2021
Drought and Dry Year Actions Report

BUREAU OF RECLAMATION

Mission Statements

The Department of the Interior (DOI) conserves and manages the Nation's natural resources and cultural heritage for the benefit and enjoyment of the American people, provides scientific and other information about natural resources and natural hazards to address societal challenges and create opportunities for the American people, and honors the Nation's trust responsibilities or special commitments to American Indians, Alaska Natives, and affiliated island communities to help them prosper.

The mission of the Bureau of Reclamation is to manage, develop, and protect water and related resources in an environmentally and economically sound manner in the interest of the American public.

The mission of the California Department of Water Resources is to sustainably manage the water resources of California, in cooperation with other agencies, to benefit the state's people and protect, restore, and enhance the natural and human environments.

Cover Photo: Lupine bloom at Folsom Lake 2021 (Reclamation/Cindy Meyer).

2021
Drought and Dry Year Actions Report

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Acronyms and Other Abbreviations

°C	Degrees Celsius
ARG	American River Group
CCTT	Clear Creek Technical Team
CCWD	Contra Costa Water District
CDEC	California Data Exchange Center
CDFW	California Department of Fish and Wildlife
cfs	Cubic Feet Per Second
CIMIS	California Irrigation Management Information System
CNRA	California Natural Resources Agency
CSTARS	Center for Spatial Technologies and Remote Sensing
CVO	Central Valley Office
CVP	Central Valley Project
DCC	Delta Cross Channel
DCP	*State Water Project and Central Valley Project Drought Contingency Plan*
Delta	Sacramento-San Joaquin Delta
DJFMP	Delta Juvenile Fish Monitoring Program
DRY	Drought Relief Year
DSM2	Delta Simulation Model II
DWR	California Department of Water Resources
EAV	Emergent Aquatic Vegetation
EDSB	Emergency Drought Salinity Barrier
EDI	Environmental Data Initiative
eDNA	Environmental DNA
EDSM	Enhanced Delta Smelt Monitoring Program
EMP	Environmental Monitoring Program
°F	Degrees Fahrenheit
FAV	Floating Aquatic Vegetation
FHAB	Freshwater and Estuarine Harmful Algal Bloom
FMWT	Fall Midwater Trawl Survey
FRFH	Feather River Fish Hatchery
FRSC	Feather River Settlement Contractors
GIS	Geographic Information Systems
gph	Gallons Per Hour
gpm	Gallons Per Minute
HAB	Harmful Algal Bloom
HFC	High Flow Channel
IEP	Interagency Ecological Program
ITP	Incidental Take Permit
kVA	Kilovolt-ampere

kW	Kilowatt
LAR	Lower American River
LFC	Low Flow Channel
LSNFH	Livingston Stone National Fish Hatchery
MRH	Mokelumne River Hatchery
MWh	Megawatt Hour
PFAS	Poly- and Perfluoroalkyl Substances
PM	Project Manager
NFH	Nimbus Fish Hatchery
NMFS	National Marine Fisheries Service
Reclamation	United States Bureau of Reclamation
RWA	Regional Water Authority
SAV	Submerged Aquatic Vegetation
SFEI	San Francisco Estuary Institute
SRSC	Sacramento River Settlement Contractors
SWRCB	State Water Resources Control Board
SWP	State Water Project
TAF	Thousand Acre Feet
TAO	Thermalito Afterbay Outlet
TCD	Temperature Control Device
TNS	Summer Townet Survey
TUCP	Temporary Urgency Change Petition
UCD	University of California Davis
USACE	United States Army Corps of Engineers
USFWS	United States Fish and Wildlife Service
USGS	United States Geological Survey
WOMT	Water Operations Management Team
WY	Water Year
YBFMP	Yolo Bypass Fish Monitoring Program

Purpose

This document provides information on the drought response actions implemented in Water Year (WY) 2021. The included actions are from the *State Water Project and Central Valley Project Drought Contingency Plan (DCP) (DWR 2021)*, voluntary actions taken by Central Valley water users, and the Drought Relief Year (DRY) Team and the subsequent Drought Action Information 2021 document (Reclamation 2021a). This report includes the evaluation of actions implemented in 2021 based on staff observations of effectiveness and concludes with recommendations for how to address water supply and fish effects associated with future drought conditions.

Background

As detailed in the Drought Toolkit (Reclamation 2021b), the DRY Team can be activated by Water Operations Management Team (WOMT) in water years where hydrology or water storage and environmental conditions (e.g., drought) present challenging water management decisions that cannot be fully addressed by annual operations planning. In those years, and once activated, the DRY Team will coordinate and select potential actions to avoid or mitigate drought impacts. For WY 2021 these actions have been compiled in the Drought Action Information 2021 document (Reclamation 2021a), where technical staff provided information pertaining to the implementation and effectiveness of these actions. The DRY Team (Table 1) has reviewed the information and provided an evaluation of the completed actions for 2021. However, evaluation of ongoing actions that will continue in 2022 are not provided in this report.

The membership of the DRY team for each participating agency will be evaluated at each activation of the DRY team by WOMT.

Table 1 DRY team representatives. Updated 8/5/2021.

Agency	Representative
Reclamation	Cynthia Meyer, Armin Halston
USFWS	Jana Affonso, Jim Earley, Kim Squires
NMFS	Evan Sawyer, Amanda Cranford
DWR	Kevin Clark, Chris Wilkinson
CDFW	Ken Kundargi, Crystal Rigby
SWRCB	Craig Williams, Erin Foresman

WY 2021 was the first year that the DRY Team was activated, which presented a unique set of challenges regarding the development of an interagency response to drought conditions. Specifically, the DRY Team was charged with developing a process for implementation, while also developing the drought response actions that would comprise

the Drought Toolkit (Reclamation 2021b). DRY Team objectives were initially scoped in the May 10, 2020 *Project Charter for the Drought and Dry Year Planning Toolkit*, consistent with the United States Bureau of Reclamation's (Reclamation) *Final Biological Assessment and the National Marines Fisheries Service (NMFS) Biological Opinion*. These objectives included the development of an operational framework for implementation of the toolkit actions.

In January 2021, the California Department of Water Resources (DWR) with Reclamation worked to develop a DCP that provided an initial outline of areas of potential concern given the observed dry hydrology of 2021. The first iteration of the DCP was submitted by DWR to the California Department of Fish and Wildlife (CDFW) on February 1, 2021 in response to Condition 8.21 of CDFW's Incidental Take Permit (ITP). During discussions of the DRY Team, it was acknowledged that the DCP provided an efficient way of communicating the interagency drought response such that it could be used to satisfy both the commitments made in Reclamation's Final Biological Assessment and the requirements of the NMFS biological opinion, as well as the requirements of ITP. As such, the multiple iterations of, and addendums to, the DCP have been used as a means of disclosing and communicating actions taken to address drought conditions in WY 2021.

Key to understanding and improving drought response actions is evaluation of those actions. This report, which satisfies the commitment made in Reclamation's biological assessment to assess the effectiveness of drought response measures, also satisfies the similar reporting requirement of the ITP.

Discussion

Implemented Drought Actions

Each drought action was evaluated based on criteria identified in the Drought Toolkit (Reclamation 2021b) by the staff leading the action. The evaluation templates are brief summaries of more extensive evaluations of the actions that are currently in development. Many of these actions have limited data on which to base an evaluation and some of these actions are ongoing, and thus cannot yet be evaluated. For those actions that could be evaluated, the evaluation templates give an overall picture of which actions occurred in 2021, whether the actions were executed as planned, and whether the actions are worth including in future dry year plans.

Additional drought actions were considered but not implemented. See the Drought Action Information 2021 document (Reclamation 2021a) for more information on those actions that were not implemented. DCP actions not implemented include: (1) Accelerated Habitat Restoration and (2) Directors Meeting (low egg-to-fry-survival triggered). Habitat restoration actions continued during this time; however, no habitat restoration actions were accelerated in response to the drought. The Directors Meeting, which is also a commitment in Reclamation's 2019 BA (Section 4.10.1.5.2 Conservation Measures), did not occur due Reclamation and DWR's request for Reinitiation of Consultation on October 1, 2021.

Drought actions implemented in 2021 (Table 2) addressed a wide array of management problems that occur during dry years. Many of the actions addressed water supply and water quality for human use, while other actions addressed deteriorating environmental conditions to support fish and other ecosystem components. Many of the actions had multiple benefits and were focused on improving our understanding of the system through science and monitoring.

Water Supply

The Summer 2021 Temporary Urgency Change Petition (TUCP) and the West False River Emergency Drought Salinity Barrier (EDSB) were important actions that successfully preserved water quality at the State Water Project (SWP) and Central Valley Project (CVP) while preserving upstream storage. However, the EDSB may have contributed to a harmful algal bloom (HAB) in the central Sacramento-San Joaquin Delta (Delta), so expanded monitoring and mitigation options are being explored in the future. Reductions in deliveries to the Feather River Settlement Contractors, curtailments, water transfers, and other delivery modifications allowed DWR and Reclamation to maintain human health and safety water deliveries and provided more water for in-stream flow. Conservation and efficiency improvements by water contractors allowed for reduced demand which in turn mediated reductions in reservoir releases.

Fish

All the fish actions included in the Drought Toolkit in 2021 focused on Central Valley salmonids, particularly steelhead and winter-run and spring-run Chinook Salmon.

Because wild fish spawning success and survival were expected to be very low due to high temperatures and difficulty in managing limited cold-water volumes above dams, Livingston-Stone National Fish Hatchery (LSNFH) increased production of winter-run Chinook Salmon juveniles and made temporary infrastructure improvements, via an emergency rental of water chillers. Together, these actions allowed the hatchery to operate at maximum capacity without any discernable loss of fish due to high temperatures. However, the effectiveness of this action on the winter-run salmon population will not be clear until juveniles are released from the hatchery in 2022 and survive to return. Nimbus Fish Hatchery (NFH) also made infrastructure improvements to ensure they could maintain appropriate water temperatures.

To improve conditions for wild fish, several actions were taken to improve migration pathways, improve timing of flows, and conserve cold-water to provide for upstream spawning habitat. One of the most successful of these actions was the pulse flow in spring of 2021 on Clear Creek which allowed adult spring-run Chinook Salmon to access spawning habitat upstream without negative impacts on water supply. A large number of spring-run Chinook Salmon entered Clear Creek, likely in part to variations in water temperatures between Clear Creek (cooler) and the Sacramento River (warmer). Monitoring conducted by the United States Fish and Wildlife Service (USFWS) revealed the largest number of spring-run Chinook Salmon ever counted in Clear Creek, but with a concerning distribution and high densities of fish in the lowermost reaches. The drought action to implement a water-neutral pulse flow and temporarily reduce base flows appeared to have been successful in moving this large number of fish upstream into areas of Clear Creek where they would be safer through the hot, summer months. Surveys in the summer and fall of WY2021, showed little pre-spawn mortality in Clear Creek. Consistent cool water in the upper reaches of Clear Creek was a key component of the spring-run Chinook Salmon survival through the summer and drought conditions. Other Central Valley spring-run Chinook Salmon populations were not as lucky. For example, the Butte Creek spring-run Chinook Salmon population also returned in high numbers, but unfortunately, they experienced very high pre-spawn mortality. Clear Creek's spring-run Chinook Salmon were helped throughout WY2021, due to instream flow and temperature management. Clear Creek benefited from high water trans-basin deliveries from the Trinity River (through the Carr Tunnels). Futures years may not be as successful for Clear Creek Chinook Salmon, if water exports from the Trinity River are curtailed.

Similarly, redistribution of flows on the Feather River allowed more spring-run Chinook Salmon to reach the Feather River Fish Hatchery (FRFH), provided better over-summering habitat, and increased number of salmon to receive thiamine injections. On the American River, brood year 2021 steelhead at the NFH were moved to the Mokelumne River Hatchery (MRH) to prevent mass mortality of the cohort that would result from both temperature induced mortality and increases in bacterial and viral infections. Several of the water supply actions taken to conserve cold-water pools and support

temperature management below dams, also provided for human use of water. However, like the hatchery actions, the full benefits of these actions will not become clear until juveniles produced in Clear Creek, Feather River, and American River out-migrate and successfully return to the Central Valley.

Science and Monitoring

Some of the actions taken this year did not have immediate benefits to water supply or the ecosystem; however, they helped us better understand the impacts of drought so that we can better predict and respond to future droughts. The Chinook Salmon environmental DNA (eDNA) study will allow us to better assess the effectiveness of our efforts to improve conditions for Chinook Salmon during droughts as well as provide better triggers for other management actions – such as adjustments to Delta Cross Channel (DCC) Gate operations and pumping. The Chinook Salmon Snow Globe modeling study will allow us to target pulse flows for juvenile Chinook Salmon out-migrating, providing new tools for increasing survival in dry years. Increased monitoring of HABs and aquatic weeds allowed us to assess the impacts of the summer TUCP and EDSB, and the information provided will be useful in designing future drought actions in ways that avoid exacerbating these problems. The Delta Ecosystem Synthesis project will provide a suite of information on how drought impacts the Delta environment, allowing managers to plan future drought actions.

Opportunities for Synergies

There were opportunities for synergies of drought actions. For example, there was necessary synergy between the two LSNFH drought toolkit items, 1) Increased Winter-run Chinook Salmon Production at LSNFH and 2) LSNFH Infrastructure Improvements. It was vitally important for LSNFH to receive and implement the water chillers. The chillers allowed continuous salmon aquaculture through the summer and fall months, as water temperatures from the Shasta Dam penstocks exceeded aquaculture thresholds. Increased winter-run Chinook Salmon production, which doubled normal production, maxed out the hatchery's capacity. Increased production would not have been possible without the chillers. Further hatchery infrastructure improvement will be required to safeguard the hatchery from droughts and remove risk associated from increased production targets.

There was also a necessary synergy between the TUCP and EDSB actions. The EDSB would not have been possible without the change in compliance point provided by the TUCP, and water quality in the south Delta would have degraded under TUCP outflow standards if the EDSB had not been built. However, there was a missed opportunity for further synergy between the EDSB and Delta Cross Channel Gate operations, which could have improved salinity in the South Delta further.

There were other opportunities for synergies of actions that were not considered or evaluated. Synergies between drought actions should be explored and evaluated in future years for actions where synergies may exist.

Table 2 List of implemented drought actions for 2021 including DRY Team and DCP considered actions.

Implemented Drought Actions	Lead Agency	Action Type
Chinook Salmon eDNA Early Warning	DWR	Science and monitoring
Chinook Salmon Snow Globe: late-winter pulse flows to distribute pre-smolt (fry-migrant) Chinook Salmon into estuarine tidal marsh rearing habitat	DWR	Science and monitoring
Emergency Clear Creek Pulse Flow (net zero water requirement)	Reclamation	Fish
LSNFH Infrastructure Improvements	Reclamation	Fish
Aquatic Vegetation Monitoring	DWR	Science and monitoring
Delta Ecosystem Monitoring and Synthesis	DWR	Science and monitoring
Increased Winter-run Chinook Salmon Production at LSNFH	Reclamation	Fish
Feather River Spring Flow Redistribution	CDFW/DWR	Fish
Power Bypass at Folsom Dam in Early or Late Fall to Lower American River (LAR) Temperatures for Supporting Endangered Species Act Listed Fish	Reclamation	Fish
Feather River Settlement Contractors (FRSC) Delivery Reduction	DWR	Water Supply
TUCP	DWR	Multi-benefit

Implemented Drought Actions	Lead Agency	Action Type
EDSB	DWR	Water Supply
CVP/SWP Operational Exchange at San Luis Reservoir	DWR	Water Supply
NFH Drought Preparations	Reclamation	Fish
Harmful Algal Bloom Monitoring	DWR	Science and Monitoring
Additional Implemented Drought Actions	Lead Agency	Action Type
Curtailments	SWRCB	Water Supply
Water Transfers	Reclamation	Multi-benefit
Diversion and Operation Communication	Reclamation	Multi-benefit
Request Modified Fall Diversion Schedule	Reclamation	Multi-benefit
Request Modified Spring Diversion Schedule	Reclamation	Multi-benefit
Release Water through River Outlets	Reclamation	Water Supply
Agricultural Delivery Efficiencies and Reductions	SRSC	Water Supply
Water Transfer Demand Delay Programs	SRSC	Water Supply
Water Acquisition Programs	Reclamation	Water Supply

Implemented Drought Actions	Lead Agency	Action Type
Install emergency pumps at Folsom to continue minimal deliveries	Reclamation	Water Supply
Folsom Shutter De-ganging	Reclamation	Fish
Water Use Efficiency and Conservation	Water Contractors	Water Supply
Sacramento River Meet and Confer Actions	Reclamation	Multi-benefit
Shasta Temperature Management Plan	Reclamation	Multi-benefit
Feather River Temperature Management	DWR	Multi-benefit

Additional Implemented Drought Actions

Additional drought actions were implemented in 2021 and evaluation templates were not submitted for inclusion in this report. For example, Reclamation submitted the *2021 Shasta Temperature Management Plan* to the SWRCB on May 28, 2021 (Reclamation 2021c) and an evaluation template was not submitted to the DRY Team. While evaluation templates were not submitted, summary information on these additional implemented drought actions was provided.

Water Transfers by Sacramento River Settlement Contractors

Water transfers by the Sacramento River Settlement Contractors played an important role in helping to manage both temperature targets on the Sacramento River and end of September storage targets for WY 2021. Just over 204 thousand acre-feet of water was made available for transfer for export to South of Delta Contractors. This water would normally be delivered during the transfer window of July and August but utilizing the flexibility provided in the *2019 Biological Opinion for CVP Long-term Operations*, this water was exported in September, October, and early November to maximize temperature benefits of that additional water.

Sacramento River Settlement Contractors Diversion and Operation Communication

Sacramento River Settlement Contractors were active participants in public discussions with the State Water Resources Control Board as well as with Reclamation, Fish and Wildlife Service, and National Marine Fisheries. They provided information on their diversions and outflow and provided timely schedules that assisted in determining water needs from Shasta. Ultimately the year proved much dryer than expected and water demands and depletions on the Sacramento River were much greater than we had hoped. However, tracking these demands and depletions would have not been possible had we not had regular and ongoing communication regarding their diversions and return flows regularly. This communication continues to provide important technical and anecdotal information as to the operations on the Sacramento River.

Request Modified Fall Diversion Schedule by Sacramento River Settlement Contractors

An effort was made by the Sacramento River Settlement Contractors to increase groundwater pumping and reduce surface diversions during the fall months to increase flows returning to the river from return flows and lower demand from Shasta Releases. Ground water levels were largely at risk of exceeding historic lows by the late Summer into early fall. Sacramento River depletions remained greater than anticipated during the fall months and savings from groundwater pumping were not as significant as we had hoped. Ground water substitution for reducing surface diversions remains a good tool and is likely more effective when groundwater levels are not at or exceeding their historic baseline lows.

Request Modified Spring Diversion Schedule by Sacramento River Settlement Contractors

The Sacramento River Settlement Contractors took proactive measures to make voluntary reductions to surface diversions with a goal of reducing surface diversions to 65% of contract total deliveries. As a result, Reclamation provided some incentives that allowed for the rescheduling of base supply at no cost into the critical months, waiving of the take or pay provisions in the contract so they only paid for what they took, and Reclamation agreed to explore a program to assist with groundwater pumping. Ultimately the Settlement contractors were unable to meet the 65% goal but were successful in reducing their deliveries to 69.5% of the contract total. The use of incentives to promote contract reductions should remain a tool in the toolkit for helping reduce contract totals if it is needed to meet objectives for Shasta storage and fish and wildlife benefits but it would appear that the benefits may only result in a slightly better than 5% reduction in contract deliveries.

Release Water through River Outlets

On April 18, 2021 Reclamation adjusted operations to bypass Shasta Dam's powerplant and temperature control device (TCD) due to the low water elevation in Shasta Reservoir. Reclamation released water from the warmer, upper layers of Shasta Reservoir directly through the dam's river outlets into the Sacramento River. The purpose of this warm water release was to maintain Sacramento River flows through the spring while preserving the limited supply of colder water for use later in the summer when most critical for endangered winter-run Chinook Salmon. Fishery agencies provided preliminary guidance on the maximum temperatures (60 °F at Clear Creek - CCR) and Reclamation coordinate with the fishery agencies weekly for any potential revisions. Monitoring for unanticipated effects included monitoring temperatures and their impacts to hatchery winter-run Chinook Salmon at LSNFH and monitoring winter-run Chinook Salmon in the Sacramento River (e.g., observations of pre-spawning mortality in adults). When fisheries conditions showed possible adverse effects from the warmer release, Reclamation began to manage the river temperatures to 57 °F at the SAC gage (Sacramento River upstream from Highway 44 bridge) beginning on May 15 by adjusting the release blend from the bypass with the powerplant and TCD. The bypass continued to be reduced as water temperatures in Shasta Lake increased to maintain downstream river temperatures at 57 °F at SAC. The bypass was ended on May 24, 2021. The estimated cold water pool savings with this action was 300 Thousand Acre Feet (TAF). The action also resulted in an estimated loss of hydropower production of around 121,000 megawatt hour (MWh) with an approximate value of $5,000,000.

Water Use Efficiency and Conservation

In response to the extreme dry conditions, CVP and SWP water contractors and public water agencies implemented several actions to reduce water use and provide additional flexibility for drought operations including: conservation and public outreach campaigns to reduce demands; requiring mandatory/voluntary conservation actions as part of early stages of the water shortage contingency plans; enhanced rebate programs

for turf replacement and efficient appliances; maximizing recovery of banked water supplies as a means to preserve carryover water to the extent possible; pursuing water transfers; refurbishing wells/fast tracking of treatment on Poly- and perfluoroalkyl substances (PFAS) impacted groundwater wells/Drilling new wells for recovering additional groundwater supply; pump-in programs; attempting to overcome regulatory hurdles for serving additional recycled water; re-operating conveyance systems to use other water supply sources; enacting drought rates as needed; and planning for emergency pump-back projects.

Contra Costa Water District

In supplying water to approximately 550,000 people in the Bay Area, Contra Costa Water District (CCWD) implements a robust conservation program, providing tools and resources to encourage its customers to use water wisely and prevent waste. When asked to step-up conservation efforts during the 2014-15 drought, CCWD's customers demonstrated a strong conservation ethic, reducing use beyond what was required and maintaining a large portion of that reduction for years after the drought. Water use in CCWD's treated water service area in 2020 remained 10% to 15% below the water use in 2013 (pre-drought). In 2021, after DWR's hydrology forecasts were revised to reflect lower than anticipated snowmelt runoff and after CCWD's CVP allocation was reduced starting in June, CCWD called for an additional 10% conservation. CCWD's customers responded with a 13% reduction in use from July through December 2021, relative to water use in 2020.

CCWD's conservation efforts have been successful due to actions by CCWD's Board of Directors to adopt permanent prohibitions on water waste and unreasonable use and to continually invest in the conservation program with new outreach efforts, rebates, and other resources. For example, CCWD offers its residential customers a free personalized consultation with a conservation specialist to identify potential water savings; during 2021, consultations for single-family homes increased 20% and consultations for multi-family homes increased 64% compared to the pre-drought 2017-2019 period. CCWD also offers a free online portal to customers to help track and manage water use; in 2021, registrations for the online tool are 58% greater than the average number of registrations in the pre-drought years of 2017-2019.

Friant Water Authority

Friant Water Authority (FWA) Landowners in the Friant Division fallowed lands as a result of water shortages while working to increase the installation of drip systems and other water saving technologies. FWA completed an upgrade of the Supervisory Control and Data Acquisition (SCADA) system to add more efficiency and precision to operation of the Friant-Kern Canal and supported Reclamation in final design and compliance, land acquisition, and construction award for the Friant-Kern Canal Middle Reach Capacity Correction Phase I project. FWA and Friant Division Contractors executed exchanges of 48.5 TAF of Millerton Lake water supplies for supplies in San Luis

Reservoir in order to support various CVP purposes; these exchanges resulted in a water savings of 22.5 TAF if they had been sent down the San Joaquin River in addition to mitigating catastrophic temperature impacts to the San Joaquin River Restoration Program. Additionally, FWA conducted reverse flow operations in the Friant-Kern Canal to help contractors retrieve supplies banked in Kern County and facilitated a transfer program to allow farmers to pump water into the canal and deliver it to other contractors in need totaling over 50 TAF.

Kern County Water Agency

Kern County Water Agency and many of the SWP agricultural contractors worked closely with DWR to successfully facilitate operational exchanges to recover banked groundwater to meet critical deliveries. Several drought planning efforts were implemented, initiated and/or investigated, such as investments in groundwater banks, canal lining projects, and investments in efficient irrigation practices. Many growers implemented scheduling services and technologies to optimize irrigation, or redeveloping land by removing permanent crops from service or planting crops that require less water.

Sacramento Water Forum and Regional Water Authority

The Regional Water Authority (RWA) issued a regional call for 15 percent conservation among its members. As of November 2021, water conservation region-wide was at 26 percent as compared with November 2020. Additionally, the City of Sacramento shifted most of its surface water diversions to the Lower Sacramento River to alleviate pressure on the LAR. As planned for through water banking and conjunctive use efforts, the region also shifted to using 34 percent more groundwater during the summer and fall than previous years, leaving more water available in surface storage. Thanks to local public messaging campaigns, RWA members in the region experienced record-breaking interest in rebate programs that promote water use efficiency, such as turf replacement and water saving fixtures for homes. In continuing to promote conjunctive use – meaning recharging groundwater in times of plenty and using groundwater in dry conditions – some entities, like the City of Roseville are actively recharging their aquifer storage and recovery wells using unstored flows being released from Folsom Reservoir.

The Water Forum, in coordination with Reclamation, conducted water temperature modeling to inform power bypass timing and duration, for the most efficient use of a limited coldwater pool to reduce pre-spawn mortality and improve egg-to-fry survival for Fall Run Chinook Salmon. The power bypass resulted in lower water temperatures earlier in the fall-run Chinook Salmon spawning season than would have otherwise occurred due to the 2021 drought conditions. Additionally, construction of a salmonid habitat restoration project at Ancil Hoffman Park was completed in October. Enhancements included gravel placement for a 1,200-foot spawning riffle and creation of a 1,000-foot-long alcove for rearing juveniles. The site was almost immediately used by spawning fall-run Chinook Salmon in 2021 and Steelhead redds were observed in January 2022.

Valley Water

On June 9, 2021, the Valley Water Board of Directors declared a water shortage emergency condition pursuant to California Water Code §350, called for water use reduction of 15% compared to 2019, and urged the County of Santa Clara to proclaim a local emergency. After months of progress, Santa Clara County met Valley Water's call to reduce water use in October 2021, when Valley Water's retailers used 16% less water than in October 2019. The trend continued in November 2021 when Valley Water's retailers used 20% less water in November 2021 compared to November 2019.

Turf conversion and free water saving services were particularly popular. The Landscape Rebate Program received 2.5 times as many applications in 2021 compared to 2020, tallying nearly 3,000 new application submittals. Over 520,000 square feet of high-water use landscape was converted through this program in 2021. A new platform for reporting and tracking water waste reports was launched in 2021 to provide greater functionality and streamlined communication with water retailer partners and people who reported water waste. Over 1,300 water waste reports were received and responded to in 2021. For reducing indoor water use, Valley Water also launched a new online eCart Program for free ordering and delivery of water-efficient tools and resources to Santa Clara County residents and businesses. In 2021, over 5,600 orders were fulfilled for high-efficiency showerheads and aerators as well as educational resources. Valley Water increased outreach and education and hosted a drought summit with local agencies and organizations in 2021 to promote implementation of additional requirements by cities to ensure continued water savings.

Westlands Water District

In 2021, Westlands implemented all best management practices in the district's water management plan, including drip irrigation, relying on conserved/stored water from the previous year through the peak irrigation season, and participating in programs to acquire water through groundwater substitution, land fallowing, and reservoir releases, from willing sellers. Many of these practices have been employed for many years as part of ongoing conservation and sustainability practices. Nevertheless almost 212,000 acres were fallowed throughout the District. An additional 4,150 acres of annual and permanent crops were not harvested because of insufficient water. Municipal and Industrial users were provided a public health and safety allocation. Additionally, Westlands prohibited all outdoor water use, including landscape watering, and requested all water users voluntarily reduce all indoor consumption by 25%.

Conclusions and Recommendations

DRY Team

Conclusion: The 2021 application of the DRY Team provided a useful structure and venue for the coordination and collaboration on actions necessary to address adverse effects of drought on water supply and the environment.

Recommendation: Continued and improved coordination, collaboration and processes are needed for the success of a future DRY Team and drought action implementation and evaluation. There could be benefits to better coordination between DCP development and the DRY Team. For example, not all of the DCP drought actions were included in the DRY Team's Drought Action Information 2021 document (Reclamation 2021a). Evaluation templates were not submitted to the DRY Team for some of the actions identified in the DCP, and as such those actions were not reviewed by the DRY Team.

Conclusion: The DRY Team was able to successfully integrate more of the technical information from staff across agencies which allowed the DRY Team to consider drought actions from the ground up.

Recommendation: Collaboration amongst all agencies to ensure drought action operations are approved in a timely manner could be improved. For example, the NFH requires authorization from certain agencies in order to move steelhead to and from the MRH. Identifying when to move steelhead and having approval from agencies quickly leads to a more efficient operation.

Conclusion: Early drought response provides the greatest opportunity to avoid or otherwise mitigate the effects of drought.

Recommendation: The DRY Team is activated by WOMT in years when conditions warrant the implementation of drought actions. WOMT may also activate the DRY team at its discretion based on real-time conditions. WOMT should consider that every year could be a dry year and early activation of the DRY Team would provide for early communication, collaboration, and drought action planning. If drought conditions do not materialize WOMT could then suspend the DRY Team. Furthermore, WOMT received few updates from the DRY Team lead and would benefit from more frequent updates in future years.

Conclusion: The February 1st deadline for evaluating the effectiveness of many drought toolkit actions, drawing conclusions, and making recommendations is too short for all but a superficial effort.

Recommendation: The DRY Team should consider how best to evaluate drought actions for which effectiveness cannot be determined in an annual report. The reasons for this are multifold. Primarily, the effects, both positive and negative, take time to manifest and in some cases, such as increased production at LSNFH, it will take multiple years before the actions can be evaluated. Additionally, many of the actions require larger efforts to analyze and synthesize data, beyond the scope of the drought action

evaluation templates, require more time to write, review, and finalize. Ultimately, the conclusions of these larger analysis efforts will be necessary to fully evaluate drought actions or conversely, to determine if existing monitoring programs and data analysis and synthesis efforts are adequate to evaluate drought actions. There is no clear process on how the DRY Team would continue to evaluate drought actions and make recommendations as new information becomes available.

Monitoring

Conclusion: Monitoring is a critical part of the overall drought response in that it is needed for drought action planning, implementation, and evaluation.

Recommendation: Existing monitoring can be used to determine if a drought action needs to be developed and/or implemented. However, existing monitoring may not provide the necessary information to evaluate the effectiveness of a specific drought action. The timing of existing monitoring may also not align with the timeline of a drought action. Several of the implemented drought actions in 2021 lacked the necessary monitoring to evaluate effectiveness. Additionally, better metrics need to be developed to evaluate the effectiveness of specific actions. Current metrics did not allow for determining the effectiveness of several drought actions implemented in 2021. Prior to the next drought the DRY Team should compile the specifics of which actions could not be evaluated due to poor metrics and/or inadequate monitoring infrastructure then develop recommendations to address these deficiencies.

Hatcheries

Conclusion: Drought response actions that include hatchery infrastructure improvements or changes to hatchery operations may require both short-term and long-term investments.

Recommendation: The LSNFH rented emergency water chillers as a short-term measure to allow continuous Chinook Salmon aquaculture through the summer and fall months, as water temperatures from the Shasta Dam penstocks exceeded aquaculture thresholds. LSNFH also increased production to maximum capacity. However, there is an inherit risk of running an aquaculture facility at maximum capacity. Further hatchery infrastructure improvement will be required to safeguard the LSNFH from droughts and remove risk associated from increased water temperatures and increased production targets. A long-term solution is needed to ensure future hatchery success.

The NFH trucked BY 2021 steelhead to the MRH due to high water temperatures on the American River. This is an extreme action of last resort and should not be considered standard operating procedure during drought years in lieu of adequate temperature management. Additionally, long term Folsom Dam and NFH infrastructure improvements to better manage temperature will likely be necessary for the American River and NFH to remain viable for over-summering steelhead juveniles.

Potential for Implementation of Drought Actions in all WY Types

Conclusion: Some actions developed and implemented as part of a drought response may be appropriate for implementation in all water year types.

Recommendation: Drought toolkit actions to minimize impacts on fish species are often implemented during a drought because no other management options exist. Consideration should be given to implementing these and other actions during other water year types to recover fish populations from drought effects prior to the next drought thereby increasing the resiliency of the species. Examples of drought actions implemented in 2021 that should be conducted in all water year types include the Feather River Flow Redistribution and the Power Bypass at Folsom.

Synergies Between Drought Actions

Conclusion: Some of the drought actions benefited from synergies between actions.

Recommendation: Synergies between drought actions should be explored and evaluated in future years for actions where synergies may exist. Actions that are close to one another in space and time may affect the other such that coordination of actions could provide greater overall benefit. For example, actions to improve water supply would benefit from clearly defined nexuses to how use of that water will be optimized to benefit fisheries resources during and after droughts.

Clear Creek

Conclusion: The Clear Creek temperature management benefited from high water trans-basin deliveries from the Trinity River (through the Carr Tunnels).

Recommendation: WY 2021 may have been a good year for spring-run Chinook Salmon in Clear Creek because of the high trans-basin deliveries from the Trinity River. Future drought years may not be as successful for Clear Creek Chinook Salmon, if water exports from the Trinity River are curtailed. The evaluation and potential future application of any drought response action should consider the conditions that contributed to an action's success or failure.

Drought Action Evaluation Templates

Action Evaluation: Chinook Salmon eDNA Early Warning

Point of Contact

Brett Harvey
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Dates Implemented

Pilot/Calibration Study action implemented May-July 2021; intended implementation December – May in drought years.

Water Year (description of conditions)

Calibration measurements were taken over the summer to establish background Chinook Salmon eDNA levels during a period when juvenile salmon were not expected to be present in the action area. Action implementation was not needed during WY2022 due to high outflow and early migration of juvenile Chinook Salmon into the Delta.

Timeframe and Milestones

The Pilot/Calibration Study report was completed in November 2021. An implementation plan was drafted in November 2021. Implementation could now occur at any time with very little lead time but was not practical this year given the heavy fall rainfall and outflow.

Intended Effect

Long-term monitoring of Chinook Salmon that relies on physical capture and enumeration to determine spatial distribution has proven particularly unreliable during drought conditions due to low capture efficiency. This has forced management of water operations to minimize impact on salmon populations to rely on historical patterns of salmon migration to infer population distributions and risk. This proposed management action for the Drought Toolkit is to monitor Chinook Salmon eDNA found in water samples, and to use this as an indicator of the arrival and duration of presence of migrating juvenile Chinook Salmon at critical monitoring locations including the point of Delta Entry on the Sacramento River, and distributary routes to the south Delta along the DCC, and Georgiana Slough.

eDNA monitoring at the point of Delta Entry, and at other critical management location such as the DCC channel and Old River corridor, is intended to improve information used by Salmon Management Team and WOMT for developing Chinook Salmon risk assessments and water operations recommendations. In particular, eDNA monitoring is intended to improve the ability of these teams to track presence of migrating juvenile Chinook Salmon at the point of Delta Entry and at or along distributary junctions and channels leading to south Delta. Detection of initial arrival of Chinook Salmon at these locations could be used to verify and validate date-based triggers such actions as DCC Gate closures, and also the down-ramping of actions based on assumptions regarding the end of Chinook Salmon presence in an action area.

Effects/Outcomes
The study ascertained the most effective protocol for sampling eDNA in the study area. In the Pilot/Calibration Study, there was a clear tapering of eDNA signals corresponding with juvenile presence at the tail end of the migration season in June. However, eDNA was again detected in July, presumably due the presence of adults staging in the lower Sacramento River near Sacramento.

Relation to Other Drought Actions
None currently identified.

Data Used for Evaluation
None currently identified.

Other Considerations
The study identified the need for race specific eDNA assays, which could help distinguish between Chinook Salmon races (winter, spring, fall, late-fall runs), and to some extent between adults and juveniles. The study further recommended development of eRNA assays to specifically distinguish between juvenile and adult life stages. The study explains the importance of establishing regular eDNA monitoring, especially in conjunction with traditional monitoring (trawls, beach seines) to allow management to become familiar with the constraints and interpretability of eDNA data, and to establish a record for interpreting.

Resources Needed/Used
Funding: dependent on the scale of eDNA monitoring and the contracted vendor, but ballpark between $150,000 to $400,000 per year.

Recommendations for Modifications
Fund development of Chinook Salmon race-specific eDNA assay, and life-history stage specific eRNA assay. Include monitoring locations at the new Delta Entry rotary screw trap, in the DCC, in the lower Old River corridor, and possibly in Georgiana Slough.

Lessons Learned
eDNA is a practical, easy to deploy, relatively inexpensive, and potentially informative means to augment current monitoring for the purposes of assessing juvenile salmon distribution and risk in the Delta.

Figures/Tables (if applicable)
None.

Action Evaluation: Chinook Salmon Snow Globe: late-winter pulse flows to distribute pre-smolt (fry-migrant) Chinook Salmon into estuarine tidal marsh rearing habitat

Point of Contact

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Dates Implemented

Feasibility Analysis and Trial Action Planning implemented May 2021 through January 2022; potential for implementation of trial action in February 2022.

Water Year (description of conditions)

Scenarios for a trial flow pulse action are being planned for the Feather River to test minimum threshold river velocity/flow conditions required to mobilize recently emerged juvenile Chinook Salmon to distribute into downstream habitat. Conditions in 2022 may prove perfect for such a trial because Feather River will have experienced close to "drought-like" flow conditions preceding the trial flow pulse, while high flows in the mainstem Sacramento River would help to further distribute Chinook Salmon downstream of the Feather River confluence without additional water releases.

Timeframe and Milestones

The analysis to establish trial velocity thresholds for fish mobilization, and flow thresholds in the Feather River to achieve those velocities, was completed in October 2021. Since then, DWR has been developing water-neutral scenarios to bank water in Lake Oroville in conjunction with altered flow diversion to Thermalito Afterbay to achieve a two-day trial flow pulse, including expected costs in terms of potential lost power generation.

Intended Effect

Research in the Bay-Delta increasingly supports the conclusion that rearing conditions are good in many locations of the Bay-Delta during dry conditions. However, pre-smolt Chinook Salmon are seldom detected using these habitats, presumably because low winter flows in dry years do not provide adequate cues and conditions for recently emerged pre-smolt Chinook Salmon to distribute into these rearing habitats. As a result, the majority of juvenile Chinook Salmon remain in the Sacramento River for the extent of the rearing season (January through May). Pre-smolt Chinook Salmon that do trickle out of the Sacramento River and into the Delta over the rearing season in dry years have a low probability of surviving and reaching estuarine rearing habitat due to poor rearing conditions in the narrow, deep, rip-rap-lined and low turbidity conditions of the lower Sacramento River, and slow movement rates (i.e., high residence time) in

this poor habitat – the result of low transport flows in the lotic reach and tidal influence occurring far upstream. At the same time, Chinook Salmon that remain in the river (most of the cohort in dry years) exhibit poor in-river survival. Suggested causes of poor in-river survival include elevated pathogen loads, limited habitat due to shrinking cold-water patches, and limited food supply, all associated with warmer temperatures and lower flows. River-rearing Chinook Salmon also exhibit slower growth rates (a predictor of future survival) compared to salmon rearing in Bay-Delta habitats. River-rearing Chinook Salmon that survive to migrate into the Delta in the spring experience poor survival due to temperature caused elevation in predator activity and impairment of predator avoidance ability. Such dry-year conditions are expected to increase in duration and magnitude in future years, and current management strategies are not addressing this problem.

Action: We suggest an experimental winter flow pulse sufficient to mobilize recently emerged pre-smolt Chinook Salmon, like shaking a "Chinook Salmon snow globe", so that young Chinook Salmon move downstream to distribute and settle out into habitat throughout the lower Sacramento Bay-Delta. Some Chinook Salmon will settle in poor habitat, but many will also settle into good habitat, including the North Delta Cache Slough Complex and tidal marsh habitat downstream of the Delta in Suisun Bay and Suisun Marsh.

The Winter Flow Pulse Action (aka Chinook Salmon Snow Globe) is intended to improve dry-year cohort replacement rates by diversifying rearing habitat used by juvenile Chinook Salmon (spreading the risk), by reducing population level exposure to pathogens, poor river rearing conditions, and high-temperature migration routes, and by capitalizing on unused estuarine habitat that has demonstrated high growth rates. Juveniles mobilized into the Bay-Delta (aka tidal parr) are expected to experience conditions supporting high growth rate relative to river habitat, may avoid infection from the high in-river pathogen loads that occur in dry years, and will avoid late-season, temperature-related, high mortality rates experienced by late-emigrating juvenile Chinook Salmon in the lower Sacramento River and Delta.

Effects/Outcomes

The mobilizing velocity and winter flow pulse feasibility study estimated a threshold mobilization velocity, and corresponding Feather River flow to test the hypothesized velocity threshold. The study team planned several water-neutral scenarios for testing the Winter Flow Pulse Action and are currently evaluating the scenarios to estimate cost in lost power generation.

Relation to Other Drought Actions

None currently identified.

Data Used for Evaluation

The study used fisheries, flow and velocity data from monitoring stations on the Sacramento River to estimate threshold flows and associated velocities, and existing velocity/

flow relationships for the Feather River to translate threshold velocities to flows specific to the proposed trial action location in the low flow channel.

Other Considerations
High juvenile densities and low Feather River flow concurrent with high flows in the Sacramento River may make this trial action particularly beneficial in WY 2022.

Resources Needed/Used
Amount of Water: the water banking would make this action water neutral.
Funding: the trial action would use existing monitoring to evaluate the action at no additional cost. Some of the proposed scenarios have a cost to power generation, which is currently being estimated.

Recommendations for Modifications
None.

Lessons Learned
None currently identified.

Figures/Tables (if applicable)
None.

Action Evaluation: Emergency Clear Creek Pulse Flow (net zero water requirement)

Point of Contact

Derek Rupert
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Dates Implemented

Reduced base flows from May 27-June 20 and June 25-July 1.
Emergency pulse flow from June 21 - 24.

Water Year (description of conditions)

Action implemented during WY2021.

Timeframe and Milestones

Upon discovering that a record number of spring-run Chinook Salmon were occupying the lower reaches of Clear Creek following the single planned spring pulse flow (attraction flow) of a Critical water year, an ad hoc Clear Creek Technical Team (CCTT) meeting was called May 24 to discuss the possibility of an emergency action. This meeting followed the USFWS's post-attraction flow snorkel survey (May 17). The attraction flows occurred May 8-11, with an 840 cubic feet per second (cfs) peak. The USFWS's data showed a record number of spring-run Chinook Salmon in the creek and a significant proportion of the fish downstream of the Gorge. The CCTT discussed possible emergency actions and developed tentative plan (May 24). On May 25, a proposal was distributed to the CCTT and sent to Reclamation's Central Valley Office (CVO) (Figure 1). Further discussion occurred with CVO operators for concurrence and panning. The proposed plan was initiated on May 27, with a base flow reduction. These reduced flows (125 cfs) occurred both before and after the emergency pulse (from May 27-June 20, and June 25-July 1). The emergency pulse occurred from June 21-24, with a 500 cfs peak.

Intended Effect

The proposed flow actions were intended to encourage spring-run Chinook Salmon upstream into the reaches of Clear Creek upstream of the Gorge. The Gorge is a steep cascade located a river mile 6.5 that is often difficult for migrating fish to pass, and it an important division point between the lower and upper reaches of Clear Creek. Fish downstream of the Gorge are vulnerable to excessively warm water, increased poaching pressure, and possible impacts with fall-run Chinook Salmon (i.e., hybridization). The CCTT devised a proposal that utilized both a low flow period and pulse flow that when combined, was water-neutral (i.e., did not use additional water beyond normal operation). The period of reduced flows was anticipated to cause the water temperatures in the creek to warm and stimulate fish movement (i.e., they would seek cooler water upstream). The pulse flows would cause rapid drop in water temperature and increase turbidity, again stimulating fish migration. The preferred outcome would be to

have 100% of spring-run Chinook Salmon to migrate upstream of the Gorge where they could hold in the safety of deep pools and cooler water.

Effects/Outcomes

The combination of reduced base flows and an additional pulse flow was successful in encouraging many spring-run salmon to move upstream. Early snorkel surveys (May 17) showed that 85% of the observed 1,035 spring-run Chinook Salmon were downstream of the Gorge. Following the reduced flow period and emergency pulse flow, snorkel surveys (June 28) revealed that only 31% of the observed 1,423 fish were downstream of the Gorge (Figure 4)

Relation to Other Drought Actions

None currently identified.

Data Used for Evaluation

The USFWS conducted several snorkel surveys in the 2021 to count and determine the distribution of spring-run Chinook Salmon in Clear Creek. Each snorkel survey was conducted along the entire length the Lower Clear Creek (i.e., Whiskeytown Dam to Sacramento River confluence). This data clearly showed that the distribution of spring-run Chinook Salmon continually moved upstream with following each flow action (Figure 4).

Water temperature data is collected continuously at the Igo gage station. This information showed a response flowing the reduced flow periods (warmer water) and during the emergency pulse (cooler water; Figure 3). Even with the reduced base flows and a heat wave (>115 degrees fahrenheit (°F) max daily air temperature), Clear Creek did not exceed the 60°F mean daily water temperature criteria.

All of this information will be documented in the Clear Creek Summary of Activities for WY 2021. This report is anticipated for completion and distribution in January 2022.

Other Considerations

The rapid increase in flows associated with any pulse flow action on Clear Creek can be disturbing to unknowing public users. The CCTT has previously received criticisms from users that were caught unaware of the flow changes. As such, the CCTT aims to improve communications with the public about all future pulse flows. The CCTT produced posters describing the pulse flow and timing. These posters were then posted at all the popular access points and trailhead on Clear Creek. Also, Reclamation produced a news release that was published by their public affairs office. Finally, the CCTT has added a small flow bench (~300 cfs) to all of the recent pulse flows to act as a warning that flows are increasing. The cold water and increased turbidity should discourage recreation in the creek.

In WY2021, Clear Creek has received a record-breaking number of spring-run Chinook Salmon. The snorkel surveys conducted during the week of June 28 revealed 1,423 adult salmon in Clear Creek. This number of spring-run Chinook Salmon is more than double the previous record set in 2011 (659 fish). These fish are ESA-listed as threat-

ened and this record run is a significant deviation from the poor escapement levels of recent years in Clear Creek and across the Central Valley.

Some abnormal temperature management occurred on the Sacramento River in the spring of 2021, which may have influenced spring-run Chinook Salmon migration into Clear Creek. Operators released higher than normal water temperatures out of Shasta Dam to conserve cold water pool for later in the year. Around April 21, the mean daily water temperatures in the Sacramento River (just upstream of the confluence with Clear Creek) began to climb above those of Clear Creek (just upstream of the Sacramento River confluence) and remained so for about a 3-week period. This temperature difference was even greater during May 8-12, when the Clear Creek spring attraction flows were released from Whiskeytown Dam. One intention of these Clear Creek pulse flows is to lower Clear Creek temperature to attract spring-run Chinook Salmon that may be holding the mainstem Sacramento River. This coincides with the highest rates of entry into Clear Creek by spring-run Chinook Salmon from data collected at the video monitoring weir near the mouth of Clear Creek.

Resources Needed/Used

Amount of Water: The emergency flow actions proposed by the CCTT were water neutral actions. That is, the amount of water needed for the pulse flow was equivalent to the water "banked" by reducing normal base flows in June and July.

Recommendations for Modifications

None.

Lessons Learned

In May and June of 2021, water temperatures in the Sacramento River at Clear Creek were often warmer than the incoming water from Clear Creek. Some have hypothesized that the water temperatures in the Sacramento River may have encouraged spring-run Chinook Salmon to migrate into Clear Creek. The CCTT should consider the temperatures and flow actions occurring on the Sacramento River when they propose future years' pulse flows.

Figures/Tables (if applicable)

Figure 1 Spring-run Chinook Salmon in Clear Creek

Figure 2 The CCTT proposed emergency pulse flow and corresponding reduced base-flow periods compared to the CVP operations plan minimum base flows. From CCTT's Emergency Flow Management Action for Clear Creek Spring-run Chinook Salmon proposal.

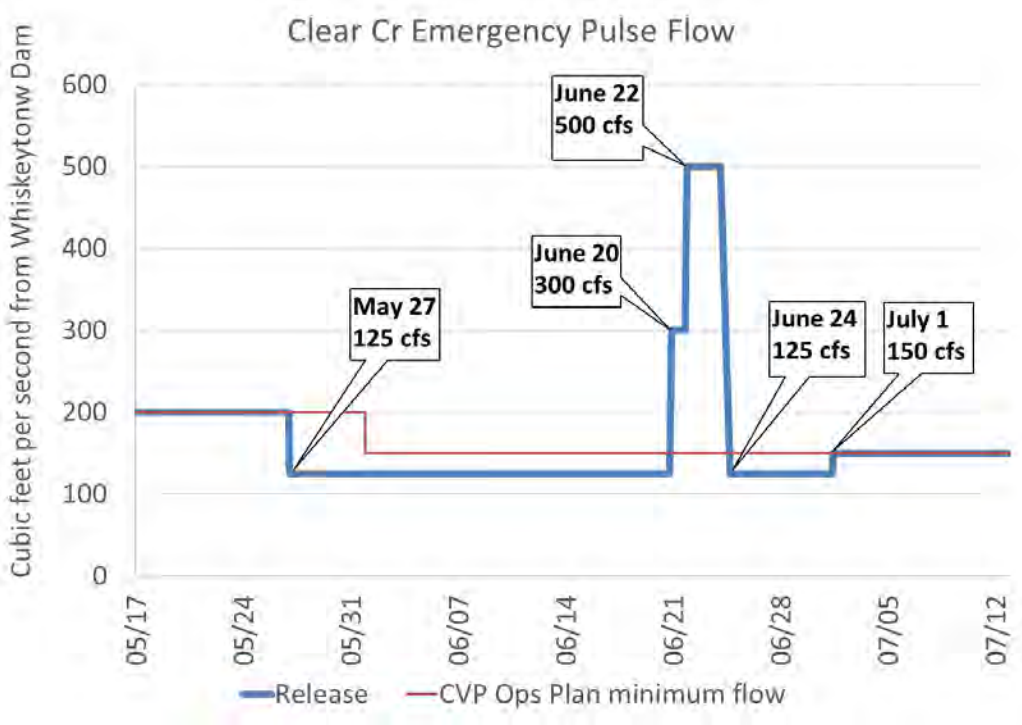


Figure 3 The spring attraction pulse and the emergency pulse, as measured at the Igo gage. The distribution of fish encountered during each survey is represented as black dots. The dots are 'jittered' so that fewer are obscured from being in the same location.

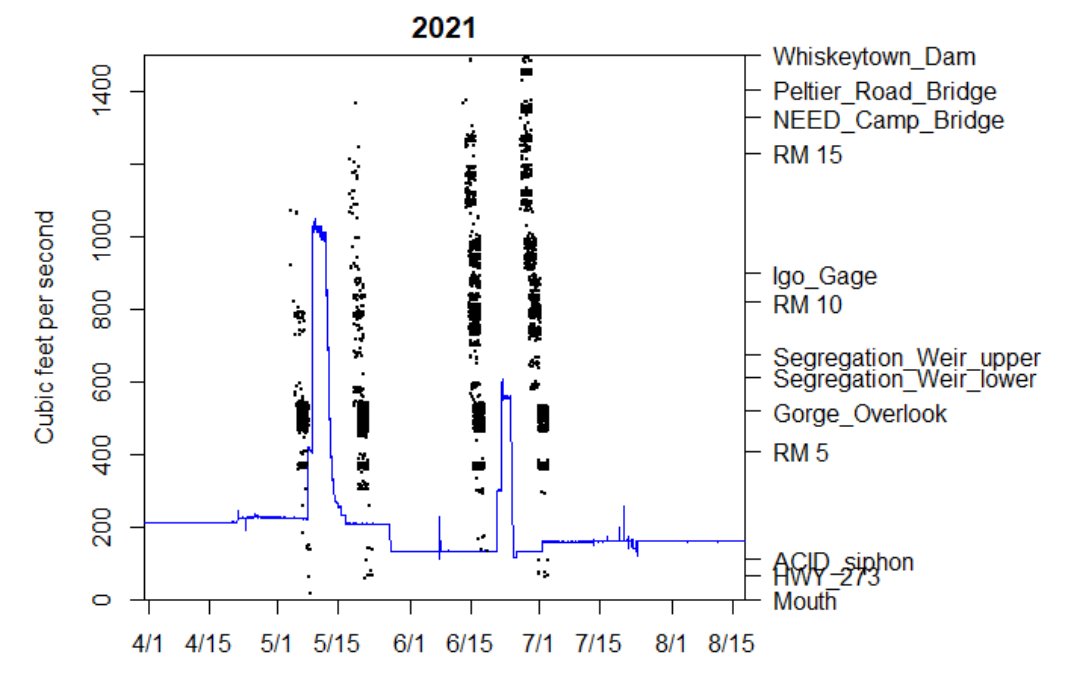


Figure 4 The Clear Creek mean daily water temperatures at the Igo gage station. Figure from http://www.cbr.washington.edu/sacramento/data/tc_clear.html.

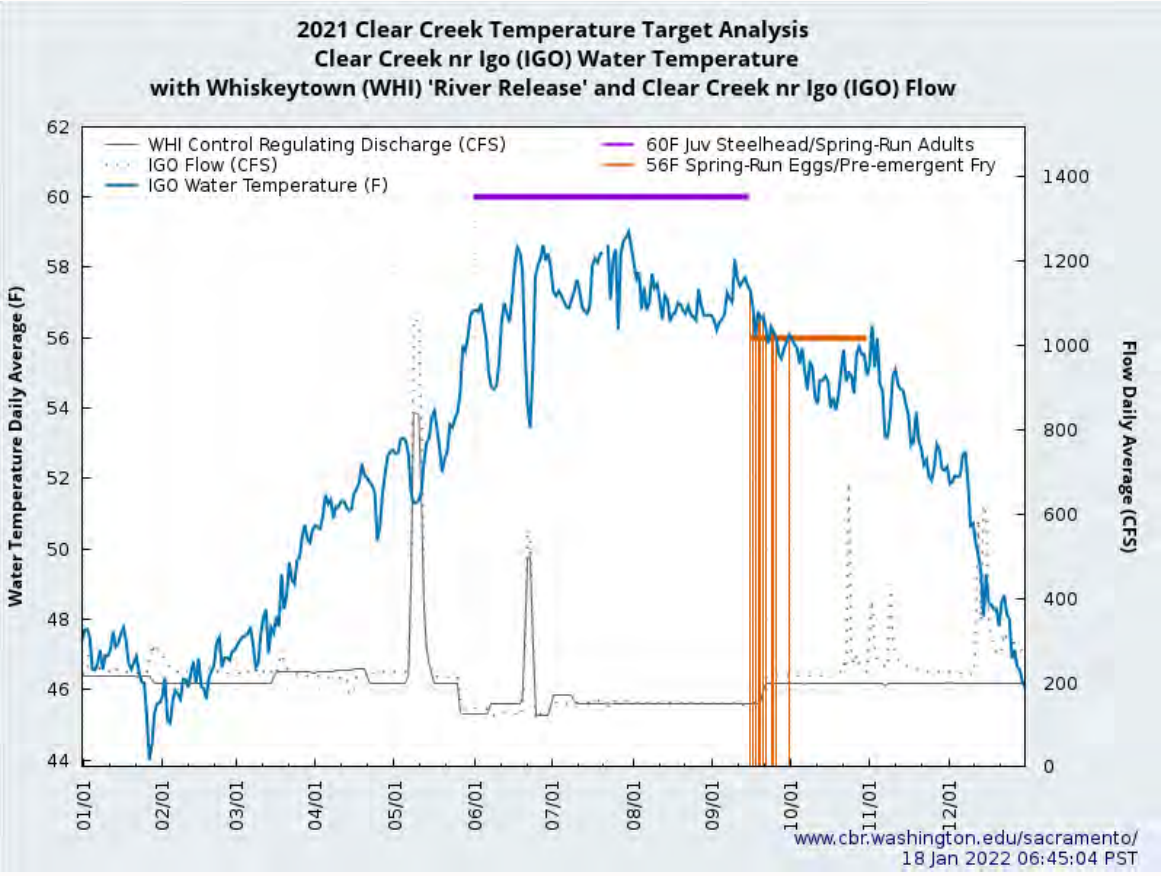


Figure 5 The distribution of spring-run Chinook Salmon in Clear Creek r elative to the Gorge Overlook. From USFWS-Red Bluff unpublished data.

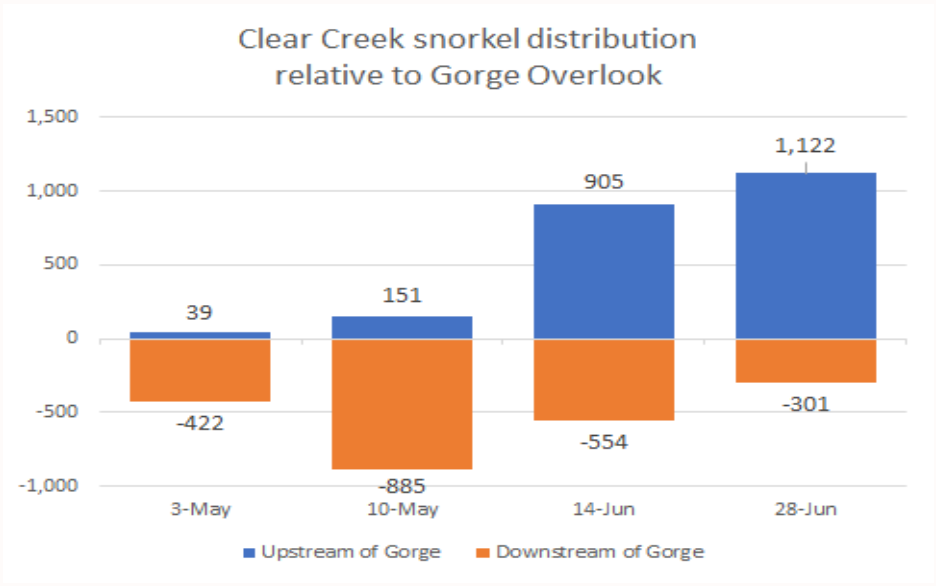
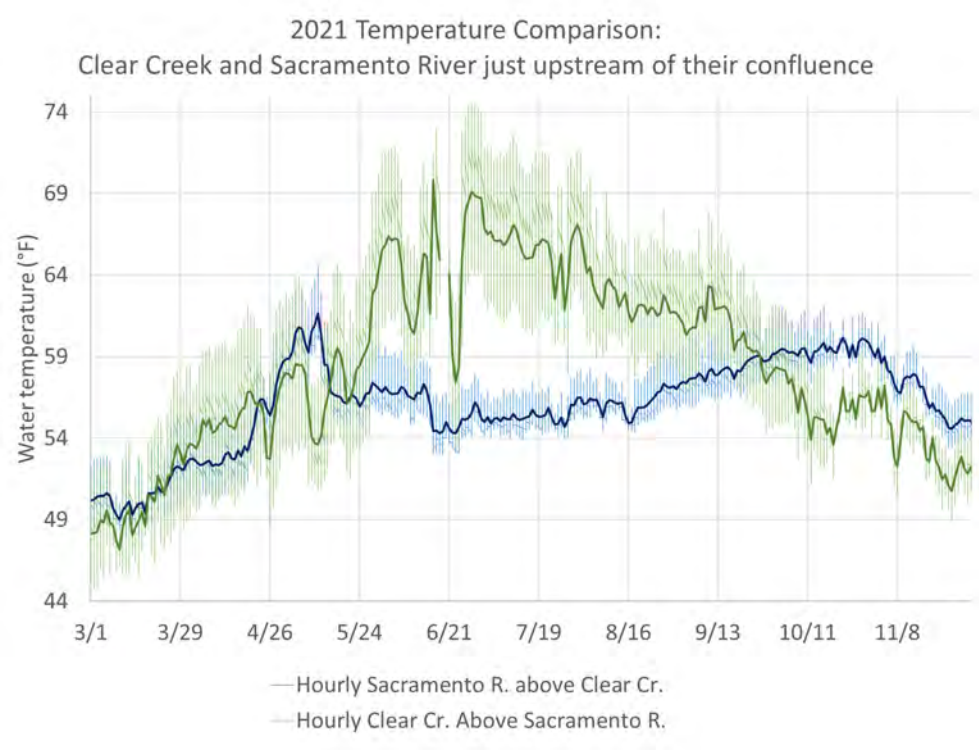


Figure 6 Water temperature data from loggers on Clear Creek and in the Sacramento River. The green lines represent hourly and mean daily Clear Creek water temperatures at the Video Station Weir. The blue lines represent hourly and mean daily Sacramento River water temperatures just upstream of the confluence with the Clear Creek. USF-WS-Red Bluff unpublished data.



Action Evaluation: LSNFH Infrastructure Improvements

Point of Contact

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Dates Implemented

Chiller rental and operations occurred August through November 2021 (See Appendix A for additional details on chiller operation timeline).

Hatchery infrastructure improvements are ongoing.

Water Year (description of conditions)

Action implemented during WY2021 and WY2022. Additional actions are required in WY2022 and beyond.

Timeframe and Milestones

Reclamation awarded a contract for the chiller rental on July 27, 2021

The contractor mobilized and delivered on the chillers beginning August 9, 2021.

The first chiller became operational on August 16, 2021, with remaining chillers fully operational on August 27, 2021.

The chillers were utilized continuously between August 16 and Nov 28, 2021.

The chillers were such off and demobilized starting November 29, 2021.

Intended Effect

The intended effect of this project is to improve LSNFH's infrastructure for operational resiliency during drought years (e.g., provide adequate water quality for aquaculture) and to allow for increased fish production potential (e.g., increase the facilities current carrying capacity). In the short term, this required installing temporary large water chillers to cool and stabilize the hatchery's water supply. In the long-term this will require renovations/additions to the facility's systems (e.g., upgraded water intake, permanent water chillers, replacing plumbing, providing overhead cover, duplicate charcoal filters, larger adult salmon collection facilities, increased number of rearing raceways/ponds, etc.) to increase aquaculture capacity and improve facility resilience.

Effects/Outcomes

In WY 2021, temporary large-scale water chillers were installed at LSNFH (7). Three chiller units (each 500-ton units) were installed in a parallel configuration with system redundancy, to allow for quick transfers between units when breakdowns occurred or when maintenance was required. One chiller was powered from a direct electrical connection to the grid and had diesel a generator backup. Another chiller was continu-

ously powered by a diesel generator, while the third remained on standby throughout the contract period. The minimum requirement of the chillers was to reduce the water temperatures of 2,500 gallons per minute (gpm) (approximately 5.6 cfs) of water by 10 °F. The chillers were rented for 4.5 months, including an option for an additional 2-month extension. The rental for the chills cost Reclamation approximately $1.6 million.

The chillers and related equipment were mobilized to LSNFH on August 9, 2021. The first chiller came online during the week of August 16, 2021. All three chillers were fully operational on August 27, 2021. The chillers were utilized continuously throughout the intervening time, with their shut down occurring on November 28, 2021, and demobilization thereafter.

The chillers were able to lower and stabilize the fluctuating water temperatures of the incoming water supply from Shasta Dam penstocks #4 (8 and 9). The water supply from the penstock often experienced temperature fluctuations of 10 F within a 24-hour period. The chillers were generally able to maintain hatchery temperatures between 50 and 56 °F for most of the operational period. There were at least 7 unexpected breakdowns/outages of the chillers, causing temperature spikes in the hatchery (9). These unplanned outages required the contractor to make several system reconfigurations and repairs to the chillers during the operational period (Appendix A). There were no immediate losses in fish during these unexpected temperature spikes.

Relation to Other Drought Actions

None currently identified.

Data Used for Evaluation

The USFWS is continually evaluating temperature, in addition to general fish health as it relates to fluctuations in water temperature. Data related to total production at LSNFH throughout drought operations will be finalized upon release of pre-smolt winter-run Chinook Salmon in early 2022.

Other Considerations

The USFWS installed temperature loggers throughout the facility, which were checked regularly and compared to penstock temperatures to ensure adequate chiller performance. In addition, USFWS installed an alarm system on the rented chillers to alert staff when outages occurred. Outages throughout the rental period were primarily associated with generator failure. Future configurations for rented and/or purchased chiller infrastructure will include the installation of additional electrical service to directly power all chillers, while generators will serve as backup power.

Resources Needed/Used

Funding: Water chiller rentals in WY 2021 cost approximately $1.6 million. Additional funding is needed in WY 2022 and beyond to install permanent water chillers and improve/modernize the overall facility.

Recommendations for Modifications

None.

Lessons Learned

Aquaculture at LSNFH was pushed to its limits in WY2021. The combination of increased Chinook Salmon production with the unstable and elevated water temperatures kept stress levels high for the fish and hatchery staff alike. Further preparations and infrastructure improvements are needed to eliminate the weak points in the LSNFH facility and to provide a more stable and resilient aquaculture environment.

Figures/Tables (if applicable)

Figure 7 The temporary water chillers and related equipment installed at LSNFH in WY 2121.

Figure 8 The water temperature fluctuation within the Shasta Dam penstock #4 during the Fall of 2021. This penstock provides the water supply to LSNFH.

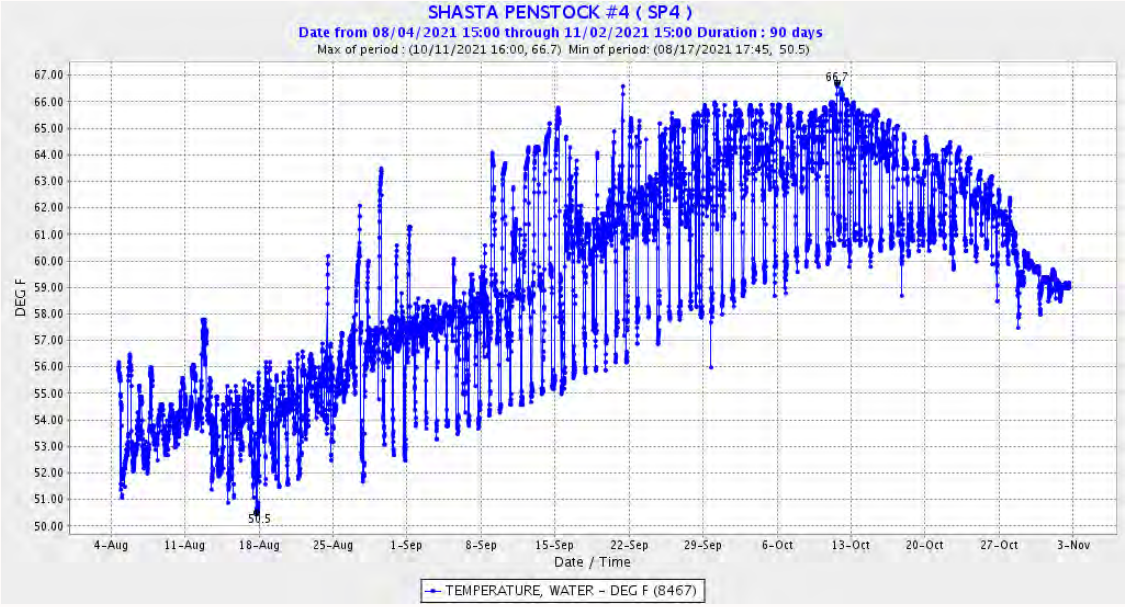
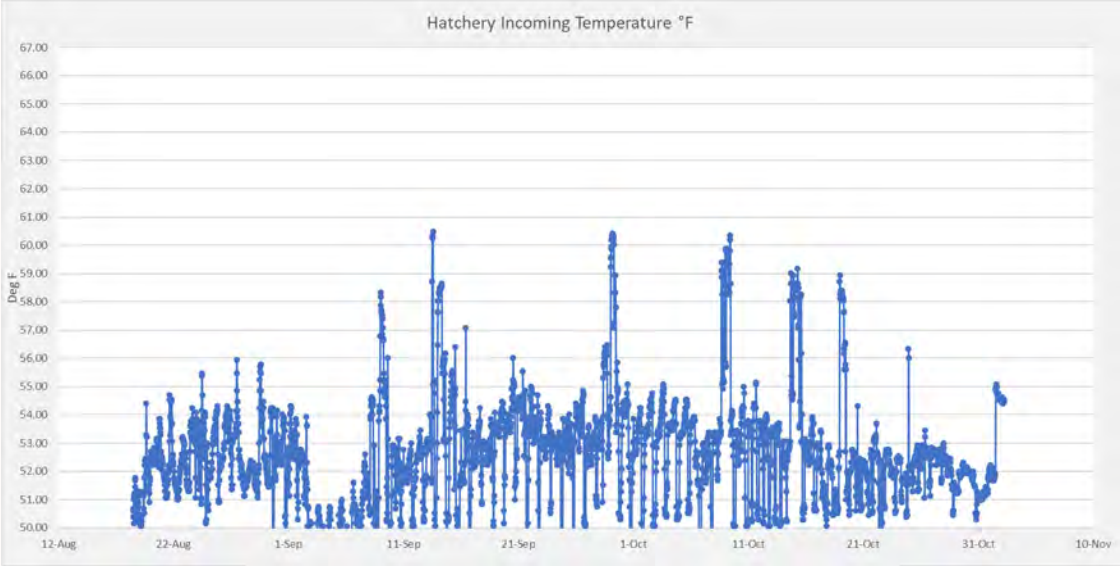


Figure 9 An example of the water temperatures entering LSNFH in the Fall of 2021. A chiller breakdowns and outages occurred on throughout the operational period, which are seen as significant spikes in water temperatures.



Appendix A: Chiller Rental Contract and Operations Timeline

10/01/2020

Project initiation:

- Alternatives Analysis project assigned to Reclamation Project Manager (PM) S. Rooklidge at Keswick to review purchase vs rental of chiller equipment.
- PM investigated prior drought events and the equipment used to satisfy hatchery flow and temperature demands.
- Keswick PM requested design information and past invoices of chiller rental projects from USF&W. Air-cooled chiller equipment was not satisfactory during late summer temperatures greater than 100°F.
- The USFWS contacted a contractor (Aggreko) who bid on the 2014 drought chiller proposal to request a cost estimate for a future rental event. This information, and communication with that event's final contractor Peterson Power, produced a cost estimate of $400,000 for chillers and generators over a 4-month rental period. This cost was used to develop a project fund budget.
- Due to prior drought event equipment limitations, USFWS described preferred chiller design requirements as 2500 gpm flowrate with a minimum of 10 °F drop in supply water temperature.
- PM described basic design and gathers information for document review by supervisor.

05/11/21
Statement of Work submitted to Reclamation contracting.

05/26/21
Sources sought for contractor interest opened on SAM.gov.

06/16/21
Final contract bids opened. Questions from contractors answered and clarifications responded to, primarily regarding mobilization schedule and coordination.

07/6/21
Final evaluation of three contractor bids submitted to Contracting.

07/22/21
Reclamation maintenance crew finished installation of supply and return pipes across the road along the hatchery. Shallow, 10-inch diameter pipes, encased in slurry and covered in steel plate. The supply pipe is 12-inch; however, no PVC was available at the time of need, so local 10-inch pipe was acquired and additional stored parts were used to complete the pipe installation.

07/26/21
Award made to Peterson Power. RedOrange was non-responsive. Cobalt design used two generators running in tandem and fuel costs were much higher over the rental period.

08/18/21
Breakers installed at the utility pole by the subcontractor at the hatchery to service the rented 750 kilovolt-ampere (kVA) transformer.

08/19/21
Peterson Power initiated installed chiller system (2x500-ton chillers; one on 800-kilowatt (kW) generator, one on Reclamation power; additional standby 800kW generator and 500-ton chiller). Chillers maintained hatchery water under 56 °F; however, twice failed in early morning hours. Subsequent service found a loose wire connection in the #2 generator that was repaired. Generator #2 averaged 24 gallons per hour (gph) diesel burn rate. Chiller system failed the 10 °F temperature differential test. Generator #1 was found to have lower temperature and flow values produced as Chiller #2.

09/02/21
MSR and Peterson Power on site to initiate usage of Chiller #2. In an effort to maximize chilling efficiency, valves were manipulated to balance water between heat exchangers. Partially open valves restricted overall flow to the hatchery, leading to low water alarms. Flow restriction was addressed by opening 2 hatchery supply valves at penstocks 2 and 4.

09/08/21
Generator #2 (supplying power to Chiller #2) down upon arrival at 6:00am. Outage occurred at ~2:00am. Hatchery temperatures remained suitable throughout outage, with high temperatures reaching 54.5 °F. Peterson Cat mechanic from Redding arrived on seen to fire the generator back up, but the underlying issue was not addressed.

09/09/21
Generator #2 down again upon arrival at 6:00am. Outage occurred at ~12:00am. Hatchery temperatures increased to 58.5 °F, including egg stacks in hatchery building due to concurrent outage of in-house hatchery chiller. Increase in temperature during egg incubation may have led to increased temperature dependent mortality. A faulty wire in the control panel of the generator was discovered to be the cause of the two outages and was fixed. Coleman National Fish Hatchery maintenance staff installed wires for alarm system phone call-out.

09/15/21
MSR and Peterson Power on site to complete connection of additional heat exchangers and switching chillers #1 and #3. 2500 gpm test run in afternoon. Failed the 2500 gpm test by only producing 9 °F temperature drop. Peterson Power specified the temperature differential would not be met unless inlet water was a minimum of 65 °F.

9/20/21
Chillers delivered are 500-ton York units. The system has not yet performed to required specifications. The chillers proposed during the bid process are York 525-ton units.

The difference between unit production may be the reason for the specification failure. Email discussion with contractor claims this discrepancy is a suitable substitution for the design submitted under the proposal.

09/29/21
Generator for chiller #2 shut down in the morning, causing inlet water temperatures to rise above 60 °F. USFWS called the contractor and Generator #2 was found to have low oil volume because the required 500-hour maintenance service had not been performed. The chiller was returned to service after ~12 hours of outage and Generator #2 was serviced. Generator #1, used for standby power, has low operation hours and does not yet need service.

09/30/21
Peterson Power installed an additional 150-ton chiller (Chiller #4) in-line with the standby chiller (Chiller #3) and is powered by Generator #2. The extra chiller, running with Chillers #1&2, provided the hatchery water temperature differential greater than 10 F°.

9/30/21
Contracting sends Letter of Non-Compliance to Peterson to address the lack of the installed system meeting the temperature specifications and unstable operation of the chillers.

10/01/21
Peterson Power responds by email that the installed chiller system is currently meeting the temperature and flow requirements and a maintenance schedule will be forthcoming.

10/09/21
Chiller #2 failed during the night, but the generator remained running at idle. Redding Peterson staff could not find cause. Inlet water to the hatchery was 60 °F during the outage.

10/15/21
Chiller #2 failed during the night, and the generator remained operational. Inlet water reached 58F. Peterson mechanical staff from Benicia arrived at 2pm and found the cause of the recent outages to be burned wire at the breakers in the main breaker cabinet. The wires were stripped back and reattached. The system has been functioning adequately since this repair.

10/19/21
Chiller #2 failed during the night and the generator remained operational. Inlet water reached 59 °F. Peterson mechanical staff determined that the recurring issue was related to a faulty breaker within the generator. The decision was made to bring in a new generator to replace the faulty equipment.

10/20/21
New generator installed.

11/1/21
Chiller #2 turned off for the season in response to cooler temperatures. Chiller #1 maintaining temperature below 55 °F.

11/29/21
All chiller usage stopped. Penstock temperatures consistently below 56 °F.

Action Evaluation: Aquatic Vegetation Monitoring

Point of Contact
Rosemary Hartman
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Dates Implemented
July 8-September 13

Water Year (description of conditions)
Action implemented during WY2021.

Timeframe and Milestones
DWR executed a task order through a master services agreement with SpecTIR on May 18, 2021 to collect hyperspectral imagery over the Delta and Suisun Marsh. Imagery was collected during July 8 to August 11 of 2021. DWR executed a contract with the University of California, Davis, (UCD) Center for Remote Sensing and Spatial Technologies (CSTARS) on June 30, 2021, to collect field data for ground truthing the hyperspectral imagery and to analyze the imagery to create landscape scale distribution maps of aquatic vegetation. The CSTARS staff collected ground-truthing field data by surveying the community composition of submerged (SAV), emergent (EAV), and floating (FAV) forms of aquatic vegetation at over a thousand locations across the Delta and Suisun Marsh from July 13 to September 13. On September 20, 2021, CSTARs Geographic Information Systems (GIS) specialists began analyzing imagery by using ground-truthing data in a random forest classification to categorize the pixels in the imagery as covered by open water, SAV, EAV, or FAV. The data analysis is still ongoing as of late December 2021. Some preliminary classification maps should be available in April 2022, and final maps should be complete by June 30, 2022.

Intended Effect
Track any expansion of weeds due to decreased flow, prioritize areas for weed treatment/control, assess impacts of other drought response actions, and evaluate effectiveness of restoration sites.

Effects/Outcomes
Hyperspectral imagery for the entire Delta and Suisun Marsh has been collected. Data processing is ongoing.

Relation to Other Drought Actions
Data collected by this action will be used in a special study on the impact of the 2021 TUCP and Emergency Barrier on aquatic weeds and harmful algal blooms.

Data Used for Evaluation
The initial report on the impact of the TUCP and Barrier on aquatic weeds is available here: https://www.waterboards.ca.gov/drought/tucp/docs/2021/20211215_dwremail_cond8.pdf

This will be updated when the 2021 weed data is finalized. This data contributes to a long-term data set that includes 11 years of weed data from the Delta collected between 2004 and 2020.

Other Considerations
None currently identified.

Resources Needed/Used
Funding: Department of Water Resources State Water Project funds, up to $268,000

Recommendations for Modifications
Future contracts should require data be produced faster (within six months of imagery collection).

Lessons Learned
Contracting mechanisms took significantly longer than expected. Contracting for Spec-Tir imagery should be on a separate contract from the UCD contract.

Figures/Tables (if applicable)
None.

Action Evaluation: Delta Ecosystem Monitoring and Synthesis

Point of Contact
Rosemary Hartman
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Dates Implemented
February 2021-ongoing

Water Year (description of conditions)
2021

Timeframe and Milestones
A team of Interagency Ecological Program (IEP) scientists was formed in spring of 2021 and developed a workplan for evaluating the 2020-2021 drought, assessing impacts of previous droughts, and assessing management actions. A preliminary study plan was included with the February DCP and refined with updates to the Plan. During the summer and fall of 2021, they assembled data set of relevant water quality, phytoplankton, zooplankton, vegetation, and fish data to identify large-scale ecosystem responses to drought and drought actions. From Sept-Dec 2021, the team has been analyzing this data set using a variety of analytical and statistical approaches to see how historic droughts compare to historic wet periods, and how the drought of 2020-2021 compares to previous droughts.

Intended Effect
Improve our understanding of the environmental impacts of drought. Assess the environmental effects of actions included in the Drought Toolkit in the Delta and develop recommendations for future drought actions.

Effects/Outcomes
The analysis and report writing is still ongoing; however, the data integration efforts have already assisted in the development of a report on the effects of the summer 2021 TUCP on harmful algal blooms and weeds in the Delta. Preliminary findings suggest some ecosystem components responded negatively to drought, others responded positively, and others differed by region. Abundance of Longfin Smelt and Striped Bass decreased. Secchi depth, salinity, temperature, aquatic vegetation, and Microcystis all increased with drought. Zooplankton and chlorophyll increased during droughts in the South Delta but decreased during droughts in Suisun Marsh and Suisun Bay. Jellyfish were confusing and Delta Smelt were inconclusive. The EDSB may have exacerbated a dense cyanobacterial bloom within Franks Tract in the summer of 2021, but no other effects of the EDSB or TUCP could be measured above the impact of the drought itself.

Relation to Other Drought Actions
The monitoring and synthesis work can also be used in the monitoring plan for various other Toolkit actions, including the EDSB and TUCP.

Data Used for Evaluation

The drought synthesis team assembled data from many different IEP datasets, including, but not limited to the datasets in Table 3, below. A preliminary report detailing the analyses the team has completed to date will be submitted along with this report in February 2022. If 2022 is also a drought year, this preliminary report will be updated in February 2023 with an additional year of data and finalized in summer of 2023. If 2022 is above normal or wet, the preliminary report will be finalized in summer of 2022.

Resources Needed/Used

Funding: Approximately $200,000 in staff time, re-allocated from other projects.

Recommendations for Modifications

This project is focused on assessing the impacts of drought on the Delta ecosystem. However, many agencies and stakeholders have been interested in upstream impacts of drought on water supply and salmonid population viability. A similar project on drought impacts on salmon across their life history would be a useful addition.

Lessons Learned

The term "drought" is poorly defined, and may be different for water project managers, ecologists, fisheries biologists, and social scientists. An official definition of a "drought" for projects like this would be useful.

Figures/Tables (if applicable)

Table 3 Datasets used in the Delta Ecosystem Monitoring and Synthesis Report.

Metric	Data set	Notes
Delta Outflow	California Data Exchange Center (CDEC) Station DTO and/or DAYFLOW CNRA portal	
Precipitation	CDEC or California Irrigation Management Information System (CIMIS)	
Water temperature	CDEC and Integrated data set	May need to use discrete data set for the long-term drought analysis.
Salinity	Sondes from CDEC, integrated data set of discrete data, and/or modeling	

Metric	Data set	Notes
Turbidity	Sondes from CDEC, integrated data set of discrete data, and/or modeling	
LSZ area	Modeling	DSM2 and SCHISM modeling conducted for TUCP and barrier impacts
Nutrients	CDFW/DWR Environmental Monitoring Program (EMP)	
Nutrients	United States Geological Survey (USGS) data dashboard	Continuous mapping cruises and in-situ sensors
Microcystis and other harmful algal blooms	EMP, DWR, SWRCB, and USGS	
Phytoplankton	EMP	Contact Tiffany Brown. Tiffany.Brown@water.ca.gov
Zooplankton	EMP, 20mm. FMWT, Summer Townet	
Zooplankton	Reclamation Directed Outflow Project	
Fish - Delta Smelt	Enhanced Delta Smelt Monitoring Program EDSM	Can also be used for salmon and longfin smelt
Fish - Salmon	Delta Juvenile Fish Monitoring Program (DJFMP) Chipps and Sac trawls	May not be as effective in clear, slow-moving water
Fish – salmon	Acoustic telemetry	Used for routing and survival.
Fish – general	Salvage	Tracy Fish Collection Facility & Skinner Delta Fish Protective Facility
Fish - general	DJFMP beach seines	Published on Environmental Data Initiative (EDI)
Fish - general	Fall Midwater Trawl (FMWT)	CDFW ITP site
Fish - general	Summer Townet Survey (TNS)	CDW ITP site
Fish - general	Spring Kodiak Trawl	Published on EDI

Metric	Data set	Notes
Fish – general	20 mm Survey	Published on EDI
Fish - general	Bay Study	Contact Kathy Heib
Fish – general	UCD	Suisun and Cache, Contact Teejay O'rear
Fish – general	Yolo Bypass Fish Monitoring Program (YBFMP)	Beach seines, screw trap, and fyke

Action Evaluation: Increased Winter-run Chinook Salmon Production at LSNFH

Point of Contact

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Dates Implemented

February-August 2021 (adult collections and spawning)

Water Year (description of conditions)

Action implemented during WY2021.

Timeframe and Milestones

Adult winter-run Chinook Salmon collections occurred February through August 2021.

Winter-run Chinook Salmon spawning occurred May through August 2021.

Egg incubation, hatching, and juvenile production began in May 2021, with the process continuing through to the anticipated release of the fish in early 2022.

Intended Effect

Due to the drought conditions in WY 2021 and the expectation that suitable temperatures would not likely be maintained within natural spawning areas of winter-run Chinook Salmon, the Fish and Wildlife Service assembled an interagency technical team to consider mitigation measures that could be undertaken at the LSNFH. In February 2021, the technical team recommended to agency managers to increase the number of winter-run brood fish spawned at the hatchery. The additional fish would partially mitigate for lost in-river production. The adult collection and egg take goals were effectively doubled when compared to normal CVP mitigation goals.

Effects/Outcomes

The USFWS, who operates LSNFS, collected 134 and spawned 118 female salmon and collected 159 and spawned 129 male salmon, to produce 589,489 eyed eggs. Due to the warm and fluctuating water temperatures from Shasta Dam, Reclamation rented temporary water chillers to maintain satisfactory water quality for hatchery operations (please see the LSNFH Infrastructure Improvement Project drought toolkit charter for more information on the water chillers). The eggs collected in WY2021 will be reared at the facility through the winter and released into the Sacramento River in February 2022, dependent on environmental conditions and fish densities at the hatchery. The fish will receive a unique coded wire tag and an adipose fin clip, prior to their release.

Relation to Other Drought Actions
None currently identified.

Data Used for Evaluation
The USFWS is continually evaluating water quality, fish health, and population dynamics, particularly as it relates to increased production. Data related to total production at LSNFH throughout drought operations will be finalized upon release of pre-smolt winter-run Chinook Salmon in early 2022.

Other Considerations
ncreased production of winter-run Chinook Salmon at LSNFH in 2021 resulted in maximum capacity conditions at the hatchery. This, coincident with the emergency rental of chillers to combat critically warm incoming water temperatures, created a high-risk scenario that should be avoided through the implementation of infrastructure improvements at LSNFH.

Resources Needed/Used
Funding: Additional funding is required to procure coded wire tags for the additional production. Large-scale water chillers were rented to maintain adequate water quality for salmon propagation at LSNFH (please see the Livingston Stone National Fish Hatchery Infrastructure Improvement Project drought toolkit charter for more information on the water chillers).

Recommendations for Modifications
None.

Lessons Learned
Aquaculture at LSNFH was pushed to its limits in WY2021. The combination of increased salmon production with the unstable and elevated water temperatures kept stress levels high for the fish and hatchery staff alike. Further preparations and infrastructure improvements are needed to eliminate the weak points in the LSNFH facility and to provide a more stable and resilient aquaculture environment.

Figures/Tables (if applicable)
None.

Action Evaluation: Feather River Spring Flow Redistribution

Point of Contact

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Dates Implemented

This specific action was implemented from June 1-July 1, 2021.

Water Year (description of conditions)

Lake Oroville water enters the Feather River Diversion Pool typically after power generation at the Hyatt Power Plant (when on-line), otherwise it bypasses Hyatt Power Plant. Water diverted from the Diversion Pool is routed through the Thermalito Forebay and Thermalito Power Plant before entering the North Thermalito Afterbay. Water held within the Thermalito Afterbay is released through the radial gates at the Thermalito Afterbay Outlet (TAO). Downstream of the TAO is referenced as the HFC. Beginning in May WY 2021, DWR began increasing reservoir storage releases to meet the Delta environmental standards. These larger releases of reservoir water are typically made through the Thermalito Complex entering the Feather River via the TAO downstream at river mile 59. As releases are increased through the TAO, the discrepancy in flow rate between the LFC minimum instream flow and the HFC deliveries widens. For migrating spring-run Chinook Salmon navigating the Feather River during the spring of WY 2021, this flow release coming from the TAO may serve as an attractant that may lead to delayed migration.

Annually, DWR tags spring-run Chinook Salmon broodstock as they enter FRH in the spring and early summer, then releases these tagged fish to over-summer in the Feather River. This is done to ensure that during the fall, spawn pairings at FRH occur between spring-run Chinook Salmon and do not include later arriving fall-run Chinook Salmon. The annual adult tagging goal is a minimum of 3,000 adults; however, tagging as many spring-run Chinook Salmon as possible increases the likelihood that the annual smolt production goal of two million will be met. This is particularly important in drought years when overall natural origin brood year production of spring-run Chinook Salmon in the Feather and Sacramento Rivers and tributaries may decline as a result of poor environmental conditions due to drought as exacerbated by thiamine deficiency syndrome.

It is equally important to provide thiamine HCl injections to as many adult spring-run Chinook as possible to overcome thiamine deficiency issues which lead to poor survival of natural origin and hatchery juvenile spring-run Chinook Salmon in 2019 and natural origin juvenile spring-run Chinook Salmon 2020. Thiamine deficiency issues may become an increasingly common occurrence due to changes in a salmon's ocean diet

prey source. Attraction of spring-run adults to the low flow channel may increase the likelihood that spring-run Chinook will over-summer in the cooler temperatures of the low flow channel due to its proximity to the discharges from Lake Oroville. Recreational angling is also prohibited in the low flow channel and this action would decrease the likelihood that spring-run Chinook would be subjected to recreational angling harvest in the waters below the TAO.

Timeframe and Milestones

As early as the April 15, 2021, Feather River Operations Group Meeting, attending CDFW staff stated that a flow redistribution proposal was likely, pending the maintenance schedule for work being done at the TAO. CDFW staff also stated that additional flow release down the LFC were needed to incentivize spring-run Chinook Salmon to migrate through the LFC and into the FRH. On May 28, 2021, CDFW requested a flow redistribution proposal via email, to start on June 2, 2021. DWR proposed delaying the action until June 15, 2021, at which time TAO releases would cease for scheduled maintenance requiring all flow to be redirected to the LFC.

In preparation for the TAO gate work scheduled between June 15 and June 21, a flow redistribution was scheduled for Friday, June 11, where the flow in the LFC increased from 950 cfs to 2,550 cfs; and the flow from the TAO decreased from 1,600 cfs to 0 cfs by June 14, 2021. Upon completion of the work, initially the flow was scheduled to return to 650 cfs in the LFC with the remainder of Feather River flow released through the TAO into the HFC. Ultimately, the distribution of higher flow in the LFC continued until August 3 for management of Complex operations including temperature management requirements.

Intended Effect

The action was implemented to achieve the following objectives:

- Attract listed spring-run Chinook Salmon into the FRH to facilitate marking broodstock for fall spawning to meet annual spring-run Chinook Salmon production goals.
- Provide thiamine HCl injections to as many adult spring-run Chinook Salmon as possible to overcome thiamine deficiency issues and increase survival of natural origin and hatchery juvenile spring-run Chinook Salmon
- Increase spring-run Chinook Salmon over-summering in the LFC which offers better over-summer holding temperatures.

Effects/Outcomes

The action was successful in achieving all of the intended objectives. The spawning of spring-run Chinook Salmon by CDFW staff during September was successful with more than 3 million eggs harvested as necessary to meet annual production goals. In total 4,793 spring-run Chinook Salmon were tagged exceeding the minimum target of

approximately 3,000. Of these, 4,582 were thiamine treated and 211 control fish were injected with a saline control. Once the spring-run spawning production goals were met, the hatchery returned excess, healthy adult broodstock that had been treated for thiamine deficiency back to the river to spawn naturally and promote in-river production. The fish that were returned to the river had an additional tag to distinguish them when carcass surveys collected them once they had spawned. DWR reported that initial evaluation indicates successful spawning of released thiamine treated spring-run Chinook Salmon and that this action should increase survival of juvenile spring-run Chinook Salmon. In addition, further study is ongoing to evaluate the benefit of action particularly the benefit of thiamine treatment. Upon reaching egg production goals, non-thiamine treated control spring-run Chinook Salmon were spawned and an additional thirty thiamine treated pairs were spawned for a joint NFMS-UCD study. Results are pending the completion of field work and data analysis and synthesis. A joint DWR-NMFS-UCD study also looked at the ability of naturally occurring thiamine produced in-river to "rescue" naturally spawned eggs from TDS. Results will be forthcoming in 2022.

Relation to Other Drought Actions

None currently identified.

Data Used for Evaluation

- CDFW - Feather River Flow Redistribution Memorandum (CDFW internal memo dated June 22, 2021)
- DWR - Feather River Spring-run Chinook Salmon 2021 Management Challenges & Solutions

Other Considerations

There was no additional water needed to direct salmonids upstream into the hatchery to be Hallprint tagged and injected with thiamine. Therefore, this is an action that should be taken whenever possible, especially in drought conditions, to protect adult spring-run Chinook Salmon that migrate up the Feather River.

Resources Needed/Used

Amount of Water: This action was water neutral. Flows were redirected from the HFC to the LFC.
Funding: Although this was water neutral, there was a power cost that has not yet been disclosed.

Recommendations for Modifications

Figure 10 demonstrates the pattern of fish movement in 2021. The LFC provides better temperatures, habitat, and helps prevent spring-run Chinook Salmon from being potentially exploited by the fishery, which begins on July 15 in the HFC. In 2021, more

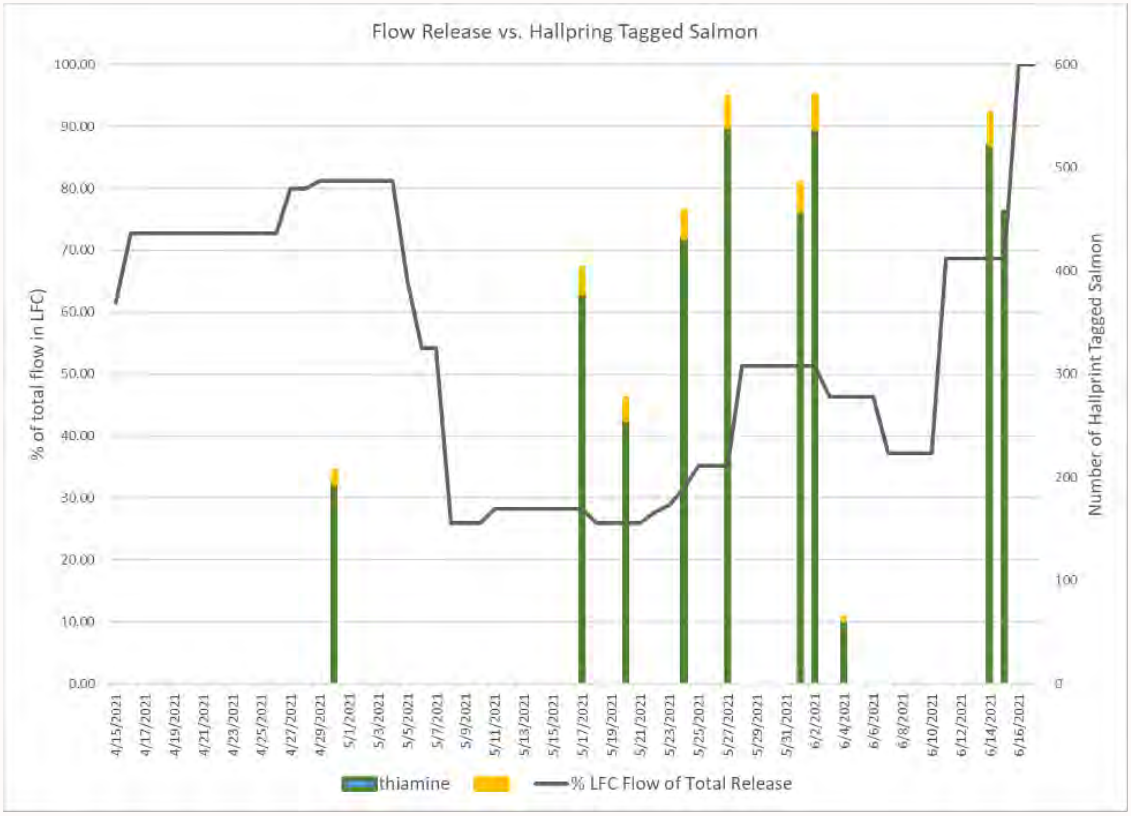
than half of the fish were tagged and treated at the hatchery prior to June 2, highlighting the need to better understand the natural timing of spring-run Chinook Salmon in the Feather River. DWR will be implementing a fish monitoring station in the LFC in 2023, providing much more detailed information on migration timing in the LFC. DWR data demonstrates that arrival to the hatchery typically peaks in mid-June. However, investigation on whether this peak is due to natural migration timing or is the result of an artificially induced response because of Oroville Complex flow distributions is warranted.

Lessons Learned

None currently identified.

Figures/Tables (if applicable)

Figure 10 Percentage of total flow in the LFC versus numbers of salmon Hallprint tagged at the hatchery.



Action Evaluation: Power Bypass at Folsom Dam in Early or Late Fall to LAR Temperatures for Supporting Endangered Species Act Listed Fish

Point of Contact

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Dates Implemented

The 2021 Folsom Power Bypass was implemented from October 11 to December 5, 2021 (WY 2022).

Water Year (description of conditions)

Drought conditions in 2021 and associated low reservoir storage in Folsom Reservoir, and diminished cold-water pool made this action particularly important in trying to achieve suitable spawning temperatures for fall-run Chinook Salmon in the LAR.

Timeframe and Milestones

On October 1, 2021, Reclamation received a Folsom Power Bypass proposal from CDFW and on behalf of the state and federal fisheries agencies. The proposal contained three bypass scenarios that would access Folsom's cold-water pool below the power unit penstocks to reduce LAR water temperatures to benefit spawning fall-run Chinook Salmon; with the ancillary benefit of reducing stress on rearing and migrating California Central Valley steelhead. This proposal was provided to the American River Group (ARG) for review and comment. The proposal drew upon numerous Folsom power bypass and LAR temperature management discussions held at the monthly and ad hoc ARG meetings over the summer of 2021. The proposal was presented and discussed at the September 24, 2021 ARG ad-hoc meeting. Bypass "C" was adopted. Bypass "C" had a start date of October 11, 2021.

Bypass "C" began with a release of 150 cfs on October 11, 2021.The bypass was increased to 350 cfs starting on October 25, 2021 to lower the water temperatures into the lower 60's, in the 62-64 range in order to significantly reduce the Chinook Salmon pre-spawning mortality. The further bypass increased was also planned to help provide favorable egg incubation temperatures for the bulk of the Chinook run starting in the third week of November.

Intended Effect

By late October, it is typical for Folsom Reservoir to have depleted the cold-water pool. The primary way to provide additional instream cooling is to release water from the lower outlet works. The intended effect of this water release, known as a Power Bypass, is to lower temperatures in the LAR to a temperature of 56 °F to relieve temperature

related effects on migrating and spawning fall-run Chinook Salmon, and migrating and rearing Central California Valley steelhead.

Rationale for Implementation

The regulatory impetus was because Reclamation is required to address American River temperature management as per the Reclamation 2019 Biological Assessment which also states that Reclamation will attempt a target temperature of 56 °F starting November 1 if cold water pool allows. Furthermore, it states that Reclamation will limit power bypass operations solely to respond to emergency or unexpected events or during extreme drought years when a drought emergency has been declared by the Governor of California. On April 21, 2021, Governor Newsom declared a Drought Emergency Proclamation due to dry conditions as of that date which included the Delta Watershed Counties.

The biologically impetus was because fall-run Chinook Salmon redd development typically begins in late October. Elevated water temperatures are a major stressor for Sacramento River fall-run Chinook Salmon (e.g., egg survival, pre-spawn mortality, disease). This is especially critical given that the LAR was operated in summer of 2021 to a temperature of 71 °F due to the extremely dry hydrology and low Folsom reservoir storage. Because of these extreme circumstances, there was consensus among the fishery agencies and Reclamation biologists that a power bypass approach was warranted and would have significant biological benefits which results in improved fall-run Chinook Salmon spawning and egg incubation success.

Effects/Outcomes

Temperature at Hazel reached 56 °F consistently at the end of November. As a result, Reclamation kept the bypass going until 12/5/21. Destratification didn't occur until roughly 12/6/21. All the cold water in the dam was used this year.

Data related to pre-spawn mortality before, during, and after the Power Bypass has been collected. Data processing is ongoing.

Relation to Other Drought Actions

None currently identified.

Data Used for Evaluation:

- ARG Notes
- Temperature data from the Fair Oaks, CA monitoring station on the LAR

Other Considerations

This action was an extreme measure and should only be considered after all other options to maintain a suitable cold-water temperature regime in the LAR have been exhausted. These alternative measures include short term reservoir management and

temperature management planning to control and manage reservoir and in-river temperature more efficiently.

Resources Needed/Used

- Amount of Water: 29.3 TAF
- Folsom Daily Lost Power Production MWH: 6,148 MWh
- Daily Weighted MWH Value: $522,225
- Tons of CO2 Production for Bypass: 4,791 Ton

The Folsom Powerplant bypass resulted in a loss of 6,148 MWh had the 29.3 TAF of water been released through the powerplant. When not generated, CVP Hydropower is displaced in the power system, typically by fossil fuels. The generation lost due to the Folsom bypass is equivalent to approximately 10,900,000 tons of carbon dioxide. This amount of greenhouse gas is equivalent to 948 passenger car mileages or 24 railcars of coal.

Recommendations for Modifications

None.

Lessons Learned

A Folsom Power Bypass has occurred in 13 of the previous 21 water years, with an average Bypass lasting 28.2 days. However, the 56-day long (longest by 19 days), 2021 Power Bypass was a deviation from current practices and required reliable temperature modeling tools, advance logistics planning, and extensive communication and coordination between agencies, including CDFW, NMFS, and Reclamation. During WY 2021, systemwide planning considerations resulted in delays to temperature management planning on the American River. The draft temperature management plan, due May 15, 2021, was not submitted until June 16, 2021, and the final management plan was not submitted until June 30, 2021. Additionally, the primary temperature modeling tool for the American River, the icPMM, is outdated and requires the use of CE-QUAL-W2 model runs to supplement temperature management planning.

Figures/Tables (if applicable)

Figure 11. Modeled summary results for temperature scenarios at Hazel Avenue, CA. "Bypass C" was selected and implemented from 10/11 to 12/15/2021.

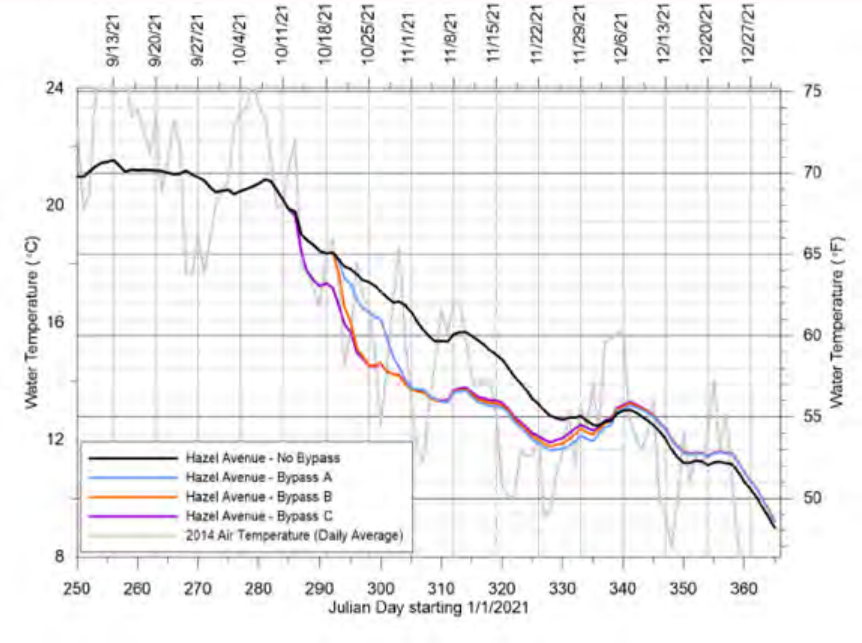

Table 4 Dates and duration of the 12 previous Folsom Power Bypasses over the previous 20 years. The 2021 Power Bypass began on 10/11/2021 and lasted 56 days; 19 days longer than the second longest Power Bypass (2014, 2015). Including the 2021 Power Bypass, the average Power Bypass is 28.2 days.

Folsom Dam Power Bypass for Temperature Management

2000-2020

Year	Start	End	Total Days of Bypass (TAF)
2000	n/a		
2001	11/10/2001	11/26/2001	17
2002	10/25/2002	11/19/2002	26
2003	n/a		
2004	n/a		
2005	n/a		
2006	n/a		
2007	11/09/2007	11/29/2007	21
2008	11/10/2008	11/28/2008	19
2009	11/10/2009	11/25/2009	16
2010	n/a		
2011	n/a		
2012	10/22/2012	11/24/2012	34
2013	10/28/2013	10/28/2013	31
2014	10/20/2014	11/25/2014	37
2015	10/29/2015	12/04/2015	37
2016	10/28/2016	11/24/2016	28
2017	n/a		
2018	11/04/2018	11/19/2018	16
2019	n/a		
2020	10/29/2020	11/25/2020	28

Figure 12. LAR in stream temperatures at Fair Oaks, CA before, during, and after the 2021 Power Bypass.

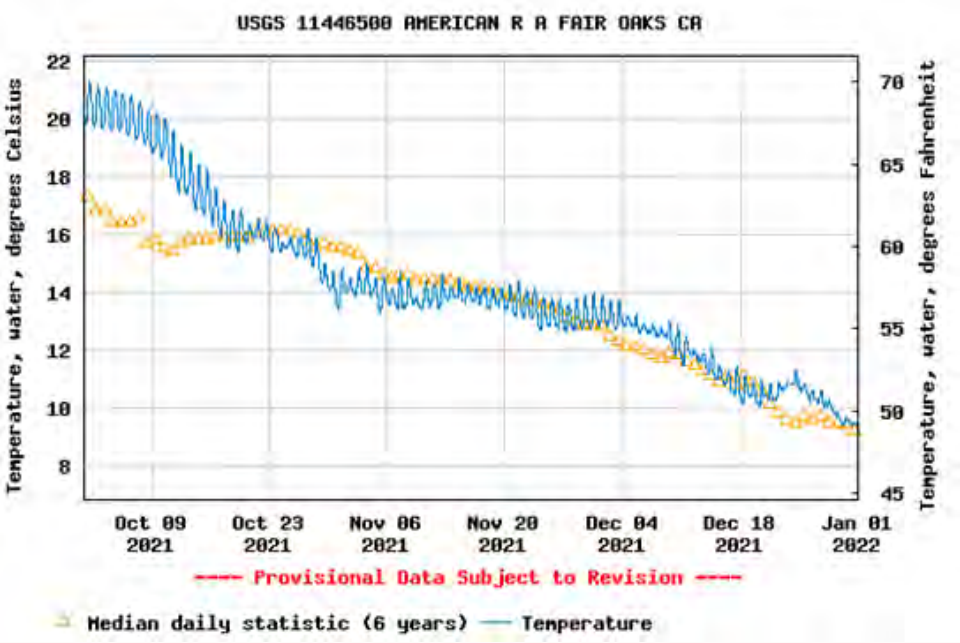

Table 5 Date of Power Bypass release changes.

Date	Release
10/11/2021	0 cfs to 50 cfs
10/12/2021	50 cfs to 100 cfs
10/13/2021	100 cfs to 150 cfs
10/25/2021	150 cfs to 250 cfs
10/26/2021	250 cfs to 350 cfs
11/26/2021	350 cfs to 250 cfs
11/28/2021	250 cfs to 200 cfs
12/3/2021	200 cfs to 100 cfs
12/5/2021	100 cfs to 0 cfs

Action Evaluation: FRSC Delivery Reduction

Point of Contact
Tracy Pettit
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Dates Implemented
2021 Calendar Year

Water Year (description of conditions)
Critically dry water year had associated low Oroville inflow amounts.

Timeframe and Milestones
Based on annual inflow to Lake Oroville in 2021, the settlement water to the FRSC was reduced from 966 TAF (full delivery amount) to 561 TAF, a savings of 394 TAF to Lake Oroville storage, during their contractual period (March through October).

In addition, DWR worked with the FRSC to reduce the amount of water delivered during the November through January period which is typically used for rice stubble decomposition and waterfowl habitat. To reduce their water deliveries, the FRSC took voluntary actions of extending the delivery of contractual water into this period, as well as reducing those demands (up to 280 TAF) by about 90%. This volume, however, does vary in any given year due to hydrology.

Intended Effect
The reduction in the delivery of settlement water increases the amount of 2022 WY carry-over water stored in Lake Oroville.

Rationale for Implementation
Implemented Per SWP Contract Provisions.

Effects/Outcomes
None currently identified.

Relation to Other Drought Actions
None currently identified.

Data Used for Evaluation
None currently identified.

Other Considerations
None currently identified.

Resources Needed/Used
None currently identified.

Recommendations for Modifications
None.

Lessons Learned
None currently identified.

Figures/Tables (if applicable)
None.

Action Evaluation: TUCP

Point of Contact
Ryan Reeves
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Dates Implemented
June 1-August 15, 2021

Water Year (description of conditions)
WY 2021 is currently the driest on record since 1977. Although well below average rainfall, the snowpack in March 2021 indicated that sufficient reservoir inflow was likely available to meet requirements. Conditions significantly changed at the end of April 2021 when it became clear that expected reservoir inflow from snowmelt failed to materialize. The May 90% exceedance forecast for the water year Sacramento Valley Four River Index identified a reduction of expected runoff of 685 TAF from those generated only a month earlier in April.

Timeframe and Milestones
See "Date Implemented."

Intended Effect
Reclamation and DWR jointly submitted the 2021 TUCP to request the SWRCB consider modifying requirements of Reclamation's and DWR' s water right permits to enable changes in operations of the CVP and SWP that will allow for delivery of water with conservation for later instream uses and water quality requirements.

Effects/Outcomes
- Reduce impact on the SWP and CVP operations.
- Conserve cold-water pools in upstream reservoirs.
- Protect future cold-water needs for natural resources.

Relation to Other Drought Actions
The TUCP is coordinated with development of the DCP, and implementation of the EDSB.

Data Used for Evaluation
Monitoring and reporting is on-going in accordance with the temporary urgency change order issued by the State Water Resources Control Board on June 1, 2021.

https://www.waterboards.ca.gov/waterrights/water_issues/programs/drought/tucp/docs/2021/20210601_swb_tuco.pdf

Other Considerations
DWR did not remove the EDSB in November as originally planned in order to extend salinity protection into the fall, and facilitate quick implementation in the spring of 2022 should severe drought conditions persist. DWR is preparing to notch that barrier in January 2022 to allow for fish and boating passage as well as any available hydraulic circulation. The notch would be refilled in April should dry conditions persist.

Resources Needed/Used
CY 2021 TUCP Cashflow ~1.0M

Recommendations for Modifications
Future TUCP development schedules should be several weeks in duration.

Lessons Learned
The SWRCB requires at least 60 days of administrative processing time from the submittal date until the first day the TUCP is in effect. Depending on the complexity of the TUCP technical staff may require 30-60 days to develop the required materials in support of the petition.

Figures/Tables (if applicable)
None.

Action Evaluation: EDSB

Point of Contact
Robert Trang
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Dates Implemented
The planning for the 2021 EDSB, made of embankment rock across West False River in Contra Costa County, began on May 5, 2021. The environmental permitting was completed on June 3, 2021.

Water Year (description of conditions)
On September 30, 2021, Lake Oroville and Lake Shasta storage were at 22% and 24%, respectively, with Lake Oroville being the lowest it has ever been. The very dry conditions and low storage levels reflected how dire hydrologic conditions were across the State.

Timeframe and Milestones
The installation of the EDSB was initiated on June 3, 2021 and was completed on June 24, 2021. The EDSB remains in West False River. Removal of the EDSB will begin in early October 2022 and require about 60 days to fully remove by November 30, 2022.

Intended Effect
The EDSB is effective at minimizing saltwater intrusion into the Delta from the Bay thus maintaining water quality objectives in the central and south Delta. This reduces demand for water in upstream reservoirs by reducing impact on the SWP and CVP operations, conserving cold-water pools in upstream reservoirs, and protecting future cold-water needs for natural resources later in the year.

Effects/Outcomes
The EDSB has reduced saltwater intrusion from the Bay. It continues to provide protection with approval from the permitting agencies to delay its removal from November 30, 2021 to November 30, 2022.

Relation to Other Drought Actions
The EDSB project is related to the SWP/CVP 2021 Temporary Urgency Change Petition (June-August).

Data Used for Evaluation
A draft report with preliminary results on the impact of the EDSB on harmful algal blooms and aquatic weeds in the Delta (required by the *SWP/CVP 2021 June-August Temporary Urgency Change Order*) will be provided to the permitting agencies by December 15, 2021.

Other Considerations
DWR is partially removing the EDSB (i.e., creating a notch through barrier) in January

2022 to allow for fish and boat passage through West False River. The notch will be filled in April 2022. The EDSB will remain fully intact with complete removal by November 30, 2022. If hydrologic conditions improve before November 30, and DWR determines the EDSB is no longer needed, they will confer with the regulatory agencies prior to early removal of the barrier.

Resources Needed/Used

As the project is ongoing the total cost has yet to be realized.

Recommendations for Modifications

As the project is ongoing recommendations have yet to be developed.

Lessons Learned

Regular and transparent communication between DWR with USACE, USFWS, NMFS, SWRCB, and CDFW has been critical to the project's overall success. This has allowed DWR to adaptively manage the project (e.g., delay barrier removal date from Nov 2021 to Nov 2022) due to the ongoing drought conditions in cooperation and collaboration with the agencies. Regular and transparent communication will continue to be critical moving forward.

Figures/Tables (if applicable)

None.

Action Evaluation: CVP/SWP Operational Exchange at San Luis Reservoir

Point of Contact
Tracy Pettit
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Dates Implemented
Reclamation and DWR received an approved consolidated place of use from the SWRCB for the exchange of up to 200 TAF of water in San Luis Reservoir on July 8 and August 25, 2021. The action implementation follows the terms of the agreements between Reclamation and DWR, signed on July 15 and August 16, 2021.

Water Year (description of conditions)
Spring through Fall of WY2021.

Timeframe and Milestones
Allow for up to 200,000 acre-feet of SWP water supply in San Luis Reservoir to be used incrementally by Reclamation for meeting its CVP purposes in Summer/Fall 2021, when CVP supplies in San Luis Reservoir are projected to be fully depleted in the absence of said action and CVP upstream storage is at or projected to be at critically low levels. The total borrowed amount will be based on actual need and the feasibility for repayment by the end of the year

Intended Effect
The action will help alleviate the effects of limited storage releases from the CVP's upstream reservoirs due to critically low storage levels, which has limited Reclamation's ability to export sufficient water from the Delta to meet current demands. The action will also minimize releases needing to be made from Millerton Reservoir (to meet the current demands), which could have significant impacts on fishery conditions in the Upper San Joaquin River. The action will not increase the total water supply available to the CVP for this year.

Effects/Outcomes
Successful

Relation to Other Drought Actions
Independent utility of action

Data Used for Evaluation
Numerical accounting of action by projects

Other Considerations
Not applicable

Resources Needed/Used

Amount of Water: Up to 200 TAF was considered. 100 TAF was exchanged to Reclamastion and all water was returned to DWR in San Luis by 12/2/2021.

Recommendations for Modifications

None.

Lessons Learned

None currently identified.

Figures/Tables (if applicable)

None.

Action Evaluation: NFH Drought Preparation

Point of Contact
Crystal Rigby
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Dates Implemented
06/01/2021 - 10/25/2021

Water Year (description of conditions)
Action implemented during WY 2021.

Timeframe and Milestones
CDFW, Reclamation, and NMFS had a series of conversations and meetings in April and May 2021 on anticipated conditions and water temperatures in the LAR as well as associated impacts to hatchery steelhead production at NFH. It was agreed by CDFW and Reclamation on May 25th and May 26th that relocating all NFH 2021 brood year hatchery steelhead would be carried out. On June 1st and June 2nd, 2021, all NFH steelhead were transferred to the MRH. On October 25, 2021, conditions were appropriate to transfer the fish back to NFH where they are being held until release in February 2022.

Intended Effect
The intended effect of relocating the NFH 2021 brood year steelhead to MRH was to prevent mass mortality and meet annual mitigation goals for production. Steelhead mortality at NFH was projected to increase during the summer months with rising water temperatures producing both temperature induced mortality and increases in bacterial and viral infections.

Effects/Outcomes
Implementation of the action appears to have been a prudent decision and likely prevented significant loss of the NFH 2021 brood year steelhead cohort given LAR water temperatures during the summer of WY 2021. Source water temperatures above 68°F approach the upper thermal tolerance of steelhead trout in a hatchery setting and often results in widespread disease and mortality due to thermal stress. In this situation, hatchery staff rely on medicated feed to prevent disease outbreaks, but no options are available with the current infrastructure of NFH to reduce temperature dependent mortality. Temperatures in excess of 70 °F exceed the thermal tolerance of cold-water species and would result in significant mortality. Drought conditions pushed reservoir storage and cold-water pool volumes to historically low levels in Folsom Reservoir for WY 2021. Daily temperatures at the NFH during May fluctuated between 64 °F and 67 °F causing disease outbreaks and stress on fish. Based on verbally communicated information from Reclamation, temperatures were likely to exceed 68°F at Hazel Avenue on the LAR by June 8, 2021. Hazel Avenue serves as a proxy for CDFW in terms of anticipating what temperatures can be expected at NFH. Over-summer temperatures from June through July at Hazel Ave averaged monthly between 68 °F and 70 °F, respective-

ly. However, steelhead are not only affected by average temperatures but instead are affected by daily high temperatures, so it is important to note that peak temperatures in June reached 70.3 °F and 72.5 °F in July (USGS Water Data, Figure 10). In mid-October, temperatures at Hazel Ave began to decrease below 68°F, which allowed for the 2021 brood year steelhead to be transferred back to NFH on October 25, 2021.

Relation to Other Drought Actions
None currently identified.

Data Used for Evaluation
- LAR Memo
- Water Year 2021 Temperature Management Plan for the Lower American River – Final
- Draft ARG Summary of Activities for WY 2021

Other Considerations
This action was an extreme measure and should only be considered after all other options to maintain a suitable cold-water temperature regime in the LAR and the hatchery have been exhausted. These alternative measures include short term reservoir management and temperature management planning and long-term measures, including hatchery infrastructure upgrades such as recirculating aquaculture technology, UV treatment, and water filtration, to improve the ability to more efficiently control and manage reservoir and in-river temperature.

The relocation of NFH steelhead to another watershed is not without risks, including thermal shock and mortality during transport, straying of adult returns, and fish pathology issues. During WY 2021 medicated feed was implemented to treat diseases in steelhead that began prior to transport; however, vector potential for transfer of fish diseases from one hatchery/watershed to another could have far reaching and long-lasting consequences that outweigh the short-term benefit of the action. As such fish pathology issues could prevent the action from being implemented in the future. Initial planning and coordination of this action included the application of a unique, secondary external mark, in addition to an adipose fin clip, of the NFH 2021 brood year steelhead. Unfortunately, this did not occur. Reclamation intends to develop, with fisheries agency input, a genetic monitoring plan to be implemented at the MRH to assess straying of NFH origin steelhead into the Mokelumne River.

Resources Needed/Used
Funding: The action was accomplished with existing CDFW staff and budget resources

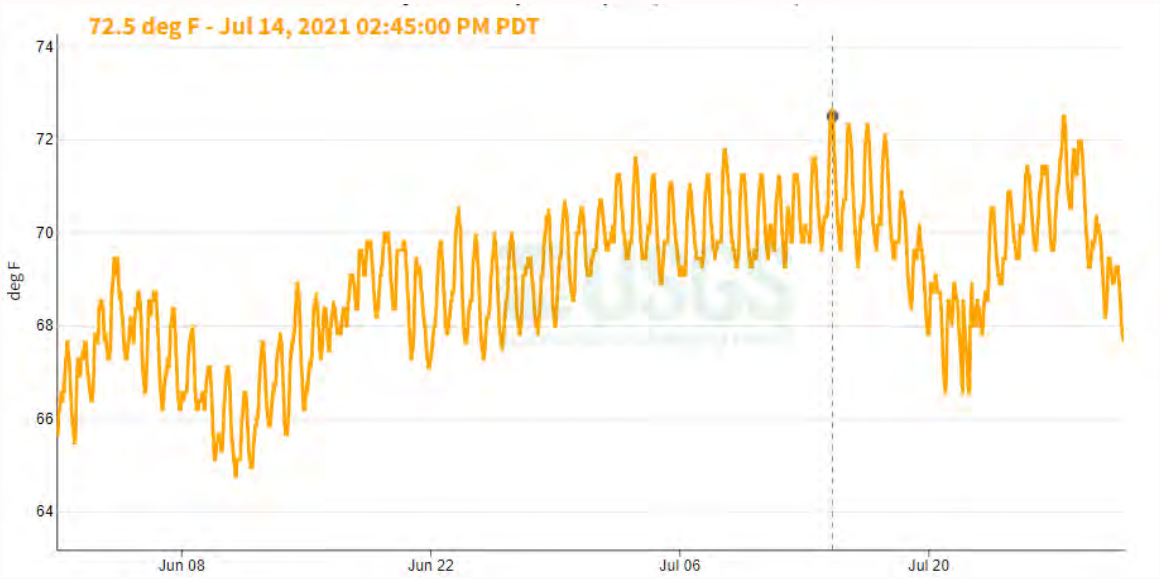
Recommendations for Modifications
None.

Lessons Learned

Relocation of NFH steelhead to the MRH is a significant deviation from current practices and requires reliable temperature modeling tools, advance logistics planning, and extensive communication and coordination between agencies, including CDFW, NMFS, and Reclamation. During WY 2021, systemwide planning considerations resulted in delays to temperature management planning on the American River. The draft temperature management plan, due May 15, 2021, was not submitted until June 16, 2021, and the final management plan was not submitted until June 30, 2021. Additionally, the primary temperature modeling tool for the American River, the icPMM, is outdated and requires the use of CE-QUAL-W2 model runs to supplement temperature management planning. This iterative approach, while suitable for in-river temperature management, is not amenable to efficient decision making as required for this action.

Figures/Tables (if applicable)

Figure 12. American River Gauge for Hazel Ave from USGS. This shows temperature from June 1, 2021- July 30, 2021 to show the fluctuations in temperature throughout the summer. Peak temperature in July is highlighted at 72.5 °F.



Action Evaluation: Harmful Algal Bloom Monitoring

Point of Contact
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Dates Implemented
May occur year-round or only in summer and fall months.

Water Year (description of conditions)
Action should be implemented during below normal, dry, and critically dry years; however, it can be done any water year.

Timeframe and Milestones
HABs typically occur in summer and fall months but since drought can extend the duration of blooms, visual assessments should be made year-round. HABs typically occur in warmer months once water temperature reaches above 19 degrees Celsius (°C) and may last until water temperatures drop below 15 °C during cooler months. Results and recommendations will be in the annual drought contingency plan.

Intended Effect
Track development and possible expansion of HABs due to decreased flow, increased water temperatures and other possible water quality changes and assess impacts of other drought actions (e.g., temporary barriers). If funds and resources allow determine what photosynthetic plankton and toxins are present. This action will help assess the impact of other Drought Toolkit Actions, including Delta outflow and temporary barriers, as well as plan mitigation strategies if the drought continues.

Data Used for Evaluation
Water quality and phytoplankton from existing IEP monitoring programs. Existing satellite imagery from the San Francisco Estuary Institute (SFEI) and Freshwater and Estuarine Harmful Algal Bloom (FHAB) Satellite Analysis Tool (https://fhab.sfei.org/). Field work, analysis and data processing will be completed by monitoring surveys from the IEP.

Other Considerations
Sample depth and methodologies should be consistent as possible across monitoring programs based on guidance from IEP's Water Quality and Phytoplankton Project Work Team. If available, additional resources may be used for additional monitoring and laboratory analyses.

Resources Needed/Used
Funding: Overhead costs to agencies. Possibly more costs due to additional equipment and laboratory analyses

Lessons Learned

From 2021, a cyanobacteria HAB was present in Frank's Tract. Based on existing monitoring data, results are expected to be inconclusive whether Action 21: EDSB influenced the size, duration and severity of the bloom. Additional data will provide more information on potential impacts of installing temporary barriers and drought conditions in general including warmer water temperatures and decreased outflow.

Figures/Tables (if applicable)

None.

References

United States Bureau of Reclamation. 2021. 2021 *Drought Action Information.* Version 5: December 2021. 60 pp.

United States Bureau of Reclamation. 2021. *Drought Toolkit*. 2021. 60 pp.

United States Bureau of Reclamation. 2021. *Shasta Temperature Management Plan*. May 2021. 28 pp.

United States Bureau of Reclamation. 2021. *Sacramento River Temperature Management Plan for Water Year 2021*. May 2021. 25pp.

https://www.waterboards.ca.gov/drought/sacramento_river/docs/2021/wro90/2021-05-28_sacramento_river_temp_mgmt_plan_complete.pdf

California Department of Water Resources. 2021. *State Water Project and Central Valley Project Drought Contingency Plan.* May 2021. 36 pp.