the beginning of May, and Reclamation can meet a daily average water temperature of 53.5 degrees F on the Sacramento above Clear Creek (CCR). Conditions on May 1, along with modeling based on measured reservoir profiles, confirm that WY2023 is a Tier 1 temperature management season.

## **MODELING ASSUMPTIONS, LIMITATIONS, AND OTHER UNCERTAINTIES**

A seasonal water temperature forecast describes future expected downstream water temperature. This forecast, or simulation of expected water temperature performance is based on the targets specified in the TMP. Future water temperature is forecasted, using computational tools, at various elevations in the reservoirs and downstream in the river. These tools are based on conservative assumptions regarding hydrology, operations, and meteorology. Because this forecast (using conservative estimates in May to estimate what might happen at the end of October) can never exactly predict the actual hydrology, operations, and meteorology, the model results are not expected to precisely match actual water temperatures. The expectation is, however, that forecasted downstream water temperatures generally have an accepted measure of error regardless of the uncertain future conditions. In this case, there are generally two types of simulation error; uncertainty of the future conditions (e.g. inputs such as meteorology); and inherent model error or bias. To better understand the inherent model error or bias, a hindcast evaluation is typically performed. A hindcast, rather than looking forward to forecast, simply uses the actual input/forcing data after it's observed (e.g. hydrology, operations, and meteorology) to determine how well the model reproduced a condition such as actual downstream water temperatures.

Reclamation has proposed the use of NOAA-NWS Local Three-Month Temperature Outlooks (L3MTO) and historical meteorology as a means of estimating air temperature expectations for modeling purposes. In coordination with SRTTG, Reclamation has the choice of five exceedance threshold options, varying from those that serve more conservative stream temperature planning (e.g., 10% exceedance) to those that serve more aggressive planning (e.g., 90% exceedance). In past years, SRTTG has recommended the use of a conservative approach that uses the 25% exceedance L3MTO forecast. Therefore, Reclamation's May model runs utilized historical 25% exceedance meteorology.

## **RELEASE OUTLOOK**

The Shasta Reservoir release strategy and temperature modeling included in this plan is based on the CVP's May 90% forecast of operations. This release schedule is intended to guide the monthly average releases from Keswick Dam. Daily releases may vary from these flows to adjust for real-

time operations. Trinity River releases below Lewiston Dam were based on a forecasted Wet Year type and diversions through Carr Powerplant were adjusted to balance storage, flow, and water temperature goals. Significant uncertainties exist within the forecast that will require intensive real-time operations management throughout the summer to achieve the various goals and targets throughout the system. Reclamation commits to reporting out on the status of this release outlook, temperature management, and overall system operations at the monthly SRTTG meetings. Table 1 describes the monthly forecasted operations for releases and storage targets which were taken from the May 90% CVP forecast of operation (Attachment 1).

Table 1. Monthly forecasted operations for Shasta and Keswick reservoir releases and storage estimates.

<b>Operations Information/Month</b>	<b>June</b>	<b>July</b>	<b>August</b>	<b>September</b>
Shasta Releases (TAF)	535	553	553	416
Keswick Releases (cfs)	9,000	9,000	9,000	6,100
Keswick Releases (TAF)	535	553	553	363
Spring Creek Power Plant (TAF)	0	0	0	0
Shasta End-of-Month Storage (TAF)	4,174	3,844	3,470	3,288

## KEY AREAS OF UNCERTAINTY

Operational decisions on the upper Sacramento River are influenced by local and CVP and SWP system-wide multi-purpose objectives, including those that are planned and uncertain. Many factors contribute to operational actions including, but not limited to flood protection/storage management, forecasted inflows, facility maintenance schedules, physical/mechanical facility limitations, upstream operations, minimum in-stream flow criteria, public health and safety criteria, downstream Delta regulatory requirements, Delta exports, power generation, recreation, fish hatchery accommodations, temperature management capabilities, and others. In addition, uncertain or unplanned events can also influence real-time operation decisions (e.g., wildfires and equipment malfunctions). To address uncertainty, Reclamation typically uses conservative estimates of future conditions in the modeling assumptions (e.g., hydrology, operations, and meteorology) and projections are updated through the management period.

The release forecast and temperature modeling used for this temperature management plan is based on a number of assumptions that each come with a level of uncertainty. Uncertainty areas include:

- Inflow hydrology
- Meteorology
- Reservoir stratification
- Accretions and depletions
- Public health and safety demands
- Infrastructure limitations

- Trinity River imports and Trinity River temperature management
- Reservoir thermodynamics
- Delta water quality

## TEMPERATURE STRATEGY

The Keswick Reservoir release schedule was developed by Reclamation as part of the May 90% forecast of operations. Reclamation completed HEC-5Q modeling on May 31, 2023. The temperature modeling is presented here and is reflected in resulting biological and water supply performance metrics as shown in Table 2, Table 3, and Attachment 2. Modeling targeted a water temperature of 53.5 degrees F at CCR. Further refinement to the temperature management strategy will occur through coordination with SRTTG and SPG as the temperature management season progresses.

Table 2. Estimated water temperature in degrees Fahrenheit at Shasta, Keswick and CCR based on May 32 model run. HEC-5Q does not perform well after mid-September. Water temperatures may be warmer than these targets and HEC-5Q results. Warmer water temperatures described in Attachment 2 describe the late season water temperatures that were used for the temperature dependent mortality modeling.

Month	Shasta	Keswick	CCR
June	49.2	51.6	53.1
July	48.1	51.0	52.7
August	48.9	51.2	52.5
September	49.1	51.3	52.6
October	50.0	50.8	51.4
November	49.9	50.1	50.6

Trinity River and Clear Creek modeled temperatures are included in Attachment 2.

In addition to the above temperature management strategy of meeting 53.5 degrees F at CCR, HEC-5Q modeling was performed and included in Attachment 3 to determine the location upstream of the Red Bluff Diversion Dam where a daily average water temperature of 56 degrees F could reasonably be met. The operation in Attachment 3 utilizes Shasta TCD Side Gates intermittently beginning in July to meet a 56 degrees F temperature target at Balls Ferry Bridge (BSF) during the temperature management season. The strategy of meeting 53.5 at CCR will likely result in average daily temperatures at or near 56 degrees F at BSF. Reclamation does not propose to operate the TCD explicitly to meet 56 degrees F at BSF under conditions that may require changes to TCD operations that could risk cold water pool resources for use later in the temperature management season. This would cause an unreasonable risk to other goals and objectives.

Further, additional modeling presented to SRTTG demonstrated that it would not be feasible to target 53.5 degrees F in the Sacramento River at BSF primarily due to the high, warm water flow from tributaries entering the Sacramento River.

Table 3. Fish and water performance metrics.

<b>Metric</b>	<b>May 31 Scenario</b>
Stage-independent TDM	0%
Stage-dependent TDM	0%
End of Sept CWP Storage (TAF)	1.50 MAF
First Side Gate Use	N/A
Full Side Gate	N/A
End of September Storage (MAF)	3.3 MAF

Water temperature forecasts indicate favorable temperatures for winter-run chinook salmon egg incubation with TDM estimates equal to 0. Modeled water temperature forecasts also indicate suitable temperatures for spring-run and fall-run Chinook salmon incubation; however, temperature models are more uncertain during the fall period.

Reclamation will continue to coordinate through SRTTG to review these and other model results and may update these TDM estimates based on those discussions.



## Attachment 1

# Estimated CVP Operations 90% Exceedance

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

Facility	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr
Trinity	890	1087	1223	1221	1172	1126	1112	1108	1129	1130	1147	1206	1254
Trinity Elev.	N/A	2265	2279	2278	2273	2269	2267	2267	2269	2269	2271	2277	2281
Whiskeytown	236	238	238	238	238	238	206	206	206	206	206	206	238
Whiskeytown Elev.	N/A	1209	1209	1209	1209	1209	1199	1199	1199	1199	1199	1199	1209
Shasta	4430	4381	4174	3844	3470	3288	3154	3133	3175	3222	3369	3614	3718
Shasta Elev.	N/A	1061	1054	1042	1027	1020	1014	1014	1015	1017	1023	1033	1037
Folsom	805	917	835	708	611	601	518	442	382	337	357	452	584
Folsom Elev.	N/A	461	453	440	430	429	419	409	400	393	397	410	427
New Melones	1514	1722	1930	1958	1937	1939	1901	1914	1928	1931	1939	1966	1877
New Melones Elev.	N/A	1026	1046	1048	1047	1047	1043	1044	1046	1046	1047	1049	1041
Federal San Luis	958	871	690	360	122	93	149	209	347	489	451	398	276
<b>Total</b>	<b>8833</b>	<b>9216</b>	<b>9101</b>	<b>8330</b>	<b>7550</b>	<b>7284</b>	<b>7040</b>	<b>7012</b>	<b>7168</b>	<b>7314</b>	<b>7469</b>	<b>7842</b>	<b>7947</b>

State End of the Month Reservoir Storage (TAF/Feet)

Facility	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr
Oroville	3230	3340	3333	2994	2517	2130	1862	1746	1701	1762	1864	2034	2143
Oroville Elev.	N/A	888	887	864	828	795	796	757	753	759	769	786	796
State San Luis	1056	1078	945	860	761	759	725	647	568	604	591	552	286
Total San Luis (TAF)	2014	1949	1635	1220	883	853	875	857	915	1092	1042	950	561
Total San Luis Elev.	N/A	537	511	473	441	438	440	438	444	462	457	448	405

Monthly River Releases (TAF/cfs)

River	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr
Trinity (TAF)	111	38	28	53	52	23	18	18	18	17	18	32
Trinity (cfs)	1805	639	456	857	870	373	300	300	300	300	300	540
Clear Creek (TAF)	18	14	9	9	9	12	12	12	12	11	22	12
Clear Creek (cfs)	291	242	150	150	150	200	200	200	200	200	363	200
Sacramento (TAF)	738	535	553	553	363	369	268	277	277	250	277	363

River	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr
Sacramento (cfs)	12000	9000	9000	9000	6100	6000	4500	4500	4500	4500	4500	6104
American (TAF)	492	416	277	215	119	123	119	123	108	83	77	74
American (cfs)	8000	7000	4500	3500	2000	2000	2007	2000	1750	1500	1250	1250
Stanislaus (TAF)	96	56	18	18	18	48	12	12	14	13	12	83
Stanislaus (cfs)	1555	940	300	300	300	774	200	200	226	229	200	1400
Feather (TAF)	553	238	326	455	470	295	104	108	108	97	108	104
Feather (cfs)	9000	4000	5300	7400	7900	4800	1750	1750	1750	1750	1750	1750

### Trinity Diversions (TAF)

Diversions Facility	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr
Carr PP	0	0	7	10	9	0	6	1	13	20	9	56
Spring Creek PP	4	0	0	0	0	22	0	1	8	20	6	27

### Delta Summary (TAF)

Facility	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr
Tracy	215	250	265	265	255	234	172	220	225	92	105	60
USBR Banks	0	0	0	0	0	44	44	44	0	0	0	0
Contra Costa	9.5	9.5	7.4	8.3	9.5	14.0	14.0	14.0	13.7	13.7	10.5	9.5
Total USBR	225	260	272	273	265	292	230	278	239	106	116	69
State Export	307	293	401	402	396	308	222	200	160	108	198	30
Total Export	532	553	673	675	661	600	452	478	399	214	314	99
COA Balance	0	0	0	0	0	0	0	0	0	0	0	0
Vernalis (TAF)	1565	893	697	210	182	201	83	83	93	112	120	173
Vernalis (cfs)	25461	14010	11345	3423	3057	3263	1393	1355	1511	2012	1957	2901
Old/Middle River calc.	4202	-987	-3919	-7508	-7764	-6637	-5813	-5968	-4904	-2648	-3636	-563
Computed DOI	50103	22844	13355	7402	7699	7109	4505	7288	9321	11400	11403	9733
Excess Outflow	23767	7665	5352	3400	605	0	0	2782	3319	0	0	235
% Export/Inflow	14%	25%	38%	49%	51%	52%	57%	49%	42%	24%	31%	12%
% Export/inflow std.	35%	35%	65%	65%	65%	65%	65%	65%	65%	45%	35%	35%

### Hydrology

Statistic	Trinity	Shasta	Folsom	New Melones
Water Year Inflow (TAF)	1348	5703	4383	2232
Year to Date + Forecasted % of mean	112%	103%	161%	211%

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



## Attachment 2

# Sacramento River Temperature Modeling

Table 1. Facility Temperature Outlook in Degrees Fahrenheit

Month	Shasta	Keswick	CCR	Igo	Trinity	Lewiston
June	49.2	51.6	53.1	50.5	45.6	54.4
July	48.1	51.0	52.7	53.0	46.2	55.7
August	48.9	51.2	52.5	52.5	46.1	51.9
September	49.1	51.3	52.6	52.1	46.4	50.7
October	40.0	50.8	51.4	51.2	46.6	50.0
November	49.9	50.1	50.6	50.2	46.5	48.1

Run date: 5/31/23

EOM September Storage: 3.3 MAF

Trinity profile date: 5/18/23

Whiskeytown profile date: 5/9/23

Shasta profile date: 5/24/23

Projected side gates: First N/A Full N/A

September – November for Shasta, Keswick, and CCR output has limited model capabilities – see Fall Temperature Index

End of September Cold-Water-Pool less than 56 degrees Fahrenheit: 1.5 MAF

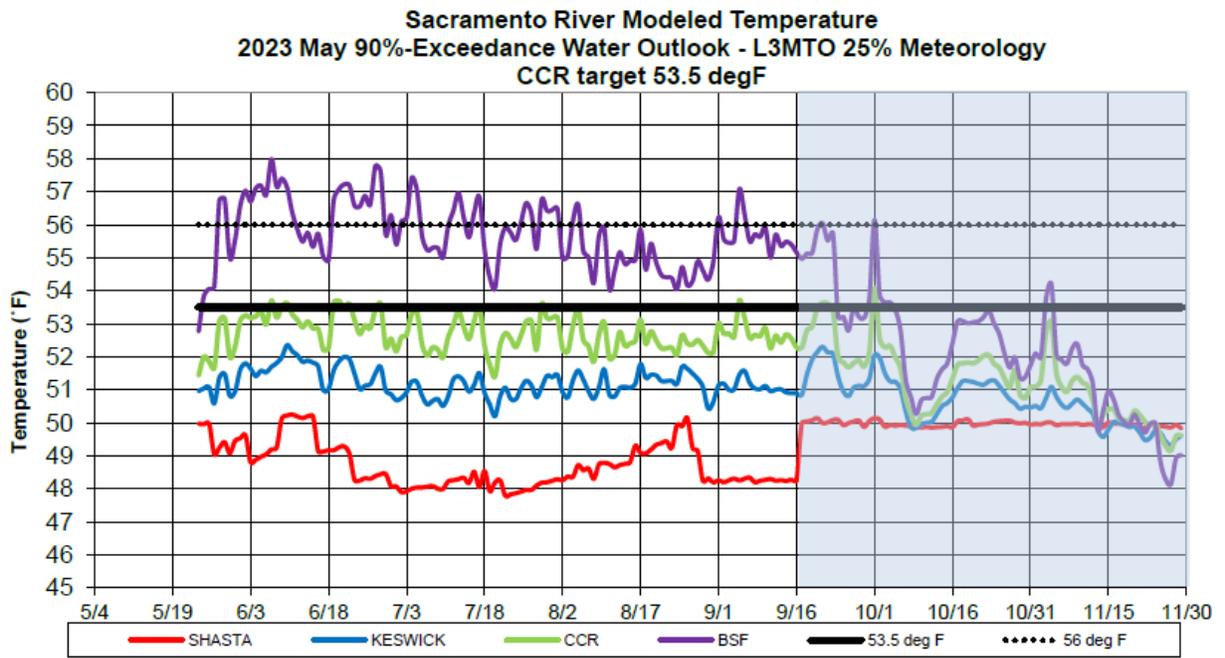


Figure 1: Sacramento River Modeled Temperature – May 2023 90%-Exceedance Water Outlook Historical 25% Meteorology

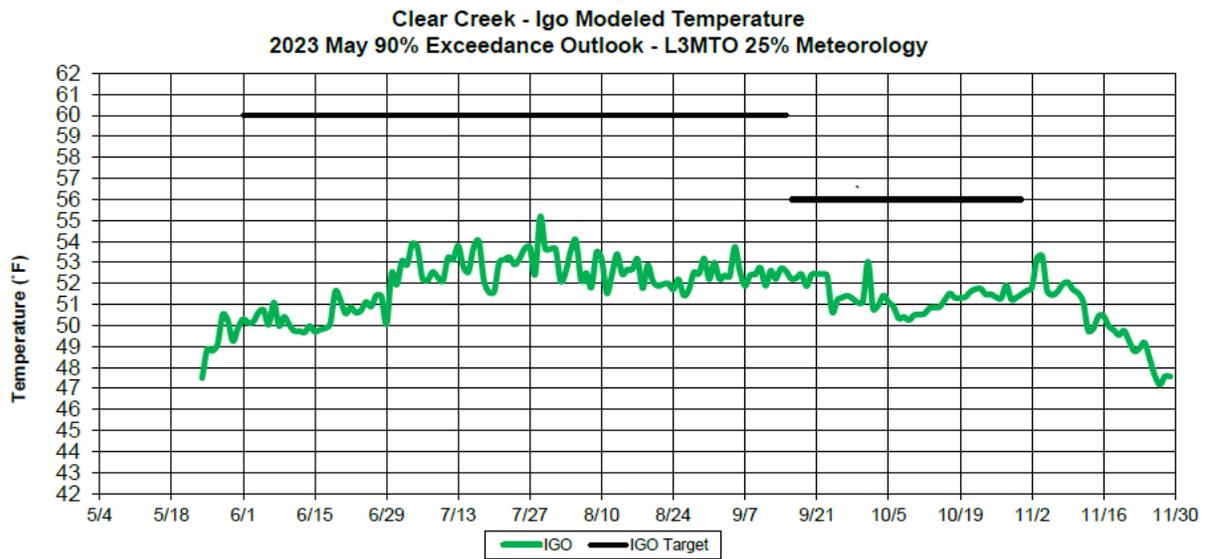


Figure 2: Clear Creek Igo Modeled Temperature – May 2023 90%-Exceedance Water Outlook Historical 25% Meteorology

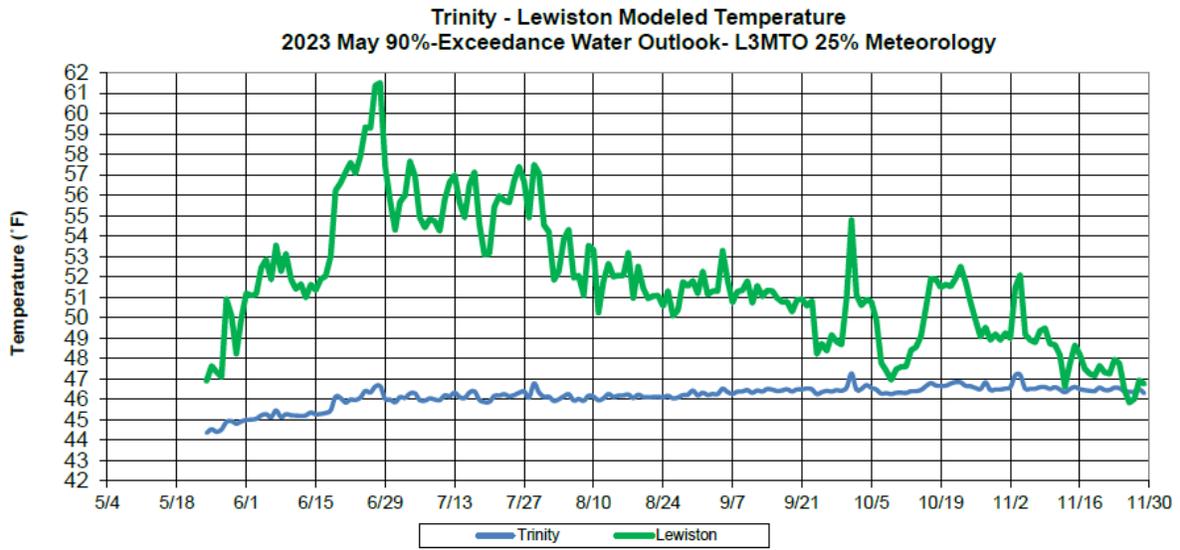


Figure 3: Trinity – Lewiston Modeled Temperature – May 2023 90%-Exceedance Water Outlook Historical 25% Meteorology



## Attachment 3

# Sacramento River Temperature Modeling – BSF Target 56 Degrees Fahrenheit

Table 1. Facility Temperature Outlook in Degrees Fahrenheit

Month	Shasta	Keswick	CCR	BSF	Igo	Trinity	Lewiston
June	47.7	50.3	51.9	55.6	50.5	45.6	54.4
July	47.5	50.4	52.2	55.5	53.0	46.2	55.7
August	49.1	51.4	52.6	55.1	52.5	46.1	51.9
September	48.9	51.1	52.5	55.0	52.1	46.4	50.7
October	50.0	50.8	51.4	52.4	51.2	46.6	50.0
November	49.9	50.1	50.6	50.8	50.2	46.5	48.1

Run date: 5/31/23

EOM September Storage: 3.3 MAF

Trinity profile date: 5/18/23

Whiskeytown profile date: 5/9/23

Shasta profile date: 5/24/23

Projected side gates: First July 2 Full N/A

September – November for Shasta, Keswick, CCR, and BSF output has limited model capabilities – see Fall Temperature Index

End of September Cold-Water-Pool less than 56 degrees Fahrenheit: 1.47 MAF

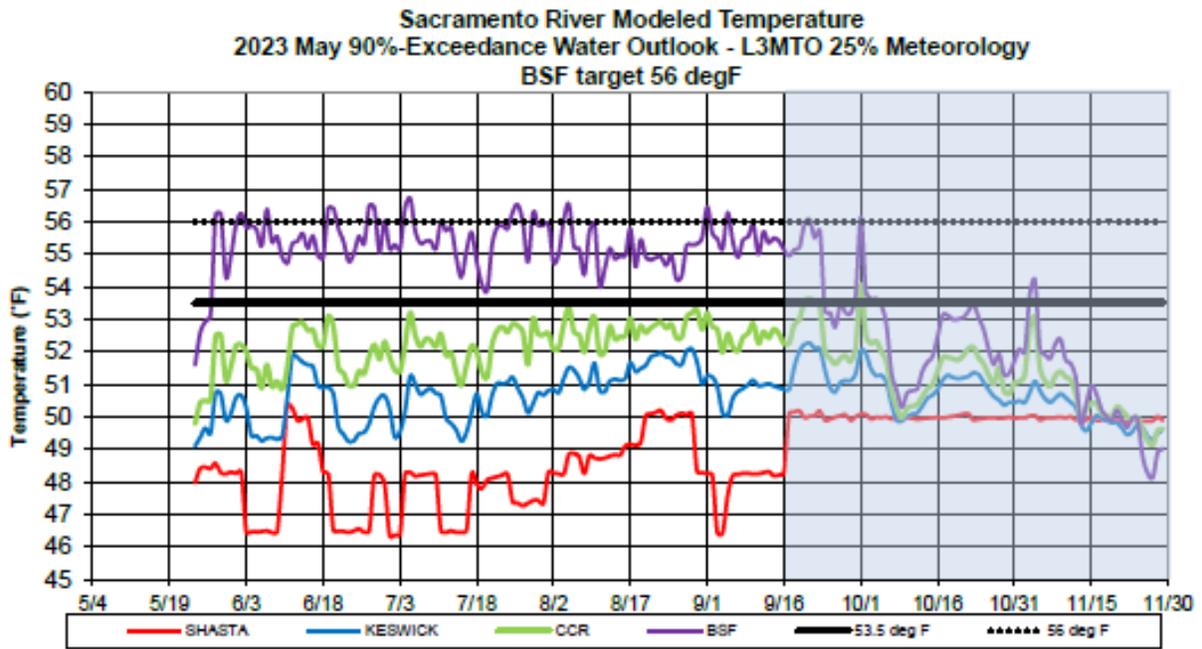


Figure 1: Sacramento River Modeled Temperature – May 2023 90%-Exceedance Water Outlook Historical 25% Meteorology

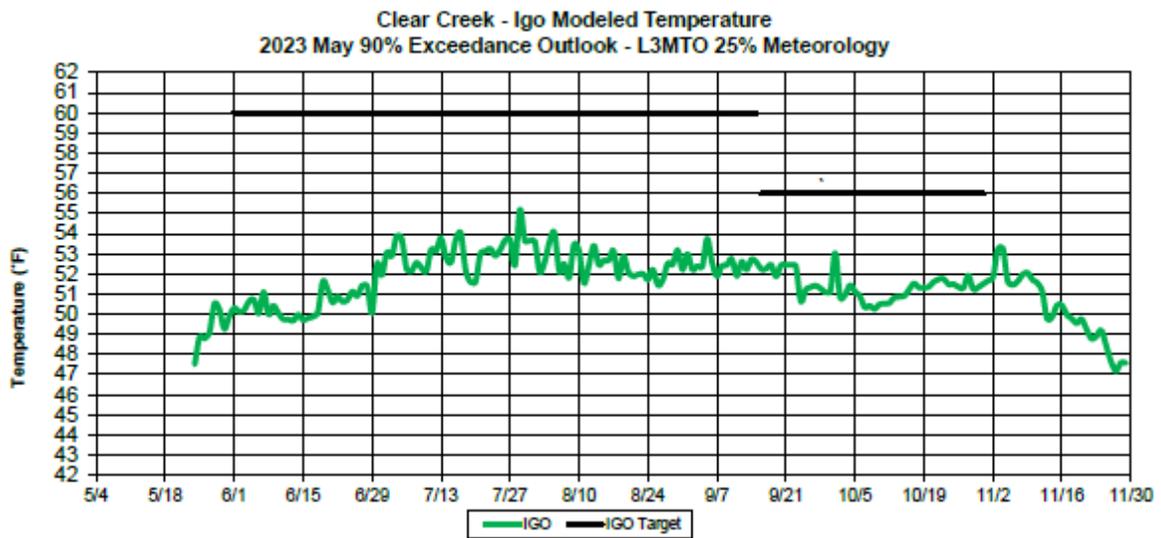


Figure 2: Clear Creek Igo Modeled Temperature – May 2023 90%-Exceedance Water Outlook Historical 25% Meteorology

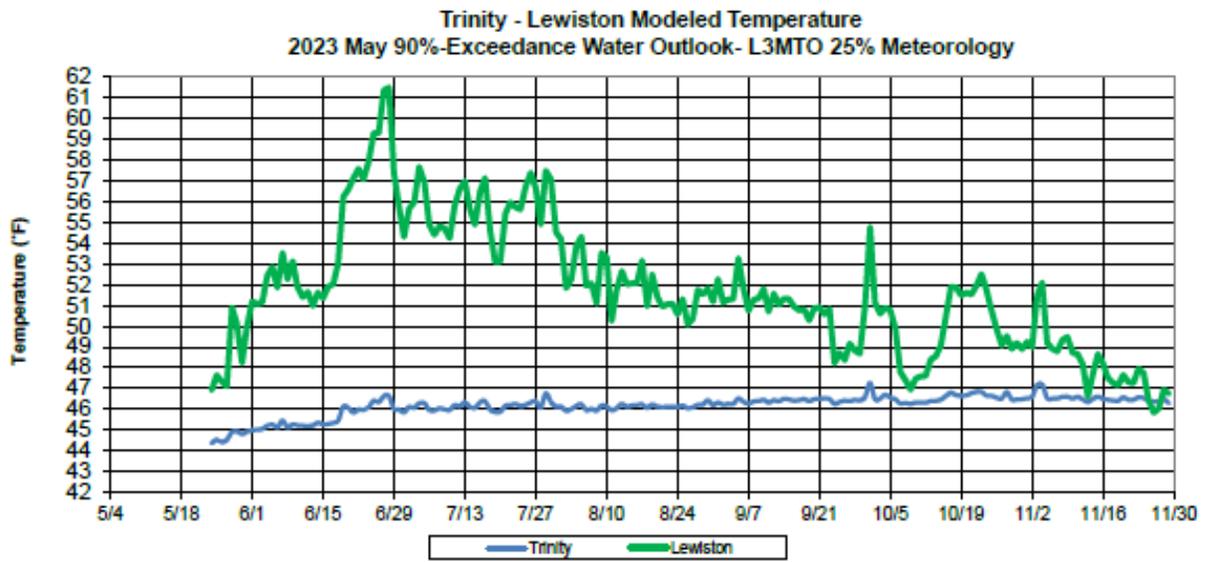


Figure 3: Trinity – Lewiston Modeled Temperature – May 2023 90%-Exceedance Water Outlook Historical 25% Meteorology



## Attachment 4. Biological Modeling

Spatially-explicit daily average Sacramento River water temperatures forecasts from the HEC-5Q model results are used as inputs to generate temperature-dependent egg mortality estimates. For this period, modeled temperatures, actual temperatures until May 31, 2023, and modeled temperatures after that, on the Sacramento River at Keswick Dam, above Highway 44, above Clear Creek, and Balls Ferry bridge, and interpolated temperatures at other locations are used to estimate temperatures at river miles where simulated winter-run redds were located.

Temperature-dependent egg mortality estimates are calculated by modeling a redd’s lifetime based on the days required to cross a known cumulative degree-day threshold and estimating mortality as an increasing function of temperature past a temperature threshold. Martin et al (2017) was used to estimate stage-independent modeling whereby a single temperature threshold is used from spawning and incubation through emergence (Figure 1). Anderson et al. (2021) was used to estimate stage-dependent modeling for targeting different temperatures before, during, and after the most sensitive stages during egg incubation (Figure 2). The methods are applied to a set of simulated redds representative of redd construction timing and location from 2001-2022 and the results summarized on a population level for comparison. Further information about the model’s assumptions are documented in Table 1 below.

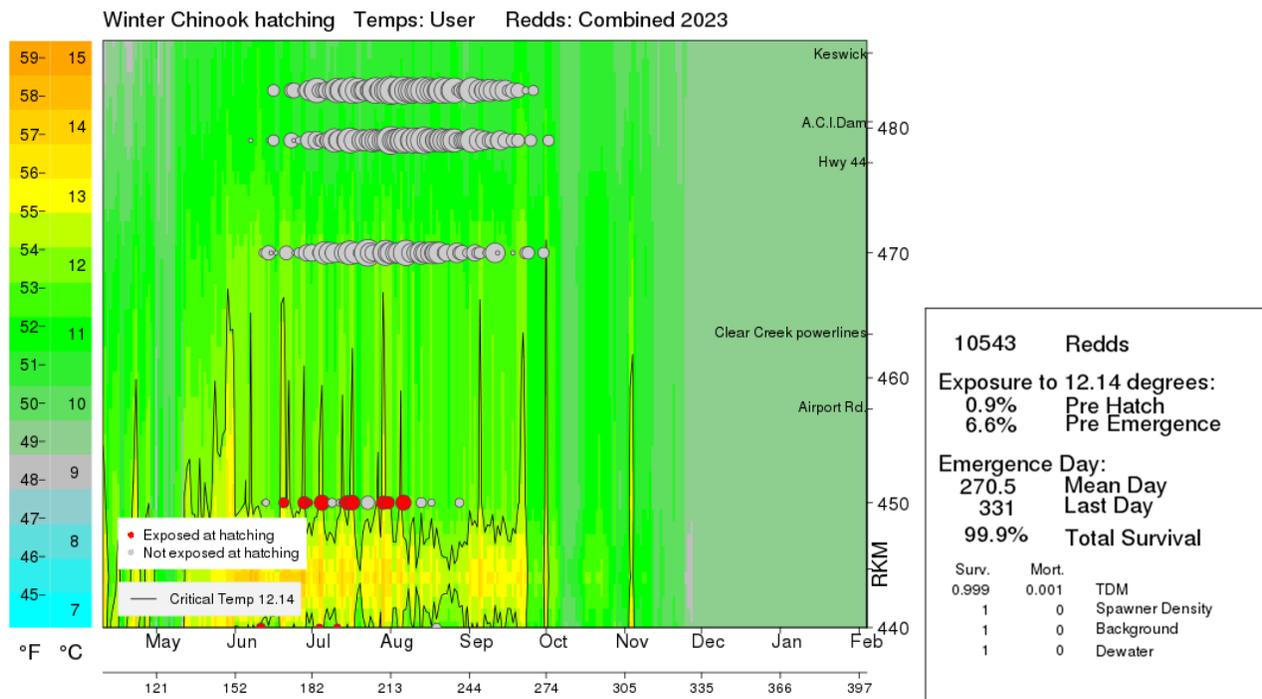


Figure 1. May 31 temperature landscape with modeled temperatures starting June 1 and

2001-2022 redd locations and timing (Stage-independent mortality).

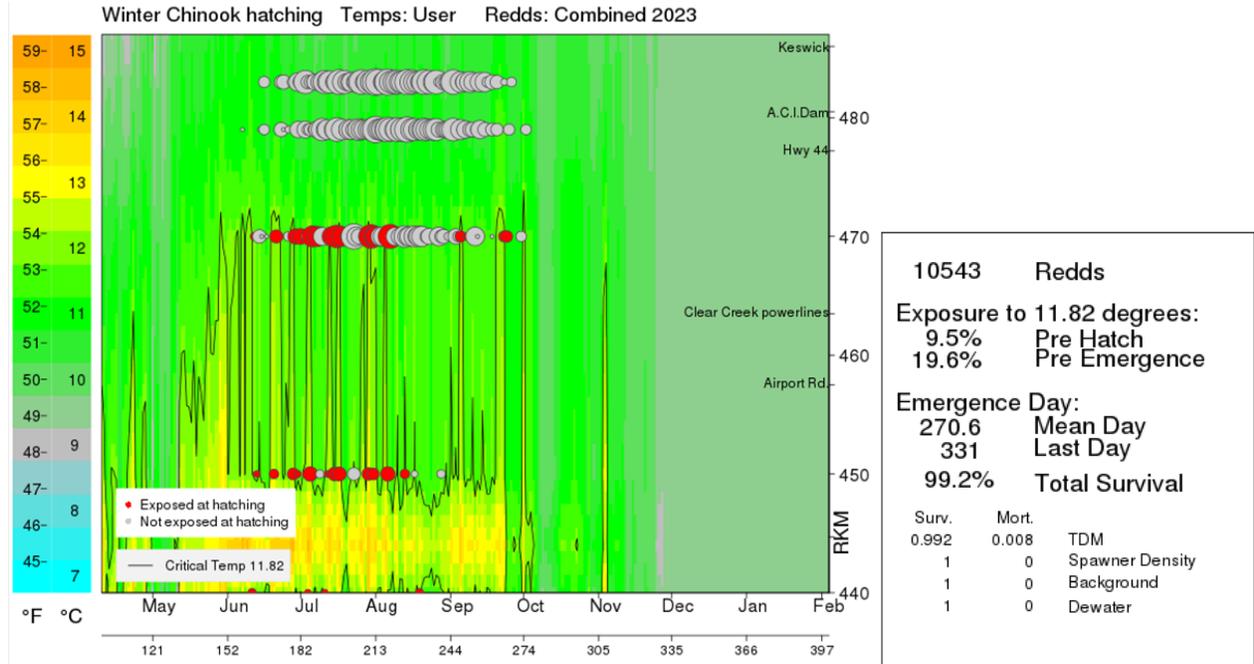


Figure 2. May 31 temperature landscape with modeled temperatures starting June 1 and 2001-2022 redd locations and timing (Stage-dependent mortality).

Table 1. Biological modeling parameter information.

Parameter	May 31, 2023 Scenario
Meteorology source	L3MTO Meteorology 25%
Time period	1/1/23-5/31/23: Observed temperature 6/1/23-11/29/23: Simulated
Reservoir Model used	HEC-5Q
River Model used	HEC-5Q
Shasta Profile date	5/24/23
TCD Gate operations	HEC-5Q
Sacramento water temperatures used	HEC-5Q output at Keswick, Highway 44, Clear Creek, and Balls Ferry.
Biological Model used	SacPAS Fish model (Temperature effect only)
Temperature Mortality Models	Stage-independent mortality Stage-dependent mortality
Egg emergence timing model	Linear. 958 ATUs (degrees C), as indicated for Zeug et al. on SacPAS under Egg to emergence timing model.

<b>Parameter</b>	<b>May 31, 2023 Scenario</b>
TDM redd time distribution	Aerial Surveys 2001-2022 (10,543 redds)
TDM redd space distribution	Aerial Surveys 2001-2022 (10,543 redds)
TDM Tcrit (50th percentile)	Stage-independent mortality: 12.14°C Stage-dependent mortality: 11.82°C
TDM bT (50th percentile)	Stage-independent mortality: 0.026°C <sup>-1</sup> d <sup>-1</sup> Stage-dependent mortality: 0.436°C <sup>-1</sup> d <sup>-1</sup>
Critical Days	Stage-independent mortality: All Stage-dependent mortality: 4 days
TDM estimate	See Figures 1 and 2