Sacramento River Temperature Task Group

Annual Report of Activities

October 1, 2015 through September 30, 2016

Sacramento River Temperature Task Group Annual Report
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2. Acronyms

af	acre feet
BiOp	Biological Opinion
BND	Bend Bridge compliance point
BSF	Balls Ferry compliance point
CDFG	California Department of Fish & Game
CDEC	California Data Exchange Center
CVPIA	Central Valley Project Improvement Act
cfs	cubic feet per second
CVP	Central Valley Project
DWR	California Department of Water Resources
EOS	End-of-September
ESA	Endangered Species Act
FWS	U.S. Fish & Wildlife Service
JLF	Jellys Ferry compliance point
maf	million acre feet
NMFS	National Marine Fisheries Service
NASA	National Aeronautics and Space Administration
RBDD	Red Bluff Diversion Dam
Reclamation	U.S. Bureau of Reclamation
RPA	Reasonable and Prudent Alternative
SRTTG	Sacramento River Temperature Task Group
SWIM	Shasta Water Interagency Management
SWRCB	State Water Resources Control Board
taf	thousand acre feet
TCD	Temperature Control Device (Shasta Dam)
TCP	Temperature Compliance Point
WAPA	Western Area Power Administration
WR	Water Rights

3.1 Shasta – Trinity System Geographic Orientation

The CVP's Shasta Division includes facilities that conserve water in the Sacramento River for (1) flood control, (2) navigation maintenance, (3) agricultural water supplies, (4) M&I water supplies (5) hydroelectric power generation, (6) conservation of fish in the Sacramento River, and (7) protection of the Sacramento-San Joaquin Delta from intrusion of saline ocean water. The Shasta Division includes Shasta Dam, Lake, and Powerplant; Keswick Dam, Reservoir, and Powerplant, and the Shasta Temperature Control Device. Shasta Dam is located on the Sacramento River just below the confluence of the Sacramento, McCloud, and Pit Rivers. The dam regulates the flow from a drainage area of approximately 6,649 square miles. Shasta Dam was completed in 1945, forming Shasta Lake, which has a maximum storage capacity of 4,552,000 af. Water in Shasta Lake is released through or around the Shasta Powerplant to the Sacramento River where it is re-regulated downstream by Keswick Dam. Keswick Reservoir was formed by the completion of Keswick Dam in 1950. It has a capacity of approximately 23,800 af and serves as an afterbay for releases from Shasta Dam and for discharges from the Spring Creek Powerplant. All releases from Keswick Reservoir are made to the Sacramento River at Keswick Dam. The Trinity River Division, completed in 1964, includes facilities to store and regulate water in the Trinity River, as well as facilities to divert water to the Sacramento River Basin. Trinity Dam is located on the Trinity River and regulates the flow from a drainage area of approximately 720 square miles. The dam forms Trinity Lake, which has a maximum storage capacity of approximately 2.4 million acre-feet (maf). See map in Figure 1.

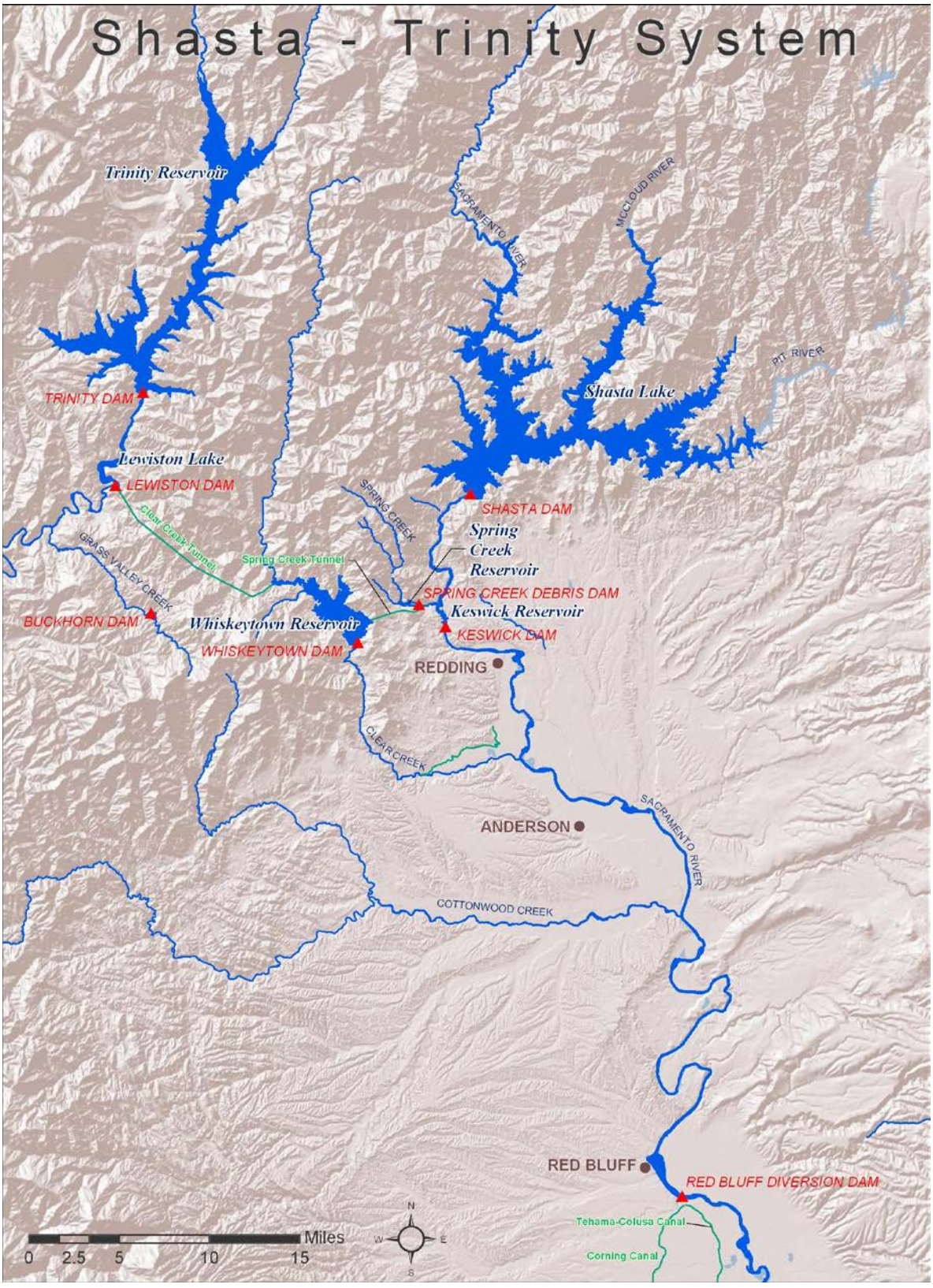

Figure 1. Shasta - Trinity System

3.2. Background

The purpose of the Sacramento River Temperature Task Group (SRTTG) is to provide advice to Reclamation on managing water temperatures downstream of Central Valley Project (CVP) reservoirs in the Sacramento River, Trinity River and Clear Creek. The SRTTG deals with the short-term operational aspects of reservoir management such as coordinating real-time operations. The Clear Creek Technical Team plans and implements long-term restoration actions and reports on such things as pulse flows, gravel augmentation, and channel forming flow required in the National Marine Fisheries Service (NMFS) 2009 Biological Opinion (BiOp). It also coordinates monitoring for these actions. The SRTTG reports on the temperature requirements as specified in the State Water Resource Control Board (SWRCB) Water Rights Order (WR) 90-5 and also the required actions described in NMFS' 2009 reasonable and prudent alternative (RPA) with 2011 amendments

The SRTTG advises the U.S. Bureau of Reclamation (Reclamation) on the best course of action to take to implement Water Rights Order 90-5 to establish a temperature compliance point (TCP) for winter-run Chinook salmon, depending on carryover storage, water year type, and fish distribution. The SRTTG uses historical data, the latest modeled water temperatures, operator experience, and the latest biological data available to adaptively manage water releases from Shasta, Trinity and Whiskeytown Reservoirs. In most years, it is not possible to attain 56° Fahrenheit (F) at Bend Bridge, and the SRTTG will advise that the TCP be established farther upstream. This was the case from 2009 through 2016. A salmon decision tree process was used as initial guidance in prioritizing actions.

The objectives of the May 15 through October 31 Sacramento River in-stream temperature criteria are to manage the cold water storage within Shasta Reservoir and make cold water releases from Shasta Reservoir to provide suitable habitat temperatures for winter-run Chinook salmon, spring-run Chinook salmon, California Central Valley steelhead, and the Southern Distinct Population Segment of North American green sturgeon in the Sacramento River between Keswick Dam and Bend Bridge, while retaining sufficient carryover storage to manage for the following year's winter-run Chinook salmon cohort. In addition, to the extent feasible, another objective is to manage for suitable temperatures and stabilize flows for naturally-spawning fall-run/late-fall-run Chinook salmon.

This document describes the water year (WY) 2016 actions taken in the upper Sacramento River to meet the requirements in the NMFS BiOp on the long-term water operations of the CVP and State Water Project (SWP). In contrast to previous years, the SRTTG was not heavily involved in the decision-making process in 2016. Instead, a new management team called the Shasta Water Interagency Management (SWIM) Team was formed to fulfill this function.

3.3. Participants

The SRTTG consists of representatives from Reclamation, FWS, NMFS, California Fish and Wildlife Service (CFWS), State Water Resources Control Board (SWRCB), Western Area Power Administration (Western), and the Hoopa Tribe. Other agencies have participated in the past and may be added to the SRTTG, provided existing agencies approve of the addition in membership. The SWIM team is composed of management-level representatives from Reclamation, NMFS, the U.S. Fish and Wildlife Service, the California Department of Water Resources, the California Department of Fish and Wildlife, and the State Water Resources Control Board. There were six SRTTG meetings/calls in 2016 on 5/3, 5/26, 6/23, 7/28, 8/25 and 9/22. The SWIM team weekly conference calls began on June 20, 2016 and continued through early November.

4. Water Year Conditions

Water year 2016 yielded some hydrologic relief following four years of consecutive dry year conditions. The 2016 Water Supply Index came in at a "Below Normal" Sacramento Valley Index (SVI). Statewide precipitation measured 110%, runoff 95% and reservoir storage 85% of average through the end of July (DWR 2016). Although rain and snow-melt runoff conditions significantly improved in WY 2016, NMFS and SWRCB requirements to minimize releases from the Sacramento River to protect endangered species resulted in significant impacts to the American River, the Feather River, and the Delta.

5. Hydrologic Conditions – Sacramento River

Watershed runoff in California is typically driven by winter precipitation and spring snow-melt runoff and is quantified as a late spring through summer inflow volume (April through July volume, in addition to a water year total volume). Approximately 1.1 maf was gained in Shasta storage between March 3 and March 17, 2016. The actual April to July full natural flow volume in 2016 was 1.22 maf which was 68% of the average April-July runoff. The total Water Year 2016 full natural flow was 5.35 maf which was 91% of average.

6. Summary of Actions and Results

A. Actions and Operational Considerations

The water resources of water year 2016 were a substantial improvement as compared to previous years 2014 and 2015. Ample cold water was available at Shasta Lake, given the improved natural water supply. However, due to the loss of the 2 previous year's winter-run year classes (2014 and 2015) the fishery agencies were extremely concerned about temperature dependent mortality in 2016 and they wanted to prioritize winter-run salmon protection.

After numerous modeling iterations for various scenarios, the Sacramento Temperature Plan was finalized on June 24, 2016. To secure protection for the Sacramento River winter-run Chinook salmon, the plan prescribed flows not to exceed 9,000 cfs in June, 10,500 cfs in July, 10,000 in August, 9,000 in September, and 6,500 cfs in October. The temperature model inputs that supported the temperature plan were extremely conservative to provide the best conditions for the winter-run salmon. NMFS requested that the modeling be based on a 90% exceedance hydrology forecast and a 10% historical L3MTO (the warmest months in the temperature season from a historical 86-year set: 1920-2005) meteorological data set. The Temperature Control Point (TCP) of 56° was set at Balls Ferry on June 17, 2016. Because of the fishery agencies desire to provide optimal temperatures to protect the winter-run salmon, Reclamation agreed to evaluate a management strategy at a location closer to the actual redd locations (close to the Sacramento River at Clear Creek gaging station(CCR)) that attempted to maintain water temperatures below 55°F, provided such operational adjustments did not impede Reclamation's ability to meet the temperature compliance metric and location of 56.0°F DAT at Balls Ferry. Table 1 below summarizes the TCP for 2016.

Table 1. 2016 Temperature Compliance Point Data

Months	TCP	TCP Degree (F)	Observed Avg Monthly Temp CCR	Observed Avg Monthly Temp BSF	Observed Avg Monthly 7DADM at CCR 55 degree
May 2016	CCR	56°	54.1°	n/a	n/a
June 5, 2016	CCR	58°	53.0°	55.4°	n/a
June 17, 2016	BSF	56°	53.0°	55.4°	54.6°
July 2016	BSF	56°	52.8°	54.7°	54.6°
August 2016	BSF	56°	53.0°	54.7°	54.9°
September 2016	BSF	56°	52.6°	53.9°	54.5°
October 2016	BSF	56°	52.6°	53.7°	54.2°
November 2016	BSF	56°	52.6°	52.7°	53.9°

Decision-making for significant changes in real-time operations was coordinated with the SWIM team. The team utilized information from its member agencies and other relevant stakeholders to inform decisions and changes in operations. The SWIM Team met weekly to review the tracking of the Shasta cold water storage. Tracking activities each week compared new model runs based on the most current profiles with the official June Temperature Plan. The items evaluated included an updated Shasta profile/isothermobath, the volume of Shasta water less than 49°F, updated temperature modeling that met 56°F at Balls Ferry, Martin et al (2016), temperature dependent mortality estimates, and current TCD configuration and projected date of full side gate operation. . Figure 2 and Table 2 below summarize the seasonal tracking.

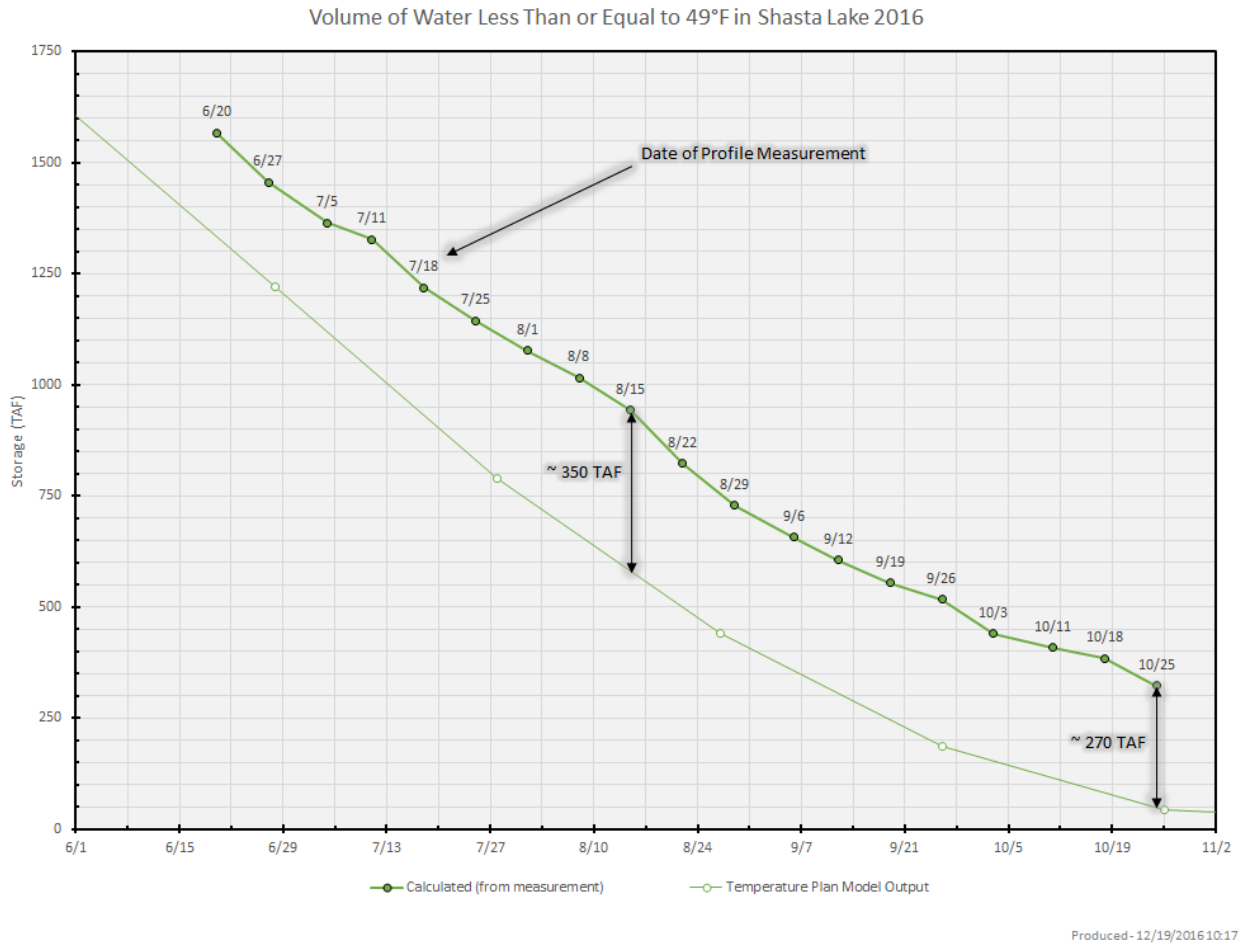

Figure 2. Shasta Lake Profile Data 2016

Table 2. Shasta Lake Profile Data Used for Tracking 2016

WY 2016 -- Shasta Lake Profile Tracking				
Date	Balls Ferry 56°	Vol of 49° in Shasta Lake (within 5% of plan)	Date of Full Side Gate	Martin et al Mortality Estimate (%)
Final Temp Plan	*met*		*Oct 9*	*6.0%*
June 27 Tracking	met	met + 200 TAF	Oct 25	6.8%
July 5 Tracking	met	met + 230 TAF	Oct 19	7.5%
July 11 Tracking	met	met + 285 TAF	Oct 29	4.0%
July 18 Tracking	met	met + 280 TAF	Oct 31	3.4%
July 25 Tracking	met	met + 325 TAF	Oct 28	3.0%
Aug 1 Tracking	met	met + 325 TAF	Oct 28	2.8%
Aug 8 Tracking	met	met + 350 TAF	Oct 23	2.0%
Aug 15 Tracking	met	met + 350 TAF	Oct 23	2.1%
Aug 22 Tracking	met	met + 325 TAF	Oct 23	2.2%
Aug 29 Tracking	met	met + 300 TAF	Nov 3	2.2%
Sep 6 Tracking	met	met + 300 TAF	Nov 9	2.2%
Sep 12 Tracking	met	met + 300 TAF	Nov 7	2.2%
Sep 19 Tracking	met	met + 310 TAF	Nov 4	2.2%
Sep 26 Tracking	met	met + 325 TAF	Nov 10	2.0%
Oct 3 Tracking	met	met + 300 TAF	Nov 12	2.0%
Oct 11 Tracking	met	met + 300 TAF	Nov 22	2.0%
Oct 18 Tracking	met	met + 300 TAF	Not needed	2.0%
Oct 25 Tracking	met	met + 270 TAF	stop model	2.0%

From the onset of the Temperature Plan in June, modeling and actual Shasta Lake profiles indicated that there was a cold water pool volume of 49°F or less in excess of 200 taf. This volume continued to grow through the end of October.

Delta export pumping in May was restricted by the San Joaquin River Inflow-to-Export (I: E) Ratio of 2:1 based on a May 1, 2016 San Joaquin Valley Index of “Dry”. Some additional export was allowed during May due to the release of supplemental spring pulse flow water on the Stanislaus River. Overall combined State and Federal pumping averaged about 2000 cfs for the month. In spite of the low combined pumping, D-1641 Delta Outflow of 11,400 cfs began to control in May, necessitating an increase in flows coming in to the Delta. Due to the release restriction at Keswick, the Federal share of the outflow requirement had to be met by releases at Nimbus and flows on the American River increased as high as 5000 cfs. Delta Outflow as well as salinity continued to be an issue in both June and July and flows on the American River continued to be higher than normal. An additional impact of the restricted releases was very low flows on the lower Sacramento River which impeded the ability of water right contractors to pump water from the river.

A further consequence of the CVP's inability to meet its share of the Delta water quality requirements was Federal export pumping in June and July largely held to one unit except for a brief period in June when State Banks Pumping Plant had an outage and higher Oroville Reservoir releases than called for under the Coordinated Operation Agreement (COA). Nimbus releases remained high at 5000 cfs throughout the month of July. The low pumping had tremendous impacts on Federal San Luis storage. By mid-July there was no longer any Federal water available for delivery in the reservoir. In order to continue to make deliveries to M&I customers and water rights contractors, Reclamation borrowed water from the State Water Project and emergency exchanges were made with Friant contractors. This impact will last well into the new 2017 water year. Typically pumping for the next year's water supply begins in September after irrigation demands ease and San Luis lowpoint storage has been reached. Payback of the borrowed water wasn't achieved until early December 2017 and the storing of water for 2017 didn't begin until mid-December. This could have serious implications for 2017 water supplies.

In August, the Temperature Plan called for Keswick releases of 10,000 cfs, however, NMFS agreed to allow a higher release of 10,500 cfs because of the favorable reservoir cold water pool conditions (in excess of 300 taf more cold water less than 49°F than the June Temperature Plan had predicted) and modeling that indicated little impact to meeting downstream temperatures. The higher release combined with a decrease in Sacramento River depletions helped to alleviate Folsom storage depletion when conditions finally allowed flow decreases on the American River. Salinity continued to be a problem in the Delta but eventually Reclamation was able to gradually increase Federal Delta pumping. San Luis storage remained very low and many deliveries had to be postponed until more water was available.

The increased late spring and summer flows on the American river resulted in lower Folsom storage and the degraded temperature performance on the river for steelhead and fall-run salmon. Had Folsom reservoir filled in May as was projected before flows were increased to make up for reduced flows on the Sacramento river, Reclamation would have been able to meet a target of 65°F instead of the 68°F target that ended up in the American River Temperature Management Plan.

September brought increased Federal Delta pumping with more water available in the Delta due to a continued reduction in depletions. Reclamation returned the water borrowed from DWR in July and was able to put a small amount of water into storage in San Luis. Keswick releases averaged about 8900 cfs. The last profile tracking on Sept. 26th showed approximately 325 taf of cold water less than 49°F.

In Summary, the Sacramento Temperature Plan for 2016 provided good conditions for winter-run salmon but had significant impacts to the CVP as a whole. Typically, Reclamation operates

the CVP as a multi-use project, attempting to balance institutional and regulatory requirements, municipal, industrial and agricultural water demands, and flood control, recreation, and fish and wildlife benefits throughout the system. As experienced in 2016, focusing on only one beneficial use can have serious consequences for the other parts of the project. These impacts are summarized below:

- Reclamation was unable to provide enough water to meet our share of Delta requirements and incurred considerable debt to the SWP under the COA throughout the late spring and summer in spite of very limited CVP pumping.
- Oroville and Folsom Reservoirs significantly over contribute water to help control salinity and outflow in the Delta.
- Some contractors with senior water rights on the lower Sacramento River were unable to access water due to low river levels.
- Limited CVP pumping leads to low storage levels in Federal San Luis Reservoir. CVP has to borrow water from the SWP and Friant contractors to continue to make deliveries in July and August.
- Effects of an unbalanced COA and borrowing water carry through until December 2016 as water and COA debt are repaid. This has grave repercussions for 2017 water deliveries.
- High late spring/summer flows from Folsom led to low storage and degraded American River temperature conditions for steelhead and fall-run salmon (68°Finstead of 65°F)
- Large remaining quantity of cold water "left on the table" that could have been used during the summer to alleviate above stated operational difficulties. High EOS storage in Shasta increases the likelihood of flood control operations.

The temperature season ended on November 16, 2016 when the Keswick, CCR, and Balls Ferry water temperatures were cooler than the TCD water temperature. This is when the air temperature had significantly cooled enough to influence the water temperature downstream.

Ultimately, the 2016 Sacramento Temperature season provided very good conditions for the winter-run Chinook salmon with a substantial amount of cold water resource unused. The end of temperature season results was:

- over 250 TAF volume of less than 49°F remaining in Shasta Lake
- full side gate on the TCD was never utilized compared to the modeled October 9, 2016 June Temperature Plan date
- The October 18, 2016 tracking report of Martin et all estimated mortality at 2.0% compared to 4.0% estimate of the June Temperature Plan

By the end of November, the TCD configuration was as shown below with two open side gates and three open Pressure Relief Gates (PRG). Figure 3 displays the last temperature TCD blending needed (profile of Shasta Lake on November 15, 2016). Shasta Reservoir encroached on December 18, 2016 and a flood release was made on December 21, 2016.

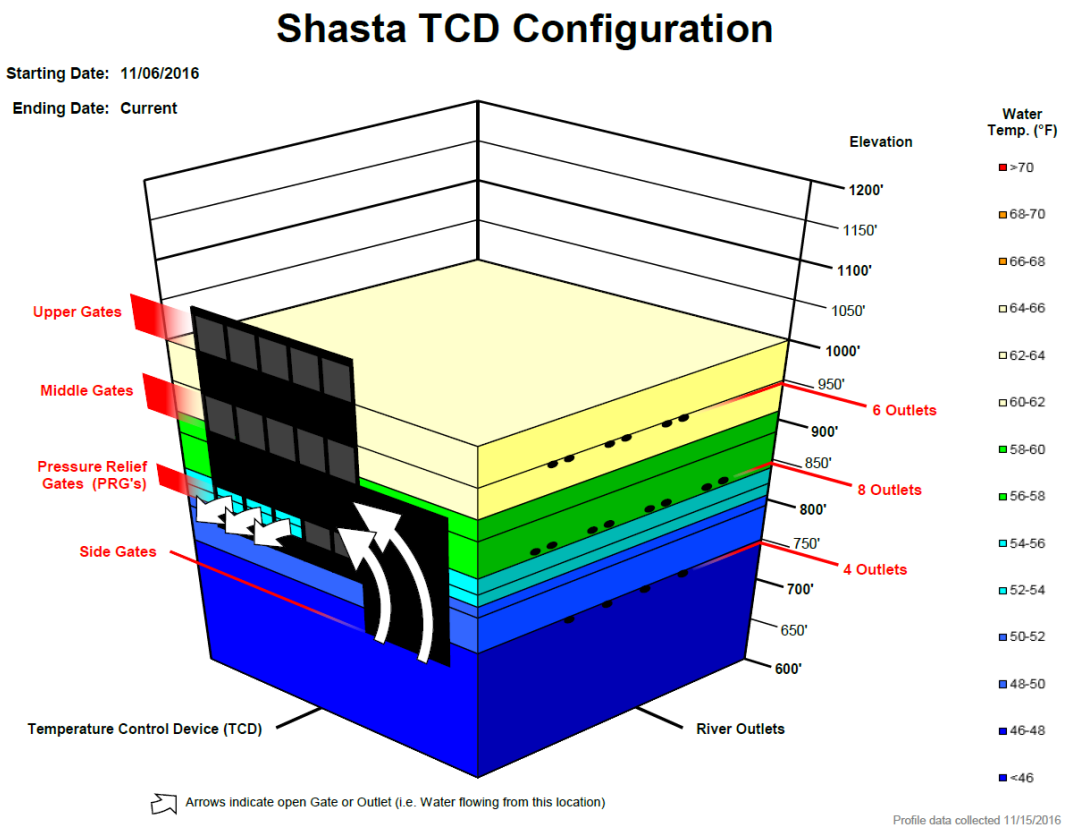

Figure 3. Shasta Lake Profile and TCD Configuration on November 15, 2016

B. RPAs and Results

RPA Action I.2.1. Shasta Operation Performance Measures

Action: The following long-term performance measures shall be attained. Reclamation shall track performance and report to NMFS at least every 5 years. If there is significant deviation from these performance measures over a 10-year period, measured as a running average, which is not explained by hydrological cycle factors (*e.g.*, extended drought), then Reclamation shall reinitiate consultation with NMFS.

Measured as a 10-year running average, performance measures for temperature compliance points during summer season shall be:

Meet Clear Creek Compliance point 95 percent of time
Meet Balls Ferry Compliance point 85 percent of time
Meet Jelly's Ferry Compliance point 40 percent of time
Meet Bend Bridge Compliance point 15 percent of time

Result: Since the RPA has been in place, Reclamation has met the TCP with the exception of WY 2014 and 2015, given the drought conditions. In WY 2016, the temperature modeling results suggested that the TCP should be targeted at Balls Ferry and, after coordination of the data with the SWIM Team, the TCP was maintained at Balls Ferry.

RPA Action I.2.2. Fall Actions, Keswick Releases (November – February)
Action: Depending on EOS carryover storage and hydrology, Reclamation shall develop and implement a Keswick release schedule, and reduce deliveries and exports as detailed below.

Action I.2.2.C. Implementation and Exception Procedures for EOS Storage of 1.9 MAF or Below

If the EOS storage is at or below 1.9 MAF, then Reclamation shall:
1) In early October, reduce Keswick releases to 3,250 cfs as soon as possible, unless higher releases are necessary to meet temperature compliance points (see action I.2.3).

2) Starting in early October, if cool weather prevails and temperature control does not mandate higher flows, curtail discretionary water deliveries (including, but not limited to agricultural rice decomposition deliveries) to the extent that these do not coincide with temperature management for the species. It is important to maintain suitable temperatures targeted to each life stage. Depending on air and water temperatures, delivery of water for rice decomposition, and any other discretionary purposes at this time of year, may coincide with the temperature management regime for spring-run and fall-run. This action shall be closely coordinated with NMFS, USFWS, and CDFG.

3) By November 1, submit to NMFS storage projections based on 50 percent, 70 percent, and 90 percent hydrology through February. In coordination with NMFS, Reclamation shall: (1) develop a monthly average Keswick release schedule similar in format to that in Action I.2.2.B, based on the criteria below and including actions specified below; and (2) review updated hydrology and choose a monthly average release for every month, based on the release schedule. November releases shall be based on a 90 percent hydrology estimate.

Result: WY 2016 began with 1.6 maf of storage in Shasta Reservoir and releases of 6,500 cfs into the Sacramento River. Reclamation and the fishery agencies worked together to reduce flows into the Sacramento River, recognizing that there was a desire to keep flows higher to prevent dewatering of fall-run Chinook salmon redds. Per RPA Action I.2.2.C, Reclamation should have reduced releases to 3,250 cfs but the fall-run Chinook salmon was considered and flows were not reduced as prescribed in the RPA until December 26, 2015.

RPA Action I.2.3. February Forecast Keswick Releases (March – May 15)

Action: Reclamation shall make its February 15 forecast of deliverable water based on an estimate of precipitation and runoff within the Sacramento River basin at least as conservative as the 90 percent probability of exceedance. Subsequent updates of water delivery commitments must be based on monthly forecasts at least as conservative as the 90 percent probability of exceedance. NMFS shall review forecast and allocations for consistency with temperature management and provide written evaluation to Reclamation. Reclamation must maintain a TCP not in excess of 56°F between Balls Ferry and Bend Bridge between April 15 and May 15.

RPA Action I.2.3.C Drought Exception Procedures if February Forecast, Based on 90 Percent Hydrology, Shows that Clear Creek Temperature Compliance Point or 1.9 MAF EOS Storage is Not Achievable

1) On or before February 15, Reclamation shall reduce Keswick releases to 3,250 cfs, unless NMFS concurs on an alternative release schedule. This reduction shall be maintained until a flow schedule is developed per procedures below.

2) In coordination with NMFS, by March 1, Reclamation shall develop an initial monthly Keswick release schedule, based on varying hydrology of 50 percent, 70 percent, and 90 percent (similar in format to the fall and winter action implementation procedures – see table above). These schedules shall be used as guidance for monthly updates and consultations.

3) Based on this guidance, Reclamation shall consult with NMFS monthly on Keswick releases. Reclamation shall submit a projected forecast, including monthly average release schedules and temperature compliance point to NMFS every month, within 7 business days of receiving the DWR runoff projections for that month. Within 3 business days of receiving this information from Reclamation, NMFS will review the draft schedule for consistency with the criteria below and provide written recommendations to Reclamation.

4) The initial monthly Keswick release schedule, and subsequent monthly updates, shall be developed based on the following criteria and including the following actions:

   a) Maintain minimum monthly average flows necessary to meet nondiscretionary delivery obligations and legal requirements.
   b) Provide for flow-related biological needs of spring life stages of all species covered by this Opinion in the Sacramento River and Delta, to the greatest extent possible.
   c) If operational changes are necessary to meet Delta outflow, X2, or other legal requirements during this time, then:

      - CVP/SWP Delta combined exports shall be curtailed to 2,000 cfs if necessary to meet legal requirements while maintaining a 3,250 cfs Keswick Dam release (or other planned release based on biological needs of species); and
      - if it is necessary to curtail combined exports to values more restrictive than 2000 cfs in order to meet Delta outflow, X2, or other legal requirements, then

Reclamation and DWR shall, as an overall strategy, first, increase releases from Oroville or Folsom Dam; and

- in general, Reclamation shall increase releases from Keswick Dam as a last resort.
- Based on improvements in updated monthly hydrology, this restriction may be relaxed, with NMFS' concurrence.

5) By March 1, provide a contingency plan with a written justification that all actions within Reclamation's authorities and discretion are being taken to preserve cold water at Shasta Reservoir for the protection of winter-run.

6) The contingency plan shall also, at a minimum, include the following assessments and actions:

   a) Relaxation of Wilkins Slough navigation criteria to at most 4,000 cfs.
   b) An assessment of any additional technological or operational measures that may be feasible and may increase the ability to manage the cold water pool.
   c) Notification to State Water Resources Control Board that meeting the biological needs of winter-run and the needs of resident species in the Delta, delivery of water to nondiscretionary Sacramento Settlement Contractors, and Delta outflow requirements per D-1641, may be in conflict in the coming season and requesting the Board's assistance in determining appropriate contingency measures, and exercising their authorities to put these measures in place.

Results: The beginning of WY 2016 did not look favorable for Shasta Reservoir storage (EOS storage of 1.6 maf). Releases from Keswick weren't dropped to the minimum of 3,250 until early January 2016 and by that time storage was merely 1.4 maf. Several significant storm events in late January and February through March 2016 boosted Shasta Reservoir storage into encroachment. Flood control releases up to 20,000 cfs were made on March 18, 2016 for 5 days before ramping down to 5,000 cfs. Shasta Reservoir storage rebounded to 4.2 MAF by May 1, 2016. Due to the exceptional increase in Shasta Reservoir storage, RPA Action I.2.3. no longer applied.

RPA Action 1.2.4. Keswick Release Schedule (May 15 –October)
Action: Reclamation shall develop and implement an annual Temperature Management Plan by May 15 to manage the cold water supply within Shasta Reservoir and make cold water releases from Shasta Reservoir and Spring Creek to provide suitable temperatures for listed species, and, when feasible, fall-run.

Reclamation shall manage operations to achieve daily average water temperatures in the Sacramento River between Keswick Dam and Bend Bridge as follows:

1) Not in excess of 56°F at compliance locations between Balls Ferry and Bend Bridge from May 15 through September 30 for protection of winter-run, and not in excess of 56°F at the same compliance locations between Balls Ferry and Bend Bridge from October 1 through October 31 for protection of main stem spring run, whenever possible.

2) Reclamation shall operate to a final Temperature Management Plan starting May 15 and ending October 31.

3) As part of the adaptive management process, and in coordination with NMFS, by March 2010, Reclamation shall fund an independent modeler to review these procedures and the recommendations of the Calfed Science Panel report on temperature management and recommend specific refinements to these procedures to achieve optimal temperature management.

Results: The first WY 2016 temperature modeling run was completed in February 2016. Shasta Lake had not yet stratified and the model output was deemed uncertain. Four temperature model scenarios were studied which included two 90% exceedance runs and two 50% exceedance runs with all scenarios targeting 56°F at CCR. Each scenario had different releases from Keswick, with NMFS favoring flows of 7,250 cfs from June to August 2016 and Reclamation preferring higher flows of 9,500 cfs in June 2016 and 10,500 cfs in July 2016. As modeled, the scenario with higher flows met 56°F at CCR and the lower flows in the 90% exceedance scenario met 56°F until October 1, 2016 , after which temperatures ramped up to 58°F.

In March 2016, there were only two temperature scenarios studied using a 90% and a 50% exceedance hydrology. Both studies were very similar in that 56°F was mostly met at CCR. With multiple storm events in March 2016, the next month's temperature model runs were anticipated to improve.

In April 2016, Shasta Lake was near stratification and storage increased by over 1 maf from March 2016 storm events, There were six temperature model runs completed which indicated that a target of 56°F at Balls Ferry could be met. The temperature model runs varied between the 90% exceedance and 50% exceedance hydrology with both higher and lower flows from Keswick. Results from the six models were once again very similar. All six scenarios met 56°F at Balls Ferry.

Between May and June 2016, 47 temperature model scenarios were run. The temperature management plan process was tumultuous and took multiple rounds of negotiation and agreements by agency managements before the temperature management plan was finalized. The process was prolonged by numerous requests for different scenarios and the plan was elevated for discussion to Washington DC several times. Table 3 below shows the 7 final considerations for the 2016 Sacramento River Temperature Management Plan:

Table 3. Shasta Temperature Management Plan Final Scenarios 2016

Scenario 1A 8,000	June	July	Aug	Sep	Oct	Full Side Gates	Sept Shasta Storage	July Export	Aug Export	Sep Export	Folsom EOM Sept Storage	Major Consequences/Choices	Egg to Emergence temp dependent mortality above Clear Creek (Zeug et al 2012)	Martin et al (2015) Temperature dependent mortality estimates
Keswick	8000	8000	8000	8000	6500	Aug 23/ Aug 31/ Oct 1	2.9	60	150	270	305	* No 5% SOD allocation * Friant releases needed for Exchange Contractors * Delta Outflow - difficult to meet * American River 68 degrees * Off Ramp year at Folsom	5%	3.1%
Keswick	51.88	51.87	51.90	52.43	51.98									
Balls Ferry	54.91	55.24	54.65	54.07	52.75									
Jellys Ferry	56.47	56.98	56.13	55.04	53.23									
Scenario 2A 10,000	**June**	**July**	**Aug**	**Sep**	**Oct**	**Full Side Gates**	**Sept Shasta Storage**	**July Export**	**Aug Export**	**Sep Export**	**Folsom EOM Sept Storage**	**Major Consequences**	**Egg to Emergence temp dependent mortality above Clear Creek (Zeug et al 2012)**	**Martin et al (2015) Temperature dependent mortality estimates**
Keswick	9000	10000	10000	8500	6800	16-Sep	2.7	140	250	270	403	* 5% SOD allocation preserved * Friant releases not needed * Delta Outflow is met * American River 67 degrees * Folsom storage target met	5.1%	3.4%
Keswick	51.85	51.91	51.94	52.28	53.13									
Balls Ferry	54.56	54.64	54.19	53.86	53.64									
Jellys Ferry	56.02	56.13	55.45	54.80	54.03									
Scenario 3A 11,500	**June**	**July**	**Aug**	**Sep**	**Oct**	**Full Side Gates**	**Sept Shasta Storage**	**July Export**	**Aug Export**	**Sep Export**	**Folsom EOM Sept Storage**	**Major Consequences**	**Egg to Emergence temp dependent mortality above Clear Creek (Zeug et al 2012)**	**Martin et al (2015) Temperature dependent mortality estimates**
Keswick	10000	11500	10000	8500	6800	9-Sep	2.5	230	258	270	403	* 5% SOD allocation preserved * Friant releases not needed * Delta Outflow met * American River 67 degrees * Folsom storage met	5.2%	5.0%
Keswick	52.03	51.88	51.83	52.54	53.83									
Balls Ferry	54.46	54.31	53.13	54.07	54.22									
Jellys Ferry	55.78	55.66	55.36	54.99	54.57									
Scenario 4A 9,000	**June**	**July**	**Aug**	**Sep**	**Oct**	**Full Side Gates**	**Sept Shasta Storage**	**July Export**	**Aug Export**	**Sep Export**	**Folsom EOM Sept Storage**	**Major Consequences**	**Egg to Emergence temp dependent mortality above Clear Creek (Zeug et al 2012)**	**Martin et al (2015) Temperature dependent mortality estimates**
Keswick	9000	9000	9000	8500	6800	10-Sep	2.8	75	160	270	361	* No 5% SOD allocation * Friant releases needed for Exchange Contractors * Delta Outflow - difficult to meet * American River 68 degrees * Off Ramp year at Folsom		2.9%
Keswick	51.88	51.83	51.95	52.14	52.97									
Balls Ferry	54.61	54.84	54.43	53.83	53.27									
Jellys Ferry	56.05	56.45	55.79	54.81	53.70									
Scenario 5A 8,500	**June**	**July**	**Aug**	**Sep**	**Oct**	**Full Side Gates**	**Sept Shasta Storage**	**July Export**	**Aug Export**	**Sep Export**	**Folsom EOM Sept Storage**	**Major Consequences/Choices**	**Egg to Emergence temp dependent mortality above Clear Creek (Zeug et al 2012)**	**Martin et al (2015) Temperature dependent mortality estimates**
Keswick	8500	8500	8500	8500	6500	Aug 18/ Aug 31/ Sep 2	2.8	60	180	270	336	* No 5% SOD allocation * Friant releases needed for Exchange Contractors * Delta Outflow - difficult to meet * American River 68 degrees * Off Ramp year at Folsom		2.9%
Keswick	51.75	51.63	51.78	52.27	52.79									
Balls Ferry	54.64	54.77	54.4	53.85	53.41									
Jellys Ferry	56.15	56.43	55.82	54.78	53.84									
Scenario 6A 9,500	**June**	**July**	**Aug**	**Sep**	**Oct**	**Full Side Gates**	**Sept Shasta Storage**	**July Export**	**Aug Export**	**Sep Export**	**Folsom EOM Sept Storage**	**Major Consequences/Choices**	**Egg to Emergence temp dependent mortality above Clear Creek (Zeug et al 2012)**	**Martin et al (2015) Temperature dependent mortality estimates**
Keswick	9500	9500	9500	8500	6500	17-Sep	2.7	91	160	270	400	* No 5% SOD allocation * Friant releases needed for Exchange Contractors * Delta Outflow - difficult to meet * American River 68 degrees * Off Ramp year at Folsom		3.3%
Keswick	51.86	51.87	52.02	52.26	52.94									
Balls Ferry	54.46	54.74	54.36	53.85	53.51									
Jellys Ferry	55.85	56.29	55.66	54.78	53.93									
Scenario 7A 7,500	**June**	**July**	**Aug**	**Sep**	**Oct**	**Full Side Gates**	**Sept Shasta Storage**	**July Export**	**Aug Export**	**Sep Export**	**Folsom EOM Sept Storage**	**Major Consequences/Choices**	**Egg to Emergence temp dependent mortality above Clear Creek (Zeug et al 2012)**	**Martin et al (2015) Temperature dependent mortality estimates**
Keswick	7500	7500	7500	7500	6500	18-Sep	3.1	25	100	270	252	* No 5% SOD allocation * Friant releases needed for Exchange Contractors * Delta Outflow - difficult to meet * American River 68 degrees * Likely off Ramp year at Folsom *Wilkin Slough cut by 1200 cfs in July		3.0%
Keswick	52.04	52.05	52.05	52.03	51.8									
Balls Ferry	55.22	55.58	54.95	53.85	51.80									
Jellys Ferry	56.83	57.39	56.49	54.89	53.09									

The 2016 Sacramento Temperature Plan was finalized on June 24, 2016 and by June 27, 2016 NMFS had concurred with the plan. Table 4 shows the final plan's schedule:

Table 4. Sacramento River Temperature Management Plan Final Schedule

	June	July	August	September	October
Keswick Average Flow (cfs)	9,000	10,500	10,000	9,000	6,500
Keswick Average Temperature (deg F)	52.42	52.41	52.39	52.35	52.30
Balls Ferry Average Temperature (deg F)	55.03	54.96	54.58	53.85	53.01
Jellys Ferry Average Temperature (deg F)	56.42	56.37	55.82	54.75	53.47

In conjunction with the Sacramento Temperature Management Plan, the SWIM Team was formed In order to track the plan performance. The SWIM Team met on a weekly basis to review the weekly updated Shasta profile and the weekly updated temperature model run in order to verify that 56°F at Balls Ferry was being met, that full TCD side gate operation was not forecasted as occurring prior to October 9, 2016, and that the volume of water less than 49°F was not less than 95% of the forecasted volume as predicted by the June 7, 2016, temperature model run (base for the plan).

7. Fisheries Monitoring Activities

1.1 RPA Action I.2.2 November through February Keswick Release Schedule (Fall Actions)

CDFW observed 291 dewatered fall-run redds and one spring-run redd during the 2015-2016 survey period, a dewatering rate of 2.14% (Stompe *et al.* 2016). Figure 4 plots the Keswick Dam release flows compared to the number of dewatered redds by date observed. The first reduction of flows by Reclamation started between September 15 and September 24, 2015, from 7,250 cfs to 6,850 cfs. It had the potential to affect 49 active winter-run redds, however because of CDFW monitoring efforts, winter-run redd dewatering was avoided (although one fall-run redd was dewatered). The next flow reduction occurred on October 19, 2015, reducing flows by approximately 1,850 cfs over an 8-day period, stabilizing at 5,000 cfs. There were four winter-run redds which had not yet emerged. These redds were monitored for depth which prevented their dewatering. This flow event was also responsible for dewatering 16 fall-run redds. The next flow reduction to 4,250 cfs occurred between November 12 and November 16, 2015, dewatering an additional 112 fall-run redds and one spring-run redd. The larger number of dewatered redds during this period presumably occurred due to the increased abundance of fall-run redds. The final flow reduction of 1,000 cfs occurred between December 23 and December 26, 2015 and brought the river down to its minimum level of 3,250 cfs, resulting in 162 additional dewatered fall-run redd.

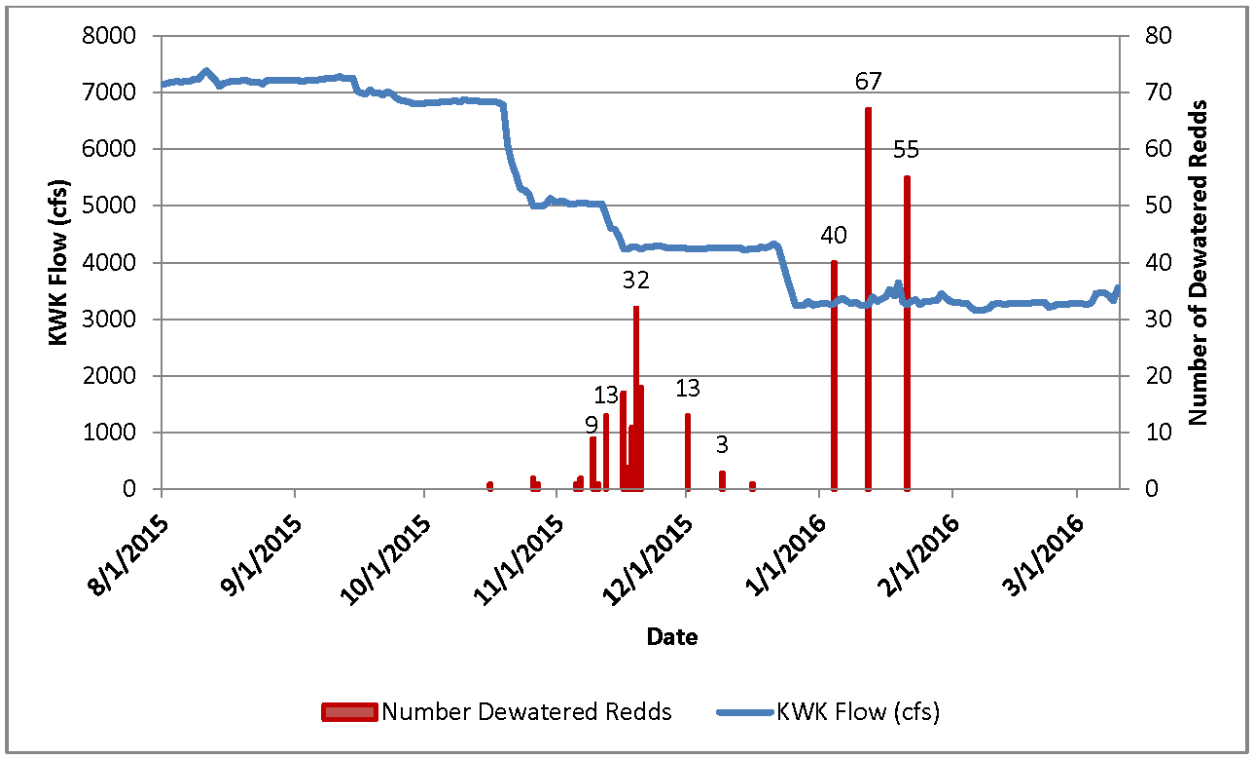

Figure 4. Keswick Dam (KWK) release flows in cubic feet per second compared to the number of dewatered redds, by date observed.

1.2 RPA Action I.2.3 – March - May 14 (Spring Actions) and RPA Action I.2.4 – May 15 - October 31 (Summer Actions) Adjustments

Entering into WY 2016 California was in its fourth consecutive year of below-average rainfall and snowpack, resulting in significant adverse effects to juvenile winter-run Chinook salmon populations over the last four years. Due to a lack of sufficient inflow and cold water pool in Shasta Reservoir and competing water demands in 2014 and 2015, Sacramento River water temperatures rose to sub-lethal and lethal levels contributing to very low egg-to-fry survival of juvenile winter-run Chinook salmon estimated to pass Red Bluff Diversion Dam (RBDD) in brood years 2014 (5.9%) and 2015 (4.2%), well below the 18-year average of 23.8% survival. Using a newly developed temperature-dependent mortality model (Martin model), NMFS Southwest Fisheries Science Center (SWFSC) found that in 2014 and 2015, temperature dependent mortality alone resulted in a loss of approximately 77% and 85% of the population, respectively (Martin *et al.* 2016). In addition, egg-to-fry survival of juvenile winter-run Chinook salmon in brood year 2013 was estimated to be 15.1%, approximately 36% below the 18-year

average of 23.6% survival (Figure 5). Adults returning in 2016 are largely the progeny from brood year 2013[1].

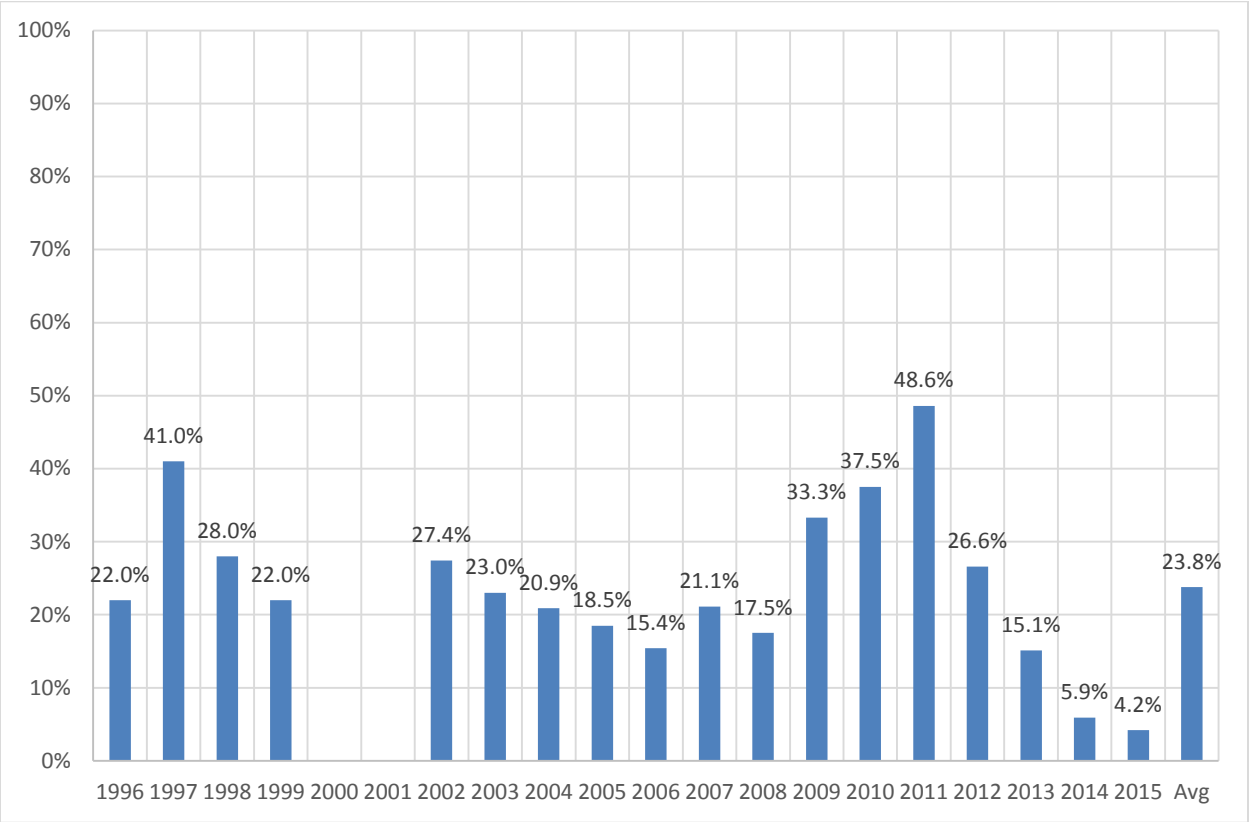

Figure 5. Estimated egg-to-fry survival from passage at Red Bluff Diversion Dam

Since winter-run Chinook salmon spawn every three years and because of this low survival in two of three cohorts, the overall risk to the survival and recovery of winter-run was much higher this year than in the past. In order to stay within the anticipated effects of implementing the 2009 RPA with 2011 amendments, the risk of mortality from temperature-related effects was to be reduced to the maximum extent this year, which necessitated a less flexible approach than has been employed in the past.

As a result of poor egg-to-fry survivals in 2014 and 2015, NMFS evaluated the scientific literature of temperature effects on salmon, reexamined the Sacramento River Water Quality

[1] This year the draft percentage of 2 year olds is about 35%, much higher than any previous year since 2003, with 2004 and 2011 the previous highs at 24%.

Model used for temperature management in the upper Sacramento River, and arrived at three main findings:

1. Best available scientific data indicate that water temperatures up to 50°F (6-10°C constant) are optimal for salmon egg and fry survival and development [U.S. Environmental Protection Agency (EPA) 2003]. To avoid high mortality of winter-run eggs and fry and staying within the effects anticipated from implementation of the RPA, best available science further points to using EPA's (2003) temperature maximum of 55°F for the 7-Day Average of the Daily Maxima (7DADM). By calculating a running average of the maximum water temperatures each day for 7 days, the 7DADM metric captures conditions that winter-run eggs and fry are exposed to on a daily basis while reducing the potential that one extremely high daily maximum temperature would result in exceeding the temperature criterion. The previous approach of managing to 56°F daily average temperature at the location of the redds was not supported by the literature; it is a sub-optimal temperature that is not sensitive to extreme high or low water temperatures within a given day.

2. NMFS-SWFSC new temperature-dependent mortality model, which uses field data to calibrate temperature effects on salmon, identified 53.7°F as the critical temperature at which temperature-related winter-run egg and fry mortality increases with increasing water temperatures (Martin *et al.* 2016), corroborating the EPA temperature criteria recommendations above.

3. The CVP/SWP Opinion, RPA Action I.2.4, required Reclamation to fund an independent modeler to review the current temperature management planning and the recommendations of the CALFED Science Panel report on temperature management (Deas *et al.* 2008) and recommend specific refinements to these procedures to achieve optimal temperature management. Upon written concurrence of NMFS, refinements to the implementation procedures for this action suite, based on the independent contractor's report, may be adopted and implemented. However, that RPA action has not been implemented.

A full explanation, development, and chronology of the temperature planning process is explained in the June 28, 2016, NMFS concurrence on the Bureau of Reclamation's Sacramento River temperature management plan[2]. In summary, Reclamation's June Sacramento River Temperature Management Plan consisted of:

- Significantly lower than normal summer Keswick release flows
- Actions to ensure temperature compliance point and metric that will not exceed 56.0°F daily average at Balls Ferry
- Full side gate operation of the Shasta Dam Temperature Control Device (TCD) on or after October 9, 2016

[2] http://www.westcoast.fisheries.noaa.gov/publications/Central_Valley/Water%20Operations/nmfs_concurrence_on_the_bureau_of_reclamation_s_sacramento_river_temperature_management_plan-_june_28__2016.pdf

- Monitoring of the 7DADM temperatures at the SAC (Sunset Pumps) and CCR CDEC gauging stations
- Actions to ensure the volume of water in Shasta Reservoir < 49°F is not less than 95% of the forecasted volume as predicted by the June 7, 2016, temperature model run (*i.e.*, the basis for the Plan)
- Revising the Plan to create a modified temperature compliance metric and location of 55.0°F 7DADM through the spawning area if overall conditions are better than forecasted (*e.g.*, greater than anticipated cold water volume).

1.3 Brood Year 2016 Winter-run Chinook Salmon Assessment and Monitoring

Through August 29, 2016, CDFW counted a total of 297 adult winter-run Chinook salmon carcasses (Table 5) and observed 18 winter-run Chinook salmon redds (Table 6) through their aerial redd surveys. These were the lowest carcass and redd numbers on record since monitoring began in 2003 (Figure 6). However, due to high turbidity, conditions for observing carcasses and redds were poor for the entire season. The poor summer visibility was very unusual for the river which is normally very clear in the summer. In addition, this year's recapture rate of tagged female carcasses was 23%, the lowest on record; the historical average is 52%. Finally, male salmon made up a higher percentage of the population than in previous years, primarily due to the large number of 2-year old males. Poor visibility, low recapture rate, and unusually high male sex ratio will be accounted for in the Cormack-Jolly-Seber model used to develop the final population size estimate that will be completed after the run is over in September and the data are analyzed.

Table 5. 2016 winter-run carcass counts by river area as of August 29, 2016.

Section	Carcasses	2015 Percent	% Average (2003-2015)
Keswick Dam to ACID Dam (rm 302 to 298)	76	25.6%	36.5%
ACID Dam to Hwy 44 Brg (rm 296)	139	46.8%	38.8%
Hwy 44 Brg down to Clear Crk Powerlines (rm 288)	64	21.5%	21.4%
Clear Crk Pwrl to Balls Ferry Brg (rm 276)	18	6.1%	3.2%
Total	297	100.0%	100.0%

Table 6. 2016 winter-run aerial redd counts by river areas as of August 24, 2016

Flight Sections	Redds	2015 Percent	% Average (2003-2015)
Keswick to A.C.I.D. Dam (rm 302 to 298)	0	0.0%	44.5%
A.C.I.D. Dam to Highway 44 Bridge (rm 296)	12	66.7%	43.6%
Highway 44 Br. to below Clear Crk. (rm 284)	6	33.3%	11.3%
Below Clear Crk. to Balls Ferry Br. (rm 275)	0	0.0%	0.0%
Balls Ferry Br. to Battle Creek (rm 271)	0	0.0%	0.2%
Battle Creek to Jellys Ferry Br. (rm 266)	0	0.0%	0.1%
Jellys Ferry Br. to Bend Bridge (rm 257)	0	0.0%	0.1%
Bend Bridge to Red Bluff Diversion Dam (rm 242)	0	0.0%	0.1%
Red Bluff Diversion Dam to Tehama Br. (rm 229)	0	0.0%	0.0%
Total	**18**	**100.0%**	**100%**

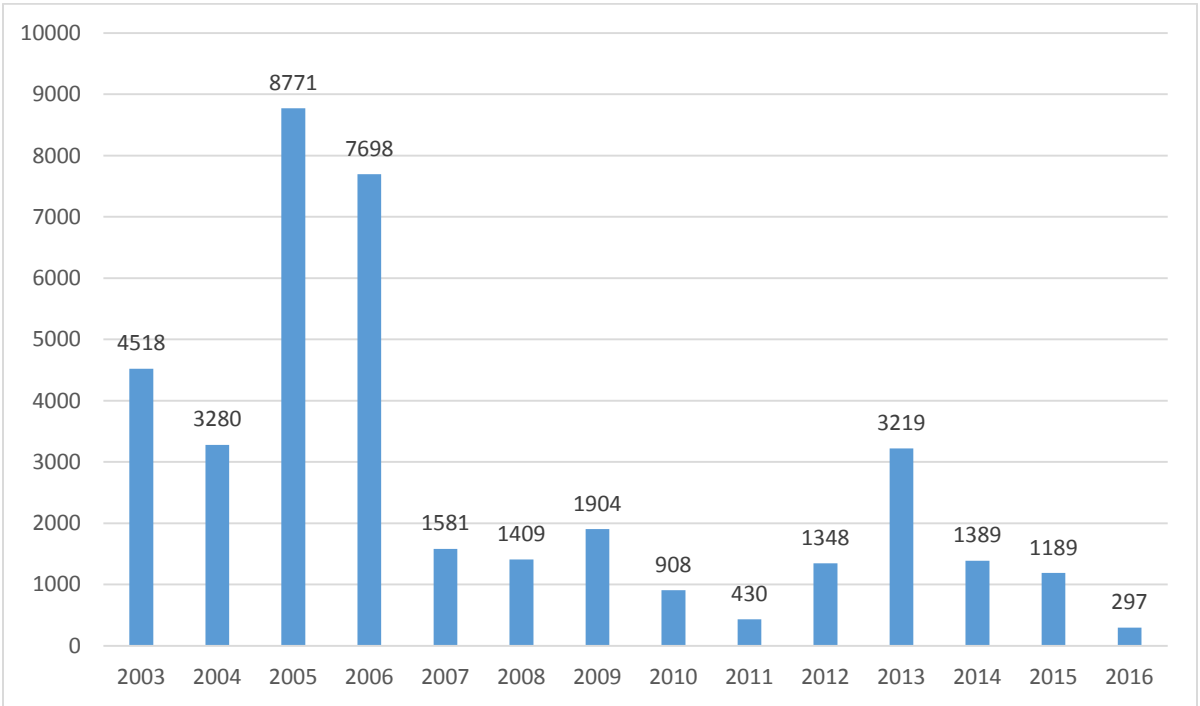

Figure 6. Annual winter-run Chinook salmon carcass counts

1.4 Shasta Storage, Water Temperature and Flow affects to Brood Year 2016 Winter-run Chinook Salmon

As of August 29, 2016, the volume of water less than or equal to 49°F in Shasta Reservoir is greater than 700 thousand acre-feet (taf) and has tracked about 300 taf more than what was modeled in the June 7, 2016, draft Sacramento River Temperature Management Plan (Figure 7). This has allowed for a cold water volume to meet the needs of winter-run Chinook salmon spawning and egg incubation throughout the temperature management season.

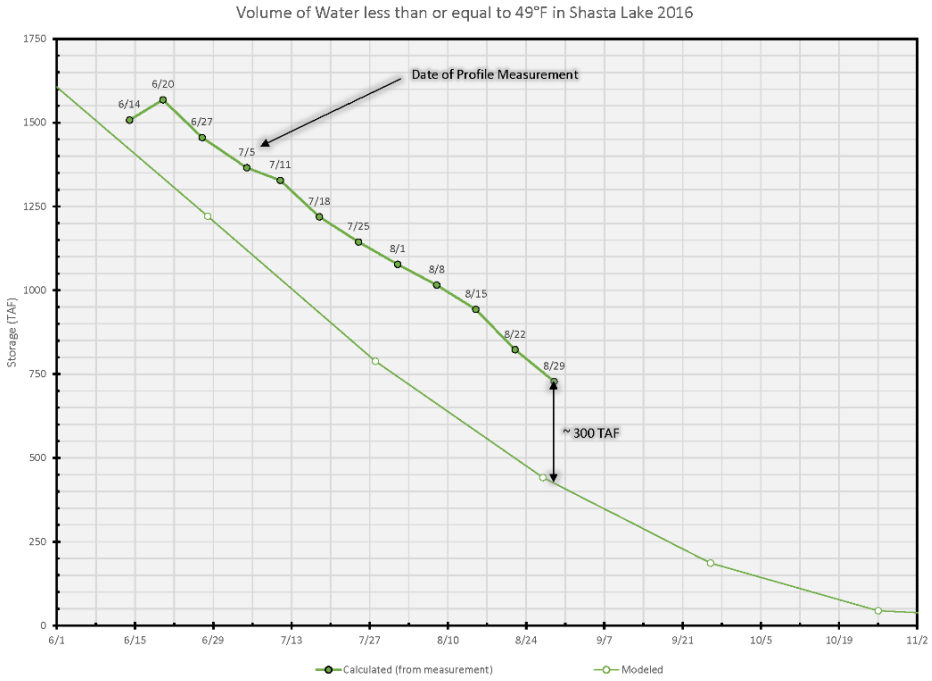

Figure 7. Shasta Coldwater volume of less than 49°F modeled on June 7, 2016 vs. observed

Reclamation operated to a temperature compliance point of 58 °F at CCR through June 5, 2016. On June 17, 2016, the temperature compliance point was set at a daily average temperature (DAT) of 56°F at Balls Ferry. (Figure 8). After that date, Reclamation was able to meet 55°F 7DADM at SAC (rm 297). There were slight exceedances of 55°F 7DADM at CCR (rm 292) towards the end of June and the beginning part of August. There was difficulty in meeting the 55°F 7DADM at the downstream most redd, located at the confluence of Clear Creek, approximately 3 miles downstream (rm 289) from CCR.

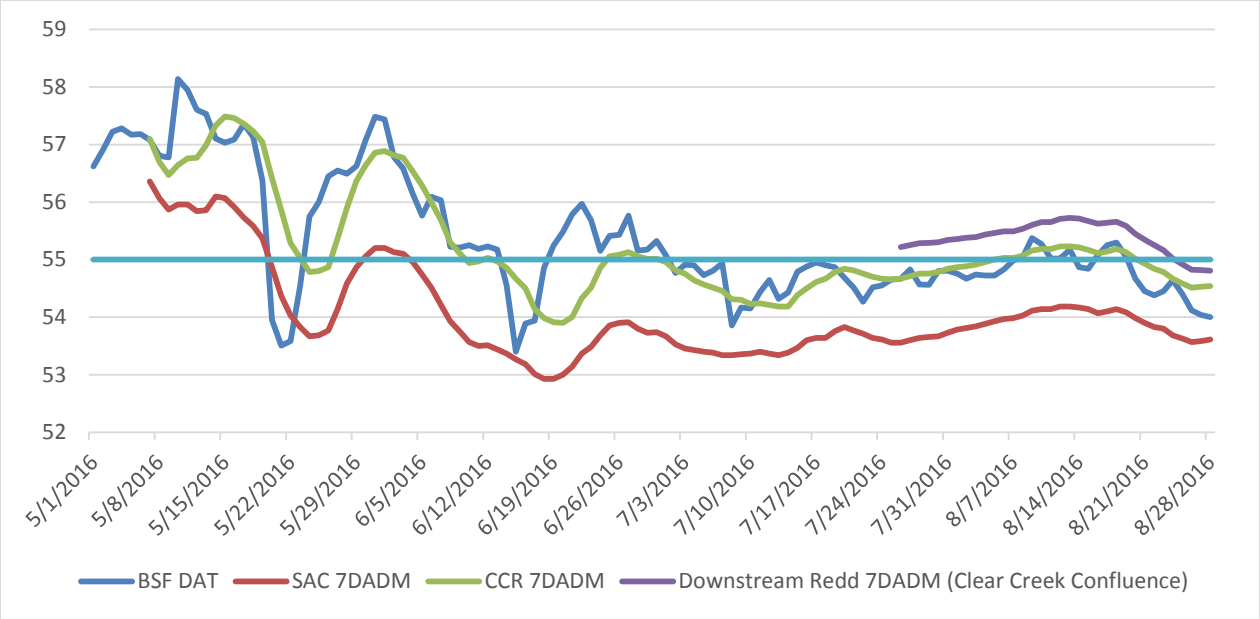

Figure 8. Sacramento River Temperatures

The NMFS-SWFSC River Assessment Forecasting Temperature (RAFT) landscape profile in Figure 9 depicts the August 29, 2016, hindcast and forecast results. The graph on the left depicts daily average temperature by the distance downstream of Keswick Dam. This gives a depiction of the water temperatures that winter-run spawning adults, eggs, alevin, and fry experience in the upper Sacramento River. The graph on the right depicts the actual and forecasted mean temperature for the entire development period of winter-run redds based the spawn date. So for example, if spawning occurred on July 1, 10 miles downstream of Keswick Dam, the redd would experience temperature below 53.726 ^{o}F for its entire egg incubation period until fry emergence. The isohaline line at 53.726 ^{o}F represents the T_{crit} value. For temperatures below T_{crit} there is no expected mortality due to temperature. Temperatures above T_{crit} assume an instantaneous mortality rate increasing linearly with increasing temperature.

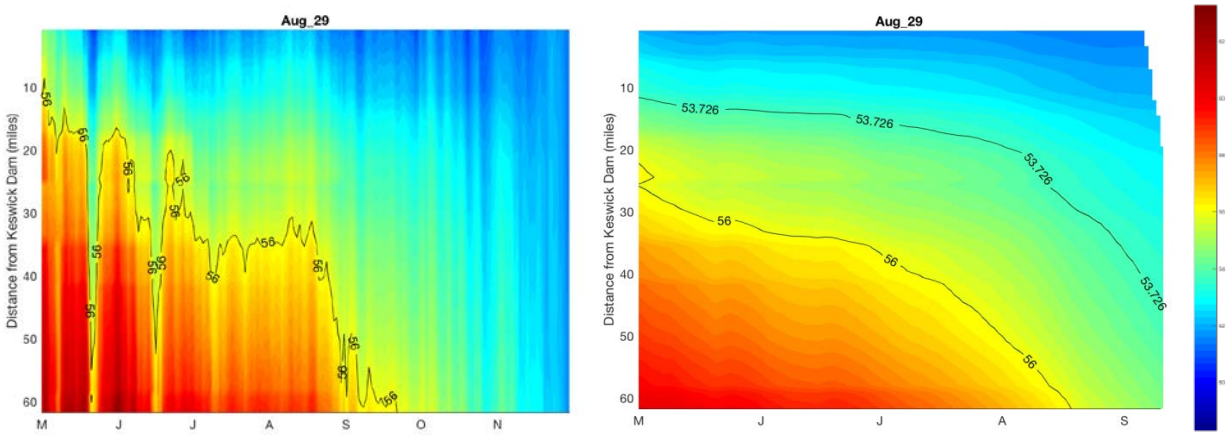

Figure 9. Temperature landscape, daily average temperature (left) and mean temperature during development period (right) based on River Assessment Forecasting Temperature modeling.

Despite the temperature compliance exceedances experienced in May and early June, the temperature dependent mortality model (Martin *et al*. 2016) based on the August 29, 2016, Shasta Reservoir temperature profile predicts that temperature dependent mortality would be very low; the mean cumulative temperature dependent mortality is estimated to be 2.21% (0.1 - 22.4 95% confidence interval). Results of the Martin (*et al*. 2016) model's temperature dependent survival are depicted Figure 10. The graph on the left takes the RAFT temperature information from Figure 6 and converts it into temperature dependent survival probabilities. The black circles represent actual spawning locations downstream of Keswick Dam from 2012-2015. These data are representative of spawning locations for this year. According to the graph, all of the redds have a greater than 90% probability of temperature-dependent survival (or conversely a less than 10% probability of temperature-dependent mortality). The graph on the right is another way of looking at temperature dependent survival based on when a winter-run spawned. Based on the graph, there is very little temperature-dependent mortality (mean in red, 10% and 90% confidence intervals shaded in grey).

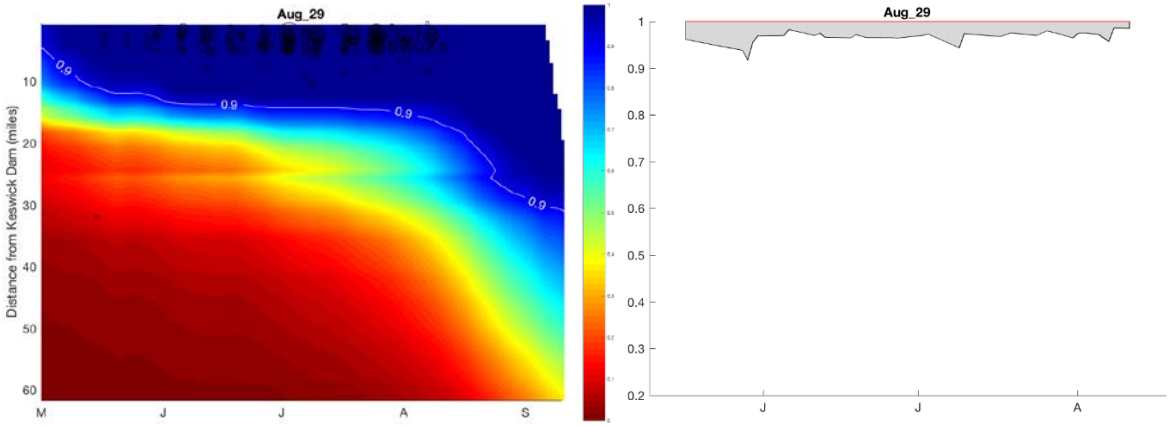

Figure 10. Temperature-dependent survival using 2012-2015 redd data, survival landscape (left) and survival uncertainty (right) (mean in red and 90% confidence interval shaded in grey).

As Keswick releases in the fall are reduced to stabilize flows for fall-run Chinook salmon spawning and to maximize water storage for the next water year, CDFW will continue to monitor for redd dewatering and stranding.

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