Chapter 4

Future Climate Conditions

This chapter explains how climate change is projected to affect the Ventura River Watershed, from hotter temperatures and more intense droughts to larger storms, shifting fog patterns, and coastal hazards. It translates global climate science into local, watershed-specific implications.

Introduction

This chapter describes the climate projections used to understand how conditions in the Ventura River Watershed may change over time and provides the scientific foundation for the climate vulnerability assessments that follows. It explains how the latest global and statewide climate datasets were downscaled to locally relevant projections for extreme heat, drought, precipitation, wildfire, sea level rise and storm surge, and marine fog.

These climate projections provide a basis by which to evaluate how people, infrastructure, ecosystems, and water resource systems may be exposed to and affected by climate-related hazards, supporting informed selection of adaptation strategies.

Methodology and Assumptions

Global and California Climate Projections

This Plan relies on climate projections developed for California's Fifth Climate Change Assessment (CCA5), which began releasing updated climate data and research products in 2023 and continues through 2026. California's Fifth Climate Change Assessment draws from the most recent scientific assessments of the Intergovernmental Panel on Climate Change (IPCC), whose Sixth Assessment Report was published between 2021 and 2023. These projections are based on the Coupled Model Intercomparison Project Phase 6 (CMIP6) global model ensemble and integrate information on future greenhouse gas emissions pathways and global climate simulations. As part of the CCA5 process, state research teams at Scripps Institution of Oceanography and the University of California, Los Angeles evaluated global climate models (GCMs) for their performance in representing California's historical climate. Downscaling for California uses the LOCA2 dataset, which applies a statistically based method to translate CMIP6 global model results into high-resolution projections suitable for local to watershed-scale climate analysis.

Application to the Ventura River Watershed

The localized CCA5 projections provide a consistent scientific basis for assessing climate-related hazards in the Ventura River Watershed. These projections characterize potential future changes in:

- Extreme heat
- Drought
- Precipitation
- Wildfire
- Marine fog
- Sea level rise and storm surge

The metrics used in this assessment were developed in collaboration with the Advisory Group. This collaborative process helped ensure that the metrics reflected local expertise, operational realities, and lived experiences across the watershed. In many cases, metrics were aligned with established standards, such as National Weather Service (NWS) definitions for heat-index categories, to maintain consistency with widely recognized guidance. Where appropriate, the Advisory Group also helped refine locally meaningful metrics that better capture the watershed's unique climate and hydrologic conditions. This

approach ensured that the metrics used were both scientifically grounded and relevant to local conditions.

Climate projections used in this VRWRP are organized around Shared Socioeconomic Pathways (SSPs), a set of global scenarios developed by the IPCC to represent alternative future trajectories of population growth, energy use, economic development, and greenhouse gas emissions. SSPs do not represent predictions, but rather plausible "what-if" futures that help evaluate climate risks under different levels of global greenhouse gas mitigation and societal change.

Each SSP combines a socioeconomic storyline with a corresponding greenhouse gas emissions pathway, resulting in different levels of global warming by the end of the century. For example:

- **SSP2-4.5** reflects an **intermediate** or "middle-of-the-road" trajectory in which emissions stabilize and gradually decline.
- **SSP3-7.0** represents a **higher-emissions** pathway driven by regional competition for resources and slower technological change.
- **SSP5-8.5** reflects **very high emissions** associated with fossil-fuel-intensive development.

Using multiple SSPs allows this VRWRP to evaluate climate risks across a range of plausible futures, rather than relying on a single assumed emissions outcome.

Global Warming Levels

To evaluate when major climate thresholds may be reached, this VRWRP uses Global Warming Levels (GWLs) as defined by the IPCC. GWLs represent specified amounts of global mean temperature increase relative to the pre-industrial period (1850–1900), such as 1.5 °C, 2.0 °C, or 3.0 °C of warming. The IPCC estimates the timing of each GWL based on the first 20-year period during which global temperatures exceed that threshold, providing a standardized method for comparing climate outcomes across greenhouse gas emissions pathways and modeling approaches.

Using GWLs supports planning by providing a consistent reference point for comparing climate projections, clarifying how different greenhouse gas emissions pathways influence the pace of global warming, and aligning impact assessments with temperature thresholds used in global climate policy. Based on recent global emissions trends and assessments synthesized in the IPCC's Sixth Assessment Report and subsequent analyses, current implemented policies and emissions trajectories are broadly consistent with an intermediate-to-high pathway between SSP2-4.5 and SSP3-7.0. While future emissions remain uncertain and subject to policy and technological change, observed global greenhouse gas emissions to date most closely align with scenarios that reach 1.5 °C of warming in the 2020s–2030s and approach 2–3 °C later in the century.

Exposure to climate hazards was evaluated by comparing projected conditions at GWL 3 °C with those at GWL 0.8 °C, which represents approximately present-day baseline climate conditions. The difference between these two warming levels isolates the magnitude of climate-driven change in key hazard indicators (e.g., temperature, precipitation, runoff), allowing the analysis to quantify how much conditions may shift under higher levels of global warming. This approach focuses on the incremental climate signal rather than absolute values, providing a consistent way to assess how exposure to climate hazards may intensify across the watershed as warming increases. These projections combine results from multiple GCMs and show changes at a local, neighborhood-scale level across the watershed.

A summary of the projected timing of key GWLs under multiple greenhouse gas emissions pathways is provided in Table 5 below.

Table 5 Estimated Timing of Global Warming Levels (1.5 °C, 2.0 °C, 3.0 °C) Under Different Emissions Scenarios (IPCC AR6)

GWL [1]	SSP2-4.5 [2]	SSP3-7.0	SSP5-8.5
1.5 °C (2.7 °F)	2021-2040	2021-2040	2018-2037
2.0 °C (3.6 °F)	2041-2060	2036-2055	2030-2049
3.0 °C (5.4 °F)	n.c.	2066-2085	2055-2074

[1] GWL = Global Warming Level (refers to the amount of global average temperature increase relative to pre-industrial conditions)

[2] SSP = Shared Socioeconomic Pathway (SSPs are "what if" scenarios developed under the coordination of the IPCC to explore how global society, demographics, and economics might change over the next century)

The entries report the timing of when each GWL is first crossed, expressed as a 20-year period. This central estimate represents the median crossing period across IPCC models. An entry "n.c." indicates that the GWL is not crossed during the period 2021–2100.

Source: IPCC Climate Change, 2021

Hydrologic and Coastal Projections

CCA5 includes watershed-scale hydrologic modeling based on the Variable Infiltration Capacity model, using an ensemble of GCMs to simulate future changes in runoff, streamflow, and related hydrologic metrics. Variable Infiltration Capacity simulations translate climate projections into estimates of flood magnitude, seasonal runoff timing, and drought severity by running multiple climate scenarios through a consistent land-surface model framework. These results support the analysis of watershed-scale exposure to future hydrologic hazards.

For coastal portions of the watershed, projections of sea level rise and storm surge draw from work conducted by the California Ocean Protection Council, Scripps Institution of Oceanography, and the U.S. Geological Survey's Coastal Storm Modeling System (CoSMoS) modeling system. These datasets provide consistent scenarios for evaluating future sea level rise and coastal flooding.

Summary of Results

Across all metrics and global warming levels (1.5 °C, 2.0 °C, and 3.0 °C), the projections indicate that climate change will produce a hotter and more variable future, with increased extremes across the climate hazards in the watershed. Key findings include:

- **Daytime temperatures are projected to increase** across seasons, with the largest warming in summer and fall. Figure 20 and Figure 21 show that median daily maximum temperatures rise under all GWLs, with fall warming exceeding 4 °F at 3.0 °C (GWL 3.0).
- **Nighttime temperatures will rise substantially**, reducing the number of cold nights by more than 40 days per year at higher warming levels. Figure 22 shows a sharp decline in days below 40 °F, driven by higher minimum temperatures.
- **Winter heat-index advisories will become more common**, including conditions that rarely occur under the current climate. Figure 23 and Figure 24 show increases in NWS "Caution" and "Extreme Caution" days, including in December–February.
- Drought frequency remains similar, but **droughts become more severe**, shifting from mild/moderate events toward more severe dry periods. Figure 25 and Figure 26 show that while the proportion of dry months remains stable, the distribution shifts toward "severe" Standardized Precipitation Index (SPI) conditions under higher GWLs.

- **Total precipitation increases modestly in winter but declines in spring and fall**, reshaping seasonal water availability. Figure 27 and Figure 28 show winter increases up to ~4 inches in some locations under 3.0 °C and drying in spring and fall.
- **Daily extreme precipitation intensifies**, even as multi-day storm totals weaken, shifting flood risks toward short-duration, high-intensity events. Figure 29 - Figure 31 show increases in 1-day extremes (up to ~2 inches) and decreases in 2-day and 10-day event magnitudes.
- **Compound storm sequences become more frequent**, increasing the likelihood of cascading flood and debris-flow impacts. Figure 32 shows a near doubling of sequences where a 3-inch storm is followed by a 1-in-2-year rainfall event within one week.
- **Wildfire-favorable weather conditions increase**, with more Red Flag–level days during dry, windy periods. Figure 33 shows 10–20 additional Red Flag–threshold days per year under 3.0 °C.
- **Marine fog (marine stratus) declines** by 5–10 days during summer months, intensifying coastal heat and evapotranspiration. Figure 34 shows reductions in June–September cloud-cover days, particularly in the lower watershed.
- **Sea level rise will progressively narrow** beaches and degrade coastal and estuarine habitats with sunny day flooding. Figure 35 and Figure 36 demonstrate the extent and frequency of 100-year coastal storm flooding near the Ventura River mouth, particularly under higher sea level rise scenarios that constrain shoreline migration.

Relationship to Prior Climate Studies and Sustainability Plans

Climate projections applied in this VRWRP build on the earlier analyses completed for Ventura County, including the Western Regional Climate Center's Projected Changes in Ventura County Climate report (Oakley and Hatchett 2019) and Upper Ventura River and Ojai Valley GSPs, which incorporated climate change data for their assessment of future groundwater conditions.

The Western Regional Climate Center's Projected Changes in Ventura County Climate report relied on the 4th California Climate Assessment and quantitively evaluated precipitation and temperature changes under the RCP 8.5 scenario. The report identified both maximum and minimum temperature changes, with changes greatest in the summer and fall seasons. Inland areas were identified as areas most likely to see an increase of at least 3–5 °F. Coastal areas were identified as areas likely to see an increase of at least 2–3 °F. Inlands areas with low-to-moderate elevation were identified as areas to see the greatest change in number of days exceeding extreme/impactful temperature thresholds. The report also indicated an increase in the number of dry days in the spring and fall; and little change projected in precipitation totals, implying intensification of precipitation. The report also identified the possibility of more frequent days exceeding historic 85th percentile daily precipitation. While there are some differences in the seasonal timing of precipitation changes between the Western Regional Climate Center's Projected Changes in Ventura County Climate report and this VRWRP's findings, the overall predictions for intensification of storms are aligned. Predictions in temperatures between the report and this VRWRP are generally aligned.

Both the Upper Ventura River and Ojai Valley GSPs relied on technical methods consistent with SGMA requirements, focusing primarily on groundwater models, historical hydrology, and adaptive management, rather than quantitative climate-change scenario modeling. These models were driven by historical climate and hydrologic data, consistent with SGMA's requirement to use a 50-year historical hydrologic baseline as the basis for projected water budgets, as required in §354.18(c)(3) of SGMA. Change-factor climate-change datasets, provided by DWR, were applied to historical hydrology and included projected climate and hydrologic data for 2030 central tendency scenario, 2070 central

tendency scenario, and 2070 extreme scenarios (drier with extreme warming and wetter with moderate warming). Both GSPs consider climate change qualitatively and acknowledge that warming temperatures, hydrologic variability, and wildfire may influence groundwater recharge and surface-water interactions over time. The GSPs apply DWR's climate change adjustment factors to develop future water-budget components and use SGMA's adaptive-management framework and ongoing monitoring to address remaining uncertainties.

The VRWRP should be viewed as a complementary study to these previous efforts, using the CMIP6 data consistent with California's 5th Assessment climate data to provide updated, downscaled, and watershed-specific projections of extreme heat, drought severity, precipitation extremes, wildfire-related conditions, marine fog, and sea level rise and storm surge. This expanded analysis identifies climate-driven stressors that may reduce water supply reliability, alter groundwater–surface water interactions (such as diminished baseflows and changes in recharge patterns), degrade ecological conditions, and increase infrastructure exposure to flooding, erosion, wildfire, and power disruptions, while remaining consistent with the resilience-based planning framework embedded in SGMA. Specific updates provided by the VRWRP include CMIP6 climate simulations, 3-km Weather Research and Forecasting (WRF) dynamical downscaling, and LOCA2 hybrid statistical downscaling. The newer VRWRP findings produce high-resolution watershed-specific projections of the climate hazards using data that was not available or used during GSP development. The VRWRP therefore provides a more realistic and spatially focused assessment of how climate hazards may evolve, which provides forward-looking climate stressor information that can complement the existing GSPs.

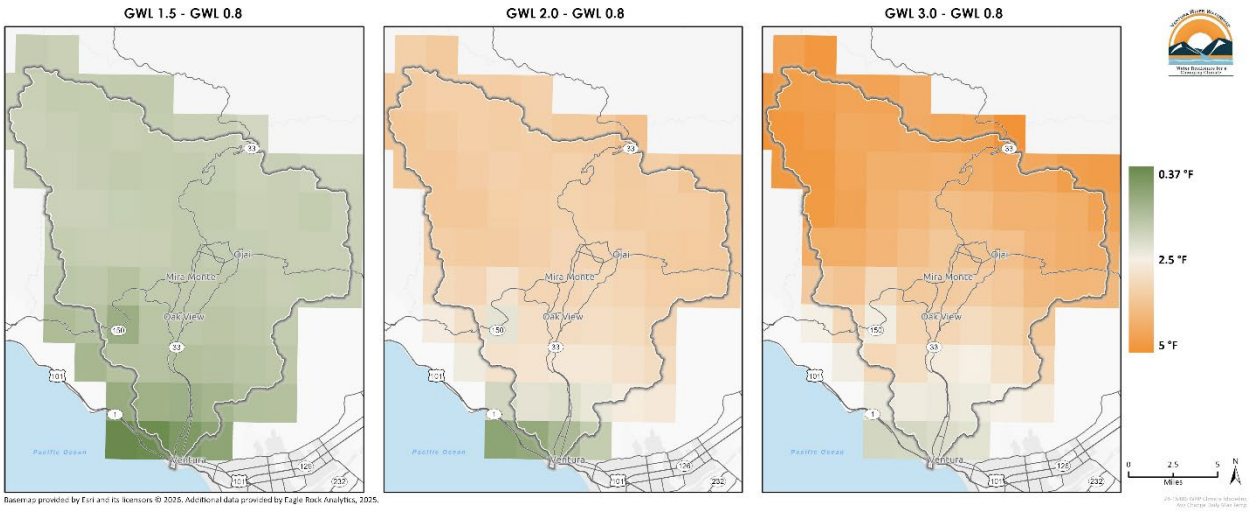
Extreme Heat Discussion

Extreme heat, defined as anomalously high temperatures for extended periods of time, directly impacts human health, heat sensitive economies, ecosystems, and infrastructure. Characterizing the changes in duration and intensity of both daytime and nighttime temperatures under a warming climate is critical for making climate-informed adaptation decisions for the Watershed. Multiple metrics analyzing daily highs and lows as well as heat indices were developed to assess the risk of extreme heat for the Watershed.

Under 3.0 °C of warming, the number of days exceeding the historical extreme heat threshold (89.9 °F) within the watershed is expected to increase by roughly 25 days. Daily max temperatures are expected to increase by 2 °F on average for the entire year by mid-century and 4 °F near the end of the century. The largest increase will occur during the spring and fall, with over 4 °F of warming expected by the end of the century in fall (September, October, November). Nighttime temperatures will provide little relief with an anticipated increase in nighttime temperatures (i.e., an increase in minimum temperatures) of over 6 °F during fall. Nights with lows below 40 °F will decrease by at least 40 days per year. The figures below use the anticipated change in median daily maximum temperature, showing how a typical day's high temperature increases as global warming levels rise, relative to a 0.8 °C baseline. The 0.8 °C baseline refers to the amount of global mean temperature warming above pre-industrial conditions that is used as the reference period for comparison in this analysis.

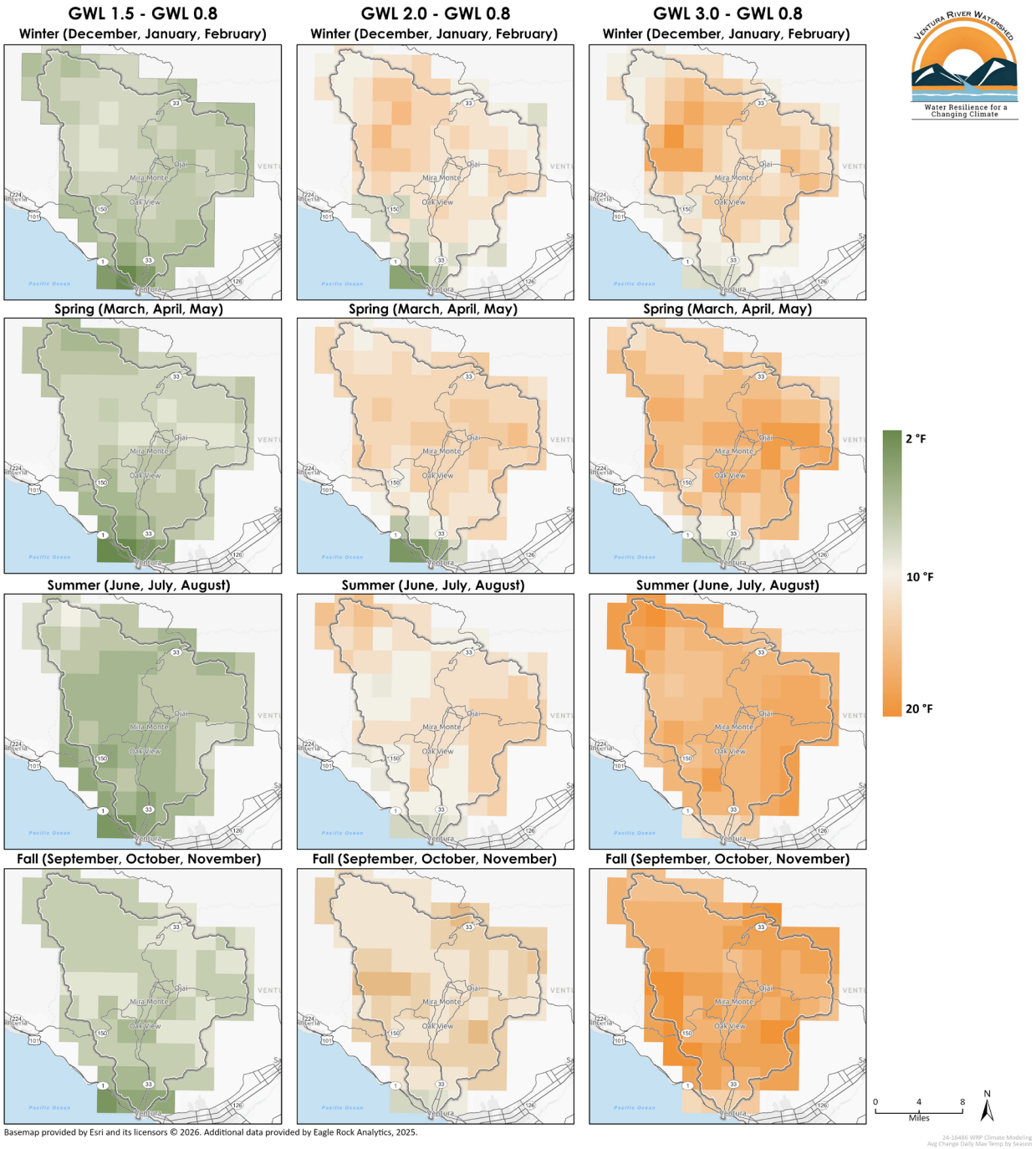
The NWS issues heat warnings depending on the severity of the heat index, a derived metric that incorporates humidity and temperature. The watershed should anticipate at least 20 more 'Extreme Caution' or higher days by midcentury. Under 3 °C of warming, the Ventura River Watershed could see 'caution advisories' issued during winter (December, January, and February), something typically not observed. This suggests little seasonal reprieve in heat index.

Figure 20 Average Change in Daily Maximum Temperature



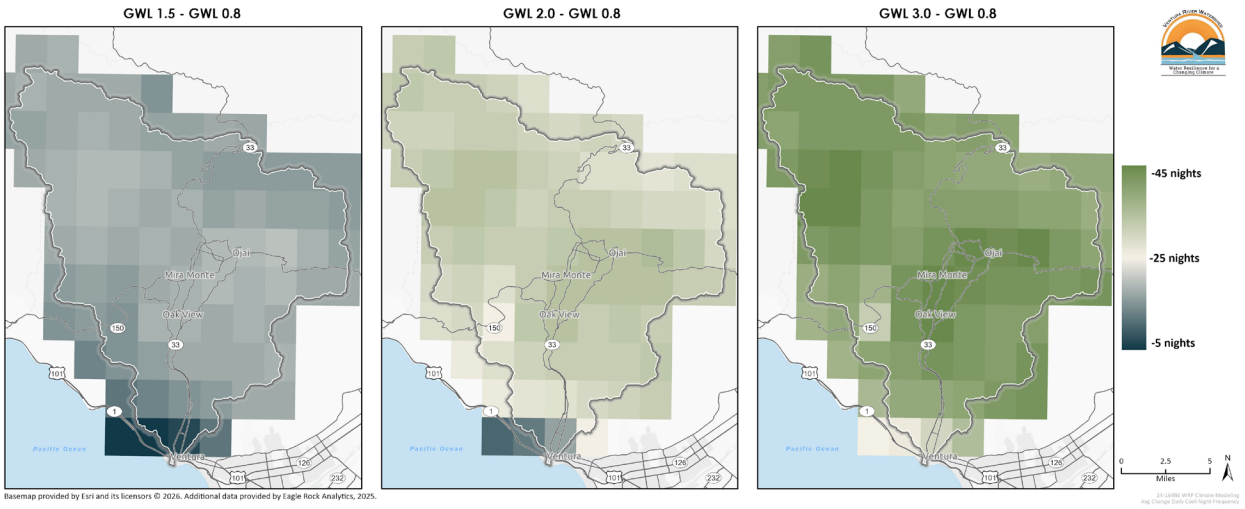
This figure shows projected changes in average daily maximum temperature under 1.5 °C, 2.0 °C, and 3.0 °C GWLs, relative to a 0.8 °C reference GWL. Each panel illustrates the spatial distribution of temperature change for the watershed at a different warming level, depicting how average daytime high temperatures increase across the landscape as global warming intensifies.

Figure 21 Average Change in Daily Maximum Temperature by Season



This figure shows projected changes in average daily maximum temperature by season (winter (DJF), spring (MAM), summer (JJA), and fall (SON)) under 1.5 °C, 2.0 °C, and 3.0 °C GWLs, relative to a 0.8 °C reference GWL. Each panel illustrates the spatial distribution of temperature change for the corresponding season and warming level, allowing comparison of how projected warming varies across the watershed throughout the year.

Figure 22 Average Change in Cool-Night Frequency

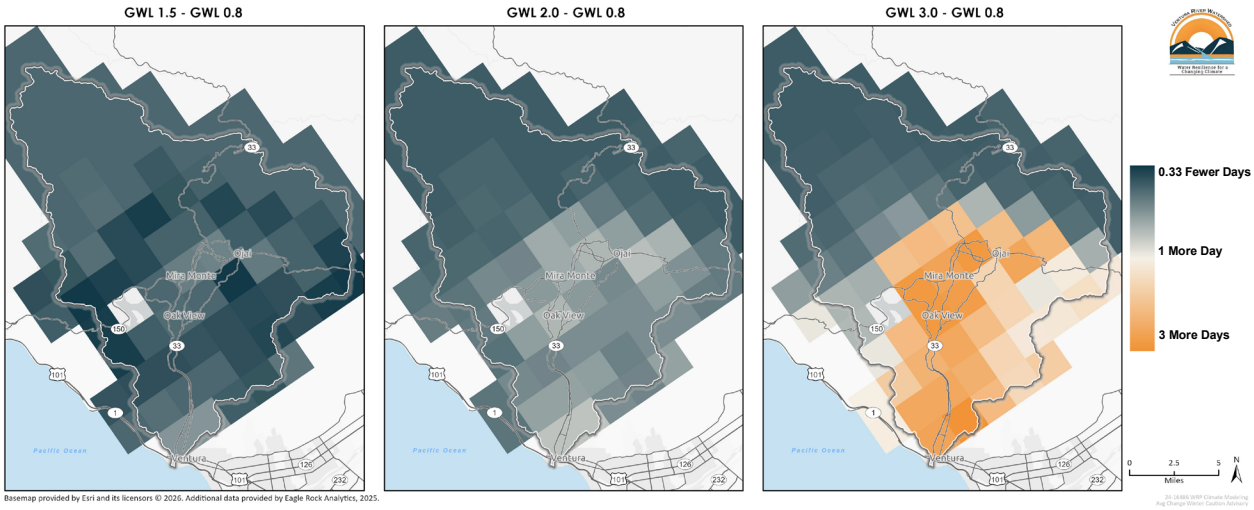


The figure depicts the difference in the average number of nights per year falling below the historical 25th-percentile minimum temperature threshold (40 °F), comparing future GWLs to a 0.8 °C reference GWL. Across all warming levels, the region experiences a substantial decline in cool nights, with losses increasing at higher global warming levels. Reduced nighttime cooling contributes to greater heat stress for people, ecosystems, and infrastructure, and limits the overnight recovery period that typically moderates daytime heat impacts.

Figure 23 Average Change in the Number of Days per Year with an 'Extreme Caution' Advisory Issued from the NWS

The figure shows projected changes in the average annual number of days triggering an "Extreme Caution" advisory from the NWS, defined by the National Oceanic and Atmospheric Administration (NOAA) Heat Index as temperatures between 90–103 °F, under 1.5 °C, 2.0 °C, and 3.0 °C GWLs, relative to a 0.8 °C reference GWL. Each panel displays the spatial distribution of changes in 1-day consecutive heating events for the corresponding warming level, showing how increasing temperatures lead to more frequent heat-stress conditions in the watershed, particularly in areas near Ojai, Mira Monte, and Oak View.

Figure 24 Average Change in the Number of Days per Winter with a 'Caution' Advisory Issued from the NWS



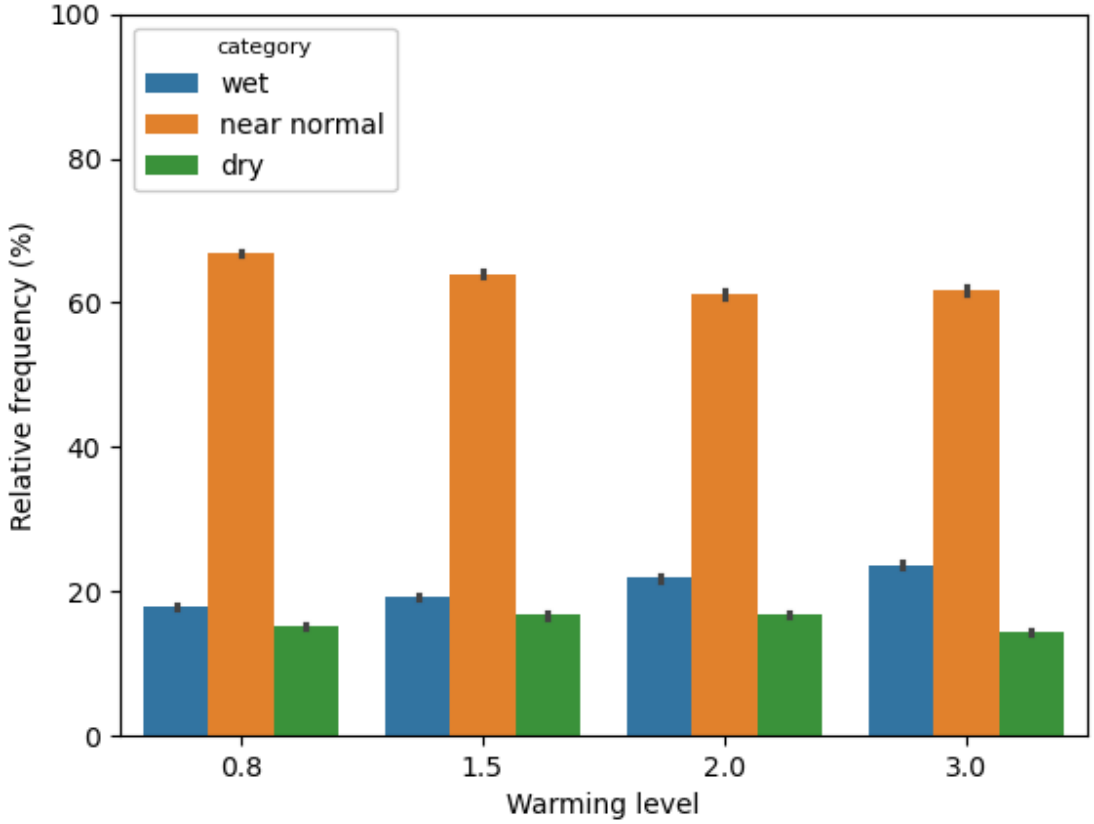
This figure shows projected changes in the number of winter days (December–February) triggering a "Caution" advisory from the NWS, defined by the NOAA Heat Index as temperatures between 80–90 °F, under 1.5 °C, 2.0 °C, and 3.0 °C GWLs, relative to a 0.8 °C reference GWL. Each panel presents the spatial pattern of changes in 1-day consecutive heating events for the corresponding warming level. These patterns illustrate how continued warming increases the projected frequency of hot winter days in the watershed, particularly in the City of Ventura, City of Ojai, and towns of Oak View and Mira Monte.

Drought Discussion

Droughts can span timescales ranging from weeks (flash droughts) to years. There are many different types of droughts (hydrological, meteorological, snowpack, etc.) and many metrics to characterize. The SPI was selected, a common statistical tool used to characterize meteorological droughts by measuring how much precipitation deviates from the long-term historical average over a specific period, . SPI values are interpreted as standard deviations from the historical mean.

The SPI is broken into three main categories, providing an overview of the general change or shift in precipitation patterns in the future: Wet (SPI of +1.00 or higher), Normal (SPI of -0.99 to +0.99), and Dry (SPI of -1.00 or lower). The watershed should anticipate little to no change in the frequency of dry periods. Within the dry category, however, SPI can be further broken into mild, moderate, and severely dry subcategories. While the frequency of dry periods is projected to remain constant, the split between the three subcategories will likely change. The watershed should anticipate the frequency of severe droughts to increase while the frequency of mild and moderate droughts decreases, suggesting an overall shift from mild to severe. Thus, though the frequency of droughts is projected to remain the same, they will likely become more severe.

Figure 25 Relative Frequency of Precipitation Conditions by Global Warming Levels



This figure shows the relative frequency of wet, near-normal, and dry conditions within the Ventura River Watershed based on the 36-month SPI. Values represent the percentage of total months classified into each SPI category across four GWLs (0.8 °C, 1.5 °C, 2.0 °C, and 3.0 °C).

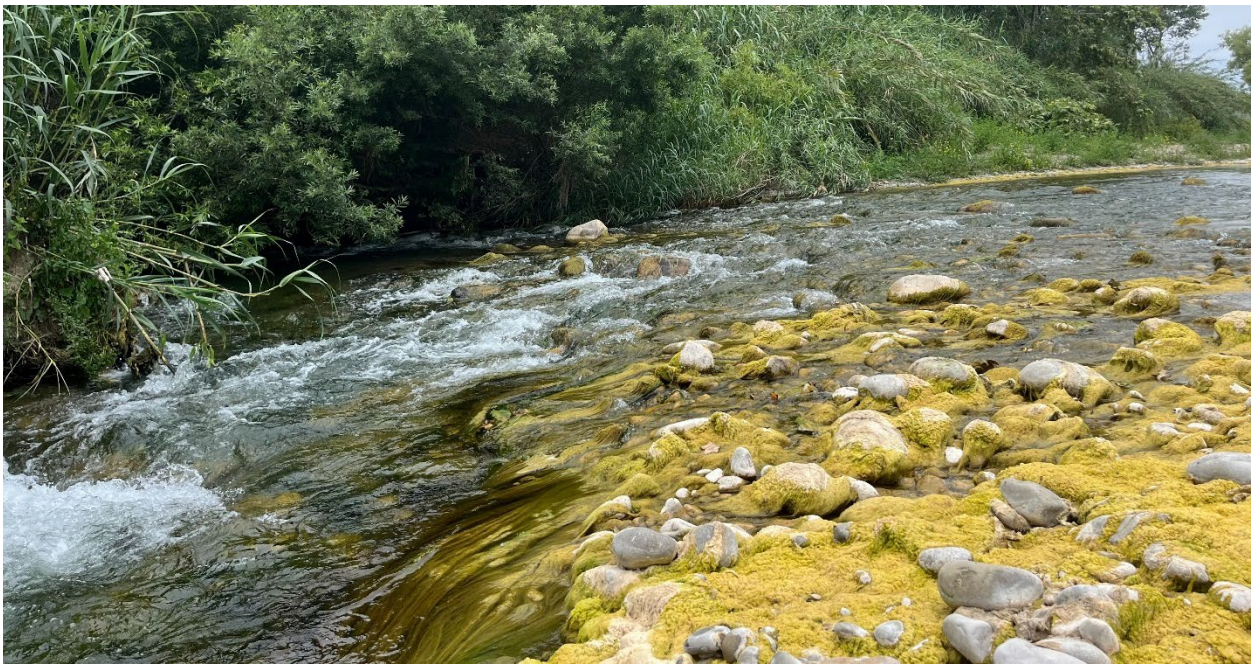
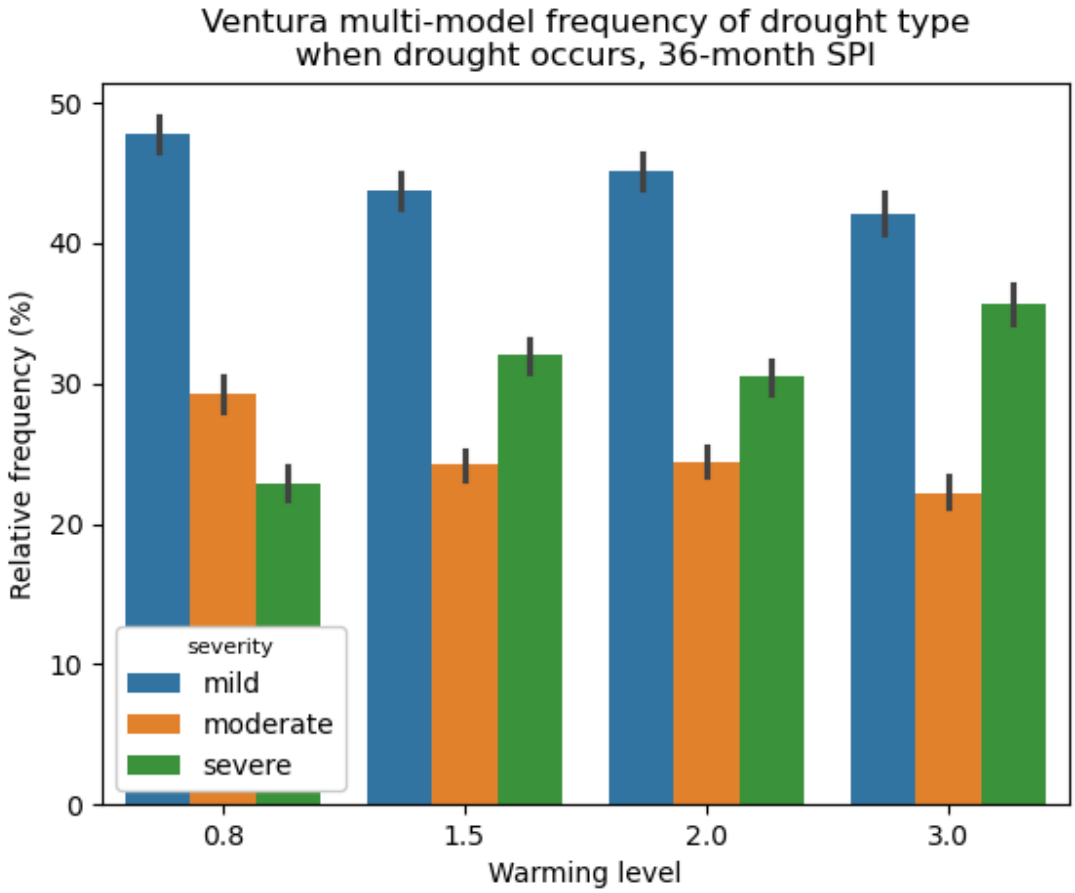


Figure 26 Relative Frequency and Severity of Droughts by GWL



This figure illustrates the relative frequency of mild, moderate, and severe drought conditions within the "dry" category defined in Figure 26, based on the 36-month SPI. Values represent the percentage of drought months falling into each severity class across four GWLs (0.8 °C, 1.5 °C, 2.0 °C, and 3.0 °C).

Precipitation Discussion

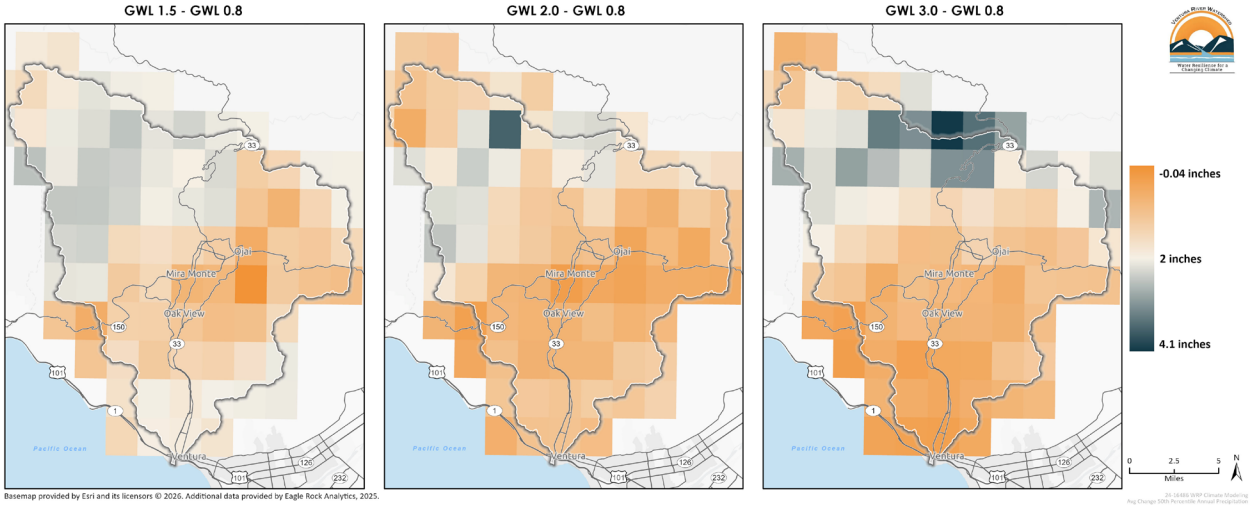
Intense periods of heavy rain extending hours to days can impact water infrastructure, water quality, transportation systems, and result in compounding events, such as mudslides. Understanding how the sequencing of storms, annual median precipitation, and daily extreme precipitation will change under a warming climate is critical for water resource and flood management. Three metrics were selected for characterizing changes in precipitation: median annual precipitation, daily precipitation, and the frequency of back-to-back heavy rain events.

Median Annual Precipitation

The watershed should anticipate an increase of up to 4 inches for both wet and dry years in median annual precipitation under 3 °C of warming, consistent with the drought metric, SPI, which showed a shift towards more wet periods. The median of all simulations across all years shows an increase in precipitation under 3 °C of warming, up to 4 inches in some locations within the watershed but with ranges from 0–4 inches overall. The expected increase will come during winter (December, January, and

February). Drying is anticipated in the shoulder seasons of spring (March, April, and May) and fall (September, October, and November).

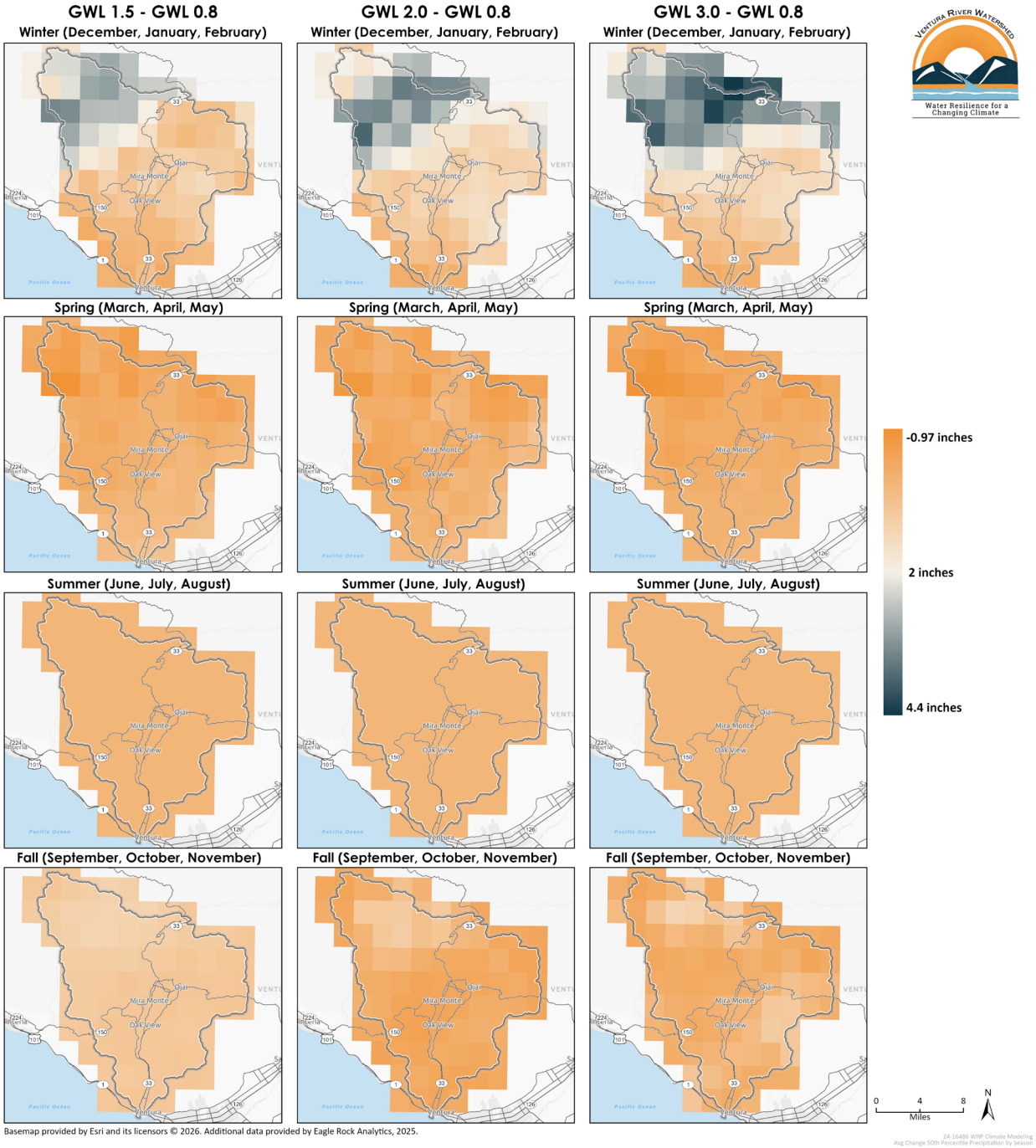
Figure 27 Average Change in 50th Percentile (Median) of Annual Precipitation



This figure shows projected changes in 50th percentile (median) of annual precipitation under 1.5 °C, 2.0 °C, and 3.0 °C GWLs, relative to a 0.8 °C reference GWL. Each panel illustrates how median annual precipitation shifts across the watershed, highlighting increases in precipitation or drying depending on location.

Photo Credit: Rich Reid/Surfrider Foundation

Figure 28 Average Change in 50th Percentile (Median) Precipitation by Season

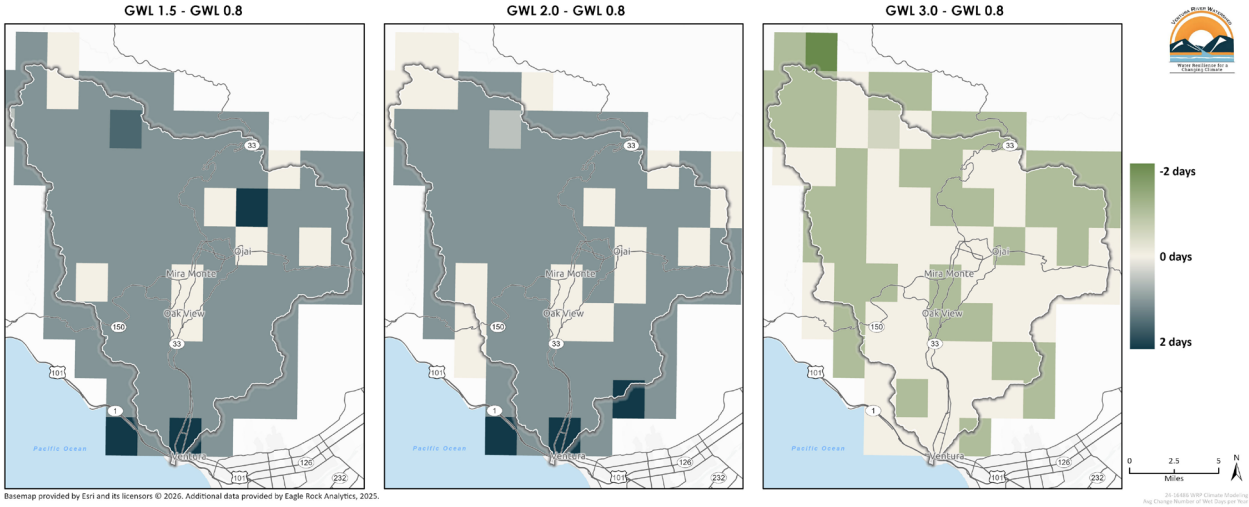


This figure illustrates projected changes in median seasonal precipitation, winter (DJF), spring (MAM), summer (JJA), and fall (SON), under 1.5 °C, 2.0 °C, and 3.0 °C GWLs, relative to a 0.8 °C reference GWL. Each panel shows the change in the median (50th percentile) seasonal precipitation for the corresponding season and warming level, allowing comparison of how projected precipitation patterns vary across the watershed throughout the year. An increase in precipitation is expected to occur during winter (December, January, and February) and drying is anticipated in the shoulder seasons of spring (March, April, and May) and fall (September, October, and November).

Daily Precipitation

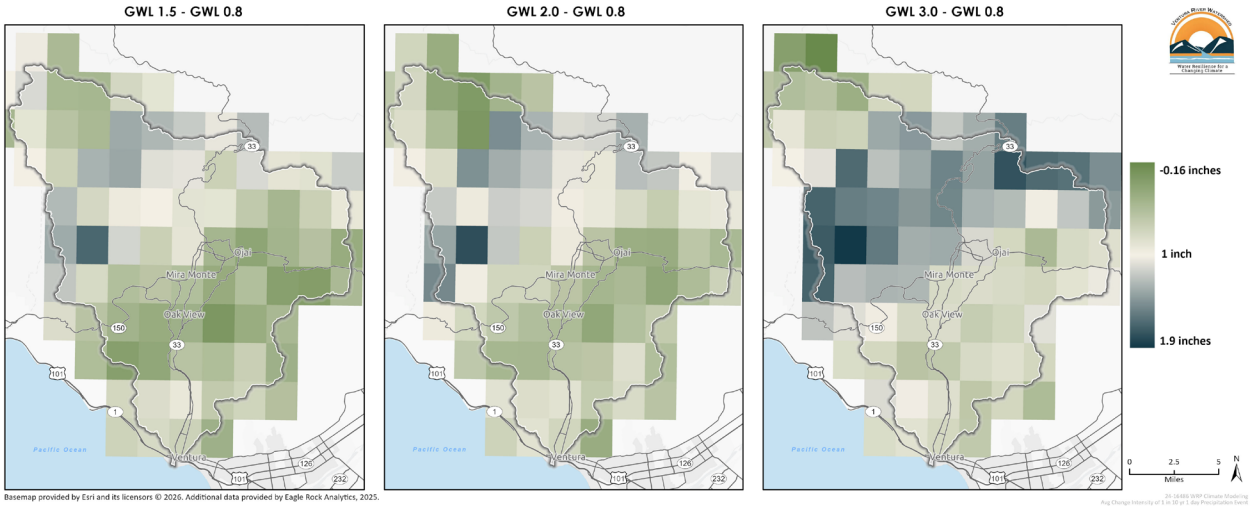
Projected changes in the number of wet days are modest and mixed across scenarios, generally increasing under 1.5 °C and 2.0 °C GWLs and decreasing under 3.0 °C, while short-duration precipitation intensity increases across scenarios. This indicates that a larger share of annual precipitation is expected to be delivered in heavier events. The intensity of the 1-day total 1-in-10-year (an event that has a 10 percent chance of occurring in any given year) precipitation event will increase by the end of the century. These 1-day events could increase by up to 2 inches while the 2-day and 10-day 1-in-10 year events are all expected to decrease substantially in the future; confirming the overall increase in annual precipitation is coming from an increase in the intensity of short-duration (daily) precipitation events instead of long-duration (multi-day) events.

Figure 29 Average Change in the Number of Wet Days per Year



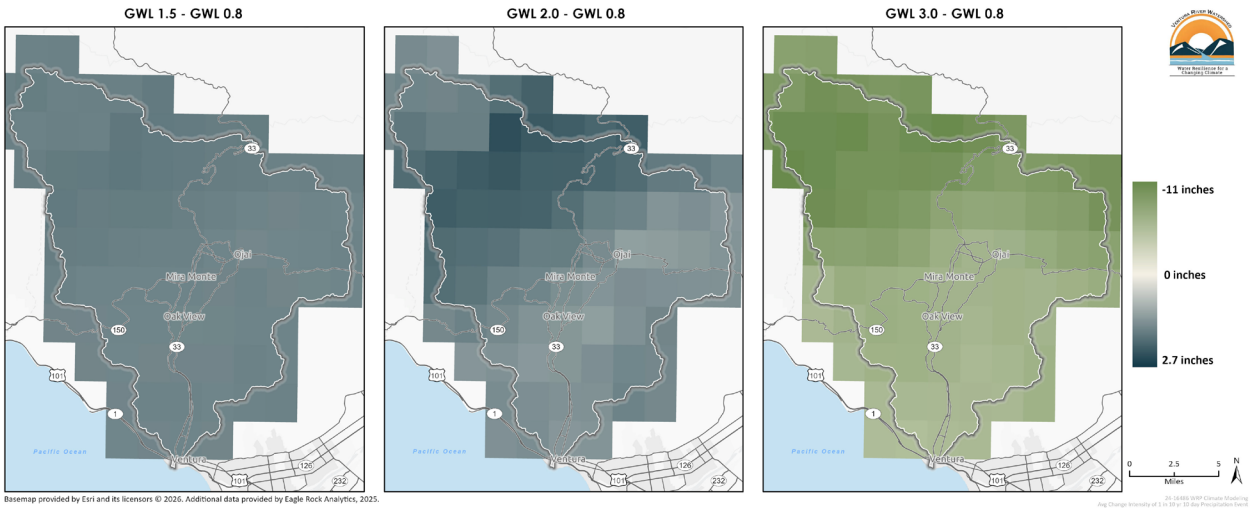
This figure shows projected changes in the number of wet days per year under 1.5 °C, 2.0 °C, and 3.0 °C GWLs, relative to a 0.8 °C reference GWL. Each panel illustrates the spatial distribution of changes in annual wet-day frequency for the corresponding warming level, allowing comparison of how the occurrence of wet days is expected to shift across the watershed under increasing warming. The increases in wet-day frequency at 1.5 °C and 2.0 °C, followed by a decline at 3.0 °C, reflect a modeled shift toward fewer but more intense precipitation events under higher levels of warming—an emerging pattern in many CMIP6 projections for California. This reversal highlights the uncertainty in future storm behavior at higher warming levels and indicates that increases in storm intensity do not necessarily correspond to increases in the number of wet days.

Figure 30 Average Change in the Intensity of a 1-in-10-Year 1-Day Precipitation Event



This figure shows projected changes in the intensity of a 1-in-10-year, 1-day precipitation event under 1.5 °C, 2.0 °C, and 3.0 °C GWLs, relative to a 0.8 °C reference GWL. Each panel presents the spatial distribution of changes in extreme 1-day precipitation intensity for the corresponding warming level, highlighting where rare heavy-rainfall events are expected to strengthen or weaken across the watershed.

Figure 31 Average Change in the Intensity of a 1 in 10 year 10-day Precipitation Event

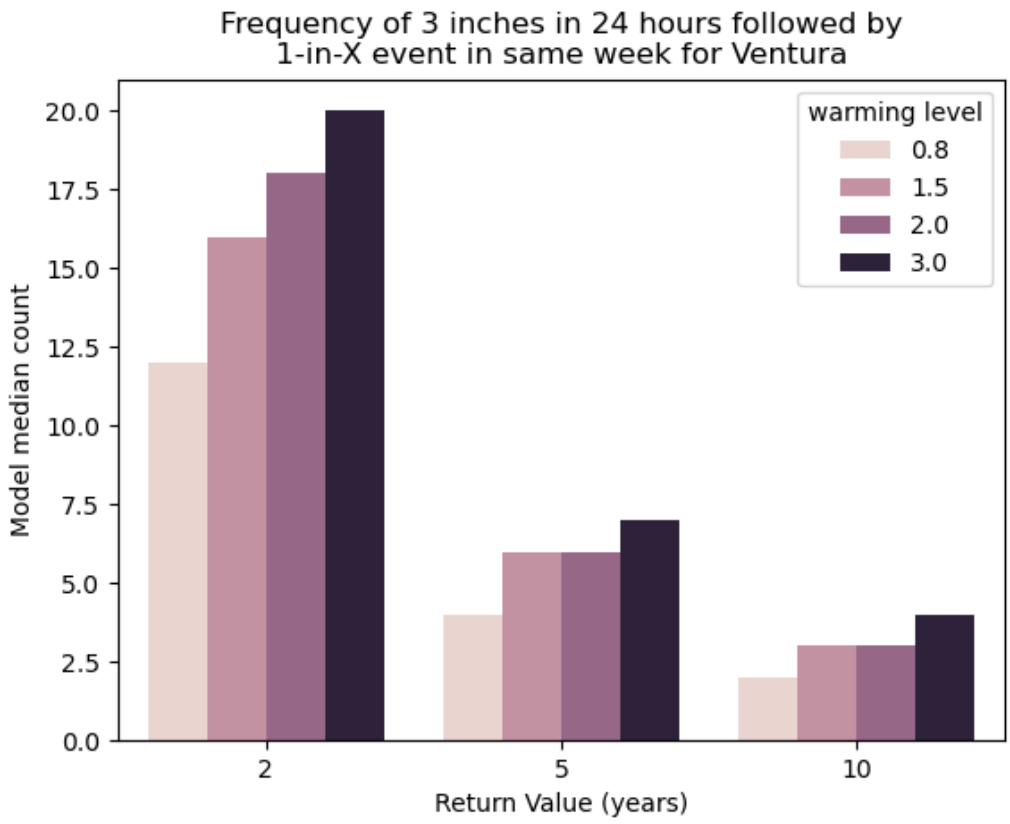


This figure shows projected changes in the intensity of a 1-in-10-year, 10-day precipitation event under 1.5 °C, 2.0 °C, and 3.0 °C GWLs, relative to a 0.8 °C reference GWL. Each panel illustrates the spatial distribution of changes in multi-day extreme precipitation for the corresponding warming level, highlighting where prolonged heavy-rainfall events are expected to strengthen or weaken across the watershed.

Back-to-Back Heavy Rain Events

Back-to-back storms can create cascading impacts in the watershed, especially when soils are saturated and streamflows remain elevated. For this analysis, a representative storm sequence was selected to reflect the types of conditions known to cause problems locally: a 3-inch, 24-hour storm followed by a 1-in-2-, 1-in-5-, or 1-in-10-year event within the same week. A 1-in-2, 1-in-5, and 1-in-10 year storm events are defined by their annual exceedance probability (representing a 50%, 20%, and 10% chance of occurring in any given year, respectively) and are quantified by the specific precipitation depth and intensity reached over a set duration (under 3 °C warming, these return-interval storms produce roughly 9, 12, and 15 inches of rain, respectively). The results show that the frequency of a 3-inch storm followed by a 1-in-2-year event could nearly double by the end of the century (from roughly 10 such sequences per year to about 20), indicating that compound, back-to-back storm events may become increasingly common. These sequences are significant because closely spaced storms reduce the time available for natural and engineered systems to drain, recover, or be cleared of debris. When soils remain saturated and channels stay near capacity, the likelihood of flooding, debris movement, and infrastructure strain increases even if individual storms are not extreme.

Figure 32 Frequency Back-to-Back Rain Events by Global Warming Levels



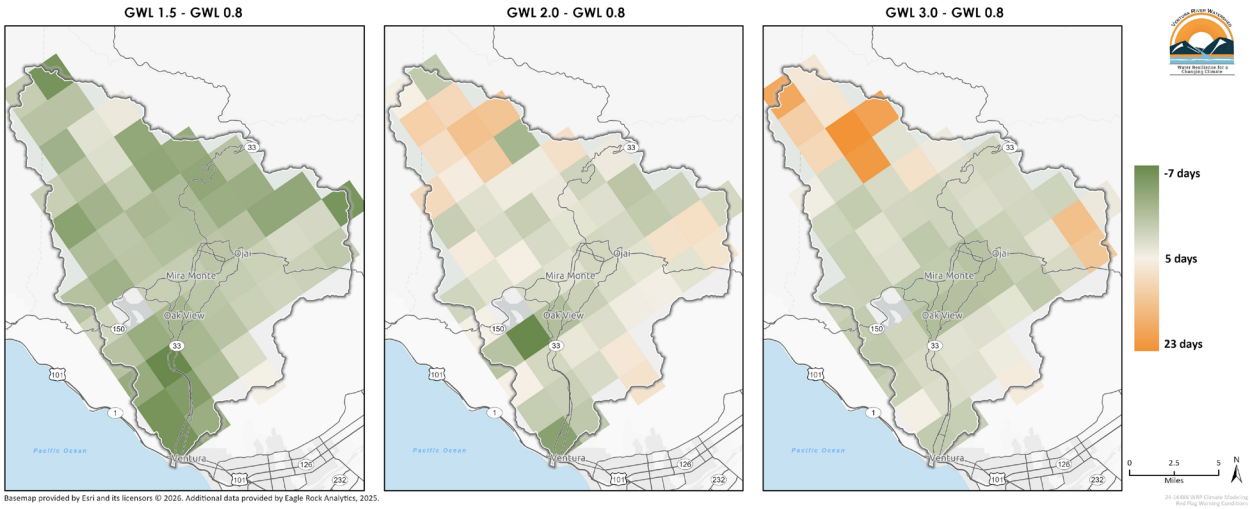
This figure shows how often a 24-hour rainfall event of 3 inches is followed within the same week by a 1-in-2, 1-in-5, or 1-in-10-year precipitation event under four GWLs (0.8 °C, 1.5 °C, 2.0 °C, and 3.0 °C). Each bar group represents the model-median count of these compound extreme-rainfall sequences for a given return interval, illustrating how the likelihood of back-to-back heavy precipitation events increases with higher warming levels.

Wildfire Discussion

Wildfires can cause widespread destruction, threatening local water quality, interrupting supplies, destroying infrastructure, impacting homes and businesses, and disrupting ecosystems. Identifying high wildfire risk regions is critical for proactive management and adaptation planning, however there are many factors that lead to wildfire risk that stem beyond the natural environment. Therefore, the metric developed to characterize wildfire risk was built to understand the weather conditions that are commonly used to signal a potential wildfire threat.

Red Flag Warnings, issued by the NWS, are used to inform the public, firefighters, and land management agencies that conditions are ideal for wildfire combustion and rapid spread. The NWS will issue a red flag warning when an anomalously dry period coincides with wind speeds greater than 15 miles per hour. Under 3 °C of warming, the Watershed should expect 10 to 20 additional days per year where conditions are met to issue Red Flag Warnings.

Figure 33 Change in the Number of Days per Year with Red Flag Warning Conditions



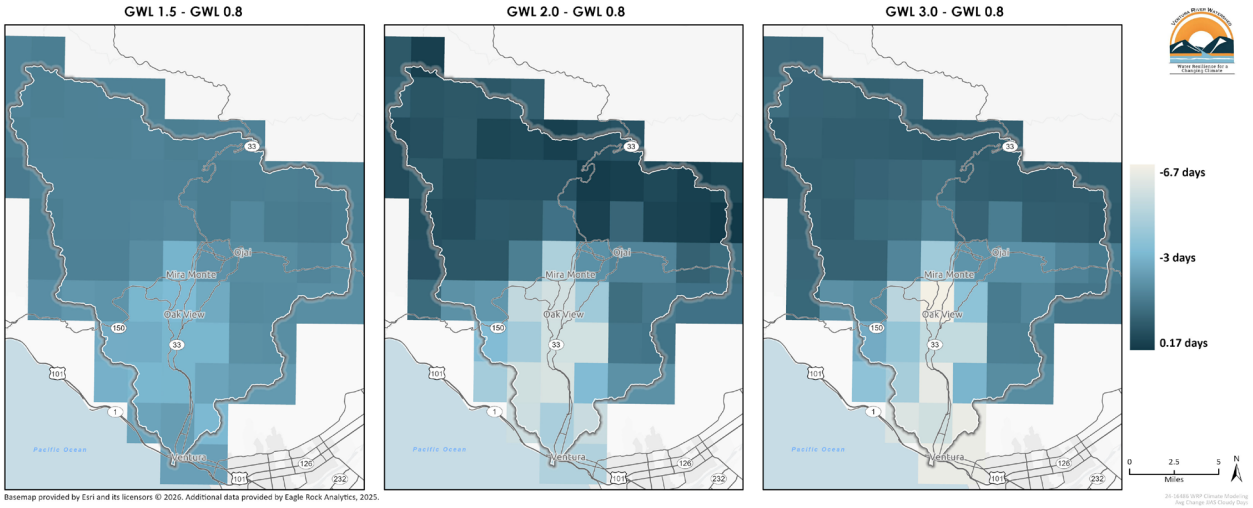
This figure shows projected changes in the number of days per year with Red Flag Warning conditions, defined as days with winds exceeding 15 mph during a six-month anomalously dry period, under 1.5 °C, 2.0 °C, and 3.0 °C GWLs, relative to a 0.8 °C reference GWL. Each panel illustrates the spatial distribution of changes in Red Flag–level wind conditions for the corresponding warming level, highlighting where fire-weather risk is expected to intensify across the watershed under an extreme climate projection scenario.

Marine Fog Discussion

Marine fog, or marine stratus clouds, are an important weather phenomenon in Ventura during June, July, August, and September. Marine fog influences evaporative demand and moderates temperature directly. Declines in the frequency of marine fog days could increase evaporative demand, leading to an increase in drought stress and reducing the moderation of temperature thereby increasing the chance of heatwaves along the coast. Such declines will impact crop productivity, ecosystem health, and reduction in streamflow. Cloud fraction for low clouds along the coast during June, July, August and September in the morning (5:00 a.m.–11:00 a.m.) was selected as a proxy for marine fog.

In both mid-term and long-term planning scenarios (2.0 °C and 3.0 °C), coastal parts of the watershed should expect a decrease in 5 to 6 days with marine fog present. These decreases directly align with increases in hotter temperatures and evapotranspiration, consistent with results from both the temperature and drought findings (overall warmer temperatures and more severe droughts).

Figure 34 Average Change in June, July, August and September Cloudy Days



This figure shows projected changes in the number of days during June, July, August, and September (JJAS) with morning marine fog clouds present between 5:00 a.m. – 11:00 a.m. under 1.5 °C, 2.0 °C, and 3.0 °C GWLs, relative to a 0.8 °C reference GWL. Each panel illustrates the spatial distribution of changes in marine-cloud mornings for the corresponding warming level, highlighting where coastal cloud cover is expected to decrease or increase across the watershed.

Sea Level Rise and Storm Surge Discussion

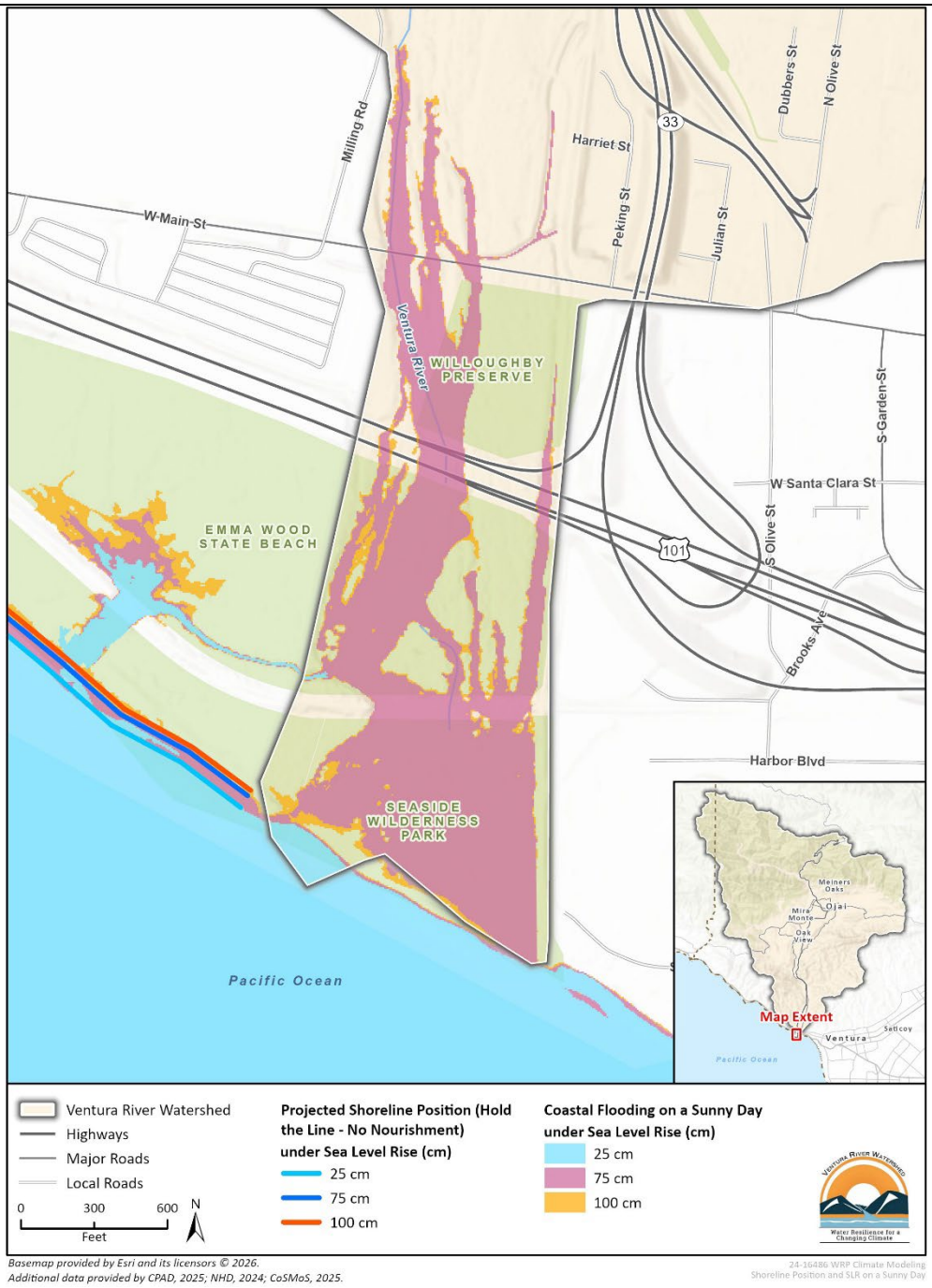
Sea level rise presents a growing climate hazard for the lower Watershed, particularly at the river mouth and along the open coast where shoreline response and coastal flooding processes intersect. Figure 35 illustrates projected shoreline positions under incremental sea level rise scenarios of 25, 75, and 100 centimeters, which are estimated to result in approximately a 65, 115, and 135 feet dry beach loss, respectively. This beach narrowing estimation assumes a “hold the line, no nourishment” management approach in which existing development and coastal infrastructure prevent the shoreline from migrating landward, and no additional sediment is added to offset erosion. As sea levels rise, this constraint leads to progressive beach narrowing, increased wave reflection and eventual loss of dry beach and intertidal habitat, especially under the higher sea level rise scenarios. It is important to note that these modeled shoreline positions do not reflect recent coastal adaptation projects in the watershed, including the Surfer’s Point Managed Shoreline Retreat project, which was designed to allow for inland migration of dunes and beaches and reduce reliance on hardened coastal infrastructure. Additionally, these beach narrowing scenarios are estimated directly north of the mouth of the Ventura River, and can vary significantly depending on tidal conditions and the topography of the sand where the measurements are taken along the coast.

In addition to chronic shoreline erosion, Figure 36 shows coastal flooding extents associated with a 100-year storm event superimposed on rising sea levels. Even at lower sea level rise increments, low-lying areas near the Ventura River mouth and estuarine margins experience inundation, reflecting the

exposure of these areas to elevated coastal water levels. These conditions can impede river discharge to the ocean, exacerbate flooding during high flows, and increase exposure of transportation corridors, utilities, and nearby communities. Together, these projections demonstrate that sea level rise will drive both gradual and episodic hazards, including chronic beach loss, degradation of coastal and estuarine habitats, and increased frequency and severity of coastal flooding during extreme storms.

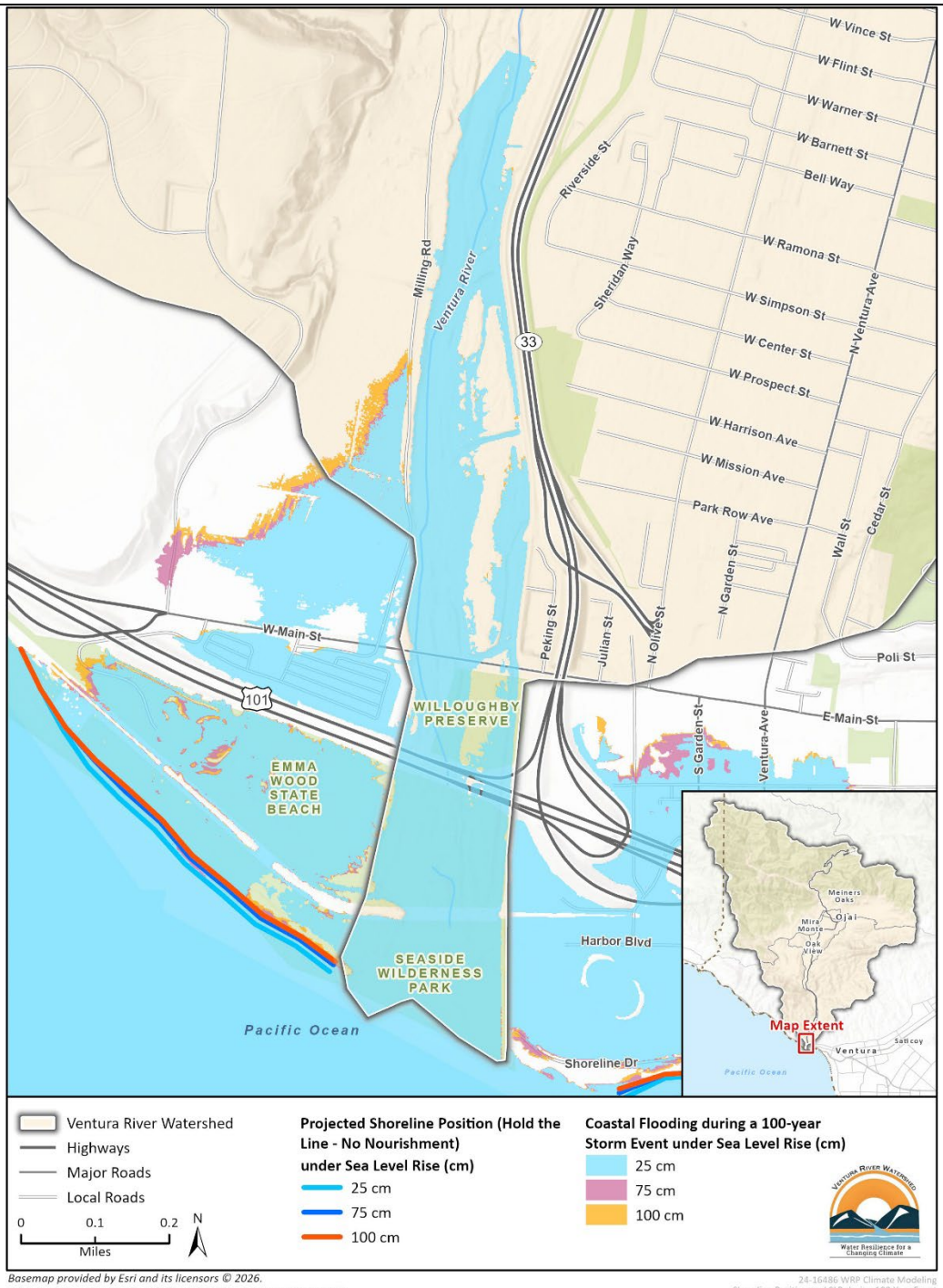
The figures below demonstrate impacts from sea level rise solely within the watershed boundary. However, the WRP includes analysis, strategies, and actions for watershed systems and infrastructure that are important to the watershed but may lie outside this boundary. The sea level rise and coastal flooding projections shown in these figures are based on CoSMoS data, which integrates global and regional sea level rise scenarios with physics-based modeling of tides, storm surge, wave setup, and coastal processes. CoSMoS simulates shoreline response and 100-year coastal storm-driven inundation to evaluate future hazards under incremental sea level rise conditions.

Figure 35 Projected Shoreline Position and Coastal Flooding on a Sunny Day



This figure shows projected shoreline position and coastal flooding in the lower Ventura River Watershed during a sunny-day tidal condition under 25 cm, 75 cm, and 100 cm of sea level rise. The map displays how static coastal water levels expand landward under higher sea level rise scenarios, illustrating the progression of shoreline retreat and the increasing extent of inundation associated with rising ocean levels.

Figure 36 Projected Shoreline Position and Coastal Flooding During a 100-year Storm Event Under Sea Level Rise (25cm, 75 cm, and 100cm) in the Lower Ventura River Watershed



This figure shows projected shoreline position and coastal flooding in the lower Ventura River Watershed during a 100-year coastal storm event under 25 cm, 75 cm, and 100 cm of sea level rise. The map displays how the extent of flooding and shoreline retreat increases under higher sea level rise scenarios, illustrating the progressive landward shift of coastal hazard exposure with rising ocean levels.

Chapter 5

Climate Change Vulnerability

This chapter assesses how climate hazards interact with the watershed's natural systems, built infrastructure, and communities. It identifies where vulnerabilities are highest, what systems are most at risk, and how climate impacts may compound across the landscape.

Introduction

This chapter describes the methods and results of the climate change vulnerability assessments conducted for the watershed's water resource systems. The assessments combine quantitative analysis (flood modeling under future climate scenarios) with qualitative, community-informed evaluations to understand how climate hazards affect water resource systems across the Ventura River Watershed and increase risks and consequences for the community.

The goal of this chapter is to identify which assets and system components are most vulnerable to climate change, and why. These findings directly inform the adaptation strategies and implementation roadmaps presented in **Chapter 6**: Adaptation Strategies, Actions, and Implementation Roadmaps.

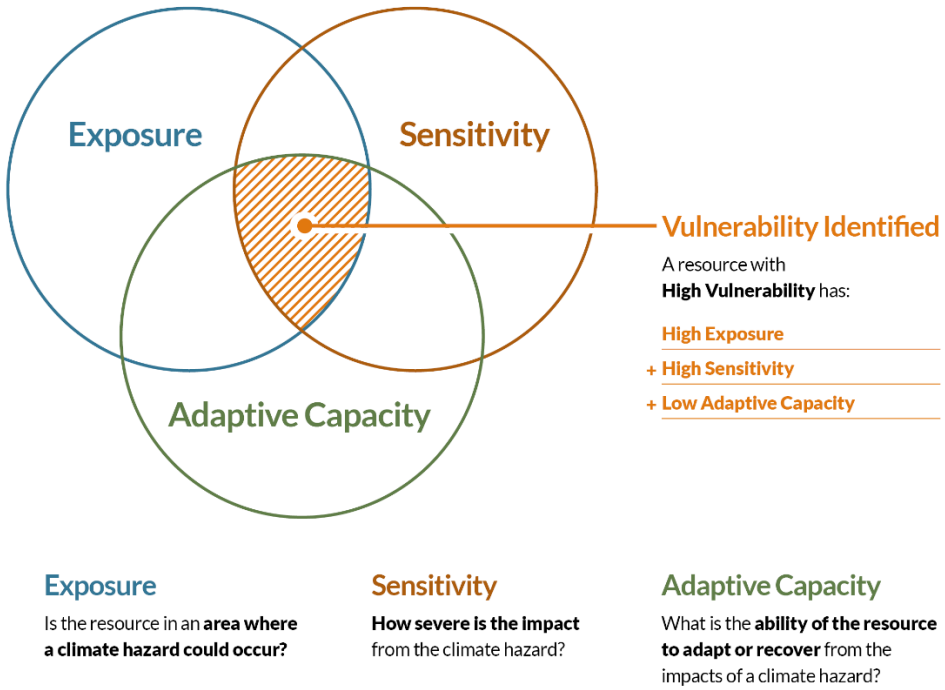
Definitions

Vulnerability refers to the degree to which a system is susceptible to harm from climate hazards, based on three interacting components:

- **Exposure**: the extent to which an asset or system is physically in harm's way (e.g., located in a flood zone, burn area, or drought-sensitive reach).
- **Sensitivity**: how severely the asset or system would be affected if exposed (e.g., whether it can maintain function, how it performed in past events).
- **Adaptive Capacity**: the inherent ability of the asset or system to adjust, absorb impacts, or recover based on its existing design, operations, or management (excluding speculative future upgrades).

This framework, depicted in Figure 37, is consistent with California Department of Water Resources' (DWR) Watershed Resilience Framework (DWR 2024) and is used throughout the qualitative assessment.

Figure 37 Vulnerability Assessment Components



Assessment Approach

The vulnerability assessment uses two complementary approaches: a qualitative evaluation of watershed assets and a targeted quantitative analysis of future flood conditions. The qualitative assessment evaluated 89 water-resource system assets and features. Each asset and feature was rated for exposure, sensitivity, and adaptive capacity across six climate hazards: extreme heat, drought, precipitation/flooding, wildfire, marine fog decline, and sea level rise/storm surge. Scores were combined into final vulnerability ratings based on standardized criteria aligned with DWR guidance.

The flood hazard quantitative assessment presented in this chapter was developed in response to the vulnerabilities identified in the qualitative assessment, guidance from DWR, the priorities raised during asset manager interviews, and a gap identified in existing quantitative studies. Across discussions with partners, the need to better characterize future flood conditions was consistently emphasized, leading to the focused hydrologic and hydraulic analysis that centers on future flood conditions. This analysis models projected changes in flood magnitudes, frequencies, and compound storm sequences under multiple future warming levels. Future quantitative assessments will be needed to asses in greater detail the other critical hazards and key vulnerabilities identified in the qualitative assessment, including drought and the impacts on ecosystems and water supply.

Together, these methods provide a comprehensive picture of where vulnerabilities exist, what drives them, and which assets warrant priority attention. This assessment highlights opportunities for resource managers to reduce vulnerabilities and manage climate-related risks through targeted actions.

Qualitative Assessment

Methodology

For the qualitative vulnerability assessment, a comprehensive list of assets and features was developed. Each asset or feature was then assigned scores for exposure, sensitivity, and adaptive capacity for each of the six climate hazards considered. Scores followed a standardized qualitative scale: low, low/moderate, moderate, moderate/high, or high.

Assets and Features

Assets and features included water supply, water quality, groundwater and flood management infrastructure, natural systems, cultural resources, and community-serving locations. Advisory Group (AG) members, Tribal partners, and community forum participants helped to identify locally important resources and confirm the list of assets evaluated. Where assets were functionally interconnected or co-located, they were grouped and assessed together.

Exposure

Exposure describes the degree to which watershed assets are expected to experience climate hazards. Climate data and climate change projections informed the selection of hazard indicators and exposure metrics used to evaluate exposure in the qualitative vulnerability assessment. This information is based on statewide climate projections developed for California's Fifth Climate Change Assessment, the State's multi-year scientific research program that provides updated, downscaled climate projections for climate hazards across the state.

Many different climate indicators were reviewed as part of this effort, but only one was selected for each hazard to assess exposure and highlight areas most likely to be affected. Exposure metrics were identified using a combination of published guidance, local data, and professional judgment from senior technical experts, and were then reviewed and confirmed by the Advisory Group and local managers to ensure they reflected conditions known to trigger stress or damage in the watershed. Table 6 summarizes the exposure metrics used for each climate hazard. Where future trends were unclear, current conditions and alternative indicators were used to provide a more complete picture.

Exposure scores were assigned by visually overlaying asset locations with the exposure metrics. A full GIS-based spatial analysis was considered, but due to variation in asset-level data resolution and the purpose of the assessment (to compare relative exposure rather than calculate quantitative impacts) a visual overlay method was used. Each exposure metric is linked to a performance threshold that reflects when climate-driven conditions begin to meaningfully impair system function. These thresholds draw from regulatory guidance (e.g., SGMA Sustainable Management Criteria and GSP-defined minimum thresholds for groundwater), observed ecological and hydrologic conditions (e.g., streamflow reductions that impede fish passage or disconnect habitat), and the professional judgment of local managers and technical experts. Because thresholds vary by water-resource system, hazard indicators were applied flexibly—for example, interpreting more than five 2-day 99th-percentile precipitation events as a meaningful stress point for flood-related impacts. These conceptual thresholds informed the scoring of exposure and sensitivity across the qualitative assessment.

Table 6 Selected Climate Hazard Indicators and Exposure Metrics for the Vulnerability Assessment

Climate Hazard	Exposure Metrics
Extreme Heat	Median change in the average annual frequency of 3-day heat events and median average annual frequency of days above 95 °F by future global warming level (GWL), calculated projection-specific and summarized across CMIP6 models relative to GWL 0.8.
Drought	Changes in long-term (3-year) drought conditions across the watershed using the Standardized Precipitation Index, combined with temperature-based SPI indicators (days above 95 °F) to capture increasing water stress and runoff losses driven by warming.
Precipitation	Spatially distributed change in the 2-day 99th-percentile precipitation between future GWLs and GWL 0.8, supplemented with FEMA Flood Insurance Rate Map Special Flood Hazard Areas to account for downstream and floodplain exposure.
Wildfire	Change in future GWLs relative to GWL 0.8 in the annual frequency of wind events exceeding 15 mph during the 6-month dry season, combined with present-day State of California Fire Hazard Severity Zones (LRA and SRA) to characterize existing wildfire exposure.
Marine Fog (Marine Stratus)	Projected change in the mean number of cloudy days under future GWLs relative to GWL 0.8, based on marine stratus cloud definitions, used as a proxy for potential reductions in marine fog associated with warmer and drier future conditions.
Sea Level Rise & Storm Surge	Coastal Storm Modeling System-modeled coastal flooding, groundwater emergence, and shoreline change under 25, 75, and 100 cm sea level rise scenarios, evaluated for both sunny-day and 100-year coastal storm conditions, including shoreline evolution under hold-the-line and no-hold-the-line assumptions.

Sensitivity

Sensitivity reflects how severely an asset would be affected if exposed to a hazard. Ratings were informed by asset function, known performance during past events, and inherent physical or ecological characteristics. Assets that have historically experienced damage or disruption under similar conditions

were assigned higher sensitivity ratings. Assets designed to withstand or rapidly recover from hazard conditions were assigned lower sensitivity ratings.

Adaptive Capacity

Adaptive capacity captures an asset's inherent ability (under current conditions) to adjust or continue functioning during climate hazards. Only existing infrastructure, operations, and management practices were considered; potential future upgrades or planned improvements were intentionally excluded due to uncertainty in timing and design. Assets with flexible operations, redundancy, or natural resilience characteristics received higher adaptive-capacity ratings.

Vulnerability Scoring

Initial vulnerability scores were assigned by combining sensitivity and adaptive capacity. High sensitivity paired with low adaptive capacity yielded high initial vulnerability; low sensitivity paired with high adaptive capacity yielded low initial vulnerability. See the scoring matrix below in Figure 38 for how initial vulnerability scores were assigned.

Exposure was then applied as a secondary screen to obtain a final vulnerability score: assets with moderate to high exposure retained their initial rating, while assets with low or moderate-low exposure received a final rating of "N/A," indicating negligible vulnerability under future climate scenarios. An additional category, H*, was assigned to assets with both high exposure and high initial vulnerability (high sensitivity × low adaptive capacity). H* identifies assets requiring priority attention in subsequent adaptation planning. See Figure 39 for the final vulnerability scoring matrix.

Figure 38 DWR Vulnerability Scoring Matrix (Sensitivity x Adaptive Capacity)

Source: California Department of Water Resources, Watershed Resilience Framework and Toolkit

Figure 39 Final Vulnerability Scoring Matrix (Screening with Exposure)

Community Input

Community input played a central role in shaping the asset list and priorities used in the qualitative vulnerability assessment.

During the July 2025 community forum, participants helped identify the key water-related assets and resources across the watershed (including infrastructure, natural systems, cultural areas, and community spaces) and described how they rely on these assets in their daily lives. This input directly informed the list of assets and features evaluated in the vulnerability assessment. Community members also provided insight into which system components would have the most significant consequences if damaged or disrupted. This helped inform the preliminary vulnerability ratings assigned during the qualitative assessment.

After preliminary vulnerability ratings were developed by the project team, the AG and individual asset-managing entities provided input on the initial scores between September and November 2025 to review and revise the draft results. AG members provided detailed feedback on exposure, sensitivity, and adaptive-capacity scores and helped validate where the assessment aligned with on-the-ground experience. Their input refined the ratings, improved system-specific accuracy, and informed prioritization of assets and climate risks for further analysis and adaptation planning. A subsequent AG meeting focused specifically on the risks associated with the identified key vulnerabilities. During that session, AG members ranked the vulnerabilities based on the consequences of asset or resource failure or damage. This input further guided the prioritization of key vulnerabilities and helped shape the development of related adaptation strategies in later stages in the project.

Asset manager interviews also contributed essential system-level expertise. During these discussions, interviewees assessed the likelihood and consequences of climate hazard impacts on their assets and reviewed draft ratings. This process allowed the project team to qualitatively assess risk and incorporate local operational knowledge. As conversations evolved both through the asset manager interviews and in AG meetings, partners consistently emphasized flood-related risks, which informed the decision to focus the quantitative assessment on future flood conditions and hydrologic and hydraulic changes associated with intensifying precipitation events.

Feedback was received from:

- Participants from the general public in attendance at the July Forum
- AG members
- Asset-managing entities:
  - California State Parks
  - Chairman of Barbareño-Ventureño Band of Mission Indians
  - Chumash Elder Julie Tumamait-Stenslie
  - City of Ventura
  - County of Ventura
  - Ojai Basin Groundwater Management Agency
  - Ojai Valley Land Conservancy
  - Ojai Sanitation District
  - Upper Ventura River Groundwater Management Agency
  - Ventura Land Trust
  - Ventura River Water District

Results

In total, the qualitative vulnerability assessment produced 534 final vulnerability scores. Of these, 58 ratings resulted in high vulnerability and 99 resulted in exceptionally high vulnerability (H*). The qualitative vulnerability assessment ratings key is presented in Table 7 below. Ratings on individual asset groups by water system are documented below in Table 8 through Table 13, and additionally in **Appendix P**: Qualitative Vulnerability Assessment Results. A summary of total scores is displayed below in Figure 40.

The distribution of scores shown in Figure 40 indicates that vulnerability is spread across all categories rather than concentrated in a single level. The results of this qualitative assessment were used to distinguish the watershed's key vulnerabilities (focusing on those that scored higher) and inform prioritization of assets for additional analysis and development of adaptation strategies capable of reducing the identified vulnerabilities.

Figure 40 Breakdown of Final Vulnerability Scores

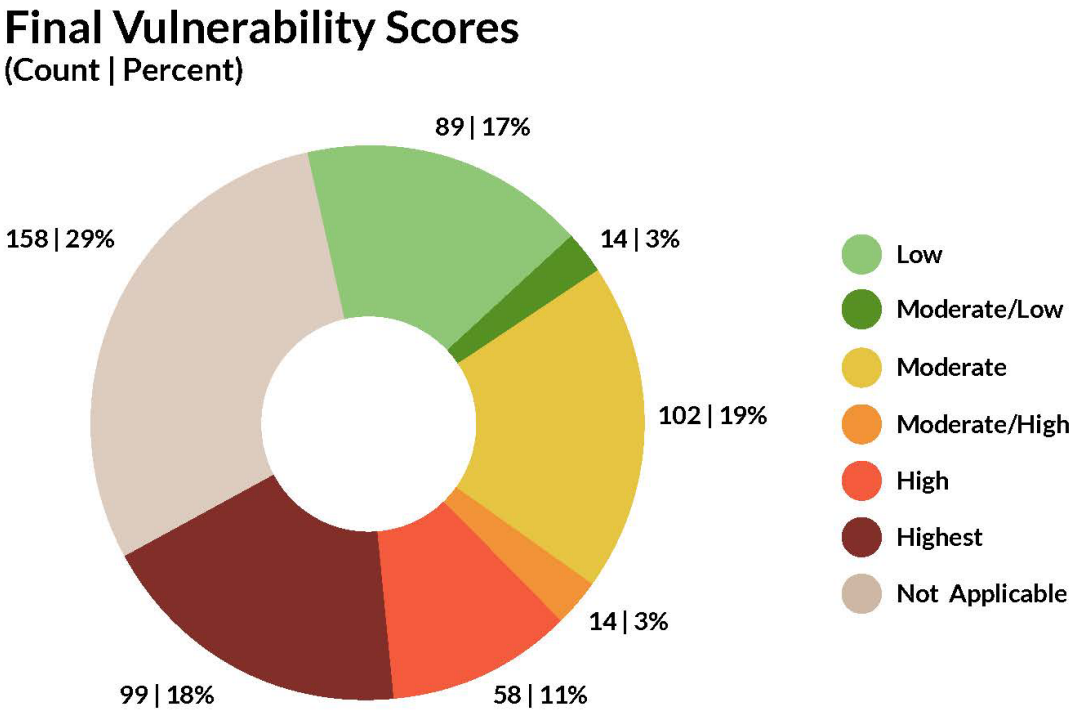


Table 7 Qualitative Vulnerability Assessment Ratings Key

Code	Level	Color
L	Low	Green
M	Medium	Yellow
H	High	Red
H^+	Highest	Dark Red

Table 8 Qualitative Vulnerability Assessment Ratings for the Water Supply System

Functional Group Components (Assets)	Extreme Heat	Extreme Precipitation and Flooding	Sea Level Rise and Storm Surge	Drought	Wildfire	Marine Fog
Lake Casitas, Robles Canal, Robles Diversion & Fish Passage Facility, Marion Walker Pressure Filtration Plant	M	H*	N/A	H	H	N/A
Ojai Water System Wells; San Antionio Manganese Filtration Treatment Plant	L	M	N/A	H*	M/L	N/A
San Antionio Manganese Filtration Treatment Plant Distribution Lines	L	M	N/A	H*	H	N/A
Foster Park Subsurface Intake*, Foster Park Subsurface Dam, Foster Park Wells	N/A	H	N/A	H	H*	N/A
Avenue Water Treatment Plant	N/A	M	N/A	H	H*	N/A
Avenue Water Treatment Plant Distribution Lines	N/A	H	N/A	H	H*	N/A
Wastewater conveyances to Ventura Water Reclamation Facility	N/A	L	H	M	M/L	L
Mira Monte Well (CMWD), Meiners Oaks County Water District Wells, Ventura River Water District Wells	L	M	N/A	H*	M/L	N/A
Senior Canyon Reservoir	H*	H	N/A	H*	H*	N/A
Unincorporated domestic and agricultural infrastructure (Matilija Creek and North Form Matilija Creek; Coyote Creek and Upper Ventura River; San Antonio Creek; Lower Ventura River Watershed)	L	L	N/A	H	L	N/A
	L	L	N/A	H*	L	N/A
	L	L	N/A	H*	L	N/A
	N/A	L	M	H	L	L
Matilija Reservoir	L	H*	N/A	L	H	N/A
Ojai Valley Sanitary District Wastewater Treatment Plant	L	H	N/A	L	H*	N/A
Ojai Valley Sanitary District Wastewater Treatment Plant Distribution Lines	L	H	N/A	L	H*	N/A

Table 9 Qualitative Vulnerability Assessment Ratings for the Flood Management System

Functional Group Components (Assets)	Extreme Heat	Extreme Precipitation and Flooding	Sea Level Rise and Storm Surge	Drought	Wildfire	Marine Fog
Matilija Creek and North Fork Matilija Creek, floodplains	L	L	N/A	L	M	N/A
Santa Ana Creek, Coyote Creek, floodplains	L	L	N/A	L	M	N/A
Lake Casitas, Robles Diversion, Robles-Casitas Canal	L	H*	N/A	M/L	H	N/A
Meiners Oaks SD Infrastructure (no levee), Mira Monte SD Infrastructure, Oak View SD Infrastructure (leveed), McDonald Canyon Detention Basin	L	H*	N/A	M/L	M	N/A
Meiners Oak Floodplains, Ojai Meadows Preserve	L	L	N/A	L	M	N/A
Live Oak Creek Dam and Diversion Channel, Live Oak Acres Levee	L	H*	N/A	M/L	M	N/A
Ojai SD Infrastructure (eastern Ojai Region, no levee), Senior Canyon Dam, (storm drainage infrastructure in other municipalities)	L	H	N/A	M/L	M	N/A
San Antonio Creek Floodplains (Mira Monte & East Ojai Alluvial Fans), Valley View Preserve	L	L	N/A	L	M	N/A
Ventura River Floodplain, Foster Park/Weldons/Ortonville SD Infrastructure (no levee)	N/A	H	N/A	L	M	N/A
Casitas Springs SD Infrastructure, Casitas Springs Levee, Fresno Canyon Debris Trap	N/A	H	N/A	M/L	M	N/A
Ventura SD Infrastructure, Ventura River Levee, Dent Debris Basin	N/A	H	H*	M/L	M	N/A
Surfer's Point Managed Shoreline Retreat; Ventura River Estuary, coastal beaches and wetlands	N/A	H	H*	L	M	N/A

Table 10 Qualitative Vulnerability Assessment Ratings for the Groundwater Management System

Functional Group Components (Assets)	Extreme Heat	Extreme Precipitation and Flooding	Sea Level Rise and Storm Surge	Drought	Wildfire	Marine Fog
San Antonio Creek Spreading Grounds; Private managed recharge	M	L	N/A	H*	H*	N/A
Matilija Creek and North Fork Matilija Creek fractured bedrock recharge areas, riparian areas	M	L	N/A	H	L	N/A
Coyote Creek and Upper Ventura River Ventura River alluvial recharge reach, fractured bedrock recharge areas, riparian areas	M	L	N/A	H*	L	N/A
San Antonio Creek mountainfront recharge, fractured bedrock recharge areas, riparian areas	M	L	N/A	H*	M	N/A
Lower Ventura Ventura River alluvial recharge reach (Lower Basin floodplain/estuary corridor)	N/A	L	H*	H	M	N/A

Table 11 Qualitative Vulnerability Assessment Ratings for the Ecosystems System

Functional Group Components (Assets)	Extreme Heat	Extreme Precipitation and Flooding	Sea Level Rise and Storm Surge	Drought	Wildfire	Marine Fog
Beaches and Coastal Dunes	N/A	M	H*	M	L	M
Estuary	M	H	H*	H	M	M
Aquatic; Wetlands; Riparian Corridors - Matilija Creek and North Fork Matilija Creek	M/H	M	N/A	H	M	N/A
Aquatic; Wetlands; Riparian Corridors - Coyote Creek and Upper Ventura River	M/H	M	N/A	H*	M	N/A
Aquatic; Wetlands; Riparian Corridors - San Antonio Creek	M	M	N/A	H*	H	L
Aquatic; Wetlands; Riparian Corridors - Lower Ventura	H	L	H*	H	H*	M/H
Valley floor and Foothills (grasslands, coastal sage scrub, chaparral, oak woodlands and savannas) - Matilija Creek and North Fork Matilija Creek	M	L	N/A	H	M	N/A
Valley floor and Foothills (grasslands, coastal sage scrub, chaparral, oak woodlands and savannas) - Coyote Creek and Upper Ventura River	M	L	N/A	H*	M	N/A
Valley floor and Foothills (grasslands, coastal sage scrub, chaparral, oak woodlands and savannas) - San Antonio Creek	M	L	N/A	H*	M	L
Valley floor and Foothills (grasslands, coastal sage scrub, chaparral, oak woodlands and savannas) - Lower Ventura	N/A	L	N/A	H	H*	M
Headwater Forests and Mountainous Areas (mixed chaparral, Montane hardwood and coniferous forest) - Matilija Creek and North Fork Matilija Creek	M	L	N/A	H	H*	N/A
Headwater Forests and Mountainous Areas (mixed chaparral, Montane hardwood and coniferous forest) - Coyote Creek and Upper Ventura River	M	L	N/A	H*	H*	N/A
Headwater Forests and Mountainous Areas (mixed chaparral, Montane hardwood and coniferous forest) - San Antonio Creek	M	L	N/A	H*	H*	L
Agricultural Lands and Orchards - Matilija Creek and North Fork Matilija Creek	H	M	N/A	H	M	N/A
Agricultural Lands and Orchards - Coyote Creek and Upper Ventura River	H*	M	N/A	H*	M	N/A
Agricultural Lands and Orchards - San Antonio Creek	H*	M	N/A	H*	M	M
Agricultural Lands and Orchards - Lower Ventura	N/A	H	H*	H	L	M

Table 12 Qualitative Vulnerability Assessment Ratings for the Water Quality System

Functional Group Components (Assets)	Extreme Heat	Extreme Precipitation and Flooding	Sea Level Rise and Storm Surge	Drought	Wildfire	Marine Fog
Septic Systems/ Individual Septic Treatment systems - Matilija Creek and North Fork Matilija Creek	M/L	H	N/A	L	L	N/A
Septic Systems/ Individual Septic Treatment systems - Coyote Creek and Upper Ventura River	M/L	H	N/A	L	L	N/A
Septic Systems/ Individual Septic Treatment systems - San Antonio Creek	M/L	H*	N/A	L	L	N/A
Septic Systems/ Individual Septic Treatment systems - Lower Ventura	N/A	H	N/A	L	L	N/A
Natural Waterways and Waterbodies - Matilija Creek and North Fork Matilija Creek	H	M	N/A	H	M	N/A
Natural Waterways and Waterbodies - Coyote Creek and Upper Ventura River	H	M	N/A	H	M	N/A
Natural Waterways and Waterbodies - San Antonio Creek	H	M	N/A	H	M	L
Natural Waterways and Waterbodies - Lower Ventura	N/A	H	N/A	H	M	M
Source-Water & Watershed Protection Areas - Matilija Creek and North Fork Matilija Creek	M	M	N/A	H	M/H	N/A
Source-Water & Watershed Protection Areas - Coyote Creek and Upper Ventura River	M	M	N/A	H	M/H	N/A
Source-Water & Watershed Protection Areas - San Antonio Creek	H	H	N/A	H	M/H	N/A
Source-Water & Watershed Protection Areas - Lower Ventura	N/A	M	N/A	H	M/H	N/A

Table 13 Qualitative Vulnerability Assessment Ratings for the Cultural Resources System

Functional Group Components (Assets)	Extreme Heat	Extreme Precipitation and Flooding	Sea Level Rise and Storm Surge	Drought	Wildfire	Marine Fog
Villages, Sacred Sites, and Ceremonial Places - Matilija Creek and North Fork Matilija Creek	M	H*	N/A	M	H*	N/A
Villages, Sacred Sites, and Ceremonial Places - San Antonio Creek	M	H	N/A	M	H*	L
Villages, Sacred Sites, and Ceremonial Places - Coyote Creek and Upper Ventura River	M	H*	N/A	M	H*	L
Villages, Sacred Sites, and Ceremonial Places - Lower Ventura	M	H	H	M	H*	M/H
Traditional Subsistence and Cultural Vegetative Resources - Matilija Creek and North Fork Matilija Creek	M	L	N/A	H	H*	N/A
Traditional Subsistence and Cultural Vegetative Resources - San Antonio Creek	M	L	N/A	H*	H*	L
Traditional Subsistence and Cultural Vegetative Resources - Coyote Creek and Upper Ventura River	M	L	N/A	H*	H*	L
Traditional Subsistence and Cultural Vegetative Resources - Lower Ventura	M	M/H	H	M/H	H*	H
Traditional Subsistence and Cultural Animal Resources - Matilija Creek and North Fork Matilija Creek	M	M	N/A	H	H*	N/A
Traditional Subsistence and Cultural Animal Resources - San Antonio Creek	M	M	N/A	H*	H*	L
Traditional Subsistence and Cultural Animal Resources - Coyote Creek and Upper Ventura River	M	M	N/A	H*	H*	L
Traditional Subsistence and Cultural Animal Resources - Lower Ventura	M	M	H	M	M	M/H
Coastal Beaches & Parks	N/A	H	H*	L	L	M
Rivers, Reservoirs & Trail Corridors - Matilija Creek and North Fork Matilija Creek	L	H*	N/A	M	H*	N/A
Rivers, Reservoirs & Trail Corridors - San Antonio Creek	L	H	N/A	M	H*	M
Rivers, Reservoirs & Trail Corridors - Coyote Creek and Upper Ventura River	L	H	N/A	M	H*	N/A
Rivers, Reservoirs & Trail Corridors - Lower Ventura	N/A	H	H*	M	M/H	M
Natural hot springs	M	H*	N/A	M	M/H	N/A

Community Insight: Evolving Vulnerability Scores Through Asset Manager Review

Through review with asset managers and technical staff, vulnerability scores across the watershed were refined to more accurately reflect observed system performance, site-specific conditions, and evolving hazards. In the Lower Ventura watershed, exposure ratings for aquatic habitats, wetlands, and riparian corridors were increased from Low to Moderate, recognizing that even small increases in temperature can drive disproportionate ecological responses in these sensitive environments. At the same time, sensitivity scores for these assets were reduced where evidence shows that portions of the lower watershed have demonstrated resilience to extreme precipitation. Wildfire vulnerability for riparian systems in the San Antonio Creek area was elevated due to close adjacency to chaparral and sage scrub vegetation, increasing the likelihood of fire-related impacts.

Similar refinements were made across other water resource systems. Groundwater recharge areas were characterized as less sensitive to extreme heat and flooding, reflecting conditions where episodic flooding supports recharge and sediment impacts remain manageable. Water quality assets were reassessed and assigned lower wildfire sensitivity based on historical fire events that resulted in short-term, recoverable impacts. Cultural resource vulnerabilities were assigned higher scores to better capture exposure to extreme heat and marine fog, acknowledging that climate-driven changes can affect sacred sites and ceremonial places.

Key Vulnerabilities

The qualitative vulnerability assessment identified 13 key climate-related vulnerabilities facing the Ventura River Watershed. These vulnerabilities do not occur in isolation; they interact across systems, where impacts in one area can trigger cascading effects on public health, ecological function, and emergency response. For example, wildfire can set the stage for damaging post-fire floods, and prolonged drought can degrade water quality and sensitive ecosystems. The following statements summarize the watershed's most significant climate-related vulnerabilities, highlighting where exposure, sensitivity, and adaptive capacity converge.

- **Wildfire and post-fire erosion pose severe risks to water infrastructure, cultural resources, and downstream communities** as fires damage tanks, pipes, power supply, access roads, and critical cultural resources. Destabilized slopes generate debris flows that threaten heritage sites, river corridors, and critical facilities during subsequent storm events, as occurred during and after the 2017 Thomas Fire.
- **Extreme precipitation and flooding overwhelm aging stormwater, flood control, drinking water, and wastewater systems**, leading to infrastructure failures, sewage spills, degraded water quality, and public health risks, particularly where levees, debris basins, and conveyance facilities, such as the Robles Diversion and Foster Park water production facilities and distribution lines which are already exposed to flooding impacts.
- **Drought and extreme heat reduce surface water flows and limit natural water availability**, increasing pressure on already local-dependent supplies during prolonged dry periods. These conditions can heighten competition among urban, agricultural, ecological, and cultural water needs, underscoring the importance of coordinated drought-resilience strategies as climate extremes intensify.
- **Water quality and wastewater treatment systems are increasingly vulnerable to compounded climate-driven hazards.** Prolonged drought reduces dilution capacity and allows pollutants to

accumulate, while wildfire introduces ash and sediment that can be rapidly mobilized during subsequent storms. Extreme precipitation can overwhelm stormwater drainage infrastructure, accelerating erosion, increasing maintenance demands, and generating high sediment loads that reduce diversion capacity and limit opportunities for stormwater capture and reuse. At the same time, centralized and onsite wastewater treatment systems face heightened risks of hydraulic overload, inundation, and physical damage from flooding and erosional processes, underscoring the need for integrated, climate-informed planning to protect water quality and system resilience.

- **Aquatic, riparian, groundwater-dependent, and other sensitive ecosystems are degraded** by drought, extreme heat, and wildfire, which contribute to reduced instream flows and shifts in seasonal flow timing, leading to higher water temperatures, reduced dissolved oxygen, declining habitat quality for sensitive species such as Southern California steelhead, and impacting sensitive species and habitat relied upon by Tribes.
- **Invasive species expansion is accelerated by climate extremes**, as drought-stressed native vegetation, post-fire runoff, and flood scouring create conditions for aggressive species like *Arundo donax* to proliferate, displacing native plants, increasing wildfire risk, and degrading cultural and ecological resources across the watershed.
- **Sea level rise and storm surge threaten the Ventura River estuary and coastal ecosystems**, driving saltwater intrusion, altered sediment dynamics, and habitat erosion that reduce estuarine function, compromise flood buffering capacity, and endanger culturally significant coastal landscapes and species.
- **Declining marine fog threatens cultural practices and exacerbates drought stress in coastal and lower-watershed ecosystems**, increasing irrigation demand on agricultural lands, reducing vegetation health, shortening windows for cultural burning and restoration, and weakening the resilience of fog-dependent habitats that historically moderated heat and water stress.
- **Agricultural lands are highly vulnerable to extreme heat, drought, flooding, and wildfire**, which increase irrigation demand, erode soils, damage infrastructure, affect farmworker health and livelihoods, and can permanently remove productive land from use, threatening local food security and the watershed's agricultural economy.
- **Legacy land use patterns and infrastructure decisions have altered natural river processes, reducing floodplain function,** sediment transport, and groundwater recharge. These changes amplify vulnerabilities for downstream communities, and unhoused individuals living in or near river corridors, who face heightened exposure to flooding, debris flows, and water quality hazards.
- **Recreational resources and public access points face increasing climate-related disruptions**, from flood-damaged trails and access points to wildfire-related closures and drought-limited water recreation, interrupting daily use and place-based cultural connections to the river, beaches, and outdoor gathering areas, with disproportionate impacts on residents who depend on these spaces for cooling, recreation, and community well-being.
- **Operational resilience of water and emergency services is undermined by power disruptions and access constraints.** Flood-damaged roads and limited backup power capacity can impair pumping, treatment, firefighting, and emergency response during climate events.
- **Chronic funding gaps, fragmented governance, and outdated permitting and insurance frameworks limit proactive climate resilience**, forcing agencies to respond reactively to disasters, constraining nature-based solutions, excluding Indigenous stewardship, and leaving critical infrastructure and overburdened communities exposed to escalating climate risks.

Quantitative Assessment

As discussed in the Assessment Approach section above, the quantitative assessment centers on future flood conditions. This analysis models projected changes in flood magnitudes, frequencies, and compound storm sequences under multiple future warming levels.

Extreme precipitation and flooding increasingly strain aging stormwater, flood control, drinking water, and wastewater systems, a key vulnerability across the watershed, potentially leading to infrastructure failures, sewage spills, degraded water quality, and public health and safety risks. These risks are particularly relevant for flood management infrastructure such as levees, debris basins, and key conveyance facilities, such as Robles Diversion and Foster Park water production facilities and associated distribution infrastructure that are already experiencing flood impacts. As climate change intensifies hydrologic extremes, understanding system vulnerability under future flood conditions is critical for protecting both natural and built assets within the watershed.

The DWR Watershed Resilience Framework and Toolkit outlines an approach for conducting quantitative assessments of high-vulnerability water resource system components. Following this guidance, the analysis compares system performance under historical and future climate conditions, evaluates future performance without adaptation, and identifies opportunities for reducing vulnerability through natural system protection or infrastructure improvements. Results are intended to inform and strengthen the selection of adaptation strategies in watershed planning.

The flood-hazard quantitative assessment presented in this chapter was developed in response to the vulnerabilities identified in the qualitative assessment, guidance from DWR, the priorities raised during asset manager interviews, and a gap identified in existing quantitative studies. Across discussions with partners, the need to better characterize future flood conditions was consistently emphasized, leading to the focused hydrologic and hydraulic analysis that follows.

Several entities in the watershed have completed or are currently conducting related quantitative analyses that provide useful context for this assessment. An account of modeling tools assessed for potential use in this study are summarized in **Appendix Q**: Quantitative Assessment. Examples of such models include:

- **Matilija Dam Ecosystem Restoration Project**: Multiple studies (2003–2025) evaluating sediment loading, dam-removal impacts, and mitigation measures such as bridge replacements, levee improvements, and sediment-sluicing modifications at the Robles Diversion.
- **Estuarine Coastal Modeling Study (2019)**: Assesses the combined effects of variable river flows, sea-level rise, and sedimentation on estuary dynamics over a 50-year horizon after Matilija Dam Removal.
- **Lake Casitas Water Supply Analysis (2021)**: Evaluates climate impacts on evaporation, storage loss from sedimentation, and sustainable yield under future conditions.
- **Upper Ventura River Groundwater Model (2022):** Assesses groundwater levels, surface-water depletions, and basin budgets under historical and future conditions.
- **Ojai Basin Groundwater Model (2022):** Assesses groundwater levels, surface-water depletions, and basin budgets under historical and future conditions.
- **Instream Flow Study (2024-2025)**: Analyzes instream flow needs for anadromous fish under unimpaired, existing, and anticipated future conditions (including climate change, fire impacts, dam removal, and invasive species mitigation).

System Performance Metrics and Thresholds

System performance metrics and thresholds were defined for specific hazard–system combinations. Multiple metrics can be used to assess flood management system performance, depending on duration, system component, and local conditions. To ensure the analysis was broadly applicable to the flood management system and usable by multiple flood management entities, annual maximum one- and three-day runoff events were selected as the threshold variables for the vulnerability analysis. Since GCMs do not represent instantaneous peak flows directly, daily average flows over one- and three-day durations were used to approximate peak discharges for different return events. This limitation reflects the scale constraints inherent in climate-driven hydrologic modeling. Historical flood records show that extreme river floods often involve elevated discharge sustained for 24 hours or longer, supporting the use of daily flow metrics in climate-scale flood assessments.

Described in detail in **Appendix Q**: Quantitative Assessment, the climate-driven increase in daily average flows is extrapolated to estimate corresponding changes in peak flows. This assumes that changes in daily averages are equivalent to changes in peak flows, though some uncertainty remains. Peak instantaneous flows could be higher than the daily averages presented, and it is not known whether this method overestimates or underestimates actual peak flows.

Methodology

The approach includes hydrologic and hydraulic analysis of projected future watershed flood conditions under a range of climate scenarios. The evaluation was performed at selected locations within the watershed that correspond to key flood management systems in major subwatersheds. Locations of interest include points along the San Antonio Creek and the Ventura River. Utilizing a scenario-based approach, future flood hydrology was characterized at six locations. The hydraulic analysis was completed for two example hydrologic assessment locations, prioritizing high-vulnerability locations in the Ojai Valley and in the downstream region of the Ventura River near the City of Ventura. Assessment locations are identified in Figure 41.

Figure 41 Quantitative Assessment Locations within the Ventura River Watershed

Basemap provided by Esri and its licensors © 2026.
Additional data provided by CPAD, 2025; NHD, 2024; US EPA, 2022; USGS, 2025; Stantec, 2026.

24-16486 WRP Climate Modeling
Quantitative Assessment Locations

Together, the analyses rigorously characterize future flood hazard and exposure under projected climate conditions. Because flood sensitivity varies by asset type and function, a detailed asset-level sensitivity analysis was not the focus of this watershed-scale evaluation. The intent of the quantitative assessment is to provide broadly applicable hazard information that is usable throughout the watershed. This is accomplished by providing projected future hydrology metrics alongside location-specific examples of application of the projected future climate hydrology metrics through the hydraulic analysis. Accordingly, recommendations for adaptation strategies focus on increasing adaptive capacity and reducing vulnerability across exposed assets. Detailed methodology and results are documented in **Appendix Q**: Quantitative Assessment.

Hydrologic Projections

The goal of the hydrologic projections is to estimate how flood flow magnitudes could change under the influence of climate change. The method uses recent results from GCMs coupled with models of water runoff during high flow events. Climate and hydrology data were utilized from the recently developed California's Fifth Climate Change Assessment and include GCM outputs from the CMIP6 projections downscaled for California. The downscaled climate projections were used to drive Variable Infiltration Capacity hydrologic modeling, producing 21 hydrologic projections representing multiple GCMs and emissions pathways (i.e., Shared Socioeconomic Pathways) that reflect different future climate forcing assumptions (Bass 2023; Bass, Su, and Lettenmaier 2023). These results were processed to estimate runoff change from historical to two future periods (i.e., near and distant futures).

The hydrology projections provide simulated daily runoff throughout the watershed from water year 1951 to 2100. The projections were evaluated for flood hydrology metrics (i.e., annual maximum one- and three-day maximum flows) during historical, near future, and distant future periods, which revealed changes in flood hydrology metrics by either future period. While this is a robust and readily available dataset, use of the data is subject to limitations, discussed in **Appendix Q**: Quantitative Assessment.

Hydraulic Assessment

Higher peak flows result in increased flood elevations. The potential increase in flood elevations due to the estimated increase in peak flow was evaluated using existing Federal Emergency Management Agency (FEMA) floodplain models. Existing FEMA models simulate the peak water surface elevations within the Ventura River Watershed for a large range of flow rates (FEMA 2024). These simulations identify maximum water surface elevations experienced along reaches for simulated peak flow events. Using this relationship between peak flow and water surface elevations, the increases in water surface elevation and flow depth during peak flows (10-year, 50-year, and 100-year return periods) under climate change were estimated.

The analysis computed the percentage change in annual maximum daily average flows over the future period 2025–2100. This change in daily average flows was extrapolated to estimate corresponding changes in peak flows up to the 100-year recurrence interval. There is significant uncertainty associated with this extrapolation, and extending the analysis beyond the 100-year flood was not considered methodologically useful. As a result, the analysis does not address the rarest events, including the 500-year flood extents used in FEMA flood mapping, which may be relevant for certain planning and risk-management decisions.

San Antonio Creek near City of Ojai

At the furthest upstream hydrologic assessment location along San Antonio Creek, hydrology projections indicate variable change (-3 to +23 percent) in peak flow for near-future climate (2015–2057) and a significant (+35 to +83 percent) increase in peak flow for the distant-future climate (2058–2100) conditions. Near-future climate conditions (2025–2057) generally correspond to the period when global warming levels approach ~1.5–2 °C, which aligns with the early- to mid-century timeframes shown for SSP2-4.5 and SSP3-7.0. In contrast, distant-future conditions (2058–2100) align more closely with ~2–3 °C warming, consistent with the later-century projections under higher-emissions scenarios such as SSP3-7.0 and SSP5-8.5. With a +60 percent increase in annual peak flow representing an average of the potential changes in the distant-future climate hydrology, water surface elevations (i.e. flood depth) during peak flow events are estimated to increase by 1.4 to 2.1 feet, varying by location and return period, across the studied reach.

Ventura River near City of Ventura

At the furthest downstream hydrologic assessment location along Ventura River (W. Stanley Ave.), hydrology projections indicate a relatively small (+4 to +16 percent) increase in peak flow for near-future climate (2015–2057) and a significant (+34 to +48 percent) increase in peak flow for the distant-future climate (2058–2100) conditions. With a +40 percent increase in annual peak flow representing an average of the potential changes in distant-future climate hydrology, water surface elevations (i.e., flood depth) during peak flow events are estimated to increase by 2.1 to 3.3 feet, varying by location and return period, across the studied reach.

Vulnerability Assessment and Priority Adaptation Strategies

Floodplain inundation extents are affected by the projected changes in flood elevations, resulting in additional exposure to flooding in river-adjacent communities. Approximately 1,000 parcels in each of the watershed's major cities (Ojai and Ventura) are located within current FEMA Flood Hazard Zones for the 100- and 500-year events. These zones will be affected by flooding more frequently, according to the distant-future hydrology projections. Long-term planning efforts should prioritize non-structural adaptation measures (e.g., flood easements, zoning restrictions, development controls, land buy-backs, establishment of open space in flood zones, and flood-anticipating building standards) to enhance adaptive capacity to future flood hazard in the Ventura River Watershed.

Due to the scale of vulnerability, nonstructural measures are needed to protect watershed assets from flooding that is projected in the distant-future climate. Site-specific flood management system structural improvements would complement non-structural measures. However, current projects (e.g., the Ventura River Levee Rehabilitation Project and Robles Diversion upgrades) alone are insufficient to prevent projected flooding. Reducing flood vulnerability in these river-adjacent communities in the current FEMA Flood Hazard Zones will depend on implementing non-structural measures over the next 30 years to prepare for the higher flood hazards projected later in the century.

The adaptation strategies presented herein focus on non-structural approaches, including active floodplain management measures such as removing structures from the floodplain and promoting flood-proofing of existing structures. These measures are intended to reduce flood damages, rather than to alter flood peaks, water surface elevations, or the physical extent of flooding. Implementation would likely occur on a parcel-by-parcel basis, with minimal impact on floodplain storage or conveyance. The purpose of these non-structural strategies is not to reduce the flood extent or magnitude, but rather to mitigate the consequences of flooding on people and property. There are negligible benefits to the

modeling of these adaptation strategies due to the lack of structural changes in post-adaptation strategy conditions.

Discussion

Projected mean-annual precipitation change reflects changes in all-weather types, from drizzle to downpours. The analysis of flood cases focuses on changes in downpours. GCMs show that warmer air holds more moisture (about 7 percent more moisture capacity per degree Celsius warming) which translates into potential increase in precipitation (National Aeronautics and Space Administration 2022). In addition, the relative increase in runoff is often greater than the relative increase in precipitation; for western U.S. basins, the increase in mean-annual runoff is typically a factor of two greater than the relative increase in precipitation (Tang 2012). Catchment-storm relationships suggest that smaller catchments may respond to warming more strongly than larger catchments because of a stronger relationship between increased temperature and increased precipitation. As a result, upper watershed areas often show larger increases in flooding than lower watershed areas (Sharma et al. 2018). Therefore, peak runoff increases of approximately 60 percent for San Antonio Creek and 40 percent for Ventura River for the one and three-day extreme events are conceptually reasonable.

Key Findings

Key findings from the quantitative assessment are discussed below, along with the associated adaptation measures developed to help address key challenges. Measures referenced here are developed and discussed in **Chapter 6**: Adaptation Strategies, Actions, and Implementation Roadmaps.

- Annual peak flow events are projected to increase in magnitude by the end-of-the-century.
  - *Adaptation measure*: Modernize infrastructure design criteria to address projected increases in runoff (Strategy 4.1)
- Elevated flood depths are expected in areas adjacent to rivers throughout the watershed during floods.
  - *Adaptation measure*: Mitigate flood impacts in developed areas via non-structural adaptation (Strategy 4.2)
- While the increases in peak flow are significant, the flow events are expected to remain consistent in terms of timing during the year (winter and early spring) and approximate duration.
  - *Adaptation measure*: Where feasible and beneficial, pursue managed recharge or increase natural recharge potential (Strategy 4.2)
- Vulnerability due to flooding is likely to increase significantly by the end of the century.
  - *Adaptation measure*: Refine emergency response plans (Strategy 7.2)