Appendix H
Climate Change Adaptation for the CVFPP Conservation Strategy Update Memorandum

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Contents

Attachment

Tables

Tables (continued)

Figures

Figures (continued)

Acronyms and Abbreviations

Acronym	Definition
AEP	annual exceedance probability
AR	atmospheric river
CMIP5	Coupled Model Intercomparison Project Phase 5
Conservation Strategy (or Strategy)	Central Valley Flood Protection Plan Conservation Strategy
CPA	conservation planning area
CVFPP	Central Valley Flood Protection Plan
EcoFIP	Ecological Floodplain Inundation Potential
ET	evapotranspiration
FIP	floodplain inundation potential
FIRO	Forecast-informed Reservoir Operations
Flood-MAR	flood-managed aquifer recharge
FROA	Floodplain Restoration Opportunity Analysis
GCM	general circulation model
HEC-RAS	Hydrologic Engineering Center River Analysis System
HEC-ResSim	Hydrologic Engineering Center Reservoir System Simulator
IEA	International Energy Agency
km	kilometer(s)
memorandum	Climate Change Adaptation for the CVFPP Conservation Strategy Update Memorandum
Portfolio	Water Resilience Portfolio
RCP	representative concentration pathway
SPA	systemwide planning area
SPFC	State Plan for Flood Control
SRA	shaded riverine aquatic

Acronym	Definition
SSIA	State Systemwide Investment Approach
State	State of California
Strategy (or Conservation Strategy)	Central Valley Flood Protection Plan Conservation Strategy
SWE	snow water equivalent
VIC	variable infiltration capacity

Glossary

Glossary Term	Definition
adaptation	The process of adjustment to actual or expected climate and its effects. In human systems, adaptation seeks to moderate or avoid harm or exploit beneficial opportunities. In some natural systems, human intervention may facilitate adjustment to expected climate and its effects. (Definition from International Panel on Climate Change 2014.)
adaptation measure	An adaptation measure refers to an action that enhances resilience or reduce vulnerability to observed or expected changes in climate.
adaptation strategy	An adaptation strategy refers to a policy or planning approach designed to enhance resilience or reduce vulnerability to observed or expected changes in climate.
adaptive management	(1) a framework and flexible decision-making process for ongoing knowledge acquisition, monitoring, and evaluation leading to continuous improvement in management planning and implementation of a project to achieve specified objectives (California Water Code Section 8502). (2) management that improves the management of biological resources over time by using new information gathered through monitoring, evaluation, and other credible sources as they become available, and adjusts management strategies and practices to assist in meeting conservation and management goals. Under adaptive management, program actions are viewed as tools for learning to inform future actions (California Fish and Game Code Section 13.5).
conservation planning area (CPA)	One of five subdivisions of the Systemwide Planning Area that differs from other CPAs in regard to natural resources and CVFPP activities. Each CPA consists of one or more regional flood management plan regions and the adjoining upstream portions of the SPA.
dynamic hydrologic and geomorphic processes	In the context of river systems, the dynamic processes of water flow subsurface, overland, and in rivers and the resulting entrainment, transport, and storage of sediment in river channels and on floodplains.

Glossary Term	Definition
floodplain	*Active (or "connected") floodplain:* The geomorphic surface adjacent to the stream channel that is typically inundated on a regular basis (i.e., with a recurrence interval of about 2 to 10 years or less). It is the most extensive low-depositional surface, typically covered with fine overbank deposits, although gravel bar deposits may occur along some streams.
"Inactive" (or "disconnected") floodplain	Historical floodplains that are no longer inundated because of channel incision, flow regime changes, or intervening levees. The floodplain surface often contains abandoned channels or secondary channels (i.e., chutes).
geomorphology	The study of the characteristics, origins, and development of landforms.
multi-benefit project	In the context of the CVFPP, projects designed to reduce flood risk and enhance fish and wildlife habitat. Multi-benefit projects may also create additional public benefits such as sustaining agricultural production, improving water quality and water supply reliability, increasing groundwater recharge, supporting commercial fisheries, and providing public recreation and educational opportunities, or any combination thereof. (Definition from California Department of Water Resources 2017a.)
operations and maintenance (O&M)	The effort that must be expended to keep project facilities in good working condition so they continue to operate as designed—wear and tear on facilities that are not adequately maintained can reduce their capacity or make them more vulnerable to failure. O&M also refers to the management of adjustable features (e.g., flow rate, stage, reservoir storage) to achieve the desired conditions.
resilience	The capacity of a resource and natural or constructed system to adapt to and recover from changed conditions after a disturbance. (Definition from California Department of Water Resources 2018.)
shaded riverine aquatic cover	The unique, nearshore aquatic area occurring at the interface between a river (or stream) and adjacent woody riparian habitat. Key attributes of this aquatic area are as follows: (1) The adjacent bank is composed of natural, eroding substrates supporting riparian vegetation that either overhangs or protrudes into the water; and (2) the water contains variable amounts of woody debris, such as leaves, logs, branches, and roots; often has substantial detritus; and has variable velocities, depths, and flows. (Definition from U.S. Fish and Wildlife Service 1992.) SRA cover provides structural and functional integrity for several regionally important fish and wildlife species. It has drastically declined in area and has become increasingly fragmented in the Central Valley.

Glossary Term	Definition
State Plan of Flood Control	The State and federal flood control works, lands, programs, plans, policies, conditions, and mode of O&M of the Sacramento River Flood Control Project, described in California Water Code Section 8350, and of flood control projects in the Sacramento River and San Joaquin River watersheds, authorized pursuant to Article 2 (commencing with Section 12648) of Division 6, Part 6, Chapter 2, for which the CVFPB or DWR has provided the assurances of nonfederal cooperation to the United States, and those facilities identified in California Water Code Section 8361 (California Water Code, Section 9110[f]).
Systemwide Planning Area	The geographic area that encompasses lands receiving flood damage reduction benefits from the existing SPFC facilities and operation of the Sacramento–San Joaquin River Flood Management System.
vulnerability	The propensity or predisposition to be adversely affected. Vulnerability encompasses a variety of concepts and elements including sensitivity or susceptibility to harm and lack of capacity to cope and adapt. (Definition from International Panel on Climate Change 2018.)
watershed	The land area from which water drains into a stream, river, or reservoir. The watershed for a major river may encompass a number of smaller watersheds that ultimately combine at a common point. (Definition from California Department of Water Resources 2018.)

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CHAPTER 1

Introduction

The Central Valley Flood Protection Plan (CVFPP) Conservation Strategy (Conservation Strategy, or Strategy) (California Department of Water Resources 2016) provides specific goals and objectives related to the conservation and restoration of ecological processes, habitats, and species, as well as the alleviation of ecological stressors within the Central Valley flood system. It is a critical supporting document of the CVFPP, and is being used as key guidance by State of California (State), regional, and local partners to implement multi-benefit projects that advance flood protection and ecosystem restoration. A key theme of the 2022 update to the CVFPP and Conservation Strategy is climate resilience; supported by a body of work to describe and better understand flood-related risks and vulnerabilities, and to provide a set of recommendations and adaptation strategies related to climate change. In addition, the 2020 Water Resilience Portfolio (Portfolio) identifies climate change as a key driver for California water resources and environmental management in the coming decades, and proposes management actions to mitigate impacts and improve system resiliency.

Climate change is a critically important issue, with major ecological consequences leading to changes in the abundance and distribution of many populations (Dunn and Møller 2019; Rosenzweig et al. 2008), including for the flood system in the Central Valley. The resilience thresholds of many ecosystems, including the riverine and floodplain habitats in the Central Valley flood system, are likely to be exceeded this century by an unprecedented combination of climate change and associated disturbances. This, combined with the cumulative effects of other anthropogenic activities, such as land use alterations and water use activities, will result in major impacts to ecosystem structures and functions (Trenberth and Hurrell 2019, Saether et al. 2019).

This Climate Change Adaptation for the CVFPP Conservation Strategy Update Memorandum (Memorandum)(i.e., Appendix H) uses recent climate modeling analyses that have been developed to inform the 2022 CVFPP Update. Results are used to determine climate risks, vulnerabilities, and a fraction of the full range of uncertainties in the context of the Conservation Strategy, focusing on the measurable objectives and target species at the Conservation Planning Area (CPA) scale. This evaluation involves three fundamental steps:

1. Estimate climate change drivers (e.g., changes in temperature, precipitation, and hydrology) at the scales and frequencies relevant to the Conservation Strategy’s measurable objectives.

2. Consider ecosystem responses to those changes, for the ecosystem process, habitats, species, and stressors identified in the Conservation Strategy.

3. Describe preliminary adaptation and management measures based on identified risks and vulnerabilities.

A companion study, entitled “Climate Change Adaptation Measures Report,” is in progress and describes the climate change risks, vulnerabilities, uncertainties, and adaptation approaches for the overall CVFPP planning area; climate change modeling data and information on risks, vulnerabilities, and adaptation approaches are being shared between these two efforts (California Department of Water Resources 2022a). This memorandum is consistent with, and supports the implementation of, the climate change adaptation measures described by Governor Gavin Newsom’s Water Resilience Portfolio. The Portfolio was finalized on July 28, 2020 and provides the Administration’s blueprint for equipping California to cope with more extreme droughts and floods and rising temperatures, while addressing long-standing challenges that include declining fish populations, over-reliance on groundwater, and a lack of safe drinking water in many communities. The Portfolio embraces a broad, diversified approach. Goals and actions are organized into four categories, one of which, “Protect and Enhance Natural Ecosystems,” describes adaptation measures that are congruent with similar actions described by the Conservation Strategy.

This document is intended to inform the 2022 update to the Conservation Strategy, provide the basis to re-evaluate or refine measurable objectives in future updates, and more broadly, provide a template and process for how other State and regional programs can develop ecologically based climate change adaptation approaches.

Specifically, the objectives of this memorandum are to:

1. Identify current climate modeling data and results that can be used to assess the spectrum of changes in hydrologic and geomorphic processes that could impact Conservation Strategy’s measurable objectives and target species.

2. Estimate the ecological, habitat, and species-specific responses to these physical changes.

3. Describe preliminary adaptation measures and considerations for increasingly resilient multi-benefit projects.

4. Identify data gaps and additional tools or analyses that could be used to inform ecosystem responses and the development of adaptation measures.

5. Consider how Conservation Strategy-specific adaptation measures also provide benefits for larger CVFPP flood-related goals.

This memorandum is organized into the following sections:

- **Chapter 2 – Background on Climate Modeling Research and Adaptation Approaches**: Summarizes existing climate change modeling and adaptation planning efforts, as well as key climate adaptation guidance relevant to the objectives of the Conservation Strategy.
- **Chapter 3 – Projected Hydroclimate Changes and Ecosystem Responses**: Analyzes projected changes in temperature, precipitation, and hydrology throughout the Central Valley, and describes the associated impacts of climate change on watersheds and ecosystems. Also characterizes the projected responses of the Conservation Strategy objectives to the effects of climate change.
- **Chapter 4 – Potential Adaptation Strategy and Measures**: Lists potential adaptation measures to improve the resilience and reduce the vulnerability of ecosystem processes, habitats, and species in the face of climate change.
- **Chapter 5 – Summary of Regional Climate Change Adaptation Strategies**: Identifies regional ecological risks and vulnerabilities, as well as opportunities to build ecological resiliency and mitigate the impacts of climate change.
- **Chapter 6 – Conclusions**: Summarizes key takeaways and recommendations from this memorandum.

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CHAPTER 2

Background on Climate Modeling Research and Adaptation Approaches

Research on climate change and its potential impacts has progressed rapidly in recent decades, although a great deal remains to be studied moving forward. Existing science has projected future changes in air temperature, precipitation, hydrologic responses, and sea level rise under numerous models and scenarios. However, ecological responses to these changes, particularly for habitats and species, have yet to be assessed in great detail. Uncertainties are also prevalent throughout much of this work, mainly due to the variability between climate models and lack of insight into all facets of hydroclimatic mechanisms and their changes. Nevertheless, climate change impacts on specific species and habitats represent an active field of scientific research, and these relationships are becoming increasingly well-understood.

The following tables summarize climate change modeling and adaptation planning efforts included for the 2022 CVFPP Update, as well as other climate adaptation guidance relevant to the Conservation Strategy’s measurable objectives. Table H-1 includes brief descriptions and key findings of various reports focusing on climate change impacts. In general, these sources identify and estimate projected physical responses to climate change, assess impacts on ecosystems and human infrastructure, and provide strategies for adapting to future conditions. These sources are included within the Climate Change Adaptation Measures Report of the 2022 CVFPP Update, which further discusses climate change impacts (California Department of Water Resources 2022a). Table H-1 lists reports that provide a broad and inclusive overview of climate change impacts, and additional sources with a more focused approach can be found in Table H.1-1 of Attachment H.1.

Table H-2 provides a brief overview of a number of identified sources that provide climate adaptation guidance for the Conservation Strategy objectives, including physical processes, habitats, species, and stressors. Vulnerabilities and adaptation strategies related to climate change are also described for various listed species and habitats. The purpose of this table is to highlight key reports and studies that may be particularly insightful for the ecological processes, habitats, and species identified in the Conservation Strategy. Additional sources can be found in Table H.1-2 of Attachment H.1.

Table H-1. Summary of Climate Change Modeling and Adaptation Planning Efforts

Document Title and Author	Description	Reference
2022 CVFPP Update Climate Modeling Work and Key Results – California Department of Water Resources (2022)	The 2022 CVFPP Update is building on the climate analyses conducted for the 2017 update, and highlights three overarching themes: climate resilience; project implementation, accomplishments, and performance tracking; and alignment with other State efforts. Related climate modeling work and key results are referenced from the 2022 CVFPP Update Technical Analysis Appendix A: Climate Change Analysis.	Central_Valley_Flood_Protection_Plan
Climate Change Adaptation Measures Report – California Department of Water Resources (2022)	The Climate Change Adaptation Measures Report (in progress) will discuss the projected changes in temperature, precipitation, snowpack, and hydrology; vulnerabilities for upper watersheds, major reservoirs, rivers and floodplains, groundwater, and the Delta; and the development and application of adaptation strategies to address the impacts of climate change on the Central Valley. Additionally, the Climate Change Adaptation Measures Report will include some discussion of projected impacts to ecosystems and habitats, as well as their associated vulnerabilities. To assess the projected impacts of climate change, three climate change scenarios are assessed and compared: low, median, and high. This approach aids in identifying vulnerabilities that result from these changes, and it helps to frame the adaptation strategies included in the report. Projected changes exhibit differing trends for each hydrometeorological component. In general, temperatures are expected to increase under all future climate scenarios. Average annual precipitation trends vary between climate scenarios, with decreases shown for the low and median scenarios, but an increase for the high climate scenario. Extreme precipitation is projected to increase under all scenarios. Increased temperatures will lead to precipitation falling more as rain rather than snow in higher elevations, leading to decreased snowpack and earlier spring snowmelt. These changes will shift peak flows and timing, increasing flood management concerns in the wet season while creating water availability risks in the dry season. In combination with sea level rise, levee infrastructure, particularly in the Delta, will be under increased stress.	A reference will be provided once the document has been completed.

Document Title and Author	Description	Reference
California Adaptation Planning Guide (APG)–California Governor's Office of Emergency Services (2020)	The California APG provides guidance to support local governments in addressing the impacts of climate change through local adaptation and resiliency planning. The APG is designed to be flexible for communities that wish to examine the consequences of climate change in a broader or more specific manner. The first APG was released in 2012 and was updated in 2020 to integrate and account for recent changes to information and practices. California Government Code § 65302 requires local cities and counties to include climate adaptation and resiliency strategies in the safety section of their general plans. This planning guide aims to aid these local communities in their compliance with this code. The APG divides the adaptation planning process into four phases. Phase 1 (Explore, Define, and Initiate) includes identifying key assets of the local community, potential impacts of climate change, and important stakeholders in the area. Phase 2 (Assess Vulnerability) analyzes the climate change impacts identified in Phase 1 and determines the vulnerability of the community's assets. Phase 3 (Define Adaptation Framework and Strategies) takes the results from Phase 2 and develops an adaptation framework and strategies to address the local community's listed vulnerabilities. Finally, Phase 4 (Implement, Monitor, Evaluate, and Adjust) implements the adaptation framework from Phase 3 and continually monitors and evaluates its performance. Adjustments are made, if necessary.	2020-Adaptation-Planning-Guide-FINAL-June-2020-Accessible.pdf

Document Title and Author	Description	Reference
Delta Adapts: Creating a Climate Resilient Future – Delta Stewardship Council (2021)	Delta Adapts seeks to highlight future conditions and vulnerabilities to climate change in the Delta, and to describe mitigation and adaptation methods for communities, infrastructure, and ecosystems to address these impacts. Delta Adapts is divided into two phases: a vulnerability assessment (currently available), and an adaptation plan (in development). The vulnerability assessment characterizes existing and future vulnerabilities under climate change, and the adaptation plan aims to identify approaches that can be employed to enhance the region's resiliency. Primary climate stressors discussed in this report include precipitation and hydrologic patterns, air temperature, sea level rise, and extreme events. Secondary climate stressors include wind, fog, and wildfires. Key findings of the vulnerability assessment include worsening flood events, spatially varied climate change impacts on Delta residents, less reliable Delta exports, a lack of reservoir storage, water quality changes, threats to Delta ecosystems, and shifts in agricultural production trends.	Delta-Adapts-Vulnerability-Assessment

Document Title and Author	Description	Reference
CA Water Resilience Portfolio – California Natural Resources Agency, California Environmental Protection Agency, California Department of Food and Agriculture (2020)	The CA Water Resilience Portfolio contains recommended goals and actions for local and regional bodies to address water challenges in California. These are divided into four main categories: maintain and diversify water supplies, protect and enhance natural ecosystems, build connections, and be prepared. The Portfolio is a byproduct of Governor Newsom's Executive Order N-10-19 and was created with seven key principles in mind. These include: prioritize multi-benefit approaches that meet several needs at once; use natural infrastructure such as forests and floodplains; embrace innovation and new technologies; encourage regional approaches among water users sharing watersheds; incorporate successful approaches from other parts of the world; integrate investments, policies, and programs across State government; and strengthen partnerships with local, federal, and tribal governments, water agencies, irrigation districts, and other stakeholders. Vulnerability assessments are performed for various regions across California. Vulnerabilities are ranked in order of increasing vulnerability, from 1 to 4. Categories assessed include drinking water threats, water scarcity, unsafe beach conditions, impaired water quality, flood risks, limited drought readiness, threats to ecosystem vitality, challenges to sustainable groundwater management, sea level rise, affordability challenges, threats to agricultural sustainability, and aging infrastructure of statewide significance. Like adaptation planning, this Portfolio addresses various adaptation strategies to meet the State's water needs going forward. Specific adaptation strategies are listed under the four categories highlighted within the Portfolio, and additional adaptation strategies are included under the "Executing this Portfolio" section. In total, 32 adaptation actions are listed.	California-Water-Resilience-Portfolio-2020

Document Title and Author	Description	Reference
California's Fourth Climate Change Assessment – California Governor's Office of Planning and Research, State of California Energy Commission, California Natural Resources Agency (2018)	California's Fourth Climate Change Assessment identifies key vulnerabilities that the State faces as a result of climate change and provides guidance for actions that can improve resiliency. The assessment informs a number of State guidelines, programs, policies, and plans that aim to promote resiliency in California. The assessment outlines the vulnerabilities for individuals within California in the "Impacts of Climate Change on People" section. A map displaying the social vulnerability to heat using various health, social, and environmental factors is shown. The impacts of climate change on people, infrastructure, natural and working lands and waters, and the ocean and coast are assessed. Adaptation strategies are outlined throughout the assessment for the State to become more resilient in the face of climate change. Specific adaptation strategies include improvements to emergency management, disaster prevention, and increases to the institutional capacity of local and regional governments to protect all aspects of their regions.	www.climateassessment.ca.gov

Note:
APG = Adaptation Planning Guide

Table H-2. Summary of Climate Adaptation Guidance Relevant to Conservation Strategy Objectives

Document Title and Author	Description	Reference
Overview of Projected Future Changes in the California Central Valley – Central Valley Landscape Conservation Project (2017)	The Central Valley Landscape Conservation Project provides a general overview of the projected physical changes associated with climate change. These changes include the following: warming air temperatures, more arid landscapes, less snow with a higher percentage of precipitation as rain, more intense droughts and extreme heat, increased frequency and intensity of wildfire, changes to species phenology, declining groundwater levels, changes in stream flows, increased frequency and severity of flooding, increased stream temperatures, less agricultural acreage, more urban acreage, and shifts in vegetation types and composition. For floodplain inundation, stronger storms and higher peak flows earlier in the year as a result of more rapid snowmelt will likely lead to an increase in winter and spring flooding. Likewise, reduced snowpack and earlier snowmelt runoff have the potential to result in a decrease in mean annual flow. For impacts to streamflow regimes, runoff changes have the potential to impact sediment transport, channel migration, and the development of riparian zones.	http://climate.calcommons.org/article/central-valley-change
Projected Effects of Climate Change in California: Ecological Summaries Emphasizing Consequences for Wildlife – PRBO Conservation Science (2011)	The Projected Effects of Climate Change in California report gives a broad overview of the ecoregional-specific projected effects of climate change in California. The two main areas of interest for the Conservation Strategy are the Sacramento Valley Ecoregion and the San Joaquin Valley Ecoregion (pages 27 to 33). Each of these chapters covers the projected effects of climate change including changes to temperature, precipitation, streamflow and water availability, vernal pool hydrology, sea level rise, fire, vegetation change, and threats to wildlife. Projections to future time periods are included for each of the impacts of climate change.	Climate_Change-Consequences-for-Wildlife

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CHAPTER 3

Projected Hydroclimate Changes and Ecosystem Responses

3.1 Climate Change Modeling Approach and Results

This section uses climate change modeling the California Department of Water Resources (DWR) conducted to inform the 2022 CVFPP Update. As Chapter 1 described, some of this modeling output has been re-evaluated to advance the assessment of risks and vulnerabilities to the Conservation Strategy's measurable objectives. In particular, temperature, precipitation, and hydrology outputs were used to understand climate change impacts at the scale of the CPAs and to analyze changes in hydrology at ecologically important flow frequencies. Projected changes to sea levels, groundwater, and wildfires affecting the Central Valley are also discussed in a more qualitative manner using other supporting literature and studies. The following section summarizes the climate change modeling approach and results is provided in the following section; more detail can be found in the Climate Change Analysis Technical Memorandum (California Department of Water Resources 2022a), which is currently under development.

Figures H-1 and H-2 provide a basin-scale overview of the five CPAs. The Sacramento River Basin contains the Upper Sacramento, Feather, and Lower Sacramento CPAs, and the San Joaquin River Basin contains the Lower San Joaquin and Upper San Joaquin River CPAs. Locations of index points are superimposed onto each map to highlight areas used in the subsequent analysis of regulated flow and stage in this chapter.

Figure H-1. Sacramento River Basin Conservation Planning Areas and Analysis Locations

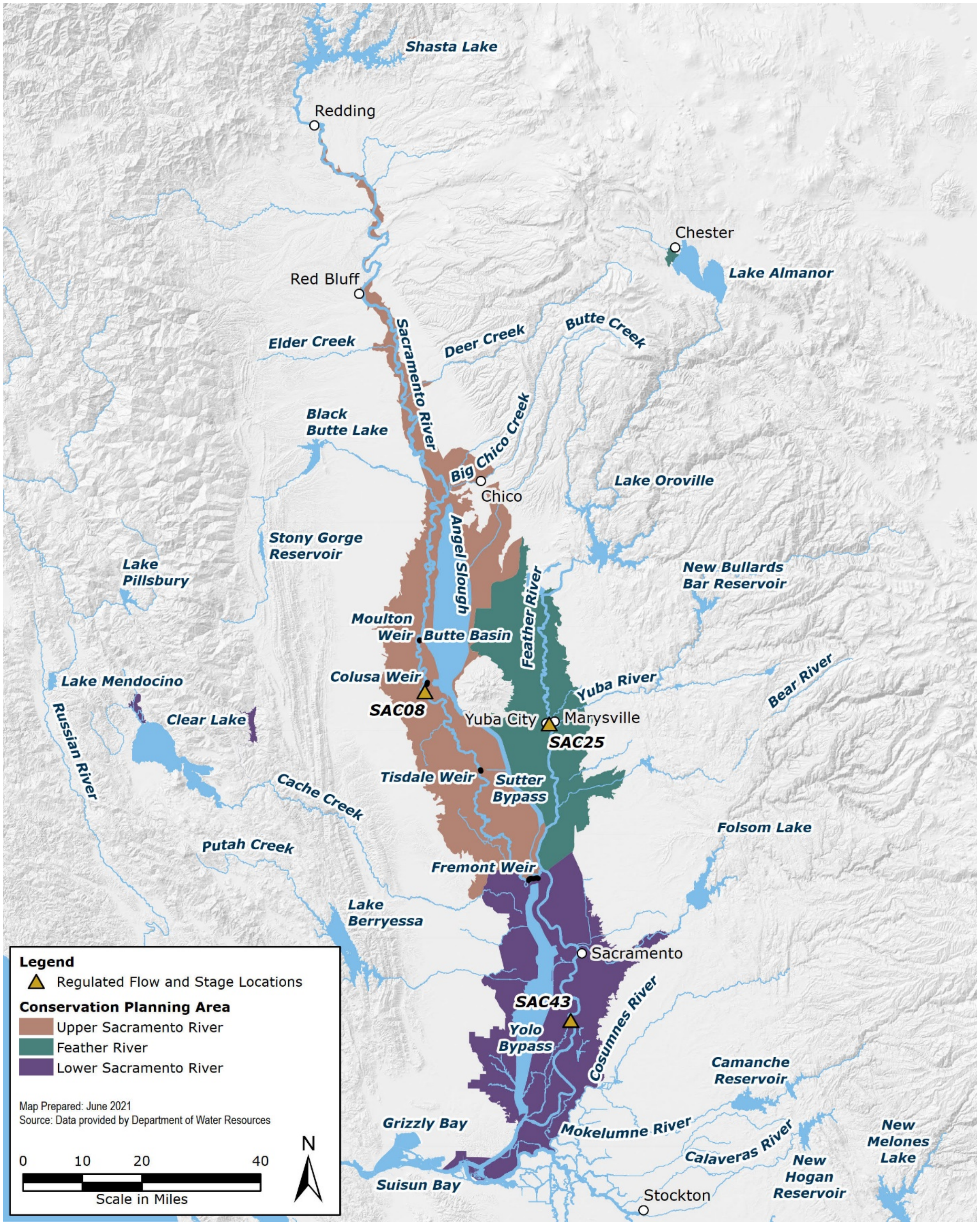
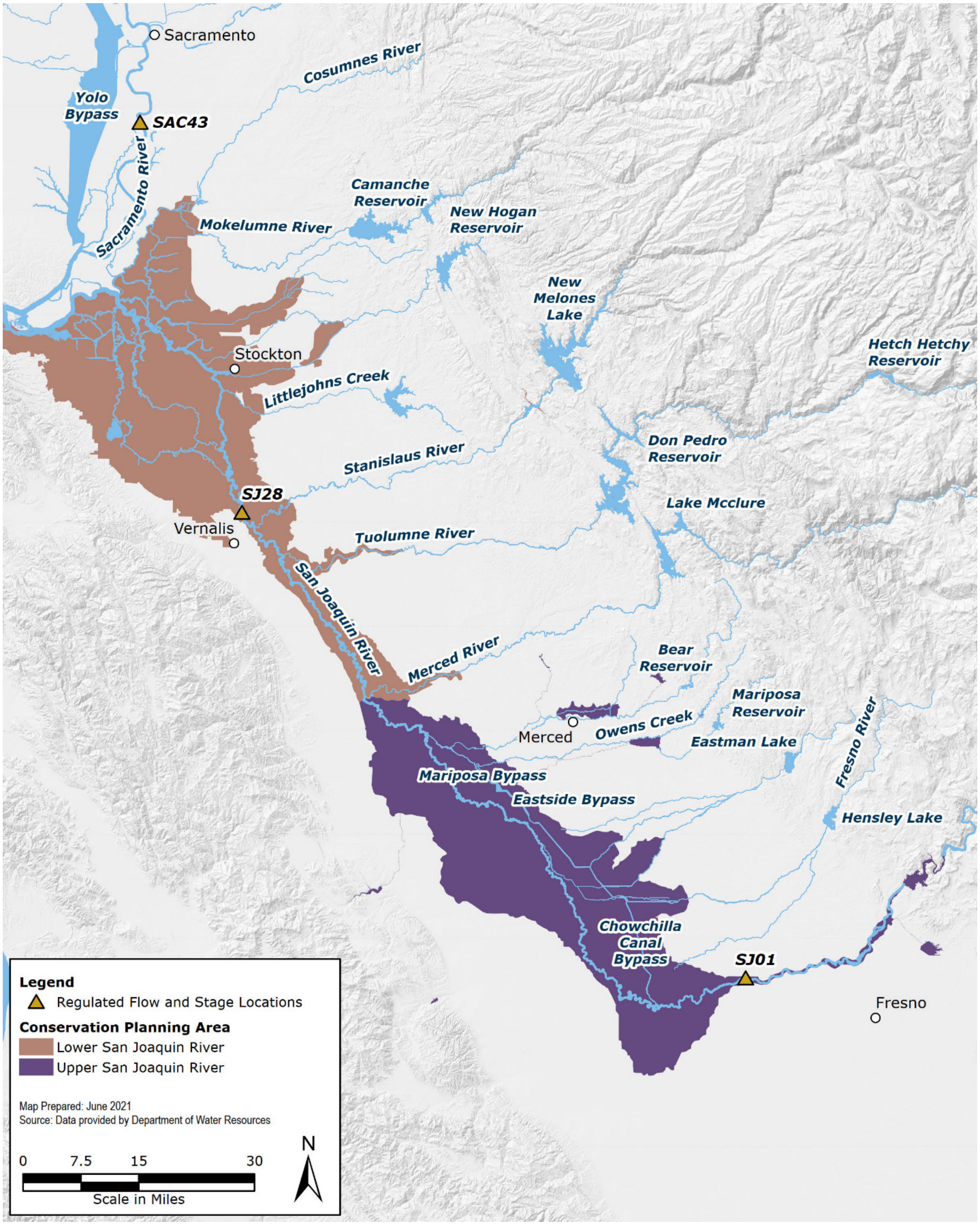


Figure H-2. San Joaquin River Basin Conservation Planning Areas and Analysis Locations

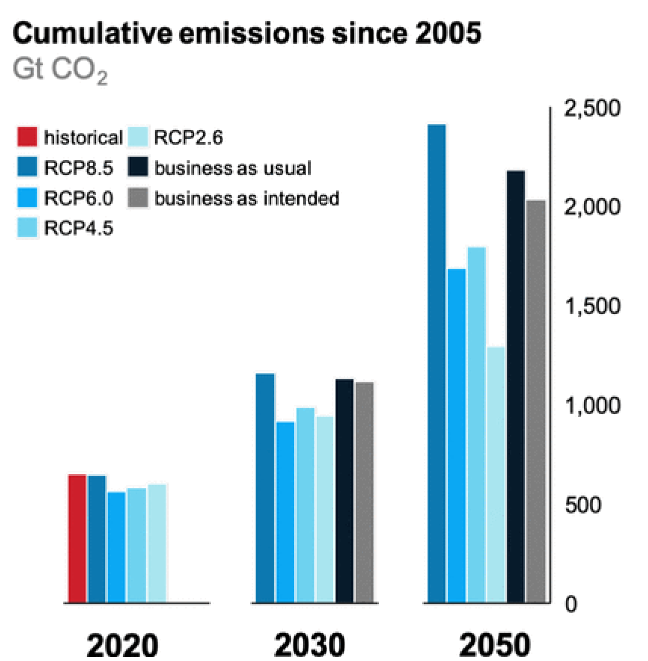


3.1.1 Climate Scenarios

Future climate scenarios used in the 2022 CVFPP Update climate change analysis are based on climate model simulations from the Coupled Model Intercomparison Project Phase 5 (CMIP5) (van Vuuren et al. 2011). The climate models in the CMIP5 (Taylor et al. 2012; Rupp et al. 2013; California Department of Water Resources 2017b) were driven using a set of emission scenarios (called Representative Concentration Pathways [RCPs]) to reflect the potential trajectories of greenhouse gas emissions over the course of the century. The CMIP5 (van Vuuren et al. 2011) uses four scenario pathways (RCP2.6, RCP4.5, RCP6.0, and RCP8.5). Each RCP defines a specific emissions trajectory and subsequent radiative forcing (i.e., change in energy flux in the atmosphere).

Figure H-3 compares historical and projected trends and the four RCPs. Historically, emissions between 2005 and 2020 most closely resembled the RCP 8.5 scenario. For 2030 and 2050, “business-as-usual” (no efforts to reduce current emission trends) and “business-as-intended” (incorporation of announced policy changes and emissions targets) projections are included to highlight the Stated Policies and Current Policies forecasts from the International Energy Agency (IEA) (International Energy Agency 2019). For these two additional scenarios, emissions from energy use were combined with future land use and industrial emissions to estimate what cumulative emissions could be like under current trends. The IEA scenarios appear to fall between the RCP 8.5 and RCP 4.5 scenarios, with RCP 8.5 providing an overestimation of future emissions trends and RCP 4.5 displaying an underestimation (Schwalm et al. 2020).

Figure H-3. Total Cumulative Carbon Dioxide Emissions since 2005 through 2020, 2030, and 2050



Source: Schwalm et al. 2020

Climate change scenarios for the 2022 CVFPP Update were developed using 64 climate model projections downscaled from 32 CMIP5 general circulation models (GCMs) and 2 RCPs (RCP4.5 and RCP8.5) using the localized constructed analogs method (Pierce et al. 2014). Three statistically representative climate change scenarios for low, median, and high climate change were constructed based on the ensemble-informed climate scenarios method, as well as a 30-year range of climate signals centered at 2072 (California Department of Water Resources 2022a). Ensemble members are plotted based on the projected change in precipitation and temperature. The median scenario was developed from the 32 climate projections nearest to the median change in temperature and precipitation. For the low and high climate change scenarios, a nearest-neighbor approach was used to sample the 10 nearest neighbors of the minimum (low) and maximum (high) change in both temperature and precipitation (California Department of Water Resources 2022a). These three scenarios improve on the median scenario used in the 2017 Update and should lead to an improved understanding of the uncertainty in hydroclimate outcomes.

Historical daily climate information (precipitation, minimum temperature, and maximum temperature) was available for the entire study area for the period of 1915 through 2011 at 1/16th degree (approximately 6 kilometers [km] or 3.75 miles) spatial resolution (Livneh et. al. 2013). The statistical changes calculated for the GCMs identified for the low, median, and high scenarios were then mapped onto the historical information to develop climate-adjusted records that reflect future climate conditions. These climatologies are used to assess the projected changes described in the remainder of Section 3.1. In this methodology, the natural variability, which is best characterized through the observed records, is maintained and combined with the projected changes in climate patterns (California Department of Water Resources 2022a).

3.1.2 Summary of Climate and Hydrology Scenario Results

Table H-3 summarizes the projected climate change trends discussed within Section 3.1. Temperature and precipitation were analyzed at both annual and monthly temporal scales. Changes to snowpack, streamflow seasonality and timing, regulated hydrology, sea level rise, groundwater, and wildfires were also examined.

Table H-3. Summary of Climate Projections Included in this Report[a]

Climate Change Component	Projected Change[b]
Mean Annual Temperature	Between a 2°C to 4°C increase by 2072, depending on climate projection model. (3.1.3)
Extreme Temperature	Extreme temperatures to increase under all three climate scenarios for all CPAs. (3.1.3)
Mean Monthly Temperature	Increased temperatures throughout the year, with greater divergence from historical temperatures in the summer. (3.1.3)

Climate Change Component	Projected Change[b]
Mean Annual Precipitation	Variable, depending on climate change scenario used (decreases under low and median; increases under high). (3.1.4)
Extreme Precipitation	Annual average three-day maximum precipitation to decrease under the low climate scenario and increase under the median and high climate change scenarios. Annual 99th percentile three-day maximum precipitation is projected to increase under all climate scenarios. More severe atmospheric river events are anticipated. (3.1.4)
Mean Monthly Precipitation	Variable, depending on climate change scenario used for winter months (decreases under low; increases under median and high). Decreased mean monthly precipitation during the remainder of the year. (3.1.4)
Snowpack	Reduced snowpack due to changing form of precipitation (rain than snow) and earlier spring snowmelt. (3.1.6)
Streamflow Seasonality and Timing	Shift in streamflow to the earlier months because of earlier spring snowmelt runoff and more precipitation as rain than snow. (3.1.7)
Regulated Hydrology	Varying projected changes to flow and stage, based on CPA and 2072 project implementation. In general, most CPAs show projected increase in both flow and stage. Three CPAs show minor increase in flow and stage for 10-year flood events, accompanied by a larger increase in flow and stage for 100-year flood events. (3.1.8)
Sea Level Rise	Increasing rate of sea level rise as warming conditions continue. Increased water levels and salinity in the Delta. (3.1.9)
Groundwater	Greater stress on groundwater supplies from decreased surface water quantities and evapotranspiration in summer months (3.1.10)
Wildfires	More severe wildfires in upper watersheds under increased warming conditions. Increased peak flows, debris flows, and contaminant presence downstream of burned areas. (3.1.11)

[a] Each component of climate change is described by its estimated changes (trends) in the adjacent column.

[b] Numbers in parentheses correspond to the section each climate change component is described.

Notes:

°C = degree(s) Celsius

CPA = conservation planning area

3.1.3 Changes in Temperature

Figure H-4 includes projected changes in mean annual temperature for each CPA. The Upper Sacramento and Feather River CPAs are projected to experience the greatest change in mean annual temperature. The Lower Sacramento and Lower San Joaquin River CPAs are projected to experience the lowest change in temperature of the CPAs, but only by a small margin. Overall, all CPAs will experience a relatively similar increase in mean annual temperature. In general, warmer temperatures are expected to decrease soil moisture and increase evapotranspiration (ET), particularly under periods of sustained drought (Ullrich et al. 2018; Mann and Gleick 2015). Drier soils and increased temperatures are also observed following years of below-average precipitation, suggesting drought conditions may be a key driver for these changes (Cayan et al. 2010).

Figure H-4. Projected Changes in Mean Annual Temperature (°C) by CPA

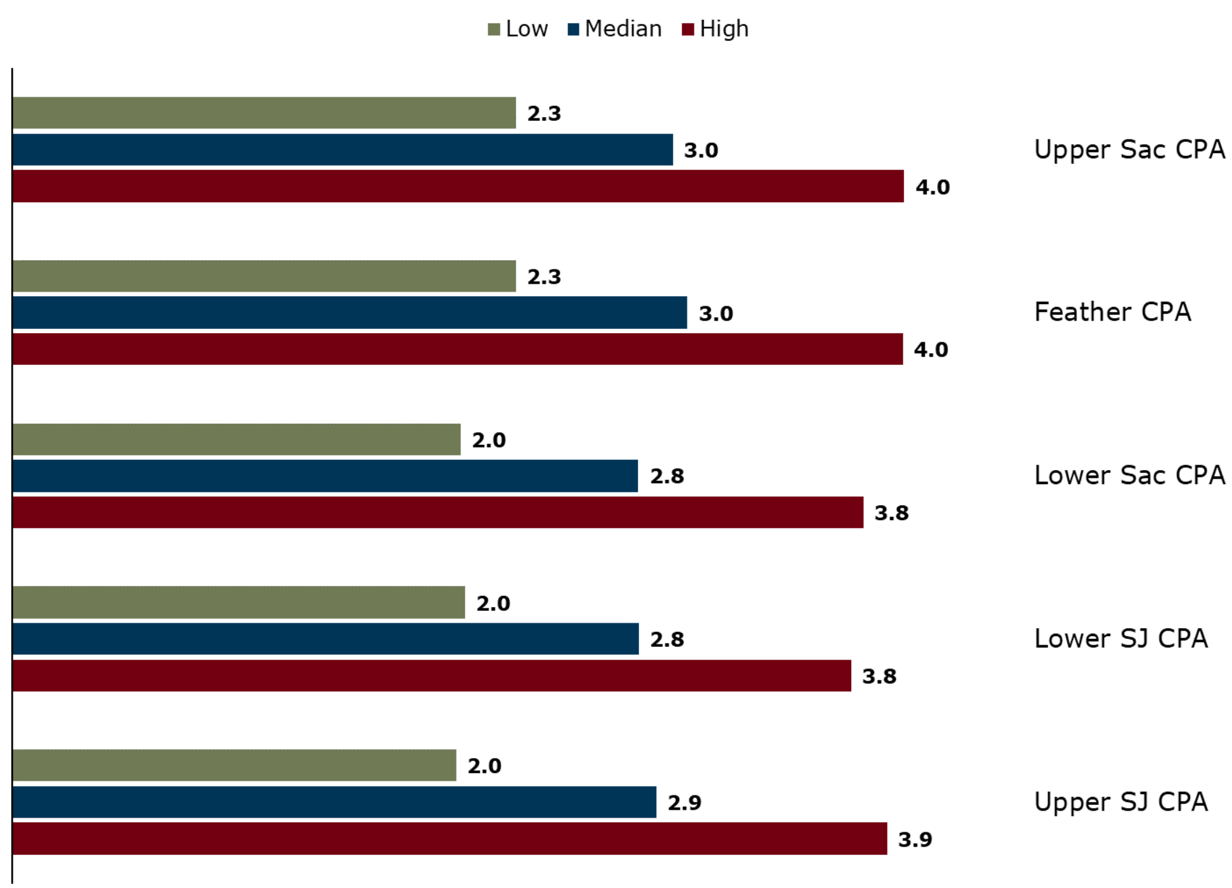
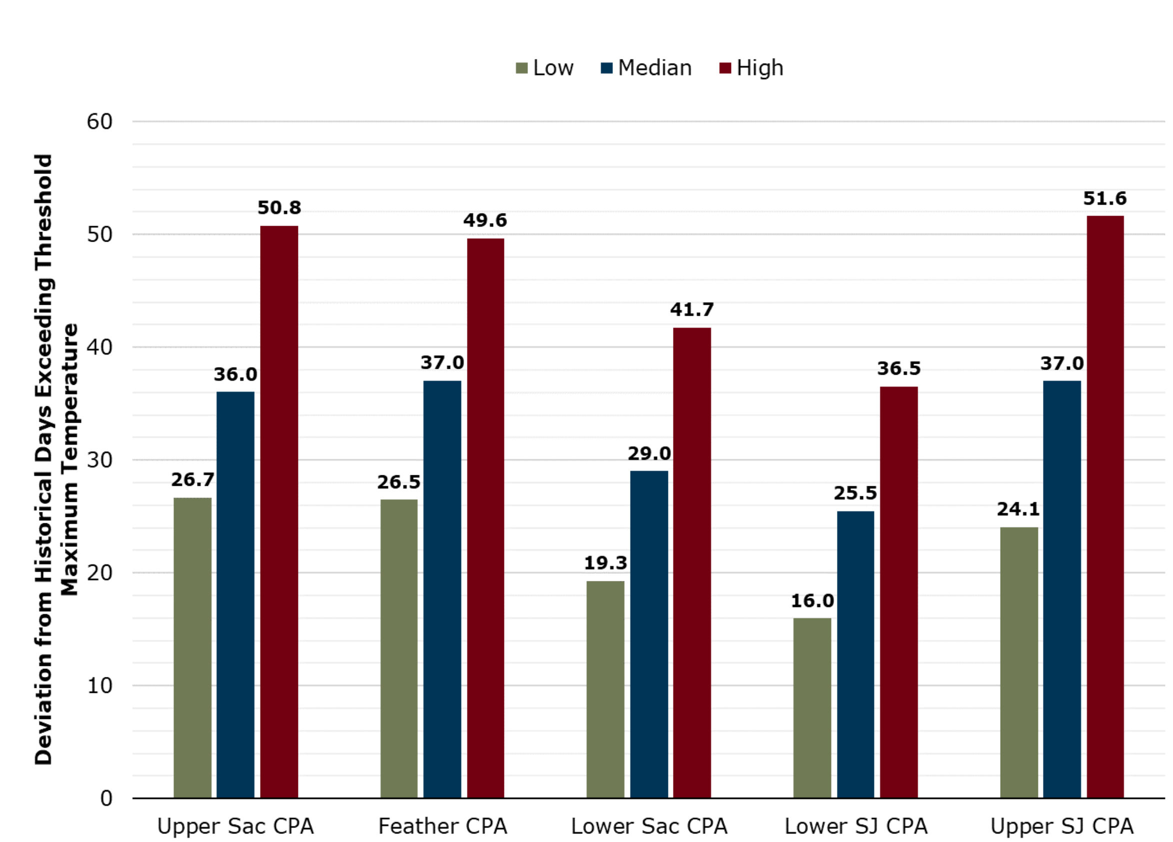


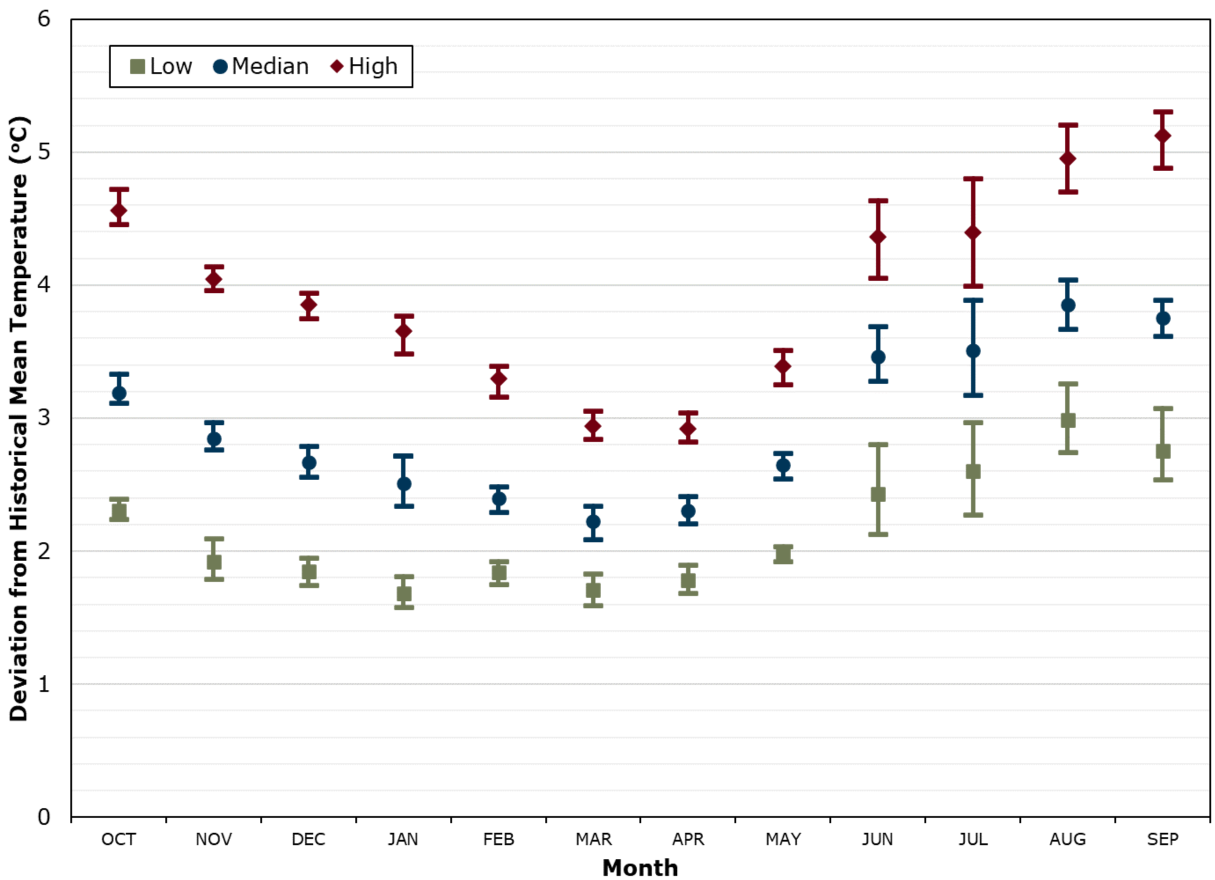
Figure H-5 examines maximum temperature changes for all CPAs. For this analysis, a threshold temperature was determined using the 98th percentile of daily maximum temperature between January 1, 1971 and December 31, 2000. This historical reference period was selected to be consistent with the approach used for climate change analyses in the 2022 CVFPP Update. The thresholds for the Upper Sacramento, Feather River, Lower Sacramento, Upper San Joaquin, and Lower San Joaquin CPAs ranged from 38.4°C to 39.4°C (101.1 to 102.9 degrees Fahrenheit). This threshold temperature is then compared with the daily maximum temperature for each day between January 1, 1915 and December 31, 2011 for the baseline scenario as well as the low, median, and high scenarios (climate scenarios are incorporated into historical temperatures to project changes in temperature). Days determined to be greater than or equal to the threshold temperature are summed for each water year (October 1 to September 30). The average number of annual days exceeding the threshold temperature were compared to the baseline scenario to produce Figure H-5. The deviation from historical days exceeding the threshold maximum temperature increases from low to high climate scenarios. Downstream CPAs (Lower Sacramento and Lower San Joaquin) show a smaller magnitude of change than upstream CPAs (Upper Sacramento, Feather, and Upper San Joaquin), likely due to the proximity to coastal regions. Section 3.3 describes species-specific impacts of extreme temperature days.

Figure H-5. Deviation from Historical Days Exceeding Threshold Maximum Temperature (°C) by CPA



On a monthly scale, all CPAs show similar trends in projected changes to mean temperature. Figure H-6 shows the range of mean monthly predicted temperature deviations for all CPAs under the low, median, and high climate change scenarios. The upper and lower whiskers for each month indicate the 90th and 10th percentile mean temperature deviations from all CPAs, and the point lying between them displays the average deviation from mean historical temperature. June through September show the largest range of mean monthly temperature deviations, while late-winter and spring months show the smallest. This indicates changes to mean monthly temperature have greater variation between CPAs during the transition to warmer months. CPA-specific plots showing the deviation from historical monthly mean temperature under each of the three climate scenarios can be found in Attachment H.1 (Figures H.1-1 through H.1-5).

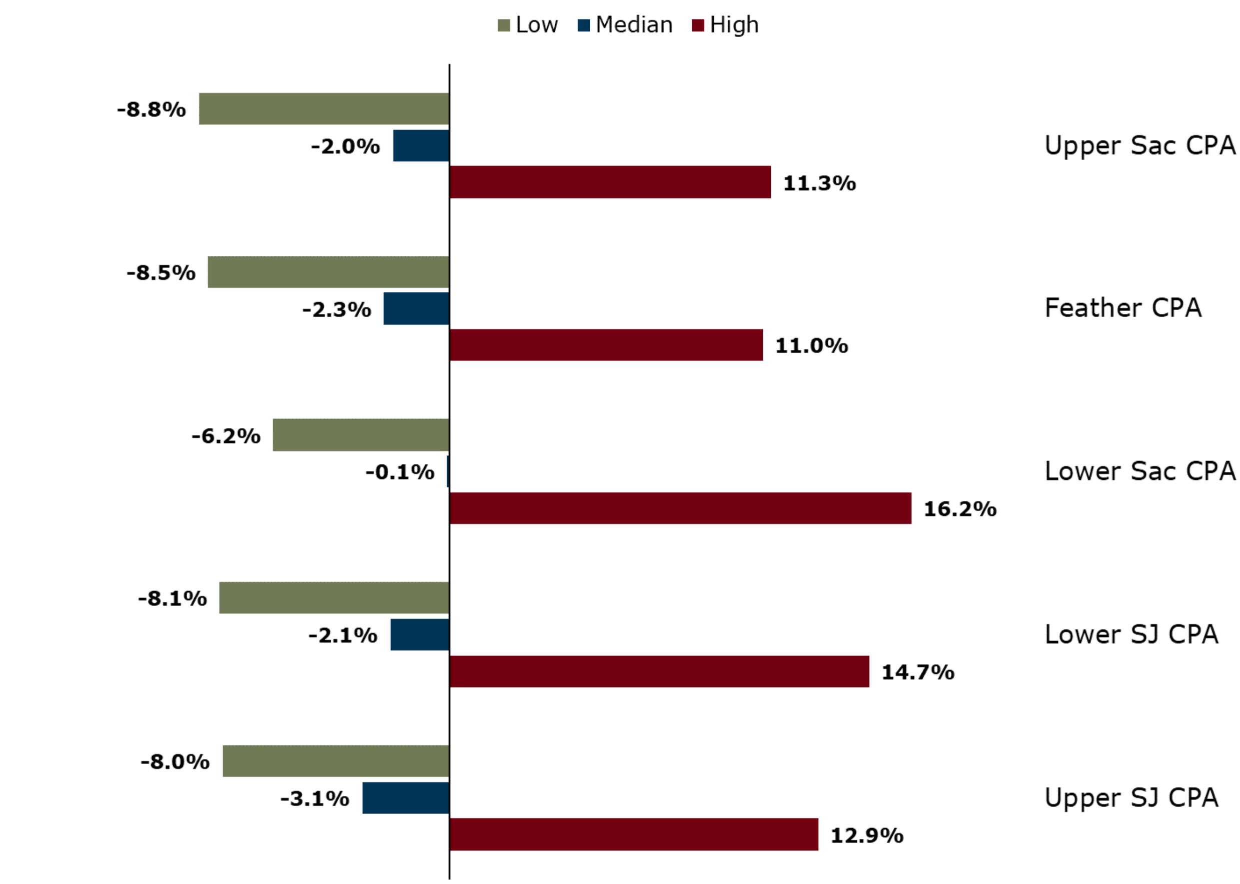
Figure H-6. Range of Projected Changes in Mean Monthly Temperature for all CPAs



3.1.4 Changes in Precipitation

Projected changes in mean annual precipitation vary greatly, depending on the climate change scenario used. Figure H-7 highlights the percent change in average annual precipitation for all CPAs. Under the low and median climate change scenarios, mean annual precipitation is projected to decrease; the high climate change scenario displays an increase across all CPAs.

Figure H-7. Projected Percent Change in Mean Annual Precipitation by CPA

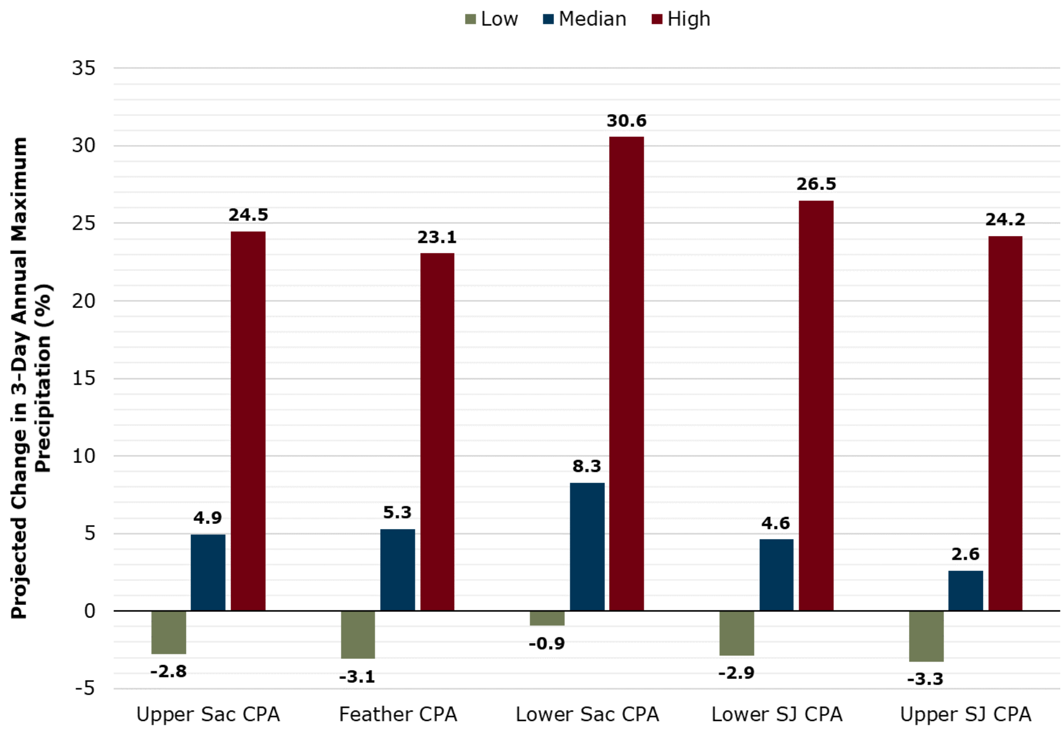


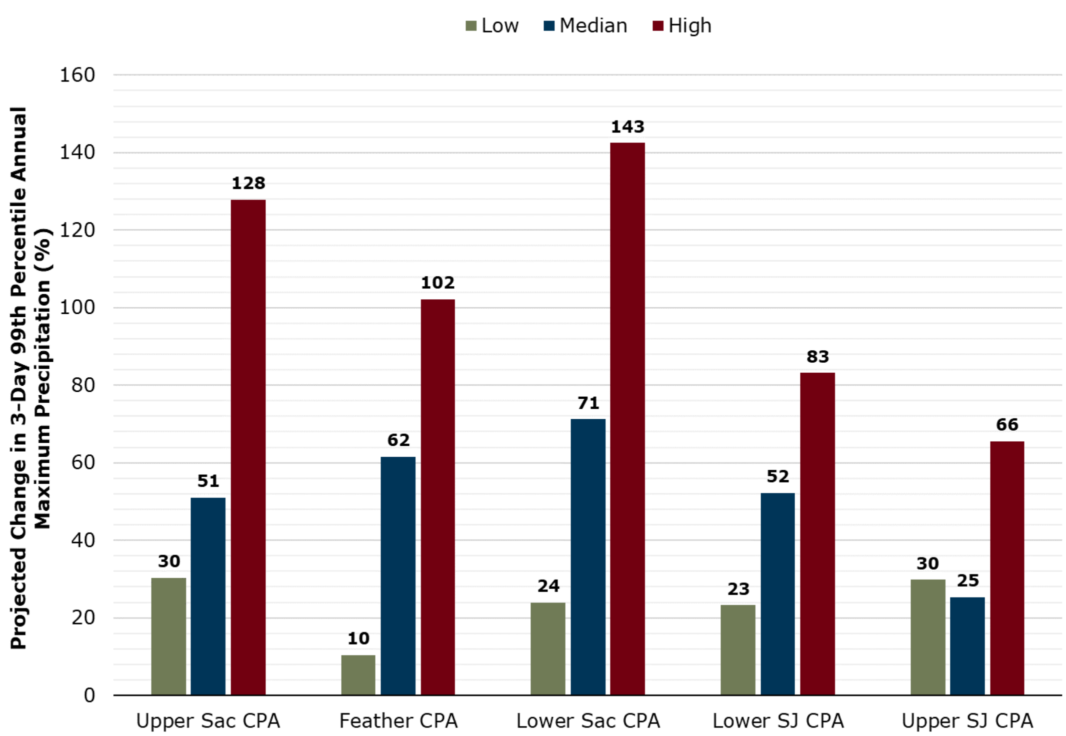
The annual maximum precipitation amounts for the historical period of water years between 1916 and 2011 were compared to the low, median, and high climate change scenarios. The three-day average (shown on the first panel of Figure H-8) and 99th percentile (shown on the second panel of Figure H-8) annual maximum precipitation were calculated for each CPA under each scenario and compared to baseline conditions.

For projected changes to three-day 99th percentile annual maximum precipitation, each CPA displays a significant increase from baseline conditions under all future climate change scenarios. Under the low climate change scenario, upstream CPAs (Upper Sacramento and San Joaquin) display the greatest increase. For the median and high climate change scenarios, the magnitude of change is greater in the Sacramento River Basin than the San Joaquin River Basin. In the Sacramento River Basin under the high climate change scenario, three-day 99th percentile annual maximum precipitation is projected to increase by over 100 percent for each of the three CPAs.

The increase in three-day 99th percentile annual maximum precipitation can be attributed to more intense atmospheric river (AR; a long narrow, band of condensed water vapor that transports moisture from in the atmosphere) precipitation events. AR events have historically contributed between roughly one-third and one-half of California's annual precipitation (Florsheim and Dettinger 2015); however, increased warming from climate change will likely result in less frequent, more severe AR events, leading to an increased prevalence of AR conditions (Espinoza et al. 2018; Huang et al. 2020). Furthermore, AR storms are projected to contribute to a greater amount of total annual precipitation under future conditions (Gershunov et al. 2019).

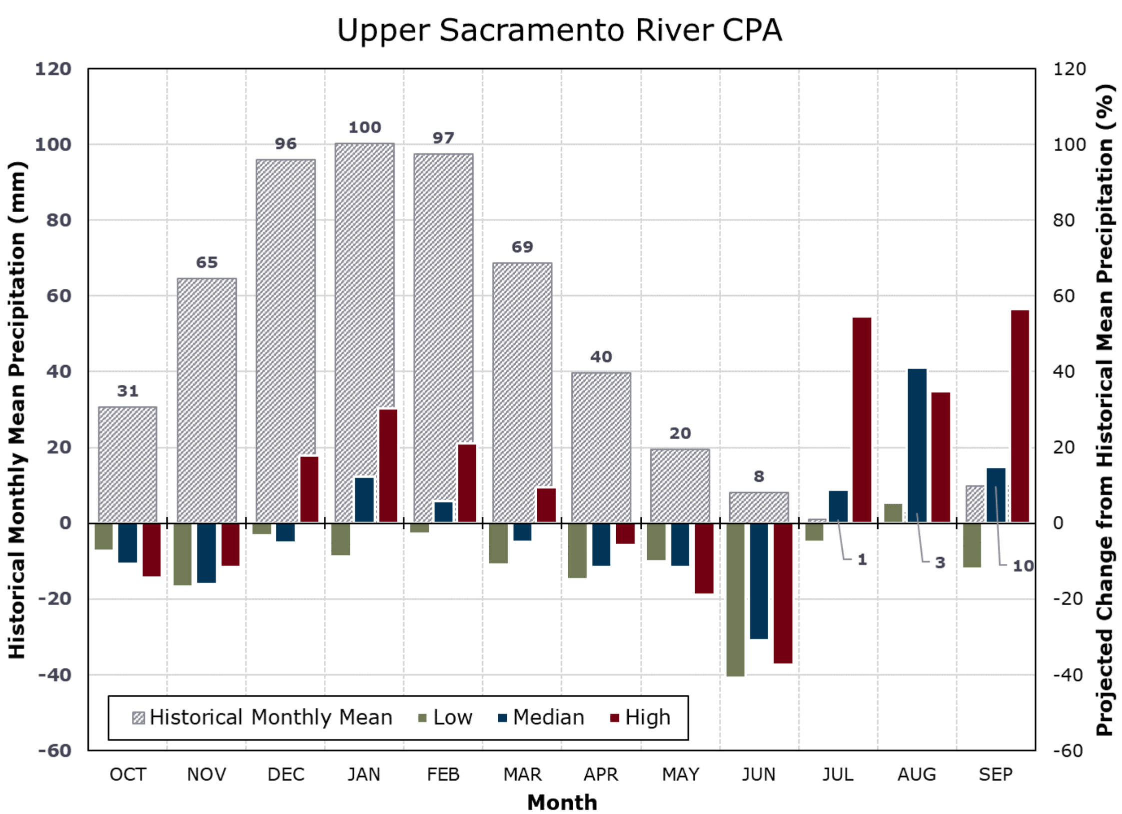
Figure H-8. Projected Change in Three-day Mean (first panel) and 99th Percentile (second panel) Annual Maximum Precipitation by CPA

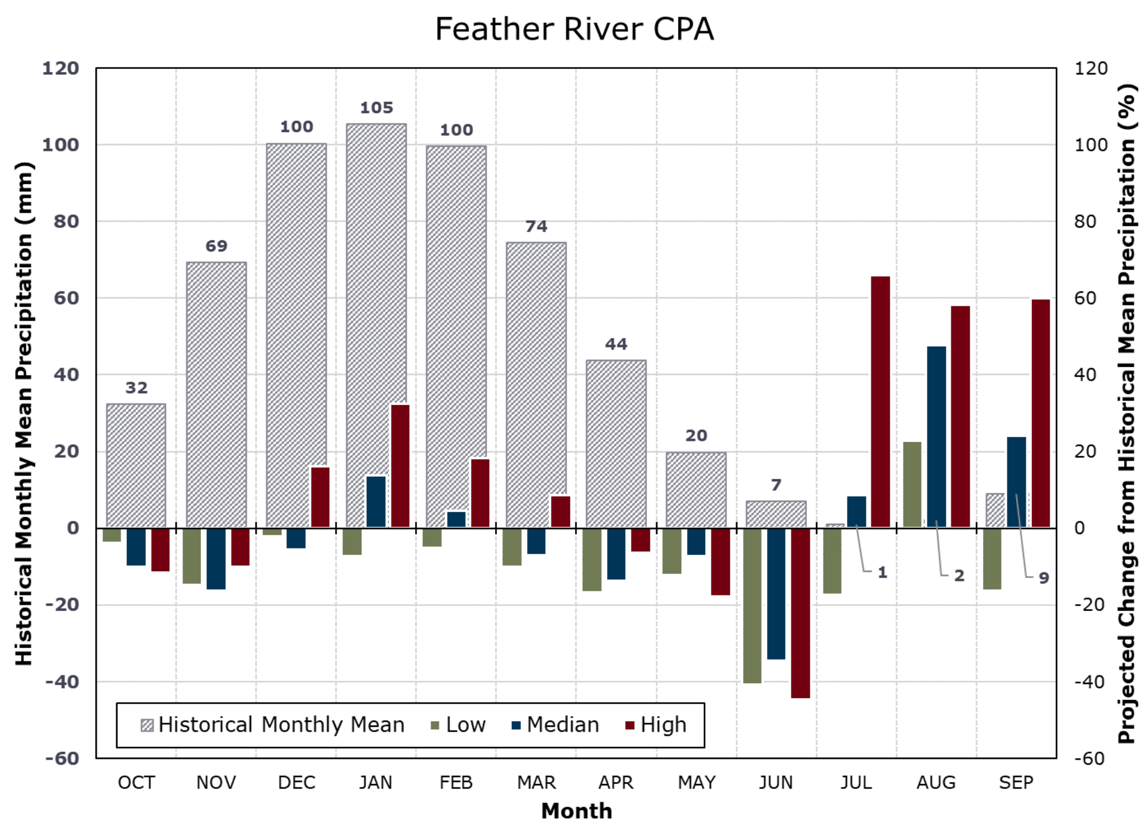


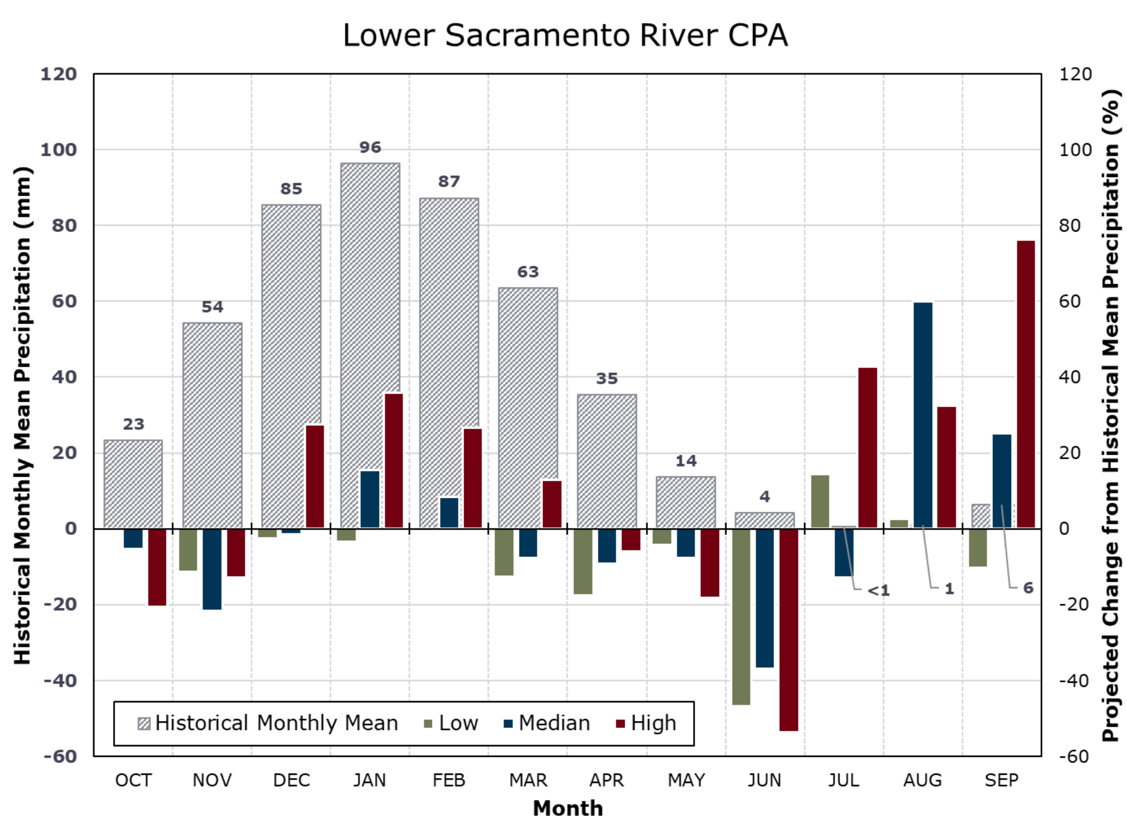


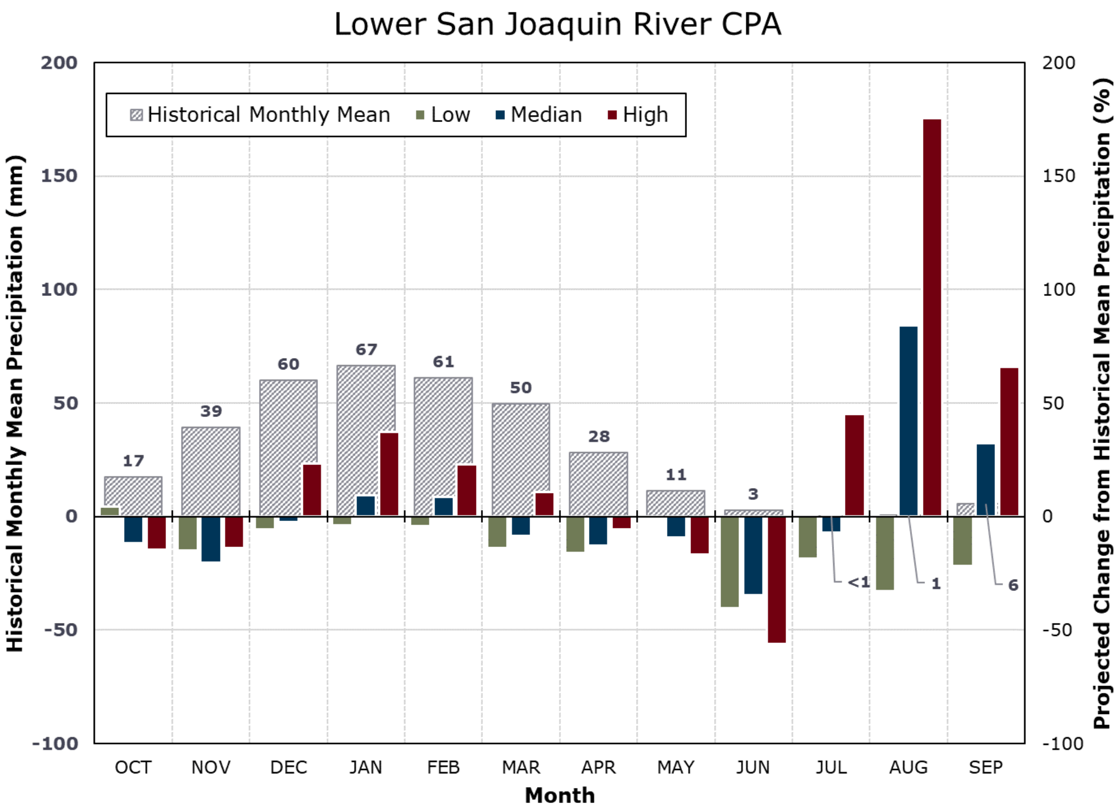
As depicted with the monthly projected changes in mean temperature, all CPAs show similar precipitation trends over the course of the year. Figure H-9 highlights the change in average monthly precipitation for all CPAs under each of the climate change scenarios, as well as baseline quantities (values labeled on the plots). During wetter months (December through March), the high and median scenarios show the greatest increases in mean precipitation depths over baseline, while the low scenario shows reductions during this period. In addition, all the scenarios show a decrease in monthly mean precipitation compared to the baseline from April to July and October to November. For the median scenario, this suggests both an overall decrease in mean annual precipitation (as Figure H-5 shows) and more condensed precipitation events in winter months. With the high climate change scenario, the precipitation extremes in the winter months make up for the loss of precipitation at other points throughout the year to result in a net increase to annual precipitation. For late summer and early fall months, the percentage change in monthly mean precipitation shows a much greater magnitude, although the absolute change in precipitation is relatively small in comparison to other months. For the Upper and Lower San Joaquin CPAs in particular, August shows an increase of over 100 percent, but the overall increase in mean precipitation is roughly 1 inch.

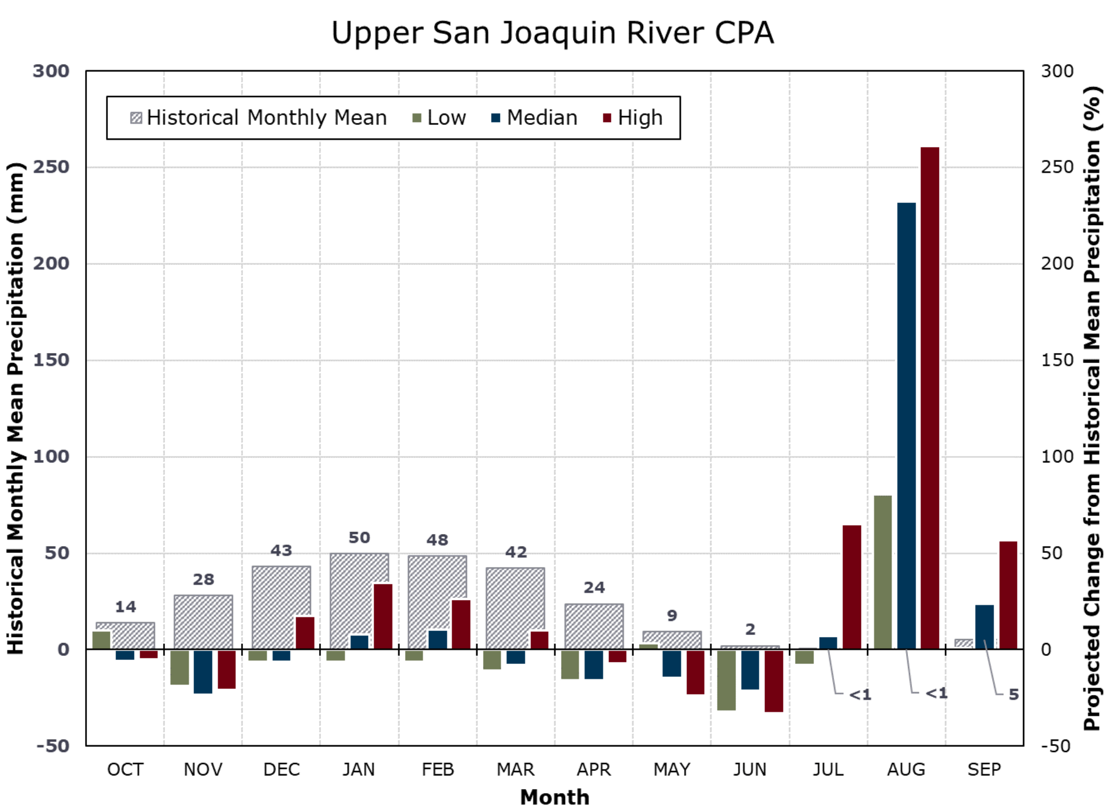
Figure H-9. Projected Changes in Mean Monthly Precipitation by CPA




Feather River CPA
Historical Monthly Mean Precipitation (mm)
Projected Change from Historical Mean Precipitation (%)
Month
OCT NOV DEC JAN FEB MAR APR MAY JUN JUL AUG SEP
32 69 100 105 100 74 44 20 7
1 2 9
Historical Monthly Mean Low Median High


Lower Sacramento River CPA
Historical Monthly Mean Precipitation (mm)
Projected Change from Historical Mean Precipitation (%)
Month
OCT NOV DEC JAN FEB MAR APR MAY JUN JUL AUG SEP
23 54 85 96 87 63 35 14 4
<1 1 6
Historical Monthly Mean Low Median High


Lower San Joaquin River CPA
Historical Monthly Mean
Low
Median
High
Historical Monthly Mean Precipitation (mm)
Projected Change from Historical Mean Precipitation (%)
200
150
100
50
0
-50
-100
17
39
60
67
61
50
28
11
3
<1
1
6
OCT
NOV
DEC
JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
Month


Upper San Joaquin River CPA
Historical Monthly Mean
Low
Median
High
Historical Monthly Mean Precipitation (mm)
Projected Change from Historical Mean Precipitation (%)
300
250
200
150
100
50
0
-50
14
28
43
50
48
42
24
9
2
<1
<1
5
OCT
NOV
DEC
JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
Month

3.1.5 Hydrology Scenarios

The historical and three future climate change scenarios were used as inputs to the Variable Infiltration Capacity (VIC) model to simulate future hydrologic conditions. The VIC model (Liang et al. 1994, 1996; Nijssen et al. 1997) is a spatially distributed hydrologic model that simulates land surface-atmosphere exchanges of moisture and energy at each model grid cell. The VIC model incorporates spatially distributed parameters describing topography, soils, land use, and vegetation classes. The outputs from this hydrologic model are used to assess changes in hydrologic variables described in Sections 3.1.6 and 3.1.8.

The future impacts of climate change on the flood management system were examined by considering the existing state of the system, future population and land use changes, and implementation of the State Systemwide Investment Approach (SSIA). Elements of the SSIA include physical improvements (e.g., levee setbacks) for systemwide, urban, rural, and small community areas, as well as residual risk management actions focusing on enhanced flood response and emergency management. Three project implementation scenarios were developed, including a baseline scenario for 2022 without-project implementation (existing condition), a 2072 scenario without-project implementation (without implementation of the SSIA), and a 2072 scenario with-project implementation (with implementation of the SSIA). The *2022 CVFPP Update Evaluation Scenarios and Analysis Setup memorandum* (California Department of Water Resources 2022b) provides more details. Scenarios reflect watershed-specific assumptions for climate change, and both of the 2072 projections are presented for the median climate change scenario.

3.1.6 Changes in Snowpack

Snowpack is an integral component of the hydrologic system in California. While only covering approximately a quarter of the total land area in the state, the Sierra Nevada region provides approximately 60 percent of California's water, with much of this water originating in the form of snowpack (Reich et al. 2018). Historically, snowpack in the Sacramento and San Joaquin River Basins has typically developed at higher elevations from November through March (California Department of Water Resources 2022a). As temperatures begin to rise in the spring months, the snowpack gradually melts, supplying water to communities, ecosystems, and agriculture through the spring and summer.

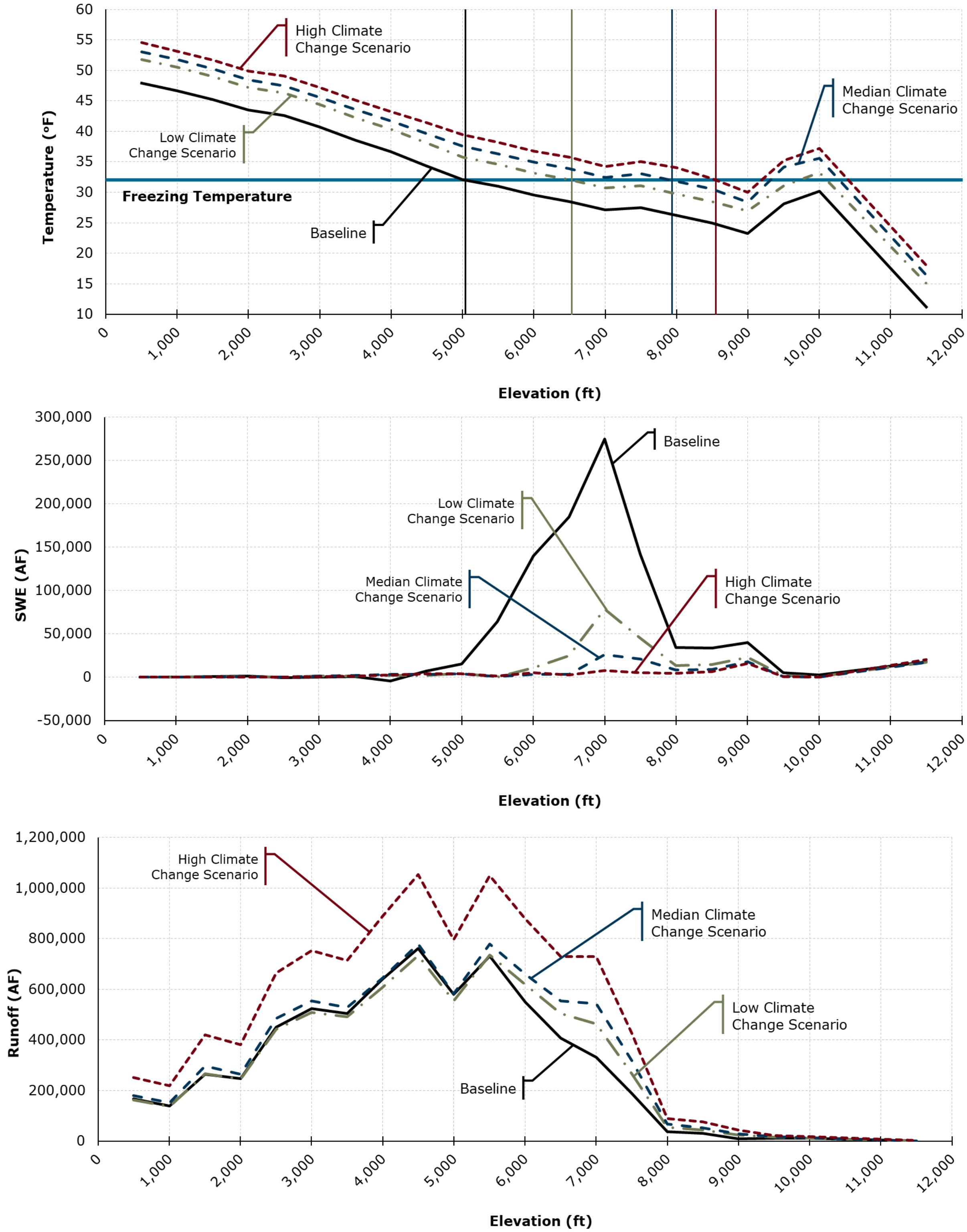
However, given the changes to both temperature and precipitation, the timing of snowmelt and composition of snowpack is projected to change, ultimately altering runoff characteristics (Pierce et al. 2018). Figures H-10 and H-11 display the change in the 1997 flood event average temperature (top panel), snow water equivalent (SWE; middle panel), and runoff (bottom panel) under the low, median, and high climate change scenarios at different elevations in watersheds upstream of reference gauges (SAC-42 and SJR-75; locations roughly correspond to the SAC43 and SJ28 regulated flow and stage points as displayed on Figures H-1 and H-2) in the Sacramento and San Joaquin River Basins, respectively. The 1997 flood event, caused by a landfalling AR that resulted in an estimated $2 billion in damages (the largest in California's history), is displayed to highlight the magnitude and pattern of these projected changes (California Department of Water Resources 2022a).

Under the conditions of the 1997 flood event, the Sacramento River Basin shows a freezing level elevation of about 5,000 feet under baseline conditions, and this elevation increases to roughly 6,500, 8,000, and 8,500 feet under the low, median, and high climate change scenarios, respectively. For the San Joaquin River Basin, the baseline freezing elevation is slightly higher than 8,000 feet. Under the low, median, and high climate change scenarios, this elevation is projected to increase to approximately 9,500, 10,200, and 11,500 feet, respectively. These findings indicate warmer temperatures are projected to occur at higher elevations (and potentially at a higher rate than lower elevations; Mountain Research Initiative EDW Working Group 2015), shifting the composition of precipitation from snow to rain (California Department of Water Resources 2022a). Precipitation that is no longer captured in snowpack will travel downstream as runoff, and higher temperatures will likely increase the rate and timing of snowmelt.

Furthermore, increasing temperatures and changes to snowpack composition will impact SWE (the volume of liquid water contained in snowpack) at different elevations. In the Sacramento River Basin, SWE is projected to decrease dramatically, with near-zero volumes across all elevations under the high climate change scenario. SWE volumes are still accumulated at higher elevations in the San Joaquin River Basin (California Department of Water Resources 2022a).

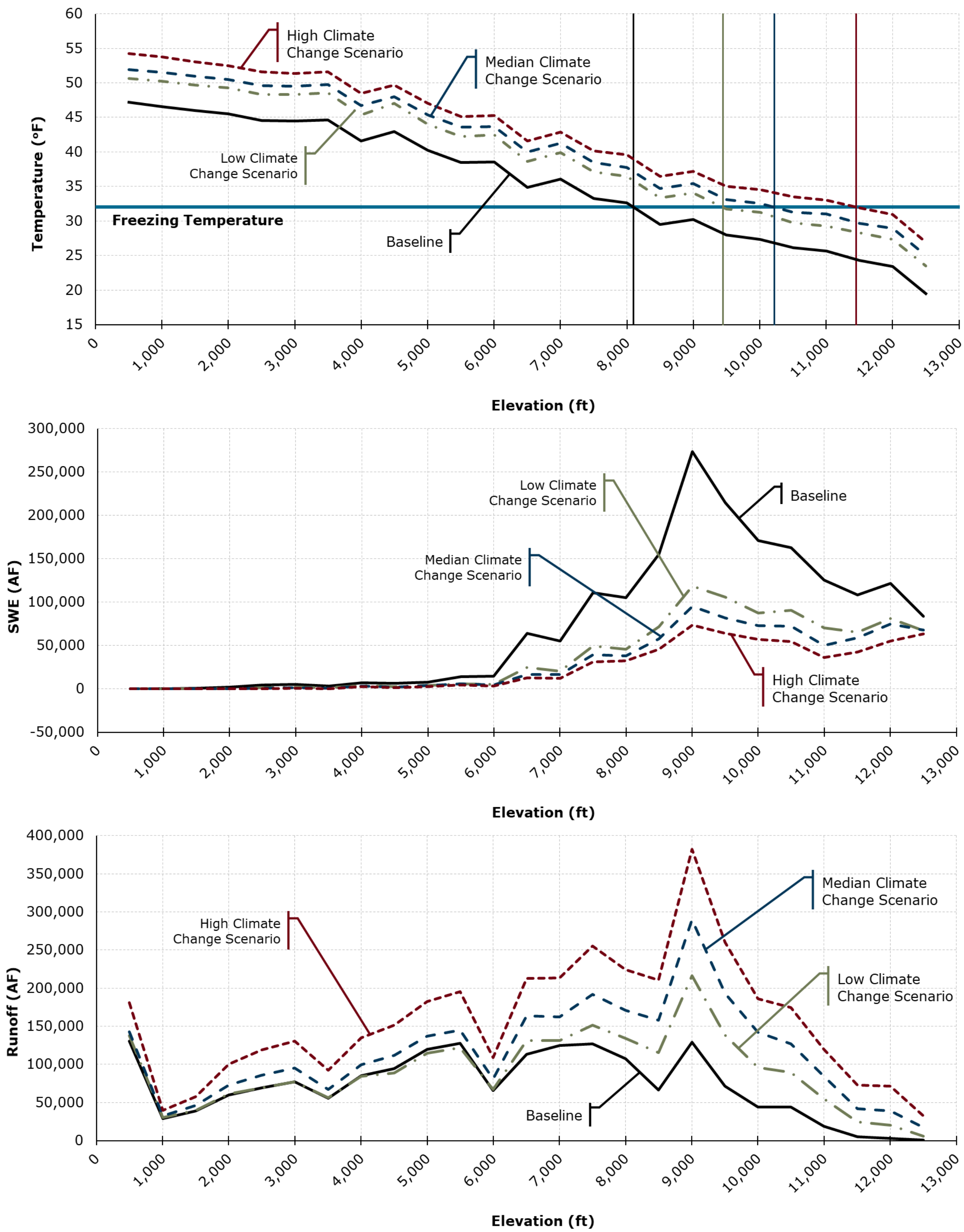
As a result of the overall decrease in snowpack, SWE, and timing of snowmelt, water networks will experience higher runoff flows earlier in the year, which are likely to induce increased flood risks and changes to water management operations. Under the high climate change scenario, runoff volumes are projected to increase across all elevations in both the Sacramento and San Joaquin River Basins. In the Sacramento River Basin, runoff volumes are also projected to increase under the low and median climate change scenario between elevations of roughly 5,500 feet and 8,000 feet. In the San Joaquin River Basin, runoff volumes are projected to increase under all climate change scenarios at elevations greater than 6,000 feet.

Figure H-10. 1997 Flood Event Projected Change in Average Temperature (top), SWE (middle), and Runoff (bottom) at Different Elevations Upstream of the Sacramento River below Elk Slough (SAC-42)



Source: Modified from DWR (2022a)

Figure H-11. 1997 Flood Event Projected Change in Average Temperature (top), SWE (middle), and Runoff (bottom) at Different Elevations Upstream of the San Joaquin River below the Stanislaus River (SJR-75)



Source: Modified from DWR (2022a)

3.1.7 Changes in Streamflow Seasonality and Timing

Historically, streamflow volumes have peaked in the winter and spring when precipitation and snowmelt quantities are largest (Lund 2016). As described in Section 3.1.6, changes in temperature and precipitation composition are projected to result in a decrease in snowpack and shift in snowmelt timing to earlier in the year. These changes will ultimately shift peak flows to earlier in the winter and spring (Reich et al. 2018). As such, late-spring and summer flows are expected to decrease.

Differences in watershed characteristics between the Sacramento and San Joaquin River Basins affect the historical patterns of streamflow as well as the magnitude of projected changes under climate change. In rain-dominated watersheds like the Sacramento River Basin, flows are projected to peak earlier and higher than historical flows (He et al. 2019). In snow-dominated watersheds like the San Joaquin River Basin, shifts in timing and changes in peak flows are projected to be minor by 2050, but substantial decreases in late-spring to early-summer (April through July) peak flows are projected by late-century (Delta Stewardship Council 2021b). The magnitude of changes in both the Sacramento and San Joaquin River Basins are also expected to be more significant under the conditions described by the high climate change scenario as compared to the low climate change scenario.

3.1.8 Changes in Peak Flood Events Using Regulated Hydrology

To examine changes in peak events, regulated (altered by human intervention) hydrology across all CPAs for current- stage (2022 without-project) and flow frequencies were compared to 2072 future conditions (without-project and with-project) using the median climate change scenario. Regulated hydrology is generated through Hydrologic Engineering Center Reservoir System Simulator (HEC-ResSim) and Hydrologic Engineering Center River Analysis System (HEC-RAS) to simulate future flow regimes downstream of reservoirs (California Department of Water Resources 2022a). Data are compiled from specific index point locations identified on Figures H-1 and H-2. To develop regulated flow-frequency information under future climate change conditions at locations throughout the Sacramento and San Joaquin River Basins, climate change ratios and unregulated-to-regulated flow transforms were applied to unregulated volume-frequency curves. Note, unregulated flow volumes and regulated peak flows do not scale uniformly with one another due to operating regimes. Additional information is available in Appendix B of the 2022 CVFPP Update Technical Analysis Report: Climate Change Volume Frequency Analysis (California Department of Water Resources 2022c).

For each CPA, the regulated flow and stage-frequency curves are plotted for the 2022 without-project, 2072 without-project, and 2072 with-project scenarios (as described in Section 3.1.5). Figures H-12 through H-16 display these plots., Tables H-4 through H-8 also provide quantitative analyses of the 10-year (annual exceedance probability [AEP] = 0.1) and 100-year (AEP = 0.01) flood event characteristics, as well as comparisons for both the listed flow and stage values.

The Upper Sacramento CPA (Figure H-12 and Table H-4) shows a minor increase to flow and stage for 10-year events, accompanied by a much larger increase for 100-year events. Table H-4 provides insight into the quantitative changes in magnitude for both flow and stage at this location. Differences between the 2072 with-project and without-project scenarios are minor, as there are no upstream project improvements included in the 2072 with-project scenario at this index point. As such, both scenarios display roughly a 12-percent increase in flow and 1.7-foot increase in stage for 100-year events. Likewise, 10-year events are projected to increase by approximately 2.5 percent for flows and 0.5 feet for stage by 2072.

For the Feather River CPA (Figure H-13 and Table H-5), 10-year flood events increase in both flow and stage, while 100-year events remain roughly the same. For infrequent events beyond return periods of roughly 250 years, climate change conditions will likely result in more breach flows upstream, reducing 2072 flow and stage values from 2022 quantities. Similar to the Upper Sacramento CPA, differences between the 2072 without-project and with-project projections are minor due to a lack of upstream project improvements in the 2072 with-project scenario at this location. A 37.8-percent and 40.3-percent increase in flow can be seen for the 2072 without-project and with-project projections, respectively. Additionally, 3.5-foot and 3.2-foot increases (respectively) in stage are displayed.

For the Lower Sacramento CPA (Figure H-14 and Table H-6), the 2072 without-project projection results in an overall increase for both flow and stage for 10-year and 100-year events. A 27.3-percent increase in flow and 1.3-foot increase in stage are seen for the 10-year event, and a 9.0-percentincrease in flow and 0.8-foot increase in stage are seen for the 100-year event. However, when compared to the 2072 with-project projection, an increase in flow and a decrease in stage can be seen for 10-year and 100-year events, likely due to levee setback and weir expansion projects in the region. Flows are projected to increase by 28.3 percent and 15.3 percent for 10-year and 100-year events, respectively. Stage, on the other hand, is projected to decrease by -0.3 foot and -0.5 foot for 10-year and 100-year flood events, respectively.

The Lower San Joaquin River CPA (Figure H-15 and Table H-7) shows an overall increase for both flow and stage with 10-year events. For regulated flow, a 7.3-percent increase and 42.1-percent increase are shown for the 2072 without-project and 2072 with-project projections, respectively. For regulated stage, a 0.6-foot- and 2.9-foot increase are shown for the 2072 without-project and 2072 with-project projections, respectively. However, for 100-year events, the 2072 without-project projection results in a higher stage and flow than the 2072 with-project projection. A 152.4-percent increase in flow is shown for the 2072 without-project scenario, whereas the 2072 with-project shows a 119.0-percent increase. Likewise, a 3.0-foot and 2.8-foot increase in stage are shown for the 2072 without- and with-project scenarios, respectively. Higher flows for the Lower San Joaquin CPA are expected at this location due to the presence of downstream tributaries. Larger projects on the Tuolumne River have a pronounced impact on this location specifically.

The projected changes to regulated hydrology for Upper San Joaquin CPA are described on Figure H-16 and in Table H-8. Due to both the upstream location of this index point (SJ01) and the lack of adjacent planned project implementations, there are no differences between the 2072 without-project and with-project scenarios. For 10-year events, there are no projected differences in flow and stage between 2022 and 2072 scenarios. However, for 100-year events, a nearly 400-percent increase in flow and a 12-foot increase in stage are shown. These results are likely explained given SJ01's location downstream of Friant Dam. High-flow events that cannot be captured in Lake Millerton are released downstream, while lower-flow events (i.e., return periods lower than roughly 25-years [AEP = 0.04]) can be properly managed upstream.

Figure H-12. SAC08 (Upper Sacramento River CPA) Regulated Flow (Left) and Stage-frequency (Right) Curves

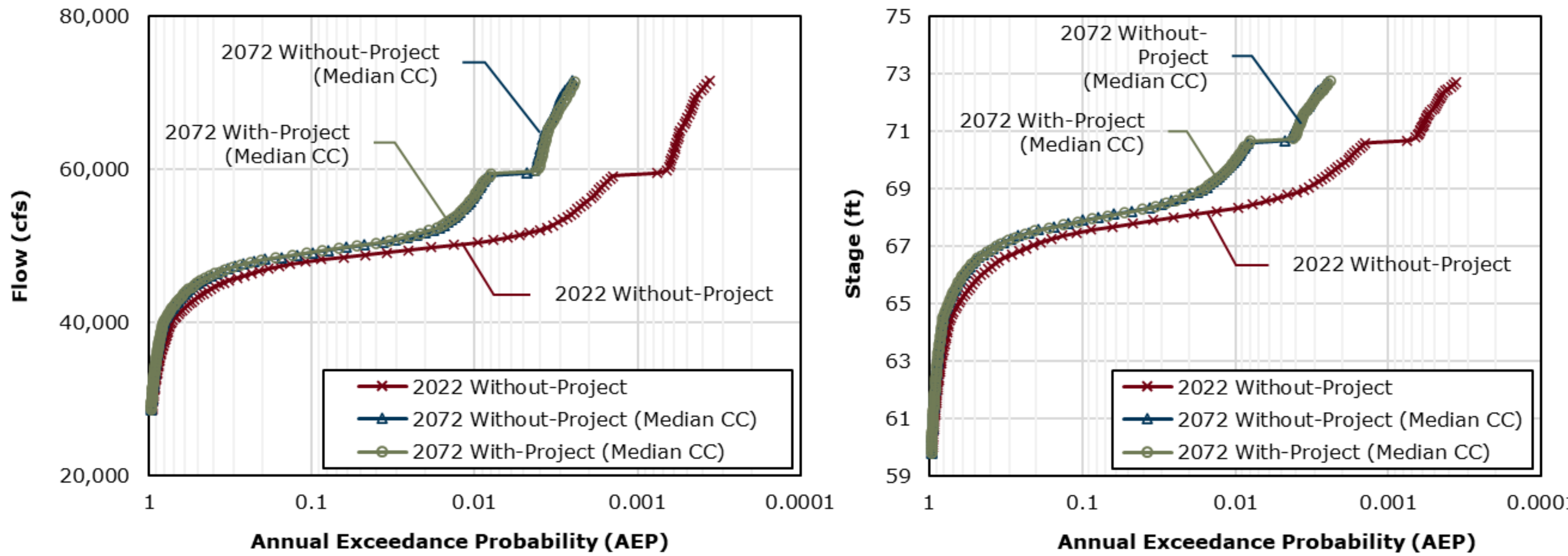


Table H-4. SAC08 (Upper Sacramento River CPA) 10-year and 100-year Flow and Stage Quantities

AEP	2022 Without-project Flow (cfs)	2072 Without-project (Median CC) Flow (cfs)	2072 With-project (Median CC) Flow (cfs)	2022 Without-project vs 2072 Without-project Percent Change	2022 Without-project vs 2072 With-project Percent Change	2072 Without-project vs 2072 With-project Percent Change
AEP = 0.1	48,000	49,100	49,200	2.3	2.5	0.2
AEP = 0.01	50,400	56,500	56,600	12.1	12.3	0.2
AEP	**2022 Without-project Stage (ft)**	**2072 Without-project (Median CC) Stage (ft)**	**2072 With-project (Median CC) Stage (ft)**	**2022 Without-project vs 2072 Without-project Difference (ft)**	**2022 Without-project vs 2072 With-project Difference (ft)**	**2072 Without-project vs 2072 With-project Difference (ft)**
AEP = 0.1	67.5	67.9	67.9	0.4	0.4	0.0
AEP = 0.01	68.3	70.0	70.0	1.7	1.7	0.0

Notes:
AEP = annual exceedance possibility
CC = climate change
cfs = cubic foot (feet) per second
ft = foot (feet)
vs = versus

Figure H-13. SAC25 (Feather River CPA) Regulated Flow (Left) and Stage (Right)- frequency Curves

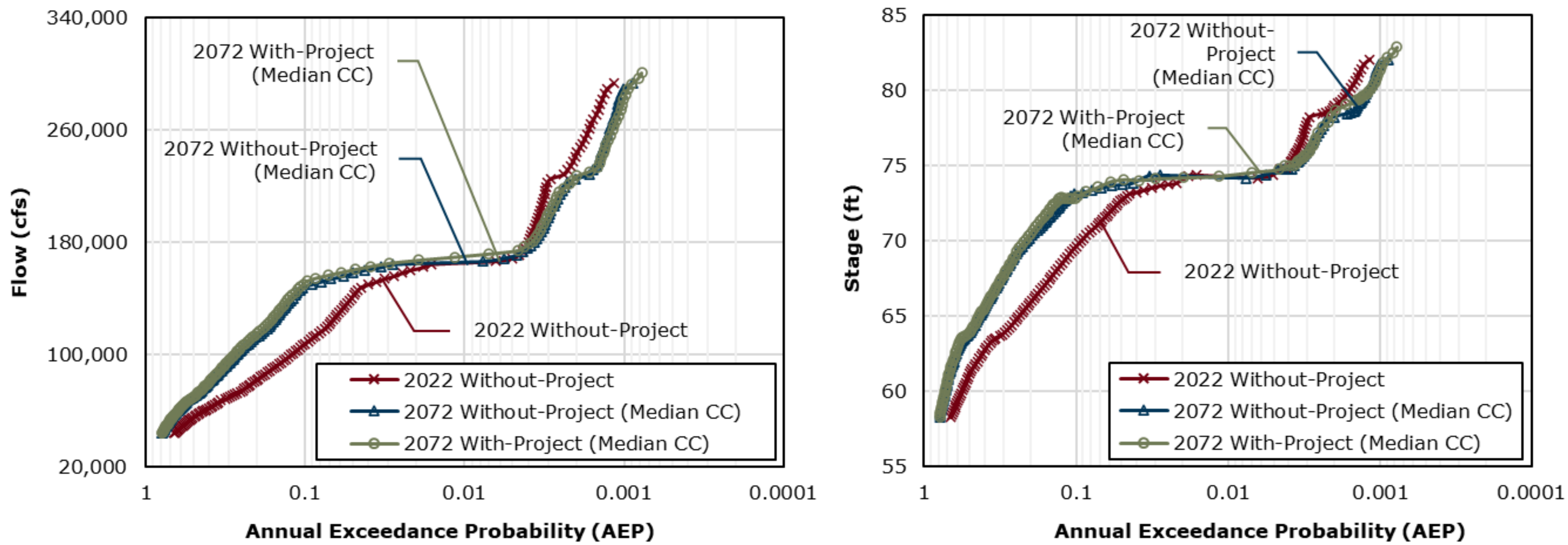


Table H-5. SAC25 (Feather River CPA) 10-year and 100-year Flow and Stage Quantities

AEP	2022 Without-project Flow (cfs)	2072 Without-project (Median CC) Flow (cfs)	2072 With-project (Median CC) Flow (cfs)	2022 Without-project vs 2072 Without-project Percent Change	2022 Without-project vs 2072 With-project Percent Change	2072 Without-project vs 2072 With-project Percent Change
AEP = 0.1	107,800	148,600	151,200	37.8	40.3	1.7
AEP = 0.01	165,800	166,400	170,400	0.4	2.8	2.4
AEP	**2022 Without-project Stage (ft)**	**2072 Without-project (Median CC) Stage (ft)**	**2072 With-project (Median CC) Stage (ft)**	**2022 Without-project vs 2072 Without-project Difference (ft)**	**2022 Without-project vs 2072 With-Project Difference (ft)**	**2072 Without-project vs 2072 With-project Difference (ft)**
AEP = 0.1	69.6	73.1	72.9	3.5	3.2	-0.3
AEP = 0.01	74.2	74.2	74.4	0.0	0.1	0.2

Notes:
AEP = annual exceedance possibility
CC = climate change
cfs = cubic foot (feet) per second
ft = foot (feet)
vs = versus

Figure H-14. SAC43 (Lower Sacramento River CPA) Regulated Flow (Left) and Stage (Right)-frequency Curves

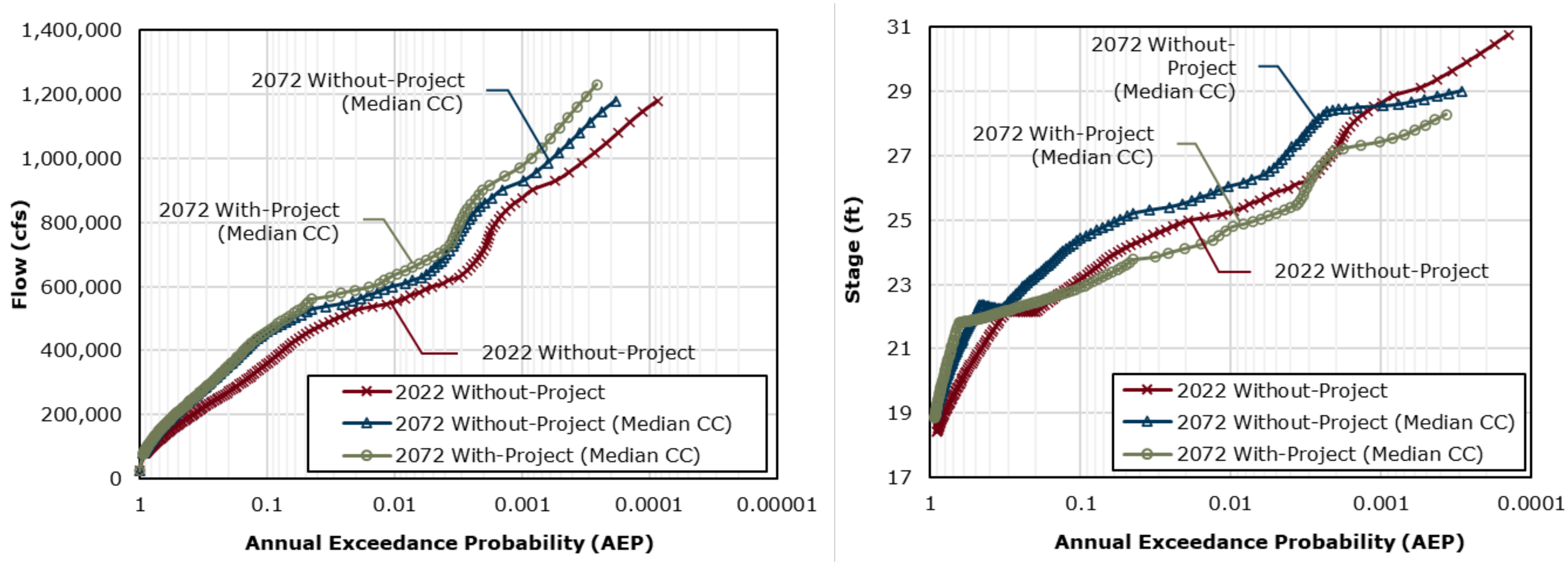
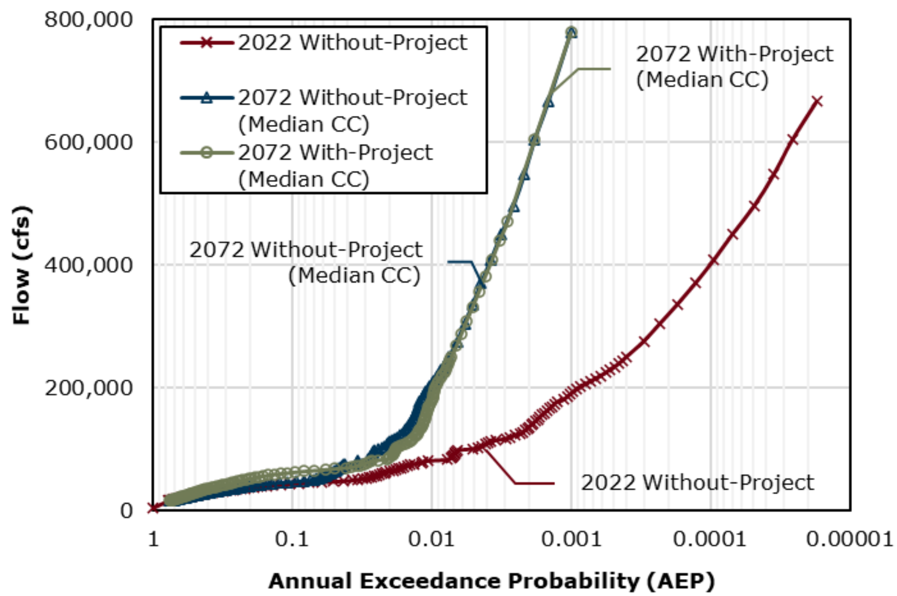


Table H-6. SAC43 (Lower Sacramento River CPA) 10-year and 100-year Flow and Stage Quantities

AEP	2022 Without-project Flow (cfs)	2072 Without-project (Median CC) Flow (cfs)	2072 With-project (Median CC) Flow (cfs)	2022 Without-project vs 2072 Without-project Percent Change	2022 Without-project vs 2072 With-project Percent Change	2072 Without-project vs 2072 With-project Percent Change
AEP = 0.1	360,000	458,200	461,700	27.3	28.3	0.8
AEP = 0.01	552,000	601,800	636,200	9.0	15.3	5.7
AEP	**2022 Without-project Stage (ft)**	**2072 Without-project (Median CC) Stage (ft)**	**2072 With-project (Median CC) Stage (ft)**	**2022 Without-project vs 2072 Without-project Difference (ft)**	**2022 Without-project vs 2072 With-project Difference (ft)**	**2072 Without-project vs 2072 With-project Difference (ft)**
AEP = 0.1	23.2	24.4	22.9	1.3	-0.3	-1.5
AEP = 0.01	25.3	26.1	24.8	0.8	-0.5	-1.3

Notes:
AEP = annual exceedance possibility
CC = climate change
cfs = cubic foot (feet) per second
ft = foot (feet)
vs = versus

Figure H-15. SJ28 (Lower San Joaquin River CPA) Regulated Flow (Left) and Stage (Right)-frequency Curves



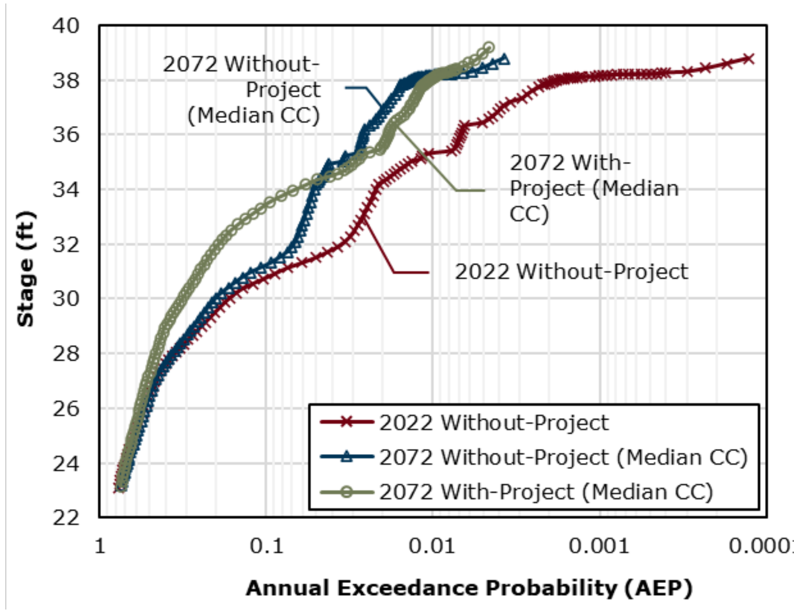


Table H-7. SJ28 (Lower San Joaquin River CPA) 10-year and 100-year Flow and Stage Quantities

AEP	2022 Without-project Flow (cfs)	2072 Without-project (Median CC) Flow (cfs)	2072 With-project (Median CC) Flow (cfs)	2022 Without-project vs 2072 Without-Project Percent Change	2022 Without-project vs 2072 With-project Percent Change	2072 Without-project vs 2072 With-project Percent Change
AEP = 0.1	43,900	47,100	62,400	7.3	42.1	32.5
AEP = 0.01	82,000	207,000	179,600	152.4	119.0	-13.2
AEP	**2022 Without-project Stage (ft)**	**2072 Without-project (Median CC) Stage (ft)**	**2072 With-project (Median CC) Stage (ft)**	**2022 Without-project vs 2072 Without-project Difference (ft)**	**2022 Without-project vs 2072 With-project Difference (ft)**	**2072 Without-project vs 2072 With-project Difference (ft)**
AEP = 0.1	30.6	31.2	33.5	0.6	2.9	2.2
AEP = 0.01	35.2	38.2	38.1	3.0	2.8	-0.1

Notes:
AEP = annual exceedance possibility
CC = climate change
cfs = cubic foot (feet) per second
ft = foot (feet)
vs = versus

Figure H-16. SJ01 (Upper San Joaquin River CPA) Regulated Flow (Left) and Stage (Right)-frequency Curves

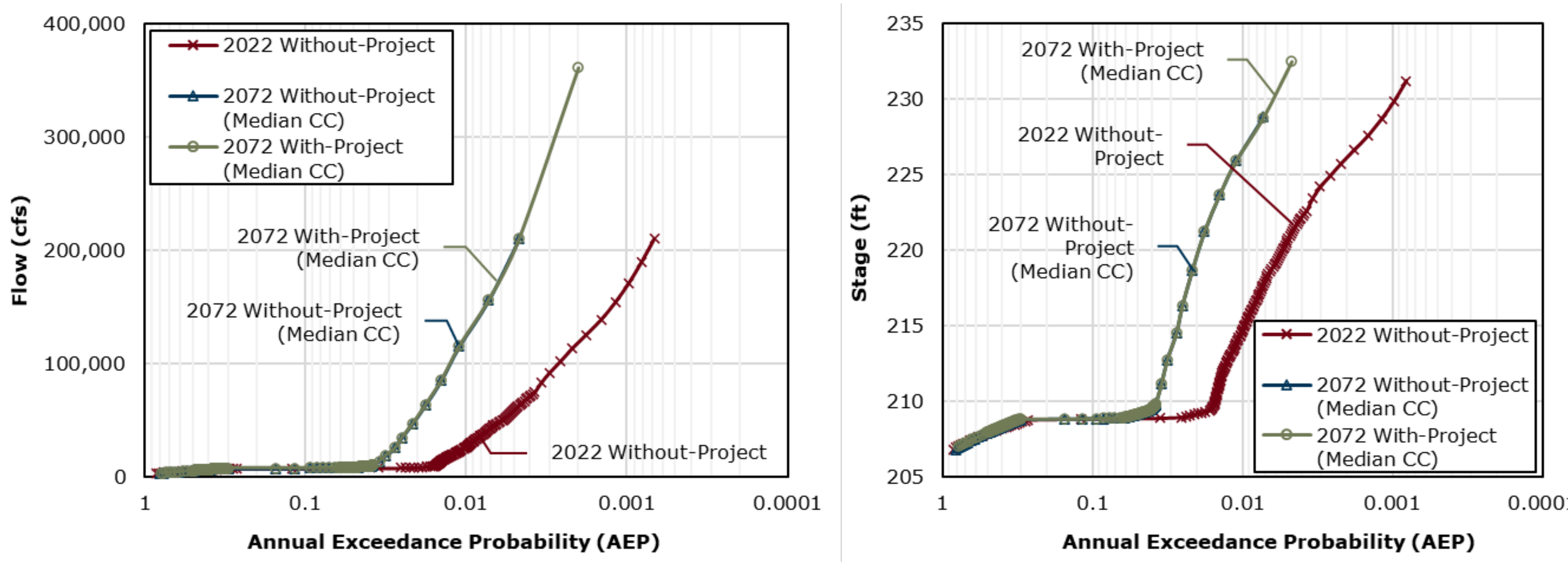


Table H-8. SJ01 (Upper San Joaquin River CPA) 10-year and 100-year Flow and Stage Quantities

AEP	2022 Without-project Flow (cfs)	2072 Without-project (Median CC) Flow (cfs)	2072 With-project (Median CC) Flow (cfs)	2022 Without-project vs 2072 Without-project Percent Change	2022 Without-project vs 2072 With-project Percent Change	2072 Without-project vs 2072 With-project Percent Change
AEP = 0.1	8,100	8,100	8,100	0.0	0.0	0.0
AEP = 0.01	26,500	126,800	126,800	378.5	378.5	0.0
AEP	**2022 Without-project Stage (ft)**	**2072 Without-project (Median CC) Stage (ft)**	**2072 With-project (Median CC) Stage (ft)**	**2022 Without-project vs 2072 Without-project Difference (ft)**	**2022 Without-project vs 2072 With-project Difference (ft)**	**2072 Without-project vs 2072 With-project Difference (ft)**
AEP = 0.1	208.8	208.9	208.9	0.0	0.0	0.0
AEP = 0.01	214.7	226.7	226.7	12.0	12.0	0.0

Notes:
AEP = annual exceedance possibility
CC = climate change
cfs = cubic foot (feet) per second
ft = foot (feet)
vs = versus

3.1.9 Changes in Sea Level

Global and regional sea levels have been increasing over the past century and are expected to rise at an increasing rate throughout this century as the warming effects of climate change continue. Coastal sea levels impact Delta communities, infrastructure, and ecosystems as water levels and water quality conditions (i.e., salinity) propagate upstream. Severe precipitation events (particularly from ARs) and increased regulated flows and stages will further exacerbate flood risk throughout the Delta (Figure H.1-6 in Attachment H.1; Delta Stewardship Council 2021a).

The 2022 CVFPP Update projection for sea level rise is developed with a planning horizon of 2072, using the medium-high risk, high emissions scenario from the State's *Sea Level Rise Guidance 2018 Update* (Figure H.1-7 in Attachment H.1; California Natural Resources Agency and California Ocean Protection Council 2018). The sea level projection for the San Francisco tide gauge was interpolated using a third order of polynomial regression line. The sea level rise projection for 2072 (i.e., the boundary condition at the Golden Gate Bridge) was determined to be roughly 3.68 feet. In addition, some sensitivity analyses were conducted with a range of sea level rise from 0 to 6 feet to capture a range of outcomes.

Projections for sea level rise are incorporated into hydrodynamic modeling (i.e., stage-frequency determinations) for the 2022 CVFPP Update to assess impacts to the Delta. Three conditions were used to develop stage-frequency relationships: existing hydrology conditions, existing hydrology conditions with sea level rise, and future climate change hydrology with sea level rise. Simulated water surface elevations along the Sacramento and San Joaquin Rivers under various historical flood event conditions were also compared to current top-of-levee elevations to assess life and flood risk in the Delta. Sea level rise will likely have a greater effect on water surface elevations for smaller flood events. This effect will decrease with more significant flood events induced by future climate change hydrology, further increasing water surface elevations (Maendly 2018).

3.1.10 Changes in Groundwater

As described, temperatures are projected to increase under the low, median, and high climate change scenarios. With reduced snowpack and earlier snowmelt, reservoirs are projected to fill earlier in the year. Existing reservoir operations may require this water to be released to mitigate flood risk, reducing the amount of reservoir storage available for spring and summer. As such, groundwater sources, which supply roughly 40 percent of the water in California, may undergo additional stress as pumping intensifies under a reduction in surface water and increased ET (California Department of Water Resources 2013a).

In the Central Valley alone, groundwater storage levels declined by 13 million acre-feet between 2005 and 2010 (California Department of Water Resources 2018a). Between 1996 and 2015, the Merced Subbasin declined at a rate of roughly 120,000 acre-feet per year, totaling an approximate 2.4 million acre-feet deficit (California Department of Water Resources 2020). If unchecked and exacerbated by the impacts of climate change, continuous declines in aquifer storage can lead to increased costs, subsidence, and strain on water supply and flood infrastructure (Water Environment Federation 2017).

3.1.11 Changes in Wildfires

Wildfire risk is associated with a variety of climatological factors (temperature, soil moisture, drought, etc.) that are projected to shift under the effects of climate change. Over the last few decades, the number and severity of wildfires have steadily increased in the western United States, and further increases in magnitude and frequency are anticipated throughout the century. In the Sierra Nevada region of California, the annual average area burned is projected to increase between two and four times the 1961 to 1999 averages by the end of the century (2070 to 2099) under extreme warming conditions (Westerling 2018).

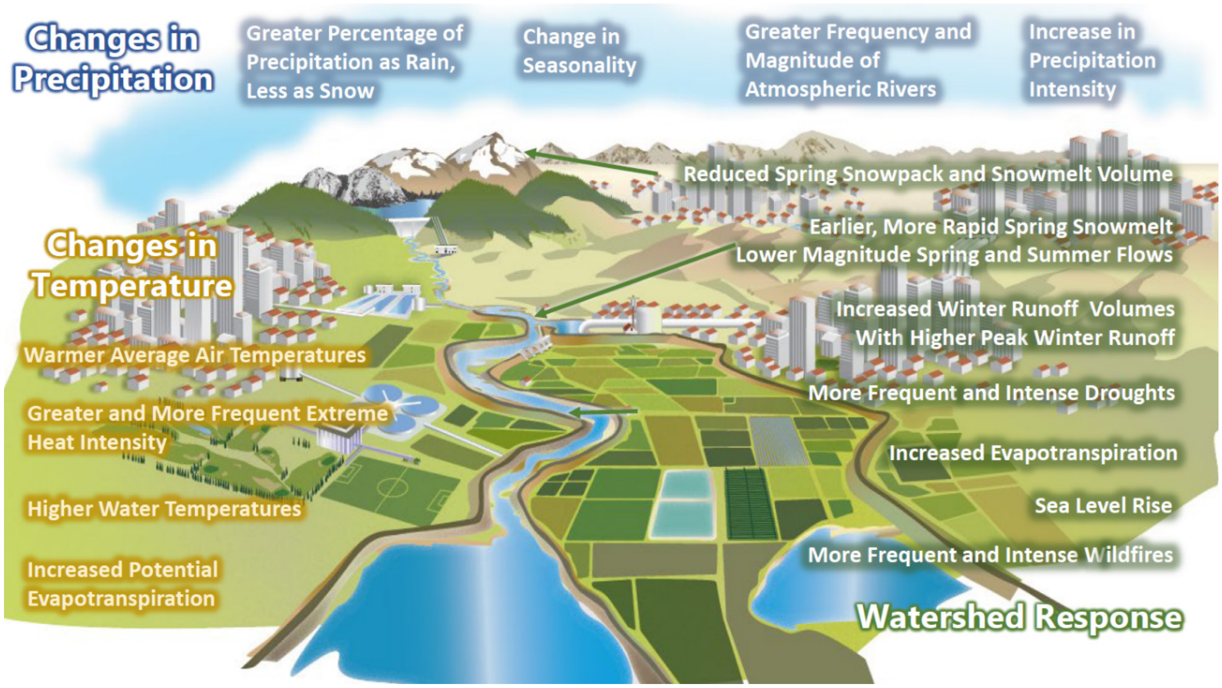
Wildfires are not only associated with substantial damages to property, infrastructure, lives, and ecosystems; they can also lead to downstream impacts. Because most fires in California occur in upper watersheds where there are the greatest number of forested areas, debris and other wildfire-related pollutants and compounds are carried downstream by runoff (Pennino et al. 2022). Wildfires can remove the tree canopy layers and biomass, resulting in decreased capacity to intercept and absorb rainfall. The soil surface is altered by high-severity fires, potentially collapsing soil structure and clogging soil pores with ash, or hydrophobic topsoil. These factors combine to dramatically increase peak runoff and sedimentation during post-fire rainfall events.

3.2 Watershed Response

The changes in temperature, precipitation, and hydrology are likely to result in a watershed-scale changes that are specific to each CPA. The watershed response resulting from the climate drivers quantified in Section 3.1 are described generally here to provide an example of how large-scale climate impacts may result in ecosystem changes. Specifically, changes in precipitation include a greater percentage of precipitation occurring as rain and less as snow, shifts in precipitation seasonality, increased prevalence of AR conditions, and increases in extreme precipitation intensity. Changes in temperature include warmer average air temperatures, more frequent and intense extreme heat events, higher water temperatures in surficial water bodies (especially lakes and rivers), and an increase in potential evapotranspiration. The watershed-scale responses (Figure H-17) to these changes include the following:

- A reduction in spring snowpack and snowmelt volume.
- Earlier, more rapid snowmelt and lower-magnitude spring and summer flows.
- Increased winter runoff volumes and higher peak-winter runoff rates.
- More frequent and intense droughts.
- Increased ET.
- More frequent and intense wildfires.
- Sea level rise.

Figure H-17. Changes in Precipitation and Temperature, and Watershed Responses as a Result of Climate Change



The watershed responses to climate drivers listed on Figure H-17 will exert further stress on a system that already struggles to supply adequate water to meet agricultural and environmental demands. The increased winter runoff with higher peak flows will lead to increased flooding and stress on the levees. The shift in timing of snowmelt toward winter could cause reservoirs to fill up earlier in the season, and current flood rule curves would require this water to be released, leading to a deficit of water in spring and summer. The reduction in spring snowmelt and lower magnitude of spring and summer flows will reduce floodplain inundation and associated geomorphic processes.

The increased temperatures can stress riparian vegetation and create growing conditions potentially favoring many species of invasive plants. More frequent droughts and increased water demand by plants due to greater ET stress will increase the agricultural water deficit and will likely increase groundwater extraction, which could threaten groundwater-dependent ecosystems. Furthermore, drier conditions will reduce the accretion of creeks, driving the water system to be less elastic and recoverable during periods of stress. For October and November specifically, less precipitation will likely impact fall runs and the robustness of the water system to manage initial precipitation events. Sea level rise will exacerbate flooding in low-lying areas near the Sacramento-San Joaquin Delta and alter the boundaries of the salt water/freshwater interface. Riverine ecosystems in these areas will also become more tidally influenced with sea level rise, shifting the habitats for specific species. The increasing prevalence of high-intensity wildfires will affect rainfall runoff and flooding characteristics by potentially altering sediment loads and generating more rapid, higher-magnitude flood events.

3.3 Ecosystem Response

The process of predicting the nature and magnitude of ecosystem response to climate change, and associated changes to watershed processes summarized earlier, is complicated because ecosystem responses may be directly (e.g., increases in stream temperatures that reduce habitat suitability for fish) or indirectly (e.g., changes in plant phenology, which affect the availability of invertebrate prey, which affect productivity and survivorship of birds) related to climate change. Furthermore, the nature and magnitude of ecosystem responses may vary both spatially and temporally.

Ecological responses to climate change also vary among different scales of ecological organization from individual plants and animals to populations of species to communities consisting of multiple populations, and there is overwhelming evidence that recent, rapid global changes in climate are affecting ecosystems at all scales of organization (Teplitsky and Charmantier 2019). Examples include changes in distribution, migration patterns; timing of breeding and reproductive success; and changes in physiology and morphology (Ambrosini et al. 2019; Dunn 2019, McKechnie 2019, Radchuk et al. 2019).

To effectively manage natural resources and prioritize conservation efforts in response to climate change, it is important to identify key characteristics among individuals, populations, and communities that may be most affected by a changing climate (Van de Pol and Bailey 2019). The complex relationships among climate change; the watershed-scale response to climate change; and the response of ecological processes, habitat, and species is well-illustrated by the native fishes addressed in the Conservation Strategy (i.e., anadromous salmonids, green sturgeon, and Delta smelt). These species' responses to climate change and changes in watershed processes are particularly difficult to estimate because the changes to physical conditions are likely to be location-dependent; and these species are potentially affected through multiple mechanisms that include changes to flow timing, duration, magnitude, and water temperature.

Changes in flows or water temperatures may, in turn, affect access to habitat, the timing of environmental cues that trigger critical behaviors (e.g., spawning), and the quality or quantity of suitable habitat, all of which may vary by life stage (e.g., egg, fry, juvenile, adult). These changes may also affect the food web of these species, as well the abundance and composition of predators on these species, both of which can affect the survival and growth of individual fish, which then are upscaled to effects on fish populations and aquatic communities.

For example, seasonal changes in hydrology are important cues for migration timing for upstream-migrating adult salmonids and downstream-migrating juvenile salmonids. Climate change-driven changes to these cues, coupled with increased water temperature, may result in adults spawning when temperatures may become unsuitable for egg survival (Jennings and Hendrix 2020) or juveniles out-migrating at a size or time when ocean conditions may not be favorable (Herbold et al. 2018). Climate change also is predicted to result in decreased snowmelt that will lead to lower spring peak flows and summer baseflows, which when coupled with the potential for increased drought frequency, can increase the vulnerability of juvenile salmonids to predation and improve habitat conditions for nonnative predators (Michel et al. 2020). In addition, end-of-May storage in reservoirs, which provides sources of cold water supporting salmonid habitat downstream of dams, is projected to fall to less than historical levels more frequently, further degrading salmonid habitat quality (U.S. Department of the Interior, Bureau of Reclamation 2016).

Furthermore, the effects of climate change on water temperature, a critical component of fish habitat suitability, are likely to depend greatly on location and to vary seasonally. As an example, greater warming is expected in winter and early spring in the upper San Francisco Estuary than in the western estuary, and greater warming overall is occurring in the northern part of the estuary than in the western region of the estuary (Bashevkin et al. 2021). Increases in San Francisco Estuary water temperatures are predicted to reach sublethal levels for Delta smelt, ultimately compressing suitable habitat for the completion of their life cycle and resulting in timing shifts of their life cycle and a mismatch with important food resources or spawning windows (Brown et al. 2016). Elevated water temperature also significantly increases predation risks for juvenile salmonids (Michel et al. 2020). When combined with other factors, such as the use of large rock to protect levee slopes from erosion (which may become more frequently necessary to protect levees from higher-magnitude peak flows predicted to occur with climate change), the impacts on salmonids and other native fishes may be exacerbated by a loss of vegetative cover resulting in reduced shade, reduction in the food web, and improved habitat conditions (e.g., open water) for predatory species.

Despite these complexities and uncertainties, and to provide a basis for the identification of adaptation measures, the Conservation Strategy's measurable objectives and target species were evaluated to generalize their potential ecological responses to climate change's impacts (Table H-9). The evaluation was informed by key references (described in Table H-1), the technical appendices and documents associated with the Conservation Strategy, and the professional judgment of ecologists, biologists, hydrologists, and geomorphologists supporting DWR with the development of the Conservation Strategy Update and the publication of this report. Chapters 4 and 5 provide specific adaptation measures, drawing from those formulated for the Conservation Strategy, and additional guidance for increasing ecosystem resilience throughout the Systemwide Planning Area (SPA).

Table H-9. Response of Conservation Strategy Measurable Objectives to Climate Change Drivers

Measurable Objectives	Climate Change Drivers and Ecological Responses
Ecosystem Processes: Floodplain Inundation	Increased magnitude of flooding and peak flows would lead to more extensive floodplain inundation where levees do not occur (or are already set back) and in existing floodways. However, much of this increased flooding would be expected in the winter over shorter durations, and ecologically beneficial spring flooding would be reduced in extent, duration, and magnitude throughout the SPA, particularly along the San Joaquin River.
Ecosystem Processes: Riverine Geomorphic Processes	Increased magnitude of flooding and increased peak flows potentially could increase riverine geomorphic processes (e.g., sediment transport, sediment deposition, erosion) throughout the SPA. However, the decreased duration of storms and reduced duration of spring snowmelt and runoff (particularly along the San Joaquin River) may reduce the spatial extent or magnitude of these processes throughout the SPA.
Stressors: Invasive Plants	Warmer air temperatures, more frequent and intense droughts, and increased severity and frequency of disturbances (in the form of wildfires) are likely to create conditions that favor the establishment of plants that are adapted to frequent and repeated disturbance, which include most species of invasive plants. These same climate changes also may reduce the influence of abiotic conditions (e.g., elevated soil moisture) that favor riparian and wetland plants (e.g., willow, cottonwood, tule, cattail) over upland plants (e.g., nonnative annual grasses and herbaceous broadleaf plants) within floodways.
Stressors: Fish Passage Barriers	As defined in the 2016 Conservation Strategy, fish passage barriers are water management structures such as dams, weirs, control structures, and water diversions that block, delay, strand, or otherwise adversely influence anadromous fish as they migrate upstream or downstream. Reductions in spring and summer flows, particularly during dry years and prolonged droughts, can further exacerbate existing fish passage barriers or result in new barriers.
Stressors: Revetment	The need for revetment is likely to increase, at least to some degree, for the reasons described in the “Ecosystem Processes: Riverine Geomorphic Processes” row of this table, primarily in portions of the SPA where levees occur directly adjacent to river channels.
Stressors: Levees	Increased flooding magnitude and peak flows may require larger levees (e.g., taller, wider), levee structural improvements (e.g., cutoff walls, stability, and underseepage berms), levee extension, relocation, or removal. Levees that are relocated (i.e., setback levees) or removed increase the size of the floodway allowing for more transient storage, greater system resiliency (particularly related to climate change factors), and improved ecosystem functions and values.

Measurable Objectives	Climate Change Drivers and Ecological Responses
Habitats: Shaded Riverine Aquatic (SRA) Cover	Climate change drivers related to SRA cover are discussed in the "Ecosystem Processes: Riverine Geomorphic Processes," "Stressors: Revetment," and "Habitats: Riparian" sections throughout this table. Overall, some elements of SRA cover, such as natural, eroding banks may become more common with climate change and associated increases in peak flows; however, the potential for increased use of revetment and the expected decrease in riparian vegetation are likely to result in an overall decline in SRA cover throughout the SPA.
Habitats: Riparian	Several climate change factors are likely to affect riparian vegetation. More frequent flooding and increased peak flow magnitudes may increase the scouring of existing riparian vegetation stands, particularly where there is not adequate space in the floodplain to spread out floodwaters. Shifts in the amount, timing, and duration of spring runoff may also affect the regeneration of early-seral riparian species (e.g., cottonwoods and willows) that rely on spring flood events. Decreased summer flows, increased air temperatures, increased frequency and severity of droughts, and changes in soil moisture and atmospheric water deficit all may result in shifts to upland and nonnative species that are better adapted to increased aridity and more frequent and severe droughts. This shift in riparian vegetation community composition may be exacerbated by more frequent and intense wildfires.
Habitats: Marshes and Wetlands	Key climate change drivers include warmer air temperatures and increased frequency and severity of drought, coupled with more frequent and increased peak floods (generally earlier in the year) and altered spring and summer runoff. The San Joaquin River may be especially prone to the impacts of climate change, due to its greater reliance on spring snowmelt as a driver of wetland hydrology. Most climate change impacts are expected to negatively affect marsh and wetland habitats because the sources of wetland hydrology and extended wetland hydroperiods (e.g., spring flooding, shallow groundwater influenced by summer base flows, elevated soil moisture) would be reduced in magnitude, frequency, and/or extent (particularly in the San Joaquin River). However, increased scouring from increased winter flooding and higher peak flows may benefit marshes and wetlands by resetting succession and allowing early successional plants to establish following floods.
Target Species: Delta Button-celery Slough Thistle	In addition to the potential climate change impacts described in the "Habitats: Marshes and Wetlands" section of this table, changes in air temperatures, the amount and timing of precipitation (including more frequent droughts), decreased soil moisture, and increased evaporative demand could stress individual plants leading to reduced growth, seed output, and potential plant death. The magnitude of these impacts on Delta button-celery and slough thistle populations is difficult to predict and is likely to vary greatly from population to population based on localized edaphic conditions, location within the floodway, and other factors.

Measurable Objectives	Climate Change Drivers and Ecological Responses
Target Species: Steelhead (Central Valley Distinct Population Segment)	Steelhead migrate upstream to spawn high up in tributaries in fall and winter, usually on the descending limb of the hydrograph. Therefore, higher and earlier peak flows can decrease egg survival if there is increased gravel scour, and can affect juvenile survival by decreasing the ability of juveniles to survive over winter when rearing in natal streams. Elevated water temperatures, decreased summer flows, and more frequent and intense drought cycles may affect juvenile survival by affecting rearing habitat quantity and quality, physiology, and availability of prey. More frequent and intense wildfires may result in greater sediment loads to tributaries due to erosion and debris flows, which can decrease the quality and quantity of spawning and rearing habitat, and affect the survival of eggs and juveniles in unregulated streams used for spawning and rearing (e.g., Deer Creek, Mill Creek). Refer to the “Habitats: Riparian and Habitats: SRA Cover” section of this table for more information.
Target Species: Chinook (Fall-/Late-fall-run Evolutionarily Significant Unit)[a]	Fall/Late-fall Chinook salmon migrate upstream to spawn in tributaries in fall and winter. Therefore, higher and earlier peak flows can decrease egg survival if there is increased gravel scour, and can affect juvenile survival by decreasing rearing habitat conditions for juveniles. Elevated water temperatures, and more frequent and intense drought cycles may affect adult upstream migration and access to spawning habitat, as well as timing of egg hatching (higher temperatures will result in faster development). Refer to the “Habitats: Riparian and Habitats: SRA Cover” section of this table for more information.
Target Species: Chinook (Winter-run Evolutionarily Significant Unit)[a]	Winter-run Chinook salmon migrate upstream to spawn in the Upper Sacramento River in winter, but spawn timing is affected by water temperature, with cool spring temperatures triggering earlier spawn timing and warm spring temperatures resulting in later spawn timing. Egg survival depends on cool water temperatures in spawning habitat, which depend on releases from Shasta and Keswick dams. Therefore, higher water temperatures and more frequent and severe drought cycles can affect spawn timing and egg survival. Juveniles rear in the mainstem Sacramento River and in non-natal tributaries where elevated water temperatures, decreased summer flows, and more frequent and intense drought cycles may affect juvenile survival by affecting rearing habitat quantity and quality, physiology, and availability of prey. Refer to the “Habitats: Riparian and Habitats: SRA Cover” section of this table for more information.

Measurable Objectives	Climate Change Drivers and Ecological Responses
Target Species: Chinook (Spring-run ESU)[a]	Spring-run Chinook salmon time their adult upstream spawning migration with the snowmelt hydrograph and then hold in deep pools over the summer; therefore, changes to timing, magnitude, and duration of spring snowmelt may affect spawning behavior and timing. Higher and earlier peak flows may decrease egg survival if there is increased gravel scour, and may decrease juvenile survival by decreasing their ability to survive over winter. Elevated water temperatures, decreased summer flows, and more frequent and intense drought cycles may affect juvenile survival by affecting rearing habitat quantity and quality, physiology, and availability of prey; and may decrease the quality and quantity of adult over-summer holding habitat, which requires deep, cold water pools. More frequent and intense wildfires may result in greater sediment loads to tributaries due to erosion and landslides, which can decrease the quality and quantity of adult holding, spawning, and rearing habitat, and affect the survival of eggs and juveniles in unregulated streams used for spawning and rearing (e.g., Deer Creek, Mill Creek). Refer to the “Habitats: Riparian and Habitats: SRA Cover” section of this table for more information.
Target Species: Green Sturgeon (Southern Distinct Population Segment)	Green sturgeon adults migrate upstream to spawn in the Upper Sacramento and Feather rivers in late winter and spring in response to the snowmelt hydrograph, and hold/spawn in deep mainstem pools; therefore, changes to the timing, magnitude, and duration of spring snowmelt may affect spawning behavior and timing. Green sturgeon larval survival is negatively affected by higher water temperatures. Elevated water temperatures, decreased summer flows, and more frequent and intense drought cycles affecting summer water temperatures may affect juvenile survival by affecting rearing habitat quantity and quality, physiology, and availability of prey. Increased Delta salinity associated with sea level rise may affect the prey base for juvenile and subadult green sturgeon. Refer to the “Habitats: Riparian and Habitats: SRA Cover” section of this table for more information.
Target Species: Delta Smelt	Sea level rise, and the attendant increased salinity intrusion into the Delta, may further shrink, or shift upstream, areas of brackish water required by this species. Delta smelt require a mosaic of habitat types including wetlands and floodplains. Delta smelt require low salinity habitat, and elevated temperatures may limit habitat for juvenile Delta smelt. Refer to the “Habitats: Marshes and Wetlands” section of this table for more information.

Measurable Objectives	Climate Change Drivers and Ecological Responses
Target Species: Valley Elderberry Longhorn Beetle (VELB)	The impacts of climate change on the VELB depend largely on the impacts to the species' sole host plant, blue elderberry. Relative to many other Central Valley riparian trees and shrubs, blue elderberry tends to occur more commonly in areas of infrequent flooding and lower groundwater and soil moisture. Changes in air temperatures; the amount and timing of rainfall (including more frequent droughts); and the timing, duration, and magnitude of peak runoff and spring runoff may have positive or negative effects on blue elderberry (and thereby the VELB), with some of these effects potentially benefiting the species by creating growing conditions more suitable for blue elderberry shrubs, relative to current conditions, and other effects creating growing conditions less suitable for elderberry relative to current conditions. The net effect of these changes on the VELB cannot be predicted and likely depends to a large extent on site-specific conditions. Refer to the "Habitats: Riparian and Habitats: SRA Cover" section of this table for more information.
Target Species: Giant Garter Snake (GGS)	Wetland-dependent reptiles, such as GGS, are sensitive to changes in the amount of precipitation and snowpack, drought, timing of snowmelt and runoff, and groundwater depth, which affect the availability and distribution of wetland habitat. An increase in flooding severity and changes in flood duration and timing could displace snakes, particularly those overwintering in the bypasses. Changes in precipitation and water availability may also affect irrigation and the extent of rice acreage, an important habitat for this species. With increasing droughts resulting water scarcity, farmers may convert from rice to dry crops. Additionally, irrigation channels may become drier and obsolete, disrupting connectivity of suitable habitat and movement corridors. More significant flood events may result in increased maintenance of channels and levees, leading to the disturbance or direct mortality to this species. GGS are sensitive to disturbance regimes, and more stressful environmental conditions could exasperate emerging diseases, such as snake fungal disease and parasitic infections. Refer to the "Habitats: Marshes and Wetlands" section of this table for more information.

Measurable Objectives	Climate Change Drivers and Ecological Responses
Target Species: Yellow-billed Cuckoo	Riparian birds, including the yellow-billed cuckoo, are primarily sensitive to drought because of the impact of reduced water availability on riparian vegetation and physical processes driven by flow regimes. Increased drought frequency and intensity and warmer air temperatures result in changes in soil moisture that have indirect effects on riparian birds by increasing evapotranspiration, and by further altering riparian vegetation species composition and habitat structure, key elements associated with habitat quality for riparian birds. Changes in phenology can cause mismatches in the timing of large insect emergence, which is critical to providing amino acids for reproduction and to feed their young. Warming temperatures may cause a mismatch between the timing of genetically driven circannual rhythms (such as the timing of migration and reproduction) and resource availability. More frequent flooding and increased peak flows can destroy nests and nesting, foraging, and resting habitats. Earlier annual snowmelt and earlier peak flows, lower streamflow, and changes in length of inundation may lead to an altered hydrograph, which affects riparian vegetation and the timing and availability of food for riparian birds. More frequent and intense wildfires may result in increased a direct loss of nests, decreased food availability, and changes in vegetation species composition and structure important for riparian birds. Yellow-billed cuckoos require large blocks of riparian habitat for breeding, so factors that lead to habitat fragmentation and reduce patch size decrease habitat value and availability for cuckoos. Refer to the "Habitats: Riparian" section of this table for more information.
Target Species: Swainson's Hawk	Swainson's hawks typically nest in mature, dense-canopied cottonwoods, willows, and valley oaks associated with riparian forest habitat, and in isolated trees next to agricultural and grassland habitat. Riparian woodlands are a key nesting habitat for this species in the Central Valley. Increased drought frequency and intensity and warmer air temperatures result in changes to soil moisture that directly affect riparian habitats by increasing evapotranspiration and further altering riparian vegetation species composition and habitat structure, which could decrease both the frequency of large nesting trees and the amount of foliage on the trees. Reductions in water availability for crops may decrease the amount of row crop foraging habitat important for Swainson's hawks. Increased drought frequency and intensity and decreases in soil moisture may affect the prey base for this species by reducing the vegetation that supports small mammals and large invertebrates, both in grassland and agricultural habitats. More frequent wildfires may affect nesting trees, result in the direct take of nests, and reduce the prey base. In addition, increased droughts would decrease wetlands, which would reduce dragonfly productivity, another prey item of Swainson's hawks. Refer to the "Habitats: Riparian" section of this table for more information.

Measurable Objectives	Climate Change Drivers and Ecological Responses
Target Species: Least Bell's Vireo	Riparian birds, including the Least Bell's vireo, are primarily sensitive to drought because of the impact of reduced water availability on riparian vegetation and physical processes driven by flow regimes. Increased drought frequency and intensity and warmer air temperatures result in changes in soil moisture that directly affect riparian birds by increasing evapotranspiration, and further altering riparian vegetation species composition and habitat structure, key elements associated with habitat quality for riparian birds. Changes in phenology can cause mismatches in the timing of insect emergence critical to providing amino acids for reproduction and feeding young and the primary food source for Least Bell's vireos. Warming temperatures may cause a mismatch between the timing of genetically driven circannual rhythms (such as the timing of migration and reproduction) and resource availability. More frequent flooding and increased peak flow can destroy nests and nesting, foraging, and resting habitats. However, Least Bell's vireos typically nest in dense, low, shrubby vegetation characteristic of early successional stages in riparian areas. If the timing is appropriate, more frequent flooding and increased peak flow could result in more early successional riparian habitats. Earlier annual snowmelt and earlier peak flows, lower streamflow, and changes in length of inundation may lead to an altered hydrograph, which affects riparian vegetation and the timing and availability of food for riparian birds. More frequent and intense wildfires, which have become more prevalent in riparian areas due to more invasive weeds and the lack of floodplain inundation, may result in increased direct loss of nests, decreased food availability, and changes in vegetation species composition and structure important for riparian birds. Refer to the "Habitats: Riparian" section of this table for more information.

Measurable Objectives	Climate Change Drivers and Ecological Responses
Target Species: Yellow-breasted Chat	Riparian birds, including the yellow-breasted chat, are primarily sensitive to drought because of the effect of reduced water availability on riparian vegetation and physical processes driven by flow regimes. Increased drought frequency and intensity and warmer air temperatures result in changes in soil moisture that directly affect riparian birds by increasing evapotranspiration, and further altering riparian vegetation species composition and habitat structure, key elements associated with habitat quality for riparian birds. Changes in phenology can cause mismatches in the timing of insect emergence, which is critical to providing amino acids for reproduction and feeding young, and can also cause mismatches in the timing of vegetation fruiting in late summer and fall, which is key for postbreeding migratory fat deposition and the timing of fall migration in chats. Warming temperatures may cause a mismatch between the timing of genetically driven circannual rhythms (such as the timing of migration and reproduction) and resource availability. More frequent flooding and increased peak flow can destroy nests and nesting, foraging, and resting habitats. However, chats typically nest in dense, low, shrubby vegetation characteristic of early successional stages in riparian areas. If the timing is appropriate, more frequent flooding and increased peak flow could result in more early successional riparian habitats. Earlier annual snowmelt and earlier peak flows, lower streamflow, and changes in length of inundation may lead to an altered hydrograph, which affects riparian vegetation and the timing and availability of food for riparian birds. More frequent and intense wildfires, which have become more prevalent in riparian areas due to more invasive weeds and the lack of floodplain inundation, may result in an increased direct loss of nests, decreased food availability, and changes in vegetation species composition and structure important for riparian birds. Refer to the "Habitats: Riparian" section of this table for more information.
Target Species: Tricolored Blackbird	Tricolored blackbirds breed in continuous areas of emergent marsh vegetation and riparian scrub, for which early successional stages in both habitats are preferred. Earlier, more rapid spring snowmelt and peak runoff flows with lower-magnitude spring flows under drastic snowpack reduction could reduce the amount of water needed to support emergent marsh vegetation and affect the timing and extent of inundation of the marsh habitat, which are important aspects in creating and maintaining preferred breeding habitat. Warmer air temperatures and increased frequency and severity of drought will result in reductions in soil moisture and increased evapotranspiration, decreasing overall breeding and foraging habitats for wetland-dependent birds including tricolored blackbirds. Refer to the "Habitats: Marshes" and "Wetlands and Habitats: Riparian" sections of this table for more information.

Measurable Objectives	Climate Change Drivers and Ecological Responses
Target Species: California Black Rail	An increased magnitude of flooding and peak flows would lead to more extensive floodplain inundation and potentially longer inundation durations, where levees do not occur (or are already set back) and in existing floodways. More frequent flooding and increased flow can destroy black rail nests and nesting, foraging, and resting habitats. Black rails are also more susceptible to predation when their marsh habitats are flooded, forcing them out of the emergent vegetation. Because black rails occupy marsh islands in the Delta that are subject to flooding, changes in the timing and intensity of rain events or water storage releases could disrupt their annual life cycle if flood intensity increases during the breeding season, when higher volumes of water are released in spring due to heavy winter rains. Low flows resulting from a reduction in snowpack could create water levels that are insufficient to sustain emergent marshes and riparian vegetation during the dry season. Warmer air temperatures and higher water temperatures result in sea level rise exacerbate habitat and predation-related stresses for this species in the Delta where marshes are confined by levees that prevent the upward migration of marshes as water levels rise. As a result, the distribution of vegetation suitable for black rails will decrease in the Delta. In addition, the attendant increased salinity intrusion into the Delta may further shrink, or shift upstream, areas of brackish water marsh used by this species in the Delta. Increased drought intensity and frequency could reduce available habitat and shift areas of brackish marsh. Increased wildfires could burn both emergent marsh vegetation and associated scrub riparian habitat used by black rails in the Delta and result in the direct take of nests and displacement of individuals. Refer to the “Habitats: Marshes and Wetlands” section of this table for more information.
Target Species: Greater Sandhill Crane	Wintering habitat for greater sandhill cranes in the Central Valley generally consists of irrigated pastures and croplands, grain fields, small open ponds, wetlands, and floodplains that are open and without visual obstruction (e.g., dense vegetation). Wetlands are important for nocturnal roosts. The Central Valley wintering greater sandhill crane population does not appear to be particularly sensitive to the threat of climate change, but wintering habitat could be threatened by increased flood risk with sea level rise and increased magnitude of flooding and peak flows. Additionally, increased frequency and severity of droughts could decrease row crop planting (foraging habitat) and wetland habitat (roosting and foraging). Refer to the “Habitats: Marshes and Wetlands” section of this table for more information.

Measurable Objectives	Climate Change Drivers and Ecological Responses
Target Species: Bank Swallow	Climate change could be positive or negative for bank swallows. Higher-magnitude peak flows may create additional exposed banks that increase nesting habitat for this species; however, in other instances, the increased magnitude and frequency of flooding will likely lead to the increased use of revetment to protect levees in many locations, thereby eliminating habitat for this species. Refer to the “Ecosystem Processes: Riverine Geomorphic Processes” and “Stressors: Revetment” sections of this table for more information.
Target Species: Riparian Brush Rabbit Riparian Woodrat	These species require large patches of riparian scrub with dense understory providing sufficient cover. Flooding is a major threat to the remaining populations. Although riparian brush rabbits have been found in trees and tall shrubs during floods, it is doubtful they can survive in trees for long. Rabbits trapped in this manner are highly susceptible to predation, hypothermia, and starvation. Also, little refuge is available to brush rabbits fleeing rising waters, because agricultural fields abut the riparian corridors occupied by all three populations. Increased peak flows and more frequent flooding could affect the survival of this species, particularly within leveed reaches where higher refugia, above flood flows, do not occur or do not provide for connectivity to occupied habitat and suitable cover for the species. Additionally, more frequent and intense wildfires could eliminate habitat for these species. Riparian brush rabbits and riparian woodrats are vulnerable to environmental change of any kind because of their small population size, isolation, low genetic diversity, and inability to disperse to new habitats. Refer to the “Habitats: Riparian” section of this table for more information.

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CHAPTER 4

Potential Adaptation Strategies and Measures

This chapter is organized into two key parts:

1. A background discussion that includes fundamental conservation biology and systems resiliency principles to guide the development of measures that can reduce ecosystem vulnerability and enhance resilience.

2. An overarching climate change adaptation strategy, along with five corresponding adaptation measures.

   a. The first measure consists of direct modifications to the flood control system, grouped into landscape-scale measures, and habitat- and species-specific measures.

   b. The next four measures consist of implementation policy guidance and initiatives to improve knowledge and communication related to climate change risks, vulnerabilities, and opportunities.

These preliminary adaptation measures are intended to provide an initial set of recommendations for how DWR and its partners can most effectively conserve and restore the ecological processes, habitats, and species identified in the Conservation Strategy. These will likely be refined and improved in collaboration with project partners through the CVFPP development process.

4.1 Overview of Ecological Vulnerability, Resilience, and Adaptation

Traditionally, an ecosystem's potential vulnerability to climate change impacts has been measured in relation to the ecosystem's historical condition. The logic behind this approach is that populations, communities, and ecosystems will be best prepared to cope with new or variable conditions if those conditions fall within the historical range of variability they have adapted to (Falk et al. 2019). However, the realized and potential rates of change in temperature, precipitation, and hydrology described in Section 3.1 are outside the range of the natural variability current ecosystems in the Central Valley have historically occurred under. In addition, the increased climatic extremes also increases the frequency and magnitude of natural and anthropogenically intensified disturbances such as fire, flood, and drought. The stress these climatic changes and ecological disturbances will impart on natural communities may exceed the ecosystem's ability to recover. A species' vulnerability and its resilience are a product of many aspects of its ecology, population and conservation status, and current habitat conditions.

Vulnerability assessments help determine whether the species or systems are vulnerable to the effects of climate change and if so, to what extent. These assessments are important to link actions to impacts, and to create specific adaptation strategies and actions that reduce vulnerabilities (Stein et al. 2014). Species-specific vulnerability is based broadly on species-specific exposure, sensitivity, and adaptive capacity (Bateman et al. 2020). Species vulnerability assessments should not only address the effects of climate change; they should also include potential cumulative impacts of other, non-climate stressors and how those might interact with the effects of climate change (Gardali et al. 2012, Jongsomjit et al. 2013). Those stressors may include (among others) land conversion and development, changes in hydrology due to water management infrastructure, and channelization and disconnection of floodplain habitats due to levee construction.

Consequently, actions can be taken to reduce vulnerability or increase resilience. These actions (adaptations) are being guided by the following key principles of conservation biology and adaptive management (National Fish, Wildlife, and Plants Climate Adaptation Partnership 2012; California Natural Resources Agency 2014; Stein et al. 2014; Keeley et al. 2018):

- Where possible, reintroduce physical processes by removing impediments to natural processes and reconnecting rivers to their floodplains.
- Protect remaining habitats from loss and fragmentation and increase the size of protected areas.
- Provide for species movement and migration through habitat protection and restoration.
- Reduce other (non-climatic) stressors on species through management actions.
- Use adaptive management to take action under uncertain and changing climatic conditions and to increase understanding and inform actions.
- Increase institutional capacity for effective management.

Implementation of the CVFPP provides a critical opportunity to increase the climate change resiliency of species and habitats. This is primarily because rivers and floodplains are particularly important as corridors for the movement and migration of aquatic and terrestrial species (Seavy et al. 2009). The Central Valley's rivers and floodplains are highly managed systems; however, if enacted, many opportunities will reduce vulnerability to climate change impacts, rehabilitate the system for current conditions, and increase system resilience. As DWR, regional/local maintaining agencies, and other State and federal resource managers continue to advance multi-benefit projects within the SPA, floodplain managers will need to strive to build resilience into the system and develop countermeasures to mitigate the impacts of climate change by employing effective multi-objective adaptation approaches.

4.2 Development of Adaptation Measures

Preliminary adaptation measures specific to the Conservation Strategy objectives and target species were developed using the following process:

1. Review current literature on climate adaptation and climate change impacts in the Central Valley (refer to Chapter 2).

2. Analyze the latest climate change modeling to determine probable climatic changes in each CPA (refer to Section 3.1).

3. Estimate climate change drivers of changes to watershed processes (refer to Section 3.2) and possible ecological responses for the Conservation Strategy's measurable objectives and target species (refer to Section 3.3).

4. Identify regional climate change risks and potential opportunities within each CPA (refer to Chapter 5).

5. Develop adaptation approaches that leverage existing DWR planning processes (including the CVFPP and Conservation Strategy), provide guidance for future Plan Updates, and could initiate the development of resources and tools that can be shared with agency partners and others developing multi-benefit projects.

4.2.1 Adaptation Measure 1: Build Ecosystem Resilience

It is possible to reduce or mitigate the risks of climate change to the ecological processes, habitats, and species identified in the Conservation Strategy by implementing projects and management actions that restore ecosystem functions, increase the quantity and quality of essential habitats, and improve conditions for specific species. These adaptation measures and recommendations are organized into two groups: landscape-scale processes, and habitat and species-specific measures.

4.2.1.1 Landscape-level Hydrologic, Ecological, and Geomorphic Process-specific Adaptation Measures

- At the highest level, the most important and effective measures create more opportunities to restore and improve riverine geomorphic processes by increasing the river corridor width; allowing the formation of complex, dynamic, meandering channels; and reconnecting relict floodplains. This can be accomplished by removing or setting back levees along river corridors, removing revetment, or reconnecting and restoring floodplains. No matter where they occur geographically, these actions would generally help increase resilience. This is particularly true for climate change challenges, because they would allow more opportunities to restore natural physical and ecological processes and develop complex, diverse habitats along the channel margins, floodplains, and riparian zones. These actions would help achieve the following ecological goals: restoring ecosystem processes, increasing and improving habitats, reducing stressors, and contributing to the recovery of target species.

a) **Levee Setbacks and Removal:** Relocating levees to expand floodways and bypasses, or removing levees that are no longer needed for flood management, would increase climate change resilience. Section 3.1 describes the predicted increased peak flows, especially in the San Joaquin and its tributaries, which will greatly increase flood risk and will require major modifications to the existing levee infrastructure to minimize impacts to surrounding areas. Levees should be strategically set back to promote the formation of side channels, meander bend cutoffs, eroded banks, point bars, and similar features that create and sustain habitats for most native species. Levee setbacks also allow for the expansion of riparian and SRA habitat while promoting vegetative succession and riverine geomorphic processes that create and sustain habitats for target and other native species. Levee relocations could also be designed to meet multi-benefit project goals, such as groundwater recharge and the creation of suitable rearing habitat for target species. These also have the benefit of lowering the long-term operations and maintenance burden by decreasing erosional pressure on levees and reducing the overall length of levees along the river corridor.

b) **Unnecessary Revetment Removal:** Levees or bank revetment within a river's natural meander zone can impede the physical processes needed to support complex aquatic and riparian ecosystems (Naiman et al. 1993; Lytle and Poff 2004). Revetment and levees prevent natural processes (such as meander zone migration and meander cutoffs) in portions of the SPA, which has prevented the formation of new habitat. The locations of unnecessary revetment should be systematically identified as opportunities for removal to promote natural riverine processes.

c) **Floodplain Topographic Modification:** Floodplain modification can be used in the floodway to increase floodplain inundation for a wider range of flows by raising or lowering areas. This measure can increase the suitable inundated habitat needed to meet the Anadromous Fish Restoration Program's doubling goal for salmonid populations in the Central Valley. The current acreage of floodplain that is hydrologically connected to Central Valley rivers is extremely low relative to historical conditions, and climate change is expected to further reduce the flow-related habitat conditions needed for freshwater ecosystem health (Matella et al. 2014). Floodplain topographic modifications can be designed to promote a hydrologic connection to the river for specific target species and for a current or future flow regime. This is especially relevant along the San Joaquin River corridor, where natural flows have been modified to the extent that it is not feasible to establish the hydrologic reconnections of floodplain terraces at ecologically beneficial frequencies and durations because of to current reservoir operations and flow management paradigms.

d) **Floodplain Heterogeneity Enhancement:** Where the levees cannot be set back further, this adaptation measure can optimize floodplains to achieve resilient ecological functionality under a changing climate. Creating microtopography on the floodplain also allows for greater habitat diversity and areas for sanctuary during extreme conditions (e.g., high-ground refugia during floods and low shaded cooler areas during droughts).

e) **Intentional Levee Breaks and Planned Weir Overflows:** Another strategy to mimic floodplain inundation processes is the use of intentional levee breaks (using operable levee gates, weirs, or other mechanisms) that allow the programmed inundation and dewatering of floodplains, or planned weir overflows. This concept is discussed in a journal article by Florsheim and Dettinger (2015) and provides an alternative to full levee setbacks or levee removal where those options are not feasible. Planned weir overflows could also be used in conjunction with flood risk reduction strategies, such as transitory storage for floodwaters.

f) **Flood System Management to Promote Flood-Managed Aquifer Recharge (Flood-MAR):** Flood-MAR can be applied to use flood water to recharge water on agricultural lands, floodplains, and flood bypasses to provide the following benefits: water supply reliability, flood risk reduction, drought preparedness, aquifer replenishment, ecosystem enhancement, subsidence mitigation, water quality improvement, working landscape preservation and stewardship, and climate adaptation. Flood-MAR could be implemented at multiple scales to achieve multi-sector sustainability and climate resilience. Ongoing studies along the lower Tuolumne and Merced Rivers, and the mainstem San Joaquin River, are currently assessing the potential to evaluate the compatibility of floodplain recharge and restoration in a manner that can restore geomorphic processes, improve habitat conditions, and build ecological resilience while simultaneously improving groundwater storage.

g) **Multiple-objective Operations and Maintenance:** Operations and maintenance approaches need to include criteria that consider natural river functions and processes (such as sediment transport and the development of complex, dynamic channel features), as well as habitat and species conditions, to alleviate the ecological stressors that have historically been caused by flood operations and maintenance actions. This is a complex issue that may involve revisions to federal policies and authorizations, but it is a critical strategy to adaptively manage the flood system and gradually improve ecological conditions over time in a manner that is compatible with flood conveyance objectives. This will likely require policy changes and cooperation with federal partners, but these types of multiple-objective operations and maintenance programs are currently being employed in other regions and could be further advanced in the Central Valley by DWR with federal, State, and local partners.

h) **Reservoir Operations Updates:** Reservoir flood rule curves will need to be adapted to accommodate changing flow regimes and improved weather forecasting technology. As the snowmelt and peak flows shift to earlier in the season, reservoirs will fill sooner and be required to release flows. Reservoir management strategies (such as Forecast-informed Reservoir Operations (FIRO)) could allow for a more natural flow regime that mitigates some impacts of increasingly variable hydrology. When reservoirs are required to release flows sooner for flood control, reservoir operations need to consider the types and durations of flows needed to achieve multi-benefit ecological goals. For example, reservoirs can release flood flows in concert with downstream management to promote Flood-MAR. The term Eco-FIRO-MAR has been recently popularized to describe the importance of managing reservoirs in coordination with operations to promote groundwater recharge and ecological function.

i) **Transitory Floodplain Water Storage Increases:** As flood system operations are modified, projects may also be implemented that improve and increase the transitory floodplain storage of floodwaters downstream. Not only do these projects provide ecological benefits, they may also increase groundwater recharge, which provides regional ecosystem and water supply benefits consistent with other State and regional water management programs.

4.2.1.2 Habitat and Species-specific Adaptation Measures

Even with the restoration of natural geomorphic processes, other factors or stressors may prevent or impede natural ecological recovery in ways that do not optimize conditions for native habitats or target species. These may include (among others) elevated or monotypic floodplains, and persistent invasive weeds. In addition, improved geomorphic processes may create or sustain target habitats too slowly to maintain or increase populations of target species, especially species whose population sizes already are low or whose distributions are limited. For these reasons, species-focused habitat creation, restoration, and enhancement actions may be needed to improve climate change resilience.

Multi-benefit projects can be designed adaptively to optimize habitat conditions and mitigate the impacts of climate change; general guidance related to the design of multi-benefit projects is provided here.

General Habitat and Species–specific Design Guidance for Increasing Resilience

a) **Designs Allowing for Habitat Migration:** For restoration and conservation project planning and design, it is widely acknowledged that habitats will change and migrate in response to climate change; therefore, project planning and design should include buffers that allow this habitat evolution and migration. For example, sea level rise will change the location and distribution of tidal marsh habitat in the Delta. Therefore, estuarine restoration projects should account for this by designing projects to allow for the migration of tidal marsh habitats in the coming decades, according to current sea level rise projections.

b) **Floodplain Topographic Modification:** Floodplains can be designed to accommodate an altered hydrologic flow regime. These modifications can be targeted to improve habitat for specific species (e.g., suitable spawning and rearing habitat for salmonids) or to create high-ground refugia for aquatic and terrestrial species, such as giant garter snake, California black rail, riparian brush rabbit, and woodrat.

c) **Invasive Plant Control:** Invasive plant management, particularly following disturbances such as wildfires that create conditions suited to invasive plant colonization and spread, will be required to sustain native plant communities. The restoration of disturbed areas, using native species adapted to future climate and hydrologic conditions, can be used to minimize the impacts of invasive plants on ecosystem processes, habitats, and species.

Climate change may further exacerbate negative contributors to target species (as described in the individual target species-focused conservation plans), in addition to the stressors identified in the Conservation Strategy. These plans also identified specific actions that could be implemented to optimize conditions for target species recovery. In addition to the overall recommendations related to improving processes and habitats, additional recommendations related to target species may further be warranted when combined with climate change projections. Some species are highly localized, or their distributions within the SPA are uncertain. To the extent that any actions take place to address the broader activities described here, they would need to be spatially explicit and likely prioritized, because their distributions are much more limited. Therefore, these species are much more likely to experience population declines or go extinct if they are not specifically targeted. As such, additional recommendations may be warranted to address target species-specific life history requirements. Table H-10 provides detailed adaptation strategies for Conservation Strategy habitats and target species.

Table H-10. Conservation Strategy Habitat and Species-Specific Adaptation Measures

Conservation Strategy Targets	Adaptation Measures
Habitat: Shaded Riverine Aquatic (SRA) Cover	Increasing the ability of rivers to meander within a large floodplain supports the ecological and riverine geomorphic processes that create and sustain natural banks, encourage the succession and sustainability of riparian habitat, and thereby create and maintain SRA cover. Actively and passively restoring SRA habitat throughout the system provides key functions and values, including helping to decrease water temperatures, providing cover and refugia, providing direct and indirect sources of nutrients and food for aquatic species, and increasing habitat complexity, all of which benefit multiple aquatic and terrestrial species. **(SRA-1)**

Conservation Strategy Targets	Adaptation Measures
Habitat: Riparian	Actions that expand floodways (i.e., created new bypasses and areas of transient storage), relocate levees to expand floodways, or remove levees and revetment that do not provide public safety benefits could contribute to the formation of side channels, meander bend cutoffs, eroded banks, point bars, and similar features that create and sustain riparian habitats. Increasing the amount of available floodway would and allow for riparian species assemblages to shift spatially within the floodway in response to future climatic conditions increasing overall resiliency of riparian habitats. Restoring riparian habitat throughout the system provides for improved connectivity and sufficiently buffered landscapes to sustain multiple species and provide key functions and values, particularly when part of a connected floodplain. Increasing the quality and quantity of native habitats in the system, including riparian, provides more overall opportunities for species persistence and habitat resiliency. **(RIP-1)**
Habitat: Marshes and Wetlands	Actions that expand floodways (i.e., created new bypasses and areas of transient storage), relocate levees to expand floodways, or remove levees and revetment that are no longer needed for flood management, could contribute to the formation of side channels, and similar features that create and sustain marsh and wetland habitats. Increasing the amount of available floodway would allow for marsh and wetland species assemblages to shift spatially within the floodway in response to future climatic conditions. Actions that modified floodplain topography and restored marsh and wetland habitat within the floodway also could contribute toward the resiliency of riparian habitats. **(WET-1)**
Species: Delta Button-celery and Slough Thistle	Climate change resilience for these species would be improved through surveys to determine the locations of existing populations, thereby permitting seed collection and plant propagation, as well as facilitated colonization of other sites within the SPA using collected propagules. The better habitat conditions provided by restoring natural physical processes would provide more opportunities for native plant communities, including potentially these species, to propagate and persist. Additionally, targeted vegetation and invasive plant management actions would help sustain populations of these species in the face of climate change. **(PLANTS-1)**
Species: Delta Smelt	Modifications to bypasses, in particular the Yolo Bypass, to incorporate habitat mosaics that include wetlands and floodplains would benefit Delta smelt. Levee setbacks in the lower system and the Delta would improve and expand floodplain and heterogeneous tidal wetland habitat complexes, which are likely to improve habitat conditions for Delta smelt. **(SMELT-1)**

Conservation Strategy Targets	Adaptation Measures
Species: Steelhead; Spring-run, Fall-/Late-fall-run, and Winter-run Chinook Salmon; Green Sturgeon	Riparian and SRA habitat restoration actions (described in this table) would contribute to cooling water temperatures and provide other fish-rearing habitat benefits, including cover, production of invertebrates to sustain aquatic food web productivity, and instream wood, all of which would improve these species' abilities to adapt to climate change. Additionally, creating floodplain habitat adjacent to rivers and tributaries may help to address changes in flood magnitude expected due to climate change, improve rearing habitat, and improve habitat conditions for juveniles that overwinter in tributaries. **(SALMONID-1)**
Species: Valley Elderberry Longhorn Beetle (VELB)	Actions that provide increased opportunities for blue elderberry shrubs to colonize new locations in response to hydrologic changes (i.e., to move to relatively wetter or drier locations as site-specific hydrologic conditions are altered due to climate change) would increase climate change resilience of the VELB. Examples of these actions are: expanding floodways by relocating river levees; removing levees and revetment that do not provide public safety benefits or protect infrastructure; and modifying floodplain topography to create areas within floodways that have hydrologic conditions capable of supporting blue elderberry shrubs. **(VELB-1)**
	In addition, habitat restoration that includes elderberry shrubs would increase the climate change resilience of the VELB. To have the greatest positive effect, habitat restoration actions should be prioritized to occur within, or near, the Sacramento River Wildlife Area, Sacramento River National Wildlife Refuge, Oroville Wildlife Area, and Feather River Wildlife Area. These areas currently support dense and diverse riparian habitats and VELB populations that could be enhanced or expanded by focused habitat restoration actions. In addition, the range of VELB throughout the SPA could potentially be expanded by restoring riparian scrub and woodland habitats and incorporating dense patches of elderberry shrubs as components of restored riparian habitats, ideally by starting with areas near the locations where the VELB is known to occur, and gradually progressing to more distant locations to support metapopulation processes. **(VELB-2)**

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<tr><th>Conservation Strategy Targets</th><th>Adaptation Measures</th></tr>
<tr><td rowspan="2">Species: Giant Garter Snake (GGS)</td><td>Actions that create or support marshes inundated during the active season for GGS (May 1 to October 1), and include all elements of suitable GGS snake habitat (in-water cover with suitable prey and lack of predators, upland refugia, and basking sites), and provide connectivity to known occupied habitat would increase the resilience of this species to climate change. Created marsh habitats should have the following attributes:
• Consist of paired blocks of habitat composed of (ideally) two 539-acre blocks (minimum size) of buffered perennial wetlands per location.
• Paired blocks should be separated by less than 5 miles and should be connected by a corridor of aquatic and upland habitat not less than 0.5 mile wide.
• Paired blocks should be buffered by 0.32 mile of compatible habitat. (GGS-1)</td></tr>
<tr><td>Aside from habitat restoration, in the Yolo and Sutter Bypasses and in areas near the confluence of the Sacramento and Feather Rivers, removing levees and expanding suitable aquatic habitat could create an opportunity to connect existing suitable habitats and provide safe upland refugia, which are important habitat components for giant garter snakes (particularly with the higher river flows expected to occur during the GGS's inactive period [brumation], when the species is more susceptible to the impacts of flooding). Removing or setting back levees in areas where the species occurs also would reduce the need for levee maintenance and minimize the potential for GGS to be disturbed by levee maintenance activities. When setting back levees on waterways that may support GGS, it would be valuable to consider leaving portions of levees in place to serve as high-water refugia. (GGS-2)</td></tr>
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<tr><th>Conservation Strategy Targets</th><th>Adaptation Measures</th></tr>
<tr><td>Species: Bank Swallow</td><td> Removing revetment or setting back levees would create more breeding habitat and allow this species to better adapt to the impacts of climate change. The Bank Swallow Technical Advisory Committee (BANS-TAC) developed a Bank Swallow Conservation Strategy for California (2013). Specifically, the BANS-TAC recommends the following:

Remove 100,000 linear feet of existing revetment (19 miles) between Red Bluff and Chico Landing.
Remove 50,000 linear feet of existing revetment (10 miles) between Chico Landing and Colusa.
Remove 130,000 (25 miles) of existing revetment between Colusa and Verona, and possibly construct setback levees in this stretch.

Removing revetment along the Sacramento River from Chico Landing to Colusa would be highly beneficial to this species, because this reach provides the largest amount of suitable vertical cut banks in the SPA. This is in part because some of the levees in these reaches are set back from the river, encouraging natural meanders and facilitating erosional processes that create suitable nesting habitat. From Colusa to Verona, the Sacramento River is the river is extremely constrained and revetment is present along the banks. Setting back the levees along these reaches would restore natural processes and benefit the species over time.
Along the Feather River, the BANS-TAC recommendation for revetment removal is 10,000 linear feet (2 miles).
In addition to these actions to restore breeding habitat, habitat restoration actions that increase grassland, riparian, marsh and wetland foraging habitat near breeding habitats would increase the climate change resilience of bank swallow. (BANS-1)
The availability of breeding habitat also could be increased by managing reservoir releases on the Sacramento and Feather Rivers to promote breeding habitat formation during the nonbreeding season (September 1 to March 31). Specifically, the BANS-TAC recommends at least one bank-full flood event every three years, with the goal of promoting geomorphic processes that create bank swallow breeding habitat (e.g., bank erosion, meander migration, channel cutoff). Additionally, during the breeding season (April 1 to August 31), climate change resilience could be increased by managing reservoir releases to minimize higher flows that can destroy nesting colonies. Impacts on nesting colonies can occur when flow stages increase by as little as 1.6 to 3.3 feet during breeding. Higher flows, in the range of 14,000 to 30,000 cubic feet per second, have been associated with localized colony collapse and failure, and even higher flows (50,000 to 60,000 cubic feet per second) can cause extensive bank erosion and widespread destruction of nesting colonies. (BANS-2) </td></tr>
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Conservation Strategy Targets	Adaptation Measures
Species: California Black Rail	Climate change resilience for the California black rail would be increased by creating and maintaining shallow, emergent wetland habitat in the Lower San Joaquin and Lower Sacramento River CPAs (generally 1 inch to 2 inches in depth with minimal fluctuation). Coupled with emergent wetlands, adjacent high-water refuge sites (e.g., riparian scrub/upland transition zones) are needed to provide cover for rails when flood events force them out of emergent wetlands. Restored and created marsh habitats should be as large as possible, generally not less than 20 acres; linear habitat designs with a high habitat edge to habitat area ratio should be avoided. Additionally, in addition to supporting riverine geomorphic processes that could create marsh habitats preferred by black rails, the removal of revetment, would benefit rails by removing cover and reducing habitat suitability for rats and other potential black rail predators. **(CABR-1)**
Species: Greater Sandhill Crane	Strategically lowering floodway elevations to form seasonally inundated habitats, particularly in the floodplains of the Cosumnes and Mokelumne Rivers, and allowing scour to create new floodplain areas and remove dense vegetation, could benefit greater sandhill cranes by creating potential roosting or foraging habitat. Cranes most likely would use wider floodplains, rather than narrow floodplains, because they select open habitats without visual impediments. Floodplain modification would positively affect cranes if the topography resulted in shallowly flooded open areas that cranes could use for roosting or foraging. Floodplain modifications that submerge shallowly flooded areas with deeper water would have a negative effect on cranes, because they are less likely than waterfowl to use deep water. The addition of new inundated floodplains near the edges of currently used roosting and foraging sites would most likely benefit cranes because of the potential to expand their current distribution. **(GSHC-1)**
Species: Greater Sandhill Crane	Dam releases that allow for wetlands and agricultural fields to be shallowly flooded between mid-September and early March could benefit greater sandhill cranes by providing potential roosting habitat. These sites would be most beneficial if potential roosting habitat is flooded to depths of 2 to 6 inches and occurs near of foraging locations (i.e., within 1.3 miles). Dam releases that flood potential roosting habitat to unsuitable depths for cranes (i.e., more than 6 inches) could negatively affect greater sandhill cranes by reducing the amount of roosting habitat available. **(GSHC-2)**

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<tr><th>Conservation Strategy Targets</th><th>Adaptation Measures</th></tr>
<tr><td>Species: Least Bell’s Vireo and Yellow-breasted Chat</td><td>These species depend on early successional to mid-seral riparian habitat with willow shrubs and other dense thickets of low bushes bordering streams or other bodies or water. Creating setback levees and facilitating natural hydrologic and geomorphic processes that lead to relatively continuous and dynamic riparian successional stages will provide opportunities to renew, expand, and sustain nesting habitat in response to climate change.

Riparian restoration can be used to supplement natural succession and regeneration of riparian habitats. To be most suitable for these species, restored riparian habitats should have the following characteristics:
• Minimum patch size of 2 acres, with parches greater than 10 acres providing better-quality habitat.
• Location in or near core population areas to support metapopulation processes.
• Mix of early and mid-succession species such as mugwort, willows, and cottonwoods.
• Located in corridors wider than 800 feet. (SONG-1).</td></tr>
<tr><td>Species: Swainson’s Hawk</td><td>The regeneration and sustainability of large, contiguous stands of riparian habitat, consisting of mature cottonwoods, sycamores, oaks, and willows, all of which provide high-quality nesting habitat, are important to increasing the climate change resilience of Swainson’s hawk. Natural hydrologic and geomorphic processes that maintain a variety of age and size classes are particularly important for Swainson’s hawks, so as current nest trees die off, younger trees mature into suitable replacements. Riparian restoration that incorporates species like oaks and cottonwoods can be used to supplement natural riparian regeneration. Breeding habitat, whether created and sustained through natural processes or restored through planting, must be situated next to suitable foraging habitat that provides important prey resources during the breeding season. Suitable foraging habitat includes grassland and agricultural crops such as alfalfa and irrigated pasture that are compatible with farming in new or expanded floodways and bypasses. (SWHA-1)</td></tr>
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<table>
<tr><th>Conservation Strategy Targets</th><th>Adaptation Measures</th></tr>
<tr><td>Species: Western Yellow-billed Cuckoo</td><td>Riparian restoration in core cuckoo population areas could be important and effective in facilitating increases of this species’ population, and in creating critical dispersal corridors to mitigate the effects of climate change. Corridors and large contiguous tracts of suitable breeding habitat throughout the SPA would maximize opportunities for this species to expand. To benefit this species, areas of restored riparian habitat should meet the following criteria:
• Ideally greater than 200 acres in size and over 1,950 feet wide (smaller and/or narrower habitat patches may be suitable for the species but are not preferred).
• Not smaller than 50 acres and 325 feet wide.
• Total at least 20,450 of suitable habitat across the Sacramento River (5 locations totaling at least 9,150 acres):
– The Feather River (totaling 1,900 acres).
– The Stanislaus River (totaling 1,900 acres).
– The Cosumnes River (totaling 2,500 acres).
– The Merced River (totaling 2,500 acres).
– The Mendota Canal (totaling 2,500 acres).
Aside from restoring riparian habitat, the restoration of riverine geomorphic processes would gradually increase the extent of riparian habitat and potentially increase habitat patch size (i.e., patches at least 200 acres in size). In addition, riverine geomorphic process, such as channel migration, result in disturbances that create, sustain, and renew the early successional to mid-seral habitat that is preferred by yellow-billed cuckoos. (WYBC-1)</td></tr>
</table>

Conservation Strategy Targets	Adaptation Measures
Species: Tricolored Blackbird	Creating setback levees or removing levees and revetment will allow natural hydrologic and geomorphic processes that create and sustain a range of emergent marsh and riparian successional stages, including early successional habitats generally preferred for breeding by tricolored blackbirds. Additionally, managed disturbances (e.g., fire, mastication, discing grazing), at intervals of five years for perennial marshes or every one to two years for seasonal wetlands, may be needed to maintain breeding habitat if suitable conditions do not result from climate change (i.e., current processes are modified by climate change in ways that no longer support this species). Additionally, for seasonal wetlands, it is important to sustain shallow inundation (6 to 18 inches) through April (San Joaquin Valley) or May (Sacramento Valley) to protect nest colonies from predators while not destroying nests. Invasive plant management is important to maintain and enhance tricolored blackbird breeding habitat. New weed infestations could negatively affect the emergent marsh and early successional riparian habitats that provide tricolored blackbirds with their historical and preferred nesting habitat. Native vegetation provides breeding habitat, and is an important food source for tricolored blackbirds because it supports native invertebrate populations. In general, invasive plants displace native plant species, often over substantial areas. Managing and controlling invasive plants would minimize these impacts. **(TCBB-1)** The expansion of bypasses would protect large areas of land from development, add agricultural land and natural vegetation to the floodway, and result in periodic, prolonged inundation of land that was previously isolated from the river system by levees. Due to the nature of the bypasses, this agriculture should be limited to row, hay, or silage crops, which provide favorable foraging habitat for tricolored blackbirds. **(TCBB-2)**

Conservation Strategy Targets	Adaptation Measures
Species: Riparian Wood Rats and Riparian Brush Rabbits	Actions that expand floodways, or create new floodways, would create additional opportunities for these species to escape increased peak flows that are expected to occur with climate change. The restoration of riparian habitat suitable for both species, and vegetation management focused on maintaining these habitats, would be necessary to ensure patches of suitable habitat were large and connected enough to support both species and facilitate dispersal to higher refugia while avoiding starvation and predation. Relocating levees farther from rivers (i.e., creating setback levees) is an important approach to increase space for river meanders, reconnect floodplains, allow the transport and deposition of sediment, support natural ecosystem disturbance processes, and increase the diversity of riverine and floodplain habitats. In particular, relocating levees in the areas around Caswell State Park and the San Joaquin River National Wildlife Refuge could reduce the depth, duration, velocity, or extent of flooding, thus reducing rabbit and woodrat mortality caused by floods while providing additional riparian habitat. Constructing setback levees could also decrease the need to add revetment on existing levees, further supporting the development of suitable vegetation adjacent to occupied habitat. Retaining and revegetating old, breached levees could also provide additional flood refugia for riparian brush rabbits and woodrats. (**MAMMAL-1**)

4.2.2 Adaptation Measure 2: Further Incentivize and Prioritize the Implementation of Multi-benefit Projects

The identification, development, and implementation of multi-benefit projects in the Central Valley is the primary mechanism to improve and restore ecosystems, and gradually build ecological resilience. DWR should continue to identify and leverage opportunities to refine the CVFPP planning information in future updates to further develop climate change adaptation approaches, and promote management actions to address climate change risks to ecological conditions.

a) **Minimize or Avoid Potential Ecological Impacts of Flood Risk Reduction Infrastructure Improvements:** The CVFPP includes a broad portfolio of actions to reduce flood risk, including some single-purpose flood management actions where multi-benefit options are not feasible. These may include raising, lengthening, and/or hardening levees or removing vegetation in channel corridors to increase the conveyance capacity of floodways. In these situations, single-purpose flood management actions can exacerbate ecological risks and vulnerabilities, especially as climate change impacts are realized. Wherever feasible, it is critical that DWR and its federal, State, and regional project partners develop and prioritize broader multi-benefit projects and flood management actions that reduce or alleviate ecological stressors and that provide needed flood protection throughout the flood system to establish much-needed resilience to climate change. These adaptation measures simultaneously reduce flood risk and restore fundamental hydrologic, geomorphic, and ecological processes that build resilience into the system.

b) **Increase the Pace of Building Resilience:** There is a strong need to significantly increase the pace, scale, and geographic extent of multi-benefit project implementation, given the likely impending impacts of climate change. DWR and its project partners should work to streamline multi-benefit project implementation processes to the maximum extent feasible to increase the pace of project implementation. Adaptation Measures 3 and 4 could develop the knowledge base and evaluation criteria to increase multi-benefit project assessment, tracking, and implementation.

c) **Prioritize Funding for Multi-Benefit Projects:** Prioritization for funding/implementation of multi-benefit projects should consider relative potential to improve hydrologic, ecological, and geomorphic processes.

d) **Increase Prioritization of Climate Adaptation in the Planning Processes:** For future updates to the CVFPP and Conservation Strategy, consider ecologically based climate adaptation opportunities while developing recommendations and priority actions.

4.2.3 Adaptation Measure 3: Perform More Detailed Analyses of Climate Change Impacts to Conservation Strategy Processes, Habitats, and Species

To date, the climate change modeling that has been performed to inform CVFPP planning has focused on potential risks to human health, flood management infrastructure, and economic conditions, and has been based on peak flood conditions. However, the ecological impacts to climate change are often due to changes in lower-magnitude, higher-frequency hydrologic events. Further analyses of climate change impacts to ecologically-relevant flows are required to better understand risks and adaptation opportunities.

a) **Address Ecosystem Vulnerability Data Gaps:** Perform additional climate change modeling to better understand ecosystem-specific responses to climate change, based on changes to the frequency, magnitude, timing, and duration of regulated flows. The existing modeling approach only yields event-based floods that are scaled, depending on the climate scenario. While reservoir operations will need to be modified in the future, it is important to understand the long-term effects of a future climate scenario under current management constraints, so operations can be evaluated and improved. Modeling data would be most useful if high, median, and low climate change scenarios were evaluated for the entire period of modeled climate scenarios (present to 2099). This continuous dataset that better captures interannual and intra-annual variability would be invaluable to assess how an altered flow regime is likely to affect specific ecosystems. An example would be for salmonids, where the acre-days of suitable habitat can currently only be calculated for historical conditions across the entire Central Valley. Continuous hydrology representing future climate scenarios would let resource managers design projects that are resilient to a future flow regime, or even assess whether a modified flow regime may be required to meet ecological goals. Additionally, utilization of detrended historical hydrological data to account for current climatic conditions can capture ongoing climate change in baseline conditions.

b) **Expand Use of Decision-scaling Analyses:** Expand climate change decision-scaling analyses to better assess ecosystem sensitivities from potential stressors and evaluate the robustness of adaptation strategies. Decision-scaling considers a given system under existing conditions and applies a stress test analysis using climatic stressors to identify system sensitivities and potential vulnerabilities. This approach characterizes uncertainty in terms of future impacts for decision-making, and has been implemented by DWR to guide climate change vulnerability and adaptation planning (California Department of Water Resources 2018b). Furthermore, DWR, in collaboration with several entities, is developing a weather generator tool that will be able to reproduce realistic, long-term meteorological timeseries and create advanced climate change scenarios from processes simulated by GCMs. This weather generator will enhance the stress testing and evaluation of adaptation strategies in decision-scaling analyses.

c) **Further Develop and Integrate Watershed Evaluations to Inform Adaptation Measure Development:** DWR is conducting climate vulnerability assessment and adaptation strategy evaluations at the watershed scale. These watershed studies employ a risk-based approach to assess impacts water infrastructure. The approach relies on a collaborative approach between local, State, federal, and tribal partners to better manage water resources. The watershed adaptation strategies are intended to reduce flood risk, replenish depleted aquifers, help ecosystems, and improve water quality. The watershed studies demonstrate how adaptation measures such as Flood-MAR, in conjunction with reservoir reoperations (e.g., FIRO), can reduce climate vulnerabilities and improve groundwater recharge. Two studies are in progress on the Merced and Tuolumne Watersheds, and more studies are planned within the San Joaquin Basin.

4.2.4 Adaptation Measure 4: Develop Tools and Processes to Evaluate Climate Change Impacts at a Regional or Project-Specific Level

DWR funded the development of the Floodplain Restoration Opportunity Analysis (FROA), a geographic information system-based evaluation of floodplain inundation potential (FIP), which can help identify and prioritize the opportunity to reconnect frequently activated floodplains throughout the SPA, to a certain degree (California Department of Water Resources 2013b). While the original analysis provided valuable hydraulic assessment of potentially inundated areas systemwide, FROA is now more than 10 years old. The underlying datasets for FROA have improved vastly in the last decade (including high-quality hydraulic models, terrain, and updated hydrology). The focus on climate change and multi-benefit projects (which now includes Flood-MAR) has also created the need for improved technical analyses support implementation of floodplain restoration projects that build ecosystem resiliency while reducing flood risks.

a) **Develop New Tools to Identify Floodplain Reconnection and Groundwater Recharge Opportunities:** Update the FROA analyses using Ecological Floodplain Inundation Potential (EcoFIP) modeling tools to evaluate habitat suitability at varied spatial and temporal scales.

- Extend the EcoFIP tool to determine the potential for groundwater recharge on floodplains along the San Joaquin River corridor to address groundwater deficiencies; this should be coordinated with the DWR Flood-MAR program.
- Use the EcoFIP tool to evaluate inundation extents, habitat suitability, and groundwater recharge under historical and future climate scenarios across the SPA.
- Use the EcoFIP tool to assist with multi-benefit project identification, prioritization and evaluation. The systematic evaluation of restoration opportunities could lead to increased collaboration between agencies working on multiple objectives (e.g., flood control, ecosystem benefits, groundwater recharge), and increased funding to implement projects.

b) **Identify Additional Tools or Analyses to Determine Potential Adaptation Opportunities:** Evaluate additional tools that provide a more refined understanding of floodplain restoration and flood infrastructure modification potential throughout each CPA.

4.2.5 Adaptation Measure 5: Better Communicate Climate Changes Risks and Adaptation Opportunities to DWR Partners and Stakeholders

A high degree of cooperation and collaboration between DWR and its federal, State, regional, and local partners will need to occur to develop ecological resiliency and address the impacts of climate change. The first step in this process is the development of effective communication and outreach about the potential climate change risks and opportunities to build the governance structures and partnerships that will be required.

a) **Improve Regional Coordination:** Coordinate with regional planning groups (such as the regional flood management plans, Central Valley Flood Protection Board Advisory Committee, and others) to ensure they have current information and data pertaining to climate change, for use in their own regional or statewide planning efforts. Provide resources and tools to regional flood management plans to better develop multi-benefit projects that provide climate resiliency.

b) **Improve Climate Adaptation Communications:** Create, deliver, and publish (e.g., on the DWR website) fact sheets, workshop and conference notices, and reports of notable news regarding climate change locally and nationally.

c) **Collaborate with Partners on Developing and Implementing Climate Adaptation Measures:** Engage with regional and local partners and nongovernmental groups within each CPA to identify and pursue adaptation measures related to climate change. Work with State and federal agencies to resolve policy or mandate discrepancies regarding climate change adaptation.

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CHAPTER 5

Summary of Regional Climate Change Adaptation Strategies

Building on the potential adaptation measures identified in Chapter 4, this section highlights regional climate change adaptation opportunities, using maps, for specific reaches in each CPA. The maps were compiled using data gathered, and analyses completed, while developing the 2016 Conservation Strategy, and the adaptation opportunities highlighted generally would be achieved through the Conservation Strategy's implementation. The maps visually depict the location and extent of specific climate change adaptation opportunities and constraints, including the following:

- Locations of existing natural habitats, including uplands, perennial and seasonal wetlands, and riparian areas.
- Locations of levees and revetment.
- Potential occurrences of target species through displayed habitats.
- Potential areas that could be reconnected to the river and the target species habitat that could occur in reconnected floodplains if these areas are restored (potential floodplain, wetland, riparian and SRA habitats). These potential floodplain areas are derived from the FROA (California Department of Water Resources 2013b). They represent minimal areas where topographic and hydrologic conditions are suitable to support ecologically beneficial floodplain inundation if projects that included levee setbacks, levee removal, or programmed inundation of floodplains were implemented (i.e., floodplains inundated by a two-year event or during a flow that occurs during the spring season for seven consecutive days with a 66-percent exceedance probability). These types of floodplain inundation events would also allow the restoration of more natural geomorphic processes that create habitat complexity, variability, and resilience, as well as the native habitats (including SRA, wetland, and riparian) that are critical for the survival of the Conservation Strategy's 20 target species.

By assembling and reviewing these data layers together, the maps identify general locations where relatively greater opportunities could exist to implement adaptation actions that would build climate change resilience for the Conservation Strategy's target habitats; particularly floodplain, wetland, riparian, and SRA habitats, and the 20 target species that depend on these habitats within the SPA. Table H-11 lists these 20 species and their preferred habitat within the

SPA. Tables H-12 through H-21 indicate which of the 20 species could potentially benefit from climate change adaptation actions in the subsequent mapped reaches for each CPA (Figures H-18 to H-34). Following each set of maps, a concise summary is provided of the opportunities or constraints to building climate change resilience, for each mapped reach in each CPA, and select opportunities are highlighted to help identify and initially prioritize possible adaptation actions. Many of these actions are consistent with, and build upon, the regional conditions, needs, and objectives identified in Section 5.2 of the 2016 Conservation Strategy.

Table H-11. Potential Habitats and Species Associations

Potential Habitat Type	Species Associations[a]
Potential floodplain/SRA (reconnected/restored)	Bank swallow California Central Valley steelhead Chinook – Central Valley spring run Chinook – Central Valley fall/late-fall run Chinook – Sacramento River winter run Delta smelt Green sturgeon Least Bell's vireo Slough thistle Tricolored blackbird Western yellow-billed cuckoo Yellow-breasted chat
Riparian (restored)	Delta button-celery Least Bell's vireo Riparian brush rabbit Riparian woodrat Swainson's hawk Western yellow-billed cuckoo Yellow-breasted chat Valley elderberry longhorn beetle
Perennial wetland (restored)	Black rail Giant garter snake Greater sandhill crane Slough thistle Tricolored blackbird

[a] Species associations vary by CPA and reach, as shown in the tables within Sections 5.1 to 5.5.

Note:
SRA = shaded riverine aquatic

5.1 Lower Sacramento River CPA

Table H-12. Species Distribution by Habitat and Reach in the Lower Sacramento River CPA

Habitat Type	Species Acronym[a]	Species Name	Reach 1	Reach 2
Potential Floodplain/SRA	SALMONID	California Central Valley Steelhead	Yes	Yes
	SALMONID	Chinook – Central Valley Spring Run	Yes	Yes
	SALMONID	Chinook – Central Valley Fall/Late-fall Run	Yes	Yes
	SALMONID	Chinook – Sacramento River Winter-run	Yes	Yes
	SMELT	Delta Smelt	Yes	Yes
	SALMONID	Green Sturgeon	Yes	Yes
	BANS	Bank Swallow	Yes	Yes
Riparian	SWHA	Swainson's Hawk	Yes	Yes
	WYBC	Western Yellow-billed Cuckoo	Yes	Yes
	SONG	Yellow-breasted Chat	Yes	Yes
	SONG	Least Bell's Vireo	Yes	Yes
	VELB	Valley Elderberry Longhorn Beetle	Yes	Yes
Perennial Wetland	GGS	Giant Gartersnake	Yes	Yes
	GSHC	Greater Sandhill Crane	Yes	Yes
	TCBB	Tricolored Blackbird	Yes	Yes
	CABR	California Black Rail	Yes	Yes

[a] Species acronyms are assigned in Table H-10 of Section 4.2.1.2, "Habitat and Species-specific Adaptation Measures."

Notes:
SRA = shaded riverine aquatic

Figure H-18. Lower Sacramento River CPA Reach 1

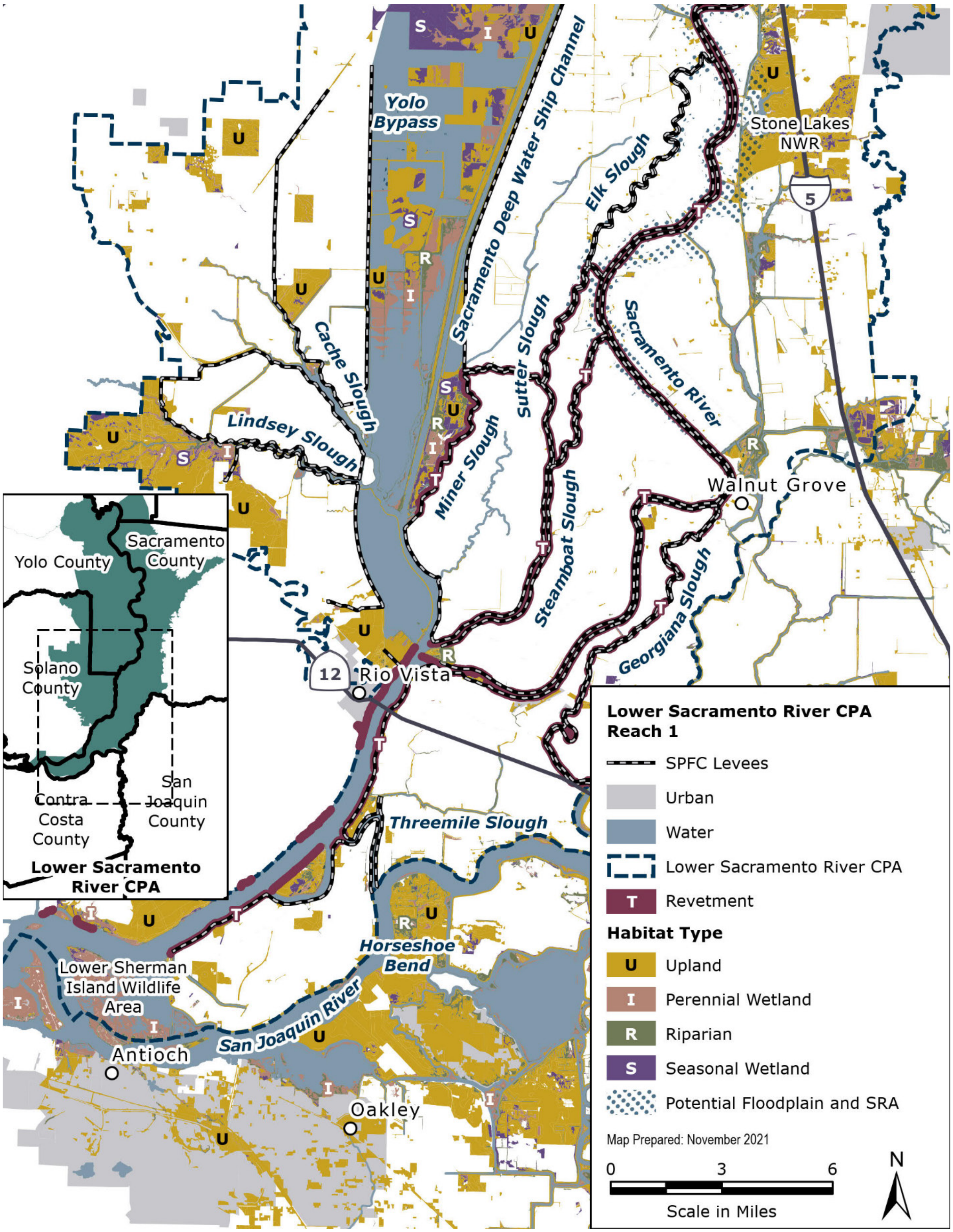
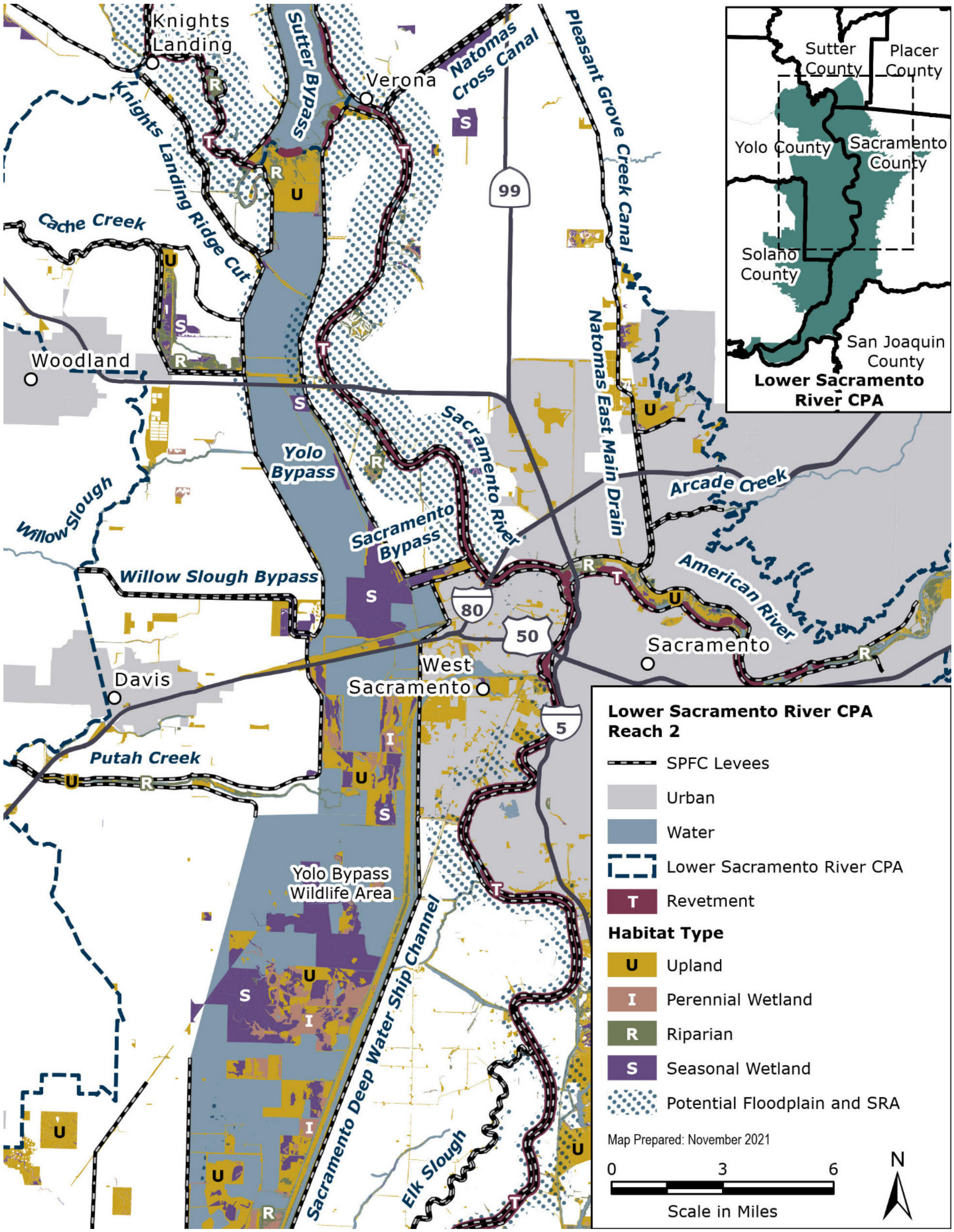


Figure H-19. Lower Sacramento River CPA Reach 2



5.1.1 Climate Change Adaptation Risks and Opportunities – Lower Sacramento River CPA

Reach 1: Adaptation potential is constrained by expansive areas of levees and revetment protecting urban areas and the Delta, resulting in very limited areas that are suitable for creating potential floodplain, riparian, and SRA habitats. However, there are limited opportunities to create habitats along the Sacramento River outside of the urban areas, along the Sacramento River's tributaries, and along the Yolo Bypass. The Yolo Bypass also contains areas that would be suitable for creating and enhancing floodplain, wetland, and riparian habitats. Reach 1 also provides opportunities to collaborate with EcoRestore.

Reach 2: Adaptation potential is constrained by expansive areas of levees and revetment protecting urban areas, although Reach 2 is less constrained than Reach 1. There are areas suitable for creating potential floodplain, riparian, and SRA habitats along the Sacramento River outside of the urban areas and along the Yolo Bypass, and like Reach 1, the Yolo Bypass has areas suitable for creating and enhancing all habitat types. Reach 2 also provides areas suitable for enhancing riparian and SRA habitats adjacent to the American River.

Table H-13. Climate Change Adaptation Strategies Available in the Lower Sacramento River CPA

Adaptation Strategy[a] Habitat-related	Adaptation Strategy[a] Species-specific	Adaptation Potential Reach 1	Adaptation Potential Reach 2
SRA-1	SMELT-1	High – Reach 1 provides nearly all of the habitat that exists for Delta smelt. Opportunities to improve and restore habitats must consider effects of climate change on increasing water temperatures, which SRA should help to moderate, although there is considerable uncertainty about the quantity of SRA habitat needed to decrease water temperatures.	Moderate – Reach 2 provides some habitat for Delta smelt and contributes to the main habitat in Reach 1, and provides the same types of opportunities as Reach 1.
	SALMONID-1	High – This reach provides important rearing and outmigration habitat for juveniles of all runs of Central Valley salmonids and green sturgeon. Opportunities to improve and restore these habitats must consider effects of climate change on increasing water temperatures similar to that described for Delta smelt.	High – Same as Reach 1.

Adaptation Strategy[a] Habitat-related	Adaptation Strategy[a] Species-specific	Adaptation Potential Reach 1	Adaptation Potential Reach 2
SRA-1	BANS-1	Limited – The extent of urban development and the extremely constrained river channels in Reach 1 limit the opportunity to remove revetment from banks and set back levees, which would allow erosional process the create suitable breeding habitat.	Moderate – Reach 2 is also constrained by expansive areas of levees and revetment protecting urban areas, but there are some opportunities for creating potential floodplain along the Sacramento River outside of the urban areas and in the Yolo Bypass.
	BANS-2	High – This CPA is occupied by breeding bank swallow. Reach 1 provides the opportunity to manage reservoir releases along the Sacramento River to promote processes to create bank swallow nesting habitat and minimize high flows during the breeding season, which can destroy nesting colonies.	High – Same as Reach 1.
RIP-1	SWHA-1	High – Reach 1 currently provides generally suitable breeding and abundant foraging habitat, and is occupied by Swainson's hawk. Climate change adaptation potential for Swainson's hawk could be improved by increasing breeding habitat by planting native tree species that will replace dead mature trees, trees lost through flooding, etc.	High – Same as Reach 1.

Adaptation Strategy[a] Habitat-related	Adaptation Strategy[a] Species-specific	Adaptation Potential Reach 1	Adaptation Potential Reach 2
RIP-1	WYBC-1	Limited – Suitable riparian habitat with the necessary characteristics does not currently occur in Reach 1, and existing urban areas constrain the opportunity for levee relocation or other actions that would allow suitable riparian habitat to be restored and self-sustaining.	Moderate – Suitable habitat with recent records for western yellow-billed cuckoo occurs in Reach 2. Although opportunities to expand suitable habitat are limited in this reach, there are some opportunities to restore additional suitable riparian habitat that would be connected to existing occupied habitats, primarily along the Sacramento River, outside of the urban areas and along the Yolo Bypass.
	SONG-1	Limited – Some suitable habitat exists in Reach 1, but yellow-breasted chat are currently relatively scarce and there is only one record for Least Bell's vireo in the reach. Existing urban areas constrain the opportunity for levee relocation or other activities that would allow for suitable dynamic flow conditions that result in continuous early to mid-successional riparian used by these species.	Moderate – Suitable habitat with recent records for yellow-breasted chat occur in Reach 2. Although opportunities to expand suitable habitat are limited in this reach, there are some opportunities to restore additional suitable riparian habitat that would be connected to existing occupied habitats, primarily along the Sacramento River outside of the urban areas and along the Yolo Bypass.
	VELB-1	Moderate – Suitable elderberry habitat exists, and the valley elderberry longhorn beetle is known to occur throughout Reach 1, so while opportunities for levee relocation are limited due to existing urban areas, modifying floodplain topography will provide new areas for elderberry shrubs to colonize in the vicinity of existing habitat.	High – Suitable elderberry habitat exists and the valley elderberry longhorn beetle is known to occur throughout Reach 2. Although opportunities to expand suitable habitat are limited in this reach, there are some opportunities to relocate the levee and modify floodplain topography, which will provide new areas for elderberry shrubs to colonize adjacent to existing habitat.

Adaptation Strategy[a] Habitat-related	Adaptation Strategy[a] Species-specific	Adaptation Potential Reach 1	Adaptation Potential Reach 2
RIP-1	VELB-2	Moderate – Reach 1 provides moderate opportunities to plant elderberry shrubs in riparian restoration areas.	Moderate – Reach 2 provides moderate opportunities to plant elderberry shrubs in riparian restoration areas and, potentially, in newly expanded floodplain areas.
WET-1	SMELT-1	High – Reach 1 provides opportunities to improve and expand floodplain and heterogeneous tidal wetland habitat complexes, which are likely to improve habitat conditions for Delta smelt. However, there are uncertainties about the effects of tidal wetland restoration on water temperatures, and the quantity of habitat needed to improve conditions that support survival of Delta smelt.	Moderate – This reach provides habitat for Delta smelt and contributes to the main habitat in Reach 1, and provides the same types of opportunities as Reach 1.
	SALMONID-1	High – Reach 1 provides opportunities to improve and expand floodplain and heterogeneous tidal wetland habitat complexes, which are likely to improve rearing habitat conditions for salmonids and green sturgeon. However, there are uncertainties similar to that described for Delta smelt.	High – Same as Reach 1.
	GGS-1	Moderate – Giant gartersnakes are present in this CPA. Existing urban areas constrain the opportunity for creating levee setbacks to expand marsh habitat, but there are opportunities to enhance and manage existing wetlands to improve suitability for giant gartersnake, particularly within the Yolo Bypass.	High – Reach 2 contains a substantial amount of areas in the Yolo Bypass that are suitable for creating and enhancing marsh habitat suitable for giant gartersnakes.

Adaptation Strategy[a] Habitat-related	Adaptation Strategy[a] Species-specific	Adaptation Potential Reach 1	Adaptation Potential Reach 2
WET-1	GGS-2	Limited – In Reach 1, there are some limited opportunities for levee setbacks where new marsh habitat suitable for giant gartersnake could be created and connected to existing suitable habitat.	High – Similar to Reach 1, but in Reach 2 there are moderate opportunities for removing levees and expanding suitable aquatic habitat along the Sacramento River outside urban areas and in the Yolo Bypass.
	GSHC-1	Limited – Greater sandhill cranes are present in this CPA. Existing urban areas constrain the opportunity for creating levee setbacks to expand floodplain habitat, but there are opportunities to enhance and manage existing floodplains to improve suitability for greater sandhill cranes.	Limited – Same as Reach 1.
	GSHC-2	High – Reach 1 provides the opportunity to manage reservoir releases along the Sacramento River to promote shallow inundation of existing greater sandhill cranes roosting habitat, which could mediate climate change effects in drought years.	High – Same as Reach 1.
	TCBB-1	Moderate – Tricolored blackbirds are present in Reach 1, but existing urban areas constrain the opportunity for creating levee setbacks to expand suitable wetland habitat. However, there are opportunities to enhance and manage existing wetlands for breeding suitability.	Moderate – Same as Reach 1.

Adaptation Strategy[a] Habitat-related	Adaptation Strategy[a] Species-specific	Adaptation Potential Reach 1	Adaptation Potential Reach 2
WET-1	CABR-1	Limited – California black rails are present in Reach 1 in low numbers, but existing urban areas constrain the opportunity for removing revetment to expand suitable habitat. However, there may be some opportunities to increase the area of shallow emergent wetlands and create adjacent high-tide refugia in the lower Yolo Bypass.	Limited – Same as Reach 1.

[a] Table H-10 provides adaptation strategy descriptions.

Notes:
CPA = conservation planning area
SRA = shaded riverine aquatic

5.2 Upper Sacramento River CPA

Table H-14. Species Distribution by Habitat and Reach in the Upper Sacramento River CPA

Habitat Type	Species Acronym[a]	Species Name	Reach 1	Reach 2	Reach 3	Reach 4	Reach 5	Reach 6
Potential Floodplain/SRA	SALMONID	California Central Valley Steelhead	Yes	Yes	Yes	Yes	Yes	Yes
	SALMONID	Chinook – Central Valley Spring Run	Yes	Yes	Yes	Yes	Yes	Yes
	SALMONID	Chinook – Central Valley Fall/Late-fall Run	Yes	Yes	Yes	Yes	Yes	Yes
	SALMONID	Chinook – Sacramento River Winter-run	Yes	Yes	Yes	Yes	No	Yes
	SALMONID	Green Sturgeon	Yes	Yes	Yes	Yes	Yes	Yes
	BANS	Bank Swallow	Yes	Yes	Yes	Yes	Yes	Yes
	SONG	Least Bell's Vireo	Yes	Yes	Yes	Yes	Yes	Yes
	TCBB	Tricolored Blackbird	No	No	Yes	No	No	No
	WYBC	Western Yellow-billed Cuckoo	No	No	No	No	No	Yes
Riparian	SWHA	Swainson's Hawk	Yes	Yes	Yes	Yes	Yes	Yes
	WYBC	Western Yellow-billed Cuckoo	Yes	Yes	Yes	Yes	Yes	No
	SONG	Yellow-breasted Chat	Yes	Yes	Yes	Yes	Yes	Yes
	VELB	Valley Elderberry Longhorn Beetle	Yes	Yes	Yes	Yes	Yes	Yes
Perennial Wetland	GGS	Giant Gartersnake	Yes	Yes	Yes	Yes	No	No
	GSHC	Greater Sandhill Crane	Yes	Yes	Yes	Yes	Yes	Yes
	TCBB	Tricolored Blackbird	Yes	Yes	No	Yes	Yes	Yes

[a] Species acronyms are assigned in Table H-10 of Section 4.2.1.2, "Habitat and Species-specific Adaptation Measures."

Figure H-20. Upper Sacramento River CPA Reach 1

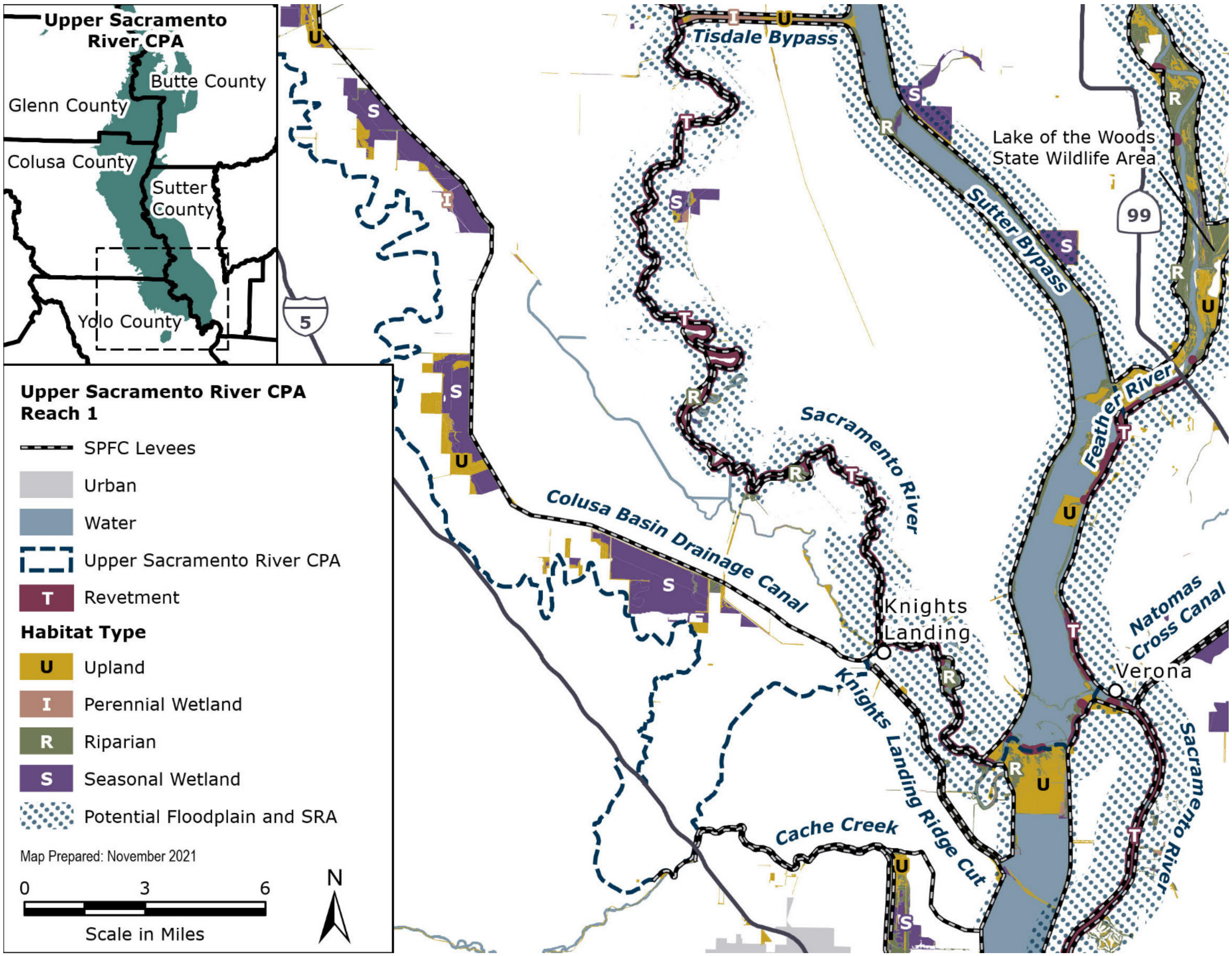


Figure H-21. Upper Sacramento River CPA Reach 2

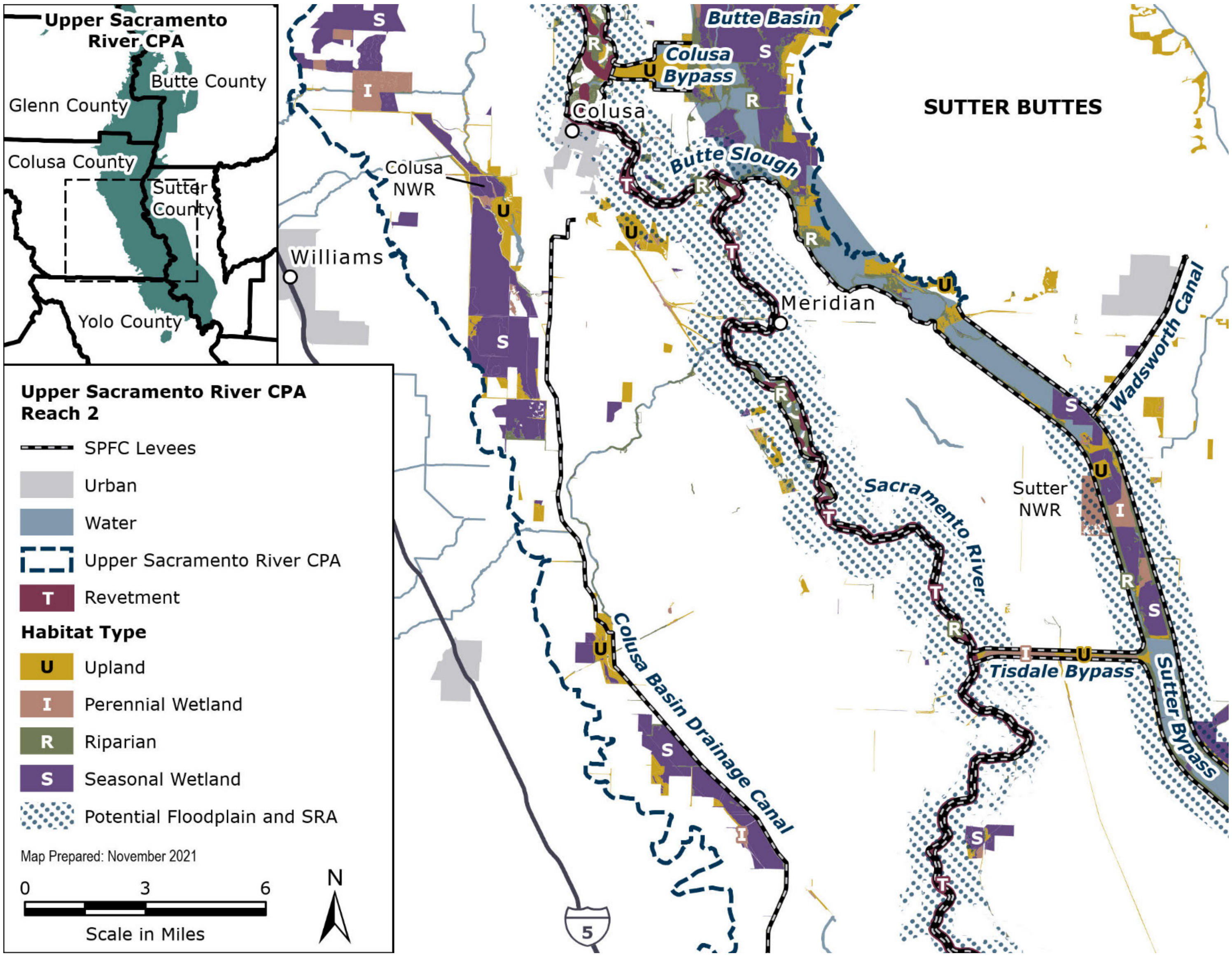


Figure H-22. Upper Sacramento River CPA Reach 3

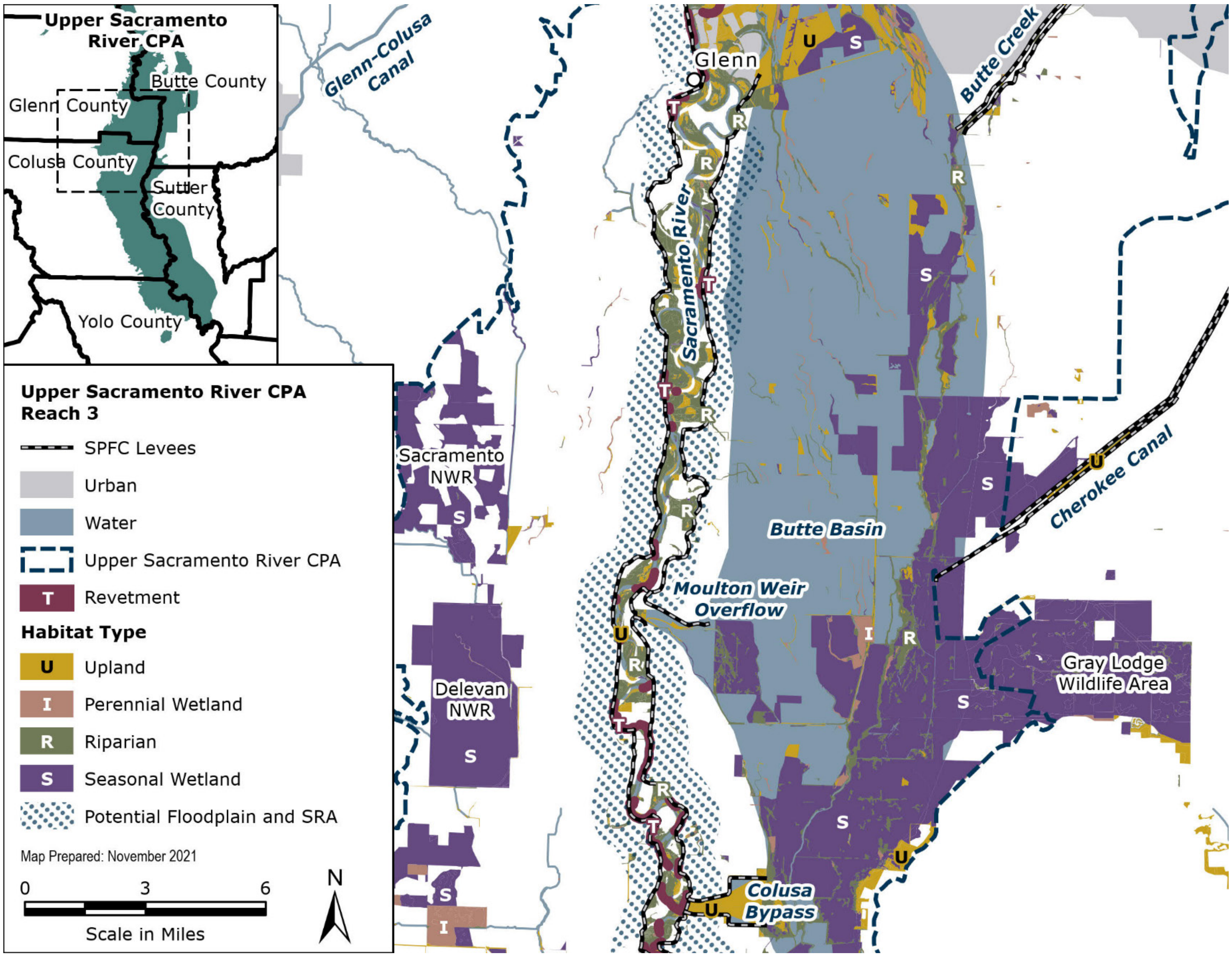


Figure H-23. Upper Sacramento River CPA Reach 4

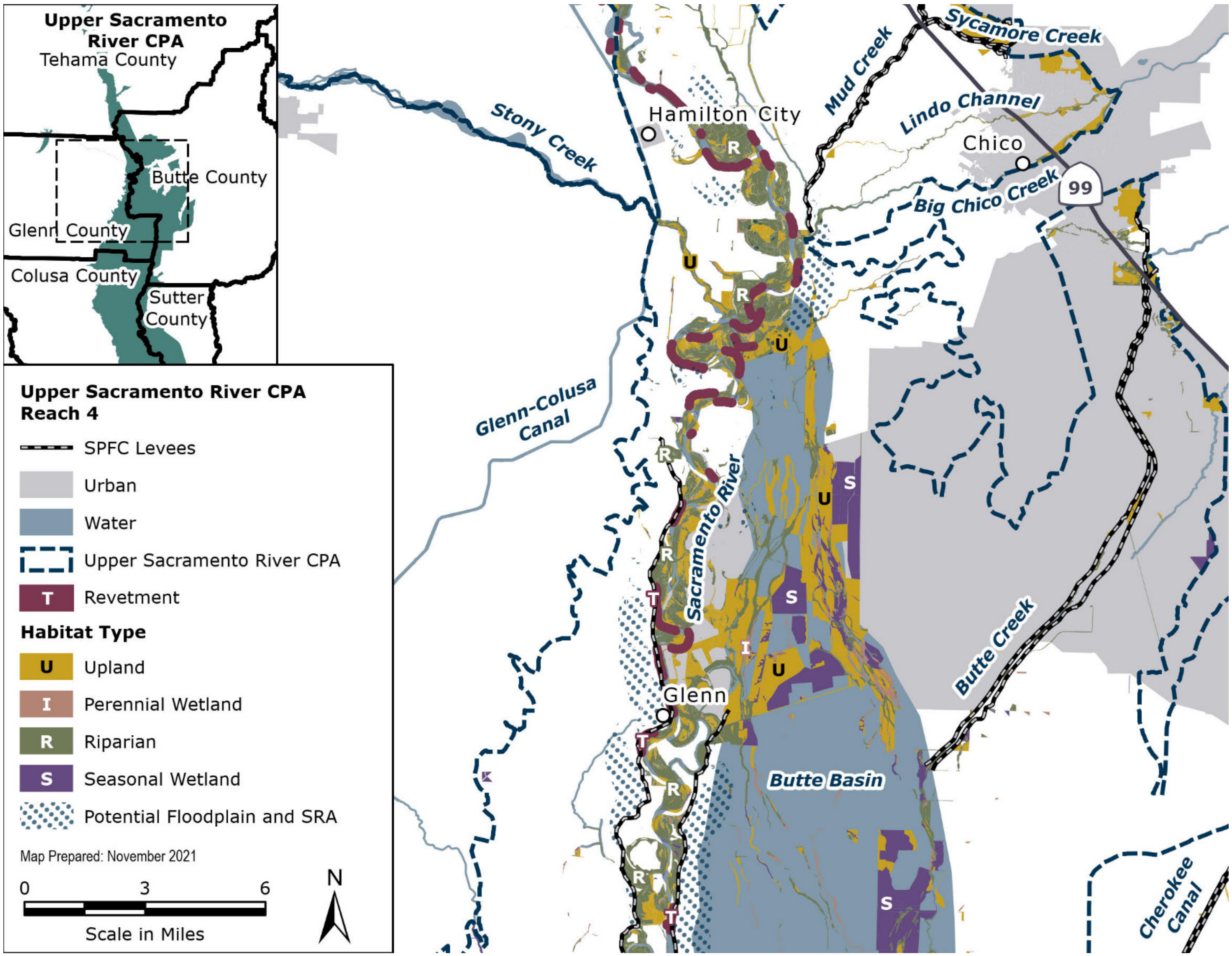


Figure H-24. Upper Sacramento River CPA Reach 5

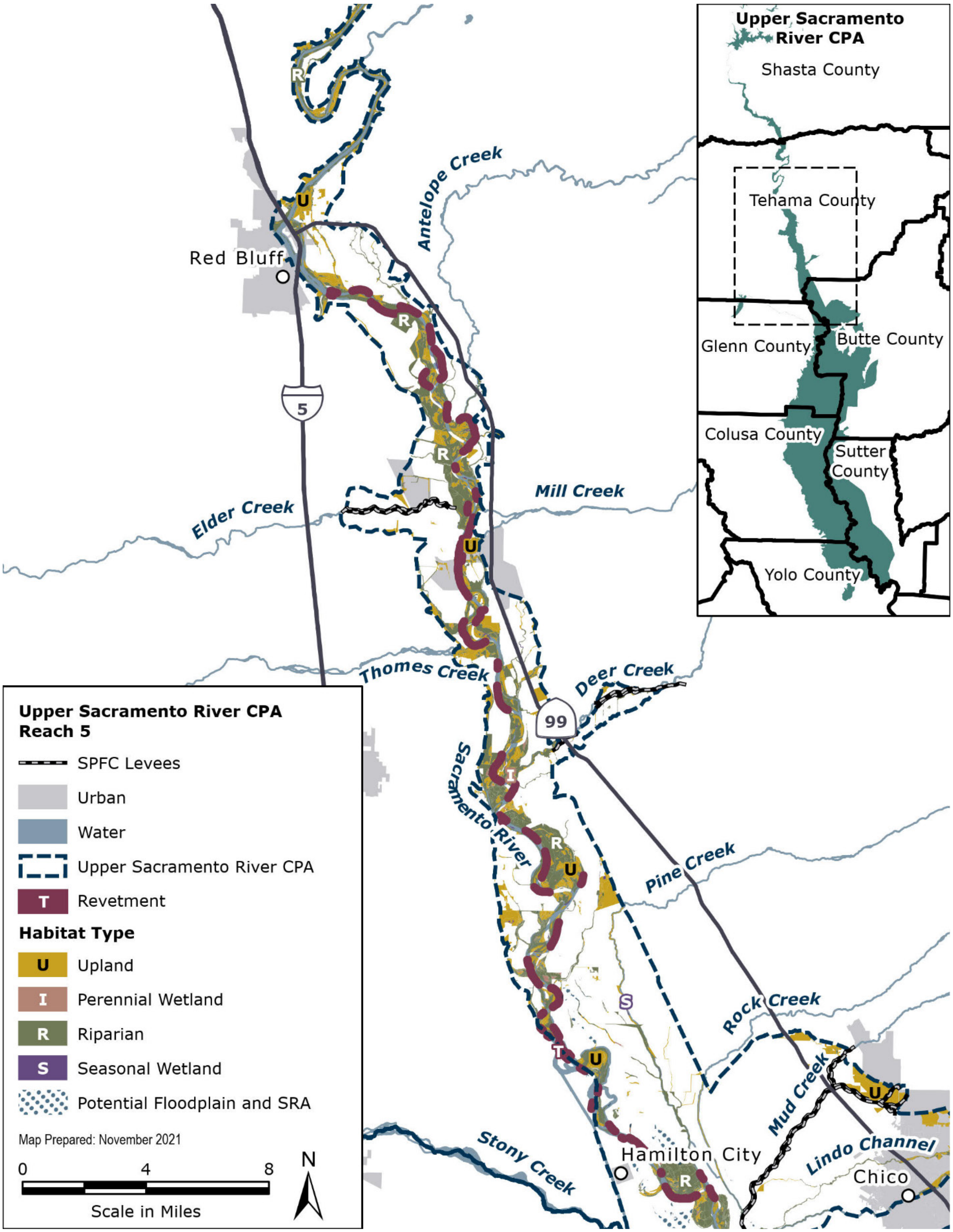
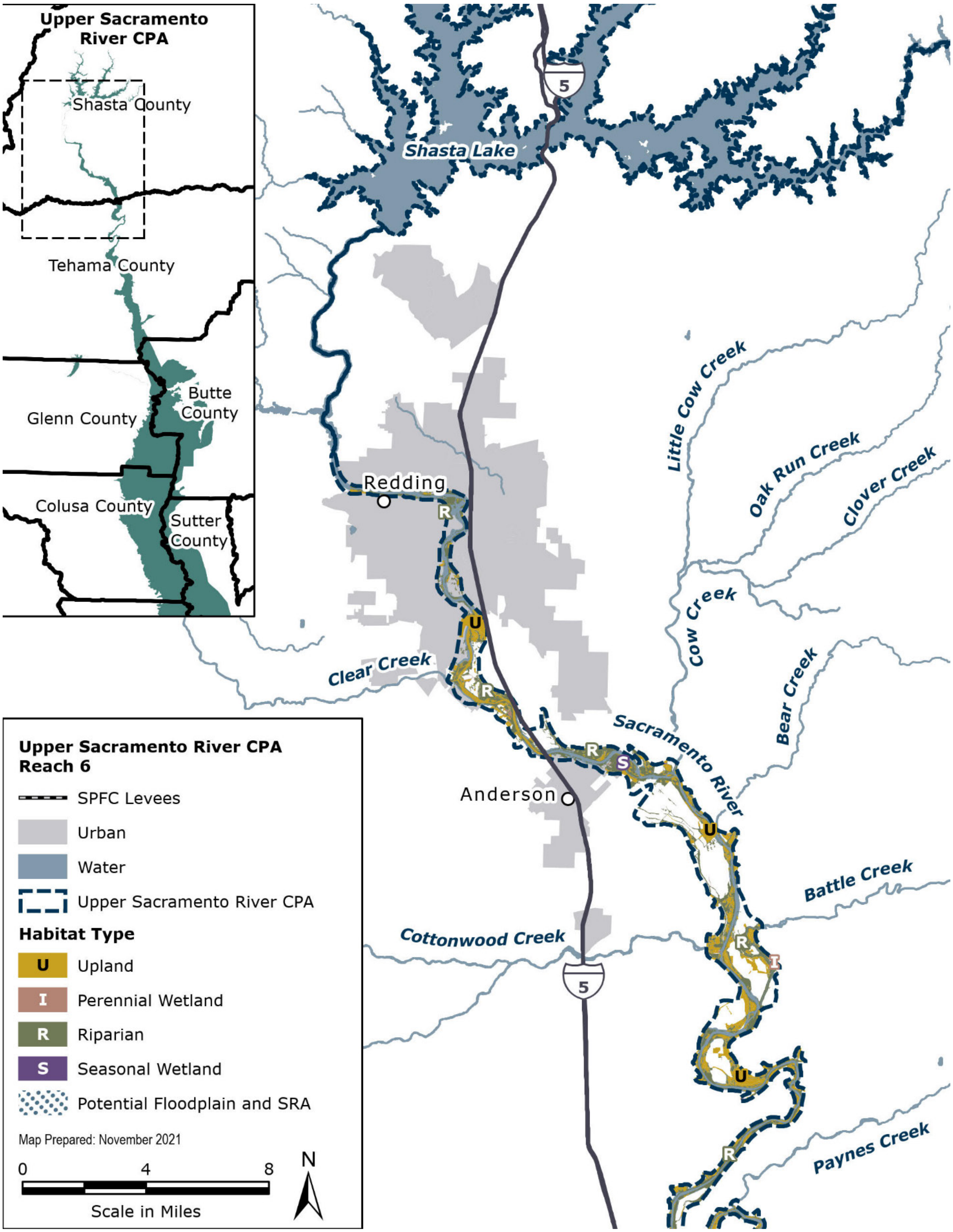


Figure H-25. Upper Sacramento River CPA Reach 6



5.2.1 Climate Change Adaptation Risks and Opportunities – Upper Sacramento River CPA

Reach 1: There are expansive areas of disconnected floodplains that would be suitable for creating potential floodplain, wetland, riparian, and SRA habitats along the Sacramento River and adjacent to the Sutter Bypass. There also are areas suitable for enhancing riparian habitat along the river itself, although these opportunities are relatively limited by the presence of levees close to the river channel. The Sutter Bypass provides ample opportunities to create and enhance wetland, floodplain, riparian, and SRA habitats, and there are smaller areas suitable for enhancing wetlands and uplands along other State Plan of Flood Control facilities and waterways within this reach.

Reach 2: Similar to Reach 1, adaptation potential is high. There is an extensive amount of existing wetland habitat that could be expanded in this reach, and opportunities exist to reconnect floodplains along nearly the entirety of the Sacramento River through this reach, thereby increasing wetland, floodplain, riparian, and SRA habitat, and improving habitat connectivity to the adjacent Butte Basin and upper Sutter Bypass within the Feather River CPA (e.g., through the Tisdale Bypass and around Butte Slough).

Reach 3: This reach, as with Reach 2, supports a nearly continuous corridor of disconnected floodplain that could be restored along the Sacramento River. Existing riparian and wetland habitat in this reach could be expanded, habitat connectivity among all habitat types could be improved through floodplain restoration, and other opportunities exist to enhance riparian and SRA habitat adjacent to the Sacramento River.

Reach 4: Relative to downstream reaches in this CPA, Reach 4 supports much less disconnected floodplain, and levees are absent from most of this reach, particularly on the left bank of the Sacramento River, roughly north of the town of Glenn. Floodplain restoration could occur around the confluence of the Sacramento River with Big Chico Creek and Sycamore Creek, and in a few other locations. Additionally, because levees already are absent from much of this reach, abundant opportunities exist to restore and enhance wetland, riparian, and SRA habitat, particularly in areas where existing revetment could be removed to allow for improved riverine geomorphic processes.

Reach 5: Few areas of disconnected floodplains occur in this reach. However, because this reach lacks levees, abundant opportunities exist to restore, expand, or enhance riparian and SRA habitat along the Sacramento River, particularly in areas where existing revetment could be removed to allow for improved riverine geomorphic processes. Opportunities to restore wetlands and floodplains are relatively limited in this reach.

Reach 6: In Reach 6, the Sacramento River is confined within natural bluffs below Anderson, and above Anderson, by urban development that in many locations approaches the banks of the Sacramento River approximately up to the Anderson-Cottonwood Irrigation District Diversion Dam. Reach 6 is relatively unaffected by levees, revetment, and similar factors that can disconnect floodplains from rivers and reduce or eliminate riverine geomorphic processes that create and sustain wetland, riparian, and SRA habitats. However, despite a relative lack of levees and revetment, only limited opportunities (i.e., in selected locations along the river where these habitats currently are absent) exist to expand, enhance, or restore riparian and SRA habitat in this reach beyond current conditions.

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Table H-15. Climate Change Adaptation Strategies Available in the Upper Sacramento River CPA

Adaptation Strategy[a] Habitat-related	Adaptation Strategy[a] Species-specific	Adaptation Potential Reach 1	Adaptation Potential Reach 2	Adaptation Potential Reach 3	Adaptation Potential Reach 4	Adaptation Potential Reach 5	Adaptation Potential Reach 6
SRA-1	SMELT-1	Limited – Reach 1 is upstream of suitable habitat for Delta smelt, but SRA contribution to nutrients and shading to decrease water temperatures could improve downstream habitat.	Limited – Same as Reach 1.	Limited – Same as Reach 1.	Limited – Same as Reach 1.	Limited – Same as Reach 1.	None.
	SALMONID-1	High – Reach 1 provides very important rearing and outmigration habitat for juveniles of all runs of Central Valley salmonids and green sturgeon. Increased SRA would improve rearing habitat by providing overhead cover that helps lower water temperatures, a substrate for food production that seasonally provides insects for fish to forage, and large wood that falls into the river which provides habitat complexity.	High – Same as Reach 1.	High – Same as Reach 1.	High – Same as Reach 1.	High– Reach 5 provides very important adult spawning habitat for green sturgeon and rearing and outmigration habitat for juveniles of all runs of Central Valley salmonids and green sturgeon. Increased SRA would improve habitat, as described for Reach 1, as well as storage of spawning gravels for green sturgeon.	Moderate – Reach 6 contains all of the spawning habitat for winter-run Chinook salmon that exists in the SPA, and also contains important rearing habitat. Although the opportunity for floodway expansion is constrained in this reach, any expansion of riparian and SRA habitat would provide a significant benefit to winter-run Chinook salmon.
	BANS-1	High – The majority of California bank swallows breed along the Sacramento River and its tributaries. This CPA lies within the area specifically recommended for revetment removal by the BANS-TAC, and the same types of opportunities exist in this reach for foraging habitat restoration as described for Reach 2 of the Lower Sacramento River CPA.	High – Same as Reach 1.	High – Same as Reach 1.	High – Same as Reach 1.	High – Same as Reach 1.	None.
	BANS-2	High – Same as Lower Sacramento River CPA.	High – Same as Reach 1.	High – Same as Reach 1.	High – Same as Reach 1.	High – Same as Reach 1.	None.

Adaptation Strategy[a] Habitat-related	Adaptation Strategy[a] Species-specific	Adaptation Potential Reach 1	Adaptation Potential Reach 2	Adaptation Potential Reach 3	Adaptation Potential Reach 4	Adaptation Potential Reach 5	Adaptation Potential Reach 6
SRA-1	SONG-1	High – Yellow-breasted chat currently occur in Reach 1, and although there are no recent records for Least Bell's vireo in this CPA, it is within the historic range. Reach 1 provides opportunities to facilitate dynamic riparian successional stages which could aid in re-colonization of Least Bell's vireo, and both species would benefit from increased riparian habitat, greater riparian patch size, and additional secondary growth used for nesting.	High – Same as Reach 1 related to nearly the entirety of the Sacramento River below Colusa.	High – Same as Reach 1.	High – Same as Reach 1.	Limited – Reach 5 lacks levees and there are few areas of disconnected floodplains available for enhancement of natural processes that support the yellow-breasted chat and Least Bell's vireo.	Limited – Reach 6 provides limited opportunities to expand, enhance or restore dynamic riparian successional stages beyond current conditions.
	TCBB-1	None.	None.	High – Tricolored blackbirds occur in Reach 3, and abundant opportunities exist to facilitate natural river processes that create nesting habitats.	None.	None.	None.
	WYBC-1	None.	None.	None.	None.	None.	Limited – Reach 6 provides limited opportunities to expand, enhance or restore dynamic riparian successional stages beyond current conditions.
RIP-1	SWHA-1	High – Same as the Lower Sacramento River CPA.	High – Same as Reach 1.	High – Same as Reach 1.	High – Same as Reach 1.	High – Same as Reach 1.	Limited – Reach 6 provides limited opportunities to expand, enhance or restore existing riparian habitat beyond current conditions.

Adaptation Strategy[a] Habitat-related	Adaptation Strategy[a] Species-specific	Adaptation Potential Reach 1	Adaptation Potential Reach 2	Adaptation Potential Reach 3	Adaptation Potential Reach 4	Adaptation Potential Reach 5	Adaptation Potential Reach 6
RIP-1	WYBC-1	High – Suitable habitat occupied by western yellow-billed cuckoos exists in Reach 1. The expansion and enhancement of riparian habitat would increase the total amount of available riparian habitat and habitat patch size, enhancing the habitat for nesting and increase connectivity of occupied and suitable habitat.	High – Same as Reach 1.	High – Same as Reach 1.	High – Same as Reach 1.	Moderate – Reach 5 lacks levees, and there are few areas of disconnected floodplains available for expansion and enhancement of riparian habitat.	Limited – Reach 6 provides limited opportunities to expand, enhance or restore riparian habitat beyond current conditions.
	SONG-1	High – The high potential of Reach 1 for floodway expansion provides substantial opportunities to enhance and expand riparian habitat suitable for the yellow-breasted chat and Least Bell's vireo.	High – Same as Reach 1.	High – Same as Reach 1.	High – Same as Reach 1.	High – Same as Reach 1.	Limited – Reach 6 provides limited opportunities to expand, enhance or restore riparian habitat beyond current conditions.
	VELB-1	High – Suitable elderberry habitat exists and the valley elderberry longhorn beetle is known to occur throughout Reach 1. The substantial opportunity in this reach to reconnect the floodplain to the river will provide new areas for elderberry recruitment adjacent to existing suitable habitat.	High – Same as Reach 1.	High – Same as Reach 1.	Moderate – Reach 4 is similar to Reaches 1 through 3, but with slightly less area available for floodplain reconnection and elderberry recruitment.	Moderate – Same as Reach 4.	Limited – Reach 6 provides limited opportunities for floodplain reconnection and elderberry recruitment.
	VELB-2	High – Reach 1 provides substantial opportunities to plant elderberry shrubs in existing and new riparian restoration areas, and potentially in newly expanded floodplain areas.	High – Same as Reach 1.	High – Same as Reach 1.	High – Same as Reach 1.	High – Same as Reach 1.	Limited – Reach 6 provides limited opportunities for additional riparian habitat beyond current conditions.

Adaptation Strategy[a] Habitat-related	Adaptation Strategy[a] Species-specific	Adaptation Potential Reach 1	Adaptation Potential Reach 2	Adaptation Potential Reach 3	Adaptation Potential Reach 4	Adaptation Potential Reach 5	Adaptation Potential Reach 6
WET-1	SMELT-1	Limited – This CPA is located upstream of existing habitat for Delta smelt, but floodplain contributions to nutrients and sediment from erosional processes could improve downstream habitat.	Limited – same as Reach 1.	Limited – same as Reach 1.	Limited – same as Reach 1.	Limited – same as Reach 1.	None.
	SALMONID-1	High – Reach 1 provides opportunities to restore and enhance floodplain and seasonally connected wetland habitats, which would improve and increase rearing habitats.	High – Same as Reach 1.	High – Same as Reach 1.	High – Same as Reach 1.	High – Same as Reach 1.	Moderate – Although the opportunity for floodway expansion is constrained in Reach 6, any enhancement or restoration of floodplain, riparian, or SRA habitat would provide a significant benefit to winter-run Chinook salmon.
	GGS-1	High – Giant gartersnakes occur throughout this CPA. Reach 1 provides substantial opportunities to enhance, expand, and restore marsh habitat suitable for the giant gartersnakes.	High – Same as Reach 1.	High – Same as Reach 1.	High – Same as Reach 1.	None.	None.
	GGS-2	High – Reach 1 provides substantial opportunities to expand the floodway, which would provide upland refugia and connect existing habitat for giant gartersnakes.	High – Same as Reach 1.	High – Same as Reach 1.	High – Same as Reach 1.	None.	None.
	GSHC-1	High – Greater sandhill cranes are present in this CPA. There are expansive areas suitable to create large areas of floodplain habitats suitable for greater sandhill cranes in Reach 1, increasing connectivity with existing habitat.	High – Same as Reach 1.	High – Same as Reach 1.	Moderate – Although Reach 4 provides limited opportunities for floodplain expansion, it contains much connected floodplain, providing substantial opportunities for enhancement of existing habitat.	Moderate – Same as Reach 4.	Limited – Reach 6 has very limited opportunities for floodplain expansion, and very little existing floodplain habitat that could be enhanced.

Adaptation Strategy[a] Habitat-related	Adaptation Strategy[a] Species-specific	Adaptation Potential Reach 1	Adaptation Potential Reach 2	Adaptation Potential Reach 3	Adaptation Potential Reach 4	Adaptation Potential Reach 5	Adaptation Potential Reach 6
WET-1	GSHC-2	High – Same as Lower Sacramento River CPA.	High – Same as Lower Sacramento River CPA.	High – Same as Lower Sacramento River CPA.	High – Same as Lower Sacramento River CPA.	High – Same as Lower Sacramento River CPA.	Limited – Reach 6 provides very little floodplain habitat that could be enhanced by reservoir releases.
	TCBB-1	High – Reach 1 includes expansive areas to create potential riparian habitat, and opportunities to create and enhance wetlands that provide breeding habitat for tricolored blackbirds.	High – Same as Reach 1.	None.	None.	None.	None.

[a] Table H-10 provides adaptation strategy descriptions.

Notes:
CPA = conservation planning area
SPA = systemwide planning area
SRA = shaded riverine aquatic

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5.3 Feather River CPA

Table H-16. Species Distribution by Habitat and Reach in the Feather River CPA

Habitat Type	Species Acronym[a]	Species Name	Reach 1	Reach 2
Potential Floodplain/SRA	SALMONID	California Central Valley Steelhead	Yes	Yes
	SALMONID	Chinook – Central Valley Spring Run	Yes	Yes
	SALMONID	Chinook – Central Valley Fall/Late-fall Run	Yes	Yes
	SALMONID	Green Sturgeon	Yes	Yes
	BANS	Bank Swallow	Yes	Yes
	SONG	Least Bell's Vireo	Yes	Yes
	WYBC	Western Yellow-billed Cuckoo	No	Yes
Riparian	SWHA	Swainson's Hawk	Yes	Yes
	WYBC	Western Yellow-billed Cuckoo	Yes	No
	SONG	Yellow-breasted Chat	Yes	Yes
	VELB	Valley Elderberry Longhorn Beetle	Yes	Yes
Perennial Wetland	GGS	Giant Gartersnake	Yes	Yes
	GSHC	Greater Sandhill Crane	Yes	Yes
	TCBB	Tricolored Blackbird	Yes	Yes

[a] Species acronyms are assigned in Table H-10 of Section 4.2.1.2, "Habitat and Species-specific Adaptation Measures."

Figure H-26. Feather River CPA Reach 1

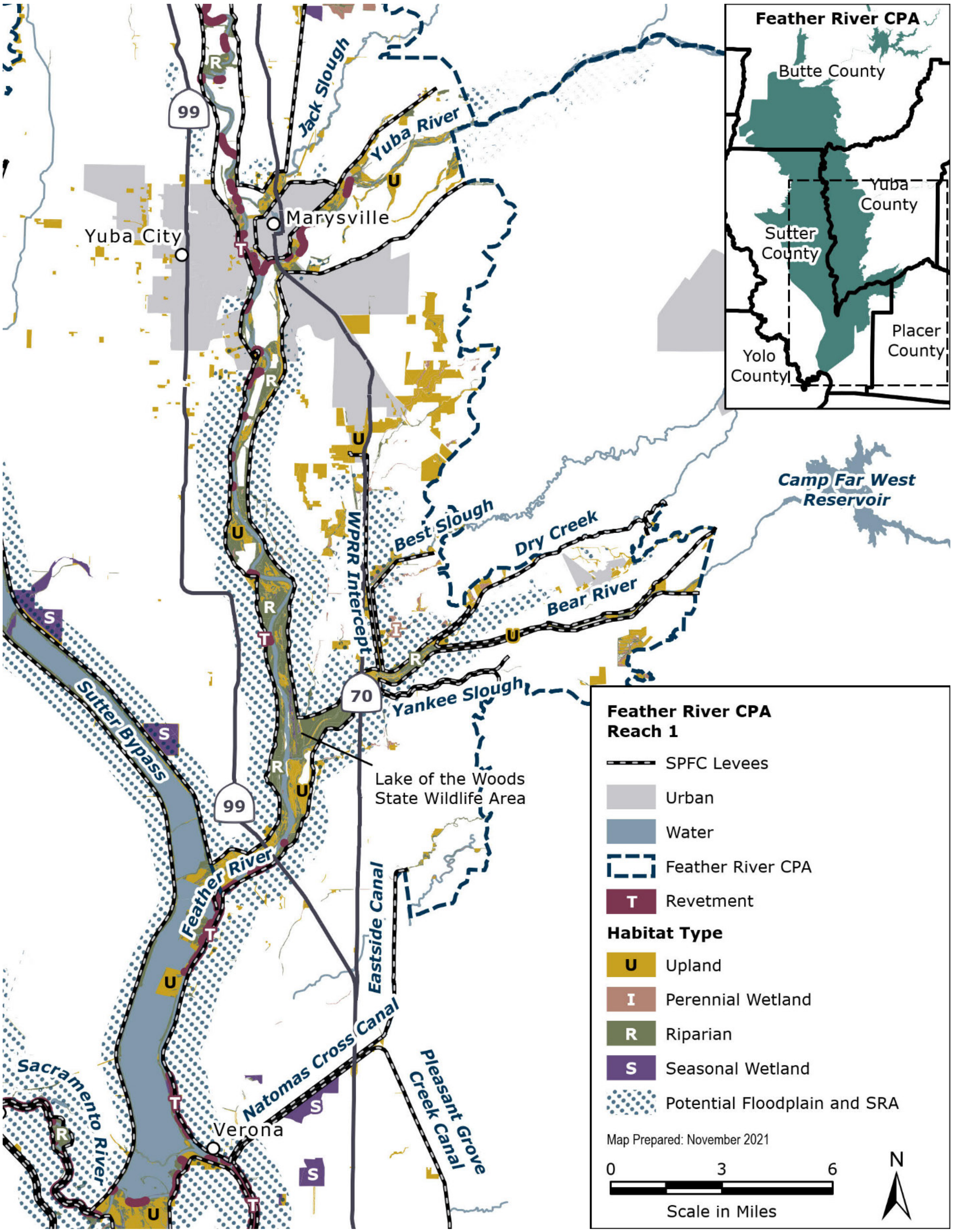
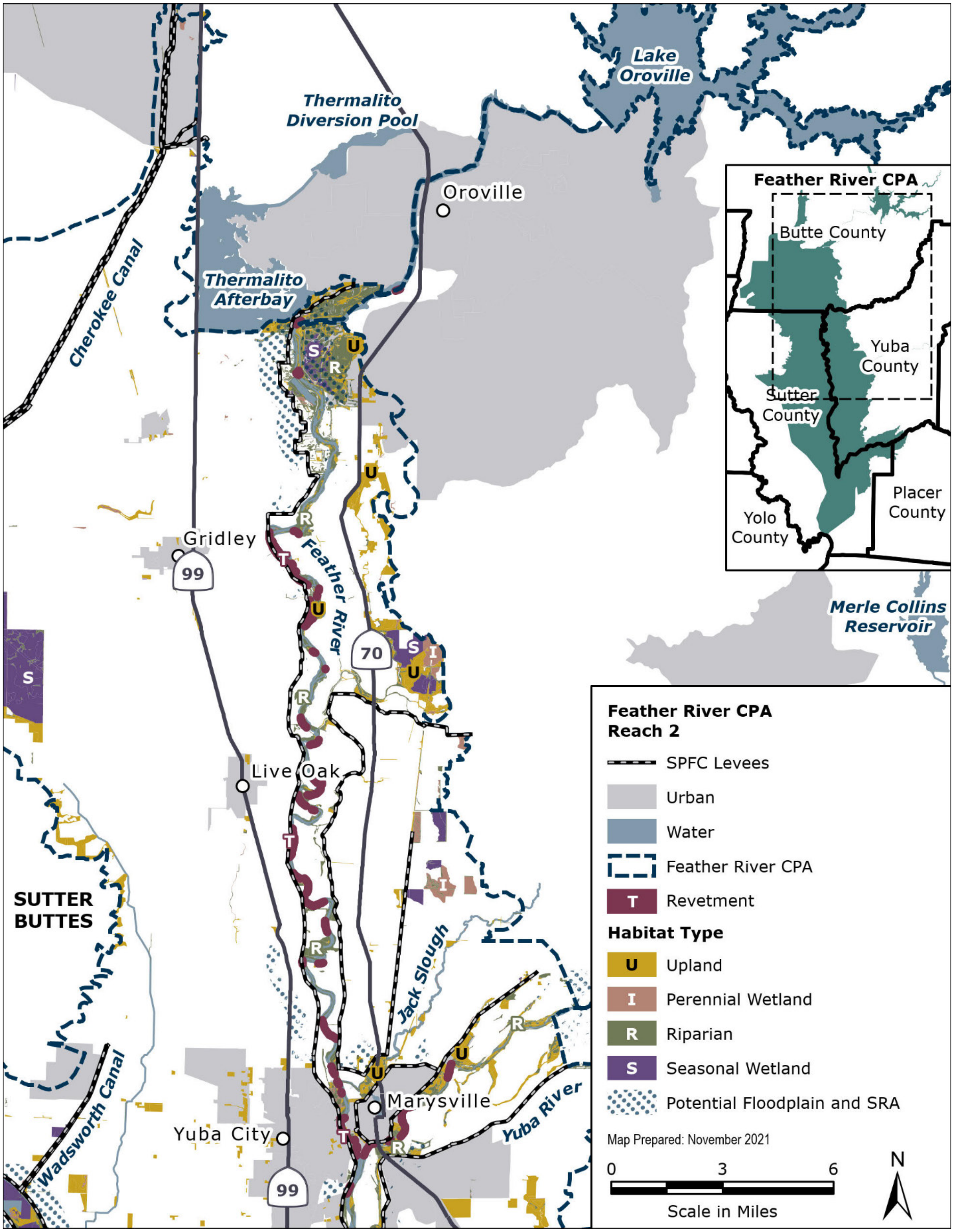


Figure H-27. Feather River CPA Reach 2



5.3.1 Climate Change Adaptation Risks and Opportunities – Feather River CPA

Reach 1: Adaptation potential is provided by expansive areas suitable for reconnecting floodplains along the Feather River downstream of Yuba City and Marysville and along Best Slough/Dry Creek/Bear River near the Feather River confluence. Aside from floodplain habitat, wetland and riparian habitat could be restored if these floodplains were reconnected to the Feather River and its tributaries. Within the Feather River channel and Sutter Bypass, extensive opportunities exist to restore and connect SRA habitat, along with additional floodplain, riparian, and wetland habitat. There are also areas suitable for enhancing wetlands and uplands along other State Plan of Flood Control facilities and waterways in this reach.

Reach 2: Adaptation potential is limited to targeted areas suitable for creating potential floodplain, riparian, and SRA habitats along the Feather and Yuba Rivers, particularly near and within the Oroville Wildlife Area and downstream from the Thermalito Afterbay outfall channel along the right bank of the Feather River. There also are areas suitable for enhancing and expanding existing riparian and SRA habitats adjacent to the Feather and Yuba Rivers, and Cherokee Canal provides numerous opportunities to enhance and restore all habitat types. Other opportunities also exist for enhancing wetlands and uplands along other, smaller State Plan of Flood Control facilities and waterways in this reach.

Table H-17. Climate Change Adaptation Strategies Available in the Feather River CPA

Adaptation Strategy[a] Habitat-related	Adaptation Strategy[a] Species-specific	Adaptation Potential Reach 1	Adaptation Potential Reach 2
SRA-1	SMELT-1	Limited – This CPA is located upstream of suitable habitat for Delta smelt, but SRA contribution to nutrients and shading to decrease water temperatures could improve downstream habitat.	Limited – Same as Reach 1.
	SALMONID-1	High – Reach 1 provides very important adult spawning, and juvenile rearing and outmigration habitat for spring and fall/late-fall runs of Central Valley salmon, steelhead, and green sturgeon. Increased SRA would improve rearing habitat in the same manner described for the Upper Sacramento River CPA.	High – Same as Reach 1.

Adaptation Strategy[a] Habitat-related	Adaptation Strategy[a] Species-specific	Adaptation Potential Reach 1	Adaptation Potential Reach 2
SRA-1	BANS-1	High – The majority of California bank swallows breed along the Sacramento River and its tributaries. This CPA lies within the Feather River region specifically recommended for revetment removal by the BANS-TAC, and the same types of opportunities exist in this reach for foraging habitat restoration as described for the Lower and Upper Sacramento River CPAs.	High – Same as Reach 1.
	BANS-2	High – Same as the Lower and Upper Sacramento River CPAs.	High – Same as the Lower and Upper Sacramento River CPAs.
	SONG-1	High – Yellow-breasted chat currently occur in Reach 1, and although there are no recent records for Least Bell's vireo in this CPA, it is within the historic range. There is a substantial amount of area suitable for expanding the floodway in Reach 1, which would facilitate dynamic riparian successional stages that could aid in re-colonization of Least Bell's vireo, and both species would benefit as described for the Upper Sacramento River CPA.	Moderate – There are a moderate amount of areas suitable for facilitating dynamic riparian successional changes adjacent to the Feather and Yuba Rivers, Cherokee Canal, and the Sutter Bypass.

Adaptation Strategy[a] Habitat-related	Adaptation Strategy[a] Species-specific	Adaptation Potential Reach 1	Adaptation Potential Reach 2
SRA-1	WYBC-1	High – Suitable habitat occupied by the western yellow-billed cuckoo occurs in Reach 1. The high potential of this reach for floodway reconnection provides substantial opportunities to facilitate dynamic riparian successional stages, which would improve climate change adaptation potential for the western yellow-billed cuckoo through increased riparian habitat overall and greater riparian patch size.	Limited – The area available for floodplain reconnection is relatively limited in Reach 2, constraining the potential to facilitate dynamic riparian successional stages and increase climate adaptation potential for the western yellow-billed cuckoo.
RIP-1	SWHA-1	High – Reach 1 currently provides suitable breeding and foraging habitat and is occupied by the Swainson's hawk. Climate change adaptation potential for the Swainson's hawk could be improved in this reach in the same manner described for the Lower and Upper Sacramento River CPAs.	Moderate – There are moderate opportunities to create and enhance riparian habitat in this reach as referenced in Reach 1.
	WYBC-1	High – The high potential of Reach 1 for floodway expansion provides substantial opportunity to enhance and expand riparian habitat suitable for he western yellow-billed cuckoo.	Limited – The area available for expanding floodplain habitats is relatively limited in Reach 2, constraining the potential to expand riparian habitat suitable for he western yellow-billed cuckoo.
	SONG-1	High – The high potential of Reach 1 for floodway expansion provides substantial opportunities to enhance and expand riparian habitat suitable for the yellow-breasted chat and Least Bell's vireo.	Moderate – The moderate amount of areas suitable for floodway expansion provides some opportunities to enhance and expand riparian habitat suitable for the yellow-breasted chat and Least Bell's vireo.

Adaptation Strategy[a] Habitat-related	Adaptation Strategy[a] Species-specific	Adaptation Potential Reach 1	Adaptation Potential Reach 2
RIP-1	VELB-1	High – Suitable elderberry habitat exists and the valley elderberry longhorn beetle is known to occur throughout Reach 1, and there are substantial opportunities for floodplain expansion, which will provide new areas for elderberry shrubs to colonize.	Limited – While suitable elderberry habitat exists and the valley elderberry longhorn beetle is known to occur in Reach 2, there are limited opportunities for floodplain reconnection that would provide new areas for elderberry shrub colonization.
	VELB-2	High – Substantial opportunities to expand suitable habitat similar to that described for the Upper Sacramento River CPA.	Moderate – There are moderate opportunities to expand suitable habitat similar to that described for the Upper Sacramento River CPA.
WET-1	SMELT-1	Limited – This CPA is located upstream of existing habitat for Delta smelt, but floodplain contributions to nutrients and sediment from erosional processes could improve downstream habitat.	Limited – Same as Reach 1.
	SALMONID-1	High – Same the Upper Sacramento River CPA.	High – Same as Reach 1.
	GGS-1	High – Giant gartersnakes occur throughout this CPA. Reach 1 provides substantial opportunities to enhance, expand, and restore marsh habitat suitable for the giant gartersnake.	Moderate – Similar to Reach 1, but opportunities are available only in select areas (e.g., within Cherokee Canal).
	GGS-2	High – Reach 1 provides substantial opportunities to expand the floodway, providing upland refugia and connecting existing habitat for the giant gartersnake.	Moderate – Similar to Reach 1, but opportunities are available in select areas.

Adaptation Strategy[a] Habitat-related	Adaptation Strategy[a] Species-specific	Adaptation Potential Reach 1	Adaptation Potential Reach 2
WET-1	GSHC-1	High – Greater sandhill cranes are present in this CPA. Reach 1 provides expansive areas suitable to create large areas of floodplain habitats suitable for the greater sandhill crane, increasing connectivity with existing habitat.	Moderate – Although Reach 2 provides limited opportunities for floodplain expansion, there are some opportunities for floodplain enhancement and creation in select areas, such as adjacent to the Feather and Yuba Rivers, Cherokee Canal, and the Sutter Bypass.
	GSHC-2	High – Reach 1 provides the opportunity to manage reservoir releases along the Feather River to promote shallow inundation of existing greater sandhill crane roosting habitat, which could mediate climate change effects in drought years.	High – Same as Reach 1.
	TCBB-1	High – Tricolored blackbirds are present in Reach 1, and the potential for floodway expansion provides extensive opportunities to create and enhance riparian and wetland habitats suitable for the tricolored blackbird within the existing floodway, thereby increase the breeding habitat available.	High – Tricolored blackbirds are present in Reach 2, and although the potential to expand the floodway is limited compared to Reach 1, there are some opportunities to expand and create suitable riparian and wetland habitats suitable for the tricolored blackbird within the existing floodway and thereby increase the breeding habitat available.

[a] Table H-10 provides adaptation strategy descriptions.

5.4 Lower San Joaquin River CPA

Table H-18. Species Distribution by Habitat and Reach in the Lower San Joaquin River CPA

Habitat Type	Species Acronym[a]	Species Name	Reach 1	Reach 2	Reach 3
Potential Floodplain/SRA	SALMONID	California Central Valley Steelhead	Yes	Yes	Yes
	SALMONID	Chinook – Central Valley Spring Run	Yes	Yes	Yes
	SALMONID	Chinook – Central Valley Fall-/ Late-fall Run	Yes	Yes	Yes
	SMELT	Delta Smelt	Yes	No	No
	SALMONID	Green Sturgeon	Yes	Yes	Yes
	WYBC	Western Yellow-billed Cuckoo	Yes	No	Yes
Riparian	SWHA	Swainson's Hawk	Yes	Yes	Yes
	WYBC	Western Yellow-billed Cuckoo	No	Yes	No
	SONG	Yellow-breasted Chat	Yes	Yes	Yes
	SONG	Least Bell's Vireo	Yes	Yes	Yes
	VELB	Valley Elderberry Longhorn Beetle	Yes	Yes	Yes
	PLANTS	Delta Button-celery	Yes	Yes	Yes
	MAMMAL	Riparian Bush Rabbit	No	Yes	Yes
	MAMMAL	Riparian Woodrat	No	Yes	Yes
Perennial Wetland	GGS	Giant Gartersnake	Yes	Yes	Yes
	GSHC	Greater Sandhill Crane	Yes	Yes	Yes
	TCBB	Tricolored Blackbird	Yes	Yes	Yes
	CABR	California Black Rail	Yes	No	No
	PLANTS	Slough Thistle	Yes	Yes	Yes

[a] Species acronyms are assigned in Table H-10 of Section 4.2.1.2, "Habitat and Species-specific Adaptation Measures."

Notes:
CPA = conservation planning area
SRA = systemwide planning area

Figure H-28. Lower San Joaquin River CPA Reach 1

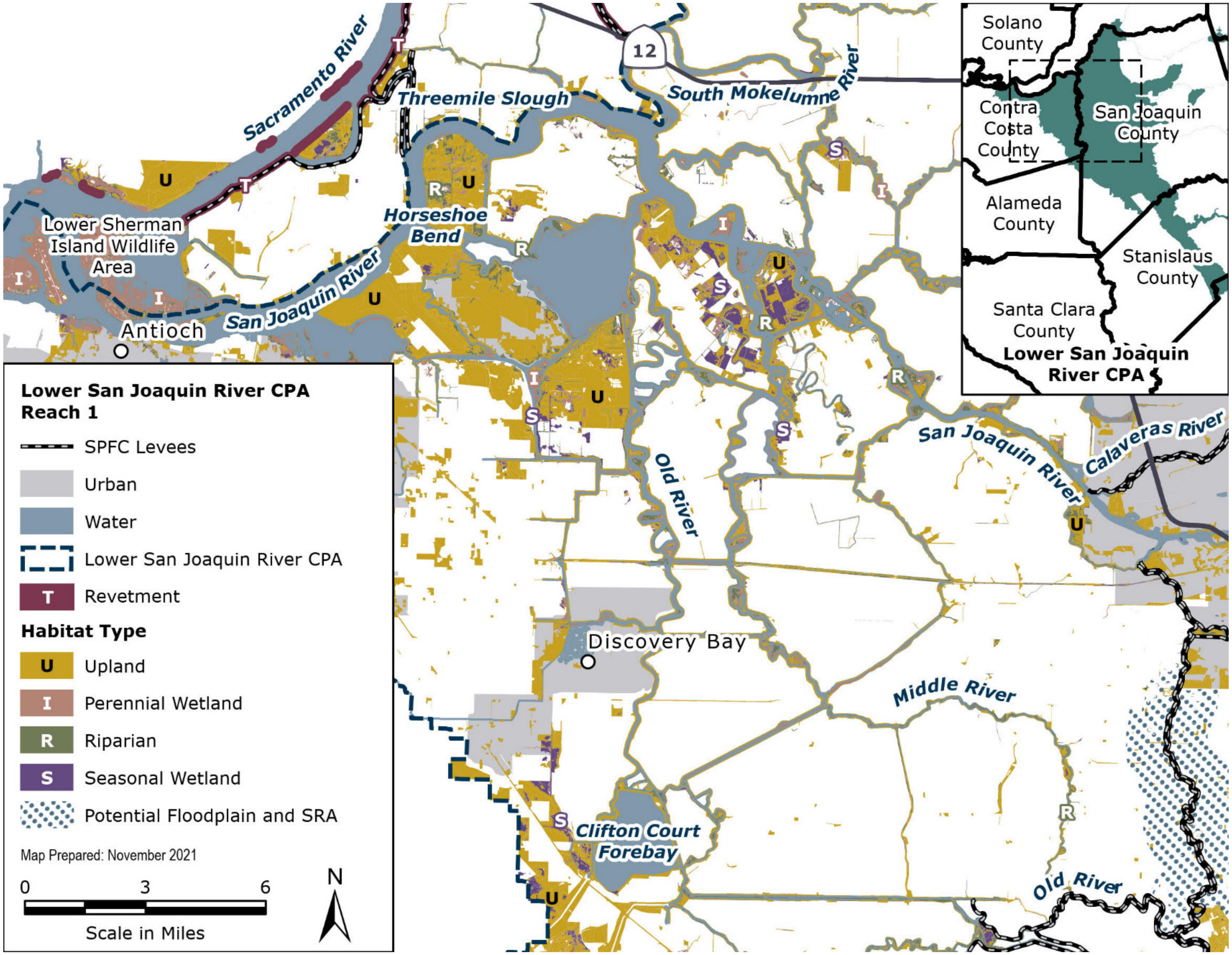


Figure H-29. Lower San Joaquin River CPA Reach 2

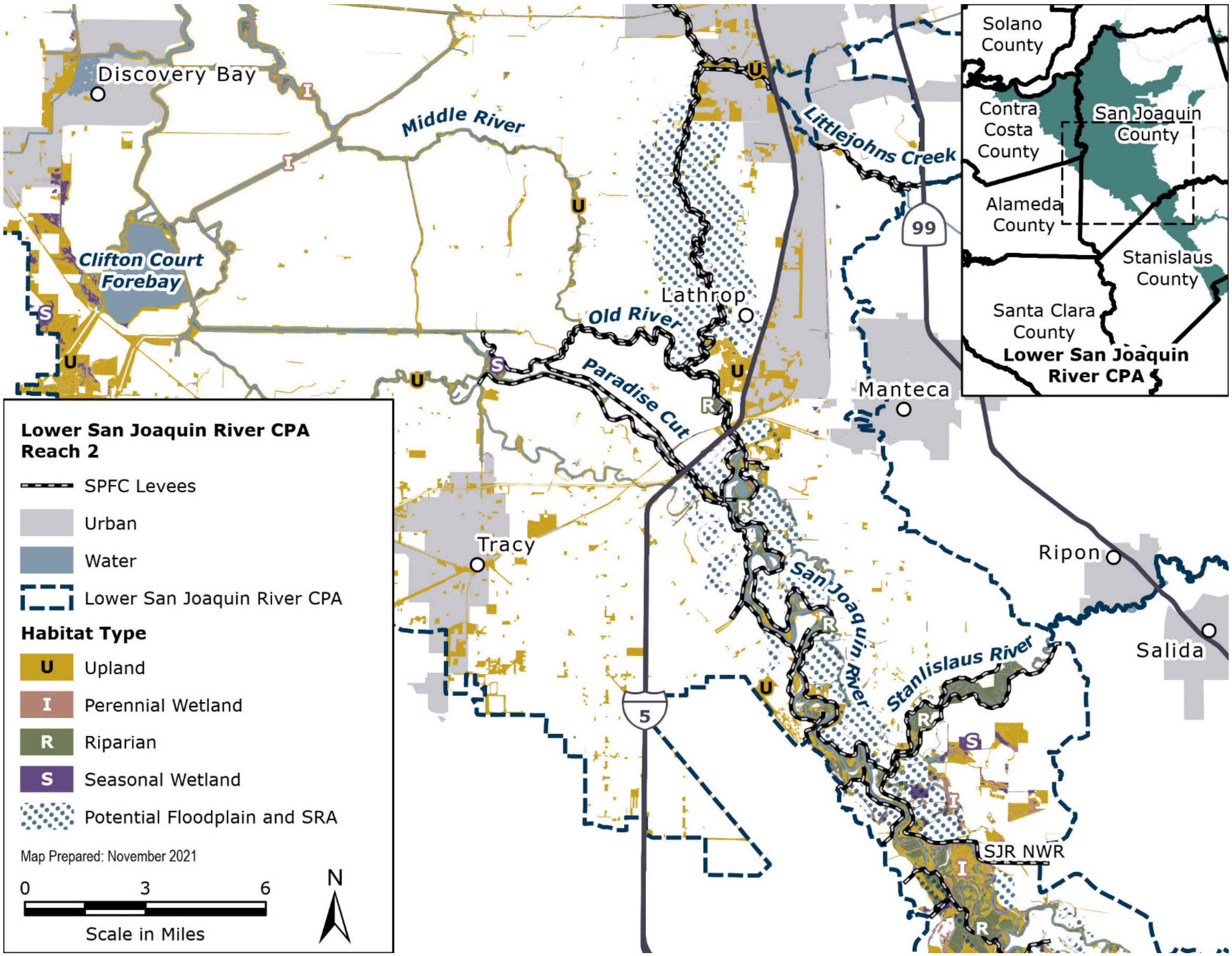
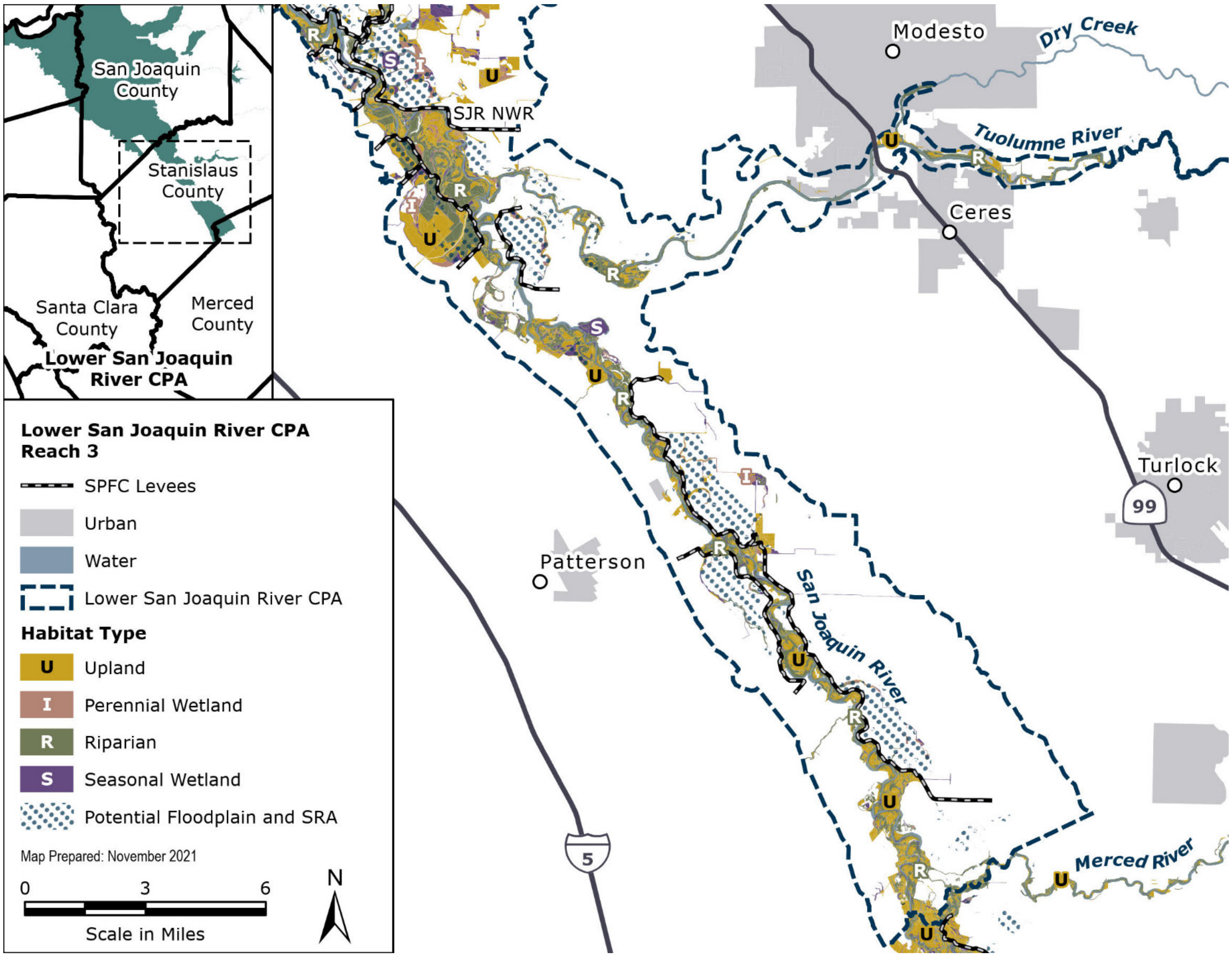


Figure H-30. Lower San Joaquin River CPA Reach 3



5.4.1 Climate Change Adaptation Risks and Opportunities – Lower San Joaquin CPA

Reach 1: Adaptation potential is constrained by expansive areas of levees and revetment protecting urbanizing areas and the Delta, providing very few areas that are suitable for creating potential floodplain, riparian, and SRA habitats. However, there are some limited areas that may be suitable for enhancing riparian and wetland habitats along the San Joaquin River and its tributaries.

Reach 2: Extensive areas of disconnected floodplain exist from south of Stockton to Lathrop, and all habitat types could be restored or enhanced in this area. Additional adaptation opportunities to reconnect floodplains and restore riparian, wetland, and SRA habitat exist in Paradise Cut and along the San Joaquin River from Paradise Cut downstream to the Stanislaus River confluence and San Joaquin River National Wildlife Area. Targeted restoration of riparian and SRA habitat could occur along the lower Stanislaus River, although the proximity of levees to the river limits the area where restoration could occur unless levees are set back.

Reach 3: Adaptation potential is provided in expansive areas suitable for creating potential floodplain, riparian, and SRA habitats along the San Joaquin River, particularly near the San Joaquin River National Wildlife Area, where existing habitats could be expanded and connected to other habitats downstream in this reach. There are also some limited areas suitable for reconnecting floodplains along the Tuolumne River, and areas suitable for enhancing riparian and wetland habitats occur adjacent to both the San Joaquin and Tuolumne Rivers.

Table H-19. Climate Change Adaptation Strategies Available in the Lower San Joaquin River CPA

Adaptation Strategy[a] Habitat-related	Adaptation Strategy[a] Species-specific	Adaptation Potential Reach 1	Adaptation Potential Reach 2	Adaptation Potential Reach 3
SRA-1	SMELT-1	High – Reach 1 provides a large portion of the existing habitat for Delta smelt. Opportunities to improve climate change adaptation are the same as those described for the Lower Sacramento River CPA.	Limited – Reach 2 contributes to the main habitat for Delta smelt in Reach 1. SRA contribution to nutrients and shading to decrease water temperatures could improve downstream habitat as described for the Lower Sacramento River CPA.	Limited – Reach 3 also contributes to the main habitat for Delta smelt in Reach 1, and provides the same opportunities as described for Reach 2.

Adaptation Strategy[a] Habitat-related	Adaptation Strategy[a] Species-specific	Adaptation Potential Reach 1	Adaptation Potential Reach 2	Adaptation Potential Reach 3
SRA-1	SALMONID-1	High – This reach provides important rearing and outmigration habitat for juveniles of all runs of Central Valley salmonids and green sturgeon. Opportunities to improve and restore these habitats must consider effects of climate change on increasing water temperatures, similar to that described for the Lower Sacramento River CPA.	High – Same as Reach 1, except this reach does not provide habitat for winter-run Chinook salmon.	High – Same as Reach 2.
	BANS-1	Limited – Recent records of bank swallows in Reach 1 appear to be migrants rather than breeders, and the reach is outside the historic and current breeding distribution of this species. Expansive areas of levees and revetment provide very limited areas that might be suitable for creating potential breeding habitat.	Limited – Reach 2 appears to have had a very small breeding population of bank swallows that is now extirpated. Although this reach provides substantial opportunities for floodplain reconnection, which could facilitate erosional processes that create nesting habitat, it is unclear the degree to which bank swallows would respond given their limited historic presence.	Limited – Same as Reach 2.
	BANS-2	Limited – Same as BANS-1.	Limited – Same as BANS-1.	Limited – Same as BANS-1.

Adaptation Strategy[a] Habitat-related	Adaptation Strategy[a] Species-specific	Adaptation Potential Reach 1	Adaptation Potential Reach 2	Adaptation Potential Reach 3
SRA-1	WYBC-1	Limited – Adaptation potential for the western yellow-billed cuckoo is constrained by expansive areas of levees and revetment in Reach 1, which provides few opportunities for floodplain reconnection.	None	High – Reach 3 provides substantial opportunities for floodplain reconnection and contains existing suitable habitat occupied by the western yellow-billed cuckoo. Facilitation of dynamic riparian successional stages should increase the total amount of riparian habitat and increase riparian habitat patch size, enhancing the reach for the nesting western yellow-billed cuckoo.
RIP-1	SWHA-1	Moderate – Reach 1 provides limited areas suitable for creating additional riparian habitat, but climate change adaptation potential for the Swainson's hawk could be improved in the same manner described for the Lower and Upper Sacramento River and Feather River CPAs.	High – Reach 2 currently provides suitable breeding and foraging habitat and is occupied by the Swainson's hawk. There are substantial areas suitable for expanding and enhancing riparian breeding habitat as described for the Lower and Upper Sacramento River and Feather River CPAs.	High – Same as Reach 2.

Adaptation Strategy[a] Habitat-related	Adaptation Strategy[a] Species-specific	Adaptation Potential Reach 1	Adaptation Potential Reach 2	Adaptation Potential Reach 3
RIP-1	WYBC-1	Limited – Adaptation potential for the western yellow-billed cuckoo is constrained by expansive areas of levees and revetment in Reach 1, which provides few opportunities to expand riparian habitat.	None.	High – Reach 3 provides substantial opportunities for floodplain expansion and contains existing suitable habitat occupied by the western yellow-billed cuckoo Increasing the total amount of riparian habitat and riparian habitat patch size would enhance this reach for nesting western yellow-billed cuckoos.
	SONG-1	Limited – The yellow-breasted chat occurs throughout Reach 1, and there is a recent record of Least Bell's vireo; however, opportunities for climate change adaptations are constrained by expansive areas of levees and revetment. There are some limited areas that may be suitable for enhancing riparian and wetland habitats along the San Joaquin River and tributaries.	High – YBC currently occur in Reach 2, there are recent Least Bell's vireo records from the San Joaquin National Wildlife Refuge, and this reach is within the historic range of Least Bell's vireo. The high potential of Reach 2 for floodway expansion provides substantial opportunities to enhance and expand riparian habitat suitable for the yellow-breasted chat and Least Bell's vireo.	High – Same as Reach 2.

Adaptation Strategy[a] Habitat-related	Adaptation Strategy[a] Species-specific	Adaptation Potential Reach 1	Adaptation Potential Reach 2	Adaptation Potential Reach 3
RIP-1	VELB-1	Limited – While suitable elderberry habitat exists and the valley elderberry longhorn beetle is known to occur in Reach 1, there are limited opportunities for floodplain reconnection that would provide new areas for elderberry colonization.	High – Suitable elderberry habitat exists and the valley elderberry longhorn beetle is known to occur throughout Reach 2. There are substantial opportunities for expansion of suitable habitat similar to that described for the Upper Sacramento River CPA.	High – Same as Reach 2.
	VELB-2	Limited – There are limited opportunities to expand suitable riparian habitat in Reach 1.	High – Reach 2 provides substantial opportunities to expand suitable habitat similar to that described for the Upper Sacramento River CPA.	High – Same as Reach 2.
	PLANTS-1	Limited – Delta button-celery is likely extirpated from Reach 1, but its historical range includes this reach. Limited opportunities exist for riparian and wetland restoration where facilitated colonization could be implemented.	Moderate – Similar to Reach 1, but Reach 2 provides more areas with opportunities for riparian and wetland restoration where facilitated colonization could be implemented.	High – Similar to Reach 1, but there are substantial opportunities for riparian and wetland restoration also exist where facilitated colonization could be implemented.

Adaptation Strategy[a] Habitat-related	Adaptation Strategy[a] Species-specific	Adaptation Potential Reach 1	Adaptation Potential Reach 2	Adaptation Potential Reach 3
RIP-1	MAMMAL-1	None.	High – Reaches 2 and 3 provide most of the remaining habitat for these species within the SPA; there are several extant occurrences of both species, and there are substantial opportunities to create or restore riparian and upland refugia habitat required by these species throughout this reach.	High – Same as Reach 2.
WET-1	SMELT-1	High – Reach 1 provides opportunities to improve and expand floodplain and heterogeneous tidal wetland habitat complexes, which are likely to improve habitat conditions for Delta smelt. However, there are uncertainties, as described for the Lower Sacramento River CPA.	Limited – Reach 2 is located upstream of habitat for Delta smelt, but floodplain contributions to nutrients and sediment from erosional processes could improve downstream habitat, as described for the Lower Sacramento River CPA.	Limited – Same as Reach 2.
	SALMONID-1	High – Reach 1 provides opportunities for restoration and enhancement, as described for the Upper Sacramento River CPA.	High – Same as Reach 1, except this reach does not provide habitat for Sacramento River winter-run Chinook salmon.	High – Same as Reach 2.

Adaptation Strategy[a] Habitat-related	Adaptation Strategy[a] Species-specific	Adaptation Potential Reach 1	Adaptation Potential Reach 2	Adaptation Potential Reach 3
WET-1	GGS-1	Limited – Giant gartersnakes occur in this CPA, and although Reach 1 has very limited opportunities for marsh expansion or restoration, there are some select areas where marsh habitat could be enhanced for the giant gartersnake along the San Joaquin River and its tributaries.	High – Reach 2 provides substantial opportunities to enhance, expand, and restore marsh habitat suitable for giant gartersnake.	High – Same as Reach 2.
	GGS-2	Limited – Reach 1 has very limited opportunities for floodplain expansion that could expand and connect suitable habitat for the giant gartersnake.	High – Reach 2 provides substantial opportunities to expand the floodway, providing upland refugia and connecting existing habitat for the giant gartersnake.	High – Same as Reach 2.
	GSHC-1	Moderate – Greater sandhill cranes are present in this CPA. Although Reach 1 provides limited opportunities for floodplain expansion, there are some opportunities for floodplain enhancement and creation in select areas along the San Joaquin River and its tributaries.	High – Reach 2 provides expansive areas suitable for creating large areas of floodplain habitats suitable for the greater sandhill crane, increasing connectivity with existing habitat.	High – Same as Reach 2.

Adaptation Strategy[a] Habitat-related	Adaptation Strategy[a] Species-specific	Adaptation Potential Reach 1	Adaptation Potential Reach 2	Adaptation Potential Reach 3
WET-1	GSHC-2	High – Reach 1 provides the opportunity to manage reservoir releases along the San Joaquin River to promote shallow inundation of existing greater sandhill crane roosting habitat, which could mediate climate change effects in drought years.	High – Same as Reach 1.	High – Same as Reach 1.
	TCBB-1	Limited – Reach 1 is within the historical breeding range of the tricolored blackbird; however, adaptation potential for this species is constrained by expansive areas of levees and revetment. There are some limited areas that may be suitable for enhancing riparian and wetland habitats along the San Joaquin River and tributaries.	High – Reach 2 is within the historical breeding range of the tricolored blackbird, and there are substantial opportunities to create and enhance wetlands for breeding habitat throughout the reach.	High – Same as Reach 2.

Adaptation Strategy[a] Habitat-related	Adaptation Strategy[a] Species-specific	Adaptation Potential Reach 1	Adaptation Potential Reach 2	Adaptation Potential Reach 3
WET-1	CABR-1	Limited – California black rails are present in Reach 1 in low numbers, but existing urban areas constrain the opportunity for removing revetment. However, there may be some opportunities to increase the area of shallow emergent wetlands adjacent to the San Joaquin River and high-tide refugia in the Delta.	None.	None.
	PLANTS-1	Limited – Slough thistle is likely extirpated from the SPA, but its historical range includes Reach 1. Limited opportunities exist for riparian and wetland restoration where facilitated colonization could be implemented.	Moderate – Similar to Reach 1, but there are more areas with opportunities for riparian and wetland restoration where facilitated colonization could be implemented.	High – Similar to Reach 1, but there are substantial opportunities for riparian and wetland restoration where facilitated colonization could be implemented.

[a] Table H-10 provides adaptation strategy descriptions.

Notes:
CPA = conservation planning area
SPA = systemwide planning area
SRA = shaded riverine aquatic

5.5 Upper San Joaquin River CPA

Table H-20. Species Distribution by Habitat and Reach in the Upper San Joaquin River CPA

Habitat Type	Species Acronym[a]	Species Name	Reach 1	Reach 2	Reach 3	Reach 4
Potential Floodplain/SRA	SALMONID	California Central Valley Steelhead	Yes	Yes	Yes	Yes
	SALMONID	Chinook – Central Valley Spring Run	Yes	Yes	Yes	Yes
	SALMONID	Chinook – Central Valley Fall/Late-fall Run	Yes	Yes	Yes	Yes
	WYBC	Western Yellow-billed Cuckoo	Yes	Yes	Yes	Yes
	PLANTS	Slough Thistle	Yes	Yes	Yes	No
	SONG	Least Bell's Vireo	No	Yes	Yes	Yes
	SONG	Yellow-breasted Chat	No	No	Yes	No
Riparian	SWHA	Swainson's Hawk	Yes	Yes	Yes	Yes
	SONG	Yellow-breasted Chat	Yes	Yes	No	Yes
	SONG	Least Bell's Vireo	Yes	No	No	No
	VELB	Valley Elderberry Longhorn Beetle	Yes	Yes	Yes	Yes
	PLANTS	Delta Button-celery	Yes	Yes	Yes	No
Perennial Wetland	GGS	Giant Gartersnake	Yes	Yes	Yes	Yes
	GSHC	Greater Sandhill Crane	Yes	Yes	Yes	Yes
	TCBB	Tricolored Blackbird	Yes	Yes	Yes	Yes

[a] Species acronyms are assigned in Table H-10 of Section 4.2.1.2, "Habitat and Species-specific Adaptation Measures."

Figure H-31. Upper San Joaquin River CPA Reach 1

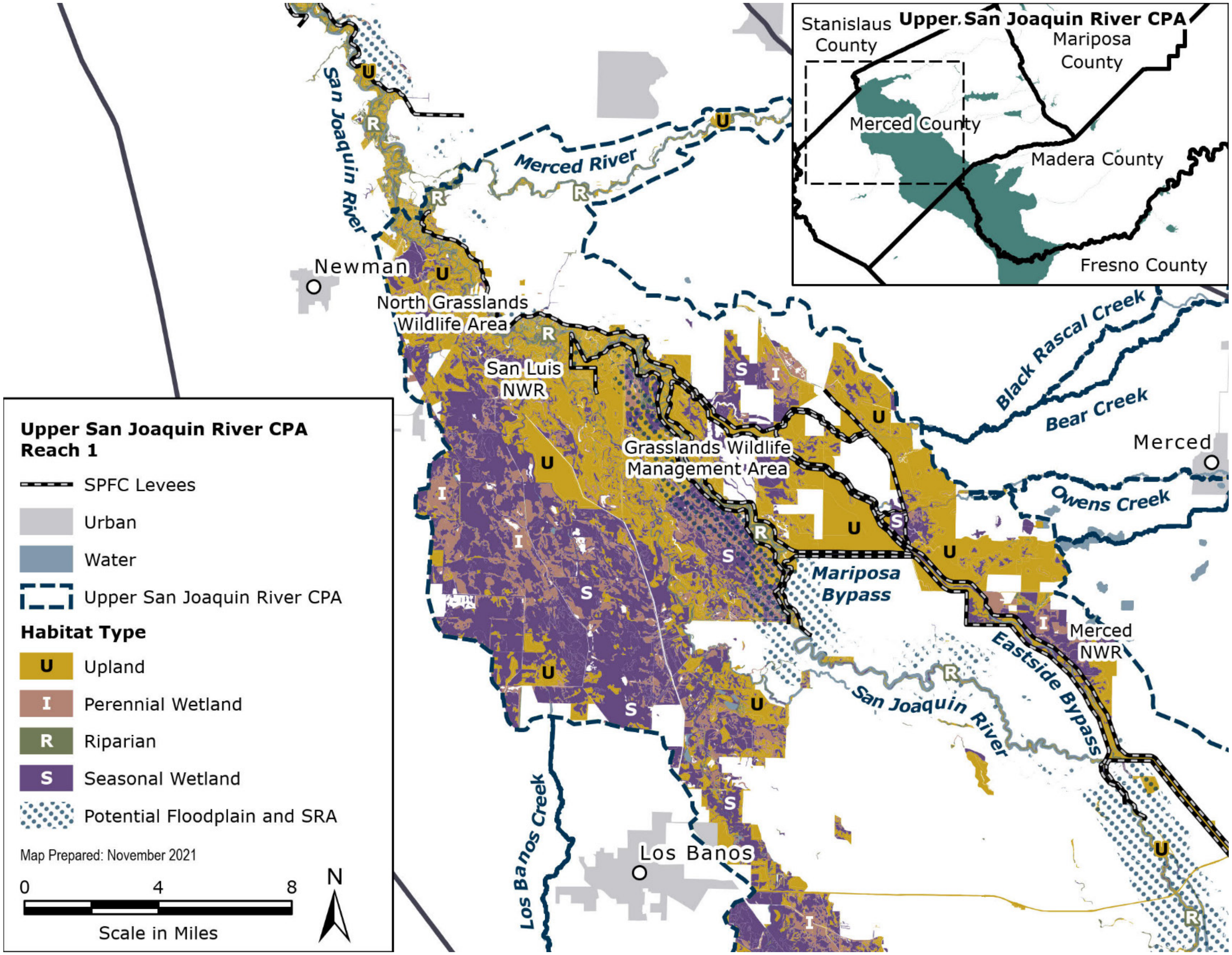


Figure H-32. Upper San Joaquin River CPA Reach 2

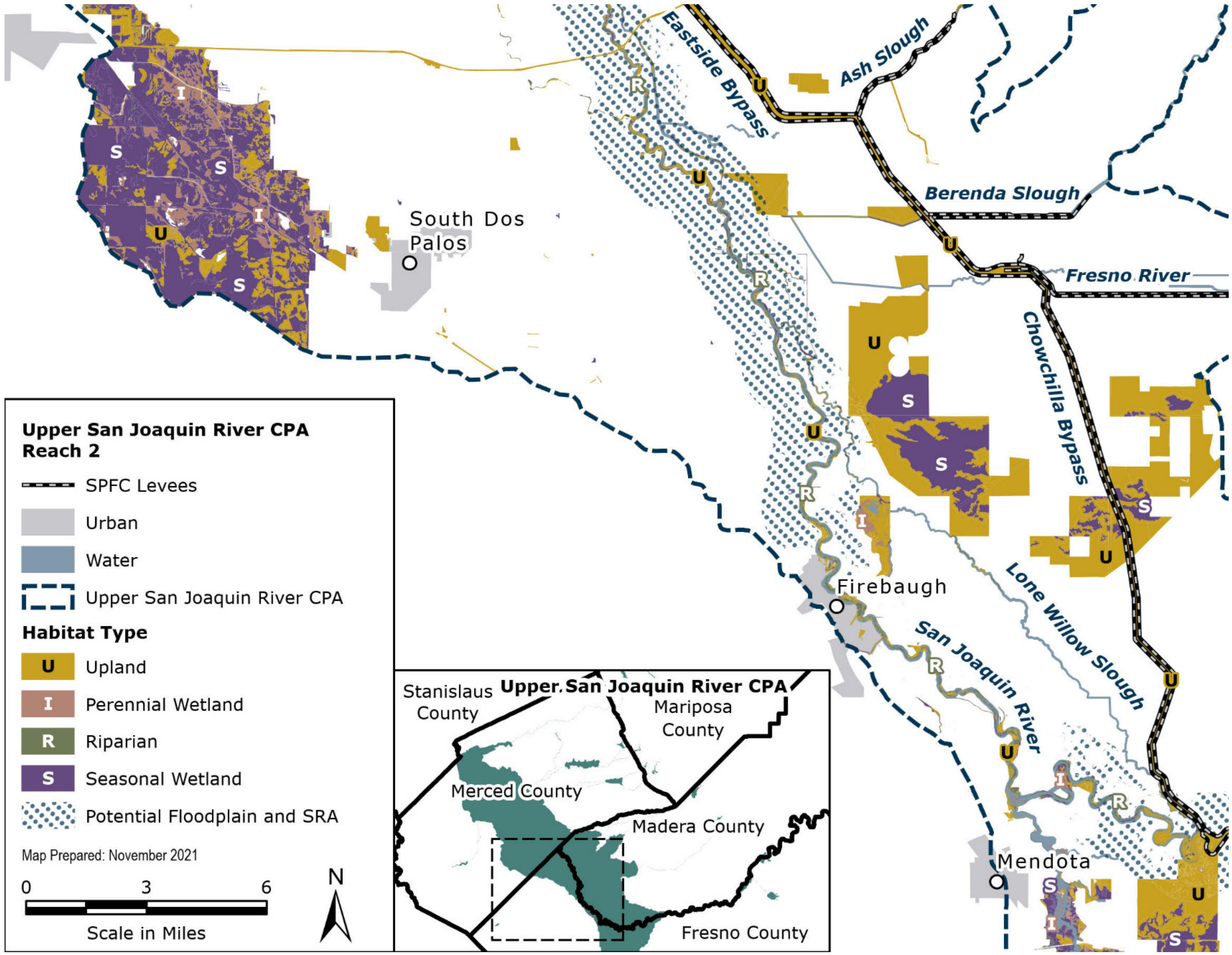


Figure H-33. Upper San Joaquin River CPA Reach 3

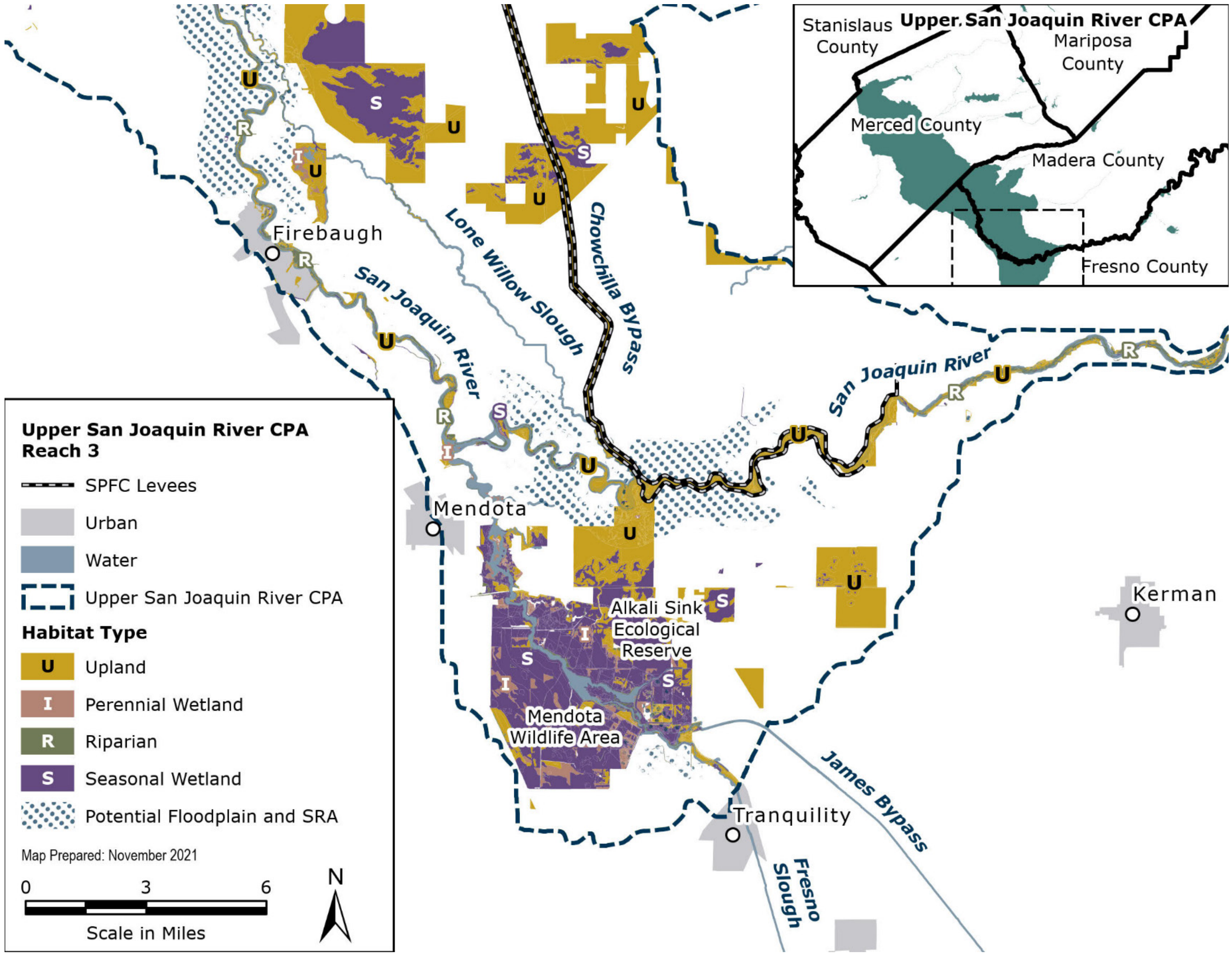
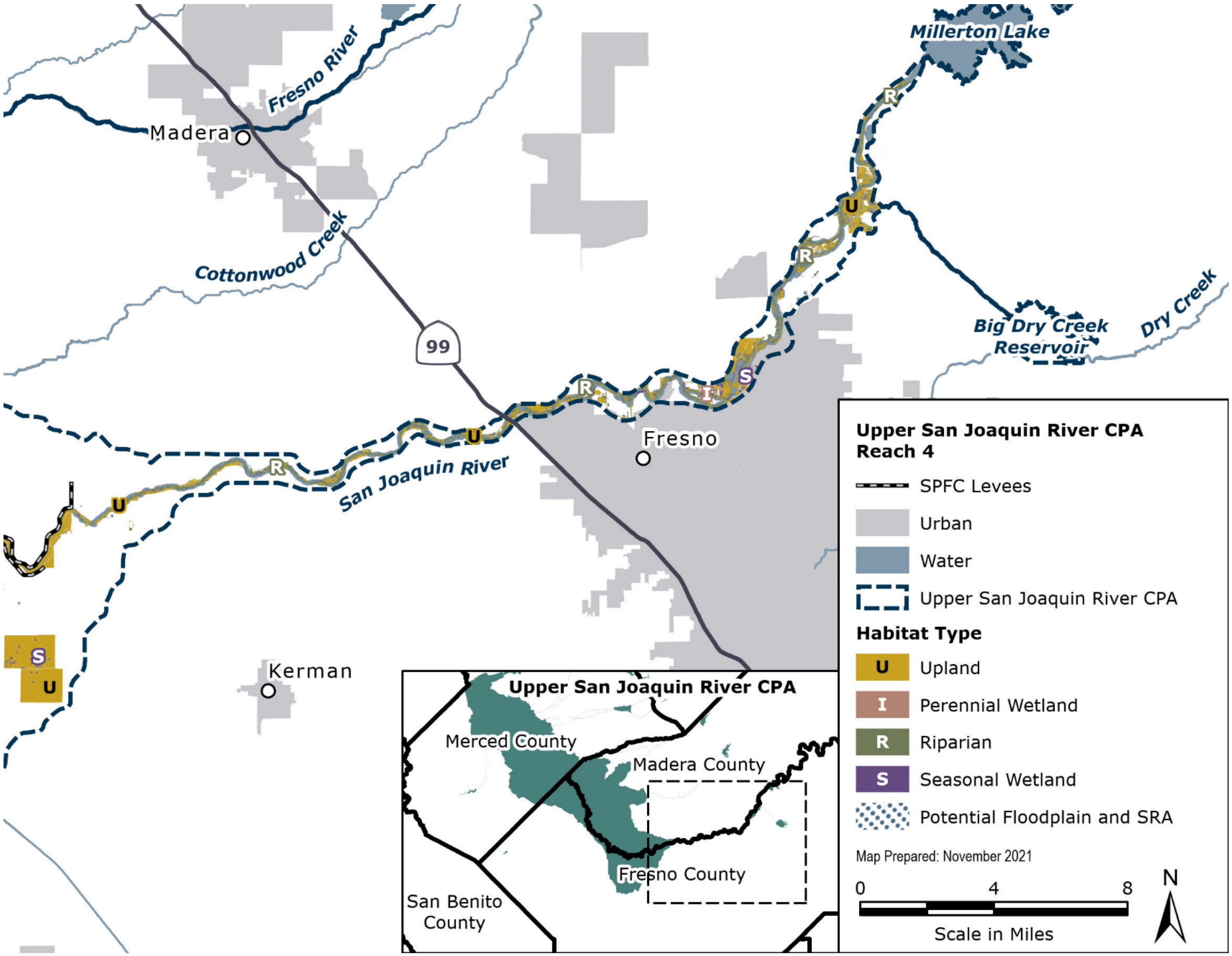


Figure H-34. Upper San Joaquin River CPA Reach 4



5.5.1 Climate Change Adaptation Risks and Opportunities – Upper San Joaquin CPA

Reach 1: This reach supports the largest remaining wetland-upland complex in the Central Valley within the Grasslands National Wildlife Area, San Luis National Wildlife Refuge, and adjacent areas. Most of the opportunities to reconnect floodplains in this reach occur in these areas, providing abundant opportunities to increase climate change resilience by reconnecting floodplains to the river and by restoring habitats to create larger, interconnected blocks of habitat. Additional opportunities to reconnect floodplains and enhance riparian, SRA, and wetland habitats occur further south along the San Joaquin River and its tributaries.

Reach 2: There are extensive areas of floodplain with topographic conditions suitable for creation of floodplain habitats. This reach of the San Joaquin River is downstream of the flood bypasses and canal diversions, and is dry during most months of the year. Enhancing this reach would require both modifications to the channels and floodplains, as well as changes in flow releases through the reach. There is no floodplain rearing currently, and agricultural diversions and return flows could pose water quality issues. The San Joaquin River Flood Control Project Levees confines the channel in many locations, and there are consequently many opportunities for floodplain reconnection. The Chowchilla Bypass and Eastside Bypasses were not designed for fish passage, and projects are underway to improve fish passage within this reach.

Reach 3: Expansive areas suitable for creating potential floodplain, wetland, riparian, and SRA habitats occur along the San Joaquin River, particularly around the Chowchilla Bypass and near the Alkali Sink Ecological Reserve and Mendota Wildlife Area, where existing habitats could be expanded and habitat connectivity could be improved. Additional areas suitable for enhancing riparian and wetland habitats occur adjacent to the San Joaquin River.

Reach 4: Adaptation potential is limited to areas suitable for enhancing existing riparian habitat adjacent to the San Joaquin River.

Table H-21. Climate Change Adaptation Strategies Available in the Upper San Joaquin River CPA

Adaptation Strategy[a] Habitat-related	Adaptation Strategy[a] Species-specific	Adaptation Potential Reach 1	Adaptation Potential Reach 2	Adaptation Potential Reach 3	Adaptation Potential Reach 4
SRA-1	SALMONID-1	High – Reach 1 provides important rearing and outmigration habitat for juvenile spring and fall/late-fall runs of Central Valley salmon and steelhead. Increased SRA would improve rearing habitat in the same manner described for the Upper Sacramento River CPA.	High – Same as Reach 1.	High – Same as Reach 1	High – Reach 4 provides important spawning habitat for spring-run Chinook salmon and steelhead, and rearing and outmigration habitat for juvenile spring and fall/late-fall runs of Central Valley salmon and steelhead. Increased SRA would improve rearing habitat in the same manner described for Reach 1 of the Upper Sacramento River CPA.

Adaptation Strategy[a] Habitat-related	Adaptation Strategy[a] Species-specific	Adaptation Potential Reach 1	Adaptation Potential Reach 2	Adaptation Potential Reach 3	Adaptation Potential Reach 4
SRA-1	WYBC-1	High – Breeding western yellow-billed cuckoos formerly occurred in the San Joaquin Valley and could become re-established with significant increases in riparian habitat. There are substantial areas suitable for floodplain expansion in Reach 1 which would allow for facilitation of dynamic riparian successional stages that could support habitat for the western yellow-billed cuckoo.	High – Same as Reach 1.	Moderate – Similar to Reach 1, but Reach 2 has less area available for floodplain expansion.	Limited – Within Reach 4, adaptation potential is limited to areas suitable for enhancing riparian habitat adjacent to the San Joaquin River.
	PLANTS-1	High – Slough thistle is likely extirpated from the SPA, but its historical range includes Reach 1. Substantial opportunities exist for riparian and wetland restoration where facilitated colonization could be implemented.	High – Same as Reach 1.	Moderate – Similar to Reach 1, but Reach 2 has slightly less are for expansion of riparian and wetland restoration where facilitated colonization could be implemented.	None.

Adaptation Strategy[a] Habitat-related	Adaptation Strategy[a] Species-specific	Adaptation Potential Reach 1	Adaptation Potential Reach 2	Adaptation Potential Reach 3	Adaptation Potential Reach 4
RIP-1	SWHA-1	High – Reach 1 currently provides suitable breeding and foraging habitat and is occupied by the Swainson's hawk. There are substantial areas suitable for expanding and enhancing riparian breeding habitat, as described for the Lower and Upper Sacramento River, Feather River, and Lower San Joaquin CPAs.	High – Same as Reach 1.	High – Same as Reach 1.	Moderate – Within Reach 4, adaptation potential is limited to areas suitable for enhancing riparian habitat adjacent to the San Joaquin River, but breeding habitat can be increased by planting native tree species used for breeding that will replace dead mature trees, trees lost through flooding, etc., and increase nesting substrate adjacent to the San Joaquin River.

Adaptation Strategy[a] Habitat-related	Adaptation Strategy[a] Species-specific	Adaptation Potential Reach 1	Adaptation Potential Reach 2	Adaptation Potential Reach 3	Adaptation Potential Reach 4
RIP-1	SONG-1	High – The yellow-breasted chat currently occurs in Reach 1. There are recent Least Bell vireo records from the San Luis National Wildlife Refuge and the Grasslands Wildlife Management Area, and this reach is within the historical range of the Least Bell's vireo. The high potential of Reach 1 for floodway expansion provides substantial opportunities to enhance and expand riparian habitat suitable for the yellow-breasted chat and Least Bell's vireo.	High – Same as Reach 1.	Moderate – Similar to Reach 1, but Reach 2 has less area available for riparian habitat creation due to expansive areas of levees.	Limited – Within Reach 4, adaptation potential is limited to areas suitable for enhancing riparian habitat adjacent to the San Joaquin River.

Adaptation Strategy[a] Habitat-related	Adaptation Strategy[a] Species-specific	Adaptation Potential Reach 1	Adaptation Potential Reach 2	Adaptation Potential Reach 3	Adaptation Potential Reach 4
RIP-1	VELB-1	High – Suitable elderberry habitat exists and the valley elderberry longhorn beetle occurs throughout Reach 1. There are substantial opportunities for levee relocation and modifying floodplain topography similar to that described for the Lower and Upper Sacramento River, Feather River, and Lower San Joaquin CPAs.	High – Same as Reach 1.	Moderate – Similar to Reach 1, but Reach 2 has slightly less area for floodplain reconnection.	Limited – While suitable elderberry habitat exists and the valley elderberry longhorn beetle is known to occur in Reach 4, there are limited opportunities for floodplain reconnection that would provide new areas for elderberry shrubs to colonize.
	VELB-2	High – Reach 1 has substantial opportunities for expansion of suitable habitat similar to that described for the Lower and Upper Sacramento River, Feather River, and Lower San Joaquin CPAs.	High – Same as Reach 1.	Moderate – Similar to Reach 1, but Reach 3 has slightly less area for expansion of suitable riparian habitat.	Limited – Adaptation potential in Reach 4 is limited to areas suitable for enhancing riparian habitat adjacent to the San Joaquin River.

Adaptation Strategy[a] Habitat-related	Adaptation Strategy[a] Species-specific	Adaptation Potential Reach 1	Adaptation Potential Reach 2	Adaptation Potential Reach 3	Adaptation Potential Reach 4
RIP-1	PLANTS-1	High - Several extant populations of Delta button-celery exist in Reach 1, so targeted vegetation management could enhance existing populations. Also, this reach provides substantial opportunities for riparian and wetland restoration where facilitated colonization could be implemented.	High – Delta button-celery is likely extirpated from Reach 2, but there are substantial opportunities for riparian and wetland restoration where facilitated colonization could be implemented.	Moderate – Similar to Reach 2, but Reach 3 has slightly less area for expansion of riparian and wetland restoration where facilitated colonization could be implemented.	None.
WET-1	SALMONID-1	High – Reach 1 provides opportunities for restoration and enhancement, as described for the Upper Sacramento River CPA.	High – Same as Reach 1.	High – Same as Reach 1.	High – Same as Reach 1.

Adaptation Strategy[a] Habitat-related	Adaptation Strategy[a] Species-specific	Adaptation Potential Reach 1	Adaptation Potential Reach 2	Adaptation Potential Reach 3	Adaptation Potential Reach 4
WET-1	GGS-1	High – Giant gartersnakes are present in this CPA, and records are especially concentrated in Reaches 1 and 2. Reach 1 provides expansive areas suitable for creating potential large areas of marsh habitat suitable for the giant gartersnake, increasing connectivity with existing habitat, especially within and adjacent to the conserved areas.	High – Same as Reach 1.	High – Same as Reach 1.	Limited – Within Reach 4, adaptation potential is limited to areas suitable for enhancing riparian habitat adjacent to the San Joaquin River, lacking opportunities to expand or create marsh habitat for the giant gartersnake.
	GGS-2	High – Reach 1 provides substantial opportunities to expand the floodway, providing upland refugia and connecting existing habitat for the giant gartersnake.	High – Same as Reach 1.	High – Same as Reach 1.	Limited – Reach 4 has very limited opportunities for floodplain expansion that could expand and connect suitable habitat for the giant gartersnake.

Adaptation Strategy[a] Habitat-related	Adaptation Strategy[a] Species-specific	Adaptation Potential Reach 1	Adaptation Potential Reach 2	Adaptation Potential Reach 3	Adaptation Potential Reach 4
WET-1	GSHC-1	High – Greater sandhill cranes are present in this CPA. Reach 1 provides expansive areas suitable for creating large areas of floodplain habitats suitable for the greater sandhill crane, increasing connectivity with existing habitat.	High – Same as Reach 1.	High – Same as Reach 1.	Limited – Within Reach 4, adaptation potential is limited to areas suitable for enhancing riparian habitat adjacent to the San Joaquin River, lacking opportunities to expand or create floodplain wetland habitats for the greater sandhill crane.
	GSHC-2	High – Same as the Lower San Joaquin CPA.	High – Same as Lower San Joaquin CPA.	High – Same as Lower San Joaquin CPA.	High – Same as Lower San Joaquin CPA.
	TCBB-1	High – Reach 1 is within the breeding range of the tricolored blackbird, and there are expansive areas available to create and enhance suitable wetland habitat.	High – Same as Reach 1.	High – Same as Reach 1.	Limited – Within Reach 4, adaptation potential is limited to areas suitable for enhancing riparian habitat adjacent to the San Joaquin River.

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CHAPTER 6

Conclusions

In the Central Valley of California, and within the CVFPP SPA in particular, ongoing and expected continued changes to temperatures, precipitation, and hydrology will affect the ecological process, habitats, and species that inhabit and use riverine corridors along the Sacramento and San Joaquin Rivers and their tributaries. These changes are already manifesting, and that rate of change has the potential to accelerate in the coming decades. The specific impacts to, and responses of, a particular natural community or species to these changes will vary depending on specific habitat needs and life history requirements. Many of the habitats and species identified in the Conservation Strategy have already been severely impacted as a result of the stressors from flood and water management infrastructure, land use changes, and other anthropogenic impacts. As climate change alters the fundamental ecological, hydrologic, and geomorphic processes that influence the distribution and quality of riverine habitats, these natural communities will undergo further stress and decline.

To mitigate the impacts of climate change, it will be necessary to build resilience by restoring these ecological, hydrologic, and geomorphic processes at a rate that can counteract the stressors of climate change. This will require the adaptation measures and actions recommended in this document to be enacted, and the pace and extent of multi-benefit project implementation to increase throughout the SPA in the coming years.

The Conservation Strategy provides guidance to make progress on developing projects that increase system resiliency; the main challenge DWR and its partners face related to climate change is primarily one of timing – for the pace of multi-benefit project implementation to increase, some of the fundamental policy issues already identified in the CVFPP and Conservation Strategy will need to be resolved, including funding, permitting, performance accounting, and addressing impediments to multi-benefit project development.

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CHAPTER 7

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Attachment H.1
Climate Change Literature Review and References

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Climate Change Literature Review and References

Table H.1-1. Summary of Climate Change Modeling and Adaptation Planning Efforts

Document Title and Author	Description	Reference
CVFPP 2017 Update Climate Modeling Work and Key Results – California Department of Water Resources (2017)	The CVFPP is an outline for improving the management of flood risk in California's Central Valley. The plan was first released in 2012 and is updated every five years. The 2017 CVFPP Update included commentary on future climate change impacts for the Sacramento River Basin and the San Joaquin River Basin. Key findings include flood volume increases of 10 to 20% over 50 years in the Sacramento River Basin and increases of 60 to 80% in the San Joaquin River Basin. The Phase IIB Climate Change Analysis provided an in-depth assessment of historical climate conditions related to flood risks and how these conditions could change under future climate scenarios. Overall, the analysis found temperatures are expected to increase, precipitation varies between scenarios, extreme precipitation is expected to intensity, and flood magnitudes and frequencies vary based on watershed but are expected to increase.	Central-Valley-Flood-Protection-Plan
Effects of Climate Change on Birds, Second Edition – Dunn and Moller eds. (2019)	This book is a collection of papers on the biological effects of climate change with an emphasis on birds, but it also discusses impacts on other taxonomic groups. It consists of four sections: a general introduction to climate and climate change; an overview of methods and data sources for studying climate change and its effects; a focus on the individual and population-level consequences of climate change, ranging from changes in physiology and behavior to shifts in distribution and abundance and long-term evolutionary changes; and a focus on interspecific effects on climate change, as well as conservation challenges faced due to climate change, and a review of how the effects on birds are linked to other taxa.	Oxford University Press

Document Title and Author	Description	Reference
Merced River Basin Flood-MAR Reconnaissance Study – California Department of Water Resources (2020)	The Merced River Basin Flood-MAR Reconnaissance Study was conducted as a 'proof-of-concept' study to apply the concepts of Flood-MAR at the scale of a watershed. This study integrated surface and groundwater models and analyses, and aimed to serve as a template for future studies. This study analyzed climate vulnerability for the Merced River Basin. Peak flow response to temperature and precipitation changes were analyzed to assess opportunities to address groundwater-depletion vulnerabilities. Adaptation strategies are provided through the Flood-MAR Scenario Planning. Three scenarios are evaluated as a means to address vulnerabilities: existing infrastructure and existing operations; existing infrastructure and reservoir reoperation; and new and/or expanded infrastructure and reservoir reoperation.	Merced-River-Flood-MAR-Reconnaissance-Study
Climate-Smart Conservation – Stein et al. 2014	Climate-Smart Conservation provides guidance to natural resource managers and conservation professionals for incorporating climate change and adapting to that change into conservation science and resource management. This document provides an overview of how climate change may affect species and ecosystems, and outlines overall principles for the successful adaptation to climate change. It presents the key aspects of climate-smart resource management and conservation, which emphasize the need to identify possible adaptation strategies and actions and implement the strategies and actions that reduce biological impacts and meet future planning conservation and management goals for particular areas of concern.	ClimateSmartGuide

Document Title and Author	Description	Reference
Tuolumne River Watershed Vulnerability Assessment and Adaptive Planning Study – California Department of Water Resources (2020)	The Tuolumne River Watershed Vulnerability Assessment was conducted to improve stakeholders' understanding of how climate change impacts water systems in this region. This study used a bottom-up approach to provide an enhanced vulnerability assessment for the Tuolumne River Watershed. The study itself is a vulnerability assessment, and some key findings include an increase in large flood events and a decrease in October storage. Impacts to flood risk, water supply/irrigation, and the environment are assessed. Following the vulnerability assessment, this study provides an adaptation assessment, which discusses adaptation strategies for the specific vulnerabilities in this watershed. Adaptation strategies include Flood-MAR, rule curve modification, FIRO, increased channel capacity, and nonstructural improvements.	Not applicable
State of California Sea Level Rise Guidance 2018 Update – California Ocean Protection Council and California Natural Resources Agency (2018)	This document provides guidance to State governing bodies in their development of risk assessments, planning, financing, and permitting associated with addressing the impacts of sea level rise as a result of climate change. The report includes a collection of the best available science on sea level rise and projections, a guide for State governing bodies to respond to these projections, and preferred adaptation approaches. The guidance does not explicitly provide vulnerability or risk assessments, but it does provide guidance on how State governing bodies should conduct them. For example, the report states risks should be assessed at community and regional levels when possible. This report does not explicitly provide adaptation strategies, but does include commentary and recommendations on how these strategies should be developed. It recommends that adaptation planning and strategies should prioritize the following considerations: social equity, environmental justice, and the needs of vulnerable communities; as well as the protection of coastal habitats and public access; and should consider the unique characteristics, constraints, and values of existing water-dependent infrastructure, ports, and Public Trust uses.	Sea-Level-Rise-Guidance

Document Title and Author	Description	Reference
Safeguarding California Plan: 2018 Update – California Natural Resources Agency (2018)	The Safeguarding California Plan: 2018 Update describes the steps the State is taking to prepare for and adapt to the effects of climate change. Over 1,000 current actions from 38 State agencies are explained. While vulnerability assessments are not explicitly performed in this plan, Principle 7: increase investment in climate change vulnerability assessments of critical built systems, outlines the importance of assessing the vulnerabilities of current infrastructure. These are also included in the list of the State's ongoing actions across sectors. Within the “water” section, some overarching actions include vigorously prepare California for flooding, support regional groundwater management for drought resiliency, diversify local supplies and increase water conservation and use efficiency, reduce Sacramento-San Joaquin Delta climate change vulnerability, and prepare California for hotter and drier conditions and improve water storage capacity.	Safeguarding-California
DWR Climate Action Plan – California Department of Water Resources (2020)	The Climate Action Plan serves as a guide to combating the effects of climate change within all aspects of the DWR. The plan is separated into three phases: a greenhouse gas emissions reduction plan, climate change analysis guidance, and a climate change vulnerability assessment. Phase III outlined an approach for the climate change vulnerability assessment and developed and implemented an adaptation plan to protect staff, business operations, and assets. An adaptation framework and approach for formulating adaptation strategies was also outlined. Furthermore, Phase III introduced concepts, framing, and the principles of adaptation, and discussed how to use these to support adaptation monitoring, evaluation, and reflection as it progresses throughout the DWR (Initial adaptation plans are outlined for DWR’s four key assets vulnerable to climate change impacts, all of which are critical to DWR’s core function: staff safety; State Water Project; Upper Feather River Watershed; and ecosystems and habitats).	Climate-Action-Plan

Document Title and Author	Description	Reference
Sacramento and San Joaquin Rivers Basin Study – U.S. Bureau of Reclamation (2016)	The Sacramento and San Joaquin Rivers Basin Study explores the potential future impacts climate and socioeconomic change can have on Central California's water supply. This study also examines how these impacts could be addressed. In particular, it assesses changes in temperature, precipitation, snowpack, runoff, and sea levels. For socioeconomic changes, increasing populations and urban growth are examined. These climate and socioeconomic changes are used to assess potential impacts to water delivery, water quality, hydropower, flood control, recreation, and ecological resources. Under ecological impacts, specifically, it considers habitats, endangered species, and flow-dependent resiliency. Here, the majority of changes result from sea level rise and temperature increases, leading to higher salinity levels and reduced cold water availability.	Sacramento-And-San-Joaquin-Rivers-Basin-Study
Sacramento-San Joaquin River Basin Case Study – RAND Corporation (2021)	The Sacramento-San Joaquin River Basin Case Study takes the findings provided by the Sacramento and San Joaquin Rivers Basin Study and creates a robust decision-making (RDM) analysis to examine the use of the "Decision-making Under Deep Uncertainty" approach to assess water resources management in the long term. The purpose of this study is to show how RDM can be applied to existing studies to strengthen results and provide a more informed manner of decision-making. The RDM steps included in this case study are framing decisions, evaluating strategies across various futures, analyzing vulnerability, analyzing trade-offs, and developing new futures and strategies. The RDM re-evaluates many of the impacts described by the Sacramento and San Joaquin Rivers Basin Study.	Sacramento-San-Joaquin-River-Basin-Case-Study

Document Title and Author	Description	Reference
Increases in Flood Magnitudes in California under Warming Climates – Das et al. (2013)	This study uses an ensemble of 16 GCMs to assess flood risk in the Sacramento and San Joaquin Valleys from changes in temperature and precipitation. These GCMs were downscaled and applied to the Northern and Southern Sierra Nevada ranges, specifically. Under these projections, the future climate appears to be either wetter or drier as a result of changing storm magnitudes and decreased snowpack. Key findings for this study include: for the Northern Sierra Nevada, half of the projections show a wetter future climate and half show a drier future climate; three-day flood magnitudes are projected to increase in both the Northern and Southern Sierra, with larger magnitudes for a 50-year return period in the Southern Sierra; the median 50-year flood magnitude increases with time, location (i.e., higher in the Southern Sierra), and climate scenario (i.e., higher with a higher emissions scenario).	Increases-In-California-Flood-Magnitudes
Potential Changes in Runoff of California's Major Water Supply Watersheds in the 21st Century – He et al. (2019)	This study examines the potential changes to runoff in eight of the major watersheds in California's Central Valley as a result of climate change. Ten GCMs under two emissions scenarios were used to feed a VIC hydrologic model, to generate general runoff projections up to the year 2099. More specifically, changes to peak, seasonal, and annual runoff at different periods are examined, in addition to changes in timing. This study finds that watersheds' geographical characteristics impact the runoff response as a result of climate change. In watersheds dominated by rainfall, runoff is expected to peak earlier in the year, with higher volumes of flow. For watersheds dominated by snow, runoff peak timing is expected to remain the same, with decreases to peak volumes as the century progresses. Overall, this study finds climate change will bring higher flood risk and increased water scarcity for supply.	www.mdpi.com

Document Title and Author	Description	Reference
Projected Changes in Water Year Types and Hydrological Drought in California's Central Valley in the 21st Century – He et al. (2021)	This study examines the potential changes to water years, hydrological droughts, and runoff in the California Central Valley as a result of climate change. To assess these changes, four climate models under two emission scenarios were used. The study finds the timing and total volume of runoff is expected to shift more toward the wetter months (October to March) from the typical snowmelt months (April to July). Under the high-emission scenario, runoff volumes show a more pronounced increase in the wet season. Under the low-emission scenario, snowmelt season runoff decreases are more apparent. Finally, the study finds that on average, the Sacramento River region will experience more wet years than the San Joaquin region in the future. The San Joaquin region is expected to experience more hydrological droughts in the snowmelt season and fewer in the wet season under climate change.	www.mdpi.com
CASCaDE Project – U.S. Geological Survey (2020)	The Computational Assessments of Scenarios of Change for Delta Ecosystems (CASCaDE) Project was developed to address and model the variety of vulnerabilities the Delta faces presently and in the future. The U.S. Geological Survey hopes to inform better decision-making by analyzing projected conditions in the Delta under various scenarios. The current CASCaDE2 model builds on the DELFT3D-FM modeling framework (which includes hydrodynamics, salinity and temperature, sediment, fish, phytoplankton, bivalves, and contaminant modeling) by applying overlying climate modeling, as well as hydrology and operations and sediment supply modeling at the watershed level. Additionally, the CASCaDE2 model includes additional output on contaminants, as well as marsh habitat.	www.cascade.gov

Table H.1-2. Summary of Climate Adaptation Guidance Relevant to Conservation Strategy Objectives

Document Title and Author	Description	Reference
A Climate Change Vulnerability Assessment of California's At-Risk Birds – Gardali et al. (2012)	This study seeks to examine, classify, and rank several bird species in California, depending on their vulnerability to climate change. Overall, 128 species, subspecies, and distinct populations were classified as vulnerable. The study includes the targeted bird species included in the 2016 Conservation Strategy (bank swallow, California black rail, greater sandhill crane, Least Bell's vireo, Swainson's hawk, and western yellow-billed cuckoo). It also assesses the vulnerability of specific habitats these bird species inhabit. Wetland and riparian habitat groups were considered some of most vulnerable to climate change, while grassland and oak woodland taxa were the least vulnerable. This study comments on the mechanisms behind the increased vulnerability of specific habitats, such as a decline in water availability leading to a reduction in freshwater wetland habitat. This study also finds that roughly 72% of the threatened and endangered species in California are at risk from the effects of climate change.	At-Risk-Birds
Why Climate Change Makes Riparian Restoration More Important Than Ever: Recommendations for Practice and Research – Seavy et al. (2009)	This study identifies and explains the importance of riparian habitats and why restoration efforts are needed to preserve the benefits they provide. Topics include the natural resilience of riparian systems, enhancing connectivity, promoting linkages between aquatic and terrestrial systems, expanding thermal refugia, and hydrological benefits. It also identifies restoration strategies that accommodate climate change, such as horticultural restoration practices, emphasizing the restoration of private lands, and promoting water and watershed management policies. This study identifies the natural resiliency of riparian ecosystems, as well as their potential to link aquatic and terrestrial ecosystems through habitat connectivity.	Riparian-Restoration-Importance

Document Title and Author	Description	Reference
Promoting Atmospheric-River and Snowmelt-Fueled Biogeomorphic Processes by Restoring River-Floodplain Connectivity in California's Central Valley – Florsheim and Dettinger (2015)	This study examines potential benefits from intentional levee breaks and weir overflow as a tool for flood management under the projected impacts of climate change. Climate change effects, such as winter flood increases, progressive spring snowmelt diminishes, and more exacerbated winter inundations are listed. To account for these changes, this study identifies that intentional levee breaks and weir overflow may serve as a method to better manage increased projected flood events while providing benefits to habitat conservation and restoration by restoring natural floodplain processes.	Atmospheric-River and Snowmelt-Fueled-Biogeomorphic-Processes
Climate Change Vulnerability of Native and Alien Freshwater Fishes of California: A System Assessment Approaches – Moyle et al. (2013)	This study performs a climate change vulnerability assessment for several native and alien freshwater fish species in the face of climate change. In total, it assessed 121 native and 43 alien fish species' current baseline vulnerability to extinction and future impacts to climate change. A total of 82% of native species were classified as highly vulnerable, with only 19% of alien species being highly vulnerable. This study determines species requiring cold water are particularly likely to go extinct. Alien species are identified as having the potential to thrive under the changing conditions.	www.ncbi.gov

Supplementary Projected Hydroclimate Changes Figures

Figure H.1-1. Projected Changes in Mean Monthly Temperature – Upper Sacramento River CPA

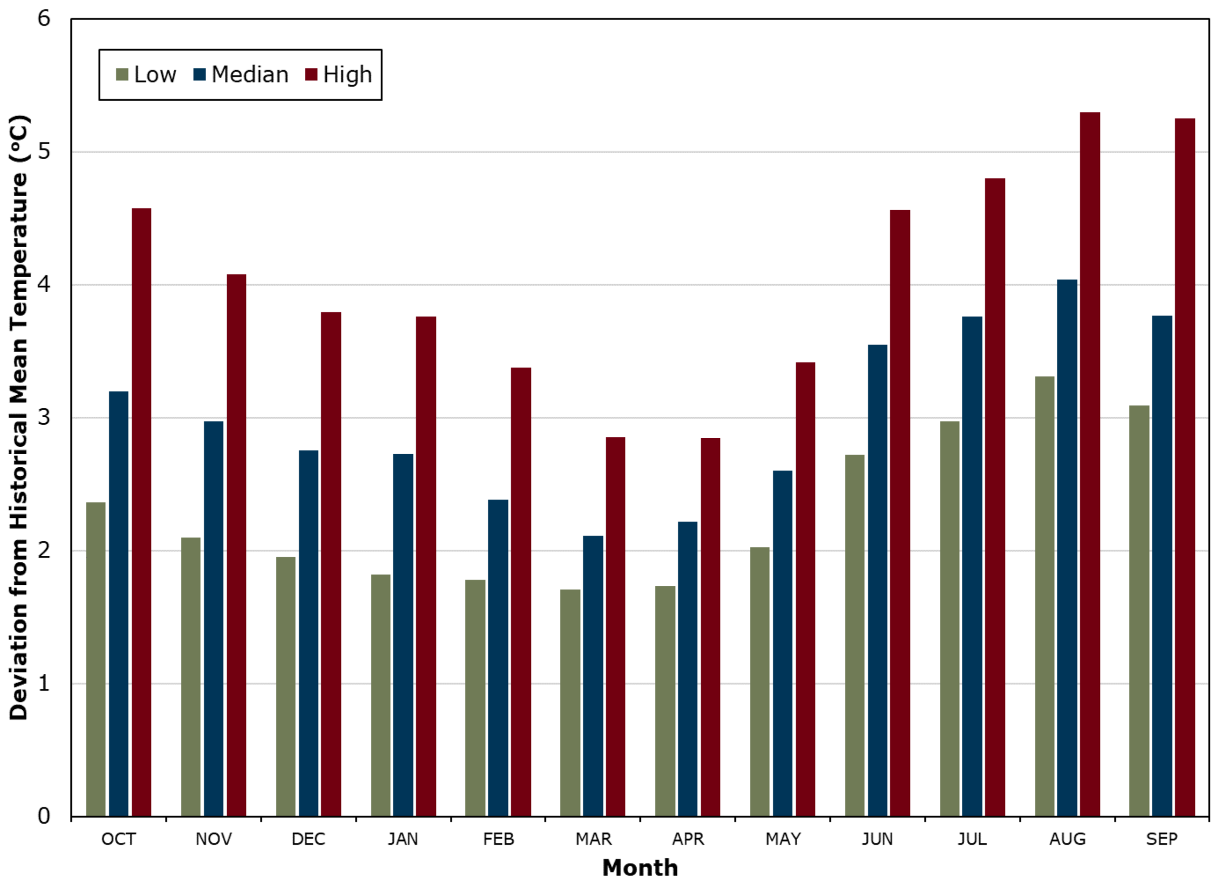


Figure H.1-2. Projected Changes in Mean Monthly Temperature – Feather River CPA

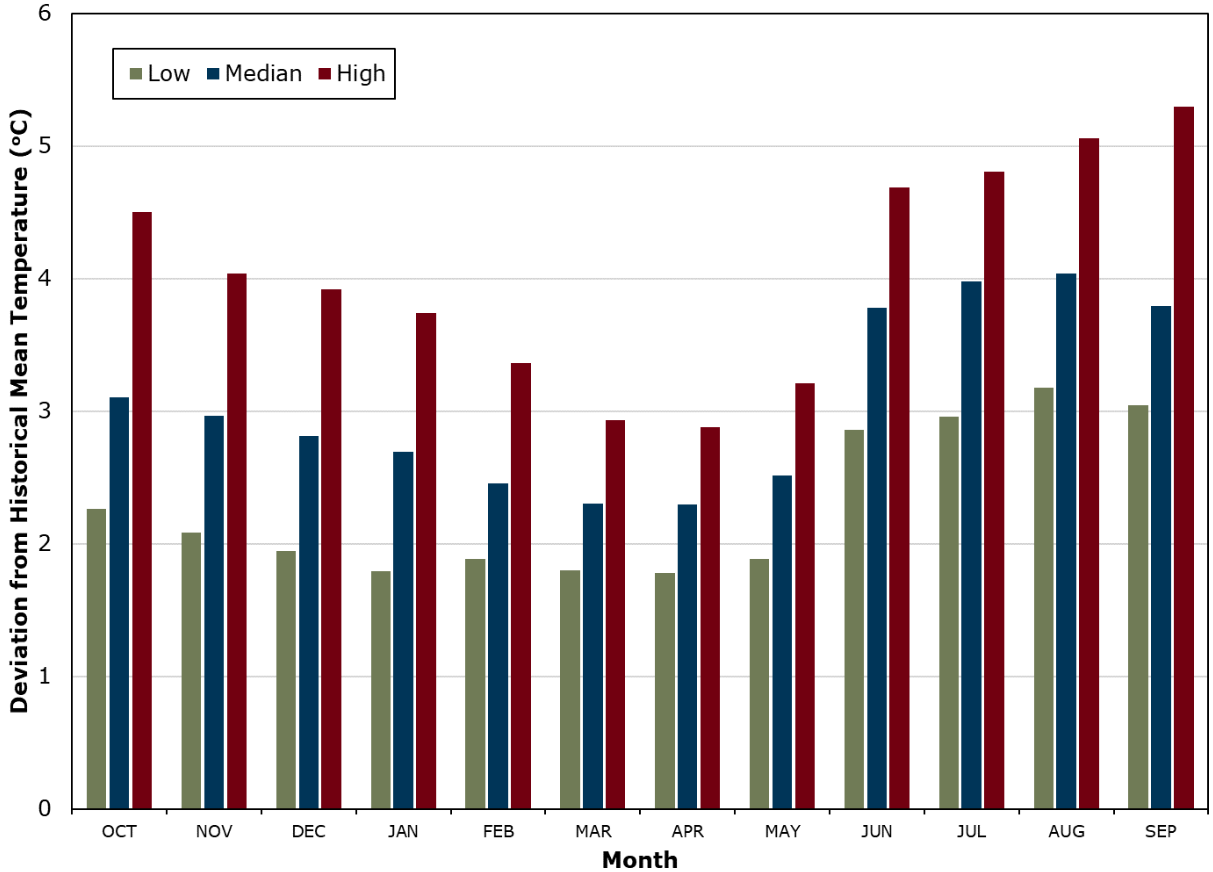


Figure H.1-3. Projected Changes in Mean Monthly Temperature – Lower Sacramento River CPA

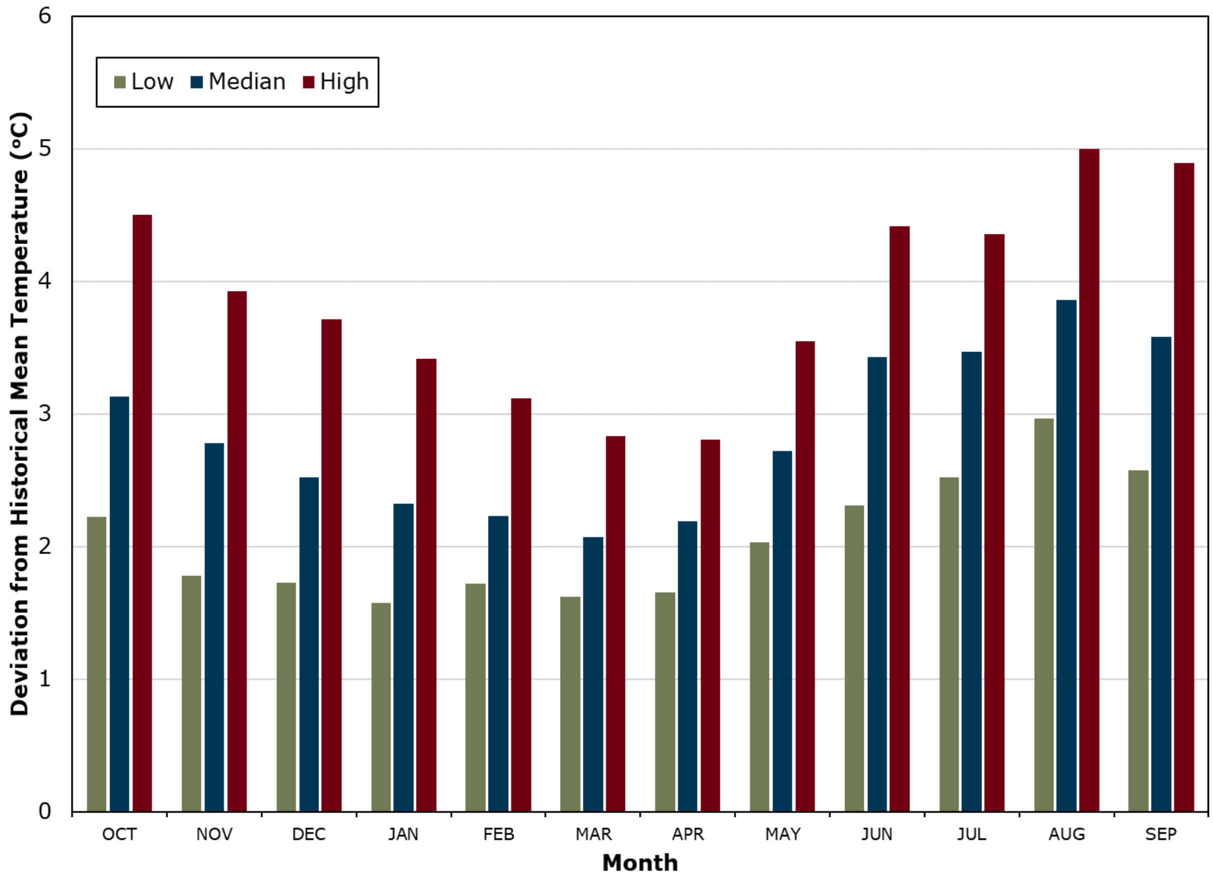


Figure H.1-4. Projected Changes in Mean Monthly Temperature – Lower San Joaquin River CPA

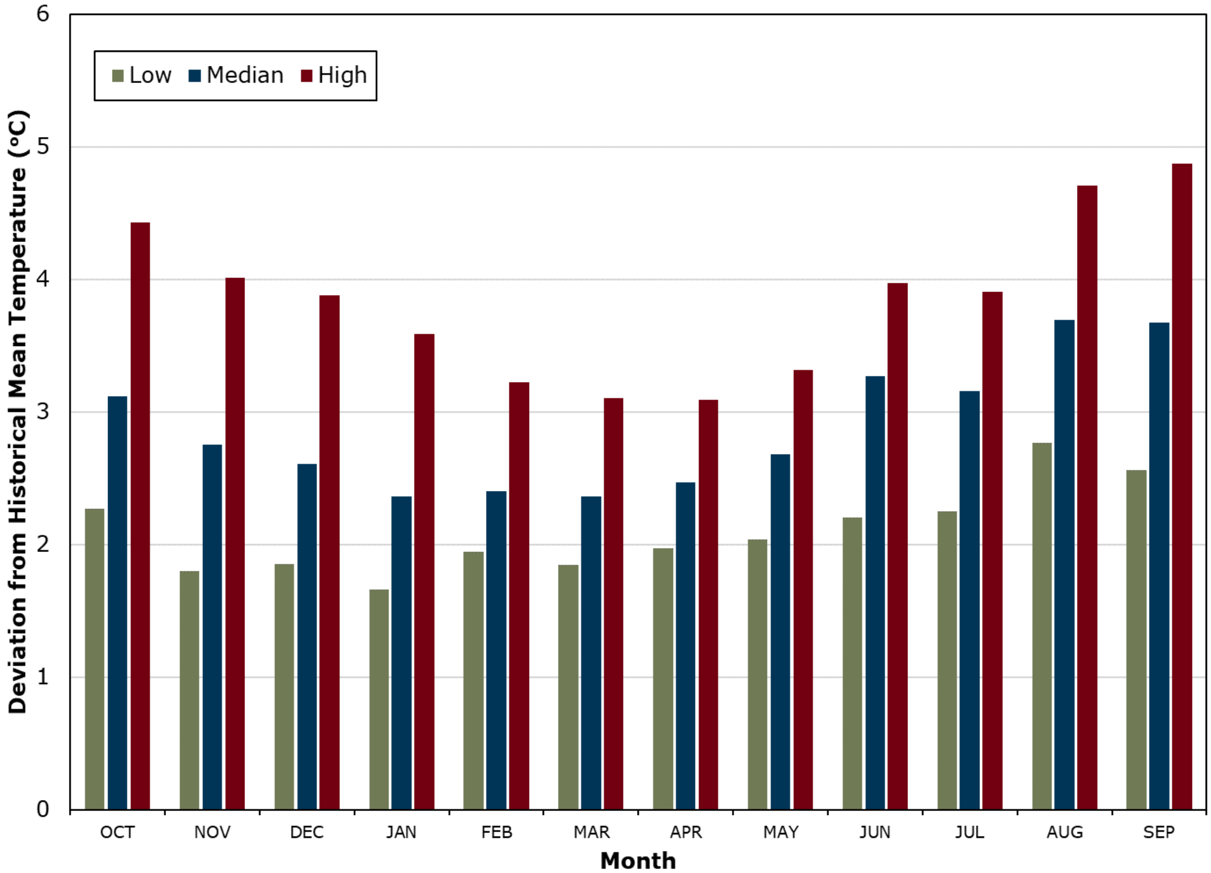


Figure H.1-5. Projected Changes in Mean Monthly Temperature – Upper San Joaquin River CPA

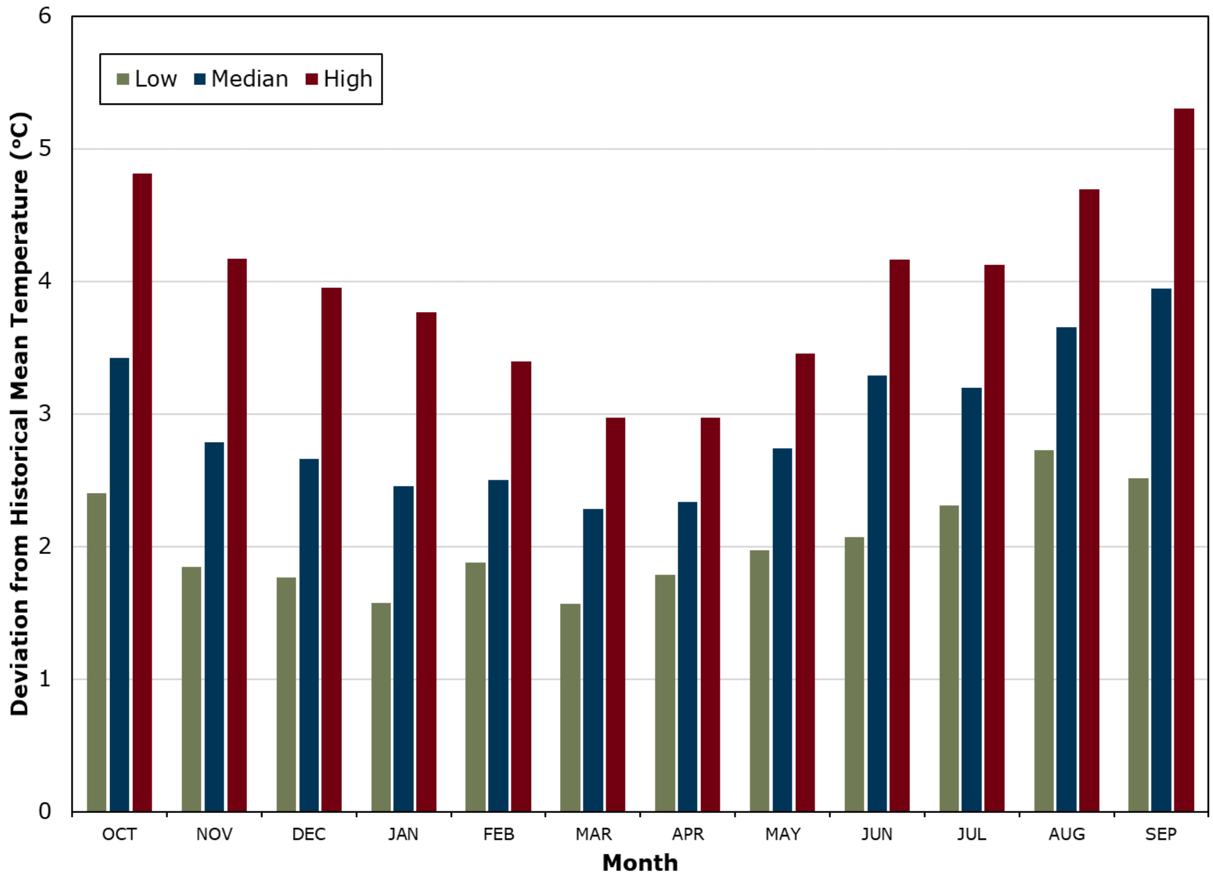
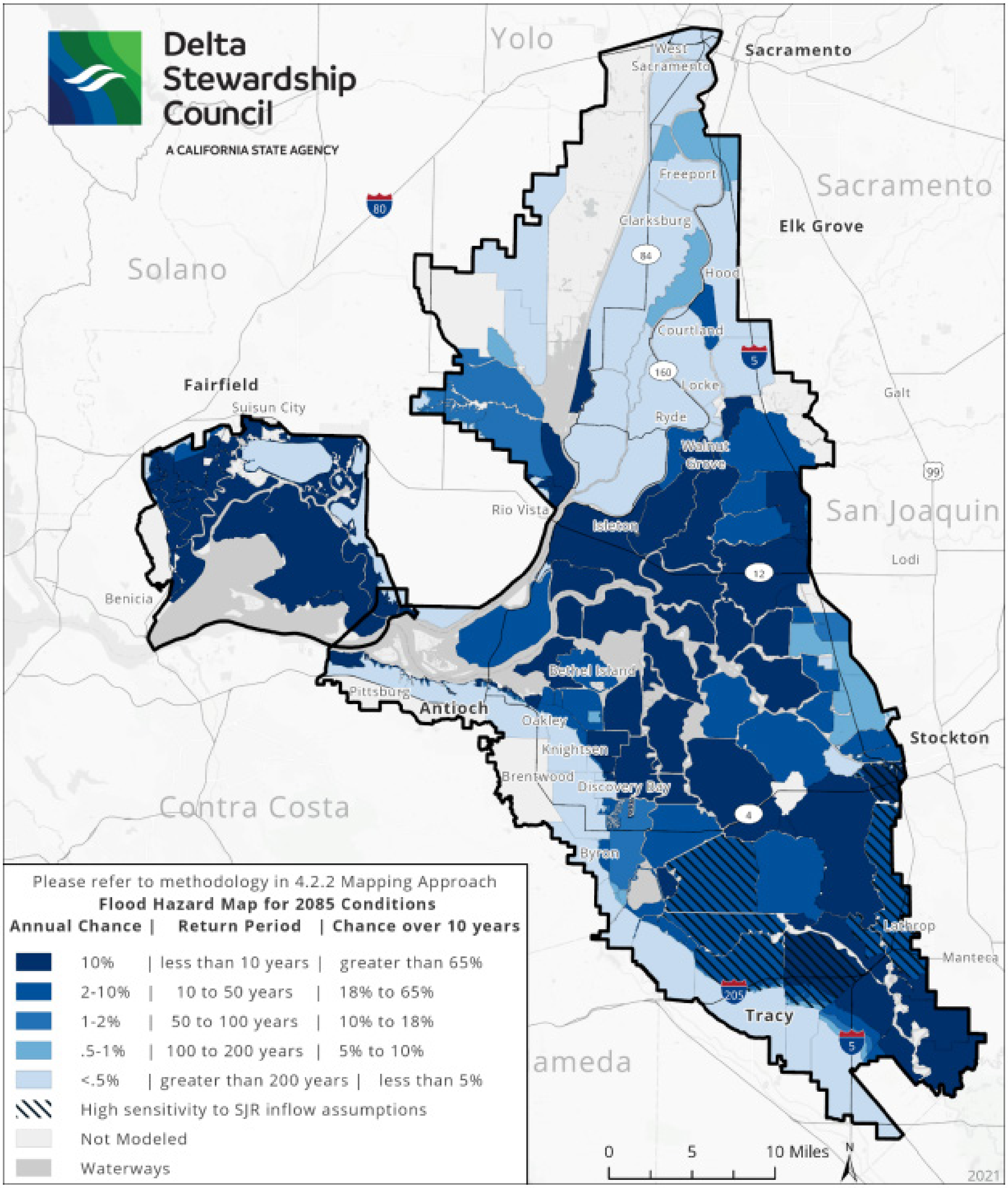
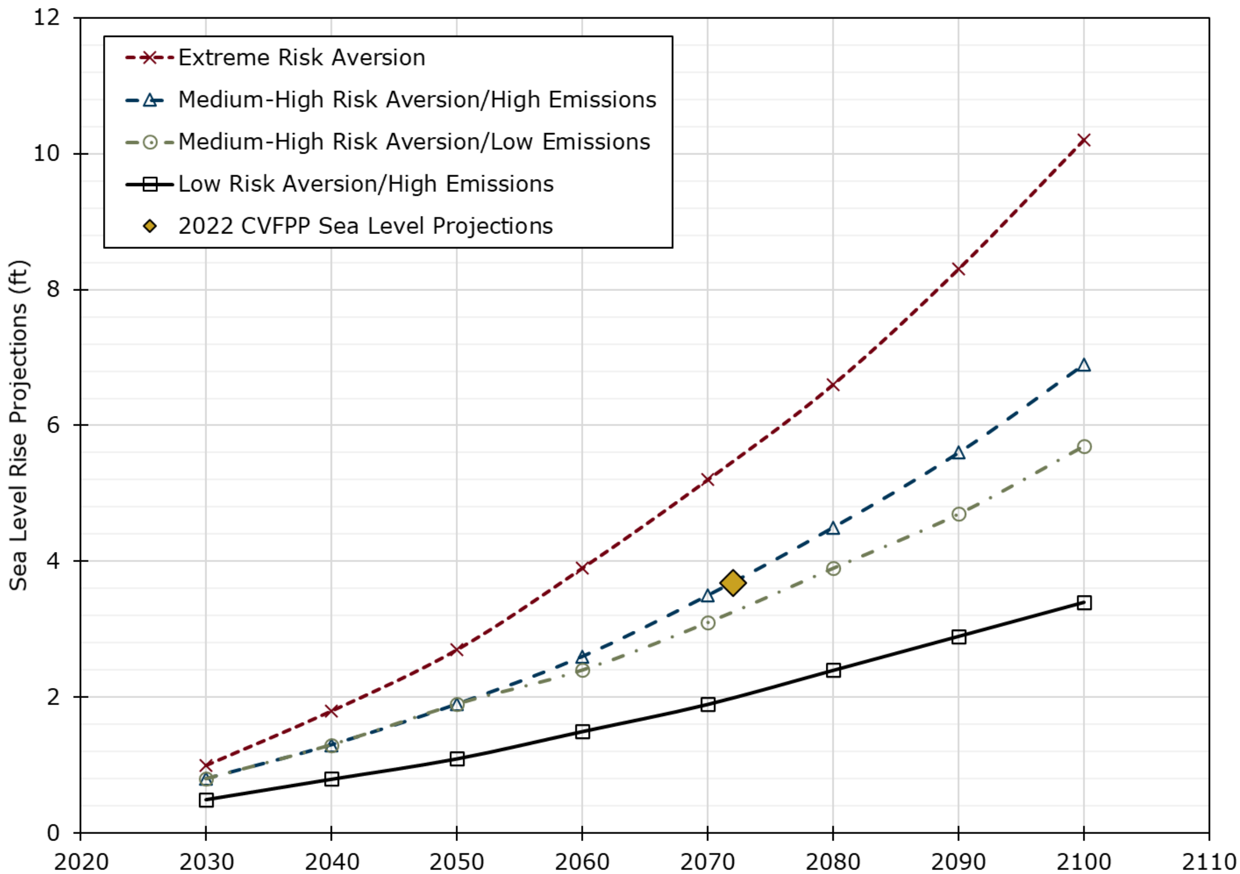


Figure H.1-6. Flood Hazard Map for 2085 Conditions



Source: Delta Adapts (Delta Stewardship Council 2021a)

Figure H.1-7. Projected Sea Level Rise (in feet) for San Francisco



Source: Adapted from CNRA and OPC (2018)