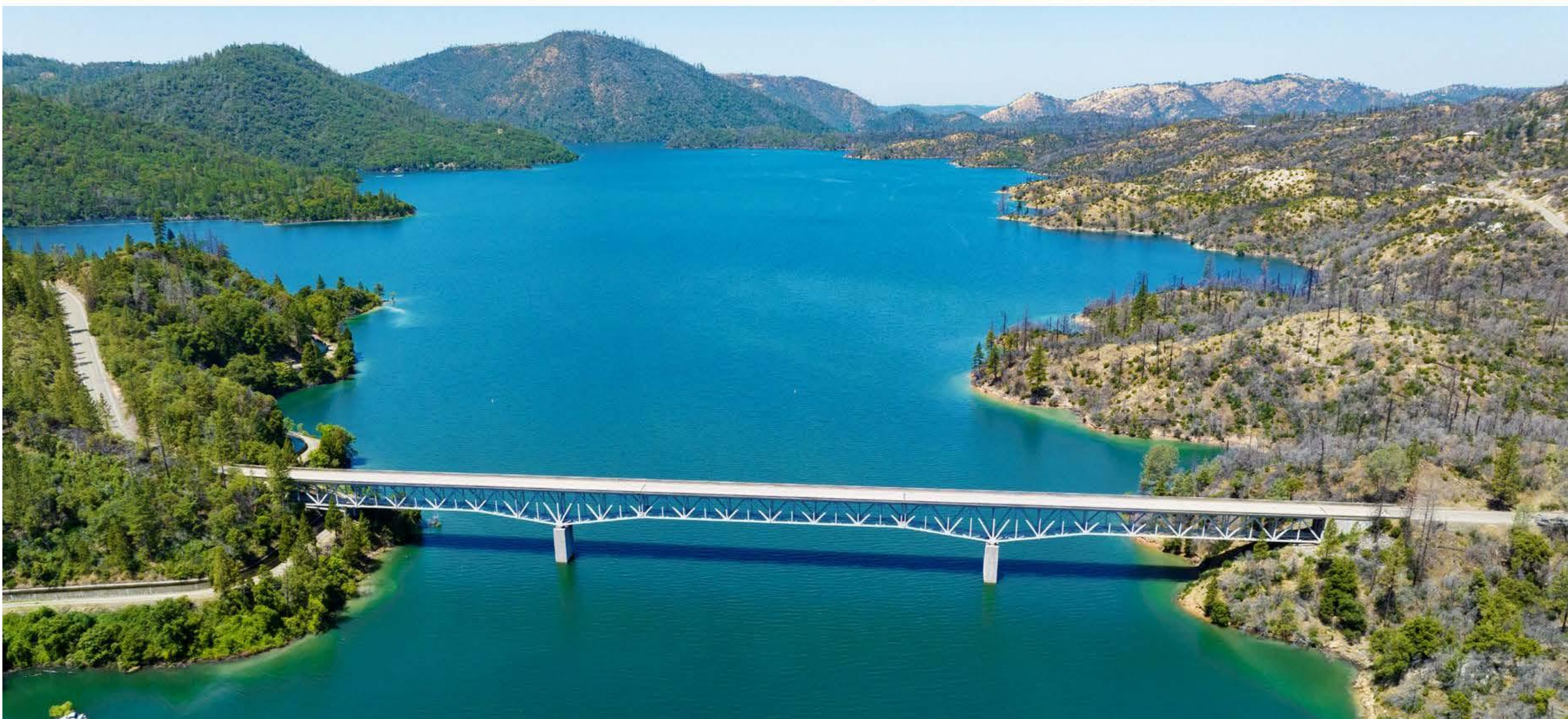
Department of Water Resources Climate Action Plan

STATE WATER PROJECT ADAPTATION STRATEGY

Reducing Vulnerabilities to Climate Change

August 2025

Lake Oroville – July 2021



Lake Oroville – July 2023

State of California

Gavin Newsom, Governor

California Natural Resources Agency

Wade Crowfoot, Secretary

Department of Water Resources

Karla Nemeth, Director

Cindy Messer, Lead Deputy Director

Deputy Directors

John Yarbrough
State Water Project

Ryan Endean
Communications

Paul Gosselin
Sustainable Groundwater Management

Laura Hollender
Flood Management and Dam Safety

Delphine Hou
Statewide Energy

Joel Metzger
Statewide Water Resources Planning and Enterprise Project Management

James Newcomb
Natural Infrastructure and Ecosystem Resilience

John Paasch
Security and Emergency Management Program

Kasey Schimke
Legislation

Preparers & Contributors

This report was prepared under the supervision of:

Andrew Schwarz, Climate Action Manager, State Water Project

This report was prepared by:

Raymond Hoang, Senior Engineer, WR, Central Valley Modeling Section

Individuals contributing to the development of the report:

Erik Reyes, Manager, Modeling Support Office

Jesse Dillon, California Aqueduct Subsidence Program Manager

David Rennie, State Water Project Asset Management Program Manager

Carolyn Buckman, Delta Conveyance Project Environmental Program Manager

Molly White, Assistant Division Manager—Water Management

Aaron Miller, Supervising Engineer, WR, Water Operations Planning Section

Nazrul Islam, Supervising Engineer, Central Valley Modeling Section

Zachary Roy, Senior Engineer, WR, Central Valley Modeling Section

Jonathan Byers, Engineer, WR, Central Valley Modeling Section

Yiwei Cheng, Senior Engineer, WR, Central Valley Modeling Section

Nicole Osorio, Engineer, WR, Central Valley Modeling Section

Jamel Lehyan, Engineer WR, Central Valley Modeling Section

Mohammad Hasan, Engineer, WR, Central Valley Modeling Section

Z.Q. Richard Chen, Senior Engineer, WR, Central Valley Modeling Section

Christopher Quan, Engineer, WR, Central Valley Modeling Section

Romain Maendly, Climate Action Advisor, Integrated Water Management

Wyatt Arnold, Senior Engineer, WR, Alternative Supplies and Operations Section

Alejandro Perez, Engineer, WR, Climate Change Program

Thomas FitzHugh, Principal Water Resources Scientist, Stantec

Puneet Khatavkar, Senior Water Resources Engineer, Stantec

Yuan Hui, Civil Engineer, Stantec

Jeffrey Weaver, Principal Engineer, HDR Inc.

Chandra Chilmakuri, Assistant General Manager, State Water Contractors, Inc.

Manny Bahia, State Water Contractors, Inc.

Director’s Foreword

The ways that California benefits from the State Water Project are so extensive and long-standing, it is easy to take this 700-mile-long system of infrastructure for granted. We cannot afford that. At age 70, the project needs revitalization that will ensure several more generations of Californians can rely upon it to deliver water, manage flood, generate clean electricity, provide flows for fish and wildlife, and give people places to boat, fish, and play. The project must be ready and able to operate through hotter overall temperatures, drier landscapes, rising sea levels, deeper droughts, and more powerful storms.

This State Water Project Adaptation Strategy describes how the California Department of Water Resources (DWR) is trying to adapt the State Water Project to the effects of climate change, which are upon us. The strategy evaluates those actions with the most promise to protect the broad benefits of the State Water Project. It concludes that steadfast maintenance of the aging project and a modernized tunnel system to transport water under the Delta are the most valuable adaptations. The Delta Conveyance Project is the single most effective strategy on its own, and it amplifies the benefits of other strategies.

The adaptations laid out in this report nest within DWR’s department-wide strategy to prepare for disruptions, withstand and recover from climate-related shocks, and adapt into the future. These documents reflect DWR’s increasingly nuanced understanding of how higher temperatures increase the demand for water by people, vegetation, and even the atmosphere itself—and what that aridification means for future water management. This strategy provides a road map for how the State Water Project can address the challenges of climate change while restoring some of the environmental health lost to California’s extensive water development.

The State Water Project is a fundamental piece of California’s backbone water infrastructure, providing the water that drives $2.3 trillion in economic activity each year. In this adaptation strategy, DWR evaluates and prioritizes five key climate adaptation strategies that, if implemented, would safeguard and revitalize the State Water Project, protecting water supplies for 27 million Californians and 750,000 acres of farmland.

This strategy is critical to achieving California’s human right to water. The State Water Project provides water supply to 75% of California’s disadvantaged communities—nearly 8 million Californians. Implementation of the adaptation strategies outlined in this report would provide broad benefits that improve the ability of public water agencies to meet the needs of all customers. State Water

Project deliveries are the foundational supplies upon which many local water districts build water conservation, recycling, and storage programs. Loss of those foundational supplies would put a heavy financial burden on customers.

Since 2006, DWR has fast-tracked its reduction of greenhouse gas emission that contribute to global warming while studying and acting on climate adaptation strategies. For example, in 2018, DWR chose to store an additional 300,000 acre-feet of water in in Lake Oroville—enough water supply nearly 1 million homes—to address rising drought risk. As I write today, crews working beneath Oroville Dam are modernizing a River Value Outlet Structure to improve our ability to release cool water to preserve critical fish habitat during extreme droughts. New State and federal endangered species protection permits signed in late 2024 and early 2025 provide improved operational flexibility. This past winter these resulted in increased water supply storage while protecting fish, wildlife, and other water users in the Sacramento–San Joaquin Delta.

This State Water Project Adaptation Strategy will be used to guide DWR executive decision-making about future investments. This strategy also provides data that will help guide leaders of California's 29 public water agencies that take delivery of State Water Project supplies and of other State, local, and federal agencies as they work to improve resiliency and safeguard their unique water portfolios for the next generation in a changed climate.

True to Governor Newsom's long-standing portfolio approach to water policy, this is an all-of-the-above strategy that harnesses the best of science, engineering, and innovation. The analysis shows that a combination of actions will be more effective than any action alone, and different actions are needed to address different climate stressors.

I hope that you find the information here accessible and useful to the conversation about what we must do today to support the California of tomorrow.

Karla A Nemeth

Karla Nemeth
Director

California Department of Water Resources

July 2025

Executive Summary

This State Water Project Adaptation Strategy, developed by the California Department of Water Resources (DWR), presents a forward-looking roadmap for adapting the State Water Project (SWP) to the challenges posed by a changing climate. The SWP is one of the largest State-built water and power systems in the United States, conveying water through over 700 miles of canal. Starting in northern California and running through the Central Valley and Southern California, it supplies water to 27 million residents, 750,000 acres of farmland, and supports over $2.3 trillion in economic activity. With climate change accelerating the frequency and intensity of droughts, floods, wildfires, and sea level rise, the SWP must be modernized to ensure long-term sustainability, reliability, and affordability in water distribution.

Purpose and Scope

This report outlines DWR's strategy to assess, prioritize, and implement adaptation measures that will allow the SWP to function under future climate conditions. It builds upon years of climate research and is aligned with DWR's Climate Action Plan, which integrates emissions reductions, climate vulnerability assessments, and long-term resilience planning. This report's analysis quantifies the potential benefits of major adaptation projects and evaluates their ability to sustain water deliveries while meeting ecosystem and water quality protection requirements. Multiple future climate scenarios were used to test these evaluations over a range of uncertain future climate conditions.

The primary goals of this analysis are to:

- Determine how planned adaptation strategies can move the SWP toward climate resilience.
- Assess whether these strategies are sufficient to manage future water supply risks.
- Identify remaining vulnerabilities and needs for further adaptation efforts.

Key Climate Risks Facing the State Water Project

California is already experiencing major climate-related challenges, including:

- Continued land subsidence, especially in the San Joaquin Valley, which is reducing aqueduct capacity.
- Increased drought frequency and duration, which is straining reservoirs and groundwater basins.
- More extreme precipitation and earlier snowmelt, which is resulting in both flood risks and storage inefficiencies.

- Temperature increases are leading to greater evapotranspiration and altered water demands.
- Rising sea levels are threatening Sacramento–San Joaquin Delta (Delta) water quality and infrastructure integrity.

Adaptation Strategies

To address these challenges, DWR has identified 17 SWP adaptation strategies, which are organized into three categories, which are described below.

1. Structural Strategies

- Delta Conveyance Project (DCP): A modernized tunnel system to transport water under the Delta, improving earthquake resilience and ability to capture water during high-flow events.
- California Aqueduct Subsidence Remediation: Implementation of preventative and corrective measures to restore aqueduct capacity lost due to over-pumping and land subsidence.
- Increased South-of-Delta (SOD) Storage: Developing up to 2 million acre-feet (MAF) of additional storage (above or below ground) to capture wet year surplus for drought-year needs.
- Delta Drought Barriers: Pre-planning for future extreme statewide drought conditions by completing environmental certification and permitting for a physical barrier in the Delta that has proved effective as an emergency action during past droughts.

2. Operations and Management Strategies

- Forecast-Informed Reservoir Operations (FIRO): Using advanced weather forecasts to optimize water releases from Oroville Dam, reducing flood risks while storing more water safely.
- Enhanced Asset Management: Implementing strategic maintenance practices to increase system reliability and avoid unplanned operational outages.
- Improved Forecasting and Modeling: Advancing short- and long-term hydrologic prediction to inform operational decisions.
- Carryover Storage Targets: Managing reservoir levels in Oroville to preserve water at the end of each water year to guard against multi-year droughts.
- Adaptive Management of Operations and Regulatory Compliance: Improving scientific insight and stakeholder engagement along with collaboration with regulatory agencies to improve permitting and operational effectiveness for achieving regulatory goals.
- Project-Level Climate Resilience Evaluations: Ensuring consistent, high-quality, and science-driven climate analysis for all projects delivers better planning outcomes.

- Shaping Power Load and Generation: Aligning SWP energy use with renewable energy availability to reduce costs and carbon emissions.
- Financial Resilience through Contract Extensions: Ensuring long-term funding capacity for major capital investments and maintenance through water contract extensions to 2085.
- Water Storage Investment Program Project Integration: 2.65 MAF of proposed new storage projects throughout the state, led by diverse partnerships, that would improve Delta ecosystem conditions and require integration with SWP operations to deliver statewide benefits.
- SWP Outdoor Staff Safety Improvements: New guidance and strategies that improve monitoring and assessment to maintain staff safety in hotter, more extreme work environments while meeting operational needs.

3. Nature-Based Solution Strategies

- Environmental Restoration Projects: Reconnecting floodplains, restoring wetlands, and improving riverine habitats to enhance ecosystem resilience.
- Delta Island Land Management: Converting land use practices on Sherman and Twitchell islands to reduce subsidence and enhance climate resilience.
- Feather River Watershed Management: Supporting forest health and wildfire resilience in the watershed that feeds Lake Oroville, a critical water source.

Adaptation Portfolios and Evaluation Framework

Of the 17 strategies listed above, five have been identified as being the most promising, and are within the SWP's authority to implement, or require consistent and sustained commitment to develop and implement. These five strategies have been organized into four adaptation portfolios and have been compared to a run-to-failure/minimal investment future and a baseline future in which only maintenance is completed and no adaptation investments are made. Multiple climate and sea level rise scenarios are explored using sophisticated modeling tools to evaluate the benefits of these investments at two future timeframes, 2043 and 2085:

- **Deteriorating System Scenario—**Assumes a "run-to-failure" future in which the SWP is starved of investment and ultimately fails to function. Leads to extreme loss of aqueduct capacity and pumping capability by mid-century. Serves as a warning of the cost of inaction.
- **Maintain System/Baseline—**Restores existing aqueduct capacity and maintains high levels of pumping availability. Represents a baseline to measure improvement from further adaptation.
- **Adaptation Portfolio 1—Delta Conveyance Project:** Builds on the Maintain System scenario by adding DCP. Demonstrates significant improvements in flexibility and water delivery reliability.

- **Adaptation Portfolio 2—FIRO:** Adds FIRO to the baseline scenario, increasing water storage, flood protection, and operational efficiency through operational changes that do not require additional infrastructure.
- **Adaptation Portfolio 3—SOD Storage:** Adds 2 MAF of storage SOD to store wet year water that can be exported without conflicting with ecosystem or water quality regulations, offering improved drought resilience.
- **Adaptation Portfolio 4—Combination:** Combines all major strategies (DCP, FIRO, and SOD storage), showing the strongest performance under all climate scenarios, and providing greater benefit than the sum of its parts.

Alignment with Statewide Policy

The strategy directly supports and integrates with broader State goals:

- **California Water Plan Update 2023**: Prioritizing infrastructure investment and watershed resilience.
- **California's Water Supply Strategy (2022):** Enabling reliable delivery and groundwater recharge in a hotter, drier future.
- **Delta Adapts Plan (2024):** Supporting regional Delta climate resilience.
- **Human Right to Water Law (Assembly Bill 685):** Ensuring water access for disadvantaged communities—75% of whom depend on the SWP.

Conclusions and Future Steps

This SWP Adaptation Strategy represents a critical step toward modernizing California's water supply system using multi-benefit projects that prepare our aging infrastructure for a 21st century climate. It offers a path to safeguard water reliability, protect environmental health, support disadvantaged communities, and maintain economic stability in the face of intensifying climate impacts.

Key conclusions include:

- **Continued maintenance and additional restoration.** Continued maintenance and additional restoration of the infrastructure system—including repairing subsidence-damaged sections of the California Aqueduct—are first-priority measures. Arresting and preventing future subsidence is a top priority that DWR and the SWP are working to achieve, and eliminating further loss of aqueduct capacity is necessary regardless of future climate. Climate change will make opportunities to capture and convey water flashier; restoring full aqueduct design capacity to the California Aqueduct will build the SWP's ability to move water through the system during high-flow events to locations where water can be used or stored.

- **Importance of the DCP.** The DCP, among evaluated strategies, is the single most effective strategy on its own, but also amplifies the impact of other strategies, making it first adaptation priority.
- **FIRO is a safe and effective strategy.** It has low costs and few if any drawbacks, but the amount of water supply it can deliver is relatively small. It should be implemented as soon as possible in coordination with U.S. Army Corps of Engineers approvals.
- **Additional SOD water storage** is a promising strategy. Additional storage, especially when paired with DCP, can help improve drought resilience.
- **Other Adaptation strategies are important for climate resilience.** Adaptation strategies like Delta drought barriers, water supply forecast improvements, Feather River watershed management, and evaluation of all DWR projects for climate resilience are important adaptation actions. DWR and, as applicable, SWP should continue to pursue these strategies. The water supply value of these strategies may be difficult to quantify, but actions in these areas will likely deliver real benefits and important future adaptation actions.
- **Individual strategies have unique benefits and should be combined.** Each individual strategy responds to different climate stressors, such as increasing drought frequency, more extreme precipitation, earlier runoff, and sea level rise. A combination of responses is needed. This analysis shows that implementation of a portfolio of strategies will result in greater adaptation than the sum of its parts, ultimately contributing to the long-term sustainability of California's water supplies.

This SWP Adaptation Strategy is a living framework for adaptation. DWR will continue to refine it as climate science, funding, technologies, and operational practices evolve, ensuring the SWP continues to serve California well into the 21st century.

Contents

Tables

Figures

Appendices

Acronyms and Abbreviations

Term	Acronym/Abbreviation
CAP	Climate Action Plan
CASP	California Aqueduct Subsidence Program
cfs	cubic feet per second
CVP	Central Valley Project
DCP	Delta Conveyance Project
DCR	Delivery Capability Report
Delta	Sacramento–San Joaquin Delta
DSC	Delta Stewardship Council
DWR	California Department of Water Resources
ESA	Endangered Species Act
FIRO	forecast-informed reservoir operation
GWL	Global Warming Level
LOC	level of concern
MAF	million acre-feet
NESP	non-exceedance subsidence percentile
SAMP	Strategic Asset Management Plan
SGMA	Sustainable Groundwater Management Act
SOD	South-of-Delta
SWP	State Water Project
SWRCB	California State Water Resources Control Board
TAF	thousand acre-feet
TOC	top-of-conservation
USACE	U.S. Army Corps of Engineers
WCM	Water control manual
WFR	West False River
WSIP	Water Storage Investment Program

1 Introduction

The California Aqueduct spans 444 miles from the Sacramento–San Joaquin Delta through the San Joaquin Valley to Southern California, and transports State Water Project water.

The far-reaching consequences of climate change continue to affect California, necessitating the adaptation of critical infrastructure systems to ensure their resilience in the face of shifting environmental conditions. This State Water Project Adaptation Strategy describes and explains more than a dozen specific strategies that the State Water Project (SWP) already is pursuing. In addition, it quantitatively evaluates five key climate adaptation strategies that are currently being planned or are in early stages of development, to show how these strategies, if implemented, could mitigate climate change impacts and safeguard water supply reliability for the SWP and generate statewide benefits.

The strategy's analysis results highlight the following key points:

- **Continued maintenance and additional restoration.** Continued maintenance and additional restoration of the infrastructure system, including repairing subsidence-damaged sections of the California Aqueduct, are first-priority measures. Arresting and preventing future subsidence is a top priority that the Department of Water Resources (DWR) and SWP are working to achieve, and eliminating further loss of aqueduct capacity is necessary regardless of future climate. Climate change will make opportunities to capture and convey water flashier, meaning they will come in shorter, more intense bursts. Restoring full aqueduct design capacity to the California Aqueduct will add to SWP's ability to move water through the system during high-flow events to locations where water can be used or stored.

- **Importance of the Delta Conveyance Project (DCP).** The DCP, among evaluated strategies, is the single most effective strategy on its own, but also amplifies the impact of other strategies, making it the first adaptation priority.
- **Forecast-Informed Reservoir Operations (FIRO) is a safe and effective strategy,** with low costs and few if any drawbacks, but the amount of water supply this option can deliver is relatively small. It should be implemented as soon as possible in coordination with U.S. Army Corps of Engineers (USACE) approvals.
- **Additional south-of-Delta (SOD) water storage is a promising strategy.** Additional storage, especially when paired with DCP, can help improve drought resilience.
- **Other Adaptation strategies are important for climate resilience.** Adaptation strategies like Delta drought barriers, water supply forecast improvements, Feather River watershed management, and evaluation of all DWR projects for climate resilience are important adaptation actions. DWR and, as applicable, the SWP, should continue to pursue these strategies. The water supply value of these strategies may be difficult to quantify but actions in these areas will likely deliver real benefits and important future adaptation actions.
- **Individual strategies have unique benefits and should be combined.** Each individual strategy provides response to different climate stressors such as increasing drought frequency, more extreme precipitation, earlier runoff, and sea level rise. A combination of responses is needed. This analysis shows that implementation of a portfolio of strategies will result in greater adaptation than the sum of its parts, ultimately contributing to the long-term sustainability of California's water supplies.

The SWP, a network of dams, reservoirs, canals, and pipelines, stands as a cornerstone of California's water management, providing a reliable source of freshwater to 27 million people and 750,000 acres of farmland. The SWP is owned and operated by DWR. The SWP is primarily funded by 29 urban and agricultural water agencies who receive water from the project. Known as the SWP contractors, these contractors finance the project's operation and maintenance, capital improvements, environmental mitigation projects, and the repayment of bond issuances. Throughout this report, "DWR" is used when referring to the State department with broad water resource and environmental management responsibilities, and "the SWP" is used to refer to the part of DWR that manages SWP utility infrastructure and operation.

As climate patterns evolve including higher temperatures, more extreme storms, longer and more severe droughts, and higher sea levels, sustainably managing the SWP will require significant new investment in upgrades to existing facilities, new facilities, and enhanced operational management to meet the challenges of 21st century climate.

The SWP provides one of California's most affordable and reliable sources of water. It powers over $2.3 trillion of economic activity throughout the SWP service area and meets the water supply needs of 75% of California's disadvantaged communities (a group of nearly 8 million Californians). Securing the reliability of the SWP into the future will help implement California's Human Right to Water law, protecting this vital water supply for communities from the Bay Area to southern California.

DWR has been evaluating and planning for the impacts of climate change since at least 2006 and has developed a comprehensive three-phase Climate Action Plan (CAP) that articulates how DWR is addressing climate change in the programs, projects, and activities under its authority.

Phase 3 of the DWR CAP, published in 2019 and 2020, provides DWR with a vulnerability assessment and a *Climate Change Adaptation Plan*, respectively. CAP's Phase 3 helps prioritize DWR's resiliency efforts such as infrastructure improvements, enhanced maintenance and operation procedures, revised health and safety procedures, and improved habitat management. It also lays out additional steps needed to continue adaptation implementation.

This strategy is specific to the adaptation actions that the SWP is taking and may take in the future to safeguard SWP water supply reliability. These are not the only strategies that DWR and other State agencies are taking to protect California's watersheds, rivers, groundwater basins, and the Sacramento–San Joaquin Delta (Delta). Section 2 of this report describes how this strategy aligns with other State efforts; in addition, there are several additional State actions working toward greater climate change resilience in other resource areas across the state.

This report is another step in DWR's ongoing efforts to refine and expand climate analysis to support adaptation planning. In analysis performed for this report, specific strategies for the SWP were identified and described. The five adaptation strategies that have been identified as the most important and impactful for the SWP include:

1. California Aqueduct subsidence remediation.
2. Enhanced asset management.
3. Delta conveyance.
4. FIRO.
5. Increased SOD storage.

These strategies are arranged in portfolios and were evaluated quantitatively over a range of potential climate conditions. Each portfolio was assessed for its ability to deliver climate change resilience. These strategies can individually and collectively move the SWP toward a more resilient and reliable future under a range of uncertain future climate outcomes and ultimately contribute to the long-term sustainability of California's water supplies.

This report does not provide a comprehensive and quantitative assessment of all actions that the SWP is taking to adapt to climate change, though Section 3 describes 17 strategies that the SWP is pursuing or already implementing to help maintain the resilience and reliability of the SWP in the face of changing climate while balancing environmental protections.

This evaluation provides critical information about the degree to which these currently planned strategies can ameliorate the impacts of climate change on SWP reliability and resilience, and at what future point and under what climate change outcomes additional strategies might be needed.

This report is an important step in DWR's and SWP's expanding efforts to respond to climate change and prepare for a warmer, more extreme climate future. Using the information in this report, DWR and SWP will continue to update and optimize the adaptation strategies evaluated here and innovate new adaptation strategies. Developing climate resilience together with the SWP contractors, other State and federal agencies, and local and regional agencies, will be an ongoing process that will accelerate and expand to fill the need of implementing changes that improve resiliency and safeguard the affordability of the SWP.

1.1 Objectives of the SWP Climate Adaptation Analysis

The questions this report's analysis attempts to answer are:

- To what degree do the planned adaptation strategies move SWP to a climate-resilient future?
- Are these strategies enough to improve SWP's resilience given the expected changes in climate?
- Even with these adaptation strategies, what conditions would continue to pose risks to the SWP and its water users?

1.2 Purpose

This report will be used to guide DWR's executive decision-making about the SWP's future needs and capabilities.

Climate adaptation is an ongoing process that requires periodic review and reassessment. This report's adaptation analysis represents the first iteration in this process. All DWR projects evaluate the impacts of climate change specific to a project's performance. The evaluation documented in this report is different because it provides an analysis of the SWP system with several additions to the existing infrastructure and management and evaluates how these additions could work together to provide climate resiliency and flexibility. The specific suite of adaptation strategies that are quantitatively evaluated in this report were chosen from the wider suite of adaptation strategies DWR and SWP are pursuing. The full list of adaptation strategies is described below, but the specific strategies selected for quantitative evaluation are those that meet at least one of the following criteria:

- Hold the most promise for significant water supply benefits.
- Require the greatest investment.
- Are furthest along in their development and path to implementation.
- Are within SWP's authority to implement and are called out in State policy and planning directives.
- Require consistent, sustained commitment to develop and implement.

The analysis provided for this adaptation strategy will help prioritize DWR resiliency efforts and establish adaptation pathways for the SWP. The strategies described and analyzed here may also help support development and deployment of the strategies described in *California's Water Supply Strategy: Adapting to a Hotter, Drier Future* by allowing water conveyance to existing and new storage facilities, helping restore groundwater levels and potentially serving communities lacking safe drinking water.

Analysis of this portfolio does not include exploration or development of additional climate adaptation strategies beyond those already under development, nor does it consider the degree to which SWP water users may be able to adapt their own systems, though these objectives are important and are being pursued independently. Additionally, analysis of this portfolio does not factor in the costs or necessary financing to implement these strategies.

1.3 Adaptation Portfolios

Section 3 describes 17 different climate adaptation strategies that the SWP is currently evaluating or implementing. While each of these strategies provides important resilience and adaptation value, five of these strategies (enhanced asset management, California Aqueduct subsidence remediation, DCP, FIRO, and SOD storage augmentation) have been selected and assembled into adaptation portfolios, which are described below. These portfolios represent alternative adaptation futures for the SWP. These portfolios should be seen as a starting point to guide SWP decision-making, further analysis, refinement, and ideation of adaptation strategies, and investment prioritization. In addition to the adaptation portfolios, two additional future scenarios are evaluated for comparison to understand the value of investments in adaptation.

1.3.1 Deteriorating System Scenario

This scenario is provided to show the benefits of the current maintenance investments and risks to the SWP if subsidence in the San Joaquin Valley continues without remediation or aqueduct upgrades. DWR is committed to ensuring that the dire outcomes of a future with unchecked subsidence does not occur. An assessment of only subsidence impacts without changes to asset maintenance management is in the SWP *Delivery Capability Report's* (DCR's) *Addendum: Impacts of Subsidence*).

This is a scenario of a run-to-failure future. In this scenario, the SWP suffers from underinvestment and deterioration and no adaptations are made. Subsidence along the California Aqueduct continues to occur with limited remediation. This scenario assumes that the Sustainable Groundwater Management Act (SGMA) is implemented, but before it reaches full implementation, significant subsidence continues to occur, assuming a 75% non-exceedance subsidence projection. This means that subsidence follows current trends and results in impacts to the California Aqueduct at a level that is equal to or worse than 75% of the projected future outcomes. Under this scenario, the capacity of the California Aqueduct to convey water is substantially reduced by 2043, and before 2085, the aqueduct ceases to be able to convey water south of southern Fresno County. Because California Aqueduct capacities are so limited at 2085 in this scenario, no 2085 climate conditions were run in CalSim3 for this portfolio.

In this scenario, loss of California Aqueduct capacity is paired with reduced maintenance of SWP's pumping plants because full pumping capabilities would not be needed if the California Aqueduct could not convey pumped water. In this scenario, the SWP retrogrades investments in asset maintenance management, failing to keep up with the *2023 Operations and Maintenance Strategic Asset Management Plan* (SAMP). Maintenance activities fall from current levels (which provide 84.6% operational availability) to 48.8% operational availability. Pumping facilities run beyond their scheduled operational lifespans resulting in greater unplanned outages and missed opportunities to deliver water due to lack of operationally available pumping capacity.

1.3.2 Baseline Maintain System Portfolio

This portfolio is a baseline future. In this portfolio, the California Aqueduct is restored to its full design capacity. In addition, SAMP continues to be fully implemented, delivering an operational availability of 84.6% of Valley String Pumping Plants.[1] No major climate adaptation investments are made. This portfolio closely resembles the future modeled in the 2023 SWP DCR, and this portfolio is treated as a baseline future from which the value of other adaptation portfolios are compared.

[1] Buena Vista, Teerink, Chrisman, and Edmonston Pumping Plants

1.3.3 Adaptation Portfolio 1—DCP

This portfolio includes the strategies described in the Baseline Maintain System portfolio plus the addition of the DCP from its *Final Environmental Impact Report*, which uses the Bethany alignment, composed of two 3,000-cubic-foot-per-second (cfs) intakes for a total of 6,000 cfs pumping capacity. Additional operational assumptions are described in Appendix A, "Modeling Assumptions." This adaptation strategy has been developed in detail, studied, has a certified environmental analysis, and is being actively pursued.

1.3.4 Adaptation Portfolio 2—FIRO

This portfolio includes the strategies described in the Baseline Maintain System portfolio plus the addition of FIRO and a water control manual (WCM) update for Oroville Dam. In this adaptation strategy, FIRO is modeled as a change to the flood conservation space rule curve, allowing additional water to be stored in the reservoir as described in Section 3 and in Appendix A. This FIRO adaptation strategy is an approximation based on DWR's best assumptions about what the future USACE WCM update for Oroville Dam might include.

1.3.5 Adaptation Portfolio 3—SOD Storage

This portfolio includes the strategies described in the Baseline Maintain System portfolio plus the addition of 2 million acre-feet (MAF) of storage SOD. This could be surface or groundwater storage and could be in a single or multiple locations. For modeling purposes, a surface storage reservoir was assumed near San Luis Reservoir. This adaptation strategy is exploratory and would require significant additional refinement. It is included here to explore whether SOD storage is an alternative to other adaptation strategies like DCP or whether it provides unique benefits. The large 2 MAF of storage capacity provides information about how much water could be stored if capacity existed. Further refinement of this concept could optimize the size, location, type (above or below ground), and number of storage units.

1.3.6 Adaptation Portfolio 4—Combination

This portfolio includes the strategies described in the Baseline Maintain System portfolio, DCP, FIRO, and SOD storage portfolios. This adaptation portfolio combines the four portfolios to explore how they work together and whether, when combined, they deliver more than the sum of their parts. In this portfolio, like the SOD Storage portfolio, significant additional refinement would need to be undertaken; however, this level of analysis provides a picture of the potential benefits of this combination of strategies.

2 Background

This section provides readers with a summary of DWR and State policies which guide and align with the analysis provided in this report.

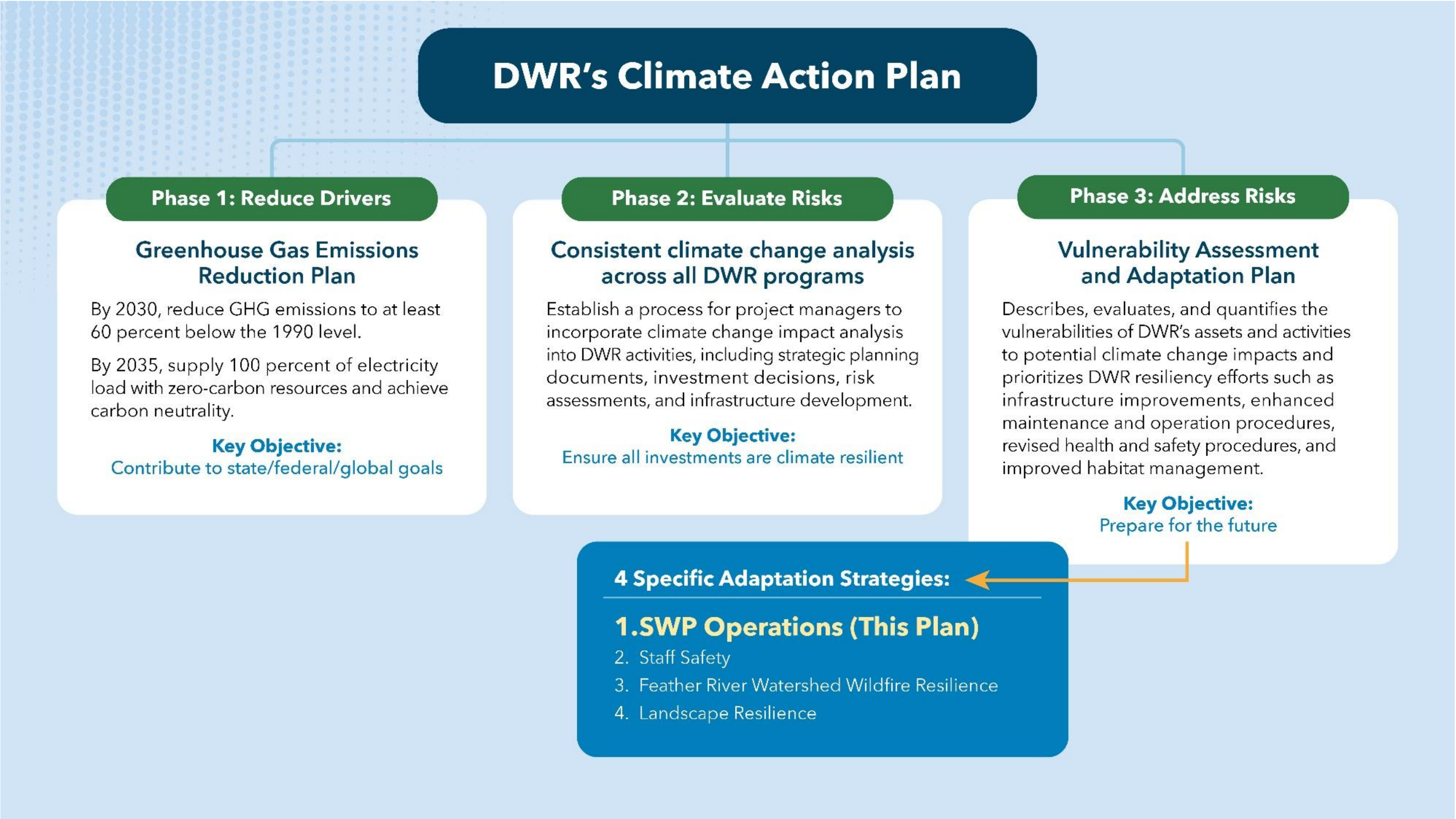
2.1 DWR Climate Action Plan

DWR's CAP guides efforts to address climate change in the programs, projects, and activities under DWR's authority. The CAP is divided into three phases to address mitigation, adaptation, and consistency in the analysis of climate change:

- Phase 1: Greenhouse Gas Emissions Reduction Plan Update 2023 lays out DWR's greenhouse gas emissions reduction targets and the strategies to achieve these goals.
- Phase 2: Climate Change Analysis Guidance (2018) establishes a framework and guidance for consistent incorporation and alignment of analysis for climate change impacts in DWR's project and program planning activities.
- Phase 3: Climate Change Vulnerability Assessment (2019) describes, evaluates, and quantifies the vulnerabilities of DWR's assets and operations to potential climate change impacts. The Phase 3: Climate Change Adaptation Plan (2020) helps prioritize DWR resiliency efforts such as infrastructure improvements, enhanced maintenance and operation procedures, revised health and safety procedures, and improved habitat management.

CAP Phase 3 evaluated and identified SWP vulnerability to hydrologic change as one of the top climate risks facing DWR. Further analyses such as the SWP DCR and other studies described below have confirmed these risks and refined DWR's understanding of them. This strategy describes how the SWP will respond to these risks as described in CAP Phase 3. Figure 2-1 shows CAP's three phases and the four specific adaptation strategies called for in CAP Phase 3. The other three specific adaptation strategies address other important aspects of the SWP and DWR's vulnerabilities to climate change.

Figure 2-1. DWR Climate Action Plan Phases 1, 2, 3



2.2 Alignment with State Policy and Other Plans

Several recent studies and reports have focused on California's water system, its vulnerability and potential adaptation to climate change, and California's responsibility to provide every Californian with access to safe, clean, and affordable water supplies. These studies and reports have informed this strategy in important ways, and are summarized below. These studies and others are described in greater detail in Appendix B, "Alignment with State Policies and Other Plans."

CAP's 2019 Climate Action Plan Phase 3 *Climate Change Vulnerability Assessment* and the 2023 SWP DCR assess climate change's effects on SWP performance, indicating reduced water delivery and storage capacity due to higher temperatures, earlier snowmelt, and more extreme precipitation events. This strategy directly responds to those identified challenges, in addition to adding evaluation and response to the additional challenge of subsidence impacting the San Luis Canal and California Aqueduct.

In 2022, *California Water Supply Strategy: Adapting to a Hotter, Drier Future* outlined how California can adapt to increasing drought conditions by promoting conservation, water recycling, desalination, and groundwater recharge. It emphasizes the need for improved infrastructure to store and move water efficiently during extreme weather events. This strategy specifically evaluates and addresses SWP resiliency to hotter and drier future conditions and the improvement of conveyance and storage infrastructure.

Delta Adapts, which is led by the Delta Stewardship Council (DSC) under its Delta Plan authority, is a comprehensive, regional approach to Delta climate resiliency. Delta Adapts began in June 2021 with a climate change vulnerability assessment titled *Delta Adapts: Creating a Climate Resilient Future*, which covers the Delta and Suisun Marsh. Findings from this vulnerability assessment in part led to DWR further developing additional tools to characterize and explore hydroclimatic variability that have informed this strategy.

In June 2025, the DSC published their *Delta Adapts: Creating a Climate Resilient Future* Adaptation Plan, detailing strategies and actions DSC and its partners can take to adapt to climate change in the Delta. The strategies described here align with several of the *Delta Adapts* strategies.

The *California Water Plan Update 2023* prioritizes climate urgency, watershed resilience, and equity, emphasizing the need for updated infrastructure investments to manage California's changing water landscape. It calls for increased investment and adaptation of critical water systems, including the SWP, to enhance long-term sustainability. This strategy helps operationalize the backbone infrastructure recommendations of the *California Water Plan*.

The California Water Resilience Portfolio 2020 outlines 142 actions to improve water supply reliability, protect ecosystems, and enhance climate adaptation. It focuses on diversifying water sources, building partnerships, and preparing for extreme weather challenges. This strategy aligns with several actions called for in the Water Resilience Portfolio.

Assembly Bill (AB) 685 went into effect in 2012, and is now codified in Water Code Section 106.3, making California the first state in the nation to legislatively recognize the human right to water. The State statutorily recognizes that “every human being has the right to safe, clean, affordable, and accessible water adequate for human consumption, cooking, and sanitary purposes.” The human right to water extends to all Californians, including disadvantaged individuals, groups, and communities in rural and urban areas. The SWP provides water to 75% of California’s disadvantaged communities, which are composed of nearly 8 million Californians. Implementation of the adaptation strategies outlined here would provide broad benefits that improve the ability of public water agencies to meet the needs of their users, including underserved, low-income, and other disadvantaged and environmental justice communities. The strategies help to improve water supply reliability, potentially reducing groundwater overdraft, dependence on contaminated water supplies, and supply interruptions. The strategies could also provide benefits for those who work in water-consumptive industries (e.g., agricultural-related industries) and economic security for those industries that rely on water.

3 State Water Project Adaptation Strategies

Clifton Court Forebay, located at the head of the California Aqueduct, provides storage and regulation of flows into Banks Pumping Plant.

SWP adaptation strategies are actions taken to reduce SWP vulnerability to the impacts of climate change. The SWP benefits its water users and provides other public benefits to Californians, including recreation, flood protection, environmental management, and power generation.

Adaptation strategies are essential for coping with changes in temperature, precipitation patterns, sea levels, loss of snowpack, and other climatic factors that result from global warming. Adaptation strategies aim to enhance resilience, increase flexibility and efficiency, minimize risks, and ensure the sustainability of the SWP system and its contribution to statewide water, energy, and ecosystem management.

Effective climate change adaptation requires a holistic and integrated approach that considers the authorities and functions of the SWP, the interconnectedness of social, economic, and environmental systems, and the challenges that different changes in climate will create. No single strategy will resolve every climate impact nor permanently resolve ever-changing impacts; nonetheless, the adaptation strategy portfolios explored here point to an adaptation pathway that prioritizes strategies for near-term and longer-term implementation in ways that amplify the benefits of earlier investments. Because of these challenges, immediate and consistent action is needed.

The following are 17 adaptation strategies, arranged into three categories:

- Structural strategies
- Operational and management strategies
- Nature-based solution strategies

These are strategies that DWR is already developing or implementing to protect and enhance the SWP. While the list of adaptation strategies is extensive, it is not exhaustive. DWR is leading, contributing to, and supporting many other activities that move California toward a more resilient water management future.

The strategies highlighted in this section are led by SWP and are specifically identified as contributing to SWP's climate adaptation goals. Figure 3-1 summarizes the 17 strategies and shows how they are located throughout the SWP system, helping to address systemwide and localized climate change vulnerabilities and risks.

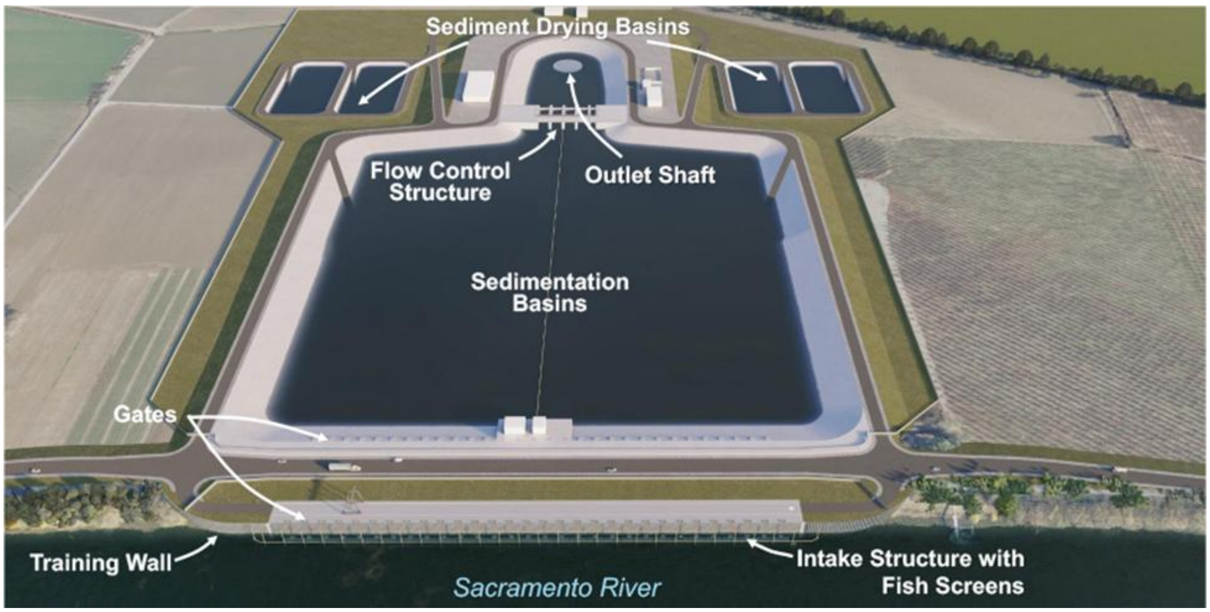
Figure 3-1. Map of State Water Project Climate Adaptation Strategies

3.1 Structural Strategies

Structural strategies are those that require significant infrastructural changes to the SWP. This may include adding facilities, or major rehabilitation or rebuilding of existing facilities. While structural strategies will often require additional operational changes, these are distinguished from operational and management strategies by their significant construction components. Structural strategies are described below.

3.1.1 DCP

This rendering by the Delta Conveyance Design and Construction Authority shows one of the DCP intakes.



The DCP entails constructing two new points of diversion along the Sacramento River and single-tunnel conveyance facilities in the Delta. The DCP would modernize water infrastructure in the Delta by making physical improvements to how SWP captures and moves water during wet periods for use during dry periods. The DCP would increase protection from earthquakes to the SWP and provide flexibility to manage climate-driven weather extremes. The DCP's Final Environmental Impact Report was released in December 2023.

The DCP helps ensure that the SWP can capture and move water during high-flow events, including short-duration flows during otherwise dry conditions. Modernizing SWP infrastructure in the Delta would provide an added tool for capturing water from brief yet high-flow and fast-moving storms and for placing that water in SOD storage for later use. DCP's added level of flexibility is meant to better manage high flows and periods of drought to provide drought relief.

The DCP is planned and designed with consideration of likely changes in hydrology and sea level rise. Future projected conditions have been used to evaluate the project and have shown that the project has a low-level of risk for direct climate change effects such as sea level rise. DCP supports statewide adaptation needs as articulated in *Water Resilience Portfolio 2020: In Response to Executive Order N-10-19* to diversify local supplies and prepare for hotter conditions and more intense floods and droughts. The DCP would increase diversions during wet conditions when excess water is available so it can be used at other times of the year and during drought conditions. DWR considers capture and conveyance in the Delta as important potential adaptations to mitigate system losses identified in CAP Phase 3.

The DCP is expected to increase resiliency in managing the combined effects of sea level rise and changes in upstream hydrology, including changes to runoff patterns from earlier snowmelt and precipitation. Furthermore, the DCP is expected to provide the future benefit of allowing continued deliveries to two-thirds of California and provides operational flexibility if there were catastrophic failure as a result of seismic activity or another disaster that temporarily disrupted the routing or quality of surface water supplies. The DCP could also play a critical role in meeting SGMA goals by conveying additional water to areas with overdraft, allowing groundwater recharge or supply switching.

DCP operation represented in modeling for this analysis was based on the most recent representation of DCP in CalSim3, which was available at the time of this analysis. This representation is consistent with models included in DWR's July 2024 Incidental Take Permit Application for the DCP. DCP operation in these models has some minor changes compared to the DCP's *Final Environmental Impact Report*, and these are detailed in Appendix A.

3.1.2 California Aqueduct Subsidence Remediation

Row and tree crops along the California Aqueduct in Fresno County.

Overdraft of San Joaquin Valley aquifers has caused land subsidence beneath the San Luis Canal and the California Aqueduct, resulting in diminished ability of this backbone infrastructure to deliver water and provide the flexibility and resilience 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 physical conveyance capacity reduction of 20%, with some locations experiencing 45% physical capacity reductions in potential flow. To mitigate these impacts, the SWP has implemented operational responses that allow water to be conveyed with less freeboard, which is the space between the top of the maximum water level and the top of the canal, allowing the system to continue functioning while minimizing loss of conveyance capacity. However, these operational responses have increased the risk of canal overtopping and have exhausted the flexibility available in the original aqueduct design, and they further limit the system’s ability to withstand any further subsidence at critical constrictions.

In 2019, the SWP established the California Aqueduct Subsidence Program (CASP) as an initiative to work in conjunction with the U.S. Bureau of Reclamation. CASP develops and implements preventative and corrective measures to mitigate the effects of subsidence while planning remediation of subsidence on conveyance, including anticipated future subsidence. Reestablishing SWP conveyance capacity lost over time to subsidence would allow the system to efficiently convey the more extreme hydrologic flows expected in California's hotter, more variable future. In its present state, SWP operations are primarily affected during wet periods and peak flow events, resulting in high Delta exports. Further degradation without remediation would drastically reduce SWP delivery capability. Reestablishing conveyance capacity would allow continuation of SWP delivery capability, and water conveyed and stored during these operations would provide critical water supplies during and when recovering from drought, improving Central Valley Project (CVP) and SWP resilience.

In the analysis performed for this report, modeling under the Baseline Maintain System, DCP, FIRO, SOD Storage and Combination portfolios assumes that CASP implementation allows the California Aqueduct and San Luis Canal to continue operating at full design capacity. The Deteriorating System scenario uses the 75% non-exceedance subsidence percentile (NESP) forecast of future California Aqueduct conditions. This forecast represents a gradual tapering off of recent historical annual subsidence rates as the subsidence sustainability objective under SGMA is eventually realized. A description of the subsidence forecast model used by CASP and the development of other NESP scenarios is documented in the technical memo *Subsidence and Hydraulic Conveyance Capacity Information for Use in the Climate Adaptation Study*.

Additional subsidence scenarios beyond the 75% NESP assessed in this report are presented in the DCR 2023 *Addendum: Impacts of Subsidence*.

3.1.3 Increased SOD Storage

This adaptation strategy has been studied before under different climate assumptions, but remains less developed than most of the other strategies evaluated. It is included here because of its potential to work in conjunction with other strategies to improve SWP resilience and reliability. The SWP currently has approximately 1.067 MAF of available storage capacity in San Luis Reservoir and approximately 800,000 acre-feet of capacity in other storage facilities SOD. These facilities enable the SWP to pump water out of the Delta when conditions allow and store the water until it is needed. In wet years, storage facilities frequently fill to capacity and pumping is curtailed because all immediate SWP demands (as specified in Table A[2] and Article 21[3] of water contracts) have been met, and no additional opportunities to store the water exist. This includes "Article 21 water—surplus, unscheduled water deliveries above a contractor's regular," or "Table A allocation," that are available when conditions allow.

[2] SWP Table A refers to the maximum amount of water each SWP contractor can request annually, as outlined in their long-term water supply contracts.

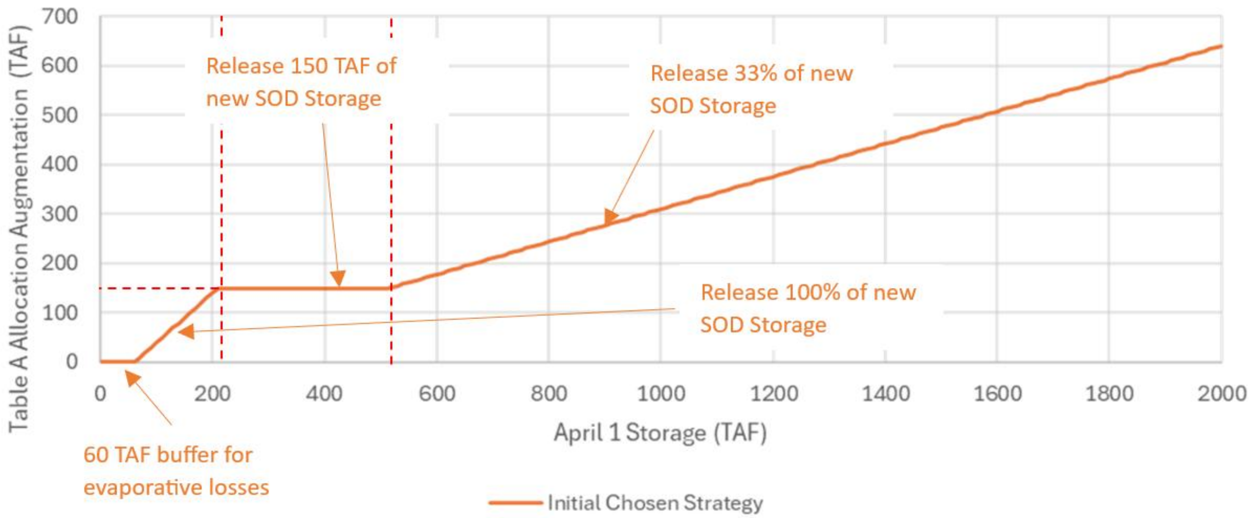
[3] SWP Article 21 water is surplus, unscheduled water deliveries above a contractor's regular or Table A allocation that are available when conditions allow.

Climate change is expected to continue amplifying California's already extreme variability in precipitation and streamflow. This amplification is likely to result in more years in which high flows exceed current storage capacity and more years in which extremely dry conditions stress the system. Additional SOD storage capacity could enable the SWP to store water in wetter years when water can be pumped safely within permit restrictions, so that the water could help alleviate water supply shortages during drought conditions and potentially reduce the need for pumping in critically dry years when water available from exports is expected to be scarce.

For this report, the SOD storage adaptation strategy is a first approximation of how a generic storage volume SOD could be integrated into the SWP system. Storage volume is modeled as a single 2-MAF surface reservoir near the existing San Luis Reservoir. This volume and location are intended to be generic for feasibility evaluation purposes, and to help assess the potential additional storage need. The volume and location would have to be evaluated in significantly more detail before any real project could be formulated or designed. Further, the type of storage facility (groundwater or surface water), whether a single facility or multiple smaller facilities, and its operation would also require significant evaluation and refinement.

The new reservoir modeled for analysis has its own operating strategy, with the goal of augmenting the SWP water supply during dry periods. The operating strategy is set up to capture surplus water that could not be captured in the current San Luis Reservoir and to preserve this water for dry year use. To capture this surplus water, priority is given to filling the SWP share of the San Luis Reservoir to its capacity before filling the new SOD storage, and to filling the new SOD storage before delivering Article 21 water. To preserve water for dry year use, the new SOD storage augments Table A deliveries when the normal baseline allocation (that is, allocation without considering SOD storage) falls below a threshold. For the initial chosen operating strategy, this threshold is set to 30%. The amount of Table A augmentation that the new SOD storage provides when baseline allocations are below the threshold depends on the April 1 storage levels of the new reservoir (Figure 3-2). If new SOD storage on April 1 is less than 210 thousand acre-feet (TAF), then 100% of new SOD storage is used to augment Table A delivery. If new SOD storage on April 1 is more than 510 TAF, then 33% of the new SOD storage is used to augment Table A delivery. If new SOD storage on April 1 is between these low and high levels, then 150 TAF of the new SOD storage is used to augment Table A delivery.

Figure 3-2. New South-of-Delta Storage Initial Operating Strategy



When DCP is considered along with new SOD storage, there is more frequent filling of the new reservoir and opportunities for a more aggressive release of the storage. As a result, a modified operating strategy is applied for the new SOD storage for scenarios in which DCP is also implemented. Figure 3-3 shows the modified operating strategy that is used when DCP is implemented compared to the initial operating strategy. Releases from the new SOD storage for this operating policy occur when the baseline allocation falls to less than 60%.

Figure 3-3. New South-of-Delta Storage with DCP Operating Strategy

Table 3-1 summarizes the differences between the two SOD storage operating policies and when they are applied in the model.

Table 3-1. South-of-Delta Storage Operating Policies Summary

Operating Strategy	Criteria for Applying Strategy	Allocation Threshold to Trigger Releases	Low-Storage Level Releases (% of new SOD Storage)	Mid-Storage Level Releases	High-Storage Level Releases (% of new SOD Storage)
Initial Operating Strategy	New SOD storage available, DCP unavailable	< 30%	100	150 TAF	33
DCP Operating Strategy	New SOD storage available, DCP available	< 60%	100	150 TAF	45

3.1.4 Delta Barriers

Temporary emergency drought barrier installation for the West False River in the Sacramento–San Joaquin Delta in Contra Costa County in April 2022.

During severe drought conditions that result in significantly decreased natural flows into the central Delta, increased needs and challenges arise with preserving upstream stored water for health, safety, and regulatory uses while preventing salinity intrusion beyond the western Delta. During normal water years, natural flows and flows from upstream releases into the Delta prevent San Francisco Bay saltwater from intruding beyond the western Delta. During previous severe drought conditions there was a significant risk of San Francisco Bay saltwater flows intruding beyond the western Delta. If this were to occur, it could require years for Delta salinity levels to return to normal.

To prevent such an event under previous severe drought conditions and through a statewide coordinated emergency response, DWR installed a temporary drought salinity barrier in the Delta's West False River (WFR). Based on data from previous installations, the WFR drought barrier has proven an effective tool for reducing saltwater intrusion into the Delta. Given the current scientific understanding of the cyclical nature of drought in California and increasing drought risk with climate change, DWR will likely have to reinstall a WFR drought barrier during future droughts. DWR certified the *West False River Drought Salinity Barrier Final Environmental Impact Report* and is working to secure all necessary environmental permits to reinstall the barrier up to two times over the next 10 years as a part of another statewide emergency response. Doing this work ahead of time reduces or eliminates the need for last-minute emergency California Endangered Species Act (ESA), federal ESA, or USACE permits to install the barrier.

The WFR is in the central Delta in a main channel located west of and connected to Frank's Tract. By hydraulically blocking the WFR, flows into Frank's Tract would be mostly from the less salty Old River further upstream on the San Joaquin River rather than further 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 Delta and consequently help maintain Delta water quality. Without the protection of the drought salinity barrier in WFR, a critical location for preventing salinity intrusion into the 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.

This adaptation strategy is not quantitatively modeled in this report.

3.2 Operations and Management Strategies

Operations and management strategies are those that do not require significant infrastructure changes to the SWP. These changes can be achieved by investing in the management and operation of existing facilities, finding partnerships and developing synergies in the operation of other facilities, using improved monitoring and scientific information, and elevating climate considerations in the planning and design of SWP operations and maintenance.

3.2.1 Oroville Dam WCM Update to Allow FIRO

Flood control releases on May 9, 2024 from Oroville Dam's main spillway located in Butte County.

FIRO is a flexible water management strategy that uses improved weather and runoff forecasts to help water managers retain or release water from reservoirs that in turn increase resilience to droughts and floods. The primary objective of the FIRO project at Oroville Dam is to reduce flood risk to downstream communities; 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 if it were not for forecasts indicating the absence of flood-threatening storms on the horizon. In addition, improved 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 could be diverted into other surface storage and groundwater basins, which would result in additional downstream storage that could be used to support water supply needs in future drought years.

Recognizing the importance of atmospheric rivers in a changing climate, DWR, in partnership with the following groups, have assessed the viability of FIRO at New Bullards Bar on the Yuba River and Oroville Dam on the Feather River:

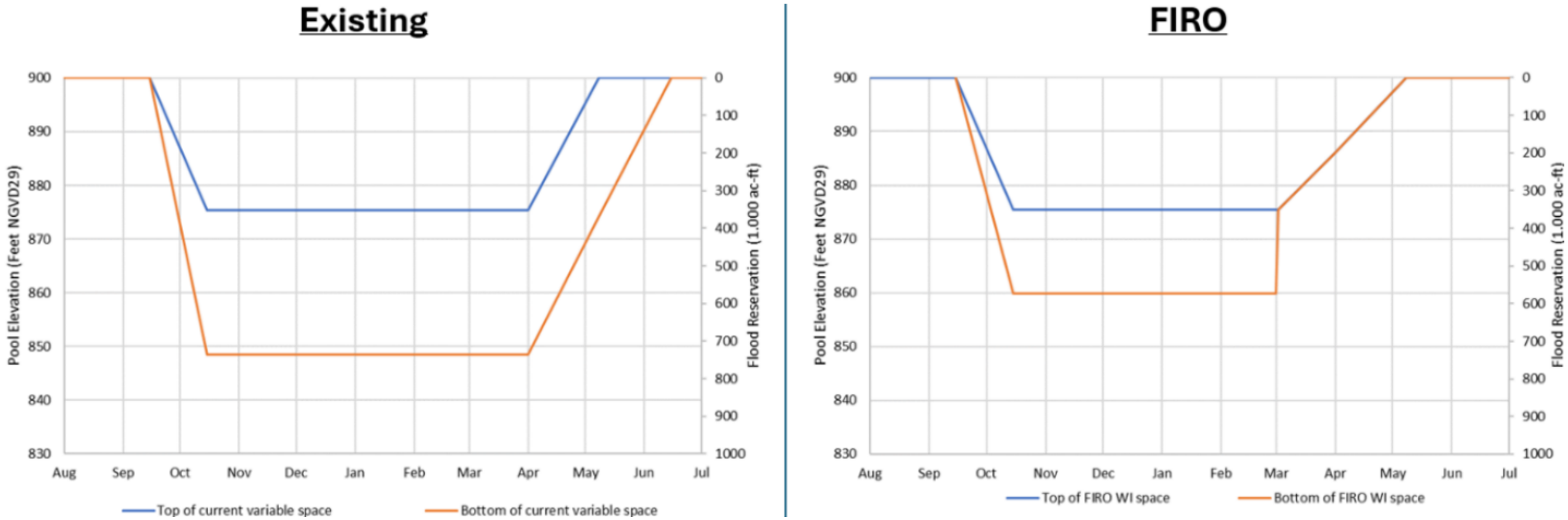
- Yuba County Water Agency
- Center for Western Weather and Water Extremes at the University of California, San Diego
- USACE
- National Weather Service
- Other members of the Yuba-Feather FIRO Steering Committee

The *Yuba-Feather Forecast Informed Reservoir Operations Final Viability Assessment* (Final Viability Assessment) was published in February 2025 and includes FIRO alternatives. USACE will consider Final Viability Assessment FIRO alternatives (or revised alternatives) in their National Environmental Policy Act process for Oroville Dam's WCM update. Planned completion of the updated WCM is anticipated in summer of 2027.

The 1970 WCM, titled *Oroville Dam and Reservoir Report on Reservoir Regulation for Flood Control*, describes a storage management plan that assigns available storage at Lake Oroville for conservation purposes (i.e., water supply, hydropower production, recreation, and environmental protection) or flood management. This plan consists of a monthly flood control diagram that shows two rule curves: one for wet ground conditions (bottom curve) and one for dry ground conditions (top curve) (Figure 3-4). In Figure 3-4, storage above the solid orange line (bottom curve) is allocated to flood management on the day shown, and the storage below is allocated to conservation. The space between these two curves is also known as top-of-conservation (TOC) variable space that is determined by watershed wetness (i.e., the wetness index). The 1970 WCM requires Lake Oroville to maintain a flood management space between 370 and 750 TAF, depending on accumulated precipitation to date (Figure 3-4, in existing scenario). From April 1 through June 15, the reservoir is allowed to refill, and by June 15 the allocation for flood management is reduced to 0 acre-feet.

To characterize and model potential FIRO at Oroville Dam and the potential water supply benefits of this operation, a simplified representation of potential operational modifications was developed for use in CalSim3. Actual operations using FIRO would occur at daily, or even hourly, timesteps. However, CalSim3 is a monthly model; representation is necessarily coarse. Nonetheless, the representation presented in this report approximates the potential water supply benefits of FIRO. In this report, an updated guide curve derived from proposed FIRO alternatives in the Final Viability Assessment allows Lake Oroville storage to be operated at higher storage levels than the current flood control diagram allows (Figure 3-4, in FIRO scenario). In the FIRO scenario, the reservoir could fill higher and only draw down if a large event is forecasted. In addition, the watershed wetness considerations end on March 1 and the allocation for flood management storage is reduced to 0 acre-feet on May 15. Refer to Appendix A for details about FIRO representation in CalSim3.

Figure 3-4. Lake Oroville Top-of-Conservation Variable Space for Existing (1970 Water Control Manual) and Forecast-Informed Reservoir Operations Alternative



Note: Derived from Figure 3-3 of Final Viability Assessment.

3.2.2 Enhanced Asset Management

Continued enhancement of existing asset management practices is an ongoing effort for the SWP. This effort includes reviewing, documenting, improving and embedding 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. These practices are described in the SAMP. Updating business processes with documented processes and tools support risk-informed decision-making that enhances SWP infrastructure reliability and helps operations and maintenance staff modify operations strategies, maintenance programs, and reprioritize planned capital projects as hydrologic conditions change. This effort allows 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, and then deliver available project and non-project (i.e., transfer) water during extreme drought conditions.

SWP is currently implementing the enhanced asset management strategy. Execution of this strategy has resulted in improvements to operational availability of the pumping plants along the California Aqueduct over pre-enhanced asset management implementation. Over recent years, operational availability on average over all pumping plants has reached 84.6%.

For the adaptation strategy portfolios described above, all include implementation of the enhanced asset management strategy except the Deteriorating System scenario. Functionally within CalSim3, this strategy is implemented by adjusting the operational availability of pumping plants along the California Aqueduct (i.e., Banks, Dos Amigos, Buena Vista, Wheeler Ridge [Teerink], Wind Gap [Chrisman], Edmonston, Pearblossom, Mojave Siphon, and Oso). CalSim3 allows for a maximum pumping capacity to be assigned for each month of the year and for each pumping plant. This value effectively establishes a maximum cap on the monthly pumping capacity through each plant. This simulates maintenance activities that take facilities offline for planned and unplanned outages.

For the Baseline Maintain System, DCP, FIRO, SOD, and Combination portfolios, an 84.6% average pumping plant operational availability is applied (refer to the Asset Management section of Appendix A for additional information). This condition simulates recent observed operational availability in which enhanced asset management procedures described in the SAMP have been employed. This operation also accounts for increased *planned* outages during low water-demand periods of the year to avoid *unplanned* outages during high water-demand times of the year. It also accounts for increased planning and resourcing to prioritize refurbishments and replacements and acquire and store long-lead replacement parts to avoid extended outages.

The Deteriorating System scenario represents a future in which the enhanced asset management strategy is *not* implemented. Little effort and few resources are expended to preemptively develop testing, evaluation, prioritization, and execution procedures to proactively maintain SWP facilities and efficiently avoid unplanned outages. The Deteriorating System scenario explores a 48.8% system operational availability condition, meaning the average availability of pumping capacity across all months and pumping plants is 48.8% (refer to the Asset Management section of Appendix A for additional information). This is a simplified representation of a scenario in which regular unplanned unit outages continue to occur. In addition, significant facility-wide outages also occur throughout the system on a periodic basis. These significant major outage events could be similar to past outages including the 2012 Thermalito Power Plant Fire, the 2023 Devil's Den Plant fire, or the 2017 Oroville Spillway incident in which entire facilities were taken offline and required multiple years to reestablish full capacity. The Deteriorating System scenario, while representing a significant decrease in asset management, does not model a complete multi-year outage of a California Aqueduct plant or Oroville facility because the bypass options under such a scenario are very limited to non-existent, and the effect could be zero flow downstream for between six months and five years, depending on the nature and location of the outage.

The Deteriorating System scenario simulates lower operational availability at all plants continuously, instead of zero capacity for a few years and then higher capacity after a facility returns to service. This is a convention used because of the way the CalSim3 model simulates system operations, which does not allow for single- or multi-year plant outages. Instead, the impacts of deteriorating plant reliability are simulated through reductions in average operational capacity. No portfolio explicitly accounts for, or models outages or maintenance issues at facilities outside of the Valley String Pumping Plants (e.g., Oroville or North Bay Aqueduct), but the conditions in each scenario are representative of the system as a whole and the resulting delivery capability would generally be indicative of maintenance considerations throughout the system.

3.2.3 Improved Forecasting

The Airborne Snow Observatory provides snow measurement data to inform water supply forecasts.

DWR, with support from SWP, 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 on 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. Both efforts support improved operation of the SWP. Overviews of each area of investment, including the status of capabilities and development, are described below.

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

DWR performs maintenance on snow monitoring equipment in a remote part of Kings Canyon National Park in the eastern part of Fresno County. Snow monitoring and forecasting benefit water users throughout the state.

Throughout the past decade, a number of efforts have been deployed to update and improve the tools used for runoff forecasting for 0- to 5-day time frames and seasonal runoff forecasting associated with Bulletin 120 (April through July snowmelt volume forecasting). Bulletin 120 is a DWR publication issued four times a year to provide information on the unimpaired runoff of California's rivers and streams. 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. The SWP provides funding for airborne snow mapping of the Feather River watershed up to four times per year to support forecast of snowmelt runoff from April through July. In addition to data collection, iSnoBal snowpack modeling[4] and WRF-Hydro runoff modeling are

[4] iSnobal is a physically-based, distributed snowmelt model used to simulate the development and melting of snowpack in mountainous regions. It's a coupled energy and mass-balance model that helps understand the timing, magnitude, and area of snowmelt under different climate conditions.

being developed[5]. Along with 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.

Improved runoff forecasts can be an important climate adaptation strategy because they provide SWP operators and water users with advanced water supply information. This allows conservation actions to be taken earlier in advance of dry conditions and water storage or transfer actions to be taken earlier in advance of additional water supplies being available during wetter times.

Previous investments in advanced weather and runoff forecasting are already being deployed to improve operational decision-making today. FIRO depend on these improvements and allow operators to make better decisions with greater foresight, which can yield both water supply and flood risk reduction benefits.

3.2.3.2 Area 2—Improved Seasonal Forecasting for Operational and Governance Planning

In this area of forecast development, DWR has spent the past decade assembling a coalition of researchers to systematically address opportunities to improve capabilities, as well as address known challenges, that limit predictability in this space. The group meets annually in November to examine water year outlook experiments, and again in summer to review outcomes and develop next steps in the research. Sponsored by DWR, the Center for Western Weather and Water Extremes posts to its website subseasonal-to-seasonal (S2S) experimental 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 this area of forecasting.

If subseasonal-to-seasonal forecasts could be improved to be more reliable, they could provide an important climate adaptation strategy allowing more water to be carried over in storage when the upcoming season is expected to be dry, and delivering more water potentially for storage in groundwater when upcoming conditions are expected to be wet.

This strategy is not quantitatively modeled in this report.

[5] WRF-Hydro is an open-source, community-based model that links multi-scale process models of the atmosphere and terrestrial hydrology.

3.2.4 Carryover Storage Targets

Lake Oroville, the largest SWP reservoir, filled to capacity in June 2023.

To prepare for future dry conditions, the SWP plans for carryover storage at the end of each water year. Carryover water is water that could have been delivered but was held in storage instead. Increasing carryover storage decreases supply delivery in the year it was stored, but may increase supply in subsequent years. If the subsequent year is wet, the additional stored water may provide little or no benefit and may result in increased releases needed for downstream flood risk reduction. DWR's carryover target was 1.3 MAF for several years, and before that the carryover storage target was 1.0 MAF. 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 during multi-year dry cycles. In 2018, the Oroville carryover target was evaluated and increased by 300 TAF, and beginning in 2019, DWR implemented an end-of-water-year storage target of 1.6 MAF.

The Oroville carryover storage target is periodically reviewed and may be updated if warranted by changed conditions, including better forecasting. Examples of changed conditions include:

- Physical capacities (such as the outlet capacities at Lake Oroville).
- Operating regulations upstream or in the Delta (e.g., Feather River temperature requirements; or new State Water Resources Control Board [SWRCB], California ESA, or federal ESA requirements).

- Operating agreements (such as the Coordinated Operations Agreement with U.S. Bureau of Reclamation).
- Observed changes to hydrology.

All scenarios evaluated in this study assume a 1.6 MAF carryover storage target. It should also be noted that carryover storage intended use is as a resource for addressing critical needs in subsequent back-to-back dry years and, inasmuch, may be used in certain circumstances.

3.2.5 Adaptive Management of Operations and Regulatory Compliance

Adaptive management of water supply in California has become increasingly critical in response to the growing challenges posed by climate change. The SWP in partnership with regulatory agencies employs flexible, science-based strategies to protect long-term water security. Adaptive management is a dynamic approach that emphasizes monitoring, learning, and adjusting policies and operations in response to changing environmental conditions. For the SWP, existing California ESA and federal ESA permits specify that operational rules can be modified considering new information or development of tools that allow for protection of water supply and endangered fish species.

Regulatory adaptation plays a central role in supporting this flexible approach. Traditional water management frameworks in California, such as the system of water rights and fixed infrastructure planning, are not agile enough to address rapid shifts brought on by climate change. In response, State agencies have begun revising regulations to encourage more sustainable and responsive water use.

Water supply operations in the Delta have undergone significant changes to address climate-related pressures. To manage these risks, State and federal agencies have implemented more flexible and responsive operational strategies. For instance, real-time monitoring of salinity and flow conditions allows managers to adjust water exports and reservoir releases to protect both water quality and endangered species.

As climate impacts intensify, the SWP will continue to pursue scientific insight and stakeholder engagement and will work with State and federal regulatory agencies to ensure that permits and operations are flexible and adaptable to keep up with California’s changing climate.

This strategy is not quantitatively modeled in this report.

3.2.6 Project-Level Climate Resilience Evaluation

In 2018, DWR adopted Phase 2 of its CAP. Phase 2 guides DWR in its decision-making and helps DWR managers incorporate climate change analyses into their strategic planning documents, investment decisions, risk assessments, and infrastructure development. Phase 2 guidance operationalizes DWR activities to implement AB 1482, AB 2800 and Executive Order B-30-15 (among other mandates and policies), which direct State agencies to consider climate change in all planning and investment decisions.

Ensuring consistent, high-quality, and science-driven climate analysis for all projects delivers better planning outcomes, including awareness of long-term risks to projects and the ability to account for those risks in the most economical manner; reduced “surprises” that affect the performance of a plan or investment; and a more systematic approach to planning and investment efforts, including increased interagency and inter-sector coordination.

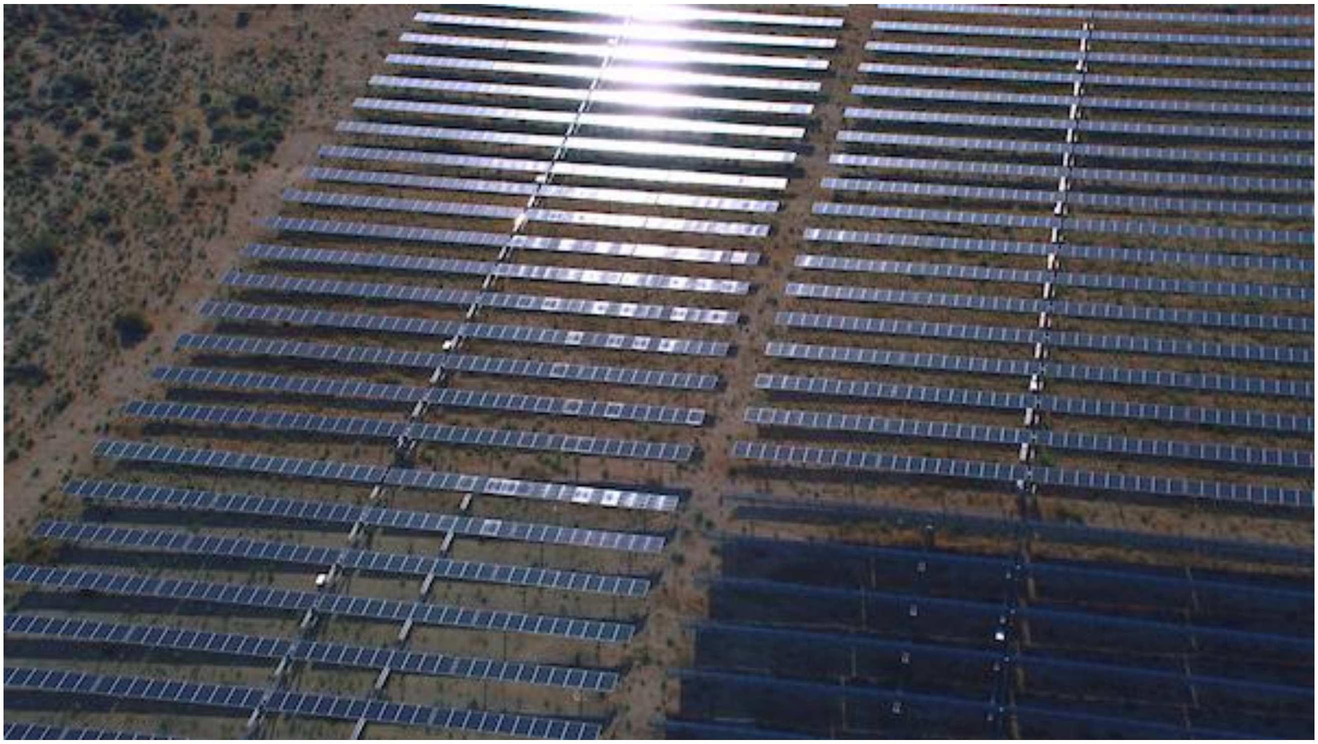
The SWP implements approximately 100 projects each year. Each project is screened to identify potential climate vulnerabilities. Those projects that identify vulnerabilities go through a defined process involving eight analytical considerations for developing and completing additional climate change analysis to ensure that the project, once implemented, will provide climate-resilient outcomes. Projects can draw on extensive departmental resources to assist with their analysis including datasets, case studies and examples of past projects, and a department-wide advisory committee.

For the SWP, this process has resulted in important changes to project objectives and design parameters for major infrastructure investments. For other projects, this process has begun to change long-standing standard practices including the use of historical data, factors of safety, and materials considerations.

This strategy is not quantitatively modeled in this report.

3.2.7 Shaping SWP Power Load and Generation

Solar panels produce energy at DWR's Pearblossom Pumping Plant in Los Angeles County



As California continues on a path toward 100% renewable resources and a zero-carbon power grid by 2045 (via Senate Bills 100 and 1020), more renewable resources, namely solar generation resources, are being integrated into the California Independent System Operator grid. SWP has an even more aggressive goal for de-carbonization and will reach 100% renewable resources, zero-carbon electricity usage, and carbon neutrality from its operations by 2035.

Integration of more solar resources has resulted in more pronounced periods of solar over-generation; these periods of over-generation by solar resources result in negative pricing, indicating that there is an oversupply of electricity causing congestion within the grid. This negative pricing is problematic for electricity providers as it means they have to pay for their energy to be consumed; this also means that any additional solar resource is disincentivized from integrating into the grid. The SWP pump load has the unique ability to shift its load and optimize the use of energy from the grid when operational conditions permit; this use of solar energy resources thereby helps current solar resources, incentivizes the integration of future renewable resources, and disincentivizes the use of fossil fuel resources by shifting the load away from the super-peak supply hours. This unique shaping of the SWP load can also be done with the SWP hydropower generation to help reduce the grid's reliance on fossil fuel resources. SWP generation can be shifted, when operational conditions permit, to help meet the peak demand by generating clean hydropower during the super-peak demand hours, when more generation resources are needed to substitute for the ramping down of solar generation in the late afternoon and displaces what would otherwise be fossil fuel generation. By shifting its generation into the super-peak demand hours and out of the solar supply hours, SWP can disincentivize the use of fossil fuel resources and incentivize renewable energy development. SWP's shaping of its load and generation helps reduce California's grid emissions and ensures disruptions in electricity development are avoided or minimized.

While this strategy is generally an energy market adaptation, it also provides additional climate resilience for the SWP during more extreme weather events when electricity grids can be strained, as it permits for the movement of water to occur during periods when electricity supplies are least strained, reducing the likelihood of electricity interruptions.

The SWP was built in the 1960s to convey water supplies. The SWP was not designed with the intent to operate as a fast-ramping, dispatchable resource that can respond to grid reliability needs. Through the SWP Flexible Resources Study, DWR has identified the ability to shape load and generation within the current system constraints and is investigating system improvements that will allow for more shaping of the SWP load and generation as California progresses to 100% renewable and zero-carbon resources.

Energy generation and consumption are not modeled quantitatively in this study.

3.2.8 Enhanced Financial Management and Contract Extensions

The SWP has an annual operating revenue of close to $1.6 billion. Although the SWP is a multi-purpose project, the costs are primarily recovered from the 29 SWP contractors pursuant to water supply contracts with repayment terms through 2035. In May 2013, DWR and the contractors began negotiations to develop contract terms to extend the term and modify certain financial provisions of the water supply contracts. On January 1, 2023, the water supply contract extension amendments became effective, extending the contracts to 2085 and requiring the implementation of new billing provisions and additional accounts to support enhanced funding mechanisms and operations.

The contract extension amendment facilitates the ability to finance capital costs beyond 2035 for a term of 30 years or more, relieving the near-term compression of the original repayment period. This will augment long-term planning with the enhancement of capital financing and financial management plans and linking asset management and maintenance management activities with cost-projection forecasting. Contract extension amendments are an important climate adaptation strategy because they support funding of longer-term investments, such as those described in this plan, that will be needed to adapt to California's changing climate.

3.2.9 Water Storage Investment Program Project Integration

The Water Storage Investment Program (WSIP) includes six projects that would boost California's water storage capacity by 2.65 MAF. Through WSIP, the State seeks to invest up to $2.7 billion in funding from a 2014 water bond in the public benefits of new water storage projects. The public benefits include ecosystem improvements, flood protection, emergency response, water quality, and recreation.

While none of the projects eligible for WSIP funding are led by the SWP, all have the potential to affect the Delta and SWP operations, providing improvements in water supplies and environmental benefits. Integration of these projects (modifying SWP operations to allow these local projects to provide statewide benefits) is included as an SWP adaptation strategy because it requires SWP action that contributes to the State's broad efforts to adapt to climate change. The integration of these projects would expand the ways in which the SWP facilitates water conveyance and storage throughout the state, providing benefits far beyond the 29 public water agencies that contract for SWP water supplies.

WSIP projects are not being proposed by DWR or SWP, nor would these projects be considered SWP facilities once constructed. WSIP projects are being carefully evaluated to ensure that they do not interfere with or impede SWP operations and may ultimately be complementary to SWP operations, allowing for both local water purveyors and the San Francisco Bay-Sacramento San Joaquin Delta environment (through WSIP projects' public benefit commitments) to benefit from their implementation.

WSIP projects that could be integrated into SWP operations consist of two surface water diversion projects and three groundwater bank projects. The five projects are in various stages of permitting and acquiring local commitments to participate in the projects.

Sites Reservoir in Colusa County is a new surface storage reservoir project. It would provide additional storage and system flexibility, capturing storm flows from the Sacramento River in wet periods, and then releasing that storage for increased water supplies and environmental benefits north and south of the Delta, primarily in dry and critical years.

Pacheco Reservoir would enlarge an existing reservoir in Santa Clara County. This project is expected to redirect some water typically stored in San Luis Reservoir to Pacheco Reservoir. This could improve management of the water supplies the proponents of this project receive from the CVP and the SWP.

The Chino Basin Program, Kern Fan Groundwater Storage Project, and Willow Springs Water Bank Conjuctive Use Project would involve development of groundwater banks that would facilitate increases in water supplies in drier periods and releases of pulse flows in the spring from Lake Oroville on the Feather River to benefit salmon and other fish species. Pulse flow releases would be facilitated by water exchange agreements with SWP Table A contractors, so that Table A water being released for pulse flows from Oroville is effectively replaced by supplies from groundwater banks. The Chino Basin Program would store treated wastewater in a groundwater bank, which would be exchanged for Oroville pulse flows over a 25-year period. After that period, Chino Basin would be operated for local water supply benefits. The Kern Fan Groundwater Storage Project would store Article 21 water and other supplies available in wet conditions. Of this water, 25% would be dedicated to Oroville pulse flows and the remaining water would go to local SWP partner contractors. Willow Springs Water Bank is still determining its operations but plans to use groundwater banking to exchange for Oroville pulse flows.

3.2.10 SWP Outdoor Staff Safety Improvements

DWR's Safety Office, SWP field divisions, and DWR's Climate Change Program staff are monitoring and assessing impacts of climate change on the safety and well-being of staff, especially for those working in outdoor and unconditioned non-office environments. Growing research suggests worsening staff safety outcomes resulting from the effects of climate change. The list of outcomes includes increasing frequency and intensity of extreme heat events, worsening air quality, expanded exposure to biological hazards (such as vector-borne diseases), and mental health impacts arising from higher work demands or response to more frequent emergency events. DWR staff safety team members are monitoring research and regulations that apply to outdoor staff, assessing what feasible adaptation strategies exist to known potential challenges and possible future risks. Safety team members are developing a living guidance document that emphasizes the need for monitoring and assessment to inform real-world adaptation approaches that maintain staff safety while meeting the operational needs of DWR and the SWP.

These strategies are not quantitatively modeled in this report.

3.3 Nature-Based Solution Strategies

Nature-based solution strategies are those that harness the power of nature to build resilience to future climate-driven extremes, protect communities from the impacts of climate change, and remove carbon from the atmosphere. These strategies may require a mix of construction and operational changes, but generally work by supporting the natural capacity of the environment to improve hydrologic function, improve conditions for aquatic organisms, and rebuild degraded land.

These strategies hold significant promise; however, the exact value of these actions can be difficult to quantify. Several efforts are underway to improve quantification and justify future action, and significant monitoring components are involved in each effort. Beyond the SWP-specific strategies described below, DWR is developing other nature-based solutions throughout California. Efforts like the San Joaquin Watershed Studies and the development of parks are providing new information and methods that will inform and improve future SWP investments. No nature-based solution strategies have been quantitatively modeled in this study given these challenges.

3.3.1 Environmental Restoration

Lookout Slough Tidal Habitat Restoration and Flood Improvement Project in Solano County is a multi-benefit effort to restore the site to a tidal wetland, create habitat that produces food for Delta smelt and other fish species, while also creating new flood capacity in the Yolo Bypass and reducing overall flood risk in the Sacramento area.

DWR has a commitment to protect and enhance the natural environment through watershed health efforts including habitat restoration, scientific exploration and environmental monitoring, community engagement, and resilience planning. Past efforts by DWR and SWP have restored tidal wetlands, river floodplains, and rearing habitat for juvenile salmonids. These projects are evaluated by a science-based adaptive management framework to maximize environmental benefits and improve the design and effectiveness of future projects. DWR's proposed Healthy Rivers and Landscapes Program would build on this knowledge and support the development of thousands of additional acres of habitat. DWR engages with universities to research topics including community wildfire resilience, restoration prioritization, and meadow science; and actively collaborates with federal agencies, private companies, and local governments to advance interagency and multi-benefit endeavors.

3.3.2 SWP Delta Islands Management

The SWP owns most of the land on Sherman and Twitchell islands near the confluence of the Sacramento and San Joaquin rivers in the Delta. Surrounding islands and the levees provide an important hydrodynamic constriction point that reduces salinity penetration between the Suisun Bay and the interior Delta.

Since purchasing these lands, DWR has worked to convert land uses on the islands from practices that contribute to subsidence and greenhouse gas emissions, to practices that accrete land, sequester greenhouse gas emissions, and provide habitat and scientific benefits. These land use changes contribute to DWR and SWP greenhouse gas emission-reduction goals and will help the SWP prepare for higher sea levels that will further stress levees.

DWR is developing a long-term strategy that will document how further land use transitions can benefit the SWP, provide important adaptation for future climate changes, and help inform future land use decisions.

3.3.3 Feather River Watershed Management

Tree burned in North Complex and Potters Fires burn scar areas in the Feather River watershed, which feeds Lake Oroville in Butte County.

The Feather River watershed is an integral part of the SWP natural infrastructure. Watershed health is necessary for ensuring that the watershed adapts to climate change and continues providing essential ecosystem services. Wildfire is a primary concern, because it can drastically alter watershed properties such as soil stability, snowmelt, and runoff characteristics, which can in turn affect SWP operations, public safety, and infrastructure. A 2024 analysis of the damage from the 2018 Camp Fire, 2020 North Complex Fire, 2021 Dixie and Sugar Fires, and 2022 Walker Fire showed that the fires were resulting in more runoff into Lake Oroville, with higher peak inflows, earlier snowmelt, and slightly higher storage and deliveries under post-fire conditions. While these findings indicate that fire has positive and negative impacts on water supply, great concern exists over what vegetation communities will repopulate the burn scars and what the impact of these new vegetation communities might be. For example, in many areas across California, wildfire has caused conifer forests to convert to dense shrublands, or to broadleaf multi-trunked trees (a disturbance recovery process known as ecological type conversion). These vegetation communities are very different in their water use properties, snow interception, and fire regimes. More active management of forests throughout the watershed holds great promise for avoiding uncontrolled, extreme fires and delivering the benefits of natural fire regimes.

DWR recognizes that overall watershed climate resilience can be improved by supporting adaptive actions that address wildfire and other inter-related climate vulnerabilities (e.g., forest ecological health, wetlands, soil health, and carbon sequestration). To address this need, DWR is developing a Feather River Watershed Resilience Strategy. The strategy's goal is to improve community resilience and natural infrastructure provided by the Feather River watershed by supporting multi-benefit and interagency efforts that enhance ecosystem services, bolster community adaptive capacity, and maintain and improve hydrologic characteristics. The strategy will build on existing efforts such as Plumas County's Thompson Meadow, which was successfully restored in 2022 by DWR and Plumas Corp with SWP funding. This project, like many other interagency meadow restoration projects across northern California, enhances meadow wetlands that contribute to landscape heterogeneity, improve habitat, and benefit water quality and hydrology. DWR's technical and financial support of ongoing and new efforts provides opportunities for interagency collaboration and alignment to more efficiently conduct projects that improve water supply, enhance ecosystems, and provide social benefits while adapting to wildfire and other climate change vulnerabilities.

DWR is also working with multi-agency partnerships to fund forest management projects through efforts such as Forest Resiliency Bonds. These bonds allow the SWP to contribute to broad multi-party efforts to manage and restore forests throughout the Feather River watershed.

4 Technical Approach

4.1 Climate Change Hydrology and Sea Level Rise

The adaptation portfolios described here are evaluated at two future time periods, 2043 and 2085. These periods have been chosen to provide a near-term planning horizon that aligns with the projections provided in the 2023 SWP DCR and a long-term planning horizon that can be used for longer-term feasibility assessments and cost benefit assessments. This later period also aligns with the expiration of the current SWP water supply contracts. These time periods do not represent specific future years, but rather the expected range of conditions that would be projected approximately 20 and 60 years into the future, respectively. At each future period, two different climate conditions are evaluated. Multiple climate conditions for the same period provide an explicit recognition that future conditions at any time period are uncertain.

For each period, two potential climate conditions are evaluated. These climate conditions are described by a percent level of concern (LOC). Detailed information about the development and definition of these LOC scenarios can be found in the *Risk-Informed Future Climate Scenario Development for the State Water Project Delivery Capability Report*, which describes the method used to develop the 2043 scenarios. The same method and data were followed to develop the 2085 scenarios. The term "level of concern" is used to describe the severity of the climate conditions represented in the scenario. For example, a 95% LOC scenario uses climate conditions that stress the system as much, or more, than 95% of the model informed uncertainty space at the given time frame. Stress to the system is defined by a chosen system performance metric important to interested parties. Substantial effort was expended to select a metric for the generation of these scenarios as described in the *Risk-Informed Future Climate Scenario Development for the State Water Project Delivery Capability Report*. The metric used to identify future climate projections provides generalized Central Valley hydrologic conditions and these climate projection scenarios are, as a result, valid for systems throughout the Central Valley.

For each period, a median or expected value condition is provided, denoted as 50% LOC conditions. A more pessimistic but plausible condition is also provided. For 2043, 95% LOC conditions are provided. For 2085, 75% LOC conditions are provided. These conditions explore climate conditions that are hotter and drier and include more sea level rise than the 50% LOC. A very extreme (95% LOC) condition is used for 2043 to provide exploration of adaptation strategies under extreme or rapid climate change conditions and to show how the value of the adaptation strategies improve, maintain, or deteriorate under more extreme conditions. For 2085 explorations, the 75% LOC conditions are used. For 2085, 95% LOC conditions are not used largely because the sea level rise projections for 2085 at a 95% LOC would have required very uncertain assumptions about Delta land use, levee construction, and water quality regulations that were beyond the scope of this project and would have required substantial speculation. Projections for 2085 at the 50% and 75% LOCs, to a lesser degree, also require assumptions about Delta land use, levee construction, and water quality regulations which should be kept in mind when using these scenarios.

Table 4-1 provides summary climate and hydrologic metrics for each of the scenarios.

Table 4-1. Summary Climate and Hydrologic Metrics (Change from Current Conditions) for Selected Scenarios

Year	Level of Concern	Basin-area Wide Average Temperature Increase (°C)	Basin-area wide Average Precipitation Change (%)	Increase in Extreme Precipitation[a] (%)	Sea Level Rise (feet)	Change in Average April 1 Snow Water Equivalent[b] (TAF)	Change in Average Annual 8 River Index Flow[b] (TAF)	Change in Average April to July 8 River Index Flow[b] (TAF)
2043	50th	1.5	1.5	10.5	0.5	-2,633	-156	-1,852
2043	95th	1.8	-1.8	12.6	1	-3,158	-1,261	-2,474
2085	50th	3.4	3.3	23.8	1.8	-4,549	-284	-3,293
2085	75th	3.9	0.4	27.3	3.5	-4,960	-1,258	-3,835

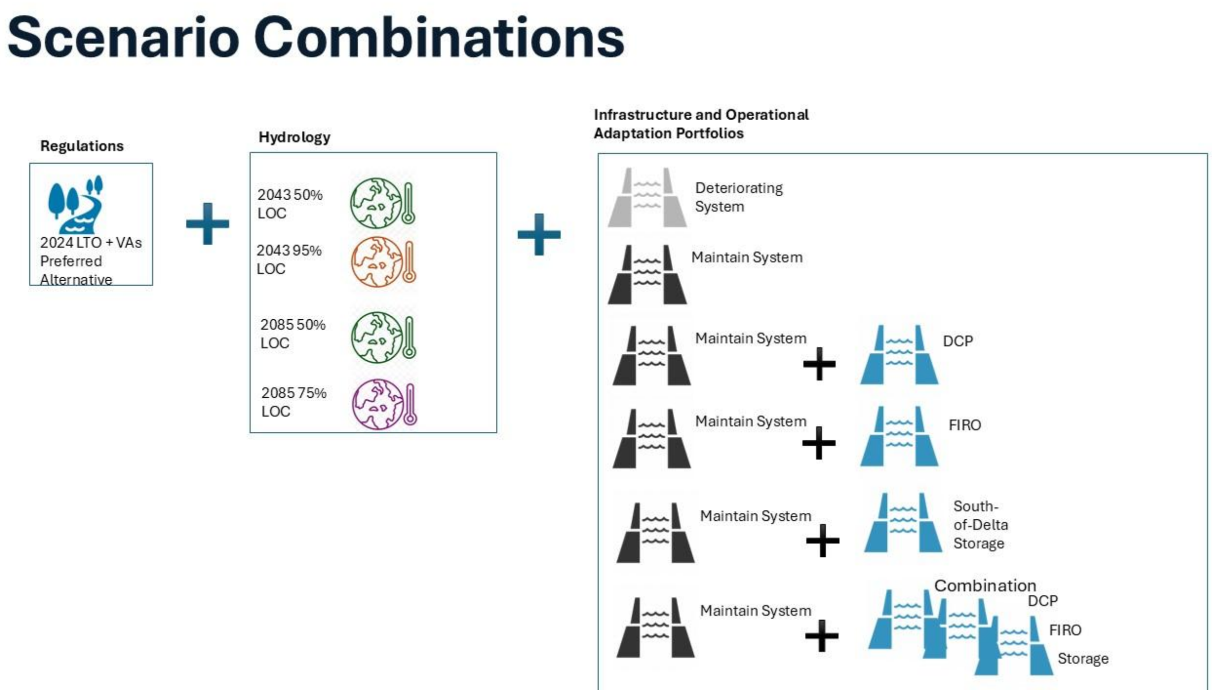
[a] Change in extreme precipitation is modeled using Clausius-Clapeyron scaling of 7% per degree Celsius (°C) (WGEN reference). As the atmosphere warms, the largest precipitation events (above the 99th percentile) are expected to grow larger. The percent increase value represents the change in daily precipitation of events above the 99th percentile. Events below the 99th percentile are also scaled (usually downward) to fit within the overall metric of average precipitation change.

[b] Refer to Appendix A Section 2.3 for additional analysis and documentation of snow water equivalent and snow-covered area evaluations.

4.2 Scenario Combinations

For each adaptation portfolio and climate change hydrology described above, CalSim3 was run to evaluate system performance and resiliency. All scenarios are run with the 2024 Long-term Operating Agreement and Healthy Rivers and Landscapes preferred alternative to represent regulations and operating criteria for the system. This yields 26 different scenario combinations (Figure 4-1).

Figure 4-1. Combinations of Regulations, Hydrology, and Adaptation Portfolios Modeled



5 Results

5.1 Portfolio Evaluations

In this section, each of the adaptation portfolios (Section 1) is evaluated for three key performance metrics:

- SWP annual Table A water deliveries.
- Lake Oroville carryover storage at the end of September.
- Annual total Delta outflow.

These performance metrics (defined below) are chosen to show the impact of climate change and the value of adaptation portfolios on important resources.

- Table A water deliveries is the water supply metric of importance to SWP users and the broad California economy.
- Carryover storage is important for representing drought resilience and is indicative of the SWP's ability to meet regulatory and environmental conditions. Oroville carryover storage is presented as the percent of years in which carryover storage is *less than* the storage target of 1.6 MAF (i.e., the percent of years in which the winter rainy season begins with less water in storage than the threshold currently desired).
- Total Delta outflow is an important environmental metric that has been a focus of SWRCB deliberations for the Bay-Delta and other investigations. Additional performance metrics are provided in Appendix A and on the Adaptation Strategy Results dashboard.

In Figures 5-1 through 5-6, each adaptation portfolio is evaluated against current conditions (with no adaptation) and future conditions with varying degrees of climate change. The first horizontal bar (dark gray) is the average long-term performance of the system for the given metric (Table A deliveries, Oroville carryover storage, or total Delta outflow). This bar shows the long-term average of system performance under current climate, infrastructure, operations, and regulations. The lighter gray bars under each climate scenario show the same thing except assume changed climate conditions. Four different climate conditions are presented as described in Section 4. These bars show the long-term average of system performance under future climate, and current infrastructure, operations, and regulations. These represent potential futures if the system is just maintained but fails to add any significant proactive adaptation measures. Finally, the colored lines show long-term average system performance at each climate condition with different portfolios of adaptation strategies implemented. These are potential futures if proactive adaptation strategies were implemented or, in the case of the Deteriorating System portfolio, if plans to implement maintenance and restoration actions for the system were retrogressed.

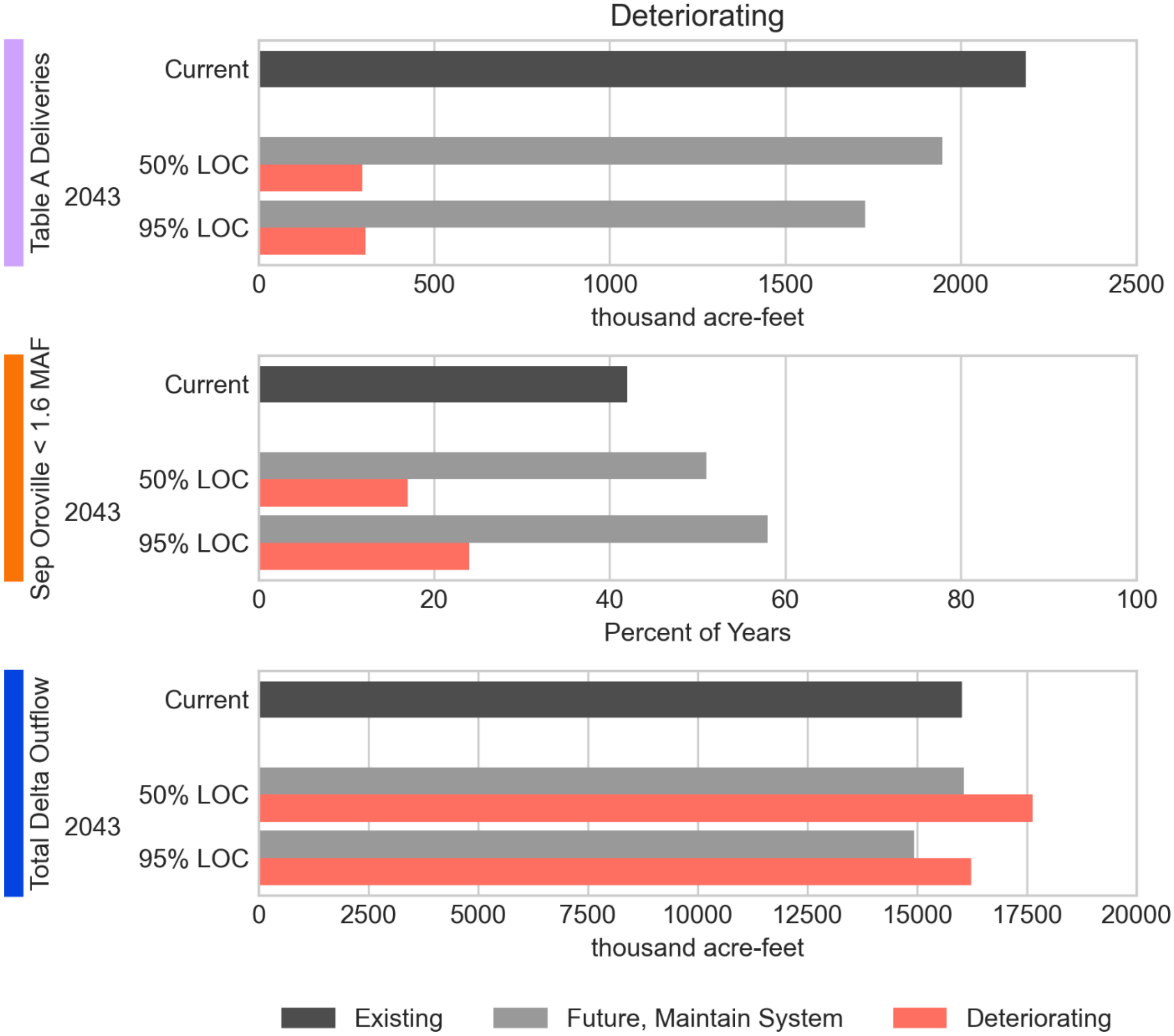
5.2 Deteriorating System Scenario

This scenario is a run-to-failure future, including retrogressing on current ongoing maintenance and restoration efforts. In this scenario the SWP suffers from underinvestment and deterioration and no adaptations is made. Subsidence along the California Aqueduct continues to occur with limited remediation. This scenario is provided to show the benefits of the current maintenance investments and the risks to the system if subsidence in the San Joaquin Valley continues without remediation or aqueduct upgrades. DWR is committed to ensuring that the dire outcomes of a future with unchecked subsidence do not occur. In this scenario, subsidence along the California Aqueduct continues to occur with limited remediation and assumes reduced planned maintenance of SWP’s other assets. This portfolio shows that without current investments, including work to address subsidence, SWP capacity diminishes to about 300 TAF per year.

Realization of this portfolio would involve reductions in current investments and failure to address subsidence impacts in the San Joaquin Valley. Under 2085 conditions, the capacity of the California Aqueduct to convey water is so critically restricted that it ceases to be able to convey water south of southern Fresno County. Because California Aqueduct capacities are so limited at 2085 for this portfolio, no 2085 climate conditions are run in CalSim3 and no results are reported.

Figure 5-1 shows that under both 2043 50% LOC and 95% LOC, SWP Table A deliveries are substantially diminished to about 300 TAF per year. The delivery values under both 2043 climate scenarios for the degraded system portfolio are nearly identical, indicating that the system has lost so much capacity to deliver water that the hydrology of the climate scenario is no longer the limiting factor in deliveries, rather the limiting factor is the California Aqueduct’s limited capacity to move any available water through the system.

Figure 5-1. Key Water Supply Metrics for the Deteriorating System Portfolio



Years in which Oroville carryover storage fails to meet targets fall significantly because so little water can be delivered to SOD service areas; thus, more water is held back in storage. Note that even under this condition in which SWP conveyance capacity is severely limited and SWP Table A deliveries are about 300 TAF, Oroville still fails to reach carryover storage targets in about 20% of years (specifically 17% for 2043 50% LOC and 24% for 2043 95% LOC). This shows that extreme hydrology is a major factor in whether carryover storage targets can be reached, regardless of operations strategies or priorities.

There are modest increases in total Delta outflow due to reduced Delta export pumping with this scenario.

5.3 Baseline Maintain System Portfolio

This portfolio represents a baseline future in which investments are made to maintain and restore existing infrastructure. In this portfolio the California Aqueduct is restored to its full design capacity. In addition, the SAMP continues to be fully implemented delivering an operational availability of Valley String Pumping Plants of 84.6%. No other major climate adaptation investments are made. This portfolio closely resembles the future modeled in the 2023 SWP DCR and this portfolio is treated as a baseline future from which the value of other adaptation portfolios is compared. Results for this portfolio are depicted in the light gray lines in Figures 5-2 through 5-6 and are described for each portfolio above and below.

5.4 Adaptation Portfolio 1—Delta Conveyance Project

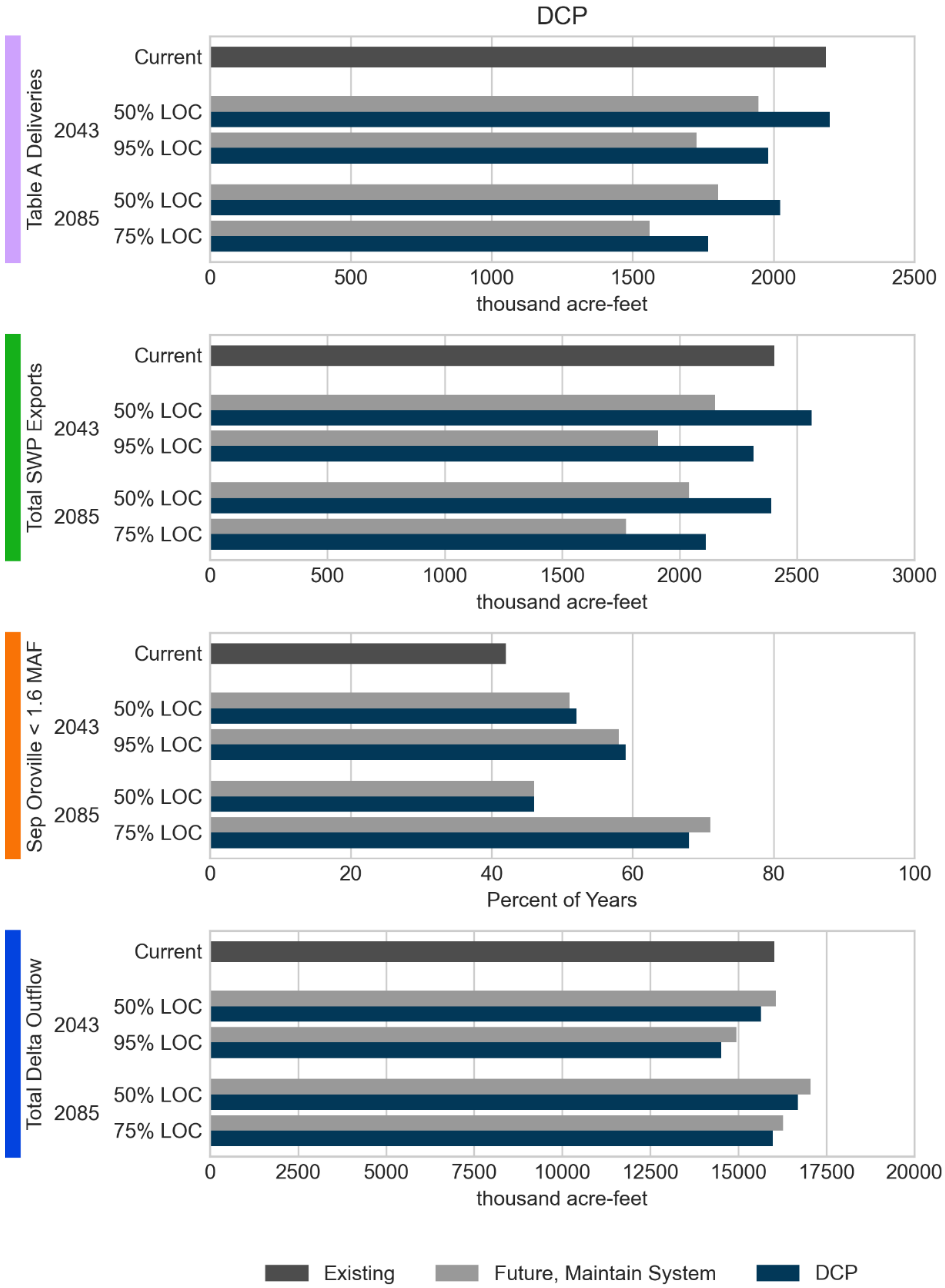
This portfolio includes the strategies described in the Baseline Maintain System portfolio plus the DCP preferred alternative which uses the Bethany alignment, a system of two 3,000-cfs intakes for a total of 6,000 cfs pumping capacity.

Figure 5-2 shows that this portfolio can significantly increase SWP Table A deliveries under all climate futures. Table A deliveries increase by 12–15% (208–254 TAF per year on average), depending on the climate scenario. At the 2043 50% LOC, Table A deliveries can be restored to current levels, avoiding the projected loss of about 12% of deliveries shown in the 2023 SWP DCR and illustrated by the performance of the Baseline Maintain System portfolio. DCP also leads to a substantial increase in Article 21 deliveries (129–155 TAF per year on average). To illustrate the combined benefits to Table A and Article 21 deliveries, Figure 5-2 also shows total SWP exports, which include diversions for both of those delivery categories. At 2043, total SWP exports with the DCP increase by 17–21% (341–411 TAF per year on average).

The percentage of years in which Oroville carryover storage fails to meet the 1.6 MAF target does not change significantly, though it does decrease about 3% for the 2085 75% LOC scenario under this portfolio. Delta outflow shows consistent, albeit small (2–4%) decreases with DCP across both time periods and LOCs, due to increased exports of surplus flows in the Delta. Outflow reductions from DCP are primarily in wetter periods with higher flows and are always reducing only surplus outflow (i.e., flow that is in addition to all regulatory requirements for Delta outflow).

Overall, this adaptation portfolio significantly improves the system’s ability to manage climate change impacts that result in changes to the timing of flows and the potential that the San Joaquin basin will see greater declines in precipitation and streamflow than areas further north, including the Sacramento basin. DCP also helps the system function more efficiently even with higher sea levels.

Figure 5-2. Key Water Supply Metrics for the Delta Conveyance Project Portfolio



DCP Portfolio Summary

- By implementing the DCP portfolio, annual average Table A deliveries improve by 12–15% (208–254 TAF per year on average) with total SWP exports (including Article 21) increasing total by 17–21% (341–411 TAF per year on average).

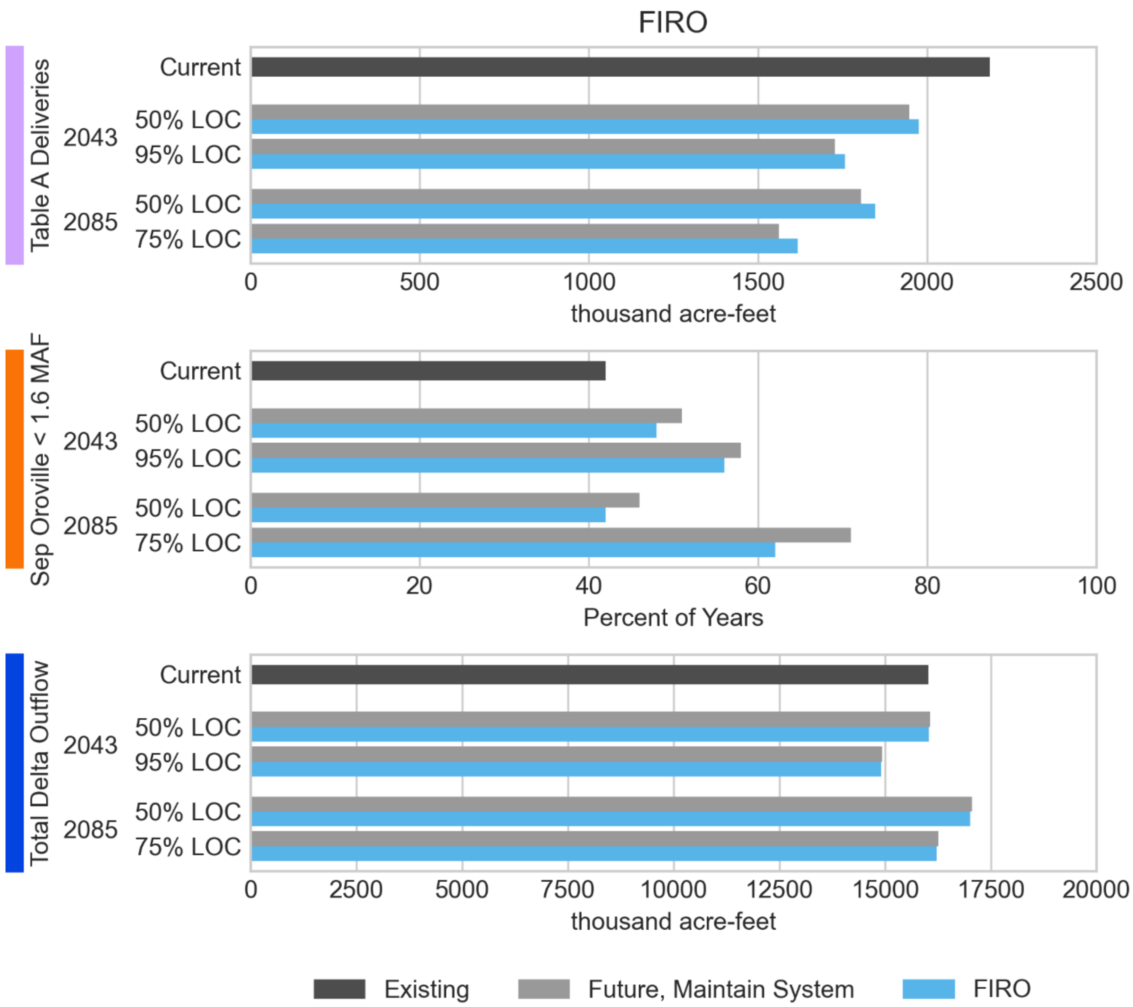
- Article 21 deliveries increase by 129–155 TAF per year on average, helping SWP contractors that have their own storage facilities be more resilient to drought.
- With the DCP scenario, decreases in Delta Outflow are relatively small (2–4%), concentrated in wetter periods, and only affect surplus Delta Outflow.

5.5 Adaptation Portfolio 2—Forecast-Informed Reservoir Operations

This portfolio includes the strategies described in the Baseline Maintain System portfolio plus the Oroville FIRO program as described above. Effects of FIRO actions are modeled implicitly through an updated flood control diagram with the assumption that the FIRO Lake Oroville storage can be operated at higher levels than the current (1970 WCM) flood control diagram allows. The FIRO adaptation portfolio moderately increases SWP Table A deliveries under all climate futures, increases range from 29–31 TAF per year on average under 2043 conditions to 42–57 TAF per year on average under 2085 conditions. The benefits of FIRO adaptation portfolio are most pronounced when looking at the percentage of years Oroville carryover storage is lower than 1.6 MAF. Across all climate scenarios, the percentage of years in which Oroville carryover storages are lower than target of 1.6 MAF decreases by about 3–13%, indicating that the FIRO adaptation portfolio can provide additional protection against drought. This degree of improvement in reservoir storage is not observed in other adaptation strategies. It is important to note that the benefits of the FIRO portfolio are not evident in all years. In very wet years Lake Oroville fills even without FIRO and in very dry years the lake is not encroached into the conservation storage, and FIRO is not activated. However, in the years when FIRO is activated, the differences can be significant, exceeding 100 TAF improvement for both Oroville carryover storage and deliveries. The FIRO adaptation portfolio delivers these benefits without creating significant differences in total Delta outflow.

Overall, this adaptation significantly improves the system's ability to manage climate change impacts that result in more variable or whiplash hydrology. Specifically, this adaptation allows for greater storage of water in Lake Oroville in years that go from wet to dry within the same year. Because of this ability to store additional water, FIRO provides additional resilience to increasing drought severity.

Figure 5-3. Key Water Supply Metrics for the Forecast-Informed Reservoir Operations Portfolio



FIRO Portfolio Summary

- By implementing only FIRO alone, average annual Table A deliveries increases are marginal.
- Under the 2085 75% LOC condition, FIRO significantly improves the percentage of years in which Lake Oroville reaches its carryover storage target (+13%), improving drought resilience.
- FIRO alone has marginal impacts on total Delta outflow.

5.6 Adaptation Portfolio 3—South-of-Delta Storage

This portfolio includes the strategies described in the Baseline Maintain System portfolio plus the new SOD storage capacity of 2 MAF. The operating strategy captures surplus water that could not be captured in the San Luis Reservoir and preserves this water for dry year use.

Table 5-1 shows that the SOD Storage portfolio provides modest improvements in annual average Table A deliveries of 3–4% (60–71 TAF per year on average) at 2043 conditions and about 6% (89–99 TAF per year on average) at 2085 conditions as shown in Figure 5-4. However, some of the increased Table A deliveries come at the expense of Article 21 deliveries. The SOD storage portfolio works by storing wet year water, some of which would have otherwise been delivered as Article 21. Benefits of the SOD Storage portfolio are most pronounced during extended and severe drought periods. During a severe two-year drought (e.g., 1976–1977) under 2085 climate conditions, Table A deliveries increase by 22–35% (125–171 TAF per year on average) and during an extended six-year drought (e.g., 1987–1992) Table A deliveries increase by 39–41% (225–229 TAF per year on average). These results show significant improvements considering the typically lower allocations during droughts.

Table 5-1. Change in Table A Deliveries for South-of-Delta Storage Portfolio Compared to Baseline Maintain System Portfolio

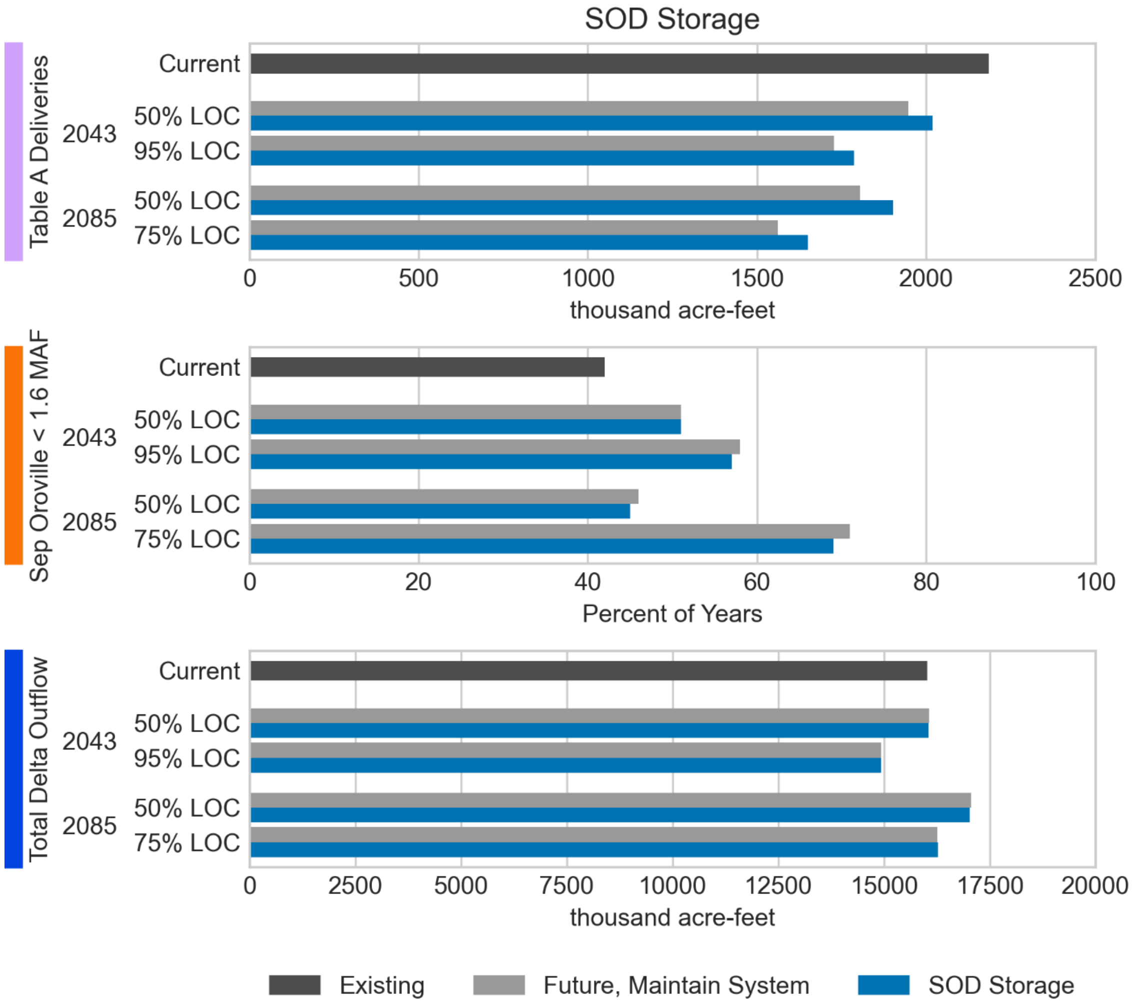
Year	Level of Concern	Long-term Average	2-Year Drought (1976–1977)	6-Year Drought (1987–1992)
2043	50th	+3.7% (71 TAF)	+13.1% (123 TAF)	+24.0% (174 TAF)
2043	95th	+3.5% (60 TAF)	+14.5% (120 TAF)	+27.3% (175 TAF)
2085	50th	+5.5% (99 TAF)	+21.9% (171 TAF)	+38.8% (229 TAF)
2085	75th	+5.7% (89 TAF)	+34.9% (125 TAF)	+41.4% (225 TAF)

Years in which Oroville carryover storage fails to meet targets slightly decrease (improve) with the SOD Storage portfolio, indicating that the new SOD storage provides additional ability to back up water in Lake Oroville providing additional upstream drought benefits. There are also no significant differences in total Delta outflow with the SOD Storage adaptation portfolio.

Figure 5-4 also demonstrates that the SOD Storage adaptation portfolio is robust across all climate futures. The Table A deliveries, years in which Oroville carryover storage fails to meet targets, and total Delta outflow provide similar values or even improve under more extreme climate changes.

Overall, this adaptation significantly improves the system's ability to manage climate change impacts that result in wetter wet years and increasing drought severity and length. Specifically, the additional storage provided with this adaptation portfolio allows additional water to be captured in wet years and stored for future dry years.

Table 5-2. Key Water Supply Metrics for the South-of-Delta Storage Portfolio



SOD Storage Portfolio Summary

- By implementing SOD storage alone, annual average Table A deliveries improve by 3–6%.
- SOD storage serves as an effective strategic water reserve for dry years. By 2085, Table A deliveries during a six-year drought improve by 39–41%.
- Benefits realized with minor improvements to carryover storage in Lake Oroville and minimal impacts to total Delta outflow.
- SOD Storage portfolio is robust across all climate futures evaluated.

5.7 Adaptation Portfolio 4—Combination

This portfolio includes the strategies described in the Baseline Maintain System portfolio plus the DCP, FIRO and SOD storage portfolios. By integrating this combination of adaptation strategies, the overall system is transformed to be far more 21st-century-climate-resilient. Starting at Lake Oroville, FIRO allows for the storage of additional water, especially as the climate becomes more variable and whiplashes from wet to dry and dry to wet. Delta conveyance adds flexibility for the changing timing of runoff and potentially multiplies the benefits of FIRO by allowing for the safe conveyance of water to areas south of the Delta. It also adds significant additional flexibility to convey large winter flood flows resulting from bigger storms and a warmer climate that delivers more rain and less snow. The SOD storage adaptation multiplies the benefits of both DCP and FIRO adaptations by allowing significantly more water during these wet periods to be placed in storage and saved for increasingly severe and longer drought periods. Overall, these three key adaptations address the major changes we expect to see in California's hydroclimate and help deliver a 21st century water supply system.

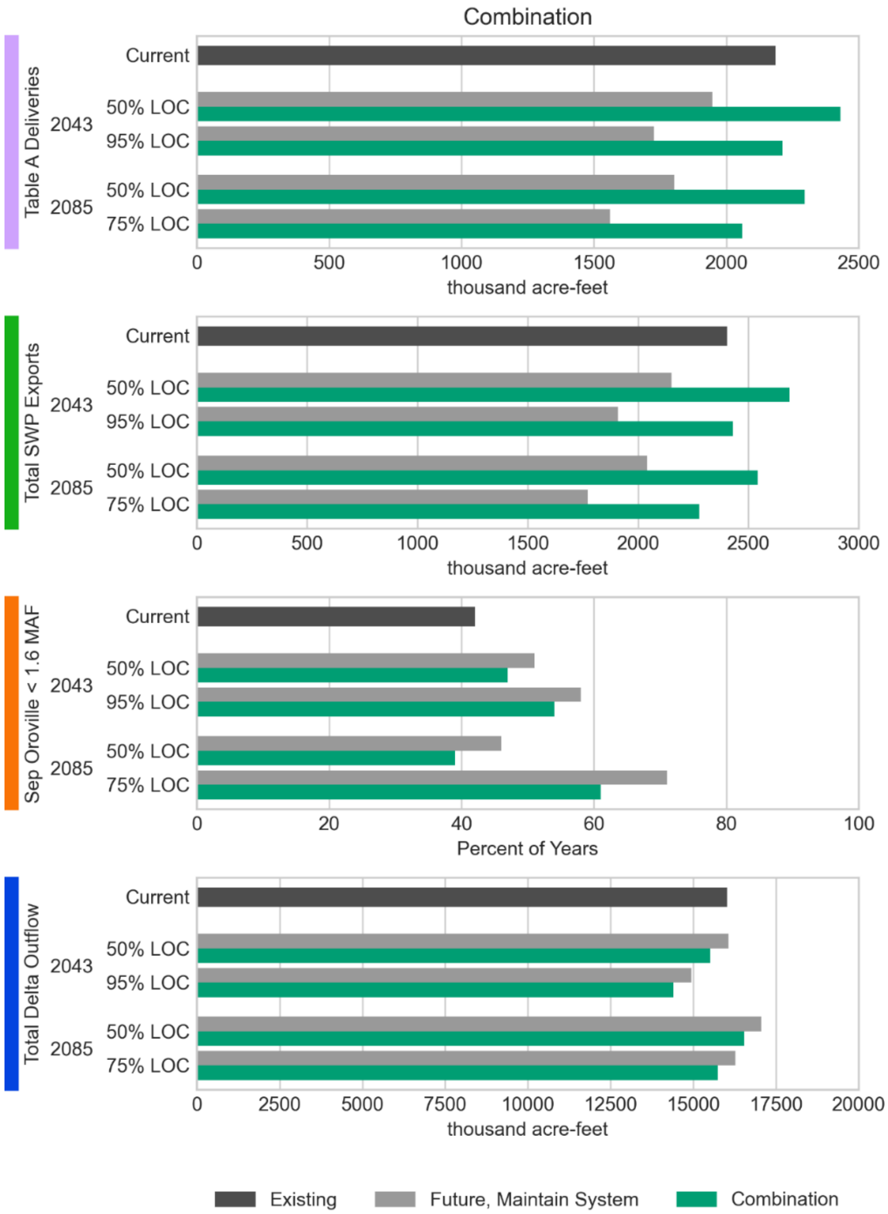
As shown in Figure 5-5, the Combination portfolio results in significant improvements in Table A deliveries. With 2043 climate, improvements are expected to deliver 25–28% more water (484–486 TAF per year on average), even exceeding current Table A deliveries. By 2085, the overall amount of water provided by this portfolio decreases slightly from 2043 levels but the benefits over the without-adaptation or Baseline Maintain System condition increase by 27–32% (493–500 TAF per year on average). In all but the 2085 75% LOC scenario, the Combination portfolio maintains Table A deliveries at or above current levels.

Because the Combination portfolio also includes DCP, a significant portion of its benefits are provided through additional deliveries beyond Table A (known as Article 21). The SWP total export metric captures these additional benefits, pushing the total water supply improvement over the without-adaptation or Baseline Maintain System conditions to 501–534 TAF per year on average, depending on the climate condition.

In all climate conditions, the Combination portfolio enhances SWP's ability to maintain Lake Oroville end-of-September storage greater than the 1.6 MAF target, indicating that drought resilience and ecosystem protection would also be improved along with water supply resilience. Specifically, across all climate scenarios, the percentage of years in which Lake Oroville carryover storages are lower than the target of 1.6 MAF decreases by 7–15%. The Combination portfolio results in modest reductions in Delta outflow of about 3%, with all of those reductions coming during high-flow periods when there are excess Delta outflows that exceed regulatory requirements.

The Combination portfolio demonstrates how the adaptation portfolios complement each other. The increase in Table A deliveries in the Combination portfolio is much larger than the sum of the individual project portfolios (484–500 TAF per year on average compared to 345–361 TAF per year on average). This is primarily due to the synergy between the DCP and SOD storage. DCP diversions can often be limited by available demands and storage capacity SOD, so when combined with SOD storage, the DCP contribution to increased Table A deliveries becomes larger. Another example of complementary impacts is demonstrated by the percentage of years in which Lake Oroville carryover storages are lower than target of 1.6 MAF. Using the 2085 75% LOC scenario as an example, the FIRO portfolio reduces (improves) the number of years in which storage targets are not met by 13% (Figure 5-3). The Combination portfolio further improves the SWP's ability to meet carryover storage targets by decreasing the percentage of years in which the storage target are not met by 14% (i.e., one percentage point better than the FIRO portfolio alone) (Figure 5-5).

Figure 5-4. Key Water Supply Metrics for the Combination Portfolio



Combination Portfolio Summary

- The improvement in Table A deliveries and Total SWP exports and ability to meet Oroville carryover storage targets with the Combination portfolio are better than the improvements from the sum of the individual adaptation portfolios, showing that these projects unlock synergies that provide amplified benefits.
- The Combination portfolio is particularly effective because it addresses the key ways that climate change challenges the system.

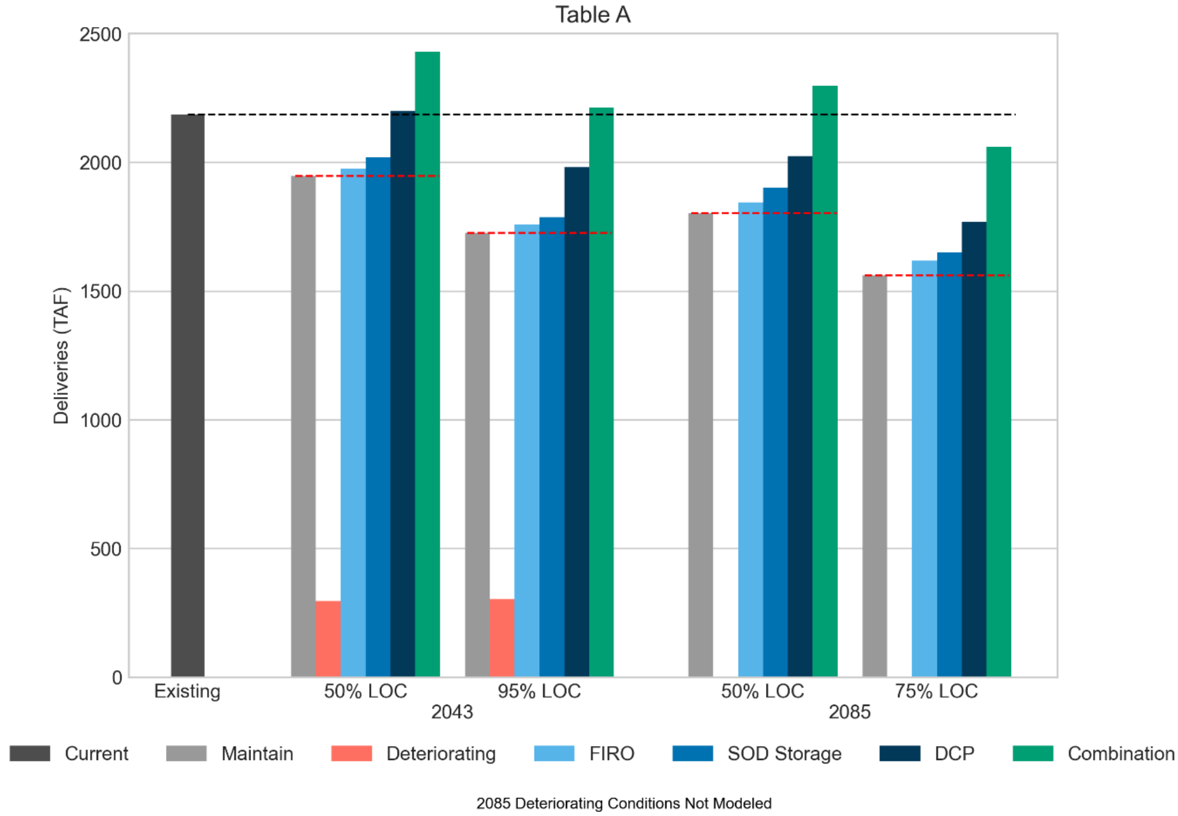
- With the Combination portfolio, changes to Delta Outflow are relatively small (3%) while Table A and Total SWP export improvements are substantial (25–32% and 25–29% respectively).
- In all but the 2085 75% LOC scenario, the Combination portfolio maintains Table A deliveries at or above current levels.

5.8 Portfolio Comparison

In this section, the four adaptation portfolios are compared to each other, showing the relative contribution that each makes to a more resilient future. Figures 5-5 to 5-7 show the three performance metrics described above (SWP Table A deliveries, Oroville September storage percent of years below 1.6 MAF target, and Delta outflow) at each of the four future climates, but all adaptation portfolios are plotted together so that they can be compared and contrasted.

The Baseline Maintain System portfolio for every climate shows a reduction in annual Table A deliveries compared to existing conditions, as shown in Figure 5-5. This serves as a clear call to action, underscoring the need for adaptations to the SWP. Table A deliveries can be recovered and even exceed existing levels with the DCP and Combination adaptation portfolios in the 2043 50% LOC climate scenario. For the 2043 95% LOC and 2085 50% LOC climate scenarios, Table A deliveries can be recovered and exceed existing levels with only the Combination adaptation portfolio. Table A deliveries decrease for all adaptation portfolios in the 2085 75% LOC climate scenario compared to existing levels. For each climate scenario, the Combination portfolio has the largest recovery/increase in Table A deliveries, followed by the DCP portfolio, SOD Storage portfolio, and the FIRO portfolio. The Deteriorating System scenario results in significant decreases on Table A deliveries that fall to about 300 TAF in the 2043 climate scenarios and were not modeled in the 2085 climate scenarios because system conveyance under 2085 Deteriorating System scenario assumptions drop to near zero.

Figure 5-5. State Water Project Annual Table A Deliveries for Each Adaptation Portfolio at the Four Future Climate Scenarios

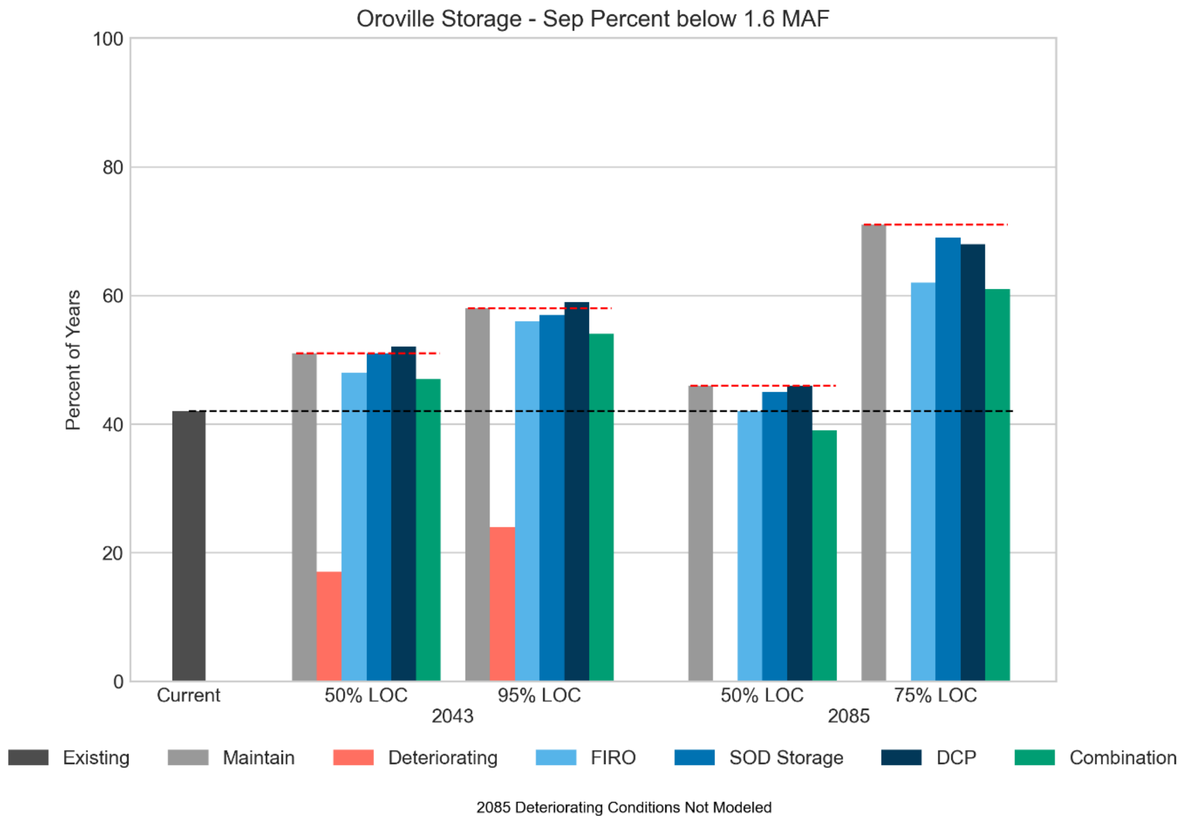


Comparison Summary

- Table A deliveries decrease from existing levels for every future climate scenario with the Baseline Maintain System portfolio.
- Depending on the climate scenario, the DCP and Combination portfolios can recover and even exceed existing levels of Table A delivery.
- For each climate scenario, all adaptation portfolios (disregarding the Deteriorating System scenario) increase Table A deliveries compared to the Baseline Maintain System portfolio. The Combination and DCP portfolios are responsible for the highest increases, followed by the SOD Storage and FIRO portfolios.

The percentage of years that Oroville end-of-September carryover storage levels fall below the 1.6 MAF target increase from existing levels for every future climate scenario with almost all the adaptation portfolios, as shown in Figure 5-6. For each climate scenario, the adaptation portfolios generally maintain or decrease (improve) the percentage of years that Oroville September storage levels fall below the 1.6 MAF target compared to the Baseline Maintain System portfolio. FIRO and the Combination portfolios are responsible for the largest decreases, while the SOD Storage and DCP portfolios either slightly decrease, maintain, or slightly increase this percentage. Other than the Deteriorating System scenario, the Combination portfolio in the 2085 50% LOC climate scenario is the only adaptation portfolio that results in a decrease of the percentage of years that Oroville September storage levels fall below the 1.6 MAF target compared to *existing* levels.

Figure 5-6. Percentage of Years Oroville End-of-September Carryover Storage Below 1.6 MAF Target for each Adaptation Portfolio at the Four Future Climate Scenarios

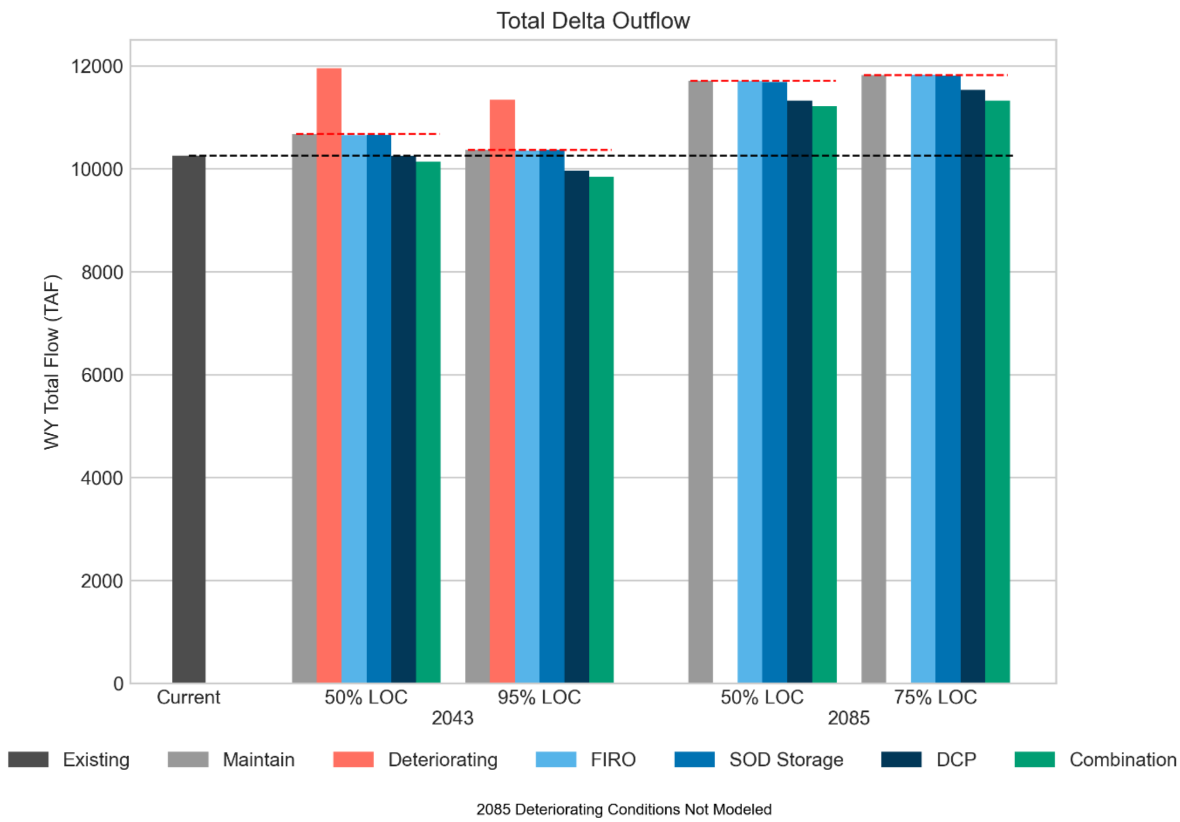


Carryover Summary

- The percentage of years that Oroville September storage levels fall below the 1.6 MAF target increase from existing levels for every future climate scenario with the Baseline Maintain System portfolio.
- Compared to the Baseline Maintain System portfolio, FIRO and the Combination portfolios are responsible for the largest decreases (improvements) in this percentage. The DCP and SOD Storage portfolios either slightly decrease, maintain, or slightly increase this percentage.

Total annual Delta outflow is expected to increase from existing levels as a consequence of climate change under all climate change scenarios. This is due in large part to more water arriving during times of the year where it cannot be captured, meaning more direct runoff in winter and earlier spring snowmelt. This is shown in Figure 5-7, comparing the gray bars (Baseline Maintain System portfolio) to the black bar (current conditions and existing infrastructure and operations). Under all climate scenarios (with the Baseline Maintain System portfolio), total Delta outflow is higher than the existing conditions. These changes are the impact of climate change, not any action DWR is proposing to take, and these changes, particularly by 2085, can be quite large. The effect of each adaptation strategy on total Delta outflow is small. The FIRO and SOD Storage adaptation portfolios have almost no effect on the level of total Delta outflow, while the DCP and Combination adaptation portfolios slightly decrease the total Delta outflow from where it would have otherwise been with climate change and only maintenance adaptations.

Figure 5-7. Total Annual Delta Outflow for Each Adaptation Portfolio at the Four Future Climate Scenarios



Delta Outflow Summary

- Total Delta outflow increases from existing levels for every future climate scenario due to climate change.
- The effect on total Delta outflow from climate change is larger compared to the effect from the adaptation portfolios.

5.9 Drought Period Performance

Drought period performance improves for the SWP with the adaptation projects primarily because of the ability of DCP and SOD storage to divert and store wet year supplies, which then contribute to increased carryover storage that can then be delivered during droughts. In almost every case, during dry-critical years, adaptation projects lead to at least a minor increase in Table A deliveries and in some cases, a much larger increase. The FIRO portfolio shows increases from 2–3% (17–32 TAF per year on average), the SOD Storage portfolio shows increases of 9–17% (92–161 TAF per year on average), the DCP portfolio shows increases of 19–21% (173–217 TAF per year on average), and the Combination scenario shows increases of 50–60% (498–566 TAF per year on average).

These results are further reinforced by comparing the Baseline Maintain System portfolio performance to the adaptation portfolios during historical drought sequences of various lengths. This analysis used one-year droughts 1977 and 2014, two-year droughts 1976–1977 and 2014–2015, and six-year droughts 1929–1934 and 1987–92). In almost every case, each of the adaptation portfolios provides increased water supply during drought periods compared to what would have existed without the adaptation. The Combination portfolio shows increases in Table A deliveries of 157–773 TAF, depending on the drought sequence and climate change scenario; refer to Table 5-3.

Table 5-3. Change in Table A Deliveries for Historical Drought Periods with Combination Portfolio, Percent Change (TAF/year)

Year	Level of Concern	Long-term Average	1-Year Drought (1977)	1-Year Drought (2014)	2-Year Drought (1976-1977)	2-Year Drought (2014-2015)	6-Year Drought (1929-1934)	6-Year Drought (1987-1992)
2043	50th	+24.9% (484 TAF)	+233.8% (491 TAF)	+96.6% (396 TAF)	+66.8% (629 TAF)	+112.1% (434 TAF)	+48.2% (283 TAF)	+47.2% (342 TAF)
2043	95th	+28.1% (486 TAF)	+442.3% (491 TAF)	+84.3% (268 TAF)	+70.3% (584 TAF)	+79.4% (274 TAF)	+43.8% (242 TAF)	+45.9% (293 TAF)
2085	50th	+27.3% (493 TAF)	+291.6% (449 TAF)	+28.7% (161 TAF)	+89.7% (703 TAF)	+55.7% (255 TAF)	+35.4% (216 TAF)	+66.8% (394 TAF)
2085	75th	+32% (500 TAF)	+346.4% (575 TAF)	+72.7% (157 TAF)	+215.3% (773 TAF)	+97.6% (248 TAF)	+49.7% (246 TAF)	+68.4% (372 TAF)

Improvements (i.e., reductions) in the percentage of years with Lake Oroville storage below 1.6 MAF, which occurs for all Combination scenarios, also indicates improvements in drought performance, as it shows higher carryover storage in Oroville occurring during drier periods.

5.10 Remaining Vulnerability After Implementation

While the adaptation strategies analyzed here do provide substantial benefits, vulnerability may still remain. The climate scenarios evaluated here provide a range of plausible future conditions including more severe future droughts. However, they do not explore all possible future conditions or potential extreme conditions. The analysis shows that the portfolios of adaptation strategies explored in this analysis provide significant additional robustness to a range of future conditions and if all key adaptation strategies were implemented (i.e., the Combination portfolio), the SWP would be well prepared for expected climate conditions well past 2050 and all but the most extreme outcomes through the end of the 21st century.

Even with these adaptations, periods of extreme drought would still stress the system and lead to limited water supplies; however, available water in storage to meet the challenge of these droughts would likely be hundreds of thousands of acre-feet more than without the adaptations. For example, under the most severe climate evaluated, 2085 75 LOC, and the most severe six-year drought (represented by a climate change intensified 1929–1934 dust bowl period) water available for water supply increases from 495 TAF per year on average during the drought with the Baseline Maintain System portfolio to nearly 750 TAF per year on average with the Combination portfolio. While 750 TAF is still a relatively low water allocation (about a 17th percentile level under current conditions), it is over 100 TAF more than the estimated SWP deliveries would be during a Dust-Bowl-level drought, were it to recur with today’s climate, infrastructure, and regulations (683 TAF).

6 Other Projects and System Adaptations

This adaptation strategy focuses on actions that the SWP can take to improve system resilience and reliability under a range of uncertain future climate outcomes. The SWP is a piece of California's diverse water supply system that encompasses upper watershed forests, rivers, groundwater basins, and flood plains, and is managed by federal, State, regional, and local water management agencies. Actions the SWP is taking will support broad benefits to California's water management and contribute to the long-term sustainability of California's water supplies.

As the SWP considers and pursues these strategies, the federal and State governments, and regional and local entities are pursuing additional investments to adapt California's water management to 21st-century conditions. Many of these projects will need to be integrated into SWP operations, such as those described in Section 3.2.9, "WSIP Project Integration." Other actions, such as those described below will be undertaken at the use points of the SWP and can amplify the impact of SWP adaptation actions.

6.1 State Water Project Contractor Projects

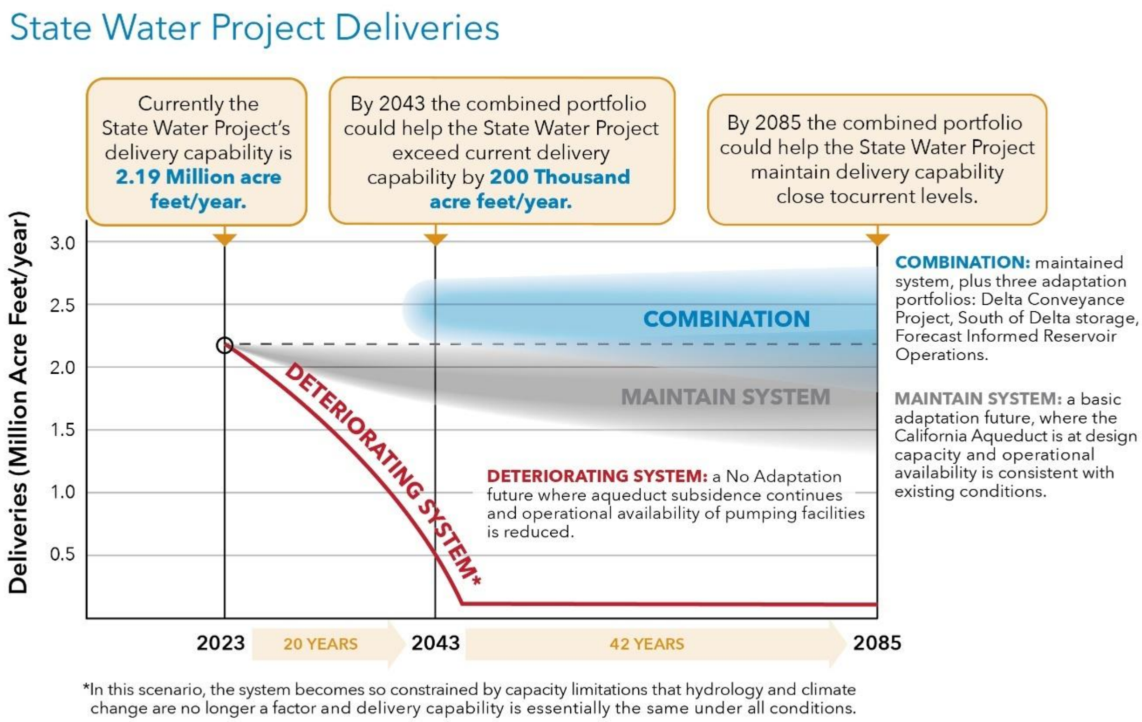
Storage, regional conveyance, conservation, and efficiency projects undertaken by users of SWP water can further amplify the benefits of these adaptation strategies by further increasing the ability of public water agencies to save and store water during wetter times so that water generated by the adaptation strategies described above can address acute water shortages during droughts. The SWP public water agencies continuously plan for the projected changes in the future water supply reliability. Recent efforts include consideration of local and regional storage, replumbing for local and regional flexibility, water recycling, conservation and efficiency projects, and long-term transfers or exchange agreements that enable individual public water agencies to secure a future with reliable water supplies.

7 Conclusions and Next Steps

Analysis performed for this report supports the following conclusions and priorities for SWP investments in climate adaptation. Figure 7-1 highlights some of the key conclusions and priorities for the system.

- **Continue maintenance, repair and additional restoration.** Continued maintenance, subsidence repairs, and additional restoration of the infrastructure system are required to avoid devasting impacts to SWP deliveries. Additionally, a maintained system makes any additional investment worthwhile.
- **Importance of the DCP.** The DCP, among evaluated strategies, is the highest priority beyond maintaining existing infrastructure and the single most effective strategy on its own, but also amplifies the impact of other strategies.
- **FIRO is a safe and effective strategy.** It has low costs and few if any drawbacks, but the amount of water supply it can deliver is relatively small.
- **Additional SOD water storage** is promising as a third priority strategy. Its benefits are limited without including DCP but with DCP, storage can help improve drought resilience.
- **Other Adaptation strategies are important for climate resilience.** Adaptation strategies like Delta drought barriers, water supply forecast improvements, Feather River watershed management, and evaluation of all DWR projects for climate resilience are important adaptation actions that SWP should continue to pursue. It may be difficult to quantify the value of these strategies but actions in these areas will likely deliver real benefits and may provide the beginnings of SWP’s next big adaptation.
- **Individual strategies have unique benefits and should be combined.** Each individual strategy provides response to different climate stressors such as increasing drought frequency, more extreme precipitation, earlier runoff, and sea level rise. A combination of responses is needed. This analysis shows that implementation of a portfolio of strategies will result in greater adaptation than the sum of its parts.

Figure 7-1. Summary Changes in State Water Project Deliveries from Adaptation Portfolios



7.1 Monitoring and Tracking Climate Change to Inform Adaptation Strategies

California's hydroclimate is one of the most variable on earth, and attributing extreme events or even decadal shifts in precipitation to climate change (as opposed to natural variability) can be challenging. However, global and, by extension, regional temperature changes are more directly linked to climate change and can serve as a reliable and important indicator of how quickly our climate conditions are shifting.

Recent major climate assessments like the Intergovernmental Panel on Climate Change and United States National Climate Assessment have adopted a Global Warming Level (GWL) framing approach. This method evaluates the impacts that are likely to occur at a given GWL (e.g., 1 °C) rather than focusing on impacts at a given time frame (e.g., 2050). While the system risk-informed scenarios used in this report are tied to specific timeframes (i.e., 2043 and 2085), each also incorporates a corresponding level of regional warming. Tracking climate change trajectories helps identify deviations from planning assumptions and necessary adjustments to adaptation strategies.

Data from the Coupled Model Intercomparison Project Phase 6 (CMIP6) archive of global climate models and the archive of CMIP6 model projections downscaled using Localized Constructed Analogs version 2 (LOCA2) indicate that temperature increases in the Central Valley watersheds closely follow GWL. Table 7-1 illustrates expected local temperature changes corresponding to different GWL.

Table 7-1. Global Warming Levels and Associated Regional Warming Levels over Central Valley Water Supply Watersheds, and Associated Risk-informed Scenarios

Global Warming Level (°C)	Warming Level-Central Valley Watersheds Area (°C)	Associated System Risk-informed Scenario
1.36	1.50	2043 LOC 50
1.68	1.80	2043 LOC 95
3.30	3.40	2085 LOC 50
3.77	3.90	2085 LOC 75

Since warming levels in the Central Valley Watershed area align closely with GWL, they serve as a reliable and informative proxy for monitoring overall climate trends. Unlike precipitation variability, temperature changes are more directly linked to climate change, enhancing their utility in risk assessments and adaptation planning.

As 2040 approaches, tracking the amount of GWL that has already occurred can help clarify which trajectory is being followed. For example, suppose global temperatures have increased by approximately 1.4°C, and Central Valley temperatures are around 1.5°C higher. In that case, there is confidence that temperatures are tracking closer to the 50th percentile LOC projection, and there is increased confidence that some of the worst impacts of climate change may be forestalled further into the future. However, if global temperatures increase by 1.7 °C or more and the Central Valley has warmed by 1.8 °C, it would indicate that even the most extreme projections may have been too optimistic. In such a case, adaptation planning must be revisited to ensure resilience under accelerated climate change.

Tracking climate trajectory also plays a critical role in understanding key thresholds, a fundamental aspect of “adaptation pathways” planning. This method, recognized by experts, including most recently the Public Policy Institute of California, promotes flexible and scalable public investment that can be adjusted as climate change thresholds are reached or exceeded. An adaptation pathways approach may suggest deferring investments and other implementation requirements in SOD storage until there is clear evidence that climate change and/or other factors necessitate this adaptation. For example, this analysis indicates that the DCP alone can maintain SWP performance under the 2043 LOC

50 condition. However, under the more extreme 2043 LOC 95 condition, the DCP alone is insufficient to maintain the performance of the SWP.

Well-designed adaptation pathways framework allows for adjustments based on observed changes, reducing the risk of over- or under-investing in infrastructure and management strategies. A temperature increase of 1.7 °C globally could serve as a trigger point, indicating that additional SOD storage is necessary to maintain SWP reliability. Future adaptation decisions must be guided by real-time climate data and observed trends to ensure that the SWP remains resilient in an evolving climate. By continuously monitoring and refining adaptation strategies, the SWP can better respond to the uncertainties of climate change and safeguard California’s water resources for future generations.

8 Web Links

This section is a list of all web links mentioned in this strategy. All links were accessed in July, 2025.

8.1 General

Abolafia-Rosenzweig et al.: *Quantifying the Impacts of Fire-Related Perturbations in WRF-Hydro Terrestrial Water Budget Simulations in California's Feather River Basin*
https://onlinelibrary.wiley.com/doi/10.1002/hyp.15314

Blue Forest: Forest Resiliency Bond
https://www.blueforest.org/finance/forest-resilience-bond/

Center for Wester Weather and Water Extremes: Subseasonal and Seasonal Experimental Forecasts
https://cw3e.ucsd.edu/s_and_s_forecasts/

Intergovernmental Panel on Climate Change
https://www.ipcc.ch/

PCMDI: Earth System Model Evaluation Project: CMIP6—Coupled Model Intercomparison Project Phase 6
https://pcmdi.llnl.gov/CMIP6/

Plumas Corp: Thomspon Meadow Project
https://experience.arcgis.com/experience/9d864d78d31349abbf8d00b10cfae33c/#data_s=id%3AdataSource_1-c66daad2a2e4469c8cd24c780ac9414c%3A69

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

State Water Resources Control Board: Human Right to Water Portal
https://www.waterboards.ca.gov/water_issues/programs/hr2w/

U.S. Army Corps of Engineers Sacramento District: *Report on Reservoir Regulation for Flood Control*
https://water.sec.usace.army.mil/cda/documents/wc/3136/Oroville1970WCManual%5bR%5d.pdf

United States National Climate Assessment
https://nca2023.globalchange.gov/

Yuba-Feather FIRO Steering Committee: *Yuba-Feather Forecast Informed Reservoir Operations Final Viability Assessment*
https://cw3e.ucsd.edu/FIRO_docs/Yuba-Feather_FVA/Yuba-Feather_FVA.pdf

8.2 California Department of Water Resources

Bulletin 120 Water Supply Forecast Summaries
https://cdec.water.ca.gov/snow/bulletin120/

California Aqueduct Subsidence Program
https://water.ca.gov/Programs/Engineering-And-Construction/Subsidence

California Water Plan Update 2023
https://water.ca.gov/Programs/California-Water-Plan/Update-2023

CalSim3
https://water.ca.gov/Library/Modeling-and-Analysis/Central-Valley-models-and-tools/CalSim-3

Climate Action Plan Phase I: *Greenhouse Gas Emissions Reduction Plan Update 2023*
https://water.ca.gov/-/media/DWR-Website/Web-Pages/Programs/All-Programs/Climate-Change-Program/Climate-Action-Plan/Files/Exhibit-C-CAP-Phase-1-Update-2023.pdf

Climate Action Plan Phase II: *Climate Change Analysis Guidance*
https://water.ca.gov/-/media/DWR-Website/Web-Pages/Programs/All-Programs/Climate-Change-Program/Climate-Action-Plan/Files/CAPII-Climate-Change-Analysis-Guidance.pdf

Climate Action Plan Phase III: *Climate Change Adaption Plan*
https://water.ca.gov/-/media/DWR-Website/Web-Pages/Programs/All-Programs/Climate-Change-Program/Climate-Action-Plan/Files/Adaptation_Plan.pdf

Climate Action Plan Phase III: *Climate Change Vulnerability Assessment*
https://water.ca.gov/-/media/DWR-Website/Web-Pages/Programs/All-Programs/Climate-Change-Program/Climate-Action-Plan/Files/CAP-III-Vulnerability-Assessment.pdf

Climate Action Plan
https://water.ca.gov/Programs/All-Programs/Climate-Change-Program/Climate-Action-Plan

Decision Scaling Evaluation of Climate Change-Driven Hydrologic Risk to the State Water Project Final Report
https://water.ca.gov/-/media/DWR-Website/Web-Pages/Programs/All-Programs/Climate-Change-Program/Climate-Action-Plan/Files/CAP-III-Decision-Scaling-Vulnerability-Assessment.pdf

Delta Conveyance Project
https://www.deltaconveyanceproject.com/

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

Delta Conveyance Project: *Incidental Take Permit Application*
https://www.deltaconveyanceproject.com/planning-processes/california-endangered-species-act/incidental-take-permit-application

Final State Water Project Delivery Capability Report 2023
https://data.cnra.ca.gov/dataset/finaldcr2023/resource/92356681-957a-48ee-97c4-529d25b9dbb2

Park of the Future
https://water.ca.gov/News/Blog/2024/Jun-24/DWR-Collaborates-on-the-Park-of-the-Future-Teaming-with-Nature-based-Solutions

Risk-Informed Future Climate Scenario Development for the State Water Project Delivery Capability Report
https://data.cnra.ca.gov/dataset/finaldcr2023/resource/e41f531d-dace-4d37-b52e-35a6ddd2224e

San Joaquin Valley Watershed Studies
https://water.ca.gov/News/Blog/2024/Apr-24/Watershed-Study-Highlights-How-Innovative-Tools-Help-Build-Climate-Resilience-in-SJV

State Water Project Adaptation Strategy CAP Results Console (ReCon) Dashboard
https://cap-recon.azurewebsites.net/

State Water Project Delivery Capability Report 2023 *Addendum: Impacts of Subsidence*
https://data.cnra.ca.gov/dataset/a3bb1ddd-624b-4c3d-95e7-2aa6b3bf2b5b/resource/478ff1a8-b7fb-4d3f-95de-3bc90cf047f0/download/dcr2023_impacts_of_subsidence_20250506.pdf

State Water Project
https://water.ca.gov/programs/state-water-project

Subsidence and Hydraulic Conveyance Capacity Information for Use in the Climate Adaptation Study
https://cadwr.box.com/s/ss88gxso1qh2a3ekin6u4ksgvs3zvc0s

Sustainable Groundwater Management Act (SGMA)
https://water.ca.gov/programs/groundwater-management/sgma-groundwater-management

West False River Drought Salinity Barrier Project Final Environmental Impact Report
https://water.ca.gov/-/media/DWR-Website/Web-Pages/Water-Basics/Drought/Files/Saltwater-Intrusion-and-Drought-Salinity-Barriers/West-False-River-Drought-Salinity-Barrier-Final-EIR.pdf

8.3 California Natural Resources Agency

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

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

Water Resilience Portfolio 2020: In Response to Executive Order N-10-19
https://resources.ca.gov/-/media/CNRA-Website/Files/Initiatives/Water-Resilience/Final_California-Water-Resilience-Portfolio-2020_ADA3_v2_ay11-opt.pdf

Water Resilience Portfolio 2021: Progress Report
https://resources.ca.gov/-/media/CNRA-Website/Files/Initiatives/Water-Resilience/CA-WRP-Progress-Report.pdf

Water Resilience Portfolio 2023: Progress Report
https://resources.ca.gov/-/media/CNRA-Website/Files/Initiatives/Water-Resilience/WRP_PR23_Progress_Report_2023.pdf

Water Resilience Portfolio
https://resources.ca.gov/Initiatives/Building-Water-Resilience/portfolio

8.4 Legislation and Code

California State Assembly: Assembly Bill 685, 2012
http://www.leginfo.ca.gov/pub/11-12/bill/asm/ab_0651-0700/ab_685_bill_20120925_chaptered.pdf

California Water Code Chapter 1, General State Policy, Section 106.3
https://leginfo.legislature.ca.gov/faces/codes_displaySection.xhtml?lawCode=WAT&sectionNum=106.3

8.5 California Water Commission

Proposition 1 Water Storage Investment Program: Funding the Public Benefits of Water Storage Projects
https://cwc.ca.gov/Water-Storage

State Water Project Flexible Resources Study
https://cwc.ca.gov/-/media/CWC-Website/Files/Documents/2021/08_August/August2021_Item_11_SB49SWPFlexibleResourcesStudy_Final.pdf

8.6 Delta Stewardship Council

Delta Adapts: About
https://www.deltacouncil.ca.gov/delta-plan/climate-change

Delta Adapts: Creating a Climate Resilient Future
https://deltacouncil.ca.gov/delta-plan/climate-change

Delta Adapts: Creating a Climate Resilient Future Adaptation Plan https://deltacouncil.ca.gov/pdf/delta-plan/2025-06-26-delta-adapts-adaptation-plan.pdf