United States Department of the Interior

BUREAU OF RECLAMATION
Central Valley Operations Office
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Sacramento, California 95821

IN REPLY
REFER TO:

CVO-100
WTR-2.00

JUN 27 2016

Ms. Maria Rea
Assistant Regional Administrator
California Central Valley Area Office
National Marine Fisheries Service
650 Capitol Mall, Suite 5-100
Sacramento, CA 95814

Subject: Transmittal of Final Sacramento River Temperature Management Plan per Reasonable and Prudent Alternative (RPA) I.2.4 of the National Marine Fisheries Service 2009 Coordinated Long-term Operation of the Central Valley Project (CVP) and State Water Project (SWP) Biological Opinion (NMFS 2009 BiOp)

Dear Ms. Rea:

Please find attached the Sacramento River Temperature Management Plan (SRTMP) for Water Year 2016. The Bureau of Reclamation (Reclamation) is requesting concurrence from the National Marine Fisheries Service (NMFS) on the SRTMP as required by NMFS 2009 BiOp RPA Action I.2.4.

NMFS 2009 BiOp RPA Action I.2.3 requires Reclamation to submit a series of forecasts of CVP operations and corresponding Sacramento River temperature modeling runs to NMFS for review and concurrence. In accordance with this requirement, Reclamation has provided several sets of forecasts and temperature model runs and worked closely with NMFS during early spring 2016 to develop a management plan to protect the cold water pool in Shasta Reservoir. As you know, appropriate management of the Shasta Reservoir cold water pool is important so that suitable spawning and egg/alevin incubation can be maintained in the Sacramento River during the summer and fall season for federally-listed endangered Sacramento River winter-run Chinook salmon and threatened Central Valley spring-run Chinook salmon. This is especially critical this year given that the last two cohorts of winter-run Chinook salmon have been impacted by poor freshwater survival during the egg and juvenile life stages. On March 31, 2016, NMFS concurred with Reclamation's proposed Keswick release schedule and initial water supply allocation, and committed to work with Reclamation to adjust the Keswick release schedules to minimize the potential for winter-run and fall-run Chinook salmon redd dewatering.

The SRTMP represents a focused effort by Reclamation to develop a balanced approach to management of the limited cold water pool in Shasta Reservoir during the summer and fall of 2016. Reclamation is recommending an approach that focuses on maintaining a reasonable temperature target that will maximize protection of the species, while ensuring that the limited cold water will be able to be fully utilized through the season. This approach will help

Reclamation meet other obligations and maintain commitments for operation of the CVP and SWP. The SRTMP has also been developed to limit impacts to other beneficial uses, such as Folsom Reservoir levels, American River temperature management for species protection, Delta water quality, and water supplies for contractors throughout the CVP and SWP.

The SRTMP consists of projected flow schedules from June through October consistent with your March 31, 2016 concurrence letter, with monthly average flow rates ranging from 6,500 cfs to 10,500 cfs (see attached for specific details). The proposed temperature compliance point is at Balls Ferry, using a 56 degree F daily average temperature (DAT). To achieve compliance at this location, an average release temperature of about 52.5 degrees F will be targeted from Keswick Dam. Under this proposal, the end of September storage in Shasta Reservoir is 2.6 million acre-feet (MAF), and use of the Shasta Reservoir Temperature Control Devise (TCD) full side gates would begin on October 9, 2016.

The success of the 2016 SRTMP is predicated on how closely actual operations align with the currently predicted hydrologic and biologic modeling results. Therefore, the 2016 SRTMP includes multiple commitments for frequent updates to detailed temperature profiles, modeling projections, TCD gate operations, meteorological data, etc. via weekly and monthly conference calls, meetings, and data exchanges. Reclamation stands ready to adjust operations to improve temperature conditions if needed as the season progresses.

As you know, RPA Action I.2.4. requires that Reclamation achieve DATs "[n]ot in excess of 56°F at compliance locations between Balls Ferry and Bend Bridge" from June through October of each year. It also requires Reclamation to manage Shasta Reservoir in a way that provides "cold water releases from Shasta Reservoir to provide suitable habitat temperatures . . . in the Sacramento River between Keswick Dam and Bend Bridge, while retaining sufficient carryover storage to manage for next year's cohorts." Given the terms of RPA Action I.2.4 and the commitments above, Reclamation believes that the attached SRTMP is fully compliant with the NMFS 2009 BiOp and the guidance provided in your March 31, 2016, concurrence letter. We therefore request your concurrence on the SRTMP as required under RPA Action I.2.4.

We look forward to working with you and your staff as we find innovative ways to operate through another challenging water year and we appreciate your willingness to work with us on this time sensitive matter.

Sincerely,

Ronald Milligan

Ronald Milligan
Operations Manager

Enclosures - 1

cc: See next page.

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2016 Sacramento River Temperature Management Plan

Bureau of Reclamation
June 7, 2016 (updated June 24, 2016)

This document represents the Bureau of Reclamation's (Reclamation) Sacramento River Temperature Management Plan for Water Year 2016 (2016 Plan) pursuant to the Reasonable and Prudent Alternative (RPA) Action I.2.4 of the 2009 National Marine Fisheries Service (NMFS) Biological Opinion (2009 BiOp) for the Coordinated Long-Term Operation of the Central Valley Project (CVP) and State Water Project (SWP), as well as State Water Resources Control Board (SWRCB) Order 90-5. The 2016 Plan was formulated with considerable technical input from Federal and State biologists and from stakeholders. The Plan represents Reclamation's best effort to balance numerous system-wide water demands and the seasonal river temperatures to be protective of winter-run Chinook salmon in their early life stages. The Plan helps maintain water supplies and provides a foundation to improve summer outflow to benefit delta smelt.

Plan Description

Base Operations

After several severe drought years, storage conditions at Shasta Lake are much better than in water year (WY) 2014 and WY 2015 in terms of both total storage and volume of cold water. The 2016 Plan consists of Keswick releases through the summer ranging from average monthly flows of 9,000 cfs in June and 10,500 cfs in July to 5,500 cfs by November. These flows are consistent with the operations outlined by Reclamation in March of this year. The temperature compliance point and metric would be not to exceed 56.0° Fahrenheit (F) daily average temperature (DAT) at Balls Ferry, in compliance with RPA Action I.2.4 of the 2009 BiOp. To achieve compliance at this location, an average release temperature of 52.5°F is planned from Keswick Dam. Anticipated temperature performance of the 2016 Plan is reflected in Table 1, as well as the projected temperatures at various locations in the Sacramento River (Attachment A). Average flows by month are shown in Table 1 below, and would be subject to adjustment for real-time conditions based on performance of the plan. The timing for reductions in flows in September and October would be scheduled in coordination with the fishery agencies to reduce risk of redd dewatering. Fall flow reductions would occur once all winter-run Chinook salmon fry are estimated to have emerged from their redds, but as early as possible to reduce stranding of fall-run Chinook redds in the upper Sacramento reach. Under the 2016 Plan, full side gate operation of the Shasta Dam Temperature Control Device (TCD) is not projected to occur until October 9, 2016.

Table 1 - Average Monthly Flow/Temperature

	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 order to mitigate risk for maintenance of the temperature at this location, the modeling is based on a 90% exceedance hydrology forecast, and a 10% L3MTO (local 3 month temperature outlook) meteorological data set. Reclamation will monitor temperature performance, TCD operations, and isothermobath characteristics on a weekly basis through increased monitoring of the Shasta Lake isothermobath profile and temperature modeling to provide an opportunity for in-season assessment of cold water volume and monthly release objectives.

Real-time Management

The average flows shown in Table 1 are guidelines for base operations; actual daily releases will be based on real-time monitoring to ensure temperature compliance is accomplished, winter-run redd dewatering is minimized, and other downstream diversion, flow, and Delta requirements are met. Decision-making for significant changes in real-time operations will be coordinated with a group of Federal and State agencies including Reclamation, NMFS, the U.S. Fish and Wildlife Service, California Department of Water Resources, California Department of Fish and Wildlife, and State Water Resources Control Board. This group, recently referred to as the Shasta Water Interagency Management (SWIM) Team, will utilize information from its member agencies, as well as technical information from the Sacramento River Temperature Task Group (SRTTG) and other relevant stakeholders, to inform decisions and changes in operations.

Reclamation will monitor temperature performance, TCD operations, and isothermobath characteristics on a weekly basis. The specific tasks include:

- Increased frequency of temperature profiles at Shasta Lake (weekly on Mondays, on Tuesdays if the Monday is a holiday);
- Temperature Model update every week based on the new profile (to be provided to the SWIM Team 2 days after the temperature profiles);

- Comparison of forecasted inflow volume and air temperatures with observed;

- Weekly SWIM team update calls.
  - Reclamation will ensure that materials are sent out to the SWIM Team members prior to the weekly meetings. These materials will include the results of all real-time monitoring [including reporting of the 7-day average of the daily maximums (7DADM) temperatures at the SAC and CCR CDEC gaging stations] and modeling efforts. Reclamation also commits to sharing all data files within 24 hours of requests;

  - The SWIM Team will strive to reach consensus on various temperature management strategies including anticipated TCD gate operations and intermediate river temperatures upstream of Balls Ferry (e.g. viability of a supplemental or exception criteria for a 7DADM objective through the spawning areas). The SWIM team shall consider the location of redds, the weather forecasts, the volume of available cold water, inflows, the integrated operations with the Trinity River Division, and other real-time considerations. The SWIM team will also provide advice on minimizing potential effects of redd de-watering and stranding, based on any flow changes resulting from implementation of the Plan. If SWIM Team consensus cannot be reached, then Reclamation will formulate an action consistent with the Plan, which can be implemented pending Reclamation consultation with NMFS. At all times, 56.0°F DAT at Balls Ferry will be maintained as the temperature compliance location.

- Continue the Monthly in-person SRTTG meetings. These meetings will include a phone-in option for members who cannot participate in person.

Based on the monitoring information and temperature model results, Reclamation will closely track the following critical monitoring metrics, and Reclamation will promptly make operational adjustments as outlined below to carry out the objectives in the plan.

- Verify that 56.0°F DAT at Balls Ferry can continue to be met through the temperature management season. If not, Reclamation will adjust the flow schedule so that the Balls Ferry temperature compliance point can be met;

- Verify Full Side Gate operation is not forecasted prior to October 9. The June 7, 2016, temperature model run (basis for the plan) indicates that Full Side Gate operations will begin starting 9 October, but if the Full Side Gate operation shifts and is predicted prior to October 9, Reclamation will adjust the flow schedule so that Full Side Gate operation is not needed before October 9;

- Verify that the volume of water < 49°F is not less than 95% of the forecasted volume as predicted by the June 7, 2016, temperature model run (basis for the plan). For this year, Reclamation will use the volume of water < 49°F as a surrogate to track the overall status of the cold pool volume. If this volume is less than 95% of the forecasted amount, Reclamation will reduce Keswick releases by 1,000 cfs for one week in an effort to allow the volume of water < 49° F to make progress back to at least 100% of the 7 June projection. If, after one week the volume of water < 49°F is not equal to or greater than 100% of the June 7 projection, Reclamation will reduce the Keswick release by another 1,000 cfs (but not to a release less than 8,000 cfs), and Reclamation will immediately call a special Directors-level meeting to assess whether the variation in overall cold water pool is significant enough to require a reformulation of the Plan.

- If overall conditions are better than forecasted (*e.g.*, greater than anticipated cold water volume), then the plan may be revised through the SWIM team process with the goal to create a modified temperature compliance metric and location of 55.0°F 7DADM through the spawning area.

It is understood that any needed reductions in the planned Keswick release schedule will have water supply effects and that some water deliveries could be delayed or reduced as a result of these changes.

Additional Actions

The estimated 10,500 cfs Keswick release rate for July represents a monthly average release, but Reclamation has agreed to cap daily average releases through the temperature management season at this flow rate in order to reduce the potential for winter-run redd dewatering later in the season. In reaching the 10,500 cfs release in July, flows would be ramped up in two 750 cfs increments, each based on, and following the review of, the weekly Shasta Lake temperature profiles and temperature model runs to ensure that all metrics (*e.g.*, full side gate operation, 56.0°F DAT at Balls Ferry, cold water pool volume at <49°F) continue to be attainable.

To benefit Delta fisheries, the 10,500 cfs July release includes, at a minimum, water diverted through the Glenn Colusa Irrigation District system to support smelt actions in the Yolo Bypass, as well as an increased Delta Outflow Index for the month of July.

Also, Reclamation will closely monitor temperature conditions (including 7DADM) in the Sacramento River at the SAC gage location (approximately 0.75 river miles upstream of the

Highway 44 Bridge and 6 miles downstream of Keswick Dam) and the CCR gage location (at Bonnyview Bridge, approximately 14 miles downstream of Keswick Dam).

Although the temperature compliance point would remain at Balls Ferry (approximately 26 miles downstream of Keswick Dam), Reclamation is willing to make short-term operational changes to adjust water temperatures at the most downstream redd, which is currently approximately 1.2 miles downstream of the SAC gage location (*i.e*., the recent Painters Riffle restoration project funded by CVPIA Section 3406 b13) to try and maintain water temperatures below 55°F 7DADM, provided such operational adjustments do not impede Reclamation's ability to meet the temperature compliance metric and location of 56.0°F DAT at Balls Ferry.

Reclamation will operate in a manner to avoid any exceedance of 56.0°F DAT at Balls Ferry and Reclamation will promptly implement steps to reduce the temperature to the compliance objective to deal with any unforeseen transitions to periods of very high air temperatures and to assure that any exceedance is minimized. In addition, during any exceedance, Reclamation will take immediate action to lower the daily maximum water temperatures to at or below 55.0°F through the area of the most downstream redd and will maintain the 55.0°F daily maximum water temperature through the period where water temperatures at Balls Ferry may exceed 56.0°F

Throughout the temperature management season, Reclamation will be watchful for opportunities to optimize the release of cold water from Shasta Lake. The use of Power Bypass is available as a tool to access cold water should the need arise.

Biological Analysis of Plan

Status of winter-run Chinook Salmon

Winter-run Chinook Salmon are most sensitive to temperature during their early life stages (eggs, alevin, and fry). A conceptual model provides a holistic framework to consider effects of summer operations on winter-run Chinook salmon eggs and early juvenile stages (Figures 1-2, Johnson et al. 2016). Operational and temperature modeling provide information to evaluated potential temperature and flow related biological response of the 2016 Plan. In other cases, habitat attributed have been monitored as part of the enhanced monitoring program over the past two years to evaluate effects of drought operations, and the observations related to disease/pathogens and dissolve oxygen provide information regarding predicted effects of these habitat attributes in the 2016 Plan.

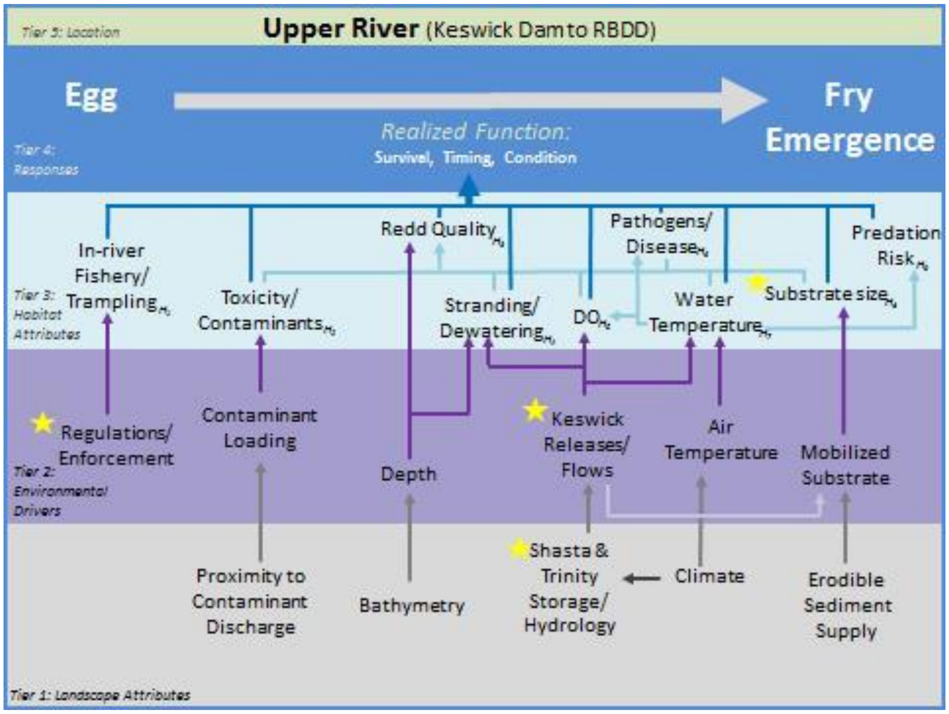

Figure 1. Conceptual model of Winter-run Chinook Salmon egg and alevin in the upper Sacramento River.

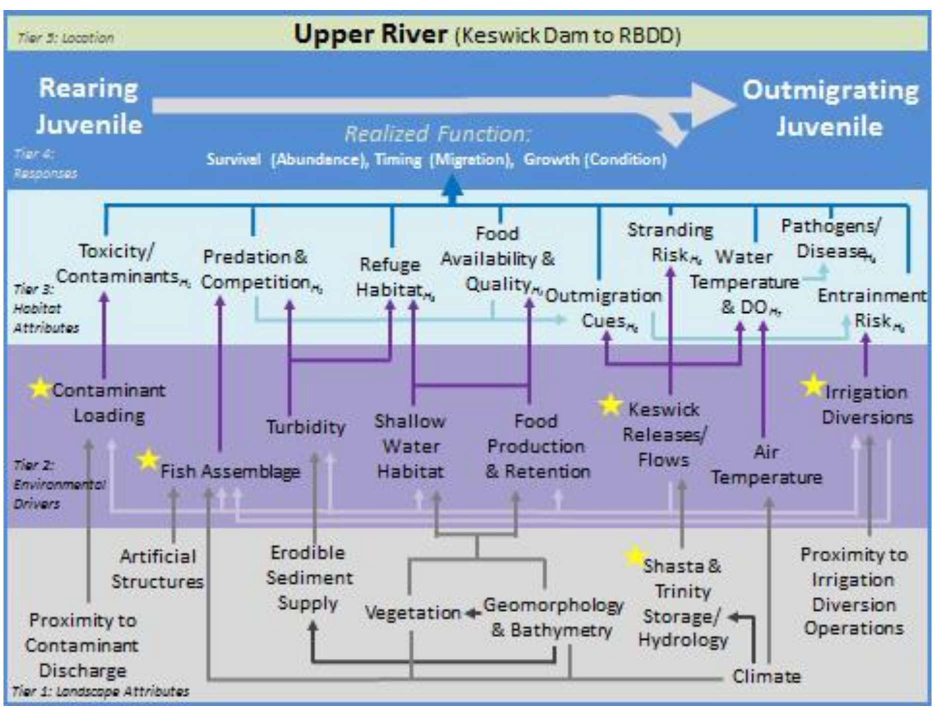

Figure 2. Conceptual model of Winter-run Chinook Salmon fry in the upper Sacramento River.

The last three cohorts of winter-run Chinook salmon have been impacted by poor freshwater survival during the egg and juvenile life stages due to prolonged drought and very low Shasta storage conditions. In WY 2015, a temperature management strategy to maintain suboptimal, yet stable temperature throughout the temperature control period was implemented and temperature-dependent mortality appeared to be extremely high (85%; NMFS 2016). In WY 2014, a temperature management strategy to maintain optimal temperature as long as possible was implemented. Control of Shasta reservoir release temperatures was lost in September, which was a few weeks earlier than predicted by the model and temperature-dependent mortality appeared to also be very high (77%; NMFS 2016). Some lessons from these two recent years is that temperature management (especially in low storage years) should focus on a strategy that maintains suitable temperature throughout the period (potentially May 15 through October 31) when eggs are incubating, delays use of the full side gate configuration until later in the fall operations, and provides some adaptability if the actual operations and cold water pool characteristics do not reflect forecasted operations and reservoir characteristics.

The 2016 spawning winter-run Chinook salmon are the first returning cohort impacted by drought conditions during WY 2014 (Reclamation 2015), and the 2016 carcass survey is the second lowest on record as of June 20. A majority of carcasses have been observed above Highway 44 (63.8%), although more carcasses have been observed between Clear Creek and Balls Ferry than on average (13.8% vs. 3.2% (2003-2015)). Aerial redd surveys show a similar distribution and have observed a majority of redds to be upstream of Highway 44 (75.0%), although a greater proportion of redds between this location and Clear Creek have been seen so far this year than on average (25.0% vs. 11.3% (2003-2015)). Spawning appears to be focused upstream of Highway 44 with a moderate proportion downstream to Clear Creek. In this way, the winter-run Chinook salmon spawning distribution appears similar to brood year (BY) 2011 spawning distribution.

Chinook salmon egg incubation and emergence is typically modeled between 73 to 87 days, and it is estimated fry could emerge as soon as July 29 from the first observed redds (May 17). This is a week later than the average first capture date of winter-run Chinook salmon in the Red Bluff Diversion Dam (RBDD) rotary screw trap juvenile salmonid monitoring (Poytress et al. 2014), but the same week as the first winter-run Chinook observed in 2011 RBDD monitoring. Spawning will likely continue into early August, with close to 15% of carcasses typically recovered during August. Eggs spawned in August are estimated to emerge in October. Maintaining cold water temperatures and stable release rates in spawning areas through mid-October is needed for avoiding increased temperature-dependent or dewatering egg mortality in the BY16 cohort.

Biological Modeling of Temperature Management Plan

In spring 2016, Sacramento River temperature management planning efforts have focused on determining the appropriate strategy for maintaining maximum egg incubation temperatures less than 56°F. This strategy relied on extensive operational and biological modeling to forecast critical cold water operations necessary to avoid further endangerment of imperiled winter-run Chinook salmon. A number of biological metrics (Table 2) are useful for considering how the 2016 temperature management plan are predicted to influence habitat attributes and biological responses of winter-run Chinook Salmon.

Table 2. Biological and Operational Metrics of Temperature Management Plan Scenario.

Metric	Temperature Management Plan Scenario
Estimated Date of Full Side Gate Configuration	October 9
Zeug et al. (2012) Egg to emergence temperature dependent mortality above Clear Creek	6.0%
Zeug et al. (2012) Egg to emergence Temperature dependent mortality above CCR with 0.5-1.0°F increase	7.4-9.2%
Martin et al (2016) Temperature dependent mortality estimates (95% Confidence Interval)	4.6% (0.08 – 43.01)
Martin et al (2016) Temperature dependent mortality estimates w/ 0.5–1.0°F sensitivity analysis (95% CI)	8.0 – 15.7% (0.08 – 61.00)
Winter-run Chinook Redd dewatering	September and October flow reduction to be managed in-season to avoid dewatering.
Fall-run Chinook Redd dewatering (FWS 2006)	Percent of total redd dewatering based on 9,000 cfs spawning flows is 1.1%.

In 2015, the date of full side gate use was an important criterion for temperature management decision making since it represents the date when the coldest water is being accessed and temperatures can no longer be modified through TCD operation. The modeled temperature management plan predicts full side gate use in early October (October 9). A set of modeled sensitivity scenarios (see Attachment B) were reviewed by the SWIM Team during plan development, and these runs show earlier full side gate use when a cooler release temperature value or a higher release rate was modeled. The sensitivity analysis also showed that lower release rates led to earlier use of the lower row of gates (Pressure Relief Gates) creating an earlier draw on the coldest water stored in Shasta Lake. Based on these sensitivity runs and various estimates of temperature related mortality, the proposed plan was formulated to best balance management of the cold water resources, operation of the TCD, and meet system-wide water supply needs. The risk of increased temperature-dependent mortality late in the egg incubation period is low with the proposed plan based on projected full side gate operation, utilization of the overall cold water pool, and proposed temperature compliance point.

Modeled daily temperatures from the proposed temperature management plan indicate a temperature compliance point and limit of 56.0°F DAT at Balls Ferry can be met through the control period. The single simulated temperature exceedance observed in late June is due to extremely high air temperatures embedded in the input data set. As the season progresses, it is estimated that temperatures at Balls Ferry should be consistently lower than 56.0°F by August. These modeled seasonal temperatures result in estimates of low temperature dependent egg mortality (6.0% and 4.6%) with the Zeug et al. (2012) model and Martin et al. (2016) model, respectively.

Recent discussions have also focused on the imprecision of the model to consistently predict late summer TCD operations and temperatures when temperature plans are developed early in the spring. In particular, the challenge of predicting spring lake stratification and the late season temperature management in low storage years like 2008, 2009, 2014 and 2015. In these low storage years, observed September and October water temperature have deviated at times by more than 0.5°F from a 56°F objective. Fortunately Shasta Lake storage levels are much higher this year increasing confidence in the forecasted late-season temperature performance.

Recognizing that increased egg mortality will occur if observed temperatures are higher than the forecasted values, various model assumptions have been adjusted over the last two years to better account for temperature related uncertainties. These include use of a 10% exceedance probability for meteorological data and TCD strategies to delay key critical gate configurations that tap into the coldest regions of the seasonal cold water pool.

To further assess potential risk factors associated with higher than anticipated late-summer and fall water temperatures, an additional sensitivity evaluation was conducted to estimate increased temperature mortality if September and October estimates of water temperatures were consistently higher by 0.5°F and 1.0°F over both months. For this sensitivity evaluation, increased egg mortality is observed in the modeled scenarios when 0.5°F is added over these months demonstrating a sensitivity of winter-run Chinook salmon to extended exceedances from the predicted temperatures. When assessing this uncertainty by adding 1.0°F to the predicted temperature at Clear Creek over September and October, temperature-dependent mortality increases approximately to 9.2%. The Martin et al. (2016) model show greater temperature-dependent mortality (15.7%) if 1.0°F is added to the modeled Keswick release temperatures.

Close monitoring to ensure that summer 2016 observed water temperatures do not deviate from the implemented temperature management plan's predicted isothermobath characteristics will greatly help reduce risks of higher late summer egg-to-emergence mortality than predicted from the modeled temperature forecast.

Temperatures and flows in this 2016 Plan may influence other habitat attributes that cause mortality. In early fall 2015, rearing habitats of winter-run Chinook salmon were highly infectious for *Ceratonova Shasta* and prevalence of C. Shasta infections was likely higher than observed by histology based on high prevalence of *Parvicapsula minibicornis*, another myxozoan parasite that uses the same polychaete alternative host as *C. Shasta*. In 2015, the infection of winter-run Chinook salmon was largely at an early stage, but conditions could have resulted in disease-related impairment of survival of out-migrants (Foott 2015). The susceptibility of infection is hypothesized to be increased with the warmer water temperatures observed (>60°F river exposure and >64°F laboratory rearing) in 2015. The 2016 predicted early fall temperatures are unlikely to increase susceptibility of egg or juvenile winter-run Chinook salmon to pathogens and disease.

In 2014, enhanced dissolved oxygen (DO) monitoring of winter-run Chinook redds showered that overall DO levels in the Sacramento River were suitable for Chinook survival throughout the spawning and red juvenile occupancy period (CDFW 2015). In 2015, enhanced DO monitoring adjacent to redds found variable results among sites, some of which were suspected to be caused by sensor inaccuracy. In 2015, low DO could have contributed to some early life stage mortality in monitored redds where DO fell to 0mg/L. In a majority of 2015 monitored sites, observed DO levels were fairly consistent and remained above 6mg/L (CDFW 2015), which is greater than levels causing egg mortality or juvenile rearing (Bergendorf 2002, Allen and Hassler 1986). With predicted cooler temperatures and higher release rates in the 2016 temperature management plan, dissolved oxygen is not predicted to cause detrimental effects to winter-run Chinook salmon eggs and juveniles

One objective of the 2016 Plan is to avoid winter-run Chinook Salmon redd dewatering by carefully planning flow reductions until the last winter-run Chinook fry have emerged from the gravel in October. The 2013 and 2014 dewatering surveys included Keswick release reductions below 10,500 cfs in later summer, but did not detect any dewatering of redds until releases were reduced below 8,000 cfs (Jarrett and Killam 2014, 2015). Although not anticipated due to the tenets of the 2016 Plan regarding avoiding winter-run red dewatering and recent observations of redd dewatering in 2013 and 2014, the potential effect being avoided by including this objective in the Plan can be assessed based on a RIVER2D redd dewatering model (USFWS 2006). Based on summer spawning flows of 10,500 cfs, the estimated percent of winter-run Chinook salmon redd dewatering at late summer release rates of 8,000 cfs is 2.9%. The risks of redds dewatering increases with higher spawning flows. Regardless, redd dewatering is dependent on location and the relationship is likely not linear (J. Roberts, pers comm). Although the estimated potential winter-run dewatering is minimal, actual location of at-risk redds will be monitored closely.

Another objective of the 2016 Plan is to reduce Keswick releases immediately following 100% winter-run fry emergence, and stabilize those flow through the fall-run incubation season. However, during September through November spring-run and fall-run Chinook salmon spawn in the upper Sacramento River. Although redds surveyed during September are typically considered to be constructed by spring-run Chinook salmon with fall-run Chinook salmon redds starting to be built in October (CDFW 2016), Fisher (1994) described spawning during late September to be fall-run Chinook salmon. Williams (2006) estimated 5% of fall-run Chinook salmon spawn in the Sacramento by mid-October. Although redd surveys are frequently limited by conditions and occur irregularly during the spawning period of spring-run and fall-run Chinook salmon during the 72 aerial redd surveys (2001-2015) more than 24,854 redds were enumerated between August 29 and December 16 (CDFW 2016). From these surveys, less than 1% of redds were counted in September, approximately 15% were counted in October, and the approximately 85% of the remaining fall-run Chinook salmon redds were observed in November and early December (Table 3). In the 2016 Plan, reductions in releases rates during the two-week periods in September and October may increase spring-run and fall-run Chinook redd dewatering. Based upon redd surveys in the past, the first two weeks in October are when redd constructions increases, and over this period represented 5.8% of redd building on average.

Table 3. Late Summer/Fall redd survey data from 2001-2015 (CDFW 2016)

	Redd survey completed during this period								
Year	9/2 - 9/15	9/16 - 9/29	9/30 - 10/13	10/14 - 10/27	10/28 - 11/10	11/11 - 11/24	11/25 - 12/8	12/9 - 12/16	Annual Total
2015				12.0%	42.0%	31.6%	14.4%		1530
2014			2.5%	27.5%	70.0%				483
2013		0.7%		24.8%	51.8%	22.8%			1457
2012			2.5%		62.5%	34.9%			1452
2011					49.8%	50.2%			251
2010					63.4%	36.6%			437
2009			22.9%		49.7%	27.4%			350
2008			7.9%		68.7%	23.5%			469
2007					50.9%	33.8%	15.3%		1111
2006	1.1%	0.3%	3.3%		25.8%	30.3%	39.2%		2150
2005	3.9%	0.6%	3.4%		32.2%		59.9%		1343
2004	0.1%	2.5%	3.9%			61.6%	31.8%		1659
2003			0.5%	7.5%	27.6%	64.3%			3851
2002	0.2%		2.1%	12.9%	26.5%	40.0%	18.3%		4525
2001		0.8%	8.7%	35.0%	55.5%				3786
Average	1.3%	1.0%	5.8%	20.0%	48.3%	38.1%	29.8%	0.0%	
Period total	89	97	790	2877	9458	8152	3391	0	24854

Potential redd dewatering risk for fall-run Chinook salmon with this strategy was evaluated based on a RIVER2D redd dewatering model (USFWS 2006). Based on early fall spawning flows of 9,000 cfs, the estimated percent of fall-run Chinook salmon redd dewatering at late fall release rates of 5,500 cfs is 13.5%. Based on 8.1% of upper Sacramento River Chinook spawning during this period (long term survey averages between 9/2-10/13) and 13.5% of these redds being dewatered, it is predicted that 1.1% of fall-run Chinook redds built in September and early October are likely to be dewatered. The exact overall percentage of the fall-run will depend on run timing that will also be monitored, and the later into October release rates remain above 5,500 cfs, the greater that proportion of fall-run Chinook redds that will be affected by the flow reductions.

Impacts of Lower Flow Scenarios

During the development of the 2016 Plan, Reclamation worked with other Federal and State agencies to evaluate potential scenarios with differing ranges of release rates (see Attachment B). The 2016 Plan represents an effort to minimize the impact to winter-run egg and fry incubation, while striving to ensure that other requirements of the CVP and SWP system are met and impacts to other beneficial uses of the system are limited to the extent possible. Based on these efforts, the 2016 Plan contains a set of flowrates that, if reduced, would result in impacts to other beneficial uses of the CVP and SWP. Those impacts include, but are not limited to:

- Reduced storage in Folsom Reservoir, potentially resulting in the triggering of an off-ramp criteria from the American River flow actions contained in RPA II.1 of the 2009 BiOp later in the water year. The 2016 Plan is expected to result in an end-of-September storage in Folsom of about 300,000 acre-feet; reductions in flows in the Sacramento River would likely impact the ability to maintain this projected storage level.
- Cuts to CVP water service contractors along the Sacramento River.
- Loss of the 5% allocation for CVP water service contractors south-of-Delta.
- Shortage of water at Mendota Pool to supply San Joaquin River Exchange Contractors, requiring supplemental releases from Millerton Lake and resulting in high channel losses and subsequent supply reductions to Friant Division contractors.
- Likely limitations to potential summer supplies for south-of-Delta refuges.
- Increased CVP debt under the Coordinated Operation Agreement (COA), resulting in potential future impacts to CVP water supplies.

Reclamation acknowledges that some of these impacts may occur under the 2016 Plan, should real-time operations require adjustments so that actual conditions more closely match projected modeled results. Attached is a draft operational forecast illustrating the projected operation of other components of the CVP based on the Sacramento River flowrates contained in the 2016 Plan (Attachment C).

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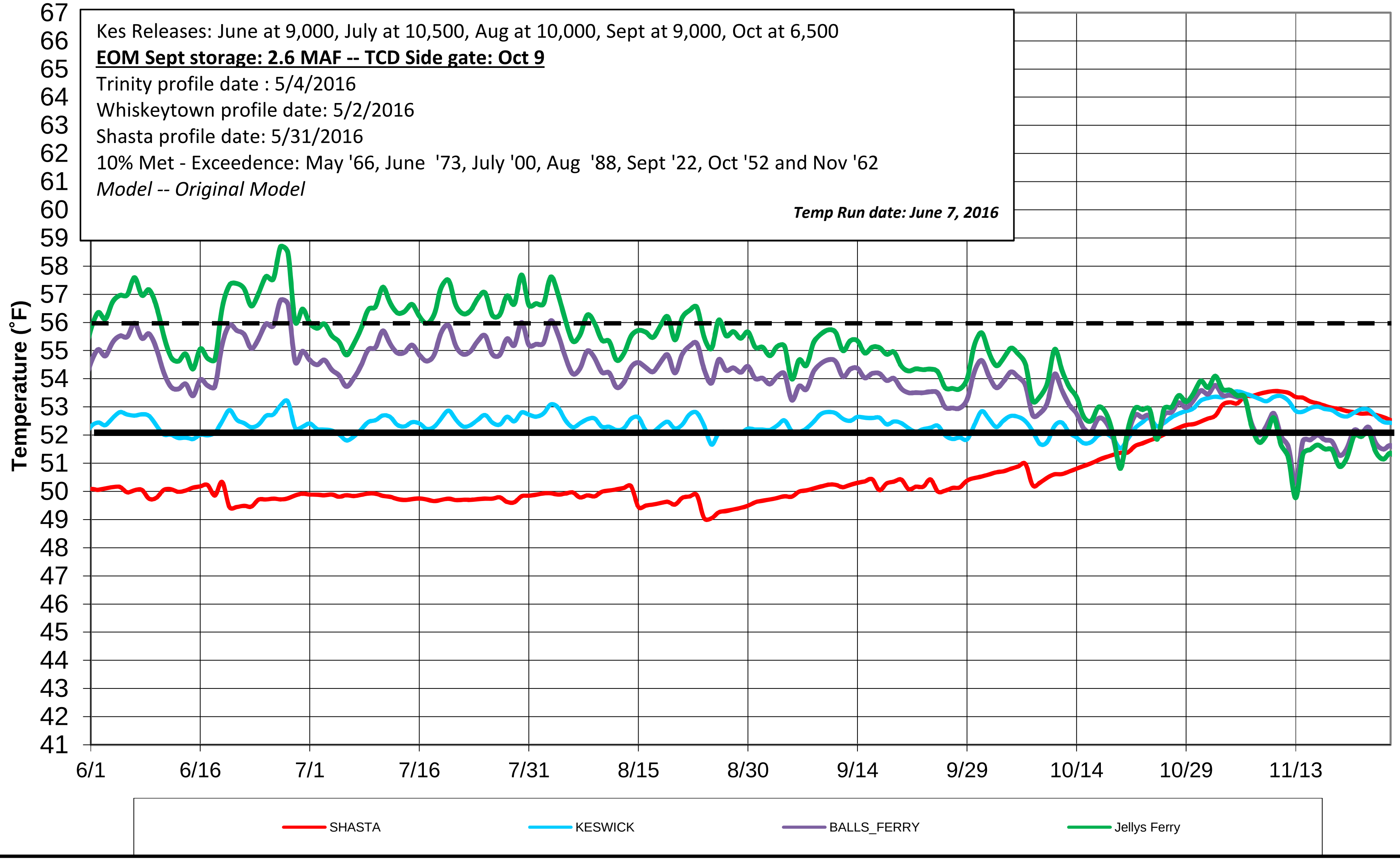
Sacramento River Modeled Temperature
2016 June 90%- Hydrology
2016 Temperature Management Plan -- Attachment A



Attachment B - Summary of Sensitivity Analysis
Bureau of Reclamation
2016 Sacramento River Temperature Management Plan
June 7, 2016

Introduction

Attachment B-1 contains a table and plots showing the temperature performance and characteristics of sensitivity modeling scenarios. These scenarios illustrate the temperature performance of a variety of different potential water operations, ranging from lower flow scenarios that focus on conserving storage, to higher flow scenarios that more fully utilize available storage. The modeling of these scenarios is based on the May 31, 2016 Shasta Lake temperature profile. The scenarios evaluated do not represent potential operating plans, but these results helped inform the formulation of the plan.

By design, all scenarios generally target a similar release water temperature at Keswick Dam of approximately 51.9° F through August 2016. In order to accomplish this target for the various flow rates, different configurations of the gates on the Shasta Dam Temperature Control Device must be utilized. The purpose of this analysis was to illustrate the range of potential end-of-season temperatures and to help assess the range of direct temperature related effects to winter-run Chinook salmon.

Discussion

The table and plots in Attachment B-1 highlight the trade-offs of the various approaches for managing storage and the available cold water pool (CWP) in Shasta Lake. The table and plots illustrate two points:

1) The combination of higher release rates and a low early season release temperature result in increased late season temperatures as the final full side gate operation of the TCD is called on earlier with these higher flow scenarios. This final full side gate operation signals the need to access the remainder of the CWP. For example, "Scenario 8,000" shows that with lower releases of approximately 8,000 cubic feet per second (cfs), the final full side gate operation occurs October 1 (with an initial opening and closing of the side gates in late August due to cold water requirements), whereas "Scenario 10,000" with releases of approximately 10,000 cfs requires final full use of the side gates on the TCD by September 16. The 10,000 cfs scenario results in final release temperatures from Shasta Dam approaching 54°F, whereas release temperatures later in the season are closer to 52°F under the 8,000 cfs scenario.
2) Lower release rates result in the need to utilize the coldest water stored in Shasta Lake at an earlier date. This is identified in the table by the dates when the use of the Pressure Relief Gates (PRGs) on the TCD are fully utilized under the various scenarios. The dates of the use of the PRGs are generally earlier for lower flow scenarios. The reason this occurs is that at lower release rates, cooler water must be released from Shasta Dam in order to meet a particular target release temperature from Keswick due to increased heating of the water between Shasta and Keswick Dams, particularly during the summer months. For example, the plot for the 8,000 cfs scenario illustrates that in order to meet a target daily average Keswick release temperature of approximately 51.9° F, Shasta Dam

release temperatures closer to 48° F must be maintained. The plot for the 10,000 cfs scenario shows that the same Keswick release temperature target can be held using Shasta Dam release temperatures generally near 49°F. The higher flow rates have the effect of pushing the cool water downstream from Shasta Dam to Keswick Dam with less heating, allowing for the use of slightly warmer releases from Shasta Dam and reducing the need to access the coldest water earlier in the season. The table shows that for these two scenarios, the use of the PRGs begins at July 14 and August 1 respectively, illustrating the need to more fully access the coldest water in the reservoir earlier with lower flows. This also increases the risks associated with loosing temperature control in the late summer/early fall as a result of running out of the majority of the CWP resource.

It should be noted that a similar condition of increased heating in lower flow scenarios can be seen in the river water temperatures downstream of Keswick Dam. The table and plots show that, particularly during the summer months of June through August, the water temperatures reaching Balls Ferry and Jellys Ferry under the higher flow scenarios is slightly cooler.

Summary

Overall, the sensitivity analysis provides an evaluation of the performance of two management approaches. Under the first approach, lower flows are used and overall storage is conserved, but due to the increased need for colder water to offset the increased heating that occurs in the river downstream at these lower flowrates, the deeper CWP resource is accessed earlier ultimately utilizing a smaller portion of the total CWP.

The other approach utilizes higher flow rates and more of the overall storage. With these increased flows there is not as much early dependence on the colder water that exists deeper in Shasta Lake, since the higher flows lessen the effects of the heating that occurs downstream of Shasta Dam. However, the higher release rates coupled with a low early season release temperature can result in higher temperatures later in September and October. This condition is associated with earlier use of the full side gates on the TCD.

Ultimately, selection of a plan involves the melding of these two considerations to create a seasonal temperature target that can be maintained at appropriate flow rates without risking later-season temperature increases associated with depletion of the CWP and not limiting use of the CWP through early use of the PRGs only. This is accomplished by setting an initial Keswick Dam release temperature that can be maintained without triggering the need for full side gate operation too early in the temperature management season.

Attachment B-1

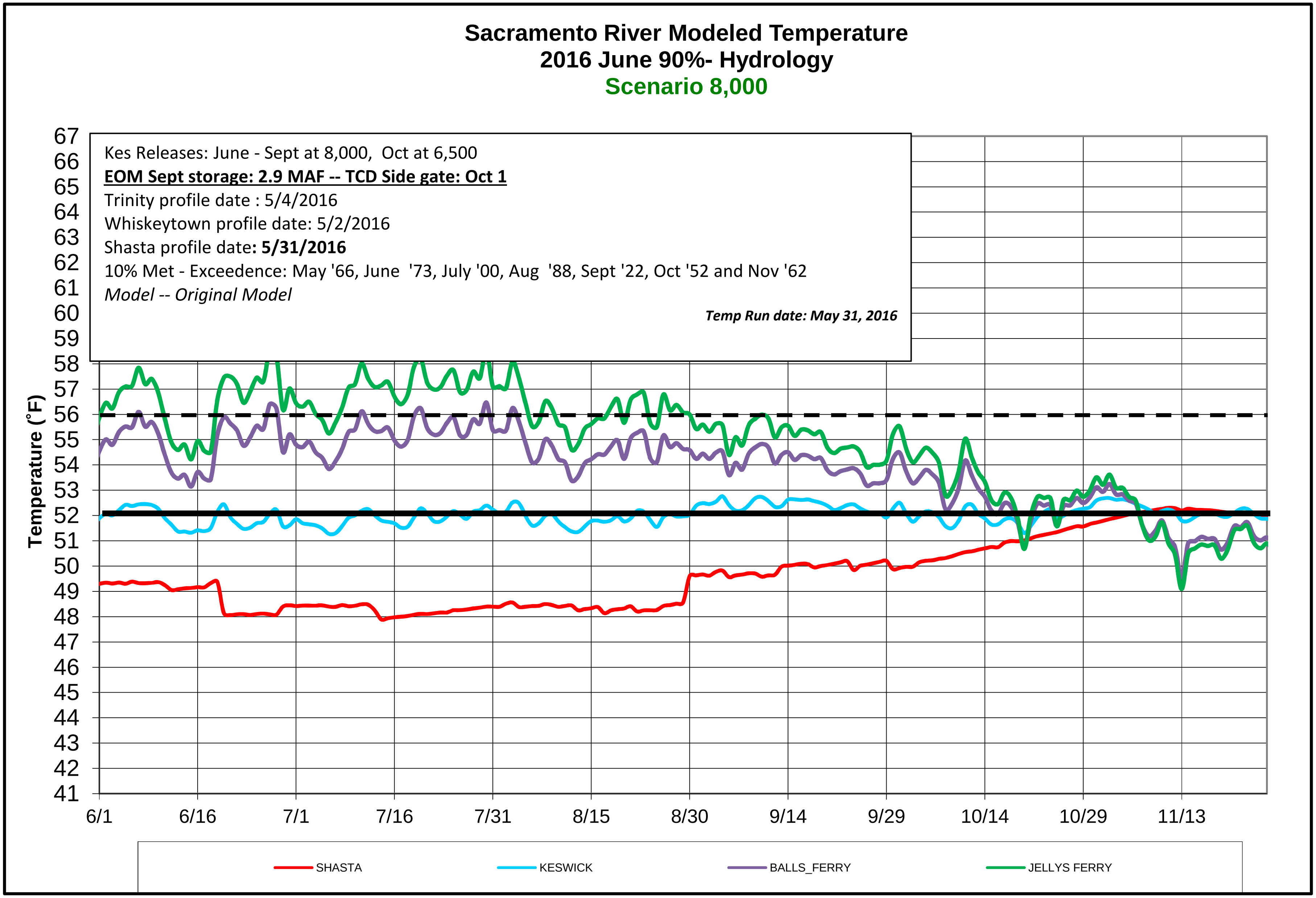
Scenario 8,000	June	July	Aug	Sep	Oct	Nov	*PRG Only*	*Full Side Gates*	*Sept Shasta Storage*	*July Export*	*Aug Export*	*Sep Export*	*Folsom EOM Sept Storage*	*System-Wide Effects*	Egg to Emergence temp dependent mortality above Clear Creek (Zeug et al 2012)	*Martin et al (2015) Temperature dependent mortality estimates*
Keswick	8000	8000	8000	8000	6500	5500	14-Jul	Aug 23/ Aug 31/ Oct 1	2.9	60	150	270	305	* loss of 5% SOD allocation * Friant releases needed for Exchange Contractors * Delta Outflow - difficult to meet * 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											

****Wilkins had to be cut by 600 cfs in July*

Scenario 9,000	June	July	Aug	Sep	Oct	Nov	*PRG Only*	*Full Side Gates*	*Sept Shasta Storage*	*July Export*	*Aug Export*	*Sep Export*	*Folsom EOM Sept Storage*	*System-Wide Effects*	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	5500	20-Jul	10-Sep	2.8	75	160	270	361	* loss of 5% SOD allocation * Friant releases needed for Exchange Contractors * Delta Outflow - difficult to meet * Off Ramp year at Folsom	5.0%	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 10,000	June	July	Aug	Sep	Oct	Nov	*PRG Only*	*Full Side Gates*	*Sept Shasta Storage*	*July Export*	*Aug Export*	*Sep Export*	*Folsom EOM Sept Storage*	*System-Wide Effects*	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	5500	1-Aug	16-Sep	2.7	140	250	270	403	* 5% SOD allocation reduced * Friant releases may be needed * Delta Outflow is met * 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 11,500	June	July	Aug	Sep	Oct	Nov	*PRG Only*	*Full Side Gates*	*Sept Shasta Storage*	*July Export*	*Aug Export*	*Sep Export*	*Folsom EOM Sept Storage*	*System-Wide Effects*	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	5500	31-Jul	9-Sep	2.5	230	258	270	403	* 5% SOD allocation preserved * Friant releases not needed * Delta Outflow met * 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											



Sacramento River Modeled Temperature
2016 June 90%- Hydrology
Scenario 8,000
Kes Releases: June - Sept at 8,000, Oct at 6,500
EOM Sept storage: 2.9 MAF -- TCD Side gate: Oct 1
Trinity profile date : 5/4/2016
Whiskeytown profile date: 5/2/2016
Shasta profile date: 5/31/2016
10% Met - Exceedence: May '66, June '73, July '00, Aug '88, Sept '22, Oct '52 and Nov '62
Model -- Original Model
Temp Run date: May 31, 2016
Temperature (°F)
67
66
65
64
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62
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60
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52
51
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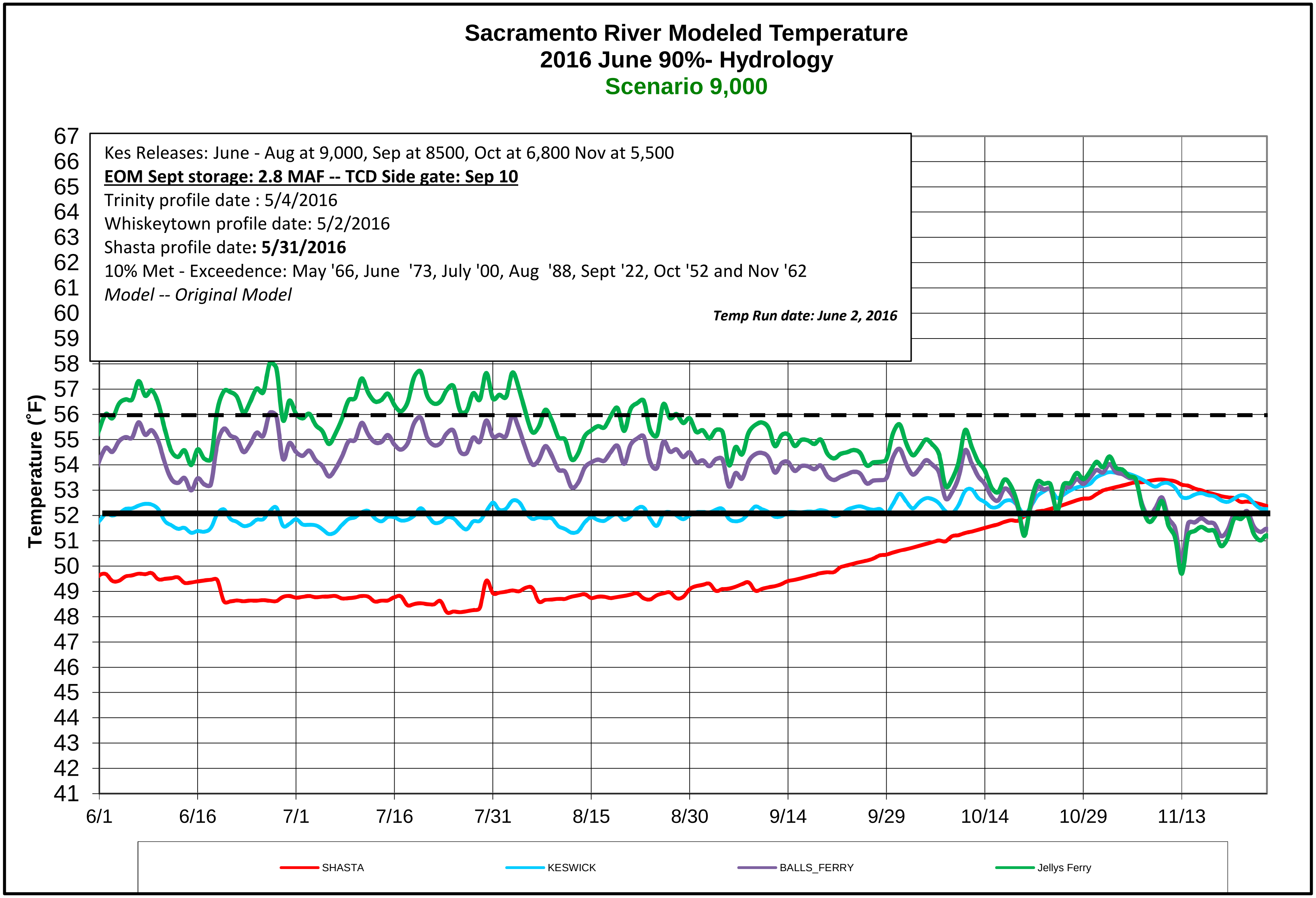
49
48
47
46
45
44
43
42
41
6/1
6/16
7/1
7/16
7/31
8/15
8/30
9/14
9/29
10/14
10/29
11/13
SHASTA
KESWICK
BALLS_FERRY
JELLYS FERRY



Sacramento River Modeled Temperature
2016 June 90%- Hydrology
Scenario 9,000
Kes Releases: June - Aug at 9,000, Sep at 8500, Oct at 6,800 Nov at 5,500
EOM Sept storage: 2.8 MAF -- TCD Side gate: Sep 10
Trinity profile date : 5/4/2016
Whiskeytown profile date: 5/2/2016
Shasta profile date: 5/31/2016
10% Met - Exceedence: May '66, June '73, July '00, Aug '88, Sept '22, Oct '52 and Nov '62
Model -- Original Model
Temp Run date: June 2, 2016
Temperature (°F)
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46
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44
43
42
41
6/1
6/16
7/1
7/16
7/31
8/15
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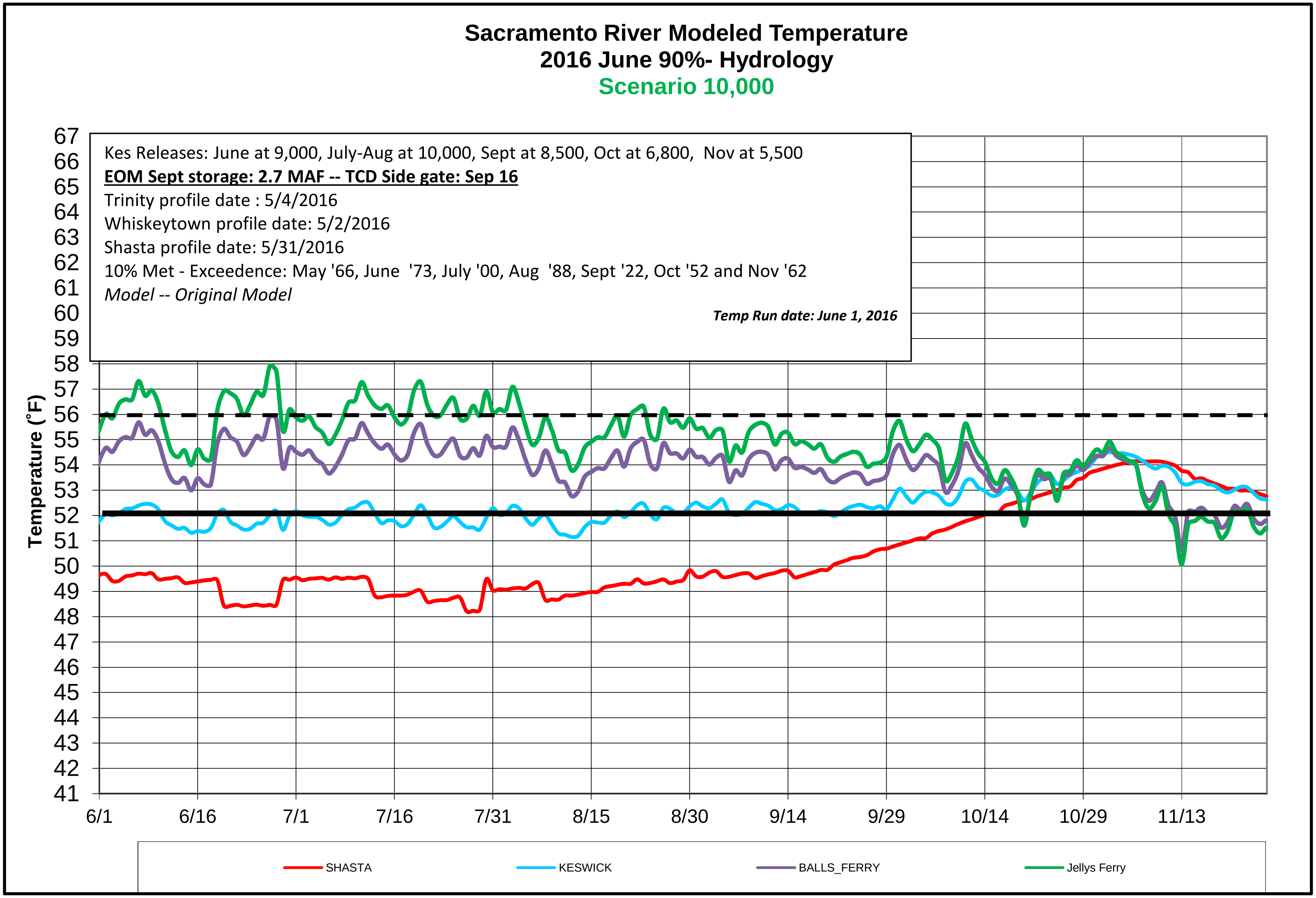
10/14
10/29
11/13
SHASTA
KESWICK
BALLS_FERRY
Jellys Ferry



Sacramento River Modeled Temperature
2016 June 90%- Hydrology
Scenario 10,000
Kes Releases: June at 9,000, July-Aug at 10,000, Sept at 8,500, Oct at 6,800, Nov at 5,500
EOM Sept storage: 2.7 MAF -- TCD Side gate: Sep 16
Trinity profile date : 5/4/2016
Whiskeytown profile date: 5/2/2016
Shasta profile date: 5/31/2016
10% Met - Exceedence: May '66, June '73, July '00, Aug '88, Sept '22, Oct '52 and Nov '62
Model -- Original Model
Temp Run date: June 1, 2016
Temperature (°F)
67
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6/16
7/1
7/16
7/31
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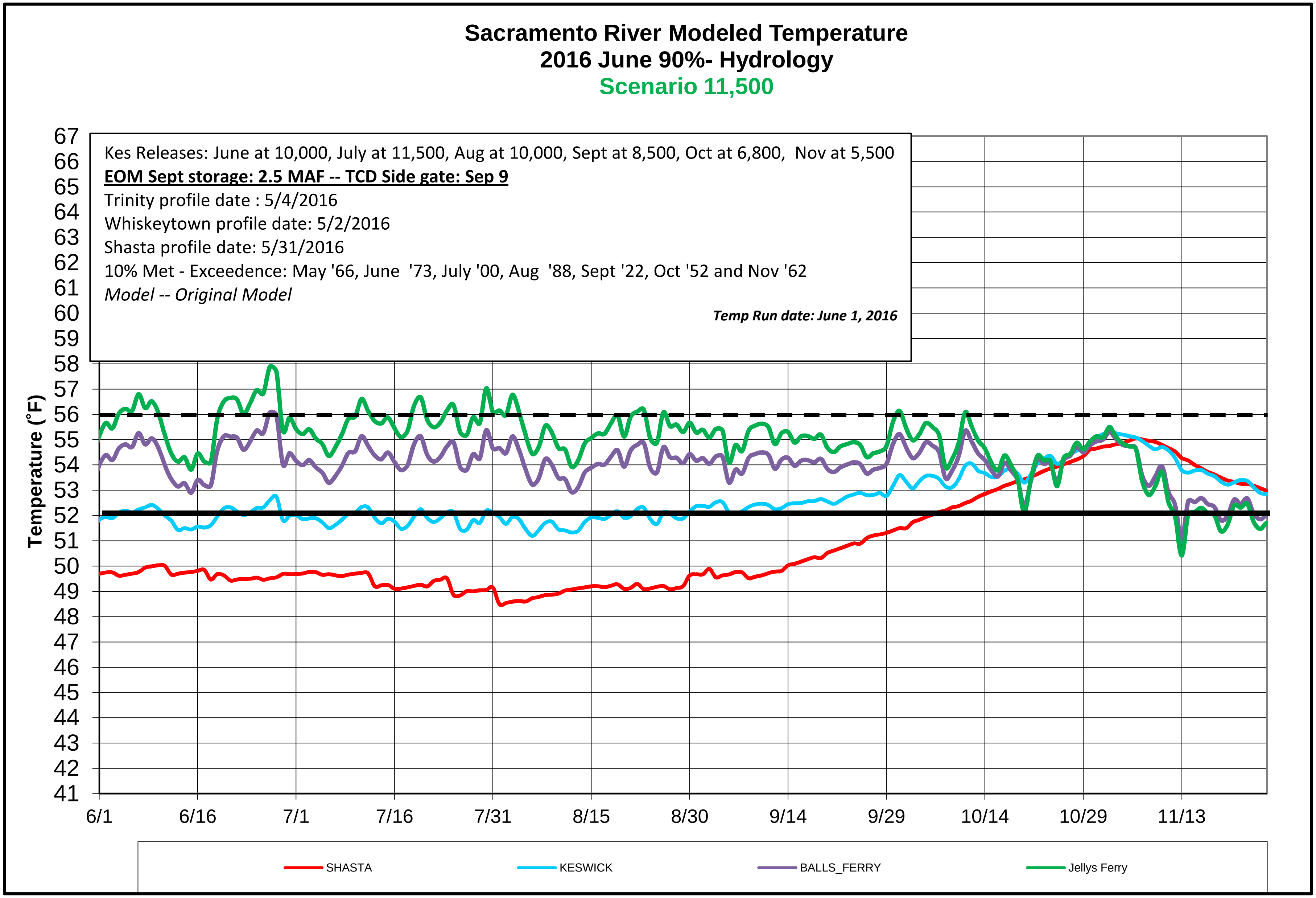
SHASTA
KESWICK
BALLS_FERRY
Jellys Ferry


Sacramento River Modeled Temperature
2016 June 90%- Hydrology
Scenario 11,500
Kes Releases: June at 10,000, July at 11,500, Aug at 10,000, Sept at 8,500, Oct at 6,800, Nov at 5,500
EOM Sept storage: 2.5 MAF -- TCD Side gate: Sep 9
Trinity profile date : 5/4/2016
Whiskeytown profile date: 5/2/2016
Shasta profile date: 5/31/2016
10% Met - Exceedence: May '66, June '73, July '00, Aug '88, Sept '22, Oct '52 and Nov '62
Model -- Original Model
Temp Run date: June 1, 2016
Temperature (°F)
67
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49
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44
43
42
41
6/1
6/16
7/1
7/16
7/31
8/15
8/30
9/14
9/29
10/14
10/29
11/13
SHASTA
KESWICK
BALLS_FERRY
Jellys Ferry

2016 Sacramento River Temperature Plan
Attachment C

Storages

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

		Jun	Jul	Aug	Sep	Oct	Nov	Dec
Trinity	**1392**	**1233**	**1110**	**1002**	**900**	**887**	**876**	**878**
	Elev.	2279	2267	2255	2244	2242	2240	2241
Whiskeytown	**232**	**238**	**238**	**238**	**230**	**206**	**206**	**206**
	Elev.	1209	1209	1209	1207	1199	1199	1199
Shasta	**4167**	**3876**	**3405**	**2968**	**2599**	**2426**	**2351**	**2373**
	Elev.	1043	1025	1004	989	980	977	978
Folsom	**826**	**699**	**474**	**349**	**328**	**269**	**233**	**218**
	Elev.	439	413	395	392	382	374	371
New Melones	**624**	**617**	**565**	**515**	**470**	**460**	**477**	**495**
	Elev.	881	871	861	851	849	853	856
Total San Luis (TAF)	677	467	584	671	656	785	955	1190

Monthly River Releases (TAF/cfs)

		Jun	Jul	Aug	Sep	Oct	Nov	Dec
Trinity	TAF	150	68	45	44	23	18	18
	cfs	**2,526**	**1,102**	**734**	**744**	**373**	**300**	**300**
Clear Creek	TAF	9	7	5	9	14	10	11
	cfs	**150**	**120**	**85**	**150**	**225**	**175**	**175**
Sacramento	TAF	535	645	615	535	400	327	307
	cfs	**9000**	**10500**	**10000**	**9000**	**6500**	**5500**	**5000**
American	TAF	268	306	203	96	95	76	77
	cfs	**4505**	**4984**	**3301**	**1612**	**1543**	**1283**	**1250**
Stanislaus	TAF	15	12	12	12	35	12	12
	cfs	**250**	**200**	**200**	**200**	**577**	**200**	**200**

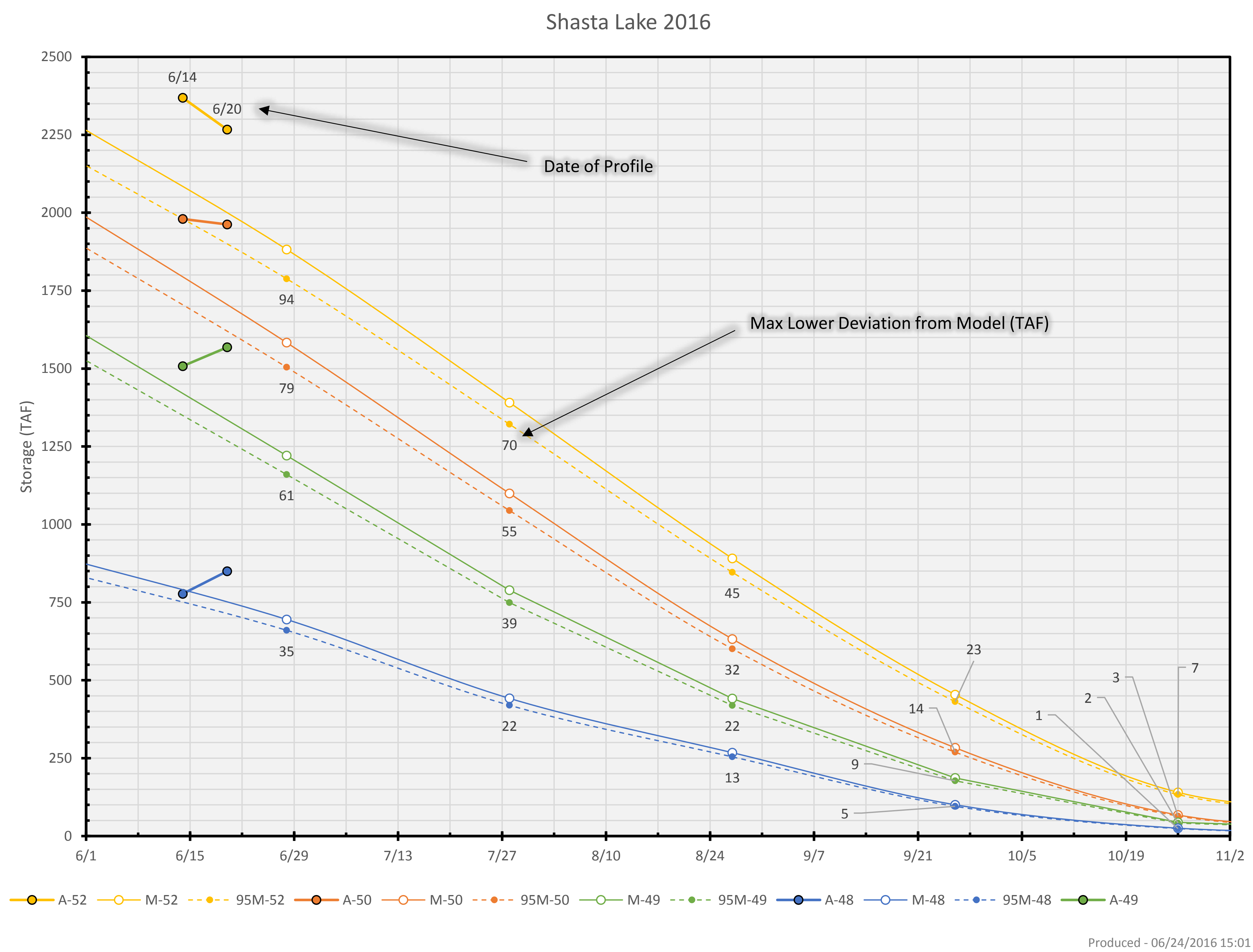
Trinity Diversions (TAF)

	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Carr PP	73	68	67	62	0	14	19
Spring Crk. PP	**60**	**60**	**60**	**60**	**12**	**5**	**12**

Delta Summary (TAF)

		Jun	Jul	Aug	Sep	Oct	Nov	Dec
Tracy		79	150	165	272	282	270	225
USBR Banks		0	0	0	0	0	0	0
Contra Costa		9.8	11.1	12.7	14.0	16.8	18.4	18.3
Total USBR		89	161	178	286	299	288	243
COA Balance		-54	-63	-63	-6	40	0	0
Old/Middle River Std.								
Old/Middle R. calc.		-3,478	-7,617	-7,684	-5,772	-6,334	-6,081	-5,905
Computed DOI		7094	6507	5401	4656	4002	4505	7678
Excess Outflow		0	0	0	0	0	0	3172
% Export/Inflow		28%	46%	49%	47%	59%	58%	48%
% Export/Inflow std.		35%	65%	65%	65%	65%	65%	65%

CVP actual operations do not follow any forecasted operation or outlook; actual operations are based on real-time conditions.
CVP operational forecasts or outlooks represent general system-wide dynamics and do not necessarily address specific watershed/tributary details.
CVP releases or export values represent monthly averages.
CVP Operations are updated monthly as new hydrology information is made available December through May.


Shasta Lake 2016
Storage (TAF)
2500
2250
2000
1750
1500
1250
1000
750
500
250
0
6/1
6/15
6/29
7/13
7/27
8/10
8/24
9/7
9/21
10/5
10/19
11/2
6/14
6/20
Date of Profile
Max Lower Deviation from Model (TAF)
94
79
61
35
70
55
39
22
45
32
22
13
23
14
9
5
1
2
3
7
A-52
M-52
95M-52
A-50
M-50
95M-50
M-49
95M-49
A-48
M-48
95M-48
A-49
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