11 May 2020

Eileen Sobeck
Executive Director
State Water Resources Control Board
1001 I Street
Sacramento, CA 95814
Via e-mail Bay-Delta@waterboards.ca.gov

RE: Comments on *Draft Temperature Management Plan Water Year 2020*

Dear Ms. Sobeck:

The California Sportfishing Protection Alliance, California Water Impact Network and AquAlliance (hereinafter "CSPA") have reviewed the U.S. Bureau of Reclamation's (Reclamation) initial 23 April 2020 draft and subsequent 30 April 2020 *Draft Temperature Management Plan* ("Draft Plan") and respectfully submit the following comments, which include the attached *Review of U.S. Bureau of Reclamation's Draft Sacramento River Temperature Management Plan for 2020* by CSPA fishery consultant Thomas Cannon. We also incorporate by reference the comments submitted by NRDC et al.

The Draft Plan fails to comply with explicit requirements of State Water Resources Control Board (State Board) Order 90-05 and the temperature standards and controllable factors policy in the Central Valley Regional Water Quality Control Board's (Regional Board) Water Quality Control Plan for the Sacramento and San Joaquin River Basins (Basin Plan) that were reviewed and approved by both the State Board and U.S. Environmental Protection Agency.[1] It is not protective of winter-run, spring-run and fall-run Chinook salmon and is inconsistent with requirements of the 2009 National Marine Fisheries Service's (NMFS) Biological Opinion, the 19 January 2019 Proposed Amendment to the Reasonable and Prudent Alternative (RPA) of the Opinion[2] and the 1 July 2019 Biological Opinion regarding long-term operation of the Central Valley and State Water Project that concluded that long-term operations would jeopardize the continued existence of species.[3] The October 2019 Biological Opinion that was released by the

[1] Available online at: https://www.waterboards.ca.gov/centralvalley/water_issues/basin_plans/sacsjr_201805.pdf. Sacramento River temperature standards are found on p. 3-14 and the controllable factors policy on p. 3-2.
[2] Available online at: https://www.fisheries.noaa.gov/webdam/download/96691677.
[3] Available online at: https://www.documentcloud.org/documents/6311822-NMFS-Jeopardy-Biop-2019-OCR.html.

Trump Administration is scientifically inadequate, fails to protect listed species and is being litigated by the State of California.

The present situation was created by Reclamation's failure to provide adequate carryover storage during the winter, excessive water deliveries during April and May 2020 and unreasonable projected deliveries of water through the summer. However, as we show below, there are reasonable measures that can be required to better protect the spawning, incubation, emergence and migration of winter-run Chinook salmon this year, while ensuring sufficient cold water remains to protect spring-run and fall-run Chinook salmon spawning later in the year. These include reducing deliveries to Sacramento River Settlement Contractors to levels consistent with their historic water right entitlements to natural flow, shifting contractor deliveries to later in the year, protecting cold water reserves by shifting power-demand hydro diversions at Shasta Dam to cooler periods of the day, increasing the import of cold water from the Trinity River during spring and early summer and reducing the transfer of warmer Trinity River water in late summer and implementing long-overdue fixes to the Whiskeytown Reservoir temperature control curtain and Shasta Dam's temperature control outlets. Implementation of these measures would greatly improve the likelihood of survival of endangered winter-run and threatened spring-run Chinook salmon this year. Unfortunately, Reclamation failed to model or evaluate any of these measures.

Inexplicably, Reclamation is in open defiance of the State Board's water rights authority. It refused to comply with requirements in the State Board's 23 and 29 April 2020 letters that directed Reclamation to evaluate additional actions within its control to manage temperature in the Sacramento River, including reduced deliveries to Sacramento settlement contractors. The State Board must protect its water right authority and fulfill its obligation to protect the public trust resources of the Sacramento River.

Our specific comments follow.

Reclamation is Openly Defying the State Board's Water Rights Authority

Inexplicably, Reclamation blatantly refused to comply with the State Board's express direction in its 3 April 2020 letter to "submit information to evaluate additional actions within Reclamation's control to manage temperatures on the Sacramento River in a manner that would be more protective."[4] The letter pointed out that:

> Actions within Reclamation's control include deliveries of water diverted under Reclamation's water rights, including deliveries to settlement and exchange contractors. Reclamation should evaluate different water supply delivery assumptions to provide for improved cold water pool maintenance, including evaluation of lower releases from Shasta Reservoir during the spring and summer that meter out the cold water pool resources in order to provide for improved temperature control throughout the temperature control season and improved cold water pool levels going into next year.

[4] SWRCB Executive Director Eileen Sobeck to Central Valley Project Operations Manager Kristin White Re: Order 90-05 Sacramento River Temperature Management Planning, 3 April 2020.

Reclamation responded to the State Board's letter on 17 April 2020[5] by stating:

> …Reclamation's view is that your request for multiple modeling scenarios of actions "within Reclamations control" is inconsistent with Order 90-05, which requires that Reclamation "file an operation plan show [its] strategy to meet the temperature requirement at the new location." It is also inconsistent with Reclamation's limited discretion regarding such contracts with senior water users and wildlife refuges.

The State Board sent Reclamation another letter on 29 April 2020[6] reminding the agency that:

> When Reclamation proposes a new compliance location, Order 90-05 states that "whether a particular factor is within [Reclamation's] reasonable control depends on the specific facts and is a matter for the [Deputy Director] or the Board to decide…" (Order 90-05, p. 20). Evaluating scenarios with different water supply delivery assumptions is necessary to inform the State Water Board's consideration of the Temperature Management Plan ensure that Reclamation develops a plan that satisfies Reclamation's obligation under WR 90-05, and evaluates actions that are or could be within Reclamation's "reasonable control."

The State Board then refuted Reclamation's claim of limited discretion regarding contract deliveries to senior water users by pointing out that the settlement contractor's riparian and pre-1914 water rights are limited to natural flow. The State Board stated:

> Reclamation's April 17 letter claims that evaluation of additional scenarios within Reclamation's control is inconsistent with Order 90-5, because Reclamation claims limited discretion regarding contract deliveries to senior water users and wildlife refuges. The State Water Board recognizes that Reclamation's contractual obligations to the Sacramento River settlement contractors are unique because they claim to hold riparian and pre-1914 appropriative water rights, which are not subject to Order WR 90-5 requirements. However, evaluation of alternative operational scenarios with different water supply delivery assumptions is not inconsistent with Reclamation's contractual obligations to the settlement contractors or their senior claims of right, provided that none of the operational scenarios evaluated involve a reduction in deliveries of natural flows to which senior water right holders may be entitled. During much of the temperature management season, releases from Keswick Dam are typically well above natural inflows to Shasta Reservoir, especially in a dry year such as this one, and therefore this is unlikely to be an issue. Moreover, it should be possible to structure the operational scenarios to ensure that releases are not reduced below natural inflows.[7]

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[5] Operations Manager Kristin White to SWRCB Executive Director Eileen Sobeck, Subject: Order 90-05 Sacramento River Temperature Management Plan, Your Letter Dated April 3, 2020, 17 April 2020.
[6] SWRCB Executive Director Eileen Sobeck to Operations Manager Kristin White Re: Order 90-05 Sacramento River Temperature Management Planning, 29 April 2020.
[7] *Id*.

On 30 April 2020, Reclamation submitted its 2020 Draft Sacramento River Temperature Management Plan. The cover letter stated:

> We are also aware of Ms. Riddle's letter of April 29, 2020 regarding Order 90-05 and Sacramento Temperature Management Planning. We disagree with a number of the assertions in that letter and will respond separately. Please be aware that we have not developed extensive additional modeling scenarios for today. We are unable to provide additional modeling in addition to the extensive modeling already provided within your deadlines provided, especially modeling that does not constitute Reclamations proposed operations.

Reclamation is openly challenging the water rights and water quality authority of the State Board as it is currently doing in Phase 1 of the Bay-Delta Update proceeding. The State Board's response will have enormous consequences for public trust resources and the people of California in the future.

Reclamation Has Failed to Comply with Legally Promulgated Water Quality Standards and State Board Order 90-05

The Central Valley Regional Water Quality Control Board's (Regional Board) Water Quality Control Plan for the Central Valley Region (Basin Plan) was developed pursuant to federal Clean Water Act (CWA) and California Porter-Cologne Act (Porter-Cologne) requirements. It covers the Sacramento River and San Joaquin River Basins and has long included water quality standards for temperature in the Sacramento River.[8] The specific standard for the Sacramento states, "the temperature shall not be elevated above 56ºF in the reach from Keswick Dam to Hamilton City nor above 68ºF in the reach from Hamilton City to the I Street Bridge during periods when temperature increases will be detrimental to the fishery." Temperature standards are dependent upon controllable factors, i.e., resulting from and controllable by human activity.[9] Delivery of water is a controllable factor.

State Board Order 90-05 requires Reclamation to meet a daily average temperature of 56ºF at Red Bluff Diversion Dam when higher temperatures will be detrimental to the fishery, subject to controllable factors.[10] The Order allows Reclamation to petition the Board to change this requirement in any year if factors beyond Reclamation's control prevent Reclamation from achieving this 56 degrees Fahrenheit requirement, and instead allow Reclamation to meet 56 degrees daily average temperatures in a different reach that is within Reclamation's reasonable control.[11] The Board further addressed controllable factors in Order 92-02 when it advised

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[8] Basin Plan, Specific Temperature Objectives, Table 3, p. 3-14: https://www.waterboards.ca.gov/centralvalley/water_issues/basin_plans/sacsjr_201805.pdf.
[9] *Id*., p. 3-2.
[10] Order 90-05: https://www.waterboards.ca.gov/waterrights/board_decisions/adopted_orders/orders/1990/wro90-05.pdf.
[11] *Ibid*., p. 20.

Reclamation that water deliveries are not available for delivery if needed as carryover storage to protect the fishery.[12]

Order 90-05 failed to protect 44 miles of historic spawning habitat between Red Bluff Diversion Dam (RM 243) and Hamilton City (RM 199). Between 1980 and 1990, an average of 11.7% of winter-run, 5.8% of spring-run, 35.2% of fall-run and 26.5% of late fall-run Chinook salmon spawned below Red Bluff Diversion Dam. Failure to meet Basin Plan standards led to a significant decline in spawning below Red Bluff. Between 2007-2017, no winter-run and only 2.5% of spring-run, 13.5% of fall-run and 4.3% of late fall-run spawned below Red Bluff.[13]

Reclamation has not met the 56ºF temperature requirement at Red Bluff during the compliance period since 2001.[14] Nor has the 56ºF temperature standard been met at the upstream compliance points of Bend Bridge (RM 257.8) or Jelly's Ferry (RM 266.8).[15] Even in the wettest years, Balls Ferry (RM 276) or Clear Creek (RM 292) have become the defacto compliance points and they have experienced frequent temperature exceedances. However, Reclamation has been more successful in delivering water. Between 2001 and 2019, Sacramento River settlement contractors received 100% of contracted allocations with the exception of the drought years 2014 and 2015, when they received 75%.[16]

The prioritization of water deliveries over fish protection and permit compliance effectively eliminated 34 to 47 miles of spawning habitat protected by Order 90-05 and 77 to 93 miles of habitat protected by the Basin Plan. It compressed spawning into the short reach below Keswick Dam (RM 302). For example, in the extremely wet year of 2017, all winter-run and spring-run, 71% of fall-run and 90% of late fall-run Chinook salmon spawning occurred in the 19 miles above the Airport Road Bridge (RM 284).[17] Compression of spawning habitat eliminates the necessary spatial separation between overlapping stocks and leads to superimposition of redds.

As discussed below, the Draft Plan proposes a temperature compliance schedule that is conservatively estimated to kill 27-28% of critically endangered winter-run Chinook salmon as a result of temperature dependent mortality. The combination of lethal temperatures and habitat loss is a principal cause of the population declines that has brought species that survived and prospered for millennia to the brink of extirpation.

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[12] Order 92-02, Footnote 3, p. 9: https://www.waterboards.ca.gov/waterrights/board_decisions/adopted_orders/orders/1992/wro92-02.pdf.

[13] CDFW, *Salmonid Populations or the Upper Sacramento River Basin In 2017*, Appendix Table A3, Redd Counts 1967-2017, pp. 45-47: http://calsport.org/news/wp-content/uploads/Salmon-Pop-Sac-R-2017-CDFW-copy.pdf.

[14] CDEC data: http://calsport.org/news/wp-content/uploads/Red-Bluff-Temperature-2001-2019-pdf-copy.pdf.

[15] University of Washington website (SacPas: Central Valley Prediction & Assessment of Salmon) that is funded by Reclamation for Central Valley Project Improvement Act and federal Endangered Species Act purposes. Temperature compliance data (2006-2020) can be accessed at: http://www.cbr.washington.edu/sacramento/tmp/tc_sacramento_1589079723_465.html#graph.

[16] Reclamation, Water Allocations (Historical): https://www.usbr.gov/mp/cvo/vungvari/water_allocations_historical.pdf.

[17] CDFW, *Salmonid Populations or the Upper Sacramento River Basin In 2017*, Appendix Table A2, Summary of new redd count data collected from aerial flights for year 2017, p. 44: http://calsport.org/news/wp-content/uploads/Salmon-Pop-Sac-R-2017-CDFW-copy.pdf.

Reclamation's right to use water is dependent upon compliance with water quality standards established to protect the public trust resources belonging to all Californians. Water delivery is a controllable factor. In the absence of any analysis demonstrating that compliance with water quality standards is attributable to uncontrollable factors, Reclamation must be required to comply with legally promulgated water quality standards.

Reclamation Has Historically Failed to Comply with the Biological Opinion

Compliance with ESA Biological Opinions is not a substitute for compliance with CWA and Porter-Cologne requirements. Biological Opinions only protect against extinction of listed species, ignore unlisted species and fail to address whether fish are "reasonably protected." However, Reclamation and members of the Sacramento River Temperature Task Group have routinely proposed temperature management plans that seemingly assume that the Biological Opinions do operate as a substitute. Regardless, over the last decade, Reclamation has blatantly failed to comply with the most fundamental RPA requirements of the NMFS 2009 Biological Opinion,

The 2009 Biological Opinion's Reasonable and Prudent Alternative (RPA) to prevent jeopardy specifically requires a running ten-year temperature compliance at Clear Creek (RM 292), Balls Ferry (RM 276), Jelly's Ferry (RM 266) and Bend Bridge (RM 258) of 95, 85, 40, 15 percent of the time, respectively.[18] However, a review shows that the ten-year (2009-2018) running average temperatures exceeded 56ºF at Balls Ferry, Jelly's Ferry and Bend Bridge of 89.9%, 100% and 100% of total compliance days, respectively. Further, between 2009 and 2018, there were exceedances of 56ºF daily average temperature at Clear Creek, Balls Ferry, Jelly's Ferry and Bend Bridge in 30%, 90%, 100% and 100% of the years, respectively.[19]

The RPA also prescribes specific end-of-season storage requirements for Shasta Reservoir. Performance measures for end-of-September (EOS) include: 87 percent of years, minimum EOS storage of 2.2 MAF; 82 percent of years, minimum EOS storage of 2.2 MAF and end-of-April storage of 3.8 MAF in following year (to maintain potential to meet Ball's Ferry compliance point); and 40 percent of years minimum EOS storage 3.2 MAF (to maintain potential to meet Jerry's Ferry compliance point in the following year). Review shows that between 2009 and 2018 Reclamation met the 2.2 MAF EOS storage only 60% of the time, met the 2.2 MAF EOS

[18] NMFS, Biological Opinion for Long-Term Operation of CVP and SWP, RPA Performance Measures, p. 592. Available at: https://archive.fisheries.noaa.gov/wcr/publications/Central_Valley/Water%20Operations/Operations,%20Criteria%20and%20Plan/nmfs_biological_and_conference_opinion_on_the_long-term_operations_of_the_cvp_and_swp.pdf

[19] University of Washington website (SacPas: Central Valley Prediction & Assessment of Salmon) that is funded by Reclamation for Central Valley Project Improvement Act and federal Endangered Species Act purposes. Temperature compliance data (2006-2020) can be accessed at: http://www.cbr.washington.edu/sacramento/tmp/tc_sacramento_1589166659_520.html.

storage and 3.8 MAF end-of-April storage requirement 60% of the time and met the 3.2 MAF EOS storage requirement only 30% of the time.[20]

As noted and cited above, NMFS proposed a 2017 amendment to the 2009 Biological Opinion that would have limited temperature dependent mortality of winter-run Chinook salmon to 8%, limited Keswick releases to 10,000 cfs in June and July and required a minimum end-of-September carryover storage requirement of 2.2 MAF in a dry water year similar to 2020. NMFS subsequently prepared a 1 July 2019 Biological Opinion, concluding that the proposed long-term operations of the CVP would jeopardize the continued existence of listed species, that the Trump Administration refused to publicly release. A political appointee subsequently released an October 2019 non-jeopardy Biological Opinion that would allow three years of 100% mortality to winter-run Chinook salmon before reinitiation of consultation is required.

Both the State Board and California Department of Fish and Wildlife (CDFW) submitted highly critical comments on the Draft Environmental Impact Statement for the Reinitiation of Consultation on the Coordinated Long-Term Operation of the Central Valley Project and State Water Project. The State of California is currently litigating the October 2019 Biological Opinion and NEPA document and quotes from the State Board and CDFW comments.[21] Apparently, Reclamation now asks the State Board to approve a Draft Plan based upon the October Biological Opinion and Central Valley Project operations proposed in the NEPA document.

To our knowledge, CDFW has not issued a Consistency Determination on the October 2019 Biological Opinion. The State Board should request that CDFW issue or deny a CESA permit on Reclamation's CVP operations and the Draft Plan.

The Draft Plan is Not Protective of the Fishery

Sacramento River winter-run Chinook salmon are listed as endangered under both the federal Endangered Species Act (ESA) and California Endangered Species Act (CESA) and Sacramento Valley spring-run Chinook salmon are listed under ESA and CESA as threatened. Both species have experienced magnitude declines and their continued existence is seriously in doubt.

The extent of the decline is illustrated by the following graphs of mainstem Sacramento River adult escapement that were extracted from the University of Washington website that is funded by Reclamation for Central Valley Project Improvement Act and ESA purposes.[22]

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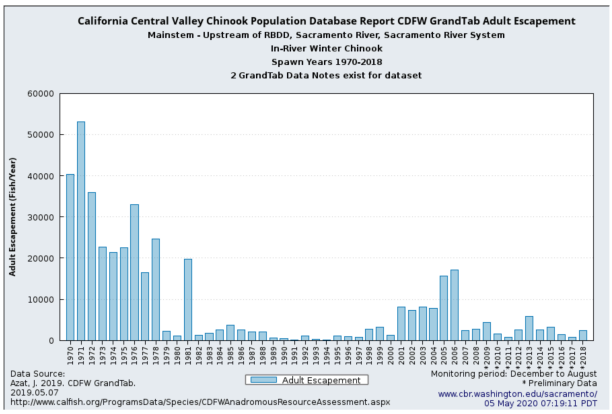
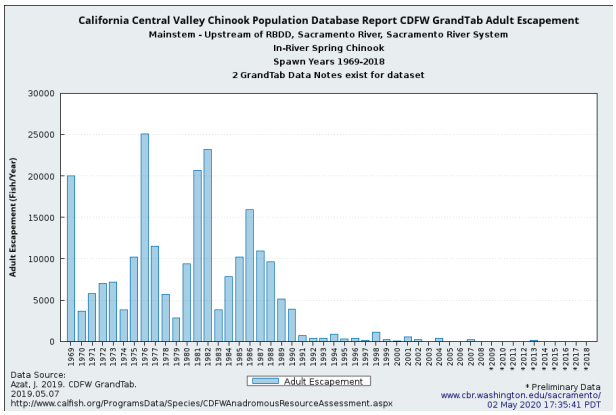
[20] University of Washington website (SacPas: Central Valley Prediction & Assessment of Salmon), Performance Measures RPA I.2.1 End-of-September Carryover Storage. http://www.cbr.washington.edu/sacramento/data/pm_storage_RPAI.2.1.html.

[21] California's Attorney General's Office, First Amended Complaint for Declaratory and Injunctive Relief, 21 April 2020, No. 80 pp. 22, 23 and No. 81 pp. 23, 24. Available at: http://calsport.org/news/wp-content/uploads/CNRA-et-al.-v.-Ross-et-al.-First-Amended-Complain-042120.pdf.

[22] Available online at: http://www.cbr.washington.edu/sacramento/data/query_adult_grandtab.html.

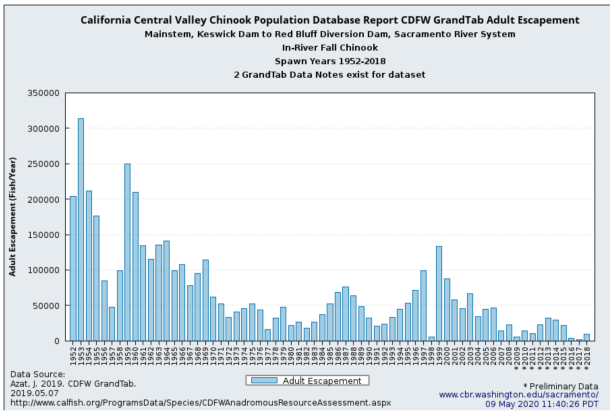


Winter-run upstream of Red Bluff 1970-2018

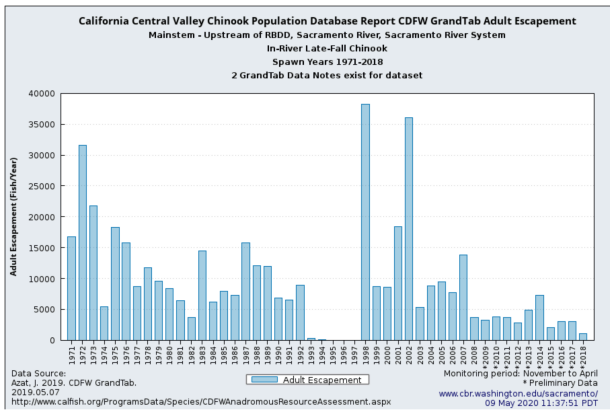


Spring-run upstream of Red Bluff 1969-2018

But Reclamation's failure to comply with protective temperature requirements below Shasta Dam has also led to significant declines of fall-run and late fall-run Chinook salmon. Spawning.



Fall-run upstream of Red Bluff 1970-2018



Late fall-run upstream of Red Bluff 1969-2018

While the Basin Plan, Order 90-05 and the NMFS 2009 Biological Opinion employed a 56ºF daily average temperature standard, scientists with NMFS have concluded that these requirements fail to protect salmon and that mortality occurs when maximum daily temperatures exceed 53.5ºF when eggs are laid. In recent years, NMFS has been recommending a 55ºF seven-day daily maximum (7 DADM) to protect areas where spawning occurs.

The Draft Plan proposes to meet a daily average temperature at Balls Ferry (RM 276) of 56ºF through mid-September and a daily average temperature at Clear Creek (RM 292) of 54.5ºF (beginning 14 May), 53.5ºF (beginning 31 May), 54ºF (beginning 30 June), 56ºF (beginning 21 September through 31 October). A 56ºF or even a 54ºF daily average is not protective of spawning. We also note the lack of proposed temperature standards after 31 October, before all winter-run Chinook salmon have emerged from their redds.

Reclamation estimates that the Draft Plan will kill 27-28% of critically endangered winter-run Chinook salmon as a result of temperature dependent mortality. This projected temperature dependent mortality rate is far higher than the 8% mortality rate NMFS recommended for a dry year in the 2017 proposed amendment to the 2009 Biological Opinion[23] or the 12% mortality rate NMFS said should not be exceeded in a year like 2020 to avoid jeopardy in the 1 July 2019 Biological Opinion.[24] Reclamation's modeling should be considered with caution as it has been severely criticized over the years as underestimating actual temperature and salmon mortality. The Draft Plan employs less conservative meteorological data than NMFS recommends that more accurately reflects actual air temperature and allows an escape hatch, which would permit higher mortality and water temperatures due to "unforeseen conditions." And, as noted above, compression of spawning habitat into a ten-mile reach between Clear Creek and Keswick Dam leads to superimposition of redds and resulting spawning failure causing additional losses. Actual temperature dependent mortality is likely to be considerably higher than Reclamation's 27-28% estimate. But even that number cannot be justified as "reasonably protective" of species on the brink of extirpation.

Order 90-05 and the Basin Plan are not limited to protecting winter-run Chinook salmon; they also protect spring-run and fall-run Chinook salmon, which spawn later. The Draft Plan fails to even mention spring-run and fall-run Chinook salmon, let alone analyze or discuss impacts to these species or propose any temperature standards after 31 October. Review of the Draft Plan's proposed Shasta summer river release schedule (12,000+ cfs in June and July) raise serious concern about whether there will be sufficient remaining cold water to protect spring-run and fall-run Chinook salmon.[25]

Conclusion

There are reasonable measures within Reclamation's control that can be implemented to provide significantly better protection for fisheries and water quality. CSPA urges the State Board to reject the Draft Plan and require Reclamation to submit a revised plan that:

1. Given Reclamation's well documented modeling flaws, evaluates alternatives using reasonable assumptions, Board approved model inputs and a margin of safety.
2. Addresses protection of spring-run and fall-run Chinook salmon.
3. Reduces contractor deliveries.
4. Reduces projected temperature dependent mortality of winter-run Chinook salmon.
5. Maintains protective water temperatures throughout the 15 May - 31 October compliance period and provides reasonable temperature protection of spring-run and fall-run Chinook salmon.

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[23] NMFS, Proposed Amendment to the Reasonable and Prudent Alternative of the 2009 Opinion, 19 January 2017: http://calsport.org/news/wp-content/uploads/nmfs_s_draft_proposed_2017_rpa_amendment_-_january_19__2017.pdf.

[24] NMFS, Biological Opinion regarding long term operations of the Central Valley Project and State Water Project, 1 July 2019, p. 946: https://www.documentcloud.org/documents/6311822-NMFS-Jeopardy-Biop-2019-OCR.html.

[25] Reclamation, Draft Temperature Management Plan Water Year 2020, Estimated CVP Operations, Monthly River Releases, pdf pp. 12, 13. Available at: http://calsport.org/news/wp-content/uploads/4-30-20-drafrt-TMP.pdf.

6. Provides increased carryover storage.
7. Bypasses power penstocks during hotter daytime periods.
8. Increases release of cold water from Trinity River via Whiskeytown Reservoir in spring and early summer and reduces such release when temperatures increase in late summer/early fall.
9. Establishes a timeline to implement long overdue fixes to the Whiskeytown Reservoir temperature control curtain and Shasta Dam temperature control tower outlets.

For succeeding years, CSPA urges the State Board to require Reclamation to evaluate scenarios that include an array of measures, including water delivery reductions, sufficient to achieve temperature compliance at each of the identified temperature compliance points of Clear Creek, Balls Ferry, Jelly's Ferry, Bend Bridge and Red Bluff Diversion Dam. Scenarios should also include increased overwinter storage necessary to meet temperature requirements in the event of a subsequent dry or critical water year.

The State Board must protect its water right and water quality authority and fulfill its obligation to protect the public trust resources of the Sacramento River. Reclamation's intransigence in responding to the State Board's reasonable requests make clear the need for a more transparent and timely Order 90-05 review process.

We appreciate the opportunity to review and comment on the Draft Plan. Thank you for considering our comments.

Respectfully submitted,

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Attachment 1

Review of U.S. Bureau of Reclamation's Draft Sacramento River Temperature Management Plan for 2020

Prepared by
Thomas Cannon

For the
California Sportfishing Protection Alliance

May 11, 2020

Review of U.S. Bureau of Reclamation's Draft Sacramento River Temperature Management Plan for 2020

Summary

The Draft Sacramento River Temperature Management Plan (TMP) for 2020 (April 23, 2020, revised on April 30, 2020) lays out the Bureau of Reclamation's plan to operate the Shasta/Trinity Division of the CVP. In the TMP, Reclamation describes how it will use Shasta Reservoir's cold-water pool (portion of deeper stored water colder than 50°F) to maintain cold water in the Sacramento River downstream of Shasta Reservoir from May through October in order to benefit and protect winter-run Chinook salmon.

The Sacramento River must be cool to sustain eggs, embryo, and alevin in gravel spawning beds (redds). If water warms above about 53°F in the 30-mile spawning reach below Keswick Dam (RM 300) near Redding, significant mortality of winter-run will start to occur, and spawning fish will move upstream for more optimal water temperatures, potentially crowding prime spawning habitat.

A daily average water temperature of 56°F at Red Bluff (RM 240) is generally considered protective of 97% of the spawning distribution from Redding to Balls Ferry (RM 270), because it maintains water temperatures upstream of Balls Ferry below 54°F. In recent years, Reclamation and the fisheries agencies have treated a daily average temperature of 56°F at Balls Ferry (RM 270) as adequate protection, based on recent studies for the upper 10 miles of the spawning reach where the majority of the winter-run spawning occurs. Protective means there is an adequate cold water pool supply in Shasta Reservoir to sustain the primary 10-mile spawning reach below 54°F through October. A more optimal regime would be to sustain the entire 30-mile spawning reach down to near Balls Ferry by meeting the original Water Right Order 90-05 requirement of 56°F at Bend/Red Bluff. Shifting the compliance point in recent years (including wet years such as 2019) from Bend/Red Bluff to Balls Ferry has forced more winter-run spawning upstream into the 10-mile prime spawning reach below Keswick Dam, the upstream limit of salmon migration. Overall, it has not protected the winter-run population, which has continued to decline and become more dependent on hatchery contributions.

The October 2019 Biological Opinion (B0) specifies management of the spawning reach in four water year types (Tiers 1-4, wettest to driest). Year 2020 has been designated a Tier 3 (critically dry, low precipitation and snowpack) year. Despite its relatively high Shasta storage on May 1, Reclamation states in its TMP that there is potential to run out of cold water later in the season. Thus Reclamation proposes to exercise the management option in the BO to move the 56°F compliance point upstream from Balls Ferry (RM 270) to Clear Creek (RM 290) during the summer season. In moving the compliance point upstream, Reclamation proposes to accept some significant winter-run mortality (27-28%) in order to prevent nearly complete mortality (95%) such as that which occurred in 2015, when Reclamation ran out of cold water in Shasta Reservoir even after moving the compliance point to Clear Creek.

Water Right Order 90-05 places conditions on Reclamation's water right, requiring operation of Shasta Reservoir to protect water temperatures in the Sacramento River downstream, with annual approval by the State Water Resources Control Board (Board). In the draft TMP, Reclamation asks the Board to approve, if necessary, the relocation of the Sacramento River temperature compliance point upstream to Clear Creek in 2020. This relocation would allow Reclamation to meet commitments to supply 75% deliveries to Sacramento River Settlement Contractors, 75% deliveries to North of Delta (NOD) CVP municipal and industrial contractors, and 50% deliveries to NOD CVP agricultural contractors, and to maintain a 460 thousand acre-feet (TAF) end-of-September (EOS) Shasta cold water pool (CWP) to protect those spring-run and fall-run salmon that spawn in the Sacramento River. The higher EOS storage will also limit the potential for dewatering the redds of late-fall-run, spring-run and fall–run Chinook salmon, and will preserve storage for the following year's water needs.

But dry year 2020 is not a water supply year like 2015. Year 2019 was a wet year, whereas years 2013 and 2014 were critical drought years. At the end of April 2020, Shasta Reservoir had 3.6 million acre-feet (MAF) of water in storage, compared to 2.6 MAF in 2015. Reclamation has already prescribed higher deliveries to water contractors in 2020 than 2015. April 2020 CVP contractor deliveries in the Sacramento Valley and Delta were much higher than April deliveries in 2015 or 2016. Despite the better water supply conditions in 2020, Reclamation requests the Tier 3 option with a 2015 compliance regime, so that Reclamation can meet the higher 2020 contractor commitments, while acknowledging a substantial mortality to winter-run salmon 2020 egg/fry survival (27%). Though Reclamation proposes to shift the compliance point only in late summer, this will harm winter-run redds in the lower spawning reach and will harm spring-run and fall-run at the peak of their spawning throughout the entire 60-mile spawning reach above Bend/Red Bluff. **Such a late season shift in compliance point may force more spring-run and fall-run spawners to spawn in the prime 10-mile spawning reach immediately below Keswick, resulting in significant disturbance (superimposition) of winter-run redds, as well as spring and fall run redds.**

In past drier years similar to 2020, including recent drier years like 2010, 2012, 2016, and 2018, the Balls Ferry target has been met. In drought years 2007-2009 and 2013, the target was largely met. Reclamation can meet Balls Ferry compliance in 2020, as it did in 2016, a year with a similar May 1 CWP volume. Dry year compliance has occurred by shifting compliance from Red Bluff to Jellies Ferry or Balls Ferry, and reducing allocations and deliveries of Shasta/Trinity water to NOD and SOD contractors. Year 2020 compliance can be achieved in the same way. With the anticipated lower spring through fall inflows to Shasta in 2020, reducing downstream deliveries is entirely reasonable. Even 75% Settlement contractor delivery allocations are higher than expected inflows. Settlement contractors should not expect deliveries beyond natural inflows to Shasta, which are the basis of their underlying water rights. Such deliveries would put an unreasonable burden on downstream storage-right contractors and salmon populations.

How might maintaining the 2020 compliance point at Balls Ferry be accomplished?

1. Reduce contractor allocations and deliveries
2. Take more Trinity water though the spring when it is colder (preserves Shasta storage and CWP).
3. Take less Trinity water in late summer when it is warmer (preserves Shasta CWP).
4. Reduce peak-power-demand hydropower generation at Shasta Dam during the warmer afternoons and increase releases to Keswick Reservoir in cooler periods of the day (preserves Shasta CWP).

5. Shift contractor demands to later in summer or even fall-winter (preserves Shasta storage and CWP), noting that shifting demands has only limited potential.
6. Implement prescribed fixes to the Whiskeytown Reservoir temperature control curtain and Shasta Dam's temperature control tower outlets (preserves Shasta CWP).

Reclamation Proposal

Reclamation requests approval from the State Water Resources Control Board to adopt a Tier 3 water year designation as stipulated in the October 2019 BO LTO. Specifically, the request is to shift the Water Right Order 90-05 56°F Daily Average Temperature compliance point from the present Balls Ferry gage (BSF) to the gage upstream above the mouth of Clear Creek (CCR), thus maintaining EOS Shasta CWP at 460 TAF. The proposal would result in substantial winter-run egg-embryo mortality (~27%), but would forestall loss of Shasta's cold water pool before the end of October, with associated possibility of 95% mortality as occurred in 2014 and 2015. Reclamation's modeling efforts predict without such change there would be insufficient cold water to sustain egg-embryo salmon through October in the entire spawning reach, causing a catastrophic failure of winter-run for brood year 2020.

This Review

This review intends to show that it remains possible to sustain high survival of the brood year by keeping the designated compliance point at Balls Ferry as was possible in 2016 and 2018, drier years not unlike 2020.

Comparison of 2020 with 2016

The focus of this review is on comparing 2020 with 2016, a similar dry year when the BSF 56°F compliance point was met after 15 June. If Reclamation complied in 2016, it can comply in 2020.

To start, consider April and early May in these two years for Shasta reservoir. Year 2016 had higher Shasta storage conditions in early May 2016 (Figures 1 and 2). Shasta storage was 400 TAF (10%) less in 2020 (Figure 3). Shasta inflow in April and early May was slightly lower in 2020 (Figures 4 and 5). Air temperatures were similar (Figures 6-8). Shasta releases were higher (about 70 TAF) in April and early May in 2020 (Figures 6-8) to meet higher NOD and SOD demand/deliveries. In total, this put Shasta storage about 500TAF less in 2020 compared to 2016.

There are two primary ways to make up the deficit: Allowing end of September storage of 2.3 MAF in 2020 compared to 2.8 MAF IN 2016, or reducing contractor deliveries from 1.8 MAF to 1.3 MAF (2015 level, Figure 9), or combinations thereof. The problem with further reducing storage is that even at the 2016 level, the target end of September CWP target of 460 TAF cannot be met. It took a 2019 EOS storage of 3.2 MAF to achieve EOS storage of 460 TAF of CWP (Figure 10). Note the 2009 BO mandated EOS storage of only 1.9 MAF. Given that expected Shasta inflows are lower in 2020 than 2016, delivery allocations should also be lower.

Other options to conserve the CWP this summer include the following:

1. Take more Trinity water through the spring when it is colder (preserves Shasta storage and CWP). The Spring Creek Powerhouse (SPP) water temperature remains at 50°F or below, lowering the need for cold water from the Shasta TCD (Figure 6). The amount of potential savings is small given that summer is nearly here.

2. Take less Trinity water in late summer when it is warmer (preserves Shasta CWP). Reducing late summer Trinity (SPP) warm water (>54F) inputs reduces Shasta CWP use if deliveries are reduced similarly.
3. Reduce peak-power-demand hydropower generation at Shasta Dam during the warmer afternoons and increase releases to Keswick Reservoir in cooler periods of the day (preserves Shasta CWP). The savings of CWP could be significant especially at high release levels of 10,000 cfs (20 TAF/d) or higher.
4. Shift contractor demands to later in summer or even fall-winter (preserves Shasta storage and CWP). Most of this potential occurs in early spring, so the potential employment of this tool is minimal during the remainder of 2020. This option was not employed in early spring in 2020 (Figure 11).
5. Implement prescribed fixes to the Whiskeytown Reservoir temperature control curtain and Shasta Dam's temperature control tower outlets (preserves Shasta CWP). These options could preserve significant amounts of CWP storage.

Other Comments

2020 Sacramento River Temperature Task Group Meeting Notes

The Sacramento River Temperature Task Group (SRTTG) advises Reclamation on real time operations. The SRTTG reports on the temperature requirements as specified in the State Water Resource Control Board (SWRCB) Water Rights Order (WR) 90-5 and also the required actions in NMFS' biological opinion. The SRTTG has concluded:

- In most years, it is not possible to attain 56°F at Bend Bridge, and the SRTTG will advise that the TCP be established farther upstream.
- 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.
- Clear Creek (CCR) daily average temperature of 53˚F (a surrogate for 55˚F 7DADM) is recommended. That target was met in 2016 (Figure 12), but not in the critical drought years of 2013-2015.

Historical Data 1970s-1980s-1990s

Average or medium daily temperatures at Bend Bridge (RM 260) were maintained in the 56-58°F range in summer in the 1970-80 decade except in critical drought years 1976 and 1977 (Figure 13). The exceptions in 1976-77 are most likely the cause of the winter-run salmon crash in 1979-80 (Figures 14 and 15). The 1981 dry year conditions including summer warm water releases from Shasta/Keswick (Figure 16) also contributed to the initial crash by reducing survival of the last strong run year in 1981. Extreme conditions in the 1987-1992 drought (Figure 17) were the primary cause of the 1991 and 1994 population extreme lows. These same conditions plus redd dewatering in the late fall likely were a major factor in the demise of the upper Sacramento spring run salmon population (Figure 18).

Downstream Effects

Low flows and high deliveries in spring 2020 led to high water temperatures in the lower Sacramento River that threaten immigrating adult winter-run salmon (Figure 19).

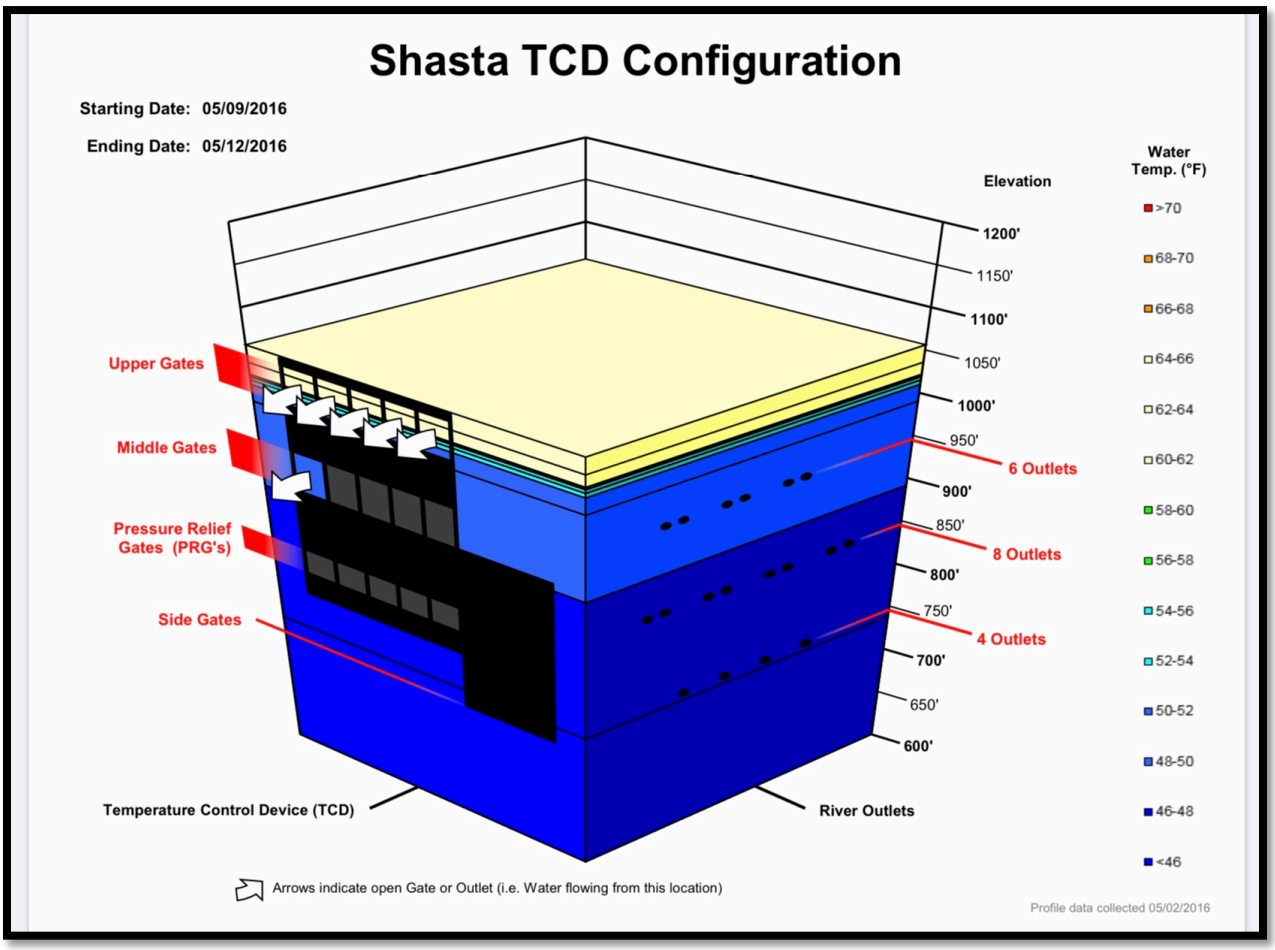


Figure 1. Shasta Reservoir water temperature profile and TCD gate operation in early May 2016.

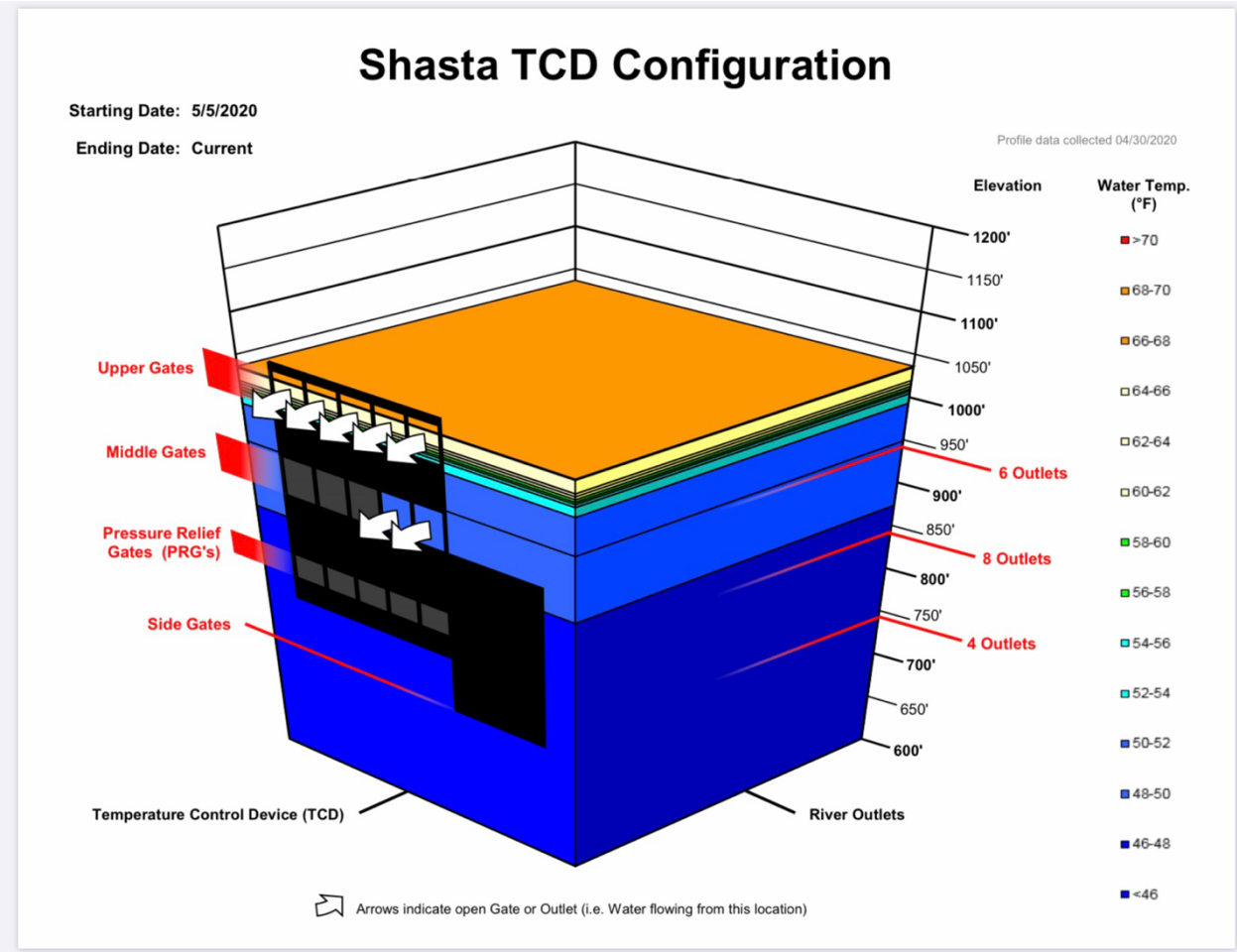


Figure 2. Shasta Reservoir water temperature profile and TCD gate operation in early May 2020.

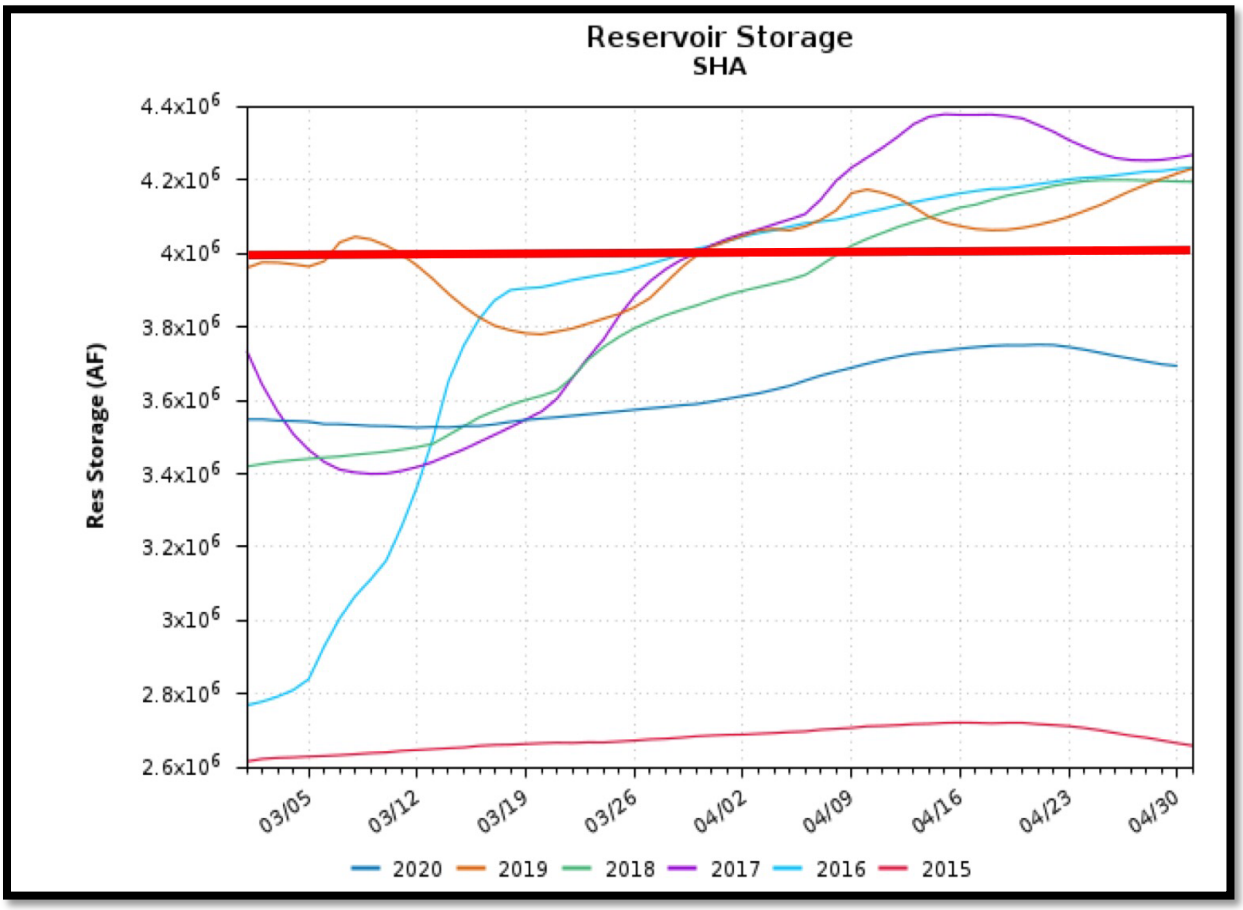


Figure 3. Mar-Apr Shasta storage 2015-2020. Red line is target storage to apply spring flow pulse prescription in BO LTO.

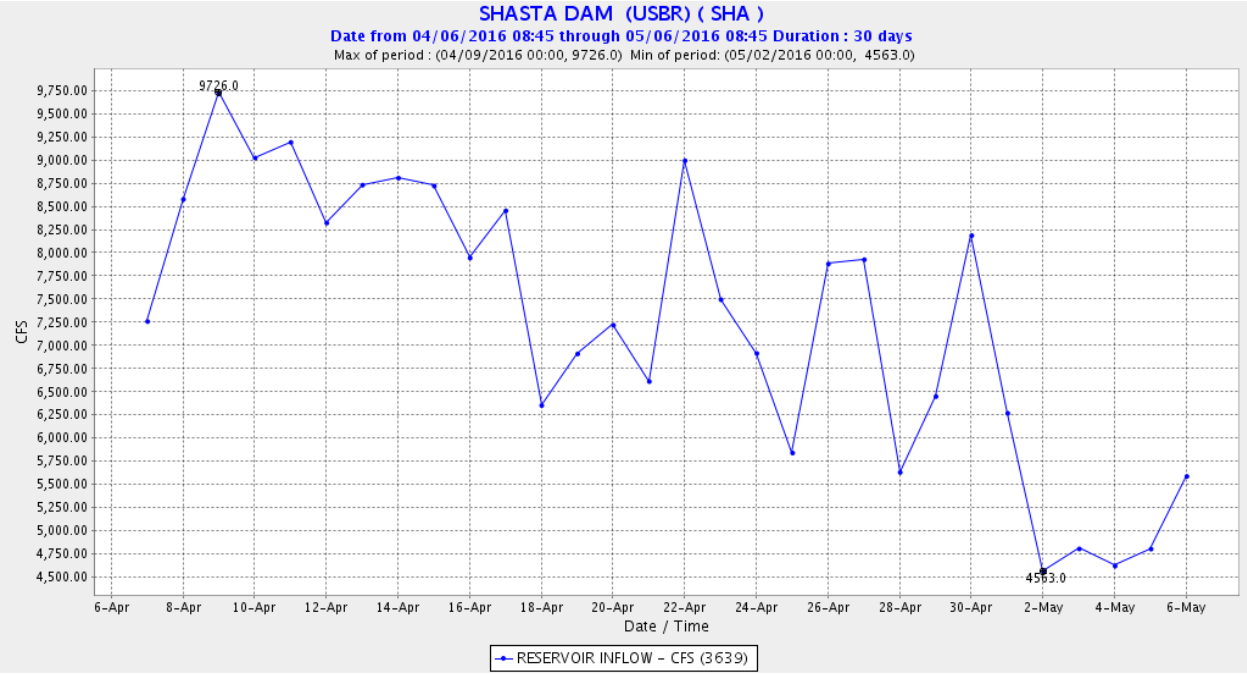


Figure 4. Inflow to Shasta Reservoir Apr-May 2016.

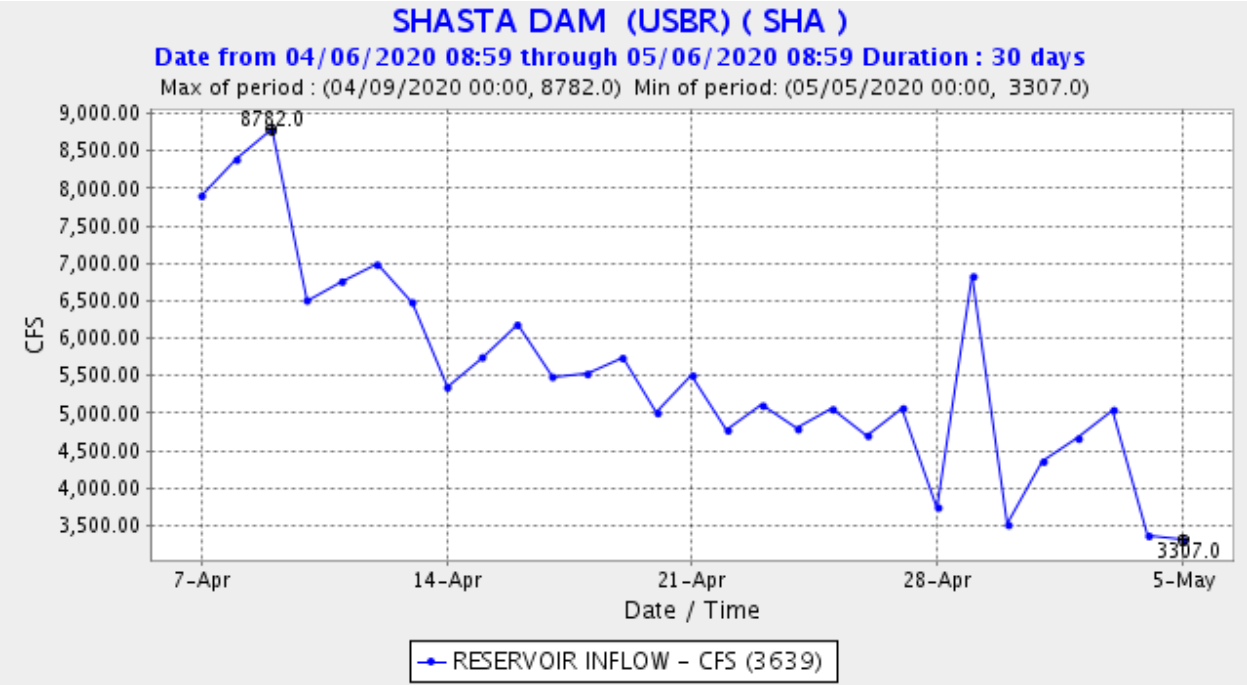


Figure 5. Inflow to Shasta Reservoir Apr-May 2020.

DATE	Mean Daily Water Temperatures (°F)													Mean Daily Release (CFS)			Mean Daily Air Temperatures (°F)			
	TCD[1]	SHD	SPP[1]	KWK	SAC	CCR	BSF[2]	JLF	BND	RDB	IGO	LWS	-----	Shasta Generation	Spring Creek P.P.	Keswick Total	RDD	BSF	RDB	LWS
Mar	49.4	48.7	48.7	49.2	49.6	50.0	50.6	51.3	51.6	51.9	49.0	47.6	-	3693	969	4891	53.2	51.7	53.3	-
04/01	49.2	48.6	49.6	49.2	49.9	50.3	**51.5**	52.5	53.0	53.6	50.3	47.9	-	3219	1644	4949	50.5	49.9	52.6	-
04/02 #	-	? 49.1	49.5	49.4	50.1	50.6	**51.4**	52.2	52.5	53.0	50.3	47.8	-	2731	1907	4958	53.0	52.2	53.5	-
04/03 #	-	48.7	49.5	49.3	50.1	50.7	**51.7**	52.5	52.9	53.4	50.5	47.8	-	2795	1880	4956	50.5	50.7	52.9	-
04/04 #	-	? 48.5	49.1	49.3	49.5	49.5	**50.2**	51.2	51.8	52.5	49.0	46.3	-	3249	1909	4961	46.0	45.3	47.1	-
04/05 #	-	48.6	48.9	49.1	49.6	49.8	**50.1**	50.5	50.5	50.6	49.2	46.7	-	2635	1800	4958	51.0	51.8	51.4	-
04/06 #	-	48.8	49.1	49.0	49.9	50.5	**51.3**	51.9	52.0	52.1	50.3	47.1	-	3127	1813	4794	54.0	51.3	52.1	-
04/07 #	-	49.4	48.9	49.2	50.1	50.7	**52.3**	53.3	53.6	54.0	50.9	48.2	-	2592	1814	4610	54.5	53.5	54.9	-
04/08 !	-	50.4	48.8	49.9	50.8	51.6	**53.5**	54.6	55.0	55.4	52.0	49.0	-	2496	1900	4493	66.5	61.0	62.1	-
04/09	50.8	50.5	48.6	49.8	50.6	51.3	**53.6**	55.1	55.8	56.2	50.8	49.7	-	2708	1830	4500	53.5	54.7	54.7	-
04/10	50.4	50.0	48.6	50.2	51.3	52.2	**54.1**	55.2	55.7	56.5	52.4	51.0	-	1952	1834	4478	63.0	61.9	63.2	-
04/11	51.0	49.9	48.8	50.5	51.6	52.7	**55.3**	56.8	57.4	58.1	52.6	51.4	-	2342	1944	4483	62.5	61.5	62.0	-
04/12	51.5	? 51.1	48.7	51.1	52.0	53.0	**55.7**	57.5	58.3	59.3	52.7	51.7	-	1911	1819	4478	65.5	65.1	66.0	-
04/13	51.5	? 50.6	48.8	51.3	52.1	52.9	**55.1**	56.5	57.1	58.2	51.5	50.8	-	3172	1368	4472	62.0	58.3	61.5	-
04/14	51.6	! -	48.9	50.9	51.9	52.8	**54.7**	55.9	56.4	57.4	51.5	49.8	-	3075	1797	4982	60.0	58.3	61.9	-
04/15	51.8	? 51.1	49.0	51.0	51.8	52.7	**54.7**	56.0	56.6	57.6	51.9	49.5	-	3328	1883	5466	64.5	62.3	62.5	-
04/16	52.5	? 51.6	? 49.0	51.5	52.3	53.2	**55.0**	56.4	56.9	57.8	52.3	49.7	-	3497	1866	5501	68.0	63.6	64.6	-
04/17	52.1	! -	49.0	51.4	52.3	53.2	**55.2**	56.6	57.1	58.0	52.1	49.0	-	3712	1888	5888	68.5	61.9	64.3	-
04/18	51.8	! -	? 49.0	51.6	52.1	52.7	**54.4**	55.7	56.4	57.6	51.8	49.0	-	3914	1850	6246	59.0	58.3	58.4	-
04/19	52.2	51.6	49.2	51.5	52.3	53.0	**54.5**	55.6	56.0	56.7	52.1	48.9	-	5252	1928	6676	59.5	59.4	59.5	-
04/20	52.5	51.6	49.2	51.4	52.0	52.5	**54.1**	55.3	55.7	56.7	51.8	49.6	-	4901	1933	6969	59.0	56.3	57.4	-
04/21	52.8	? 52.3	49.4	51.8	52.5	53.1	**54.6**	55.6	55.9	56.5	52.4	49.9	-	5127	1917	7466	63.0	60.9	62.1	-
04/22	52.7	51.8	49.5	52.2	52.8	53.4	**55.1**	56.3	56.8	57.7	52.5	49.1	-	5859	1893	8265	64.0	64.3	66.4	-
04/23	53.5	52.8	49.6	52.6	53.2	53.8	**55.5**	56.7	57.2	58.1	53.1	49.2	-	8282	360	9000	66.0	66.0	69.8	-
04/24	54.0	53.2	50.9	53.4	53.9	54.6	**56.0**	57.1	57.5	58.3	53.0	49.1	-	9131	37	9403	70.5	66.9	70.6	-
04/25	53.4	52.8	50.9	54.0	54.3	55.0	**56.3**	57.4	57.9	58.7	53.3	48.9	-	8645	37	9499	70.5	67.8	70.5	-
04/26	52.9	52.2	49.6	53.4	54.3	55.0	**56.8**	58.1	58.5	59.1	53.5	48.9	-	9275	619	9755	68.5	67.6	71.2	-
04/27	52.6	51.3	49.8	52.7	53.4	54.0	**55.9**	57.4	58.0	59.4	53.5	49.2	-	8435	1137	9758	71.5	68.9	72.4	-
04/28	53.2	52.0	49.8	52.5	53.3	54.0	**55.8**	57.2	57.8	58.9	53.9	49.8	-	8045	594	9701	↑ 74.0	71.3	73.0	-
04/29	52.7	51.6	49.8	53.0	53.4	54.0	**55.6**	57.1	57.7	58.8	53.4	49.2	-	8210	1137	9764	73.0	70.9	70.8	-
04/30	52.5	51.4	49.9	52.7	53.2	53.9	**55.8**	57.2	57.7	58.7	53.6	49.2	-	7932	1920	9720	70.5	70.4	69.9	-
Apr	52.1	50.8	49.3	51.2	51.9	52.5	54.2	55.4	55.9	56.6	51.9	49.1	-	4718	1542	6505	62.1	60.4	62.0	-
05/01	53.2	? 51.7	49.8	52.3	52.8	53.4	**55.1**	56.5	57.0	58.2	53.0	49.6	-	7929	1920	9713	65.0	63.3	65.9	-
05/02	52.6	51.4	49.9	52.5	52.8	53.2	**54.7**	55.9	56.5	57.4	52.1	49.0	-	7358	1925	9705	63.5	60.5	63.8	-
05/03	53.2	? 51.5	50.0	52.2	52.7	53.2	**54.7**	55.7	56.1	56.8	52.4	48.8	-	7137	1890	9737	60.5	59.5	61.4	-
05/04	53.1	51.6	50.0	52.7	53.0	53.5	**54.6**	55.7	56.1	57.0	52.9	48.6	-	7614	1919	9724	63.0	61.3	63.8	-
05/05	51.9	50.8	50.2	52.7	53.1	53.7	? **55.2**	56.3	56.7	57.6	53.1	49.0	-	7447	1903	9648	66.5	63.9	66.8	-

Figure 6. April through early May 2020 water conditions below Shasta reservoir in 2020.

DATE	Mean Daily Water Temperatures (°F)														Mean Daily Release (CFS)			Mean Daily Air Temperatures (°F)			
	TCD[1]	SHD	SPP[1]	KWK	SAC	CCR[2]	BSF	JLF	BND	RDB	IGO	LWS	-----[3]		Shasta Generation	Spring Creek P.P.	Keswick Total	RDD	BSF	RDB	LWS
Mar	49.4	48.8	49.1	49.8	50.2	50.4	52.0	51.9	52.0	52.6	50.5	48.2	-		6043	1206	7445	56.7	54.7	59.6	47.5
04/01	50.9	49.6	50.3	51.4	52.2	52.8	# -	55.9	56.1	57.0	52.4	51.2	-		4584	28	4991	61.5	58.7	59.6	57.1
04/02	50.9	49.5	50.5	51.7	52.5	53.1	# -	56.7	57.0	58.0	52.8	51.6	-		2167	14	4900	63.5	60.5	62.4	58.2
04/03	50.8	49.8	50.5	51.6	52.6	53.3	# -	57.5	57.8	59.0	53.2	51.6	-		5460	219	4919	66.0	62.9	64.7	57.5
04/04	51.1	50.0	50.4	51.8	52.6	53.2	# -	57.3	57.8	59.2	52.4	51.7	-		4787	15	4840	64.0	63.0	64.3	54.9
04/05	52.6	50.9	50.5	51.6	52.4	52.9	# -	56.4	56.7	58.0	52.3	51.9	-		4678	15	4728	72.0	67.0	69.1	55.1
04/06	52.3	50.7	50.7	51.9	52.7	53.4	# -	57.1	57.4	58.4	52.9	52.5	-		5183	28	4587	↑ 76.0	67.1	71.2	61.8
04/07	51.7	50.3	50.7	52.8	53.7	54.2	# -	58.0	58.3	59.6	53.2	52.9	-		5124	18	4594	↑ 72.0	65.7	69.0	63.9
04/08	51.4	50.0	50.7	53.0	53.9	54.5	# -	58.5	58.9	60.1	53.3	53.5	-		4644	14	4587	66.0	63.9	65.1	63.7
04/09	50.8	49.5	50.2	52.4	52.9	53.4	# -	57.8	58.3	59.5	52.4	53.3	-		3622	893	4582	63.0	61.0	60.5	58.1
04/10	51.1	49.5	50.7	52.0	52.5	53.0	# -	56.1	56.5	57.7	52.6	53.1	-		4799	18	4588	62.5	60.0	60.9	58.3
04/11	50.9	49.6	50.1	51.3	52.1	52.7	# -	56.5	56.8	58.0	52.7	53.5	-		3401	1124	4588	65.0	63.3	63.9	58.8
04/12	51.2	50.0	50.6	51.1	51.5	52.0	# -	56.4	56.9	58.2	52.8	? 53.7	-		4462	18	4612	61.0	61.1	61.8	57.8
04/13	51.0	49.9	50.8	51.4	52.0	52.5	# -	55.8	56.0	57.3	52.1	52.5	-		4229	14	4659	58.5	57.6	59.8	51.8
04/14	50.9	49.8	51.1	51.5	51.5	51.8	# -	55.0	55.4	56.8	51.4	51.2	-		4694	14	4645	53.5	51.1	52.9	43.7
04/15	51.7	50.4	51.6	51.6	52.3	52.7	# -	54.6	54.7	55.5	51.5	52.3	-		4492	14	4648	57.5	54.5	57.7	48.9
04/16	52.4	50.9	51.9	51.7	52.5	53.2	# -	56.2	56.4	57.2	52.4	52.8	-		4442	14	4644	↑ 67.5	61.3	64.3	55.8
04/17	52.3	50.5	52.2	52.1	52.9	53.7	# -	57.4	57.8	58.8	53.0	53.0	-		4760	14	4647	↑ 69.5	64.5	68.0	60.1
04/18	52.3	51.4	52.4	52.7	53.7	54.3	# -	58.4	58.8	60.1	53.2	53.4	-		4887	14	4648	70.0	64.9	67.2	61.9
04/19	? 52.4	50.9	52.7	53.2	54.0	54.6	# -	59.2	59.7	61.0	53.5	53.9	-		4468	0	4648	71.5	66.0	68.5	62.0
04/20	? 52.1	50.5	52.8	53.2	54.1	54.9	# -	59.5	60.0	61.3	53.4	54.3	-		4598	14	4650	69.5	65.2	65.8	61.0
04/21	51.5	50.6	53.0	53.2	53.8	54.4	# -	58.6	59.2	60.6	52.2	52.6	-		4025	14	4667	63.5	61.2	63.0	54.2
04/22	51.9	? 51.0	53.2	53.0	53.0	53.3	# -	57.1	57.7	58.8	51.9	53.0	-		4535	14	4669	54.5	55.2	55.8	49.7
04/23	52.3	51.3	53.2	52.0	53.0	53.8	# -	56.1	56.2	57.0	51.8	53.0	-		4982	14	4667	57.5	55.6	56.4	51.0
04/24	52.3	50.7	52.8	52.5	53.1	53.7	# -	57.2	57.6	58.6	52.2	52.3	-		4781	14	4669	60.0	59.0	60.4	50.8
04/25	53.5	52.0	52.5	52.7	53.2	53.7	# -	56.4	56.7	57.7	51.8	51.8	-		4818	14	4669	58.0	56.0	57.6	46.4
04/26	53.2	51.7	52.7	52.8	53.2	53.5	# -	56.1	56.4	57.3	51.4	51.2	-		4708	14	4589	61.5	58.2	59.6	49.1
04/27	52.6	51.5	52.9	53.6	54.0	54.5	# -	56.3	56.6	57.2	52.0	50.3	-		4508	14	4689	59.0	57.5	58.1	48.6
04/28	53.0	51.6	53.1	53.6	54.5	55.1	# -	57.7	57.8	58.4	52.8	49.1	-		4550	14	4717	67.0	63.0	64.5	53.4
04/29	53.5	52.0	53.4	53.7	54.4	55.1	# -	58.7	59.2	60.2	53.2	48.9	-		4381	14	4743	69.5	62.8	65.4	54.7
04/30	53.9	52.6	53.6	54.0	54.7	55.2	# -	58.4	58.8	59.8	53.0	49.4	-		4757	14	4743	69.5	65.3	67.5	54.8
-																					
Apr	51.9	50.6	51.7	52.4	53.1	53.6	-	57.1	57.5	58.5	52.5	52.2	-		4518	88	4684	64.3	61.1	62.8	55.4
														Total CFS	135526	2642	140527				
														Total AF	268810	5240	278730				

Legend

Notes

Figure 7. April 2016 water conditions below Shasta reservoir.

DATE	Mean Daily Water Temperatures (°F)													Mean Daily Release (CFS)			Mean Daily Air Temperatures (°F)			
	TCD[1]	SHD	SPP[1]	KWK	SAC	CCR[2]	BSF	JLF	BND	RDB	IGO	LWS	-----[3]	Shasta Generation	Spring Creek P.P.	Keswick Total	RDD	BSF	RDB	LWS
Apr	51.9	50.6	51.7	52.4	53.1	53.6	-	57.1	57.5	58.5	52.5	52.2	-	4518	88	4684	64.3	61.1	62.8	55.4
05/01	53.5	51.9	53.9	54.4	55.2	55.8 #	-	59.4	59.8	60.8	53.4	48.4	-	5242	14	5178	72.0	70.3	71.8	58.1
05/02	53.0	52.3	54.3	54.6	55.5	56.1 #	-	60.1	60.6	61.9	53.4	47.9	-	5090	14	5192	68.0	65.3	67.8	58.6
05/03	53.6 !	-	54.5	54.4	54.9	55.4 #	-	59.4	60.1	61.6	52.7	47.8	-	5425	14	5192	69.5	64.9	67.8	56.1
05/04	54.2 !	-	54.6	53.9	54.3	54.8 #	-	58.3	58.8	60.1	52.9	47.6	-	5403	14	5672	69.5	63.5	66.0	56.3
05/05	52.8 ?	51.6	54.6	54.0	54.6	55.1 #	-	58.6	58.8	59.7	53.6	46.6	-	5577	14	5696	67.0	60.3	59.6	54.3
05/06	53.3 ?	51.9	54.5	54.2	54.6	54.9 #	-	57.8	58.3	59.5	52.9	46.5	-	5974	14	5692	60.5	58.7	59.1	54.7
05/07	52.8	51.6	54.5	53.4	53.6	53.9 #	-	56.8	57.2	58.1	52.5	46.3	-	5855	14	5756	59.5	58.6	59.1	57.8
05/08	53.2	52.2	53.9	53.0	53.7	54.3 #	-	57.3	57.4	58.1	53.0	46.7	-	5462	14	5842	65.5	63.2	63.2	61.3
05/09	52.2	51.9	53.4	53.3	54.1	54.7 #	-	58.7	59.2	60.8	54.2	46.8	-	5628	14	5953	72.0	68.1	67.8	63.9
05/10	52.0	51.0	53.3	54.1	54.8	55.4 !	-	59.5	59.9	61.4	54.1	46.1	-	6251	14	6237	73.5	68.1	70.5	62.0
05/11	52.1	50.8	53.5	52.9	53.9	54.8	57.9	59.5	60.1	61.6	53.7	46.2	-	5895	14	6242	71.5	67.9	71.7	62.0
05/12	51.7	50.5	53.3	52.9	53.7	54.4	57.6	58.9	59.8	61.5	53.9	46.6	-	5890	14	6241	72.0	68.9	71.0	62.5
05/13	51.8	51.0	53.2	52.7	53.8	54.6	57.5	59.4	60.3	61.9	54.5	46.7	-	5820	14	6199	75.0	71.7	72.1	66.0
05/14	51.6	50.6	53.3	52.8	53.4	54.2	57.1	58.9	59.8	61.4	53.7	46.2	-	5853	14	6193	65.5	64.3	63.9	59.7
05/15	51.9	50.8	53.3	52.7	53.6	54.5	57.0	58.7	59.5	61.0	53.8	46.2	-	5725	14	6194	68.5	67.8	70.0	58.4
05/16	50.9	50.1	53.3	52.6	53.5	54.4	57.1	58.8	59.8	61.4	54.2	46.7	-	5955	14	6193	74.5	71.0	72.6	60.8
05/17	50.7	50.0	53.3	52.6	53.7	54.7	57.4	59.1	60.0	61.5	54.3	47.2	-	6264	14	6195	80.5	75.6	76.9	63.3
05/18	50.7	49.9	53.6	51.7	52.7	53.9	57.1	59.2	60.3	62.2	54.6	46.8	-	6124	14	6192	79.5	76.1	79.3	66.4
05/19	50.9	50.2	52.9	51.8	52.6	53.6	56.4	58.3	59.4	61.1	54.0	47.2	-	6492	20	6191	72.0	67.8	72.8	59.3
05/20	50.6	49.9	51.9	51.3	51.5	52.1	54.0	55.4	56.4	58.2	52.3	47.3	-	6069	14	6193	56.0	55.5	56.4	50.0
05/21	50.3	49.4	51.8	50.8	51.2	51.8	53.5	54.4	54.9	55.6	52.1	46.5	-	5913	14	6193	58.5	56.1	56.8	47.7
05/22	51.3	49.6	51.8	50.6	51.1	51.8	53.6	54.7	55.4	56.4	52.8	46.4	-	5653	14	6193	62.0	59.3	59.9	52.6
05/23	51.0	50.2	51.9	51.0	51.6	52.3	54.5	55.5	56.0	57.1	53.5 ?	46.7	-	6077	14	6192	65.5	62.1	62.0	54.9
05/24	51.3	50.1	51.5	51.6	52.4	53.1	55.7	57.2	58.0	58.9	53.5	46.8	-	6475	70	6194	68.5	63.8	63.7	56.9
05/25	50.8	50.0	52.2	51.8	52.7	53.5	56.0	57.5	58.3	59.9	53.4	47.0	-	5828	14	6192	69.5	66.0	67.9	59.9
05/26	51.0	49.9	51.6	52.1	53.0	53.8	56.5	58.1	59.0	60.7	53.4	47.3	-	4796	1089	6229	70.0	69.0	70.8	61.0
05/27	51.0	50.2	52.4	52.1	53.0	53.8	56.6	58.3	59.3	60.9	53.7	47.5	-	6297	14	6243	72.0	71.0	73.1	60.0
05/28	51.3	50.1	52.2	52.0	52.9	53.8	56.5	58.1	59.1	60.7	54.0	47.9	-	5571	14	6242	77.0	74.6	76.4	61.8
05/29	51.4	49.9	52.3	52.0	52.9	53.8	56.6	58.4	59.4	61.1	54.9	47.7	-	6369	14	6241	75.0	74.4	74.8	64.9
05/30	51.6	50.0	52.3	52.4	53.3	54.2	57.1	58.9	59.9	61.7	55.4	47.8	-	5548	14	6243	83.5	77.1	78.1	67.7
05/31	51.5	50.4	52.3	52.5	53.5	54.5	57.5	59.5	60.6	62.4	55.7	47.9	-	6478	20	6244	↑ 80.5	79.1	80.8	70.2
May	51.8	50.6	53.1	52.7	53.4	54.1	56.3	58.2	58.9	60.3	53.7	47.0	-	5839	51	6027	70.1	67.1	68.5	59.6
												Total CFS		180999	1577	186849				
												Total AF		359004	3128	370607				

Legend

Notes

Figure 8. May 2016 water conditions below Shasta reservoir.

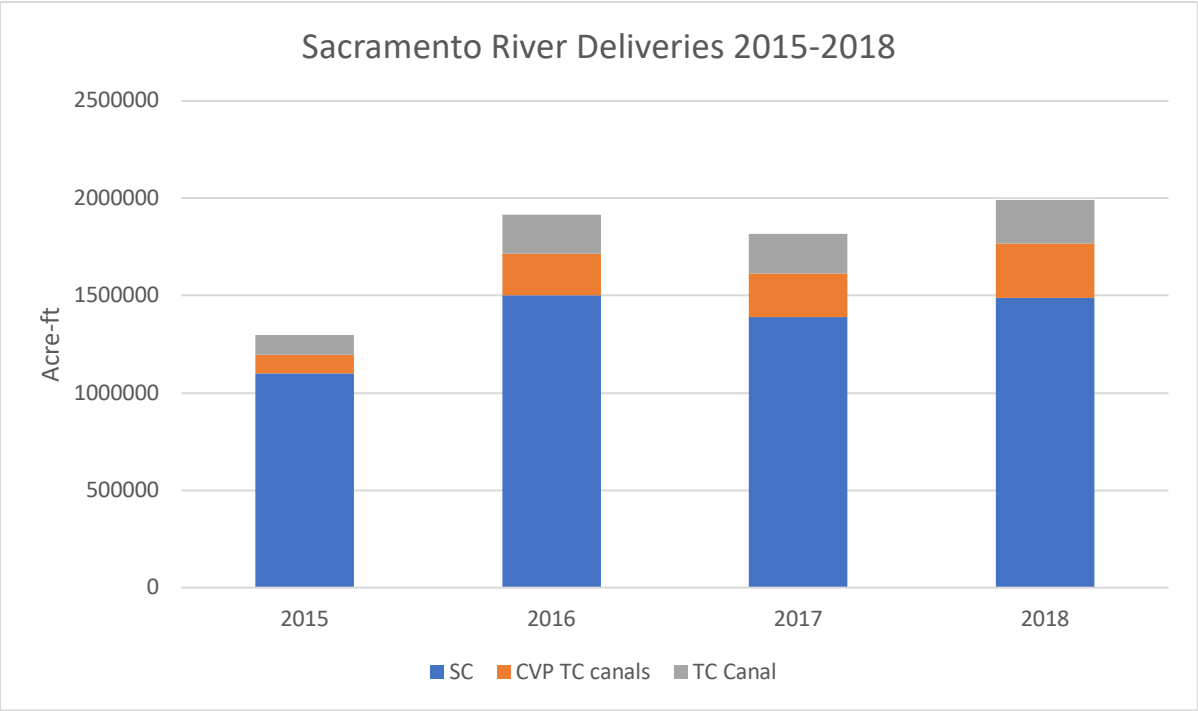


Figure 9. Annual Shasta reservoir Sacramento River contractor deliveries 2015-2017.

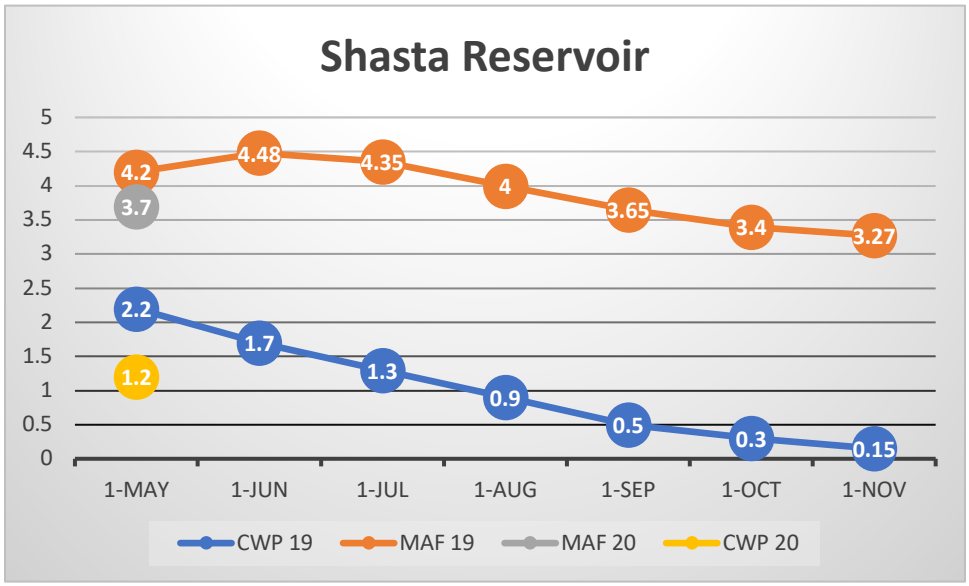


Figure 10. Shasta reservoir total and cold-water pool (<50°F) storage (MAF) on first day of month May-Nov 2019 and May 2020.

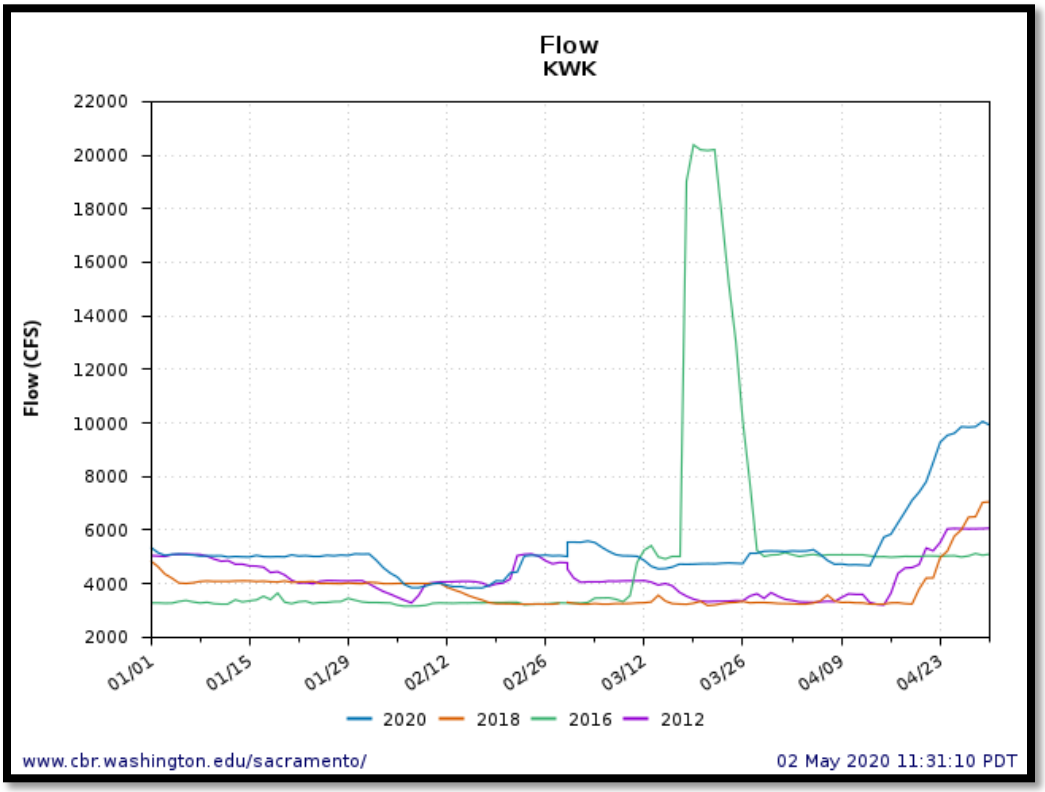
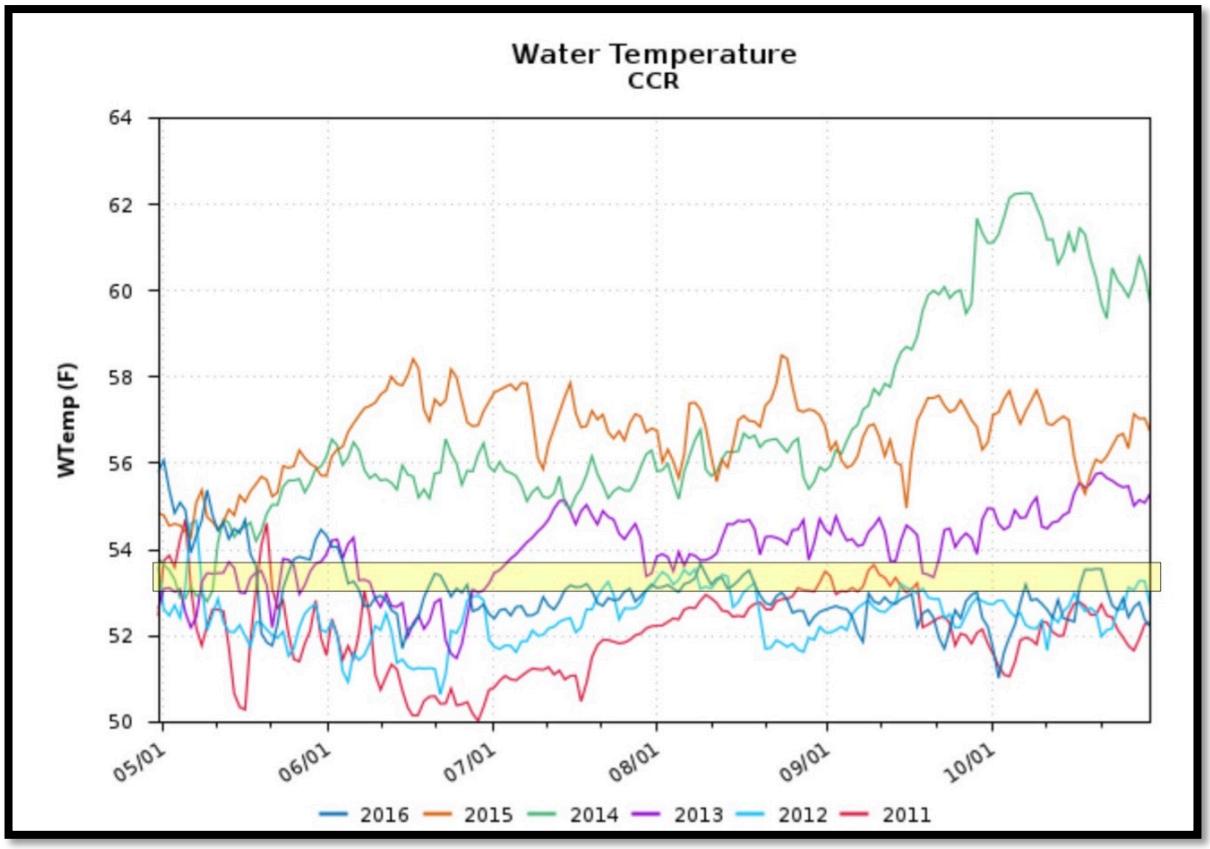


Figure 11. Daily average Sacramento River streamflow below Shasta/Keswick dams from January through April of dry-normal water years 2012, 2016, 2018, and 2020. Note prescribed spring flow pulse in 2016 in late March as Shasta storage approached 4 MAF.



.Figure 12. Water temperature in upper Sacramento River at Clear Creek gage (CCR) May 1-Oct 31 2011-2016. Target temperature of 53.5°F is in yellow highlight. Note water temperature exceeded target in summer and fall of 2013-2015 critical drought years, thus leading to substantial winter run salmon egg/alevin mortality.

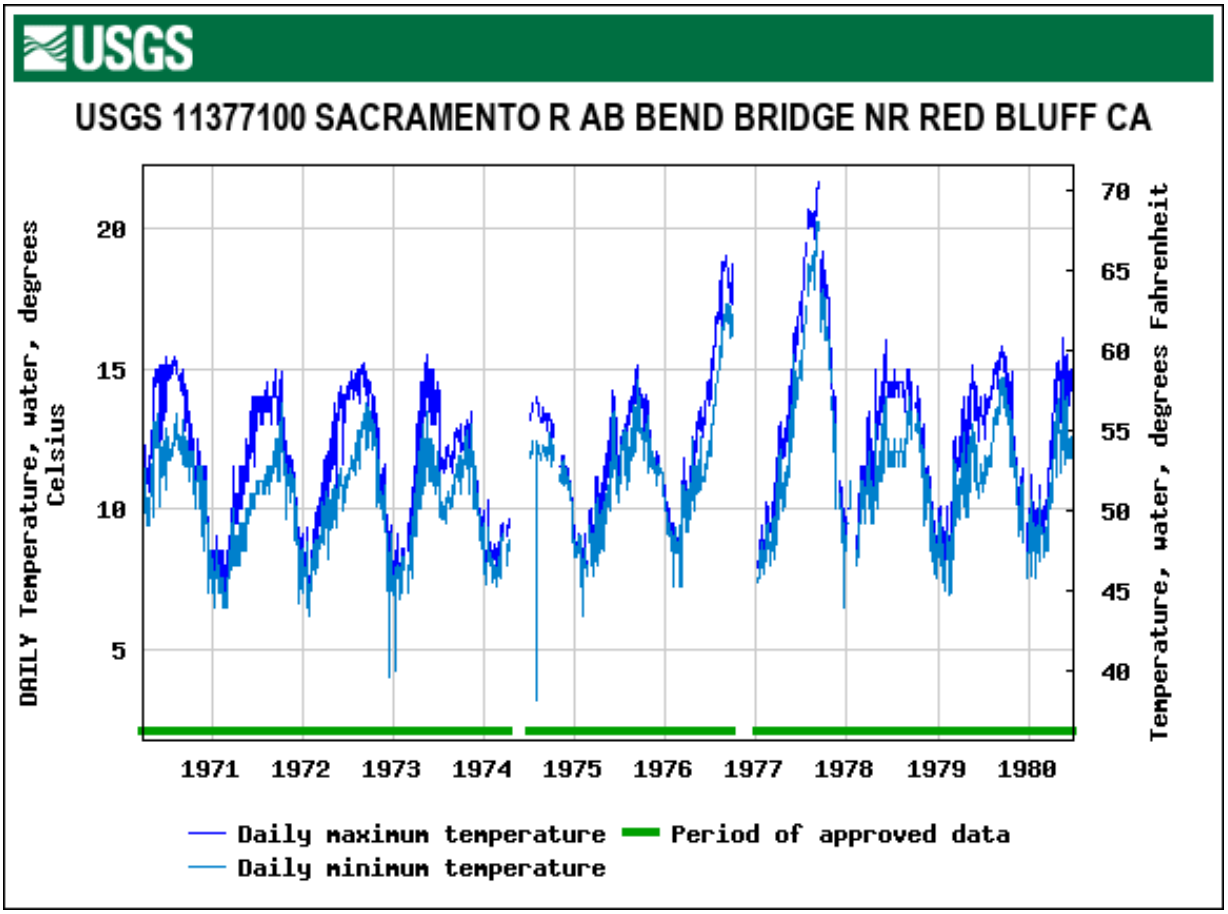


Figure 13. Daily minimum and maximum water temperature in upper Sacramento River at Bend Bridge (RM 256) 1987-1993. Note warm late summer and fall conditions during 1976-1977 drought.

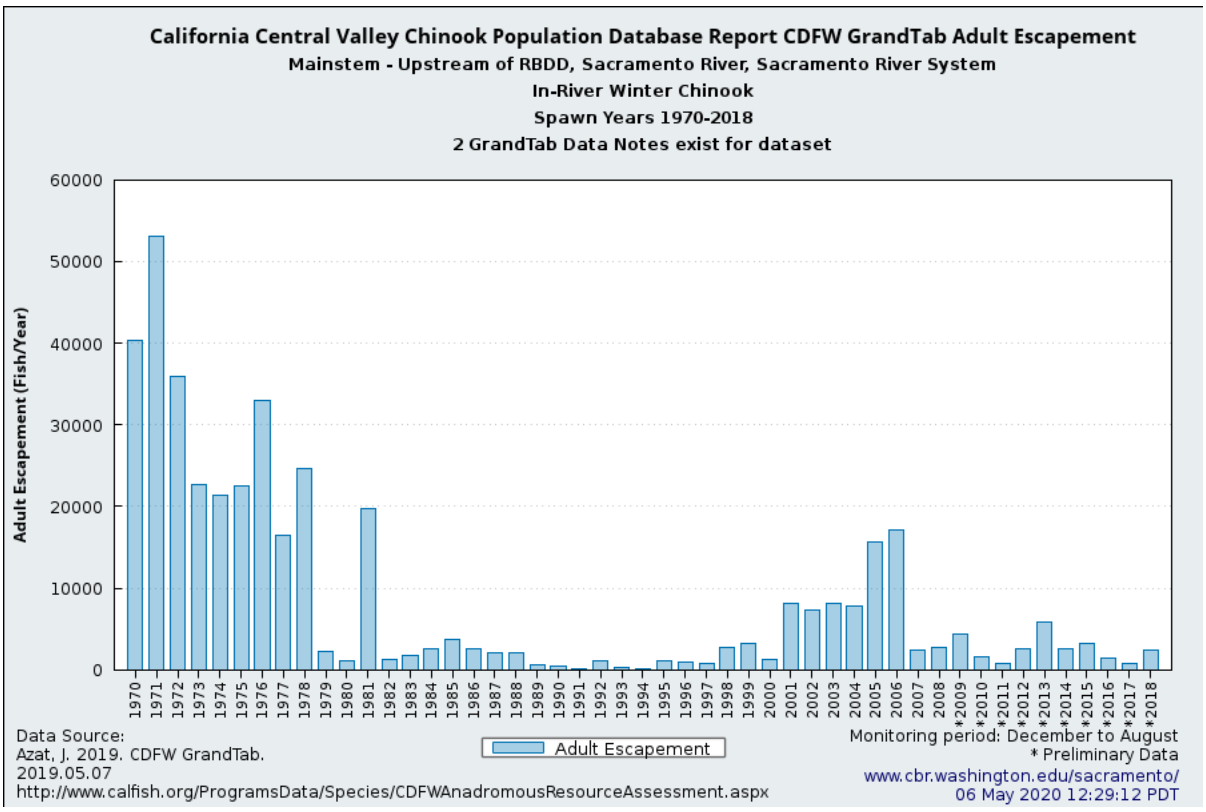


Figure 14. Upper mainstem Sacramento winter-run salmon population escapement 1970-2018.

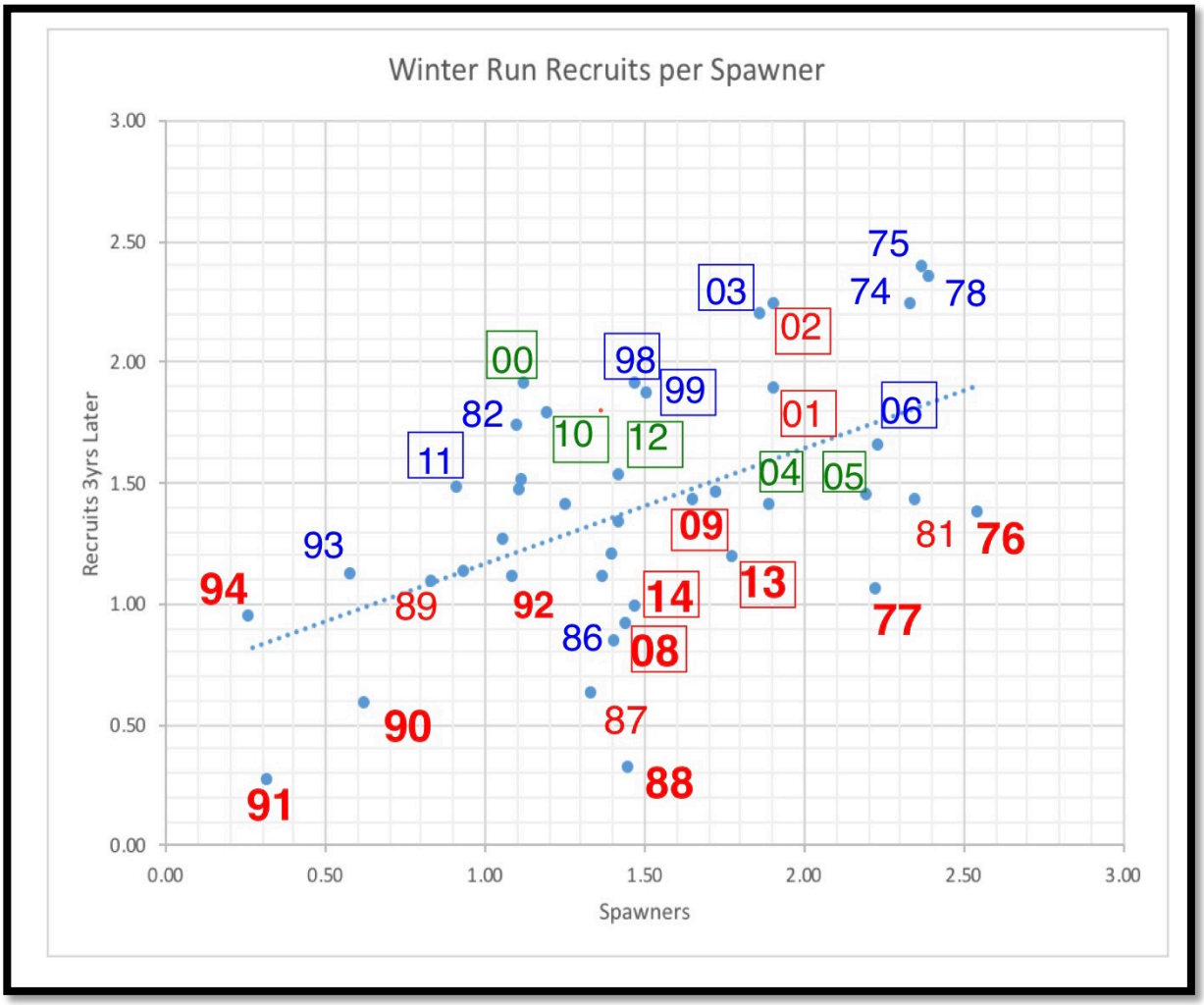


Figure 15. Winter Run spawners versus recruits (spawners three years later) transformed (logx minus 2). Year is spawner year. For example, 2014 is spawning year with 2017 recruits. Color denotes water-year type in spawning year: bold red is critical year, non-bold red is dry year, green is normal year, and blue is wet year. For example, red 13 represents critical water year 2013. Squares around numbers indicate the presence of hatchery contributions (begun in 1998).

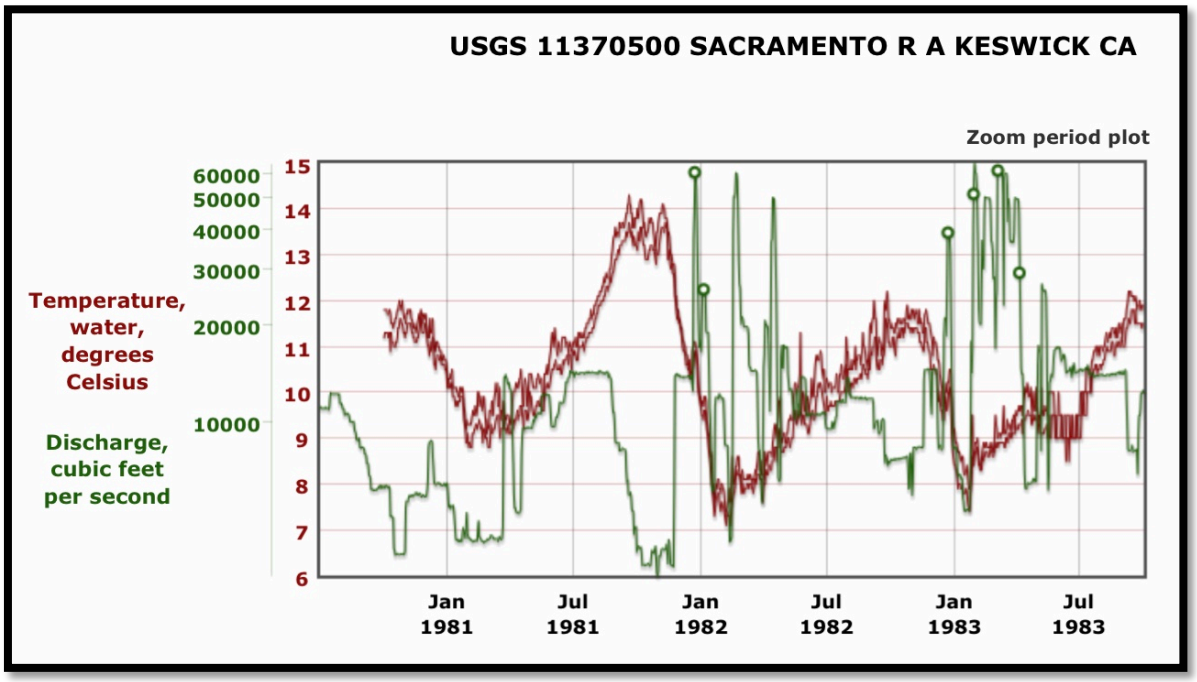


Figure 16. Water temperature and streamflow in Sacramento River below Keswick Dam 1980-1983.

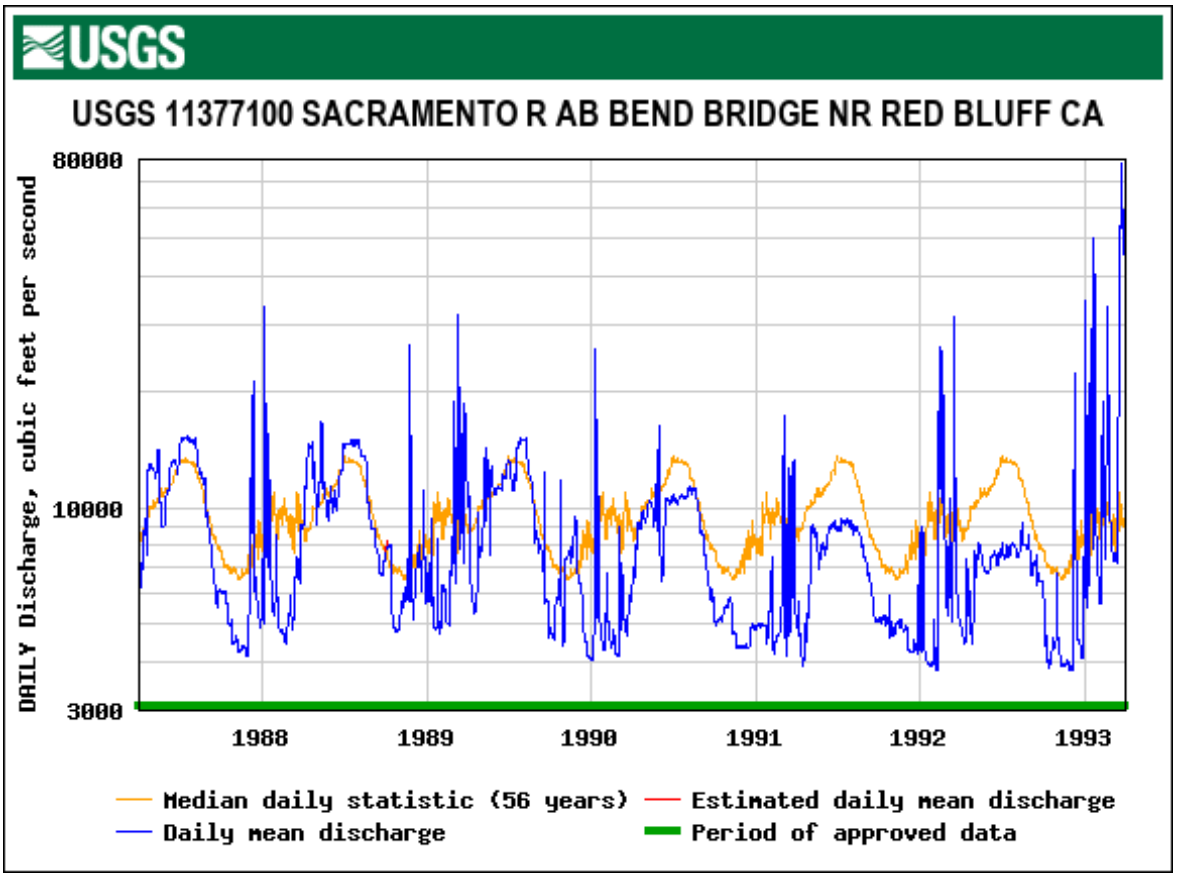


Figure 17. Daily average streamflow in upper Sacramento River at Bend Bridge (RM 256) 1987-1993, and 56-year median flow. Note dry late summer and fall conditions during 1987-1992 drought.

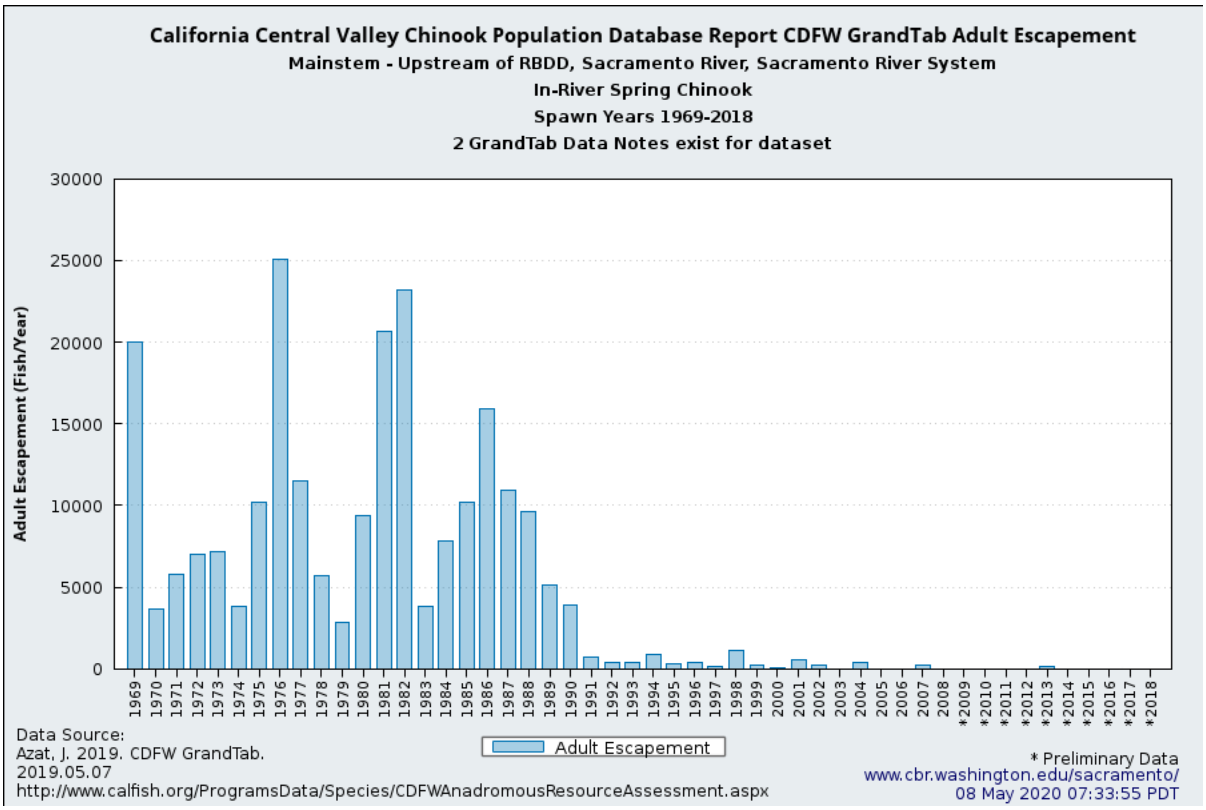


Figure 18. Upper mainstem Sacramento spring-run salmon population escapement 1969-2018.

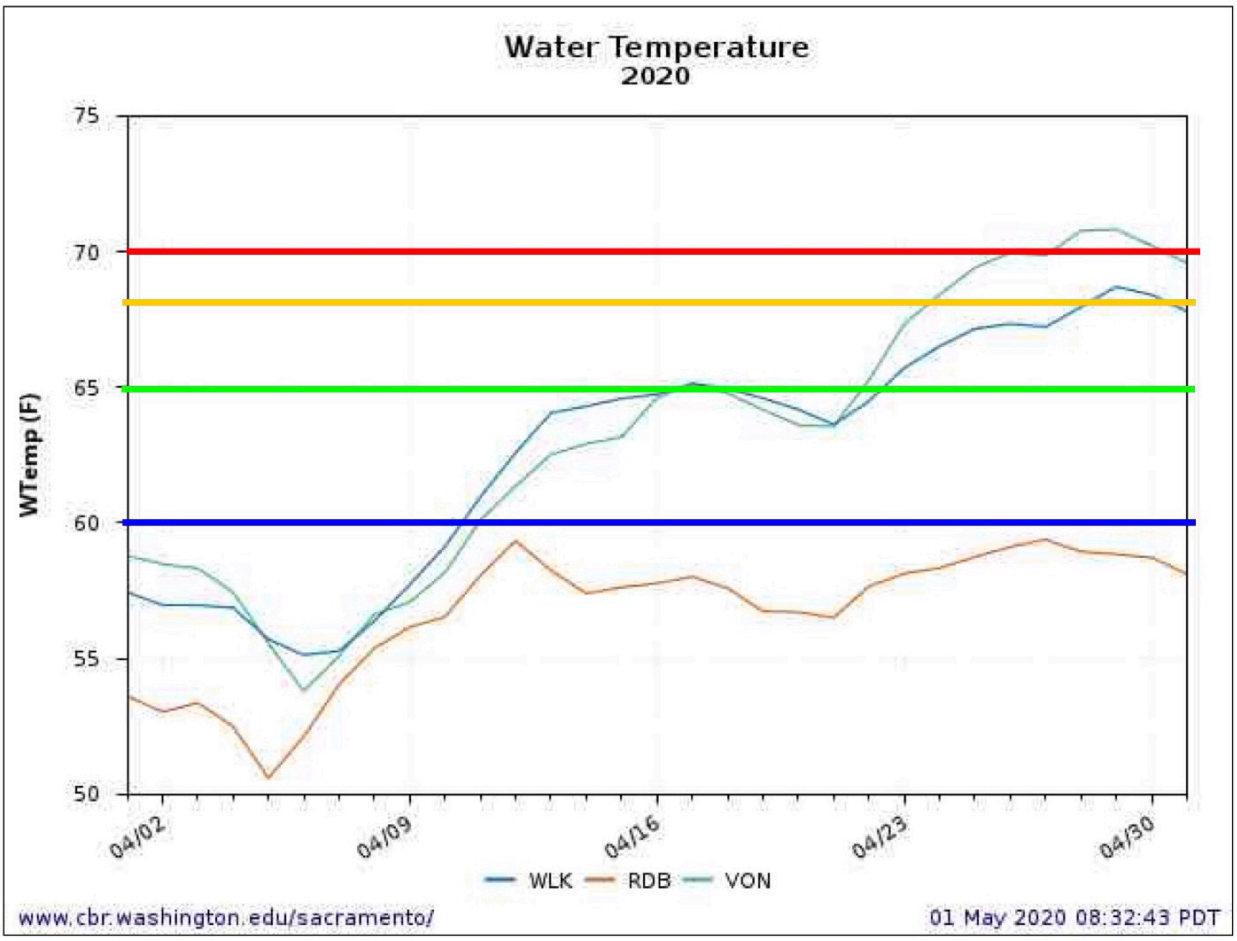


Figure 19. Spring 2020 Sacramento River water temperatures near Red Bluff (RDB, RM 240), Wilkins Slough (WLK, RM 120), and Verona (VON, RM 80). Blue line is upper limit of optimal migration temperature. Green line is safe limit. Orange line is beginning of stressful level. Red line is beginning of lethal or avoidance/blockage level.