FEBRUARY 2020

ELK GROVE COMMUNITY MOBILITY RESILIENCE PLAN WHITE PAPER

Climate Change, Precipitation Change, and Flooding in Elk Grove, California

PREPARED FOR:

City of Elk Grove
8401 Laguna Palms Way
Elk Grove, CA 95758

Climate Change, Precipitation Change, and Flooding in Elk Grove, California

Elk Grove Community Resilience Plan White Paper

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LIST OF ABBREVIATIONS

ADT	average daily traffic
APA	American Planning Association
AR	atmospheric river
Cal EMA	California Emergency Management Agency
Cal OES	California Office of Emergency Services
CalEPA	California Environmental Protection Agency
Caltrans	California Department of Transportation
CAP	Climate Action Plan
CEC	California Energy Commission
CI	confidence interval
City	City of Elk Grove
CNRA	California Natural Resources Agency
CVFPP	Central Valley Flood Protection Plan
Delta	Sacramento River–San Joaquin River Delta
District 3 VA	Caltrans District 3 Climate Change Vulnerability Assessment
DWR	California Department of Water Resources
EO	Executive Order
EPA	U.S. Environmental Protection Agency
FEMA	Federal Emergency Management Agency
FHWA	Federal Highway Administration
GP	General Plan
GHG	greenhouse gas
HPI	Healthy Places Index
I-5	Interstate 5
IDF	intensity, duration, and frequency
IRWM	Integrated Regional Water Management
IPCC	Intergovernmental Panel on Climate Change
LHMP	Local Hazard Mitigation Plan
NOAA	National Oceanic and Atmospheric Situation
OPR	Governor’s Office of Planning and Research
Plan	City of Elk Grove Community Mobility Resilience Plan
ppm	parts per million
RCP	Representative Concentration Pathways
Regional San	Sacramento Regional County Sanitation District
SACOG	Sacramento Area Council of Governments
SB	Senate Bill
SDMP	Storm Drainage Master Plan
SPFC	State Plan of Flood Control
SR	State Route
VA	vulnerability assessment

1 INTRODUCTION

This white paper has been developed as part of a larger planning process undertaken by the City of Elk Grove (City) to develop the Elk Grove Community Mobility Resilience Plan (Plan). The Plan will serve as the City's primary climate adaptation planning document and help the City respond to the impacts of climate change. It will focus on three transportation system-related climate impacts identified by the City as high priorities: flooding, extreme heat, and the fiscal impact on the City of declining sales tax revenue related to an expected reduction in driving and vehicle and fuel sales.

Resilience planning is increasingly important as the impacts of climate change intensify. Resilience refers to the capacity of individuals, communities, institutions, businesses, and systems to survive, adapt, and thrive in the face of chronic stresses and acute shocks (APA 2017). As has been demonstrated by the recent catastrophic wildfire seasons, the more frequent severe storms, the prolonged drought periods and the longer and hotter summer seasons, the effects of climate change are already occurring in California. Planning for how to mitigate and adapt to these impacts is important to ensure the City is able to respond and continue to prosper. This white paper focuses on one aspect of the Plan, that related to likelihood and intensity of flooding. It is organized into two main components developed, in part, to be integrated into the larger Plan document further into the planning process:

- Precipitation and Flood Vulnerability Assessment —This section provides a summary of the changes in precipitation and characteristics of storm events projected to occur in areas affecting the City through 2099. It also includes analysis of how these changes will affect the City's stormwater management system and, subsequently, the City's transportation system, City residents, and typical functions in the City. The section uses the five-step vulnerability assessment process outlined in the *California Adaptation Planning Guide* (Cal EMA and CNRA 2012) and the *Draft California Adaptation Planning Guide 2.0* (Cal OES 2019) to analyze impacts.
- Flood Resilience Strategies—This section includes a proposed set of strategies to mitigate and adapt to projected impacts from precipitation and flooding in the City. The strategies also include key information regarding implementation of the strategies.

This report was developed using the best available information regarding climate change projections for the region, relevant information on current regional efforts to adapt to climate change, and best practices and guidance provided by the State and other sources specific to climate adaptation planning. The primary resources used in developing this white paper are:

- *California Adaptation Planning Guide* (Cal EMA and CNRA 2012);
- *Draft California Adaptation Planning Guide 2.0* (Cal OES 2019);
- *Safeguarding California Plan: California's Climate Adaptation Strategy* (CNRA 2018);
- Cal-Adapt 2.0 (CEC 2019);
- *California's Fourth Climate Change Assessment Statewide Report* (OPR et al. 2018a) and the *Fourth Climate Change Assessment Sacramento Valley Report* (2018b);
- *City of Elk Grove General Plan* (2019a);
- *State of California General Plan Guidelines* (OPR 2017);
- State Adaptation Clearinghouse in the Integrated Climate Adaptation and Resiliency Program;
- *Sacramento County Local Hazard Mitigation Plan* (Sacramento County 2017a);
- *Vulnerability Assessment and Adaptation Framework* (FHWA 2017);
- *Addressing Climate Change Adaptation in Regional Transportation Plans* (Caltrans 2013); and
- California Department of Transportation (Caltrans) *District 3 Climate Change Vulnerability Assessment Summary Report* (Caltrans 2019a); and associated Technical Report (Caltrans 2019b).

As part of the development of the Plan, a Flood Working Group was formed to provide input on climate adaptation analysis and strategies specific to flooding impacts in the City. The working group is comprised of representatives from local, regional, and State agencies and stakeholders who can provide expertise specific to the issues of flooding, land use planning, water management, and transportation-related flooding issues. The members of the working group are providing input on this white paper and supporting the City throughout the development of the Plan.

1.1 CLIMATE CHANGE OVERVIEW

Climate change has been important issue for the State for several decades. The State has remained a leader in addressing climate change through both government policy and private enterprise. Beginning in 2005, with the signing of Executive Order (EO) S-3-05 by Governor Schwarzenegger, which established long-term emissions reduction goals for the State by 2050, the State began to greatly increase its efforts to reduce greenhouse gas (GHG) emissions contributing to climate change in the State. In 2015, with the signing of EO S-30-15 by Governor Brown, State agencies were directed to begin incorporating climate change impacts into the State's *Five-Year Infrastructure Plan* as well as identify how climate change will affect California infrastructure and industry and what actions the State can take to reduce the risks posed by climate change. The impacts of climate change are being felt across the state, increasing the frequency and severity of existing natural hazards while introducing new and challenging issues for local communities and State agencies. As a result, understanding and preparing for the impacts of climate change is becoming an increasingly important part of local planning.

In 2019, the City completed an update to its *General Plan* (GP) as well as the *Climate Action Plan* (CAP). The CAP is intended to reduce GHG emissions from activities in the City. Chapter 2 of the City's CAP includes an overview of the science of climate change, projected impacts in the state, and a State and Federal regulatory framework of policies addressing climate change. As part of the GP update, a Climate Change Vulnerability Assessment was conducted to provide an overall assessment of the potential impacts from climate change on the City (See Chapter 12 of the GP). Chapter 8 of the GP, "Service, Health, and Safety," provides a comprehensive set of policies to address the impacts of climate change using information gathered in the vulnerability assessment. This whitepaper and the Plan overall are intended to provide in-depth analysis of potential flooding impacts on the City and help support the previous work completed as part of the City's GP to prepare for the impacts of climate change.

1.2 PRECIPITATION AND STORM EVENT METRICS AND TERMINOLOGY

The analysis presented in this white paper focuses heavily on anticipated precipitation and storm-related impacts on the City. Because the analysis is partly technical in nature, it uses metrics and phrases pertaining to precipitation and storm events that may not be common knowledge. Provided below is a brief summary of the metrics discussed in the analysis. Scientists, engineers, and planners all use a specific system to measure and plan for certain sizes of storm events and flood impacts associated with these events. These events are measured by the probability that they are likely to occur in a given year. The phrase "100-year storm," for example, refers to a storm event with a 1-in-100 likelihood of occurring in any given year. The size and other aspects of these storms are identified to characterize the nature of the events based on historic data. The metrics are then used to plan and design stormwater management systems that can cope with storm events of these sizes. The Federal Emergency Management Agency (FEMA) uses certain larger storm events (i.e., 100-, 500-year storms) to identify flood hazard areas in the United States. FEMA administers flood insurance based on location and extent of impacts from these storm events, which influences land use patterns and development in cities. The following metrics are used in this report to discuss storm events and are included in projections from the Cal-Adapt tool:

- Intensity—The amount of rainfall that occurs over a certain period (e.g., 1 hour, 24 hours, 5 days) during storm events of different sizes (e.g., 100-year storm event, 2-year storm event)
- Duration—The longest stretch of consecutive days during a water year (October through September) with rainfall above a certain threshold

- **Count**—The number of days during a water year (October through September) with rainfall over a certain period (e.g., 1 hour, 24 hours, 5 days) above a certain threshold
- **Timing**—The timing during the year in which rainfall events exceeding a certain threshold occur

These phrases are used in the assessment discussions to describe storm events, including how these characteristics will change in the future.

2 PRECIPITATION AND FLOOD VULNERABILITY ASSESSMENT

The vulnerability assessment process is used to understand how a city will be exposed to climate change, how and when this exposure will affect the city, and to what degree the city and regional partners are prepared to adapt to these effects. This analysis was conducted using guidance from the *California Adaptation Planning Guide* (Cal EMA and CNRA 2012), the *Draft California Adaptation Planning Guide 2.0* (Cal OES 2019), and the Federal Highway Administration's (FHWA's) *Vulnerability Assessment and Adaptation Framework*, which provides guidance on assessing climate vulnerabilities to the transportation system (FHWA 2017). The assessment includes five steps with results from the previous step being incorporated into the subsequent step. The analysis process and results for each of the five steps are summarized below.

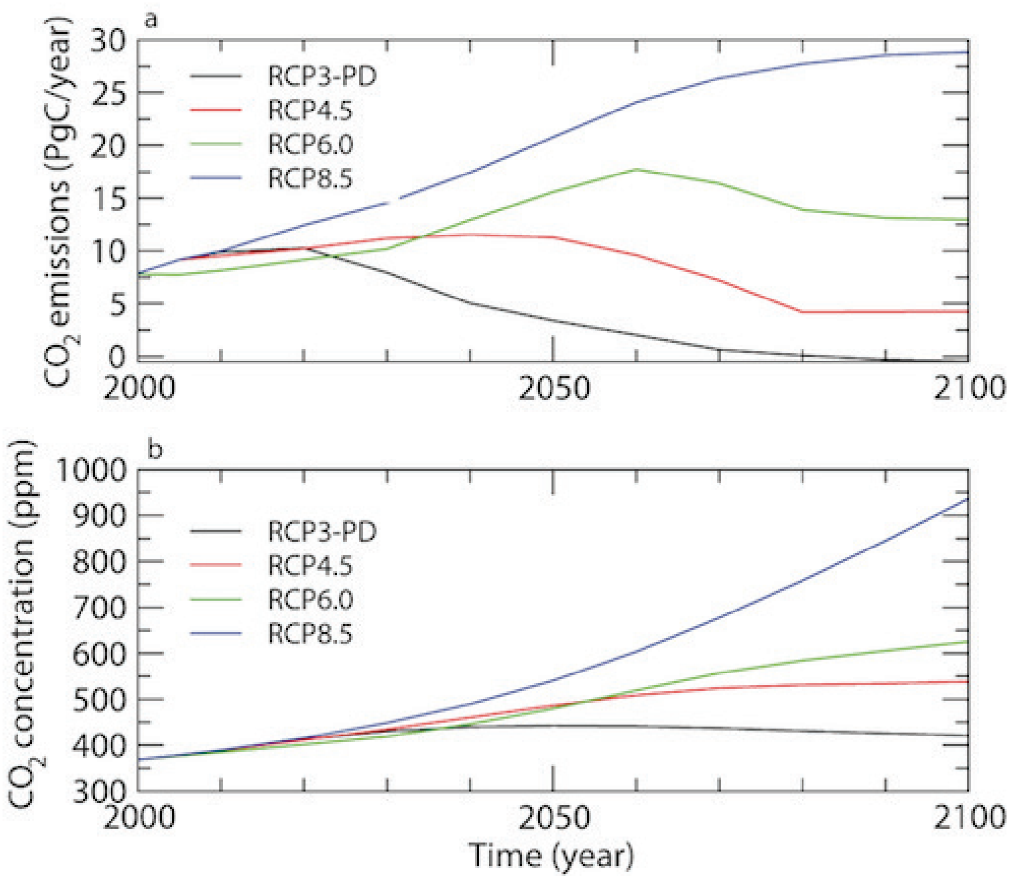
2.1 CLIMATE CHANGE IMPACT MODELING AND PROJECTIONS

According to the work of Intergovernmental Panel on Climate Change (IPCC) and research conducted by the State and partner agencies and organizations, climate change is already affecting and will continue to affect the physical environment throughout California, including the City of Elk Grove. To identify the local impacts of climate change in California, the California Energy Commission (CEC) and the University of California Berkeley Geospatial Innovation Facility developed the scenario planning tool Cal-Adapt. The Cal-Adapt tool uses global climate simulation model data downscaled to a local and regional resolution to identify localized exposure from various climate metrics. Developers of the Cal-Adapt tool selected four priority global climate models to include in projections provided in the tool. This analysis uses the average of these four models to identify changes in precipitation and storm events.

The projected effects of climate change over the next century will vary depending on global GHG emissions trends. The Cal-Adapt tool includes global climate simulation model data from two emissions scenarios, known as Representative Concentration Pathways (RCPs), that were used in *Intergovernmental Panel on Climate Change's (IPCC's) Fifth Assessment Report*. The RCPs represent scenarios that estimate the level of global GHG emissions through 2099. The RCP scenarios used in the Cal-Adapt tool are the RCP 8.5 scenario, which represents a business-as-usual future emissions scenario that would result in atmospheric CO_2 concentrations exceeding 900 parts per million (ppm) by 2100, and the RCP 4.5 scenario, which represents a lower GHG emissions future and likely the best-case scenario for climate impacts, under which GHG emissions would peak in 2040 and then decline through the rest of the century, resulting in a CO_2 concentration of about 550 ppm by 2100. The RCP trends assumed in the analysis are illustrated in Figure 1. The emissions scenarios depend on global GHG emissions trends in the future and the efficacy of global GHG reduction strategies proposed by the international community. Because the efficacy of the GHG reduction strategies and the likelihood that a certain RCP scenario will occur are uncertain, a discussion of both emissions scenarios and their subsequent impacts are included in this analysis.

The State's draft *Adaptation Planning Guide 2.0* (Cal OES 2019), as well as the Governor's Office of Planning and Research's (OPR) guidance for State agencies (OPR 2018), provide guidance on choosing appropriate RCP scenarios to be included in the analysis. For analysis of impacts through 2050, the draft Adaptation Planning Guide 2.0 suggests using a conservative approach and using the RCP 8.5 scenario, to assume a worst-case scenario but notes that impacts by 2050 under the RCP 4.5 and RCP 8.5 scenarios will vary based on local context. Based on State guidance and to remain consistent with the methodology used in the *Caltrans District 3 Climate Change Vulnerability Assessment* (District 3 VA), this analysis uses the RCP 4.5 and RCP 8.5 scenarios to assess the full extent of potential impacts that could occur in the future.

Figure 1 Representative Concentration Pathway Used in Global Climate Modeling



Notes: CO_2= carbon dioxide; ppm = parts per million; PgC = one billion metric tons of carbon; RCP = Representative Concentration Pathway

Source: Goosse et al. 2010

The Cal-Adapt tool provides data on projected changes in annual precipitation and changes in the intensity, duration, and frequency (IDF) of extreme precipitation events that will affect the City, and it has the ability to identify changes at various geographic levels. Considering that impacts on the City from shifts in precipitation are affected by watersheds both within and outside the City boundaries, the analysis identifies precipitation changes at the larger, watershed level for four watersheds affecting the City. These four watersheds include Morrison Creek, Snodgrass Slough, Deer Creek, and Upper Cosumnes River. Cal-Adapt also allows users to specify what size storm event (e.g., 100-year storm event) would occur to analyze how different size storms will shift in intensity and frequency over the century. This exposure analysis evaluated changes in 2-, 10-, and 100-year storm events based on their consistency with the three storm events used to design the capacity of stormwater management and flood control system in the City. The analysis also identifies at what point over the next nearly 80 years (2020–2099) changes in precipitation will begin to occur and at what magnitude. This topic is discussed further in Section 2.6. The exposure analysis used the time periods listed below to analyze changes in annual average precipitation under both the RCP 4.5 and RCP 8.5 scenarios. The time periods are established as 30-year time intervals to gather accurate data on average changes in the climate, with 30-year periods or longer being typical for climate analysis. This results in overlap among some time periods. Due to annual fluctuations in climate variables, climate data on periods less than 30-years may be less accurate and not reflect long-term averages (NOAA 2018). The three time periods are:

- near-term (2020–2050),
- midterm (2040–2070), and

- long-term (2070–2099).

For changes in the IDF of extreme weather events, the following periods for both the RCP 4.5 and RCP 8.5 scenarios are used based on the established time periods used in the Cal-Adapt tool:

- midcentury (2035–2064) and
- late century (2070–2099).

2.2 EXPOSURE ANALYSIS

As the first step in the process, the exposure analysis provides an overview of how the City will be exposed to various climate variables. Specifically, for this report, the analysis looks at changes in precipitation at the regional and local level as well as changes in the characteristics of extreme precipitation events affecting the City. As the City begins to plan for the impacts of climate change, it is essential to understand the magnitude and specific characteristics of the changes in precipitation and storm events that are projected to occur over the century. The exposure analysis includes information from the *Fourth Climate Change Assessment Sacramento Valley Report* specific to precipitation and storm events, as well as data from the Cal-Adapt planning tool. The analysis discussion is organized into two sections: "Regional Exposure" and "Local Exposure."

2.2.1 Regional Exposure

This section discusses changes in precipitation that are expected to occur at the regional level and could have an impact on the City, specifically during large storm events affecting the Sacramento River and its tributaries. As discussed in the *Fourth Climate Change Assessment Sacramento Valley Report*, changes in precipitation patterns in northern California are anticipated to affect the Sacramento Valley region as well as adjacent regional watersheds which affect the Sacramento Valley (OPR et al. 2018b). Projected shifts include increases in the intensity of large storms events, which could compromise the performance of the Sacramento Valley and Central Valley flood management systems (Pierce et al. 2018). Given the City's proximity to the Sacramento River (approximately 1-mile northwest of the City limits), it is important to understand how precipitation changes in regions affecting the Sacramento River and its tributaries also may affect the City. The regional exposure analysis provides a snapshot of projected changes in precipitation in four key Integrated Regional Water Management (IRWM) regions, regional boundaries established by the California Department of Water Resources (DWR), that affect the Sacramento Valley region and the City. The four IRWM regions included in the analysis are listed in Table 1 and shown in Figure 2. Major waterways in these four IRWM regions include the Feather River, Sacramento River, Yuba River, Bear River, American River, and the Cosumnes River, as well as portions of their tributaries. The three rivers closest to and most likely to affect the City are the American, Sacramento, and Cosumnes Rivers.

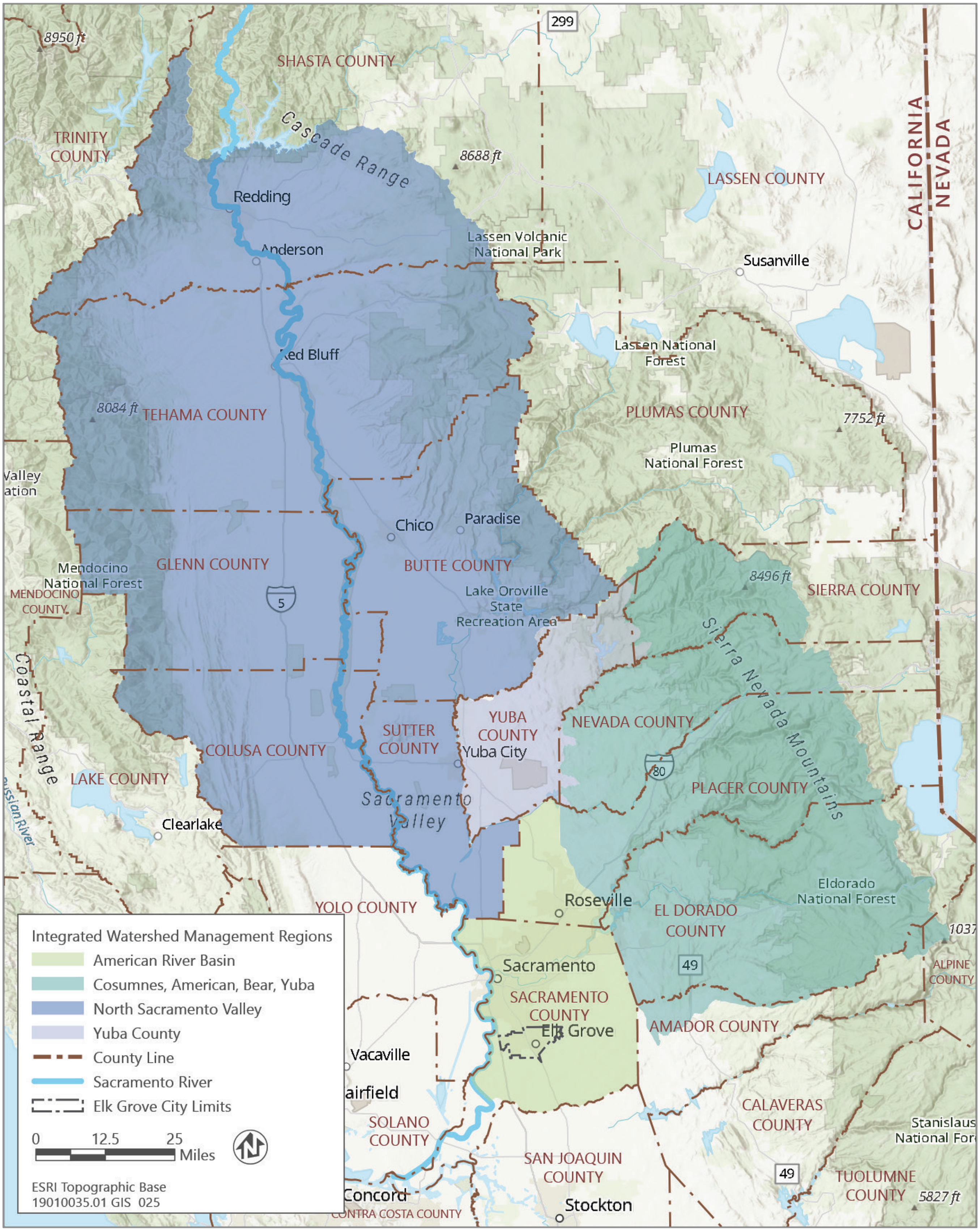
Table 1 Regional Annual Precipitation Changes (Historic to 2099)

IRWM Region	Historic (1961–1990)	RCP Scenario	Change in Annual Mean Precipitation (Inches)					
			Near Term (2020–2050)	Percent Change (Historic to 2050)	Midterm (2040–2070)	Percent Change (Historic to 2070)	Long Term (2070–2099)	Percent Change (Historic to 2099)
Northern Sacramento Valley	35	4.5	38.5	8%	38.7	11%	38.5	10%
		8.5	38.1	8%	38.2	9%	41.9	20%
Yuba County	36.8	4.5	40.9	10%	40.7	11%	40.4	10%
		8.5	39.9	8%	40.3	10%	44.1	20%
Cosumnes, American, Bear, Yuba, Sacramento	51.5	4.5	56.3	8%	56.2	9%	56.0	9%
		8.5	55.5	7%	56.2	9%	61.2	19%
American	20.6	4.5	23.3	12%	22.7	10%	22.7	10%
		8.5	22.5	8%	22.6	10%	24.6	19%

Notes: IRWM = Integrated Regional Water Management; RCP = Representative Concentration Pathway.

Source: CEC 2019

Figure 2 Regional Exposure – IRWM Region Boundaries



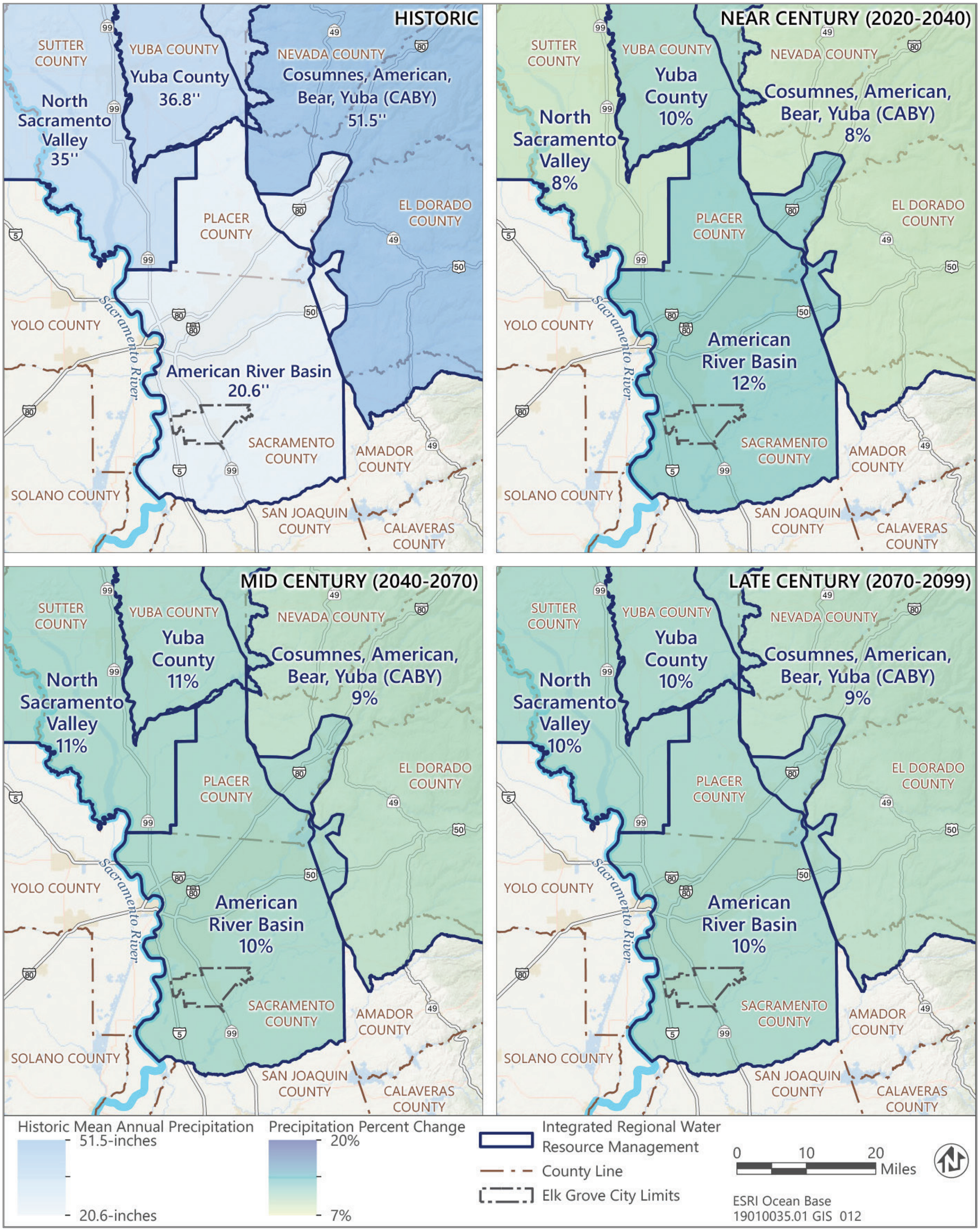
Source: data downloaded from DWR in 2019

Table 1 provides a summary of the annual changes to average precipitation projected to occur at the regional level under the RCP 4.5 and RCP 8.5 scenarios. This information is also presented graphically in Figures 3a and 3b. As shown in Table 1, under the RCP 4.5 scenario, annual precipitation in the four IRWM regions increases between 7 and 12 percent in the near-term period. During the midterm and long-term periods, the change in annual precipitation remain relatively the same with a 9 to 10 percent increase between the historic baseline and 2099 under the RCP 4.5 scenario. Under the RCP 8.5 scenario, annual precipitation in the four IRWM regions increases between 9 and 11 percent in the midterm period and continues to increase through the long-term period, resulting in an approximately 20 percent increase over historic levels by the end of the century. It is important to note that because the projected precipitation changes under the RCP 4.5 and RCP 8.5 scenarios are relatively the same through the midterm period at the regional level, these changes will occur with a higher degree of likelihood, regardless of what trends occur in global emissions reductions by the end of the near-term period (2040). Even if global emission peak by 2040 (i.e., RCP 4.5 scenario), the region will still experience an 8 to 12 percent increase in annual mean precipitation. Notably, the American River experiences the highest increase in annual precipitation, at 12 percent, under the RCP 4.5 scenario in the near-term, meaning a high likelihood of occurrence. Although the Sacramento Valley and adjacent regions are anticipated to experience only moderate increases in annual precipitation, research indicates that the majority of the increase in annual rainfall at the regional and local level are anticipated to occur during large storm events, which are projected to increase in size and frequency.

Based on California's location next to the Pacific Ocean, the state is exposed to the atmospheric river (AR) phenomenon, a narrow corridor of concentrated moisture in the atmosphere. California is subject to precipitation from an AR that transports water vapor from as far south as Hawaii to the state. The presence of the AR contributes to the frequency of "wet years" in the state, when there is an above-average number of AR storms and above-average annual precipitation. While research indicates that the frequency of large storms events does increase in these wet years, the most severe flooding from ARs may not be in wet years (Swain et al. 2018). The largest flooding impacts are caused by persistent storm sequences on sub-seasonal timescales (i.e., short time periods, typically 2 weeks to 3 months), which bring a significant fraction of annual average precipitation over a brief period. These are storms events similar to the Great Flood events of 1861–1862 which caused widespread damage throughout northern California (Swain et al. 2016). Based on current climate modeling, the frequency of these large storm sequences over short timeframes are projected to increase noticeably under the RCP 8.5 scenario. It is estimated that a storm similar in magnitude to the Great Flood events is more likely than not to occur at least once between 2018 and 2060 (Swain et al. 2018). A storm of this size would likely compromise large portions of the flood control systems in the Sacramento and the Central Valleys (Swain et al. 2018).

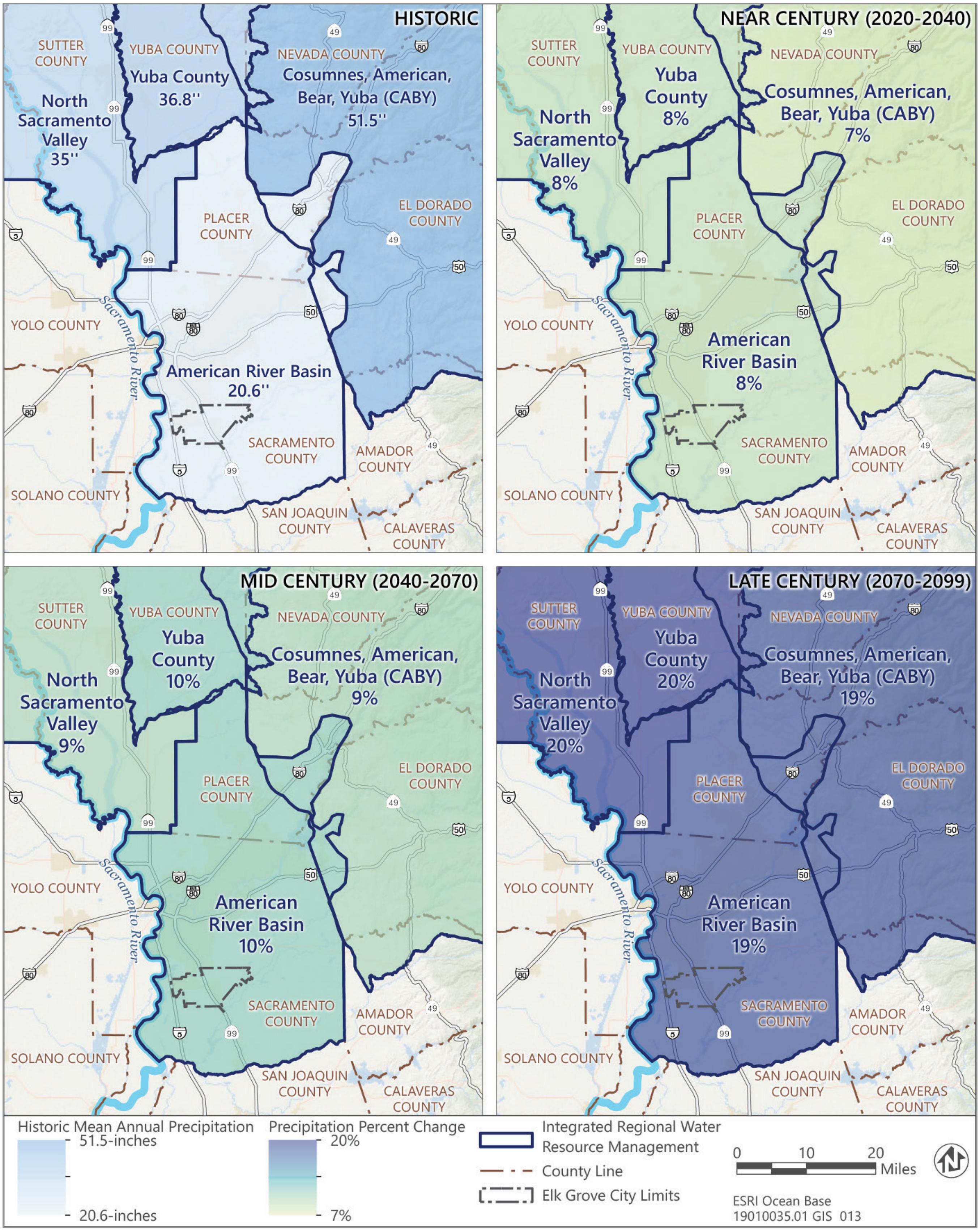
As noted in the *Fourth Climate Change Assessment Sacramento Valley Report*, although annual precipitation is anticipated to increase in the region, California's climate oscillates between extremely dry and extremely wet periods with annual precipitation varying widely from year to year. Climate change is anticipated to exacerbate these seasonal extremes with dry periods becoming dryer and wet periods becoming wetter (OPR et al. 2018b:19). As a result, the frequency and severity of large storm events are anticipated to increase as well. These oscillations between extremely dry and extremely wet periods, which have occurred historically in the state, are anticipated to become more severe with rapid shifts from dry to wet periods known as "whiplash events" (Swain et al. 2016). As Swain et al. note in their research, the recent 2012–2016 drought followed by the 2016–2017 flood events throughout the state serve as a good example of the type of whiplash events that will occur more frequently over the next century. These types of events are estimated to increase by approximately 25 percent in northern California, with increases in frequency occurring largely after 2050 (Swain et al. 2016).

Figure 3a Regional Annual Precipitation Change - RCP 4.5 Scenario through 2099



Source: data downloaded from CEC and DWR in 2019

Figure 3b Regional Annual Precipitation Change - RCP 8.5 Scenario through 2099



Source: data downloaded from CEC and DWR in 2019

SEA LEVEL RISE AND FLOODING

Although the City is not located directly in the Sacramento–San Joaquin Delta (Delta), it is located adjacent to the Delta region and could be affected by flood impacts from the system. When the Sacramento River reaches its peak capacity, the American River and other tributaries that flow into the Sacramento River cannot discharge at normal rates. These conditions result in "backflows," which can cause tributaries to overflow and flood local areas. The areas of the Sacramento River closest to the Delta are also affected by ocean tides. High tides that occur simultaneously with high river flows could increase the chances of flooding. Research conducted for California's *Fourth Climate Change Assessment Statewide Report* and the *Central Valley Flood Protection Plan* indicate that future changes in hydrologic patterns and sea level rise will impact water levels in the Delta (CEC and CNRA 2018). This research includes hydrologic modeling to understand the affect both sea level rise and projected increase in the intensity of storm events will have on the Delta, particularly during large storm events. Research results indicate that sea level rise will increase the base elevation of waterways in the delta and, therefore, will have an impact on upstream waterways which feed into the Delta (e.g., Cosumnes River, Sacramento River). However, the research notes that sea level rise has a larger effect on water surface elevation in locations closer to the center of the Delta, toward the San Francisco Bay. Further upstream to the riverine system, sea level rise has a smaller effect on water surface elevation because the channel bottom's slope increases while amplitude of the tide further up the Delta and away from the coast decreases. Notably, the research indicates that the water surface elevation in the San Joaquin River could increase as much as 7 feet for the 200-year return period flood event, which would overtop the levee near the City of Stockton (CEC and CNRA 2018). Current efforts to address this issue and increase resiliency in the Sacramento Valley and adjacent regions is discussed in Section 2.5, "Adaptive Capacity Analysis."

2.2.2 Local Exposure

Regional changes in precipitation over the century will subsequently result in local changes in both annual precipitation and changes in the characteristics of storm events in the City and Sacramento County more broadly. Table 2 includes the projected precipitation changes in Sacramento County and the City through 2099 under the RCP 4.5 and RCP 8.5 scenarios. The precipitation changes included in Table 2 are illustrated in Figures 10 and 11 in Appendix C.

Table 2 City of Elk Grove and Sacramento County Precipitation Change (Historic to 2099)

Geographic Area	Historic (1961–1990)	RCP Scenario	Change in Annual Mean Precipitation (Inches)					
			Near Term (2020–2050)	Percent Change (Historic to 2050)	Midterm (2040–2070)	Percent Change (Historic–2070)	Long Term (2070–2099)	Percent Change (Historic to 2099)
City of Elk Grove	17.6	4.5	20.3	15%	19.6	11%	19.8	13%
		8.5	19.5	11%	19.6	11%	21.8	24%
Sacramento County	18.3	4.5	20.9	14%	20.2	10%	20.3	11%
		8.5	20.1	10%	20.2	10%	22.1	21%

Source: CEC 2019

As shown in Table 2, annual precipitation in the City is estimated to increase between 13 and 24 percent by 2099 under the RCP 4.5. and RCP 8.5, respectively. A similar increase is anticipated to occur in Sacramento County with annual precipitation estimated to increase between 11 and 21 percent by 2099 under the RCP 4.5. and RCP 8.5, respectively. Similar to the regional changes in precipitation shown in Table 1, under the RCP 4.5 scenario, precipitation in both the City and the County increase between 14 and 15 percent by 2050 and decreases slightly by the end of the century. Under the RCP 8.5, precipitation in both the City and the county increase between 10 and 11 percent by 2050 and increase an additional 21 and 24 percent by the end of the century. Based on these projections, it is highly likely that the City and Sacramento County will experience a 14 to 15 percent increase in annual precipitation by 2050, regardless of global emissions trends later in the century.

As discussed in Section 2.2.1, "Regional Exposure," although annual precipitation is anticipated to increase in the City over the coming decades, the majority of the increase in precipitation is likely to occur during extreme precipitation events (Swain et al. 2018). As a result, it is important to understand how these shifts in extreme precipitation events will affect the City and regional watersheds which affect the stormwater management system and larger waterways within the City, though they begin outside the City boundaries. The Cal-Adapt Extreme Precipitation Event tool provides information on how the characteristics of extreme precipitation events will change over the century, including the ability to analyze changes at the watershed level. This analysis includes data from four watersheds which affect the City's stormwater management system and waterways in or near the City (Morrison Creek and Snodgrass Slough) and have importance to regional flooding issues (Deer Creek and the Cosumnes River). As shown in Figures 4a and 4b, the Morrison Creek watershed affects northern and eastern portions of the City and includes tributaries to Laguna Creek which runs east to west through the City and flows into Morrison Creek just north of the City limits. The Morrison Creek watershed also affects Elk Grove Creek which flows into Laguna Creek near Lewis Stein Road. The Snodgrass Slough watershed effects the southern and eastern portions of the City and contribute to runoff in the Shed C Channel, Franklin Creek, and Ehrhardt Channel in the southern part of the City as well as the detention basins in areas west of Bruceville Road. The Deer Creek and Upper Cosumnes River watersheds are located to the southeast of the City and affect regional flooding issues.

Discussed in more detail in Section 2.4, "Impact Analysis," the characteristics of extreme precipitation events are what are most commonly used to model and design urban stormwater management systems to ensure the system can withstand the rainfall and stormwater runoff that occurs during these events. For the purpose of this analysis, the specific storm events chosen are consistent with three size storm events used to design the City's stormwater management system and are included in the *Sacramento County Drainage Manual*. These include the 2-, 10-, and 100-year storm events for rainfall over a 24-hour period. Table 3 through Table 5 summarize the changes in amount of rainfall projected to occur in the four watersheds affecting the City for the 2-, 10-, and 100-year storm events through 2099 under the RCP 4.5 and RCP 8.5 scenarios.

Table 3 Changes in Rainfall During Extreme Precipitation Events – Morrison Creek Watershed

Watershed	Storm Event Size	RCP Scenario	Historic (1961–1990)	Change in 24-Hour Rainfall Period (Inches) for 100-Year Storm Event			
				Midcentury (2035–2064)	Percent Change (Historic to 2064)	Late Century (2070–2099)	Percent Change (Historic to 2099)
Morrison Creek	100	RCP 4.5	4.9	4.2	-14%	5.1	5%
	10		2.99	2.9	-3%	3.2	6%
	2		1.97	2.0	3%	2.4	20%
	100	RCP 8.5	4.92	4.1	-16%	6.2	26%
	10		2.99	2.8	-5%	3.7	22%
	2		1.97	2.0	3%	2.4	20%
Snodgrass Slough	100	RCP 4.5	3.9	3.7	-5%	4.2	8%
	10		2.5	2.6	6%	2.8	12%
	2		1.7	1.9	12%	1.9	13%
	100	RCP 8.5	3.9	3.5	-9%	4.9	26%
	10		2.5	2.6	3%	3.2	27%
	2		1.7	1.9	11%	2.2	28%

Notes: This table shows estimated intensity (Return Level) of Extreme Precipitation events, which are exceeded on average once every 2, 10, and 100 years (Return Period). Extreme Precipitation events, defined here, are days during a water year (October through September) with 1-day rainfall totals above an extreme threshold set for each of the watersheds, which is based on the lowest annual maximum storm intensity in historic records.

Source: CEC 2019

Table 4 Changes in Rainfall During Extreme Precipitation Events – Deer Creek and Upper Cosumnes River Watershed

Watershed	Storm Event Size (Year)	RCP Scenario	Historic (1961–1990)	Change in 24-Hour Rainfall Period (Inches) for Storm Events			
				Midcentury (2035–2064)	Percent Change (Historic to 2064)	Late Century (2070–2099)	Percent Change (Historic to 2099)
Deer Creek	100	RCP 4.5	5.1	4.6	-10%	5.1	-1%
	10		3.3	3.2	-5%	5.1	-3%
	2		2.3	2.2	-3%	3.2	-3%
	100	RCP 8.5	5.1	4.8	-6%	5.9	15%
	10		3.3	3.1	-5%	5.9	12%
	2		2.3	2.2	-3%	3.7	11%
Upper Cosumnes	100	RCP 4.5	4.7	4.9	4%	5.8	23%
	10		3.4	3.3	-3%	3.6	6%
	2		2.5	2.4	-5%	2.5	-2%
	100	RCP 8.5	4.7	5.5	17%	6.6	40%
	10		3.4	3.5	2%	4.0	17%
	2		2.5	2.4	-3%	2.7	8%

Notes: This table shows estimated intensity (Return Level) of Extreme Precipitation events, which are exceeded on average once every 2, 10, and 100 years (Return Period). Extreme Precipitation events, defined here, are days during a water year (October through September) with 1-day rainfall totals above an extreme threshold set for each of the watersheds, which is based on the lowest annual maximum storm intensity in historic records.

Source: CEC 2019

Table 5 Changes in Maximum Duration of Extreme Precipitation Events (Historic to 2099)

RCP Scenario	Watershed	Maximum Duration of Extreme Precipitation Events (Days)				
		Historic (1961–1990)	Midterm (2035–2064)	Percent Change (Historic to 2064)	Long Term (2070–2099)	Percent Change (Historic to 2099)
RCP 4.5	Morrison Creek	2.3	2.6	13%	2.8	22%
	Deer Creek	2.6	2.8	8%	3.2	23%
	Upper Cosumnes River	2.2	2.6	18%	2.7	23%
	Snodgrass Slough	2.1	2.4	14%	2.6	24%
RCP 8.5	Morrison Creek	2.3	2.7	17%	3.1	35%
	Deer Creek	2.6	3.1	19%	3.4	31%
	Upper Cosumnes River	2.2	2.7	23%	3.1	41%
	Snodgrass Slough	2.1	2.6	24%	2.9	38%

Notes: This table shows estimated intensity (Return Level) of Extreme Precipitation events, which are exceeded on average once every 2, 10, and 100 years (Return Period). Extreme Precipitation events, defined here, are days during a water year (October through September) with 1-day rainfall totals above an extreme threshold set for each of the watersheds, which is based on the lowest annual maximum storm intensity in historic records.

Source: CEC 2019

By midcentury, the Morrison Creek watershed is projected to experience a decrease in the rainfall during the 100- and 10-year storm event and a slight increase in the 2-year storm event under the RCP 4.5 and RCP 8.5 scenarios. By late century, the Morrison Creek watershed will experience slight increases in the 100- and 10-year storm event and a more substantial increase (20 percent) in the 2-year storm event under the RCP 4.5 scenario. Under the RCP 8.5 scenario, the watershed will experience an approximately 20 to 26 percent increase in the rainfall under all three storm events.

By midcentury, the Snodgrass Slough watershed is projected to experience a slight decrease in rainfall during the 100-year storm event and a noticeable increase in the 2- and 10-year storm event under the RCP 4.5 and RCP 8.5 scenarios. By late century, the watershed will experience an 8 percent increase in the intensity of the 100-year storm events and a more substantial increase (12 to 13 percent) in the 2- and 10-year storm events under the RCP 4.5 scenario. Under the RCP 8.5 scenario, the watershed will experience an approximately 27 percent increase in rainfall under all three storm events.

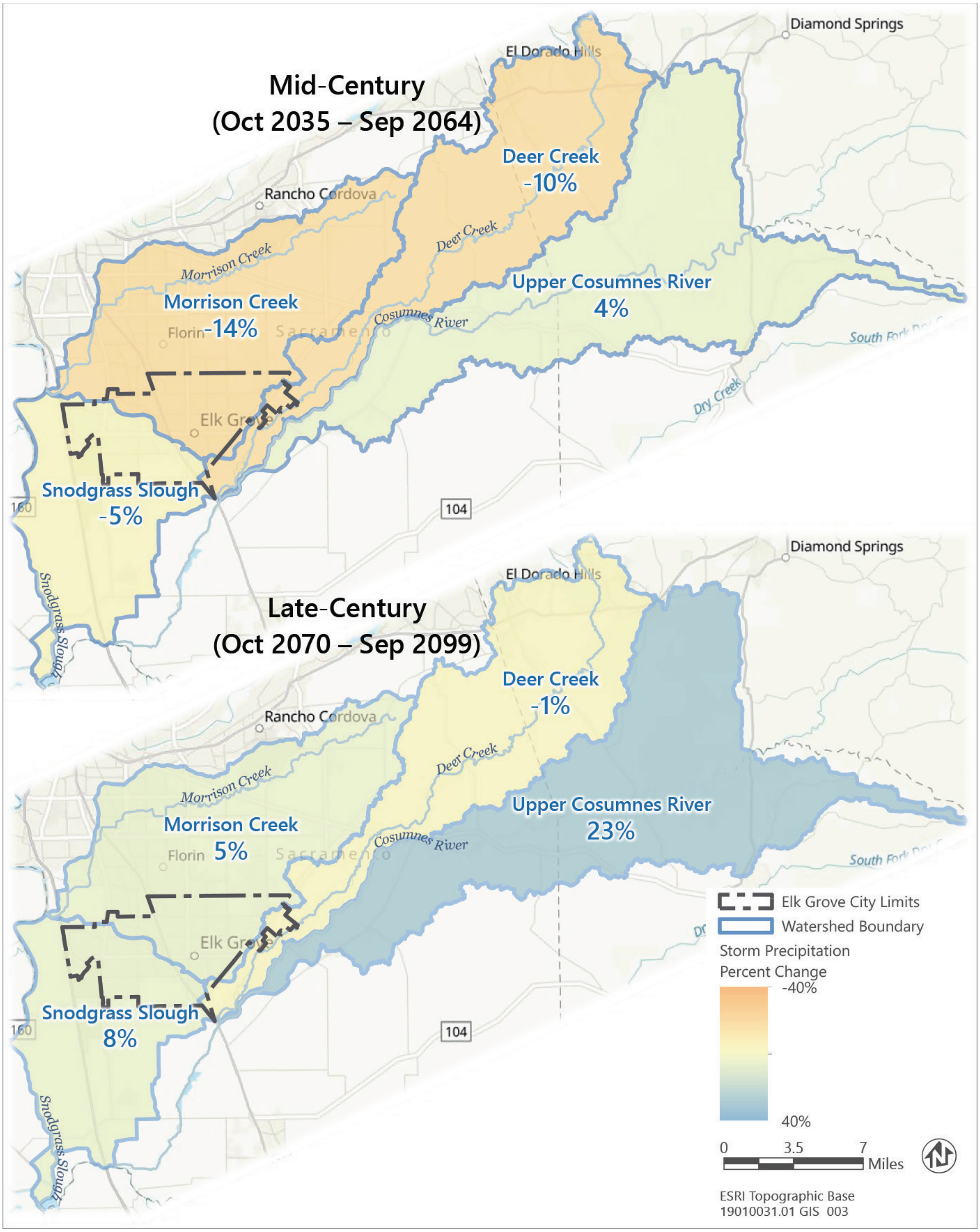
As shown in Figures 4a and 4b, the Deer Creek and Upper Cosumnes River watersheds are located directly southeast of the City and can affect eastern portions of the City during large storm events, particularly areas to the east of Grant Line Road. Table 4 provides a summary of the projected changes in these two watersheds. As show, the Deer Creek Watershed will experience a slight decrease in rainfall during storm events under the RCP 4.5 and RCP 8.5 scenarios by midcentury. By late century, Deer Creek watershed will remain relatively the same under the RCP 4.5 scenario and experience an 11 to 15 percent increase in rainfall during storm events under the RCP 8.5 scenario. The Upper Cosumnes River watershed will experience relatively the same amount of rainfall during storm events under the RCP 4.5 by midcentury and experience a 17 percent increase in rainfall during the 100-year storm event under the RCP 8.5 scenario. By late century, the Upper Cosumnes River watershed will experience a 23 percent increase in the 100-year storm event under the RCP 4.5 scenario and a 40 percent increase under the RCP 8.5 scenario.

The maximum duration of the 100-year storm event is also anticipated to shift as a result of climate change. Table 5 provides a summary of the increases in the maximum duration of extreme precipitation events that will occur in the four primary watersheds that affect the City.

Under the RCP 4.5 scenario, the four watersheds will experience increases in the maximum duration of events during the 100-storm by midcentury, with a range between 8 and 18 percent depending on the watershed. By late century under the RCP 4.5 scenario, all four watersheds will experience an increase between 23 and 24 percent in the length of the 100-year storm event. Under the RCP 8.5 scenario, the four watersheds will experience increase in the maximum duration during the 100-storm event by midcentury, with a range between 17 and 24 percent depending on the watershed. By late century under the RCP 4.5 scenario, all four watersheds will experience a substantial increase between 31 and 41 percent in the maximum possible duration of the 100-year storm event.

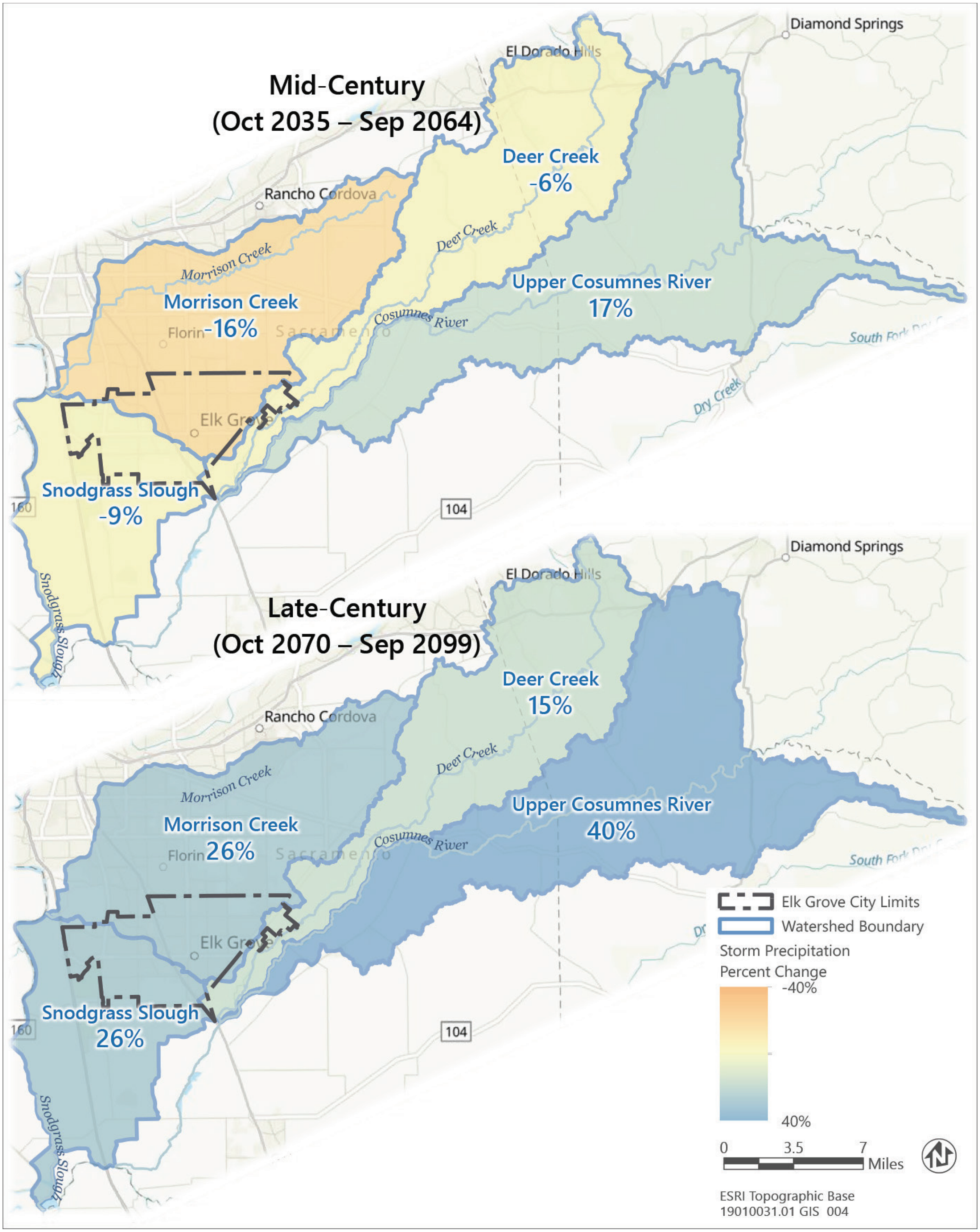
Additionally, the number of extreme precipitation events during the water year (October through September) is projected in increase as well. Under the RCP 4.5 scenario, all four watersheds experience a one day increase in the total number of extreme precipitation events during the year by the end of the century. Under the RCP 8.5, compared to historic records, all four watersheds would see a three day increase in the total number of extreme precipitation events by the end of the century. The timing of when these extreme precipitation events will occur during the year is also anticipated to change over the century. Extreme precipitation events will occur over a more condensed period in December through February with a decrease in events during October and November (CEC 2019).

Figure 4a Changes in Rainfall during Extreme Precipitation Events in Watersheds Affecting Elk Grove – RCP 4.5



Source: data downloaded from CEC and DWR in 2019

Figure 4b Changes in Rainfall during Extreme Precipitation Events in Watersheds Affecting Elk Grove – RCP 8.5



Source: data downloaded from CEC and DWR in 2019

2.3 SENSITIVITY ANALYSIS

The sensitivity analysis is conducted to identify and characterize the City's existing sensitivities to precipitation, flood events, and localized flooding impacts. By identifying key sensitive areas in the City, the analysis can better identify areas within the City which may be particularly vulnerable to shifts in precipitation or increases in the intensity of storm events. The sensitivity analysis also provides an overview of the City's existing stormwater management and flood control system to help contextualize the City's current sensitivities.

2.3.1 Existing Stormwater Management and Flood Control System

The City maintains a traditional storm drainage and flood control system, much of it inherited from Sacramento County after the City's incorporation in 2000 and annexation of Laguna West in 2004. The storm drainage collection and conveyance system consists of channels, creeks, ditches, pipes, streets, and detention basins throughout the City and has been designed to effectively control and drain stormwater runoff during normal rainfall events and larger storm events. The system consists of about 400 miles of underground pipes and 60 miles of natural and constructed channels draining within 13 watersheds in the City (City of Elk Grove 2019b). Within these 13 watersheds, there are ten major natural creeks or open channels that convey runoff within the City, including Elk Grove Creek, Laguna Creek, Strawberry Creek, Whitehouse Creek, Deer Creek, Ehrhardt Channel, Franklin Creek, Shed C Channel, Grant Line Channel, and Laguna West Channel. Four of the creeks convey runoff that originates outside the City limits: Elk Grove Creek, Laguna Creek, Strawberry Creek, and Deer Creek. All the watersheds and channels located in the City ultimately drain into the Stone Lakes National Wildlife Refuge floodplain with the exception of the Deer Creek and Grant Line Channel watersheds, which drain to Deer Creek and then to the Cosumnes and Mokelumne Rivers. The City's storm drainage and flood control system consists of a gravity-flow system for the portion of the City east of the Union Pacific Railroad tracks near Franklin Boulevard and a pump system, in which water is conveyed through the stations to specific locations, west of these Union Pacific Railroad tracks for the area referred to as the Laguna West communities. The City's current system of waterways and channels, as well as major transportation assets, can be seen in Figure 5.

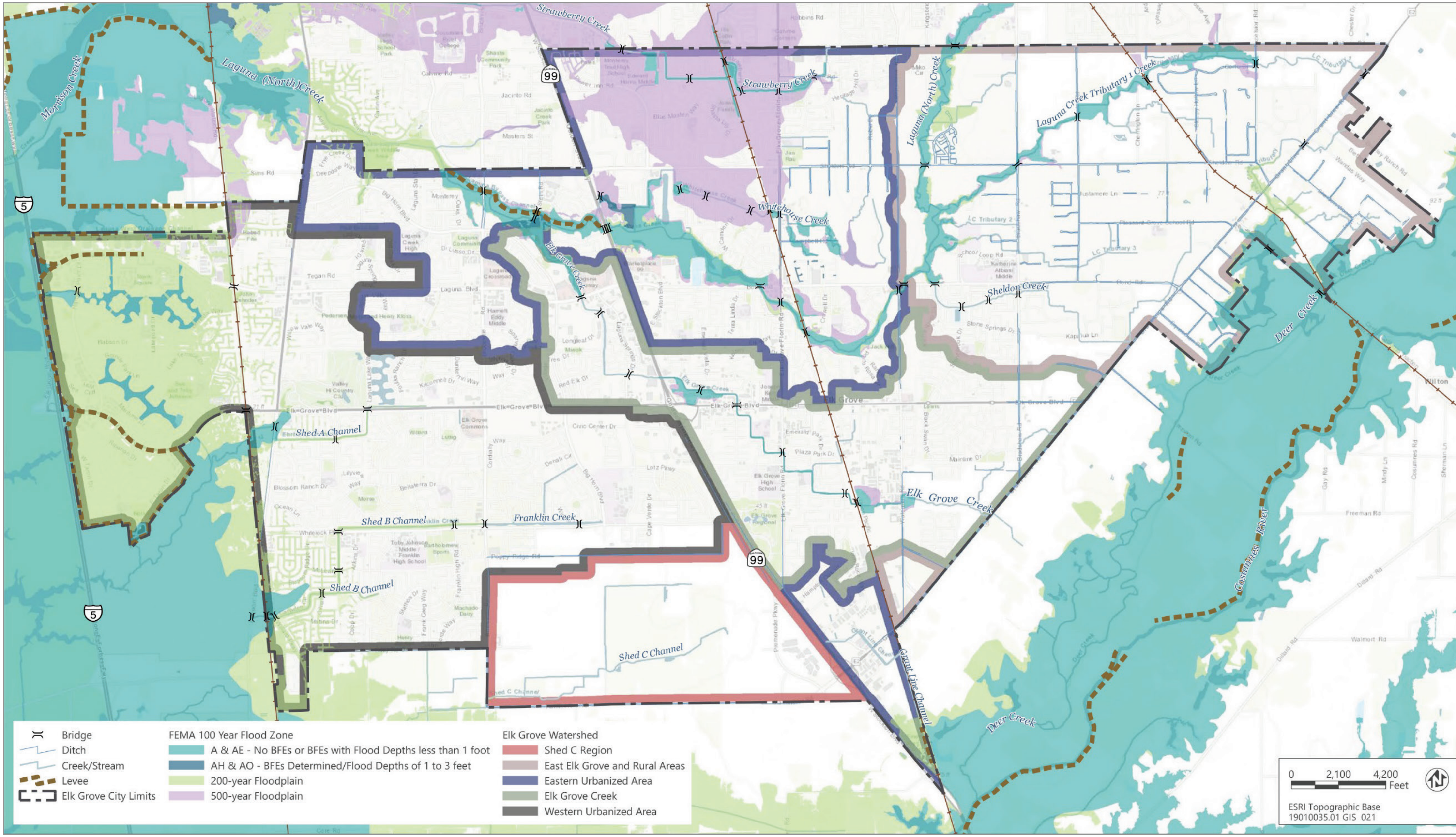
In 2011, the City adopted a comprehensive *Storm Drainage Master Plan* (SDMP), which assessed the City's system and provided a variety of drainage concepts for upgrading the existing storm drainage and flood control collection system. The SDMP also included technical analysis of the performance of the stormwater management system within the City's 13 watersheds and provided specific recommendations for improvements that balance cost, safety, and ecosystem benefits. The SDMP has identified four key drainage areas in the City based on unique drainage characteristics in the regions, which have been modified to five regions for this analysis. They include:

- Elk Grove Creek Region,
- East Elk Grove Area/Rural Region,
- Eastern Urbanized Area,
- Western Urbanized Area, and
- Shed C Region.

In 2019, the City prepared a minor update to the SDMP. The purpose of the minor update was to provide a summary of projects completed since 2011, provide details regarding remaining projects, including implementation costs and schedules (if available) and provide information regarding new regulatory requirements related to stormwater management and flood control.

To align with current work done in the SDMP, this vulnerability analysis has been conducted using the same four regions included in the SDMP to analyze and discuss the City's existing sensitivities to climate impacts on the City and its transportation system. However, for this analysis, due to the large size of the Other Urbanized Areas region, it has been divided into the Urbanized Western Region and Urbanized Eastern Region. The boundaries of the analysis regions used can be seen in Figure 5.

Figure 5 Existing Flood Conditions in Elk Grove



Source: Data received and downloaded from City of Elk Grove in 2019

2.3.2 Existing Sensitivities

As part of the City's *Local Hazard Mitigation Plan* (LHMP), which was developed as an annex to *the Sacramento County Local Hazard Mitigation Plan* update in 2016, existing natural and manmade hazards affecting the City have been analyzed to assess current risks levels for each hazard (Sacramento County 2017a). The LHMP provides details on the planning process, risk assessment, and mitigation strategies for the City to address specific hazards including large flooding events and flood related hazards. Additionally, the City's LHMP and SDMP both identify existing areas within the City that have the potential to flood during large storm events or that are subject to more localized flooding. Based on a review of these documents, the identified hazards can be classified into two categories: Large Flood Events and Localized Roadway Flooding. These two categories are discussed in detail below.

LARGE FLOOD EVENTS

As noted in the LHMP, the City has not experienced any large flooding events since incorporation, although smaller localized flooding events occur annually. As shown in Figure 5, portions of the City are located within the FEMA floodplains for the 100- and 500-year storm events. Figure 5 also includes areas within the 200-year flood zone which were mapped as part of the City's GP updated process and used to comply with the requirements of Senate Bill (SB) 5, which requires cities in the Sacramento-San Joaquin Valley area to assess risk-levels and provide increased flood protection for properties in the 200-year floodplain. The northern portion of the City is located within the Morrison Creek watershed, which includes Laguna Creek and several tributaries located in the City, including Elk Grove Creek, Sheldon Creek, and Whitehouse Creek. Areas surrounding portions of Laguna Creek, Whitehouse Creek and Elk Grove Creek are located in the FEMA 100-year floodplain. Based on information in the City's LHMP, there are 27 properties located in the 100-year flood zone valued at a total of $35.7 million. Certain areas in the western portion of the City, specifically the Laguna West, Lakeside, and Stonelake neighborhoods, are located within the 100-year floodplain but are currently protected by the Laguna West levee system, which is located along the western, as well as portions of northern and southern, boundaries of these neighborhoods.

The City Public Works Department is actively working on assessing the integrity and performance of Laguna West levee system because of the potential flooding from a 200-year storm event that would include a failure of the Sacramento River levee near the City. In July 2019, the City released a staff report summarizing the results of analysis being conducted regarding the performance of the City's levee system. The report states that the Laguna West levee system has been accredited by FEMA as meeting 100-year storm event standards and provides properties in the Laguna West and Lakeside areas with significant flood protection. However, the system would need to be raised by an average of approximately 3.5 feet to comply with the 200-year flood protection standard. The cost of these improvements would be approximately $12.2 million to raise 4.5 miles of existing Laguna West levees, with an additional $3.0 million that may be required to extend the levees in some areas. There is also the potential for under-seepage and stability issues within the levee system. The potential costs to address these issues could require an additional $7 million to $30 million to achieving 200-year flood protection. The City is currently performing additional geotechnical data collection and analysis on the levee system to better understand potential under seepage issues (City of Elk Grove 2019c).

As illustrated in Figure 5, the 500-year floodplain impacts the northern central portion of the City with 3,949 mostly residential properties located within this zone. There is a total population of 118 residents at risk to flooding in the 100-year flood zone and 12,558 residents in the 500-year flood zone. Elk Grove has 17 critical facilities located in the 100-year flood zone and 39 critical facilities in the 500-year flood zone. While portions of the City are within the 100- and 500-year flood zones, there have been no historical insurance claims for flood losses in the City (Sacramento County 2017a:B-44).

As shown in Table 6, there are several areas in the City with various land uses in the 100- and 500-year flood zone. As discussed above, the presence of the Laguna West Levee System near the Laguna West neighborhood is protecting 2,073 parcels from the 100-year flood event. Parcels located in the 100-year flood zone are located in flood zone areas surrounding Laguna Creek and Deer Creek. Alongside an analysis of land uses at risk of flooding, the City's LHMP also analyzed the number of essential service facilities, and at-risk populations that are located within the 100- and 500-year flood zones. Table 7 summarizes the number and type of critical facilities located within the 100- and 500-year flood zones.

Table 6 City of Elk Grove Properties by Land Use in FEMA Flood Zones

Land Use	100-Year Flood Zone	500-Year Flood Zone	Protected by Laguna West Levee System
Residential	27	3,903	2,029
Retail/Commercial	5	26	27
Office	0	2	12
Industrial	2	10	2
Care/Health	1	2	1
Church/Welfare	1	2	1
Recreational	1	2	1
Vacant	0	2	0
Total	**37**	**3,949**	**2,073**

Note: FEMA = Federal Emergency Management Agency.
Source: Sacramento County 2017a

Table 7 City of Elk Grove – Critical Facilities and Populations in FEMA Flood Zones

Flood Event	Critical Facility Category	Count
1% Annual Chance (100-Year)	Essential Services Facilities	15
1% Annual Chance (100-Year)	At Risk Population Facilities	2
0.2% Annual Chance (500-Year)	Essential Services Facilities	10
0.2% Annual Chance (500-Year)	At Risk Population Facilities	29
	Total	56

Note: See the City's LHMP for full definitions critical facilities categories.
Source: Sacramento County 2017a

LOCALIZED ROADWAY FLOODING

Localized flooding occurs primarily during the winter and spring months in the City, with several areas of concern primarily near waterways and creek systems that swell during heavy rainfall events, as noted in the City's LHMP (Sacramento County 2017a). Additionally, the City experiences localized flooding along roadways in the City which are caused by either inadequate drainage structures in the City's more rural regions or blockages in the stormwater drainage system due to debris and leaf buildup.

The five regions (Elk Grove Creek Region, East Elk Grove Area/Rural Region, Eastern Urbanized Area, Western Urbanized Area, and Shed C Region) have been used to organize the discussion on localized roadway flooding and are used in subsequent portions of the analysis. As noted in the City's LHMP and observed by City staff, during heavy rainfall events, major streets in the City experience localized flooding due to inlets being blocked with leaves resulting in standing water on one or more lanes in the roadway. Major streets of primary concern that are monitored during rain events are Big Horn Boulevard, Laguna Boulevard, Bruceville Road, Elk Grove Boulevard, and Franklin Boulevard. For a more detailed summary of the five regions and existing flood issues in these regions, see Appendix A.

2.4 IMPACT ANALYSIS

The impact analysis is conducted by considering the results from the exposure and sensitivity analyses and assessing their impact on transportation assets, key sensitive areas, populations, and City functions. The results of this impact analysis include a general discussion of impacts to the City from climate-related flooding as well as 10 sensitive areas in the City which have been identified as experiencing increased risk to flooding impacts.

2.4.1 Impact Analysis and Sensitivity Thresholds

In preparation for the impact analysis, it is important to identify the existing sensitivities related to flooding in the City and develop thresholds for affected systems and populations. FHWA's *Vulnerability Assessment and Adaptation Framework* provides guidance for local jurisdictions on how to incorporate climate change projections into the transportation asset operations and maintenance process. The document also provides resources to analyze transportation asset sensitivity to key climate stressors and has developed climate stressor threshold suggestions to determine when various assets may begin to fail or decrease in performance based on key climate variables. This document was used do guide the development of a set of climate stressor thresholds that are used in the impact analysis.

METHODOLOGY

Based on the information included in the exposure and sensitivity analysis, the impact analysis is intended to identify and describe the impacts anticipated to occur to the City including the affects to the stormwater management and transportation system. The impact analysis also identifies how these systems could result in secondary impacts to specific vulnerable populations in the City as well as specific critical community functions. The impact analysis focuses on specific areas identified as having reoccurring localized flooding issues as identified in the SDMP and in discussion with City staff. The analysis also looks at areas within or adjacent to the existing waterways (e.g., creeks, channels, detention basins), particularly areas within the 100-, 200-, and 500-year floodplains. As part of the analysis, eight key focus areas in the City were identified that are in or near FEMA 100- or 500-year floodplain and areas that have been subject to repeat flooding in the past. The eight key areas were also identified through information included in the LHMP, discussion with stakeholders during the first Flood Working Group meeting. These areas were then analyzed based on the type of flood impact which may affect the area (i.e., size of 2-, 10-, and 100-year storm events) as well as analyzed for any other secondary vulnerabilities in or near these areas. The analysis then uses a series of indicators to score the overall risk and severity of impacts that could occur in these eight focus areas based on the exposure analysis projections. These indicators include (1) aspects of the City's drainage and transportation system that may be impacted by flooding, (2) characteristics of the population surrounding these areas which may be particularly vulnerable to flooding impacts, and (3) key components of the built environment surrounding the area which support the City's daily function. Based on their final score, these key focus areas are prioritized based on both the projected severity and likelihood of impacts to the location but also who and what will be impacted at these locations. A discussion of the sensitivity thresholds used in the analysis are included in Appendix A.

TRANSPORTATION SENSITIVITY THRESHOLDS

Stormwater Drainage System

In current practice, the stormwater management systems in urban areas are modeled to manage large storm events based on characteristics of rainfall specific to the region from observed historical data. These characteristics are described using IDF curves which are used to design various components of urban drainage systems including pipes, culverts, waterway channels, and detention ponds. Because climate change is anticipated to shift precipitation patterns during storm events, these changes could impact the performance of urban stormwater management systems (CEC 2018). Increases or changes in the IDF curve can impact the integrity of stormwater infrastructure, particularly natural and engineered slopes such as levees (CEC 2018).

Volume II of the City's SDMP provides the technical components to support the Plan and includes the criteria used to evaluate the storm drainage systems, evaluation of existing facilities, identification of performance deficiencies, and further technical analysis to identify existing and new facilities upgrades to serve buildout conditions of the City's GP. The City has developed storm drainage standards based closely on the County of Sacramento Public Works Agency Improvements Standards and the *Sacramento City/County Drainage Manual*. As discussed in Section 2.3, based on current design standards, the City's drainage system has been designed based on the 2-, 10-, and 100-year storm events. Consistent with these standards, the primary sensitivity threshold for this analysis is the exceedance of the historic intensities of the 2-, 10-, and 100-year storm event for the 24-hour period. This threshold is developed from the understanding that the City's current stormwater management and flood protection system is designed based on historic observations for the size of flood events. If these historic storm intensities are exceeded, this would likely begin to disrupt, deteriorate, damage, or generally affect the performance of the City's stormwater management and flood protection systems (CEC 2018). The analysis also considers the magnitude of the increase above the historic storm levels in the severity of the impacts that may occur.

Large Storm Events and Flood Protection

For this analysis the FEMA floodplain for the 100-year storm event is used as the sensitivity threshold for large storm events. Specifically, for future scenarios in which the intensity of the 100-year storm events is exceeded, parcels and roadways within these floodplains are seen to be at increased risk from large storm events. The analysis also considers the magnitude of the increase above the 100-year storm event in the severity of the impacts that may occur. Exceedance and shifts in the amount of rainfall, duration, or frequency of these events compared to historical records may affect the performance of the City's drainage and flood control system. Increases in precipitation and particularly in the intensity and frequency of extreme precipitation events due to climate change can also have impacts on the integrity of levee systems (Jasim et al. 2017). Levee systems, particularly systems not maintained over time, are subject to other factors which can compromise their structural integrity including land subsidence and climatic conditions such as drought, which will be exacerbated by climate change (Jasim et al. 2017). Although local and regional increases in the intensity and frequency of large storm events are projected to occur, this does not translate to direct impacts to the City because the City has a base level of flood management in place. However, increases in the intensity of large storm events does increase overall flood risk at the local and regional level and, therefore, areas within FEMA floodplains are considered at increased risk due to climate change.

Based on these two sensitivity thresholds, six indicator variables were identified that characterize the nature of the impact on the City's drainage and transportation systems. The eight key locations identified were analyzed based on the presence of certain drainage and transportation assets and the extent these assets would be affected. However, the final list of key locations identified in the analysis may change during the development of this white paper based on City priorities. The indicators included are the presence of a:

- **road** adjacent to or in the identified flood area,
- **railway** adjacent to or in the identified flood area,
- **road or rail bridge** adjacent to or in the identified flood area,
- **bus route** adjacent to or in the identified flood area,
- **bike lane** adjacent to or in the identified flood area, or
- **stormwater detention basin** adjacent to or in the identified flood area.

Secondary Impacts and Sensitivities

Potential impacts on stormwater management and transportation systems can also result in secondary issues in the surrounding areas of the City, depending on the severity of flood impacts and the sensitivity of effected land uses. While impacts to the drainage and transportation system remain the primary focus of the analysis, it is important to understand how impacts to these systems may have a larger effect on the City's residents and normal functions in the surrounding area. As a result, the analysis includes key indicator metrics to identify vulnerable populations who are at increased risk from the effects of flooding events, particularly large storm events. For this analysis, it is understood that demographic characteristics in certain areas in the City will change over time and change their overall vulnerability to potential impacts. The Social Vulnerabilities indicators in the analysis provide a snapshot of vulnerable populations under existing conditions that are not expected to change greatly over the near-term period. The analysis here also recognizes potential impacts on unhoused populations in the City from flood events. Shelters and encampments built by unhoused individuals are often developed in or near flood plains, placing these populations at increased risk during flood events, particularly in areas with lower levels of access to transportation in emergency events (Ramin and Svoboda 2009). While not included as an indicator here, increased risk to the unhoused community in the City is being considered as part of the Plan development process. The analysis also identifies key components of the City's normal functions that may be at increased risk from flooding impacts in specific areas of the City. Below is the list of social and community function-related indicators that were included in the overall scoring analysis. For a full description of the indicators and data sources used for these indicators, see Appendix A.

- Social Vulnerabilities
  - Senior populations (65 and older)
  - Youth populations (5 years and younger)
  - Households experiencing linguistic isolation
  - Low-Income households
  - Households without access to a vehicle
  - Census tract scores from the CalEnviroScreen 3.0 tool
- Community Function Vulnerabilities
  - Average daily traffic (ADT) on adjacent roadways
  - Presence of electrical substation in or near identified flood area
  - Commercial or Industrial land use in or near identified flood area
  - Presence of government facility in or near identified flood area
  - Presence of other critical facilities in or near identified flood area

Tools used to gather data on these indicator metrics included:

- California Healthy Places Index (HPI) tool,
- CalEnviroScreen 3.0 online tool (2018 Updates), and
- The U.S. Environmental Protection Agency's (EPA's) Environmental Justice Screening and Mapping Tool (Version 2019).

2.4.2 Impact Analysis Results

STORMWATER MANAGEMENT AND DRAINAGE IMPACTS

As discussed in the sensitivity analysis, the City's stormwater management and flood protection system is the primary mechanism in place to manage stormwater runoff during rainfall and storm events and protect properties from larger storm events (Sacramento County 2017a). Increases in precipitation and intensity of storm events, as discussed in Section 2.4.1, will affect the performance of the City's stormwater management system and, as a result, affect the local transportation system and other key community components. Below is a discussion of how these changes will specifically affect the City's stormwater management and flood protection system. Impacts to the transportation system and other community components are then discussed by the five key drainage regions in the City, discussed in Section 2.3.1 and shown in Figure 5 and 7.

Climate change is projected to shift precipitation patterns of storm events in watersheds affecting the City. Discussed in detail in Section 2.2.2, watersheds affecting stormwater infrastructure in the City will experience increases and decreases (ranging from 12 to 16 percent) in the intensity of 2-, 10-, and 100-year storm events by as early as 2035. These shifts are not anticipated to have a large impact on the performance of the City's stormwater drainage system, particularly because there will be decreases in the intensity of the 100-year storm events (see Tables 3 and 4). However, the maximum duration and frequency of storm events are both anticipated to increase by 2035 under both the RCP 4.5 and RCP 8.5 scenarios, which provide additional stress to the City's stormwater drainage system. As discussed in

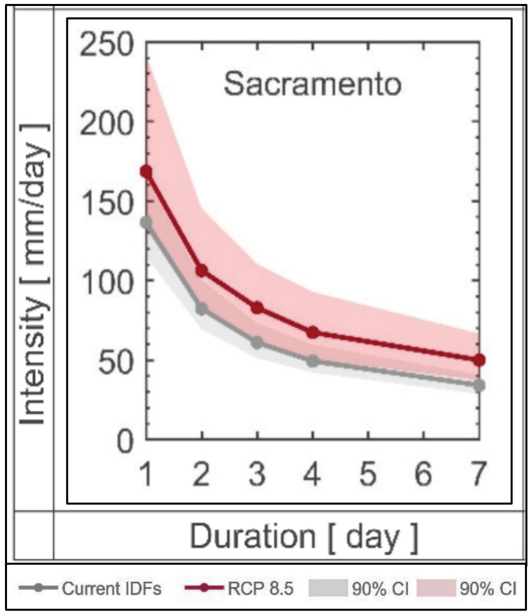
Section 2.2.1, the increased intensity and frequency of large storm events (e.g., AR storms) is likely to compromise the performance of the City's stormwater drainage system.

By as early as 2070, all watersheds affecting stormwater infrastructure in the City will experience increases in the IDF of 2-, 10-, and 100-year storm events under both the RCP 4.5 and RCP 8.5 scenarios. The range of increases varies based on the RCP emissions scenario and the watershed. Notably, under the RCP 8.5 scenario by 2070, both the Morrison Creek and Snodgrass Slough watersheds will experience a 26 percent increase in the intensity of the 100-year storm event as well as increases in the maximum duration and annual frequency of these events. These changes are anticipated to have substantial impacts on the City's stormwater drainage system (e.g., decreased performance, localized flooding for facilities not able to manage increased rainfall, degradation of the subbase foundations for roadways, bridge scour) and areas adjacent to the waterways in the City including those located in or near FEMA 100-year floodplain.

Bridges, culverts, and channels are all designed assuming certain flow rates (e.g., cubic feet of water per second passing through a culvert) for different size storm events and specific characteristics of stormwater runoff based on local variables (e.g., land uses, soil types). Increases in the intensity of future storms could increase the flow rate of water in creeks and channels in the City during these events and, depending on the size of the storm event, could exceed the design capacity of these components of the stormwater infrastructure. This could result in existing components of infrastructure not being able to manage future flows leading to backups that cause localized flooding on roadways and properties adjacent to culverts and channels (McCurdy and Travis 2018). Because the City's stormwater drainage system is designed to manage large storm events, increases in the intensity of smaller events may not affect the system to the same degree. However, increases in the intensity of 100-year storm events will have much larger impacts on the City's stormwater drainage system.

Shifts in the IDF curve can also increase the risk that detention basins, which are designed to store-and-release runoff during heavy rainfall events, can exceed their design capacity and cause localized flooding near detention basins (Elshorbagy et al. 2018). These detentions basins will exceed their design capacity due to increased intensity of storm events under both the RCP 4.5 and RCP 8.5 scenario, likely resulting in impacts to the surrounding area, particularly during large storm events. As noted in research conducted for California's Fourth Climate Change Assessment, increases in the IDF of extreme precipitation can adversely impact the integrity of infrastructure, particularly natural and engineered slopes (CEC 2018). As part of the research for California's Fourth Climate Change Assessment, new IDF curves have been developed for various parts of California, taking into account the projected increase in the intensity of storm events under RCP 8.5 by 2100. Figure 6, below, shows the expected shifts in the IDF curves for the Sacramento region by 2100 under the RCP 8.5 scenario, including the confidence interval (CI) for both current and future IDF curves. As shown in Figure 6, the increases in the variability of the 90 percent confidence interval for the future IDF curve illustrates that the uncertainty in the size of storm events will increase, making the task of designing new facilities for future storm intensities more difficult. The exact impacts on stormwater infrastructure from shifts in the IDF curve depend on the specific geographic context of the systems as well as the magnitude of the anticipated shifts. However, the repeated occurrence of storm events which exceed the designed capacity of a stormwater systems would likely impact the integrity and performance over the systems lifetime (CEC 2018). Additionally, data included in Cal-Adapt provides further details for changes to the IDF of storm events for specific watersheds affecting the City. See the exposure analysis in Section 2.2.1 and Section 2.2.2.

Figure 6 Changes in Sacramento Region IDF Curve



Source: CEC 2018

LEVEE IMPACTS

Increases in precipitation and particularly in the intensity and frequency of extreme precipitations due to climate change will have impacts on the integrity of levee systems (Jasim et al. 2017). Shifts in the IDF curve, particularly during multi-day events, can increase the risk of levee failure. A study which modeled the impacts of projected changes in IDF curves on the Elkhorn Levee in Sacramento County found that the probability of levee failure could increase between 3 and 12 percent during projected extreme precipitation events under the RCP 8.5 scenario when compared to the baseline scenario. Levee systems, particularly systems not maintained through the Federally protected levee system, are subject to other factors which can comprise their structural integrity including land subsidence and climatic conditions, which will be exacerbated by climate change (Jasim et al. 2017). The combination of land subsidence and specific climatic conditions including drought and severe flooding can further threaten the structural integrity of these aging levees (Robinson and Vahedifard 2016). The City is subject to protection by a number of levee systems including the Laguna West system, levees along the Sacramento River near the City, and older levees which protect some properties along the Cosumnes River and Deer Creek. Based on the research referenced above, these levee systems will be at increased risk of failure due to increasingly intense storm events as well as increases in the frequency of these events.

KEY IMPACT AREAS

As part of the impact analysis, eights areas in the City were identified as experiencing increased flood risk as a result of climate change. These areas, in some cases, are located in areas of the City adjacent to vulnerable populations or critical facilities or assets. The areas identified were ranked (i.e., Low, Mid, and High) based on the characteristics and magnitude of flood impacts anticipated to occur as well as the sensitivity of surrounding land uses, facilities, and populations. The locations of the focus areas are shown in Figure 7 and listed below in Table 8. Because the impact areas face varying levels of risk under the RCP 4.5 and RCP 8.5 scenarios, the areas included in Table 8 are not ranked based on priority but rather illustrate the various risk level to each area under both the RCP 4.5 and RCP 8.5 scenarios by midcentury and late century. For a detailed discussion on the indicators used to identify and rank these key impact areas, see Appendix A.

Table 8 Key Precipitation and Flooding Focus Areas

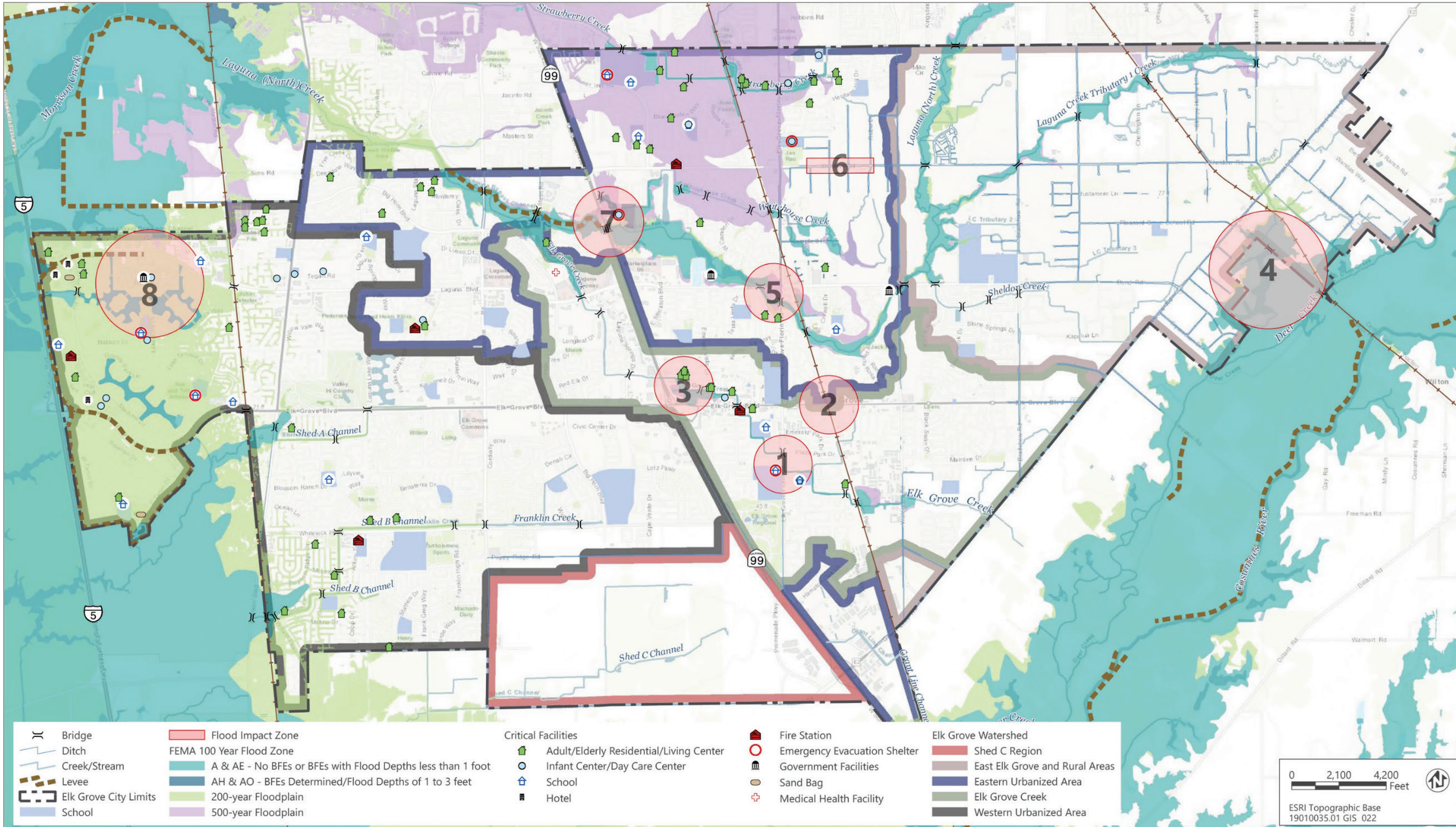
Analysis Region	Area #	Focus Areas	Priority Ranking			
			RCP 4.5		RCP 8.5	
			Midcentury (2035–2064)	Late Century (2070–2099)	Midcentury (2035–2064)	Late Century (2070–2099)
Elk Grove Creek Region	1	Valley Oak Lane at Elk Grove High School	Low	Mid	Low	High
	2	Old Town Elk Grove Area	Low	Mid	Low	High
	3	East Stockton Boulevard at Emerald Vista Drive	Mid	Mid	Mid	High
East Elk Grove Area/Rural Region	4	Sheldon Area east of Grant Line Road	Low	Mid	Low	High
Eastern Urbanized Area	5	Laguna Creek at Bond Road and Elk Grove Florin Road	Mid	Mid	Mid	High
	6	Sheldon Road between Scenic Elk Ct. and St. Anthony Ct.	Low	Low	Low	High
	7	Laguna Creek at State Route 99 and surrounding area	Mid	Mid	Mid	High
Western Urbanized Area	8	Laguna West Neighborhood and surrounding area	Mid	Mid	Mid	High

Note: Low, Mid, and High rankings are based on the overall scores each impact area received as part of the impact analysis process.

Source: Focus areas identified by Ascent Environmental 2019

As shown in Table 8, several locations are at the midlevel of risk under both the RCP 4.5 and RCP 8.5 scenarios by the midcentury period. In both scenarios, the risk to these areas grows by late century with increases in the magnitude of the 100-year storm events increasing above historic levels. Under the RCP 4.5, by the late century, the risk of impacts to these areas is considerably lower compared to the RCP 8.5 scenario. However, increases in the size of large storm events and subsequent increases in flood risk will still occur under the RCP 4.5 scenario by late century. Under the RCP 8.5 scenario, all key impact areas will be at high-risk from increased flooding impacts, due to significant increases in the size, duration, and frequency of 2-, 10-, and 100-year storm events as well as increased regional flooding risk. Importantly, by midcentury, impacts to these areas will occur at relatively the same level under the RCP 4.5 and RCP 8.5 scenarios, regardless of future global emissions trends, meaning the impact projections for midcentury can serve as a baseline for the level of impacts anticipated to occur in the City by this time period. However, increases in the severity of these impacts by late century, will depend on global emissions trends, with much larger impacts expected to occur if global emissions do not peak by 2040 and decrease substantially over the rest of the century. Below is a discussion of anticipated impacts to the five regions in the City with a discussion of the key focus areas included in each of these regions. The five regions discussed below can be seen in Figure 7.

Figure 7 Flood and Precipitation Impacts in Elk Grove from Climate Change



Source: Data received and downloaded from City of Elk Grove in 2019

Elk Grove Creek Region

The Elk Grove Creek Region is located in the Morrison Creek Watershed. This watershed's projected shifts in precipitation during the 100-year storm event (14 to 16 percent decrease) under both the RCP 4.5 and RCP 8.5 scenarios are not anticipated to have a noticeable impact on localized flooding in the region by midcentury. However, between 2070-2099 the region will experience a noticeable increase (5 to 20 percent) in precipitation during both the 100- and 2-year storm events under the RCP 4.5 scenario. Under the RCP 8.5 scenario, the watershed will experience a 26 percent increase in the intensity of the 100-year storm event and similar increase in the 2- and 10-year storm events by 2070. These increases by late century are anticipated to impact sensitive areas in the region.

As noted in SDMP's analysis of the Elk Grove Creek Region, the majority of this region is developed, meaning the intensity of stormwater runoff from new development in the region is not likely to increase greatly in the future. However, because there are existing flooding problems along the creek, the SDMP recommends that any potential increase in peak runoff due to future development be fully mitigated (City of Elk Grove 2019b). Infill development is anticipated west of Waterman Road but is not predicted to cause large increases to the peak flows and water surface elevations in Elk Grove Creek. However, as discussed in Section 2.4.1, the City's drainage system is modeled and designed for the 100-, 10-, and 2-year storm events which are all anticipated to increase in IDF by 2070 and will likely have impacts on the performance of the drainage system in the Elk Grove Creek Region. Areas within the region that are sensitive to repeat flooding and areas in and adjacent to the 100-year floodplain are also are at increased risk of flooding by 2099.

Valley Oak Lane at Elk Grove High School (Impact Area 1)

Valley Oak Lane near Elk Grove High School has experienced repeat localized flooding in the past, largely due to debris and leaf clog in the streets drainage system during rainfall events. Increases in the maximum duration of storm events (minimum of 13 percent by midcentury and 22 percent by late century), under the RCP 4.5 scenario, will likely exacerbate existing localized flooding along Valley Oak Lane by as early as 2035. Elk Grove High School also includes large impervious surfaces (e.g., parking lots, buildings) which likely contribute to the area's localized flooding issues from stormwater runoff. Elk Grove High School is designated as one of the City's emergency evacuation shelters for use during emergency events and is also located directly to the west of Elk Grove Creek. However, the presence of Elk Grove Creek in this area will only become an issue after 2070 when 100-year storm intensities will exceed historic levels by approximately 5 percent under the RCP 4.5 scenario and 26 percent under the RCP 8.5 scenario. Additionally, the census tract north of Elk Grove High School includes 23 percent of households that are over the age of 65, placing it in the 90th percentile of census tracts in California for this metric. These factors increase the sensitivity of this area and increase the priority on addressing potential future issues.

Old Town Elk Grove Area (Impact Area 2)

The Old Town Elk Grove Area has experienced repeat localized flooding along Elk Grove Boulevard in the past due to an older undersized drainage system. Small increases in the intensity and duration of the 2-year storm event, projected for this area by 2035 under both emissions scenarios, may exacerbate local flooding issues. Larger increases in the 2-, 10-, and 100-year storm by 2070 under both emissions scenarios will result in more extensive impacts in Old Town Elk Grove, particularly if the drainage system in the area is not updated before this period. Old Town Elk Grove is the historic center of the City and is an important commercial and transportation corridor. The census tract to the west of the rail line which runs through this area includes an above-average percentage of households that are experiencing linguistic isolation, are designated low-income, and have children under the age of 5. Although the impacts in this area are limited to localized flooding, these factors increase the sensitivity of this area and increase the priority on addressing potential future issues.

East Stockton Boulevard at Emerald Vista Drive (Impact Area 3)

The portion of Elk Grove Creek near East Stockton Boulevard and Emerald Vista Drive has not experienced localized flooding impacts in the past. However, areas surrounding this location, as shown in Figure 7, are within the 100- and 500-year floodplains. Areas within these floodplains include commercial and multi-family land uses to the south of East Stockton Boulevard. These floodplains also include portions of East Stockton Boulevard, Emerald Vista Drive, and Elk Grove Boulevard. Similar to other areas in the Elk Grove Creek Region, this area will only become an issue after 2070 when 100-storm intensities will markedly exceed historic levels. However, the anticipated increase in the intensity and frequency of large AR storm events before 2070, increases the probability of impacts occurring in this area by midcentury. This impact area includes commercial land uses and also affects a major roadway, Elk Grove Boulevard, which has an ADT of 27,000. Additionally, in the census tract directly north of Elk Grove Boulevard, 10.5 percent of households do not have access to a vehicle. These factors increase the sensitivity of this areas and increases the priority for addressing potential future issues.

East Elk Grove Area/Rural Region

The majority of the East Elk Grove Area/Rural Region is located in the Morrison Creek Watershed. Changes in precipitation to this watershed are discussed above under the impacts to the Elk Grove Creek Region. The eastern most portion of the region includes the community of Sheldon and areas in the City east of Grant Line Road. These areas are within the Deer Creek watershed and can also be affected by the Upper Cosumnes River watershed. As shown in Table 4, by midcentury the Deer Creek watershed will experience a decrease in intensity of 2-, 10-, and 100-year storm events under both emissions scenarios. By late century, Deer Creek watershed will experience a slight decrease in intensity of the 2-,10-, and 100-year storm events under the RCP 4.5 scenario and a 15 percent increase in the 100-year storm event under the RCP 8.5 scenario by 2035. The Upper Cosumnes River watershed will experience a 4 percent increase in intensity of the 100-year storm event under the RCP 4.5 scenario and a 17 percent increase under the RCP 8.5 scenario by 2035. By late century, the Upper Cosumnes River watershed will experience a 23 percent increase in intensity of the 100-year storm under the RCP 4.5 scenario and a 40 percent increase under the RCP 8.5 scenario.

The majority of the East Elk Grove Area/Rural Region (primarily east of Waterman Road) does not have an underground pipe system, curbs or gutters. Stormwater runoff is collected and conveyed by roadside ditches that have very limited flow carrying capacity causing backflow issues and are prone to blockages from debris. In discussion with the City for this analysis, staff noted that many of the identified problem areas in this region have been resolved due to updates in drainage systems as part of implementation of the SDMP. Small shifts in the intensity and duration of the storm events, projected for the Morrison Creek watershed by 2035 under both emissions scenarios, are not anticipated to exacerbate existing flooding issues in the region. However, larger increases in the 2-, 10-, and 100-year storm by 2070 under both emissions scenarios in the Morrison Creek watershed, which affects Laguna Creek and Elk Grove Creek, will result in more extensive impacts in this region, particularly areas which may still have undersized or inadequate drainage systems in place by this period.

Roadways subject to repeat flooding events will also be at a higher likelihood of experiencing increased deterioration rates. Additionally, roadway and rail bridges subject to increases storm intensity could also result in increased deterioration rates and compromised structural integrity (Willway et al. 2008; Caltrans 2013). Roadway flooding could also result in decreased safety for roadway users as well as traffic congestions and delays during road closures. Although this region includes tributaries of Laguna Creek and areas in the 100-year floodplain, due to the lower density and larger lot sizes in this area, the region overall is at decreased risk compared to other parts of the City. It is likely that some amount of development will occur in the region between 2020 and 2070 and could result in upgrades to existing drainage facilities in the region, which will mitigate some current and future localized flooding issues. However, future development in the region, particularly after 2070 may experience flooding issues, particularly if stormwater infrastructure is designed using historic rainfall levels and does not account for future storm intensities.

Sheldon Area East of Grant Line Road (Impact Area 4)

The eastern most portion of the region includes the community of Sheldon, centered along Grant Line Road near Pleasant Grove School Road and includes the portions of the City west of Grant Line Road. This area is characterized by rural residential parcels. Portions of this area are located in the 100-year floodplain including large portions of Wilton Road which connects the Sheldon area with the unincorporated community of Wilton to the southeast. The relatively minor changes in storm events for the Deer Creek and Upper Cosumnes River watershed by midcentury under the RCP 4.5 scenario will likely not have a large impact on areas of the City affected by these watersheds compared to existing conditions. However, due to the sensitive nature of flooding in this area, small increases in intensity of storm events by midcentury may lead to large impacts, particularly in areas where properties are protected by old unmaintained levees.

By late century, shifts in the Deer Creek watershed precipitation patterns will likely not affect this area under the RCP 4.5 scenario. Under RCP 8.5 scenario, increases in the intensity in the 100-year storm event (15 percent) will likely result in increased frequency and severity of impacts to locations in and around the 100-year floodplain including areas east of Grant Line Road. Additionally, increases in the intensity of the 100-year storm event in the Upper Cosumnes River watershed under the RCP 4.5 scenario (23 percent) and under RCP 8.5 scenario (40 percent), will have a larger impact on this area of the City as well as areas south-east of the City located along the Cosumnes River. These increases will likely compromise the performance of levees built along the Cosumnes River and Deer Creek, particularly during whiplash events when levees may be degraded by a long drought period followed by large precipitation events (Robinson and Vahedifard 2016). Flood impacts in this area would largely affect residential land uses with potential impacts to commercial uses along Grant Line Road. Although not in the floodplain, there is an electrical substation approximately 1,000 feet to the northwest of the 100-year floodplain along Grant Line Road. Of the four watersheds included in this analysis, the Upper Cosumnes River watershed will experience the largest increase in the intensity of storm events under both emissions scenarios. Because the Cosumnes River is undammed, the flow of the river cannot be controlled during large storm events to the same degree as damned rivers. This increases overall risk to properties within or near the river's 100-year floodplain in this area.

Eastern Urbanized Area

The Eastern Urbanized Area is located in the northern central portion of the City and also includes a small industrial area located in the southern tip of the City. This region contains a large portion of Laguna Creek, the largest creek in the City. It is located in the Morrison Creek watershed. Changes in precipitation to this watershed are discussed above under the discussion of impacts to the Elk Grove Creek Region. Similar to other areas in the Morrison Creek watershed, projected shifts in precipitation by midcentury, under both the RCP 4.5 and RCP 8.5 scenarios, are not anticipated to have a noticeable impact on localized flooding in this region. Small increases in the intensity and duration of the 2-year storm event as well as increases in the maximum duration of storm events, projected for this area by 2035 under both emissions scenarios, may exacerbate localized flooding issues in this region. However, between 2070 and 2099, the region will experience a noticeable increase (20 percent) in precipitation during the 100-year event under the RCP 4.5 scenario, which will likely impact the City's stormwater management system and properties in and potentially near the 100-year floodplain. By late century, under the RCP 8.5 scenario, the watershed will experience a 26 percent increase in the intensity of the 100-year storm event and similar increase in the 2- and 10-year storm events. Under both emissions scenarios, the increases in the intensity of the 100-year storm by late century will compromise the performance of the City's stormwater management system, largely due to the limited capacity of the City's existing stormwater infrastructure to manage increasingly large storm events.

Laguna Creek at Bond Road and Elk Grove Florin Road (Impact Area 5)

The area surrounding the intersection of Bond Road and Elk Grove Florin Road includes areas in the 100- and 500-year floodplains of Laguna Creek. As shown in Figure 7, this includes commercial properties west of Elk Grove Florin Road in the 500-year floodplain and residential areas east of Elk Grove Florin Road in the 100- and 500-year floodplain. Small shifts in the intensity the 100-year storm in this area by midcentury are not anticipated to impact the City's stormwater management system. However, by late century under both emissions scenarios increases in the intensity of the 100-year storm event will compromise the performance of the City's drainage system due to undersized stormwater infrastructure. Impacts by late century from potential large storm events will likely affect properties in the 100-year floodplain. This may also result in flood impacts to areas outside the historically mapped 100- and 500-year floodplains. In the census tract to the southwest of this intersection, 11.5 percent of households do not have access to a vehicle. Floodplains near this intersection would impact traffic on Bond Road, which is a high-volume roadway in the City with ADT of 35,500 vehicles. There is also an electrical substation located approximately 130 feet from the 100-year floodplain in this area. These factors increase the sensitivity of this areas and increases the priority for addressing potential future issues.

Sheldon Road between Scenic Elk Court and St. Anthony Court (Impact Area 6)

This portion of Sheldon Road has experienced repeat localized flooding in the past, in part due to undersized drainage facilities down stream of this area. This area is not located in or near the 100-year floodplain. Small increases in the intensity and duration of the 2-year storm event, projected for this area by 2035 under both emissions scenarios, may exacerbate localized flooding issues along Sheldon Road. By late century, an approximately 20 percent increase in the intensity of the 2-, 10-, and 100-year storm event will have much larger impacts in this area, especially if drainage facilities are not updated by this period (2070). The census tract directly north of this area has a high percentage (18 percent) of households experiencing linguistic isolation. (See Appendix A for full definition of linguistic isolation.) Although the impacts in this area are limited to localized flooding, these factors still increase the sensitivity of this areas and increase the priority on addressing potential future issues.

<u>Laguna Creek at State Route 99 (Impact Area 7)</u>

Areas surrounding the bridge at the intersection of State Route (SR) 99 and Laguna Creek are in the floodplain for both the 100- and 500-year storm event, including areas of SR 99 located within the 500-year floodplain. Large areas along the banks of Laguna Creek in this area are undeveloped because they lie within the 100- or 500-year floodplain. Similar to other areas in the Morrison Creek watershed, small shifts in the intensity of storm events, projected for this area by 2035 under both emissions scenarios, will likely not have substantial impacts on this area. By late century, an approximately 5 percent increase in the intensity of the 100-year storm event under RCP 4.5 scenario and 20 percent under the RCP 8.5 scenario, will have larger impacts in this area. A large church, which includes a day care center and serves as an emergency evacuation shelter for the City, is located directly north of Laguna Creek, with portions of the property in the 100- and 500-year floodplain. Stormwater facilities near the church have been upgraded, resulting in documented decreased flood risk in the area. Upgrades are documented as part of a Letter of Map Revision administered by FEMA, which allows communities to improve flood control in a certain area and request to be reevaluated for flood risk from FEMA. The census tract to the east of SR 99, near this area, has a high percentage (21 percent) of households experiencing linguistic isolation. This same census tract includes 5.5 percent of households that do not have access to a vehicle. These factors increase the sensitivity of this areas and increases the priority for addressing potential future issues in this area. Additionally, the presence of a high-volume roadway (SR 99) increases the risk from potential impacts.

Western Urbanized Area

The Western Urbanized Area includes portions of the City west of Big Horn Boulevard and Laguna Creek all the way to the western boundary of the City. This area does not include any of the City's major waterways. However, this area does include the Laguna West and Lakeside neighborhoods, both of which are protected by the Laguna West levee system that protects these areas from 100-year flood events. This region is located in the Snodgrass Slough watershed, which is projected to experience larger increases in the intensity of storm events compared to the Morrison Creek watershed. See Table 3 for changes projected to occur in the Snodgrass Slough watershed under both the RCP 4.5 and 8.5 scenarios.

This region is largely urbanized and includes a number of large detention basins to capture stormwater runoff during rainfall events including during 100-year storm events. The Laguna West neighborhood currently experiences minor flooding near the Laguna Main Street area along Renwick Avenue, Vaux Avenue, and Benedix Way resulting in minor street flooding due to the lake system. City staff have noted, as part of this analysis, that the issues in the Laguna Main Street area are being addressed as part of upgrades to the stormwater drainage system and the pump station used as part of the system. Increases in the intensity of the 2- and 10-year storm events by 2035 could still affect performance of the stormwater management system in this region. Additionally, the increases in the maximum duration of 2-, 10-, and 100-year storm events projected to occur by midcentury (see Section 2.2.2) will also likely impact the performance of the stormwater management system in the region. Slight decreases in the intensity of the 100-year storm event by midcentury will likely not result in large impacts to the stormwater management system in this region. However, the projected intensity and frequency of larger AR events will likely have long-term impacts on the stormwater management system, when events do occur, by placing increased stress on existing infrastructure, potentially decreasing the overall usable life of certain drainage facilities. By late century under the RCP 4.5 scenario, increases in the intensity of the 2-, 10-, and 100-year storm events (see Table 4) will have a more substantial impact on the stormwater management system. Specifically, an approximately 12 percent increase in the intensity of the 2- and 10-year storm events will likely increase the frequency of localized flooding in the City.

Under the RCP 8.5 scenario, the increases in storm intensities would be relatively the same as under the RCP 4.5 with similar levels of impacts to occur, specifically more localized flooding with increases in the 2- and 10-year storm events. By late century, this watershed will experience an approximately 27 percent increase in the intensity of all three size storm events. Given that this portion of the City is almost entirely developed and partly relying on pump conveyance system for drainage, adapting to increases in the intensity of storm events may prove more difficult and require more extensive planning than other parts of the City.

Laguna West Neighborhood and Surrounding Area (Impact Area 8)

The Laguna West community is protected from the 100-year storm event by the Laguna West levee system. The neighborhood's flood control and drainage system consists of pump stations, lakes (detention storage) and the perimeter levee system. The levee system is designed to protect the communities from the backwater effects of the Cosumnes and Mokelumne Rivers, while the pump stations and lakes protect the community from internal flooding from stormwater runoff.

While this area will experience minor increases in the smaller storm events under both emissions scenarios and the area is at increased sensitivity due to repeat flooding issues along certain streets, the largest threat to this area is posed by large storm events in the larger northern California region. As discussed in Section 2.2.1, the larger region which affects the Sacramento River is projected to experience increases in the intensity of storm events and place increased pressure on the flood management systems controlling rivers in the Sacramento Valley region. As discussed above, levee systems are subject to climate related factors which can compromise their structural integrity including land subsidence and climatic conditions such as drought, which will be exacerbated by climate change (Jasim et al. 2017). Increases in the intensity of extreme precipitation events in the Sacramento region, under the RCP 8.5 scenario, would increase the probability of levee failure between 3 and 12 percent during projected extreme precipitation events (Jasim et al. 2017). As noted in Section 2.2.1, even if global emission peak by 2040 (i.e., RCP 4.5 scenario), the larger Sacramento region would still experience an 8 to 12 percent increase in annual mean precipitation by as early as 2035. Additionally, the frequency of large storm sequences caused by atmospherics rivers are projected to increase noticeably under the RCP 8.5 scenario by midcentury. It is estimated that a storm similar in magnitude to the Great Flood events of 1865-1866 is more likely than not to occur at least once between 2018 and 2060 (Swain et al. 2018). All the factors discussed above place the Laguna West-Lakeside community at increased risk from large regional storm events (e.g., 100-year storm or larger).

As noted above, the Laguna West levee system has been accredited by FEMA as meeting 100-year standards and provides properties in the Laguna West and Lakeside areas with significant flood protection. However, the system would need to be raised by an average of approximately 3.5 feet to comply with the 200-year flood protection standard, with potential additional upgrades to prevent under seepage of the levees (City of Elk Grove 2019c).

Shed C Region

There are no impact areas located in the Shed C Region, which covers only a small portion of the southern part of the City. However, this area is located in the Snodgrass Slough watershed, which is projected to experience increases in intensity of the 2-year storm event by midcentury and substantial increase in the intensity of the 2-, 10-, and 100-year storm event by 2070 under both emissions scenarios. These projections for increases in precipitation in this area should be taken into consideration for future development projects which will occur here. As part of the analysis for this report, City staff noted that recent upgrades to infrastructure in this region help to alleviate some of the repeat flooding locations in the area, specifically near the intersection of Kammerer Road and Bruceville Road.

Key Focus Areas Summary

Table 9 provides a summary of the level and characteristics of potential impacts in the eight focus areas. This summary table helps to identify which aspects of the community are being affected the most and which focus areas are projected to experience the largest impacts. Table 9 will also help identify, based on the indicators impacted in each area, what types of strategies and improvements should be potentially implemented to increase resilience in these areas. To see which indicators are affected in each focus area, see Appendix B.

Table 9 Precipitation and Flooding Focus Area Scoring Summary

Analysis Region	Area #	Focus Areas	Focus Area Scoring Categories				
			Stormwater and Transportation (6 Indicators)	Social Vulnerability (6 Indicators)	Social Vulnerability (4 Indicators)	Land Use	Critical Facility
Elk Grove Creek Region	1	Valley Oak Lane at Elk Grove High School	4/6	3/6	2/6	R	Yes
	2	Old Town Elk Grove Area	4/6	4/6	2/6	R, C	No
	3	East Stockton Boulevard at Emerald Vista Drive	4/6	4/6	2/6	R, C	No
East Elk Grove Area/Rural Region	4	Sheldon Area east of Grant Line Road	3/6	1/6	2/6	R, C	No
Eastern Urbanized Area	5	Laguna Creek at Bond Road and Elk Grove Florin Road	6/6	2/6	3/6	R, C, I	No
	6	Sheldon Road between Scenic Elk Ct. and St. Anthony Ct.	2/6	1/6	0/6	R	No
	7	Laguna Creek at State Route 99 and surrounding area	4/6	4/6	2/6	R, C	Yes
Western Urbanized Area	8	Laguna West Neighborhood and surrounding area	5/6	1/6	2/6	R, C, I	No

Note: R = Residential; C = Commercial; I = Industrial

Source: Focus areas identified by Ascent Environmental 2019

2.5 ADAPTIVE CAPACITY ANALYSIS

The adaptive capacity analysis is conducted by taking the results from the impact analysis and assessing what current capacity exists in the City and among regional partners to address the projected impacts from precipitation and flooding in the City. This analysis focuses on the adaptive capacity of agencies and regional stakeholders that have representatives included in the Flood Working Group formed for development of the Plan. The section also includes a list of resilience strategy opportunities for each agency and stakeholder. The list is intended to provide a high-level description of potential opportunities for collaboration between the City and relevant agencies and stakeholders to address precipitation and flooding impacts in the City and the region. Many of the potential opportunities identified for each of the agencies and stakeholders are a result of discussions between members during the Flood Working Group first meeting.

2.5.1 Federal

STONE LAKES NATIONAL WILDLIFE REFUGE

Established in 1994, the Stone Lakes National Wildlife Refuge, is located to the west and south of the City limits and managed by the U.S. Fish and Wildlife Service. The refuge is a destination for thousands of migrating waterfowl, shorebirds, and other water birds. Stone Lakes National Wildlife Refuge contains seasonal and permanent wetlands, riparian forest, and grasslands, as well as some of the last remaining freshwater lakes in the central valley. Responsibilities of the refuge include wildlife monitoring, wetland management, habitat restoration, and invasive species control. Management activities at the refuge are guided by the refuge's *Comprehensive Conservation Plan*. The plan does not explicitly address climate change. However, it does discuss several key topics regarding watershed management and maintaining the health of the refuge which relate to the impacts of climate change. As part of this analysis, representatives from the Stone Lakes National Wildlife Refuge participated in the Flood Working Group and provided input on the development of this white paper. In discussions with representative from the refuge, staff mentioned that they work with the City to outline strategies to preserve water quality and mitigate increased stormwater discharge.

Resilience Strategy Opportunities

- Coordinate closely with the Stone Lakes National Wildlife Refuge on implementation of measure which would affect the refuge, specifically strategies which address anticipated impacts to water quality as a result of climate change.
- Work with the Stone Lakes National Wildlife Refuge to identify how local flora and fauna are anticipated to be impacted by climate change and work to mitigate impacts on sensitivity species and habitats.

2.5.2 Regional

CALIFORNIA DEPARTMENT OF WATER RESOURCES

DWR has begun to develop a comprehensive framework for incorporating the projected impacts of climate change into the operations and management of the State's water resources under the Department's authority. In February 2019, DWR completed Phase III of the CAP, the Department's first climate change VA for facilities owned and operated by DWR and the activities that DWR performs. The assessment is intended to evaluate, describe, and quantify DWR's vulnerabilities to expected increases in wildfire, extreme heat, and sea level rise, as well as to changes in hydrology and ecosystems that will impact DWR's facilities, operations, and other activities (DWR 2019). As part of the assessment, DWR has identified the Department's adaptive capacity to respond to climate hazards including short-term extreme precipitation events. The assessment includes a list of 19 Federal/State flood damage reduction projects that have been undertaken by a Federal or State agency that will reduce flood risk across the areas included in the State Plan of Flood Control (SPFC) including several projects which would reduce flood risk in the Sacramento region. As an example, the Sacramento River Bank Protection Project conducted by the USACE Sacramento District is an ongoing project to evaluate the levees bordering the river and reduce stream bank erosion to minimize the threat of a flood along the Sacramento River. A full list of projects can be found in the DWR *State Plan of Flood Control Descriptive Document Update* (DWR 2016.)

As part of the Plan development process, representatives from DWR participated in the Flood Working Group and provided input on the development of this white paper. As part of discussions with staff members it was noted that, DWR is also working with the California Flood Forecast Center to more closely monitor the occurrence of large AR storms, how they are affected by climate change, and their impacts on DWR facilities and operations. Although DWR manages water resources throughout the state, there are several DWR facilities which affect the Sacramento River and could affect the City during a levee breach event. As DWR continues to assess the risks from climate change on their facilities, the City should stay up to date on what DWR projects may affect the City and increase flood protection for the community. As part of its responsibilities, DWR manages the SPFC, which collectively includes the facilities, lands, programs, conditions, and mode of operations and maintenance for the State-Federal flood protection system in the Central Valley. In 2007, when bond funding became available to evaluate the adequacy of the SPFC, the Central Valley Flood Protection Board in cooperation with DWR developed the *Central Valley Flood Protection Plan* (CVFPP) finalized in 2012 and updated in 2017. The CVFPP includes an assessment of how climate change will impact the central valley and provides strategies to adapt to these impacts.

Resilience Strategy Opportunities

- Share adaptation strategies and tools for specific climate impacts relevant to the City.
- Coordinate regarding regional climate risks, including regional flooding events.
- Coordinate with DWR on the use of early warning systems for AR storms.

CALTRANS

The Climate Change Branch in Caltrans' Division of Transportation Planning is responsible for overseeing the development, coordination, and implementation of climate change policies in all aspects of the Department's decision making. In 2013, Caltrans completed its first report intended to help reduce GHG emissions and adapt the State's transportation system to prepare for the impacts of climate change (Caltrans 2013), which includes a series of strategies to reduce the risk from various climate change impacts, increasingly intense precipitation events among them.

Caltrans facilities located in the City of Elk Grove include SR 99 which runs northwest-southeast through the center of the City and Interstate 5 (I-5) which also runs northwest-southeast along the western border of the City. Impacts from climate change on these facilities would have a direct impact on the City. The key waterways in or near the City that intersect Caltrans facilities are:

- SR 99 at the Cosumnes River located just south of the City limit,
- SR 99 at Elk Grove Creek near Elk Grove Boulevard,
- SR 99 at Laguna Creek near East Lawn Elk Grove Memorial Park,
- SR 99 at Strawberry Creek located just north of the City limit,
- I-5 at Franklin Creek just north of Hood Franklin Road, and
- I-5 at the Laguna West Pump Station near Laguna Boulevard.

As part of the Plan development process, representatives from Caltrans participated in the Flood Working Group and provided input on the development of this white paper. As part of discussions with Caltrans representatives, they highlighted key changes they have made in their operations to adapt to climate change. These include using vegetation to prevent erosion along roadways, assessing and resizing culverts to accommodate increased precipitation, coordinating with local jurisdictions regarding route closures as well as pursing individual projects included in the Caltrans District Vulnerability Assessments. In 2019, Caltrans completed the District 3 VA which provides an overview of potential climate impacts to the district's portion of the State Highway System. The District 3 VA is part of a larger adaptation process undertaken by Caltrans to assess risk to Caltrans assets in the district and prioritize adaptation strategies from various climate impacts. The District 3 VA includes projected climate change exposure from precipitation change, flooding, temperature change, wildfire, storm surge, and sea level rise.

Resilience Strategy Opportunities

- Share adaptation strategies and tools for specific climate impacts on roadway systems.
- Coordinate regarding regional climate risks, including regional flooding events.
- Coordinate on adaptation projects that affect both Caltrans and City facilities.

SACRAMENTO REGIONAL COUNTY SANITATION DISTRICT

The Sacramento Regional County Sanitation District (Regional San) is the wastewater treatment utility for the greater Sacramento region. Regional San's service area is more than 250 square miles with more than 1.4 million residents. In 2016, the district adopted the *Regional San 10-Year Strategic Plan*, which serves as the Agency's guiding document for future growth, operations, and maintenance of the facilities under Regional San's management. The plan notes that a key challenge has been California's recent extended drought (2011–2017). Drought periods have provided opportunities for water conservation and recycling programs. However, as noted in the plan, decreasing water in the wastewater system creates operational challenges for Regional San's conveyance and treatment systems, resulting in cost increases due to corrosion and increased difficulties in meeting some regulatory requirements. As part of the Plan development process, representatives from Regional San participated in the Flood Working Group and provided input on the development of this white paper. Representatives noted that Regional San has not conducted a full assessment of how climate change may affect their operations or facilities, although staff expressed some concern for potential increases in stormwater flow due increased intensity of precipitation events. Staff also noted that they coordinate with Sacramento Area Flood Control Agency (SAFCA) on levee maintenance.

Resilience Strategy Opportunities

- Coordinate with regional partners regarding climate risks, including regional flooding events—specifically, events that may affect the Regional San facilities located directly north of the northwest portion of the City.

SACRAMENTO AREA COUNCIL OF GOVERNMENTS

The Sacramento Area Council of Governments (SACOG) is the Metropolitan Planning Organization (MPO) for the six-county Sacramento region including the 22 cities within El Dorado, Placer, Sacramento, Sutter, Yolo, and Yuba Counties. SACOG develops the region's long-range transportation plan which guides transportation and land use planning in the region. In 2015, SACOG adopted the *Sacramento Region Transportation Climate Adaptation Plan* to address how potential climate change impacts affect the region's transportation infrastructure. The plan highlights key impacts from climate change that could occur on the Sacramento region's transportation system in the future as well as a guiding Action Plan for future adaptation planning and implementation. Strategies included in the adaptation plan are:

- Work with stakeholders to conduct an asset-level criticality and climate change VA on the region's transportation network.
- Form a Technical Advisory Committee to help guide ongoing climate adaptation planning, implementation and monitoring efforts.
- Work with the SACOG Board of Directors to determine how climate adaptation should be addressed in the biennial regional funding round.
- Work with stakeholders on long-term monitoring of climate conditions and transportation infrastructure adaptability.

As part of the Plan development process, representatives from SACOG participated in the Flood Working Group and provided input for the development of this white paper. They noted that SACOG is currently developing a vulnerability assessment similar to the City's planning effort which includes using GIS analysis to understand how transportation infrastructure overlaps with climate risks to inform current and future development efforts.

Resilience Strategy Opportunities

- Work with SACOG to align the goals and implementation of adaptation strategies and projects relevant to both SACOG and the City.
- Work with SACOG to share climate impact data related to the transportation system, when appropriate, to increase collaboration on potential adaptation projects relevant to both SACOG and the City.
- Work with SACOG on opportunities for Federal, State, and regional funding opportunities to increase climate resilience in the City.

SACRAMENTO COUNTY AND SACRAMENTO OFFICE OF EMERGENCY SERVICES

Sacramento County completed a vulnerability assessment in 2015 that assessed the projected changes associated with climate change in the county, including impacts from changes in precipitation patterns and increased flooding. The assessment highlighted the unique vulnerabilities of Sacramento County to climate change including projected increases in the frequency, intensity, and duration of extreme storm events as well as projected regional temperature increases leading to earlier and more rapid melting of the Sierra Nevada snowpack and subsequent increases in flow rate of surface waters in Sacramento County (Sacramento County 2017b).

The Sacramento County Office of Emergency Services (Sacramento OES) provides support and resources for emergency preparedness through its Sacramento Ready Program and operates the county's Emergency Alerts Notification System.

Sacramento, Yolo, and Placer County residents can use the Citizen Opt-In portal to receive critical and time sensitive alerts regarding flooding, levee failures, severe weather, disaster events, unexpected road closures, missing persons, and evacuations of buildings or neighborhoods in specific geographic locations. Sacramento OES coordinates with police and fire departments in the incorporated cities in the County for emergency planning and response purposes. Sacramento OES also develops and updates planning documents including the County's *Evacuation Plan*, *Emergency Operations Plan*, *Mass Care and Shelter Plan,* and the County's LHMP. The City's Annex in the LHMP includes climate change as an identified hazard and discussed how climate change will impact other hazards in the City, rating the likelihood of occurrence and the vulnerability to climate change both as high. As part of the Plan development process, representatives from Sacramento County OES participated in the Flood Working Group and provided input on the development of this white paper.

Resilience Strategy Opportunities

- Work with Sacramento County OES to ensure that Elk Grove residents know about all available emergency preparedness and recovery resources, including the county's Emergency Alert System.
- Continue to work with Sacramento County OES to identify and mitigate local hazards through the LHMP planning process with particular attention to hazards exacerbated by climate change.

2.5.3 Local

CITY OF ELK GROVE

In February 2019, the City of Elk Grove completed an update to its GP that included both a climate action plan and a vulnerability assessment to identify, at a high level, the risks to the City posed by climate change. The vulnerability assessment provides adaptive capacity policies and action recommendations specific to flooding impacts, including to:

- Continue to advocate for the implementation of regional plans to upgrade levees along the Sacramento and American Rivers and to the Folsom Dam and reservoir.
- Continue to implement measures in the adopted CVFPP relevant to Elk Grove.

The Services, Health, and Safety chapter of the City's GP also includes a summary of how climate change may affect the City and policies to ensure it is adequately prepared for potential future impacts from climate change. Specifically, the chapter includes a set of policies regarding flooding and drainage risk mitigation and preparation to reduce the risk to existing and future development in the 100- and 200-year floodplain (Policy ER-2-1 through Policy ER-2-18). The City adopted amendments to the Elk Grove Municipal Code (EGMC) Title 23 (the Zoning Code) to include identification of the 100- and 200-year floodplains and require development standards that prohibit new development in the 200-year floodplain unless the property achieves an Urban Level of Flood Protection, defined in SB 5 (Machado). The specific requirements for an Urban Level of Flood Protection can be found in the City's Services, Health, and Safety chapter and the DWR website.

The City also developed design guidelines to implement the GP land use policies and strategies relative to urban design, pedestrian circulation, community and neighborhood identity, and residential, commercial, and industrial project design. The guidelines include standards for landscaping, open space, parking as well as the massing, scale, and form, all of which can have an effect on local drainage patterns and stormwater management.

Resilience Strategy Opportunities

- Identify all existing policies and standards in the City's GP, Design Guidelines, and other relevant documents that could be updated or enhanced to address climate change impacts.
- Continue to identify relevant State regulations specific to climate adaptation relevant to the City to remain consistent with the State's adaptation efforts.

CITY OF ELK GROVE PUBLIC WORKS DEPARTMENT

The Elk Grove Public Works Department supports important activities and functions for the City's stormwater management system including designing, constructing, operating and maintaining the City's road network and drainage systems. PW is also responsible for management of the City's solid waste (trash) and transit services. In 2011, the City adopted a comprehensive SDMP, which was updated in 2019. The SDMP provides a variety of drainage concepts for upgrading the existing storm drainage and flood control collection system. The plan includes a discussion of existing and proposed program activities to improve the City's existing storm drainage and flood control collection system as well and valuation of the performance level of the existing drainage and flood control facilities and identification of performance deficiencies, identification of potential impacts of future development on existing major facilities, and identification of existing and new facilities upgrades to serve buildout conditions of the City's GP. The Public Works Department oversees traffic operations in the City including the traffic signals through the City's traffic management center as well as managing maintenance of the City's roadway network through the Department's pavement management program. The Department's traffic and roadway operations could both be affected by climate change due to increases in the intensity of extreme precipitation events. As discussed above in Section 2.3.2, the Public Works Department has completed an assessment of the Laguna West levee system, which provides flood protection to the Laguna West, Lakeside and Stonelake neighborhoods in the City. As part of the Plan development process, representatives from the Public Works Department participated in the Flood Working Group and provided input on the development of this white paper.

Resilience Strategy Opportunities

- Coordinate closely with the City Public Works Department on all aspects of the plan related to strategy implementation and analysis that affect flooding impacts on the City, including the City's stormwater management system.
- Continue to work with the City Public Works Department to assess risks associated with the Laguna West levee system and ensure that the future assessment and projects incorporate precipitation changes from climate change.

CITY OF ELK GROVE POLICE DEPARTMENT

The Police Department provides law enforcement and policing services throughout the City. The Department provides a host of resources to the community regarding safety and emergency preparedness including the Citizen's Academy Program, the Project Lifesaver program, and much more. The Department assists in emergency situations in the City including road closures, signal outages, flooding, and evacuations. As part of the Plan development process, representatives from the Police Department participated in the Flood Working Group and provided input on the development of this white paper. Department representatives said they do not have any programs that address climate change directly but noted that the Department's work may be affected by increase in emergency events caused by flooding and related hazards.

Resilience Strategy Opportunities

- Coordinate closely with the City Police Department to increase the robustness of emergency response resources and training for large storm events.
- Identify secondary impacts from large flood events that may affect the Police Department and develop strategies to prepare for these impacts.

2.6 RISK AND ONSET ANALYSIS

The risk and onset analysis section provides a summary of the overall risk projected from changes in precipitation and storm events in areas affecting the City. The analysis also provides a summary of the onset of projected impacts, detailing when and at what magnitude these impacts may occur over the next century.

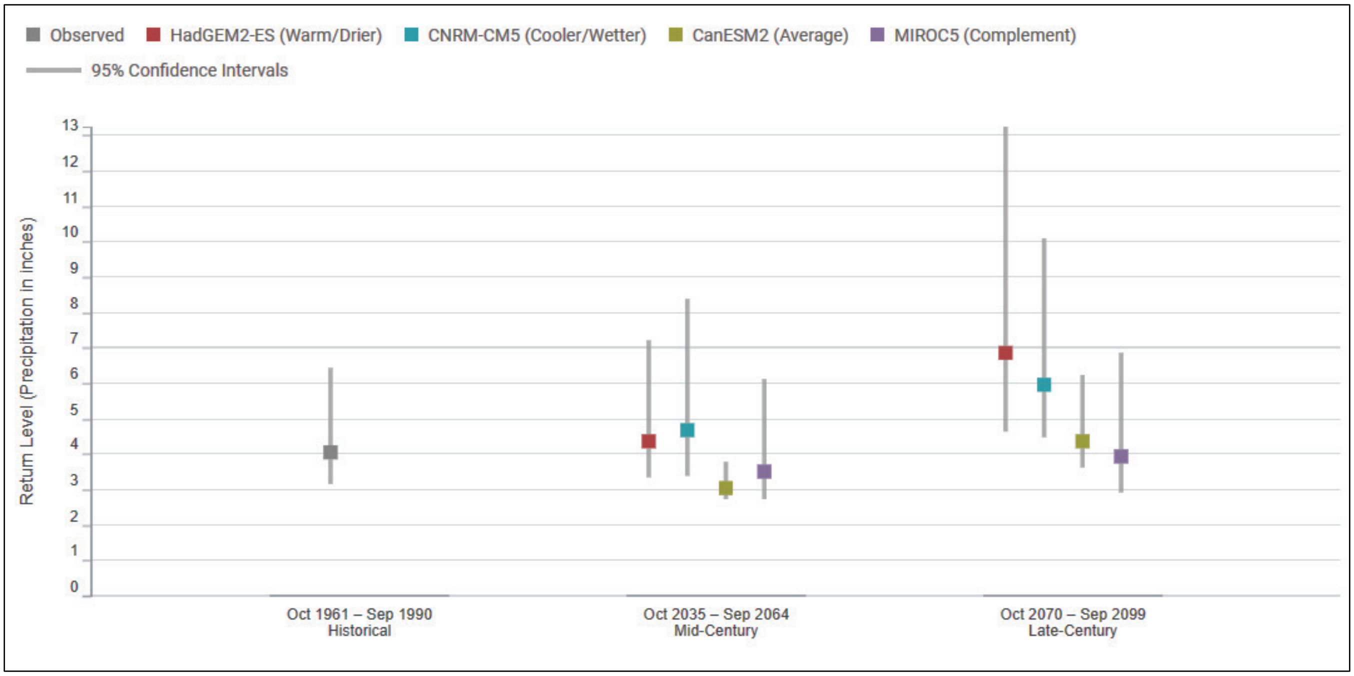
2.6.1 Risk of Impacts

The City's risk related to the impacts of precipitation and flooding from climate change depends on several variables. The most important variables for this analysis are the two emission scenarios, RCP 4.5 and RCP 8.5. As discussed in Section 2.1, because the severity of exposure and impacts to the City are dependent on future global emissions trends, the probability that each scenario would occur affects the overall risk to the City. Guidance from the State suggests that adaptation planning efforts should assume the impacts of RCP 8.5 through 2050 are likely to occur, due to the relatively small difference between RCP 4.5 and RCP 8.5 by midcentury. As such, this analysis uses the RCP 8.5 scenario as the baseline for impacts that will occur by midcentury in regard to planning and prioritizing flood risk. The uncertainty of future impacts largely depends on global emissions trends occurring around 2040 and whether they will decrease or increase. As discussed in Section 2.2.1, under RCP 8.5 by late century, precipitation and the severity of storm events increases substantially for all the watersheds affecting the City with noticeably smaller increases under RCP 4.5 scenario. As the City continues to plan for and reassess the impacts of climate change on the community overtime, it is important to remain up to date on the latest projections of climate impacts and global emissions trends. The analysis in this report serves as a baseline of data about future impacts which can be refined as more data and information about future impacts are developed and published.

It is also important to recognize the inherent uncertainty in the projections of climate models. Climate projections are at best approximations of future conditions, but as with any statement about the future, there is no way to be certain they are 100 percent accurate. Because the climate model data used for this analysis, in Cal-Adapt, uses two emissions scenarios, if actual global emissions pathway follows a different trend then those used to develop the RCP scenarios, there will be different levels of exposure and impacts. As noted on the Cal-Adapt website, the average values across different model projections in the Cal-Adapt tools are considered more likely than any individual model value.

Finally, like any modeling effort, there is a certain degree of confidence in the results of each modeling scenario. The data used in this analysis also includes a level of variation in the results produced in the modeling. Figure 8 serves as an example of this variation. In Figure 8, the gray lines shown for the four models included in Cal-Adapt represent the 95 percent confidence interval. The 95-confidence interval is the range of values that you can be 95 percent certain contains the average of the values. As shown in Figure 8, the range of the confidence interval increase over the century, meaning that while the annual mean precipitation increases, the probability of years with annual precipitation rates much larger and lower than the annual average also increases. This variability increases the unpredictability of precipitation from year to year and makes it more difficult to plan long-term, given the increasing uncertainty. However, knowing there will be more uncertainty for annual precipitation totals from year to year can also help long-term planning efforts overall.

Figure 8 Example of Confidence Intervals in Climate Modeling – Snodgrass Slough Watershed RCP 8.5



Note: Figure illustrating 100-year storm intensities.
Source: CEC 2019

2.6.2 Onset

The onset of impacts refers to the time period over the next century at which point certain changes in the climate occur and begin to result in impacts to the City. The onset of impacts is partly dependent on the thresholds used to determine an impact. As discussed in Section 2.4.1, the thresholds used for this analysis are based on whether there is an exceedance of the intensity of the 2-, 10-, and 100-year storm events for the 24-hour storm period.

As shown in Table 10, under the RCP 4.5 scenario by midcentury, the largest increases to occur will be in the Snodgrass Slough for the 2- and 10-year storm, affecting the south and western portions of the City. Because the RCP 4.5 scenario represents a best-case scenario of projected climate impacts, it is highly likely these increases will occur. However, because there will be only slight increases in intensity of the 100-year storm event in one watershed by midcentury, more large-scale flooding impacts are not projected to increase greatly over existing conditions. By late century under the RCP 4.5 scenario, larger increases in the intensity of all three size storm events will occur in the Morrison Creek and Snodgrass Slough watersheds. The Upper Cosumnes River watershed will also experience a significant increase in intensity of the 100-year storm event, resulting in larger impacts in the Sheldon area and eastern portions of the City by late century. Overall, under the RCP 4.5 scenario, the onset of changes will fully occur only in the Snodgrass Slough watershed by midcentury, with the onset of these changes spreading to the Morrison Creek, Deer Creek, and Upper Cosumnes River watersheds by late century.

Table 10 Onset of Changes in Intensity of Storm Events through 2099 under RCP 4.5 Scenario

Watershed	Midcentury (2035–2064)			Late Century (2070–2099)		
	2-Year	10-Year	100-Year	2-Year	10-Year	100-Year
Morrison Creek	3%	-3%	-14%	20%	6%	5%
Snodgrass Slough	12%	6%	-5%	13%	12%	8%
Upper Cosumnes	-5%	-3%	4%	-3%	2%	17%
Deer Creek	-3%	-5%	-10%	-3%	-5%	-6%

Source: Impact areas identified by Ascent Environmental 2019

As shown in Table 11, under the RCP 8.5 scenario, by midcentury the largest increases to occur will be in the Upper Cosumnes River watershed with a 23 percent increase in intensity of the 100-year storm event. By late century, all four watersheds will experience increases in the intensity of all three storm sizes with large increases in the intensity of the 100-year storm event. As noted above, the probability the RCP 8.5 scenario occurring is dependent on a number of geopolitical and social factors which are very difficult to predict. Because trends by midcentury are relatively similar under both emissions scenarios, the City can plan for the onset of impacts by midcentury with a higher degree of certainty. Depending on global emission trends leading up to and in 2040, the City and the general public will know whether the worst impacts of climate change have been avoided or whether the intensity and severity of the impacts will continue to increase by late century. At this point, the City will be able to plan with a greater degree of certainty whether further adaptation actions need to be taken to address the largest impacts to occur under the RCP 8.5 scenario.

Table 11 Onset of Changes in Intensity of Storm Events through 2099 under RCP 8.5 Scenario

	Midcentury (2035–2064)			Late Century (2070–2099)		
	2-Year	10-Year	100-Year	2-Year	10-Year	100-Year
Morrison Creek	6%	-5%	-16%	20%	22%	26%
Snodgrass Slough	-2%	3%	-9%	28%	27%	26%
Upper Cosumnes River	-2%	6%	23%	8%	17%	40%
Deer Creek	-3%	-3%	-1%	11%	12%	15%

Source: Impact areas identified by Ascent Environmental 2019

2.7 SUMMARY OF FINDINGS

The five-step vulnerability process conducted and summarized above provides a substantive level of detail on the City's exposure to changes during precipitation and storm events over the century, along with how these changes will affect important aspects of the City, including the stormwater management system and transportation system, as well as vulnerable populations and key functions and facilities in the City. The analysis provides a level of detail that can help the City develop a strategy to adapt to both near- and longer-term impacts on the City. It provides a baseline for how the City will be affected by climate-related precipitation and flooding issues in the future. However, because the severity of these impacts depends on factors outside the City's control, it is important that the City consider taking a conservative approach and planning for the worst impacts of climate change.

The key findings in the vulnerability analysis are summarized as follows:

- The City will experience slight increases in annual average precipitation and the intensity of smaller (2- and 10-year storms) by midcentury. With the addition in projected maximum duration of these events, these increases will likely contribute to localized flooding impacts in the City. The largest increase in the intensity of storm events will occur in the Snodgrass Slough watershed under both emission scenarios by 2035. By late century, under the RCP 4.5 scenario, the City will experience increases in the intensity of the 2-, 10-, and 100-year storm events, with the largest increases (20 percent) occurring during the 2-year storm event in the Morrison Creek watershed. Because the RCP 4.5 is a best-case scenario by midcentury, this emission scenario can be used a baseline for projected impacts.
- By late century, under the RCP 8.5 scenario, the two primary watersheds (Morrison Creek and Snodgrass Slough) will experience a 26 percent increase in the intensity of the 100-year storm with a similar increase in the smaller storm events. The two watersheds affecting the eastern portion of the City (Sheldon area), Deer Creek and Upper Cosumnes River, will also experience a 15 and 40 percent increase in the intensity of the 100-year storm event by 2070, respectively. This will likely result in impacts to the Sheldon area and areas to the southeast of the City.
- Future emissions scenarios in which the City's watershed will experience increases in the intensity of storm events are more likely to have an impact on the City's stormwater management and related systems. Increases in the 2- and 10-year storm events during these periods will likely contribute only to localized flooding impacts with increases in the 100-year storm event leading to more widespread impacts when these events do occur. Key sensitive flood

areas in the City under existing conditions will be at increased risks of flooding, particularly for localized flooding impacts.

- Increases in the precipitation and the intensity of storm events in the larger region will increase the City's risk to impacts from larger flood events. The Laguna West -Lakeside and Stonelake neighborhoods, given their location near the Sacramento River and geographic context, are at increased risk of impacts from larger storm events, particularly if the events involve levee breaches along the Sacramento River.
- Key populations in the City, discussed in Section 2.3.1, that are at increased sensitivity to flooding hazards are at higher levels of risk from the impacts of flooding, as well as, in some cases, the ability to recover from flooding events. These populations should be given specific consideration in adaptation planning efforts.
- Most relevant local and regional agencies have either begun to take action or have completed actions to increase their resilience to the impacts of climate change. There are a number of opportunities for collaboration with regional partners and stakeholders to develop and help implement resilience strategies for the City.
- Because the severity of flood impacts is dependent on a number of factors outside the City's control, namely global emission trends, it is important that the City remain engaged with the latest information on the projected impacts of climate change, which will likely change in the future. The analysis provides a baseline of impacts projected to occur that the City can use to develop resilience strategies.

3 RESILIENCE STRATEGIES

The Resilience Strategies section provides a matrix that includes proposed strategies to address the specific impacts discussed in precipitation and flood vulnerability assessment. The section includes a set of preliminary adaptation strategies to be considered by the City, relevant stakeholders, and the general public based on the projected impacts to occur in the City. After a more refined list of measures has been chosen, a subset of these strategies will be fully developed with implementation mechanisms and opportunities for funding and included in the Plan. Table 12, below, includes the set of proposed strategies, characterized at a high level, to help the City mitigate and adapt to impacts of climate change on flooding and storm events in the City. The table also includes key information about the strategy, including what impact it is addressing, what mechanism is being used to address the impact, how the strategy may be implemented, and the source document used to develop the strategy. The following types of information are presented in the different columns in Table 12:

- **Primary Impact**: This column provides a summary of the primary impact being addressed by a set of strategies.
- **Strategy Category and Number**: This column provides the number of the strategy for reference purposes and a set of categories summarizing the aspect or system in the City that the strategy is addressing. Categories include:

  A) **A Resilient Stormwater Management System:** These strategies focus on incorporating projections for future storm intensities into the design of the City's stormwater management system and design standards to account for climate change. This category prioritizes upgrades to the City's traditional "gray" stormwater infrastructure systems.

  B) **Climate-Smart Green Infrastructure:** These strategies focus on prioritizing stormwater management updates that increase flood protection while providing ecosystem and other co-benefits. These strategies prioritizes using natural flood control systems (e.g., increased creek setbacks, increased open space, bioswales).

  C) **Climate-ready community:** These strategies focus on ensuring the City's and residents are aware of all future flood risks caused by climate change and are adequately prepared to respond to small and large flooding events.

  D) **A Coordinated Regional Flood Management System:** These strategies focus on working with regional partners to understand and prepare for increases in the frequency and intensity of larger regional storm events that would affect waterways in or near the City (Sacramento River, Cosumnes River).

E) **A Resilient Transportation System:** These strategies focus on improving the City's transportation system (e.g., roads, bridges, parking lots, railways, and public transit) to prepare for the impacts from the increased frequency and intensity of storm events and associated flooding.

F) **Social and Economic Resilience:** These strategies focus on ensuring that residents and businesses are adequately prepared for flood events and have adequate resources to recover during the post-flood period.

- **Strategy Description**: This column provides a description of the strategy and highlights where there is crossover between the strategy and actions included in Chapter 10 "Implementation Strategy" of the City's GP.
- **Adaptation Mechanism:** This column provides a description of the principle being used to increase the resilience and mitigate flood impacts in the City.
- **Implementation Mechanism**: This column provides a description of how the strategy would be implemented. The categories provided in this column are consistent with those included in EPA's Regional Resilience Toolkit (EPA 2019).
- **Responsible Department**: This column identifies the City department likely responsible for implementing the strategy, as well as supporting departments and regional partners.
- **Timeline**: This column identifies the period when the strategy should be implemented with a total timeframe between 2022 and 2035.
- **Source/Example**: This column identifies the source document or plan that was used to develop the strategy and provides information about the effectiveness of the strategy and implementation details.

Table 12 Precipitation and Flooding Resilience Strategies Recommendations

Primary Impact	Strategy Number and Category	Strategy Description	Adaptation Mechanism	Implementation Mechanism	Responsible Department	Timeline	Source/ Example
Increased localized flooding: Storm events will exceed storm levels for facilities designed to manage smaller storm events (2- and 10-year storms) resulting in increased localized flooding	A1: A Resilient Stormwater Management System (IDF Curves)	Conduct appropriate analysis and begin the process to update the IDF curves used in stormwater infrastructure standards used for managing localized runoff and smaller precipitation events. Incorporate updated modeling in standards for new development in the City including capital improvement projects.	Increased stormwater infrastructure capacity	Plans, regulations, and policy development	Development Services, Public Works	2022-2025	Transportation Research Board and National Research Council 2008, Caltrans 2013, Wang 2015, Peck et al. 2012.
	A2: A Resilient Stormwater Management System (Stormwater Management Planning)	Incorporate projections for future precipitation characteristics, including changes in storm events, as part of the next update to the City's SDMP. Develop a comprehensive list of existing stormwater and drainage facilities that are at increased risk from failure or loss of performance from increases in the intensity of storm events.	Increased stormwater infrastructure capacity	Plans, regulations, and policy development	Development Services, Public Works	2022-2025	Caltrans 2013, Cal EMA and CNRA 2019, Doroszkiewicz et al. 2017; Burrel et al. 2007
	B1: Climate-Smart Green Infrastructure (Flood Management and Ecosystem Benefits)	Prioritize sustainable flood risk management strategies that provide increased flood protection and ecosystem benefits (e.g., increased creek setbacks, increased open space, sponge City strategies, bioswales). This strategy aligns with GP Implementation Strategy Action 8.3 "Open Space Conservation and Management Plan."	Increased awareness of vulnerabilities	Plans, regulations, and policy development	Development Services, Public Works	2022-2025	Green 2010, ASLA 2018
	B2: Climate-Smart Green Infrastructure (Green Stormwater Management)	Develop a comprehensive strategy and set targets to decrease stormwater runoff from existing residential and nonresidential land uses through green infrastructure approaches (e.g., rain gardens, rainwater catchment barrels, green stormwater infrastructure, permeable parking lots and pavement) to help offset impacts on the City's stormwater management system from climate change.	Reduced stormwater runoff impacts on creeks and waterways during storm events	Programmatic	Development Services, Public Works local agency partners	Ongoing	EPA 2016, ASLA 2018
	B3: Climate-Smart Green Infrastructure (Green Stormwater Management Planning)	As part of implementation of the SDMP, integrate green stormwater infrastructure and low impact development strategies to offset impacts on the City's stormwater management system from changes in future storm events as a result of climate change. Incorporate climate-informed hydraulic modeling during the next update to the SDMP. This strategy aligns with GP Implementation	Reduced stormwater runoff impacts on creeks and waterways during storm events	Plans, regulations, and policy development	Updated Design Standards, Long-Range Planning	2022-2025	Green 2010, ASLA 2018

Primary Impact	Strategy Number and Category	Strategy Description	Adaptation Mechanism	Implementation Mechanism	Responsible Department	Timeline	Source/ Example
		Strategy Action 1.8 "Sustainable Stormwater Management Ordinance."					
	B4: Climate-Smart Green Infrastructure ("Sponge City" Strategies)	Explore "sponge city" strategies and principles that can be appropriately incorporated in the City's landscape requirements and urban design guidelines. A "sponge city' is a city designed to passively absorb, clean, and use rainfall while mimicking the drainage patterns of natural landscapes.	Increased stormwater infrastructure capacity	Plans, regulations, and policy development	Development Services	2022-2025	Nguyen et al. 2019
	B5: Climate-Smart Green Infrastructure (Urban Forest)	Develop strategy consistent with the City's CAP to increase tree planting (Measure BE-9) in the City that also provides stormwater runoff benefits while ensuring leaf and debris drainage issues are not exacerbated.	Increased stormwater infrastructure capacity	Plans, regulations, and policy development	Development Services	2022-2025	Berland et al. 2017
	C1: Climate-ready community (Local Flood Monitoring)	Develop and regularly update a map of areas in the City prone to localized flooding that includes the latest observational data on localized flooding near creeks, waterways, roads, and other emerging flooding areas.	Increased awareness of vulnerabilities	Evaluation	Development Services, Public Works, GIS	2022-2025	Caltrans 2013, City of Seattle 2017
Increased risk of flood impacts during large storm events: Large storm events that exceed the design storm levels for flood management systems such as levees (100-year storms and above) will result in increased stress on these systems and potentially compromise the integrity of flood management assets.	D1: A Coordinated Regional Flood Management System (Regional Partnerships)	Work with regional partners to explore options and cost for conducting a hydraulic study of waterways in the City that incorporates future intensities of large regional storm events (i.e., 50-, 100-, 200-year storms) affecting regional waterways which could impact the City (e.g., Sacramento River, Cosumnes River). This strategy aligns with Action 9.5 "Floodplain Data Update" in the GP Implementation Strategy.	Increased awareness of vulnerabilities	Evaluation	Development Services, Public Works, regional partners	2022-2025	Wright et al. 2012, Mauger and Lee 2014
	D2: A Coordinated Regional Flood Management System (Climate-Informed Flood Modeling)	Work with Sacramento County and regional partners to develop regional flood risk analysis that incorporates projected increase in storm intensities from climate change, including analysis of increased risk from levee failure.	Increased awareness of vulnerabilities	Analysis and Inventory	Development Services, Public Works, regional partners	2025-2030	Caltrans 2013
	D3: A Coordinated Regional Flood Management System (Flood Management Planning)	Work with regional partners to update the IDF curves used in the regional flood management system for components designed to manage larger regional flood events (i.e., 50-, 100-, 200-year storms) affecting regional waterways, which could impact the City (e.g., Sacramento River, Cosumnes River). Continue to evaluate potential upgrades to the Laguna West Levee	Increased awareness of vulnerabilities	Capital improvement projects	Public Works, regional partners	2022-2025	Transportation Research Board and National Research Council 2008, Caltrans 2013, Wang 2015

Primary Impact	Strategy Number and Category	Strategy Description	Adaptation Mechanism	Implementation Mechanism	Responsible Department	Timeline	Source/ Example
		system to increase the City's resilience to large scale flooding events. This strategy aligns with Action 9.6 "Infrastructure to Reduce Flood Hazards" in the GP Implementation Strategy.					
	D5: A Resilient Flood Management System (Adaptive Management Approach)	Considering the City's low level of risk by midcentury, continue to monitor the characteristics of future flood events to identify whether actions need to be taken for certain facilities or portions of the City. Continue operation of the City stormwater and flood management system as normal and address new flooding issues as needed.	Increased awareness of vulnerabilities	Evaluation	Development Services, Public Work	Ongoing	City of Seattle 2017, Pregnolato et al. 2016 Kuklicke et al. 2016
	D6: A Resilient Flood Management System (Detention Basins)	Explore opportunities to add redundancy to the City's existing stormwater and flood management systems (e.g., additional detention basins) to mitigate impacts from increased storm intensities as needed.	Increased stormwater infrastructure capacity	Plans, regulations, and policy development	Public Works	2022-2025	Pregnolato et al. 2016, Hettiarachchi et al. 2018, Markolf et al. 2019
	C2: Climate-ready community (Flood Warning System)	Explore opportunities to support updates to Sacramento County's early warning system from flood events as necessary.	Increased preparedness for large flood events	Education, outreach, and coordination	Sacramento County, Police Department, Public Works	2022-2025	Kundzewic 2013
Secondary impacts on the City's Transportation System: Impacts on the City's stormwater and flood management systems could result in secondary impacts on specific transportation assets in the City including increased degradation rates for specific facilities and decreased system performance.	A3: A Resilient Stormwater Management System (Bridge Scour)	Explore and identify feasible strategies (e.g., rip rap, hardening) to mitigate scour for bridges.	Increased stormwater infrastructure capacity	Capital improvement projects	Public Works	2025-2030	Nemry and Demirel 2012, Wright et al. 2012
	A4: A Resilient Stormwater Management System (Rail Network)	Identify segments of railway particularly vulnerable to flooding impacts and potential subgrade erosion. Work with regional partners to assess risk level and upgrades needed to mitigate future storm intensities.	Increased awareness of vulnerabilities	Evaluation	Public Works, Union Pacific, Caltrans regional partners	2025-2030	Caltrans 2013
	E1: A Resilient Transportation System (Roadway Degradation)	Explore options and implement strategy to increase durability of materials and roadway subbase design to mitigate degradation impacts from future storm intensities.	Increased resilience in roadways	Plans, regulations, and policy development	Public Works	2025-2030	Willway et al. 2008, Li et al. 2011
	A4: A Resilient Stormwater Management System (Permeable Pavement)	Assess feasibility of incorporating permeable pavements into aspects of the City's infrastructure to decrease stormwater runoff impacts during storm events. Conduct	Increased stormwater infrastructure capacity	Capital improvement projects	Public Works	2022-2025	Selbig and Buer 2018

Primary Impact	Strategy Number and Category	Strategy Description	Adaptation Mechanism	Implementation Mechanism	Responsible Department	Timeline	Source/ Example
		pilot project at a City facility to better understand costs and benefits.					
	E2: A Resilient Transportation System (Flood Communication)	Develop a City-specific flood warning website and notification system to notify resident about flood areas in the City to help residents avoid flooded areas and reduce impacts to traffic operations. This strategy aligns with GP Implementation Strategy Action 9.11 "Public Information on Preparedness and Services for Extreme Weather Events."	Increased awareness of vulnerabilities	Education, outreach, and coordination	City Manager's Office, Emergency Operations, Public Works	2025-2030	Sacramento County 2019
	C3: Climate-ready community (Evacuation Routes)	Work with Sacramento County to identify and protect evacuation routes from future flood impacts. Prioritize stormwater system and roadway upgrades along evacuation routes. This strategy aligns with GP Implementation Strategy Action 9.14 "Public Agency Cooperation Guidelines for Emergency and Disaster Response."	Increased awareness of vulnerabilities	Evaluation	Development Services, regional partners	2022-2025	Caltrans 2013
Impacts on Social Functions: Impacts on the City's stormwater and flood management systems could result in secondary impacts on the vulnerable populations in the City as well and critical community functions including economic activity and emergency operations.	C4: Climate-ready community (Flood Preparedness Education)	Work with Sacramento County OES, Community organizations, and regional partners to increase flood preparedness education and training opportunities for City residents.	Increased social resilience	Education, outreach, and coordination	City Manager's Office	Ongoing	Sacramento County 2019
	F1: Social and Economic Resilience (Vulnerable Populations)	Continue to track sociodemographic factors to identify areas in the City with populations at increased risk to flooding. Prioritize flood adaptation strategies to reduce risk and impacts to the City's vulnerable populations. This strategy aligns with GP Implementation Strategy Action 15.2 "Outreach Techniques for Minority and Disadvantaged Communities."	Increased awareness of vulnerabilities	Evaluation	City Manager's Office, regional partners	Ongoing	Sherwin 2018, Montgomery and Chakraborty 2015, Mohnot et al. 2019
	C5: Climate-ready community (Flood Protection for New Development)	In coordination with future updates to the CVFPP (per SB 5), continue to assess Urban Level of Protection for properties in the City and update the City's elevation and construction standards accordingly for new construction. As part of this process, identify list of priority critical facilities that are at increased risk from flooding based on hydraulic modeling that includes future storm intensities. Implement strategies to reduce risk for flooding in and near these facilities including potential relocation of facilities.	Increased awareness of vulnerabilities	Evaluation	Public Works	2022-2025	EPA 2016

Primary Impact	Strategy Number and Category	Strategy Description	Adaptation Mechanism	Implementation Mechanism	Responsible Department	Timeline	Source/ Example
	C6: Climate-ready community (Neighborhood Readiness Plans)	Work with community organizations to develop neighborhood readiness plans for areas of the City at increased risk of flooding.	Increased preparedness for large flood events	Education, outreach, and coordination	City Manager's Office, Development Services	2022-2025	Cal OES 2019
Impacts on Community Functions: Impacts on the City's stormwater and flood management systems could result in secondary impacts on critical community functions including economic activity and emergency operations.	E3: A Resilient Transportation System (Traffic Operations)	Analyze the City's traffic signal system to identify key points of sensitivity to flooding. Prioritize reducing risk of flooding impacts to key points of sensitivity for the City's traffic signal system.	Increased awareness of vulnerabilities	Evaluation	Public Works	2022-2025	Caltrans 2013
	F2: Social and Economic Resilience (Post-Disaster Recovery)	Explore opportunities to expand access to post-disaster recovery resources for residents and businesses (e.g., recovery funding, recovery services) and remove barriers for rebuilding in post-disaster situations. This strategy aligns with GP Implementation Strategy Action 9.3 "Post-Disaster Recovery Ordinance."	Increased economic resilience	Programmatic	City Manager's Office	2022-2025	Mohnot et al. 2019
	F3: Social and Economic Resilience (Business Resilience)	Prioritize adaptation projects and strategies which reduce risk to the City's businesses and industrial areas to avoid loss of economic activity.	Increased economic resilience	Plans, regulations, and policy development	Development Services	Ongoing	EPA 2016
	C7: Climate-ready community (Capital Improvement Projects)	Incorporate projected changes in precipitation and storm intensity to the City's capital improvements planning process, specifically projects in areas anticipated to be impacted by climate change.	Increased stormwater infrastructure capacity	Education, outreach, and coordination	Public Works	2022-2025	City of Seattle 2017
	F4: Social and Economic Resilience (Climate-Related Infrastructure Fund)	Establish funding reserves for future repairs to damaged infrastructure that may be required due to increased stress from extreme heat, extreme storms, and other climate impacts. This strategy aligns with GP Implementation Strategy Action 9.12 "Climate-related Infrastructure Repair Reserve."					

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Appendix A

Vulnerable Populations, Community Functions and Existing Conditions

IMPACT ANALYSIS INDICATOR SUMMARY

As discussed in Section 2.4.1, the impact analysis methodology includes a set of indicator metrics which allow the analysis to incorporate potential impacts to areas of social vulnerability and normal community functions in the City. The impact analysis focuses on the location of these indicators relative to the 10 key impact areas identified in Section 2.4.2. Provided below is a summary of the social and community function indicators that have been included in the impact analysis and why they were chosen for inclusion.

Social Vulnerability and Sensitivities

Flood impacts to a community can disproportionately impact certain residents and neighborhoods based on a variety of factors which may increase an individual or family's sensitivity to flood impacts and/or capacity to recover from flooding events (Pacific Institute 2012). For this analysis, six indicator variables were chosen to identify social vulnerabilities in key flood impact areas in the City as well as the City overall. Below is a brief description of each indicators.

Many of the indicators used in the analysis identify vulnerabilities in census tracts by identifying tracts with a high percentile for a given indicator. The census tracts percentile identifies roughly what percent of the state's population lives in a tracts that has a lower value (or in some cases, a tied value). For example, if a tract is in the 75th percentile for low-income households, this means that 75 percent of census tracts in the state have lower percentages of low-income households. Data included in this category is from the 2013-2017 5-year summary file for the City as part of American Community Survey from the US Census Bureau.

Senior Populations – This metric identifies whether there is senior facilities or similar facility within or near identified sensitive areas. The metric also identifies if census tracts adjacent to the sensitive area have a much higher than average percentage of the population within the tract above 65 years of age (i.e., census tract in 80th percentile or above for percentage of residents above 65 years of age). This data was retrieved from the City of Elk Grove and data from the US Census Bureau using the EPA's Environmental Justice Screening and Mapping Tool (EJSCREEN).

Youth Populations – This metric identifies whether there are any youth-related facilities (e.g., school, day care center) or similar facility within or near an identified sensitive area. The metric also identifies if census tracts adjacent to the sensitive area have a much higher than average percentage of the population within the tract below 5 years of age (i.e., census tracts in 80th percentile or above for percentage of residents below 5 years of age). This data was retrieved from the City of Elk Grove and data from the U.S. Census Bureau using the EPA's EJSCREEN tool.

Linguistic Isolation – This metric identifies if census tracts adjacent to the sensitive area have a high percentage of the population within the tract that are linguistically isolated, meaning the percent of households in which no one age 14 and over in the household speaks English "very well" nor speaks English only (as a fraction of households). This data was retrieved from the US Census Bureau using the EPA's EJSCREEN tool.

Low Income Population – This metric identifies if census tracts adjacent to the impact area have a high percentage of the population that are designated as low-income, defined as households where the household income is less than or equal to twice the Federal "poverty level." For this analysis, this includes census tract in 70th percentile or above for percentage of residents designated as low-income. This data was retrieved from the US Census Bureau using the EPA's EJSCREEN tool.

Household vehicle access – This metric identifies if census tracts adjacent to the sensitive area that have a high percentage of households without access to a vehicle. For this analysis, this includes census tracts that have 5 percent or more of households without access to a vehicle. This data was retrieved from the US Census Bureau using the Healthy Places Index (HPI) tool developed by the Public Health Alliance of Southern California.

CalEnviroScreen Score – This metric identifies if census tracts adjacent to the sensitive area scored in the 60th percentile for high scores in the CalEnviroScreen scoring tool, which identifies census tracts in California that are most affected by various sources of pollution and where people are often especially vulnerable to pollution's effects. This data was retrieved from the CalEnviroScreen 3.0 tool developed by the California Office of Environmental Health Hazard Assessment (OEHHA) in 2018. Although the CalEnviroScreen tool was developed to identify and prioritize resources for census tracts within the top 25 percentile of scores, the tool still provides important information about pollution exposure and other variables for census tracts in the City.

Community Function Vulnerabilities

Flood events in urban areas can result in impacts to important community facilities and functions essential to daily life in the City. Impacts can include power outages, flooding impacts to commercial and industrial areas, flood impacts on government and emergency facilities, road and rail closures, and damage to residential properties. For this analysis, five indicator variables were chosen to identify Community Function vulnerabilities in the City with a focus on important flood sensitive areas. Below is a brief description of each indicator.

Average Daily Traffic – This metric identifies whether a key impact area intersects with a high-volume roadway and, therefore, is at increased risk of causing disruption in traffic operations along the roadway. For this analysis, high-volume roadways are considered those with ADT of 25,000 vehicles or more. This data was retrieved from the City of Elk Grove.

Electrical Substation – This metric identifies whether a key impact area includes a substation in or near (within 500 feet) of the 100 or 500-year floodplain and, therefore, is at increased risk of impacts to the electricity grid and power supply to residents during large flood events. This data was retrieved from GIS data provided by the CEC.

Economic Activity – This metric identifies whether a key impact area includes industrial or commercial land uses and, therefore, is at increased risk of impacting short and long-term economic activity from large flood events (Pregnolato et al. 2017). This data was retrieved from the City of Elk Grove.

Government Facility – This metric identifies whether a key impact area includes or is near (within 500 feet) a government facility as well as buildings designated as evacuation shelters. The facilities play a critical in the City's operations during emergency evacuation events (Pregnolato et al. 2017). This data was retrieved from the City of Elk Grove.

Land Use - This metric identifies what type of land use is included in each of the impact areas. It helps inventory which land uses will potentially be impacted and what types of land uses are disproportionately represented in the impact areas. Land use categories included residential, commercial and industrial. This data was retrieved from the City of Elk Grove.

- **Critical Facilities** - This metric identifies whether a critical facility is located in or near (within 500 feet) the impact area. These facilities include those that serve sensitive populations, provide essential services, and house hazardous materials that allow the community to function during large flood events. This data was retrieved form the City's local hazard mitigation plan (LHMP). The critical facility categories are:
- **At Risk Populations** (i.e., Adult Residential Facilities, Assisted Living Centers, Day Care Centers, Group Homes, Infant Centers, all public and private schools, and Senior Centers)
- **Essential Service Facilities** (i.e., Stormwater Detention Basins, Emergency Evacuation Shelters, Fire Stations, Medical Health Facilities, Urgent Care Facilities, Sandbag distribution areas, police facilities, fire stations, government-owned facilities, and emergency operations centers)
- **Hazardous Materials Facilities** (i.e., oil collection center, propane storage)

APPENDIX A REFERENCES

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Appendix B

Impact Analysis Scoring and Exposure Analysis Data

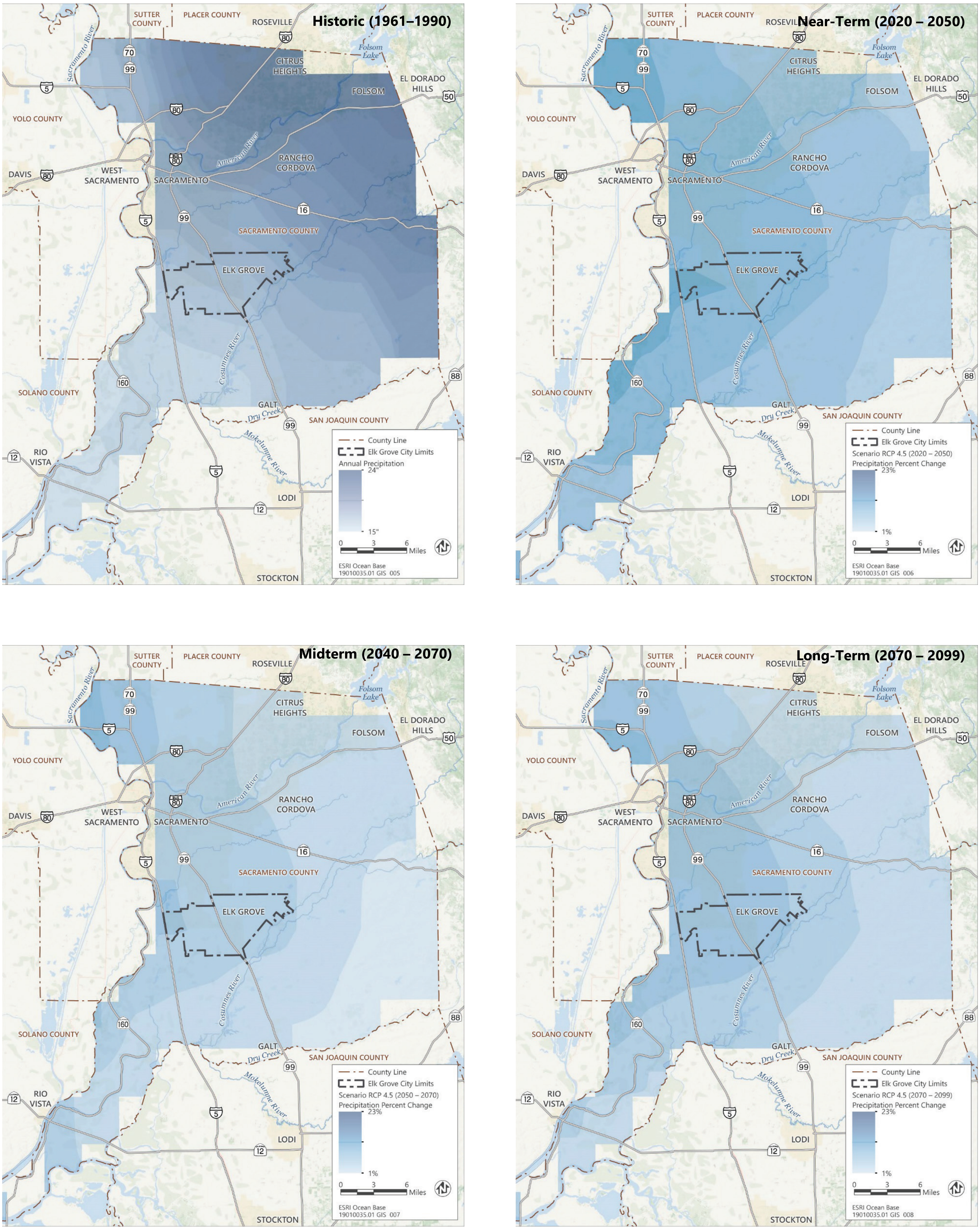
Focus Area Scoring Summary Table by Indicator

Watershed	Analysis Region	Area #	Focus Areas	Stormwater and Transportation System						Social Vulnerabilities						Community Function Vulnerabilities				Land Uses			
				Detention Basin	Roads	Rail	Bridges	Public Transit	Active Transit	Elderly	School	Linguistic Isolation	Low Income	Vehicle Access	Calenviro screen	Traffic Operations	Utility Operations	Economic	Government Facility	Residential	Commercial	Industrial	Critical Facility
Morrison Creek	Elk Grove Creek	1	Valley Oak Lane at Elk Grove High School		X		X	X	X	X	X				X		X		X	X			X
	Elk Grove Creek	2	Old Town Elk Grove Area		X	X		X	X		X	X	X	X		X		X		X	X		
	Elk Grove Creek	3	East Stockton Boulevard at Emerald Vista Drive		X		X	X	X	X			X	X	X	X		X		X	X		
	East Elk Grove	4	Sheldon Area east of Grant Line Road	X	X		X			X							X	X		X	X		
	Urbanized Eastern Area	5	Laguna Creek at Bond Road and Elk Grove Florin Road	X	X	X	X	X	X				X	X		X	X	X		X	X	X	
Upper Cosumnes and Deer Creek	Urbanized Eastern Area	6	Sheldon Road between Scenic Elk Ct. and St. Anthony Ct.		X				X			X								X			
Morrison Creek	Urbanized Eastern Area	7	Laguna Creek at State Route 99 and surrounding area	X	X		X	X			X	X		X	X	X			X	X	X		X
Snodgrass Slough	Urbanized Eastern Area	8	Laguna West Neighborhood and surrounding area	X	X		X	X	X		X					X		X		X	X	X	
Frequency of Indicator Impact (8 Focus Areas)				4	8	2	6	6	6	3	4	3	3	4	3	5	3	5	2	8	6	2	2

Appendix C

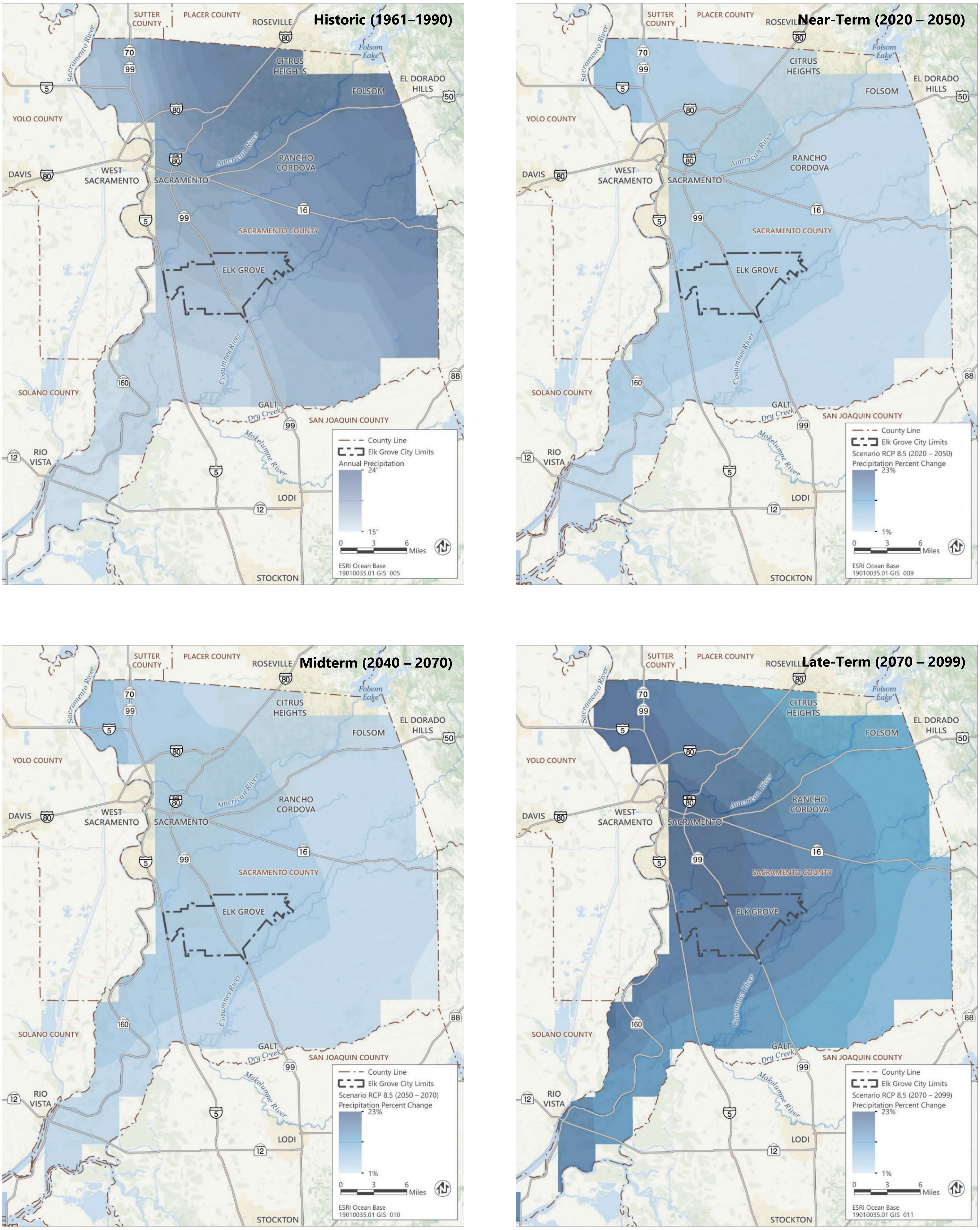
Sacramento County Annual Average Precipitation Change

Figure 10 Sacramento County Annual Average Precipitation Change – RCP 4.5 Scenario through 2099



Source: data downloaded from CEC and DWR in 2019

Figure 11 Sacramento County Annual Average Precipitation Change – RCP 8.5 Scenario through 2099



Source: data downloaded from CEC and DWR in 2019