State of California
California Natural Resources Agency
Department of Water Resources

State Water Project Long-Term Drought Plan

March 2024

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Acronyms and Abbreviations

AR	atmospheric river
B120	Bulletin 120
CASP	California Aqueduct Subsidence Program
CDFW	California Department of Fish and Wildlife
CVP	Central Valley Project
CW3E	Center for Western Weather and Water Extremes
DCR	Delivery Capacity Report
Delta	Sacramento-San Joaquin Delta
DFM	Division of Flood Management
DRA	drought relief action
DRY	Drought Relief Year
DWR	California Department of Water Resources
D-1641	Water Rights Decision 1641
ESA	Endangered Species Act
FIRO	forecast-informed reservoir operations
HAB	harmful algal bloom
HHS	human health and safety
ITP	incidental take permit
LTO	long-term operation
maf	million acre-feet
NMFS	National Marine Fisheries Service
Reclamation	U.S. Bureau of Reclamation
RVOS	River Valve Outlet System
State Water Board	California State Water Resources Control Board

SWC	state water contractor
SWP	State Water Project
taf	thousand acre-feet
TUCP	temporary urgency change petition
USACE	U.S. Army Corps of Engineers
USFWS	U.S. Fish and Wildlife Service
WFR drought barrier	West False River drought salinity barrier
WOMT	Water Operations Management Team
1983 Agreement	"Agreement Concerning the Operation of the Oroville Division of the State Water Project for Management of Fish and Wildlife" between the California Department of Fish and Wildlife and the California Department for Water Resources, August 1983

Chapter 1. Introduction

The 2024 State Water Project (SWP) Long-Term Drought Plan consolidates information and actions taken during past droughts along with descriptions of the actions taken by the SWP to plan for and prepare for future droughts.

The scope of the SWP's drought planning activities is driven by the role the SWP plays within California's water management system during times of drought. The SWP's planning is specific to its role as a wholesale water provider. The SWP's drought planning is necessarily different from the planning by other water managers that are responsible for directly providing water to end-use customers. For these water managers, drought planning generally includes identifying a portfolio of different water supplies and demand management actions that ensures a minimum amount of water can be provided with a set degree of certainty. Retail water suppliers have a "duty to serve" water demand within their service areas and must have detailed contingency plans for meeting demand during drought conditions.

The SWP, as a wholesale water supplier, makes no guarantee of annual water deliveries. Instead, the SWP stores and delivers available water to the maximum extent possible within regulatory, contractual, and operational constraints. Users of SWP water acknowledge and understand that SWP water supplies will fluctuate significantly from year to year. Nonetheless, the SWP is focused on maintaining, to the maximum extent possible, the reliability and resiliency of SWP water supplies and other benefits in the face of climate change and other system stressors. In addition, SWP encourages public water agencies to do their own planning in accordance with state requirements and Federal Emergency Management Agency and National Drought Mitigation Center recommendations. Key to supporting those efforts, the SWP Delivery Capability Report (issued every two years) provides probabilistic estimates of current and future SWP deliveries to support risk assessments, impact analysis, and investment planning.

The SWP is a critical backbone water supply and water conveyance system that provides water to other water agencies — not to individual customers. The water supplied by the SWP becomes part of the water supply portfolio of those public water agencies that have contracted to receive SWP water. The water supply obligations upon the SWP are defined within the contracts between DWR and these agencies. This water supply obligation is based on the concept that the SWP will convey and deliver water — as it is available. By design, the amount of water that the SWP is obligated to provide varies with hydrology.

In addition to providing water supply, the SWP has an important role, along with others, in meeting Sacramento-San Joaquin Delta (Delta) flow and water quality objectives set by the California State Water Resources Control Board (State Water Board). The SWP operates its reservoirs and pumping facilities to meet these objectives, which are a condition of the SWP's water rights permits. During a drought, circumstances may arise where, independent of system operations and management, not enough water is available to meet all needs. In these circumstances, the SWP is a partner with the Central Valley Project (CVP), the State Water Board, California Department of Fish and Wildlife (CDFW) and other resource agencies, to allocate water to meet the most critical needs given the limited amount of water and uncertainty about future conditions.

Changing hydrology — including more frequent, longer, and extreme droughts resulting from climate change — will challenge the SWP and other water suppliers throughout California. Addressing these climate change challenges will require planning, investment, and innovation at State, regional, and local levels. This SWP Long-Term Drought Plan is one part of a multi-pronged response to these challenges. Additional drought planning and climate adaptation information is provided in the *California Water Plan Update 2023*, SWP Delivery Capability Report (DCR), and DWR's permits to operate the SWP. Further analysis and planning will be provided later in 2024 in the *SWP Climate Adaption Analysis, Watershed Resiliency Grants, and San Joaquin Basin Watershed Studies*.

The scope of actions taken by the SWP to plan and prepare for future droughts is intended to maximize the storage, conveyance, and delivery of available water within physical and regulatory constraints. This SWP Long-Term Drought Plan describes historical California climate and droughts, analysis of future climate and drought vulnerability, SWP water supply planning objectives, SWP water supply allocation planning and operations, SWP drought planning actions, lessons learned from previous droughts, and SWP actions to improve long-term drought resilience and enhance the physical capabilities and flexibility of the system.

Consolidating this information into a single document is intended to provide additional clarity on the scope of SWP drought planning activities as well as to show how many different activities work together to provide a comprehensive planning approach for SWP water management.

DWR will review this drought plan every five years, at a minimum, and will update the plan following significant drought events.

1.1 SWP Water Supply Planning Objectives

The SWP adheres to the following objectives to guide operational decision-making and development of SWP water supply allocations. These objectives require considered decision-making to manage trade-offs during critically dry years:

- *Deliver water supply to meet minimum human health and safety (HHS) needs*.
  HHS demand for water is based on minimum unmet water demands to meet domestic supply, fire protection, and sanitation needs during the year. The minimum Delta export threshold needed to support annual HHS demands varies from year to year and by season. Pursuant to the SWP's 2022 HHS guidelines, demands are currently based on minimum water supply and are limited to 55 gallons per capita per day. These guidelines are expected to be updated because of recent legislation.
- *Preserve upstream storage for future dry year and drought protection*. To prepare for future dry conditions the SWP plans for targeted carryover storage. (Carryover water is water that could have been delivered but was held in storage instead; increasing the carryover storage decreases the supply delivery in the year it was stored but may increase supply in subsequent years. However, if the subsequent year is wet, the additional stored water may provide little or no benefit and may have a cost in terms of flood protection.) This carryover target was 1.3 million acre-feet (maf) for several years. During the 2012– 2016 drought, it became evident that DWR needed to preserve additional carryover storage in Lake Oroville to meet contractual and regulatory requirements should the following water year be dry. In 2018, the Oroville carryover target was evaluated and increased by 300 thousand acre-feet (taf), and beginning in 2019, DWR implemented an end-of-water year storage target of 1.6 maf.

- *Meet regulatory requirements.*
  The State Water Board issued Water Rights Decision 1641 (D-1641) to DWR and U.S. Bureau of Reclamation (Reclamation) in 1999. D-1641 includes water right permit terms and conditions to implement water quality objectives to protect municipal and industrial and agricultural beneficial uses in the Delta as well as water quality and flow objectives to protect fish and wildlife beneficial uses. The objectives vary by month and by water year classification. In addition to D-1641 objectives, the SWP also provides for minimum instream flows to the Feather River as well as additional flows through export reductions in the south Delta for State and federal Endangered Species Act (ESA) protections as required by the biological opinions issued by the National Marine Fisheries Service (NMFS) and U.S. Fish and Wildlife Service (USFWS) and the incidental take permit issued by the California Department of Fish and Wildlife (CDFW).
- *Deliver water based on water rights priority.*
  In addition to providing water to meet minimum HHS and Delta water quality and flow objectives, other deliveries are made under contract to entities downstream of Lake Oroville that assert senior water rights. Upon the construction of the Oroville Reservoir facilities in the 1960s, DWR entered into agreements with districts that claimed more senior water rights than the State and that divert water downstream from the City of Oroville. Pursuant to these agreements, DWR supplies up to approximately 955 taf of water each year during the contracted irrigation season (typically March through October). Outside of the irrigation season, these districts historically have taken delivery of water for beneficial uses, such as rice stubble decomposition and waterfowl habitat.
- *Maximize diversion to storage and delivery of water supply.*
  During winter and spring, when storm events produce natural runoff, to the extent possible, the SWP maximizes diversion to upstream storage to be released later for rediversion at the SWP south Delta export facility or for Delta requirements. In addition to capturing runoff upstream, the SWP maximizes south Delta exports during the winter and spring for direct delivery and for storage in San Luis Reservoir for future delivery to state water contractors (SWCs).

Chapter 2. California Climate, Variability, and Historical Droughts and Impacts

California has a natural landscape that is diverse from its coastal shores, deserts, and fertile central valley to its foothills and mountain ranges. California has a widely variable climate dependent upon the latitude, elevation, and proximity to the coast and has generally been described as a Mediterranean climate of warmer, drier weather in the summer and cooler, wetter weather in the winter. California's climate is more variable than any other location in the United States with annual precipitation across the state varying from a less than 11 inches to almost 43 inches. This variability seems to be increasing in recent decades, with California experiencing its second driest year on record in 2021 and its wettest year on record in 2023. California's natural variability has historically resulted in periods of extended dry conditions, often resulting in significant droughts. But not all droughts are the same, and not all parts of California experience the same dry conditions. The following summary describes some of the important aspects of California climate, its variability, and descriptions of significant drought periods and their impacts. The difficulty in predicting these conditions and the uniqueness of each past drought provide insights into the challenges of managing one of California's most important water resource projects.

2.1 California Climate and Variability

California's hydroclimate presents a complex picture marked by geographical disparities, climatic extremes, and a critical dependence on precipitation patterns. The majority of precipitation occurs in the winter months and falls over the northern half of the state, particularly along the coastal western region and Sierra Nevada mountains. Throughout California, atmospheric rivers (ARs) play a pivotal role. These intense concentrated pulses of water vapor can deliver upwards of 50% of annual rainfall in just a few days. (Dettinger et al. 2011)

The hydroclimate variability in California is closely connected to the state's Mediterranean climate, characterized by a narrow window of opportunity for annual precipitation during the cool season. In the winters of 2012–2013, 2013–2014, and 2014–2015, a ridge of high pressure off the west coast of California redirected the normal storm track away from California for several months during the core of the wet season resulting in a historic drought (Lund et al. 2018). Conversely, between December 2022 and January 2023, nine ARs hit California in the longest stretch of continuous AR conditions in the 70 years that records have been collected (The Atmospheric Rivers Program 2023).

California's precipitation variability stands out within the conterminous United States, with dramatic year-to-year fluctuations driven by the wettest days contributing disproportionately to overall precipitation (Dettinger 2016). The dominance of large storms in California, responsible for approximately two-thirds of the variance in water-year precipitation, sets the state apart (Dettinger 2016). Climate-change projections indicate potential increases in precipitation from the largest storms, underscoring the influence of these events on the state's regimes of wet and dry spells. Managing these hydroclimate challenges requires a nuanced understanding of California's unique precipitation patterns, the impact of atmospheric rivers, and the evolving dynamics influenced by both natural and climatic factors.

2.2 Historical California Droughts

1976–1977 Drought

The 1976–1977 drought is considered the state’s worst two-year drought period on record. Statewide runoff in 1977 hit a record low of 15 maf and was preceded by a dry year. Those conditions contributed to the first time California water agencies had to prepare for major cutbacks to their water supplies. The record low in statewide runoff created conditions whereby 47 counties declared local drought-related emergencies and an estimated 125,000 acres of irrigated cropland were fallowed despite a significant increase in groundwater extraction.

The response to the 1976–1977 drought was multifaceted from many levels of government. The federal government passed three laws to provide economic relief with objectives to augment community water supplies, improve water systems, aid in the purchase and transport of water, and promote water conservation. The State established a Drought Emergency Task Force which responded to the drought by utilizing educational communication and creating legislative and direct assistance approaches.

These efforts, combined with a wide publicly accepted conservation effort, guided the state out of the drought and into subsequent years of wetter conditions.

1987–1992 Drought

The 1987–1992 drought was a six-year period of dry to critically dry conditions. The Sacramento Valley experienced four out of six critically dry water years and two dry water years, while the San Joaquin Valley experienced all six water years as critically dry. Twenty-three counties declared local drought emergencies by the end of 1991. During the 1987–1992 drought, statewide reservoir storage was approximately 40% of average by the third year of the drought, and it did not return to average conditions until 1994. SWP allocation was still 100% until 1990, when allocations for agriculture dipped to 50%. In 1991, SWP allocations dropped severely to 20% for municipal and industrial and 0% for agriculture. A 1991 governor executive order created a drought action team and directed DWR to implement a drought water bank. Implementation led to a pilot program wherein DWR purchased water to deposit into a drought water bank to be used as needed on an annual basis.

2007–2009 Drought

The 2007–2009 drought was characterized by three consecutive dry or critically dry water years and the fourth highest total fire acreage of 1.6 million acres in 2008. Unique to this drought was a period of unprecedented restrictions on diversions from the SWP and federal CVP for the protection of federal and State-listed fish species in danger of extinction. The 2007–2009 drought was also the first time a statewide proclamation of emergency was issued. Compared to past droughts, the statewide hydrologic conditions during this drought were not extremely severe, but southern California experienced its single driest year in which parts of southern California, including the City of Los Angeles, experienced record low precipitation in 2007.

The area most severely affected by this drought was the west side of the San Joaquin Valley where CVP deliveries decreased from 50% and 40% in 2007 and 2008, respectively, to 10% of contractors’ allocations in 2009. SWP deliveries decreased from 60% and 35% to 40% of contractor’s allocations in 2009. This drought was characterized by water shortages directly linked to significant economic impacts to agriculture and rural communities. The 2007–2009 drought highlighted the need for establishing methodologies and metrics to assess socio-economic impacts as well as increasing the understanding and status of groundwater resources. The State also recognized and established standards for water suppliers to receive credit for substantial capital investments in urban water conservation and water management planning.

2012–2016 Drought

Just three years after the previous drought, the 2012–2016 drought was characterized by the driest four consecutive water years on record for statewide precipitation, which include two of the warmest calendar years on record in statewide average temperatures, 2014 and 2015. The drought hit its lowest record for monthly runoff of 3 inches in 2014. Warmer temperatures resulted in higher freezing elevations for winter storms, much of the precipitation falling as rain rather than snow, and increased evapotranspiration rates. In April 2015, the amount of water stored in California’s snowpack, referred to as snow-water content, was as low as 5% of average. The SWP water supply allocations began to decrease during that period and eventually dropped to a record (at the time) low of 5% in 2014. This dramatic reduction led to increased groundwater extraction, and groundwater levels in many parts of the state fell below previous historical lows. For the first time, satellite imagery revealed the broad spatial extent of damaging land subsidence occurring throughout the San Joaquin Valley in response to drought-induced groundwater extraction. San Joaquin Valley land subsidence rates matched historical record levels, and impacts included massive tree mortality in the central and southern Sierra, and then-record levels of wildfire costs.

This prompted the second statewide emergency proclamation for drought. The State Water Board required a stress test process from water agencies. In 2016, those stress tests showed that almost 10% of the state’s larger water systems would need some level of mandated water use reduction over the next three years, based on a conservative assumption of continued record dry hydrologic conditions. Additionally, the extent of issues surrounding drinking water shortages for small rural water systems and dry private wells was elevated by the severity of water shortage conditions that occurred during the 2012–2016 drought and beyond. The 2012–2016 drought also reflected an intensification of historically observed drought impacts and the emergence of new impacts, such as the challenge of maintaining sufficient cold water to support ESA-listed salmonids habitat as well as increased threats to water quality from harmful algal blooms (HABs).

2020–2022 Drought

The 2020–2022 drought is characterized by three consecutive La Niña weather patterns that traditionally equate to drier conditions in Southern California. The La Niña weather patterns produced drier-than-average years and very low annual runoff. The drought was highlighted by the second year that the state hit its lowest record of 3 inches for monthly runoff, matching that of 2014. Snow-water-content levels dropped as low as 35% of average in April 2022. Reduced snowpack and earlier spring warming led to an 8% drop in the fraction of spring snowmelt runoff into the Sacramento River and the San Joaquin River over the past century. Throughout summer 2021, almost 100% of the state was in drought conditions with approximately 90% of the state in extreme or exceptional drought conditions. One extreme outcome from the 2020–2022 drought was the impact on domestic wells. More than 1,200 domestic wells went dry in 2022, which was almost a 50% increase from 2021.

Extreme drought conditions during the 2020–2022 drought created a very dry and arid landscape and produced some of the state’s largest wildfire seasons on record. In 2020, almost 4.4 million acres burned from more than 9,600 fires, which destroyed more than 10,000 structures. The first giga fire (a wildfire that exceeds 1 million acres), the August Complex, burned more than 1 million acres in 2020. In 2021, almost 2.6 million acres burned from more than 8,800 fires, which destroyed more than 3,600 structures. The Dixie Fire very nearly became the second giga fire, burning almost 1 million acres of the SWP’s primary watershed.

The 2020–2022 drought also affected most of the Western United States; one of California’s water sources, the Colorado River system, saw its water supply continue to trend downward. During the worsening drought conditions, the largest storage units in the Colorado River system, Lake Powell and Lake Mead, had a combined storage of 25% of total capacity in 2022, which was down from 39% in 2021.

2.3 Uniqueness of California Droughts

From the description of the listed historical droughts above, it is clear that California's droughts are not identical, but are unique in their own conditions and impacts. Some droughts can be localized and affect regions of the state, while others can be broad and have statewide impacts. Some droughts can be quick and short, but still challenge management of water supplies, while others are longer with more exaggerated or extreme impacts. California droughts can vary by location and scale, periods of time and duration, climate and landscape conditions, and impacts to communities and economies. But one current trend of droughts that appears to be consistent is their magnification by climate change and subsequent heightened impacts. This danger drives the need for DWR and California to prepare for more impactful droughts and water shortages in its future.

The wide range of impacts to the environment, landscape, economy, and people of the state have spurred State government to take additional action in a variety of ways to improve the state's resiliency to droughts and water supply shortage conditions. Senate Bill 552 requires County governments to develop drought plans to support small water suppliers and rural communities that are often frequently affected most by droughts and water supply shortage conditions. Another example of actions taken are legislative mandates Assembly Bill 1668 and Senate Bill 606 that require urban water managers to adopt water shortage contingency plans, drought risk assessments, and annual water supply and demand assessments. DWR is also leading a task force, the Drought Resilience Interagency & Partners Collaborative, which is a public forum with State and non-State agency members to advance pre- and post-drought planning actions to build resiliency to the increasingly arid conditions. The California Water Commission has developed a white paper, *Potential State Strategies for Protecting Communities and Fish and Wildlife in the Event of Drought* (2024); this paper highlights strategies to address drought and water shortage impacts, such as integrating groundwater recharge opportunities with federal- and State-operated reservoir management through the development of forecast-informed reservoir management, managed aquifer recharge, and reservoir reoperation to improve the capture and storage of flood waters for recharge of groundwater basins.

Chapter 3. Analysis of Potential Future Droughts

A wide array of scientific literature documents the likely impacts of climate change on California hydroclimate and water resource systems (Vicuna et al. 2007; Dettinger et al. 2015; Diffenbaugh et al. 2015; Ray et al. 2020). Droughts are likely to be more severe and frequent in the future because of exacerbating climate change, as well as other factors including increasing human demands, and increasing environmental demands. Climate change likely will result in higher temperatures, more variable precipitation, greater evapotranspiration, and higher sea levels, all of which will impact the SWP and likely will lead to hydrologic drought conditions that are more stressful than historical experience in both severity and frequency.

The Delta Adapts Water Supply analysis, completed in 2021 for the *Delta Adapts Climate Change Vulnerability Assessment* by the Delta Stewardship Council, shows that each of these climate stressors will have slightly different impacts on the SWP. Higher temperatures will result in higher snowlines, earlier snow melt, and greater evapotranspiration generally resulting in early peak runoff, lower spring runoff, and greater trade-offs between flood protection and water supply operations. Lake Oroville plays an important flood protection role from October to May each year, with the 1970 U.S. Army Corps of Engineers (USACE) *Water Control Manual for Lake Oroville* setting forth required flood control storage and flood control releases needed for downstream flood risk reduction during this time of the year.

Greater evapotranspiration, generally resulting from higher temperatures but also from changed vapor pressure deficits, results in greater demand for water from plants (both natural communities and agricultural) and greater evaporation; these in turn result in reduced soil moisture, deep percolation, and streamflow downstream. More variable precipitation was shown to generally have a greater impact on the driest years because dry years tend to get even drier and more frequent. More variable precipitation is also expected to result in wetter wet years. These wetter wet years, similar to what was experienced in 2023, could be so wet that existing export, conveyance, and storage capacity are fully utilized, and excess water cannot be managed for beneficial use. Moderate sea level rise (less than 2 feet) was shown to have a somewhat subtle but chronic impact on SWP performance. As sea levels increase, more water is required to maintain compliance with environmental and water quality regulations in the Delta. The Delta serves as a transition zone between freshwater from the confluence of the Sacramento and San Joaquin rivers and saltwater from the Pacific. The amount of freshwater flowing into and through the Delta drives seasonal and annual salinity levels. Where freshwater and saltwater meet is referred to as X2. (X2 is a measurement of distance from the Golden Gate Bridge where water salinity is 2 parts per thousand of isohaline salt at 1 meter off the bottom of the waterbed.) A rising sea level threatens the Delta with greater salinity intrusion by moving the X2 location further east into the Delta estuary. Counteracting this saltwater intrusion requires increasing the volume of water released from reservoirs or other tradeoffs, such as salty water quality.

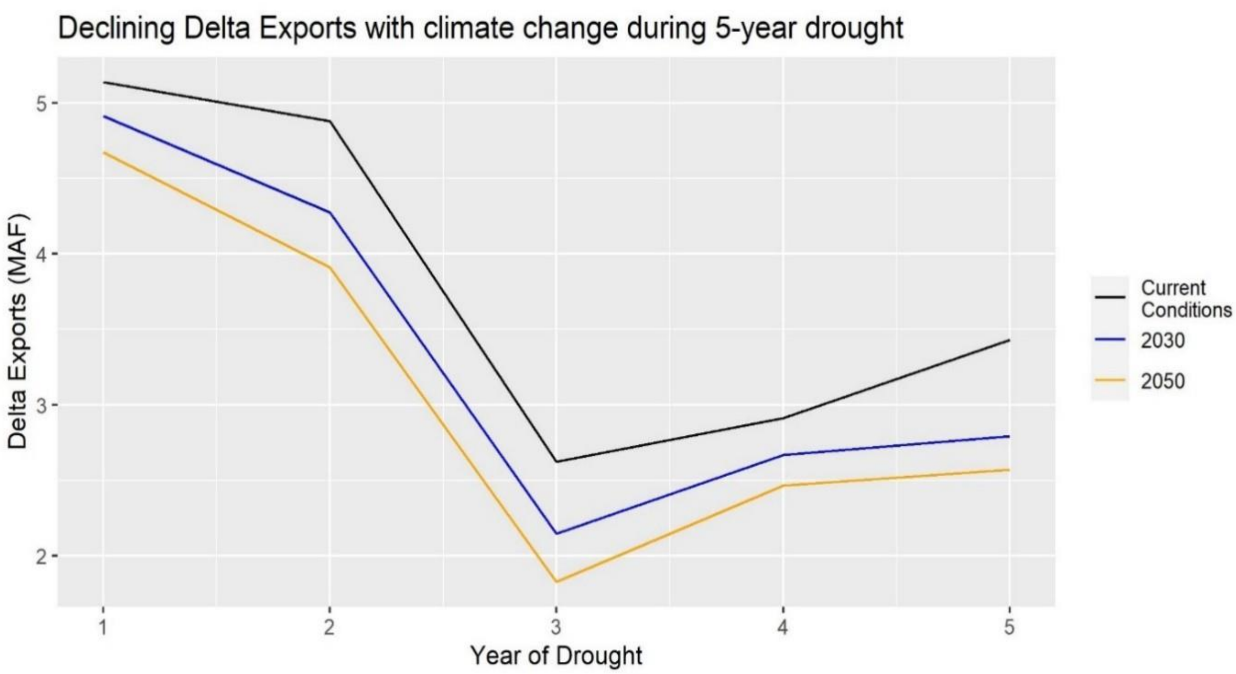
Where the additional water required to counteract sea level rise comes from increased releases of upstream storage, it will contribute to lower reservoir carryover storage, making the system more vulnerable to drought conditions. Analysis showed that higher levels of sea level rise were strongly correlated with the most significant water shortage conditions in simulations of future conditions.

Delta Adapts also included a comprehensive drought analysis of impacts on Delta water supplies. The analysis looked at both severity of drought impacts (i.e., the degree to which a historical drought might be exacerbated by climate change if it were to reoccur under future climate conditions) and frequency of drought impacts (i.e., the degree to which a historical drought of a given severity might reoccur more frequently under future climate conditions). Delta Adapts estimated that under today’s climate conditions and with the water management infrastructure, operations, regulations, and current demands, conditions as severe as during the 2012–2016 drought would only be experienced twice in 1,100 years. Figure 3-1 shows how Delta exports during that 5-year drought period would compare under current, 2030, and 2050 conditions. Average exports over the 5-year period decline 11.5% below current conditions under 2030 conditions and 18.5% under 2050 conditions. Figure 3-1 also highlights that the worsening conditions of the drought are not due solely to warmer and more variable conditions during the drought; exports are also reduced because of the warmer, more variable conditions of the climate in years running up to the drought. In

September of the year (2011) prior to the start of the drought, storage in the major North-of-Delta CVP and SWP reservoirs declined as well. Under current conditions, simulations show more than 8 million acre-feet of water being carried over from September of the year before the drought into the first year of the drought.

Under 2030 climate conditions, carryover storage going into the first year of the drought is reduced by 400,000 acre-feet (5%), and under 2050 conditions carryover storage going into the first year of the drought is reduced by 760,000 acre-feet or nearly 10%.

Figure 3-1 Declining Delta Exports with Climate Change during Five-Year Drought



Warming temperatures, more variable precipitation, and higher sea levels all place additional stress on the water management system and will reduce its ability to meet all demands. Delta Adapts found that under future climate conditions, the likelihood of experiencing drought conditions similar to the 2012–2016 drought increase as temperatures increase, sea levels rise, and precipitation becomes more variable. By 2050, temperatures are expected to be approximately 2 degrees Celsius warmer than today, precipitation approximately 12% more variable, and sea levels approximately 1 foot higher; combined, those conditions would result in drought conditions comparable to the drought of 2012–2016 becoming 5 to 7 times more common.

The 2023 Draft SWP Delivery Capability Report also explores potential future drought conditions. The SWP Delivery Capability Report models slightly different conditions than those modeled by Delta Adapts but finds similar results. The historically experienced drought periods of 1929–34 (6 years), 1976–77 (2 years), 2014–15 (2 years), and 1987–1992 (6 years) all show increasing severity under 2043 conditions with climate change. Table 1 below, excerpted and adapted from the 2023 Draft SWP Delivery Capability Report, shows how climate change makes each of the historical droughts worse. Modeled SWP Table A deliveries are reduced by 10–46% below deliveries during the same drought with historically experienced conditions and contemporary regulations. The range of potential decreases is driven by the conditions of the specific drought and the severity of climate impacts.

Table 1 Estimated Average and Dry-Period Deliveries of SWP Table A Water (2043 Climate Change Conditions without Adaptation, in TAF/year) and Percent Reduction in SWP Table A Amount From the Same Drought With Current Climate Conditions

Period*	Current Conditions (1922–2021)	2043 Future Climate Change Scenarios 50% LOC** (1922–2021)	75% LOC** (1922–2021)	95% LOC** (1922–2021)
Long Term Average	2,238	1,990 -11%	1,852 -17%	1,770 -21%
2 Year (1976–1977)	935	623 -33%	532 -43%	503 -46%
2 Year (2014–2015)	399	357 -11%	348 -13%	322 -19%
6 Year (1987–1992)	902	644 -29%	629 -30%	588 -35%
6 Year (1929–1934)	612 -15%	543 -11%	549 -10%	451 -26%

* Periods were manually selected to include the driest, most notable, and most recent years from the simulation.

** LOC= Level of Concern as defined in Draft SWP Delivery Capability

Report. 50% LOC describes a median climate change condition at 2043, 75% and 95% LOC describe increasingly severe and less likely, but plausible, climate change conditions at 2043.

Chapter 4. SWP Water Supply Allocation Planning and Operations

Drought is a normal part of California's hydroclimate, and the SWP has operated through numerous drought periods in the past. Despite this history, California's unpredictable climate makes it extremely challenging to foresee when conditions will slide into drought or when a large storm will arrive to alleviate drought conditions and recharge reservoirs. To help anticipate future conditions, the SWP employs a tiered yearly, monthly, and daily planning and operational scheme to forecast as best as possible this uncertainty and ever-present risk of drought conditions.

4.1 SWP Annual Allocation Planning

The annual SWP water supply allocation planning cycle begins each year in November, using information from runoff forecasts. These runoff forecasts are produced by DWR's Division of Flood Management (which is independent of the SWP) starting in December and continuing through May. The runoff forecasts are used with water supply allocation models and produce water supply allocation studies that explore possible operational outcomes given current conditions and forecasted future outcomes. By December 1 of each year, DWR's Director issues an initial SWP water supply allocation (in accordance with the long-term water supply contracts). DWR's Director may issue updates to the allocation as conditions evolve throughout the year with a final allocation issued in May.

4.1.1 Water Supply (Runoff) Forecasts

The runoff forecasts are a key factor in determining the SWP water supply allocation. Beginning in December, DWR's Division of Flood Management (DFM) produces monthly water supply forecasts for the runoff from Sacramento and San Joaquin watersheds. The runoff forecasts issued February through May (Bulletin 120 [B120]) incorporate actual snowpack measurements in addition to precipitation data. These forecasts provide a probabilistic range of hydrologic outcomes. DWR provides the B120 forecasts to the public and water agencies on its website. The B120 forecasts are used by the SWP and many other water managers throughout the state to inform their water supply planning activities. Water supply forecasts produced by

DWR's DFM are developed independently so there is no operational or management overlap between the DFM and the SWP. Although the SWP contributes funding and operational expertise to the forecasting team, the SWP does not contribute to forecast calculations or decision-making. This distinction is important to ensure scientific independence of forecasts and allow for rigorous and unbiased assessments.

4.1.2 SWP Water Supply Allocation Process

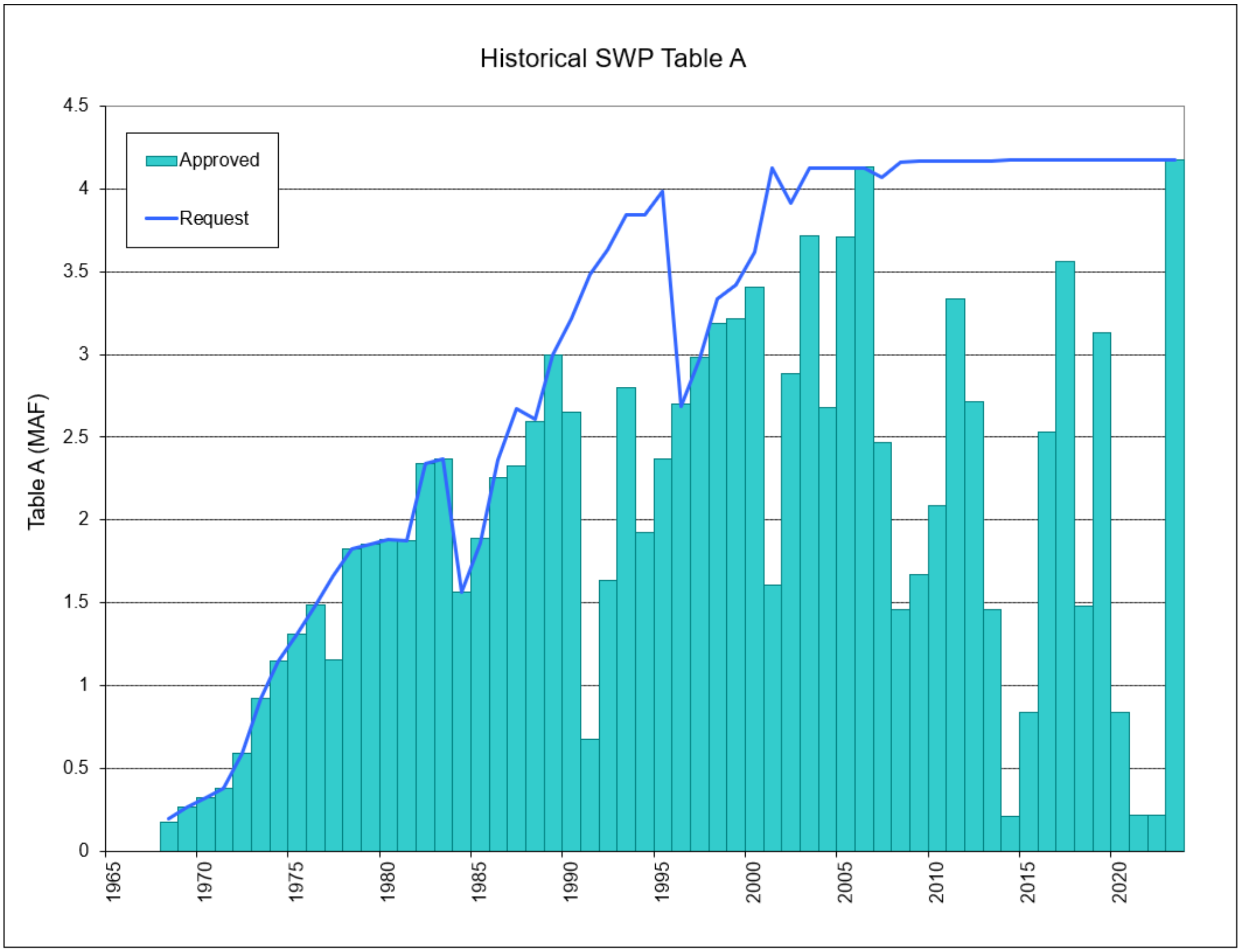
At the beginning of the annual water supply planning cycle (November of each year), significant uncertainty exists as to the hydrologic conditions for the water year. So, the runoff forecasts (described above) provide a range of potential hydrologic conditions that inform SWP estimates of possible available water deliveries. The SWP develops several allocation studies that explore the range of potential water supply availability resulting from a probabilistic range of water supply runoff forecasts provided by DFM. At a minimum, an average (50% hydrology exceedance) and dry (90% hydrology exceedance) hydrology are used to inform potential operations and allocations. Additional information that explains water supply forecasts and exceedance probabilities can be found on the National Resource Conservation Service website. The allocation studies also evaluate a range of potential regulatory requirements that are uncertain and dependent on hydrology, temperature, and other uncertain conditions.

In consideration of hydrologic uncertainty, the water supply allocation makes conservative assumptions that precipitation for the remainder of the year will be much lower than average. Therefore, the study used for allocation recommendations is based on a dry hydrology assumption of a 90% exceedance, where there is only a 10% probability that actual conditions will be drier than the conditions assumed for the study. (A 50% probability assumes there is even chance that actual conditions will be drier or wetter by the end of the year.)

Given the changing hydrologic conditions as the water year unfolds, the studies are updated monthly January through May of each year. If actual observed hydrology improves, water supply allocation increases may be issued by DWR's Director, and the final allocation is typically issued in May. Decreases in the allocation may be warranted in very dry years but every effort is made to avoid decreasing the allocation after March.

It is important to note that demands for SWP water, which used to fluctuate, are now largely fixed. In every year since the mid-2000s SWP contractors have requested their full SWP Table A allocation. Figure 4-1 below shows the requested and approved SWP Table A deliveries in each year since 1968.

Figure 4-1 Historical SWP Table A Water Amounts requested by Water Contractors and Approved for Delivery, 1968–2023



4.2 Real-Time Operations

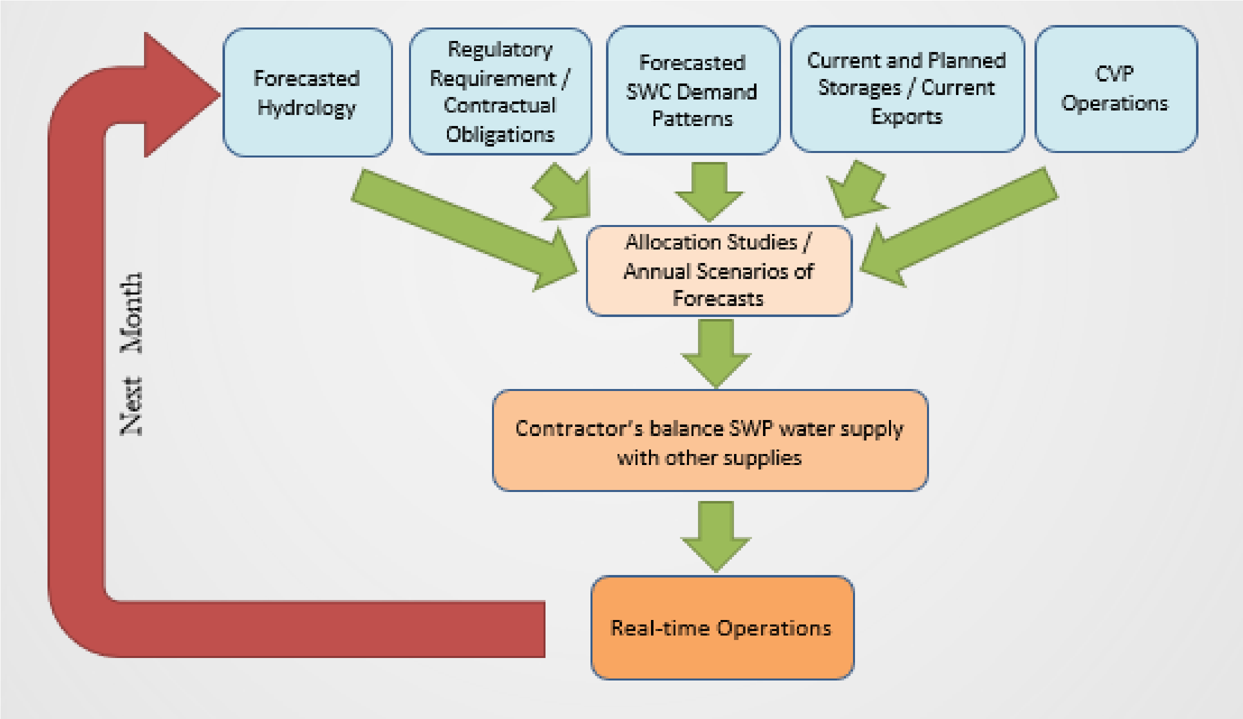
The allocation studies provide a range of forecasted SWP water supply availability as well as a range of monthly averages of system-wide conditions (e.g., Feather River releases, Delta outflow, SWP exports, etc.) based on a range of hydrologies and regulatory requirements. Ranges of forecasts must be considered because not only are hydrologic conditions subject to change as the year unfolds, but many regulatory requirements are dependent on hydrology.

The actual day-to-day SWP operations (e.g. south Delta exports and Feather River releases) will differ from those forecasted in monthly operations in allocation studies because day-to-day SWP operations respond to actual experienced physical and regulatory conditions. At any given time, the SWP is operating its facilities to meet the project objectives and priorities (listed in Section 1 above) as well as manage flood protection throughout the winter season. Operations are updated weekly and/or daily (and sometimes even more frequently) based on real-time conditions. Each of these planning and operational actions is described in greater detail below. These actions are considered part of the SWP's drought action plan because they occur in all years and provide the earliest indications of, and responses to, dry conditions.

These daily operations address the real-time conditions encountered, such as hydrologic, meteorological, tidal, and ecological conditions, which deviate from monthly forecast information and are outside the control of the SWP. SWP operators meet daily with CVP operators to coordinate and adjust operations as needed to meet water quality and flow standards required under D-1641, or flows needed for compliance with State and federal ESA permit requirements.

Figure 4-2 provides a depiction of how the SWP allocation studies are trued up with real-time operations.

Figure 4-2 SWP Allocation Process and Forecasted Operations



4.3 Additional Allocation and Real-Time Operations Considerations

Within both the annual allocation planning and real-time operations decisions, a number of considerations are included in developing the allocation studies and real-time operations.

4.3.1 Central Valley Project Operations and Coordinated Operations Agreement

As a condition of their water rights permits, the SWP and Reclamation's CVP are jointly obligated to meet flow and water quality requirements to support in-basin uses — legal uses of water in the Sacramento Basin, including municipal and industrial, fish and wildlife, agriculture, and recreation. DWR and Reclamation share the obligation for meeting in-basin uses through a coordinated operations agreement signed in 1986. This agreement is subject to periodic review and was most recently amended in 2018. The coordination of project operations to meet the joint obligations occurs through ongoing interaction and information sharing, at times requiring multiple interactions

4.5.1 Annual SWP Drought Contingency Planning

The 2020 incidental take permit (ITP) issued by the CDFW to DWR for the long-term operation (LTO) of the SWP requires the development of a drought contingency plan under the following conditions:

> On October 1, if the prior water year was dry or critical, Permittee, in coordination with Reclamation, shall meet and confer with the USFWS, NMFS, State Water Board, and CDFW to develop a drought contingency plan to be implemented if dry conditions continue into the following year. On February 1, if dry conditions continue, Permittee shall submit the drought contingency plan to the CDFW and shall update the plan monthly based on current and forecasted hydrologic conditions. If dry conditions continue, Permittee shall regularly convene this group to evaluate hydrologic conditions and potential for continued dry conditions that necessitate implementation of measures identified in the drought contingency plan for the current water year.

The drought contingency plan solely addresses conditions for the year in which it is issued. Although the drought contingency plan is a requirement connected with the SWP’s permit, in recent years (2021 and 2022) the plan has been coordinated and developed jointly with Reclamation.

Each drought contingency plan typically will include an overview of hydrological conditions, a species status update, hydrology forecast, SWP and CVP operations forecast, areas of potential concern, and any drought actions to be implemented or that may be potentially needed. Recent experience has shown short-term swings between wet and dry conditions over the last decade, so the scope of each drought continency plan will depend on the SWP and CVP conditions and forecasts at that time. The plan is updated monthly throughout the water year, or until hydrology and conditions improve such that drought actions are no longer anticipated or required.

4.5.2 Drought Toolkit

In accordance with the 2019 biological opinions and 2020 ITP, DWR and Reclamation worked with the WOMT agencies to identify implementable actions that could be taken during a drought to manage the limited water supplies of the SWP and CVP. The Drought Toolkit provides a coordination process to implement drought relief actions and identifies potential measures to be taken during drought years and successive dry years. This Drought Toolkit describes the coordination, processes, planning and potential drought response actions in the event of a drought. The coordination process begins with WOMT. WOMT will request activation of the Drought Relief Year (DRY) team to assess the potential application of available drought actions and to plan for future actions if drought conditions persist. The DRY team comprises technical and policy makers from each of the six WOMT agencies. The DRY team is also responsible for disclosing the evaluations conducted during any implemented action for the current water year. The DRY team will, at a minimum, convene when Shasta cold water pool management is in critical condition. WOMT, however, may activate the DRY team at its discretion, based on real-time conditions.

To support an efficient and organized drought response, the Drought Toolkit contains summaries of potential drought relief actions (DRAs). These individual action summaries provide DRY team members with a quick reference that includes both the seasonal timing and implementation times for rapid evaluation. The Drought Toolkit contains an array of strategies and is intended to act as a repository of the institutional knowledge gained when a DRA is implemented. The Drought Toolkit leverages planning and communication channels to implement actions that can be taken year-round to support operational flexibility and ongoing habitat and restoration actions that may bolster the species' resilience, especially during drought and successive dry year conditions. As new DRAs are identified and developed, those DRAs will be evaluated through the LTO coordination process and will be added to the Toolkit as appropriate. At a minimum, the entire Drought Toolkit will be revisited no less often than every five years following the issuance of new biological opinions for the LTO of the SWP and CVP.

The latest version of the Drought Toolkit is available online at the Reclamation website.

4.6 SWP Operational Drought Actions

When upstream storage is insufficient to fully meet all SWP water supply objectives, tradeoffs and impacts will occur and drought actions may be necessary. Management of the SWP during such conditions requires difficult tradeoffs and informed decision making about the use or preservation of limited water supplies to minimize near-term and longer-term impacts.

These tradeoff decisions are made in consultation with other agencies and attempt to best manage uncertain future conditions.

Throughout the year, drought response actions will change as the year's hydrology develops. As noted above, every drought and drought response will be different. Duration, severity, water storage conditions, and temperatures are important variables in how a drought unfolds. A subset of actions from the Drought Toolkit presents a list of historical short-term drought actions taken during years with limited water supply to meet all water supply objectives. These decisions serve as examples of drought actions that may be considered in subsequent drought years. This is not an exhaustive list nor are actions listed in a particular order.

4.6.1 Human Health and Safety Water Supply Allocation

Under extreme drought conditions and if the forecast indicates an elevated risk of continuing drought conditions, DWR will allocate available supplies to ensure that the SWP long-term water supply contractors can meet their minimum HHS demands, based on minimum water demands for domestic supply, fire protection, and sanitation needs that cannot be met by other available water supplies.

4.6.2 One Facility Operation

A one-facility export operation uses either the SWP or CVP facility to export water from the Delta, and the limited export is distributed between the SWP and CVP through the intertie between the Delta Mendota Canal and California Aqueduct. This operation allows the SWP and CVP to limit upstream releases while maintaining minimum HHS exports. This action was implemented in 2021.

4.6.3 Facilitation of Transfers and Exchanges

Pursuant to California Water Code Section 1810, the SWP facilitates bona fide water transfers from sellers to buyers when unused SWP conveyance capacity is available. Transfer and exchange (which consist of two or more transfers) are especially important during drought as buyers acquire additional water from willing sellers to optimize water management and meet critical needs. Facilitation of transfers and exchanges enable better storage management and lower energy cost as one can access different sources of water supply when it is available instead of spending extra energy to extract and replenish within a short period of time.

4.6.4 Water Transfer Delay Programs

In dry and critically dry water years, DWR works with various water agencies across the state to facilitate water transfers from the Sacramento Valley through the Bay-Delta to meet south-of-Delta water needs. Water transfers originating from the Feather River Watershed commonly will be releases from stored water in Lake Oroville. July through November is the permitted window to release and export the transfer water. But, in most years, transfers are moved July through September. In critically dry years, the SWP has delayed releasing the stored water until the October and November period to bolster storage during the summer months and conserve cold water pool for the fall period when cold water releases are critical for the fisheries.

4.6.5 Environmental Actions

The SWP implements a number of actions and monitoring activities to understand drought effects to the aquatic environment. These actions and monitoring commitments are implemented to allow SWP scientists to better understand the system and develop action for implementation in future droughts. As an example, during the 2020–2022 drought, the SWP increased its investment in environmental monitoring of drought consequences by funding monitoring of invasive vegetation and harmful algal blooms. Staff also collaborated with other agencies within the Interagency Ecological Program to synthesize existing knowledge of environmental impacts of drought on the Delta. This project resulted in a technical report and a series of peer-reviewed journal articles to be published in a special issue of the journal *San Francisco Estuary and Watershed Sciences* in March 2024. The papers concluded with a number of recommendations that may be implemented by the SWP to reduce the impacts of drought.

The most effective actions to reduce impacts of drought on the environment are frequently actions taken in non-drought years to increase overall system resiliency. For example, restoration of tidal wetlands and floodplain habitat (including that covered by the EcoRestore program) provides benefits to at-risk fishes and other wildlife in both drought and non-drought periods. Similarly, the Yolo Bypass Salmonid Habitat Restoration and Fish Passage (Big Notch) Project will decrease the minimum flows in the Sacramento River that allow juvenile fish to access critical rearing habitat in the Yolo Bypass.

To ensure the benefits of restoration and SWP levees are maintained in the long-term, DWR is investing in assisting the CDFW Nutria Eradication Program. Drought years are particularly important for making progress in nutria eradication because droughts limit nutria dispersal.

The SWP is also developing new tools to help respond to the environmental impacts of drought faster and better. In 2023, DWR piloted a new cyanobacterial monitoring program using new tools to assess cyanotoxins at many of the routine monitoring stations throughout the Delta. In coordination with the USFWS, CDFW, and other State and federal agencies, DWR also piloted experimental release and population supplementation of Delta smelt during drought periods when populations usually decline. DWR is developing environmental DNA and other genetic tools to better monitor at-risk fishes during their migration through the Delta or at salvage facilities during drought periods when catch of fish in traditional monitoring programs is low. Environmental DNA methods are also being piloted to detect new invasive species more rapidly — invasive species that may become more easily established during drought periods when native species are stressed.

Longfin smelt have a particularly strong flow-abundance relationship, so they are particularly hard hit by droughts. The Longfin Smelt Science Program, mandated by the 2019 ITP, includes efforts to establish a refugial population in case of catastrophic loss of the wild population, which could occur during prolonged drought. The program also includes a new longfin smelt outflow study looking at mechanisms of the longfin smelt outflow abundance relationship, and a contract with the USFWS and other agencies to create a new life cycle model for longfin smelt that would, among other things, model outflow effects on longfin smelt abundance.

4.7 Statewide Drought Actions Supported by the SWP

4.7.1 West False River Drought Salinity Barrier

The West False River Drought Salinity Barrier (WFR Drought Barrier) was installed by DWR in 2015 and again in 2021–2022, both under Governor Drought Emergency Proclamations. The purpose of the barrier is to mitigate salinity intrusion in the central Delta and protect the beneficial uses of Delta water. The barrier has been proven effective to preserve water quality in the Delta when releases of fresh water from upstream reservoirs are reduced. Although the barrier provides incidental benefit to SWP operations, which are minimal during extreme drought, the benefits of the barrier to in-Delta water users and ecological conditions are much broader.

Installation of the WFR Drought Barrier was accompanied by a robust environmental monitoring program, including monitoring for impacts of the barrier on salmonid migration, predation rates, harmful algal blooms, and aquatic weed distribution. Future installations of the WFR Drought Barrier and similar drought actions also should be accompanied by environmental monitoring.

4.7.2 Temporary Urgency Change Petition

The submittal of a temporary urgency change petition (TUCP) is an emergency adaptation strategy provided for within the California Water Code. Through the submittal of a TUCP, DWR and Reclamation jointly request that the State Water Board consider a temporary modification of Delta water quality and flow standards contained in D-1641. Such requests are made when forecasting and modeling indicate that continuing to meet D-1641 standards in the near term will result in more severe impacts to water quality and aquatic resources later in the year, and that the most prudent course of action in the near term is to preserve water storage for late season temperature management, instream flow, water quality, and Delta outflow later in the year. TUCPs have been submitted and conditionally approved by the State Water Board in 2014, 2015, 2021, 2022 and 2023.

4.7.3 State Water Contractor Conservation Actions

During drought conditions, DWR regularly communicates with its customer agencies regarding expected conditions and SWP operations. This information is intended to support these agencies as they make their own drought response decisions including the degree to which to implement water conservation actions. During periods of extreme drought, DWR will also communicate publicly with its member agencies to encourage specific conservation actions or targets. In addition to DWR communications on expected conditions, SWP contractors who are required to develop Urban Water Management Plans are also required to adopt Water Shortage Contingency Plans (WSCP). The plans include required conservation actions when specific water shortage conditions occur.

4.7.4 Review of State Curtailment and Transfer Policies

DWR, as a part of a statewide drought action, prospectively considers State Water Board policies governing water right curtailments and water transfers. DWR assesses these policies within the context of DWR's role both broadly in supporting the state's water needs and as owner/operator of the SWP and its roughly 28 million water users. Where DWR identifies challenges or inconsistencies with state needs, it coordinates with the State Water Board.

4.8 Limits and Tradeoffs of Extreme Drought

In any given extreme drought condition, the SWP and CVP must respond to short-term crisis conditions while continuing to preserve the operational flexibility to respond to future, long-term conditions, should prolonged drought conditions continue. Because the end of drought conditions cannot be predicted, operations must be conducted in a manner that balances current needs with potential future needs. Consequently, there are inevitable tradeoffs that must be made in managing water project operations during a prolonged drought. Decisions are made after full consideration of all the pros and cons of any potential action. These decisions require the full and balanced consideration of the benefits and the impacts of the action on the natural environment and human activity.

Chapter 5. Lessons Learned from the 2020–2022 Drought Emergency

Although each drought is unique and poses its own challenges and requires its own customized response to conditions and impacts, new knowledge and experience is gained with each new drought event. Capturing and preserving these lessons is an important element of the SWP's efforts to continuously improve drought management and plan for more severe future droughts. A high-level summary of the lessons learned from the 2021–2022 drought is provided below.

5.1 Communication

Early and consistent communication with the public and water agencies is critical to aligning drought response efforts. The SWP's operational decisions and announcements on water allocations occur at regular intervals, starting in December with an initial allocation and concluding in May with a final allocation. But Central Valley farmers make their planting decisions for the next year in October and November. These decisions have a high impact on demand for SWP water. SWP staff recommends that communications be increased early in the water year and maintained throughout the season between SWP allocations. If conditions are well below average, in anticipation of a dry year, communication on water conservation with the SWP contractors should start well before the initial allocation.

5.2 Temporary Urgency Change Petitions

California's hydrologic conditions are dynamic, uncertain, and can change from month to month. The need for a TUCP often becomes clear only weeks before it is needed. SWP staff concluded that while TUCPs were processed relatively quickly, it was rarely possible to observe the full public review timelines that are otherwise required. SWP staff recommend working with the State Water Board to identify opportunities to streamline processes related to TUCPs, and to engage in the WQCP process so that future TUCP needs can be planned for, to the extent possible.

5.3 Delta Barriers

The SWP implemented or considered a series of temporary rock barriers in the Delta to mitigate salinity intrusion during the drought emergency. These barriers were a component of preventing saltwater intrusion as less fresh water was released from upstream reservoirs into the Delta to preserve water storage critical for HHS. Salinity intrusion threatens Delta agriculture, local municipal supplies, the natural environment, as well as the supply of drinking water south of the Delta.

From June 2021 to November 2022, the SWP installed a drought salinity barrier at West False River in the Delta. The barrier was successful at mitigating salinity intrusion and likely will be needed again based on the cyclical nature of drought in California. The SWP also planned to implement drought salinity barriers in the north Delta if drought conditions continued to worsen after the 2022 water year. Barriers were planned to be implemented as early as June 2023 at Miner Slough and Steamboat Slough but were not needed as record snowfall in 2023 alleviated drought conditions.

Because the WFR Drought Barrier has proven an effective drought measure and is expected to be needed again during future droughts, DWR is working toward a longer-term plan for the periodic and severe drought-based installation of the barrier. This effort is allowing DWR to work with permitting agencies in a more proactive manner (See description in Chapter 7.)

Funding the continued study of HABs in and around Franks Tract in the Delta will help identify and understand the growth of HABs in the area.

5.4 Aqueduct Reverse Flow Operations

The SWP examined several proposals to deliver water stored south of SWP's major reservoirs by reversing the flow in SWP aqueducts. These proposals were considered to protect HHS if 2021 was followed by another critically dry year. Kern County Water Agency and Dudley Ridge Water District requested that DWR consider a proposal to reverse the flow in the California Aqueduct by closing check site gates and pumping around the check site to deliver water to these agencies from the Cross Valley Canal and Kern Water Bank as far upstream as Check 20. In addition, the South Bay water contractors requested consideration of a proposal to reverse the flow in the California

Aqueduct as far upstream as Bethany Reservoir to deliver water from Semitropic Water District to these agencies.

Ultimately, both proposals were ruled out as either infeasible because of a mix of technical, financial, operational, and legal considerations or were found to be unnecessary as water could be delivered by a series of operational exchanges among water contractors. SWP staff recommends that the feasibility of these projects be reexamined during future drought emergencies as a potential solution during a scenario where no water is flowing through the aqueduct. Operational exchanges are typically always possible and preferred in any other circumstance.

Chapter 6. SWP Actions to Improve Long-Term Drought Resilience and Add Flexibility, Efficiency, and Capacity

In addition to management actions taken during drought conditions, the SWP is also investigating, developing, and implementing several projects that will add flexibility, efficiency, and capacity to the SWP to make the project more resilient to future droughts. The following sections describe several major investments to improve the SWP.

6.1 Delta Conveyance

Infrastructure built to accommodate seasonal patterns of the past cannot accommodate weather extremes and flashy winter flows that are becoming more common. The Delta Conveyance Project is a proposed infrastructure modernization project outlined in Governor Newsom's strategy to adapt California's water supply for a hotter and drier future. The project is essential to adapting to climate-driven weather extremes and in helping to ensure that the SWP can capture, move, and store water during extreme weather events, including extended drought conditions. Modernizing SWP infrastructure in the Delta would provide an added tool to capture water from brief yet high-flow and fast-moving storms, and place that water in storage for later use. This added level of flexibility is meant to better manage periods of drought and provide much-needed drought relief.

For example, if the Delta Conveyance Project had been operational during the high rain events of January 2022 and 2023, a modernized conveyance system could have conveyed additional water into San Luis Reservoir while still meeting fishery and water quality protections and regulations. On December 21, 2023, DWR certified the final Environmental Impact Report. This important step marks the completion of an extensive environmental review. Through the environmental review process, DWR selected the "Bethany Reservoir Alignment" for further engineering, design, and permitting.

6.2 California Aqueduct Subsidence Program

Overdraft of the San Joaquin Valley groundwater aquifers has caused land subsidence for the San Luis Canal and the California Aqueduct, resulting in a diminished ability of this backbone infrastructure to provide the flexibility and resiliency needed to address greater hydrologic variability. Because of the differential subsidence, the conveyance system has experienced a loss of operational flexibility and an overall average conveyance capacity reduction of 20%, with particularly affected locations experiencing 45% constrictions in flow.

In 2019, the California Aqueduct Subsidence Program (CASP) was established as an initiative of the SWP to work in conjunction with Reclamation, the owner of the San Luis Canal for the CVP, to develop and implement preventive and corrective measures to mitigate the effects of subsidence, while planning the remediation of anticipated future subsidence. Reestablishing the conveyance capacity of the system that has been lost over time to subsidence will allow the system to efficiently capture and convey the more extreme hydrologic flows expected in California’s hotter, drier future. Although this action will primarily affect operations during wet periods and peak flow events, the water conveyed and stored during these operations will provide critical water supplies during drought, improving the resilience of the CVP and SWP conveyances to climate change and drought.

6.3 Forecast-Informed Reservoir Operations

Recognizing the importance of atmospheric rivers in a changing climate, DWR in partnership with Yuba County Water Agency; the Center for Western Weather and Water Extremes (CW3E) at the University of California, San Diego; USACE; the National Weather Service; and other members of the Yuba-Feather Steering Committee are developing a forecast-informed reservoir operations (FIRO) program at New Bullards Bar on the Yuba River and Lake Oroville on the Feather River. FIRO is a flexible water management strategy that uses improved weather and runoff forecasts to help water managers retain or release water from reservoirs to increase resilience to droughts and floods. The primary objective of this FIRO project is to reduce flood risk; a secondary objective is to achieve water supply benefits where possible, while supporting environmental needs.

FIRO has the potential to improve drought resilience by allowing reservoir operators to retain additional water in storage that otherwise would be released had forecasts indicated the absence of flood-threatening storms on the horizon. In addition, longer lead forecasts used in FIRO often result in water being released from reservoirs in advance of approaching storms to create additional storage space for storm flows. The water released can then be diverted into other storage reservoirs (likely groundwater basins) over a longer period than would have been available without FIRO. This action results in additional water in downstream storage basins that can be used to support water needs during a drought.

6.4 Storage Investigations

The SWP Storage Investigation Initiative is an ongoing phased activity to identify, investigate, and develop potential water storage opportunities for the SWP throughout the state that could be used to store additional water during wet years for use during dry conditions. The focus of this initiative is on groundwater storage opportunities, but surface water projects could be considered if appropriate locations can be identified.

As of 2023, this initiative has focused on two specific areas for further evaluation and refinement: (1) west slope of the Sierra Nevada mountains along the San Joaquin River and tributaries and (2) south-of-Delta SWP conveyance-connected areas. The current phase of investigation involves modeling of existing and future projected conditions to estimate the volume, timing, and frequency of available water that could be safely diverted into storage within all regulatory, environmental, and physical system constraints.

New storage added to the SWP would act as both a climate resilience and drought resilience action because it would add flexibility and new operational capabilities to the SWP system, allowing the system to take advantage of wet conditions that produce excess flows and save that water for use during dry conditions.

6.5 Evaluation and Adjustment of Oroville Carryover Storage Targets

The Oroville carryover storage target will be reviewed and may be updated if warranted by changed conditions. Examples of changed conditions include:

- Physical capacities (examples include the outlet capacities at Lake Oroville).
- Operating regulations upstream or in the Delta (Feather River temperature requirements or new State Water Board or State ESA or federal ESA requirements, for example).
- Operating agreements (such as the Coordinated Operations Agreement with Reclamation).
- New tools for assessing observed changes to hydrology.

6.6 SWP Enhanced Asset Management

Continued enhancement of existing asset management practices as described in the *2023 Operations and Maintenance Strategic Asset Management Plan* (SAMP) is an ongoing effort to review, document, improve and embed strategies, processes and tools for the monitoring, inspection, condition assessment, maintenance, renewal, risk management, and long-term planning for SWP water storage and conveyance infrastructure. Updating those business processes with documented processes and tools to support risk-informed decision-making processes will enhance SWP infrastructure reliability and assist operations and maintenance staff in modifying operations strategies, maintenance programs, and reprioritizing planned capital projects as hydrologic conditions change. This effort will allow DWR to preserve and maximize the operational flexibility that was built into the SWP when it was constructed, thereby allowing DWR to reliably capture and move water into storage when it is available, then deliver available project and non-project (transfer) water during extreme drought conditions.

6.7 DWR Climate Action Plan

DWR established a climate change program in 2008 and released progressive phases of its Climate Action Plan in 2012, 2018, 2019, 2020, and 2022. Each phase of the plan provides cutting-edge analysis and responses to climate change challenges and explores how DWR will respond to these challenges.

Phase II of the Climate Action Plan (2018) lays out a systematic and comprehensive DWR-wide policy for screening and, if necessary, evaluating the resiliency of DWR projects to climate change. This process mainstreams the consideration of climate and drought risks in DWR projects and ensures that ongoing and future investments have considered the risks of a hotter-drier climate before they are built.

Phase III of DWR’s Climate Action Plan, published in 2019 and 2020, assessed climate change vulnerability and outlines DWR’s strategy for adapting to the impacts of climate change. This phase helped prioritize DWR resiliency efforts, such as infrastructure improvements, enhanced maintenance and operation procedures, revised health and safety procedures, and improved habitat management, and it laid out additional steps needed to continue adaptation implementation.

6.8 SWP Climate Change Resilience Planning

Long-term drought resilience and climate change resilience are closely related, as climate change is expected to intensify California’s natural drought cycles. Tiering off DWR’s Adaptation Plan, an SWP climate change adaptation analysis will be finalized in 2024 and will document the degree to which several major projects, that are currently in the planning phase, will help the SWP adapt to climate change — including more severe and frequent droughts. This analysis will evaluate a range of climate conditions and adaptation combinations. The SWP will use this analysis to further refine its long-term adaptation goals and strategies and the degree to which the adaptation project portfolio reduces drought risks under future climate conditions.

6.9 Climate Change and Drought Risk Communication

The SWP has a long history of providing climate change and drought risk information to the public and water agencies that use SWP water supplies. DWR has been incorporating estimates of climate change impacts on SWP deliveries since 2009 in the bi-annual SWP DCR. This report provides estimates of average and multi-year dry and wet conditions deliveries under future climate conditions. Public water agencies use this information in their planning and water resource portfolio development. In the 2023 *Risk-Informed Future Climate Scenario Development for the State Water Project Delivery Capability Report*, DWR made significant improvements to the information it provides to the public and public water agencies that use SWP water.

Major improvements included:

1. Development and inclusion of a climate-adjusted historical hydrology scenario that replaces the historical hydrology record as the baseline for current conditions. This improvement explicitly captures and accounts for changes in climate that have already occurred and provides a more accurate hydrological sequence for estimating current SWP delivery capability. This scenario indicates that the SWP has already lost approximately 2% on average of its annual delivery capability from climate changes that have already occurred. These impacts are even more pronounced in dry years.
2. Development and inclusion of new system risk-informed future climate scenarios that provide greater exploration of uncertain future conditions, including more extreme droughts and extreme wet events. These new scenarios explore conditions 20 years into the future with up to 1.8 degrees Celsius warming, 2% less average precipitation, 13% more extreme precipitation, and 30 centimeters of sea level rise. These scenarios will guide DWR and public water agencies toward greater climate and drought resilience and provide greater transparency to water users about expected reductions in future water supply and uncertainties in the magnitude of expected reductions. The DCR climate change scenarios indicate that by 2043, the SWP will lose an additional 11% to 21% of its delivery capability if no adaptation actions are taken.
3. DWR conducted an independent peer review through the Delta Science Program of the science underlying both the climate-adjusted historical hydrology scenario and the future climate scenarios. This additional effort included review by three independent experts. As a result, several improvements and additions were made to the development of the scenarios. Further, the review should provide users of the DCR scenarios with increased confidence that the analysis is best available science for decision-making.

The 2023 DCR also provides important new drought information. It shows that if a future two-year drought occurred similar to that of the 1976–1977 drought of record, but with intensified conditions resulting from expected climate changes by 2043, SWP water deliveries would decline 33% to 50% below present-day delivery capability. The report also explores multiple one-year and six-year drought periods.

Chapter 7. Actions to Improve Long-Term Drought Resilience that SWP Supports and Contributes Toward

7.1 West False River Drought Salinity Barriers Programmatic Approach

During severe drought conditions that result in significantly decreased natural flows into the central Delta, increased needs and challenges arise with preserving upstream impounded water for health, safety, and regulatory uses while preventing salinity intrusion into the central Delta. During normal water years, natural flows and flows from upstream reservoirs into the Delta prevent San Francisco Bay saltwater from entering the central Delta. But, during previous severe drought conditions there was a significant risk of San Francisco Bay saltwater flows entering the central Delta. If this were to occur, it would take years for the central Delta salinity levels to return to normal. To prevent such an event under previous severe drought conditions, DWR installed a temporary drought salinity barrier in the Delta's West False River. Based on data from these previous installations, the WFR Drought Barrier has proven an effective tool for reducing saltwater intrusion into the central Delta. Given the current scientific understanding of the cyclical nature of drought in California, DWR anticipates having to reinstall a WFR Drought Barrier up to two times over the next 10 years. DWR is finalizing an environmental impact report and working to secure all necessary environmental permits to reinstall the barrier when needed. Doing this work ahead of time will reduce or eliminate the need for last-minute emergency actions to install the barrier.

The WFR Drought Barrier would be constructed in the central Delta in West False River, a main channel located west of and connected to Franks Tract. By hydraulically blocking West False River, flows into Franks Tract would be mostly from the less-salty Old River farther upstream on the San Joaquin River, rather than farther downstream on the San Joaquin River, where it is more influenced by saltier San Francisco Bay water. The barrier would protect against saltwater intrusion into the central Delta and consequently help maintain central Delta water quality. Without the protection of the drought salinity barrier in West False River — a critical location for preventing salinity intrusion into the central Delta — during a severe drought, saltwater intrusion could render Delta water unusable for agricultural needs, reduce the value of habitat for aquatic species, and affect more than 27 million Californians who rely on the Delta for at least a portion of their water supply.

During severe drought without the barrier in place at this critical location, the saltier water carried through West False River would gradually contaminate the fresh water in Franks Tract. The central Delta would be filled with salts, a condition that cannot be reversed during drought conditions. Consequently, until the salts could be flushed from the central Delta, the salinity intrusion would create long-term impacts on the many beneficial uses of central Delta water.

7.2 Improved Seasonal Forecasting

DWR has been pursuing improvements to its forecasting capabilities for more than a decade through collaborative work with local and federal agencies and the research community. These efforts have been focused in two areas: (1) work to develop improved forecasting tools supporting emergency response to hydrologic extremes and snowmelt forecasting, and (2) improvements in seasonal forecasting capabilities to support resource and program planning within a given water year and in a multi-year environment related to recurring drought conditions. Each area of investment is described below.

Area 1 — Improved Forecasting Tools Supporting Hydrologic Extremes Response and Snowmelt Forecasting

Throughout the past decade, a number of efforts have been in play to update and improve the tools used for runoff forecasting for river forecasting time frames (zero to five days) and seasonal runoff forecasting associated with Bulletin 120 (April through July snowmelt volume forecasting). Improved observations have been undertaken by investing in remote weather station upgrades, including more gridded data products in the forecast process, and developing remote snow water-equivalent observations and associated physically based snowpack and watershed runoff modeling. Currently, funding is available to provide airborne snow mapping up to four times per year for approximately two-thirds of the watersheds that appear in the monthly B120 forecast of snowmelt runoff from April through July. In addition to the data collection, iSnoBal snowpack modeling and WRF-Hydro runoff modeling is being developed for these watersheds. In addition to these modeling efforts, additional watershed models are being developed using USACE models to support river and reservoir forecasts. An experimental research watershed model for surface water availability for the Sacramento watershed is also in development.

Area 2 — Improved Seasonal Forecasting for Operational and Governance Planning

DWR has spent the past decade assembling a coalition of researchers to begin to systematically address opportunities to improve seasonal forecast capabilities, as well as to address known challenges that limit long-term predictability. The group meets annually in November to examine water year outlook experiments and again in summer to review outcomes and develop next research steps. Sponsored by DWR, the Center for Western Weather and Water Extremes posts to their website subseasonal-to-seasonal experimental (S2S) forecast models for public viewing. Additional S2S forecasting information is provided on the S2S Coalition website.

Although some progress has been made to find forecasts of opportunity — where the climate system aligns to enable a more reliable forecast — additional work is needed to better inform long-term forecasting.

7.3 Continuing Commitments to Environmental Resiliency

The SWP continues its commitment to enhance aquatic ecosystems to increase resilience to future droughts through habitat creation, scientific exploration to inform successful management for beneficial environmental outcomes, and improved monitoring of changing conditions.

Habitat-creation projects include restoration of tidal wetlands, floodplains, and rearing habitat for juvenile salmonids as part of the proposed Healthy Rivers and Landscapes Program and other efforts. All of DWR’s habitat restoration activities are being evaluated under a science-based adaptive management framework for continuous improvement to learn how to better design and implement restoration for maximum environmental benefits.

The SWP is also researching the feasibility of many voluntary actions included in the Delta Smelt Resiliency Strategy (California Natural Resources Agency 2016) and Sacramento Valley Salmon Resiliency Strategy (California Natural Resources Agency 2017). Delta smelt Resiliency actions include contracting with the University of California, Davis, to research the potential benefits of operating managed wetlands in Suisun Marsh for production of fish food, researching potential benefits of fall flow pulses in the Yolo Bypass (Davis et al. 2022), and collaborating on research into aquatic weed monitoring and management (Rasmussen et al. 2022). Actions to improve salmonid resiliency include removal of fish passage barriers, improvements to the Yolo Bypass, and construction of a permanent non-physical barrier at Georgiana Slough. Although none of these actions are specifically targeting droughts, all are designed to increase the resiliency of at-risk fish populations to future climatic variability.

More recently, the California Salmon Strategy for a Hotter, Drier Future was released to guide progressive actions that the State can take to support resilient salmon populations as the climate changes. For the SWP, many Salmon Strategy actions focus on the Feather River because of the focus of operations there, the presence of the Feather River Hatchery, and the presence of a population of State and federally listed spring-run Chinook salmon. The SWP is already working to advance the California Salmon Strategy with several measures on the Feather River. The Strategy calls for evaluation of reintroduction of salmon to historical cold-water habitats in upstream regions above dams in order to establish populations in refuge habitats (Action 1.6). In 2023, DWR initiated a pilot program for re-introduction of Spring-run in the North Fork of the Feather River, above Lake Oroville. Studies are underway assessing the feasibility of introducing egg and juvenile life stages. Also, in keeping with Goal 1 of the Strategy to Remove Barriers and Modernize Infrastructure for Salmon Migration, the SWP is working to remove Sunset Pumps, a long-standing impediment to salmon upstream and downstream migration and predator attractant in the Feather River. Finally, DWR is working on Goal 4 (Modernize Salmon Hatcheries) with partner agencies by working to install a water treatment system at the Feather River Hatchery (Action 4.8) to improve in-hatchery survival from egg to release stages, effectively boosting the release numbers and increasing efficiency. DWR is also working with CDFW to develop a Hatchery Genetic Management Plan for Feather River Hatchery, which would ensure adoption of best practices to minimize harm to wild salmon populations (Action 4.13).

The experimental release of hatchery-raised Delta smelt conducted during the 2021–2022 drought years is continuing, with the SWP helping to design releases conducted by the U.S. Fish & Wildlife Service that will experimentally inform the growing supplementation program. Supplementation of wild fish with hatchery-raised Delta smelt has risks (Lessard et al. 2018), but may provide a necessary buffer to the population, particularly during droughts. Longfin smelt culture and propagation methods are also under development within the Longfin Smelt Science Program in the event that this species also needs a refuge population against future climatic extremes.

Recently, SWP began using innovative genetic technology to assist in rapidly and accurately identifying Chinook salmon runs (i.e., Fall, Late-Fall, Winter, Spring) to protect endangered runs (Winter and Spring-runs) and guide water operations in the Delta. Genetic run assignment enables increased confidence in identification results compared to traditional run assignment methods based solely on the length of the fish and helps ensure that water capture is not restricted unless an endangered fish is present. False identification by visual inspection can result in unnecessary reductions in water supply exports. By improving salmon run assignment, SWP can provide a more reliable water supply, especially during droughts, without compromising protections for endangered species.

Harmful cyanobacterial blooms are one of the clearest environmental impacts of droughts, and extensive research, monitoring, and collaboration are needed to identify and implement mitigation and continued monitoring. To that end, the SWP is working with multiple water boards, the Delta Science Program, and other agencies to develop a monitoring framework for harmful cyanobacteria in the Delta.

7.4 North Delta Barriers

DWR has completed extensive planning and design in support of potential north Delta drought salinity barriers during extreme drought conditions. Drought barriers in the north Delta provide salinity management benefits in the interior Delta by blocking the flow of water from the Sacramento River into Steamboat and Sutter sloughs, thus allowing more flow to remain in the

Sacramento River and pass through Georgiana Slough. This action helps to repel salinity intrusion into the interior Delta with the release of less water from upstream reservoirs. To reduce the potential impacts to north Delta agricultural diverters and potential impacts to their diversions, DWR moved the location of the drought barriers as far downstream as possible. The locations of the potential barriers are now proposed for Miner Slough on the north side of Ryer Island and Steamboat Slough on the south side of Ryer Island.

To support barrier design, DWR has completed extensive geologic explorations at the proposed barrier sites, and these explorations are being used for the geotechnical engineering design. Additionally, DWR has completed hydrodynamic modeling and begun the application process for necessary permits. DWR intends to complete the long-lead planning and permitting steps for this project so that if North Delta barriers are needed during a future drought, a project could be implemented quickly and efficiently.

Chapter 8. References

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Chapter 9. Useful Web Links

California Department of Water Resources Bulletin 120 Forecasts
https://cdec.water.ca.gov/reportapp/javareports

California's Water Supply Strategy, Adapting to a Hotter, Drier Future
https://resources.ca.gov/-/media/CNRA-Website/Files/Initiatives/Water-Resilience/CA-Water-Supply-Strategy.pdf

Center for Western Weather and Water Extremes
Subseasonal to Seasonal (S2S) Experimental Forecasts
https://cw3e.ucsd.edu/s2s_forecasts/

Delta Conveyance Project
https://water.ca.gov/deltaconveyance

Delta Conveyance Project
Adapting to Climate Change: Catching and Moving Water from Big Storms
https://water.ca.gov/-/media/DWR-Website/Web-Pages/Programs/Delta-Conveyance/Public-Information/DCP_Diversions_Final.pdf

Delta Conveyance Project Environmental Impact Report
https://www.deltaconveyanceproject.com/planning-processes/california-environmental-quality-act/final-eir/final-eir-document

Delta Harmful Algal Bloom Monitoring Strategy
https://deltacouncil.ca.gov/pdf/science-program/information-sheets/2022-10-21-draft-delta-harmful-algal-bloom-monitoring-strategy.pdf

Delta Smelt Resiliency Strategy
https://resources.ca.gov/CNRALegacyFiles/docs/Delta-Smelt-Resiliency-Strategy-FINAL070816.pdf

Drought Toolkit
www.usbr.gov/mp/bdo/docs/droughttoolkit-latest.pdf

Healthy Rivers and Landscapes Program
https://resources.ca.gov/Initiatives/Voluntary-Agreements-Page

Sacramento Valley Salmon Resiliency Strategy
https://resources.ca.gov/CNRALegacyFiles/docs/Salmon-Resiliency-Strategy.pdf

S2S Coalition
https://www.s2sforecasting.org/

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