Appendix G
Russian River Watershed Historical Weather-Related Hazards

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G.1 Purpose and Scope

This technical memorandum (TM) summarizes significant historical weather-related hazards in the Russian River watershed that could be identified from a review of publicly available sources. The purpose of preparing a summary of historical weather-related hazards is to provide context and understanding for vulnerabilities in the watershed that may be experienced under future climate conditions. Events are organized according to the type of hazard, including extreme precipitation and flooding, wildfire, extreme temperatures, and drought.

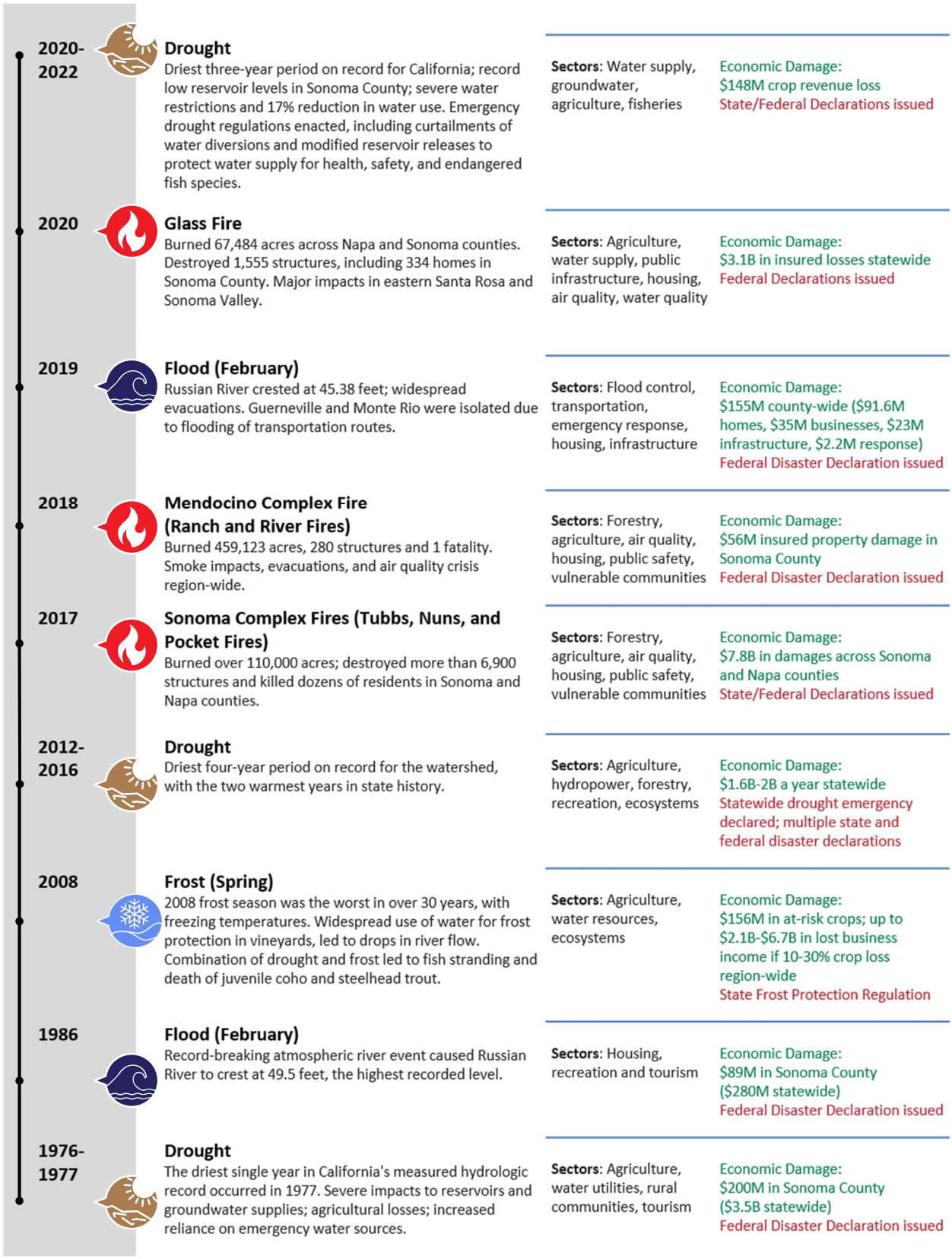
G.2 Key Weather-Related Events and Impacts in the Watershed

The Russian River watershed is experiencing a clear trend of increasing climate hazards. Rising temperatures and greater variability in precipitation are contributing to more frequent and intense floods and wildfires, prolonged droughts, and significant disruptions to water resources and ecosystems. The watershed has repeatedly experienced "weather whiplash"—rapid shifts between extreme wet and dry periods—resulting in some of the most intense floods and droughts in California's history. These shifts are becoming more pronounced with climate change, amplifying risks to infrastructure, water supply, and ecological systems.

Figure G-1 provides a summary timeline of some of the most significant weather-related events in the Russian River watershed in recent decades. These events include major droughts, floods, wildfires, and extreme temperatures that impacted the water resources of the watershed. As shown in the figure, the Russian River has experienced a range of weather-related hazards, often transitioning from an excess of rainfall (flood) to sustained deficits in rainfall (drought). This is the signature of historical climate in the watershed and likely continued and expanded variability in the future.

A comprehensive table of events—compiled as part of this assessment—is included in Attachment G-1.

Figure G-1. Summary Timeline of Major Weather-Related Events in the Watershed in Recent Decades



G.3 Extreme Precipitation and Flooding

Atmospheric rivers (ARs) are the primary driver of major flooding in the Russian River watershed. All major Russian River floods in recent decades, including the catastrophic events of 1986, 1995, 2006, and 2019, have been linked to AR conditions, which account for over 99% of flood damages in Sonoma County (Sonoma Countywide Flood Risk Management Assessment 2024; CW3E 2021). ARs are responsible for over 84% of historical flood damages in the western U.S., and annual AR-related flood damages currently average around $1 billion. Under the high-emissions RCP8.5 scenario, AR-related flood damages in Sonoma County are projected to more than double by the 2090s compared to 1990s levels, making it the county most impacted by AR-related flooding among 11 western states (Corringham et al. 2022).

Flood risk in the watershed is shaped by both natural and human factors. Steep tributary canyons such as Mark West Creek and Austin Creek rapidly funnel runoff into low-gradient floodplain areas such as Guerneville. Human alterations, which include the construction of unreinforced levees and gravel pits that have disrupted floodplain connectivity, reduce the capacity to absorb and slowly release floodwaters. Such alterations also degrade aquatic habitat. The lower Russian River's narrow floodplain accelerates and deepens floodwaters during storms, increasing risk to life and property (Permit Sonoma 2017). Chronic flooding is especially acute in lower Russian River communities such as Guerneville, Monte Rio, Rio Nido, Duncans Mills, and Mirabel Park. Many homes and businesses were built before modern flood regulations, making them especially susceptible to repeated inundation.

Sea level rise (SLR) is projected to increase flood risks in the lower Russian River, especially near Jenner, where tidal influence is significant. Modeling from the Sonoma Water Climate Adaptation Plan (2021) projects that SLR could raise baseline water levels by 0.8 to 1.6 feet by 2050 under medium- to high-risk scenarios, and up to 3 feet under extreme projections. The February 2019 AR event, which caused the Russian River to crest at 45.38 feet in Guerneville and flood over 2,000 structures, highlights the vulnerability of access routes and communities to prolonged flooding when drainage is restricted. Additionally, increased sedimentation in tributaries such as Dry Creek and Fife Creek further reduces channel capacity, compounding flood risks prior to river overtopping (Sonoma County EOP Annex 2023).

G.4 Wildfire

Wildfire has been a dominant ecological process in the Russian River watershed and throughout California and is shaped by both natural (climate and lightning) and cultural (Indigenous burning) factors. Large-scale fire suppression since the 1910s, combined with climate change, invasive species, and human encroachment, has resulted in denser forests and higher fuel loads (California Air Resources Board 2024). These factors have increased the risk of large, high-severity wildfires, which are now more frequent and severe than in the historical record. However, the frequency and severity of wildfire are projected to increase in Northern California as a consequence of climate change, which is characterized by hotter and drier conditions, longer summers, and extended fire seasons.

The Russian River watershed has experienced several significant wildfires in recent years, including the Mendocino Complex Fire, Kincade Fire, Tubbs Fire, Walbridge Fire, and Glass Fire. These events have had profound impacts on water quality, infrastructure, and ecosystems.

The combined effects of heat, ash, and sediment runoff from these wildfires pose substantial long-term risks to ecosystem health and water supply resilience. Following major fires, storm-driven erosion can sharply increase turbidity and nutrient loads, including dissolved organic carbon, nitrogen, and phosphorus. Increased turbidity following wildfires has the potential to impair Lake Sonoma's drinking water quality and threaten endangered fish species in Dry Creek, which relies on cold-water releases from Lake Sonoma to maintain suitable temperatures. Lake Sonoma, serving over 600,000 residents in Sonoma and northern Marin counties, is a critical water supply and flood control reservoir with moderate

to very high fire vulnerability. These vulnerabilities are compounded by climate change, which is expected to increase the frequency of droughts and floods, further stressing water infrastructure and ecosystem health (Sonoma Water Climate Adaptation Plan 2021).

G.5 Extreme Temperatures

The Russian River watershed is especially susceptible to temperature extremes, largely because of its dependence on agriculture. In addition to acute heat waves, chronic warming trends are evident: the region now experiences more days above 100°F than in past decades, and most of the top 10 hottest July–September periods on record have occurred within the last 20 years (California Natural Resources Agency 2024). Extreme heat exacerbates drought, alters streamflow patterns, and raises water temperatures, threatening salmon and steelhead that depend on cool, oxygen-rich waters. Frost events in low-lying valleys pose significant economic risks to frost-sensitive crops, including wine grapes (valued at $626 million in 2024) and pears. Most years require active frost protection, and rapid water withdrawals during frost events can sharply reduce streamflow, stranding juvenile salmonids and harming aquatic ecosystems (SWRCB 2011; Sonoma County Crop Report 2024).

During the spring 2008 frost, repeated freezes coincided with drought, prompting vineyard owners to simultaneously divert large volumes of river water for frost protection. This caused river flows to decrease from typical spring levels of 500–1,000 cubic feet per second to just 168 cubic feet per second. This significant reduction in flow occurred in the upper watershed, particularly between Ukiah and Hopland in Mendocino County. Such withdrawals have been documented to strand and kill threatened and endangered salmonid species, as occurred in April 2008 on Felta Creek and the mainstem Russian River near Hopland. In frost-prone areas like Grape Creek, agricultural water users have historically relied on direct diversions from streams during freezing events. Infrastructure upgrades such as off-stream storage ponds have reduced reliance on stressed streams (State Water Resources Control Board 2021). As a result, the State Water Resources Control Board adopted the Russian River Frost Protection Regulation, which requires all frost protection diversions between March 15 and May 15 to be managed under a state-approved Water Demand Management Program to coordinate and mitigate the effects on river flows and fish habitat (State Water Resources Control Board 2011).

During the June 2021 Pacific Northwest heatwave, Sonoma County experienced record-breaking high temperatures that contributed directly to the formation of harmful algal blooms in the Russian River, prompting public health warnings and recreational advisories due to risks to people and pets. The September/October 2024 heatwave drove inland Mendocino temperatures to 108°F, reducing late-season grape yields, while the June 2021 heatwave contributed to harmful algal blooms and livestock stress.

G.6 Drought

The Russian River watershed is increasingly vulnerable to extreme drought, which poses significant challenges to both water availability and quality. Unlike regions that rely on snowpack for sustained summer flows, the Russian River watershed lacks this buffer, making it especially vulnerable to prolonged droughts. This vulnerability is expected to increase, as analyses project potentially more severe droughts and low storage probabilities in the future, threatening municipal, industrial, and agricultural water supplies (Sonoma Water Climate Adaptation Plan). Droughts in this TM are classified based on the driest years or multi-year periods of record, using precipitation and hydrologic metrics as referenced by authoritative sources such as the California Department of Water Resources (2015) and the U.S. Drought Monitor (National Drought Mitigation Center n.d.). Droughts in this region develop gradually over multi-year periods, with recent severe events occurring from 2012–2017 and from 2020–2022, and historical droughts recorded in 1976–1977, 1987–1992, 2007–2009, and 2012–2016. Rising temperatures are compounding these drought impacts by increasing evapotranspiration and accelerating

soil moisture loss, further straining limited water resources. These hotter, drier conditions are also lengthening fire seasons and increasing vegetation flammability, with wildfires now threatening 44% of Sonoma County's land area, including critical infrastructure like fire stations located in high-risk zones (Sonoma County Climate Change Vulnerability Assessment 2024).

- **2020–2022 Drought:** This drought was driven by a combination of prolonged below-average precipitation and high temperatures. Several consecutive years of low rainfall led to historically low water levels in Lake Mendocino and Lake Sonoma. This drought triggered emergency declarations, drought water use restrictions, and the issuance of Temporary Urgency Change Petitions to preserve water supplies.
- **2012–2016 Drought**: One of the most severe and sustained droughts in California's recorded history, this drought had record-low snowpack (2015) and persistently low rainfall. Lake Mendocino dropped to 40% of its storage capacity, resulting in substantial agricultural losses, including a $14.7 million loss for grape growers and a 54% revenue decline for Mendocino County livestock producers. The governor of California declared a state of emergency, and Sonoma County followed with local emergency proclamations in 2014 and 2021 as water storage in Lake Mendocino and Lake Sonoma reached historic lows.
- **1976-1977 Drought**: One of the most acute single-year droughts in California's instrumental record, this drought resulted in widespread groundwater depletion and led to emergency water deliveries by rail and the first major implementation of water rationing in Marin and Sonoma counties.

The Russian River watershed is highly dependent on ARs, which provide 40% to 50% of its annual rainfall (USGS 2022). Climate projections indicate that future droughts will likely be marked by prolonged dry periods interrupted by intense AR-driven storms, increasing water management challenges (CW3E 2021). The severity of droughts is amplified when ARs are absent or less intense, as seen during the 2012–2015 drought when precipitation was 58% below average. Lake Mendocino dropped to 40% of its target storage, which resulted in emergency water restrictions and significant agricultural losses (CW3E 2021; USGS 2022). Lake Sonoma, which relies entirely on precipitation runoff, was similarly impacted after three consecutive drought years, and storage fell to a historic low of approximately 96,000 acre-feet in December 2022 (Sonoma Water 2022).

Increased reliance on groundwater during drought has stressed shallow aquifers, particularly in unincorporated and agricultural areas (Climate Ready North Bay). Low instream flows in the Russian River and tributaries such as Austin Creek and Grape Creek have blocked or delayed migration and spawning of endangered coho salmon and steelhead trout, with documented strandings and reduced juvenile survival during drought years (NMFS 2020). Vineyard irrigation demands peak during dry months, placing pressure on shared resources, especially in areas like Alexander Valley and Dry Creek (Climate Ready North Bay). Rural and agricultural communities in the Russian River watershed face disproportionate risks due to their reliance on groundwater and limited infrastructure (Hastings Environmental Law Journal 2022).

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Attachment G-1
Significant Weather-Related Events

Attachment G-1. Significant Weather-Related Events

Event Name	Impacts in Watershed	Sectors Impacted	Economic Damage Estimate	Source of Estimate	Declaration
2024 Flood	Russian River rose rapidly to nearly 30 feet, approaching moderate flood stage in the lower watershed (notably Guerneville and Forestville). USGS Gage: 11467002, crest height: 28.9 feet	Flood control, transportation, emergency response, housing, infrastructure, utilities, water supply	**$155M+** (Sonoma County estimate)	Sonoma County	State/Federal Declarations issued
2023 Flood	A series of atmospheric rivers caused widespread flooding. Evacuations and infrastructure impacts were reported. USGS Gage: 11467002, crest height: 31.8 feet	Flood control, emergency response, housing, transportation	**$148M** (Sonoma County estimate)	Sonoma County	State/Federal Declarations issued
October 2021 Atmospheric River	This is one of the largest single-day rainfall events on record. Santa Rosa received 7.83 inches in 24 hours. Dry antecedent conditions prevented major flooding, but localized landslides and debris flows occurred.	Water supply, flood control, emergency response, transportation	**$100M** in regional damages (Sonoma County, NOAA estimates)	NOAA	None
2020–2022 Drought	This was the driest 3-year period on record for California. The 2020–2021 water year is cited as the second driest single year on record, with record-low reservoir levels in Lakes Mendocino and Sonoma in fall 2021, severe water restrictions, and a 17% reduction in water use. For the first time, SWRCB issued curtailments of surface water rights and groundwater diversion to be limited to human health and safety requirements. This was a very significant regulatory response.	Water supply, groundwater, agriculture, fisheries	**$148M** crop revenue loss (regional estimate for Russian River Basin)	UC Merced Economic Impact Report	State/Federal Declarations issued
2020 LNU Lightning Complex (Walbridge and Meyers) Fires	These fires burned over 363,220 acres across multiple counties, including Sonoma County. Over 1,491 structures were destroyed, and extensive damage was done to hillsides and watersheds affecting Lake Sonoma.	Agriculture, water supply, public infrastructure, housing, air quality, water quality	**$18.1 M in Sonoma County** (includes $12.8M debris removal and public infrastructure, $5.3M emergency response)	Sonoma County Emergency Management (2020)	State/Federal Declarations issued
2020 Glass Fire	This fire burned 67,484 acres across Napa and Sonoma counties; destroyed 1,555 structures, including 334 homes in Sonoma County; and majorly impacted eastern Santa Rosa and Sonoma Valley.	Housing, public safety, air quality, water quality, tourism	**$3.1B** in insured losses statewide	CA Department of Insurance	Federal Disaster Declaration issued
2019 Kincade Fire	This was the largest wildfire in Sonoma County at the time. It burned 77,758 acres, destroyed 374 structures, and triggered evacuation of over 180,000 residents. PG&E power shutoffs affected 97,000 homes.	Housing, public safety, air quality, water quality, utilities, agriculture, tourism	**$725M total losses**	Sonoma County Resilience Fund; FEMA	Federal Disaster Declaration issued
February 2019 Flood	The Russian River crested at 45.38 feet. Evacuation orders were issued for 24 communities, affecting approximately 4,000 residents. USGS Gage: 11467002, crest height: 45.4 feet	Flood control, transportation, emergency response, housing, infrastructure	**$155M** county-wide ($91.6M homes, $35M businesses, $23M infrastructure, $2.2M response)	Sonoma County	Federal Disaster Declaration issued
Mendocino Complex Fire 2018 (Ranch and River Fires)	These fires burned 459,123 acres and 280 structures with 1 fatality, causing smoke impacts, evacuations, and air quality impacts.	Forestry, agriculture, air quality, housing, public safety, vulnerable communities	**$56M** in insured property damage in Sonoma County	Burned Area Emergency Response Mendocino Complex Fire	Federal Disaster Declaration issued
January 2017 Flood	Over 500 homes were flooded, causing widespread evacuations in low-lying areas. USGS Gage: 11467002, crest height: 38.5 feet	Housing, infrastructure, utilities, emergency response	**$155M+** with > $50M insured losses (estimated)	FEMA Damage Estimates	Federal Disaster Declaration issued
2017 Tubbs Fire	This fast-moving wildfire burned through urban-wildland interface areas in Sonoma County. It burned over 36,807 acres, destroyed more than 5,600 structures, and killed dozens of residents. It was part of the 2017 Sonoma Complex Fires.	Forestry, agriculture, air quality, housing, public safety, vulnerable communities	**$5–$7B** county-wide property loss; $1.5B in insured losses in Sonoma County	CA Department of Insurance	State/Federal Declarations issued

Event Name	Impacts in Watershed	Sectors Impacted	Economic Damage Estimate	Source of Estimate	Declaration
2017 Nuns Fire	This fire burned 56,556 acres across Sonoma and Napa counties, with 8% of the Russian River watershed affected. Over 8,000 structures were damaged or destroyed. This fire was part of the 2017 Sonoma Complex Fires.	Water quality, housing, emergency response, public health, natural resources, infrastructure	**$1.3B** in damages (2017 USD)		State/Federal Declarations issued
2012–2016 Drought	Prolonged drought conditions caused critically low streamflows and elevated water temperatures throughout the Russian River watershed. Many tributaries experienced seasonal drying, and entire year classes were lost in some streams from 2013–2014 due to impaired spawning and rearing conditions.	Agriculture, hydropower, forestry, recreation, ecosystems	**$223M** crop revenue losses statewide	UC Davis Center for Watershed Sciences; California Department of Water Resources	Statewide drought emergency declared; multiple state and federal disaster declarations
Spring 2008 Frost	The 2008 frost season was the worst in over 30 years, with freezing temperatures. Widespread use of water for frost protection in vineyards led to drops in river flow. Combination of drought and frost led to fish stranding and death of juvenile coho and steelhead trout.	Agriculture, water resources, ecosystems	**$156M** in at-risk crops; **up to $2.1–$6.7B** in lost business income if 10–30% crop loss region-wide	Sonoma State Univ. (Eyler Report); Water Boards Economic Impact Report	Led to State Frost Protection Regulation
NYE 2005 Storm and January 1, 2006, Flood	A series of storms culminating in a powerful New Year's Eve event caused major flooding across Northern California. The Russian River at Guerneville crested at 41.7 feet. USGS Gage: GUEC1	Flood control, transportation, emergency response, housing, infrastructure, utilities, water supply	**$100M+** (regional estimate; localized damages)	USGS Open-File Report 2006-1182	Federal Disaster Declaration issued
Floods 1996–1997	Severe flooding occurred from December 26, 1996, to early January 1997 due to successive warm, wet storms ("pineapple express") and rapid snowmelt. USGS Gage: 11467002, crest height: 46 feet	Agriculture, water supply, housing, infrastructure, transportation, public safety	**$200M** in damages in Northern California and western Nevada	Corringham et. al (2019)	Federal Disaster Declaration issued
Floods 1995	This severe atmospheric river event caused the river to crest at **48 feet**. USGS Gage: 11467002	Flood control, transportation, emergency response, housing, infrastructure, water supply	**$180M+** in regional damages	California Department of Water Resources	Federal Disaster Declaration issued
February 1986 Flood	This record-breaking atmospheric river event caused the Russian River to crest at 49.5 feet, the highest recorded level. USGS Gage: 11467002, crest height: 49.5 feet	Housing, recreation, tourism	**$25M in Sonoma County** (of $319M statewide)	USGS; FEMA	Federal Disaster Declaration issued
Drought of 1987–1992	This drought was characterized by record-low precipitation and reservoir levels, widespread water shortages, and increased groundwater pumping.	Water supply, groundwater, agriculture, fisheries, forestry, public health, ecosystems	**More than $3B** in statewide economic losses	California Department of Water Resources (2000); U.S. Army Corps of Engineers (1993)	State/Federal Declarations issued (CA drought emergency declared April 1988; Drought Water Bank established 1991)
Drought of 1976–1977	The driest single year in California's measured hydrologic record occurred in 1977. It had severe impacts on reservoirs and groundwater supplies, caused agricultural losses, and increased reliance on emergency water sources.	Agriculture, urban water supply, rural communities, tourism	**Statewide agricultural losses estimated at $566.5M** (of $3.5B statewide)	CA Department of Water Resources	Federal Disaster Declaration issued