Sacramento River Temperature Task Group

Bird's eye view with fisheye lens: Sacramento River winter run spawning area, July 2018, upstream of Sundial Bridge in Redding California.

Photo: John Hannon

Annual Report of Activities

October 1, 2017 through September 30, 2018

Acronyms and Abbreviations

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

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Chapter 1 Background

1.1 Shasta – Trinity System Geographic Orientation

The Central Valley Project's (CVP) Shasta Division includes facilities that conserve water in the Sacramento River for (1) flood control, (2) navigation maintenance, (3) agricultural water supplies, (4) municipal and industrial (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 (TCD). 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 6,649 square miles. Shasta Dam was completed in 1945, forming Shasta Lake, which has a maximum storage capacity of 4,552,000 acre feet (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.

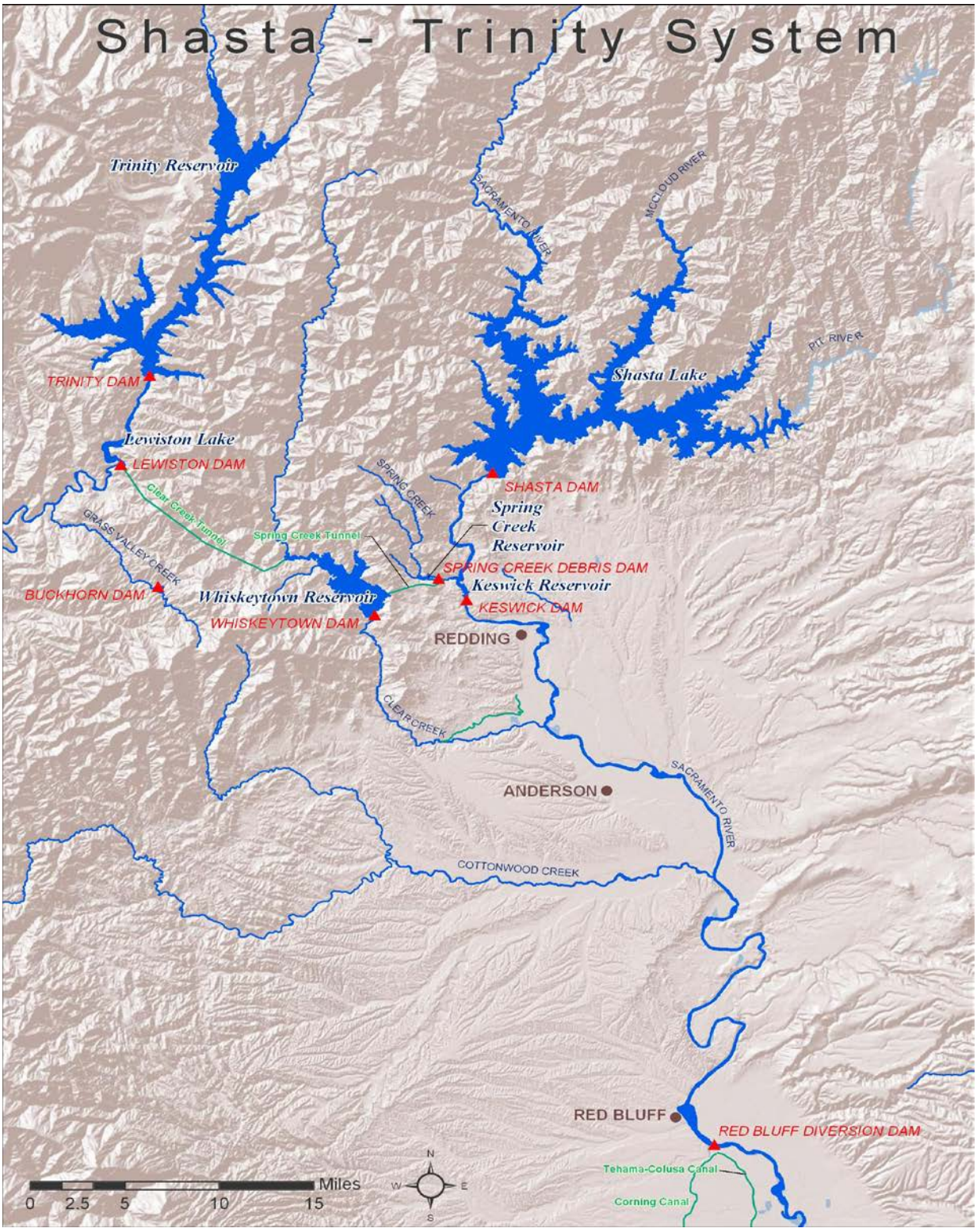

Figure 1 - Shasta - Trinity System

1.2 Upper Sacramento River Historical Background

The purpose of the Sacramento River Temperature Task Group (SRTTG) is to provide advice to U.S. Bureau of Reclamation (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 (WRO) 90-5 and also the required actions described in NMFS' 2009 reasonable and prudent alternative (RPA) with 2011 amendments.

The SRTTG advises Reclamation on the best course of action to take to implement WRO 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. WRO 90-5 requires a daily average water temperature of 56° Fahrenheit (F) in the Sacramento River at Red Bluff Diversion Dam. Since 2009 it has not been possible to sustain 56°F at Red Bluff, approximately 60 miles downstream of Keswick Dam. Instead SRTTG will advise on the location of the TCP farther upstream.

The RPA action objectives of the May 15 through October 31 Sacramento River in-stream temperature criteria (Action 1.2.4) are to manage the cold water storage within Shasta Reservoir and make cold water releases from Shasta Reservoir to provide suitable habitat temperatures for Sacramento River winter-run Chinook salmon, Central Valley 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 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 mainstem spring run, whenever possible, 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) 2018 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).

Chapter 2 - Reasonable and Prudent Alternative (RPA) Actions (NMFS 2009 BiOp): Actions

2.1 Summary of RPA Actions

On June 4, 2009, and further amended in 2011, NMFS issued its BiOp and Conference Opinion on the Long-Term Operations of the CVP and SWP that included RPA actions for the Sacramento River. The SRTTG was included amongst the four Fisheries and Operations Technical Teams whose function is to make recommendations for adjusting operations to meet contractual obligations for water delivery and to minimize adverse effects on listed anadromous fish species (see Section 11.2.1.1, NMFS 2009 BiOp with 2011 amendments). The objectives of these RPA actions are to provide flows and suitable temperatures to address the avoidable and unavoidable adverse effects of Shasta operations on winter-run and spring-run. In addition, a Temperature Management Plan is prepared for NMFS' consideration in May of each year that incorporates actions under Reclamation's authority.

The following describe a summary of the Shasta Operations RPA actions applicable for this year:

- **RPA Action I.2.1. Shasta Operation Performance Measures**
  - Action tracks Shasta Lake end of September storage and temperature compliance location performance over a 10-year period.
- **RPA Action I.2.2/ RPA Action I.2.2A November through February Keswick Release Schedule (Fall Actions)/Implementation Procedures for End of September Storage at 2.4 MAF and Above**
  - Action addresses concerns to minimize impacts to the listed species from high water temperatures, and
  - Considers Keswick release estimates for flood control, redds/egg incubation, dewatering, and juvenile stranding.
- **RPA Action I.2.3 February Forecast: March – May 14 Keswick Release Schedule (Spring Actions)**
  - Action's objective is to conserve water during the spring for summer temperature management.
- **RPA Action I.2.3.A Implementation Procedures if February Forecast, Based on 90 Percent Hydrology, Shows that Balls Ferry Temperature Compliance Point and 2.2 MAF EOS are Both Achievable.**
  - Action considers allocation of water from the project under assumed conservative hydrologic conditions.
- **RPA Action I.2.4 May 15 Through October Keswick Release Schedule (Summer Action)**
  - Action requires development and implementation of an annual Temperature Management Plan to provide suitable temperatures for listed species, and when feasible, fall-run.

In addition, based on discussions between Reclamation and NMFS, the following temperature management criteria were proposed on May 11, 2018:

- **Temperature compliance point:** 56°F DAT at Balls Ferry.
- **An operational study for evaluation:** 53.5°F daily average temperature (DAT) at the Clear Creek gaging station along the Sacramento River. This acts as a surrogate location and temperature for a 55°F seven-day average daily maximum (7DADM) at the most downstream winter-run redd. If redds are detected farther downstream from the Clear Creek gaging station along the Sacramento River, the agencies will further discuss any potential changes to the proposed operational study. This study is undertaken with the expectation to assess the efficacy of the DAT and the temperature threshold as well as identifying factors other than temperature that may be impacting survival of juvenile salmon migrating through the Sacramento River. Results should provide an opportunity to review benefits and impacts of operating to a potential new temperature compliance location, value, and metric.

Chapter 3 - Summary of SRTTG Discussions

The SRTTG consists of representatives from Reclamation, FWS, NMFS, California Department of Fish and Wildlife (CDFW), State Water Resources Control Board (SWRCB), Western Area Power Administration (Western), Hoopa Valley Tribe, and Yurok Tribe. Other agencies have participated in the past and may be added to the SRTTG, provided existing agencies approve of the addition in membership. Monthly SRTTG meetings/calls were held at various locations to accommodate group member localities. Meeting notes and supplemental SRTTG documents were also made available.

3.1 Monthly Discussion Topics

- **Sacramento River Fishery Updates**
  - The status of current fisheries monitoring activities provided by Reclamation, NMFS, FWS, and CDFW, as well as planned future fisheries monitoring activities.
- **Hydrology and Operations Update**
  - Past and expected future operations and meteorological/hydrologic conditions provided by Reclamation.
- **Temperature Studies Update**
  - Past and expected future temperature performance provided by Reclamation.

Chapter 4 - Water Operations Summary

4.1 General Water Year Conditions and Operations

Water year 2018 was marked by inconsistent rainfall and little snow throughout the winter months. Specifically at Shasta Dam, November, January, and March were more robust, rain gauges reported a combined total of 29.64 inches, but little (less than 0.5 inches) precipitation reported for the entire months of December and February combined. March precipitation was particularly advantageous, as rainfall occurring in prior months is usually evacuated to maintain U.S. Army Corps of Engineers (USACE) required flood space for flood control. Snow pack for the northern state was particularly poor, reaching only approximately 50% of the April 1 snow water equivalent average. The Sacramento Eight Station Index for water year 2018 reported 80% of average precipitation for the region. In the month of May (typically the end of the snow sampling season), water supply indices reported 75% of average for the Sacramento River Unimpaired Runoff and a "Below Normal" year for the Sacramento Valley Index (DWR 2018). Temperature conditions were unusual as well, California experienced the warmest July on record followed by the Carr Fire event that spread to Redding, CA. Smoke and haze from the fires likely influenced the heat transfer/warming at Shasta Lake and in river downstream from Keswick Dam in late July through August resulting in cooler water than expected.

4.2 Hydrologic Conditions – Sacramento River

Watershed runoff in the upper Sacramento River basin is typically dominated by winter precipitation. The runoff is quantified as a late spring through summer inflow volume (April through July volume). The Sacramento River watershed basin runoff forecasted inflow volume is fundamental in operational planning; this product is updated routinely by the Department of Water Resources (DWR) and the National Weather Service-California Nevada River Forecast Center (CNRFC), where uncertainty is represented by percent runoff exceedances. By May, water supply forecasts for Shasta Lake inflow runoff ranged between 61% and 66% of average for the 90% and 50% exceedances, respectively (DWR 2018). The actual full natural flow Shasta Lake inflow volume April through July was 1.2 MAF and the final water year volume was 3.4 MAF (DWR 2018). Table 1 provides insight to the hydrologic characteristics of water year 2018. Because operational planning is significantly influenced by future forecasts, these uncertainties and eventually modified decisions are translated into the performance and efficiency of the system-wide operation.

Table 1 2018 Water Year Northern Sierra precipitation, Sacramento Basin snowpack, and Sacramento Valley Index statistics by month.

Water Year 2018 Month	Northern Sierra 8-Station Precipitation (Cumulative water year in inches through month)	Northern Sierra 8-Station percentage of historic monthly average precipitation (for month)	Sacramento River Basin Snowpack (percent of April 1st average)	Sacramento Valley Index (40-30-30 Index 50% Exceedance)
November	11.9	168%	NA	NA
December	12.6	7%	NA	9.3
January	19.6	78%	NA	8.1
February	21.3	20%	23	6.7
March	33.9	165%	19	6.0
April	38.7	126%	36	6.9
May	40.5	81%	30	7.2

4.3 Operations – Sacramento River

4.3.1 RPA Actions: I.2.1., I.2.2, I.2.2A, I.2.3, I.2.3.A

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, downstream Delta regulatory requirements, Delta exports, power generation, recreation, fish hatchery accommodations, temperature management capabilities, and others. In addition, uncertain or unplanned events can also influence real-time operation decisions [e.g. wildfire events, or additional flow reductions for USACE downstream flood protection]. Planned operational targets are regularly updated late winter through early summer (depending on hydrologic conditions) on Reclamation's website (https://www.usbr.gov/mp/cvo/).

Key events/decisions that influenced 2018 upper Sacramento River operations:

- USACE flood control space operations: Flood control space was maintained during the month of December
- Spring Meteorology and Runoff: Strong rainfall and side flow runoff in March coupled with high winds delayed expected release operations and warmer, uncontrolled, side flow runoff was likely influencing downstream temperatures
- Cold Water Pool (CWP): The historical conditions of the CWP and temperature performance are recorded in Tables 2 and 3 for comparison. In the spring there were concerns that temperature management operation in the late summer/early fall period may be limited as a result of below average CWP less than 49°F, however, conditions recovered to approximately normal towards the end of the temperature management season.
- Carr Wildfire event beginning July 26, 2018: Trinity, Whiskeytown and Shasta facilities were evacuated during the fire and Reclamation was challenged by an interruption of communications at several locations for several months after the event.

Table 2 Historical Shasta Lake Storage Volumes and CWP volumes

Shasta Lake Historical Conditions 2010-2018*								
Water Year	Peak Storage		End of April Volume < 56°F	Date 1st Side Gate Opened	End of September Volumes			
	Volume	Date			Storage	< 56°F	< 52°F	< 50°F
2010	4507	05/22	3771	09/17	3319	1216	744	516
2011	4492	06/02	3809	N/A	3341	1340	903	707
2012	4483	05/07	3791	09/21	2592	765	598	512
2013	3887	04/18	2809	09/11	1906	425	347	309
2014	2409	04/28	1770	08/07	1157	107	81	63
2015	2722	04/15	1912	09/13	1603	358	270	228
2016	4235	05/01	3267	10/23	2811	938	730	596
2017	4389	05/13	3975	N/A	3382	1146	806	594
2018	4200	04/26	3135	09/19	2405	587	450	349

*All Volumes are in Thousands of Acre Feet (TAF)

Table 3 Historical Sacramento River Temperature Compliance Point Data

Sacramento River Historic Temperature Control Point 2010-2018 Daily Average Temperature Degrees Fahrenheit (Days Applied)									
Year	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**
2010	BSF-56°	BSF-56° (01-14) JLF-56° (15-30)	JLF-56° (01-10) BSF-56° (11-24) JLF-56° (25-31)	JLF-56°	JLF-56°	JLF-56°	JLF-56°	JLF-56°	JLF-56°
2011	BSF-56°	BSF-56°	BSF-56°	JLF-56°	JLF-56°	JLF-56°	JLF-56°	JLF-56°	JLF-56°
2012	JLF-56°	JLF-56° (01-15) BSF-56° (16-30)	BSF-56°	JLF-56°	JLF-56°	JLF-56°	JLF-56°	BSF-56°	BSF-56°
2013	BSF-56°	BSF-56°	BSF-56° (01-16) [1]BSF-**56.75°** (17-31)	[1]BSF-**56.75°**	[1]BSF-**56.75°**	[1]BSF-**56.75°**	[1]BSF-**56.75°**	[1]BSF-**56.75°**	[1]BSF-**56.75°**
2014	BSF-56° (01-27) CCR-**58°** (28-31)	CCR-**58°** (01-24) CCR-56° (25-30)	CCR-56°	CCR-56°	CCR-56°	CCR-56°	CCR-56°	CCR-56°	CCR-56°
2015[2]	CCR-56°	CCR-56° (01-17) CCR-**58°** (18-30)	CCR-**58°** (01-14) CCR-56° (15-31)	CCR-56° (01-04) CCR-**58°** (05-30)	CCR-**58°**	CCR-**58°**	CCR-**58°**	CCR-**58°**	CCR-**58°**
2016	CCR-**58°**	CCR-**58°**	CCR-**58°**	CCR-**58°** (01-16) BSF-56° (17-30)	BSF-56°	BSF-56°	BSF-56°	BSF-56°	BSF-56°
2017[3]	BSF-56°	BSF-56°	BSF-56°	BSF-56°	BSF-56°	BSF-56°	BSF-56°	BSF-56°	BSF-56°
2018[4]	BSF-56°	BSF-56°	BSF-56°	BSF-56°	BSF-56°	BSF-56°	BSF-56°	BSF-56°	BSF-56°

[1]BSF-56.75°F used as surrogate for Airport Road 56°F

[2] Year 2015 July – November the temperature target was 57°F, not to exceed 58°F

[3] Year 2017 pilot evaluation study also targeted CCR at 53°F May 15 – Oct 31

[4] Year 2018 pilot evaluation study also targeted CCR at 53.5°F May 15 – Oct 31

BSF = Balls Ferry, JLF = Jellys Ferry, CCR = Sacramento River upstream of Clear Creek confluence

Temperature control point temperatures in red are greater than 56°F

Reclamation provided NMFS average monthly Keswick release outlooks in the fall (Action I.2.2.A) and again in the spring (Action I.2.3 and I.2.3A), including initial delivery allocations and temperature performance estimations. Actual storage and flood control conditions are illustrated in Figure 2. Keswick Dam releases to the Upper Sacramento River are shown and annotated on Figure 3. Coordination of release outlooks occurred during monthly SRTTG meetings. Keswick Dam releases are listed in Table 4. Late July operations were affected by

extreme wildfire-related activities that damaged and impacted operations at Reclamation's facilities. Sacramento River flow variability is related to emergency and recovery efforts during this time.

4.3.1.1 2018 Fall Flow Reduction

Fall flow reduction schedule discussions with the fish agencies (NMFS, CDFW, and USFWS) and Reclamation began in late September, in consideration of the needs of fish, Shasta Reservoir carry over storage, and downstream water needs (rice decomposition, Wilkins Slough, waterfowl habitat, Delta water quality). Various flow reduction scenarios were developed with considerations and recommendations for fisheries to: (1) avoid or minimize dewatering of winter-run Chinook salmon redds, (2) reduce Keswick releases quickly in order to minimize the potential for fall-run Chinook salmon redd dewatering, (3) stabilize Keswick releases through approximately January 2019 to continue to minimize the potential for fall-run Chinook salmon redd dewatering, and (4) maintain base flows of 4,000 cfs or greater to maintain juvenile winter-run Chinook salmon rearing habitat and decrease juvenile stranding.

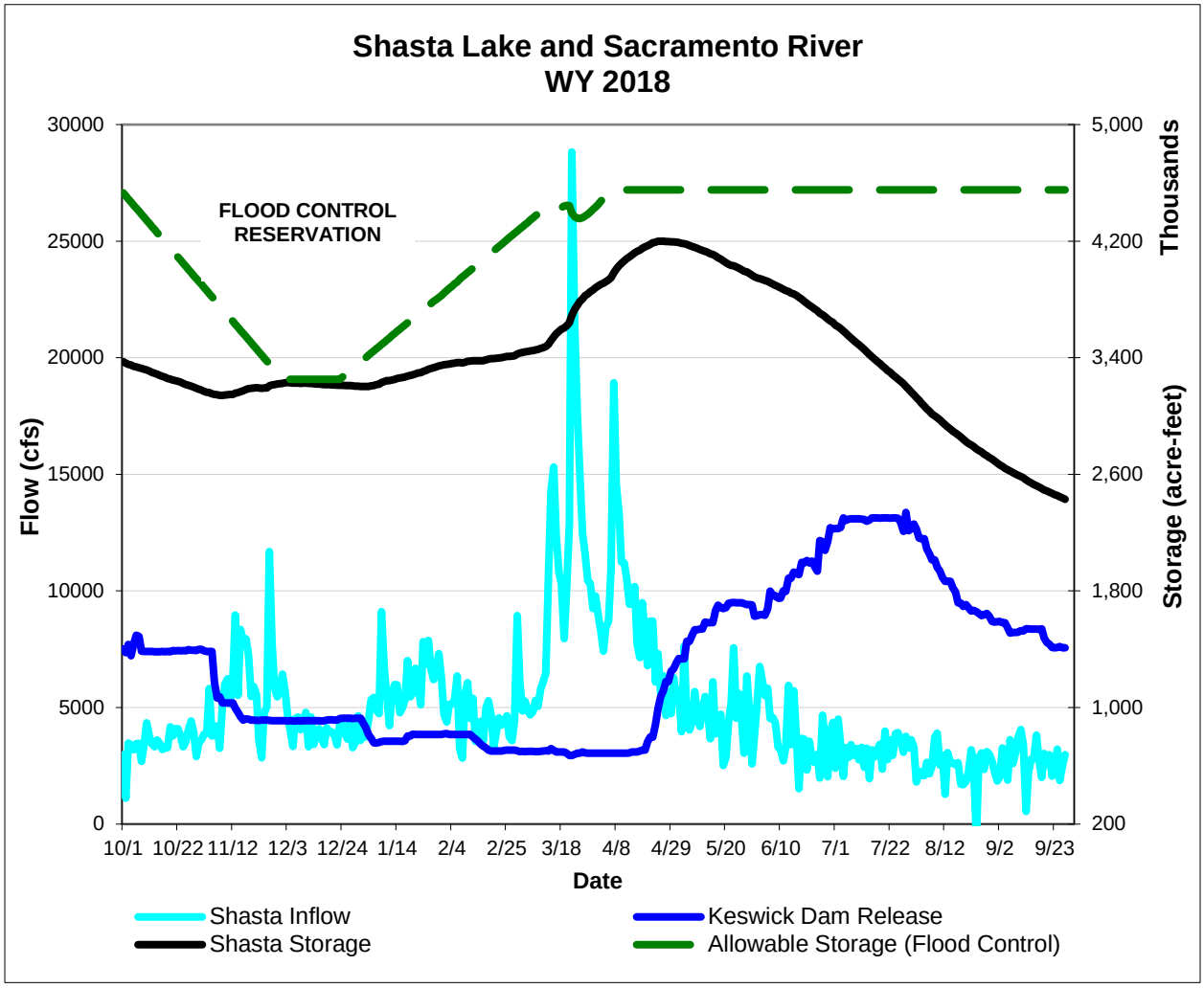

Figure 2 Summary of Shasta Lake Storage and Upper Sacramento River Releases

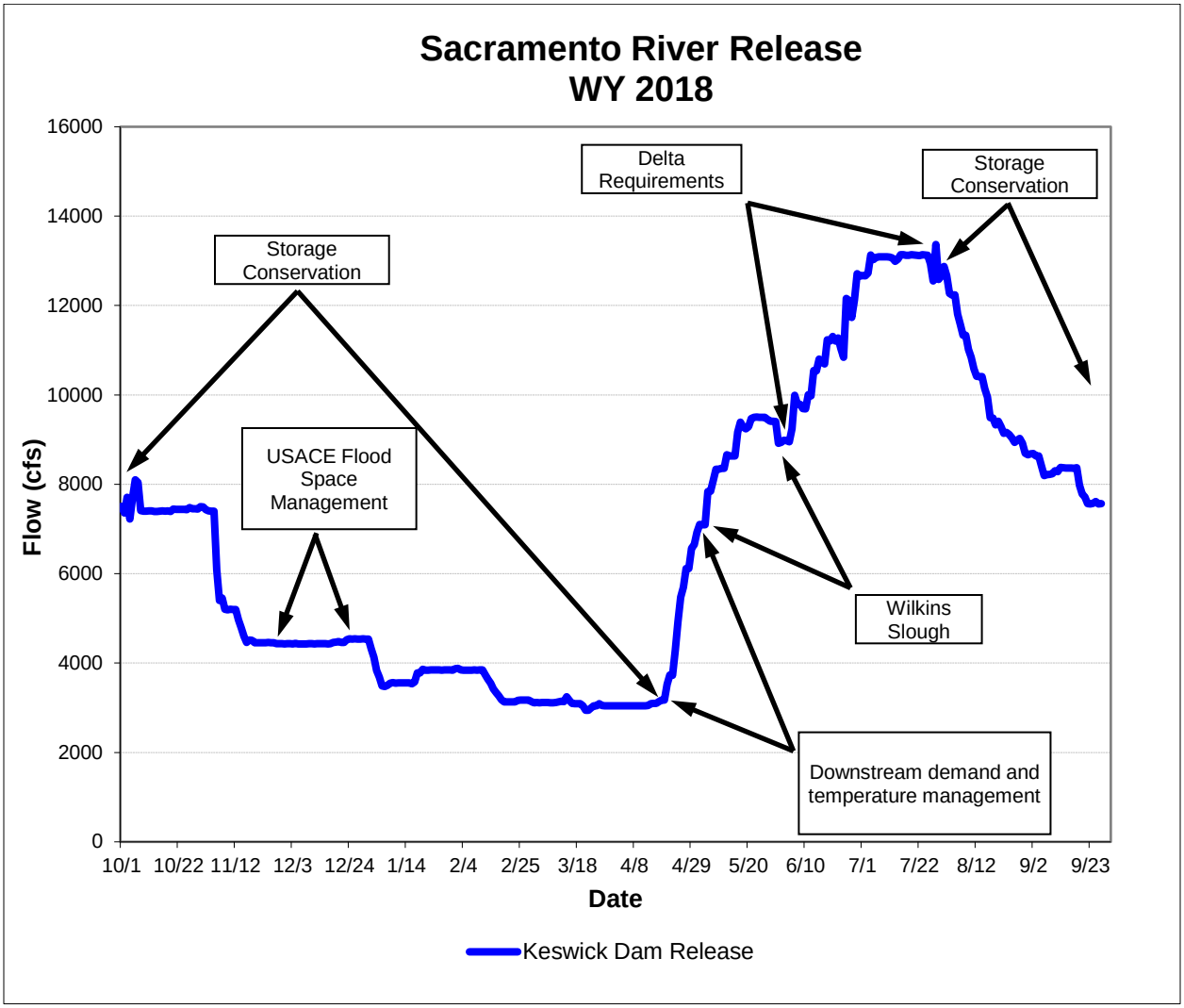

Figure 3 Summary of Upper Sacramento River Releases at Keswick Dam

Table 4 Release Changes at Keswick Dam WY 2018

2018 Change Order Log - Keswick				
Start Date	**End Date**	**Release**	**To (cfs)**	**Comment**
10/1/2017	10/1/2017	Decrease	8000	Storage conservation
11/5/2017	11/6/2017	Decrease	6000	Storage conservation/ACID flash-board removal
11/8/2017	11/8/2017	Decrease	5750	Reduction for ACID flash-board removal
11/13/2017	11/16/2017	Decrease	5000	Storage conservation
1/1/2018	1/5/2018	Decrease	4000	Storage conservation
2/12/2018	2/19/2018	Decrease	3250	Storage conservation

2018 Change Order Log - Keswick				
Start Date	**End Date**	**Release**	**To (cfs)**	**Comment**
4/20/2018	4/20/2018	Increase	3750	Downstream demand and temperature management
4/21/2018	4/21/2018	Increase	4250	Downstream demand and temperature management
4/23/2018	4/23/2018	Increase	4750	Downstream demand and temperature management
4/24/2018	4/24/2018	Increase	5250	Downstream demand and temperature management
4/25/2018	4/26/2018	Increase	6000	Downstream demand and temperature management
4/27/2018	4/27/2018	Increase	6500	Downstream demand and temperature management
4/29/2018	4/29/2018	Increase	7000	Downstream demand and temperature management
5/2/2018	5/2/2018	Increase	7250	Wilkins Slough
5/5/2018	5/8/2018	Increase	8500	Wilkins Slough
5/12/2018	5/12/2018	Increase	8750	Wilkins Slough
5/16/2018	5/17/2018	Increase	9500	Wilkins Slough
5/31/2018	5/31/2018	Decrease	9000	Adjusting for Delta Requirements
6/6/2018	6/6/2018	Increase	9500	Downstream Demands and Delta Requirements
6/11/2018	6/11/2018	Increase	9750	Downstream Demands and Delta Requirements
6/13/2018	6/13/2018	Increase	10250	Downstream Demands and Delta Requirements
6/15/2018	6/15/2018	Increase	10500	Delta Requirements
6/18/2018	6/18/2018	Increase	11000	Delta Requirements
6/25/2018	6/25/2018	Increase	12000	Delta Requirements
6/29/2018	6/29/2018	Increase	12500	Delta Requirements
7/4/2018	7/4/2018	Increase	13000	Delta Requirements
8/2/2018	8/2/2018	Decrease	12500	Storage conservation
8/5/2018	8/6/2018	Decrease	11500	Storage conservation
8/9/2018	8/12/2018	Decrease	10500	Storage conservation
8/15/2018	8/16/2018	Decrease	10000	Storage conservation
8/22/2018	8/23/2018	Decrease	9500	Storage conservation
8/29/2018	8/30/2018	Decrease	9000	Storage conservation
9/5/2018	9/6/2018	Decrease	8500	Storage conservation
9/12/2018	9/13/2018	Decrease	8000	Storage conservation
9/19/2018	9/20/2018	Decrease	7250	Storage conservation

4.3.2 RPA Action 1.2.4 and Year 2018 Pilot Evaluation Study

Prior Annual Reports documented spring and summer temperature related actions well, but were truncated ahead of the most difficult and critical period for temperature management in the fall. As a result of recent drought periods and heightened sensitivity of thermal influences on early life stages of Chinook salmon, prudent efforts to accomplish critical review and efficacy of temperature management decision making for targeted species would capture the entire active selective withdrawal period (lake stratification through de-stratification, typically April through the end of November or early December). Ideally, issuance of this report would be delayed until at least December to appropriately capture the whole temperature management cycle. Early season decisions such as temperature targets, locations, metrics, and release decisions can significantly influence fall temperature performance. Early water year 2018 hydrologic

conditions were poor and expected reservoir refill potential was diminished. However, March hydrologic events increased and reservoir refill helped recover early bleak temperature management expectations. Temperature management outlooks improved over the spring and into the summer months adding confidence to management capabilities. Variable warming in June and smoke/haze that persisted as a result of fire activity in the Redding and Shasta Lake area likely influenced (aided) downstream temperature performance.

Action I.2.4 is designed to provide suitable temperature habitat for winter-run, spring-run, California Central Valley steelhead, and Southern distinct population segment of North American green sturgeon and to the extent possible, for naturally spawning fall-run. The February 2018 forecast and modeling information provided by both Reclamation and NMFS indicated difficulty in meeting 56°F DAT at BSF temperature compliance point for the entire season (May 15 – Oct 31). In March 2018, both models indicated temperature compliance would not be met. Late spring rains improved reservoir storage and modeling output. Based on system-wide operations and temperature modeling results, Reclamation submitted a Temperature Management Plan to NMFS on May 11, 2018. The Plan included a temperature compliance point at Balls Ferry with a target of 56°F daily average temperature from May 15 through October 31. As mentioned previously, in 2017 and again in 2018, NMFS requested additional thermal protections for winter-run. Reclamation implemented a pilot study to evaluate a temperature target location closer to the actual redd locations, the Sacramento River at Clear Creek gaging station (CCR), at a lower temperature (53.5°F daily average temperature rather than 56°F) as a surrogate temperature to accommodate an average daily maximum metric and a surrogate location for the most downstream winter-run redd. This temperature target was 0.5°F higher than the pilot target during 2017 temperature management season, a target more likely to be met as informed by forecasts and modeling. These actions were provided such that operational adjustments did not adversely impact CVP/SWP operations, the environment, or other ESA listed species. Preliminary temperature management operational modeling studies were distributed in February, March, April, and May, and updated every month thereafter in preparation for the monthly SRTTG meetings. Modeling scenarios performed in late spring and summer, varying both hydrologic and meteorological conditions, indicated optimistic downstream temperature performance for the temperature management period. Temperature modeling limitations and supplemental historical data were also discussed especially for the fall period when the TCD Side Gages are typically used. Throughout the temperature management season, Reclamation provided bi-monthly comparisons between predicted cold water pool and actual volumes, and historical cold water pool statistics. As of September 30, 2018, the volume of water less than or equal to 49^{o}F in the cold water pool of Shasta Reservoir was slightly greater than what was modeled in the temperature management plan.

Temperature performance in 2018 may be a reflection of the conditions during the late summer. Smoke and fire haze conditions dominated the entire month of August. Figure 4 illustrates downstream temperature performance and Figure 5 shows Shasta Lake 2018 Isothermalbaths.

Monthly downstream temperature performance (https://www.usbr.gov/mp/cvo/temperature.htmlhttps://www.usbr.gov/mp/cvo/temperature.html) at various locations and metrics, and meteorological conditions are available on Reclamation's web-site. By the beginning of September 2018, the TCD was arranged with Pressure Relief Gates (PRG) opened. Typically the Side Gates are opened in the fall, the first Side Gate opened September 19, 2018 and full Side Gates usage (both Side Gates and all PRGs closed) was reached on October 26, 2018. Figure 6 displays the last temperature TCD blending needed (profile of Shasta Lake October 2018) and Table 5 is a compilation of TCD actions throughout the year. The entire collection of Water Year 2018 TCD configurations (https://www.usbr.gov/mp/cvo/vungvari/ShastaTCD2018.pdf) are available on Reclamation's web-site). As of October 29, 2018, the temperature criterion was exceeded at BSF 1.2% of the management season, and at CCR for 30.6% of the temperature management season, with excursions up to 55.0°F in October (Columbia Basin Research, University of Washington 2018). Adjustments were made to the temperature control device and gates to try to reduce water temperatures at CCR, and keep water temperatures cool through the estimated final emergence date in mid-November. Full side-gate operation began on October 26, 2018.

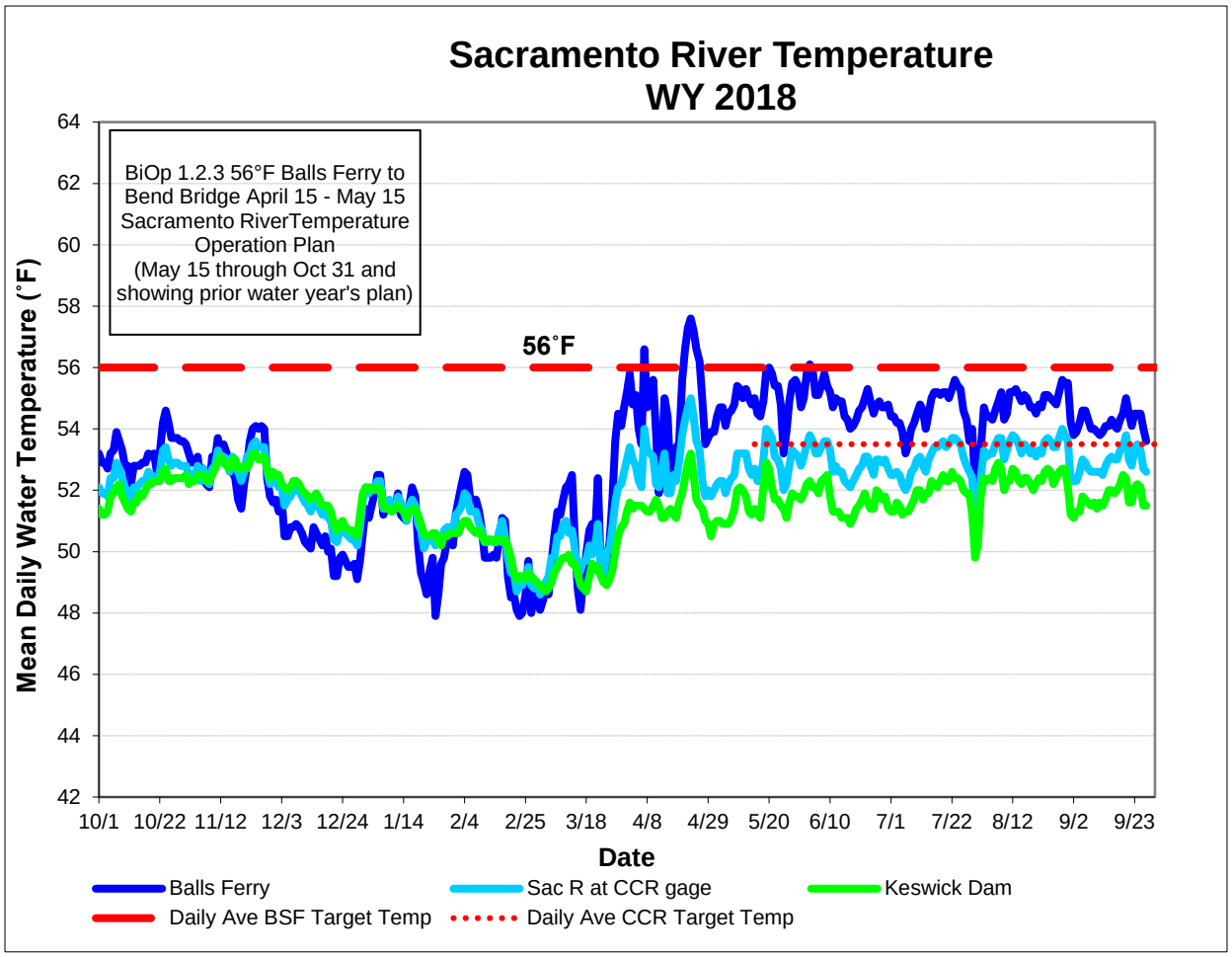

Figure 4 Summary of Temperature in the Upper Sacramento River

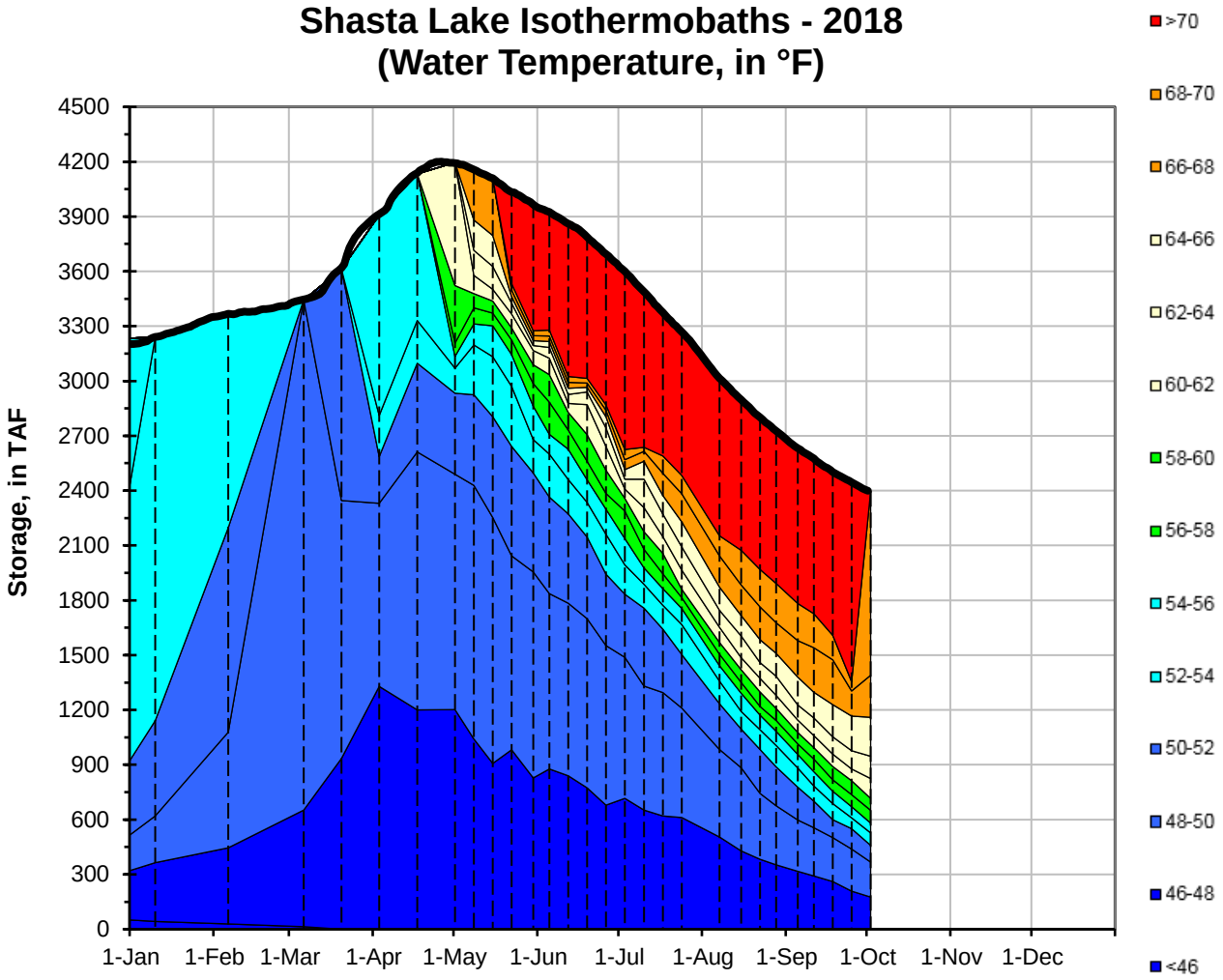

Figure 5 Shasta Lake Isothermalbaths October 2018

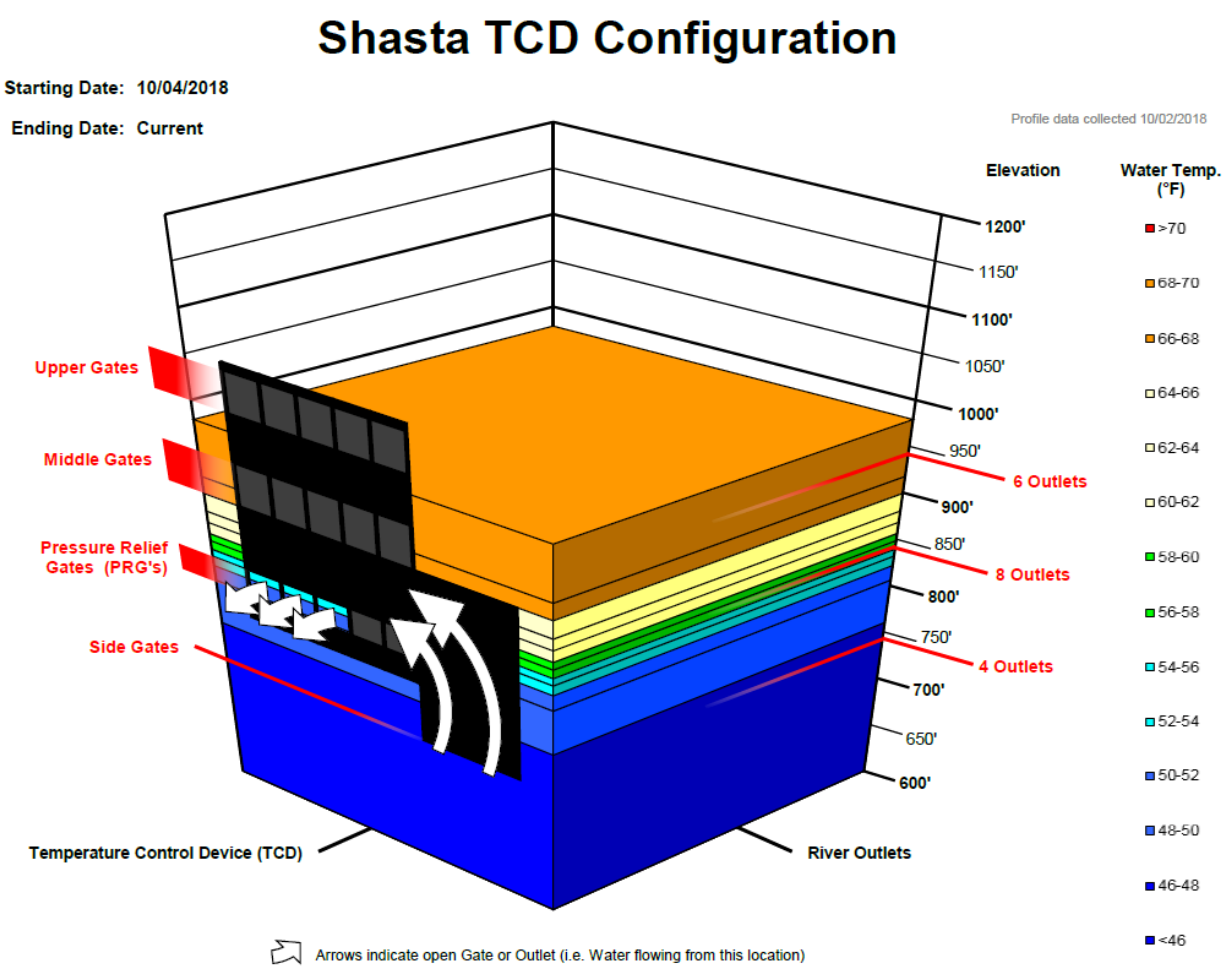

Figure 6 Shasta Lake Profile and TCD Configuration October 4 2018

Table 5 Water Year 2018 Shasta TCD Action Log

2017-2018 Change Order Log - Shasta TCD						
Year, Month, Day & Time of Email	Year, Month, Day & Time of Change	Number of Gates Open and/or Closed				Change/Comment/Reason
		Upper	Middle	Lower (PRG)	Side	
2017_10_23_0907	2017_10_23_1100	-	Close #5	-	-	On Monday, 10/23/2017 at approximately 11:00 hrs, please close Middle Gate #5.
2017_12_27_1100	2017_12_28_1300	-	Open All	Close All	-	On Thursday, 12/28/2017 at approximately 13:00 hrs, please open all Middle Gates #1, #2, #3,

2017-2018 Change Order Log - Shasta TCD						
Year, Month, Day & Time of Email	Year, Month, Day & Time of Change	Number of Gates Open and/or Closed				Change/Comment/Reason
		Upper	Middle	Lower (PRG)	Side	
						#4, and #5. Please close all PRG Gates #1, #2, #3, #4, and #5.
2018_02_08_1151	2018_02_08_1400	Open All	Close #1 & #2	-	-	On Thursday, 2/8/2018 at approximately 14:00 hrs, please open all Upper Gates #1, #2, #3, #4, and #5. Please close Middle Gates #1 and #2.
2018_03_23_1029	2018_03_23_1300	-	Close #3, #4 & #5	-	-	On Friday, 3/23/2018 at approximately 13:00 hrs, please close Middle Gates #3, #4, and #5.
2018_04_22_1120	2018_04_22_1300	-	Open #3	-	-	at approx 1300 please open the middle gate on unit 3.
2018_04_27_0953	2018_04_28_1300	-	Open #1	-	-	On Saturday, 4/28/2018 at approximately 13:00 hrs, please open Middle Gate #1
2018_05_07_0943	2018_05_07_1130	-	Close #1	-	-	On Monday, 5/7/2018 at approximately 11:30 hrs, please close Middle Gate #1
2018_05_10_0937	2018_05_11_0800	-	Open #1	-	-	On Friday, 5/11/2018 at approximately 08:00 hrs, please open Middle Gate #1
2018_05_17_1051	2018_05_17_1200	-	Close #1	-	-	On Thursday, 5/17/2018 at approximately 12:00 hrs, please close Middle Gate #1
2018_05_18_1014	2018_05_20_0800	-	Open #1	-	-	On Sunday, 5/20/2018 at approximately 08:00 hrs, please open Middle Gate #1
2018_06_08_1328	2018_06_09_1000	-	Open #2	-	-	On Saturday, 6/09/2018 at approximately 10:00 hrs, please open Middle Gate #2
2018_06_22_0932	2018_06_22_1030	Close #1, #2 & #3	-	-	-	On Friday, 6/22/2018 at approximately 10:30 hrs, please close Upper Gates #1, #2, and #3
2018_06_27_1139	2018_06_29_0730	-	Open #4	-	-	On Friday, 6/29/2018 at approximately 07:30 hrs,

2017-2018 Change Order Log - Shasta TCD						
Year, Month, Day & Time of Email	Year, Month, Day & Time of Change	Number of Gates Open and/or Closed				Change/Comment/Reason
		Upper	Middle	Lower (PRG)	Side	
						please open Middle Gate #4
2018_07_02_0916	2018_07_02_1100	Open #2	-	-	-	On Monday July 2, 2018 at approximately 1100 hrs, please open Upper Gate #2
2018_07_03_0928	2018_07_03_1100	Open #1	-	-	-	On Tuesday July 3, 2018 at approximately 1100 hrs, please open Upper Gate #1
2018_07_19_0825	2018_07_19_1000	-	Open #5	-	-	On Thursday, July 19, 2018 at approximately 1000 hrs, please open Middle Gate #5.
2018_07_20_0942	2018_07_20_1300	Close #1 & #2	-	-	-	On Friday, July 20, 2018 at approximately 1300 hrs, please close Upper Gate #1 and Upper Gate #2.
2018_07_23_0938	2018_07_23_1000	-	-	Open #5	-	On Monday, July 23, 2018 at approximately 1000 hrs, please open PRG Gate #5.
2018_08_01_1426	2018_08_01_1530	Open #1 & #2 Close #4 & #5	-	Open #4	-	On Wednesday, August 1, 2018 at approximately 1530 hrs, please open PRG Gate #4, open Upper Gates #1 and #2, and close Upper Gates #4 and #5.
2018_08_02_0854	2018_08_02_1100	Close #1 & #2	-	-	-	On Thursday, August 2, 2018 at approximately 1100 hrs, please close Upper Gates #1 and #2.
2018_08_07_1011	2018_08_07_1200	-	Close #5	Open #3	-	On Tuesday, August 7, 2018 at approximately 1200 hrs, please open PRG Gate #3 and close Middle Gate #5.
2018_08_07_1454	2018_08_07_1500	-	Close #3 & #4	-	-	On Tuesday, August 7, 2018 at approximately 1500 hrs, please close Middle Gates #3 and #4.
2018_08_13_0911	2018_08_13_1000	-	-	Open #2	-	On Monday, August 13, 2018 at approximately 1000 hrs, please open PRG Gate #2.
2018_08_17_0930	2018_08_17_1100	-	Close #2	-	-	On Friday, August 17, 2018 at approximately 1100 hrs, please close Middle Gate #2.

2017-2018 Change Order Log - Shasta TCD						
Year, Month, Day & Time of Email	Year, Month, Day & Time of Change	Number of Gates Open and/or Closed				Change/Comment/Reason
		Upper	Middle	Lower (PRG)	Side	
2018_08_30_0937	2018_08_30_1100	-	Close #1	Open #1	-	On Thursday, August 30, 2018 at approximately 1100 hrs, please open PRG Gate #1 and close Middle Gate #1.
2018_09_19_1039	2018_09_19_1200	-	-	-	Open #1	On Wednesday, September 19, 2018 at approximately 1200 hrs, please open Side Gate #1.
2018_09_24_0958	2018_09_24_1200	-	-	-	Open #2	On Monday, September 24, 2018 at approximately 1200 hrs, please open Side Gate #2.
2018_09_25_0800	2018_09_25_0900	-	-	Close #5	-	On Tuesday, September 25, 2018 at approximately 0900 hrs, please close PRG Gate #5.

Chapter 5. Sacramento River Fisheries Monitoring

5.1 Fisheries Monitoring

This portion of the annual report focuses on findings from upper Sacramento River Chinook salmon monitoring, and water temperature and flow-related impacts to salmonids during fall, spring and summer actions (RPA Actions I.2.2, I.2.3, and I.2.4) during water year 2018. Fisheries monitoring efforts summarized in this report include 1) adult escapement and juvenile emigration estimates for winter-run Chinook salmon and fall-run Chinook salmon, 2) redd dewatering results, and 3) results from fish rescue surveys after flow decreases.

Methods

The California Department of Fish and Wildlife (CDFW) Upper Sacramento River Basin (USRB) Fisheries Program, in cooperation with various agencies and organizations, conducts salmonid monitoring annually to estimate returning adult salmonid populations in the upper Sacramento River from Keswick Dam to Princeton Ferry (Table 6), and within major tributaries. During the winter-run spawning season, aerial redd surveys are conducted from Keswick Dam to Red Bluff Diversion Dam (RBDD), and the survey is extended to Princeton Ferry during fall-run spawning. Redd dewatering surveys are conducted from Keswick Dam to Tehama Road Bridge to identify salmonid redds susceptible to flow decreases, determine juvenile emergence timing, and to estimate flows at which dewatering may occur. Fish rescue surveys are conducted to remove fish from isolated pools following flow decreases resulting from 1) operational changes

at Keswick Dam, and 2) winter storm flows. Annual reports of monitoring findings, real-time data, and methods are available at the CalFish website (CDFW 2018a).

Table 6. River miles of important fisheries monitoring locations in the Upper Sacramento River, CA.

Location	River mile
Keswick Dam	302
Anderson Cottonwood Irrig. District (ACID)	298
Clear Creek (CCR) gauge	292
Airport Road	284
Balls Ferry (BSF) gauge	276
Red Bluff Diversion Dam(RBDD)	242
Tehama Road Bridge	229
Princeton Ferry	164

The US Fish and Wildlife Service Red Bluff Fish and Wildlife Office (RBFWO) monitors juvenile salmonids at their rotary screw traps at RBDD and calculates passage estimates and egg-to-fry (ETF) survival rates. Their annual reports and real time monitoring data are available at their website (USFWS 2018).

5.1.1 November 2017 through February 2018 Keswick Release Schedule (Fall Actions, RPA Action I.2.2)

Release reductions were coordinated to protect winter-run redds from dewatering, reduce fall-run redd dewatering, and protect storage conditions. Keswick releases were 8,000 cfs through October during the peak of fall-run Chinook salmon spawning. Release reductions to 6,000 cfs began on November 5, which were timed with Anderson-Cottonwood Irrigation District (ACID) dam flashboard removal, and the last date of calculated winter-run fry emergence. The flashboards were left in place after diversions ceased to protect winter-run redds located upstream of the ACID dam from dewatering following flow reductions. Flows were reduced to 5,000 cfs beginning on November 13. In early January 2018, flows were reduced to 4,000 cfs; and 3,250 cfs by February 19.

2017 Winter-Run Chinook Salmon Escapement

The 2017 winter-run Chinook salmon escapement estimate was 977, consisting of 85% hatchery origin, and 49.8% 2-year olds (Killam and Mache 2018) (Figure 7). The estimated redd count (based on the estimate of females spawning in-river) was 373. All redds were located upstream of Airport Road based on aerial redd survey results. Twenty-four shallow redds, which are those with tail-spill water depths <24 inches, were identified and monitored during the fall release reduction period, and none were dewatered due to flow reductions.

Brood year 2017 winter-run Chinook salmon ETF survival rate was estimated at 48.7% (range=31.3-66.2%). This estimate includes fish that emerged "late", according to length-at-date

(LAD) criteria and spawn timing, and were reassigned or corrected based on genetic evaluations to the winter-run Chinook salmon category from the LAD spring-run Chinook salmon category. This ETF estimate is the highest value recorded, but only slightly higher than the 2011 value of 48.6%, which was also a wet water year type. The average ETF survival based on data available from the years 1996 through 2017 (*n*=20) was 24.9%.

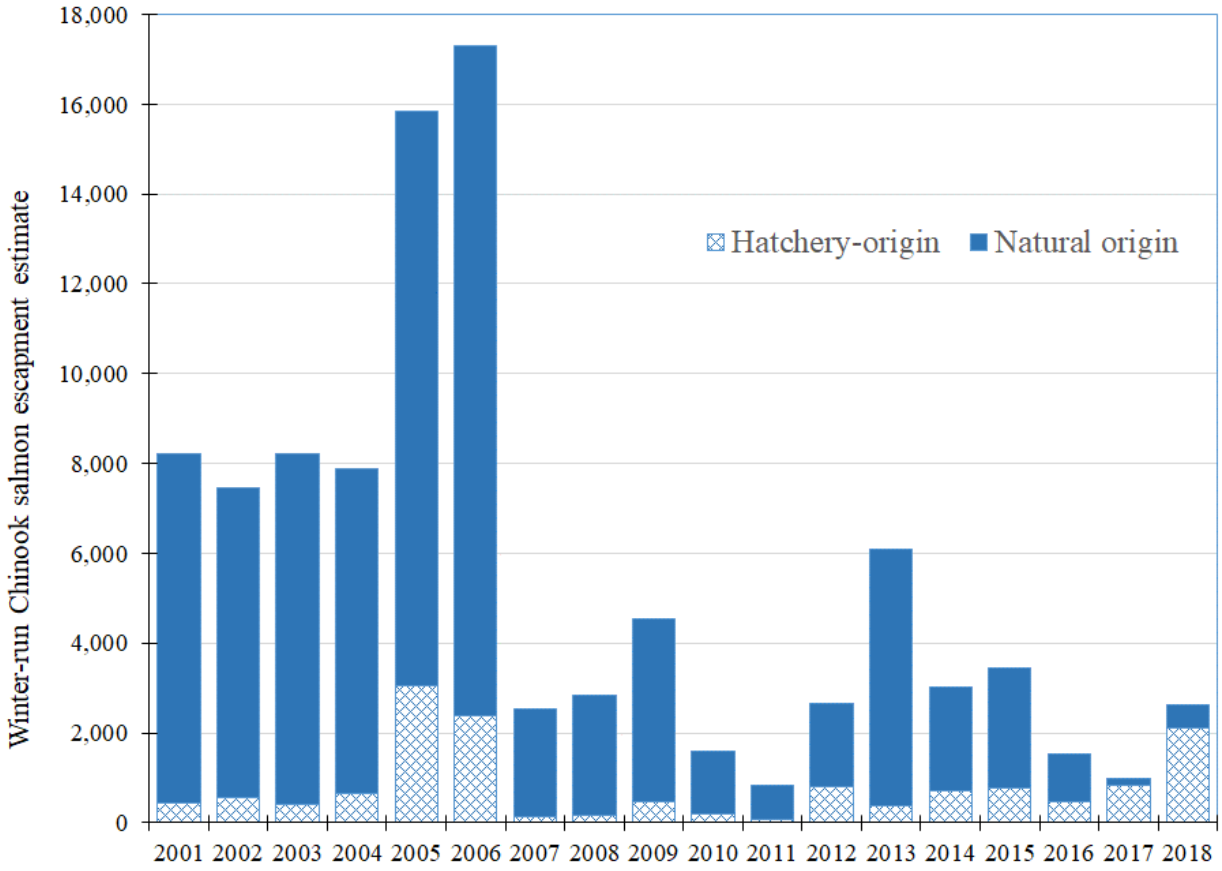

Figure 7. Annual Sacramento River winter-run Chinook salmon adult escapement estimates from 2001 to 2018. Stacked bars show the number of hatchery and natural origin fish.

Water Temperature Criteria

During the temperature management season, daily average water temperature (DAT) remained at or below 56°F at Reclamation's Balls Ferry Bridge (BSF) gaging station, and at or below the 53.0 °F target at the CCR gaging station for 99.4% and 91.8% of the period from May 15 through October 31, 2017, respectively (Columbia Basin Research, University of Washington, 2018).

2017 Sacramento River Spring-Run and Fall-Run Chinook Salmon

The 2017 in-river spawning escapement estimate for mainstem Sacramento River fall-run Chinook salmon was 1,752, with 23.6% hatchery origin, and 57.6% 2-year olds (Killam and Mache 2018). Approximately 2% of the estimate was downstream of RBDD. In addition,

approximately 3,121 adults returned to the tributaries upstream of RBDD. During the Keswick fall flow release reduction period, 15 shallow fall-run Chinook salmon redds were dewatered, which was 1.53% of the redd estimate. Estimating adult spring-run Chinook in the mainstem is difficult due to their spawn time overlap with fall-run. Based on redd counts and timing, the mainstem spring-run population was 4.

The brood year 2017 fall-run Chinook salmon ETF survival rate was estimated at 17.6% (range= 9.7 - 25.4%) as of September 23, 2018. The brood year will not be complete until approximately November 30, 2018, but only minor increases in juvenile production are expected, resulting in minor increases in ETF estimates. This ETF estimate of 17.6% is slightly above the average estimated at 16.9% from the years 2003 through 2017 (*n=15*), and much better than the 2.3% ETF survival estimated for this cohort in brood year 2014. Natural production was very low, and 2017 adult returns were dominated by 2-year olds, which influenced fecundity estimates. Water temperatures remained below 56°F at BSF through the fall-run Chinook salmon egg incubation and hatching period.

Brood Year 2017 Fish Rescue Surveys

Fish rescue surveys occurred from Keswick Dam to Tehama Bridge (73 river miles) from June 2017 through May 2018 after storm-related high flow events throughout the rain season, and after scheduled Keswick flow decreases (Figure 8). A total of 9,415 juvenile Chinook salmon (1,092 winter-run, 113 spring-run, 7,016 fall-run, 337 late fall-run), 857 juvenile and 28 adult steelhead/rainbow trout, and 6,969 individual fish of other species were rescued and returned to the Sacramento River. Winter-run Chinook salmon juveniles were the predominant fish isolated following the November Keswick flow decreases. Juvenile salmonid mortality due to isolation is difficult to assess because predation, and the dewatering and warming of isolated pools, often occur before crews can locate stranded fish. While crews survey after every flow reduction, it can take several days to cover the entire extent of the river.

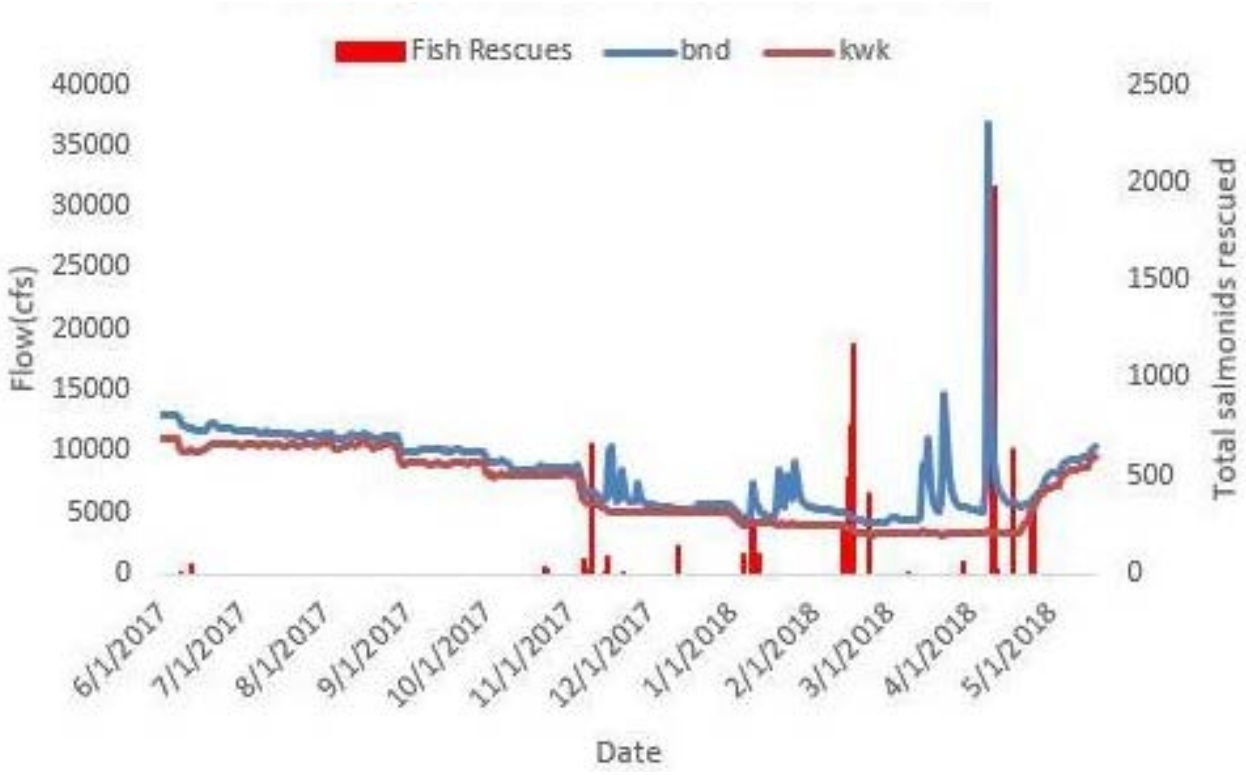

Figure 8. Occurrence of fish rescue surveys, and number of individual salmonids rescued following release reductions at Keswick Dam (KWK), and natural flow decreases following rain events measured at the Bend (BND) USGS/Reclamation gaging station on the Sacramento River, California. Fish rescue surveys were conducted between Keswick Dam and Tehama Bridge (73 miles). Flow is in cubic feet per second (cfs).

2018 Preliminary Estimates for Winter-Run Chinook Salmon Escapement

As of October 2, 2018, the preliminary winter-run Chinook salmon total escapement estimate was 2,631, with an in-river escapement of 2,451 (70% adult, 44% female, and 80% hatchery origin; preliminary CDFW estimate). Similar to 2017, based on fresh female carcass recovery data, winter-run Chinook salmon spawn timing was approximately two weeks later than the average from 2000 to 2016 (CDFW 2018).

The first detected fry emigration at the RBDD rotary screw traps was observed on July 18, and as of October 21, the preliminary estimate was approximately 707,433 (USFWS 2018). Similar to 2017, fish are falling in to the spring-run LAD category that are likely winter-run, and RBFWO is taking daily genetic samples of both LAD winter-run and spring-run Chinook for potential future corrections. Winter-run Chinook passage increased substantially on October 5-7, 2018 after a very small amount of rainfall (no appreciable flow increase ~2%), which resulted in a big spike in turbidity from the Clear Creek watershed. This first rainfall caused a high runoff event in the Clear Creek watershed due to burned areas from the Carr Fire. Thick ash and sediment flowed into Clear Creek, resulting in observed adult fall-run mortality during CDFW carcass surveys, and deposits of sediment into the spawning grounds.

Livingston Stone National Fish Hatchery achieved broodstock goals of 60 females and 120 males. On April 25, 2018, an estimated 8 adult winter-run (4 hatchery origin females, 1 natural female, 3 hatchery males) were found dead at the Kewick Dam Fish Trap. It is likely that the live winter-run accessed the area under the trap during collection of broodstock on February 20, 2018 when the trap was inadvertently not closed properly by the operator, then subsequently died when the trap was dewatered for routine maintenance between April 13-20, 2018. An additional 9 winter-run (1 hatchery female, 4 hatchery males, and 4 natural jack) were killed at the hatchery after a possible bear/predator knocked the quarantine tank cover off during the night.

Winter-Run Chinook Salmon Redd Dewatering

When considering flow reductions this year, a high priority was afforded to protect 2018 winter-run Chinook salmon redds due to (1) the poor survival of naturally-produced winter-run Chinook salmon in brood year 2015 when hatchery production at Livingston Stone National Fish Hatchery was doubled (~400,000 juveniles released), and natural production suffered an estimated 95% temperature-dependent egg-to-fry mortality to RBDD, and (2) subsequently a high proportion (80%) of hatchery returns in 2018.

Reclamation's outlook forecast projected a monthly average Keswick release of 6,000 cfs in October, however, it did not include consideration of flows necessary to minimize winter-run Chinook salmon redd dewatering. Thirty-one shallow redds were identified prior to the first Keswick release reductions, and assessed for emergence timing and dewatering flows. One shallow winter-run Chinook salmon redd was dewatered following the first flow decrease to 8,000 cfs. Flows were maintained at 7,250 through October 22 to protect all but two shallow winter run Chinook salmon redds. The last shallow winter-run redd was projected to emerge on November 11, with a dewatering flow at 5,500 cfs (as of October 23, 2018 monitoring).

Considerations for Fall-Run Redds and Juvenile Winter-Run Chinook Salmon

General fall-run Chinook salmon management recommendations suggest that stabilizing flows between 5,000 and 6,000 cfs during peak spawn timing reduces the occurrence of dewatering as flows are reduced. In addition, monitoring data have shown that fall-run Chinook salmon redds are more susceptible to flow reductions that occur below 4,500 cfs, and maintaining releases above 4,000 cfs protects more fall-run redds, and retains juvenile winter-run Chinook salmon rearing habitat.

Fall-run redd dewatering estimates for the upper Sacramento River were calculated under various flow reductions scenarios, using redd dewatering habitat suitability curves (USFWS 2006), and average fall-run spawn timing from carcass surveys from 2003-17. Under four flow reduction scenarios to drop flows down from 6,000 cfs in October through January, calculated redd dewatering estimates for total redds were 4.5% for flows down to 4,500 cfs, 7.4% for flows down to 4,000 cfs, and 13.4% and 14% for two scenarios for flows down to 3,250 cfs with two slightly different reduction timings. The CDFW has been assessing fall-run redd dewatering following Keswick release reductions in the upper Sacramento River since 2009. Annually, the estimated percent of total fall-run Chinook salmon redds dewatered has ranged up to 3.12%. Based on calculations from escapement estimate data in Grand Tab (Azat 2018), from 2009-17,

an average of 19% (range 8-40%) of the overall Sacramento River fall-run Chinook salmon population (excluding the American River) spawns in the upper Sacramento River.

Because EOS storage in Shasta reservoir was just above 2.4 MAF, there was concern for future storage risks, and a desire for release reductions to occur as soon as possible. The temperature compliance target at BSF was achieved nearly every day. The temperature target of 53.5°F was consistently not being met after October 4 at the pilot compliance point at CCR, and adjustments were being made to the temperature control device and gates to cool the river. Recommendations for operations from the fish agencies were to stabilize flows for peak fall-run spawning to decrease dewatering during subsequent decreases and maintain base flows at 4,000 cfs or greater to maintain winter-run Chinook salmon juvenile rearing habitat and decrease stranding.

2018 Preliminary Fall-Run Chinook Salmon Redd Dewatering and Fish Rescues

As of October 19, 2018, CDFW has measured 135 shallow fall-run Chinook salmon redds, and spawning is distributed from Keswick Dam to the downstream most aerial redd survey location at RBDD. The ACID flashboard dam removal began on October 24. Initial observations in October from CDFW juvenile salmonid habitat use snorkel surveys have revealed counts of 3,000-4,000 juvenile late-fall run and winter-run Chinook salmon rearing in the upper Sacramento River at the stranding monitoring sites. An interactive story map of the stranding sites can be found at CDFW's Calfish website (CDFW 2018b). As Keswick releases in the fall are reduced for storage and stabilized for fall-run Chinook salmon spawning, CDFW will continue to monitor redd dewatering, and perform juvenile fish rescues and assess stranding habitat. As of November 6, 2018, CDFW field crews removed 5,874 juvenile winter-run from stranding pools, isolated from the Sacramento River during flow reductions from 7,250 to 4,500 cfs.

5.2 Summary

In 2017, Chinook salmon returns to the Upper Sacramento River Basin were well below historic averages for all runs, and near record lows for winter-run and fall-run due to extreme drought conditions in 2014 and 2015. Preliminary findings from 2018 fisheries surveys have shown improved adult returns for both winter-run and fall-run compared to 2017, and good winter-run ETF survival based on initial juvenile emigration data at RBDD. The 2018 Carr Fire impacted water operations, water temperatures, and fisheries monitoring on the Sacramento River and Clear Creek. Sediment input from the burned areas following storm events will continue to degrade water quality, impacting fish habitat and survival, and challenge fisheries monitoring efforts in the upcoming year.

Winter-Run Chinook Salmon

In 2014 and 2015, water temperatures rose to sub-lethal and lethal levels during egg incubation, resulting in low ETF survival and high temperature-dependent mortality for winter-run Chinook salmon (Table 7). Poor in-river conditions led to low adult returns dominated by hatchery origin fish in 2017. The estimated adult winter-run returns in 2018 were improved from 2017, though similarly were dominated by hatchery-origin fish (Figure 7). Increased adult returns in 2018 were

likely due to 1) increased winter-run hatchery production in 2015, and 2) good ETF survival and low temperature-dependent mortality of brood year 2016 natural-origin winter-run.

In 2018, Reclamation implemented the second year of pilot operations to see if the alternative temperature and location is operationally feasible. In 2017, as a result of favorable hydrology and a relatively large cold water pool in Shasta Reservoir, Reclamation successfully implemented 53.0 °F DAT at CCR, and 56.0 °F at BSF, which likely contributed to a higher than average winter-run ETF survival (Table 7 and 8). Egg to fry survival for winter-run was 24 % in 2016 and 48.7% in 2017, with little to no temperature dependent mortality estimated (Table 7). In 2018, Reclamation successfully implemented 56.0 °F DAT at BSF, and for 68.4% of the period at 53.0 °F DAT at CCR (Table 8). As of October 21, 2018, preliminary juvenile winter-run outmigration estimates are the highest observed since 2013. While ETF survival rates have not been calculated for 2018, water temperature management, and fall flow reduction planning to minimize redd dewatering likely have contributed successful natural juvenile production.

Table 7. Estimated percentage egg to fry survival (ETF) and temperature-dependent mortality for winter-run Chinook salmon for brood years 2014-17.

Brood year	Winter-run Chinook salmon ETF survival	Martin Model temperature-dependent mortality
2014	5.9%	77%
2015	4.5%	85%
2016	24%	2%
2017	48.7%	0%

Table 8. Sacramento River temperature target criteria during the temperature management season (May 15 to October 31) from 2014-18. 7 day average of the daily maximum temperatures (7DADM) Daily average temperature (DAT).

Year	Temperature Management Plan Criteria					Pilot Criteria					Ideal
	Details	Percent of Period at or below Criteria	Deviation (°F)			Details	Percent of Period at or below Criteria	Deviation (°F)			Percent of Period at or below 56°F Balls Ferry
			Min	Max	Mean			Min	Max	Mean	
2014	56.0 DAT @ CCR	45.9%	-1.8	6.3	1.2	n/a	n/a	n/a	n/a	n/a	1.8%
2015	56.0 DAT @ CCR (5/15-6/4) 58.0 DAT	92.9%	-3.0	0.5	-0.9	n/a	n/a	n/a	n/a	n/a	0.6%

Year	Temperature Management Plan Criteria					Pilot Criteria					Ideal
	Details	Percent of Period at or below Criteria	Deviation (°F)			Details	Percent of Period at or below Criteria	Deviation (°F)			Percent of Period at or below 56°F Balls Ferry
			Min	Max	Mean			Min	Max	Mean	
	@ CCR (6/5-10/31)										
2016	58.0 DAT @ CCR (5/15-6/16) 56.0 DAT @ BSF (6/17-10/31)	100.0%	-6.3	0.0	-2.2	55.0 7DADM @ CCR	76.5%	-1.7	2.5	-0.2	89.4%
2017	56.0 DAT @ BSF	99.4%	-3.8	0.2	-1.8	53.0 DAT @ CCR	93.5%	-1.5	0.5	-0.5	99.4%
2018	56.0 DAT @ BSF	99.4%	-3.9	0.1	-1.3	53.5 DAT @ CCR	69.4%	-2.8	1.8	-0.3	99.4%

In 2017 and 2018, winter-run Chinook salmon carcass survey data suggested that peak spawning occurred approximately two weeks later than average spawn timing from 2001-2016 (CDFW 2018a). In 2016, hatchery-origin winter-run were observed to spawn approximately 12 days later than natural-origin winter-run (USFWS 2017). The delay in winter-run spawn timing in 2017 and 2018 may be in part explained by the high proportion of hatchery-origin fish. It has also been hypothesized that later spawning may be due to warmer river temperatures in April and May that delay the onset of spawning. This phenomenon should be evaluated more closely, because later incubation periods could lead to more challenges for maintaining flows and water temperatures longer in the fall, and balancing needs for cold water storage and deliveries

Fall-Run Chinook Salmon

Water temperatures were above 56°F in the Sacramento River for most of the fall-run spawning period in 2014, which likely resulted in very low ETF survival (2.3%) and low returns in 2017. In addition, Coleman National Fish Hatchery (CNFH) released all of the brood year 2014 fall-run Chinook salmon offsite in the spring of 2015 (approximately 11 million smolts at Rio Vista, and 1 million smolts into San Pablo Bay), which likely resulted in high stray rates and contributed to low returns of 3-year old adults to the upper Sacramento River and Battle Creek in 2017. Preliminary estimates of fall-run returns are better in 2018, and likely due to 1) improved ETF survival rates for brood years 2015 and 2016 compared to 2014, and 2) the absence of CNFH releases into the Bay and Delta in those brood years.

Recommendations

- When planning for fall temperature and flow management, in addition to taking measures to prevent winter-run redd dewatering and protect incubating eggs and pre-emergent fry, include considerations for impacts to the winter-run juvenile life stage. Monitoring has shown flow reductions cause juvenile stranding, and flow regimes decrease and alter available rearing habitat. The impacts of flow reduction releases on fall-run redd dewatering should continue to be evaluated and considered. The SRTTG should work collaboratively to find a more holistic approach to fall objectives and consideration of those when developing the spring forecasts.
- Continue studies and modeling to understand early life history of winter-run and habitat needs. Impacts of stranding due to flow reductions should continue to be monitored and future evaluations should be considered to determine population level effects further evaluated.
- Later winter-run Chinook salmon incubation periods could lead to challenges for maintaining flows and water temperatures longer in the fall, and balancing needs for cold water storage and reducing Keswick Dam releases to minimize fall-run redd dewatering. Evaluations to determine potential causes of delayed spawning, and alternative management strategies should be explored.
- Continue to evaluate the biological response of implementing the pilot temperatures, and distinguish temperature-related mortality from other sources of mortality.
- Include continued discussion and inclusion of steelhead, sturgeon and spring-run efforts in consideration for flow management actions, and late-fall and fall-run.

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