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ASCENT ENVIRONMENTAL


ELK GROVE COMMUNITY MOBILITY RESILIENCE PLAN WHITE PAPER

# Climate Change, Temperature Change, and Extreme Heat in Elk Grove, California

CITY OF ELK GROVE

**PREPARED FOR:**

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

# Climate Change, Temperature Change, and Extreme Heat in Elk Grove, California

## Elk Grove Community Mobility Resilience Plan White Paper



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# TABLE OF CONTENTS



## Figures



## Tables

# LIST OF ABBREVIATIONS

| | |
|---|---|
| °C | degrees Celsius |
| °F | degrees Fahrenheit |
| APA | American Planning Association |
| ASLA | American Society of Landscape Architects |
| Cal EMA | California Emergency Management Agency |
| Cal OES | Governor's Office of Emergency Services |
| CalEPA | California Environmental Protection Agency |
| Caltrans | California Department of Transportation |
| CAP | Climate Action Plan |
| CARB | California Air Resources Board |
| CDC | Centers for Disease Control and Prevention |
| CDD | Cooling Degree Days |
| CEC | California Energy Commission |
| CHAT | California Heat Assessment Tool |
| City | City of Elk Grove |
| CNRA | California Natural Resources Agency |
| District 3 VA | Caltrans District 3 Climate Change Vulnerability Assessment |
| DWR | California Department of Water Resources |
| DOE | U.S. Department of Energy |
| DOT | U.S. Department of Transportation |
| EO | Executive Order |
| EPA | U.S. Environmental Protection Agency |
| FHWA | Federal Highway Administration |
| GP | General Plan |
| GHG | greenhouse gas |
| HDD | Heating Degree Days |
| HHE | Heat Health Event |
| I-5 | Interstate 5 |
| IPCC | Intergovernmental Panel on Climate Change |
| LHMP | Local Hazard Mitigation Plan |
| NOAA | National Oceanic and Atmospheric Situation |
| OFCM | Office of the Federal Coordinator for Meteorological Services and Supporting Research |
| 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 |
| SACOG | Sacramento Area Council of Governments |
| SMAQMD | Sacramento Metropolitan Air Quality Management District |
| SMUD | Sacramento Municipal Utility District |
| SR | State Route |
| UHI | urban heat island |
| UHII | Urban Heat Island Index |
| USDA | U.S. Department of Agriculture |
| 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, climate-related impacts that the City has identified 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 as well as 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 the likelihood and intensity of extreme heat. It is organized into two main components developed, in part, to be integrated into the larger document further into the planning process:

- Extreme Heat Vulnerability Assessment —This section provides a summary of the changes in annual average maximum temperatures and characteristics of extreme heat events projected to occur in the City through 2099. It also includes an analysis of how these changes will affect the City's transportation system and, subsequently, the City's residents and normal community functions in the City. The section uses the five-step vulnerability assessment (VA) process outlined in the *California Adaptation Planning Guide* to analyze impacts (Cal EMA and CNRA 2012) and the *Draft California Adaptation Planning Guide 2.0* (Cal OES 2019) to analyze impacts.
- Heat Resilience Strategies — This section identifies a proposed set of strategies to mitigate and adapt to impacts from extreme heat in the City. The strategies also include key information on coordination and implementation of the strategies.

This report was developed using the best available information regarding climate change projections for the region, relevant information on current efforts to adapt to climate change in the region, and best practices and guidance provided by the State and other sources specific to climate adaptation planning. The primary resources used in developing this report 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 and the Sacramento Valley Report) (OPR et al. 2018a, 2018b);
- City of Elk Grove *General Plan* (2019);
- *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 2017);
- *Vulnerability Assessment and Adaptation Framework* (FHWA 2017); and
- *Addressing Climate Change Adaptation in Regional Transportation Plans* (Caltrans 2013);
- 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 heat impact working group has been formed to provide input on climate adaptation analysis and strategies specific to heat impacts in the City. The working group comprises representatives from local, regional, and State agencies and stakeholders who can provide expertise specific to the issues of heat, public health, land use planning, and transportation-related extreme heat 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 City's *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 white paper and the Plan overall are intended to provide in-depth analysis of potential heat 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.

# 2 EXTREME HEAT VULNERABILITY ASSESSMENT

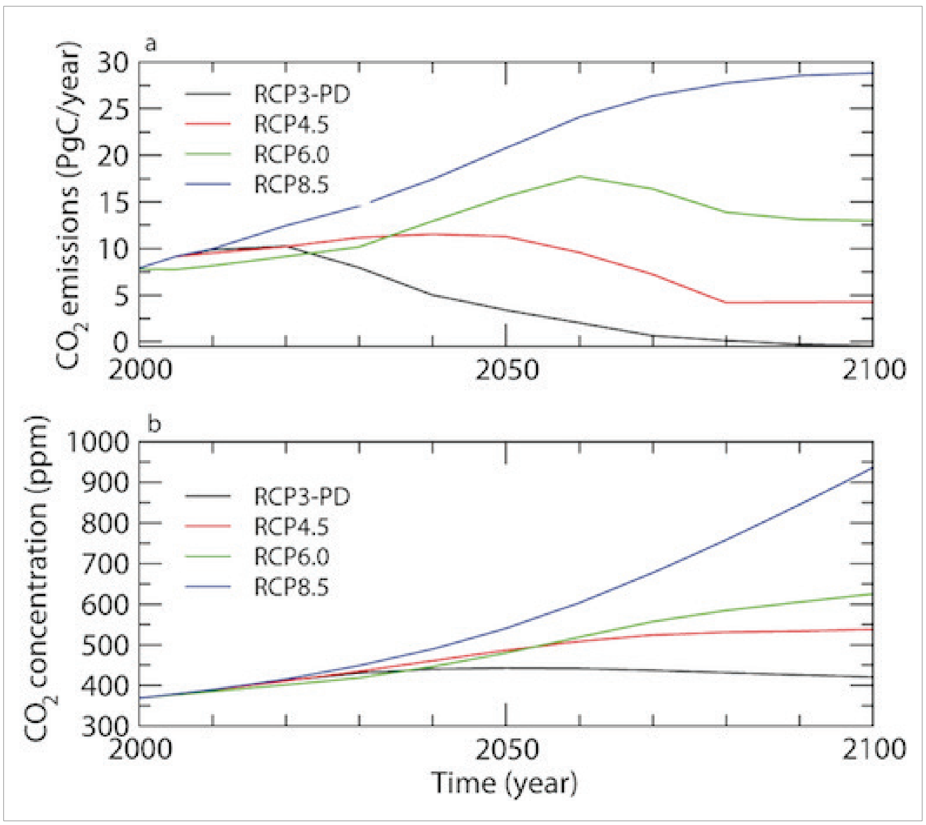
The heat vulnerability assessment is the process used to understand how the City will be exposed to changes in temperature and extreme heat, the extent of heat-related climate impacts, how and when these impacts will affect the City, and to what degree the City and regional partners are prepared to adapt to these effects. This analysis was conducted using guidance from the *California Adaptation Planning Guide* (Cal EMA and CNRA 2012), *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 IPCC and research conducted by the State of California and partner agencies and organizations, climate change is already affecting and will continue to affect the physical environment throughout California, including the City. To identify the local impacts of climate change in California, the California Energy Commission, 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 impacts 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 temperature and extreme heat 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 the *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.

**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 State's draft *Adaptation Planning Guide 2.0* (Cal OES 2019), as well as the Governor's Office of Planning and Research's (OPR's) 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 California Department of Transportation (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.

The Cal-Adapt tool provides data on projected changes in annual average temperature and changes in the frequency and severity of extreme heat events. This analysis uses Cal-Adapt data to evaluate increases in annual average maximum temperatures, as well as shifts in the duration and frequency of extreme heat events in the future. The analysis also identifies at what point over the next approximately 80 years (2020–2099) changes in temperature and extreme heat events will begin to occur and at what magnitude. This topic is discussed further in Section 2.6. This exposure analysis uses the following time periods to analyze changes in annual average maximum temperatures and changes in the intensity of heat wave events under both the RCP 4.5 scenario and the RCP 8.5 scenario. The time periods are established as 30-year time intervals to gather accurate data on average changes in the climate, which is typically measured over 30-year time periods or longer. This results in overlap among some time periods. Due to annual fluctuations in climate variables, climate data on shorter time periods 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).

## 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, the analysis looks at temperature changes at the regional and local levels, as well as changes in the characteristics of extreme heat events affecting the City. As the City plans for the impacts of climate change, it is essential to understand the magnitude and specific characteristics of the changes in temperature and extreme heat events that are projected to occur over the century. The exposure analysis relies on data from the Cal-Adapt planning tool—specifically, data from specific tools focused on annual average temperatures, extreme heat events, and extended drought scenarios.

### TEMPERATURE INCREASE

This section discusses temperature changes projected to occur at the local level that could have an impact on the City, and it provides context for impacts that are projected to occur at the regional level. As discussed in *California's Fourth Climate Change Assessment Sacramento Valley Region Report*, changes in temperature and extreme heat events in northern California are anticipated to affect the Sacramento Valley Region (boundary defined in the *Fourth Climate Change Assessment Sacramento Valley Report*) (OPR et al. 2018b). Changes for the Sacramento Valley region include more warming in the summer than the winter (with July–September increases of 2.7°F–10.8°F) and greater warming inland than in coastal regions (by as much as 7.2°F) (Pierce et al. 2018). Table 1 provides a summary of the projected temperature increases over the century for the Sacramento Valley Region, Sacramento County, and the City.

**Table 1 Regional Annual Maximum Temperature Changes (Historic to 2099)**

| Geographic Area | RCP Scenario | Change in Annual average Maximum Temperature (Fahrenheit) | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | Historic (1961–1990) | 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) |
| Sacramento Valley Region | 4.5 | 70.3 | 73.6 | 4% | 74.7 | 6% | 76 | 8% |
| | 8.5 | 70.3 | 74.1 | 5% | 76 | 8% | 79.1 | 13% |
| Sacramento County | 4.5 | 74 | 77.4 | 5% | 78.6 | 6% | 79.8 | 8% |
| | 8.5 | 74 | 78 | 5% | 79.9 | 8% | 82.7 | 12% |
| City of Elk Grove | 4.5 | 73.7 | 77 | 5% | 78.1 | 6% | 79.2 | 8% |
| | 8.5 | 73.7 | 77.5 | 5% | 79.3 | 7% | 82.1 | 11% |

Note: RCP = Representative Concentration Pathway.

Source: CEC 2019

As shown in Table 1, under both emission scenarios, all three areas will experience an approximately 5 percent increase in annual average temperature during the near-term period. By the midterm period, all areas will experience a temperature increase of 6 percent under the RCP 4.5 scenario and an estimated 7 or 8 percent increase under the RCP 8.5 scenario. By the end of the century, all areas will experience an approximately 8 percent increase in annual average temperature under the RCP 4.5. scenario and an approximately 11 to 13 percent increase under the RCP 8.5 scenario. Figure 2a and Figure 2b, below, illustrate temperature changes in Sacramento County under the RCP 4.5 and RCP 8.5 scenarios. The "historic" period in Figures 2a and 2b illustrates the historic average maximum temperature throughout Sacramento County, whereas the future projection periods illustrate the percent change in average annual maximum temperature, helping to identify the largest increases throughout the county. The total projected increases range between 4 and 15 percent under both RCP scenarios.

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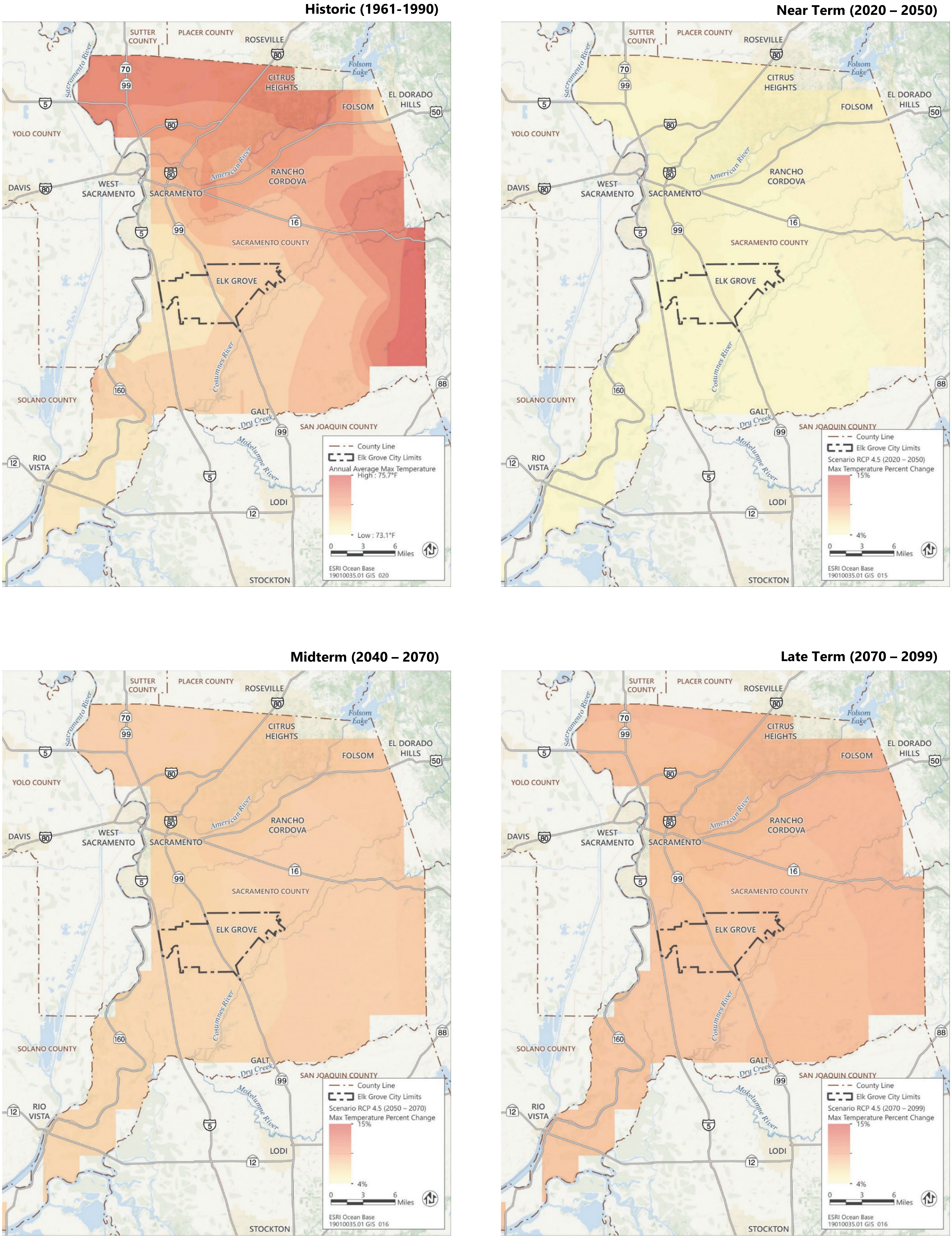
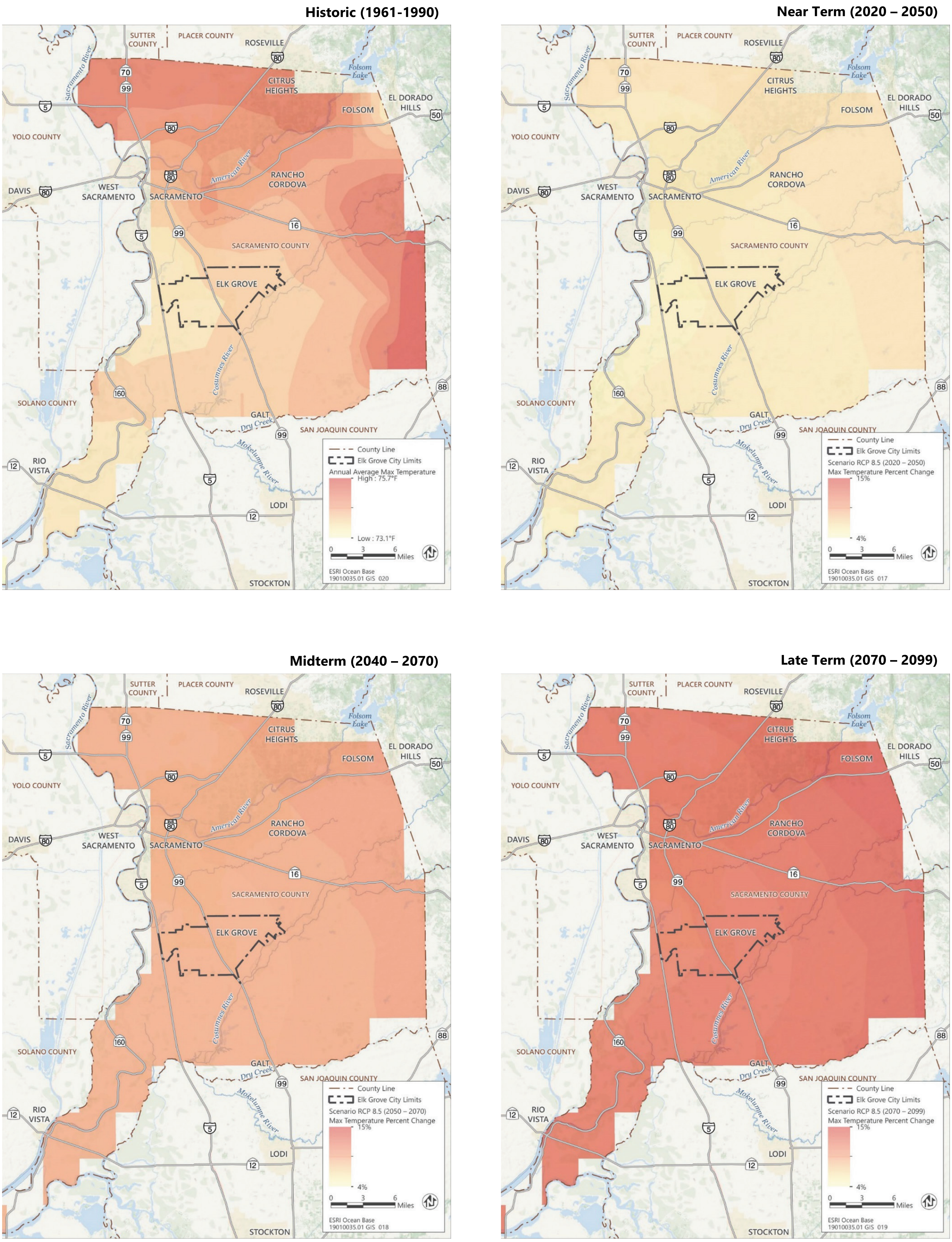
Figure 2a Sacramento County Annual Average Maximum Temperature – RCP 4.5 Scenario through 2099




Source: Data downloaded from CEC and DWR in 2019

Figure 2b Sacramento County Annual Average Maximum Temperature – RCP 8.5 Scenario through 2099




Source: Data downloaded from CEC and DWR in 2019

## EXTREME HEAT

Along with annual average temperature increases, the City is anticipated to experience increases in the average number of extreme heat days per year, as well as increases in the frequency and duration of heat wave events. Based on the parameters set in Cal-Adapt and for the purposes of this analysis, an extreme heat day is defined as a day between April and October with a maximum temperature of 103.1°F or above. This threshold was chosen because it is the 98th percentile of historic maximum temperature for days in the historic period (1961–1990), meaning 98 percent of all recorded temperatures in this period were below 103.1°F. This is also the recommended threshold by the Extreme Heat tool in Cal-Adapt. For the purposes of this analysis, a heat wave event is defined as a series of 4 or more days above 103.1°F. Table 2 illustrates the projected changes in extreme heat days and extreme heat events. In the historic period, the maximum duration of days above 103.1°F is 2 days, which does not qualify as a heat wave based on the heat wave threshold used. By the midterm period, the City will experience heat wave events that qualify based on the established threshold.

**Table 2 Changes in Annual Extreme Heat Days and Heat Wave Events (Historic to 2099)**

| Extreme Heat Indicator | RCP Scenario | Extreme Heat Days and Heat Wave Events | | | |
|---|---|---|---|---|---|
| | | Historic (1961–1990) | Near Term (2020–2050) | Midterm (2040–2070) | Long Term (2070–2099) |
| Number of Annual Extreme Heat Days | 4.5 | 4 | 15 | 18 | 23 |
| | 8.5 | 4 | 15 | 24 | 40 |
| Annual Heat Wave Event Frequency | 4.5 | 0.2 | 1.6 | 2 | 2.7 |
| | 8.5 | 0.2 | 1.6 | 3.1 | 5.8 |
| Average Heat Wave Duration (Days) | 4.5 | 2 | 5.3 | 6 | 6.6 |
| | 8.5 | 2 | 5.3 | 7 | 11.1 |

Notes: RCP = Representative Concentration Pathway; extreme heat day = day with a daily maximum temperature of 103.1°F; heat wave event = 4 consecutive days above 103.1°F.

Source: CEC 2019

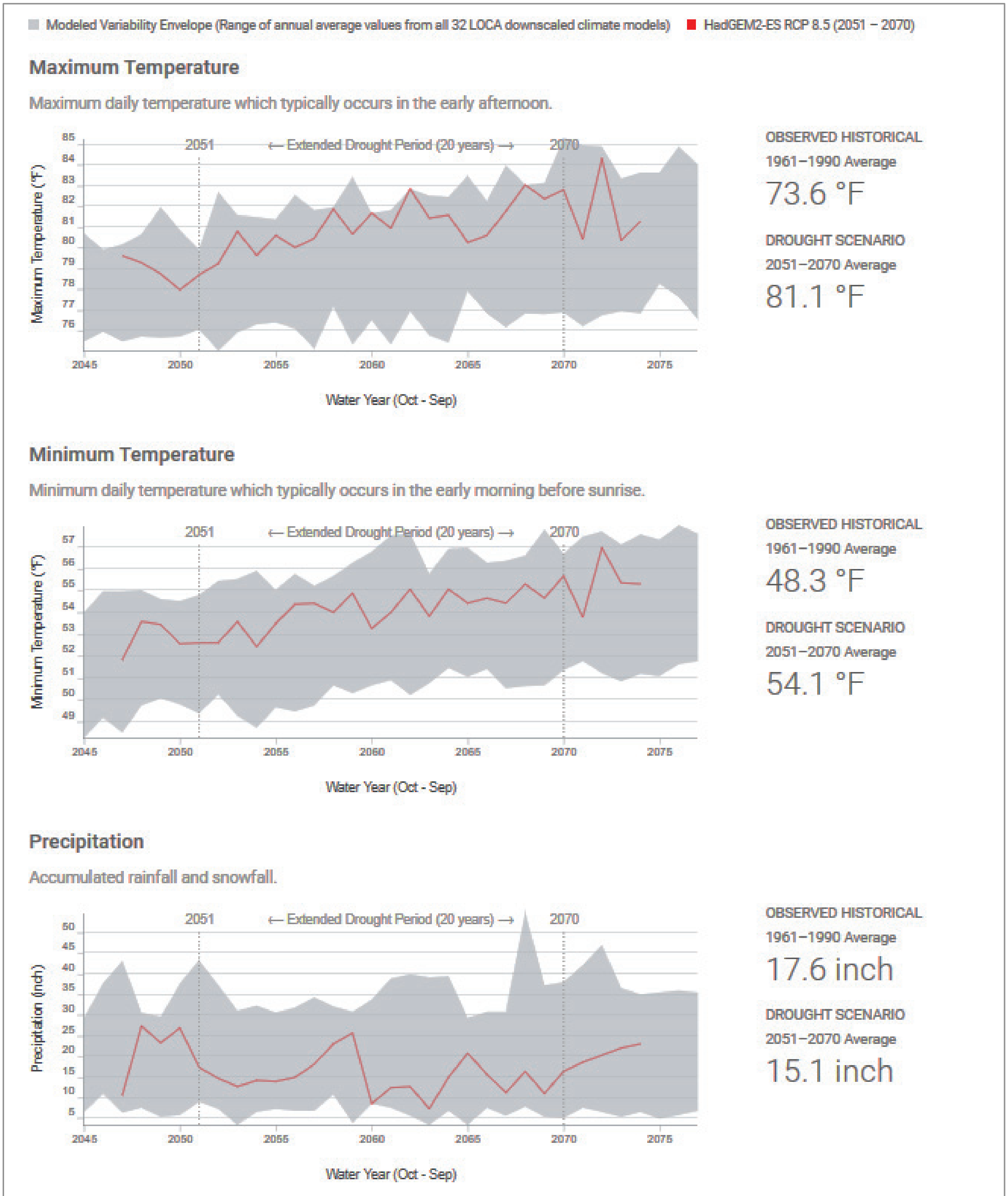
As shown in Table 2, in the near-term period under both emission scenarios, the City will experience a substantial increase in the number of annual extreme heat days from 4 historically to 15 between 2020 and 2050. In this same period, the number of annual heat wave events will increase from 0.2 historically to 1.6 events. The average heat wave duration during that period will more than double, increasing from 2 days to 5.3 days under both scenarios.

By the midterm period, the number of annual extreme heat days will increase from 4 days historically to 18 days under the RCP 4.5 scenario and 24 days under the RCP 8.5 scenario. In this same period, the number of annual heat wave events will increase from 0.2 historically to 2 events under the RCP 4.5 scenario and 3.1 under the RCP 8.5 scenario. The maximum duration of heat waves during this period will increase from 2 days historically to 6 days and 7 days under the RCP 4.5 scenario and RCP 8.5 scenario, respectively.

During the long-term period, under the RCP 4.5 scenario, the City will experience an increase in the number of annual extreme heat days from 4 historically to 23 by as early as 2070. The number of annual extreme heat days under the RCP 8.5 scenario will be 40. In the same period, the number of annual heat wave events will increase from 0.2 historically to 2.7 events under the RCP 4.5 scenario and 5.8 under the RCP 8.5 scenario. The maximum duration of heat waves during this period will increase from 2 days historically to 6.6 under the RCP 4.5 scenario and 11.1 under the RCP 8.5 scenario.

Current research suggests that extended drought periods ("mega-drought") could occur more often over the course of the century (OPR et al. 2018a). Cal-Adapt includes a tool that helps jurisdictions and agencies anticipate and plan for long-term drought events. Figure 3 presents the annual average maximum and minimum temperatures, as well as annual average precipitation, over a 20-year drought period beginning in 2051. As illustrated in Figure 3, during this extended period, annual average maximum and minimum temperature increases while precipitation decreases with wide variations in annual precipitation from year to year.

Figure 3 Extended Drought Scenario for Elk Grove during the Later Part of 21st Century (2051–2070)




- Source: Cal-Adapt. Data: Long Drought Scenarios, LOCA Downscaled CMIP5 Projections, LOCA VIC Runs (Scripps Institution of Oceanography), Gridded Observed Meteorological Data (University of Colorado, Boulder).

Source: CEC 2019

## 2.3 SENSITIVITY ANALYSIS

As the second step of the assessment process, the sensitivity analysis is conducted to identify and characterize the City's existing sensitivities to increases in temperature and in the frequency and severity of extreme heat events. By identifying critical sensitive areas and populations, the analysis can better describe existing sensitives that may be particularly vulnerable to shifts in temperature or extreme heat events. The sensitivity analysis also provides an overview of the City's land uses and a discussion of the relationship between land use patterns and temperatures in urban areas.

### 2.3.1 Existing Climate and Extreme Heat

The City has a Mediterranean climate with mild winters and dry summers. The average temperature throughout the year is 61°F, with the daily average ranging from 46°F in December and January to 76°F in July. Average daily high temperatures range from 53°F in December and January to 92°F in July (many days with highs above 100°F). Daily low temperatures range from 38°F to 58°F (Sacramento County 2017). Table 3 identifies the record high temperatures in the City for each month of the year. As noted in the City's *Local Hazard Mitigation Plan* (LHMP), the City operates cooling centers in various facilities during periods of extreme heat. Historically, cooling centers have been opened an average of five times per year but have had low attendance (Sacramento County 2017).

**Table 3 Record High Temperatures in Elk Grove**

| Month | Temperature | Date | Month | Temperature | Date |
|---|---|---|---|---|---|
| January | 74°F | 1/12/2009 | July | 114°F | 7/13/1972 |
| February | 76°F | 2/19/1964 | August | 110°F | 8/10/1996 |
| March | 88°F | 3/26/1988 | September | 108°F | 9/01/1950 |
| April | 95°F | 4/30/1996 | October | 104°F | 10/02/2001 |
| May | 105°F | 5/28/1984 | November | 87°F | 11/01/1960 |
| June | 115°F | 6/15/1961 | December | 72°F | 12/28/1967 |

Note: Temperatures recorded at Western Regional Climate Center, Federal Aviation Administration Sacramento Executive Airport Station.

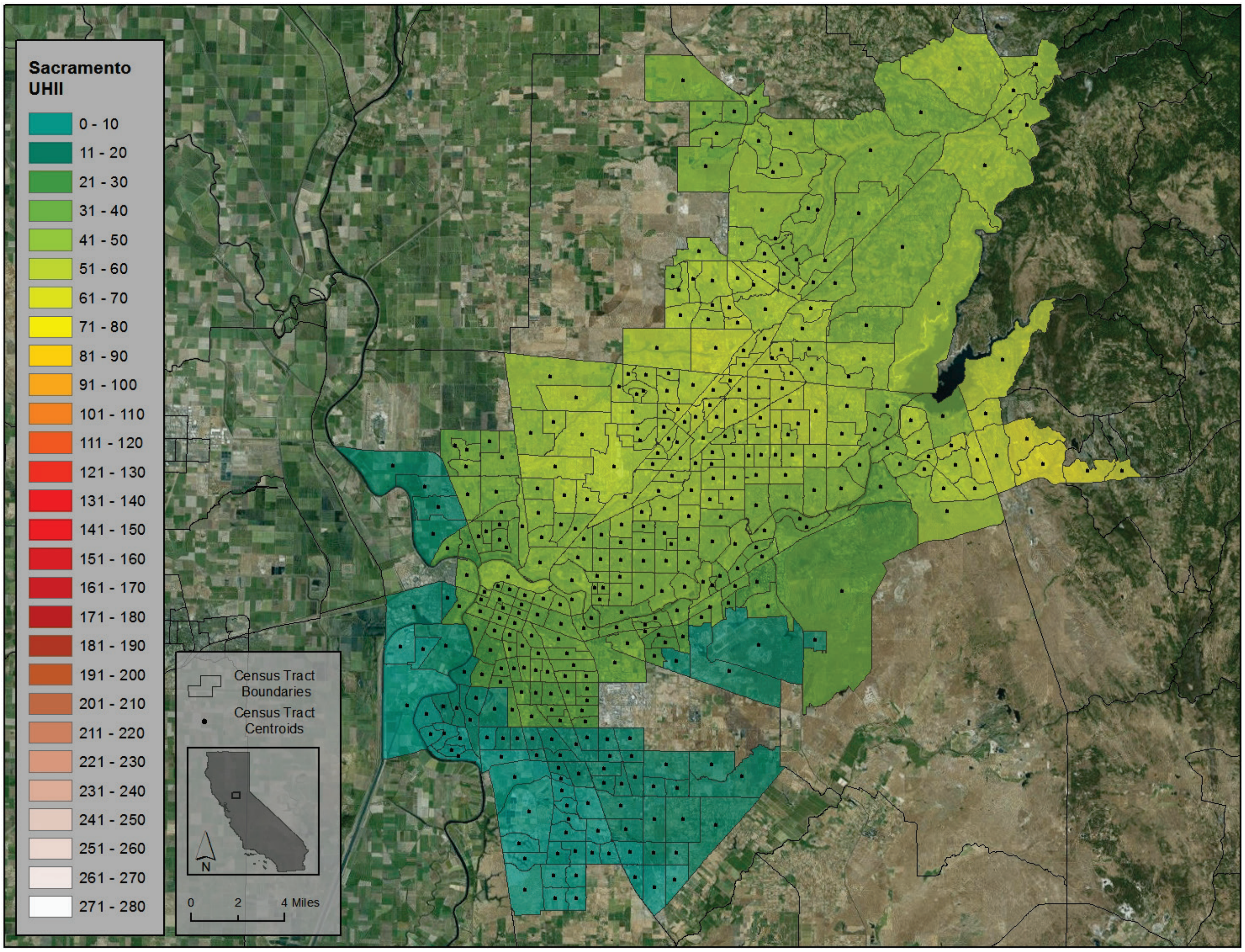
Source: Sacramento County 2017

### 2.3.2 Existing Heat Sensitivities and Urban Heat Island Effect

Although the City's Mediterranean climate includes high temperatures during summer and fall months, the City's urban land use patterns can intensify periods of extreme heat through the "urban heat island" (UHI) effect. The UHI effect is generally understood as the phenomenon of urban areas being significantly warmer than surrounding rural areas because of human activity and land use patterns in the built environment. Several factors contribute to the effect, with the primary cause being changes in land surfaces (EPA 2008). The albedo of a surface is the measure of the surface's ability to reflect or absorb solar radiation, with darker surfaces having a lower albedo and absorbing more solar radiation. As urban areas develop over time, resulting in the development of more land surfaces with low albedos (e.g., asphalt pavement, dark building surfaces), more solar radiation is absorbed in these materials causing increased ambient temperatures and warmer nighttime temperatures. Another factor contributing to the UHI effect is the loss of evapotranspiration in urban areas. Evapotranspiration, the movement of water to the air from sources such as the soil, plants, and bodies of water, reduces ambient air temperatures (EPA 2008). As cities grow and often reduce the extent of available vegetation that contributes to evapotranspiration, UHI effects are exacerbated. Additionally, waste heat from human activities involving machinery (e.g., vehicle traffic, using air conditioning, industrial activity) can also contribute to the UHI effect, with excess heat absorbed by surrounding surfaces (Sailor 2011; Zhu et al. 2017).

The California Environmental Protection Agency has developed a UHI index (UHII) to assess the severity of the UHI effect in various urban areas throughout the state. The scores are based on the temperature difference over time between urban census tracts and nearby upwind rural reference points to demonstrate the relative difference in temperature caused by the urban environment (CalEPA 2019). Figure 4 shows the UHII effect for Sacramento County by census tract.

Figure 4 Urban Heat Island Index for Sacramento County




Source: CalEPA 2019

As shown in Figure 4, compared to other urban areas in Sacramento County, census tracts in the City are relatively low on the UHII. As discussed above, a number of factors contribute to the UHI effect. Factors that could be contributing to the City's relatively low UHII score include the presence of rural land uses surrounding the City; the City's relatively low density and substantial amount of vegetation (e.g., lawns, trees); the presence of the Sacramento River–San Joaquin River Delta Breeze and the relatively low height of buildings, which allows winds to cool surfaces in the City (EPA 2008). As the City continues to grow, developing medium and high-density transit-oriented land use patterns will be an important part of helping the City achieve its greenhouse gas emissions reduction targets included in the City's CAP. As this growth occurs, it is also important to consider how new development may contribute to the UHI effect and include strategies to mitigate the UHI effect from new development in the City.

## 2.3.3 Sensitive Land Uses

Land use patterns and the design of the built environment in urban areas play a large role in an area's exposure to the UHI effect (Stone and Rodgers 2001; Solecki et al. 2005). Urban land uses with large paved areas, low albedo, and less vegetation (e.g., commercial, industrial uses) tend to be subject to the UHI effect and have higher nearby ambient temperatures. Conversely, land uses with smaller percentages of paved surfaces and abundant vegetation (e.g., parks) tend to have lower average temperatures compared to other portions of urban areas. A study looking at the relationship between land use patterns and the UHI effect in Toronto, Canada found a statistically significant difference between average maximum temperatures for commercial and resource/industrial land uses and other surrounding land uses.

The study also found the average low temperatures for parks, recreational land, and water bodies to be lower than those for surrounding land uses, likely because of increased evapotranspiration (Rinner and Hussain 2011). Additionally, areas that have higher concentrations of commercial and industrial land uses clustered together can have increased ambient and surface temperatures, with temperatures increasing relative to the size of these areas (Rinner and Hussain 2011). Increased temperatures in areas with concentrations of commercial and industrial land uses can also result in secondary impacts, including increased cooling demand for buildings, pavement deterioration, decreased air quality, and reduced stormwater quality from above-average-temperature runoff entering natural waterways and nearby ecosystems (Rinner and Hussain 2011).

To better identify portions of the City that may be particularly sensitive to the UHI effect and to help identify locations with higher- and lower-than-average temperatures, Figure 5 identifies the residential, commercial, and industrial land use designations in the City, as well as the location of parks and recreation areas and large parking lots.

### 2.3.4 Sensitive Populations

Certain populations in urban areas are particularly vulnerable to a variety of hazards, including extreme heat. Vulnerable populations include persons over the age of 65, infants and children, individuals with chronic health conditions (e.g., cardiovascular disease, asthma), low-income populations, athletes, and outdoor workers (CDC 2019). Increased temperatures have been reported to cause heat stroke, heat exhaustion, heat syncope, and heat cramps, with certain vulnerable populations at increased probability of experiencing these effects (Kovats and Hajat 2008). Extreme heat can also worsen air quality, quickening the production of ozone in areas with increased concentrations of ozone precursors (i.e., oxides of nitrogen [$NO_X$] and reactive organic gases [ROG]) (Knowlton et al. 2004). This is of particular concern to the City because the Sacramento Valley Air Basin has high concentrations of ROG and $NO_X$ emissions and is currently in nonattainment status for California ambient air quality standards for ozone (SMAQMD 2017).

Alongside populations with health sensitivities, residents with specific sociodemographic characteristics are at increased sensitivity to extreme heat events (CDC 2019). Research has found that low-income residents spend a larger proportion of their income on utilities, including electricity use for cooling, with these residents being disproportionally affected during extreme heat events (Voelkel et al. 2018). Additionally, research has found that low-income neighborhoods can often have less tree coverage and park space, further contributing to the disproportionate impact on low-income residents (Zhu and Zhang 2008). Unhoused individuals are also at increased risk from extreme heat events with, generally, less access to places to cool off and healthcare resources during these events. Additionally, decreased access to transportation services can further increase exposure and health risks from extreme heat events for the unhoused community (Ramin and Svoboda 2009).

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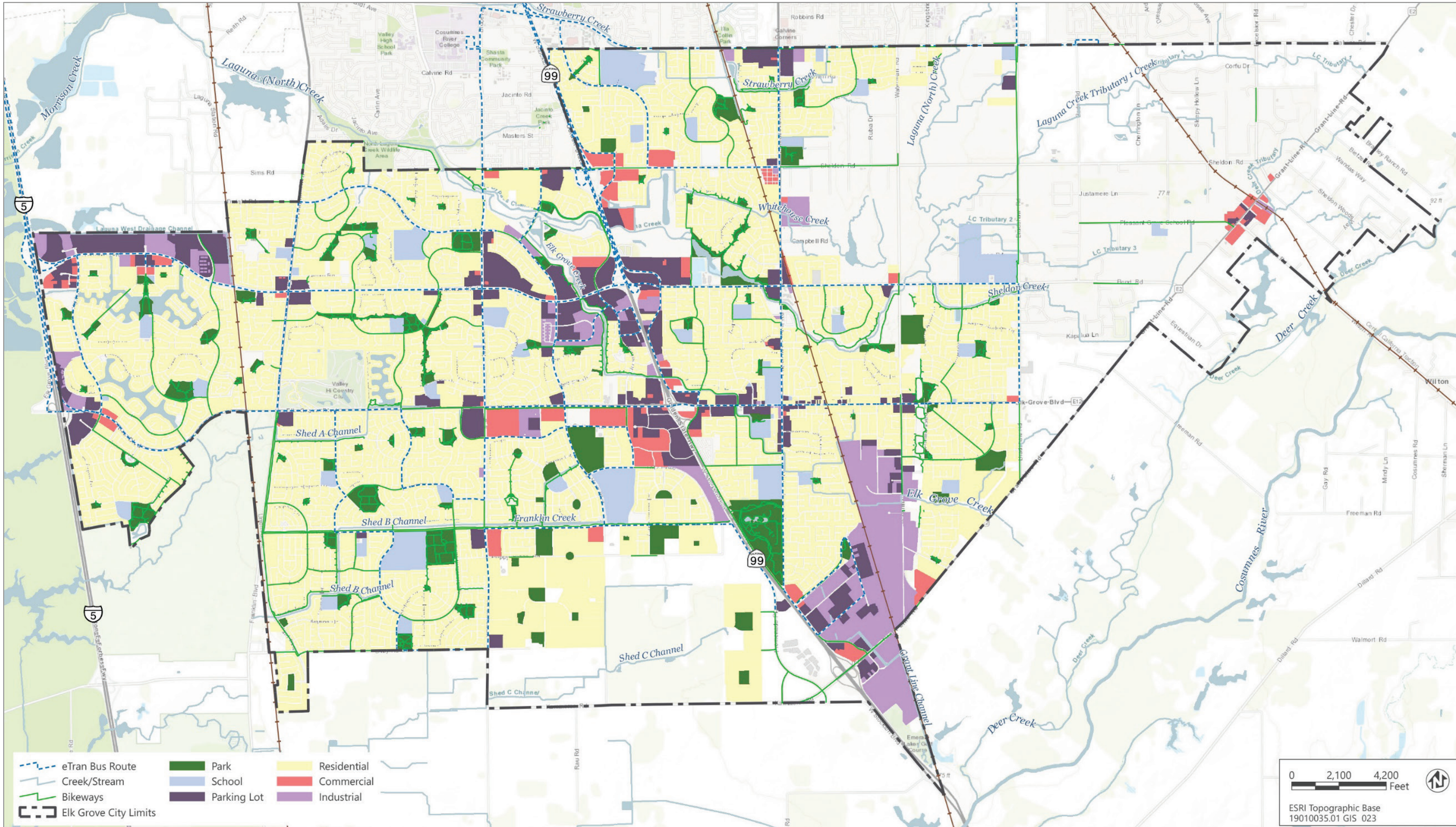
Figure 5 Existing Conditions – Heat Sensitive Assets (Land Uses, Transportation System, and Parks)




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

# 2.4 IMPACT ANALYSIS

The impact analysis was conducted by taking the results from the exposure and sensitivity analyses and assessing how increases in temperature and extreme heat events will affect the City and worsen existing sensitivities to the City's transportation system, sensitive populations, and City functions.

## 2.4.1 Impact Analysis and Sensitivity Thresholds

In preparation for the impact analysis, it is important to understand the existing sensitivities related to extreme heat in the City and develop thresholds for affected systems and populations. FHWA's *Vulnerability Assessment and Adaptation Framework* (FHWA 2017) 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 help analyze transportation asset sensitivity to key climate stressors and recommends climate stressor thresholds to use in determining when various assets may begin to fail or decrease in performance based on key climate variables. This document was used to guide the development of a set of climate stressor thresholds 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 impacts on the City's transportation system, residents, and community functions anticipated to result from temperature increases and increases in the frequency and severity of extreme heat events. To help better understand how and when these impacts will occur, a series of threshold indicators have been identified that are used to assess how various aspects of the City's normal functions are affected when temperature-related thresholds are exceeded. Because increases in temperature and in the frequency and severity of extreme heat events are anticipated to affect the City relatively uniformly across geographic areas, the analysis focuses first on how changes in temperature and extreme heat will affect the performance of the City's transportation system, sensitive population, and community functions overall. The analysis then discusses how these increases are likely to result in exacerbated impacts in certain areas of the City because of the UHI effect and the presence of specific land use patterns.

#### Transportation Sensitivity Thresholds

Transportation systems are designed and constructed to withstand certain variabilities in weather and temperature based on observations of historical weather trends for specific climate regions (Li et al. 2011). The performance of transportation assets may begin to decline when the severity of extreme heat periods exceeds historical ranges, for example, rail buckling at temperatures above 111°F. The characteristics of extreme heat events will affect different transportation assets differently. Provided below is a summary of the quantitative and qualitative thresholds used to assess the impacts of climate change on the City's transportation system.

<u>Pavement Deterioration</u>

The effect of temperature on the performance and integrity of pavement depends on a variety of factors, including material type (asphalt versus concrete), the albedo of the material, details specific to the material mixing and placement, and soils and materials in the subbase of the roadway (Harvey et al. 2000). The performance of pavement also is dependent on the traffic volumes and types of vehicles using the roadway (Harvey et al. 2000). Based on the City's Construction Specification Manual (City of Elk Grove 2018), roadways in the City use a binder within the asphalt mix with a Performance Grade of 64-16, based on Caltrans requirements. This means that roadways using this binder can withstand 7 consecutive days of pavement temperatures up to 64°C (147°F), after which point the heat can result in rutting along high-volume roadways and cause considerable safety issues. Based on guidance in the FHWA's *Vulnerability Assessment and Adaptation Framework* (FHWA 2017), this pavement temperature threshold can be translated into an ambient air temperature of 111°F. The UHI effect can increase ambient temperatures between 1.8°F and 5.4°F in urban areas compared to surrounding rural areas. Because the Cal-Adapt tool does not account for the added effects of the UHI effect in its projections, this analysis is conservative in setting a threshold for pavement impacts. As a result, the threshold used for widespread impacts on pavement in the City is a 7-day consecutive heat wave with a maximum daily temperature of 108°F. The analysis in roadways using this threshold is included below in Section 2.4.2.

#### Rail Buckling

During periods of extreme heat, rail lines can expand and result in "buckling" in which tracks come out of alignment, resulting in serious safety issue. However, the risk of buckling is managed by designing the rail neutral temperature at 95-110°F (35-45°C), with tracks designed and fit into infrastructure that assumes operations at those temperatures could occur (OFCM 2002, Transportation Research Board and National Research Council 2008). For this analysis, the threshold for increased risk from rail buckling is days in which the maximum daily temperature is 111°F or above.

#### Public Transportation Operations and Bridges

Research has found that when daily maximum temperatures reach 100°F, air conditioning units in buses are placed under increased stress and risk of failure (Cambridge Systematics 2015). For this analysis, the threshold for public transportation is days per year with maximum temperatures above 100°F.

Additionally, research indicates that bridges are at increased risk from thermal expansion during periods above 100°F. While bridges are designed to expand during periods of extreme heat, projected increases in extreme heat events could go beyond design criteria, resulting in cracking and crushing of the roadway deck, as well as increased maintenance costs (Transportation Research Board and National Research Council 2008). The number of days above 100°F is also used as a threshold to determine impacts on bridges (Zimmerman 1996).

### Vulnerable Population Sensitivity Thresholds

Unlike thresholds for transportation assets, heat-related thresholds for populations in an urban area vary widely and depend on a number of factors, including the sensitivity of specific populations to heat (e.g., elderly, children). For this analysis, the California Heat Assessment Tool (CHAT) was used to identify how Heat Health Events (HHE) would increase in the future. An HHE, for the purposes of the tool, is defined as any event that results in negative public health impacts, regardless of the absolute temperature. The tool includes unique HHE threshold for locations throughout the state, specific to the climate and the historical sensitivity of people in that area to past extreme heat events. For this analysis, the CHAT tool and the projected increase in HHEs in the City is used as the threshold for this sensitivity. The heat wave event threshold, defined as a 4-day consecutive period with daily maximum temperatures above 103.1°F, is also used to identify various impacts from heat wave events.

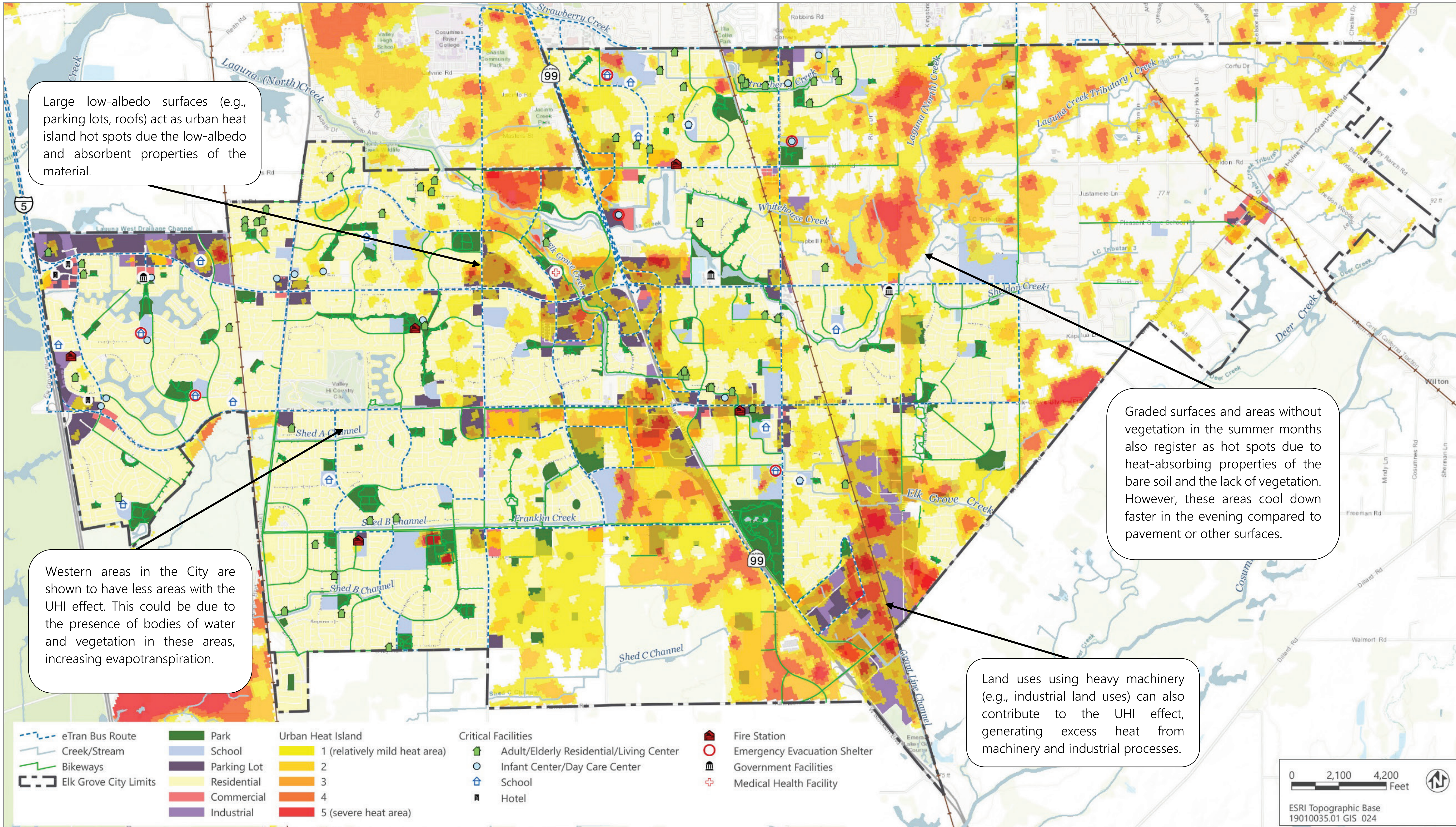
### Community Function Sensitivity Thresholds

The community function impact discussion focuses on how primary impacts on the systems in the City (e.g., roadway network, UHI effect) could have secondary impacts on community functions in the City. The community function discussion includes a qualitative assessment of how extreme heat days and heat wave events could affect the City's traffic operations and public transit system, energy demand, and economy. Data on the shifts in Cooling Degree Days (CDDs) and Heating Degree Days (HDDs), which are proxies for energy used to cool and heat buildings, also are used as the community function indicator to understand potential economic impacts from increased energy demand for cooling. The threshold used to determine CDDs was days above 65°F. The threshold used to determine HDDs was days that are below 65°F.

### Urban Heat Island

While the projected impacts discussed above are anticipated to occur as a result of increases in annual average temperatures and extreme heat events, these impacts will likely be exacerbated to some degree by the UHI effect. As discussed in Section 2.3.2, several factors contribute to the UHI effect, including land use patterns; the presence of large paved areas (e.g., roads and parking lots); traffic from high-volume roadways (Zhu et al. 2017), impervious surfaces (e.g., roofs); and the presence of vegetation and trees, which contribute to evapotranspiration. All these factors affect surface temperatures in urban areas. To show how the UHI effect may further exacerbate projected heat impacts on the City, including vulnerable populations, Figure 6 identifies land uses in the City, as well as the locations of critical facilities for vulnerable populations. Figure 6 also presents data from The Trust for Public Land, which has developed maps to identify hot spots in cities with above-average temperatures compared to the City as a whole. These maps

Figure 6 Land Uses and Degree of Urban Heat Island Effect in Elk Grove




Source: Data received and downloaded from City of Elk Grove in 2019 were developed using Landsat (ground-level thermal sensor) data pertaining to surface temperatures measured in urban areas, including in Sacramento County. The data represents a snapshot of the summer months of 2018 and 2019 and highlight the UHI effect in the City. Undeveloped areas in the City with low albedo (e.g., graded surfaces being prepared for development or areas without vegetation) also register as hot spots because of the heat-absorbing properties of the materials (e.g., bare soil) and the lack of vegetation. However, these areas cool down faster in the evening compared to pavement or other low-albedo surfaces.

## 2.4.2 Impact Analysis Discussion

This section provides an overview of the anticipated impacts on the City from increases in temperature and extreme heat and subsequent secondary impacts. The impact discussion is organized around the three analysis time periods discussed in Section 2.1. The three main impact areas (i.e., transportation system, vulnerable populations, and community functions) are discussed under each these time periods. Table 4 includes projected changes in each of the metrics used as the sensitivity thresholds for this analysis. 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. As a result, the impact analysis only looks at the RCP 8.5 scenario for the near-term and midterm period and looks at the RCP 4.5 and RCP 8.5 scenario for the long-term period.

**Table 4 Summary of Potential Heat Impacts by Impact Area through 2099**

| Impact Area | Impact Type | Threshold Criterion | Historic (1961–1990) | RCP 8.5 Near Term (2020–2050) | RCP 8.5 Midterm (2040–2070) | RCP 4.5 Long Term (2070–2099) | RCP 8.5 Long Term (2070–2099) | Threshold Source |
|---|---|---|---|---|---|---|---|---|
| Transportation system impacts | Roadways and pavement | 7 consecutive days above 108°F | 0 | 0 | 0 | 0 | 0.4 | DOT 2014 |
| | Rail buckling | Days per year with maximum temperature of 111°F | 0 | 1 | 2 | 2 | 7 | OFCM 2002 |
| | Bridges and bus operations | Days above 100°F | 12 | 30 | 42 | 41 | 62 | Zimmerman 1996, Cambridge Systematics 2015 |
| Vulnerable population impacts | Heat wave events | 4-day period above 103.1°F | 0.2 | 1.6 | 3.1 | 2.7 | 5.8 | CEC 2019 |
| | Heat wave duration | Consecutive days above 103.1°F | 2 | 5.3 | 7 | 6.6 | 11.1 | CEC 2019 |
| | Heat Health Events (HHE) | Range of potential HHEs per year | n/a | 1.5 to 2.3 | 3.1 to 3.8 | NA | 4.6 to 5.4 | CEC 2018 |
| Community function impacts | Cooling Degree Days | Days above 65°F per year | 40 | 55 | 74 | 74 | 79 | CEC 2019 |
| | Heating Degree Days | Days below 65°F per year | 86 | 69 | 60 | 60 | 45 | CEC 2019 |

Note: NA = not available.

Source: See sources in "Threshold Source" column of table.

### Near Term (2020–2050)

Annual average temperatures are projected to increase by 5 percent under both emission scenarios in the near-term period. Over this same period, as shown in Table 4, the number of annual heat wave events will increase from 0.2 historically to 1.6 events between 2020 and 2050 under the RCP 8.5 scenario. Temperature increases are not anticipated to have a large effect on the roadway conditions in the City. There would likely not be any extended periods (7 consecutive days) above 108°F during this period under either emission scenario; therefore, there would not be widespread impacts from pavement deterioration in the City. Increased risk to rail from extreme heat days will be relatively minor, with only 1 day over 111°F. There will be increased risk from thermal expansion of bridges, with increases in days above 100°F from 12 historically to 30 during this period. An increase in the number of days above 100°F will also place increased stress on buses and their air conditioning systems, as well as result in potential declines in bus ridership because of the discomfort.

During the near-term period, the City will also experience 1.5 to 2.3 HHEs, with increased risk to vulnerable populations. The frequency of extreme heat events will increase to three on average per year with the maximum duration of events increasing to 7 days during this period. These events will increase the risk of public health impacts on vulnerable populations and could result in increased burden on low-income residents because of the increased energy demand for cooling (Calkins et al. 2016). During this period, the number of CDDs will increase from 40 to 55, a 37 percent increase over historic levels. Conversely, the number of HDDs will decrease and reduce energy demand for heating, resulting in costs savings for residents and businesses during those months.

### Midterm (2040–2070)

By the midterm period, annual average temperatures are projected to increase by approximately 7 percent under both emission scenarios. Over this same period, as shown in Table 4, the number of annual heat wave events will increase from 0.2 historically to 3.1 events. Annual average temperature increases are not anticipated to have a large effect on the roadway conditions. However, increases in the duration and frequency of heat wave events will place increased stress on transportation assets that experience high traffic volumes or heavy truck traffic. There would not be any extended periods (7 consecutive days) above 108°F during this period under either emissions scenario; therefore, there would not be widespread pavement deterioration in the City. Risk to rail from extreme heat days will increase slightly, with only 2 days over 111°F. Increased risk from thermal expansion of bridges and impacts on bus operations will continue to increase, with the number of days above 100°F increasing from 12 historically to 42 during this period.

During the midterm period, the City will experience between 3.1 and 3.8 HHEs, with increased risk to vulnerable populations. The frequency and duration of heat wave events will increase considerably during this period, with the length of events almost tripling. The increased energy costs associated with these events will increase the risk of public health impacts on vulnerable populations (Calkins et al. 2016). During this period, the number of CDDs will increase from 40 to 74, an 85 percent increase over historic levels. The number of HDDs will continue to decrease and reduce energy demand for heating.

### Long Term (2070–2099)

By the long-term period, annual average temperatures are projected to increase by approximately 8 percent under the RCP 4.5 scenario and 11 percent under the RCP 8.5 scenario. Over this same period, as shown in Table 4, the number of annual heat wave events will increase from 0.2 historically to 2.7 events under the RCP 4.5 scenario. Increases in the duration and frequency of heat wave events will place increased stress on transportation assets and could result in subsequent impacts on community functions. By this period, under the RCP 8.5 scenario, there would be an average of 0.4 events per year with extended periods (7 consecutive days) above 108°F. There would be no occurrence of these events under the RCP 4.5 scenario for this period. As discussed in Section 2.4.1, these events will result in much larger impacts on the performance of pavements in the City. Extensive rutting could occur, particularly on high-volume roadways, including Elk Grove Boulevard and Laguna Boulevard, as well as on Caltrans facilities (i.e., SR 99 and I-5).

During this period, there would be significant risk to rail infrastructure from extreme heat days, with approximately 7 days over 111°F per year under the RCP 8.5 scenario. Risk of impacts on bridges from thermal expansion will also increase considerably, with the number of days above 100°F per year increasing from 12 historically to 41 under the RCP 4.5 scenario and 62 days under the RCP 8.5 scenario. During the long-term period, the City will experience between 4.6 and 5.4 HHEs, with increased risk to vulnerable populations. The increased frequency of HHEs will likely place increased demand on emergency services and emergency care facilities and could result in economic consequences from impacts on public health and work productivity (Paterson et al. 2014). The frequency and duration of heat wave events will increase considerably during this period, with the maximum duration of events increasing to 11.1 days. These events will increase public health impacts on vulnerable populations, with increased levels of risk for elderly and youth populations, as well as individuals with chronic health conditions (Voelkel et al. 2018). By the end of the century, the number of CDDs will increase from 40 to 79, with almost 3 months of the year requiring increased energy demand for cooling. By this period, the number of HDDs will decrease considerably, from 86 historically to 45 under the RCP 8.5 scenario by 2099. Increases in energy demand for cooling will also have larger impacts on the electricity grid, with increased stress on and risks to electricity generation facilities and transmission lines (DOE 2016).

#### Urban Heat Island Impacts

While the anticipated impacts on the City discussed above will occur as a result of the increase in annual average temperatures and extreme heat events, these impacts will likely be exacerbated by the UHI effect, with the severity of impacts based on existing land uses and potential future land use patterns in the City. As discussed in Section 2.3.2, the UHI effect is influenced by a number of factors, including land uses patterns, presence of pavement and impervious surfaces, and presence of vegetation and trees. Figure 6, above, illustrates areas in the City that have above-average surface temperatures because of the UHI effect and other contributing factors. The figure also identifies the locations of land uses that contribute to the UHI effect, including parking lots and commercial and industrial land uses. It also shows the locations of critical facilities for vulnerable populations to help identify whether areas with these population are being disproportionality affected by the UHI effect.

As shown in Figure 6, areas in the City with an increased concentration of commercial and industrial land uses have above-average surface temperatures; particularly those land uses adjacent to SR 99. The industrial area east of SR 99 shows the effect of clusters of land uses that contribute to the UHI effect and their potential effect on increased ambient air temperatures in surrounding land uses. Figure 6 also demonstrates the effect of large parking lots on the UHI effect, with parking lot land uses illustrated in purple. The large parking lots to the north and south of Laguna Boulevard between Bruceville Road and SR 99 illustrate this phenomenon well. Finally, Figure 6 illustrates the cooling effect that vegetation, green spaces, and parks can have in the City with park areas not experiencing above-average temperatures even when located next to other land uses that do have above-average temperatures.

## 2.5 ADAPTIVE CAPACITY ANALYSIS

The adaptive capacity analysis was 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 increases in temperature and the severity of extreme heat events. This analysis focuses on the adaptive capacity of agencies and regional stakeholders that have representatives included in the heat impact working group formed for development of the Plan. The section also includes a list of resilience strategy opportunities for each agency and stakeholder. The lists provide high-level descriptions of potential opportunities for collaboration between the City and relevant agencies and stakeholders to address heat-related 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 working group members during the heat impact working group's first meeting.

### 2.5.1 Regional

#### CALTRANS

The Climate Change Branch in Caltrans's 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 prepare the State's transportation system for the impacts of climate change (Caltrans 2013). The report presents a series of strategies to reduce the risk from various climate change impacts, including increases in temperature and the severity of extreme heat events. As part of the Plan development process, representatives from Caltrans participated in the Heat Working Group and provided input on the development of this white paper. Caltrans representatives highlighted key changes that Caltrans has made in its operations to adapt to climate change, including adjusting pavement mixes for roadways to account for increases in extreme heat, as well as using heat-resistant pavement joints to prevent pavement deterioration from thermal expansion. Caltrans facilities located in the City of Elk Grove include SR 99, which runs northwest-southeast through the center of the City, and I-5, which also runs northwest-southeast through the City. In 2019, Caltrans completed the District 3 VA, which provides an overview of potential climate impacts on 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. It 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 to address specific climate impacts on roadway systems.
- Coordinate with Caltrans regarding regional climate risks, including heat-related risks to Caltrans facilities that pass through the City.
- Coordinate with Caltrans on larger adaptation projects that affect both Caltrans and City facilities.

## SACRAMENTO AREA COUNCIL OF GOVERNMENTS

The Sacramento Area Council of Governments (SACOG) is the Metropolitan Planning Organization for the six-county Sacramento region, including the 22 cities in 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 (SACOG 2015). 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. As part of the Plan development process, representatives from SACOG participated in the Heat Working Group and provided input for the development of this white paper. SACOG representatives noted that SACOG is developing an assessment similar to the City's planning effort that includes using geographic information system 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 in 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 PUBLIC DEPARTMENT OF HEALTH SERVICES

As a division of the Sacramento County Department of Health Services, Sacramento County Public Health works to promote, protect, and ensure conditions for optimal health and public safety for residents and communities in Sacramento County. As part of its work in helping prevent health impacts from extreme heat, Sacramento County Public Health conducts community education related to public health and emergency preparedness. It also has developed plans with the Sacramento Office of Emergency Services on wildfire smoke and response plans. Sacramento County Public Health has also begun to research the impacts of climate change using available tools specific to extreme heat and public health.

### Resilience Strategy Opportunities

- Work with Sacramento County Public Health to expand outreach and education opportunities regarding extreme heat and public health with a focus on vulnerable populations.
- Work with Sacramento County Public Health on opportunities for Federal, State, and regional funding focused on climate change and public health.

## SACRAMENTO OFFICE OF EMERGENCY SERVICES

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 responses purposes. In regard to heat-related events, Sacramento OES focuses on the immediate effects of events; near-term risks from these events, particularly fires, droughts, and air pollution. Sacramento OES also maintains the County's Emergency Operation Plan, which includes protocols for emergency operations during extreme heat events. 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 and Annexes including the City of Elk Grove's. The City's Annex in the LHMP includes climate change as a hazard and discusses how climate change will impact other hazards in the City, rating the likelihood of occurrence high and vulnerability to climate change as high. As part of the Plan development process, representatives from Sacramento County OES participated in the Heat Working Group and provided input on the development of this white paper.

### Resilience Strategy Opportunities

- Work with Sacramento County OES to ensure 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 specific vulnerabilities in the City to extreme heat events as well as vulnerabilities in emergency operations during these events that may be exacerbated by climate change.

## SACRAMENTO METROPOLITAN AIR QUALITY MANAGEMENT DISTRICT

The Sacramento Metropolitan Air Quality Management District (SMAQMD) is the agency responsible for monitoring air pollution in the Sacramento Valley Air Basin and for developing and administering programs to reduce air pollution levels below the health-based standards established by the State and Federal governments. SMAQMD is working to develop a UHI model to help identify sensitivities in the district to extreme heat and climate change, as well as develop and model the effects of mitigation strategies (e.g., green roofs, cool pavements). SMAQMD is also working to develop an update to the California Emissions Estimator Model and hopes to include an element to the tool that provides quantification of the benefits of climate adaptation strategies. The agency also works to provide funding from Assembly Bill 617 for the Clean Cars for All program, which provides increased access to electric vehicles for low-income residents. As part of the Plan development process, representatives from SMAQMD participated in the Heat Working Group and provided input on the development of this white paper.

### Resilience Strategy Opportunities

- Work with SMAQMD on opportunities to incorporate the findings from the UHI model into the City's resilience strategies.
- Continue to work with SMAQMD, including seeking opportunities for public education, to address heat-related air quality impacts in the City.
- Work with SMAQMD on opportunities for Federal, State, and regional funding focused on climate change, air quality, and the UHI effect.

## SACRAMENTO MUNICIPAL UTILITY DISTRICT

The Sacramento Municipal Utility District (SMUD) is a publicly owned utility that provides electricity to Sacramento County and small portions of Placer County. In regard to climate change, SMUD has developed a sustainable communities program focusing on disadvantaged communities, as well as its *Climate Readiness Assessment and Action*

*Plan* (SMUD 2016), which is intended to help the utility to adapt to and address climate change through community engagement, enterprise programs, capital projects, and operational initiatives. SMUD also works with the Sacramento Tree Foundation to operate the Sacramento Shade Program, which provides landscape assessments and free shade trees to SMUD customers. SMUD also operates Living Future Project Accelerator, which emphasizes sustainable commercial and residential building practices, and is beginning to work toward a land-based carbon storage program.

### Resilience Strategy Opportunities

- Work with SMUD to ensure City residents are prepared for the impacts of extreme heat on energy demand and implement strategies to reduce peak demand during heat wave events.
- Continue to work with SMUD to implement to the Sacramento Shade Program and provide services to new and existing residents in the City.

## SACRAMENTO TREE FOUNDATION

The Sacramento Tree Foundation is a nonprofit organization that empowers people to plant, protect, and learn about trees in the Sacramento region. The organization has several programs that support its mission and provide services to cities and residents in the Sacramento region:

- Sacramento Shade Program – This program, in partnership with SMUD, provides free landscape assessments and up to 10 free shade trees that provide a host of benefits to the residents and the surrounding neighborhoods. The organization's work with SMUD emphasizes planting locations and tree varieties that reflect SMUD's goals for carbon sequestration.
- NeighborWoods Program – This program provides support to communities throughout the Sacramento region by offering expertise, training, tools, and advice to plant and protect trees in their neighborhoods.
- Urban Wood Rescue Program - This program works to preserve useful life of the trees by providing logging and milling services for trees which have reached the end of their life. This lumber is then sold, providing a second life for the trees while capturing carbon sequestered during their lifetime.

The organization also conducts community outreach campaigns, utilizing door to door canvassing and community meetings to promote the benefits of the urban forest. As part of the Plan development process, representatives from the Sacramento Tree Foundation participated in the Heat Working Group and provided input on the development of this white paper.

### Resilience Strategy Opportunities

- Continue to work with the Sacramento Tree Foundation to provide programs to residents with a focus on ensuring programs consider the projected increases in temperature and precipitation in the selection of tree varieties to be planted.
- Consult with the Sacramento Tree Foundation on potential upgrades to the City's landscape and tree-related regulation and design standards to increase the benefits of trees to mitigate the UHI effect in the City.

## SHELDON COMMUNITY ASSOCIATION

The Sheldon Community Association is a community organization comprised of residents living in the Sheldon community in the eastern portion of the City. The organization conducts community and youth outreach around climate change, electrical vehicle adoption, and residential energy efficiency, among other topics. The organization also implements an annual project for tree planting in rural areas of the City with help from the Sacramento Tree Foundation. As part of the Plan development process, representatives from the Sheldon Community Association participated in the Heat Working Group and provided input on the development of this white paper.

### Resilience Strategy Opportunities

- Continue to work with the Sheldon Community Association to promote community and youth outreach around climate change, climate adaptation strategies, and implementation of the City's CAP.
- Work with the Sheldon Community Association and gain insights on how to replicate the work being done by the organization to other areas in the City. Use the Sheldon Community Association as example for other neighborhood organizations wishing to address climate change at the neighborhood level.

## 2.5.2 Local

### CITY OF ELK GROVE

In February 2019, the City of Elk Grove completed an update to its GP that included both a CAP 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 temperature and extreme heat impacts. The Services, Health, and Safety chapter of the City's GP also includes a summary of how climate change may affect the City and includes policies to ensure the City is adequately prepared for potential future impacts from climate change. Specifically, the chapter includes a set of policies regarding Increased Temperature, Extreme Heat, and Heat Waves. Policies ER-6-1 through ER-6-5 focus specifically on increasing preparedness for and mitigating against the impacts of extreme heat events and reflect the policy recommendations included in the vulnerability assessment. They include but are not limited to, working to:

- Develop a guide of City procedures in the event of severe weather conditions such as excessive heat, including the deployment of emergency services, operating if local cooling shelters, and community notification procedures.
- Coordinate with the Sacramento County Office of Emergency Services and Sacramento County Public Health Department to provide information to vulnerable populations on the resources available and the key action to take both for mitigation on their property in the preparations for excessive heat events and for services during such events.
- Participate in the regional leadership organization, Valley Vision, which has launched the Business Resiliency Initiative to help reduce the risks and economic impacts of potential disasters related to extreme weather.

The CAP portion of the City's GP also includes strategies to reduce GHG emissions that will help mitigate the impacts of extreme heat events. The strategies most directly benefiting heat mitigation include strategies BE-9 (Increase City Tree Planting) and TACM-9 (EV Charging Requirements). The CAP includes measures focused on energy efficiency improvements in new and existing buildings as well as strategies to reduce the total vehicle miles traveled by residents and visitors. These strategies will help adapt to and mitigate the effects of the UHI effect in the City. As the City begins to implement its CAP, there are many opportunities to combine implementation of CAP strategies with climate adaptation strategies. GP policies ER-6-1 through ER-6-5 include measures to ensure adequate emergency services for heat wave events and changes to the built environment (e.g., landscaping, high-albedo pavement) specific to reduce risk from extreme heat in the City. 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, and parking, as well as massing, scale, and form, all of which can have an effect on UHI effect.

The City also has regulations within the Municipal Code, specifically, Chapter 23.54 "Landscaping," that provides guidance for landscaping and tree planting requirements for new development in the City. Chapter 19.12, "Tree Preservation and Protection," of the Municipal Code provides regulations regarding the preservation of trees of local importance and mitigation of tree loss. The City has also adopted design guidelines which provide guidance related to site planning, landscaping, and building material selection for new development in the City. These guidelines affect the UHI effect in the City, along with land use patterns and local geographic context.

### Resilience Strategy Opportunities

- Identify components of the City's design guidelines that can be upgraded to increase the mitigation benefits of design principles to extreme heat events.
- Identify components of the City's Municipal Code that can be updated to increase the mitigation benefits of landscaping and other regulations to extreme heat events.
- Continue to implement the City's GP and CAP related to climate adaptation to increase resiliency to current and future extreme heat impacts in the City.

## CITY OF ELK GROVE PUBLIC WORKS DEPARTMENT

The Elk Grove Public Works Department supports important activities and functions within the City, which have an impact on UHI, including designing, constructing, operating, and maintaining the City's road network and drainage systems. The Department is also responsible for management of the City's solid waste (trash) and transit services. The Public Works Department administers the Pavement Management Program and is responsible for the maintenance of nearly 1,175 lane miles of roadway with over 90 million square feet of pavement. The program uses the Pavement Condition Index to classify roads based on their condition and develops a multi-year schedule for roadway maintenance and upgrades in various parts of the City. This Department is also responsible for the City's Capital Improvements Program, which includes developing, upgrading and implementing the City's *Capital Improvements Program 5-Year Plan* – a list of improvement projects for various components of City operations. As part of the Plan development process, representatives from the City's Public Works Department participated in the Heat Working Group and provided input on the development of this white paper.

### Resilience Strategy Opportunities

- Identify strategies to implemented as part of the Public Works Department to increase resilience to extreme heat events, including a comprehensive assessment on how projected increase in temperature and extreme heat events will affect the City's roadways and other infrastructure.
- Work with Caltrans and Sacramento County to discuss upgrades to design standards used in the City's transportation system to increase resiliency to the impacts from extreme heat.

## CITY OF ELK GROVE POLICE DEPARTMENT

The Police Department provides law enforcement and policing services for the City. It 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 all emergency situations in the City including extreme heat events. As part of the Plan development process, representatives from the City's Police Department participated in the Heat Working Group and provided input on the development of this white paper.

### Resilience Strategy Opportunities

- Coordinate closely with the City's Police Department to increase the robustness of emergency response resources and training for extreme heat events, with an emphasis on protecting vulnerable populations.
- Identify secondary impacts from extreme heat events, which may impact the Police Department and their capacity to respond to these impacts.

# 2.6 RISK AND ONSET ANALYSIS

The risk and onset analysis provides a summary of the overall risk projected from increases in temperature and the frequency and severity of extreme heat events. The analysis also provides a summary of the onset of projected impacts, detailing when and at what magnitude these impacts will occur over the next century.

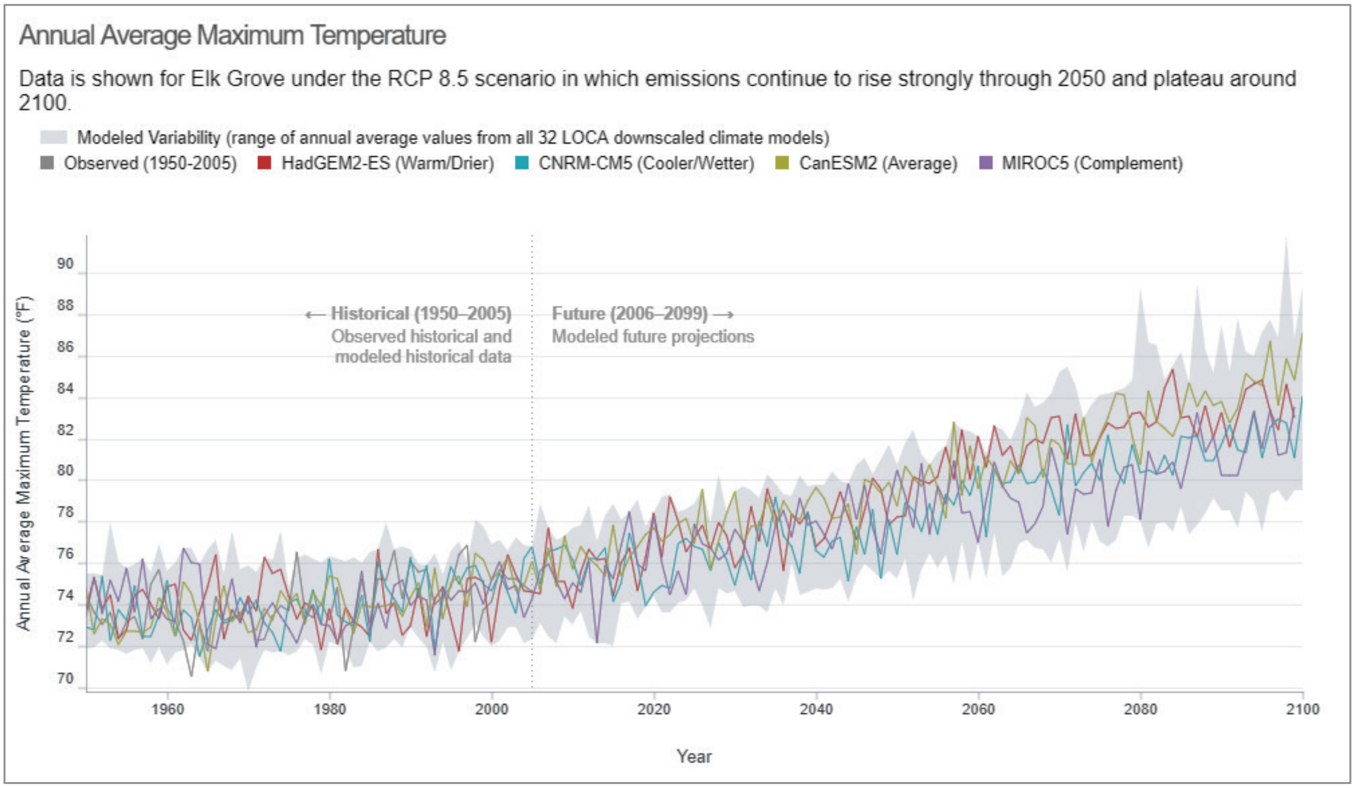
### 2.6.1 Risk of Impacts

The City's risk of impacts related to temperature and extreme heat associated with 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 on the City is dependent on future global emission trends, the probability that a certain scenario would occur affects the overall risk to the City. For example, if the RCP 4.5 emission scenario were to occur over the century, the City overall would be at lower risk because the impacts for this scenario would be less severe. As noted in Section 2.1, guidance from the State suggests that adaptation planning efforts should assume that the impacts of RCP 8.5 are likely to occur. For this reason, this analysis uses the RCP 8.5 scenario as the baseline for impacts that will occur by 2050. The uncertainty of future impacts largely depends on global emission trends occurring around 2040 and whether they will decrease or increase. As discussed in the "Temperature Increase" section, under RCP 8.5 by late century, the annual average temperature in the City will continue to increase, with large increases in the number of extreme heat days and heat wave events, as well as increases in the length of extreme heat events. These increases are much larger under the RCP 8.5 scenario compared to the RCP 4.5 scenario by the end of the century, placing the City at increased risk of heat-related impacts. As the City continues to plan for and reassess the impacts of climate change on the community over time, it is important to remain up to date on the latest projections of climate exposure and global emission trends. The analysis in this report serves as a baseline of data about future impacts that 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 from Cal-Adapt uses two emission scenarios, if the actual emissions pathway follows a different trend than those used to make the projections there will be different levels of exposure and impacts. As noted on the Cal-Adapt website, the average values across different model projections, and presented in the Cal-Adapt tool, are considered more likely than any individual model value (CEC 2019). However, it also important to look at the variation between models and the full range of outcomes.

Finally, as with any modeling effort, there is a certain degree of confidence in the results of the modeling under each scenario. The data used in this analysis also include a level of variation in the results produced in the modeling. Figure 7 serves as an example of this variation in the modeling. In Figure 7, the gray area illustrates the variability of modeling results from the various climate models. This variability increases the unpredictability of temperature changes 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 temperatures and increases in extreme heat events from year to year can also help long-term planning efforts overall.

Figure 7 Example of Confidence Intervals in Climate Modeling – Average Maximum Annual Temperature under RCP 8.5 Scenario




Source: CEC 2019

## 2.6.2 Onset

The onset of impacts refers to the period over the next century when certain changes in the climate will occur and begin to affect the City. As shown in Table 5, the City will experience a relatively steady increase in annual average temperatures over the century under both emission scenarios. However, the duration and frequency of extreme heat events are projected to increase at a much faster pace, with significant increases in the intensity of these events in the near-term period under both emission scenarios. Changes in extreme heat events will continue to increase throughout the century, with much larger increases projected to occur under the RCP 8.5 scenario.

The onset of certain heat-related impacts partly depends on the thresholds used to determine impacts. As shown in Table 4 (on page 21), impact thresholds for vulnerable populations and community functions are much lower than those for transportation assets. This means that impacts on vulnerable populations and community functions will occur earlier and at a higher frequency than impacts on the transportation system. As noted above, the UHI effect will exacerbate projected impacts in some areas of the City. As the City continues to grow, land use planning could further contribute to the UHI effect and increase the rate at which certain impacts are projected to occur.

**Table 5 Onset of Temperature and Extreme Heat Increases (Historic to 2099)**

| Temperature Metric | RCP Scenario | Onset of Temperature and Extreme Heat Increases | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | Historic (1961–1990) | 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) |
| Annual average temperature | 4.5 | 73.7°F | 77°F | 5% | 78.1°F | 6% | 79.2°F | 8% |
| | 8.5 | 73.7°F | 77.5°F | 5% | 79.3°F | 7% | 82.1°F | 11% |
| Annual heat wave event frequency | 4.5 | 0.2 | 1.6 | 700% | 2 | 900% | 2.7 | 1,250% |
| | 8.5 | 0.2 | 1.6 | 700% | 3.1 | 1,450% | 5.8 | 2,800% |
| Average heat wave duration | 4.5 | 2 | 5.3 | 165% | 6 | 200% | 6.6 | 230% |
| | 8.5 | 2 | 5.3 | 165% | 7 | 250% | 11.1 | 455% |

Note: RCP = Representative Concentration Pathway.

Source: CEC 2019

## 2.7 SUMMARY OF FINDINGS

The preceding summary of the five-step vulnerability process provides a substantive level of detail on the temperature changes and extreme heat events that will affect the City. The vulnerability 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 analysis for how the City will be affected by climate-related temperature changes and extreme heat 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 analysis are summarized as follows:

- The City will experience steady increases in annual average temperature over the century under both the emissions scenarios. Increases in the frequency and duration of extreme heat events will occur much earlier with larger increases projected to occur as early as the near-term period.
- Based on the thresholds used for this analysis, impacts on vulnerable populations and community functions will occur much earlier (beginning in the near-term period) than impacts anticipated to occur on the transportation system because of the varying sensitivity of these aspects of the community.
- Certain land use patterns in the City are contributing to the UHI effect under existing conditions. Impacts from increases in annual average temperatures and in the frequency and severity of extreme heat events will be exacerbated by the UHI effect and may disproportionately affect populations in the City that are near UHI hot spots.
- Populations near commercial and industrial land uses, as well as other large impervious surfaces, are at a higher risk from the impacts of the UHI effect, including increased energy demand for cooling, potential decreases in air quality, and increased minimum temperatures during nighttime hours.
- Extreme heat will cause roadway rutting, affecting pavement performance, particularly on high-volume roadways in the City, such as Laguna Boulevard and Elk Grove Boulevard. By the long-term period (2070–2099) under the RCP 8.5 scenario, there would be an average of 0.4 event per year, with extended periods (7 consecutive days) above 108°F. These events can cause unsafe traffic conditions.
- By the long-term period under the RCP 4.5 scenario, there would be a significant increase in risk to rail infrastructure from extreme heat days, with approximately 7 days over 111°F per year, the threshold at which rails begin to buckle, come out of alignment with the track, and potentially cause serious safety issues, including possible derailment.

# 3 RESILIENCE STRATEGIES

The Resilience Strategies section provides a matrix that identifies strategy proposals to address the specific impacts discussed in the extreme heat vulnerability assessment. It includes a set of preliminary adaptation strategies to be considered by the City, relevant stakeholders, and the general public based on the impacts projected to occur in the City. After a more refined list of measures has been identified, a subset of these strategies will be fully developed with implementation mechanisms and opportunities for funding and included in the Plan. Table 6, below, includes the set of proposed strategies, characterized at a high level, to help the City mitigate and adapt to impacts from increases in temperature and the intensity and frequency of extreme heat events. 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 6:

- **Primary Impact**: This column provides a summary of the primary impact being addressed by a set of strategies.
- **Strategy Number and Category**: 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 Roadway Network:** These strategies focus on making improvements to the way the City's roadway network is designed, constructed, and maintained over time to account for projected increases in average temperatures and frequency of extreme heat events.
  - B) **A Resilient Transportation System:** These strategies focus on ensuring that the City's transportation system as a whole (e.g., pedestrian and bicycle infrastructure, public transit, railways) is prepared for impacts associated with projected increases in average temperatures and frequency of extreme heat events.
  - C) **A Resilient Built Environment:** These strategies focus on making upgrades to the City's built environment (e.g., roads, buildings, parks, landscaped spaces) to better mitigate the impacts of the urban heat island effect and heat wave events.
  - D) **A Climate-Ready Community:** These strategies focus on ways the City and residents can better prepare for the projected increase in the frequency of extreme heat events with a focus on ensuring vulnerable populations are protected during these events.
  - E) **A Climate-Smart Electricity Grid:** These measures focus on helping the City, residents, and SMUD prepare for increases in extreme heat and associated demand for cooling, which will place increased stress on the electricity grid.
  - F) **Social and Economic Resilience:** These strategies focus on increasing the social and economic resiliency of residents and businesses during extreme heat events, which may have secondary economic impacts for the City (e.g., increased spending on cooling for homes and businesses, potential loss of productivity, decreased economic activity during heat waves).
- **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 extreme heat 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 the U.S. Environmental Protection Agency'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 6 Strategy Recommendations for Temperature and Extreme Heat Resilience**

| Primary Impact | Strategy Number and Category | Strategy Description | Adaptation Mechanism | Implementation Mechanism | Responsible Department | Timeline | Source/ Example |
|---|---|---|---|---|---|---|---|
| **Impacts on the City's Transportation Assets:** Increases in annual average temperatures and the intensity and frequency of heat wave events will place increased stress on transportation assets (e.g., roads, rails, bridges) and could result in the reduced performance or failure of the assets. | A1: A Resilient Roadway Network (Observing Extreme Heat Thresholds) | Continue to observe roadway pavement performance in extreme heat events to adjust and refine the extreme heat threshold used to determine when more large-scale impacts occur from extreme heat. | Increased awareness of vulnerabilities | Evaluation | Development Services, Public Works | 2022–2025 | Caltrans 2013, FHWA 2015, |
| | A2: A Resilient Roadway Network (Flexible Pavements) | Explore options and develop new heat-resistant asphalt mixes, including increasing the high-temperature asphalt binder grade to be used on flexible pavement on roadways in the City. Consider use of high-albedo roadway materials, which is discussed further in strategy C1. | Increased resilience of roadways to extreme heat | Plans, regulations, and policy development | Public Works | 2025–2030 | Caltrans 2013, FHWA 2015, Willway et al. 2008 |
| | A3: A Resilient Roadway Network (Rigid Pavements) | Explore options and develop new design elements to reduce damage from thermal effects (e.g., blowouts), including shorter joint spacing, thicker slabs, less rigid support, and enhanced load transfer. | Increased resilience of roadways to extreme heat | Plans, regulations, and policy development | Public Works | 2025–2030 | Caltrans 2013, FHWA 2015, Willway et al. 2008 |
| | A4: A Resilient Roadway Network (Drought) | Assess vulnerabilities to transportation assets from a long-term drought scenario with a focus on the City's bridges, roadways, and levee system. Implement strategies to mitigate identified potential impacts. | Increased awareness of vulnerabilities | Evaluation | Public Works | 2022–2025 | Caltrans 2013, Markolf et al. 2019 |
| | A5: A Resilient Roadway Network (Adaptive Management) | Continue to use the City's existing construction standards for new transportation projects developed in the City and consider updates to standards to mitigate heat impacts on an as-needed basis. Continue to monitor impacts of extreme heat events on the City's roadway network and respond to impacts as needed. | Increased awareness of vulnerabilities | Programmatic | Development Services, Public Works | Ongoing | Meyer et al. 2010 |
| | A6: A Resilient Roadway Network (Truck Routes) | Explore strategies to include diversion routes for freight and heavy trucks to more robust alternate routes during heat wave events to avoid damage to roadways. | Increased resilience of roadways to extreme heat | Plans, regulations, and policy development | Development Services, Public Works | 2025–2030 | DOT 2013, 2015 |
| | A7: A Resilient Roadway Network (Alternative Construction Schedules) | Assess how projected increases in temperature and extreme heat events will affect construction schedules for capital improvement projects in the City. Develop a strategy to adjust construction schedules to avoid impacts from extreme heat on construction workers and the design of projects. | Increased resilience of population to extreme heat | Plans, regulations, and policy development | Public Works | 2022–2025 | DOT 2015 |

| Primary Impact | Strategy Number and Category | Strategy Description | Adaptation Mechanism | Implementation Mechanism | Responsible Department | Timeline | Source/ Example |
|---|---|---|---|---|---|---|---|
| | B1: A Resilient Transportation System (Public Transit) | Work with Sacramento Regional Transit District and the Public Works Department to assess vulnerabilities to transportation operations of the e-Tran system. Incorporate projections of future extreme heat impacts into the transition to electric buses as part of the Innovative Clean Transit regulations. | Increased awareness of vulnerabilities and resilience of transit operations | Programmatic | Public Works, regional partners | 2022–2025 | Transportation Research Board and National Research Council 2008, Caltrans 2013 |
| | B2: A Resilient Transportation System (Pedestrian and Bicycle Infrastructure) | Incorporate projections of future extreme heat impacts into the design and development of pedestrian and bicycle infrastructure in the City. Identify opportunities to upgrade existing bicycle and pedestrian infrastructure to mitigate future extreme heat impacts and ensure comfort for users (e.g., tree canopy, high-albedo surfaces). | Increased resilience of pedestrian and bicycle infrastructure | Plans, regulations, and policy development | Development Services, Public Works | 2022–2025 | Caltrans 2013, City of Seattle 2017 |
| **Impacts from Urban Heat Island Effect:** Increases in annual average temperatures and the intensity and frequency of heat wave events will increase the effects of the UHI effect in the City with effects amplified in commercial and industrial land uses and surrounding areas. | C1: A Resilient Built Environment (Cool Pavements) | Develop a cool pavement "road map" to implement Policy ER-6-4 of the City's GP, which focuses on using cool pavements and higher-albedo impervious materials, as well as trees and foliage along rights-of-way. This strategy aligns with GP Implementation Strategy Action 13.2 "Public Works Standards." | Increased albedo of paved surfaces | Plans, regulations, and policy development | Development Services, Public Works | 2022–2025 | ASLA 2018 |
| | C2: A Resilient Built Environment (Green Infrastructure) | Encourage larger land development projects to incorporate principles of green infrastructure (e.g., bioswales, permeable pavements, rain gardens, linear parks, green roofs), which help mitigate the UHI effect in the City. | Increased evapotranspiration and reduced heat-absorbing surfaces | Plans, regulations, and policy development | Development Services | 2022–2025 | ASLA 2018, City of Seattle 2017, EPA 2016a, Stone et al. 2019 |
| | C3: A Resilient Built Environment (Urban Forest) | Work with the Sacramento Tree Foundation to implement measure BE-9 of the City's CAP, which focuses on increasing tree planting to sequester carbon. Ensure that implementation of the strategy considers projected increases in temperature and precipitation in selection of tree varieties to be planted. This strategy aligns with GP Implementation Strategy Action 12.1 "Urban Forest." | Increased evapotranspiration and shade | Programmatic | Development Services | Ongoing | ASLA 2018, USDA 2019, Harlan and Ruddell 2011 |
| | C4: A Resilient Built Environment (Landscaping) | Review and update Chapter 23.54, "Landscaping," of the City's municipal code and other design guidelines to incorporate strategies to mitigate future increases in temperature and extreme heat events and mitigate the UHI effect in new development. | Increased evapotranspiration and reduced heat-absorbing surfaces | Plans, regulations, and policy development | Development Services | 2022–2025 | ASLA 2018, City of Seattle 2017, Stone et al. 2019 |

| Primary Impact | Strategy Number and Category | Strategy Description | Adaptation Mechanism | Implementation Mechanism | Responsible Department | Timeline | Source/ Example |
|---|---|---|---|---|---|---|---|
| | C5: A Resilient Built Environment (Building Code) | As part of the implementation of CAP measure BE-5 (Building Stock: Phase in Zero Net Energy Standards in New Construction), incorporate projected increases in temperature and extreme heat events in building standards to mitigate impacts from the UHI effect on energy demand. | Increased resilience of building to extreme heat | Plans, regulations, and policy development | Strategic Planning & Innovation, Development Services | 2022–2025 | Nahlik et al. 2016 |
| | C6: A Resilient Built Environment (Green/High-Albedo Roofs) | Explore cost-effective strategies to integrate green roofs into the City's building code with consideration of solar photovoltaic system requirements for new development. Incentivize new development projects to include green roofs and high-albedo roofs. | Increased resilience of building to extreme heat | Plans, regulations, and policy development | Development Services | 2022–2025 | ASLA 2018, City of Seattle 2017, EPA 2016a |
| **Impacts on Social Functions:** Increases in annual average temperatures and the intensity and frequency of heat wave events will increase the risk to vulnerable populations. | D1: A Climate-Ready Community (Elderly Populations) | Identify areas in the City with increased concentrations of older residents and areas with increased density of elderly care facilities and senior homes. Prioritize emergency services to these areas during extreme heat events. | Increased resilience of population to extreme heat | Programmatic | Housing and Loans, Police Department | 2022–2025 | Voelkel et al. 2018 |
| | D2: A Climate-Ready Community (Youth Populations) | Explore opportunities to work with community organizations and schools to help mitigate the impacts of extreme heat and heat wave events on children. | Increased resilience of population to extreme heat | Education, outreach, and coordination | Development Services, Police Department, school district | 2022–2025 | Voelkel et al. 2018 |
| | D3: A Climate-Ready Community (Construction Workers) | Review and update the City's construction specification manual to bolster protections for construction workers working in the City. Provide educational material to construction workers and City staff who work outside about best practices to reduce health impacts from extreme heat. | Increased resilience of population to extreme heat | Plans, regulations, and policy development | Public Works, Development Services, Risk Management | 2022–2025 | Moda and Minhas 2019 |
| | D4: A Climate-Ready Community (Training and Education) | Increase education and training opportunities for residents to prepare for extreme heat events with a prioritization on vulnerable populations, as well as businesses and institutions that house and/or support vulnerable populations. This strategy aligns with GP Implementation Strategy Action 15.2 "Outreach Techniques for Minority and Disadvantaged Communities." | Increased resilience of population to extreme heat | Education, outreach, and coordination | City Manager's Office, Police Department, regional partners | Ongoing | White-Newsome et al. 2014 |

| Primary Impact | Strategy Number and Category | Strategy Description | Adaptation Mechanism | Implementation Mechanism | Responsible Department | Timeline | Source/ Example |
|---|---|---|---|---|---|---|---|
| | D5: A Climate-Ready Community (Elderly Outreach) | Use resources developed by Association of American Retired Persons and work with organization to educate elderly populations in the City about health impacts from extreme heat events and strategies to prevent these impacts. | Increased resilience of population to extreme heat | Education, outreach, and coordination | Housing and Loans Division | 2022–2025 | CalOES 2019, Mohnot et al. 2019 |
| | D6: A Climate-Ready Community (Cool Zones) | Develop a strategy to work with local businesses that volunteer to serve as "cool zones" during extreme heat days and allow residence to cool off in air-conditioned spaces in these businesses (e.g., coffee shops, movie theater). Provide information about the location of these cool zones to City residents. | Increased resilience of population to extreme heat | Education, outreach, and coordination | City Manager's Office, regional partners | 2022–2025 | County of San Diego n.d. |
| **Impacts on Community Function:** Increases in annual average temperatures and the intensity and frequency of heat wave events will have an impact on normal community function and operations, including potential impacts on traffic and infrastructure operations, the economy, and emergency services. | E1: A Climate-Smart Electricity Grid | Work with SMUD to promote and help educate residents about SMUD's time-of-day energy rates and the cost benefits of reducing electricity use during peak demand periods. Work to support further adaptation and resilience efforts initiated by SMUD that affect the City. This strategy aligns with Action 2.13 "Energy Efficiency in Housing" in the GP Implementation Strategy. | Increased resilience of electricity grid to extreme heat | Education, outreach, and coordination | City Manager's Office, regional partners | Ongoing | DOE 2016 |
| | B3: A Resilient Transportation System (Traffic Operations) | Identify and prioritize updates to high-volume roadways and truck routes that will be affected by extreme heat events. Use information from Strategies A1–A3 to inform strategy implementation. Identify potential vulnerabilities to signal operations from extreme heat events. | Increased resilience of traffic operations to extreme heat | Plans, regulations, and policy development | Public Works | 2025–2030 | Transportation Research Board and National Research Council 2008, Caltrans 2013 |
| | F1: Social and Economic Resilience (Energy Demand and Cost) | Work with SMUD and regional partners to promote energy efficiency upgrades and behavior change that reduces energy demand for cooling and provide cost savings for low-income residents. | Increased resilience of population to extreme heat | Education, outreach, and coordination | City Manager's Office, regional partners | Ongoing | DOE 2016, Voelkel et al. 2018 |
| | C7: A Resilient Built Environment (Parks and Recreation Areas) | Develop a strategy to educate populations that frequently use parks and recreation areas (e.g., sports teams) about the public health effects of extreme heat, and ensure facilities are adequately prepared to help mitigate heat impacts. | Increased resilience of population to extreme heat | Education, outreach, and coordination | City Manager's Office, Police Department, regional partners | 2022–2025 | ASLA 2018, USDA 2019 |
| | C8: A Resilient Built Environment | Assess effects of increases in temperature and extreme heat events on energy demands in City-owned facilities | Increased resilience of building to extreme heat | Plans, regulations, and | Public Works | 2025-2030 | Nahlik et al. 2016 |

| Primary Impact | Strategy Number and Category | Strategy Description | Adaptation Mechanism | Implementation Mechanism | Responsible Department | Timeline | Source/ Example |
|---|---|---|---|---|---|---|---|
| | (Government Facilities) | and implement upgrades to mitigate projected increases in energy demand. | | policy development | | | |
| | D7: Climate-Ready Community (Emergency Services) | Develop strategies to ensure that emergency services in the City are adequately prepared for future impacts from extreme heat events. Assess internal emergency service operations to identify sensitivities to extreme heat events. | Increased resilience of emergency services to extreme heat | Programmatic | City Manager's Office, Police Department, regional partners | 2022–2025 | Paterson et al. 2014 |
| | D8: A Climate-Ready Community (Wildfire Smoke) | Assess the City and regional partner's capacity to respond to impacts from wildfire smoke on residence and increase the City's capacity to respond to these events, if needed. | Increased resilience of population to extreme heat | Education, outreach, and coordination | City Manager's Office, regional partners | 2022–2025 | EPA 2016b |

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