Calaveras Watershed
RESILIENCE PLAN 2026

STOCKTON EAST WATER DISTRICT
PROVIDING SERVICE SINCE 1948

Woodard & Curran

The Calaveras River Watershed Resilience Plan is the result of an extraordinary collaborative effort across agencies, organizations, and community members who generously contributed their time, expertise, and local knowledge.

We thank the many Watershed Network partners including local governments, water and irrigation districts, state and federal agencies, community organizations, and environmental groups as well as local residents, Tribal members, growers, businesses, and recreational users whose input through workshops, interviews, and shared place-based knowledge ensured the Plan reflects the diverse needs, challenges, and priorities across both the upper and lower portions of the Calaveras Watershed.

Leadership of the plan was conducted by:

Stockton East Water District — Providing service since 1948

Calaveras County Water District

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Technical study teams, planners, facilitators, and subject-matter experts whose modeling, analyses, design concepts, and guidance form the backbone of this Plan include:

Woodard & Curran

in association with Vibrant Planet and FISHBIO

This Plan is a reflection of our commitment to a resilient, healthy, and thriving Calaveras River Watershed.

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ACRONYM LIST

Acronym	Definition
ACS	American Community Survey
AF	Acre-Feet
AFT	Acre-Feet Total
AFY	Acre-Feet per Year
ASR	Aquifer Storage and Recovery
BLM	Bureau of Land Management
CAL FIRE	California Department of Forestry and Fire Protection
CCCWPP	Calaveras County Community Wildfire Protection Plan
CC OES	Calaveras County Office of Emergency Services
CC RCD	Calaveras County Resource Conservation District
CCWD	Calaveras County Water District
CDFW	California Department of Fish and Wildlife
CFL	Characteristic Flame Length
CFS	Cubic Feet per Second
CPUD	Calaveras Public Utilities District
CSJWCD	Central San Joaquin Water Conservation District
CVFPB	Central Valley Flood Protection Board
CW3E	Center for Western Weather and Water Extremes
CWRP	Calaveras Watershed Resilience Plan
DAC / DACs	Disadvantaged Community/ies
DWR	California Department of Water Resources
EBMUD	East Bay Municipal Utilities District
EPA	United States Environmental Protection Agency
EPPOC	Ebbetts Pass Property Owners Council
ESJ	Eastern San Joaquin
ESJPWA	East San Joaquin Parties Water Authority
ESJWRM	Eastern San Joaquin Water Resources Model
ET	Evapotranspiration
FEMA	Federal Emergency Management Agency
FIRO	Forecast-Informed Reservoir Operations
Flood-MAR	Flood-Managed Aquifer Recharge
FSim	Fire Simulation Model
GCM	Global Climate Model
GSAs	Groundwater Sustainability Agencies
GSJCCC	Greater San Joaquin County Coordinating Committee
GSP	Groundwater Sustainability Plan
GW	Groundwater
GWL	Groundwater Level
HCP	Habitat Conservation Plan
HIFLD	Homeland Infrastructure Foundation-Level Data
HUC	Hydrologic Unit Code
HVRA / HVRAs	Highly Valued Resource(s) and Asset(s)
I-FIRM	Integrated Forecast-Informed Reservoir Management
IRWM	Integrated Regional Water Management

Acronym	Definition
ISWs	Interconnected Surface Water
LSJRP	Lower San Joaquin River Project
LUSTs	Leaking Underground Storage Tanks
MAC	Mokelumne/Amador/Calaveras
MAR	Managed Aquifer Recharge
MHI	Median Household Income
mph	miles per hour
NCEI	National Centers for Environmental Information
NGO	Non-Governmental Organization
NOAA	National Oceanic and Atmospheric Administration
NSJWCD	North San Joaquin Water Conservation District
OCR	Old Calaveras River
PDSI	Palmer Drought Severity Index
PMA	Performance and Management Action
PRISM	Parameter-elevation Regressions on Independent Slopes Model (Northwest Alliance for Computational Science and Engineering)
River	Calaveras River
RWMG	Regional Water Management Group
SEWD	Stockton East Water District
SGMA	Sustainable Groundwater Management Agencies
SJAFCA	San Joaquin Area Flood Control Agency
SSP	Shared Socioeconomic Pathway
TAF	Thousand Acre-Feet
TAFY	Thousand Acre-Feet per Year
TM	Technical Memorandum
TMDL	Total Maximum Daily Load
ULDC	Urban Levee Design Criteria
UMRWA	Upper Mokelumne River Water Authority
USACE	United States Army Corps of Engineers
USFS	United States Forest Service
USGS	United States Geological Survey
UWUO	Urban Water Use Objective
VOCs	Volatile Organic Compounds
WAFR	Water Available for Recharge
Watershed	Calaveras River Watershed
WRP	Watershed Resilience Plan
WUI	Wildland-Urban Interface

INTRODUCTION

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0. INTRODUCTION

The Calaveras River Watershed Resilience Plan (Watershed Resilience Plan or Watershed Plan) represents an innovative effort to strengthen climate resilience and integrated water management across one of California's most diverse watersheds. Developed by Stockton East Water District (SEWD), this Plan is part of the California Department of Water Resources' (DWR) Watershed Resilience Program, launched under the California Water Plan 2023. As one of five pilot watersheds selected statewide, the Calaveras River Watershed (Watershed) serves as a model for advancing regional resilience through collaborative planning, technical innovation, and equity-focused engagement. As lead developer, SEWD engaged Calaveras County Water District to form the Project Team and, through development of the Watershed Network, brought together multiple lower and upper Watershed entities as well as a broad network of interested parties,

The Calaveras Watershed spans portions of San Joaquin, Stanislaus, and Calaveras counties, encompassing headwaters above New Hogan Reservoir and downstream areas influenced by Calaveras River hydrology. This Plan addresses the unique challenges posed by climate change, such as water availability, rising temperatures, altered precipitation patterns, and increased wildfire risk, by integrating hydrologic and environmental modeling, vulnerability assessments, and adaptation strategies tailored to local conditions.

At its core, the Watershed Resilience Plan seeks to:

- Assess climate vulnerabilities and risks to water supply, ecosystems, and communities.
- Develop multi-benefit solutions that enhance watershed health and sustainability.
- Foster inclusive collaboration through the Watershed Network, ensuring the participation of diverse voices to assist in shaping priorities and strategies.
- Identify performance tracking to measure progress and inform future statewide resilience efforts.

Through a combination of technical analysis and community engagement, the Watershed Plan lays the foundation for long-term adaptation, balancing agricultural, urban, and environmental needs while maximizing the conservation of resources for future generations. This work will serve to guide local decision-making and also contribute lessons learned to inform California's broader resilience framework.

The Watershed Resilience Plan is organized into nine chapters, as outlined below.

Chapter 1 includes the Watershed delineation map used for this work and a rationale for its boundary. A summary of Watershed characteristics, such as climate, geography, demographics, and land use is also included.

Chapter 2 begins by discussing the current regional stakeholder and communication networks in the Watershed and how engagement has historically occurred. The Watershed Network is then introduced, including its structure, categories, and roles; and the Community Outreach and Engagement Plan was tailored appropriately to facilitate outreach to a variety of audiences and their needs. The chapter also includes a summary of outreach touchpoints and discusses equity elements that were considered during outreach and engagement activities. The Technical Memorandum associated with outreach and engagement efforts is referenced in this chapter and included as **Appendix A**.

Chapter 3 synthesizes the Watershed's climate planning landscape and historical and current climate dynamics. Using the EPA's Climate Resilience and Adaptation Funding Toolbox, a discussion of climate hazards and their relevance to the Watershed is included. Based on this background, a series of problem statements are presented, as well as a discussion about the challenges and opportunities for regional climate resilience. Supplemental information referenced in this chapter is included in **Appendix B**, **Appendix C**, and **Appendix D**.

Chapter 4 presents the Watershed's Resilience vision, goals, and objectives, including how they were developed in coordination with the Watershed Network. Together, these statements provide a framework for the Watershed Resilience Plan – both in what the Plan itself aims to do and what general actions will guide the Watershed towards certain desired futures.

Chapter 5 reviews the existing tools used to assess vulnerability to climate change and risk of the consequences in the Calaveras Watershed. To guide the approach for this vulnerability assessment, an analytical framework was developed and used to outline what was assessed and how. A water budget, developed based on guidance in the DWR Water Budget Handbook, helps quantify components of the assessment where tools are most conducive to simulation of the hydrologic system. The Technical Memoranda associated with wildfire analysis, hydrologic modeling, and stream temperature analysis are referenced in this chapter and included as **Appendix D**, **Appendix E**, and **Appendix F**, respectively.

Chapter 6 presents the strategies for adapting to the climate change vulnerabilities and risks discussed in Chapter 5. Strategies are organized into five categories based on development status and analytical approach: Priority Water Supply Projects, Wildfire Priority Zones, Existing Projects, New Conceptual Projects, and Other Strategies. Priority Water Supply Projects and Wildfire Priority Zones are evaluated using the integrated modeling framework described in Chapter 5, providing quantifiable performance metrics across climate scenarios. Existing, Other, and New Conceptual Strategies represent important adaptation pathways that warrant future evaluation but lack sufficient quantitative data for inclusion in the modeling framework. Additional information about the adaptation strategies is referenced in this chapter and included as **Appendix D** and **Appendix G**.

Chapter 7 discusses implementation strategies, both for the projects (adaptation strategies) presented in Chapter 6 and for the more programmatic elements of the Watershed Resilience Plan as a whole. Project implementation requires identifying the entity responsible for implementation and any currently known implementation details such as budget and schedule information. Program implementation involves strategies that support the Watershed Plan infrastructure and long-term success of the overall program.

Chapter 8 presents the performance tracking indicators that can be used to assess the overall health of the watershed and tracking progress made in adapting to climate change. The indicator, its metric, data availability, and tracking method are presented, as well as how the indicators were developed.

Chapter 9 summarizes the key findings of the Watershed Plan and recommends several next steps as the Watershed Resilience Program continues to mature and evolve.

CHAPTER 1

WATERSHED PLAN AREA DEFINITION

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1. WATERSHED PLANNING AREA DEFINITION

This chapter describes the Calaveras River Watershed (Watershed) area and how it was delineated for the purposes of this study.

1.1. WATERSHED DELINEATION

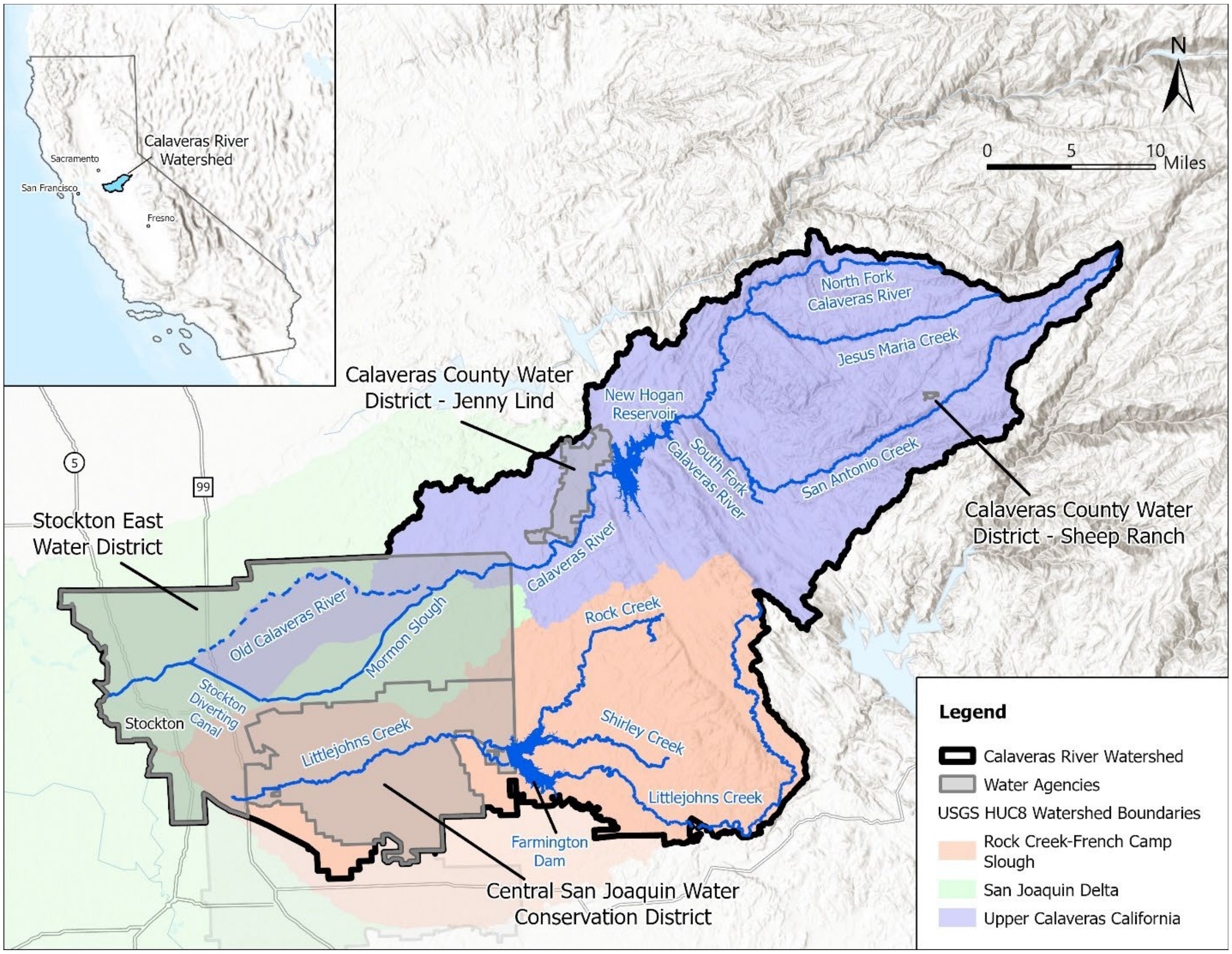
Situated between the Mokelumne and Stanislaus Watersheds in the northern portion of the San Joaquin Valley, the natural Calaveras River Watershed drains from the western slopes of the Sierra Nevada into the Calaveras River (River) upstream of the River's confluence with the San Joaquin River in Stockton, California. The Calaveras Watershed Resilience planning effort uses the Watershed delineation already in use by the California Department of Water Resources (DWR) *Calaveras River Watershed Flood-MAR Study* (DWR Watershed Study). This work established a watershed delineation for the Calaveras River using the following steps:

1. Determine the hydrologic boundary of the primary tributary to the Calaveras River;
2. Adjust the hydrologic boundary to accommodate for the administrative boundaries of any irrigation districts that overlap the hydrologic watershed and whose surface water source is primarily associated with the Calaveras River Watershed.[1]

The "Calaveras Watershed" is thus delineated based on a combination of both hydrologic and water management considerations that typify differences between the upper and lower Watershed areas. The upper Watershed, above New Hogan Reservoir, aligns with the United States Geological Survey HUC8 boundary for Upper Calaveras, California. The lower Watershed is delineated primarily by the operational boundaries of water supply districts (specifically Stockton East Water District (SEWD) and Central San Joaquin Water Conservation District (CSJWCD) that rely upon the Calaveras River for supply. **Figure 1-1** shows the delineation used for the Watershed Resilience Plan, originally established by the DWR Watershed Study.

[1] California Department of Water Resources, 2025a

Figure 1-1. Calaveras River Watershed Delineation



1.2. WATERSHED PLANNING AREA DESCRIPTION

The Calaveras Watershed spans portions of three counties: San Joaquin, Calaveras and a small portion of Stanislaus. Similar to other watersheds spanning the Sierra Nevada foothills, the topography of the Watershed gradually descends from steep, sloped terrain in the upper and eastern areas to the flat, floodplain of the greater San Joaquin Valley. The Watershed has a temperate climate, with cool winters and hot, dry summers with average temperatures ranging from 40 to 90 degrees Fahrenheit.[1] As a result of the topographic and climatic conditions, the upper Watershed is characteristic of the Sierra Nevada foothills, comprised mainly of forested land with small pockets of rural development, while the lower Watershed is characterized by relatively flat areas suitable for agriculture and larger urban development.

1.2.1. Hydrology and Water Management

During the wet season (November to March), the lower Watershed receives an average of 15 to 20 inches of precipitation per year, while the upper Watershed ranges from 20 to 30 inches per year.[1] Given that the highest elevation within the Watershed is below 5,000 feet, there is very little snowfall in winter.[2] As a result, the River's flow is primarily supplied by rainfall in the wet season without the benefit of spring snowmelt as in higher altitude watersheds.

The primary waterway in the Watershed is the Calaveras River, which flows east to west and is a tributary to the San Joaquin River which flows into the Delta (**Figure 1-2**). The headwaters of the Calaveras River and its tributaries provide direct supply to meet the demands of the local residents and commercial interests within the upper Watershed either through private rights or through the municipal systems primarily managed by Calaveras County Water District (CCWD) or the Calaveras Public Utilities District (CPUD). Groundwater use in the upper Watershed is limited to small, private wells. Calaveras River flow ends up in New Hogan Reservoir behind New Hogan Dam which is operated by the United States Army Corps of Engineers (USACE) primarily for flood control. New Hogan Dam has a capacity of 317,000 AF and also includes the small New Hogan Power Plant, a hydroelectric facility owned by CCWD and jointly managed by USACE and Modesto Irrigation District (MID).[3] The plant produces approximately 3 megawatts of electricity per year.

While the Bureau of Reclamation controls the water rights to New Hogan Reservoir, SEWD serves as the water master of its supplies and manages water supply for urban and agricultural use in lower Watershed areas of the San Joaquin Valley – either through direct use or recharge of the Eastern San Joaquin Groundwater Basin. SEWD and CSJWCD manage the majority of surface water and individual groundwater distribution (along with the City of Stockton and the California Water Service wells) in the lower Watershed, while the overall groundwater supply is managed collaboratively through the Eastern San Joaquin GSA. Additionally, New Hogan releases are a key supply source for some of CCWD's service areas via the Jenny Lind Water Treatment Plant, which is located downstream of the dam.

Downstream of New Hogan, water flow is highly managed. Prior to the construction of New Hogan Dam, the Calaveras River flowed intermittently downstream to the San Joaquin River through what is now known as the Old Calaveras River. In 1934, Bellota Weir was constructed to divert water in the wet season for delivery to downstream users via Mormon Slough. As a rain-fed system, much of this portion of the River and Mormon Slough would go dry during the summer months. The impoundment of water in New Hogan Reservoir – and its subsequent operations – has resulted in changes to the natural hydrograph by providing year-round flows. The vast majority of these flows now move through Bellota Weir, into Mormon Slough and through the Stockton Diverting Canal where flows then meet the natural riverway northeast of the City of Stockton. Along Mormon Slough, a network of canals, pipes, and natural waterways provide water supply distribution throughout the lower portion of the Watershed.

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[1] California Department of Water Resources, 2025b

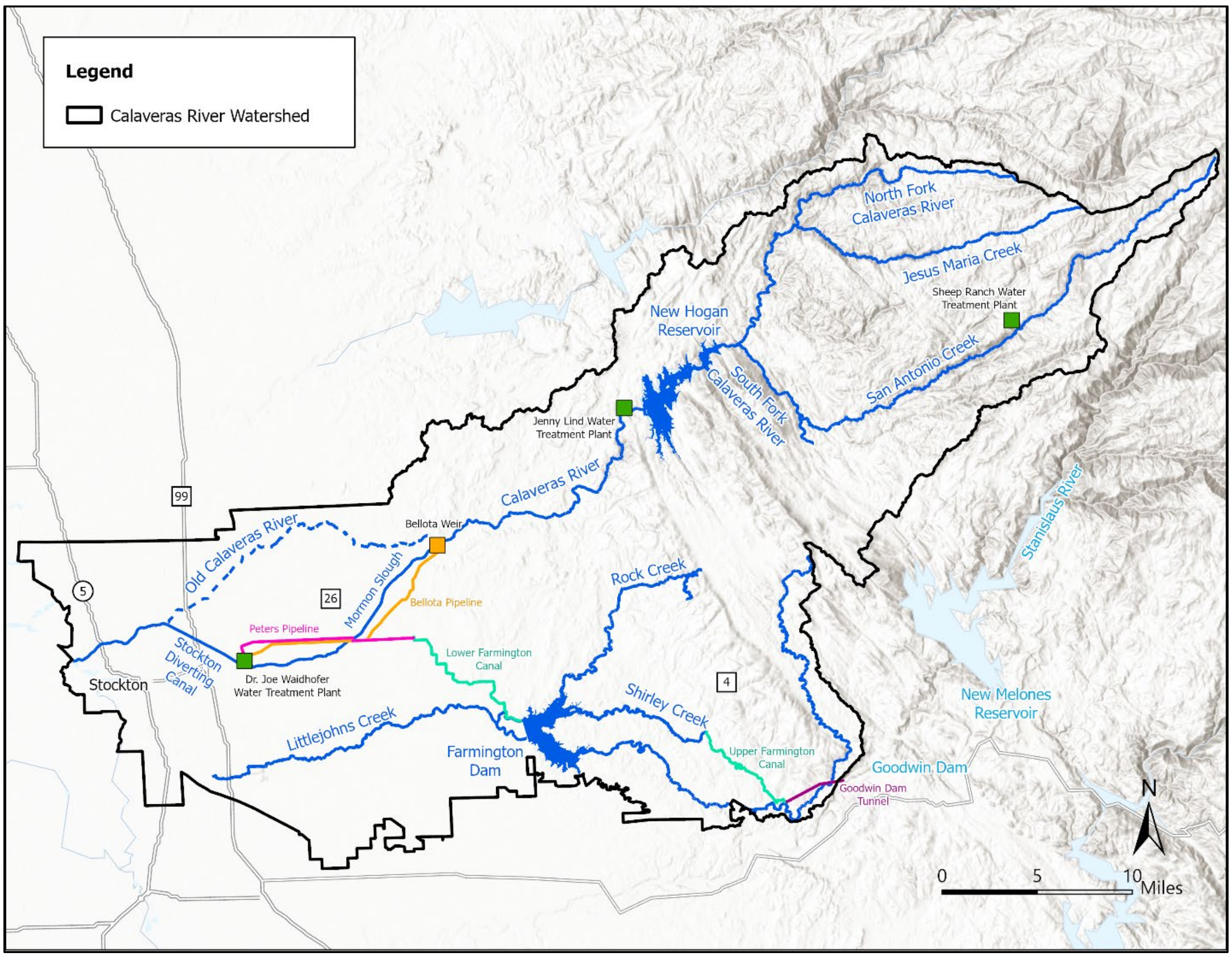
[2] Ebbetts Pass Adventures, 2026

[3] Modesto Irrigation District, 2004

Aquatic species have benefitted from New Hogan's ability to provide year-round flows and the lower Watershed now supports several native populations of anadromous fish that are an integral part of the environmental and recreational value of the region. The Calaveras River is designated as critical habitat for several threatened salmonids, including Central Valley steelhead and Chinook salmon.[1] While native fish populations are limited above New Hogan Dam, recreational stocked fishing is allowed in certain parts of the upper Watershed, including New Hogan Reservoir and White Pines Lake.

Farmington Dam and its tributaries provide additional water supply to the lower Watershed. A 52,000 AF flood control facility owned and operated by USACE, Farmington Dam was authorized by Congress in 1944 and provides flood protection to the City of Stockton, the rural towns of French Camp and Farmington, and the surrounding areas. While outside the Calaveras Watershed, water from New Melones Reservoir (in the Stanislaus Watershed) can flow into Farmington Dam via Goodwin Dam and a network of distribution infrastructure owned and operated by SEWD.

Figure 1-2: Calaveras Watershed Hydrologic and Water Management Features



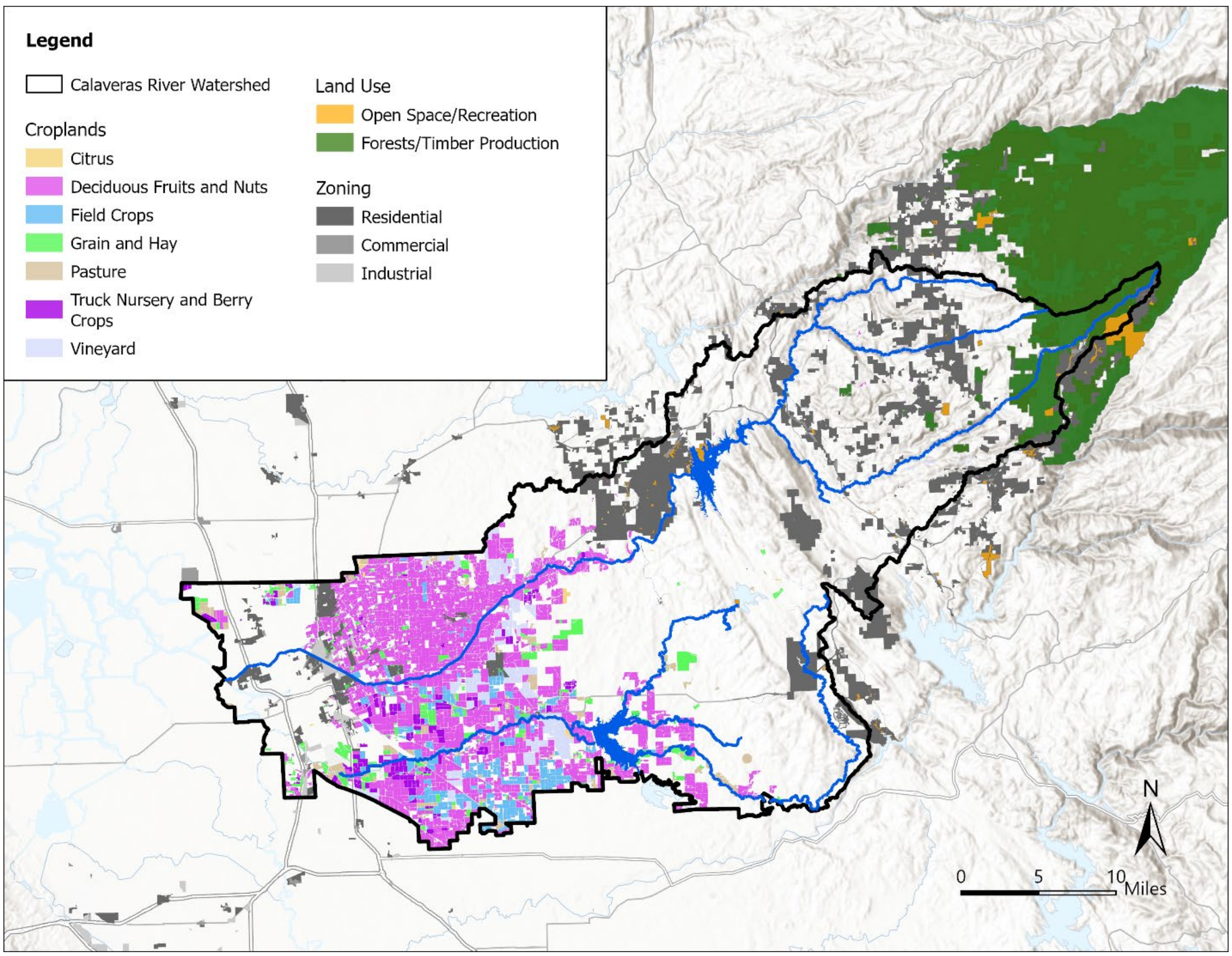
[1] Stockton East Water District & FISHBIO, 2019

1.2.2. Land Use and Resource Management

The upper Watershed is dominated by public forested land owned by the Bureau of Land Management, United States Forest Service, and California Department of Fish and Wildlife, with pockets of rural residential and small orchards and vineyard areas throughout.[1] A small portion of forested land is owned and managed by commercial interests like Sierra Pacific Industries for timber production. Several state parks and landmarks, including Calaveras Big Trees State Park and California Cavern State Historic Landmark, are a valued source of recreation for both local residents and tourists, which in turn support the local economy.[2] Major wildfires have occurred in the area (notably the 70,868-acre Butte fire in 2015) and therefore are a dominant consideration in how lands are managed in the upper Watershed. In Calaveras County, the total market value of agricultural products sold was approximately $27 million in 2017.[3]

The lower Watershed is dominated by agricultural lands as well as some larger urban areas (like the City of Stockton) with residential, commercial and industrial land uses. In San Joaquin County, agricultural production (including high-value fruit and nut orchard crops and vineyards) comprises roughly 7% of employment and 10% of the economy, contributing over $3 billion in 2023.[4] **Figure 1-3** shows the land use in the Watershed.

Figure 1-3. Calaveras Watershed Land Use



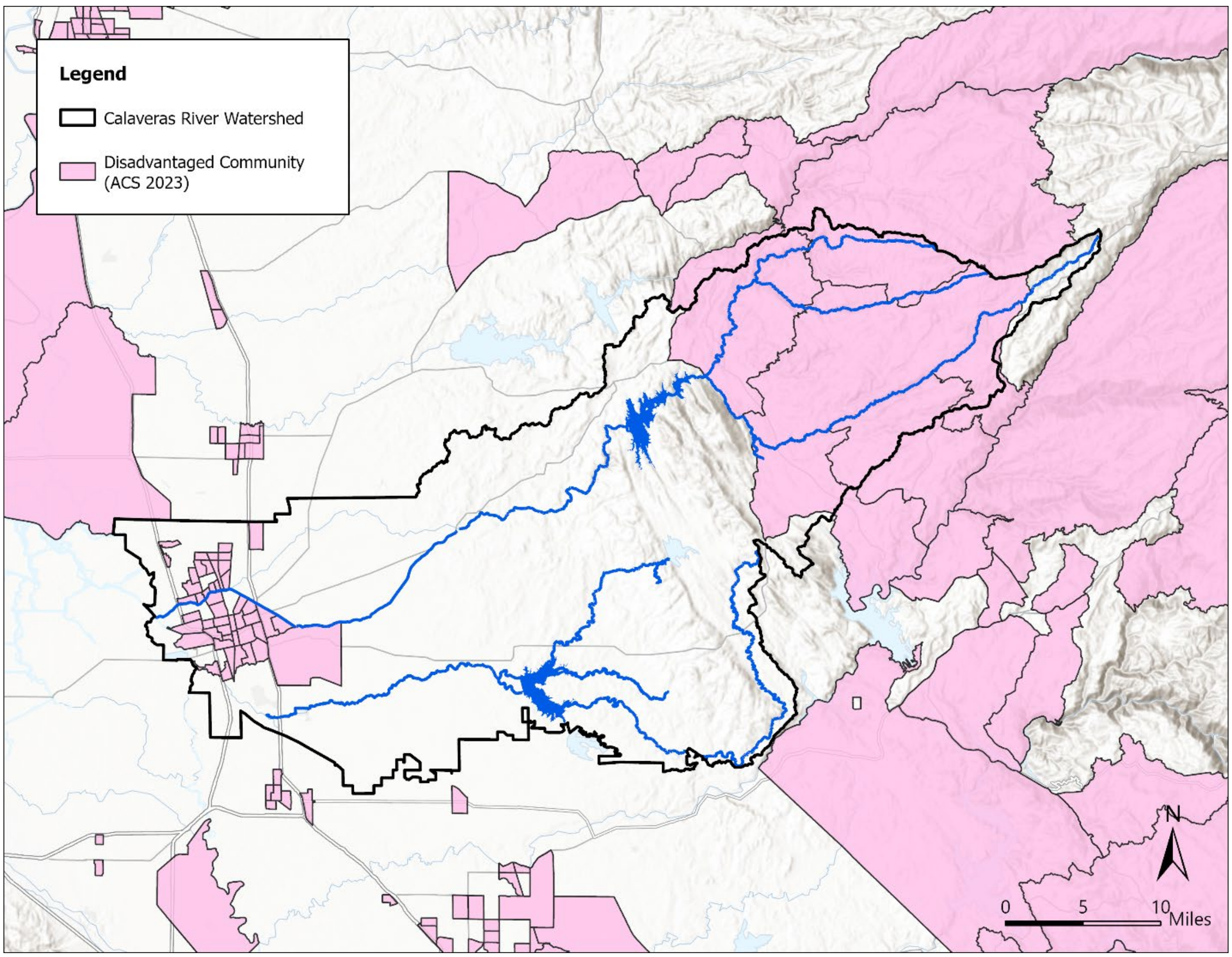
[1] Calaveras County; San Joaquin County, 2025; California Department of Water Resources, 2023
[2] Calaveras Visitors Bureau; San Joaquin County Parks
[3] United States Department of Agriculture, 2017
[4] University of the Pacific, 2024; San Joaquin County, 2023

1.2.3. Demographics

Most of the Watershed's population is concentrated primarily within urban and suburban areas in and around the City of Stockton (population of 321,000).[1] San Joaquin County's population has increased by nearly 60% (from 480,000 to 780,000) over the past three decades and is projected to reach 950,000 by 2050, including growth in the City of Stockton and other areas within the Watershed.[2] Calaveras County's population is less than 10% of San Joaquin County's and is distributed across rural and suburban communities in the upper Watershed. Although Calaveras County experienced some growth from the 1990s to early 2000s, its population has since plateaued to around 45,000 and is not expected to have any further substantial growth.

As shown in **Figure 1-4,** DWR has categorized most of urban Stockton and the rural upper foothills as disadvantaged communities (DACs), [3] representing about 30% of the Watershed's area and 45% of the population. In 2023, the median household income (MHI) in San Joaquin County was $87,418 and $79,877 in Calaveras County. These medians were 8.5% and 16.4% below the 2023 state-wide MHI of $95,521.[4]

Figure 1-4. Calaveras Watershed Disadvantaged Communities[5,6]



[1] United States Census Bureau, 2020

[2] San Joaquin Council of Governments, 2023

[3] California Department of Water Resources, 2022

[4] United States Census Bureau, 2023

[5] Census tracts classified as DACs within the Watershed, based on five-year aggregated American Community Survey (ACS) data for the period 2019–2023.

[6] California Department of Water Resources, 2025c

CHAPTER 2
WATERSHED NETWORK

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2. WATERSHED NETWORK

The development of the Watershed Resilience Plan was fundamentally shaped by outreach and engagement with a range of interested parties and the public. Significant time and resources ensured that the process was not only inclusive, but also responsive to the needs of the Watershed's diverse interests. The Project Team used an adaptive process to review contributions to previous efforts, identify gaps and challenges, look for opportunities, and ultimately develop a watershed network and associated outreach plan. This chapter provides an overview of this development process as well as a documentation of how the Community Outreach and Engagement Plan implementation was conducted within the Watershed Network. Detailed information on engagement activities can be found in the Technical Memorandum in **Appendix A**, which includes the full Community Outreach and Engagement Plan.

The Project Team's outreach efforts went beyond traditional approaches. When initial meetings yielded limited participation, the strategy evolved to embrace touchpoints, leverage online platforms, and embed engagement within existing community and partner meetings. Special attention was given to historically underrepresented groups, Tribes, and disadvantaged communities, with outreach methods tailored to reduce barriers and foster trust. The Project Team's willingness to adapt, whether by offering in-person workshops, developing accessible online tools, or partnering with trusted organizations, demonstrates a genuine dedication to equity and inclusion.

2.1. WATERSHED NETWORK DEVELOPMENT

2.1.1. Existing Regional Network Assessment

The first step in developing a watershed network was to identify and assess existing regional networks, past participant engagement, contributions, inclusivity, and health of the networks by collecting information related to existing networks and stakeholder groups. The Project Team also coordinated with DWR to understand their resources which included a "Lay of the Land" document template that was used to assess the existing watershed network. The Lay of the Land (included as part of **Appendix A**) prepared by the Project Team included information on the type of organization, key interests and issues and potential representatives. Much of this information was readily available within both the Eastern San Joaquin (ESJ) and Mokelumne/Amador/Calaveras (MAC) Integrated Regional Water Management plans and was updated as needed.

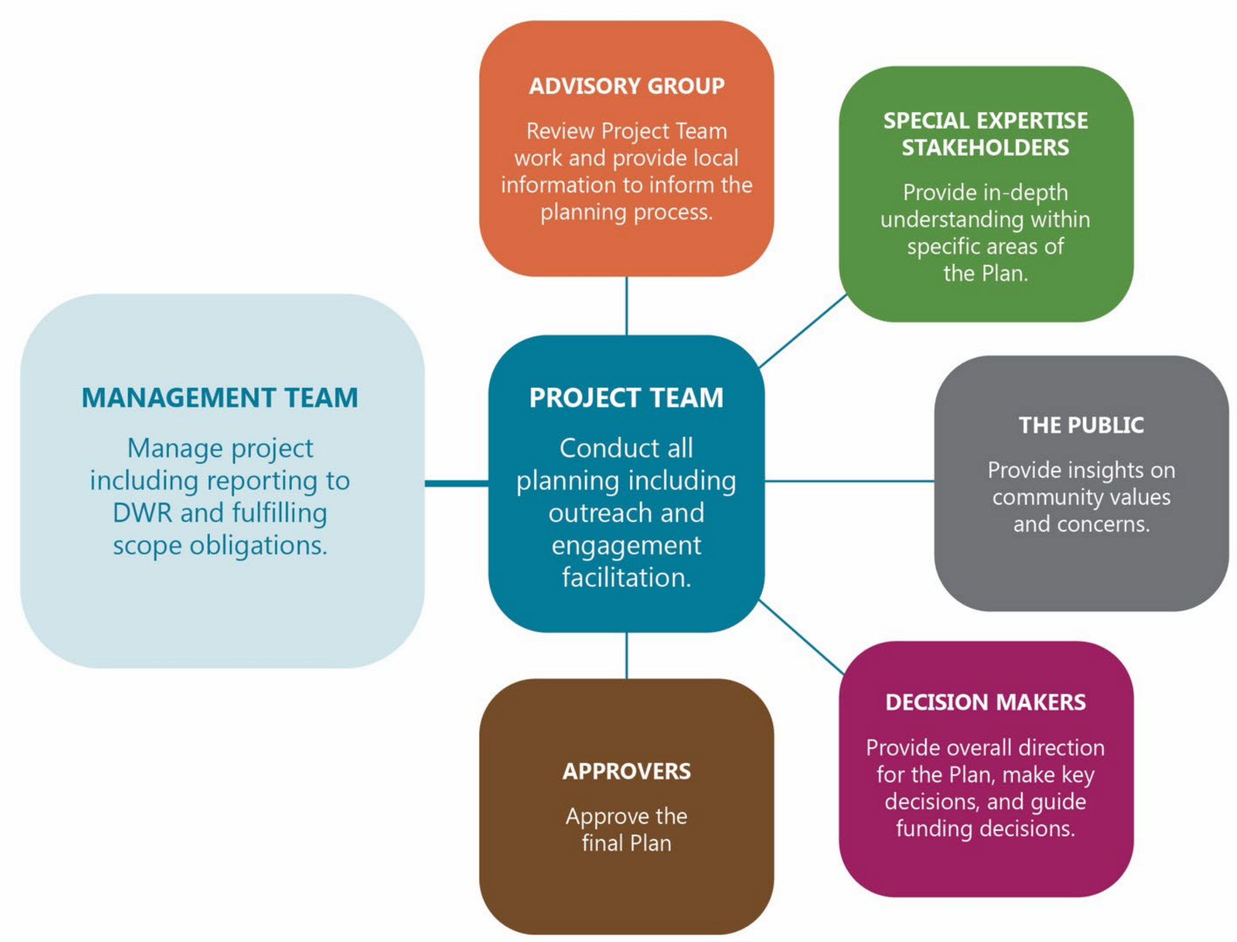
An initial assessment of the resulting IRWM list yielded gaps to be filled with additional environmental/ ecosystem, flood control, fire management, disadvantaged community, and Tribal representatives. The Project Team filled these gaps through the following actions:

- A Tribal Contract List from the Native American Heritage Commission was used to add any Tribes not previously included with individual contact to confirm representation.
- Local groups with ties to the Sustainable Groundwater Management (SGM) Program were added.
- Additional verbal and online research was conducted to identify and add any relevant organizations in the Watershed – including churches and religious institutions.
- The Watershed delineation boundary (see **Chapter 1**) was used to evaluate those with influence within the Watershed.
- A draft list was provided to DWR for input.

2.1.2. Watershed Network Structure and Community Outreach and Engagement Plan

The Project Team prepared a Regional Watershed Network Structure Categories, shown in **Figure 2-1**, consisting of seven Watershed Network Categories under which interested parties would be grouped. Each category had differing roles to play in the development of the Watershed Resilience Plan and allowed the Project Team to tailor outreach efforts accordingly. The Project Team understands that participant time is valuable and so the Watershed Network Structure was used to increase the efficiency and effectiveness of communication based on the nature of each category. The Watershed Network Structure aligns with the Spectrum of Community Engagement structure, which has become a Best Management Practice in outreach and engagement (see more in **Appendix A**).

Figure 2-1: Watershed Network Categories



To ensure that outreach efforts were strategic, inclusive, and effective, the Project Team developed a comprehensive Community Outreach and Engagement Plan (included as part of **Appendix A**) to complement the Watershed Network Structure. This plan served as a guiding framework for all outreach activities, helping the Project Team to clarify goals, define stakeholder roles, and select appropriate engagement platforms and methods. The Community Outreach and Engagement Plan was designed to allow for flexibility to respond to what was learned as the planning process evolved and as such was not followed to the letter. For detailed information on outreach activities, see **Appendix A**.

2.2. WATERSHED NETWORK ENGAGEMENT

The Project Team learned from initial engagement activities to develop future strategies that would adapt to what is learned throughout the planning process and improve the effectiveness of overall engagement. The input that resulted from the engagement activities described here are reflected throughout subsequent chapters of the plan.

2.2.1. Initial Watershed Network Meeting

An introductory email was sent to agencies included in the Lay of the Land, describing the planning effort and inviting their awareness and participation followed by a second email inviting them to attend an initial Watershed Network Meeting held in person at a relatively central location. Though more than 100 people were invited to the meeting, only 6 attended. Given the low turnout, the Project Team asked the same group to complete a survey designed to better understand barriers to participation and preferences for engagement. Through the survey, the Project Team shifted to a series of touchpoints.

2.2.2. Online Touchpoint Engagement

Touchpoints are brief, targeted interactions with the Advisory Group and public focused on providing concise updates about the Watershed Resilience Plan and sharing information on how to use the new online engagement platform, making participation more accessible and convenient. To facilitate the touchpoint concept further, the Project Team used an online interactive platform (Konveio) that allows for transparency and referencing the ideas of others (like a public meeting) but is easily updated with new opportunities for engagement and allows participants to engage with the planning effort when most convenient. The Project Team designed the online engagement platform to serve as a central location for stakeholders to join the Watershed Network, participate in workshops, meetings, and online discussions, and provide feedback on key plan components. The Team also created how-to videos and written guides to support use of the platform. The platform was structured to host a series of six online discussions throughout the project, allowing stakeholders to engage at their convenience and ensuring that input could be gathered from a broader audience on the following topics:

- Vision, Goals, and Objectives (February 2025)
- Climate Vulnerability and Risk (June 2025)
- Adaptation Strategies (October 2025)
- Strategies Summarization (December 2025)
- Watershed Resilience Plan Overview (March 2026)

2.2.3. Targeted Partner Touchpoints Engagement

In addition to the online platform, the Project Team collaborated with Special Expertise Stakeholders in more focused meetings. These touchpoints were specific to one topic and focused on aligning technical content with stakeholder interests:

Group	Special Expertise	Input
Fish and environmental	FISHBIO, NOAA, California Dept. of Fish & Wildlife, Audubon, U.S. Fish & Wildlife	Reviewed stream temperature vulnerability analysis; shared data and tools integrated with climate modeling to produce projections.
Local stakeholder groups	San Joaquin Farm Bureau, Urban Contractors, Eastern Water Alliance, EPPOC	Project Team secured agenda time in existing meetings to deliver concise updates and direct participants to the online platform.
Upper Watershed interested parties	CCWD area	Two in-person sessions (Feb 4 and June 5, 2025) at CCWD offices to honor face-to-face engagement preferences and tailor content to local priorities.
Large landowners	Vibrant Planet, Pacific Gas & Electric, Sierra Pacific Industries	Coordinated to share wildfire modeling priorities, clarify data showing limited overlap with their highest-priority zones, and maintain open lines for future meetings if requested.
Nearby utilities	CPUD, Valley Springs Public Utilities	Direct outreach for project inputs; in absence of responses, reviewed publicly available planning documents to identify relevant projects for consideration.
County and regional audiences	Growers, NSJWCD, EBMUD, San Joaquin County Water Resources Division	Delivered presentations and briefings to share climate modeling, groundwater outlooks, and water supply/demand projections tailored to each audience's decisions and interests.

2.3. EQUITY CONSIDERATIONS

The Project Team sought participation from historically excluded groups (e.g., disadvantaged communities and Tribes), reducing burdens to engagement, and tailoring communications and logistics to community needs. These commitments were embedded in the Community Outreach and Engagement Plan (included as part of **Appendix A**).

2.3.1. Tribes

Initial outreach to Tribes listed in the Lay of the Land did not elicit responses. Following DWR's advice, the Project Team obtained the Local Government Tribal Consultation List from the Native American Heritage Commission and met individually with the Calaveras Band of Mi-Wuk Indians, Confederated Villages of Lisjan, and Northern Valley Yokut Ohlone Tribe. Each Tribe appreciated the contact but noted that due to limited capacity and lack of lands within the delineated Watershed boundary, they did not have interest in further engagement in the process. All Tribes remained on the outreach list and were welcome to participate as circumstances changed. This approach respects sovereignty, acknowledges capacity constraints, and keeps doors open for future engagement.

2.3.2. Disadvantaged and Underrepresented Communities

When direct outreach produced limited response, the Project Team shifted to partnering with organizations that serve disadvantaged and underrepresented communities by requesting space in newsletters and trusted communications to share opportunities and invite feedback. This strategy broadened reach through familiar channels, reduced participation barriers, and improved visibility of the planning effort among communities less likely to engage via traditional water sector outreach. While there was still no participation from disadvantaged and underrepresented communities in the touchpoints, information was shared and made available to them via this effort.

2.3.3. Accessibility and Flexibility

To reduce time, travel, and scheduling burdens, the Project Team emphasized asynchronous online participation through Konveio, paired with short, targeted touchpoints embedded in existing meetings. In areas where stakeholders expressed a preference for in-person engagement (e.g., CCWD interested parties), the team provided local workshops. This mix of methods supports equitable access by meeting people where they are and how they prefer to engage.

CHAPTER 3
WATERSHED PROBLEMS & CHALLENGES

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3. WATERSHED PROBLEMS & CHALLENGES

This chapter provides a synthesis of initial research (including Watershed Network input) with regard to the region's climate planning landscape and was used to identify potential problems and challenges related to watershed resilience. Information included in this chapter is largely qualitative; the quantitative risk and vulnerability assessment is included in **Chapter 5**.

For the purpose of identifying problems and challenges, a 25-year time horizon was considered. This time period was selected not only because it provides a realistic planning horizon for adaptation strategies (**Chapter 6**), but because it is also consistent with DWR's Watershed Studies, a critical input to the risk and vulnerability assessment (**Chapter 5**). Thus, the Calaveras Watershed Resilience Plan uses a 2050 planning horizon.

3.1. DEFINING HAZARDS, VULNERABILITIES, AND RISKS

When considering climate resiliency, there are many different terms that are commonly used often with slight variations as to their meaning. **Figure 3-1** defines these terms as they are used for this planning effort.

Figure 3-1. Plan Definitions

Hazard	Impact	Vulnerability	Risk	Adaptation
A potentially damaging event or condition (e.g. extreme precipitation)	Problems or challenges associated with the hazard occurring (e.g. flooding)	Susceptibility of a specific asset to a hazard and its impacts (e.g. building is in 100-year floodplain)	Function of the probability of the hazard occurring and vulnerability of a particular asset	Strategy or action that reduces vulnerability to an impact, thus also reducing risk (e.g. raise building to above 100-year flood height)

The Project Team first identified climate-related hazards to Calaveras Watershed resilience from existing planning documents. These hazards were used as the basis for developing a list of problems and challenges based upon input from SEWD and CCWD staff and engagement with interested parties and the public. These problems and challenges were then used to develop the vision, goals and objectives presented in **Chapter 4** as well as to refine the analytical framework and focus the vulnerability assessment described in **Chapter 5**.

3.2. REGIONAL CLIMATE ASSESSMENT RESEARCH

Various agencies and organizations within and around the Watershed have developed plans that assess potential climate change impacts on a variety of scales. Most relevant to this planning effort are the climate analyses conducted as part of the Eastern San Joaquin Groundwater Sustainability Plan (GSP) and DWR's San Joaquin Basin Watershed Studies.[1] The analytical work conducted under these planning efforts were heavily used in developing the Watershed Vulnerability Assessment as described in **Chapter 5** and identifying the adaptation strategies provided in **Chapter 6**.

Calaveras and San Joaquin Counties' Local Hazard Mitigation Plans provide insights as to historical and anticipated impacts of climate change to infrastructure, emergency preparedness, and resource

[1] Eastern San Joaquin Groundwater Authority, 2024; California Department of Water Resources, 2025a

management, and IRWM Plans (ESJ IRWM and MAC IRWM) and MokeWISE consider climate challenges in planning for long-term water supply**.** The results of these planning efforts, in addition to the GSP and Watershed Studies, provide insights into potential problems and watershed resilience challenges that informed the content of this chapter. More information on these studies – and a list of other regional planning documents that were also reviewed – is included in **Appendix B**

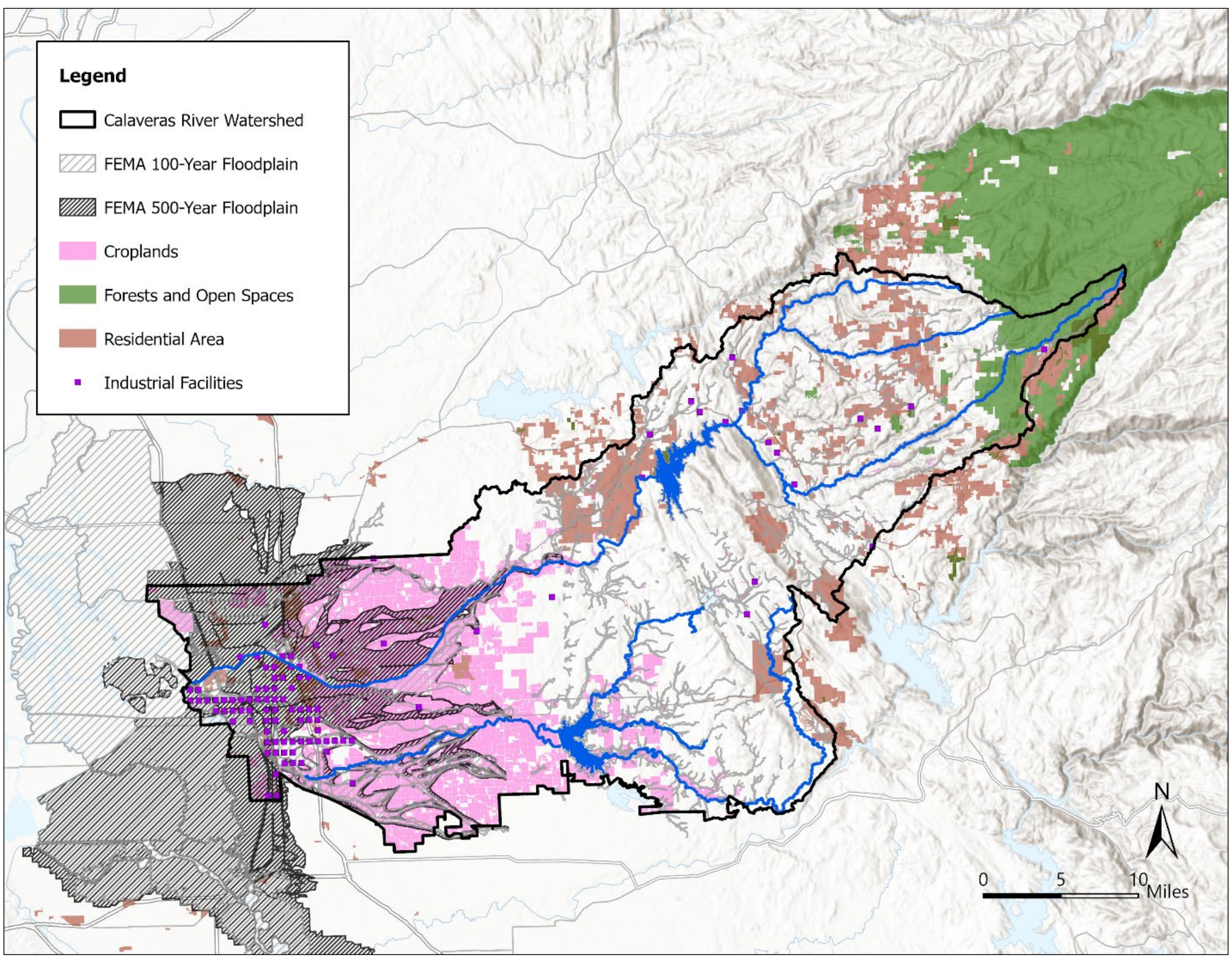
3.3. WATERSHED CLIMATE HAZARDS

Review of the aforementioned regional climate assessments resulted in the conclusion that the most prominent climate hazards in the Watershed are extreme precipitation, drought, and wildfire. The following section summarizes the historical and future impacts of these hazards and how climate change may exacerbate their effects.

3.3.1. Extreme Precipitation

There are several FEMA-designated 500- and 100-year floodplains within the Watershed including Cosgrove Creek, the Calaveras River Middle Fork, Bear Creek, Black Creek, and White Pines Lake shown in **Figure 3-2**. Flooding events have been common with the lower Watershed where the elevation drops dramatically from the foothills into the San Joaquin Valley. Much of the City of Stockton lies entirely within the 500-year floodplain and is particularly susceptible to flooding, not only from the Calaveras River, but from the Sacramento-San Joaquin Delta and other Sierra Nevada river systems that ultimately flow into the San Joaquin River such as the Stanislaus River. The Mormon Slough and the Stockton Diverting Canal were built in 1910 to bypass up to 12,600 cubic feet per second (cfs) from the Calaveras River at Bellota Weir around the City of Stockton and into the San Joaquin River, bypassing the City of Stockton.

Figure 3-2. Watershed Land Use and Floodplains



In the past decade, several large storms and atmospheric rivers (2017, 2019, 2023, and 2024[1]) have caused hazardous floods where local creeks and tributaries were unable to accommodate the increase in peak flows. During the atmospheric river events in the winter of 2023-24, major flooding caused SEWD to spend over $1M on preparations and repairs to waterways downstream of Farmington Dam [2] – which provides a tangible example as to the impacts of a changing climate.

These flooding events are further exacerbated given increasing urbanization and modified drainage conditions due to agriculture in the lower Watershed. Urbanization increases impermeable surface area and decreases the ability of the Watershed to absorb precipitation.[2] Aside from urban areas, the lower Watershed is dominated by agricultural land use, where flood risks can vary by tributaries, irrigation diversions, and soil conditions.[3] These factors can cause localized flood events in agricultural areas, which greatly increases agricultural runoff to rivers, causing elevated vulnerability to point and nonpoint source pollution, as discussed in Technical Memorandum 1, and included as **Appendix C**.

Extreme wet periods can result in an abundance of vegetation that very quickly dries out during dry periods, providing ample fuel for wildfires, which further degrade soil stability and quality.[4] Severe rainstorms can increase flood risks by causing large volumes of rain to fall in a short interval, leading to higher flowrates in runoff and waterways.[5] The runoff caused by these events can create significant water quality impacts by transporting contaminants from unstable land into water bodies that impact fish and drinking water treatment systems. Related water quality issues in the Watershed are discussed in Technical Memorandum 1, included as **Appendix C**. **Chapter 5** analyzes future water quality risks and vulnerabilities.

Climate change will increase the severity of the phenomenon known as "weather whiplash," which consists of rapid and extreme shifts between droughts and wet conditions during a relatively short period.[6] This phenomenon has the potential to heighten the impacts of all climate hazards, particularly flooding and drought (**Section 3.3.2**). Either extreme of weather whiplash can cause major impacts to public safety, water supply, and infrastructure.

Apart from the climate aspect of flooding, a significant challenge in addressing flooding and flood risk is more jurisdictional. There are a number of agencies that share management responsibilities of the larger hydrologic system, which can create unclear responsibilities, particularly when it comes to addressing flooding.

3.3.2. Drought

The San Joaquin Hydrologic Region has experienced several droughts increasing in frequency and intensity over the past 100 years. Within the last 10-12 years there have been two significant drought cycles in California that have impacted the Calaveras Watershed.

The 2012-2016 drought caused significant impacts to agriculture in the Central Valley resulting in many farmers fallowing their croplands or depleting groundwater basins to maintain crop production.[7] Water for municipal use was also in short supply, leading urban water suppliers to implement various voluntary and mandatory water reductions in their service areas.[8],

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[1] USGS, 2024
[2] Communication with SEWD, 2025
[3] Ghane, 2025
[4] USGS, 2025a
[5] California Department of Water Resources, 2025b
[6] Tan, et al., 2023
[7] U.S. Department of Agriculture; NOAA, 2025
[8] Calaveras County Water District, 2023

The 2021 State of Emergency declaration requested a voluntary demand reduction of 15% and required water suppliers to implement Level 2 water shortage contingency as part of their WSCPs within five years. The three driest consecutive years in California history were 2020, 2021, and 2022.[1]

As discussed in **Section 3.3.1**, climate change is anticipated to increase the frequency and severity of weather whiplash, which includes extended dry periods, some of which may be classified as droughts. These droughts are likely to be longer and drier than previous droughts, and may cause similar, or more severe water supply impacts than those experienced in historical dry periods.[2] Additionally, dry conditions cause vegetation in natural landscapes to become drier, increasing the risk of wildfires.[3]

3.3.3. Wildfires & Wildfire-Conducive Weather

While wildfires are an understandable (and necessary) occurrence in forested areas like the upper Watershed, climate change has extended the length of the wildfire season over the last several decades, while also increasing the size, frequency, and intensity of wildfires.[4]

The severity of wildfires is highly dependent on the strength and direction of winds, which can rapidly spread flames or embers to adjacent or distant areas.[4] FEMA has classified an area in the Central Valley—including a portion of the San Joaquin Valley—as a Special Wind Zone.[2] The region has experienced a total of 55 high wind events since 1993. In addition to these high wind events, summer high-pressure systems often bring high temperatures and strong winds to the region.[5] Furthermore, the many canyons and ridges in the upper Watershed significantly influence the magnitude and direction of winds.

Moreover, heat can further increase the risk of severe wildfires. Climate change raises ambient temperatures and can cause extended heat waves. These further dry out vegetation, increasing the likelihood of a fire igniting and creating increased flame length when that drier vegetation burns.

Intense wildfires can clear substantial amounts of vegetation in forested areas whose root systems previously helped slow the flow of water and debris during precipitation events.[6] The removal of vegetation increases the risk and intensity of debris flows and mudslides.[1] Technical Memorandum 4, included as **Appendix D**, assesses current and future wildfire hazards in the Watershed using historical data and wildfire modeling.

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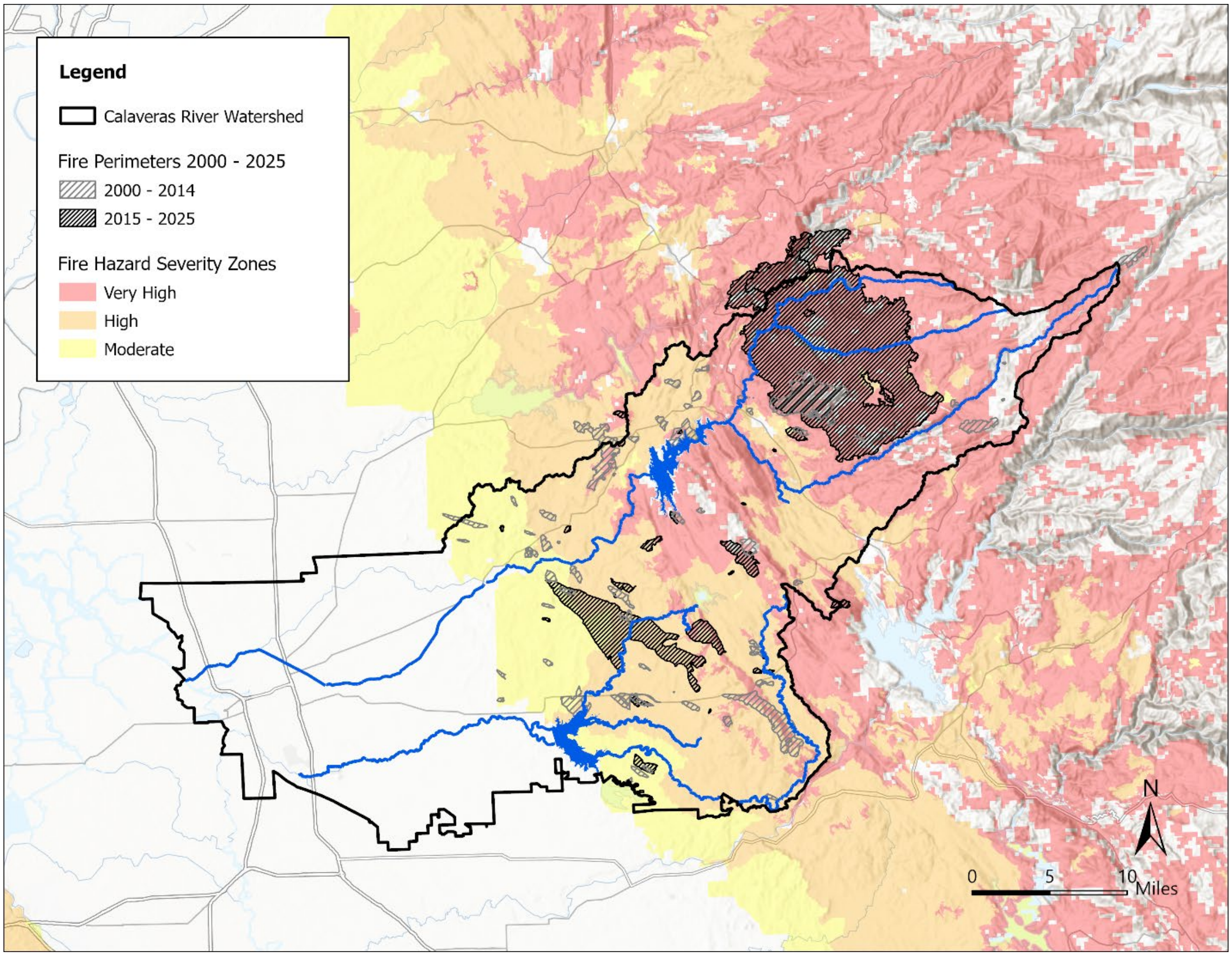
[1] California Department of Water Resources, 2023
[2] Calaveras County Water District, 2023
[3] USGS, 2025a
[4] National Wildfire Coordinating Group, 2025
[5] Calaveras Foothills Fire Safe Council, 2020
[6] USGS, 2025b

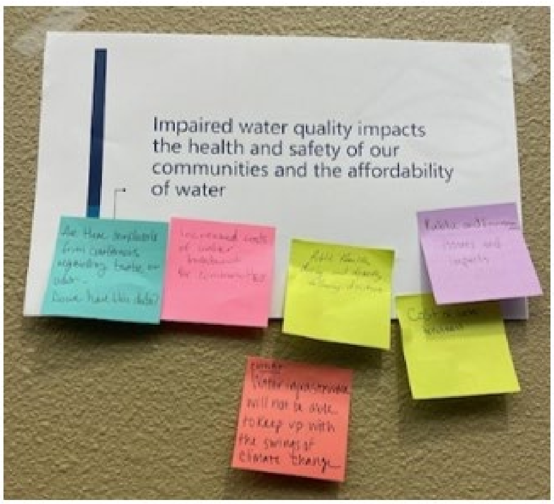
Figure 3-3. Wildfires & Fire Hazard Severity Zones in the Watershed



3.4. CLIMATE RESILIENCE PROBLEMS, CHALLENGES AND OPPORTUNITIES

The Project Team first used the researched hazards to draft initial problem statements. Through Konveio and numerous Touchpoint conversations, the Project Team then solicited discussion and input from the Watershed Network and the public to further refine the statements and define the specific challenges and opportunities that are most important to the Watershed. The problem statements and associated challenges based on this work are provided in **Table 3-1**. Climate resiliency opportunities were also identified through this process and were used to develop the goals and objectives presented in **Chapter 4**.

Through the online platform Konveio and interactive in-person activities, the Watershed Network was asked to respond to draft problem statements.



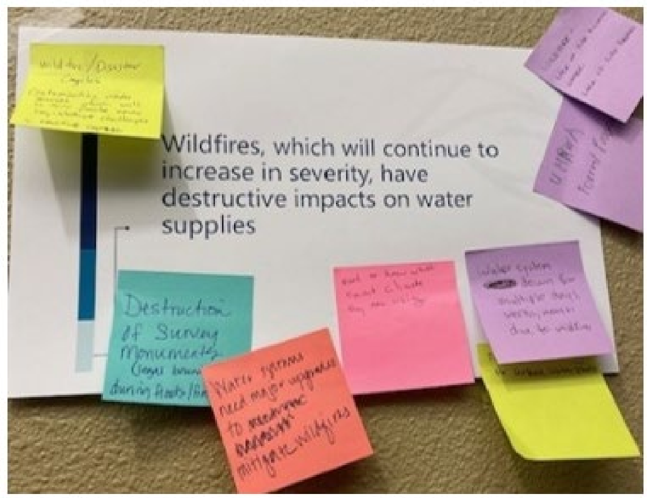


Table 3-1: Problem Statements and Challenges

Problem Statement	Associated Challenges
Groundwater overdraft threatens the economic viability of the San Joaquin Valley	• Less groundwater is detrimental to the agricultural economy and DACs with private wells that rely heavily on groundwater • Lowering groundwater levels increases energy costs for pumping • Impacts the "livability" of rural communities if private wells in the western portion of Calaveras County run dry
Impaired water quality impacts the health and safety of our communities and the affordability of water	• Sediment loading due to run-off after wildfires can mobilize contaminants trapped in soil • Current and legacy activities in the Watershed have contributed or potentially will contribute to nitrate loading, PFAS contamination, and heavy metal pollution, including elevated concentrations of mercury in some water bodies. • Harmful algae blooms in water bodies like New Hogan negatively impact the ecosystem and require increased treatment
Water supply operations may impact fish populations	• Releases from New Hogan Dam help sustain a fish population in the Calaveras River when there would otherwise not be sufficient year-round flows • Dams and other barriers can prevent the natural migration of anadromous fish without mitigation efforts • There may be accidental take of fish caused by dams and intake structures
Wildfires, which will continue to increase in severity, have destructive impacts on water supplies, ecosystems, and communities	• Damage to water and community infrastructure from wildfires • Runoff from burned areas can significantly reduce the survivability of juvenile fish, including state-listed species, or species of special concern • Impacts to recreation and the natural beauty of the Watershed
Patterns of "weather whiplash" will intensify the risk of flooding	• Increased frequency and severity of storms • Increase in impervious surfaces due to urban development • Impacts are exacerbated in burn scars after wildfires, particularly related to degraded water quality
There are competing demands on increasingly limited water	• Agriculture, urban, and environmental water needs are often pitted against one another • Increased urban development creates additional water demand • Changes in unimpaired flow requirements
Longer and more intense drought periods will worsen water restrictions	• This can particularly harm low-income communities that either rely on private wells or struggle to pay water bills • Can weaken agricultural economy • Concerns around water rights/contracts

CHAPTER 4
RESILIENCE VISION, GOALS, & OBJECTIVES

Woodard & Curran

STOCKTON EAST WATER DISTRICT
PROVIDING SERVICE SINCE 1948

4. RESILIENCE VISION, GOALS, & OBJECTIVES

Together, the Watershed Plan vision, goals, and objectives provide an overall purpose for the Plan both in what the planning process aims to achieve as well as what the collective desired outcomes are for a climate resilient future. The Project Team first drafted the vision, goals, and objectives to respond to the problems and challenges identified in **Chapter 3** and then made minor revisions based on additional input from the Watershed Network. The goals and objectives were used to develop the analytical framework for assessing watershed vulnerability (**Chapter 5**) and identify adaptation strategies (**Chapter 6**) as well as to identify meaningful performance tracking indicators as described in **Chapter 8**.

4.1. WATERSHED RESILIENCE PLAN VISION

The Calaveras River Watershed Resilience Plan seeks to enhance water resource resilience for communities, economies, and ecosystems throughout the Calaveras Watershed through regional collaboration and integrated watershed management.

4.2. WATERSHED RESILIENCE PLAN GOALS & OBJECTIVES

Plan goals articulate the desired future conditions that the Watershed Network would like to have relative to watershed climate resilience. Plan objectives are generalized conditions that, when measured, reflect the performance of the region in meeting each of the Plan goals. These goals and objectives are qualitative; **Chapter 8** discusses performance tracking with quantitative metrics.

As discussed in **Chapter 3**, the Watershed Network provided important feedback relative to climate resiliency problems and challenges. As a follow-up to that exercise, the Project Team drafted an initial set of goals as shown in **Table 4-1**. The Watershed Network, through the Konveio platform and multiple in-person Touchpoint conversations, then discussed climate resiliency opportunities, helping to shape the final goals and objectives. Some of this input is shown in **Figure 4-1** below.

Table 4-1: Translating Problem Statements to Goals

Problem Statement	Goal Area
Groundwater overdraft threatens the economic viability of the San Joaquin Valley	Groundwater basin sustainability
Impaired water quality impacts the health and safety of our communities and the affordability of water	Agricultural & urban vitality
Water supply operations may impact fish populations	Water supply resiliency Ecosystem & environmental health
Wildfires, which will continue to increase in severity, have destructive impacts on water supplies, ecosystems, and communities	Ecosystem & environmental health
Patterns of “weather whiplash” will intensify the risk of both flooding and water shortages	Agricultural & urban vitality
There are competing demands on increasingly limited water	Water supply resiliency Regional collaboration & implementation
Longer and more intense drought periods will worsen water restrictions	Water supply resiliency Regional collaboration & implementation

Figure 4-1: Watershed Network Input on Goals and Objectives

Goal 1: Groundwater Basin Sustainability

A sustainably managed groundwater basin with adequate groundwater levels, stable pumping yields, high-quality water for municipal and agricultural use, and ample groundwater storage for short- and long-term needs; carefully balanced to ensure the safety of the region's communities, economies, and ecosystems in the face of future droughts and unforeseen climate disasters.

The objectives developed to meet this goal are the following:

- Increased conjunctive use
- Maintained groundwater levels above minimum thresholds
- Preserved basin water quality

Goal 2: Water Supply Resiliency

A diversified water supply, resilient to risks enhanced by climate change, shared equitably between competing interests in the region, and sufficient to support growing urban populations and the region's agricultural economy.

The objectives developed to meet this goal are the following:

- Solidified water rights and contracts
- Improved urban and agricultural water use efficiency
- Increased supplemental surface water supply
- Increased groundwater recharge
- Increased access to alternative supplies
- Enhanced supply management during droughts
- Balanced competing water supply interests
- Improved conveyance efficiency

Goal 3: Agriculture & Urban Vitality

Sustainable water supplies support a vibrant local economy comprising a diversity of sectors: forestry, agriculture, and recreation; viable urban development is bolstered by the stability of well-managed natural resources.

The objectives developed to meet this goal are the following:

- Improved wildfire resilience
- Resilient forestry economy
- Resilient agriculture economy
- Resilient recreation economy
- Supported tribal communities
- Supported sustainable urban development
- Managed water rate affordability

Goal 4: Ecosystem & Environmental Health

Flourishing ecosystems—forests, riparian corridors, and aquatic habitats—are sustained by a pristine river and healthy groundwater basin, and protected from the worst impacts of wildfire, water pollution, droughts, and other risks exacerbated by climate change.

The objectives developed to meet this goal are the following:

- Reduced wildfire intensity
- Reduced impacts of wildfire, agriculture, and urban runoff on water quality
- Conserved and expanded anadromous fish habitat
- Increased populations of threatened anadromous fish

Goal 5: Regional Collaboration & Implementation

A region that fosters strong relationships between resource managers, business owners, tribal and community leaders, and the public; an environment that encourages effective communication and collaboration in solving shared problems by implementing innovative and multifunctional strategies.

The objectives developed to meet this goal are the following:

- Improved coordination between agricultural and urban water suppliers
- Established communication pathways between agencies, stakeholders, and the public
- Collaboration between water agencies and emergency response agencies/planners
- Collaborated with local GSAs on SGMA-related actions and management strategies
- Recognized watershed resilience leadership
- Funded strategy implementation
- Leveraged local resources efficiently
- Open communication to avoid contradicting regulations and minimize adverse actions while promoting collaboration among all parties with varying interest (urban, agricultural, and environmental)
- Public outreach and education

CHAPTER 5

CLIMATE VULNERABILITY & RISK ASSESSMENT

Calaveras Watershed Resilience Plan 2026

Woodard & Curran

STOCKTON EAST WATER DISTRICT

PROVIDING SERVICE SINCE 1948

5. CLIMATE VULNERABILTY AND RISK ASSESSMENT

This chapter provides an overview of the analytical framework developed to assess climate-related vulnerabilities and risk of the consequences in the Calaveras Watershed as well as the results of the assessment.

The exact impacts of climate change in the Calaveras Watershed and across the state are uncertain. Planning for a range of climate change impacts can help reduce that uncertainty around the vulnerabilities and risks given the hazards presented in **Chapter 3**. How vulnerable a system is to a hazard is key to understanding what the consequences may be and of the associated risk of that hazard. The results of this analysis were used to identify and articulate the performance of adaptation strategies (in Chapter 6) that could be implemented to build a more resilient Calaveras River Watershed.

5.1. ANALYTICAL FRAMEWORK

The Project Team developed an analytical framework to define the methods and indicators used to assess vulnerabilities related to climate hazards and challenges presented in Chapters 3 and 4. The framework, shown in **Table 5-1**, was refined based upon the terminology, parameters, indicators, and methods from existing climate impact forecasting models. This framework was designed to assess both climate vulnerability and evaluate improvements in climate resilience resulting from the adaptation strategies identified in **Chapter 6**. The framework was continuously refined throughout the vulnerability analysis to improve its effectiveness.

The climate vulnerability assessment and adaptation strategy evaluation are organized around this framework, which structures impacts into distinct risk categories evaluated through specific performance metrics. This framework provides a systematic approach to characterizing how climate change affects watershed function and identifies where adaptation interventions can be most effective.

The framework first forecasts direct impacts to watershed hydrology from changes in precipitation, temperature, and evapotranspiration, and applied water demand due to future climate change. These direct impacts are then used to model vulnerabilities to flood management, water supply, and the groundwater basin. Water supply evaluation addresses surface water availability, groundwater production, and supplemental water supplies including managed aquifer recharge. Basin sustainability examines long-term groundwater storage, groundwater level trends at GSP monitoring locations, and interconnected surface water depletions.

Wildfire, surface water quality, and economic risks assess indirect impacts from temperature and precipitation changes, including exacerbated wildfire conditions, changes to water body temperature and contaminant loads, and associated impacts to regional economies that depend on reliable water supplies and watershed ecological health. The key metrics in **Table 5-1** align with current metrics used for Sustainable Groundwater Management Act (SGMA) compliance.

Not all potential climate impacts can be quantified through modeled metrics. The economic risk area, encompassing agriculture, urban, and forestry and recreation sectors, relies on qualitative assessment because pathways from climate change to economic outcomes are indirect and compound in ways that fall outside the scope of the models used in this study. In these cases, the vulnerability assessment draws on modeled outputs from adjacent risk areas to characterize the likely direction and magnitude of economic consequences.

Table 5-1: Analytical Framework

Risk Area	Impact	Metric (modeled CC impact)
Direct Impacts	Hydrology	Δ Temperature
		Δ Precipitation
		Δ Extreme Precipitation
	Water Demand	Δ Evapotranspiration
		Δ Water Demand
Flood	Flood Space Management	Δ New Hogan Inflow (Maximum)
	In-Stream Flood Conditions	Δ New Hogan Outflow (Maximum)
Water Supply	Surface Water	Δ New Hogan Inflow (Average)
		Δ Surface Water Deliveries
	Groundwater Use	Δ Groundwater Production
	Supplemental Supplies	Δ Supplemental Supplies
Groundwater Basin	Groundwater Storage	Δ Groundwater Storage
	Groundwater Levels	Δ Groundwater Level
	Interconnected Surface Water	Δ Stream-Aquifer Interaction
	Inter-Watershed Dynamics	Δ Subsurface Inflow
Wildfire	Footprint	Annual Burn Probability
	Intensity	Characteristic Flame Length
	Ecosystem	Wildfire Risk to Wildlands Health
	Water Resources	Wildfire Risk to Water Resources
	Community Safety	Wildfire Risk to Community Safety
Surface Water Quality	Environmental Water Quality	Temperature (Proxy: Δ Stream Stage and Storage)
		Constituent Transport (Proxy: Δ Stream Stage)
		Sediment Yield (Proxy: Erosion Rates)
Economy	Agriculture	Indirect
	Urban	Indirect
	Forestry & Recreation	Indirect

5.2. CLIMATE VULNERABILITY ASSESSMENT APPROACH

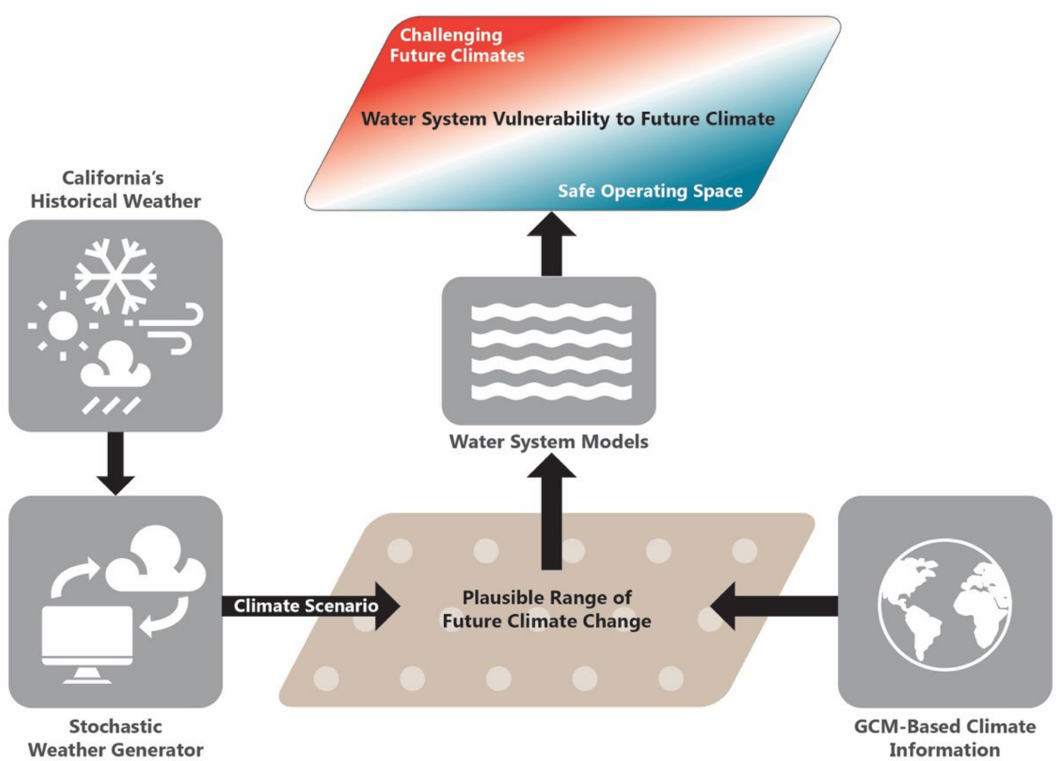
The watershed vulnerability assessment involved weaving together multiple tools, models and methods to address each element of the framework. Two primary categories of modeling were completed: hydrologic modeling and environmental modeling with the final economic analysis done qualitatively based upon the results of the other assessments. Additional details about the modeling methods and interim analysis results beyond what is described in this section can be found in Technical Memorandum 2, included as **Appendix E**.

5.2.1. Hydrologic Modeling

Hydrologic modeling was completed with the development of the Calaveras Watershed Resilience Plan (CWRP) Model, which was established as a refined version of the Eastern San Joaquin Water Resources Model (ESJWRM) Projected Conditions Baseline. The CWRP Model uses temperature-precipitation scenarios to drive runoff generation and recharge processes; evapotranspiration (ET) calculations that represent consumptive use from native vegetation, crops, and open water; surface water operations and dynamic streams that simulate reservoir management, diversions, and instream flows; initial conditions that establish starting water levels and storage volumes; and boundary conditions that define fluxes entering and leaving the model domain.

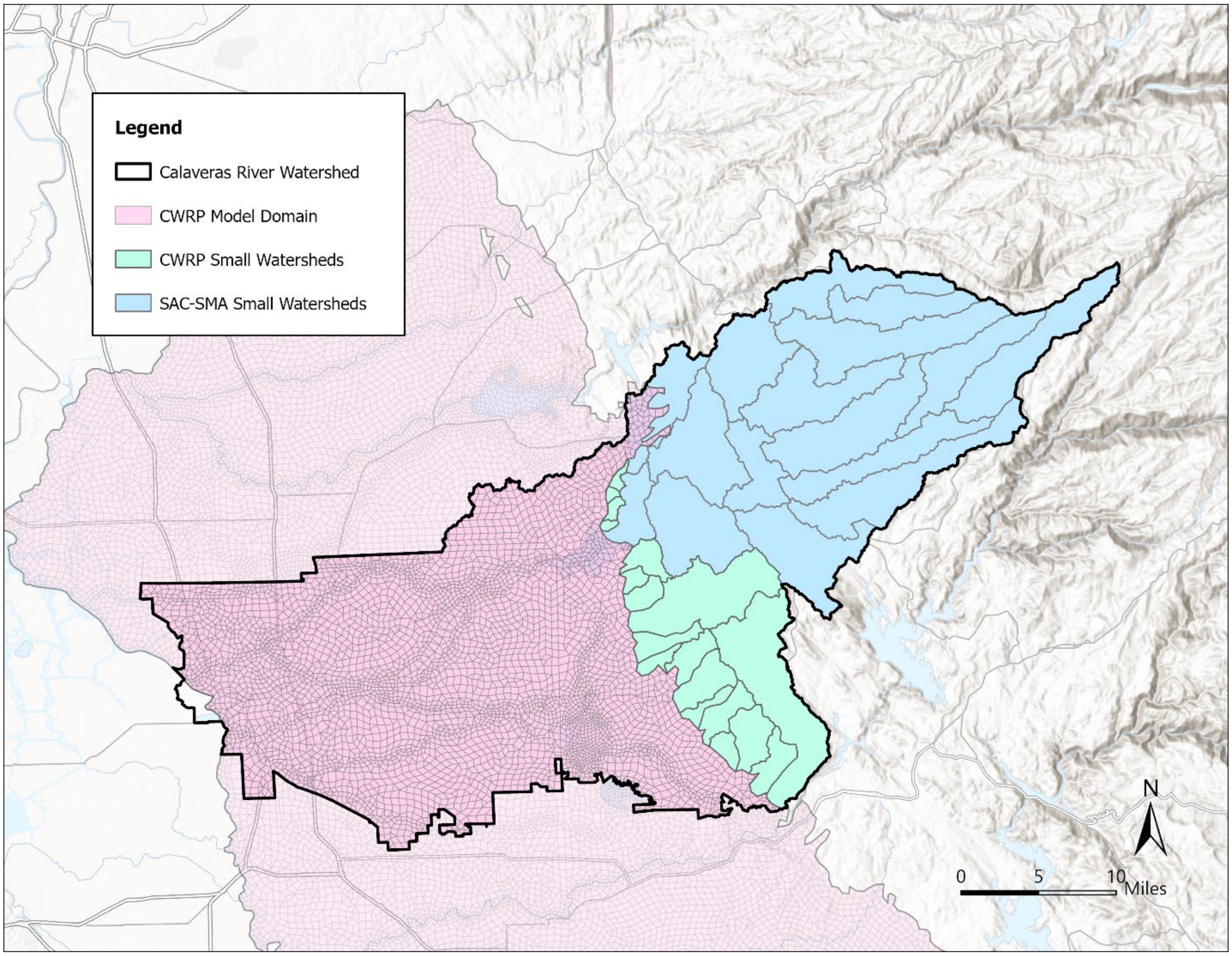
To evaluate how the Watershed will respond to future climate conditions, the CWRP Model employs a bottom-up modeling framework using stochastic weather generation to create synthetic hydrology as shown in **Figure 5-1**. The resulting 16 climate scenarios (fully described in Technical Memorandum 2 which is included as **Appendix E**) drive a fully integrated set of models that simulate hydrologic processes, reservoir operations, surface water systems, and groundwater conditions to determine climate vulnerability and the efficacy of adaptation strategies.

Figure 5-1. Simulating Future Climate Conditions



By using hydrologic and climatic datasets from DWR's Watershed Studies Program, the Project Team was able to simulate a wide variety of climate conditions throughout the Calaveras Watershed. Upper Watershed dynamics and New Hogan operations were simulated using the Sacramento Soil Moisture Accounting Model (SAC-SMA) and Hydrologic Engineering Center - Reservoir System Simulation (HEC-ResSim), developed by the DWR. Conditions in the lower Watershed were simulated using the CWRP Model, which is an application of the Integrated Water Flow Model (IWFM), a fully integrated surface water-groundwater model, designed to simulate water supply, flood, and the groundwater basin (**Figure 5-2**).

Figure 5-2: The Calaveras Watershed Resilience Plan (CWRP) Model domain



5.2.2. Environmental Modeling: Surface Water Quality

To assess the vulnerability of surface water quality under climate change, the Project Team used historical data used in conjunction with simulated climate conditions. The 2019 Calaveras River Habitat Conservation Plan (HCP) identifies critical habitat for Central Valley steelhead and potential habitat for Chinook salmon runs, requiring adaptive management to maintain adequate flows and temperatures essential for migration, spawning, and rearing. Because salmonids are highly temperature-sensitive, the HCP references EPA guidelines for optimal spawning conditions. Stream temperature was forecasted using a regression relationship tool based on New Hogan reservoir storage that is currently used to manage stream flows on the Calaveras River. It builds upon existing monitoring completed by FISHBIO and modeling completed by DWR as part of their Watershed Studies program. Technical Memorandum 3, included as **Appendix F**, provides a detailed overview of this analysis.

In water bodies already listed as impaired under Section 303(d) of the Clean Water Act, increased runoff, whether from urban or agricultural land uses, can exacerbate existing water quality problems through elevated pollutant loading, nutrient-driven eutrophication, increased turbidity and sedimentation system stress on already vulnerable waters. In the absence of a tool that directly analyzes the movement of contaminants in the Watershed, an overlay analysis was completed to identify sub-watersheds within the larger Watershed where, according to the hydrologic climate modeling, there are expected increases in runoff that could make the sub-watershed more vulnerable to contaminant mobilization. Because these approaches rely on hydrologic modeling, climate risk for surface water quality is similarly assessed.

5.2.3. Environmental Modeling: Wildfire

The Watershed's vulnerability to wildfire was assessed using open-source data layers collected, modeled, and calibrated using Vibrant Planet/Pyrologix's modeling tool WildEST. The tool assesses the potential location, intensity and extent of wildfire event hazards and then models the potential risk to valued resources and assets.[1] Although the tool could not directly quantify the impact of changing temperature and precipitation, it is understood that the projected conditions under climate change will increase fire risk within the Watershed. Climate change is assumed to be occurring in both the pre- and post-fire scenarios in Vibrant Planet's analysis and therefore it is assumed that wildfires will be a major vulnerability in the upper reaches of the Calaveras Watershed under climate change.

5.2.4. A Note on Assessment Results

The following sections provide assessment results for each of the seven risk categories in the analytical framework. Results presented in this Plan use the most probable climate conditions for the 2050 planning horizon, which include a 2°C increase in mean annual temperature, no change in mean precipitation, and a 14% increase in the intensity of extreme precipitation events (T2P100). In this Plan, the terms "most probable scenario," "climate change conditions," and "T2P100" are used interchangeably to reference this scenario.

Each section includes a results table that summarizes the climate change impact, key metric, result under the most probable climate scenario, and the relative impact. The relative impact includes a symbol (an arrow or an equal sign) that indicates how the key metric will change from current conditions under the most probable climate scenario, The color indicates a positive change (blue) or a negative change (orange).

5.3. DIRECT IMPACTS ASSESSMENT RESULTS

Direct impacts from the most probable climate scenario could raise potential evapotranspiration by 1.9 inches across all vegetation types within the Watershed. However, actual evapotranspiration increases vary by land use, averaging 0.7 inches across all vegetation types but reaching 1.7 inches for agricultural lands where irrigation practices can meet the higher demand. The increased evapotranspiration translates to greater applied water demand, with water requirements for irrigated agriculture increasing by approximately 21,300 acre-feet per year (AFY). This increase reflects a 4.5% increase in agricultural water use and a 3.8% increase to the Watershed's total water demand**. Table 5-2** summarizes the most probable result and relative impact across each of the Direct Impact indicators described.

[1] Vibrant Planet, 2025

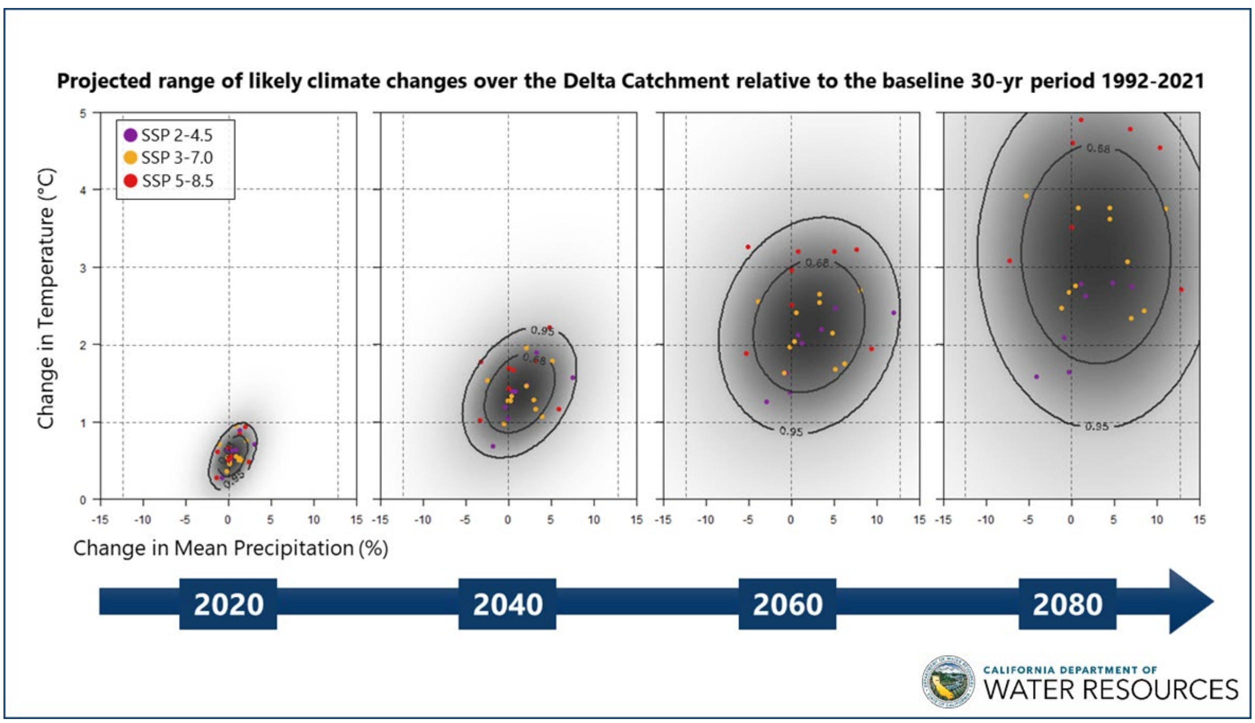
Table 5-2: Direct Impacts Results

Risk Area	Impact	Key Metric	Most Probable Scenario	Relative Impact
Direct Impacts	Hydrology	Δ Temperature	+2° Celsius	↑
		Δ Precipitation	100% of normal	=
		Δ Extreme Precipitation	+14% of normal	↑
	Water Demand	Δ Evapotranspiration	+0.7 in (+3.2%)	↑
		Δ Water Demand	21,300 AFY (+3.8%)	↑

5.3.1. Temperature

Figure 5-3 illustrates how climate conditions are projected to change over time, with elliptical contours showing probability distributions from multiple Global Climate Models under different emissions scenarios (SSP 2-4.5, SSP 3-7.0, and SSP 5-8.5). The progression from 2020 to 2080 shows temperatures rising steadily while precipitation changes remain uncertain, ranging from minus 13 to plus 13 percent of normal. The center of the mid-century distribution indicates that the most probable conditions for 2050 include a 2°C temperature increase with no change in mean precipitation (T2P100 scenario). Results throughout this report focus on T2P100 as the reference condition for long-term planning.

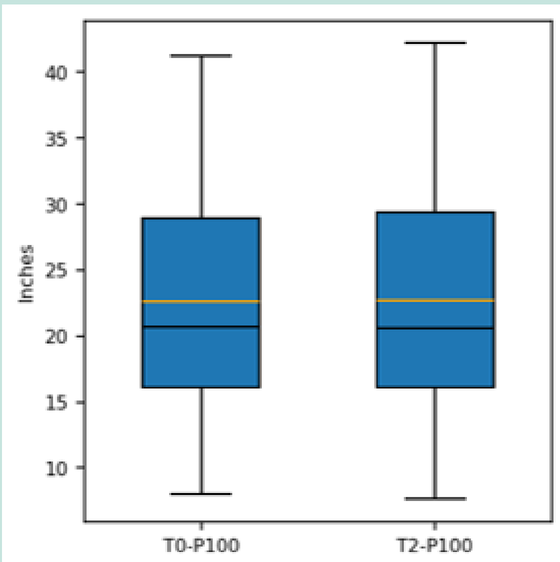
Figure 5-3: Projected Range of Climate Change Conditions



5.3.2. Precipitation

The existing conditions scenario (T0P100) and the climate change conditions (T2P100) maintain similar mean precipitation as shown by the statistical distributions in **Figure 5-4**. However, despite comparable averages, the T2P100 scenario displays greater variability in annual precipitation, with more pronounced extreme values in both wet and dry years. This increased variability reflects the 14 percent intensification of extreme precipitation events associated with 2°C warming. This distinction indicates that warming alone, even without changes in mean precipitation, alters the timing, intensity, and variability of water availability. These changes have direct implications for reservoir operations, flood risk, groundwater recharge, water supply reliability, and wildfire throughout the Watershed.

Figure 5-4: Precipitation

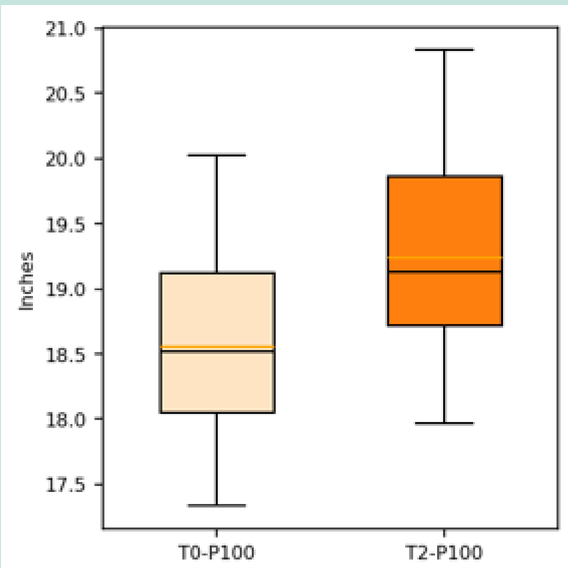


This chart compares the annual modeled precipitation for the Watershed under the existing conditions (T0P100) and climate chance conditions (T2P100). The x-axis denotes scenario identified by changes in temperature (T1) and precipitation changes (P100). Each box plot displays the interquartile range of simulated annual water supply requirements, with the central black line indicating the median value and whiskers representing the 5th and 95th percentiles. The orange line represents the mean value, and outliers are shown as individual points. It should be noted that the figure represents the conditions in the lower and upper Watersheds combined.

5.3.3. Evapotranspiration

Building upon the methodology established for the ESJWRM Projected Conditions Baseline, potential evapotranspiration was obtained from the temperature information from the Weather Generator, a stochastic tool developed by DWR that creates synthetic climate sequences based on historical weather patterns and future climate projections. Using Hargreaves methodology to estimate changes in extraterrestrial radiation, the Thiessen polygons were used to spatially distribute the effects of temperature, on evapotranspiration for each of the climate conditions. The CWRP Model calculates actual evapotranspiration for all land uses within the Watershed, including agricultural lands with varying crop types, urban landscapes, and native vegetation. Actual evapotranspiration represents the consumptive water use that occurs under field conditions, accounting for water availability constraints from both precipitation and applied irrigation.

Figure 5-5: Evapotranspiration



This figure illustrates the annual actual evapotranspiration for the Calaveras Watershed under varying climate conditions. Under the T0P100 existing conditions, the average actual evapotranspiration rate is 18.6 inches, whereas under the T2P100 condition, it increases to 19.2 inches. The results demonstrate a systematic increase of 0.35 inches in annual actual evapotranspiration for each 1°C rise in temperature. Additionally, the data show that for every 1% increase in precipitation, the actual evapotranspiration rate rises by 0.02 inches, reflecting enhanced water availability for consumptive use during wetter conditions.

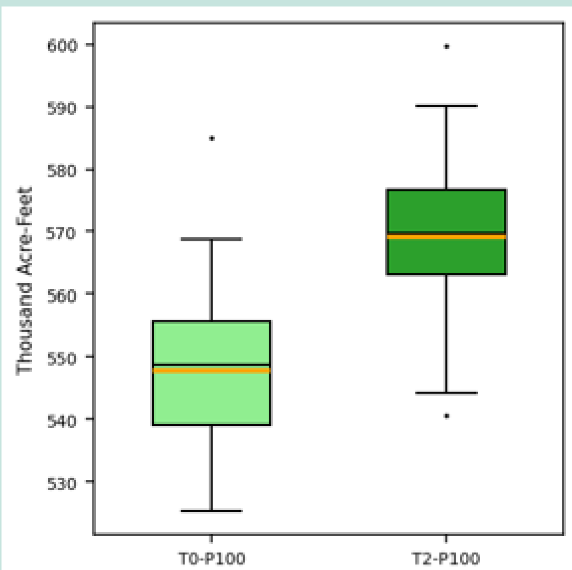
5.3.4. Water Demand

Within the direct impacts category, the model simulates applied water demand to capture total agricultural and urban needs. The CWRP Model calculates agricultural demand dynamically based on land use type, evapotranspiration rates, soil moisture conditions, and local irrigation management. Urban water demand is similarly computed dynamically based on population, per-capita consumption rates, and indoor vs outdoor water use requirements. The existing conditions scenario (T0P100) is representative of the current agricultural and urban operations and as such, land use and population growth is not accounted for over the simulation period.

Agricultural water demand in the Calaveras River Watershed is 475 thousand acre-feet per year (TAFY) over the 50-year simulation period, with annual values ranging from 450 TAFY in cooler, wetter conditions to 513 TAFY during hot, dry periods. Throughout the existing conditions, urban water demand remains constant at 72 TAFY, as urban water demand is not expected to significantly increase under climate change.

Climate change directly affects the water budget by increasing vegetative water demand and altering availability of surface water and groundwater conditions. Temperature increases drive higher consumptive use, while precipitation variability affects early season soil-moisture, surface water reliability, and the resulting need for groundwater extraction.

Figure 5-6: Water Demand



The total water demand in the Calaveras Watershed is predominantly driven by temperature as it directly drives evaporative losses and crop water requirements throughout the growing season, whereas precipitation has limited impact on annual water demand due to the region's arid conditions. Under existing conditions (T0P100), average annual demand is 547 TAFY, increasing by 4% to 569 TAFY under the T2P100 scenario. Across all scenarios, demand rises approximately 11 TAFY for each 1°C temperature increase, while a 1 percent increase in precipitation reduces demand by approximately 0.1 TAFY.

5.4. FLOOD IMPACT ASSESSMENT RESULTS

Flood-related impacts are assessed through two primary metrics, inflow to New Hogan Reservoir and the maximum in-stream flow conditions. Together, these metrics describe the system's ability to maintain adequate storage capacity for flood control and quantify the magnitude of potential downstream releases. Under the T2P100 climate conditions, flood risk, defined as the maximum monthly inflow to New Hogan Reservoir is expected to rise by 3.0% (5,600 AF) and increase the monthly maximum downstream flow by 3.1% (5,700 AF) at the Jenny Lind Gauge, as shown in **Table 5-3**.

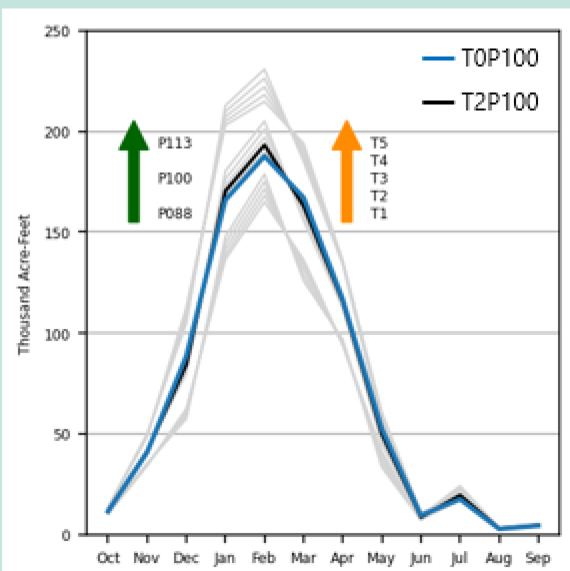
Table 5-3: Flood Impact Results

Risk Area	Impact	Key Metric	Most Probable Scenario	Relative Impact
Flood	Flood Space Management	Δ New Hogan Inflow (Maximum)	+5,600 AF (3.0%)	⇧
	In-Stream Flood Conditions	Δ New Hogan Outflow (Maximum)	+5,700 AF (3.1%)	⇧

5.4.1. New Hogan Inflow (Maximum)

New Hogan Reservoir captures runoff from the upper Watershed and regulates flood conditions through seasonal and multi-year storage. Under the T2P100 scenario, peak monthly inflows average 193 TAF, representing a 3% increase compared to the T0P100 scenario. This pattern reflects the thermodynamic intensification of extreme precipitation events, where warmer atmospheric conditions increase moisture-holding capacity and produce more concentrated, intense storms. Increased reservoir inflow increases flood risk, complicates operations, and requires larger flood control space while simultaneously reducing the water supply available.

Figure 5-7: New Hogan Inflow (Maximum)

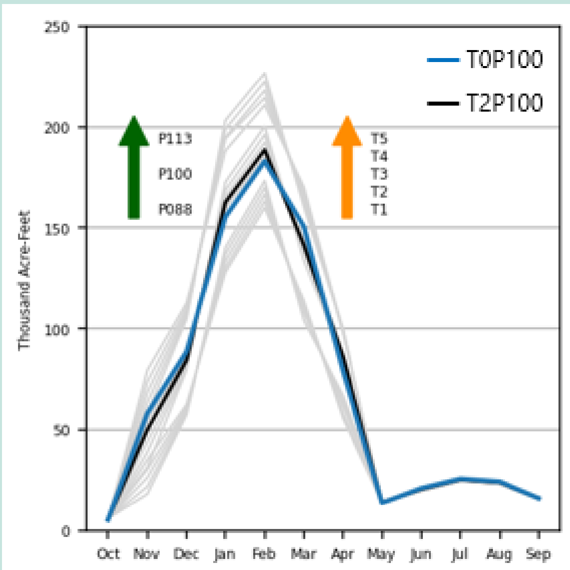


This chart shows the annual dynamic of maximum monthly reservoir inflow for the 16 climate conditions. The existing conditions scenario (T0-P100) is shown in blue, the most probable scenario (T2-P100) is shown in black, while the rest of climate conditions are shown in grey. There are three distinct precipitation-driven groupings (P arrow), showing higher inflow at higher precipitation. Within each grouping, peak inflows increase with rising temperatures (T arrow), reflecting the extreme conditions tied with higher temperatures, especially during the months of January and February, when higher runoff volume occur.

5.4.2. New Hogan Outflow (Maximum)

Maximum monthly outflows from New Hogan Reservoir provide a direct indicator of flood risk to downstream communities and infrastructure. Under existing conditions, maximum monthly outflows reach 183 TAF during exceptionally wet years when reservoir storage approaches capacity and controlled releases are necessary to maintain flood space. Climate change scenarios with intensified peak inflows increase both the frequency and magnitude of high outflow events. The T2P100 scenario produces maximum monthly outflows averaging 189 TAF, an increase of 6 TAF compared to existing conditions, reflecting the need to pass larger flood volumes through the reservoir system.

Figure 5-8: New Hogan Outflow (Maximum)



This chart shows the annual dynamic of maximum monthly reservoir outflow for the 16 climate conditions. The reservoir outflow patterns closely resemble those of reservoir inflow, particularly during the months of January and February, where higher outflow volumes occur. Maximum monthly outflow increases in conditions with high precipitation and high temperatures. Compared to the reservoir inflows, the magnitude of the outflows is lower, reflecting the effects of reservoir losses due to evaporation and seepage, as well as reservoir operations within New Hogan.

5.5. WATER SUPPLY IMPACT ASSESSMENT RESULTS

Water supply metrics are characterized by interconnected components, including the overall inflow to reservoir, environmental releases, and volumetric diversions for agricultural and urban use. These metrics collectively reveal how climate change alters both the availability of water supplies and the system's ability to manage extreme hydrologic events.

On average, 15 percent of agricultural demand is met through surface water deliveries supplied from New Hogan and New Malones, while the remaining 85 percent is supplied by groundwater pumping. The proportion of conjunctive use varies significantly with hydrologic conditions; in dry years, surface water may meet as little as two percent of the agricultural water demand. In wet years, surface water availability increases, meeting up to approximately 24 percent of the agricultural water demand, reducing stress on the groundwater system. Unlike agricultural water use, urban supplies rely more heavily on surface water deliveries, which provide an average of 68 percent of the urban demand. During wet years, surface water can meet up to 90 percent of urban demand, allowing municipal groundwater wells to operate at minimal capacity. In contrast, dry years reduce surface water availability to as low as 25 percent of urban water demand, requiring significant increases in groundwater pumping to maintain urban water services.

Water Supply risks stem from an expected reduction of 11,500 acre-feet per year (AFY) in inflow to New Hogan Reservoir under climate change, coupled with increased hydrologic volatility. This decline could reduce surface water deliveries by 15,500 AFY (12.9%), with no adaptation actions this would prompt an estimated 35,000 AFY (8.1%) increase in groundwater pumping to meet demand, as shown in **Table 5-4**.

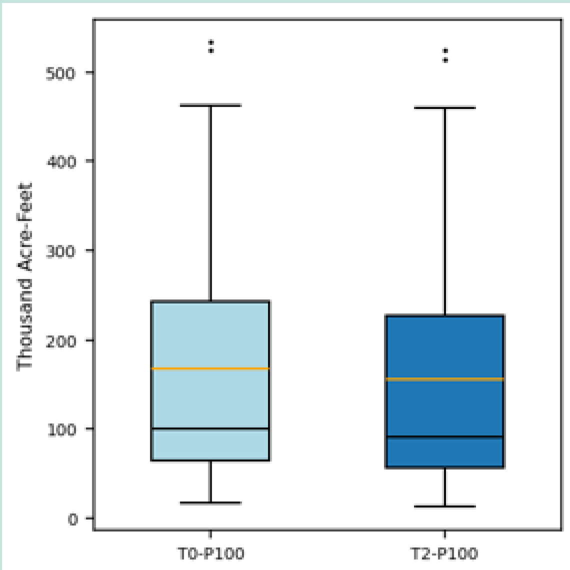
Table 5-4: Water Supply

Risk Area	Impact	Key Metric	Most Probable Scenario	Relative Impact
Water Supply	Surface Water	Δ New Hogan Inflow (Average)	-11,500 AFY (-6.9%)	↓
		Δ Surface Water Deliveries	-15,500 AFY (-12.9%)	↓
	Groundwater Use	Δ GW Production	+35,000 AFY (+8.1%)	↑
	Supplemental Supplies	Δ Supplemental Supplies	---	

5.5.1. New Hogan Inflow (Average)

New Hogan Reservoir receives inflows from the upper Calaveras Watershed, where climate conditions directly influence runoff generation through multiple interconnected processes. Higher temperatures increase evapotranspiration rates from native vegetation, reducing the proportion of precipitation that becomes runoff and limiting the reservoir's ability to maintain long-term storage.

Figure 5-9: New Hogan Inflow (Average)

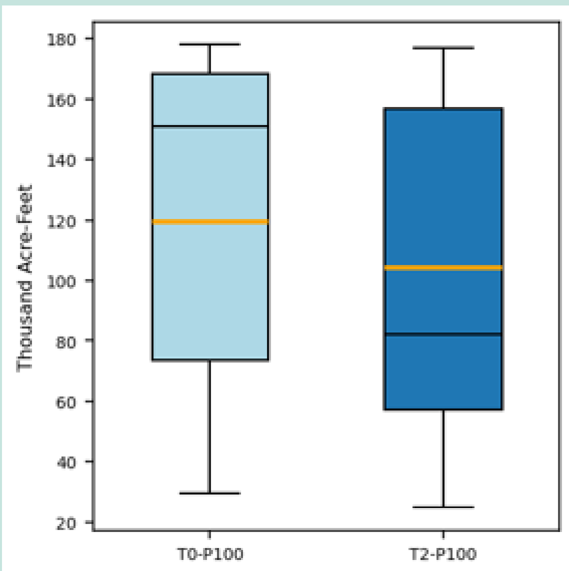


This figure shows that despite similar long-term precipitation totals between the T0P100 and T2P100 scenarios, upper Watershed systems reduce the average annual inflow to New Hogan Reservoir from 167 TAF under existing conditions to 156 TAF under the T2P100 climate change conditions. Both scenarios exhibit substantial interannual variability, with critically dry years producing as little as 13-16 TAF and exceptionally wet years generating 524-533 TAF, reflecting the high sensitivity of Watershed runoff to precipitation patterns.

5.5.2. Surface Water Deliveries

The Watershed conditions that reduce reservoir inflows subsequently affect surface water deliveries downstream of New Hogan. Surface water supplies decline systematically under warmer climate conditions as reservoir operations respond to reduced inflows, shifting seasonal patterns, and increased downstream demands (**Figure 5-10**). Across each of the climate scenarios, deliveries decrease by an average of 6.7 TAFY for every 1°C temperature increase. Precipitation changes exert a smaller offsetting effect, with deliveries increasing by 0.9 TAFY for every 1% rise in precipitation as wetter conditions enhance reservoir storage and operational flexibility.

Figure 5-10: Surface Water Deliveries

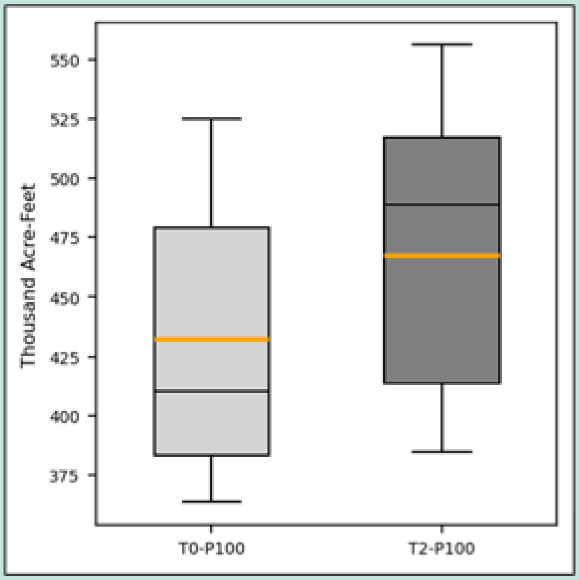


Existing conditions (T0P100) provide an average of 120 TAFY in surface water deliveries, while the T2P100 scenario reduces this to 104 TAFY, a 13% decline. Both scenarios exhibit substantial year-to-year fluctuations, with dry years in wetter scenarios producing deliveries comparable to drought conditions, and wet years in drier scenarios temporarily restoring levels similar to the existing conditions. This variability demonstrates that short-term hydrologic conditions can either mask or amplify long-term climate trends.

5.5.3. Groundwater Production

As surface water deliveries decline and consumptive demands increase under climate change, groundwater production must compensate for the widening gap between water needs and available surface supplies. The groundwater system functions as a water supply source and primary buffer against climate vulnerability.

Figure 5-11: Groundwater Production



Average annual groundwater pumping under the existing conditions (T0P100) is 432 TAFY, increasing to 467 TAFY under the T2P100 scenario. Pumping is highly sensitive to temperature, rising approximately 15.6 TAFY for every 1°C of warming. This rate is reflective of the sum of both demand increases and surface water reductions under each climate scenario. Precipitation changes provide modest relief, reducing pumping by 1.0 TAFY for every 1% increase in precipitation.

5.5.4. Supplemental Supplies

Under the no-action climate vulnerability analysis, no supplemental water supplies are identified or modeled. Existing conditions assume continuation of current operational practices without new infrastructure, expanded diversions, or managed aquifer recharge programs. This metric is included in the analytical framework specifically to assess the incremental benefits of potential adaptation strategies, which introduce new water sources through projects such as increasing reservoir storage, expanding conjunctive use, and developing managed aquifer recharge programs. The performance of these supplemental supply strategies under varying climate conditions is evaluated in **Chapter 6**.

5.6. GROUNDWATER BASIN IMPACT ASSESSMENT RESULTS

The groundwater system represents a critical hydraulic and water supply component for the Calaveras River Watershed, supporting agricultural, municipal, and domestic uses. The groundwater budget accounts for all water entering and leaving the aquifer system.

Changes in groundwater pumping due to climate conditions affect groundwater storage and levels as shown in **Table 5-5**. As a result, of hydrologic conditions under climate change and resulting land surface conditions, groundwater storage shows a reduction of 9.5 TAFY for every 1°C temperature increase, and an increase of 1.6 TAFY for each 1% rise in precipitation. Under the T2P100 scenario, it is estimated that the groundwater system will lose an average of 18,200 AFY in storage, leading to a decline of 20 feet over the 50-year simulation period compared to existing conditions. In addition to storage and head impacts, stream aquifer interaction (+4,600 AFY) and subsurface inflows (+ 16,500 AFY) are also expected to increase due to the interconnected nature of system dynamics. Subsurface flow shows a higher impact from climate conditions (about 75% of the impact in groundwater storage) compared to the impact in stream seepage (about 25% of the impact in groundwater storage).

Table 5-5: Groundwater Basin

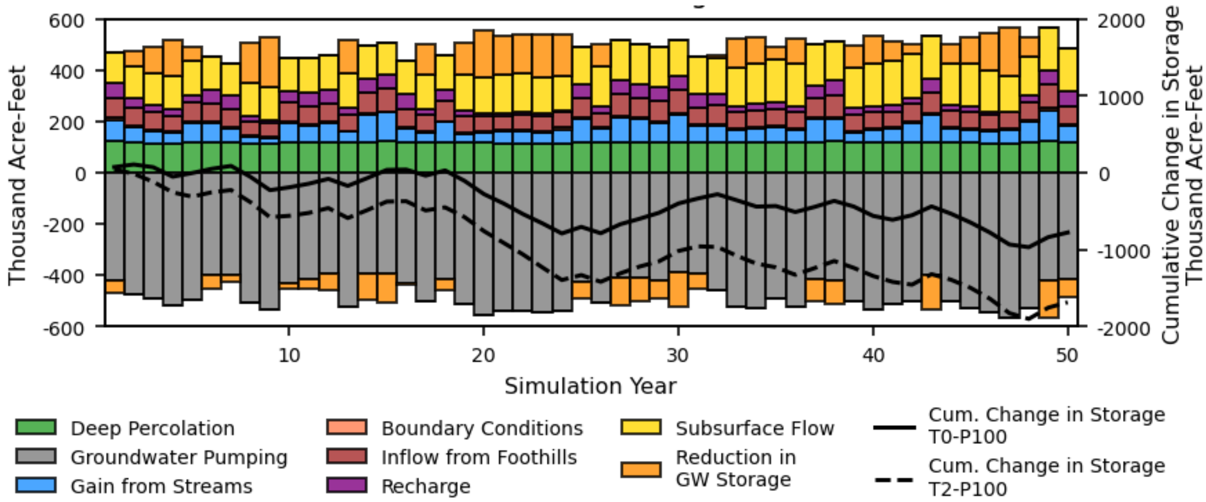
Risk Area	Impact	Key Metric	Most Probable Scenario	Relative Impact
Groundwater Basin	Groundwater Storage	Δ Groundwater Storage	-18,200 AFY (-117%)	↓
	Groundwater Levels	Δ Groundwater Level	-20 feet	↓
	Interconnected Surface Water	Δ Stream-Aquifer Interaction	+4,600 AFY (+8.2%)	↑
	Inter-Watershed Dynamics	Δ Subsurface Inflow	+ 16,500 AFY (+14.0%)	↑

Figure 5-12 shows the groundwater budget components for the T2P100 scenario, as well as cumulative storage for the T2P100 scenario and the T0P100 scenario. Inflows are represented visually on the positive y-axis and outflows on the negative y-axis. The cumulative change in storage is shown in a black line labeled on the secondary y-axis.

In the Calaveras Watershed, groundwater pumping is the largest water budget component and represents the primary outflow from the groundwater system. Deep percolation remains relatively constant throughout the simulation period. Gains from stream seepage increase during wet years, when higher streamflow increases the hydraulic gradient between the streams and the aquifer. Recharge also increases in wet years due to greater streamflow volumes and increased surface water deliveries available for recharge.

Subsurface flow is governed by the hydraulic gradient between the Calaveras Watershed and adjacent basins. At the beginning of the simulation, groundwater levels in the Mokelumne and Stanislaus watersheds are higher than in the Calaveras Watershed, producing a net inflow toward Calaveras. As the simulation progresses and groundwater storage declines within the Calaveras Watershed, this gradient steepens, resulting in increased subsurface inflow from the neighboring basins.

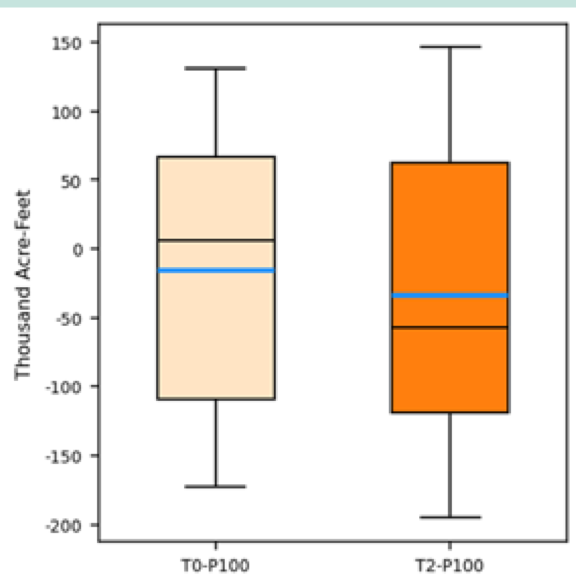
Figure 5-12: Groundwater Budget for Climate Change Conditions (T2P100)



5.6.1. Groundwater Storage

Groundwater change in storage is the difference between inflows and outflows in the groundwater system. Calaveras Watershed, inflows include deep percolation, stream seepage, canal seepage (recharge), subsurface flow from foothills and adjacent subbasins, while the main outflow is groundwater pumping.

Figure 5-13: Groundwater Storage

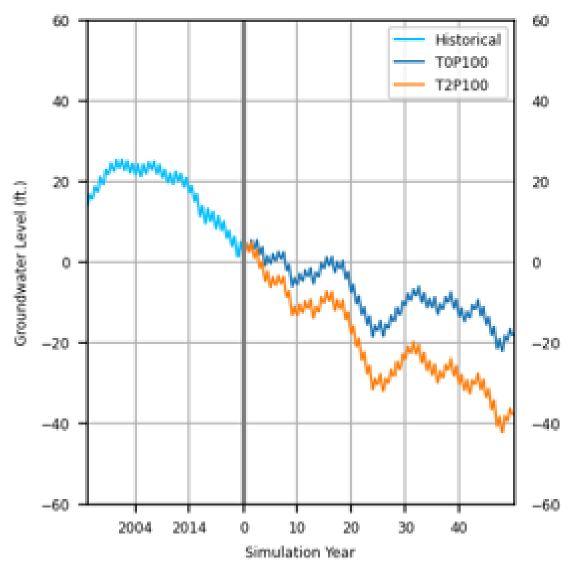


This figure presents the distribution of annual groundwater storage changes under existing conditions (T0P100) as well as 2°C warming, no precipitation change (T2P100). Under the T2P100 conditions, the Watershed experiences an average annual storage deficit of 34 TAF, an increase of 18 TAF when compared to the estimated 16 TAF under existing conditions (T0P100). Interannual variability in storage change also increases under warmer conditions and more extreme hydrology. Under the T2P100 scenario, groundwater storage ranges from +146 TAF to -195 TAF.

5.6.2. Groundwater Levels

The time series of averaged Watershed groundwater levels are shown in **Figure 5-14**. The figure also includes the historical average groundwater level derived from the ESJWRM model used in the GSP. The figure shows a continuing trend of declining groundwater levels for both current and most probable climate conditions, showing higher groundwater level decline under higher temperatures.

Figure 5-14: Groundwater Levels

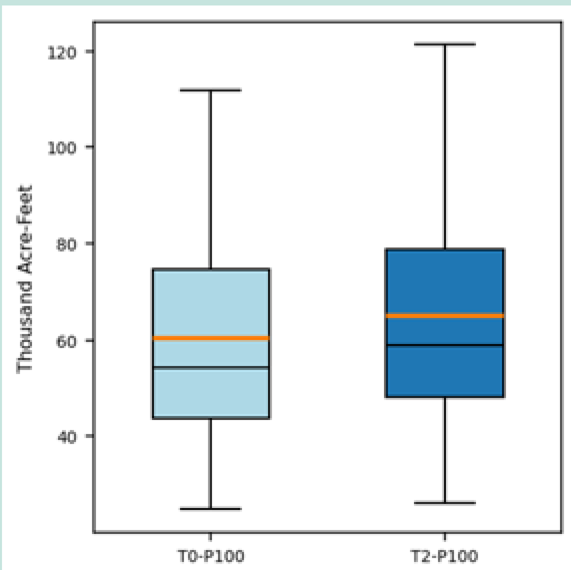


This chart presents averaged groundwater levels in the Watershed for a historical period between 1993 and 2024, and subsequent groundwater levels under existing conditions (T0P100) as well as 2°C warming, no precipitation change (T2P100). In the 50-year simulation period, groundwater levels are expected to decrease 20 feet under the existing conditions, and additional 20 feet under the most probable conditions, as warmer temperatures imply higher water demand from crops, less availability of surface water and more groundwater pumping.

5.6.3. Stream-Aquifer Interaction

In addition to groundwater storage, changes in temperature and precipitation also affect groundwater levels, and as a result, stream aquifer interaction, which depends on the gradient between surface water levels and groundwater levels. In drier scenarios, groundwater levels are expected to decrease, increasing the gradient with respect to surface water levels, and increasing stream seepage to the aquifer. **Figure 5-15** shows the distribution of annual stream seepage to the aquifer across the current climate conditions (T0P100) and the most probable conditions (T2P100). Under the T2P100 scenario stream seepage has an average annual volume of 65 TAF. Stream seepage increases with rising temperature, ranging from 60 TAF in T0P100 scenario to 72 TAF in the T5P100 scenario. Change in precipitation doesn't seem to have a significant effect on stream seepage. Stream seepage increases by approximately 2 TAF annually for each 1°C temperature increase and increases by 0.2 TAF annually for each 1% precipitation increase.

Figure 5-15. Stream-Aquifer Interaction



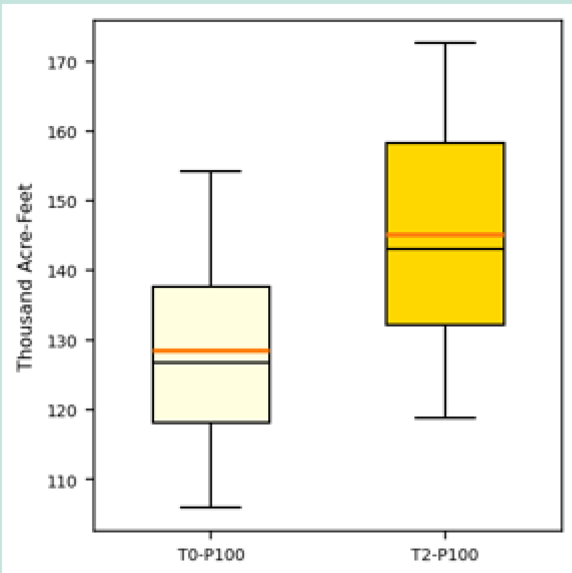
This figure presents the distribution of annual stream-aquifer interaction under existing conditions (T0P100) as well as 2°C warming, no precipitation change (T2P100). Under the T2P100 conditions, the Watershed experiences an average annual stream seepage of 65 TAF, an increase of 5 TAF when compared to the estimated 60 TAF under existing conditions (T0P100).

Interannual variability in stream seepage also increases under warmer conditions. The T2P100 scenario exhibits annual stream seepage ranging from 26 TAF to 121 TAF.

5.6.4. Subsurface Inflow

Changes in groundwater levels also affect inter-watershed flow, as the gradient between groundwater levels change between inter-connected watersheds dictate the direction and magnitude of subsurface flow. Under the most probable climate conditions, groundwater levels within the Watershed decrease, which increases the gradient and, subsequently, the subsurface flow into the Watershed.

Figure 5-16. Subsurface Inflow



This figure presents the distribution of annual inter-watershed flow under existing conditions (T0P100) as well as 2°C warming, no precipitation change (T2P100). Under the T2P100 conditions, the Watershed experiences an average inflow of 145 TAF, an increase of 17 TAF when compared to the estimated 128 TAF under existing conditions (T0P100). Interannual variability in inter-watershed flow also increases under warmer conditions. The T2P100 scenario exhibits annual stream seepage ranging from 119 TAF to 175 TAF.

5.7. WILDFIRE IMPACT ASSESSMENT RESULTS

Wildfire hazards and vulnerabilities in the Watershed were initially quantified by Vibrant Planet using the WildEST modeling tool.[1] Results of this analysis are outlined in detail in Technical Memorandum 4, which is included as **Appendix D**. While climate change is known to increase wildfire frequency and severity, WildEST does not directly account for these impacts. **Chapter 3** discusses the interaction between wildfire and climate change, in addition to their direct effects on hydrology, water quality, and infrastructure vulnerability. The wildfire vulnerability assessment presented in this Plan reflects current landscape conditions and fire behavior rather than climate-driven changes, which is a key limitation of this analysis.

In combination, the content in **Appendix D** and **Chapter 3** provide high-level insight into the Watershed's vulnerability to wildfires under climate change. Future wildfire risk analyses should integrate climate and hydrologic modeling to quantify the combined effects of climate driven wildfire. Future assessments should evaluate how different temperature and precipitation scenarios affect fire probability and post-fire responses. Furthermore, assessments should quantify the risks of wildfire-driven runoff following vegetation loss, increased erosion and sediment loading to streams and reservoirs, and infrastructure exposure in high-risk areas. Understanding wildfire-hydrology interactions would inform adaptation strategies that account for compound climate risks.

[1] Vibrant Planet, 2025

Although Technical Memorandum 4 analyzes several other vulnerabilities, this Plan will assess the impacts and key metrics shown in **Table 5-6**.

Table 5-6: Wildfire Impact Metrics

Risk Area	Impact	Key Metric
Wildfire	Footprint	Burn Probability
	Intensity	Characteristic Flame Length
	Ecosystem	Wildland Health
	Water Resources	Sediment Loading Potential
	Community Safety	Risk to HVRAs

Building off Vibrant Planet's work, the Project Team evaluated wildfire vulnerability and risk in the Watershed based on annual burn probability, characteristic and extreme flame lengths, and the impact of different levels of fire intensity on Highly Valued Resources and Assets (HVRAs), particularly ecosystems, water resources, and community safety. The wildfire risk to each HVRA is a measure of a relative score over a pre-fire baseline. This is in alignment with how climate change vulnerability and risk are also evaluated in this study but adapted for metrics that are more meaningful to wildfire.

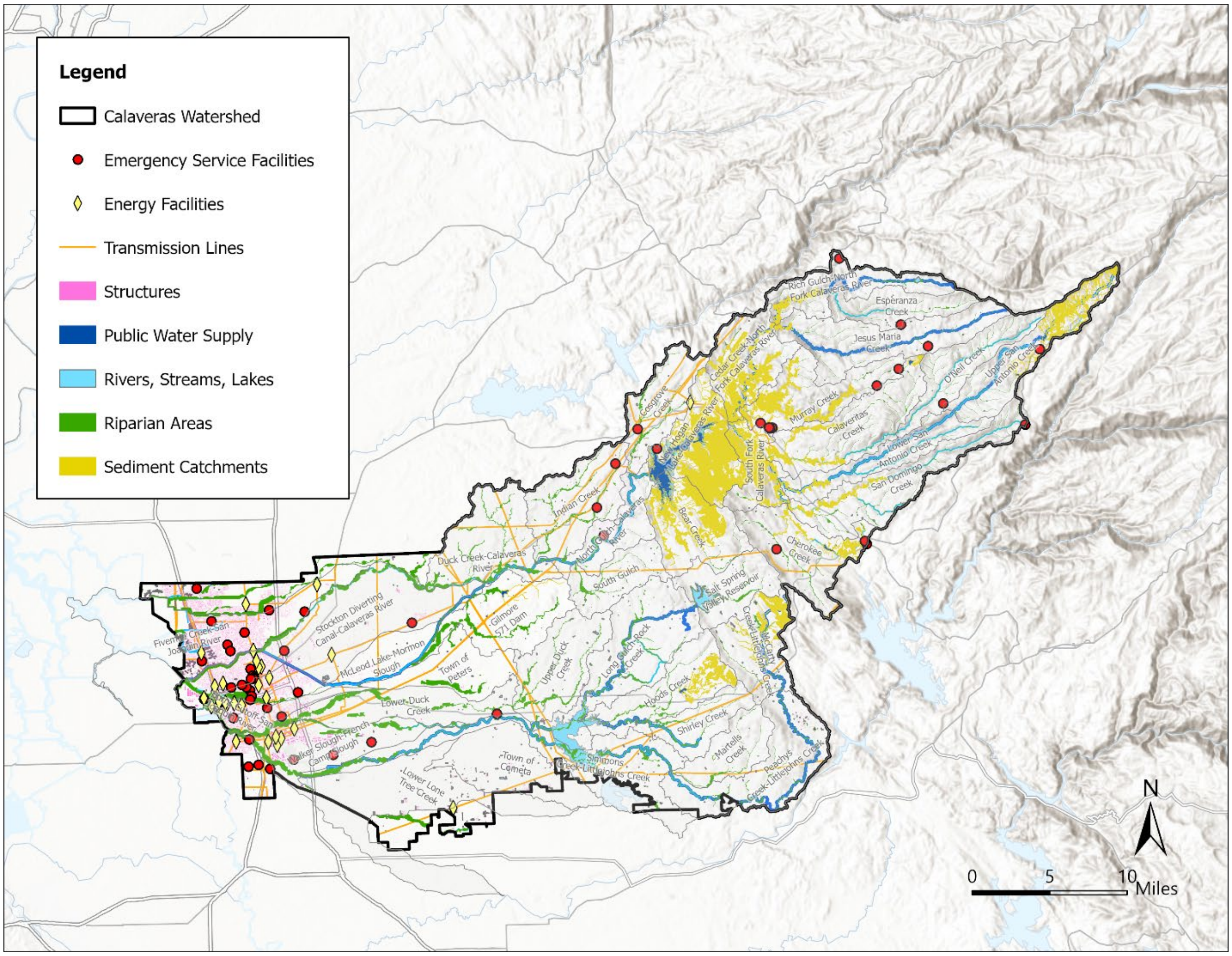
Major differences in topography and land use patterns drive contrasting vulnerabilities to the direct and indirect effects of wildfire between the two sub watersheds. The upper Watershed is dominated by dense forests and vegetation on steep terrain, making ignition more likely and suppression more difficult.[1] In contrast, the lower Watershed is dominated by irrigated agriculture and residential areas with little vegetation, preventing fires from easily igniting or spreading. Furthermore, the lower Watershed's flat terrain means that firefighting requires less specialized equipment and is less demanding in comparison. Due to these factors, burn probabilities and wildfire intensity are higher in the upper Watershed, leading to increased vulnerability of HVRAs in the area. While the lower Watershed is not particularly vulnerable to direct wildfire impacts, it does face indirect effects such as wildfire-induced runoff on surface water quality.

[1] Vibrant Planet, 2025

Table 5-7: Highly Valued Resources and Assets

Risk Type	Name	Summary
Assets	Energy Facilities	Power Plants, Power Substations
Assets	Structures	Buildings larger than 430 square feet
Assets	Transmission Lines	Transmission Lines
Safety	Emergency Service Facilities	Local Law Enforcement locations, Hospitals, Fire Stations
Safety	Structure Transmission Zone	Wildland areas with potential to expose nearby homes to fire
Safety	Wildland Urban Interface	Quarter-mile defense zone around structures
Water	Lakes	Non-flowing, contained water bodies including perennial reservoirs
Water	Perennial Rivers and Streams	Water flow lines that are perennial in nature
Water	Public Water Supply	Lakes and Reservoirs with use for public drinking water supply
Water	Water Supply Sediment Catchments	Areas of a landscape that could contribute sedimentation to specific waterbodies
Wildlands Health	Riparian Areas	Areas adjacent to water sources where ecosystem function is influenced by aquatic ecosystem

Figure 5-17: Highly Valued Resources and Assets in the Watershed



5.7.1. Footprint and Intensity

Higher annual burn probabilities are found in areas that haven't burned recently and are outside of the more populated areas, concentrated in the upper Watershed. Once a fire ignites, mean characteristic flame length describes the average intensity of the fire. The highest mean characteristic flame length in some parts of the upper Watershed is greater than 8 feet, indicating the fire may burn very hot, killing mature trees and consuming under-story and surface fuels. Under the near-worst fire conditions, much of this area of the Watershed has flame lengths of more than 12 feet, which indicates high severity conditions with scorch heights that exceed the tree height and nearly all mature trees in an area can be killed. The decimation of dense forested areas can cause increased runoff, leading to flooding and impacts to surface water quality.

Figure 5-18 shows the annual burn probability across the Calaveras Watershed. Characteristic Flame Length (CFL) represents the mean weighted flame length expressed in feet. Characteristic flame length can be expressed for any set of fire hazard weather conditions. Flame lengths are grouped into the following intensity classes: >0-2 ft, >2-4 ft, >4-6ft, >6-8ft, >8-12 ft, and greater than 12 ft, as shown in **Figure 5-19**. Extreme fire behavior is exemplified as 95th percentile flame length, which ranges from less than 10 feet to over 100 feet in particularly fire-prone areas of the Watershed (**Figure 5-20**).

Figure 5-18. Annual Burn Probability

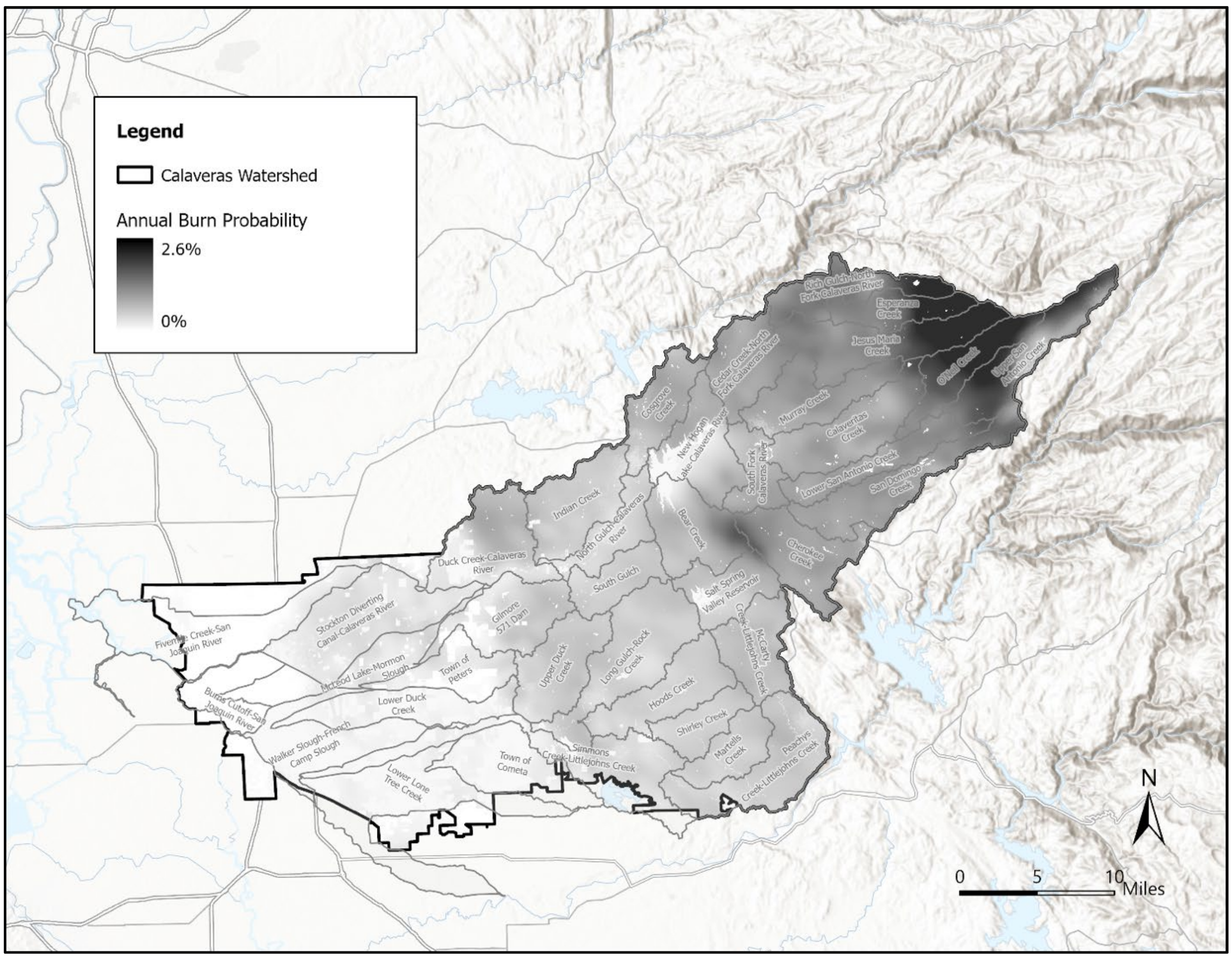


Figure 5-19: Typical Fire Behavior – Mean Flame Length

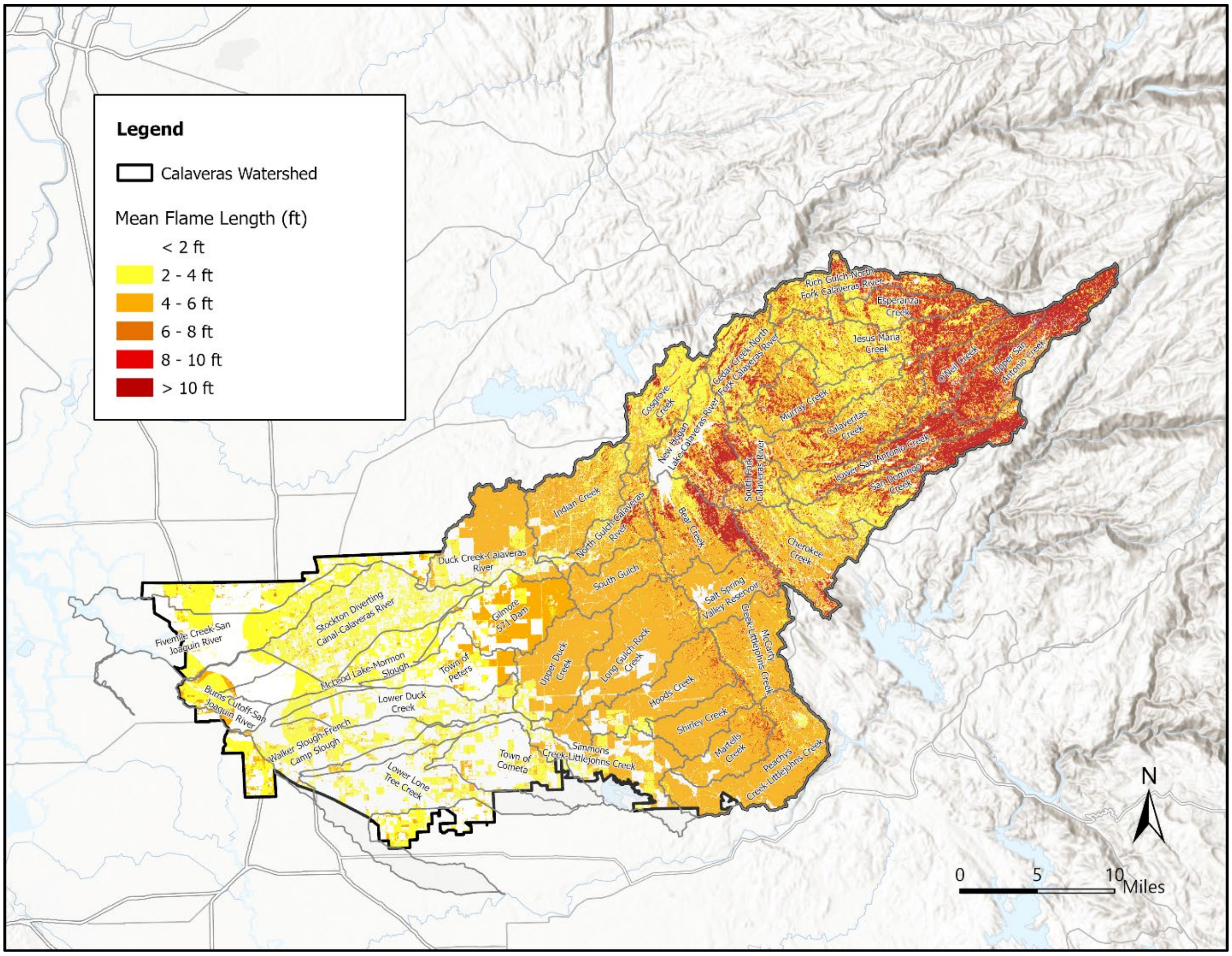
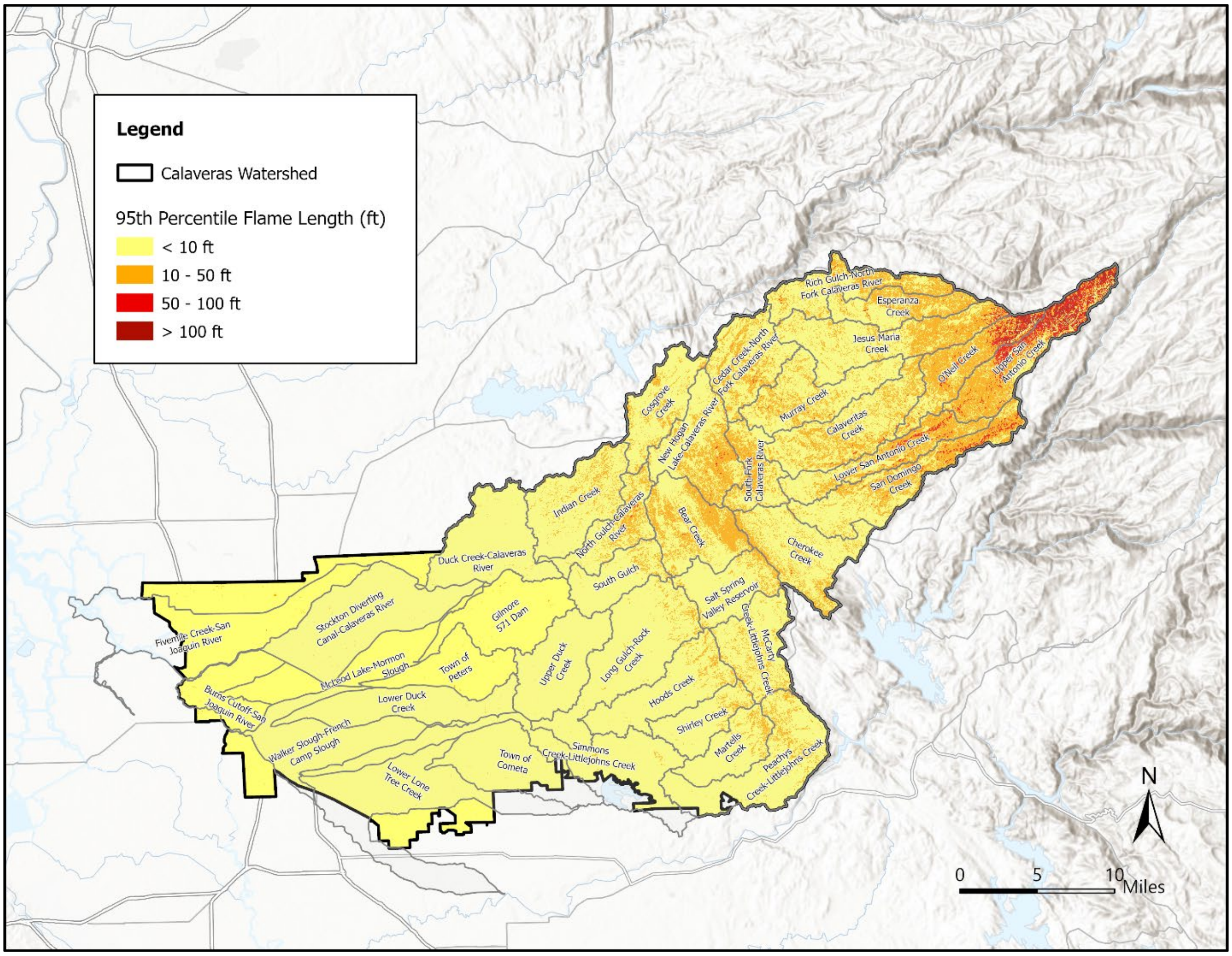


Figure 5-20: Extreme Fire Behavior – 95th Percentile Flame Length

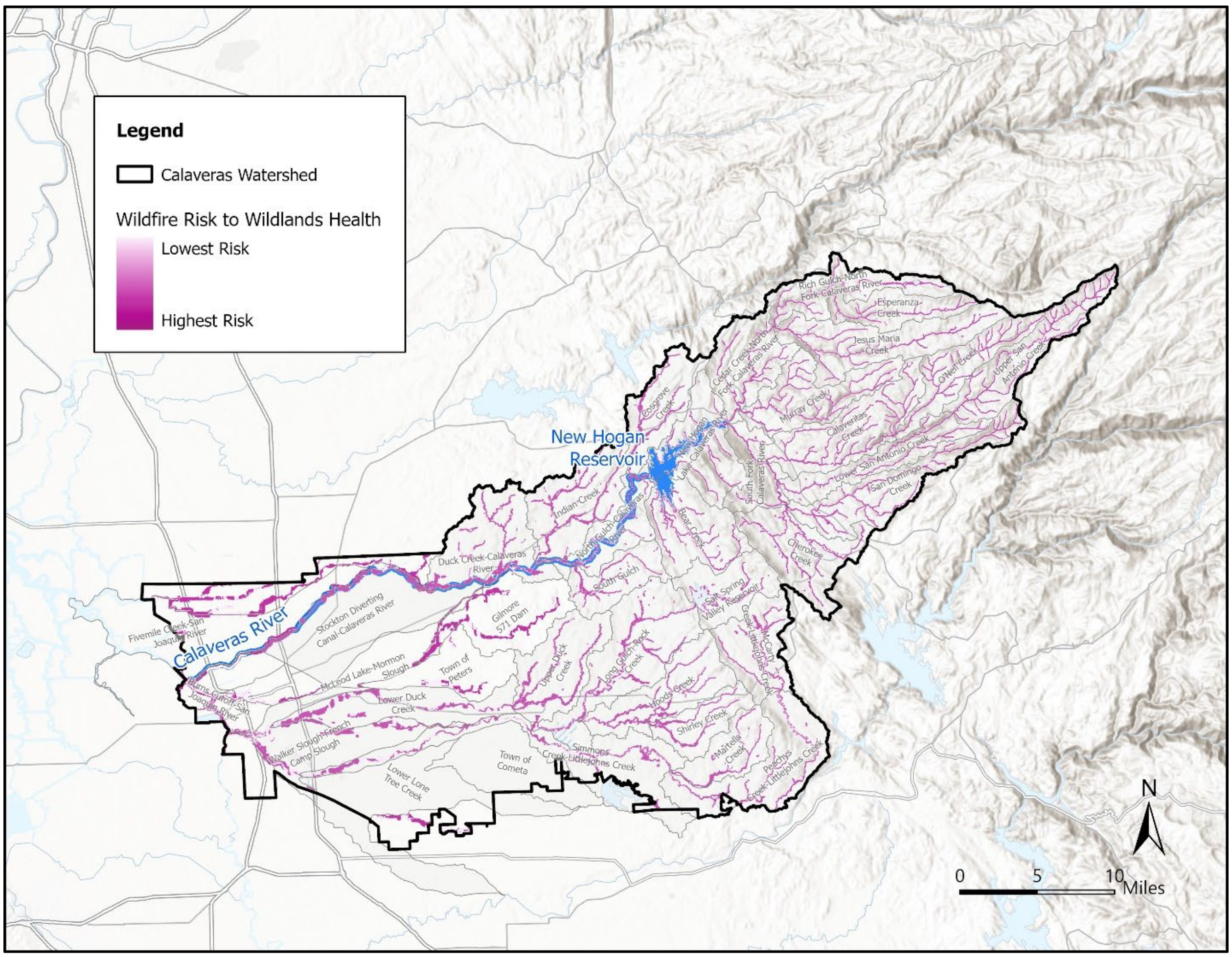


5.7.2. Ecosystems

The Wildlands Health HVRAs encompass plant associations or factors that represent ecosystem health, function, or resilience, particularly in riparian areas. Riparian areas include areas on the landscape adjacent to water sources where the ecosystem function is influenced by nearby aquatic ecosystems. As shown in **Figure 5-21**, risks to ecosystem and wildlands health are distributed throughout the Watershed on riparian corridors.

As discussed in **Section 5.7**, the upper Watershed and its wildlands are prone to direct fire impacts, while the lower Watershed is highly vulnerable to surface water quality issues from wildfire-induced runoff. Riparian corridors in the lower Watershed are at higher risk of these issues due to their topographic position downslope within the Watershed and the compounding effects of erosion, stormwater runoff, and ash deposits which can result in elevated risks to wildlands despite lower direct vulnerability to wildfire.

Figure 5-21: Wildfire Risk to Wildlands Health

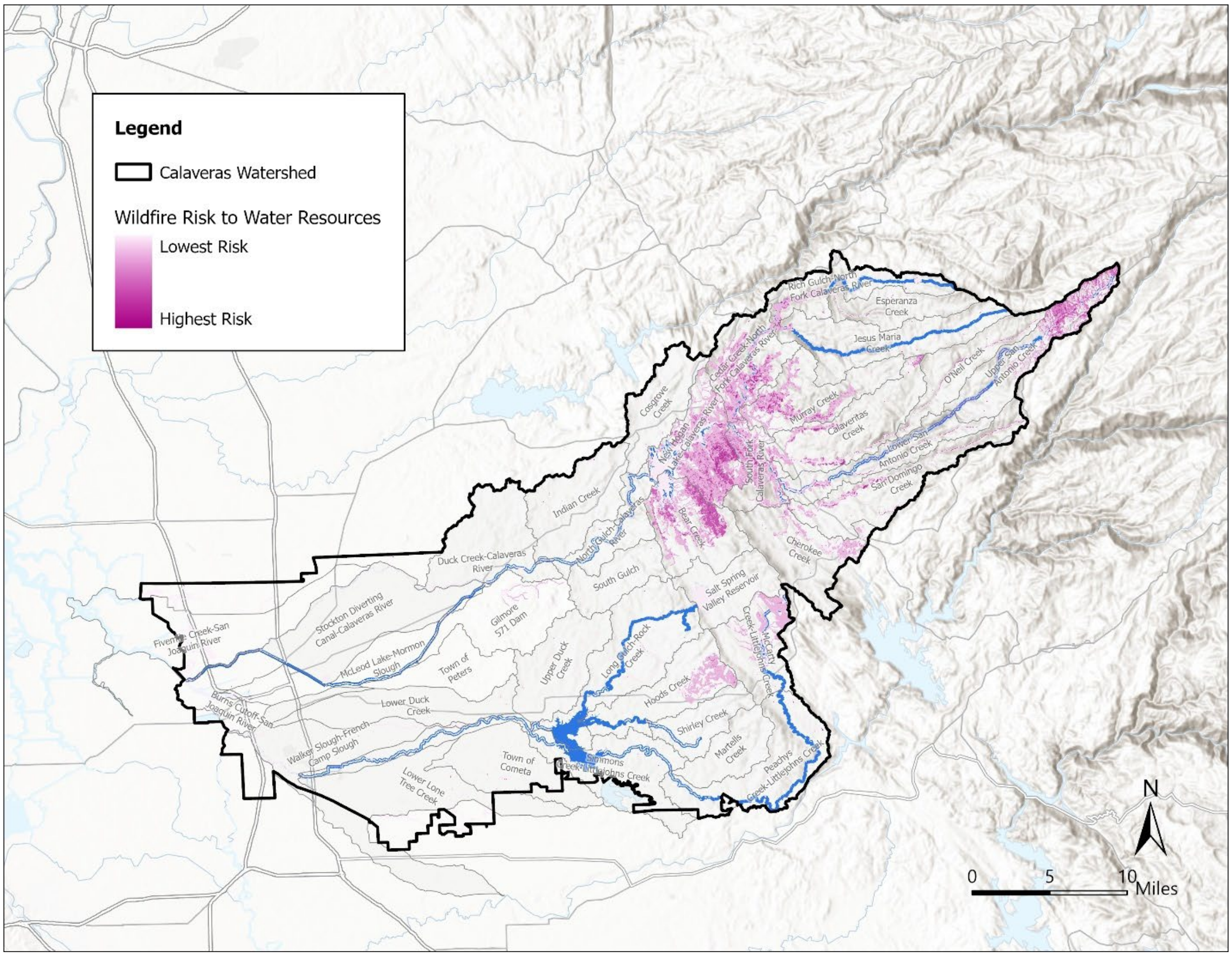


5.7.3. Water Resources

Water Resources HVRAs represent surface water features and flows across the landscape as well as resources or areas that can be impacted by post-disturbance erosion or sedimentation. Lakes encompass all non-flowing, contained water bodies and include reservoirs that perennially contain water. The Perennial Rivers and Streams HVRA represents water flow lines that are perennial in nature and does not include intermittent or ephemeral streams. The Public Water Supply HVRA and associated Sediment Catchments for Water Supply HVRA are waterbodies identified as contributing to the public drinking water supply.

Figure 5-22 shows the combined risk to water resources HVRAs. The highest risk to public water supplies are concentrated in the upper Watershed, surrounding the upstream portion of New Hogan Reservoir where tributaries flow into the reservoir and the majority of the sediment catchments are located.

Figure 5-22: Wildfire Risk to Water Resources

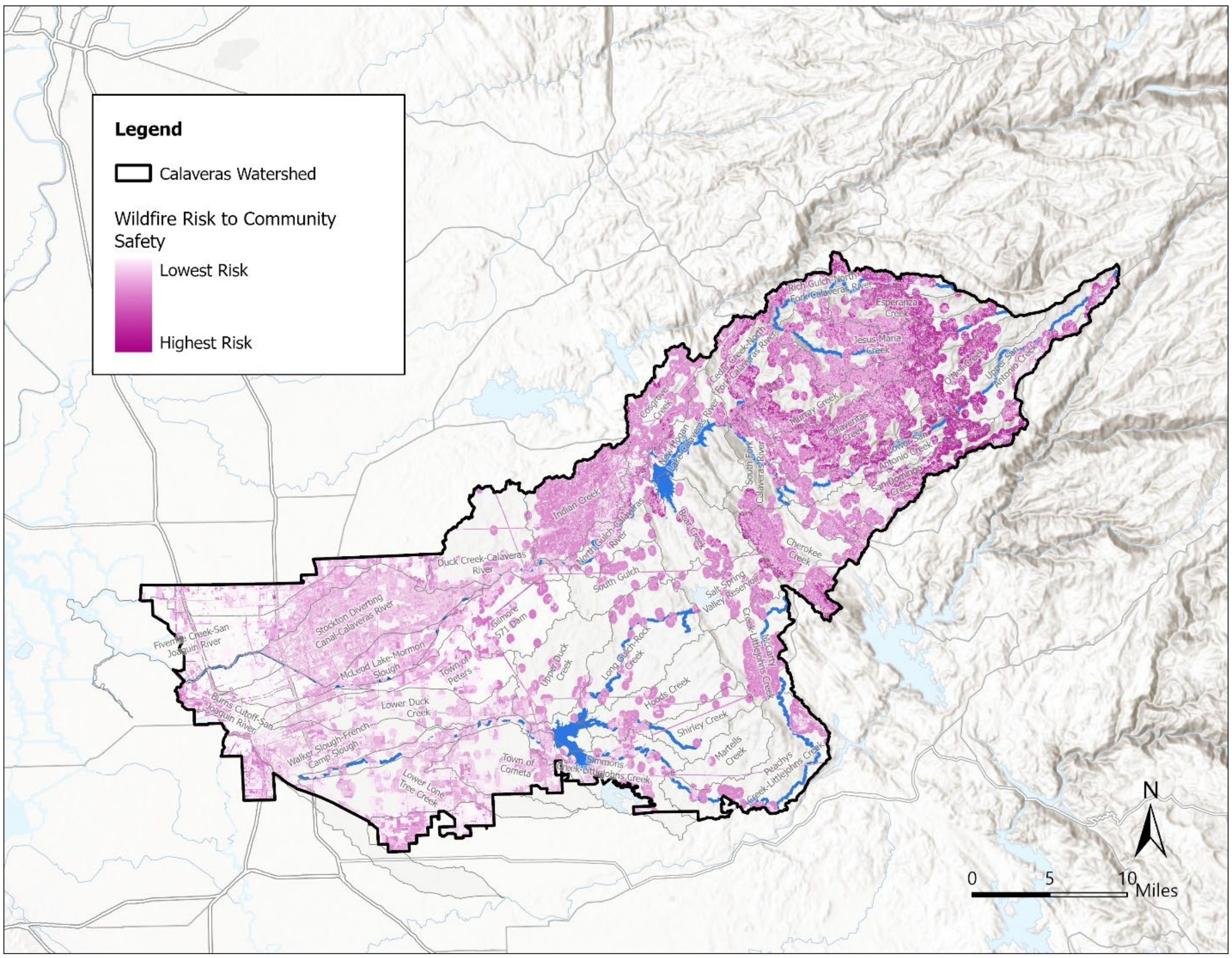


5.7.4. Community Safety

The Wildland Urban Interface (WUI) is the transition zone between human development and undeveloped lands where structures or other human development intermingle with areas of wildland or vegetative fuels. Community Safety HVRAs include first responder facilities that are essential to emergency services. The Structure Transmission Zone is made up of managed wildland areas that are of interest solely due to their potential to expose nearby structures to fire. Specifically, this data provides an estimate of how many structures annually could be exposed to wildfire regardless of point of ignition.

Risk to community safety, shown in **Figure 5-23**, is present throughout the Watershed but varies in character between upper and lower areas. The lower Watershed, including areas near Stockton, contains a higher absolute number of structures at risk due to greater population density. However, the upper Watershed exhibits higher risk intensity per structure, as homes are surrounded by dense burnable vegetation with limited defensible space, higher fire intensities, and more challenging suppression conditions due to steep terrain and limited access.

Figure 5-23: Wildfire Risk to Community Safety



5.8. SURFACE WATER QUALITY IMPACT ASSESSMENT RESULTS

Surface water pollution in the Watershed is driven by runoff from wildfires and agriculture, since the upper and lower Watersheds are dominated by forested and agricultural lands. Another area of concern is elevated stream temperatures, which detrimentally affect fish habitat in the lower reaches of the river. Climate change may indirectly impact surface water quality via wildfire-influenced erosion. Furthermore, changes in reservoir storage due to climate change have an association with stream temperatures, particularly directly downstream of the reservoir. The key metrics to assess surface water quality impacts are outlined in **Table 5-8**.

Table 5-8: Surface Water Quality Impacts

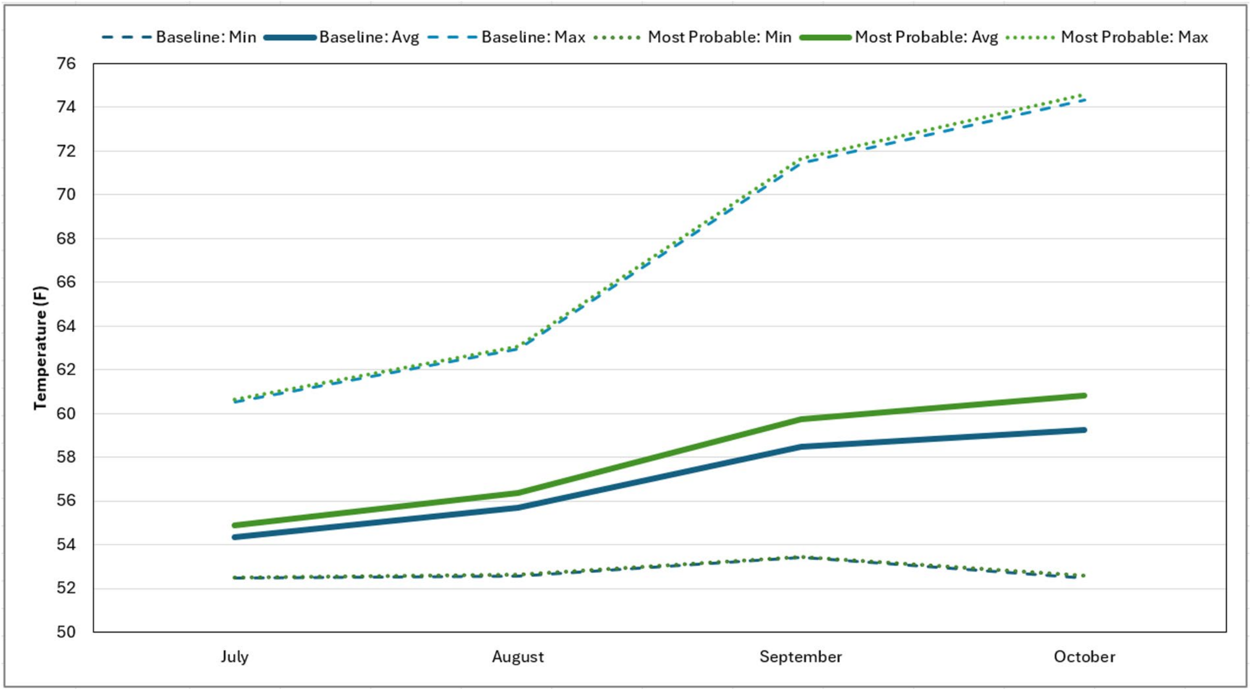
Risk Area	Impact	Key Metric	Relative Impact
Surface Water Quality	Environmental Water Quality	Temperature (Proxy: Stream Stage and Storage)	↑
		Constituent Transport (Proxy: Runoff)	↑
		Sediment Yield (Proxy: Erosion Rates)	↑

5.8.1. Temperature

Figure 5-24 shows simulated stream temperature at just below New Hogan Dam, by month during the critical rearing period (July to October) across 100 years of simulated storage for the "Most Probable" climate change scenario (green) against the existing conditions scenario (dark blue). There is a 1ºF to 2ºF increase in stream temperature under this climate change scenario. Those increases are larger in the late summer months. The minimum and maximum stream temperatures across the full hydrology period are similar under climate change conditions compared to the existing conditions scenario. Boxplots showing the results of all 15 scenarios for August and September are shown in Technical Memorandum 3, included as **Appendix F**.

The analysis indicates that climate change could increase water temperatures in the Calaveras River by approximately 1°F to 4°F at the base of New Hogan Dam, with warming trends most pronounced between July and October. Under high-precipitation scenarios, increased reservoir storage may help mitigate temperature rises more effectively than atmospheric changes alone. However, these estimates likely represent minimum impacts, as they do not account for additional downstream warming from ambient air exposure, suggesting that actual temperature increases along the river could be even greater. As discussed in Technical Memorandum 3, included as **Appendix F**, anadromous fish populations are highly vulnerable to increases in stream temperature, particularly during spawning season.

Figure 5-24: Stream Temperature



5.8.2. Constituent Transport Potential

Results of the hydrologic modeling indicate sub-watersheds in the upper Watershed where runoff is expected to change under climate change (Technical Memorandum 2 in **Appendix E**). The scale of this analysis was extended across the full Watershed to evaluate potential impacts to water quality under climate change because increased runoff may have implications for the mobilization of contaminants from known point and non-point sources. A spatial overlay analysis indicates which sub-watersheds may be vulnerable to these anticipated changes under the most probable scenario (T2P100) in relation to potentially high-risk water quality sites (Technical Memorandum 1 in **Appendix C**).

A 2021 Sanitary Survey identifies specific risk differences between different contaminant sources within the Calaveras River Watershed. These are shown in **Table 5-9** and provided guidance for what vulnerabilities to focus on in this Plan's vulnerability assessment to align these two studies. The highest potential risks, in terms of treatability and runoff concerns, are from livestock, recreation, wastewater discharge, wildfires, and wildlife.

Table 5-9: Risk Associated with Contaminant Sources

Watershed Activities	Potential Risk
Forestry	Low
Irrigated Agriculture and Pesticide Use	Low
Livestock	Medium
Mining	Low
Recreation	Medium
Solid and Hazardous Wastes	Low
Urban Runoff and Spills	Low
Wastewater	Medium
Wildfires	High
Wildlife	High

Level of potential risk associated with observed land uses and activities. Risk primarily based on treatability concerns (e.g., pathogens being a higher risk than particulates) as well as the potential for the contaminant to enter waterbodies.

Figure 5-25 shows the sub-watersheds with anticipated increases or decreases in average annual runoff under the most probable climate scenario, overlaid with impaired water bodies and various known degraded water quality sites including:

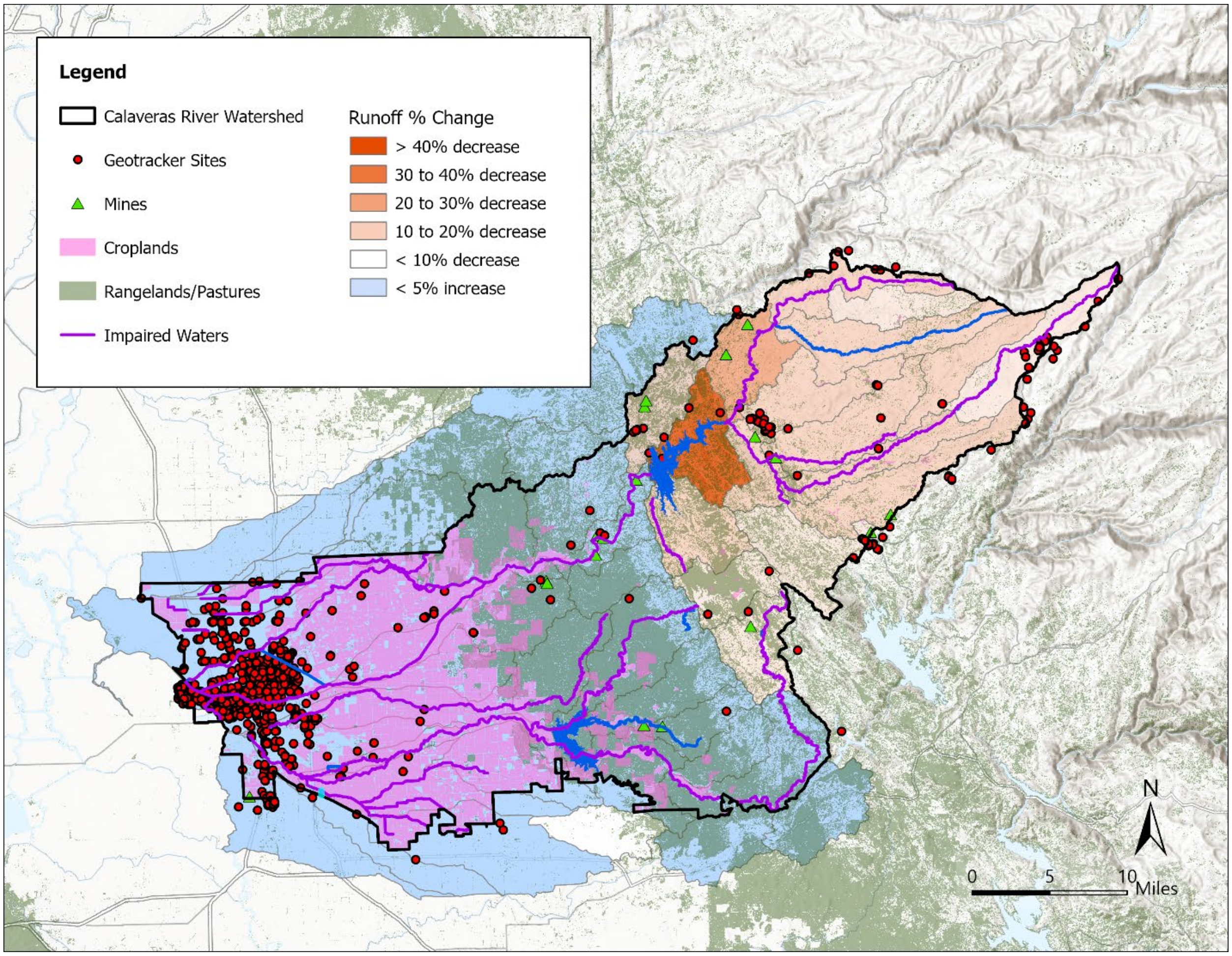
- Active clean-up sites regulated by the State Water Resources Water Quality Control Board (labeled "Geotracker Sites" in the figure)
- Active and former mining sites known to the California Department of Conservation
- Current rangelands and animal feeding operations alongside impaired waters, specifically for ammonia and indicator bacteria.

Given the increases in average annual runoff forecasted for the lower Watershed due to climate change, bodies already listed as impaired under Section 303(d) of the Clean Water Act will be challenged to make progress toward meeting TMDL targets.[1] Additional runoff introduces higher loads of nutrients, sediments, and pollutants, which push contaminant levels beyond the limits established in TMDL allocations. This not only delays restoration efforts but can necessitate recalculating TMDLs, imposing stricter limits on point and nonpoint sources, and increasing regulatory and treatment costs. Ultimately, the added pollutant burden makes compliance more complex and prolongs the recovery timeline for impaired waters.

As shown in the figure below, average annual runoff in the upper Watershed is expected to decrease, which may indicate that constituent transport will decrease. However, this analysis did not consider extreme precipitation events which will increase under climate change conditions. These extreme precipitation events will cause large flows that can carry accumulated constituents from the upper Watershed. Because of these accumulated constituents, water quality in the initial flows of these extreme events is likely to have severely degraded water quality that can further stress ecosystems and treatment systems downstream.

[1] U.S. EPA, 1972

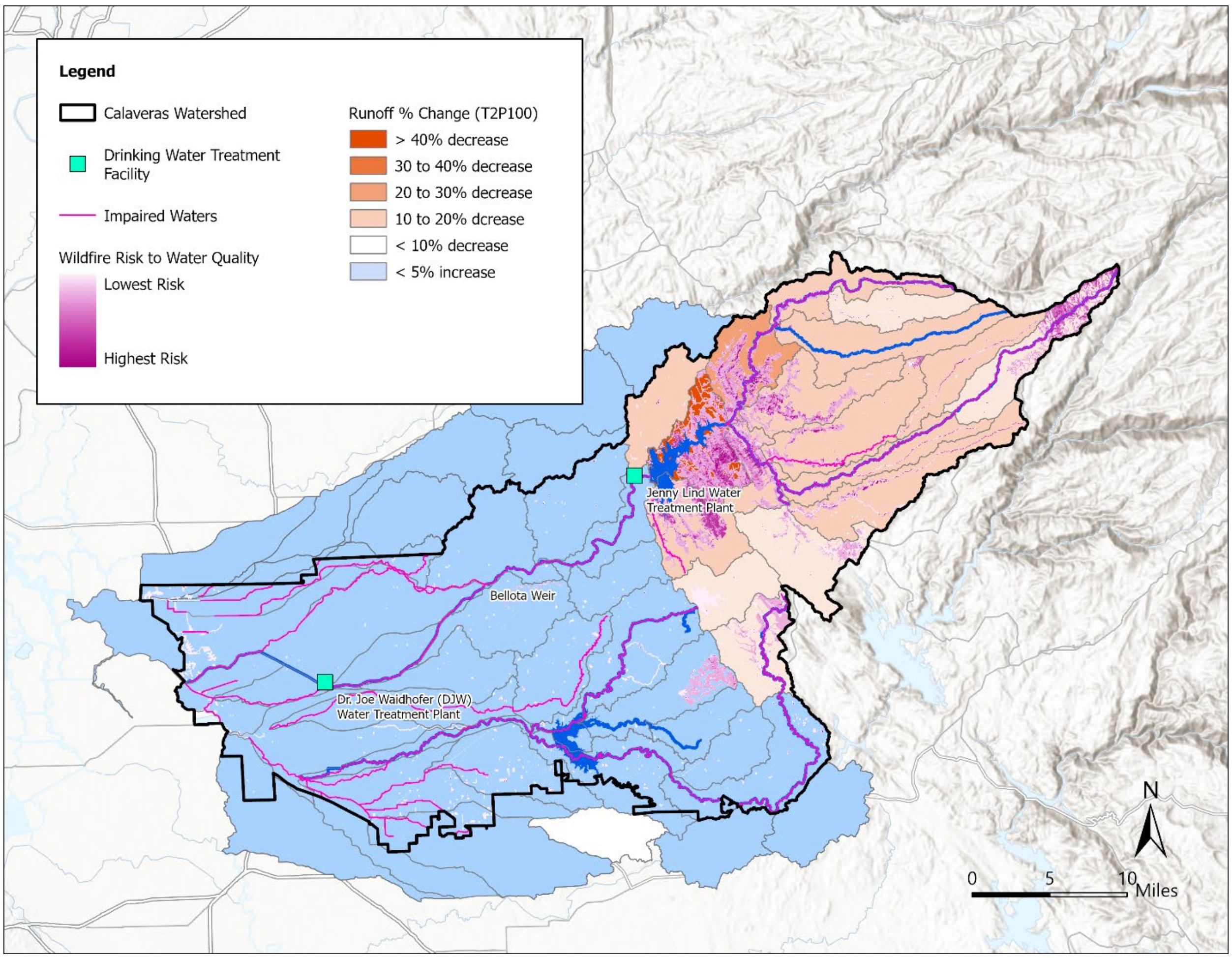
Figure 5-25: Water Quality Vulnerability



5.8.3. Sediment Yield: Wildfire Impacts on Water Quality

While not explicitly modeled in this study, wildfire also poses a risk to water quality. Runoff from wildfire can cause increases in sediment transport and turbidity through erosion of recently burned topsoil, excess nutrients, heavy metals and other toxic elements, volatile organic compounds (VOCs), among many other contaminants. Increased sediment yield after wildfire may result in detrimental effects on water quality in the streams and reservoirs of the Watershed, which may require active salt and nutrient management by resource agencies. **Figure 5-26** shows a spatial overlay between risk to water resources for runoff changes under climate change determined in this study's hydrologic modeling, and key public water supply facilities. Runoff is expected to decline under climate change in all sub-watersheds surrounding New Hogan. However, any runoff that does occur post-fire may likely be absorbed by the New Hogan reservoir system and eventually end up posing a challenge at Jenny Lind Water Treatment Plant.

Figure 5-26: Wildfire Risk to Surface Water Quality



5.9. ECONOMIC IMPACT ASSESSMENT RESULTS

When considered holistically, the projected impacts from the six other risk categories result in compounded impacts across all risk categories. In combination, these impacts are likely to negatively influence the Watershed's economy, impacting agricultural, forestry, recreation, and urban sectors (**Table 5-10**). These are discussed in further detail in the following sections.

Table 5-10: Economic Impact Areas

Risk Area	Impact	Key Metric
Economy	Agriculture	Indirect
	Urban	Indirect
	Forestry & Recreation	Indirect

5.9.1. Agriculture

The agriculture industry has a major impact on the economy of the Watershed, particularly in San Joaquin County. [1]Although agricultural employment has declined in the last decade (5% of San Joaquin County's work force), gross agriculture revenue has doubled in the same period.[2] The region's shift toward high-value permanent crops such as almonds, walnuts, and vineyards has increased economic productivity but has also heightened vulnerability to water supply variability. Unlike annual crops that can be fallowed during drought years, permanent crops require consistent irrigation to maintain tree health and productivity, creating inflexible water demands that place greater stress on groundwater and surface water supplies during extended dry periods. Climate change is expected to cause extreme water shortages during extended periods of drought, increasing the vulnerability of the agricultural industry. Growing uncertainty in water availability would thus have negative impacts on San Joaquin County's entire economy. Calaveras County has a much smaller agricultural economy than San Joaquin County; however, in the case of severe water shortages, Calaveras County could experience similar effects on a smaller scale.

5.9.2. Urban

As discussed in **Chapter 1**, the lower Watershed expects high rates of population growth, particularly in urban and suburban areas near the City of Stockton. San Joaquin County's population is projected to grow from approximately 780,000 in 2020 to over 950,000 by 2050, representing a 22% increase over the planning period.[3] Population increases will impact water demands, requiring demand management programs or other strategies to ensure adequate municipal water supply during dry periods. Furthermore, population growth is likely to increase rates of urbanization and development, leading to more impermeable surfaces and increasing flood risk. Increased population pressures may also push development into WUI areas, potentially increasing community exposure to wildfire hazards.

Additionally, energy production from the New Hogan Power Plant relies on Calaveras River flow, so changes to flow patterns may impact power production. While a more refined power analysis would need to be conducted, reservoir modeling conducted as part of this Plan shows minimal impact to releases, so it can reasonably be assumed that risks to hydropower are relatively low. Finally, communities already experiencing financial stress—particularly DACs—tend to bear an outsized burden of climate change

[1] University of the Pacific, 2024; San Joaquin County, 2023

[2] San Joaquin County Data Compass, 2023b

[3] United States Census Bureau, 2020; San Joaquin Council of Governments, 2023

impacts due to reduced adaptive capacity and limited access to resilience-building resources. This is discussed in more detail in **Section 5.10**.

5.9.3. Forestry and Recreation

Calaveras County has a significant history of logging and forestry.[1] Although the industry has declined in recent decades, Sierra Pacific Industries (SPI) owns approximately 70,000 acres of forested land within the county. Furthermore, the Bureau of Land Management and United States Forest Service own and manage over 50,000 acres of forested land within the upper Watershed.[2] In addition to private and public forestry, there are many recreational areas and open spaces in the upper Watershed, including Big Trees State Park, White Pines Lake, and New Hogan Reservoir.[3] White Pines Lake and New Hogan Reservoir are popular locations for recreational aquatic activities including fishing.[4]

The forested areas in the upper Watershed are vulnerable to the impacts of wildfire. The downstream effects of severe wildfires can lead to many economic issues, such as decreased home values and higher insurance costs. Additionally, destruction caused by wildfires is likely to have a negative impact on the upper Watershed's recreational economy by preventing and otherwise decreasing visitation. While a specific climate vulnerability metric is not assigned to recreation, the impacts described above can reasonably be assumed to affect recreational use and associated economic activity under future climate conditions.

The anticipated future volatility of surface water temperatures in certain reaches of the Calaveras River may be detrimental to anadromous fish populations (**Section 5.8.1**). A decline in anadromous fish populations would not have a major impact on the regional economy, as there are no commercial fisheries in the Watershed, but it might cause minor impacts to the recreational economy. Detriments to fish populations would increase compliance and management costs for SEWD under the HCP. Climate change is expected to result in higher rates of runoff (Technical Memorandum 2 in **Appendix E**), which may mobilize contaminants from different sources. Increased runoff of contaminants into waterways may increase operational costs for local water treatment plants and industrial facilities to maintain compliance under the Clean Water Act and other environmental regulations.

5.10. ASSESSMENT RESULTS AND EQUITY

While climate change impacts will be felt across the Watershed, DACs and other underrepresented communities (URCs) are likely to feel these impacts more acutely, amplifying existing socioeconomic vulnerabilities. As shown in **Figure 1-4**, DACs within the Watershed are found in the City of Stockton and in the upper Watershed. The assessment results outlined in the preceding sections point to several important observations about how climate change intersects with equity:

- Increasing ambient temperatures disproportionately impact populations without access to air-conditioned spaces, including DACs and unhoused populations. Heat stress and heat-related illness are a growing concern during the summer months.
- For DACs served by municipal water systems, climate-related supply constraints may be shared across all customers. However, given that rate increases will likely be required to implement climate adaptation strategies, the financial burden of these increases is not felt equally; households with lower incomes experience greater economic stress from rate adjustments.
- For DAC households that rely on private domestic wells, declining groundwater levels pose a significant concern. Limited financial resources constrain households' ability to deepen wells, connect to alternative water supplies, or invest in resilience measures.

[1] Sierra Nevada Logging Museum, 2025
[2] Vibrant Planet, 2025
[3] Calaveras Visitors Bureau, 2025
[4] California Department of Fish and Wildlife, 2025

- Flooding, while affecting all residents living in flood-prone areas, poses particular challenges for DACs. These communities are more vulnerable to the increased costs associated with mitigating flood risk (e.g., elevating structures), paying higher insurance premiums, or managing post-flood cleanup and recovery.
- Climate-driven increases in wildfire frequency and severity can have outsized impacts on DACs, where limited capacity to invest in defensible space, property hardening, and post-fire recovery exacerbates existing economic vulnerability.

5.11. WATERSHED WATER BUDGET

The water budget analysis presented in **Table 5-11** shows both existing conditions (T0P100) and climate change conditions (T2P100). These scenarios represent 50-year simulation periods, representing the 1969-2018 hydrologic period. All values are expressed as annual averages over the 50-year period and are reported in acre-feet.

The T0P100 climate condition assumes no change to the hydrologic conditions observed between 1969 and 2018. In contrast, the T2P100 climate condition incorporates a 2°C increase in temperature across the entire Watershed, reflecting projected climatic warming. The water budgets for other climate change scenarios are part of Technical Memorandum 2, included as **Appendix E**.

Table 5-11. Watershed Water Budget

		T0P100 (Acre-Feet)	T2P100 (Acre-Feet)
Upper Watershed Total Water Budget[1]			
Inflow	Precipitation	846,000	848,000
Outflow	Evapotranspiration	611,000	629,000
	Stream Inflow – Calaveras River	156,000	144,000
	Stream Inflow – Small Streams[2]	12,000	12,000
	Subsurface Flow – Lower Watershed	70,000	69,000
	Model Discrepancies[2]	-3,000	-6,000
Storage Change	*Change in Storage*	*0*	*0*
Land Surface System			
Inflow	Precipitation	449,000	450,000
	Surface Water Deliveries – Local	40,000	38,000
	Surface Water Deliveries – Import[3]	79,000	65,000
	Groundwater Extraction – Local	432,000	467,000
	Riparian Uptake from Stream	3,000	3,000
Outflow	Evapotranspiration	536,000	555,000
	Runoff	301,000	303,000
	Return Flow	46,000	45,000
	Recharge – Applied Water and Precipitation	118,000	118,000
Storage Change	*Change in Storage*	*2,000*	*2,000*
Surface Water System			
Inflow	Stream Inflow – Calaveras River	156,000	144,000
	Stream Inflow – Small Streams	12,000	12,000
	Stream Inflow – San Joaquin River	2,737,000	2,534,000
	Runoff	301,000	303,000
	Return Flow	46,000	45,000

		T0P100 (Acre-Feet)	T2P100 (Acre-Feet)
Outflow	Stream Outflow – San Joaquin River	3,131,000	2,920,000
	Stream Loss to Groundwater	60,000	65,000
	Surface Water Deliveries – Local	40,000	38,000
	Conveyance Loss to Groundwater	40,000	35,000
	Conveyance Evaporation	2,000	2,000
	Riparian Uptake from Stream	3,000	3,000
Storage Change	*Change in Storage*	*0*	*0*
Groundwater System			
Inflow	Subsurface Flow – Other Watersheds	132,000	151,000
	Subsurface Flow – Upper Watershed	70,000	69,000
	Recharge – Applied Water and Precipitation	118,000	118,000
	Recharge – Managed[4]	0	0
	Groundwater Gain from Stream	60,000	65,000
	Groundwater Gain from Conveyance	40,000	35,000
Outflow	Groundwater Extraction – Local	432,000	467,000
	Groundwater Extraction – Export	4,000	5,000
Storage Change	*Change in Storage*	*-16,000*	*-34,000*

1. The upper Watershed area analysis includes catchments contributing to the New Hogan reservoir and small streams catchments (Duck Creek, Rock Creek, Littlejohns Creek) that are outside of the model domain of the CWRP Model. The Land Surface, Stream and Groundwater systems, on the other hand, are analyzed in the Calaveras Watershed area inside the CWRP Model domain.

2. Upper Watershed flows are estimated by the Sacramento Soil Moisture Accounting Model (SAC-SMA), while the Lower Watershed flows are estimated by the CWRP model, an application of IWFM. The two models have different baseline assumptions, particularly related to evapotranspiration, which are more pronounced under high-temperature scenarios.

3. Imported water includes surface water supplies sourced from outside of the Calaveras River Watershed and may include water sources from the Mokelumne and/or Stanislaus River.

4. Includes recharge from local stream systems and imported recharge water from the Mokelumne and/or Stanislaus River Watersheds.

5.12. SUMMARY OF SUB-WATERSHED VULNERABILITIES

The vulnerabilities identified within the Calaveras River Watershed are fundamentally interdependent and should be evaluated as a cascading series of impacts. Primary climate drivers such as rising temperatures and shifting precipitation patterns initiate changes in evapotranspiration and soil moisture which directly influence regional water demands and runoff timing. These hydrologic shifts subsequently impact surface water availability and flood conditions which then place secondary stress on groundwater basin stability and water quality. Furthermore, increasing thermal stress contributes to biomass drying and altered wind patterns which elevate wildfire risks for both natural ecosystems and human communities. The following summaries utilize specific metrics to quantify these interconnected risks across the distinct geographic regions of the Watershed.

5.12.1. Upper Watershed Summary

The upper Watershed serves as the primary catchment for the system and is particularly sensitive to changes in land surface processes and forest health. The following graphic summarizes how a projected increase in temperature and more frequent extreme precipitation events drive significant shifts in the regional water balance. These data highlight a decrease in total runoff which threatens the long-term reliability of headwater contributions to the downstream system. Values represent average annual changes compared to existing conditions. The values of the wildfire metrics in the graphic highlight the upper Watershed's vulnerability to destructive wildfire, which will only increase under climate change, as outlined in **Appendix D**.

Climate Change

- Temperature: +2 degrees Celsius
- Precipitation: No change
- Extreme precipitation: +14%

Land Surface System

- Evapotranspiration: +2.5%
- Runoff: - 6.9%

Wildfire

- Annual Burn Probability: 0.8%
- Characteristic Flame Length: 6.3 feet
- Extreme Flame Length: 12.4 feet

5.12.2. Lower Watershed Summary

The lower Watershed faces a concentration of risks related to water supply reliability, flood protection, and groundwater sustainability. Because this region supports most of the Watershed's agricultural and municipal demands, the cumulative impacts of reduced reservoir inflows and increased evapotranspiration are especially acute. The graphic below details the projected declines in surface water deliveries and groundwater storage while illustrating the increasing pressure on flood management infrastructure due to more volatile peak flow events. Values represent average annual changes compared to existing conditions.

Climate Change

- Temperature: +2 degrees Celsius
- Precipitation: No change
- Extreme precipitation: +14%

Stream and Reservoir Systems

Surface Water Supply

- New Hogan Inflow: -6.9%
- Surface Water deliveries: -12.9%

Flood Risk

- Maximum inflow into New Hogan: +3.0%
- Maximum Calaveras River stream flow: +3.1%

Land Surface System

- Evapotranspiration: +3.2%
- Agricultural Water Demand: +4.5%
- Surface Water Deliveries: -12.9%
- Groundwater production: +8.1%

Groundwater System

- Aquifer groundwater storage: -117%
- Groundwater levels: -19 feet / 50-years
- Stream seepage: +8.2%
- Inter-Watershed flows: +14.0%

CHAPTER 6
CLIMATE ADAPTION STRATEGIES

Woodard & Curran

STOCKTON EAST WATER DISTRICT
PROVIDING SERVICE SINCE 1948

6. CLIMATE ADAPTATION STRATEGIES

The strategies presented in this chapter respond directly to vulnerabilities and risks identified in the climate assessment. By targeting the vulnerabilities documented in **Chapter 5**, these actions provide a pathway to mitigate the impacts of climate change in the Calaveras River Watershed. To ensure these concepts translate into measurable resilience, **Chapter 7** provides recommendations for the implementation of these strategies, which differ depending on the level of development of the strategy.

6.1. ADAPTATION STRATEGY DEVELOPMENT AND EVALUATION APPROACH

The Project Team considered the problems and challenges identified in **Chapter 3**, the goals and objectives from **Chapter 4** and the specific vulnerabilities and risks articulated in **Chapter 5** as guidelines for identifying adaptation strategies. This process involved compiling established project concepts from regional plans and integrating input from the Watershed Network to address emerging climate challenges.

Water Management Strategies

Adaptation strategies that helped to meet water supply, groundwater basin management and/or flood control objectives were grouped as Water Management Strategies. Most of these project concepts were developed as part of the Eastern San Joaquin Groundwater Sustainability Plan and the SEWD Master Plan. Because these projects were already prioritized through collaborative efforts in the lower Watershed, this Watershed Plan was able to apply the same prioritization for use as water management strategies. While the modeling focus remains on the lower Watershed where vulnerabilities are most acute, projects benefiting the upper Watershed were also identified through the Calaveras County Hazard Mitigation Plan and direct collaboration with local partners.

The Water Management Strategy list includes a wide range of projects across varying levels of development. Projects with defined facility sizing and flow estimates were simulated using the CWRP Model to quantify their performance against water supply and flood vulnerabilities. Projects that align with plan objectives but lack sufficient data for modeling are recommended for further development and potential future implementation.

The project team organized the Water Management Strategies into tiered groups to measure their performance against the metrics described in the analytical framework. Projects with sufficient data for quantitative evaluation were categorized as Tier 1 and Tier 2 and were processed through the CWRP Model. Tier 1 and 2 strategies are discussed in **Section 6.2**. Strategies that align with plan objectives but lack the technical detail required for modeling are classified as Tier 3. While these Tier 3 projects are not reflected in the modeling results, they remain vital components of the Watershed’s long-term resilience and are described further in **Section 6.3**.

Land Management Strategies

Strategies that address wildfire and surface water quality vulnerabilities are categorized as Land Management Strategies. The Project Team utilized Vibrant Planet/Pyrologix’s WildEST tool to automatically generate priority wildfire management areas based on the vulnerability and risk analysis conducted in previous chapters. These areas are paired with specific land management strategies to minimize fire potential and secondary impacts on local water systems. These efforts complement the water management strategies by protecting the integrity of the surface water system and reducing sediment loads following fire events. Land management strategies are discussed in **Section 6.4**.

6.2. TIER 1 AND 2 WATER MANAGEMENT STRATEGIES

The modeling framework evaluates adaptation performance by organizing strategies into tiers based on implementation timelines, operational complexity, and infrastructure requirements. This tiered structure allows stakeholders to assess near term actions that leverage existing systems alongside long-term investments that expand capacity through new infrastructure. The distinction between these tiers reflects practical constraints on implementation sequencing because Tier 2 strategies depend on the completion of foundational projects like the Farmington Reservoir Project before they can be fully realized. The following sections describe the development of these tiers and the specific criteria used to categorize each project.

The analysis presented in this chapter focuses on the cumulative impacts of Tier 1 and Tier 2 project portfolios to demonstrate the overall adaptation benefits achievable under each implementation scenario. Individual project performance metrics and more detailed breakdowns of program impacts are available in Technical Memorandum 2, included as **Appendix E**. Further discussion of implementation timelines, phasing strategies, and project costs can be found in **Chapter 7**.

The Farmington Reservoir Project is a critical component of the Watershed's approach to address climate change. Currently, Farmington Dam is a 52,000 AF flood control reservoir. This project would increase the total reservoir capacity to 112,000 AF, allocating 60,000 AF for water supply and retaining 52,000 AF for flood control. The remainder of the Tier 2 projects depend upon the increased surface water storage and recharge capacity of this project. Without it, none of the other Tier 2 strategies can be implemented.

6.2.1. Tier 1 and 2 Strategy Development

The Tier 1 and Tier 2 categories of water management strategies represent distinct levels of infrastructure investment and operational complexity. Tier 1 consists of near-term actions such as projects already underway or strategies that function within the existing infrastructure and operational framework. Tier 2 represents longer-term investments that require additional infrastructure, significant changes to reservoir operations, or new water management strategies. **Table 6-1** summarizes the Tier 1 and 2 projects relative to their associated Risk Area as identified in **Chapter 5.** All Tier 1 and 2 projects support one or more Plan Objectives defined in **Chapter 4**. Detailed descriptions of these projects are available in **Appendix G** and further discussion regarding project benefits is provided in **Section 6.2.2**

Table 6-1: Tier 1 and 2 Water Management Strategies

Project	Risk Area	Strategy Type
Tier 1 Water Management Strategies		
Clements Pipeline and Reservoir	Water Supply	Storage, Direct and In-Lieu Recharge
Regulating Reservoir 03	Water Supply	Storage, Direct Recharge
Regulating Reservoir 05	Water Supply	Storage, Direct Recharge
Surface Water Expansion and Flood-MAR	Water Supply	In-Lieu Recharge, Regulatory
West Linden Project	Water Supply	Direct and In-Lieu Recharge
Beckman ASR Well	Groundwater Basin	Direct Recharge
West Groundwater Recharge Basin	Groundwater Basin	Direct Recharge
Tier 2 Water Management Strategies		
Farmington Reservoir Project	Water Supply	Storage
Demartini Pipeline	Water Supply	Direct and In-Lieu Recharge
Houston Pipeline	Water Supply	Direct and In-Lieu Recharge
Mosher Pipeline	Water Supply	Direct and In-Lieu Recharge
East Mosher Creek Recharge Area	Groundwater Basin	Direct Recharge
Mosher Creek Recharge Basin	Groundwater Basin	Direct Recharge

Water supplies for Tier 1 strategies are sourced under SEWD's existing water rights and contracts allocations from New Hogan and New Melones Reservoirs. Tier 2 strategies build upon these foundational sources by incorporating water made available through the proposed Farmington Reservoir Project. This expansion is a critical component of the long-term adaptation portfolio because it increases the physical capacity to capture water and is the primary source of supply for Tier 2 projects.

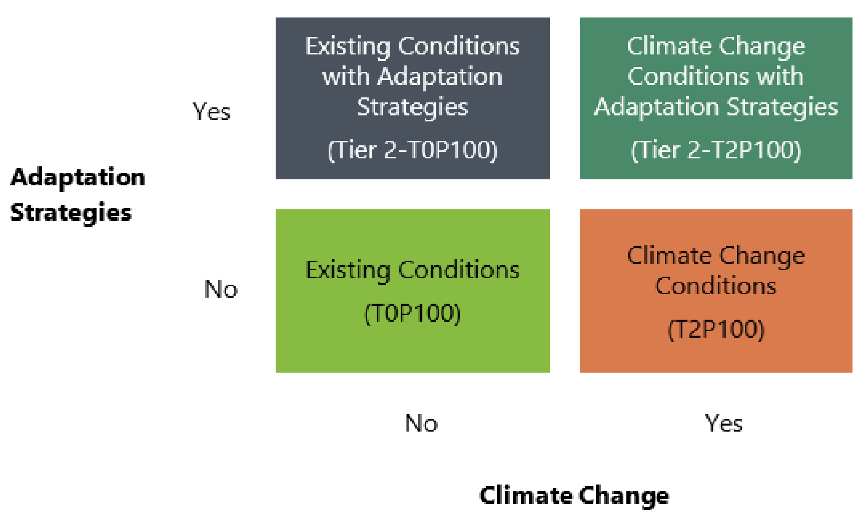
While SEWD serves as the lead agency for projects within the lower Watershed, these strategies align with broader goals outlined in the GSP. Additional strategies were proposed by local agencies promoting both climate adaptation and groundwater sustainability are categorized as Tier 3 projects. These Tier 3 initiatives remain critical components of the overall Watershed vision but were not included in the modeling for this specific assessment.

The following analysis focuses on the results from the Tier 2 scenario which represents the cumulative benefits of both Tier 1 and Tier 2 projects. Although Tier 2 initiatives involve greater infrastructure and operational complexities, they are essential for achieving meaningful climate adaptation within the Watershed. These strategies include significant infrastructure improvements such as the Farmington Reservoir Project and sophisticated operational frameworks, like the Integrated Forecast-Informed Resources Management (I-FIRM) strategy. By combining enhanced physical capacity with data driven reservoir operations, these projects promote improved flood control and generate additional water supplies for irrigation and direct recharge. Additional information on the results and strategies for both Tier 1 and Tier 2 projects can be found in Technical Memorandum 2, included as **Appendix E**.

6.2.2. Tier 2 Strategy Benefit Analysis

Tier 2 projects provide measurable improvements to many of the Watershed's vulnerabilities discussed in **Chapter 5**. The following analysis describes the modeled benefits of these projects with a focus on water supply and reliability. This benefits analysis compares several scenarios, which are outlined in **Figure 6-1** below. For reference purposes, scenarios with "T0P100" indicate existing conditions related to climate; scenarios with "T2P100" indicate future conditions related to climate change; and scenarios with "Tier 2" indicate the inclusion of adaptation strategies.

Figure 6-1: Scenario Comparison



Water Supply: Surface Water Deliveries

Tier 2 strategies provide meaningful increases in surface water deliveries across all climate scenarios. The most significant benefits occur under conditions with higher precipitation and moderate warming. Because these climate conditions typically produce more frequent wet years and fewer sustained droughts, Tier 2 infrastructure and operations are better positioned to capture and deliver high flows. **Figure 6-2** presents a contour plot highlighting the annual average benefits for the different climate conditions based on changes in precipitation from existing conditions on the x axis and temperature on the y axis. Two specific points are marked on the contour plot to show the location of current climate conditions (T0P100), and the most likely future (T2P100) involving a 2 degree increase in temperature with no change in precipitation.

Under existing climate conditions, Tier 2 strategies increase surface water supplies by an average of 9.6 TAFY, which represents an 8 percent improvement over no action conditions. Under the T2P100 scenario, deliveries increased by 8.8 TAFY, and maintained a similar 8 percent improvement.

The annual time series for the most likely climate scenario illustrates how adaptation strategies enhance water supply reliability during both wet and dry periods (**Figure 6-3**).

Under existing conditions, surface water deliveries range from approximately 30 TAFY during severe drought years to 175 TAFY during exceptionally wet years. Tier 2 projects increase peak wet-year deliveries to 195 TAFY. These adaptation projects also provide modest improvements during dry years by optimizing reservoir operations and leveraging the entirety of existing water rights and contracts. This dual benefit of enhancing both wet year capture and dry-year reliability demonstrates that the adaptation portfolio addresses multiple dimensions of climate vulnerability rather than simply shifting water within the hydrologic cycle.

Figure 6-2: Change in Surface Water Supply by Implementing Tier 2 Projects

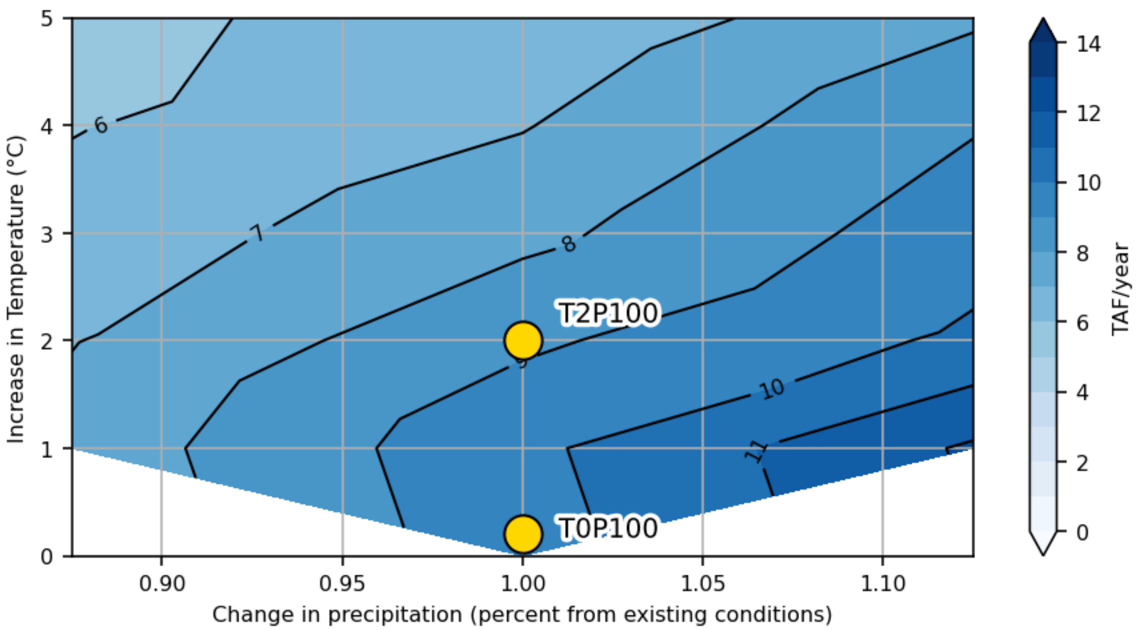
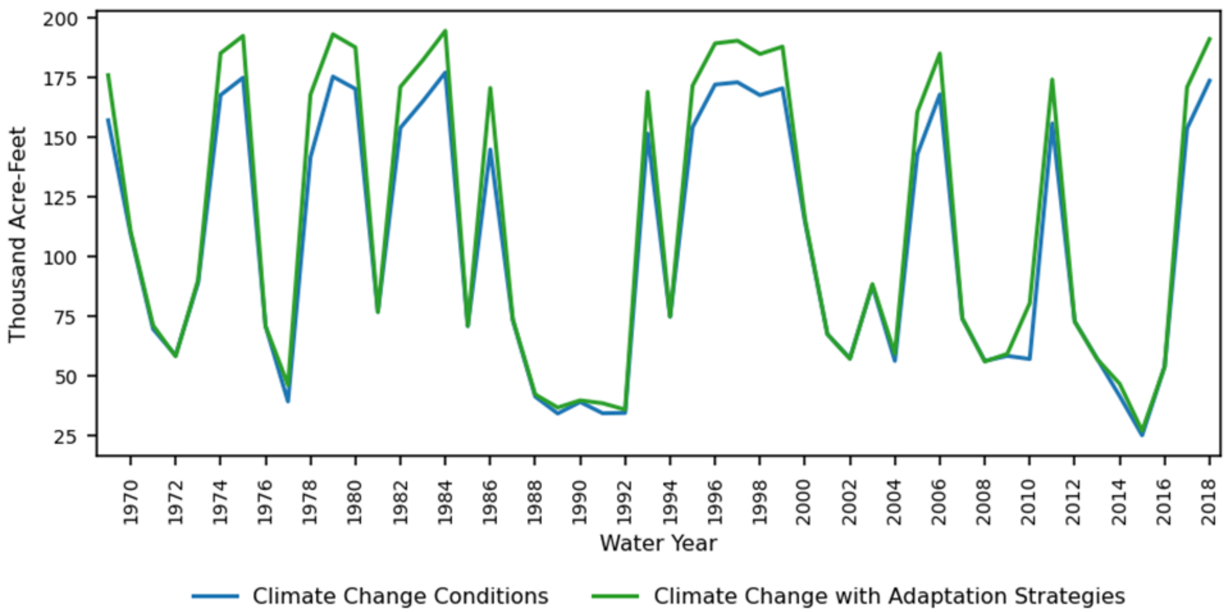


Figure 6-3: Annual Surface Water Supply for T2P100 Climate



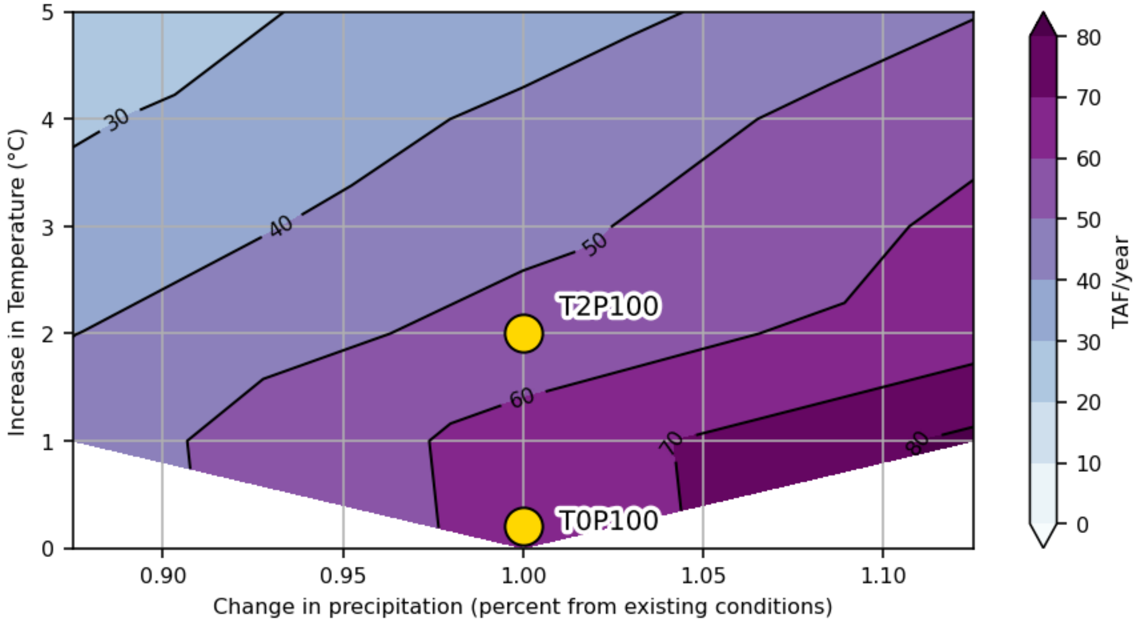
Water Supply: Groundwater Recharge

Beyond augmenting traditional surface water deliveries, Tier 2 strategies incorporate managed aquifer recharge to enhance watershed resilience and promote long-term storage. This approach leverages Water Available for Recharge (WAFR) identified through the DWR Watershed Studies, capturing flood flows that would otherwise pass through the system. Tier 2 operations utilize the I-FIRM strategy to capture high winter flows, employing forecast-informed reservoir management to increase WAFR availability beyond the capabilities of simpler diversion strategies (**Figure 6-4).** Under existing conditions (T0P100), Tier 2 projects include an average of 54 TAFY of direct recharge, increasing to 110 TAFY during wet years when coordinated reservoir releases and conveyance capacity can be optimized. Under T2P100, direct recharge remains robust at 47 TAFY, demonstrating that forecast-informed operations maintain effectiveness and the incremental recharge benefit.

The combined benefits of increased surface water deliveries for in-lieu use and direct recharge from high flow events create substantial cumulative impacts in the Calaveras River Watershed. Under climate change conditions involving a 2-degree temperature increase, the combined effect of both direct and in-lieu recharge brings a total of 54 TAFY of additional supply to the Watershed. This impact is comprised of 7 TAFY from in-lieu recharge and 47 TAFY from direct recharge under optimized reservoir operations.

Over the 50-year simulation period, the cumulative water supply benefits of adaptation strategies represent a substantial investment in long-term Watershed sustainability. Tier 2 projects contribute an estimated 2.7 million AF of total water supply augmentation under the projected climate conditions. These volumes translate to meaningful improvements in the regional water balance and help offset the systematic increases in demand and reductions in the surface water availability projected under the no-action scenarios. The specific impacts on groundwater conditions, including storage gains, water level improvements, and SGMA sustainability metrics, are detailed in subsequent sections of this report.

Figure 6-4: Annual Average of In-Lieu and Direct Recharge from Tier 2 Projects

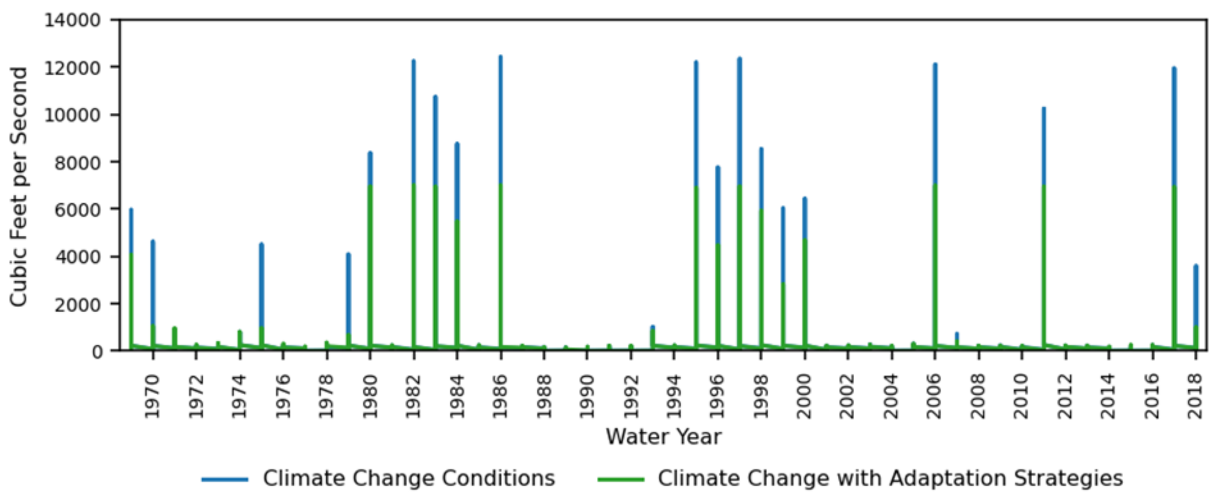


Water Supply and Flood: Surface Water Flows

Climate adaptation strategies for New Hogan Reservoir operations present significant opportunities to reduce flood risk while enhancing water supply capture through forecast-informed management. Tier 2 scenarios employ the Integrated Forecast-Informed Resources Management (I-FIRM) strategy, which uses advanced weather forecasts and hydrologic modeling to dynamically adjust reservoir operations. By anticipating incoming storms with greater accuracy, this strategy allows operators to pre-release water ahead of flood events, creating additional flood storage capacity while making that water available for beneficial recharge rather than uncontrolled spill.

The flood risk reduction benefits of I-FIRM operations are evident in daily flow patterns below New Hogan Dam (**Figure 6-5**). While the annual average streamflow remains consistent across all scenarios, the distribution of these flows differs substantially. Tier 2 operations reduce peak daily flows to approximately 7,000 cfs, compared to maximum flows of 12,400 cfs under existing and climate change conditions. This 44% reduction in peak discharge directly translates to reduced flood risk for downstream communities and infrastructure along the lower Calaveras River.

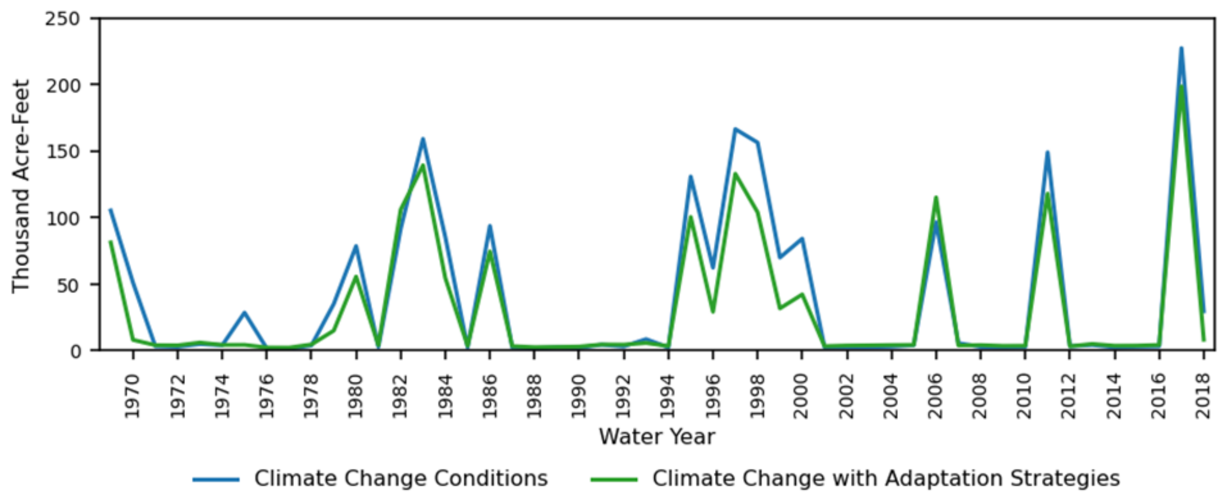
Figure 6-5: T2P100 Calaveras River Surface Flows (Inflow New Hogan Dam)



Flow patterns at Bellota Weir, upstream of the bypass to Mormon Slough, demonstrate meaningful flood protection benefits by Tier 2 strategies. Bellota Weir serves as a critical junction in the lower Watershed where flows are diverted to Mormon Slough or maintained in the main river channel. This location is a primary indicator of how upstream management affects flood pressure on agricultural lands and urban areas in the lower Watershed reaches. While **Figure 6-5** utilizes cubic feet per second to illustrate immediate daily peak reductions, **Figure 6-6** displays maximum monthly flows in thousand acre feet to demonstrate the sustained volume of water successfully managed through these strategies. Average annual flow at Bellota remains similar across all climate scenarios, ranging from 102 to 108 TAF for both scenarios with and without adaptation strategies. However, maximum monthly flows show substantial reductions under I-FIRM. Under the T2P100 climate change conditions, the monthly maximum flows are reduced from an average of 40 TAF in the no-action scenario to 31 TAF in with adaptation strategies, with higher impacts during wet years.

Tier 2 adaptation strategies reduce peak volumes by capturing and diverting water during high flow periods to manage recharge facilities. These flow reductions provide protection for agricultural lands, local communities, and habitat in the lower Watershed. During high-flow periods, diversions to recharge facilities reduce excess downstream flows that can cause erosion and habitat disturbance. During subsequent low-flow periods, the groundwater stored from those diversions returns to the stream through enhanced baseflow, sustaining higher flows when they are most needed.

Figure 6-6: Calaveras River Monthly Maximum Flow at Bellota



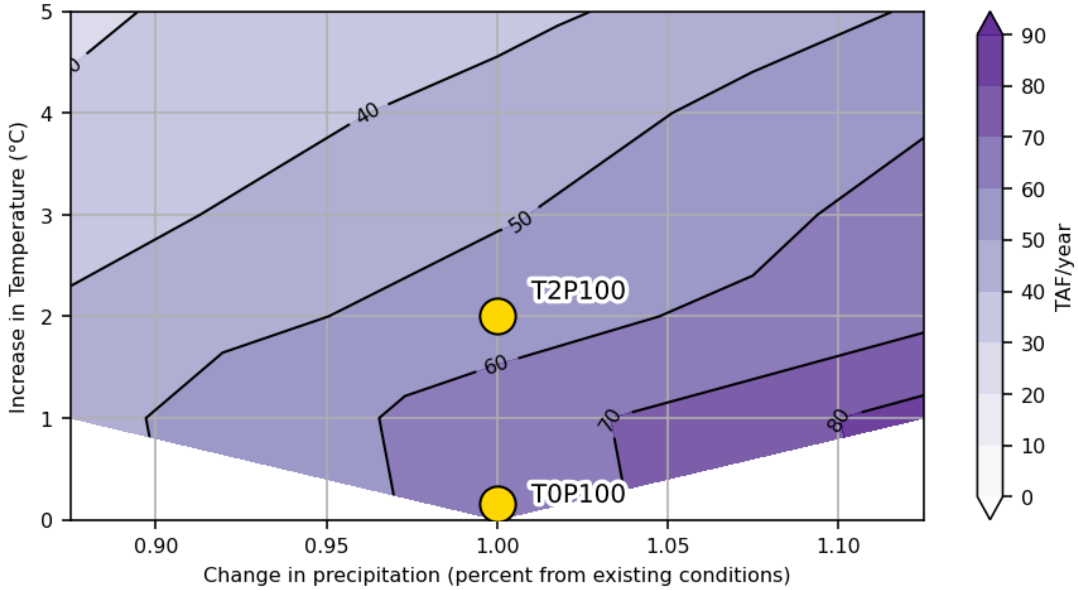
Water Supply: Recharge

Tier 2 adaptation strategies enhance groundwater sustainability through a combination of increased surface water deliveries and managed aquifer recharge. These strategies modify the groundwater budget by increasing recharge, reducing pumping demand through in-lieu surface water use, and improving deep percolation from irrigation practices. Because Tier 2 encompasses all foundational efforts from Tier 1, the following results represent the cumulative benefit of the complete adaptation portfolio.

The combined effect of these changes is quantified as "supplemental supplies," representing the net-recharge improving the aquifer conditions compared to the existing conditions (T0P100). Recharge volumes vary systematically across climate scenarios based on water availability and operational constraints. The annual recharge for the Tier 2 scenarios is presented in **Figure 6-7**, and demonstrates a clear relationship with both temperature and precipitation. Under existing conditions, the applied recharge is 64 TAF, whereas under the T2P100 scenario, the available recharge is approximately 55 TAF. In general, the applied recharge decreases by approximately 6 TAF per year for each 1°C increase in temperature, while it increases by 1.1 TAF for every 1% increase in precipitation.

Applied recharge affects the groundwater system through three primary mechanisms: (1) increasing groundwater storage as additional water percolates into the aquifer and raises groundwater levels; (2) reducing stream seepage as higher groundwater levels decrease the hydraulic gradient between the aquifer and adjacent streams; and (3) decreasing net-subsurface inflow into the Watershed, also due to reduced hydraulic gradients between the basin and neighboring groundwater systems.

Figure 6-7: Contour Plot of Annual Averaged Applied Recharge in Tier 2 Scenarios

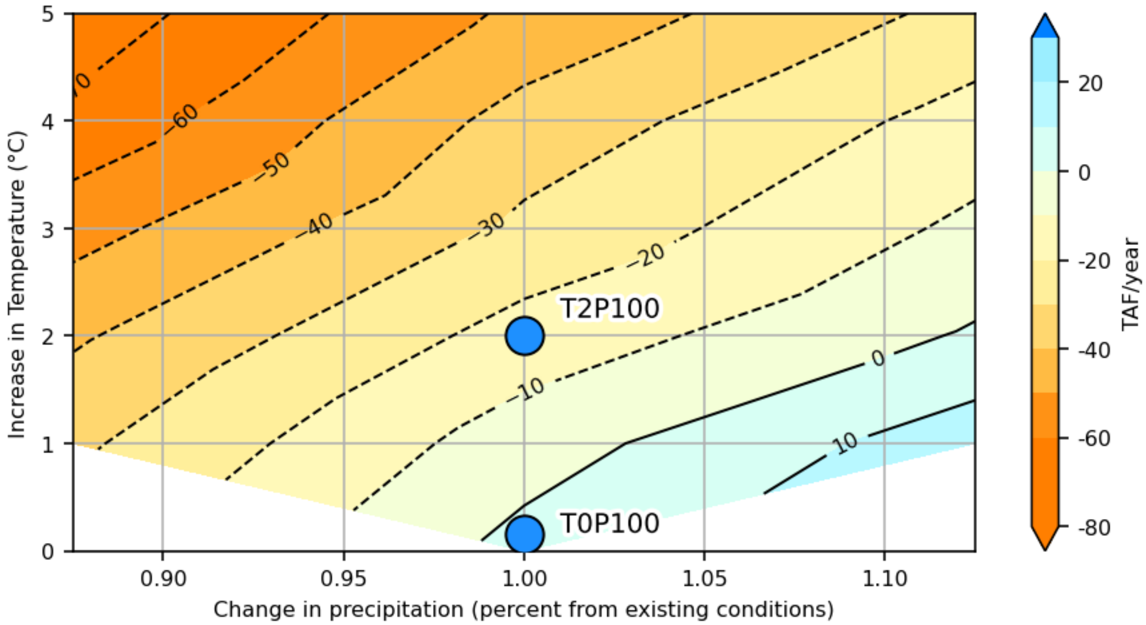


Groundwater Basin: Storage

Tier 2 strategies demonstrate a significant capacity to buffer the groundwater system against the storage declines projected under future climate scenarios. Under existing conditions (T0P100), the Watershed experiences an average annual storage deficit of 16 TAF. Climate change without adaptation (T2P100) worsens this deficit to 34 TAF annually. Implementation of Tier 2 strategies under the T2P100 scenario reduces the deficit back to 16 TAF, matching current conditions despite 2°C of warming. This represents an 18 TAF annual improvement compared to the no-action climate scenario.

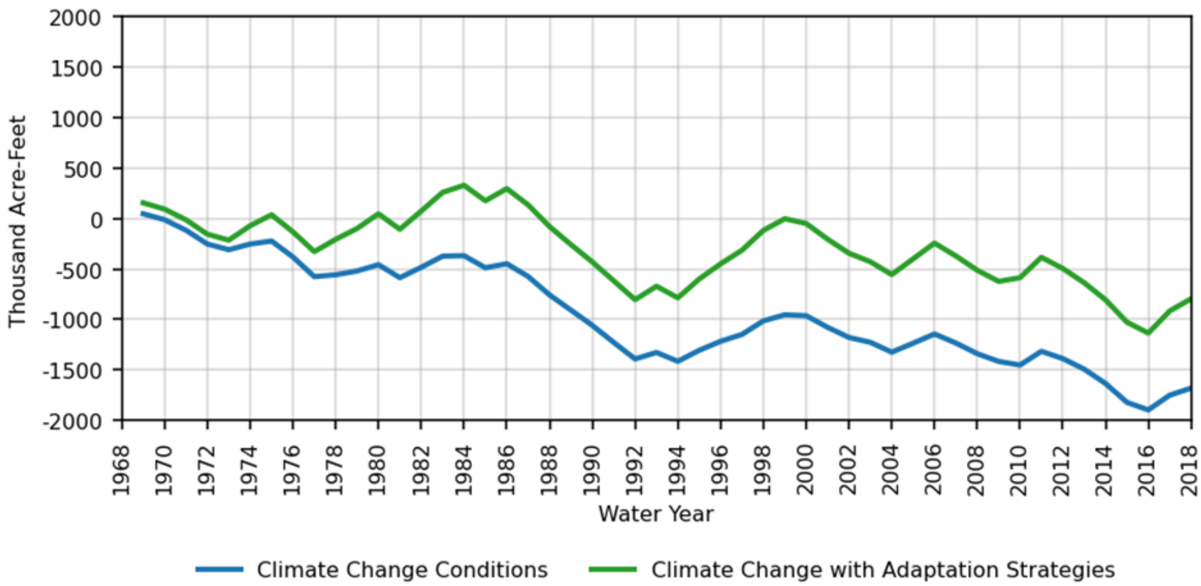
Across the full suite of climate scenarios, Tier 2 projects consistently improve groundwater storage outcomes by an average of 16 TAFY relative to baseline conditions. Benefits scale with water availability, ranging from 12 TAFY improvements in drier scenarios (P088) to 20 TAFY in wetter conditions (P113). **Figure 6-8** displays the annual average change in groundwater storage across the various Tier 2 climate scenarios, illustrating how adaptation strategies progressively reduce storage deficits as additional water supply and recharge opportunities increase.

Figure 6-8: Groundwater Storage with Adaptation Strategies



The cumulative change in groundwater storage under the most likely climate condition for the no-action, and Tier 2 scenarios is illustrated in **Figure 6-9**. These storage metrics specifically reflect the portion of the Eastern San Joaquin Groundwater Subbasin located within the Calaveras River Watershed boundary. The primary differences between these scenarios occur during wet years when the cumulative change in storage increases due to the high availability of water for managed recharge. While these adaptation strategies build substantial storage reserves during wet cycles, the positive impact is attenuated during dry years. In drought conditions, where recharge is minimal and the storage trends in Tier 2 scenarios tend to align more closely with the no-action climate change scenario. This relationship highlights the importance of maximizing recharge during wet periods to offset the unavoidable storage withdrawals that occur during sustained droughts.

Figure 6-9: Cumulative Change in Groundwater Storage (T2P100)



Groundwater Basin: Groundwater Levels

The impact of the Tier 2 adaptation package on groundwater levels is significant, particularly in areas concentrated around the primary project locations. **Figure 6-10** illustrates the difference in groundwater levels between the no-action climate change scenario (T2P100) and the climate change with adaptation strategies scenario (Tier2-T2P100) at the conclusion of the 50-year simulation period. Within the Calaveras River Watershed, the average groundwater level increases by 20 feet compared to the climate change scenario, with specific locations near recharge facilities experiencing increases of up to 55 feet. The most pronounced improvements are situated downstream of Bellota where the project infrastructure is most active.

Under the existing conditions scenario, groundwater levels in the Calaveras River Watershed are projected to decline by an average of 20 feet over the next 50 years. This historical trend is compounded by climate change, which is expected to trigger an additional 20-foot decline under the T2P100 scenario. The implementation of the Tier 2 adaptation strategies directly mitigates this total 40-foot risk by recovering 20 feet of elevation, effectively halving the projected impacts of combined groundwater overdraft and climate change.

Table 6-2 provides a comparison of average groundwater levels at the end of the 50-year simulation period when comparing conditions with and without adaptation strategies. This summary highlights the impact of both climate change and the proposed adaptation strategies across the broader Calaveras River Watershed, specifically breaking down results for the SEWD and CCWD service areas, as well as the non-district portions of the Watershed.

Figure 6-10: Groundwater Level Differences under Climate Change Condition with and without Adaptation Strategies (feet)

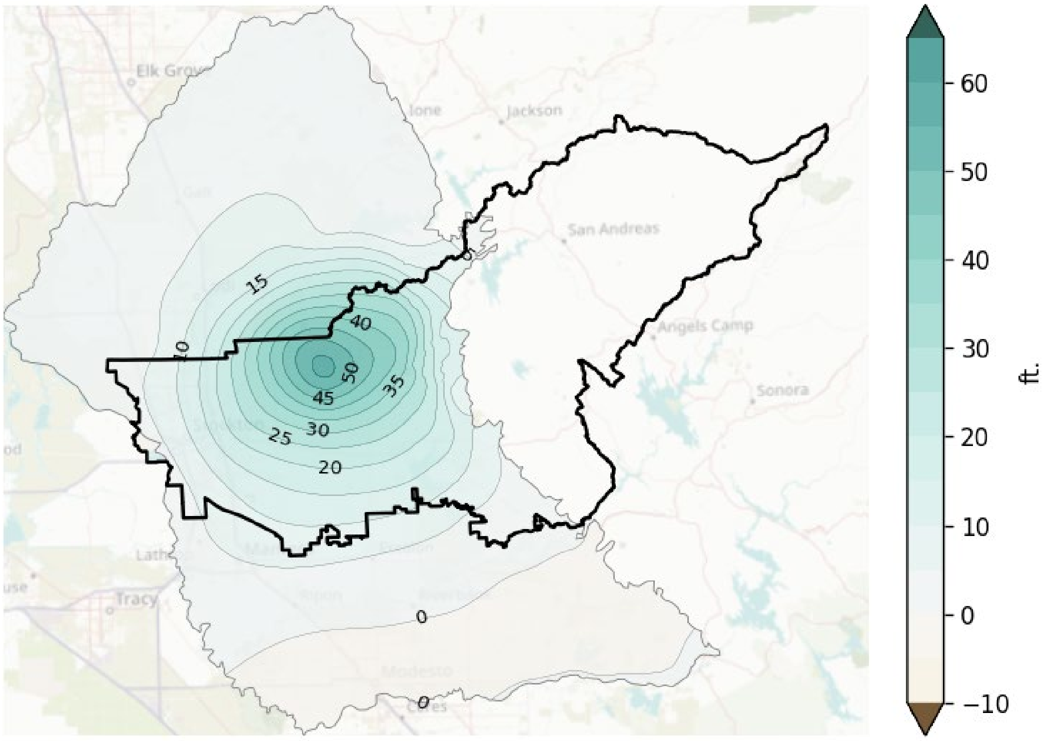


Table 6-2: Groundwater Levels Comparison

Climate Condition	Scenario	Calaveras Watershed (Feet)	SEWD (Feet)	CCWD (Feet)	Non-District (Feet)
T0P100	Without Adaptation Strategies	0	0	0	0
	With Adaptation Strategies	+21	+27	+13	+16
T2P100	Without Adaptation Strategies	-20	-20	-9	-20
	With Adaptation Strategies	0	+6	+2	-5

6.3. TIER 3 WATER MANAGEMENT STRATEGIES

Tier 3 Water Management Strategies are projects already identified by agencies participating in the Watershed Resilience Plan. These include projects developed as part of existing or ongoing efforts under other programs. The Tier 3 Water Management Strategies are summarized in **Table 6-3**, organized by the Risk Area they address. In contrast to the Tier 1 and 2 Water Management Strategies, these projects are in the conceptual or early planning stage and are not developed enough to be included in the hydrologic and climate modeling discussed in **Section 6.2.1**. Therefore, their potential effectiveness in addressing Watershed vulnerabilities is discussed at a qualitative level.

Benefits of the Tier 3 Water Management Strategies include:

- Increasing drought resilience of groundwater supplies by increasing opportunities for direct and in-lieu recharge, expanding surface water use, and implementing conjunctive use programs.

- Reducing likelihood and severity of water shortages by developing water supply interties and restoring storage capacity in existing reservoirs.

- Lowering flood risk by increasing reservoir storage and improving flood control infrastructure, such as levees or bypass channels.

- Indirectly improving water quality by maintaining adequate river flows and stream temperatures to support anadromous fish populations, while also mitigating contaminant transport by reducing volume and velocity of stormwater runoff and overflows during severe storm events.

- Improving regional awareness of climate-related water resources issues by implementing public education and outreach programs on water conservation, agricultural water use, and groundwater management.

More information on these strategies is included in **Appendix G**. While their benefits are not quantifiable, the Tier 3 strategies may provide complementary benefits to Tier 1 and 2 projects and should be considered in long-term watershed resilience planning. Strategies for implementing these projects are included in **Chapter 7**.

Table 6-3: Tier 3 Water Management Strategies

Project	Risk Area	Strategy Type
Bellota Pipeline Flood-MAR Project	Groundwater Basin	Direct and In-Lieu Recharge
Dewatered Domestic Well Mitigation Program	Groundwater Basin	Infrastructure Improvement
Groundwater Monitoring Improvements	Groundwater Basin	Infrastructure Improvement
Mormon Slough System FloodMAR Feasibility Study	Groundwater Basin	Direct Recharge
Vineyard Recharge	Groundwater Basin	Direct Recharge
Wallace-Burson Conjunctive Use Program	Groundwater Basin	Direct and In-Lieu Recharge
Agriculture and Municipal Conservation Programs	Direct Impacts	Demand Management
Demand Management Program	Direct Impacts	Demand Management
Rotational Fallowing or Permanent Fallowing of Crop Lands	Direct Impacts	Demand Management
200 Year Flood Plain Code	Flood	Flood Risk Reduction
Cosgrove Creek Flood Mitigation	Flood	Flood Risk Reduction

Project	Risk Area	Strategy Type
Flood Diversions for Groundwater Recharge Under Water Code Section 1242.1	Flood	Flood Risk Reduction
Mormon Slough Channel Bypass	Flood	Flood Risk Reduction
North Frontage Road backflow valve (North 99 Frontage Road)	Flood	Flood Risk Reduction
Oak Grove Regional Park Lake Bank Erosion Mitigation	Flood	Flood Risk Reduction
Sitkin Property Mitigation	Flood	Flood Risk Reduction
USACE Lower San Joaquin River Project (LSJRP) - Phase D Calaveras River, San Joaquin River	Flood	Flood Risk Reduction
Mormon Slough System Urban Levee Design Criteria (ULDC) Evaluation	Flood	Flood Risk Reduction
McGurk Crossing and Recharge Area	Surface Water Quality	Fish Passage and Ecosystem Improvements
Artificial Instream Structures Improvements.	Surface Water Quality	Fish Passage and Ecosystem Improvements
Bellota Weir Modifications Project	Surface Water Quality	Fish Passage and Ecosystem Improvements
Fall Flashboard Dam Removal Operations	Surface Water Quality	Fish Passage and Ecosystem Improvements
Fish Screens for Privately Owned Diversions	Surface Water Quality	Fish Passage and Ecosystem Improvements
Flashboard Dam Notches	Surface Water Quality	Fish Passage and Ecosystem Improvements
Flood Control Release Coordination	Surface Water Quality	Fish Passage and Ecosystem Improvements
Minimum Instream Flow Commitment	Surface Water Quality	Fish Passage and Ecosystem Improvements
Non-Dedicated Fall Storage Management	Surface Water Quality	Fish Passage and Ecosystem Improvements
Non-entraining Upstream Passage Barrier	Surface Water Quality	Fish Passage and Ecosystem Improvements
Old Calaveras River/Stockton Diverting Canal Fish Barrier	Surface Water Quality	Fish Passage and Ecosystem Improvements
Stakeholder Education Program regarding Fishery Issues	Surface Water Quality	Demand Management
Supervisory Control and Flow Data Acquisition System	Surface Water Quality	Infrastructure Improvement
Temporary Fish Ladders at the Bellota Diversion Facility	Surface Water Quality	Fish Passage and Ecosystem Improvements
Wastewater Collection Infrastructure Improvements	Water Quality	Infrastructure Improvement

Project	Risk Area	Strategy Type
Additional ASR Wells	Water Supply	Direct Recharge
Duck Creek Reservoir	Water Supply	Storage
FIRO Implementation at New Hogan Dam	Water Supply	Infrastructure Improvement
Groundwater Extraction Fee with Land Use Modifications	Water Supply	Demand Management
Lake Grupe	Water Supply	Direct and In-Lieu Recharge
Linden Canal	Water Supply	Direct and In-Lieu Recharge
New Hogan Reservoir Storage Assessment and Climate Change Mitigation Study	Water Supply	Flood Risk Reduction
Podesta Canal	Water Supply	Direct and In-Lieu Recharge, Storage
San Antonio Creek – White Pines – Sheep Ranch Resilience	Water Supply	Infrastructure Improvement
South Gulch Reservoir	Water Supply	Storage
White Pines Restoration Project	Water Supply	Storage

6.4. LAND MANAGEMENT ADAPTATION STRATEGIES

The following Land Management Strategies are focused on mitigating wildfire impacts in the highest priority areas of the Watershed.

6.4.1. Land Management Strategy Development

Land management measures were developed based on a modeled assessment of pre-treatment wildfire hazards and risks in the Watershed. Further modeling was used to identify 100 priority zones in the upper Watershed, each with a specific suite of wildfire mitigation treatments.

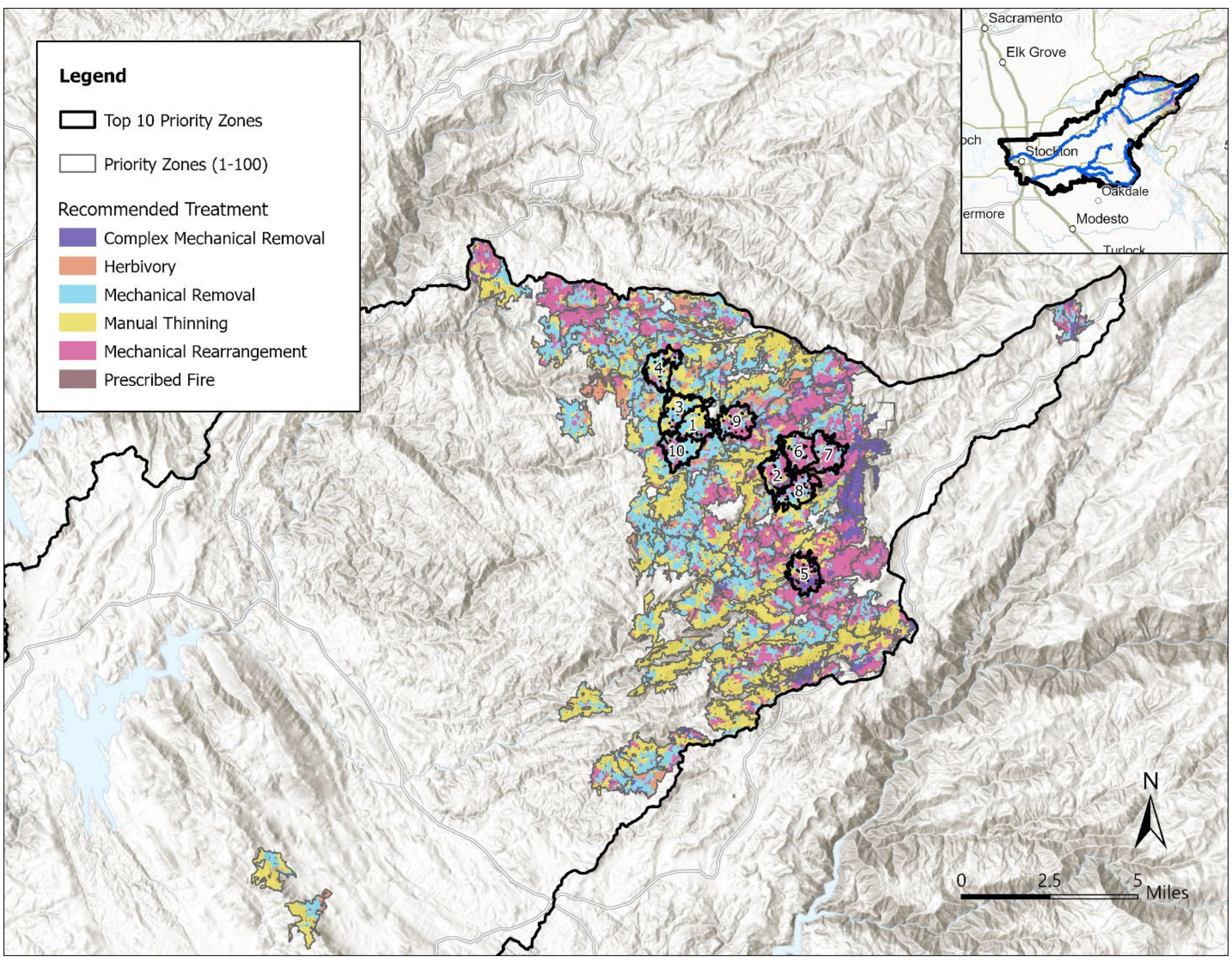
Priority zones are 500 contiguous acre areas where the highest reduction in wildfire risk could be captured. One hundred priority zones were identified as part of this analysis to allow for maximum operational flexibility and collaboration. The priority zones are sequenced, or ranked, from 1-100 with Priority Zone 1 being the most impactful for risk reduction-based wildfire hazard.

These priority zones for wildfire mitigation projects represent an initial estimation of the areas where management may have the largest benefit. The intent is for the priority zones and treatments to be used as a menu of options from which land managers can pull from based on certain constraints, such as funding or land use. The ranking of priority zones distinguishes between higher and lower benefits to inform decision making.

Management actions within the priority zones are recommended based on local conditions such as accessibility, slope, vegetation type, and more. Treatment types are recommended for individual management areas within each priority zone. **Figure 6-11** displays the top 10 priority zones (outlined in black) and the following recommended treatment types as defined by Vibrant Planet below:[1]

- **Complex Mechanical Removal** includes "…steep slope clearcut, steep slope thinning, and urban clearing, and uses steep slope logging systems such as skyline, helicopter and tethered logging."
- **"Herbivory** may be used prior to or after other treatment methods or may be used in isolation for fuels reduction. This may include the use of goats, sheep, or other livestock."
- **"Mechanical Removal**, including mechanical thinning, clearcutting, small diameter removal, thinning, and variable density thinning."
- **Manual Thinning** includes "…manual clearcuts, urban clearing, and manually removing invasives, Manual methods refer to the use of manual labor and do not require heavy machinery."
- **Mechanical Rearrangement,** "…including mastication, mowing, and grapple piling, is intended to rearrange fuels and distribute them relatively evenly across the treated ground."
- "**Prescribed Fire,** including aerial ignition and Rx ground fire low intensity, involves the intentional lighting of fire for the purpose of management."

Figure 6-11: Wildfire Priority Zones and Treatment Type



[1] Vibrant Planet, 2025

6.4.2. Land Management Strategy Benefit Analysis

Wildfire: Footprint and Intensity

Table 6-4 shows the benefits of treatment strategies for both flame length and burn probability key metrics included in the analytical framework. **Figure 6-12** shows changes in flame length values plotted spatially across the identified zones for the pre-treatment condition and the post-treatment conditions. **Figure 6-13** shows similar spatial representation of burn probability pre- and post-treatment. This indicates that, with treatment, both the likelihood of a burn occurring at any one location is lower, and the intensity of a fire that may break out, would be significantly lower. These benefits are primarily located in the upper Watershed, given that the risk of wildfire is higher in the upper Watershed compared to the lower Watershed.

Table 6-4: Pre- and Post-Treatment Benefits for Key Wildfire Hazard Metrics

Priority Zone	Area (acres)	Flame Length (feet)	Flame Length (Post-Treatment) (feet)	% Change	Average Burn Probability	Post-Treatment Burn Probability	% Change
1	497	10.5	1.3	-88%	2.05%	1.62%	-21%
2	496	11.8	1.4	-88%	2.07%	1.65%	-20%
3	502	8.4	1.2	-86%	2.02%	1.63%	-19%
4	499	9.2	1.3	-86%	1.81%	1.64%	-9%
5	500	12.2	0.9	-93%	1.56%	1.41%	-10%
6	505	8.4	1.1	-87%	2.07%	1.57%	-24%
7	503	9.3	1.1	-88%	2.01%	1.62%	-19%
8	498	9.5	1.4	-85%	2.05%	1.58%	-23%
9	504	9.4	1.3	-86%	2.09%	1.87%	-11%
10	497	8.5	1	-88%	1.77%	1.44%	-19%

Figure 6-12: Priority Zone Flame Length Pre and Post Treatment

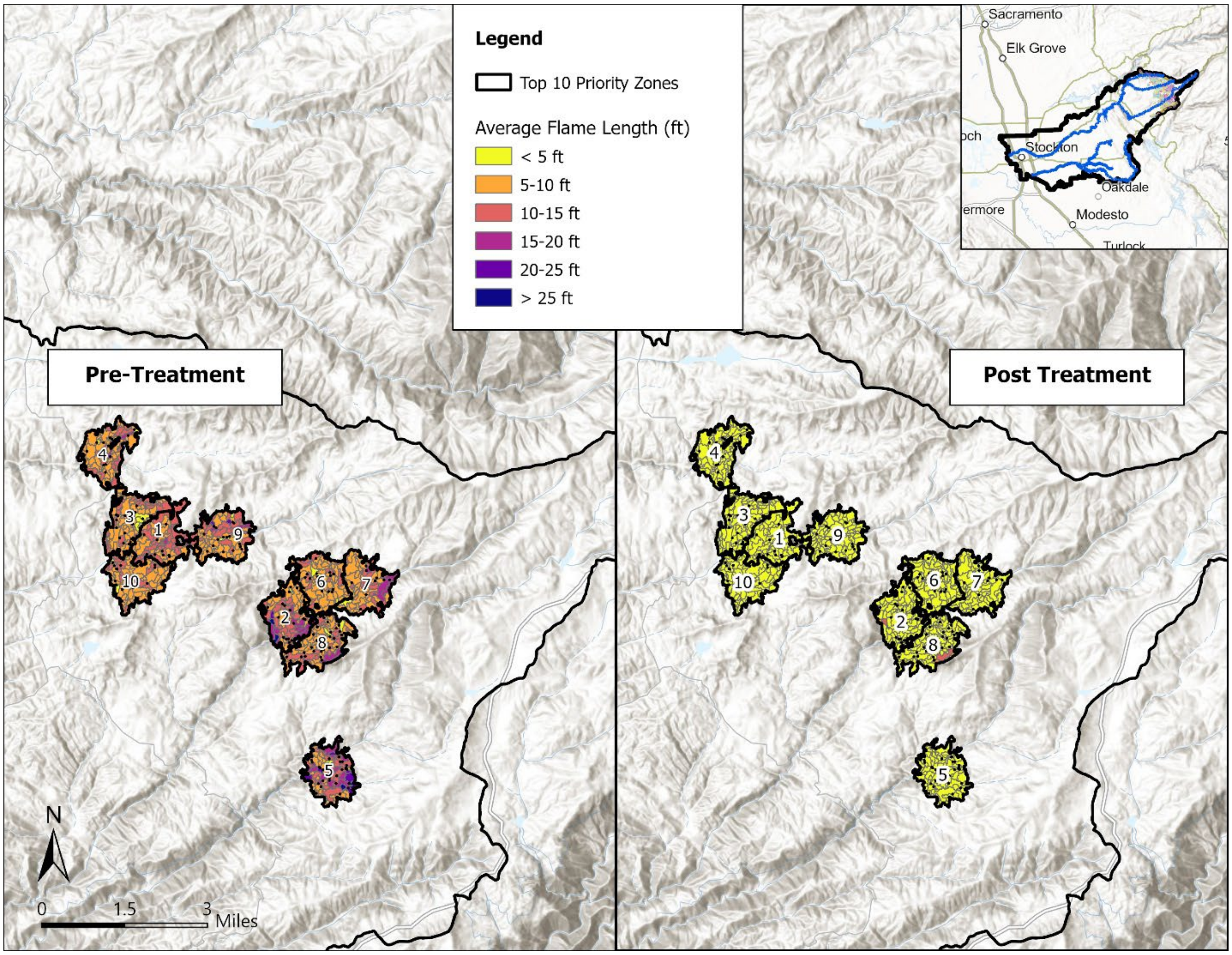
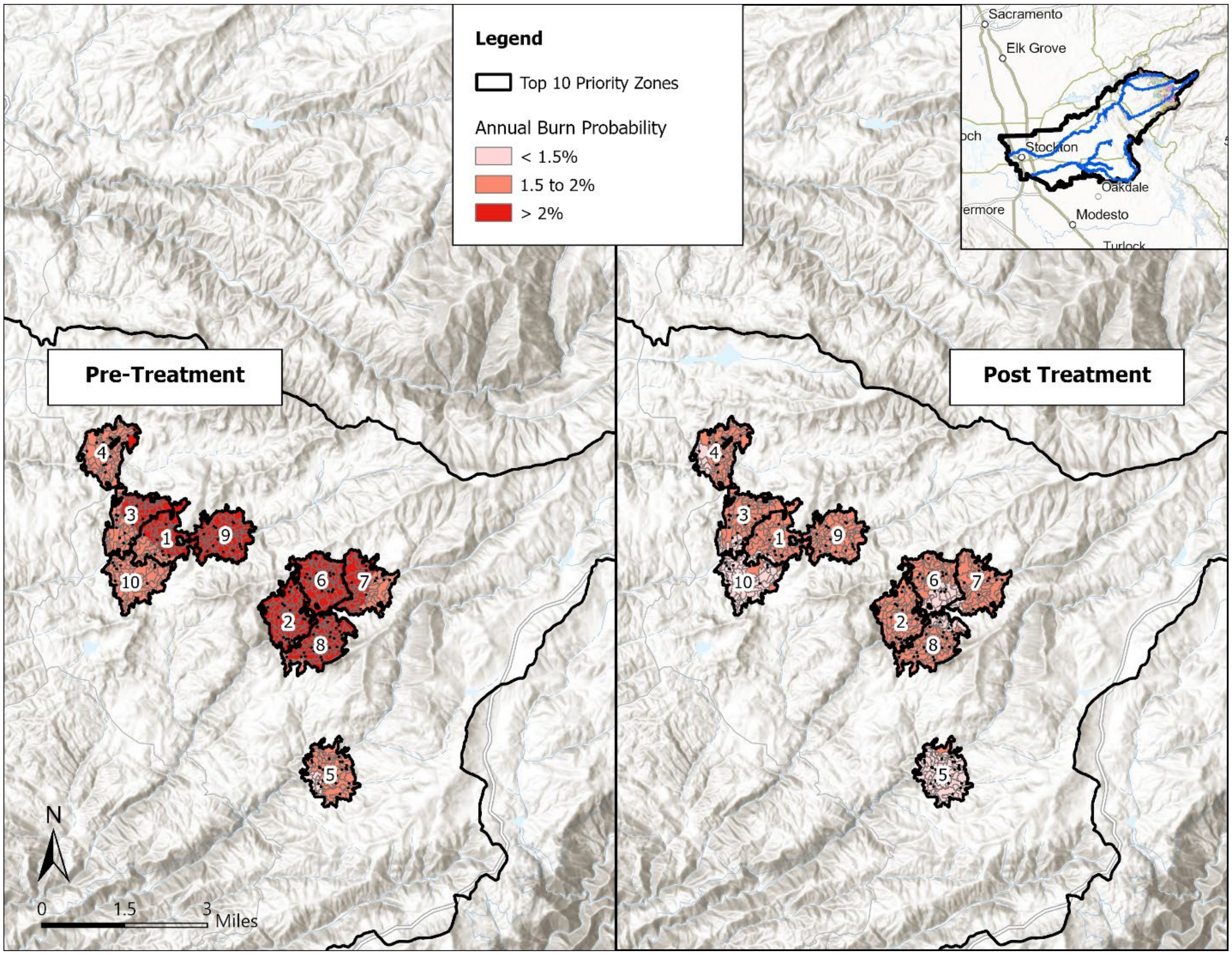


Figure 6-13: Priority Zone Burn Probability Pre and Post Treatment



Wildfire: Surface Water Quality and Water Resources

When a wildfire occurs, the loss or reduction of the live forest canopy, herbaceous ground cover, and surface litter increases the expected rate of erosion. This can threaten downslope water resources, infrastructure, and revegetation potential. **Table 6-5** shows the expected change in erosion rates between existing conditions and post-treatment conditions for the top 10 priority zones. For these zones, erosion rates are reduced by more than half. While these priority zones are all located in the upper Watershed and provide direct benefit to the upper Watershed, erosion from wildfire is also a vulnerability to the lower Watershed, and treatment in these priority zones will provide benefits to the lower Watershed as well.

Table 6-5: Priority Zones Pre- and Post-Treatment Benefits for Erosion Rates

Priority Zone	Area (acres)	Erosion Rate (tons/acre)	Erosion Rate (Post-Treatment) (tons/acre)	% Change
1	497	90.3	24.3	-73%
2	496	92.8	30.1	-68%
3	502	23.4	8.3	-65%
4	499	36.5	13.8	-62%
5	500	96	26.3	-73%
6	505	40.8	16.6	-59%
7	503	37.4	13.3	-64%
8	498	39.1	13.3	-66%
9	504	50.1	17.3	-65%
10	497	36.8	13.5	-63%

Wildfire: Wildland Health

Wildlands health aggregates wildfire impacts on riparian areas, sediment catchments, and WUI areas. Risks to wildlands health are distributed throughout the Watershed along riparian corridors. The Land Management Strategies recommended for the top 10 priority zones are likely to effectively mitigate risks to wildlands health in these areas. Additional information can be found in Technical Memorandum 4, which is included as **Appendix D**.

Wildfire: Community Safety

Community safety, discussed in **Section 5.7.4**, is influenced by impacts to HVRAs, including structures, transmission lines, and emergency facilities. Wildfire risks to communities are particularly high in the WUI areas of the upper Watershed. The Land Management Strategies recommended by Vibrant Planet's analysis significantly improve community safety in wildfire prone areas, particularly in the top 10 priority zones. Technical Memorandum 4, included as **Appendix D**, provides more detailed information on the modeled benefits to community safety.

6.5. ADAPTATION STRATEGIES AND EQUITY

Nearly half of the Watershed's population is identified as disadvantaged, meaning that investments in climate adaptation will play an essential role in reducing disproportionate climate burdens and advancing regional equity. While all communities stand to gain from the adaptation strategies recommended in this chapter, these actions provide especially meaningful benefits for DACs who often have fewer financial resources to prepare for, respond to, and recover from climate-driven disruptions. Specifically, adaptation strategies focused on flood risk reduction and sustainable groundwater management generate watershed-wide benefits, but the value of these improvements is particularly significant for DACs, which face heightened exposure to flooding and declining groundwater levels. By strengthening system reliability, reducing exposure to climate related risks, and lowering the likelihood of costly emergency interventions, these strategies help reduce long-term financial risk for lower-income households. At the same time, implementing these strategies will require significant investment, and any resulting rate increases will place a greater burden on households with limited financial resources.

Although most adaptation strategies presented in this Plan involve traditional infrastructure improvements, the cost of wildfire treatments presents a unique and ongoing challenge. Unlike one-time capital investments, wildfire risk-reduction treatments must be implemented repeatedly to remain effective, requiring a stable and long-term funding approach. Developing an equitable mechanism to support these recurring investments is critical to ensuring that DACs can benefit from sustained wildfire risk reduction. Land management strategy implementation is discussed in **Section 7.1.2**.

CHAPTER 7
IMPLEMENTATION STRATEGIES

Woodard & Curran

STOCKTON EAST WATER DISTRICT
PROVIDING SERVICE SINCE 1948

7. IMPLEMENTATION STRATEGIES

Over the last decade, statewide momentum to plan for climate resiliency has been increasing, with the release of Water Resilience Portfolio in 2020, the Water Supply Strategy in 2022, and the California Water Plan 2023 Update, all key documents that provide a blueprint to climate adaptation in the state. The Watershed Resilience Pilot Program is another example of increasing commitment to climate adaptation statewide. Simultaneously, local agencies continue to plan and implement projects that address the pressing needs of today, while also considering the impacts of future climate change.

Meeting the goals and objectives of the Watershed Resilience Plan will require implementation at both an individual adaptation strategy level and a programmatic level. To identify implementation strategies, the adaptation strategies recommended in **Chapter 6** were grouped based on their level of development. Program implementation strategies were identified to support watershed-scale climate resilience as well as the ability to track progress made on objectives (as described in **Chapter 4**).

7.1. PROJECT IMPLEMENTATION STRATEGIES

For recommended water and land management strategies, details on project status, schedule, and costs were collected from existing available documentation when available. Any gaps in implementation information will require additional planning and design level work on a project-by-project basis.

7.1.1. Water Management Strategies

Table 7-1 summarizes the implementation of the recommended water management strategies from **Chapter 6**. The table documents all known information on project status, schedule, and estimated total capital costs. These elements are crucial to effective implementation because they allow project proponents to align schedules, prioritize funding, and evaluate project feasibility. The table also includes suggested next steps for each project. Effective implementation will depend on clear project phasing, which requires defined schedules. Capital costs are estimated in 2024 dollars and from SEWD's 2025 Water Supply Master Plan unless otherwise noted. A more complete version of Table 7-1 that includes responsible leads and supportive parties can be found in **Appendix G**. In addition to continued planning of these strategies, project proponents will need to develop targeted outreach and messaging plans to sustain and expand the public support established during Plan development.

Since Tier 1 and 2 projects are already included within SEWD's Water Supply Master Plan, several implementation strategies have already been identified. The Tier 1 water management strategies can be planned and scheduled independently, as they are not reliant on the implementation of the Farmington Reservoir Project. In contrast, the Tier 2 strategies are dependent on the additional storage and recharge capacity that each specific project will provide. When and if the Farmington Reservoir Project is implemented, Tier 2 projects should be updated with further refined implementation strategies that reflect the current conditions.

Tier 3 projects are less developed and as a result, some key information necessary for implementation has not yet been established. In those cases, the implementation strategies recommended here will be to complete planning, including initiating feasibility and planning studies to define reasonable timelines and estimate project costs. It is the intent that project proponents will develop estimates for cost and schedule as projects advance through feasibility and planning work.

Table 7-1: Water Management Strategy Implementation

Project Name	Strategy Type	Status	Scheduled Completion	Capital Costs (2024$)	Next Steps
Tier 1 Water Management Strategies					
Beckman ASR Well	Direct Recharge	Planning	TBD	$320,000	SEWD is partnering with EBMUD to restore the ASR well.
West Groundwater Recharge Basin	Direct Recharge	Construction	Ongoing, 5-10 years	$9,940,000	SEWD has partnered with SJAFCA and the U.S. Army Corp of Engineers. Material removal is ongoing to reinforce area levees.
Clements Pipeline and Reservoir	Surface Water Infrastructure and Storage	Design	3-5 years	$20,260,000	Final design is ongoing and is expected to be completed by December 2026.
Reg-03	Storage	Planning	5 years	$4,520,000	The project's next steps are dependent on purchasing or leasing property in the preferred reservoir location.
Reg-05	Storage	Planning	5 years	$4,270,000	The project's next steps are dependent on purchasing or leasing property in the preferred reservoir location.
Surface Water Expansion and Flood-MAR	Surface Water Infrastructure and Regulatory	Construction	Ongoing	$10,990,000	SEWD has almost met its SGMA goal for surface water expansion. The District also maintains a Flood-MAR program for farmers.
West Linden Project	Surface Water Infrastructure	Planning	TBD	$86,380,000	SEWD is investigating partnering with EBMUD to explore bringing water from the Mokelumne Aqueduct and Calaveras River for groundwater recharge.
Tier 2 Water Management Strategies					
Farmington Reservoir Project	Storage	Planning	5-10 years	$303,404,000	A planning study is ongoing and is expected to be completed by 2028.

Project Name	Strategy Type	Status	Scheduled Completion	Capital Costs (2024$)	Next Steps
East Mosher Creek Recharge Area	Direct Recharge	Design	3-5 years	$9,940,000	Following completion of the Farmington Reservoir Project, implementation is dependent on purchasing or leasing property in the preferred reservoir location.
Mosher Creek Recharge Basin	Direct Recharge	Planning	5-10 years	$11,300,000	Following completion of the Farmington Reservoir Project, implementation is dependent on purchasing or leasing property in the preferred reservoir location.
Demartini Pipeline	Surface Water Infrastructure	Planning	5-10 years	$3,380,000	The implementation of Tier 2 priority projects relies on the Farmington Reservoir Project for increased surface water storage and recharge capacity.
Houston Pipeline	Surface Water Infrastructure	Planning	5-10 years	$4,640,000	The implementation of Tier 2 priority projects relies on the Farmington Reservoir Project for increased surface water storage and recharge capacity.
Mosher Pipeline	Surface Water Infrastructure	Planning	5-10 years	$4,000,000	The implementation of Tier 2 priority projects relies on the Farmington Reservoir Project for increased surface water storage and recharge capacity.
Tier 3 Water Management Strategies					
Old Calaveras River/Stockton Diverting Canal Fish Barriers	Fish Passage and Ecosystem Improvements	Planning	2028	$3,000,000 [1]	SEWD will conduct feasibility and/or planning studies to determine project scope, assess alternatives, and estimate project costs.
Linden Canal	Surface Water Infrastructure	Conceptual	TBD	TBD	SEWD will conduct feasibility and/or planning studies to determine project scope, assess alternatives, and estimate project costs.

[1] Estimated cost, communication with SEWD, 2025

Project Name	Strategy Type	Status	Scheduled Completion	Capital Costs (2024$)	Next Steps
Podesta Canal	Surface Water Infrastructure	Conceptual	TBD	TBD	SEWD will conduct feasibility and/or planning studies to determine project scope, assess alternatives, and estimate project costs.
Demand Management Program	Demand Management	In Progress	2028	TBD	GSAs will agree on an initial allocation of responsibility for reducing demand within their GSA areas by December 31, 2026.
Groundwater Extraction Fee with Land Use Modifications	Demand Management	Programs in the GSP are implemented as needed.			
Rotational Fallowing or Permanent Fallowing of Crop Lands	Demand Management	Programs in the GSP are implemented as needed.			
Bellota Weir Modifications Project	WTP Intake, Fish Passage and Ecosystem Improvements	Construction	2027	$83,000,000	Construction is anticipated to be completed in 2027
Agriculture and Municipal Conservation Programs	Demand Management	Management actions under the Calaveras Habitat Conservation Plan (HCP) have been implemented and are ongoing.			
Minimum Instream Flow Commitment	Fish Passage and Ecosystem Improvements	Management actions under the HCP have been implemented and are ongoing.			
Non-Dedicated Fall Storage Management	Fish Passage and Ecosystem Improvements	Management actions under the HCP have been implemented and are ongoing.			
Flood Control Release Coordination	Fish Passage and Ecosystem Improvements	Management actions under the HCP have been implemented and are ongoing.			
Non-entraining Upstream Passage Barrier	Fish Passage and Ecosystem Improvements	Management actions under the HCP have been implemented and are ongoing.			

Project Name	Strategy Type	Status	Scheduled Completion	Capital Costs (2024$)	Next Steps
Temporary Fish Ladders at the Bellota Diversion Facility	Fish Passage and Ecosystem Improvements	Management actions under the HCP have been implemented and are ongoing.			
Artificial Instream Structures Improvements	Fish Passage and Ecosystem Improvements	Management actions under the HCP have been implemented and are ongoing.			
Flashboard Dam Notches	Fish Passage and Ecosystem Improvements	Management actions under the HCP have been implemented and are ongoing.			
Supervisory Control and Flow Data Acquisition System	Infrastructure Improvement	Management actions under the HCP have been implemented and are ongoing.			
Fish Screens for Privately Owned Diversions	Fish Passage and Ecosystem Improvements	Management actions under the HCP have been implemented and are ongoing.			
Stakeholder Education Program regarding Fishery Issues	Demand Management	Management actions under the HCP have been implemented and are ongoing.			
Additional ASR Wells	Direct Recharge	Conceptual	TBD	$2,000,000 [1]	SEWD will undergo a feasibility study to determine ideal locations for ASR wells.
Vineyard Recharge	Direct Recharge	Conceptual	TBD	TBD	SEWD will conduct feasibility and/or planning studies to determine project scope, assess alternatives, and estimate project costs.
McGurk Crossing and Recharge Area	Fish Passage and Ecosystem Improvements	Design	2027	$900,000	SEWD has initiated a contract for modeling and design of the McGurk low water crossings.
White Pines Restoration Project	Storage	Planning	TBD	TBD	CCWD will undergo a feasibility study to determine costs and schedule.

[1] Estimated cost, communication with SEWD, 2025

Project Name	Strategy Type	Status	Scheduled Completion	Capital Costs (2024$)	Next Steps
Lake Grupe	Surface Water Infrastructure	Planning	TBD	$3,720,000	Phase 2 of the project is to convey stored water from Lake Grupe to local property owners. These landowners are ultimately responsible for planning, permitting, and funding Phase 2.
South Gulch Reservoir	Storage	Conceptual	TBD	TBD	SEWD will conduct feasibility and/or planning studies to determine project scope, assess alternatives, and estimate project costs.
Duck Creek Reservoir	Storage	Conceptual	TBD	TBD	SEWD will conduct feasibility and/or planning studies to determine project scope, assess alternatives, and estimate project costs.
Mormon Slough System FloodMAR Feasibility Study	Direct Recharge	Planning	2026	$1,000,000 [1]	A feasibility study will be finalized in 2026.
Mormon Slough Channel Bypass	Flood Risk Reduction	Planning	TBD	$34,000,000[1]	Planning and outreach is being finalized. Restore the Delta is in search of funding for design and implementation.
Sitkin Property Mitigation	Flood Risk Reduction	Conceptual	TBD	TBD	SEWD will conduct feasibility and/or planning studies to determine project scope, assess alternatives, and estimate project costs.
New Hogan Reservoir Storage Assessment and Climate Change Mitigation Study	Flood Risk Reduction	Planning	TBD	TBD	SJAFCA will initiate a planning or feasibility study.
Mormon Slough System ULDC Evaluation	Regulatory	Planning	TBD	$750,000 [1]	SJAFCA will initiate a planning or feasibility study.

[1] Estimated costs, communication with SJAFCA, 2025

Project Name	Strategy Type	Status	Scheduled Completion	Capital Costs (2024$)	Next Steps
USACE Lower San Joaquin River Project (LSJRP) - Phase D Calaveras River, San Joaquin River	Flood Risk Reduction	Design	2037	TBD	Project proponents will initiate the necessary project design, with support from SJAFCA.
Dewatered (Dry) Domestic Well Mitigation Program	Infrastructure Improvement	In Progress	Program has been established and implementation is ongoing.		
Bellota Pipeline Flood-MAR Project	Surface Water Infrastructure and Recharge	Planning	TBD	$20,000 per turnout	The project is part of a larger water rights request from New Hogan. It is currently in the permitting phase. SEWD is in the process of obtaining funding for this project.
Fall Flashboard Dam Removal Operations	Fish Passage and Ecosystem Improvements	Management actions under the HCP have been implemented and are ongoing.			
Cosgrove Creek Flood Mitigation	Flood Risk Reduction	Conceptual	TBD	TBD	CCWD will conduct feasibility and/or planning studies to determine project scope, assess alternatives, and estimate project costs.
San Antonio Creek – White Pines – Sheep Ranch Resilience	Infrastructure Improvement	Conceptual	TBD	TBD	CCWD will conduct feasibility and/or planning studies to determine project scope, assess alternatives, and estimate project costs.
Wallace-Burson Conjunctive Use Program	Surface Water Infrastructure and Recharge	Conceptual	TBD	TBD	CCWD will conduct feasibility and/or planning studies to determine project scope, assess alternatives, and estimate project costs.
Groundwater Monitoring Improvements	Infrastructure Improvement	Conceptual	TBD	TBD	CCWD will conduct feasibility and/or planning studies to determine project scope, assess alternatives, and estimate project costs.

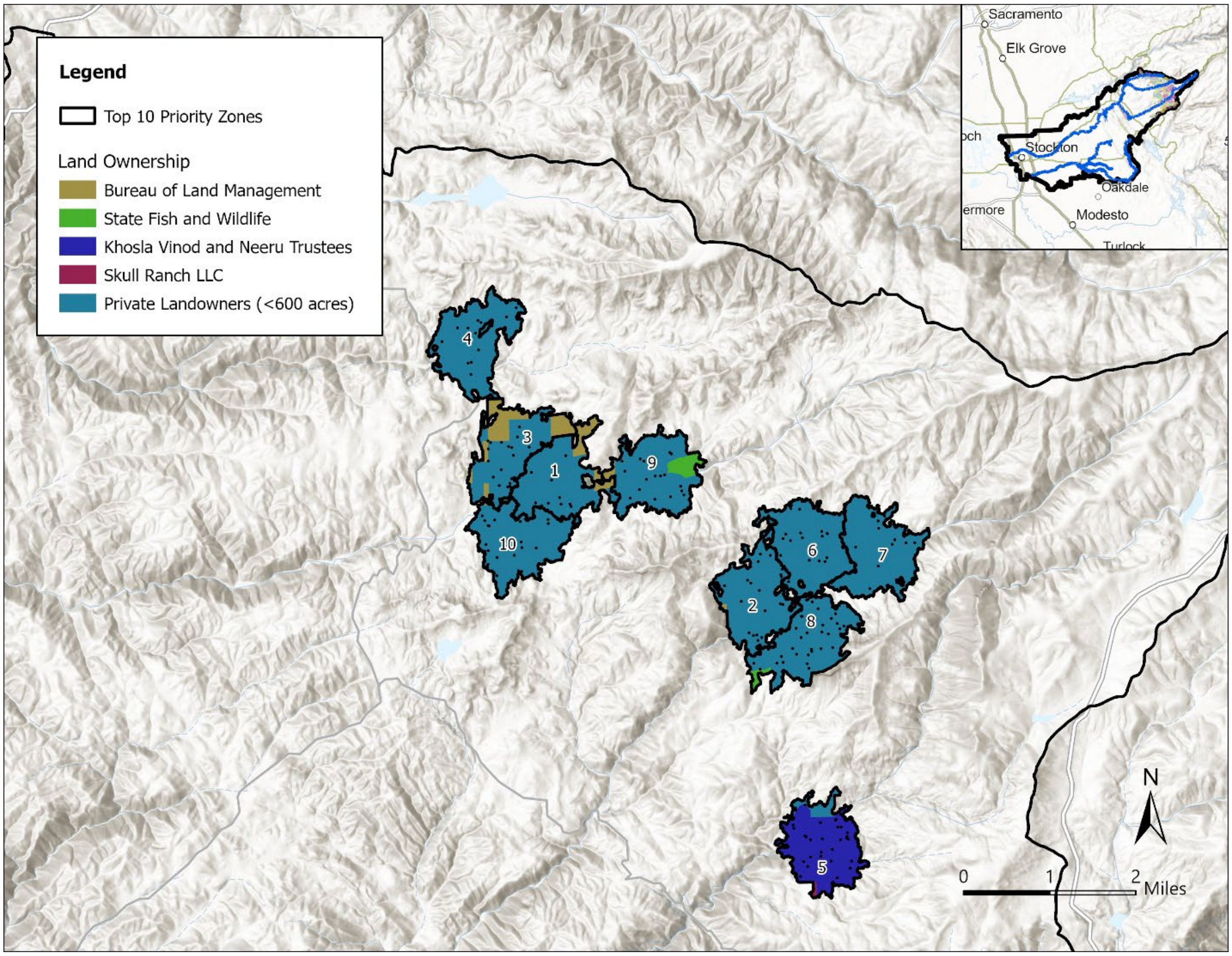
Project Name	Strategy Type	Status	Scheduled Completion	Capital Costs (2024$)	Next Steps
Wastewater Collection Infrastructure Improvements	Infrastructure Improvement	Conceptual	TBD	TBD	CCWD will conduct feasibility and/or planning studies to determine project scope, assess alternatives, and estimate project costs.
FIRO Implementation at New Hogan Dam	Infrastructure Improvement	Conceptual	TBD	TBD	CCWD and SEWD will coordinate with USACE to complete feasibility and/or planning studies to determine project scope, assess alternatives, and estimate project costs.
Flood Diversions for Groundwater Recharge Under Water Code Section 1242.1	Flood Risk Reduction	Conceptual	TBD	TBD	CCWD and SEWD will conduct feasibility and/or planning studies to determine project scope, assess alternatives, and estimate project costs.

7.1.2. Land Management Strategies

The vast majority of the land management adaptation strategies came from the analysis completed by Vibrant Planet using the WildEST model. The wildfire hazard and mitigation analysis identified 100 priority zones, ranked by their projected effectiveness in reducing wildfire risks in the Watershed. The analysis resulted in suites of recommended treatments for all 100 zones, but for the purposes of this Plan, implementation recommendations focus on the top 10 priority zones. The wildfire mitigation analysis resulted in detailed treatment recommendations for the top 10 priority zones, including mechanical removal, manual thinning, herbivory and prescribed fire in small areas. If implemented, these treatment recommendations would effectively mitigate the upper Watershed's vulnerability to wildfire.

Implementing the recommended adaptation strategies will require partnerships and coordination amongst a range of entries including the Bureau of Land Management (BLM), the United States Forest Service (USFS), CAL FIRE, California Department of Fish and Wildlife (CDFW), and Calaveras County Office of Emergency Services (Calaveras County OES). While some land in the top 10 priority zones is managed by public agencies, most is privately owned, as shown in **Figure 7-1**. Project implementation on private land will be challenging, as it requires careful coordination and is largely dependent on voluntary participation. SEWD and CCWD can help to facilitate collaboration between landowners, implementing agencies, and other interested parties.

Figure 7-1: Land Ownership in the Top 10 Priority Zones



The locations and recommended treatments for wildfire priority zones should be incorporated into existing and future wildfire prevention planning, including updates to the Calaveras County Community Wildfire Protection Plan (CCCWPP), which is regularly updated by the Calaveras County Fire Safe Council in partnership with Calaveras County OES. Furthermore, SEWD and CCWD should maintain partnerships with Calaveras County OES and the Calaveras Fire Safe Council to collaborate on funding opportunities.

Implementing the recommended treatments will require significant funding due to the complexity and diversity of the treatment types. Long-term success of wildfire mitigation projects depends on periodic maintenance, necessitating continuous funding and collaboration between agencies and landowners. Partnering entities should collaborate to identify and pursue funding opportunities for both implementation and ongoing maintenance.

7.1.3. Water Quality Adaptation Strategies

Implementation of the Tier 3 Water Management strategies which address water quality is ongoing. Projects that enhance river flow, which may indirectly reduce stream temperatures, are currently being implemented under the HCP, as shown in **Table 7-1**. Similarly, several strategies that will reduce flood risk across the Watershed are planned or underway by several organizations, including SEWD and SJAFCA. Implementation of these strategies and programs would benefit from collaboration between entities to maximize flood resilience and minimize water quality impacts. Because information on water quality is reported at a very high level in this Plan, additional work should be conducted to better understand how climate change will impact water quality. This information is critical to developing adaptation strategies that directly address water quality impacts associated with climate change. Recommendations for future work are included in Section 3 of **Appendix C**.

7.2. PROGRAMMATIC IMPLEMENTATION STRATEGIES

The process to develop the Watershed Resilience Plan included establishing a Watershed Network, identifying needs, establishing goals and objectives, as well as the recommendation of key adaptation strategies. Programmatic strategies should be implemented to ensure that the goals for future climate resilience in the Watershed can be achieved.

While the adaptation strategies focused on meeting the first four Watershed Resilience Plan goals, was the planning process itself as well as key programmatic implementation strategies that work toward meeting the fifth Regional Collaboration and Implementation goal as presented in **Chapter 4**. The objectives developed to meet this goal are reiterated here:

- Improved coordination between agricultural and urban water suppliers
- Established communication pathways between agencies, stakeholders, and the public
- Collaboration between water agencies and emergency response agencies/planners
- Collaborated with local GSAs on SGMA-related actions and management strategies
- Recognized watershed resilience leadership
- Funded strategy implementation
- Leveraged local resources efficiently
- Open communication to avoid contradicting regulations
- Public outreach and education

Programmatic implementation support of the Watershed Resilience Plan will need to come from not only SEWD and CCWD, but everyone within the Watershed Network that can benefit from its implementation. DWR will also be a key parter in ensuring that climate resilience can be achieved by continuing to direct state resources to further develop and fund the Watershed Resilience Program. The following seven programmatic strategies will support continued implementation of the Watershed Resilience in accordance with all five Watershed goals and objectives.

1. **Identify Watershed Coordinator to coordinate Watershed-wide, programmatic activities and advocate for the needs of the Watershed.** A Watershed Coordinator is critical to the long-term success of the Watershed Resilience Plan and provides a consistent point of contact for the Watershed Network and others looking to coordinate on watershed activities. Funding for this role would also need to be identified and secured.

2. **Prepare "state of the Watershed" report to document the health of the Watershed, highlighting progress towards goals and identifying future actions.** This report would compile data on the performance tracking indicators and make an assessment of the overall health of the Watershed. It should also provide overall direction for the Watershed, report on status of work being performed, and include recommendations for future work.

3. **Track progress on adaptation strategies and performance tracking indicators**. Significant effort was made in compiling the adaptation strategies and identifying the performance tracking indicators. Recognition of this effort and establishing a long-term commitment to the Watershed

Resilience Plan requires tracking progress on the strategies and indicators and reporting findings to the Watershed Network.

4. **Develop data hub to facilitate data sharing and reporting.** Development and maintenance of a data hub would facilitate data sharing between and among members of the Watershed to support collaboration and coordination of activities and adaptation strategies. The hub could also be used to report on progress made towards watershed goals via the performance tracking indicators and on adaptation strategies. An important tool for outreach, the hub could also be used as a way to continue engaging the Watershed Network.

5. **Support project proponents as needed during project implementation.** Proponents of the adaptation strategies may need support as they implement their projects. This support may include technical data, partnerships, or funding. Providing support to project proponents increases the likelihood that adaptation strategies are implemented and, where possible, coordinated with other activities in the Watershed to maximize benefits.

6. **Identify funding for adaptation strategy implementation.** Climate adaptation strategies can be challenging to implement due to their costs. Some strategies may require updates to existing infrastructure or development of new infrastructure, which can impact water supply costs. Other strategies may involve changes to water resource policies that directly or indirectly impact the agricultural economy. This is of particular concern in the Watershed as the region is dominated by agricultural land.

7. **Continue cross-agency coordination and collaboration.** Due to the nature of climate-related risks, successful climate adaptation requires collaboration between resource agencies, municipalities, and private landowners. This type of collaboration requires efficient and effective communication pathways which may or may not yet be in place. Any existing pathways are also often informal connections between individuals as opposed to formalized relationships between organizations; as staff turnover, these informal collaboration pathways are broken. In the case of wildfire, the sheer number of organizations, particularly when accounting for individual landowners, can make coordinated efforts more challenging. Additionally, the risk of many climate hazards, like wildfire, originates outside of the Watershed.

With the support of DWR and other state agencies, proponents and partners of the Watershed Resilience Plan will have opportunities to implement multi-benefit projects and strategies, collaborate on infrastructure upgrades, and develop regional partnerships to improve regional climate resilience. **Chapter 9** highlights several recommended next steps that the Watershed may take to capitalize on these opportunities to increase climate resilience in the region.

CHAPTER 8
PERFORMANCE TRACKING

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8. PERFORMANCE TRACKING

Tracking the performance of the Calaveras Watershed Plan requires the use of a suite of indicators that speak to the overall health of the Watershed. These indicators are useful in determining the success of identified adaptation strategies and identifying areas for continued improvement.

8.1. APPROACH FOR IDENTIFYING PERFORMANCE TRACKING INDICATORS

The Project Team developed a suite of performance tracking indicators that serve as vital signs for overall Watershed health. These indicators were selected based on several factors:

- Ability to represent progress toward meeting one or more Plan goals
- Existence of ongoing monitoring programs that could provide relevant data
- Level of effort needed to correlate data to progress

Using the Watershed goals and objectives that were developed with input from the Watershed Network, an initial list of indicators was prepared. While indicators were drafted to specifically address the goals, the objectives were considered as well. After the initial draft, SEWD and CCWD conducted an exercise to determine if data was already being collected for the indicators. If data was not already being collected for a particular indicator, they discussed where data could be collected and the difficulty of that collection. Where possible, the final list of indicators relies on those that have existing data; however, there are some where data collection and/or processing are required. This approach reflects the realities that funding new or extensive data collection efforts can be very challenging, especially given that a strong case can be made to prioritize the use of funding for project implementation. Should funding become available for performance tracking and data collection, the Watershed may consider expanding its performance tracking efforts. A recommendation to this effect is included in **Chapter 9**.

8.2. PERFORMANCE TRACKING INDICATORS

Table 8-1 presents the indicators for each goal area, including the metrics, data availability, and tracking method. The sections following the table briefly discuss the performance tracking indicators used for each goal and include information related to the type of indicator (qualitative or quantitative), the data available for the indicator, and the level of data processing that is required to report on the indicator. While the final list of indicators does rely on existing data, additional metrics and tracking methods that are not currently implemented could be implemented in the future as funding is identified.

Table 8-1: Performance Tracking Indicators for the Calaveras River Watershed

Indicator	Metric	Data Availability	Tracking Method
GOAL: GROUNDWATER			
Water recharged in Eastern San Joaquin (ESJ) Groundwater Basin	Acre-feet	The amount of water recharged annually into the ESJ Groundwater Basin is documented in the Groundwater Sustainability Plan (GSP) Annual Report for the ESJ Groundwater Basin	GSP Annual Report
ESJ Groundwater Basin groundwater level Minimum Thresholds are met	Yes/No	Minimum thresholds are set in the GSP and progress against minimum thresholds is documented in the Annual Report for the ESJ Groundwater Basin	GSP Annual Report
ESJ Groundwater Basin water quality minimum thresholds are met	Yes/No	Minimum thresholds are set in the GSP and progress against minimum thresholds is documented in the Annual Report for the ESJ Groundwater Basin	GSP Annual Report
GOAL: WATER SUPPLY			
Urban Water Use Objectives are met	Yes/No	SEWD & CCWD report progress against Urban Water Use Objectives to the State Board annually	SEWD & CCWD reporting to State Board
Agricultural run-off	Acre-feet per year	Upper Watershed: Data is not available on agricultural run-off; a tally of agricultural efficiency projects would need to be conducted Lower Watershed: Agricultural return flows for the lower watershed are modeled yearly during development of the Annual Report for the ESJ Groundwater Basin	Upper Watershed: Survey of project benefits Lower Watershed: GSP Annual Report modeling
New surface supply	Acre-feet	Data is available but needs to be collected: a tally of new surface supply would need to be conducted	Survey of project benefits

Indicator	Metric	Data Availability	Tracking Method
GOAL: AGRICULTURE & URBAN VITALITY			
Amount of land treated for wildfire resilience	Number of acres	Data is available but needs to be collected: a tally of the number of acres treated for wildfire resilience would need to be conducted	Survey of project benefits
Financial value of agriculture crops	Dollars ($USD)	Calaveras and San Joaquin counties prepare agriculture crop reports each year which contain financial information about the County's agriculture industry	County agriculture crop reports
Sales tax revenue	Dollars ($USD)	Calaveras and San Joaquin counties each prepare an Annual Comprehensive Financial Report, which lists revenue including sales tax	County Annual Comprehensive Financial Reports
GOAL: ECOSYSTEMS & ENVIRONMENTAL HEALTH			
Water quality parameters at SEWD and CCWD water treatment plants	TDS[1] (ppm[2]), TOC[3] (ppm), e.coli (cfu/100 mL[4]), temperature (ºF), turbidity (NTU[5]), nitrate (ppm), pH, alkalinity (ppm), hardness (ppm), iron (ppb[6]), manganese (ppb)	SEWD (at the Dr. Joe Waidhofer WTP) and CCWD (at Jenny Lind WTP) already collect influent water quality information at the intake to their water treatment plants that reflect water quality in the river	Water quality sampling
Steelhead trout (O. *mykiss*) fish count	Number of fish	The abundance (number) of steelhead trout is documented in the Annual Report for the Calaveras River Habitat Conservation Plan; status review of species of concern will occur every 5 years	HCP Annual Report / fish counts
GOAL: REGIONAL COLLABORATION & IMPLEMENTATION			
Include input across multiple interested parties and agencies in the Resilience Plan	Yes/No	Input received during development of the Resilience Plan is documented in Chapter 2 of the Resilience Plan and the associated technical memorandum on the Watershed Network	Resilience Plan published and posted on SEWD & CCWD webpages

[1] Total dissolved solids
[2] parts per million
[3] Total organic carbon
[4] Colony forming units per 100 milliliters
[5] Nephelometric Turbidity Unit
[6] parts per billion

Groundwater

The data for all three indicators is already collected and reported in the Annual Report for the Eastern San Joaquin Groundwater Basin which is published each year in April. Minimal data processing is required to report on these indicators for the Calaveras Watershed. For the two qualitative indicators, no processing is required. For the quantitative indicator related to the amount of water recharged in the Eastern San Joaquin Groundwater Basin, some moderate data processing is required to capture only the amount of water recharged to the groundwater basin from within the Calaveras Watershed. Because the groundwater basin extends beyond the Calaveras Watershed, the number presented in the Annual Report needs to be adjusted to capture only the amount of water recharged to the basin from the Watershed.

Water Supply

For the qualitative measure on Urban Water Use Objectives (UWUOs), both SEWD and CCWD collect and report this information annually to the State Board. To identify the amount of new surface supply in the both the upper and lower Watershed, a survey of project benefits would need to be conducted. Data on agricultural run-off in the upper Watershed is not collected nor modeled; a survey of benefits related to agricultural efficiency projects would need to be conducted. Agricultural run-off in the lower Watershed can be obtained from the modeling conducted for the GSP Annual Report; no data processing is required.

Agriculture & Urban Vitality

There are three indicators for the Agriculture & Urban Vitality goal area, all of which are quantitative indicators. Data for two of the three indicators is already collected and reported elsewhere. Data for the third indicator related to the number of acres undergoing wildfire treatment is not currently collected; a survey of project benefits is required to collect data related to this indicator.

Some data processing is required to report on these indicators. Because the raw data for each indicator includes areas outside the Watershed, the data needs to be adjusted to capture only the area within the Watershed. Additionally, as data is collected over time, standardization of financial data would need to conducted so as to account for inflation or other factors influencing the value (implementation of voter-approved sales tax measures, e.g.).

Ecosystem & Environmental Health

There are two indicators for the Ecosystem & Environmental Health goal area, both of which are quantitative indicators. Data for both indicators is already collected as part of other efforts. In the case of steelhead trout fish counts, this data is being collected through 2030 as part of the Calaveras River Habitat Conservation Plan; after 2030, the funding for this data collection expires and the data for this indicator needs to be collected in some other way. Water quality data is collected through at least annual sampling at SEWD and CCWD water treatment plants.

No data processing is required to report on these indicators. Water quality data and fish counts can be reported as-is.

Regional Collaboration & Implementation

There is one qualitative indicator for the Regional Collaboration & Implementation goal area. This indicator assesses the level and breadth of input received on the Calaveras River Resilience Plan and would be used at points in the future when the Plan is undergoing any updates. Input received during development of this Watershed Plan is documented in **Chapter 2** and the technical memorandum on the Watershed Network included as **Appendix A**.

CHAPTER 9

KEY FINDINGS & NEXT STEPS

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9. KEY FINDINGS & NEXT STEPS

The planning process used to develop the Watershed Plan was funded through the Watershed Resilience Pilot Study program. The recommendations and results of the planning process will be used by DWR to inform future program development and guidance. This chapter summarizes the key findings of the Watershed Study as described in previous chapters as well as several recommended next steps to inform the Watershed Resilience Program as it continues to mature and evolve.

9.1. KEY WATERSHED RESILIENCE PLAN FINDINGS

Significant effort was dedicated to the development of the climate change vulnerability and risk assessment (**Chapter 5**) and the consideration and development of adaptation strategies (**Chapter 6** and **Chapter 7**). This work led to several key findings about the climate reliance of the Calaveras Watershed.

HAZARDS	The Watershed faces three primary climate hazards: wildfire, extreme precipitation, and drought. These hazards are already affecting water supply reliability, infrastructure, and ecological conditions throughout the region, and projected to intensify under climate change.
DIRECT IMPACTS	By 2050, temperature is expected to increase by +2 degrees Celsius, water demand is expected to increase by 22,000 AFY. Although no change in average annual precipitation is expected, extreme precipitation events are expected to increase by 14 percent.
WATER VULNERABILITIES	Without intervention, stream flows will decrease by up to 65,000 AFY resulting in surface water supplies decreasing by 16,000 AFY. With decreasing surface supplies it is anticipated that the need for groundwater pumping will increase to 35,000 AFY resulting in average groundwater storage decreases by 34,000 AFY and decreased groundwater levels by an average of 40 feet. More frequent and intense precipitation events will increase peak Calaveras River flows by 3% on average, increasing flood risk as well as erosion potential that can in turn increase the mobilization and loading of contaminants in water bodies. Conversely during drought events, reductions in stream flow may increase stream temperatures below New Hogan Dam during critical spawning periods for salmonids.
WILDFIRE VULNERABILITY	The Watershed and its Highly Valued Resources and Assets (HVRAs) are highly vulnerable to several wildfire risks, including high annual burn probabilities, long characteristic flame lengths, and challenging suppression conditions, particularly in the upper Watershed.

ADAPTATION STRATEGY BENEFITS

Implementation of the Tier 1 and 2 adaptation strategy projects could mitigate declines in water supply by increasing water supply by 55,000 AFY, aquifer storage by 18,000 AFY and groundwater levels by 20 feet.

Implementing the recommended wildfire treatments in the Top 10 priority zones would significantly reduce burn probabilities by up to 25% characteristic flame lengths by up to 93%, and erosion rates by up to 73%, greatly decreasing the upper Watershed's vulnerability to wildfire.

A combination of land and water management strategies would protect surface water quality by maintaining adequate stream temperatures for anadromous fish and reducing contaminant transport.

IMPLEMENTATION PRIORITIES

The region should continue to work collaboratively in support of existing Tier 1 Water Management Strategy implementation plans. The Farmington Reservoir Project (which would allow for the implementation of Tier 2 Water Management Strategies) will need to be implemented to increase storage capacity by 60,000 AF, allow for implementation of Tier 2 projects and provide significant opportunity to lessen flooding and water supply impacts.

Wildfire land management strategies will need proponents to actively scope and fund land management strategies identified in the Top 10 priority zones.

Resources will need to be allocated to implement programmatic strategies that continue planning work and track progress.

9.2. RECOMMENDED NEXT STEPS

As the Watershed Resiliency Program is still in a pilot phase, there is uncertainty about how and when future aspects of the program will roll out. Until further direction is provided by the State, the Watershed may consider the following recommended next steps:

- **Identify a funding source(s)** to support programmatic implementation of the Watershed Resilience Plan as well as individual project strategies. Implementing these programmatic strategies comes with a significant cost, especially staff time, so partnerships between agencies may be beneficial.
- **Continue developing and implementing projects** led by the respective project proponents. The Watershed Network should identify proponents for strategies without any, particularly for projects within the Wildfire Priority Zones. Any progress made on these projects moves the Calaveras Watershed towards a more climate resilient future.
- **Advocate for the implementation of the Farmington Reservoir Project.** This project is critical to the success of Tier 2 Water Management Strategies, which rely on the additional 60,000 AF of storage that would be created. The Farmington Reservoir Project is critical to the Watershed's ability to adapt to climate change impacts.

- **Track development of a state-wide Watershed Resilience Program** and be ready to leverage any funding source(s) that arise. As this Plan was developed while the Program was in a pilot phase, there are likely to be changes or additional aspects of the Program as it rolls out statewide. The Watershed would benefit from tracking this and determining how it can address new requirements.
- **Conduct additional analysis and progress tracking** using tools and datasets developed or identified within the Watershed Plan. This work could include implementing modeling refinements to improve model fidelity and expand analytical capabilities (discussed in **Appendix E**) and expanding the scope of risk assessments to include additional risk categories related to water quality (discussed in **Appendix C**), ecosystem and habitat (discussed in **Appendix F**), and wildfire-hydrology interactions (discussed in **Section 5.7**).

CHAPTER 10
REFERENCES BY CHAPTER

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10. REFERENCES BY CHAPTER

CHAPTER 1

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APPENDIX A. TECHNICAL MEMORANDUM 5: OUTREACH ACTIVITIES

APPENDIX B. REGIONAL CLIMATE ASSESSMENTS AND RESILIENCE PLANS

APPENDIX C. TECHNICAL MEMORANDUM 1: WATERSHED WATER QUALITY RISKS

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APPENDIX E. TECHNICAL MEMORANDUM 2: HYDROLOGIC MODELING

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APPENDIX G. ADAPTATION STRATEGIES