

May 2, 2022

## **SACRAMENTO RIVER TEMPERATURE MANAGEMENT PLAN FOR WATER YEAR 2022**

### **INTRODUCTION**

Conditions in the Central Valley are critically dry, and consequently, Shasta temperature management is limited by these dry conditions. Water Year 2022 is also following a critically dry year in 2021 and a dry year in 2020. This year also had the driest January through March period on record. The Northern Sierra Precipitation 8-Station Index indicates that this year's hydrologic conditions are nearly 20 inches less than average. In mid-March, Shasta Reservoir's cold water pool used to protect winter-run Chinook salmon was projected to be comparable to other drought years such as 2014, 2015 and 2021.

This Water Year 2022 Sacramento River Temperature Management Plan (Plan) reflects numerous drought actions that were planned and/or finalized to lessen the impact of the drought on fish and wildlife, water supply, public health and safety and carryover storage for next year. These actions are outlined in the Drought Contingency Plan which is updated regularly with the latest update available by May 1, 2022. This temperature management plan includes many assumptions of drought actions in order to reach the forecasted Shasta and Keswick monthly releases; however, these actions are not fully explained in this report as they are system-wide actions rather than specific temperature management actions.

This Plan reflects coordination starting in February 2022 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°F; and
- 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.
- The Interim Operations Plan (IOP), ordered by the US District Court on March 14, 2022, 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.
- Temporary Urgency Change Order (TUCO) dated April 4, 2022

May 2, 2022

The Plan establishes temperature locations and targets through October 31 and estimates potential winter-run Chinook salmon egg mortality, dates for operation of the side gates on the Temperature Control Device (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 February 90% forecast, Reclamation identified that Water Year 2022 was likely to be a Tier 4 year. In a Tier 4 year, there is less than 2.5 MAF of total storage in Shasta Reservoir at the beginning of May, and/or Reclamation cannot meet 56°F at CCR. Conditions on March 1 along with modeling based on measured reservoir profiles confirmed that WY2022 is a Tier 4 temperature management season.

## **BACKGROUND**

The 2020 Record of Decision requires use of conservative forecasts through the seasonal planning process for reservoir releases (including developing initial and updated allocations) and temperature management planning, such that monthly release forecasts and associated allocations are typically based on a 90 percent exceedance inflow forecast through September. The Plan manages the cold water pool at Shasta Reservoir using a tiered strategy to better manage the limited cold water resource for winter-run Chinook salmon egg survival. The tiered approach recognizes the substantial influence of hydrology on available cold water and targets a temperature of 53.5°F in the upper Sacramento River above Clear Creek from May 15 to October 31. The ROD incorporates a number of measures to improve Shasta storage and the related cold water pool for the upcoming temperature management season. Reclamation will manage water temperatures based on the following tiers, depending on the actual size of the cold water pool in a given year:

- Tier 1 – Sufficient volume of cold water to target 53.5°F or lower starting May 15 through October 31
- Tier 2 – Sufficient volume of cold water to target 53.5°F during critical egg incubation period
- Tier 3 – A volume of cold water that can target 53.5-56°F during critical egg incubation period; and consideration of intervention measures in lower Tier 3 years
- Tier 4 – Insufficient cold water to maintain 56°F or lower; and consideration of intervention measures

Reclamation's Plan uses modeling and professional expertise to identify the most protective tier that can be achieved given the available cold water. Before the reservoir stratifies and the volume of cold water is known, Reclamation estimates temperature capabilities based on projections of storage.

## **PRE-SEASON ACTIONS**

As water year 2022 began to shape out, Reclamation worked with water users, the State and Federal fishery agencies and other stakeholders to implement several actions prior to the start of the temperature management season. These actions are listed below with a brief description:

*Winter-run Chinook Salmon Conservation Hatchery Production:* In February 2022, a multi-agency team discussed increasing Livingston Stone National Fish Hatchery (LSNFH) winter-run Chinook salmon production targets for Water Year 2022. Typically, the USFWS would collect 60 females and 100 males out of the Keswick fish trap; however, due to poor conditions and potential low survival of BY2022 natural winter-run Chinook salmon, they anticipate collecting up to 340 females and 340 males for broodstock. This collection will increase production to 1,500,000 juveniles.

May 2, 2022

Reclamation is also preparing chillers for use later in the season in the event that deliveries to the hatchery become too warm.

*Shasta Critical Year Determination:* In February, Reclamation notified senior water right holders on the Sacramento River of a Shasta Critical Year and a reduction to 75% of contract totals under the Sacramento River Settlement Contract. Due to the very low storage at Shasta Reservoir and the two back-to-back years of low egg to fry survival for the endangered winter run chinook salmon, Reclamation, DWR, NMFS, FWS, CDFW and the State Water Resources Control Board worked with the Sacramento River Settlement Contractors to develop a Keswick release plan that conserves Shasta storage and prioritizes temperature management in the Sacramento River. This release plan was used to determine the available water for diversion by the Sacramento River Settlement Contractors and the wildlife refuges north of the Delta. The current estimate is that approximately 18% of the total contract value will be available for delivery in WY 2022 based on this release assumption. This delivery assumption was used in the forecast included in this Plan.

## **SYSTEM-WIDE DROUGHT OPERATIONS**

As mentioned previously, a series of drought actions are being implemented or planned for implementation for WY2022 that will support reduced releases from Shasta Reservoir in order to support temperature management through the summer. These additional actions are described in more detail in the May 1, 2022 Drought Contingency Plan and are briefly listed below for reference:

- Temporary Urgency Change Petition to modify Delta requirements
- Emergency drought barrier to minimize Delta salinity intrusion
- Minimum exports to limit releases needed to support Delta needs
- Urban water conservation to limit releases needed to support system needs
- Curtailments from the SWRCB to reduce demands throughout the system
- Low or zero allocations to CVP and SWP contractors

The combination of these actions may allow for the reduced releases from Shasta Reservoir without causing detrimental impacts to other CVP or SWP reservoirs. A description of the system wide operation is included in the Drought Contingency Plan.

## **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 Plan. Future water temperature at various elevations in the reservoirs and downstream in the river is forecasted using computational tools. These tools are based on conservative assumptions regarding hydrology, operations, and meteorology. Because this forecast (using conservative estimates in April 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

May 2, 2022

performed. A hindcast, rather than looking forward to forecast, simply uses the actual input/forcing data after it is observed (e.g. hydrology, operations, and meteorology) to determine how well the model reproduced a condition such as actual downstream water temperatures.

Reclamation uses the 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 water 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. This approach was not available in March therefore Reclamation's March model runs utilized historical 25% exceedance meteorology. However, for this Plan, and future model runs, Reclamation will utilize the 25% exceedance L3MTO forecast.

## **RELEASE OUTLOOK**

The Keswick Reservoir release schedule was developed through multi-agency coordination including Reclamation, NMFS, USFWS, CDFW, California Department of Water Resources (DWR), SWRCB, the California Environmental Protection Agency (CalEPA) and the Sacramento River Settlement Contractors. This release strategy is dramatically different than any past year and releases are extremely low compared to normal summertime flows. The Plan and temperature modeling relies on numerous drought actions throughout the Sacramento watershed to reduce reliance on stored water from CVP and SWP reservoirs this summer. These drought actions have added a degree of flexibility to manage storage at Shasta, Oroville and Folsom reservoirs for meeting public health and safety needs, repelling salinity in the Delta, producing hydropower and providing additional cold water for fishery protection throughout the summer. 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 Critically Dry year type and diversions through Carr Powerplant were adjusted to balance flow and water temperature goals between Trinity and Sacramento River basins. 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 weekly Water Operations Management Team (WOMT) meeting. Table 1 describes the monthly forecasted operations for releases and storage targets which were taken from the April 90% CVP forecast of operations (Attachment 1).

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

Operations Information/Month	May	June	July	August	September
Shasta Releases (TAF)	267	253	257	257	218
Keswick Releases (cfs)	4,500	4,500	4,500	4,500	4,000
Keswick Releases (TAF)	277	268	277	277	238
Spring Creek Power Plant (TAF)	10	15	20	20	20
Shasta End-of-Month Storage (TAF)	1,646	1,523	1,382	1,238	1,135

## 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, 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 (e.g., wildfires and equipment malfunctions) can also influence real-time operation decisions. To address uncertainty, Reclamation uses conservative estimates of future conditions in the modeling assumptions (e.g., hydrology, operations, and meteorology) and projections are updated through the management period. Any necessary adjustments to this temperature management plan due to these or other uncertainties will be discussed with SRTTG, WOMT and/or the Shasta Planning Group as appropriate.

The release forecast and modeling used for this temperature management plan is based on a number of assumptions that each come with a level of uncertainty. A brief description of these uncertainty areas is included below:

- **Inflow hydrology:** This forecast is based off the 90% exceedance inflow hydrology for Shasta reservoir, Trinity reservoir and the remainder of the watershed. Inflows below the 90% may cause lower storages at the end of September and additional challenges with temperature management. By May, the difference between the 90% and the 99% exceedance forecast is low.
- **Meteorology:** California’s climate is sensitive to large-scale ocean-atmosphere oscillations and is highly variable from year to year. California has the greatest variation in precipitation compared to all other U.S. States. Significantly higher ambient air temperatures than assumed in this forecast may result in the need to adjust the temperature management plan and increase target temperatures.

May 2, 2022

Conversely, some events such as wildfires can have a large influence on reducing water temperatures as was observed during Water Year 2020. Smoke and haze may dampen the effects of unusually warm air temperature conditions on reservoir heating and downstream in-river warming.

- **Reservoir stratification:** Lake temperature profile and modeling updates will be provided to SRTTG regularly to communicate uncertainties in modeling throughout the temperature management season. A comparison between modeled profiles and actual profiles will be presented to SRTTG to help track the accuracy of forecasts and how uncertainties with the meteorology impacted Shasta Lake temperature model results. Significant changes to the reservoir stratification from what was modeled may occur and could affect both the target temperatures and the resulting temperature dependent mortality.
- **Redd Distribution:** The areas winter-run Chinook choose to spawn are variable by year and tend to be concentrated in the six miles of river immediately downstream of Keswick Dam, particularly in years with warmer water. Survival based on the TDM models will be higher in the cooler areas near the dam and decrease going downstream with lowest survival probability for the redds furthest downstream where water is warmer. The uncertainty in the redd distribution adds to the uncertainty in the TDM estimates. As fish spawn through the season, the known locations and timing of spawning will allow better estimates of survival for eggs in known locations at known times. For the purposes of modeling temperature dependent mortality as a result of this temperature management plan, Reclamation coordinated with SRTTG and the Shasta Planning Group to model two different redd distribution scenarios: 2021 redd distribution and an aggregate of the 2016-2021 redd distributions. Actual distribution may vary within or outside these assumptions.
- **Sacramento River Accretions and Depletions:** Accretions/depletions are the net gain or loss between the main upstream reservoirs (Shasta, Oroville and Folsom) and the Delta, as measured at Freeport along the Sacramento River. They include the net of inflow from smaller tributaries and creeks, diversions from various water users north of the Delta and natural losses due to infiltration and evaporation. Due to the significant reduction in available water for the Sacramento River Settlement Contractors and north of Delta wildlife refuges, the depletions throughout the system will vary significantly from past drought years. Reclamation and DWR have worked with the Sacramento River Settlement Contractors to adjust the forecasted Sacramento Valley depletions based on this reduction for a more realistic assumption of forecasted operations. Additional drought actions such as curtailments and reduced demands may further affect the depletions beyond these adjustments. Due to the implementation of several drought actions that have not been implemented in previous drought years, large uncertainties remain regarding the expected depletions for WY 2022.
- **Public health and safety demands:** Reclamation is committed to prioritizing public health and safety through both meeting minimum demands and maintaining salinity control in the Delta. Given the very low flows in the upper Sacramento under this release schedule, there may be unexpected challenges with meeting the demands due to either available supply or infrastructure

May 2, 2022

challenges in accessing the low flows. Should this become an issue, Reclamation will first respond to any emergencies and then relay the issue and discuss solutions with the Shasta Planning Group, SRTTG and/or the WOMT.

- **Infrastructure limitations:** This temperature management plan was developed with consideration of two main infrastructure limitations, although others may develop throughout the year. The two issues considered were the limitations on using the TCD and the need for temperatures below 56 deg F at the Livingston Stone National Fish Hatchery. Water elevations in spring of 2022 are the lowest they have been since operation of the TCD and as a result the middle gates have less water above them than normal. This results in needing to stop using the middle gates because of their design limitations rather than their temperature impacts. Reclamation may need to adjust operations of the middle gates to maintain a safe operation and will share any adjustments with SRTTG. The ability to meet the temperature threshold at the Livingston Stone National Fish Hatchery is based on the assumption of working chillers which can cool the water down at least 10 deg F to reach 56 deg F. Reclamation will work closely with the USFWS to identify any necessary adjustments based on infrastructure limitations at the Hatchery.
- **Trinity River imports and Trinity River temperature management:** Trinity River imports to the Sacramento basin are minimal in 2022 to support Trinity River temperature management. As the Trinity River temperature management is refined, these imports may also be refined and affect necessary releases out of Shasta.
- **Low flow river and reservoir thermodynamics** – The flows included in the Keswick release plan are more than 2,300 cfs lower than any past summer flow since the construction of the Dam. This lower flow may result in the need to adjust the temperature management plan and increase target temperatures. The temperature models used for this report rely on calibrations with historical relationships. Due to the lower flows in 2022, this relationship has not been verified and the models have not been calibrated for these low flow levels. As a result, there is significant uncertainty with the water temperature warming both in the river and in Keswick Reservoir.
- **Delta water quality:** Similar to the accretion/depletion description above, the forecasted releases made assumptions regarding necessary flows from the system to meet Delta outflow and water quality objectives. These assumptions, explained in more detail in the Drought Contingency Plan, include approval of the TUCP to relax both outflow and water quality standards from April through June and actions by the Water Board to curtail other diversions. Major increases in flows required to meet Delta water quality will first be met through releases from other reservoirs. However, if sufficient supply is not available in these reservoirs, it may lead to an increase in Shasta releases in order to maintain salinity control in the Delta.

## SACRAMENTO RIVER TEMPERATURE STRATEGY

The Keswick release schedule was finalized in late March and Reclamation completed preliminary HEC-5Q modeling on April 4. This preliminary modeling was used for the draft temperature management plan shared on April 6. This plan targeted 56 deg F at Highway 44 bridge gage (SAC) throughout the entire temperature management season until the available cold water was used. This plan resulted in a temperature dependent mortality above 70% but conserved the most cold water for maintaining temperatures in the fall. The draft plan also projected an initial side gate opening of July 16 and full side gate opening of September 1.

Reclamation received feedback from SRTTG members that the tradeoff of having lower TDM with warmer temperatures in the fall was favored and recommended targeting 54.5 deg F at SAC with the understanding

May 2, 2022

this may mean warmer fall temperatures. This tradeoff was viewed in context with the maximum temperatures allowable by the Livingston Stone National Fish Hatchery which was determined to be 66 deg F from Shasta Dam assuming 10 deg F of cooling capability with the chillers. The fall temperatures seen in the temperature modeling targeting 54.5 deg F were well below 66 deg F and therefore this was the selected plan for the final temperature management plan. Reclamation also received feedback from SRTTG members that an initial target of 58 deg F would help to conserve cold water for later during the more critical portion of the temperature management season.

The final temperature management strategy, based on recommendations received from SRTTG, is to target 58 deg F at SAC during the initial part of the season and then target 54.5 deg F for 16 weeks around the estimated peak spawning date of Aug 2. This would result in targeting 54.5 deg F from June 7 through September 27 or until the cold water is used. Due to the limitations on operating the middle gates (as described above), temperatures in June and July may be cooler than 54.5 deg F. Reclamation will operate the TCD to target as close as possible to 54.5 deg F to conserve cold water for maintaining target temperatures throughout the critical period.

Updated reservoir temperature profiles, updated meteorology, redd distribution assumptions, and shaping approaches were included in HEC-5Q modeling on April 25. The April 25 temperature modeling is presented here and is reflected in resulting biological and water supply performance metrics as shown in Table 2, Table 3, Attachment 2, and Attachment 3. Further refinement to the temperature management strategy will occur through coordination with SRTTG and SPG as the season progresses.

*Table 2. Estimated water temperature in degrees Fahrenheit at Shasta, Keswick, SAC, and CCR from April 25 HEC-5Q run. HEC-5Q does not perform well after mid-September under low storage conditions. 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	SAC (Hwy 44)	CCR
May	55.4	57.5	57.6	58.5
June	48.2	52.5	53.0	54.5
July	49.2	53.0	53.5	54.9
August	49.0	53.5	54.1	55.9
September	50.5	53.9	54.2	55.4
October	54.9	56.5	56.5	57.0
November	54.0	53.7	53.7	53.9

*Table 3. Fish and water performance metrics.*

Metric	April 25 Scenario
Stage-independent TDM	2021 redds: 42% 2016-2021 redds: 51%
Stage-dependent TDM	2021 redds: 36% 2016-2021 redds: 45%
End of Sept CWP Storage (TAF)	186 TAF
First Side Gate Use	July 27
Full Side Gate	September 1
End of September Storage (MAF)	1.14 MAF

May 2, 2022

Temperature modeling results for this same temperature strategy from the NMFS Southwest Fisheries Science Center are included in Attachment 4.

## TRINITY RIVER TEMPERATURE STRATEGY

Trinity River temperature management is expected to be very limited in 2022 due to the extremely low storage at Trinity Reservoir. The ability to modify operations to manage temperatures in the Trinity River is defined by the use of the lower level auxiliary outlet which bypasses power production from Trinity to Lewiston Reservoir. Water temperatures in the Trinity River below Lewiston may also be managed by releases to the Trinity River below Lewiston Dam and/or increased releases from Trinity Dam and diverted to the Sacramento River basin. Reclamation does expect to use the auxiliary outlet at some point in 2022 to manage temperatures in the Trinity River. SWRCB Order 90-5 requires temperature management in the Trinity River at Douglas City and downstream beginning September 15, however using the auxiliary outlet to lower temperatures this early may result in running out of available cold water early in the fall. NMFS provided the following comments regarding the temperature management plan on the Trinity River:

- The draft TMP results in a Lewiston release temperature of 56.9°F in October from Lewiston Dam (Attachment 2 in the plan), which exceeds the 56°F degree SWRCB objective without any downstream warming at both Douglas City and above the North Fork Trinity River.
- The 56°F at the Douglas City Bridge between September 15 and October 1 and at the confluence of the North Fork Trinity River between October 1 and December 31 are not sufficiently cold to prevent mortality of Chinook Salmon and Coho Salmon eggs in the Trinity River.
- After November 1, NMFS recommends Reclamation meet temperatures of 53.5°F (12°C) daily max and 50°F (10°C) daily average, or less.
- NMFS recommends that the auxiliary outlet for the Trinity Reservoir only be used following coordination with Trinity River basin stakeholders, managers, and Tribes. Unless significant impacts to Trinity River adult Chinook Salmon are expected or observed in September and October of 2022, the auxiliary outlet on Trinity Dam should only be used after November 1 to reduce take of ESA listed SONCC Coho Salmon adults and eggs.
- NMFS recommends Reclamation pursue three dimensional modeling of Trinity and Lewiston reservoirs to find methods that would result in the coldest water released from Lewiston Dam while maximizing Trinity Reservoir storage. For example, *increasing* residence time of water in Lewiston Reservoir in the fall after ambient air temperatures and the angle of solar radiation have decreased may help reduce water temperatures released from Lewiston Dam and preserve water in Trinity Reservoir. Based on the model results, we recommend measures be taken to reduce Lewiston Dam release temperatures and maximize Trinity Reservoir storage. Additional measures such as draining Lewiston Reservoir in the fall combined with significantly curtailing diversions to allow for cooling of warm water released Trinity Reservoir should be modeled.
- The Draft TMP includes the diversion of 91 TAF after October 1 2022 (Attachment 1 in the plan). We recommend that Reclamation significantly curtail all diversions to the Sacramento River after October 1, 2022, until at which time in water year 2023 it can be determined that the Trinity Reservoir will recover to a projected EOS storage of at least 1.2 MAF in 2023. This will reduce the probability of similarly low Trinity Reservoir storage in 2023.

Similar comments were received by the Yurok Tribe. Reclamation agrees with the concerns regarding fall temperatures and commits to working with Trinity River stakeholders to coordinate the appropriate date of using the auxiliary outlet for temperature management as well as potentially adjusting flows within the Trinity River system. Reclamation also agrees to work with the Trinity Management Council (TMC) on refining the volume of fall imports to support fall temperature management on the Trinity River while conserving storage in Trinity to the maximum extent possible. Changes to the fall augmentation flows may

May 2, 2022

also affect fall temperatures and Trinity Reservoir storage levels.

Results of the Trinity River temperature modeling are shown in the Table 4 and does not include the use of the auxiliary outlet because it cannot be modeled using current tools. Use of the auxiliary outlet would be expected to decrease temperatures when in use.

Table 4. Estimated monthly average water temperature in degrees Fahrenheit at Trinity and Lewiston from April 25 HEC-5Q run.

Month	Trinity	Lewiston
May	47.3	50.2
June	48.2	53.4
July	48.9	53.8
August	50.6	55.0
September	54.3	56.7
October	57.4	58.6
November	54.6	53.8

## TECHNICAL ASSISTANCE AND CONSULTATION

### *Year-round*

Agencies meet weekly in the WOMT to discuss operations at all major CVP and SWP facilities. In addition, technical teams meet regularly to review observed data and make adjustments to the plan as needed. The combination of WOMT and technical team meetings will allow for discussion and feedback on real-time management on at least a weekly basis with staff from the fisheries agencies, the State Water Board, and other appropriate entities. In addition, the Shasta Planning Group was initiated in 2022 as a management level group to review changes to the Keswick release plan and/or changes to the Sacramento River Temperature Management Plan and provide any necessary direction to the SRTTG. This group meets regularly as needed.

### *December – Conservation of Cold Water Pool and Inactive Temperature Management Period*

Reclamation provided monthly updates via e-mail to the SRTTG, outlining current river and reservoir conditions, operations, hydrology, meteorology, and long-range precipitation forecast information. No significant issues concerning temperature management arose during this period and the SRTTG was not convened.

### *January through April – Temperature Management Preparation*

Reclamation convened SRTTG meetings, starting in January 2022, on a monthly basis to ensure communication and coordination among the parties in preparation for the temperature management season.

In February 2022, a multi-agency team discussed increasing LSNFH winter-run Chinook salmon production targets for Water Year 2022. Typically, the USFWS would collect 60 females and 100 males out of the Keswick fish trap; however, due to poor conditions and anticipated low survival of BY2022 natural winter-run Chinook salmon, they anticipate targeting collection of 340 females and 340 males.

In mid-March 2022, Reclamation prepared initial projections of anticipated temperature management

May 2, 2022

capability and considerations based on the 90% March hydrologic and runoff forecasts from the Department of Water Resources (DWR) and National Weather Service River Forecast Center. Reclamation's March projections showed that a Tier 4 year was likely. Reclamation initiated interagency coordination through the Drought and Dry Year activities and stakeholder coordination through the Meet and Confer activities described in the 2020 Record of Decision (ROD). Also in mid-March 2022, the Sacramento River Settlement Contractors initiated the meet and confer commitments under the 2020 Record of Decision and began discussions on voluntary measures for Shasta Cold Water Pool Management Dry Years, Drought Years, and Successive Dry Years. Reclamation's Proposed Action 4.12.5 describes that in Tier 3 and 4 years, Reclamation shall meet and confer with USFWS, NMFS, DWR, CDFW, and Sacramento River Settlement Contractors on voluntary measures to be considered if drought conditions continue into the following year, including measures that may be beyond Reclamation and DWR's discretion.

Reclamation, DWR, NMFS, FWS, CDFW and the State Water Resources Control Board worked with the Sacramento River Settlement Contractors to develop a Keswick release plan that conserves Shasta storage and prioritizes temperature management in the Sacramento River. This release plan was used to determine the available water for diversion by the Sacramento River Settlement Contractors and the wildlife refuges north of the delta. This schedule was finalized in late March. Reclamation prepared initial projections of anticipated temperature management capability based on 90% March hydrologic and runoff forecasts, the Keswick release schedule, and historical performance. These projections were provided to the SRTTG as part of the draft temperature management plan during the March SRTTG meeting which was held on April 7th. In March, the projected total Shasta storage on May 1 was less than 2.5 MAF, so Reclamation continued discussions regarding Tier 4 operations.

In mid-April, Reclamation prepared updated projections of anticipated temperature management capability including considerations from updated 90% hydrologic and runoff forecasts. These updated projections were also shared with the SRTTG in advance of scheduled SRTTG meetings.

On May 2, 2022, Reclamation distributed the final Temperature Management Plan to the NMFS, the State Water Resources Control Board and SRTTG.

## **MONITORING AND REPORTING**

CDFW, Pacific States Marine Fisheries Commission (PSMFC), and USFWS conduct regular carcass and redd surveys for winter-run Chinook salmon starting in May. This monitoring allows for observations of pre-spawn mortality, initiation of spawning or potential effects associated with spring TMP operations. These data are being shared so Reclamation and others are notified regarding pre-spawn mortality and the initiation of spawning. From May through October, Reclamation plans to convene SRTTG meetings each month, or more often as warranted by any changing conditions, to ensure tracking and monitoring of the temperature strategy. Temporary exceedances of the daily average temperature criteria of more than 3 consecutive days will be reported to the SRTTG. Should changes to the strategy be necessary, those changes will be developed through communication and coordination with the SRTTG, the Shasta Planning Group and other interested parties as warranted.

In October 2022, data collection by CDFW and communication to CVO operations will be coordinated to determine the ending date of the temperature management period: October 31, or when the SRTTG determines, based on real-time monitoring that an estimated 95 percent of Winter-run Chinook Salmon eggs have hatched, and alevin have emerged, whichever is earlier.

In November 2022, Reclamation will operate the TCD to minimize in-river thermal impacts with remaining cold water pool resources after the end of the temperature management season, if available, until seasonal changes and ambient conditions dominate river cooling downstream.

For Water Year 2022, Reclamation will complete, in coordination with SRTTG as appropriate, the following monitoring and reporting practices:

- Monthly letters to the SWRCB containing relevant data and information as identified in Order 90-5.
- Near-real-time reporting through Reclamation’s web interface of relevant information, located at the following website: <https://www.usbr.gov/mp/cvo/vungvari/sactemprrpt.pdf>.
- Transmittal of pertinent data and information to the SRTTG prior to meetings or more often as conditions warrant, including applicable modeling and tracking information during the course of the temperature management season. The modeling and tracking information that support the Plan are attached (Attachments 1 and 2). Meeting information can be accessed at the following website: <https://www.usbr.gov/mp/bdo/sacramento-river-temperature-task-group.html> and <https://www.usbr.gov/mp/cvo/temperature.html>
- Monitoring and communication to determine on-set of winter-run Chinook Salmon spawning.
- Monitoring and communication to determine when an estimated 95% of winter-run Chinook Salmon eggs have hatched and alevin have emerged.

Reclamation intends to provide temperature profile measurements for Shasta, Whiskeytown, and Trinity Reservoirs in Water Year 2022 as shown in Table 5 below:

*Table 5. Frequency and detail of Northern Central Valley Project temperature profile monitoring*

<b>Reservoir</b>	<b>Every Month</b>	<b>Every 2 Weeks</b>	<b>Every Week</b>	<b>Comment</b>
Shasta	01/01–03/01 12/1–12/31	03/01–04/01 11/15–12/01	04/01–11/15	25 ft intervals for “Every Month,” otherwise 5 ft intervals
Whiskeytown	01/01–12/31			25 ft intervals
Trinity	01/01–12/31			25 ft intervals

The monthly temperature profiles for Whiskeytown and Trinity are sufficient to capture the thermal dynamics; both have limited abilities to actively manage selective withdrawal and the coldwater pool volume does not rapidly change for most of the year. Reclamation will post the corresponding isothermobaths on its website identified above as soon as the information becomes available.

Reclamation has relied on CDFW’s carcass and redd surveys to determine onset of winter-run Chinook salmon spawning and will rely on CDFW to calculate when an estimated 95% of eggs and alevin have hatched and emerged. As in past years, Reclamation intends to use the PSMFC and CDFW redd dewatering survey to provide information on potential redd dewatering and stranding for informing real-time operations of Shasta and Keswick Dams during the fall transition period. Reclamation will continue to support and conduct monitoring, modeling, and other evaluations needed to ensure that temperature management actions are optimized and in order to inform future management actions. Reclamation will continue to coordinate with CDFW on river operations to ensure its field monitoring program can be safely and effectively implemented. Fish monitoring and evaluations of operational actions on the Upper Sacramento River will be documented in the Shasta Cold Water Pool and Winter-Refill seasonal reports.

Reclamation’s website (<https://www.usbr.gov/mp/cvo/vungvari/sactemprrpt.pdf>) and letters provide the information to meet the needs of the SWRCB and fisheries agencies for the locations currently being monitored. Should the SWRCB or fisheries agencies require the data from any of the monitoring stations

May 2, 2022

outlined above in other formats or need to obtain data from other monitoring sites that Reclamation maintains or has access to, Reclamation can work with the SWRCB or fisheries agencies to provide that data.

### **WATER RIGHTS ORDER 90-5**

Order 90-5 identified a 56°F temperature objective as “the temperature that will protect the fishery from adverse thermal effects during salmonid spawning and egg incubation.” It further recognizes that Reclamation’s ability to control temperatures is dependent on the amount of water in storage at Shasta Reservoir, ambient air temperatures, tributary inflow and other factors, and that the length of the reach to be protected must be flexible and requires careful planning. Order 90-5 provides that factors beyond Reclamation’s reasonable control include conditions where protection of the fishery can best be achieved by allowing a higher temperature in order to conserve cool water for a later release, and conditions where allowing a higher temperature is necessary to implement measures to conserve winter run Chinook salmon. For Water Year 2022, Reclamation has determined that it cannot reasonably maintain 56°F at Red Bluff Diversion Dam and that:

- Protection of the fishery can best be achieved by allowing a higher temperature in order to conserve cool water for later release,
- A higher temperature is necessary to implement measures to conserve winter-run Chinook salmon.

Reclamation’s Plan to conserve cold water for the duration of the temperature management period and operate to a higher temperature at Red Bluff Diversion Dam will best protect the fishery from adverse thermal effects during salmonid spawning and egg incubation. More specifically, Reclamation will be operating to the temperatures and compliance locations included in the Plan which are upstream of Red Bluff Diversion Dam.

**Storages**

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

		Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar
Trinity	807	756	693	646	589	505	423	394	372	356	360	393	459
	Elev.	2225	2216	2209	2200	2186	2170	2164	2159	2155	2156	2164	2177
Whiskeytown	213	238	238	238	238	238	238	206	206	206	206	206	206
	Elev.	1209	1209	1209	1209	1209	1209	1199	1199	1199	1199	1199	1199
Shasta	1735	1746	1646	1523	1382	1238	1135	1132	1117	1106	1229	1432	1759
	Elev.	942	935	927	917	906	897	897	896	895	905	921	943
Folsom	584	670	669	556	366	302	298	274	254	243	272	345	293
	Elev.	436	436	423	398	388	387	382	379	377	382	395	386
New Melones	935	908	831	753	690	638	611	569	572	574	580	578	574
	Elev.	929	918	905	894	885	880	872	872	873	874	873	873
San Luis	333	332	300	231	142	110	87	31	73	130	332	328	311
	Elev.	445	438	422	403	391	383	369	379	399	436	432	430
<b>Total</b>		4651	4376	3947	3407	3031	2792	2606	2594	2614	2980	3281	3602

**State End of the Month Reservoir Storage (TAF)**

Oroville	1675	1920	1746	1496	1227	1087	1039	1011	1011	1061	1171	1270	1426
	Elev.	775	758	730	697	677	670	666	666	673	689	702	722
State San Luis	588	593	560	480	403	344	307	271	293	385	505	474	473
Total San Luis (TAF)	921	925	859	711	544	454	394	302	367	514	837	801	785

**Monthly River Releases (TAF/cfs)**

Trinity	TAF	80	67	27	28	53	52	23	18	18	18	17	18
	cfs	1,347	1,092	450	450	857	870	373	300	300	300	300	300
Clear Creek	TAF	12	12	12	9	9	9	12	12	12	12	11	12
	cfs	200	200	200	150	150	150	200	200	200	200	200	200
Sacramento	TAF	193	277	268	277	277	238	200	193	200	200	180	200
	cfs	3250	4500	4500	4500	4500	4000	3250	3250	3250	3250	3250	3250
American	TAF	59	64	149	226	104	33	36	33	34	34	31	225
	cfs	1000	1045	2500	3674	1698	550	581	550	555	551	551	3657
Stanislaus	TAF	27	25	17	9	9	9	35	12	12	13	12	12
	cfs	461	401	290	150	150	150	577	200	200	213	214	200
Feather	TAF	59	105	178	215	169	137	59	57	59	59	100	123
	cfs	1000	1700	3000	3500	2750	2300	960	960	960	960	1800	2000

**Trinity Diversions (TAF)**

	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar
Carr PP	38	16	25	30	31	30	10	10	10	10	5	3
Spring Crk. PP	10	10	15	20	20	20	30	0	0	5	5	10

**Delta Summary (TAF)**

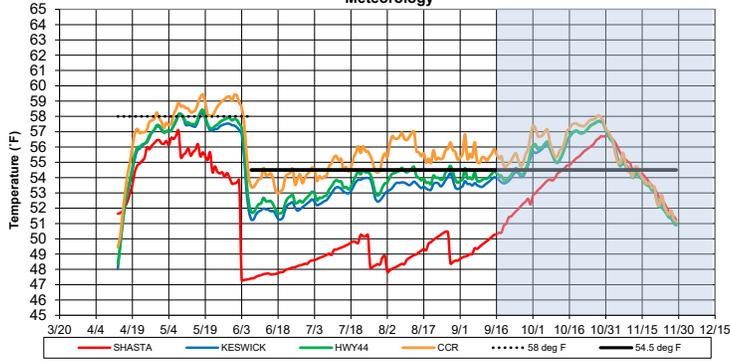
	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	
Tracy	54	56	62	49	50	80	50	114	100	219	45	52	
USBR Banks	0	0	0	0	0	0	0	0	0	0	0	0	
Contra Costa	4.3	6.6	5.9	7.3	7.3	5.6	4.6	2.8	2.7	2.1	2.0	5.2	
<b>Total USBR</b>	58	62	68	56	57	86	55	117	103	221	47	57	
State Export	36	37	18	20	21	19	18	50	95	161	18	31	
<b>Total Export</b>	94	99	86	76	78	105	73	167	198	382	65	88	
COA Balance	281	218	153	121	119	119	118	112	160	144	65	18	
Vernalis	TAF	60	58	42	32	34	40	64	46	40	74	78	37
Vernalis	cfs	1012	951	710	524	557	671	1049	772	655	1205	1403	607
Old/Middle River Std.													
Old/Middle R. calc.		-1,346	-1,404	-1,382	-1,310	-1,320	-1,642	-1,027	-2,402	-2,771	-4,834	-860	-1,422
Computed DOI		6505	4002	4001	4002	2993	3009	2993	3496	3497	6003	11400	11403
Excess Outflow		2505	0	0	0	0	0	0	0	0	0	0	0
% Export/Inflow		16%	19%	15%	12%	14%	23%	20%	39%	44%	54%	9%	11%
% 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)	421	2,725	1,387	502
Year to Date + Forecasted % of mean	35%	49%	51%	47%

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.

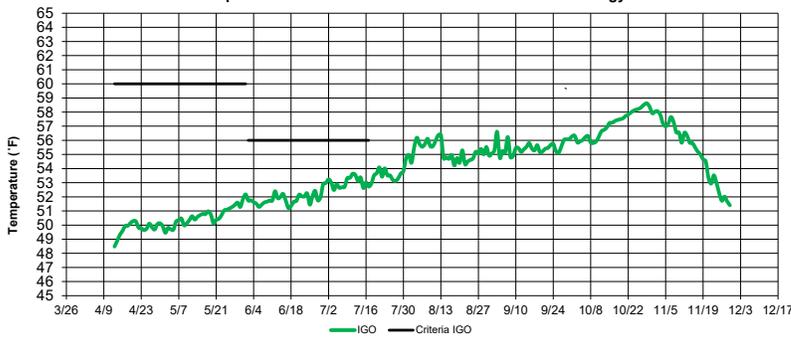
**Sacramento River Modeled Temperature**  
**2022 April 90%-Exceedance Water Outlook - L3MTO 25% Meteorology**



	Shasta deg F	Keswick deg F	Hwy44 deg F	CCR deg F	Igo deg F	Trinity deg F	Lewiston deg F
Apr							
May	55.4	57.5	57.6	58.5	50.6	47.3	50.2
Jun	48.2	52.5	53.0	54.5	51.8	48.2	53.4
Jul	49.2	53.0	53.5	54.9	53.3	48.9	53.8
Aug	49.0	53.5	54.1	55.9	55.2	50.6	55.0
Sep	50.5	53.9	54.2	55.4	55.5	54.3	56.7
Oct	54.9	56.5	56.5	57.0	57.1	57.4	58.6
Nov	54.0	53.7	53.7	53.9	55.2	54.6	53.8

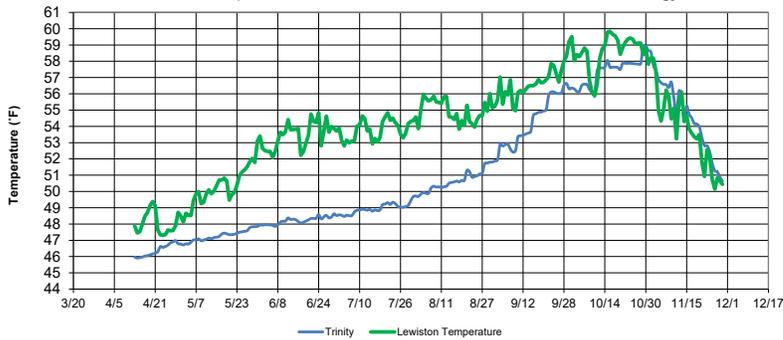
Run date: 4/25/22  
**EOM Sept storage: 1.14 MAF**  
 Trinity profile date: 4/25/22  
 Whiskeytown profile date: 4/12/22  
 Shasta profile date: 4/13/22  
 Projected Side gates: First Jul 27 Full Sep 1  
 Shaded area denotes period of model limitations - see Fall Temperature Index  
**End of September Cold-Water-Pool less than 56 deg F: 186 TAF**

**Clear Creek - Igo Modeled Temperature**  
**2022 April 90% Exceedance Outlook - L3MTO 25% Meteorology**



	Igo deg F
Apr	
May	50.6
Jun	51.8
Jul	53.3
Aug	55.2
Sep	55.5
Oct	57.1
Nov	55.2

**Trinity - Lewiston Modeled Temperature**  
**2022 April 90%-Exceedance Water Outlook- L3MTO 25% Meteorology**



	Trinity deg F	Lewiston deg F
Apr		
May	47.3	50.2
Jun	48.2	53.4
Jul	48.9	53.8
Aug	50.6	55.0
Sep	54.3	56.7
Oct	57.4	58.6
Nov	54.6	53.8

### **Attachment 3. Temperature Dependent Modeling Methods and Assumptions**

Spatially-explicit daily average Sacramento River water temperatures are used as inputs to generate temperature-dependent egg mortality estimates. Actual water temperatures at Keswick (KWK), Clear Creek (CCR), and Balls Ferry (BSF) gauges were used from January 1 to April 25. HEC-5Q output estimates water temperatures at Keswick Dam; however, there is no temperature gauge at the Keswick Dam, and therefore, the KWK gauge was used for temperature input for the time period January 1 to April 25. Simulated temperatures from the HEC-5Q model were used for April 26 to September 14.

Between September 15 and December 31, daily temperatures are estimated based on a regression relationship between cold water pool volume less than 56 deg F at the end of September in Shasta Lake and water temperatures at the KWK, CCR, and BSF gauges derived by Central Valley Operations. Adjusted Keswick and Clear Creek temperatures after September 15 are 59.4°F and 60.7°F, respectively. We provide TDM estimates using this adjusted water temperature time series (Table 1).

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. Two models were used: 1. Martin et al (2017) for stage independent modeling whereby a single temperature threshold is used from spawning and incubation through emergence; and 2. Anderson et al. (2022) for stage dependent modeling for targeting different temperatures before, during, and after the most sensitive stages during egg incubation. Model parameters are taken from Martin et al (2017) and Anderson et al (2022). The methods are applied to simulated redds representative of redd construction timing and location for two periods: 1) redds from 2021 and 2) redds from 2016-2021. The temperature dependent mortality model results are summarized at the annual scale for comparison. Further information about the model's assumptions is documented in Table 1 below.

#### Citations

Anderson, J., W. Beer, J. Israel, and S. Greene. 2022. Targeting river operations to the critical thermal window of fish incubation: model and case study on Sacramento River Winter-run Chinook Salmon. *River Research and Applications*: 1-11. DOI: 10.1002/rra.3965

Martin BT, Pike A, John SN, Hamda N, Roberts J, Lindley ST, Danner EM. 2017. Phenomenological vs. biophysical models of thermal stress in aquatic eggs. *Ecological Letters* 20(1):50–59. doi:10.1111/ele.12705.

**Table 1.** Assumption for April 25, 2022 temperature and biological modeling.

Parameter	April 25, 2022 Model Run
Meteorology source	National Weather Service forecast 25% L3MTO
Time period	1/1/22 - 4/25/22: Observed temperature 4/25/22 - 9/14/22: River Model simulated 9/15/22 - 11/29/22: Historical relationship
Reservoir Model used	HEC-5Q
River Model used	HEC-5Q until 9/14, then historic relationship to end of September storage below 56 deg F
Shasta Profile date	Shasta Profile: 4/13/2022 Whiskeytown Profile: 4/12/2022 Trinity Profile: 4/25/2022
TCD Gate operations	HEC-5Q
Temperature Model Targets	temperature target of 54.5°F at Highway 44 (SAC gauge) for 16 weeks centered on 8/2/22 and a shoulder temperature of 58.0°F.
Sacramento water temperatures used	January 1 – April 25: actual temperatures at Keswick, Clear Creek, and Balls Ferry April 26 – September 14: HEC-5Q output at Keswick, Clear Creek, and Balls Ferry September 15 to end of season: 59.4 F at Keswick and 60.7 F at Clear Creek
Biological Model used	Temperature mortality models on SacPAS Fish Model Version 2.7.4 ( <a href="#">SacPAS Fish Model v.2.7.4: SacPAS Central Valley Prediction and Assessment of Salmon (washington.edu)</a> )
Temperature Mortality Models	Stage-independent mortality (Martin et al. 2017) Stage-dependent mortality (Anderson et al. 2022)
Egg emergence timing model	Linear. 958 ATUs (deg C), as indicated for Zeug et al. 2012
TDM redd time distribution	Aerial Surveys 2021, 2016-2021
TDM redd space distribution	Aerial Surveys 2021, 2016-2021
TDM Tcrit	Stage-independent mortality: 12.14°C (Martin et al. 2017) Stage-dependent mortality: 11.98°C (Anderson et al. 2022)
TDM bT	Stage-independent mortality: 0.023°C <sup>-1</sup> d <sup>-1</sup> (Martin et al. 2017) Stage-dependent mortality: 0.436°C <sup>-1</sup> d <sup>-1</sup> (Anderson et al. 2022)
Critical Days	Stage-independent mortality: All (Martin et al. 2017) Stage-dependent mortality: 4 days (Anderson et al. 2022)
TDM estimates	Stage-independent mortality: <ul style="list-style-type: none"> <li>• 2021: 42%</li> <li>• 2016-2021: 51%</li> </ul> Stage-dependent mortality: <ul style="list-style-type: none"> <li>• 2021: 36%.</li> <li>• 2016-2021: 45%</li> </ul>

# TDM Modeling

April 27, 2022  
SWFSC

Additional information available at:  
<https://oceanview.pfeg.noaa.gov/CVTEMP/download>

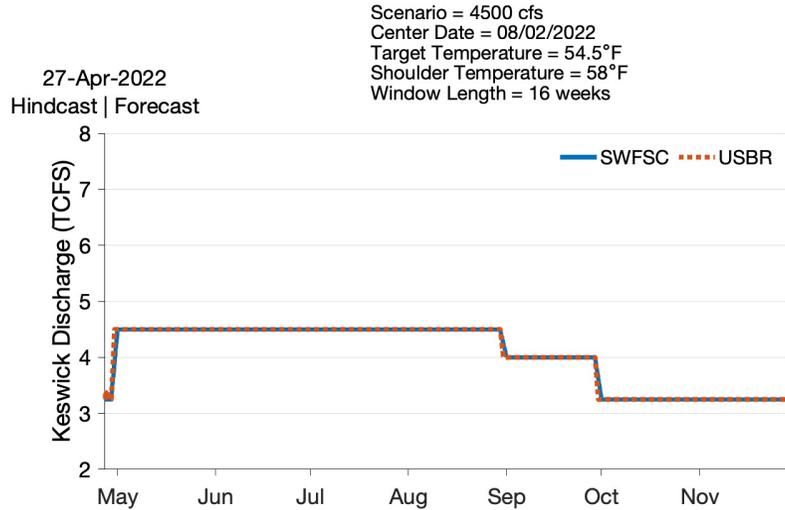
# Modeling Assumptions

1. April 99% B120 Exceedance Forecast Shasta Inflow
2. April 27 Shasta initial profile
3. 2015 meteorology
4. Spring Creek PP contributions to Keswick as provided in USBR 90% exceedance operational outlook from April 26, 2022
5. SAC gage temperature target location (achieving target NOT guaranteed)
6. Redds distributed in time and space according to 2021 aerial redd surveys (a compressed distribution relative to historical variability; 2016-2021 for comparison)
7. One scenarios considered (Target Temperature of 54.5F)
8. EOS storage estimate based on model initialized on April 27, 2022
9. Combination of CE-QUAL-W2 models for Shasta and Keswick, and RAFT for temperature predictions

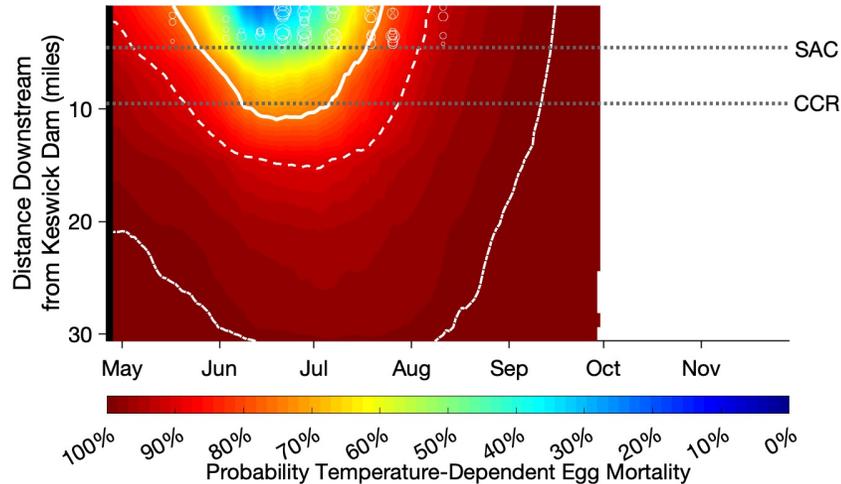
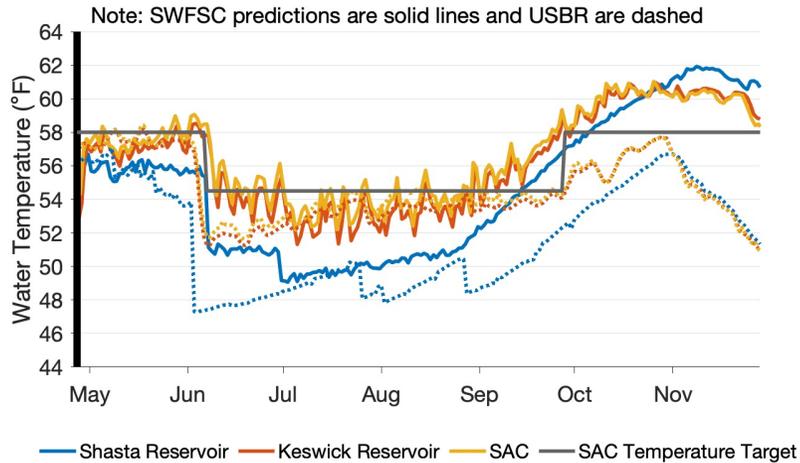
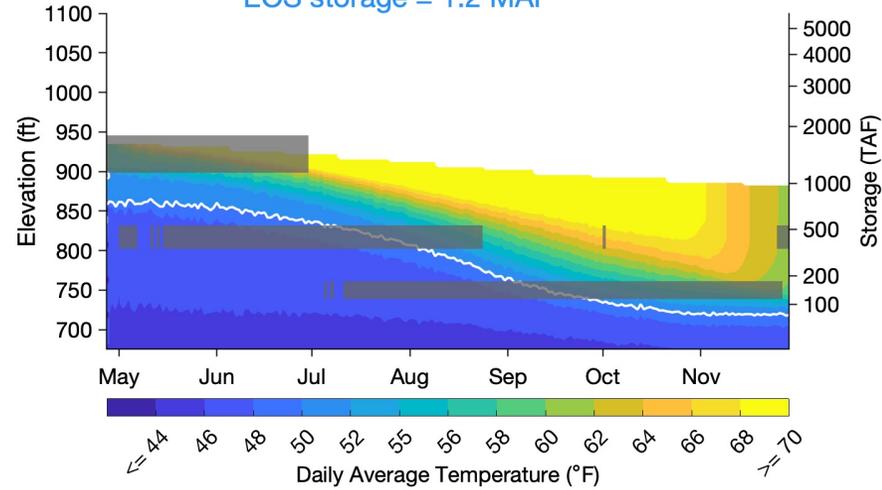
*\*\*Model results were produced as part of a deliberative SRTTG process and are provided for informational purposes only*

# Model Outputs (Scenario 1, 54.5F Target)

*\*Redd year specified*



Mean annual TDM Redd Yr 2021 = 52%  
Mean annual TDM Redd Yr 2016-2021 = 58%  
Date first side gate = 05/Jul/2022  
EOS storage = 1.2 MAF



\*Model output generated 27-Apr-2022

*\*\*Model results were produced as part of a deliberative SRTTG process and are provided for informational purposes only*