Fresno Council of Governments

Fresno Climate Resiliency Plan

May 2025

Disclaimer

This report offers information on Fresno County’s transportation assets' climate hazard exposure, vulnerabilities, and risks. Future conditions are inherently uncertain. Climate models, data, and scenarios have limitations, and regional impacts may vary. Forward-looking statements are based on current assessments and interpretations of available information, which may not reflect how actual events unfold over time. The report's information should be interpreted cautiously and with professional judgment.

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American Red Cross
Black Wellness and Prosperity
Community Care Health
Central California Asthma Collaborative
Central California Environmental Justice Network
Central Valley Community Foundation
City of Fresno – Active Transportation Advisory Committee
City of Fresno – Office of Community Affairs
City of Kerman Senior Center
Every Neighborhood Partnership

Familias en Acción
Fresno County League of Women Voters
Fresno County Bicycle Coalition
Fresno Cycling Club
Fresno Interdenominational Refuge Ministries (FIRM)
Fresno Metro Ministry
Highway City Community Development Inc.
Industrial Areas Foundation (IAF) – St. Anthony Mary Claret Catholic Church
Jackson Community Development Corporation
Kings River Conservancy
Linguística Interpretation and Translation Services
Regenerate California Innovation, Inc. (RCI)
Saint Joseph Church
San Joaquin River Conservancy
San Joaquin River Parkway and Conservation Trust
Self-help Enterprise
Sequia Riverland Trust
South Tower Community Land Trust
Stone Soup
The Children's Movement
The LEAP Institute
Tree Fresno
US Green Building Council

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Arup
Urban Diversity Design
Zack Urban Solutions

Key Terms

Adaptation: Adjusting to climate change by taking steps to reduce risks and make communities, economies, and nature more resilient.

Consequence: The costs or impacts of damage to transportation, such as repair costs, delays, or safety risks.

Criticality: How important a transportation system (like a road or bridge) is for keeping things running smoothly.

Downtime: The time when a transportation system (like a road, bridge, or airport) isn't working properly due to a disaster, causing delays and disruptions.

Dry Bulb Temperature: The actual air temperature, measured without considering humidity.

Exposure: The features of a transportation system (like location and materials) that determine how much it is affected by a hazard.

Facility: Any transportation infrastructure, such as a highway, railroad, airport, or public transit system.

Hazard: A possible climate-related event (like a flood, wildfire, or extreme heat) and how likely it is to happen.

Heat Index: A measure of how hot it feels when both temperature and humidity are considered.

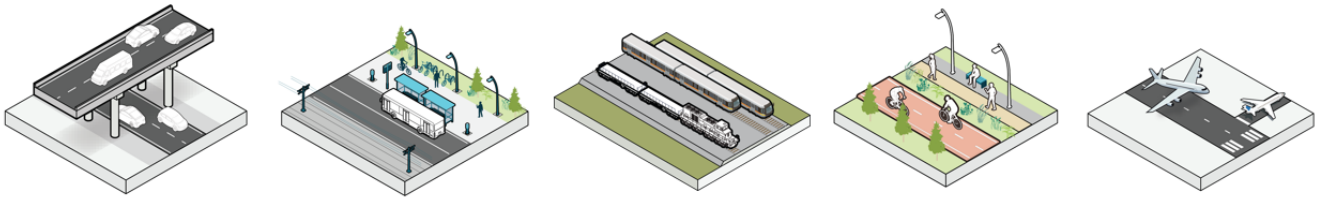
Mitigation: Actions taken to slow down or reduce the effects of climate change by cutting emissions or lessening climate-related damage.

Risk Assessment: A process that looks at the chances of a hazard happening and its possible effects on transportation, giving it a risk level from low to severe.

Vulnerability: How likely a transportation system is to be damaged when exposed to a hazard.

Executive Summary

The Fresno County Climate Resiliency Plan is a roadmap for Fresno County on its journey to become more resilient in the face of a changing climate. The Plan identifies transportation assets in Fresno County that are at risk of various climate-related impacts, including flooding, wildfire, landslides, and extreme heat, and provides a list of projects to help Fresno County adapt to its climate risk while also supporting and reflecting local and regional needs. These projects will become candidates for Fresno Council of Government's (COG) 2026 Regional Transportation Plan/Sustainable Community Strategy. The Plan specifically guides the agency toward five priority projects to advance in the near-term to increase the county's resilience in the face of climate events that are increasing in frequency and severity. The transportation assets included in this Plan are shown in the below figure.



ROADS & BRIDGES | TRANSIT NETWORK | RAIL | BIKE NETWORK | AIRPORTS

Key findings from the transportation risk assessment include:

- Flooding has the greatest impact on the county's transportation assets. The Cities of Fresno and Clovis, and western Fresno County face the highest risk.
- Wildfire primarily impacts rural and mountainous communities, many of which are also isolated.
- Extreme heat is already a major issue across the county and has the largest impact on people walking, bicycling, and taking transit, many of whom are low income.
- The risk of all climate hazards is expected to increase in the county in the future.

How This Plan Was Developed

Fresno COG led the development of this Plan over a 12-month period, with guidance from a Technical Working Group and Community Working Group. These working groups were comprised of Caltrans, Clovis Transit, Fresno Area Express, Fresno City Planning and Development, Fresno County Public Works & Planning, Fresno County Rural Transit Agency, San Joaquin Valley Air Pollution Control District, Selma Airport, Leadership Counsel for

Justice and Accountability, and Fresno County Board of Supervisors. The public also provided input into the Plan at key junctures through a workshop, a public survey, and various pop-up events.

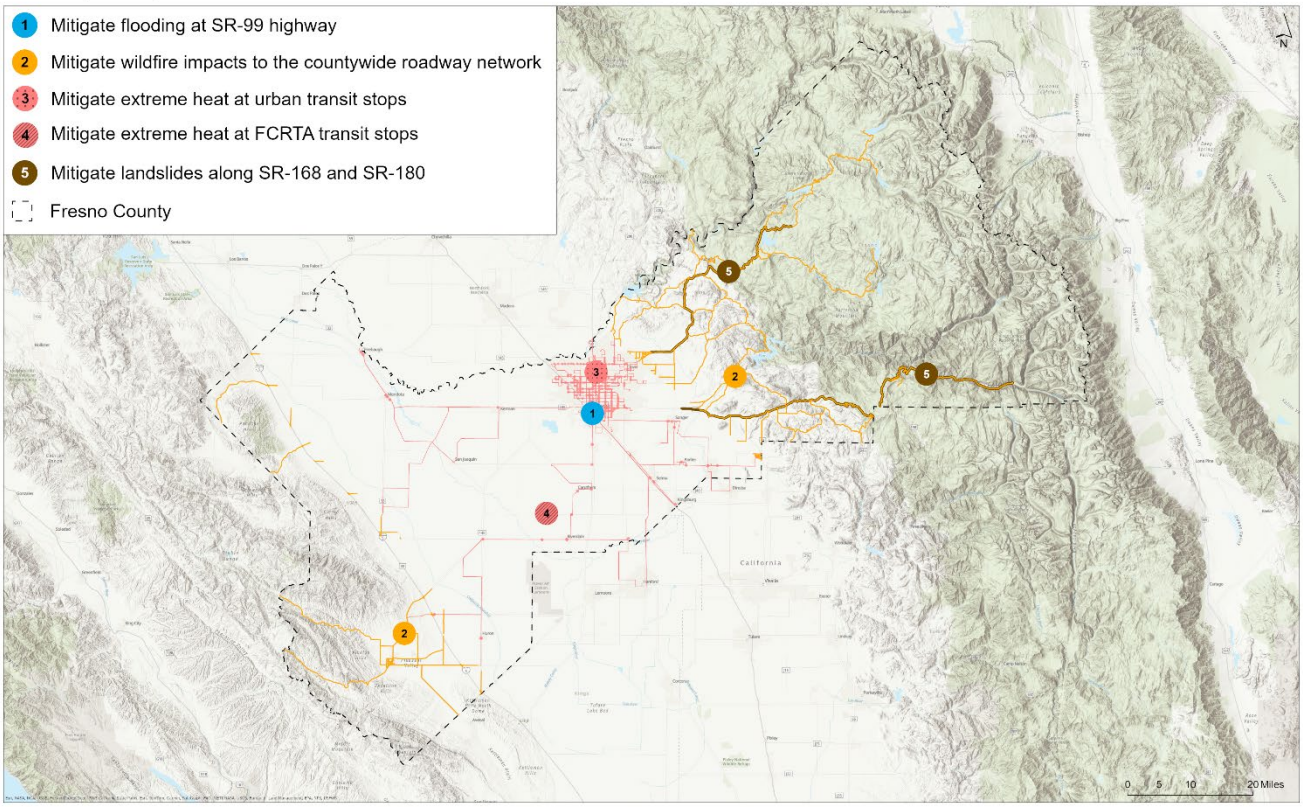
This Plan includes:

- Chapter 1: Why a Climate Resiliency Plan?: The background and context for the Plan.
- Chapter 2: Climate Projections in Fresno County: An overview of how climate is projected to change in the county.
- Chapter 3: Risk Assessment Findings: a summary of the most at risk transportations assets.
- Chapter 4: Project Opportunities: a long list of 31 transportation project opportunities to improve resilience across Fresno County.
- Chapter 5: Priority Projects: a short-list of five priority projects, including a detailed assessment of the risk and potential solutions for each, and planning-level costs.
- Chapter 6: Next steps.

The top five priority projects are included in the table below and shown on the following map. These projects were selected based on several criteria, including level of climate risk, adaptation co-benefits, criticality, and benefits to equity priority communities.

Priority Project	Description
Mitigate flooding along SR-99	Mitigate flooding along SR-99 through stormwater infrastructure improvements and effective flood management to reduce the impacts of stormwater runoff.
Mitigate wildfire impact to Fresno County's mountain road network	Mitigate the impact of countywide wildfires on the county's mountain road network through partnering with other agencies to clear ground fuels from forested areas along the high wildfire risk road network, supporting innovative financing approaches for healthy forest management, and enhancing evacuation planning.
Mitigate extreme heat at urban transit stops	Identify urban bus stops served by FAX, Clovis Transit, and FCRTA throughout Fresno and Clovis that need bus shelters, better shading, and tree canopies to provide critical health benefits to those who are transit dependent.
Mitigate extreme heat at FCRTA transit stops	Identify rural bus stops served by FCRTA transit stops that need bus shelters, better shading, and tree canopies to provide critical health benefits to those who are transit dependent.
Mitigate landslides along SR-168 and SR-180	Mitigate landslide risk along 112 road miles of SR-168 and SR-180 through interventions like landslide retention measures, erosion stabilization, and road realignment if needed. SR-168 is specifically a priority as it serves as a vital FCRTA transit route serving Auberry and other isolated mountain communities.

Priority Projects

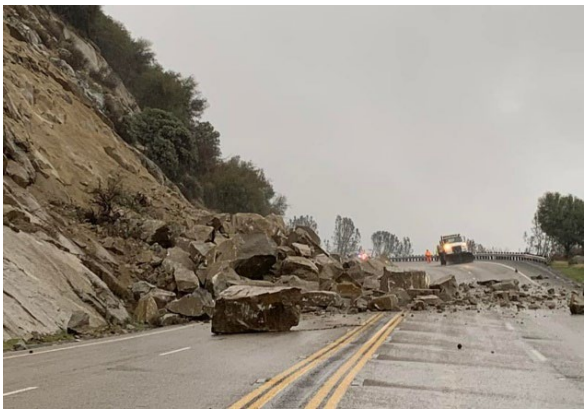


The Plan provides a strategic framework to enhance the county's transportation infrastructure against the current and increasing risks of climate change. By prioritizing key projects and integrating resilience measures, the Plan aims to protect communities, improve mobility, and ensure a more resilient and adaptive transportation network for the future.

1. Why a Climate Resiliency Plan?

The impacts from climate change are already at Fresno County's front door—from the September 2020 Creek Fire to major flooding in 2023, recent climate events have driven discourse at the government level and among the public around the need to prioritize infrastructure investments and develop a tactical strategy for implementation. Projections show that extreme climate events are expected to continue and increase in frequency and severity, elevating the importance of a resilient transportation network and blueprint for the future.

Past events in Fresno County



Rockslide on SR-168 between Prather and Shaver Lake in 2022

A bridge overtopped by floodwaters in January 2023

The Plan identifies transportation assets in the county that are at risk of various climate-related impacts, including flooding, wildfire, landslides, and extreme heat, and provides a list of projects to help the county adapt to its climate risk while also supporting and reflecting local and regional needs. These projects will become candidates for Fresno COG's 2026 Regional Transportation Plan/Sustainable Community Strategy. The Plan specifically guides the agency toward five priority projects to advance in the near-term to increase the county's resilience in the face of climate events that are increasing in frequency and severity.

In 2020, Fresno COG conducted a Regional Transportation Network Vulnerability Assessment (TNVA) using funds from 2018-2019 Caltrans Climate Adaptation Planning Grant. The TNVA included historical weather-related risks, e.g., wildfires, extreme heat, flooding, landslides, etc. and projected future climate changes, and gathered data on the county's multi-modal transportation network. This Plan was informed by a transportation system risk assessment (risk assessment) which built upon the TNVA and other past work, including the following plans, studies, and data sets in Table1-1 below. Appendix A.5 describes in further detail the past work that was reviewed.

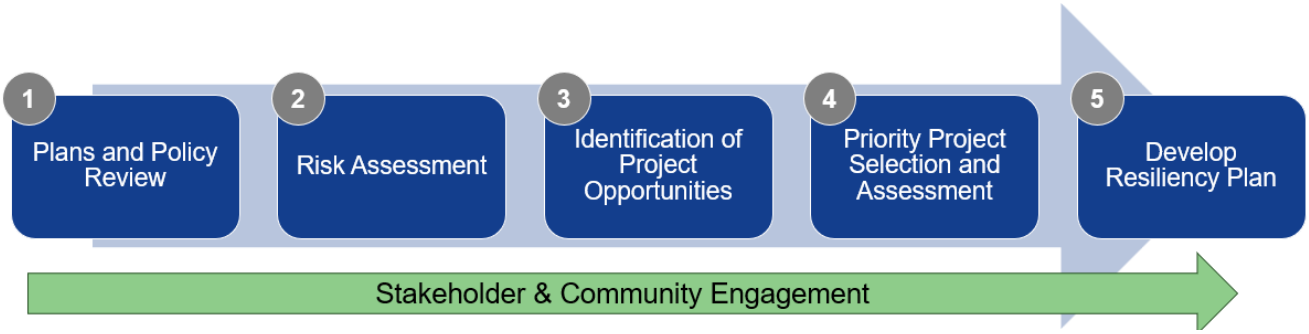
Table 1-1: Plans, studies, and data sets reviewed

Fresno County Regional Transportation Vulnerability Assessment	Blackstone Corridor Transportation + Housing Study
Federal Transportation Improvement Program	Fifth National Climate Assessment
Fresno County Multi-Jurisdictional Hazard Mitigation Plan	California Fifth Climate Assessment
Fresno County Annual Action Plan 2023-24	Cal-Adapt
Fresno County Regional Transportation Plan & Sustainable Communities Strategy	FHWA's Climate Change Adaptation Guide for Transportation Systems
Fresno Priority Climate Action Plan	California Adaptation Planning Guide
Fresno County General Plan Policy Document	U.S. Department of Transportation PROTECT Program
Fresno County Regional Safety Plan	CalEnviroScreen 4.0
Fresno-Madera State Route 41 and Avenue 9 Sustainable Corridors Study	California Public Utilities Commission Disadvantage Communities
Multi-Jurisdictional Pavement Management System	U.S. Department of Transportation Equitable Transportation Community Explorer
Eastside Transportation Corridor Improvement Study	

The risk assessment brought together all the information—mapping the likelihood of the hazards, with the consequences and impacts, to generate a risk rating for all hazards and transportation assets. These risk ratings supported the identification of a long list of project opportunities to improve the resilience of the transportation system and a prioritized a short list of five priority projects based on criteria like equity, transportation asset criticality, and overall risk level. This Plan includes a project-level deep dive for each priority project.

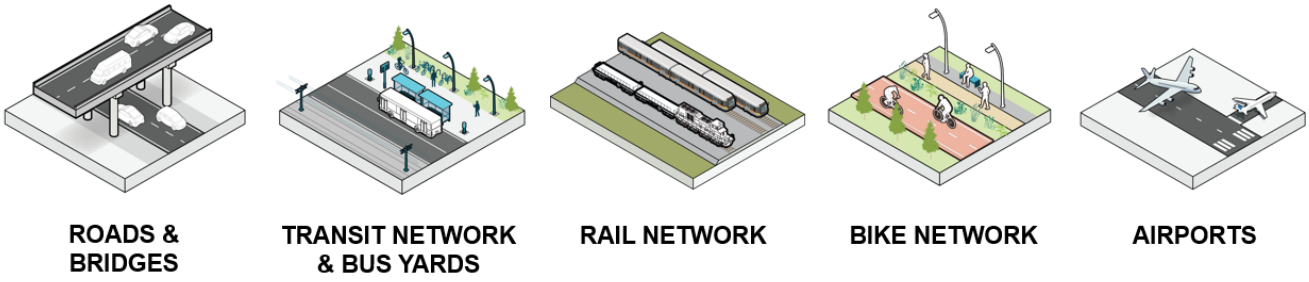
Figure 1-11 illustrates the planning process, from an initial review of existing plans, guidelines, and policies to the priority project selection and final plan development

Figure 1-11: Plan development process



The scope of the risk assessment considers the impacts of multiple climate hazards on the county's regional transportation network and infrastructure. In this risk assessment, the transportation assets detailed in Figure 1-22 were analyzed based on the risk of wildfire, flooding, extreme heat, and landslides:

Figure 1-22: Transportation assets considered in this Plan



Throughout the plan development process, community members provided feedback through a survey, meetings, pop up events, and public review. Community engagement activities and feedback are documented in Appendix A.3 and A.4. Feedback was utilized to deepen understanding of the consequences of hazard impacts, confirm prioritized projects, and provide more nuanced, relevant, and practicable recommendations for mitigating risk.

The Plan serves as a critical step to address the increasing risks posed by extreme climate events to the county's transportation network. By integrating climate hazard assessments, risk evaluations, and strategic project prioritization, the Plan provides a roadmap for enhancing transportation infrastructure resilience. With a focus on equity, asset criticality, and overall risk levels, the five identified priority projects will help safeguard Fresno County's transportation system against future disruptions and impacts to human health and wellness. As climate events continue to intensify, this Plan lays the groundwork for informed decision-making and proactive investments that will strengthen the county's ability to adapt and thrive.

2. Climate Projections in Fresno County

The county is projected to experience significant climatic changes in the coming decades. Average temperatures are expected to rise substantially, with scenarios projecting increases between 1°F and 2.3°F in California over the next few decades. By 2099, temperature increases in higher emissions scenarios could be approximately twice as high as those in lower emissions scenarios. Heat risks are also anticipated to escalate and the region is expected to face hotter, drier, and longer summers, more severe storms, and an 80 percent decline in snowpack. Future climate projections were analyzed to understand the implications of current and future climate scenarios on flooding, extreme heat, and wildfire hazards in the county.

2.1 Key Findings

The following overall trends were identified for the county:

- **Flooding:** Flooding is an issue in multiple locations across the county, though certain areas are more prone to extreme flooding such as the cities of Fresno, Clovis and western Fresno County. In the future, extreme rainfall events are projected to become more frequent.
- **Extreme Heat:** Extreme heat across the county is already a serious concern, and it is expected to get even hotter in the future. The county's heat index is projected to rise on average by 5°F to 11°F by 2050 and 2085, respectively. Similarly, temperatures are anticipated to increase, as well, causing more stress on the county's road network, which may soften and buckle with the heat.
- **Wildfires**: Wildfires predominantly impact rural and mountainous regions in the county due to the availability of wildland fuel (trees, brush, etc.). Climate change is expected to increase the likelihood and severity of wildfire significantly in certain areas. Some projections show that the chance of a wildfire occurring in heavily forested areas of the county will triple by end of century.

2.2 Methodology

Different climate scenarios and timeframes were considered for the climate hazards listed above. These scenarios were created by the United Nations Intergovernmental Panel on Climate Change. They are based on complex calculations that depend on how fast humans reduce greenhouse gas emissions. The calculations also consider changes in population, city growth, education, land use, and wealth. Each scenario is labeled to show the emissions level and the Shared Socioeconomic Pathway (SSP), used in the calculations.

- **2050 and 2085 SSP2-4.5:** This is a "middle of the road" scenario. CO2 emissions stay about the same before starting to decrease around the middle of the century, but they don't reach net-zero by 2100. Socioeconomic factors, like population and income, follow their usual trends without major changes. Progress towards sustainability is slow and uneven. In this scenario, global average temperatures rise by 2.7°C by the end of the century.
- **2050 and 2085 SSP5-8.5:** This is a future to avoid at all costs. CO2 emissions roughly double by 2050. The global economy grows quickly, but this growth relies on using

fossil fuels and energy-intensive lifestyles. By 2100, the global average temperature is 4.4°C higher.

This climate projection analysis employed the best regional public data available for the county. The future climate data was processed to translate climate indicators into specific intensity measures for different hazards like floods and wildfires. The data for extreme heat was directly taken from global climate models. Future landslide hazards were not considered in this Plan.

Present day data was used to understand where transportation assets may be exposed to a particular hazard of concern. Then, climate indicators were used to understand how that hazard may shift over time in its frequency (i.e., how might a flood or wildfire become more likely in the future?). Note there is a limitation in this approach as it does not identify areas that are not currently subjected to flooding or wildfire, that may become subject to these in the future. The following maps show how climate events are projected to change in the county, illustrating the trends described above. More detail is provided in Appendix A.6.

2.2.1 Flooding

The FEMA National Flood Hazard Layer (NFHL) provides a general understanding of the extents of extreme riverine flood events in the county for present-day climate (refer to Figure 2-1). FEMA does not provide projections of how these flood zones may change in the future. As rainfall is the primary driver of riverine flooding, climate model data, in the form of downscaled daily rainfall totals, assisted in estimating how the likelihood of these extreme flood events may change in the future. These projected changes are detailed for mid-century in Figure 2-2a and end of century in Figure 2-2b which show the percentage change in the 100-year rainfall.

Figure 2-1: Present-day FEMA National Flood Hazard Layer overlayed in Fresno County.

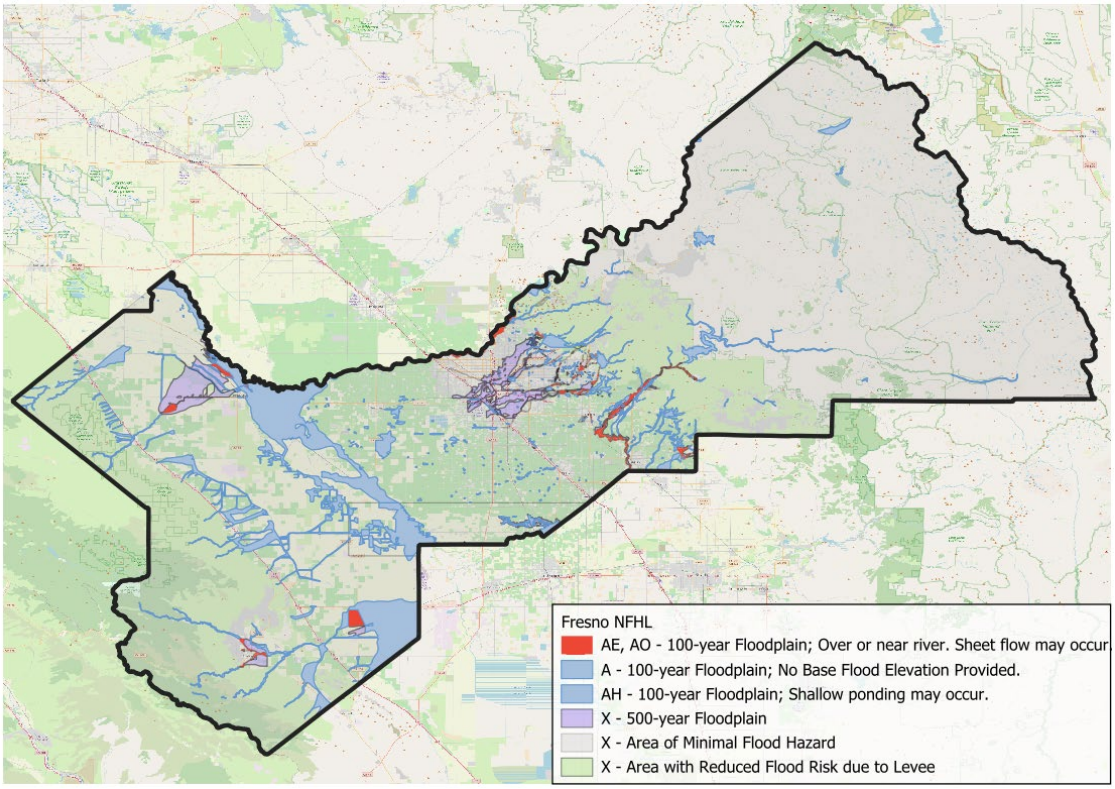
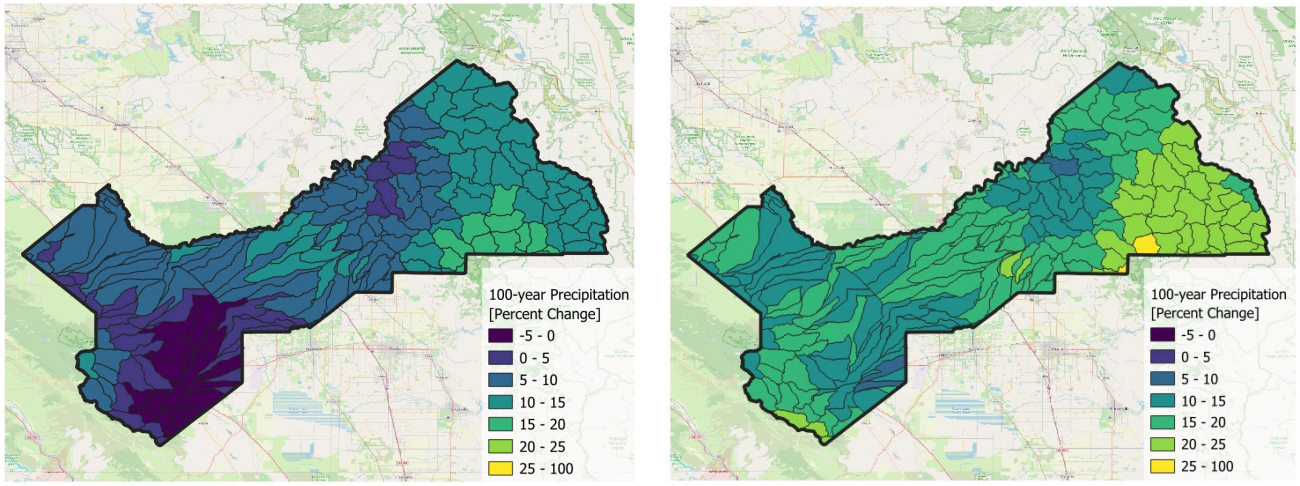


Figure 2-2: Percent change in 100-year precipitation from current climate to future climate scenarios by HUC-12s watershed scale.

(a) SSP5-8.5 2050 **(b) SSP5-8.5 2085**

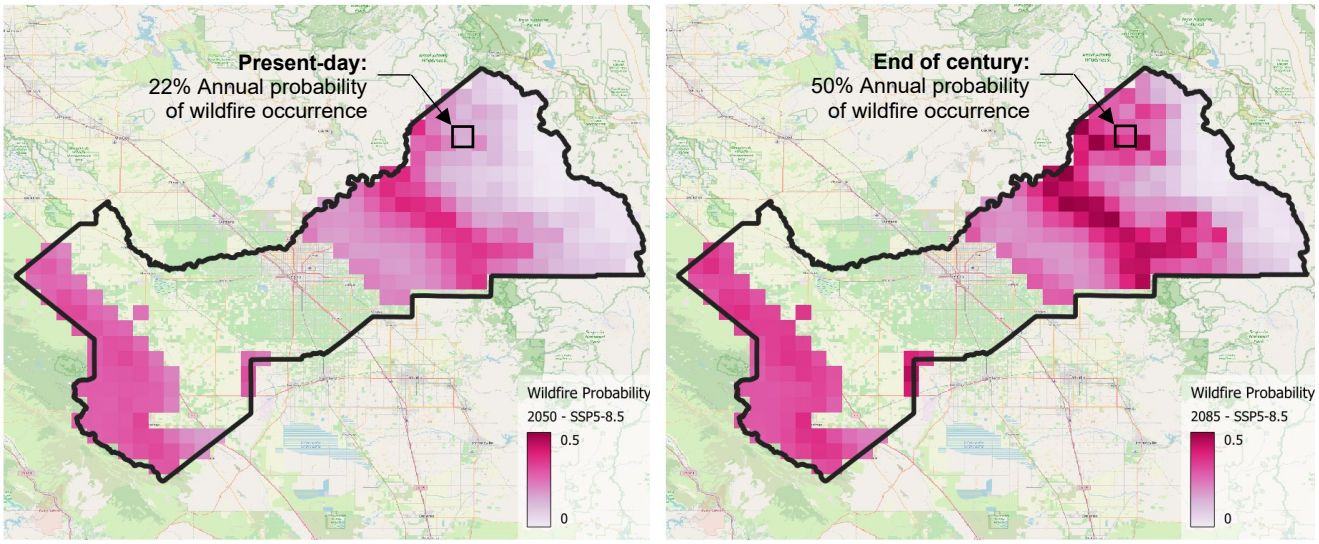


2.2.2 Wildfire

Climate projections provide a metric—the annual probability of a wildfire occurring—for how likely wildfires are to happen each year, looking at past decades (from 1950) and future decades (up to 2100). The metric compares the chance of wildfires in future decades to a baseline, which is the present-day period where climate models are tested using past data.

Figure 2-3. Increase in annual probability of occurrence of a wildfire.

(a) Present-day climate **(b) End of century climate, SSP5-8.5 2085**

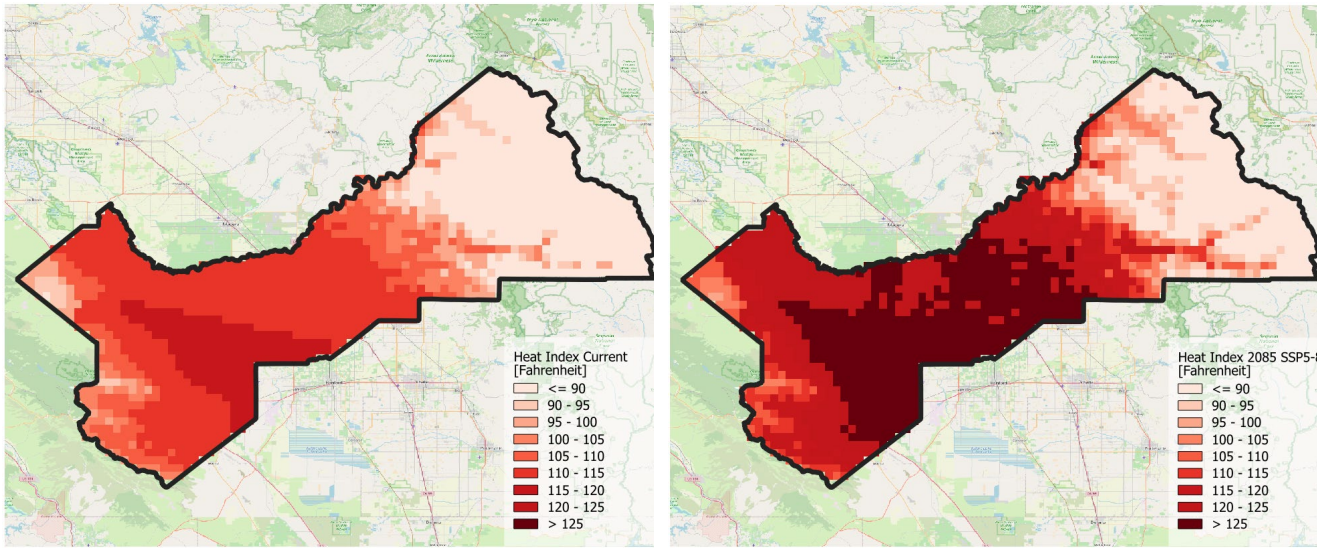


2.2.3 Heat

Heat index is a metric that combines the effects of dry bulb temperature and relative humidity to serve as a proxy for what high temperatures “feel like” on the human body. Heat index is a better reflection of a human’s thermal comfort as opposed to standard outside air temperature (dry bulb temperature).

Figure 2-4. Extreme annual heat index for 1 in 5-year extreme heat event.

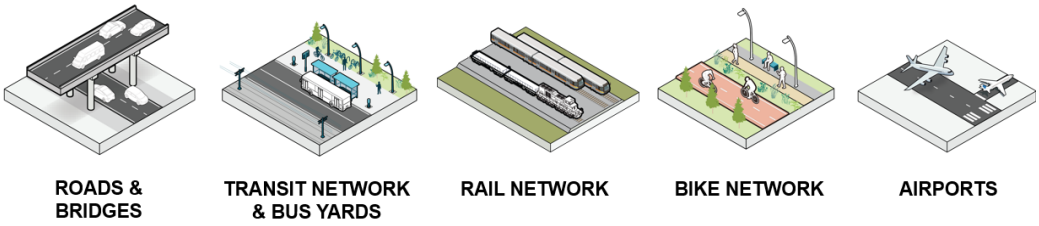
(a) Present-day climate present-day climate **(b) End of century climate, SSP5-8.5 2085**



3. Risk Assessment Findings

The goal of the risk assessment was to identify areas where flood, wildfire, extreme heat, and landslide hazard intersect with vulnerable transportation assets and result in impacts (e.g., downtime due to road closures) for the following transportation assets in the county:

Figure 3-1: Transportation assets considered in this Plan



Understanding the relative risks across these transportation assets for different climate hazards highlights the areas, assets, and hazards of most concern to help guide Fresno COG toward priority projects with the greatest potential benefits. The results from this risk assessment were a key input into the development of projects and programs to enhance the resilience of the county's transportation infrastructure.

3.1 Key Findings

The risk assessment revealed that of all the transportation assets in the county, roads and bridges, transit routes, and bike networks are at the highest risk of either downtime or human health consequences resulting from climate impacts. High level findings are described in the below and detailed findings are in the following table.

- **Roads and bridges:** The impacts of flood and wildfire are similar but impact different regions; wildfire and landslides impact mountainous roads while flooding impacts the inland valley.
- **Transit network:** Flooding primarily impacts urban transit service served by FAX (such as Routes 1, 28, and 38), while rural transit service (such as Coalinga Intercity Transit and Westside Transit Routes) is more susceptible to wildfire risk.
- **Bus yards:** Flooding has the potential to impact about 25 percent of bus yards, with the highest risk at Firebaugh Bus Yard 1, Coalinga Bus Yard, and Orange Cove Bus Yard. Wildfire does not impact any bus yards that were evaluated in this study.
- **Rail network:** Flood impacts are concentrated along the main lines through the City of Fresno and the branch lines in western Fresno County.
- **Airports:** Flooding could impact five of the nine airports in the county included in the study. These include Fresno Yosemite International Fresno Chandler Executive, Selma, William R. Johnston, and Firebaugh Airport. Wildfire does not impact any airports that were considered in this study.

Detailed risk assessment findings are organized by asset and hazard in Table 4, below. Roads and bridges, transit routes, and bike networks in the county face the most extensive risks given both their location and the preponderance of these types of assets when compared to rail, bus yards, and airports. Given this, Table 4 includes further detail only on these asset types.

Table 3-1: Risk assessment key findings by asset and hazard.

	Flooding	Wildfire	Extreme Heat	Landslides
Roads and Bridges	• Roads and highways in Fresno and western Fresno County, such as SR-99 and Belmont Avenue are at the highest risk of flooding • Bridges and road segments over water bodies are of the most pressing concern due to the potential for damage from washout which requires extensive repairs.	• The primary wildfire concern involves rural roads and highways that serve as essential connections between rural mountain communities and the inland valley (e.g. Pittman Hill Road.) • The presence of a bridge can increase a road's vulnerability to wildfire damage because of the potential for structural failure. Consequently, mountain roads that include bridges are of pressing concern.	• Extreme heat most impacts roads in the low-mountain regions. • The effects of climate change have caused portions of the high mountain and western inland valley road network to degrade more rapidly than designed.	• Both SR-168 and SR-180 are located in Fresno County's eastern mountain regions, which are prone to landslides due to slope, soil type, geomorphology, and other factors. • SR-180 has higher landslide risk when compared to SR- 168.
Transit Network	• The transit routes at high flood risk are primarily urban routes operated by FAX, specifically Routes 1, 28, and 38, which also have high weekly ridership. • Rural transit routes, operated by FCRTA, typically serve more isolated communities with smaller overall ridership. Among these routes, the FCRTA Coalinga Intercity Transit and Westside Transit Routes have the most considerable flood risk.	• Transit routes at risk of wildfire impacts include FCRTA's Auberry Transit and Coalinga Intercity Transit Routes.	• Extreme heat is a significant issue today, and it uniformly affects people walking, bicycling, and taking transit in all parts of the county. • Bus stops without shelters or tree canopy exposes transit riders to prolonged direct sunlight while waiting for the bus. Of particular concern is the first and last mile of travel where passengers are exerting themselves by walking to and from a bus stop.	
Countywide Bike network	• Across the countywide bike network, bike paths (off-street paths) are considered especially vulnerable to flood risk due to their	• Portions of the bike network leading into the mountains are particularly vulnerable to wildfire risk. The primary areas of concern	• Extreme heat is a significant issue today, and it uniformly affects people walking and bicycling in all parts of the county.	

	Flooding	Wildfire	Extreme Heat	Landslides
	proximity to bodies of water. The most vulnerable portions of the bike network are in Fresno and Clovis as well near County borders along the San Joaquin River and the Friant-Kern Canal.	are located in the eastern and western mountains of Fresno County, including routes along Auberry Road and Elm Avenue.	• Lack of tree canopy or other shade on portions of the on-street and off-street bicycle network exposes bicyclists to direct sunlight and heat. This exposure creates a health risk, especially during physical exertion.	

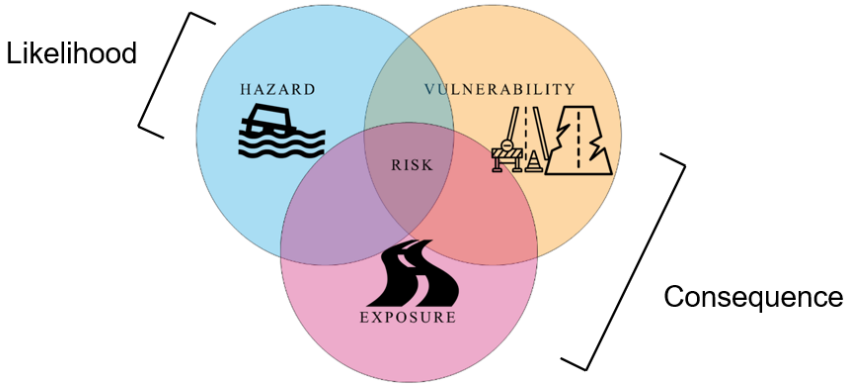
3.2 Methodology

Taking a holistic, consistent, risk-based approach to creating a resilient future required a method that allowed comparison across the potential impacts of multiple hazards, each with different likelihoods and intensities, on several types of infrastructure. For example, wildfires may impact roads much less frequently than flooding does but may impact roads more severely. The risk assessment provides a framework to be able to make these comparisons by considering both the likelihood of an event (e.g., a 100-year flood) in combination with its consequence (e.g. the amount of time the road will be closed).

The risk assessment integrates the following three key components, illustrated in Figure :

- **Hazard:** Hazard is assessed by defining the likelihood and intensity measure for a particular location. For example, in a given year a flood map may give a one percent chance of at least one to three feet of flooding occurring at a given location.
- **Exposure:** Exposure is assessed by identifying the assets in hazard-prone and understanding their characteristics to see if the hazard may impact them. For example, the elevation of a bridge may impact whether the bridge is in fact exposed to flooding. The characteristics considered in this study focused on asset location due to the number of assets and their geographical spread.
- **Vulnerability:** Vulnerability considers how an asset is expected to perform when subjected to a hazard. For example, six inches of flooding on a road can inhibit a car's ability to drive safely on the road and therefore result in road closure. One foot of flooding may damage critical maintenance equipment at a bus yard requiring it to close for a month for repair.

Figure 3-2: Key components of risk assessment



This approach can be used to assess different types of consequences. For flooding, wildfire, and landslide, downtime due to asset closures was assessed. Downtime was also assessed for extreme heat for all assets, except for the transit and bike networks where human health and wellness impacts were assessed. High heat hazards can have significant impacts on health and wellness, particularly for transit riders, and especially for those who are transit dependent. The methodology is described in detail in Appendix A.7.

Health and wellness risks were considered in conjunction with downtime risks to inform further adaptation planning decisions like developing a priority project list. To the extent possible, projects that serve multi-benefits, like reducing downtime and improving public health, or addressing flooding and heat impacts were prioritized.

4. Project Opportunities

Taken together, the climate projections and the system-wide transportation risk assessment focused the Plan on the areas where transportation assets will be most impacted by climate-related hazards either today or into the future. A list of project opportunities was developed to consider as candidates for incorporation into the 2026 Regional Transportation Plan/Sustainable Community Strategy and prioritized for consideration in the longer-term, as well.

4.1 Approach to identifying project opportunities

Project opportunities were identified by aggregating risk and criticality information to develop a long list of 31 project opportunities that can address climate impacts to important transportation assets in the county. The list of project opportunities consists of a climate hazard, and asset class (e.g., road network, bus yards), and a geographical area of high risk. The process to get to the long list was:

Figure 4-1: Approach to identifying project opportunities

Step 1: Identify high risk and critical areas

High risk geographies were identified based on the exposure of transportation assets to existing and future climate hazards, as described in Appendix A.8.

Step 2: Develop project typologies

Next, project typologies were developed that emerged from the risk assessment, to group, characterize, and score projects systematically. The project typologies are shown below.

Flooding

Figure 4-2: Project typologies for flooding

Bridge Infrastructure over major waterways

Airport runways and critical access roads susceptible to flooding

Mainline rail lines susceptible to flooding

Wildfire

Figure 4-3: Project typologies for wildfire

Wildfire-vulnerable mountain passes & bridges

Shared use paths susceptible to wildfire

Extreme Heat

Figure 4-4: Project typologies for extreme heat

Extreme heat impact on pedestrians, bicyclists & transit riders

Heat-vulnerable pavement of roads

Landslides

Figure 4-5: Project typology for landslides

Landslide and slope failure of roads & bridges

Step 3: Score and prioritize project needs locations

To compare the identified locations for prioritization, the previously developed Hazard Risk Score was combined with a Roadway Network Score to develop a final Priority Score. This resulted in a long list of 31 “Priority Need Locations” distributed throughout the county. The three scores are described below with further information in Figure 4-6.

- **Hazard Risk Scores** are a measure of the risk faced by the asset to a specific climate hazard (flood, wildfire, heat, landslide) that were outputs of the risk assessment.
- **Roadway Network Scores** are a measure of criticality, considering the following metrics which were determined in consultation with the Technical Working Group (TWG): traffic volume, presence of a transit route, presence of a bike lane, and whether it serves an equity priority community or isolated or rural populations.
- **Priority Scores** are a combination of the Hazard Risk Score and the Road Network Score and were used to prioritize the long list.

Figure 4-6: Approach to calculating priority scores

Hazard Risk Score (0-8) ✚ **Roadway Network Score (0-5)** 〓 **Priority Score (0-13)**

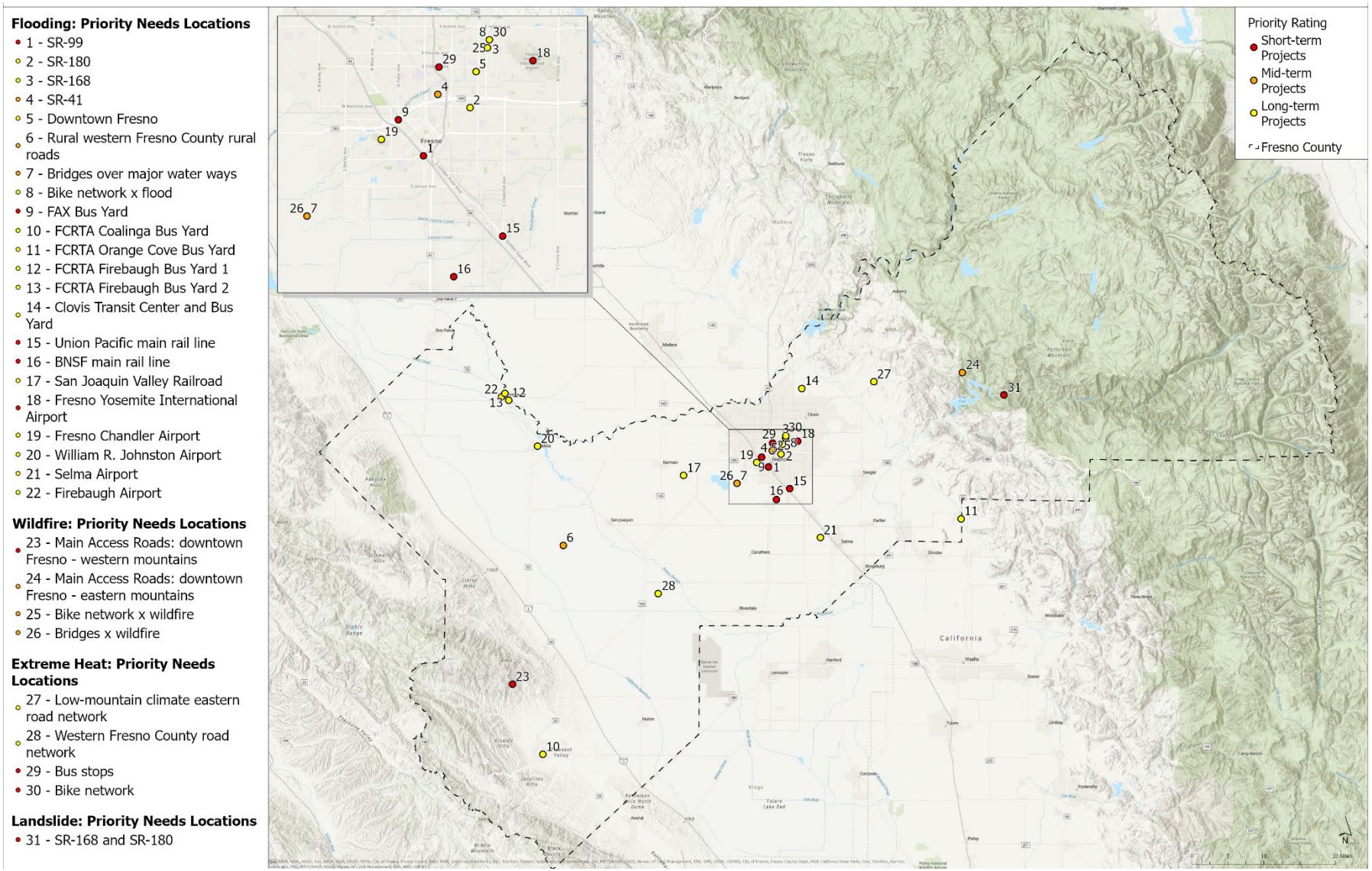
Risk Rating	Number
Negligible	0
Very Low	1
Low	2
Low-Med	3
Med	4
Med-High	5
High	6
Very High	7
Extremely High	8

Metric	Score
Transit route	0 or 1
Bike route	0 or 1
Vehicle volumes	0 to 1
Isolated/rural communities	0 or 1
Equity priority community	0 or 1

Priority Rating	Priority Score
Highest priority	Top third (quantile)
Moderate priority	Middle third
Lower-level priority	Lowest third

Figure 4-7 illustrates the project opportunity locations across the county.

Figure 4-7: Priority needs locations in Fresno County

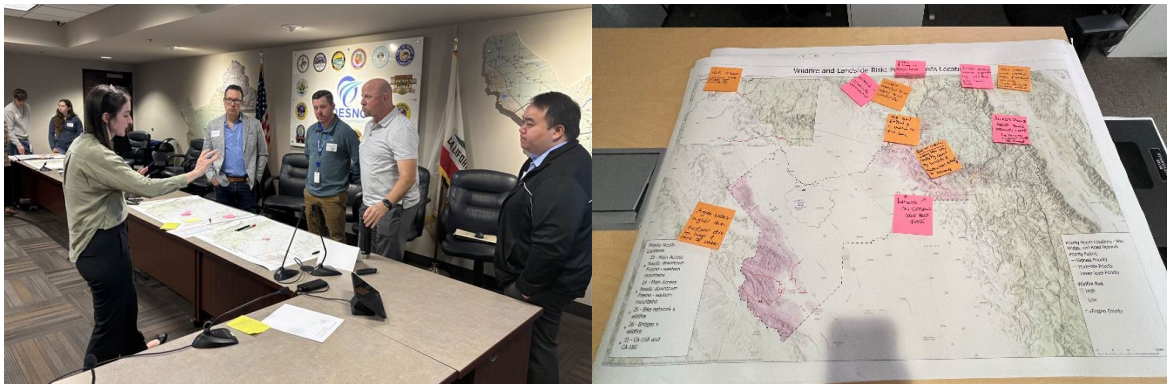


After identifying the list of project opportunities, feedback and guidance was solicited from the Technical Working Group on an approach to select a short list of five priority projects to advance.

Initially, 31 project opportunities were identified. These opportunities were scored and ranked, and then tagged as high, medium, or longer-term priorities. Five project locations scored as a high priority were selected for advancement. The selection process incorporated input from the Technical Working Group, and addressed issues identified by the Community Working Group, and community concerns raised in surveys and meetings.

The selection process also considered organizational capacity to manage the hazard, the geographical distribution of projects, the project's relevance in mitigating disproportionate risks to Equity Priority Communities, and potential co-benefits from project implementation.

Technical Working Group meeting #3 in Fresno

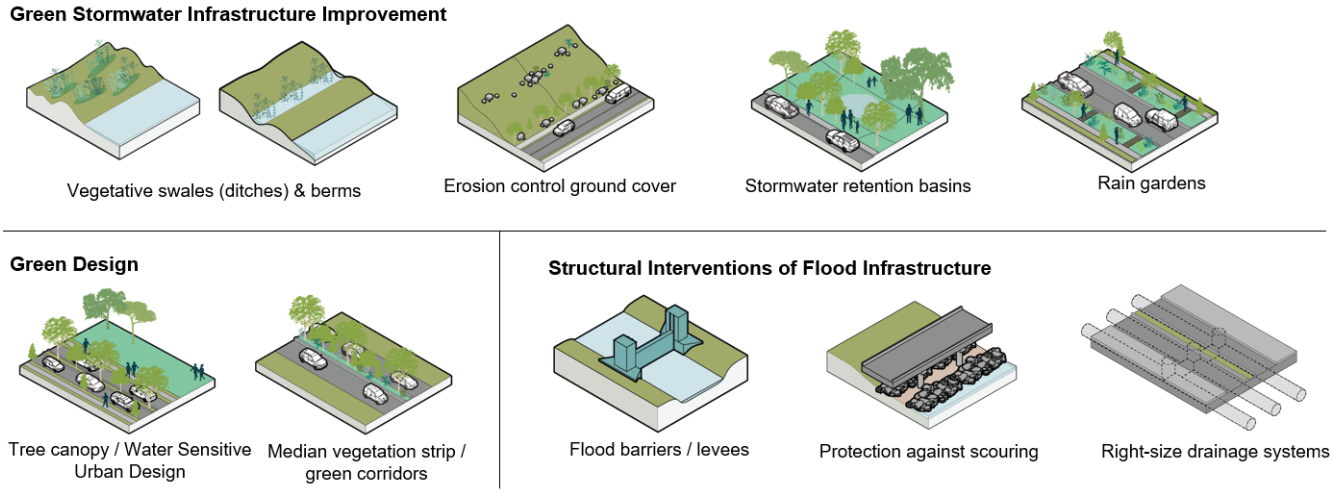


Step 4: Identify solutions for project areas

An Adaptation Solutions Toolkit was developed for each hazard featuring solutions that are suitable for application within the Fresno County context. The Toolkit is intended to provide a list of possible adaptation measures that may effectively mitigate climate impacts. The specific solutions recommended for the priority projects (detailed in Section 5), drew from the Toolkit, which illustrate the solutions' application to mitigating the hazards.

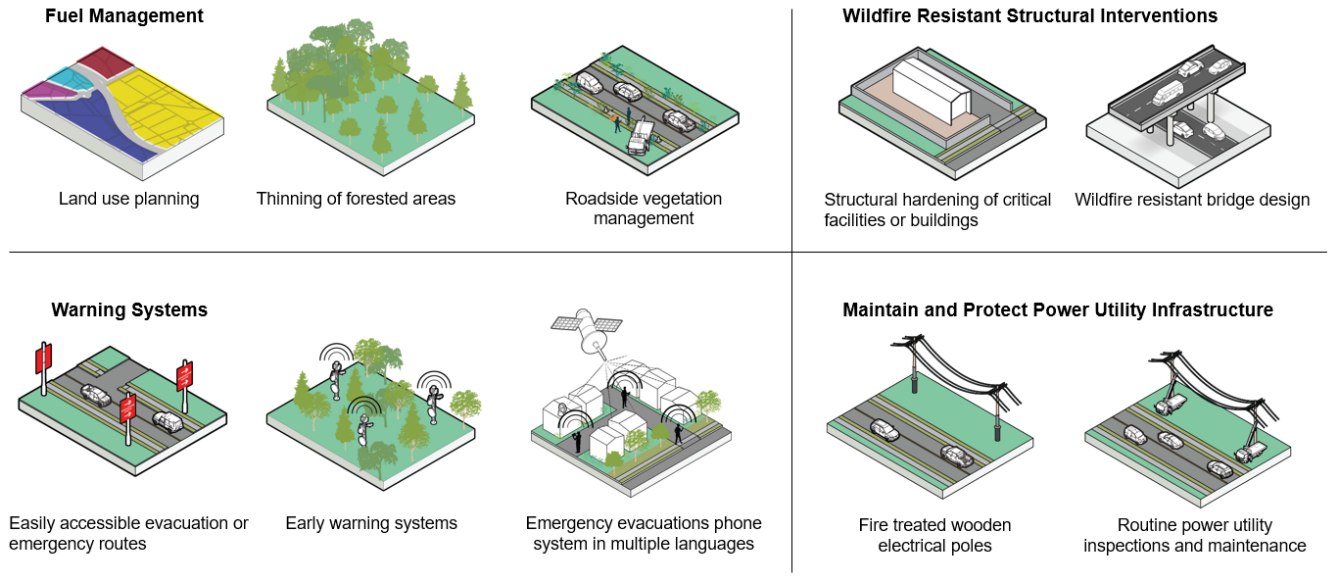
Flooding

Figure 4-88: Adaptation solutions for flooding



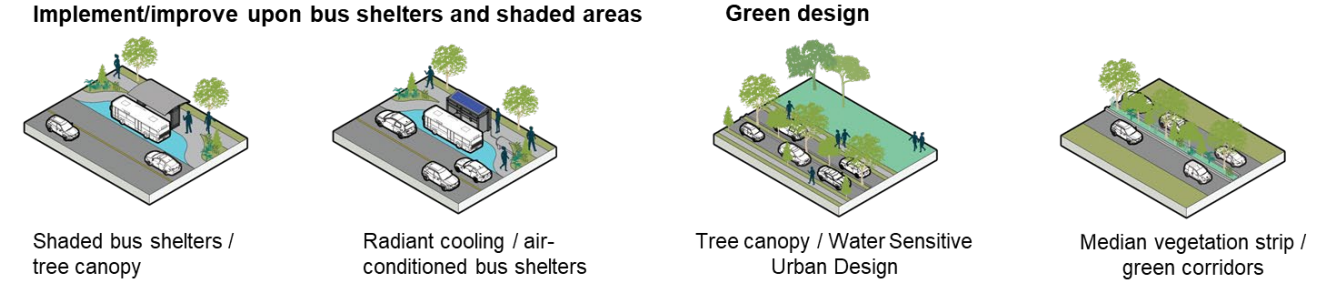
Wildfire

Figure 4-99: Adaptation solutions for wildfire



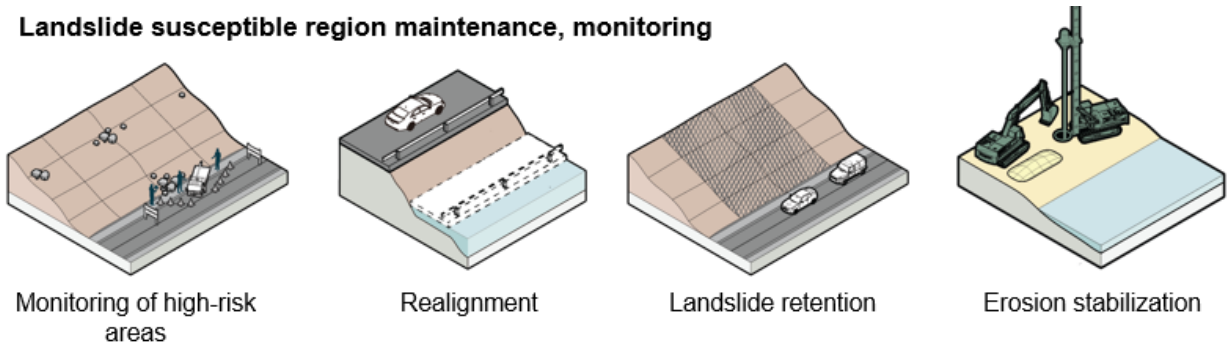
Heat

Figure 4-1010: Adaptation solutions for heat



Landslides

Figure 4-1111: Adaptation solutions for landslide



5. Priority Projects

Building resilience within the county's transportation network requires targeted investments in infrastructure that can withstand and adapt to climate-related hazards. Through a rigorous analysis of climate projections, risk assessments, and transportation asset vulnerabilities, a list of five priority projects were identified, designed to immediately enhance the county's ability to adapt to increasing frequency and severity of climate events. These projects serve as foundational efforts in mitigating risks associated with flooding, wildfires, extreme heat, and landslides.

These five priority projects were identified based on feedback and guidance from the TWG and CWG and the public, as well as the projects' ability to deliver meaningful benefits across multiple criteria, including:

- **Climate Adaptation and Resilience**: Enhancing the durability and adaptability of critical transportation infrastructure.
- **Equity and Community Well-being**: Prioritizing projects that serve equity priority communities and improve access to essential services.
- **Infrastructure Criticality**: Addressing vulnerabilities in transportation assets that are vital for economic activity and emergency response.
- **Multi-Benefit Solutions**: Designing projects that provide additional benefits beyond resilience, such as improving public safety, reducing maintenance costs, and supporting sustainable transportation modes.

The following sections provide a detailed examination of each priority project, outlining the specific vulnerabilities they address, the proposed solutions, and the expected benefits for the county's residents and transportation network. The proposed solutions include both physical infrastructure projects and programs. These adaptation and resilience projects were conceptualized and designed so that they align with – and don't unintentionally conflict with – important local goals such as sustainability, walkability, connectivity, accessibility, and economic development. Cross-agency collaboration and problem-solving can help to foster such a shared and aligned vision during future planning and implementation efforts. Across hazards, improving early warning systems, cross-agency coordination, and culturally-

appropriate communication methods will support emergency response and reduce the impacts of transportation disruptions on the most vulnerable populations. This includes Fresno COG's ongoing coordination with Fresno County's Office of Emergency Services and other response agencies.

Project costs were estimated by considering a typical installation, its appropriate estimated size, and its key components, operations, and maintenance costs. Costs have been provided for physical infrastructure projects, while programs require dedicated agency staff time and have not been costed. Costs incorporate both direct and indirect costs, including General requirements, Overhead and Profits (OH&P) and Design & Construction Contingency. References for costs include Arup benchmark projects and other industry sources.

To develop costs, unit costs were identified for each relevant treatment strategy, according the unit that was most relevant to the installation scale (e.g., mile, each, SF) with a base date of 2025, factored to Fresno County, California. Unit costs were multiplied by an estimated number of units according to assumptions regarding that project's typical installation sizing. Total indirect costs were calculated and added to total direct costs for a total construction cost, which was then applied to a low and high accuracy range -30%/+50%.

In the case of bus shelters, the estimate includes equipment pads and standard shelter units with benches but excludes excavation from the unit cost. For wildfire prevention strategies, only the cost of mechanical thinning is included.

Annual operations and maintenance (O&M) costs are derived from a variety of sources, with referenced links provided in the estimate. These costs may vary depending on the specific methods and services employed.

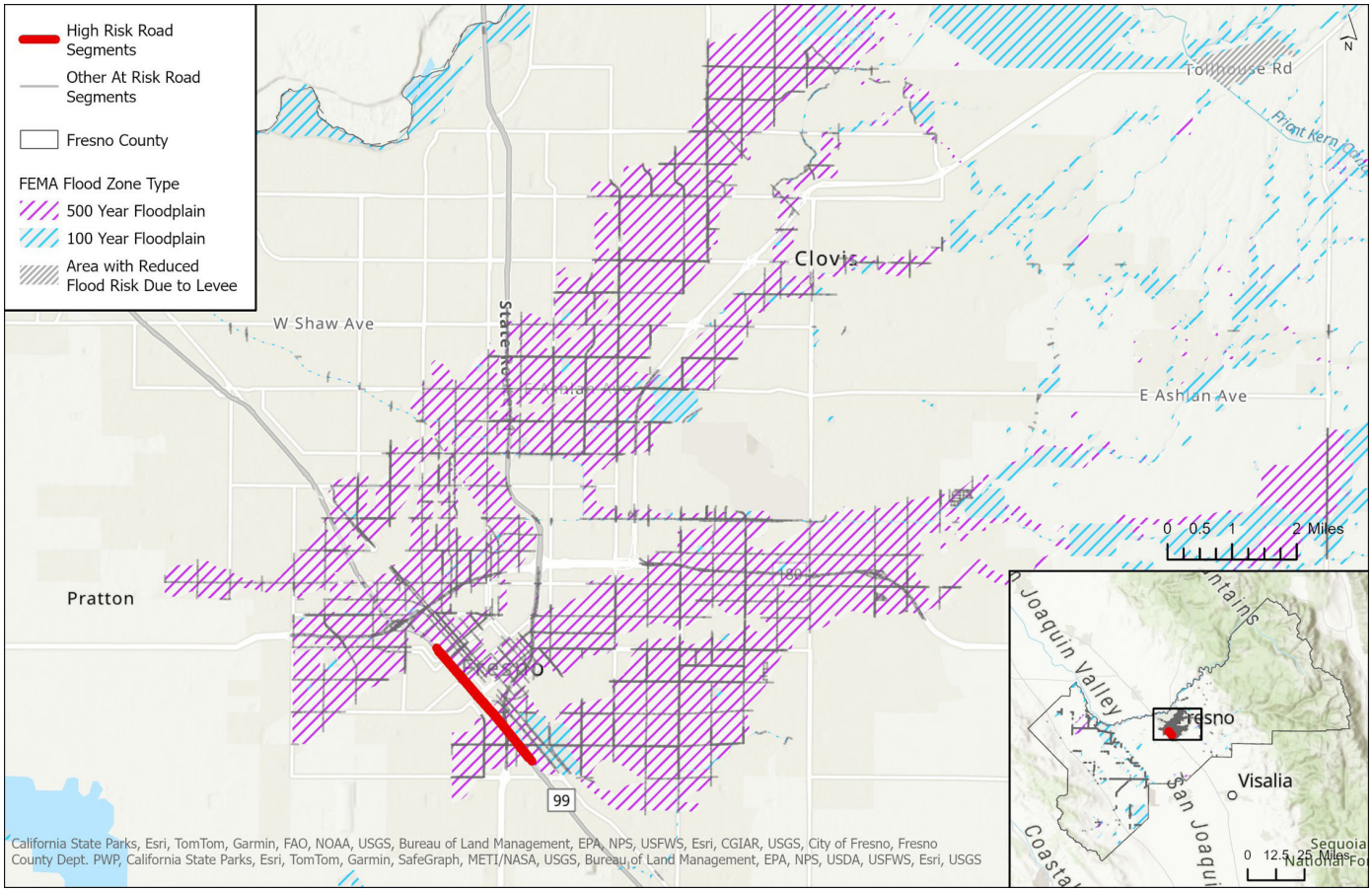
The estimate excludes a number of potential costs and risks, including Owner's soft costs such as permits, fees, and management, and those costs related to latent environmental issues, demolition, utility relocation or installation (unless explicitly stated), risk-based contingency analysis, and external testing or inspections. It also does not account for compensatory costs, regulatory changes, technological advancements, hazardous material mitigation (unless stated), agency administrative expenses, owner-led quality assurance, archaeological discoveries, or local taxes and duties.

PRIORITY PROJECT 1

MITIGATE FLOODING ALONG STATE ROUTE 99

What's At Risk

High flood risk road segment identified for urban Fresno



State Route 99 is a regionally significant north-south corridor through the Central Valley, and a locally important route for Fresno, Clovis, and many Equity Priority Communities.

Flooding along SR-99 in Fresno can cause significant road closures and delays, particularly at the SR-99 / Olive Avenue interchange. Specifically, a 4.5-mile segment (shown in red above) often fails during heavy rainfall due to its low elevation which collects stormwater, leading to hazardous driving conditions and increased accident risk. Priority Project 1 aims to mitigate flooding along SR-99 through stormwater infrastructure improvements and effective flood management to reduce the impacts of stormwater runoff.

Community members noted that the flooding risk along SR-99 extends to South Fresno communities including Calwa and Malaga. Therefore, mitigation planning studies should account for flooding not only at the indicated downtown area but also along connected reaches of SR-99.

Potential Impacts

Asset Criticality

SR-99 serves multiple purposes:

The county's most significant regional route for vehicles, freight, and transit with direct access to Fresno.

Serves Equity Priority Communities.

Potential Consequences

Flooding impacts vary depending on severity, described below:

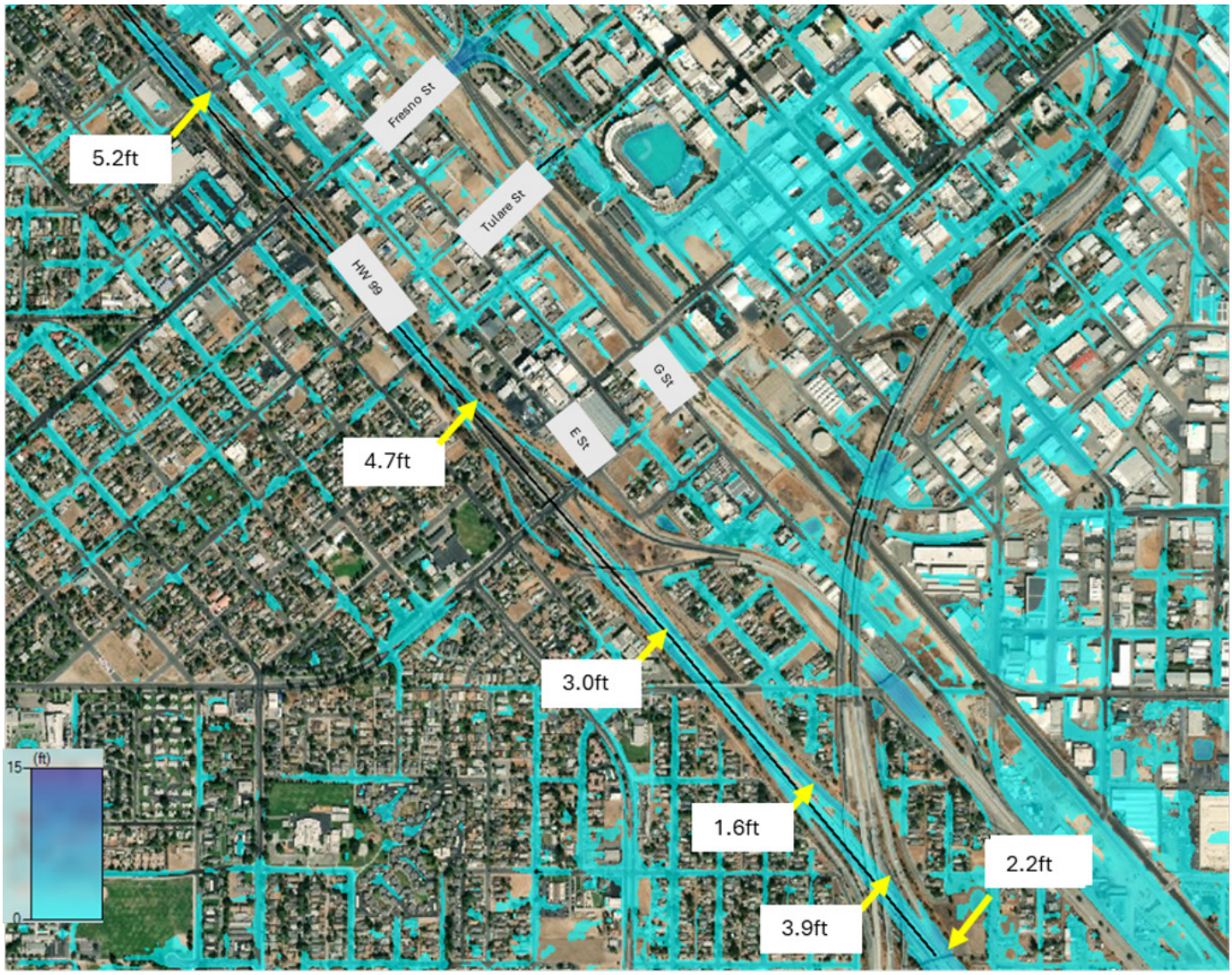
Up to six inches:
Unsafe driving conditions which can result in road closures of a few hours.

Six inches or more:
Exposure to this level of flooding causes clearance issues for vehicles and may result in a range of minor to significant repair needs, depending on the flood velocity. The resulting road damage may lead to closures lasting from several days to several weeks, especially if roads are washed out.

SR-99 underpasses can create hazardous conditions during flooding events, as they are below grade and at lower points in the urban drainage.

Additional Considerations

Projected flood depths



Flood depths of up to five feet can occur along SR-99 during a 100-year storm event, for present-day climate.

Preliminary Hydrologic Engineering Center's River Analysis System (HEC-RAS) modeling* revealed the potential for impactful flooding along this segment of SR-99, with depths reaching up to five feet for a 100-year storm event. This depth could increase to more than seven feet at the end of the century, under a high greenhouse gas emissions scenario.

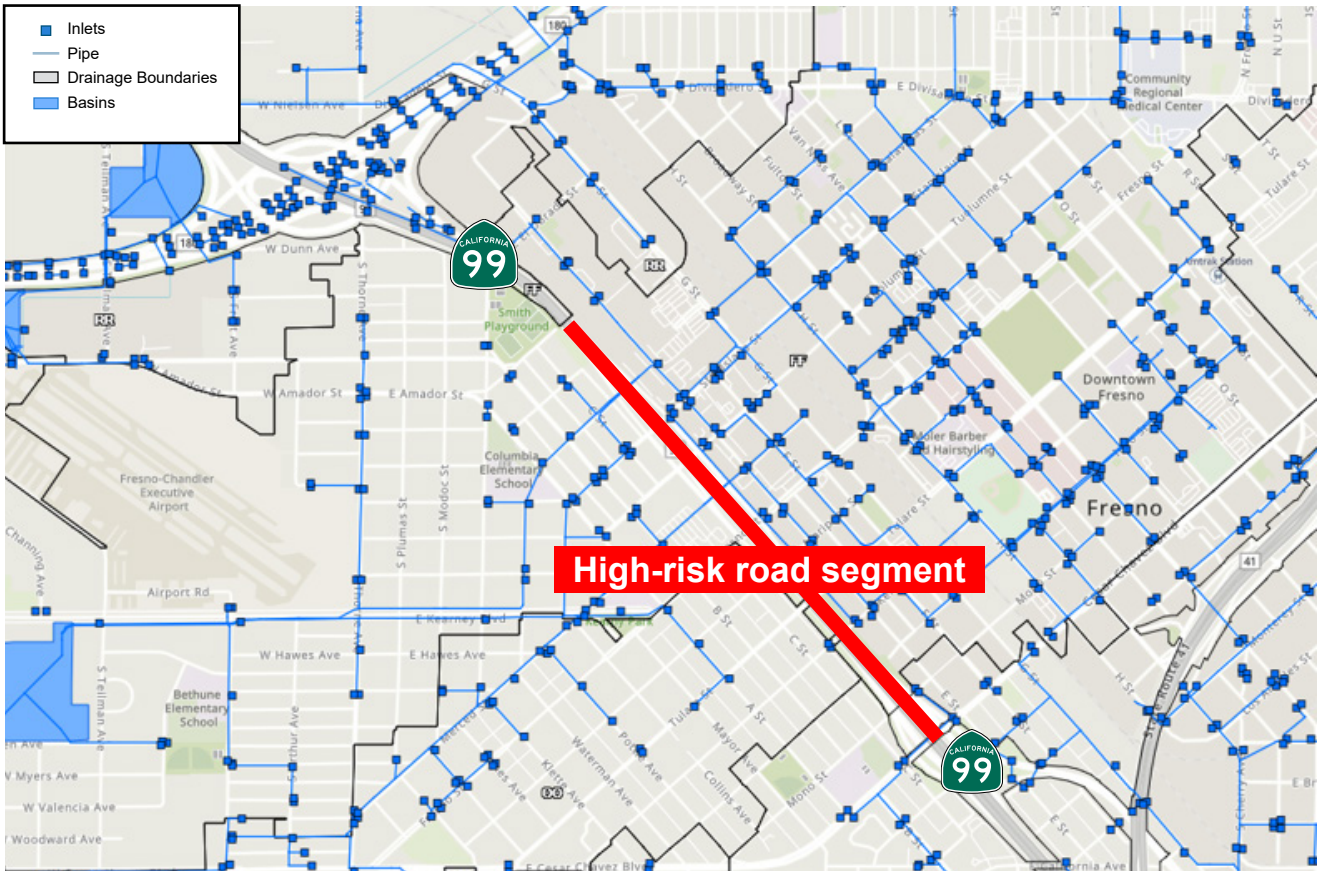
**Fresno COG performed this analysis for conceptual design level planning purposes only. Additional analysis is required for project engineering design.*

Recommended Treatments

Collaborate with the Fresno Metropolitan Flood Control District on two treatments to reduce the volume of stormwater that accumulates during rain events at underpasses and low points along SR-99:

Short Term	Long Term
Implement green stormwater infrastructure features, like bioretention basins, swales, and tree pits throughout the drainage, especially in areas northeast of SR-99.	Integrate climate projections into the storm system master plan sizing to account for more variable (more frequent and intense) storm events.

Currently, stormwater basins are located at the bottom of the drainage surrounding this high-risk segment of SR-99, as water flows northeast towards the southwest end of the drainage (see the drainage boundary in the image below).

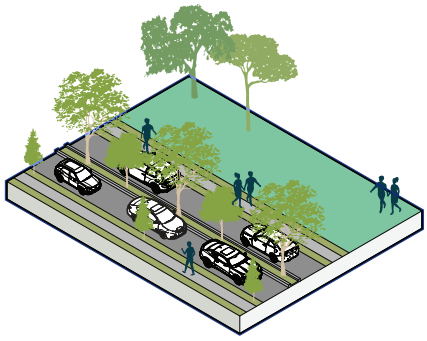


Stormwater management controls placed throughout the drainage, at the northeast end and throughout downtown Fresno, could help to mitigate the volume of runoff that enters the storm system or that flows onto this segment of SR-99. Sizing the storm system to account for larger precipitation events and flooding can help to move stormwater runoff from the street surface and into existing stormwater treatments, such as bioretention basins.

Recommended Treatments

01 | Green Stormwater Infrastructure

Regional stormwater retrofits (e.g., bioretention basins) or other green stormwater treatments could be applied throughout Fresno to reduce the volume of stormwater that collects around SR-99. This could include interventions like pervious pavement and bioretention basins, swales, and tree pits. Bioretention basins alone are not sufficient for larger storm events, but can provide multiple benefits beyond reducing stormwater volume, including supporting cooler, green, and more walkable corridors. If designed holistically, stormwater measures can could enhance connectivity and walkability.



Social / Health

- Maintains accessibility across Fresno County
- Connects communities to services
- Urban heat island reduction/heat relief and cooling
- Health improvement from improved air quality

Environmental

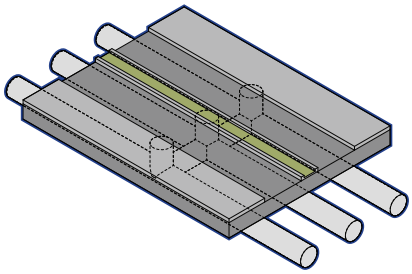
- Enhances biodiversity
- Improves water quality
- Improves air quality

Economic

- Maintains access to high demand roads
- Reduces costs of road maintenance and repairs

02 | Update the Storm System Master Plan

Incorporate climate projections into the Fresno Metropolitan Storm Drainage and Flood Control Master Plan to consider increasing variability of storm events. Collaborate with Fresno Metro Flood Control District to consider storm system sizing for more intense and more frequent storm events.



Social / Health

- Maintains accessibility across Fresno County
- Connects communities to services

Environmental

- Improves water quality

Economic

- Maintains access to high demand roads
- Reduces costs of road maintenance and repairs

Treatment Costs

Typical components of bio retention basins, bio swales, and tree pits include soil amendments, geotextiles, and substrate, vegetation, root protection, drainage and overflow mechanisms, irrigation, and aeration.

Treatment Type	Cost Range	Assumptions
Bio Retention Basin	$35k-$75k per basin	600 ft^2 @ $50/$ft^2$ (direct costs) $33/$ft^2$ (indirect costs)
Bio Swale	$59k-$126k per swale	600 ft^2 @ $85/$ft^2$ (direct costs) $55/$ft^2$ (indirect costs)
Tree Pits	$18k-$38k per tree pit	600 ft^2 @ $25/$ft^2$ (direct costs) $17/$ft^2$ (indirect costs)

Annual O&M

Annual O&M costs ($0.5-$1 / sf) include preventive maintenance costs and operational costs as per stormwater manuals.

Implementation

Implementing bioretention features like basins, swales, and tree pits throughout the urban drainage provides a cost-effective approach to managing stormwater when coupled with stormwater master planning. These features can be applied in rights of way to provide shade and vegetation along streets for more cool, walkable corridors. Stormwater volume improvements are likely to be more impactful with application of bioretention features in approximately 5-10% of the drainage area.

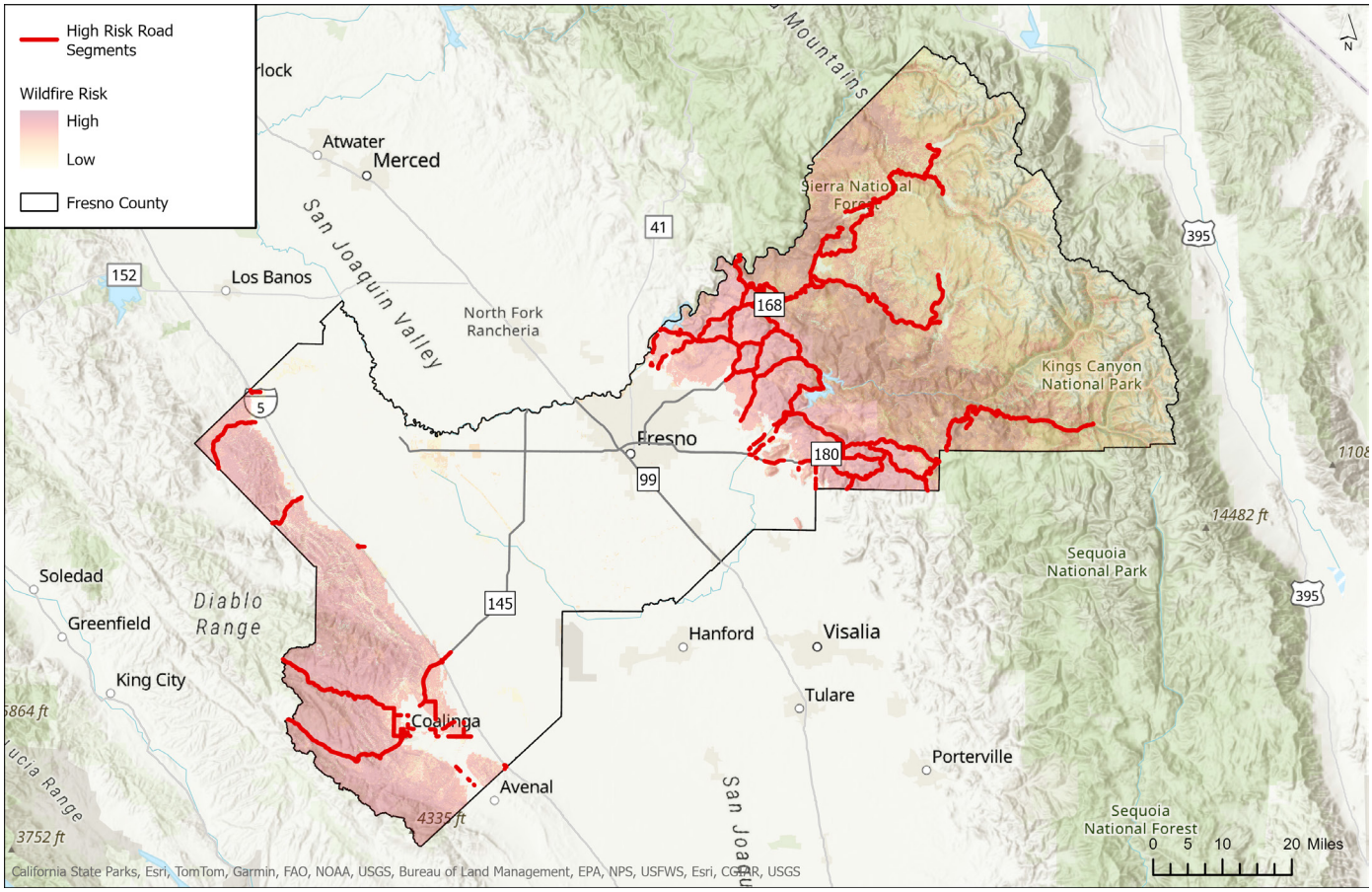
Example of a bioretention trench with trees and vegetation designed to capture, infiltrate, and release stormwater runoff from the sidewalk and a curb cut.

PRIORITY PROJECT 2

MITIGATE WILDFIRE IMPACTS TO THE COUNTYWIDE ROADWAY NETWORK

What's At Risk

High wildfire risk road segments identified in Fresno County



With 483 miles of priority road segments running through wildfire-prone foothill and mountain areas flanking Fresno County's eastern and western reaches, climate projections indicate that the likelihood of wildfires here could triple by the end of the century. These fires, along with landslides, put mountain roads at high risk of closure, isolating residents and cutting off access to essential services and evacuation routes. Additionally, disruptions to these roads impact visitors traveling to Kings Canyon National Park, a vital resource for tourism and the local economy.

Priority Project 2 aims to mitigate the impact of countywide wildfires on the county's mountain road network, ensuring safe, alternative routes for both emergency responders and the communities that depend on these roads for daily life and emergency evacuations.

Potential Impacts

Asset Criticality

The countywide roadway network serves multiple purposes:

Critical emergency access and evacuation routes.

Serves multiple FCRTA routes.

Serves rural, isolated communities and Equity Priority Communities.

Primary access routes to Kings Canyon National Park and Sierra National Forest, and several State facilities.

Potential Consequences

Wildfire impacts vary depending on severity, described below:

Small grass or brush fire near the road: Several days of downtime due to the route being closed from wildfire smoke or evacuation precautions.

Larger, high intensity forest fire near the road: Weeks of downtime due to significant loss of operability from debris or wildfire smoke.

Structural damage to bridges: months of downtime due to closure and repairs.

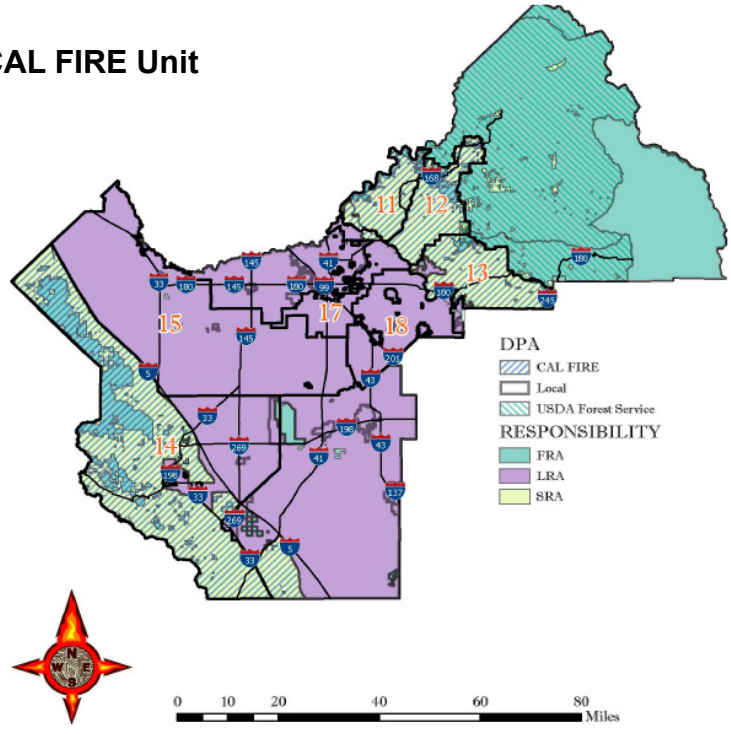
Rural populations may become endangered

if major access routes, such as SR-168 and SR-180 are obstructed during wildfire.

Emergency responders may be unable to perform lifesaving efforts due to road obstructions.

Coordination within the Fresno-Kings CAL FIRE Unit

The roads at highest risk are located within CalFIRE Federal Responsibility Areas (FRAs) and State Responsibility Areas (SRAs) pertaining to Battalions 11, 12, 13, and 14. Fresno COG should complement efforts of the US Forest Service and the Vegetation Management Program projects (VMPs) led by these CalFIRE Battalions in High and Very High Fire Hazard Severity Zones.

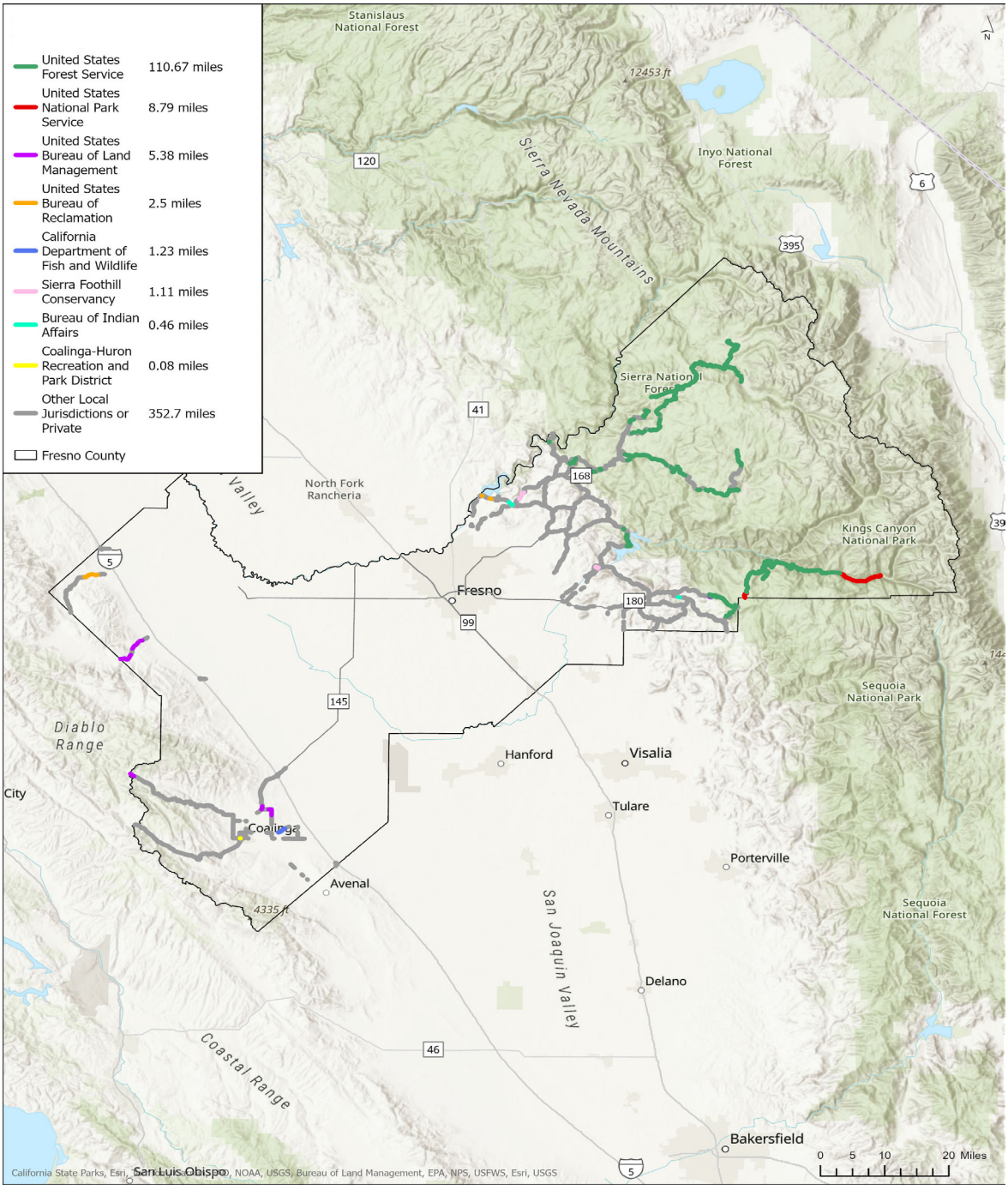


Additional Considerations

Interagency Coordination

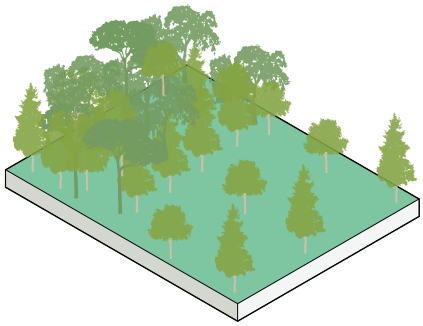
Fresno County requires a coordinated response to address future wildfires given the number of agencies and jurisdictions who manage land in the county. Of a total of 483 high wildfire risk roadway segments, 110 miles are on land managed by the U.S. Forest Service (USFS). Local jurisdictions manage another 352 miles. Working in partnership with land managers to remove deadfall from forested areas and create healthier forests will reduce risks to roadways and maintain evacuation routes during wildfires.

High risk road segments by land manager



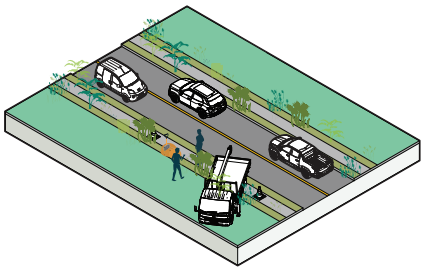
Recommended Treatments

Efforts to reduce wildfire risk should focus on clearing dry, dead vegetation (i.e., ground fuels) and enhancing evacuation plans along high-risk roads. Since the foothills and the mountains have different management needs, fire prevention strategies will vary. Fresno COG should work alongside agencies like CalFIRE, the USFS, the Sierra Resource Conservation District (SRCD), and local fire councils and departments to support ongoing fire prevention projects. For example, the SRCD is working to secure funding for wildfire protection plans along SR-168 and SR-180 in partnership with the SR-168 Fire Safe Council. Communities are working with CalFIRE and conservation districts on Firewise wildfire planning in private land and need support coordinating with Caltrans and other agencies for projects near roads.



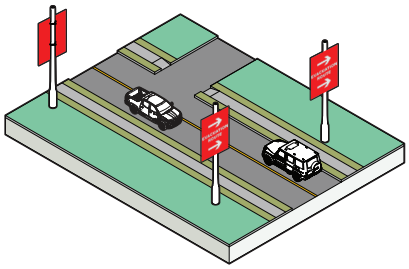
Complement Projects to Clear Ground Fuels

The high wildfire risk road network is located along land managed by the USFS (110 road miles), National Park Service (9 road miles), and the Bureau of Land Management (BLM) (5 road miles) (see map on previous page). Fresno COG should partner with CalFIRE, USFS, and SRCD to clear ground fuels from forested areas along the high wildfire risk road network and create fuel breaks, prioritizing those areas that have been impacted by beetles, including along SR-168. Resources and gaps on private lands present challenges to more comprehensive ground fuel clearance along roadways.



Support Unfunded Priority Areas & Seek Innovative Financing

Fresno COG could explore partnerships with The Nature Conservancy and Blue Forest to identify innovative financing approaches to healthy forest management and fuels reduction. These groups and others explore impact investment models and resilience bonds to reduce upfront capital costs of wildfire mitigation, including forest thinning, clearing ground fuels, reforestation, and healthy forest management.



Evacuation Planning

Enhancing emergency access roads and establishing well-coordinated evacuation plans are essential for wildfire preparedness. Fresno COG should support efforts, like those led by SRCD to improve alternative emergency routes, to mitigate risks along evacuation corridors, strengthen route redundancy, and routinely assess emergency management systems to ensure seamless communication between emergency responders, isolated communities, and road network managers.

Treatment Co-Benefits

Social / Health

- Improves air quality; reduces impacts of fires on respiratory and cardiovascular health
- Connects communities to services
- Emergency Response Preparedness: maintains ingress and evacuation access

Environmental

- Protects air quality
- Reduces greenhouse gas emissions from fires
- Reduces vulnerability to landslide and debris flow, following wildfire

Economic

- Maintains accessible roads of high demand
- Reduces costs of road maintenance and repairs following wildfire
- Avoids loss of life and property

Treatment Costs

Treatment Type	Cost Range	Assumptions
Mechanical Thinning	$38k-$82k per road mile with buffer	1 mile x 400 ft width = 50 acres; $650/acre (direct costs) $420/acre (indirect costs)

Annual O&M

Because brush removal is type of maintenance activity, no O&M costs are considered here. However, thinning and brush removal may be required every few years, depending on the type of vegetation, annual rainfall, degree of beetle damage, and other ecological factors.

Implementation

Mechanical thinning involves selectively removing brush, dead trees, and overgrowth to establish healthier, fire-resistant forests using equipment like chainsaws and precision tree removal machinery. The process may involve marking trees that will be removed for improved accuracy and reduced damage. A typical project may include about 50-100 acres, with a 200 ft buffer on either side of the road.

PRIORITY PROJECT 3

MITIGATE EXTREME HEAT AT URBAN TRANSIT STOPS

What's At Risk

The Central Valley is facing rising temperatures, posing health risks to people when they are outdoors. Today, summer temperatures already reach 116 °F, during heat waves. By 2050, the heat index in Fresno County could increase by 5°F, and by 2085, by 11°F, making heat events even more dangerous. People who walk, bike, and ride transit are particularly vulnerable to these extreme temperatures, facing risks such as heat exhaustion and heat stroke.

Priority Project 3 aims to identify bus stops served by FAX, Clovis Transit, and FCRTA throughout Fresno and Clovis that need bus shelters, better shading, and tree canopies to provide critical health benefits to those who are transit dependent. With over 1,500 bus stops across the city, stop locations and surrounding areas are scored and ranked by ridership and other factors to prioritize improvements that will protect transit riders exposed to heat in the warmer months.

Potential Impacts

Asset Criticality

Fresno's public transit system is an essential component of the countywide transportation network:

It has multiple local and regional transit routes provided by: FAX, Clovis Transit, and FCRTA.

Serves youth, seniors, and others who are unable to drive.

Serves multiple Equity Priority Communities.

Potential Consequences

Heat impacts vary depending on severity:

Increased risk of heat-related illnesses including heat exhaustion (103°F to 124°F), and heat stroke (which becomes a serious threat at 125°F and above), posing a risk of hospitalization or death.

Outdoor workers, pregnant women, and individuals with asthma or cardiovascular disease are most impacted by heat-related illness.

Dependence on public transit can further exacerbate these risks, highlighting the need for effective heat mitigation strategies.

The table below shows that heat indices of 103°F or higher can result in dangerous heat disorders with prolonged exposure or physical activity outdoors. Direct sunlight can increase temperatures by up to 15°F, highlighting the importance of shade in mitigating heat-related health risks.

Classification	Heat Index	Effect on the body
Caution	80°F - 90°F	Fatigue possible with prolonged exposure and/or physical activity
Extreme Caution	90°F - 103°F	Heat stroke, heat cramps, or heat exhaustion with prolonged exposure and/or physical activity
Danger	103°F - 124°F	Heat cramps or heat exhaustion likely, and heat stroke possible with prolonged exposure and/or physical activity
Extreme Danger	125°F or higher	Heat stroke highly likely

Source: National Oceanic and Atmospheric Administration

Existing Conditions

Given the uniformly high heat risks throughout Fresno/Clovis, Fresno COG analyzed bus stops and their surrounding areas based on the following criteria:

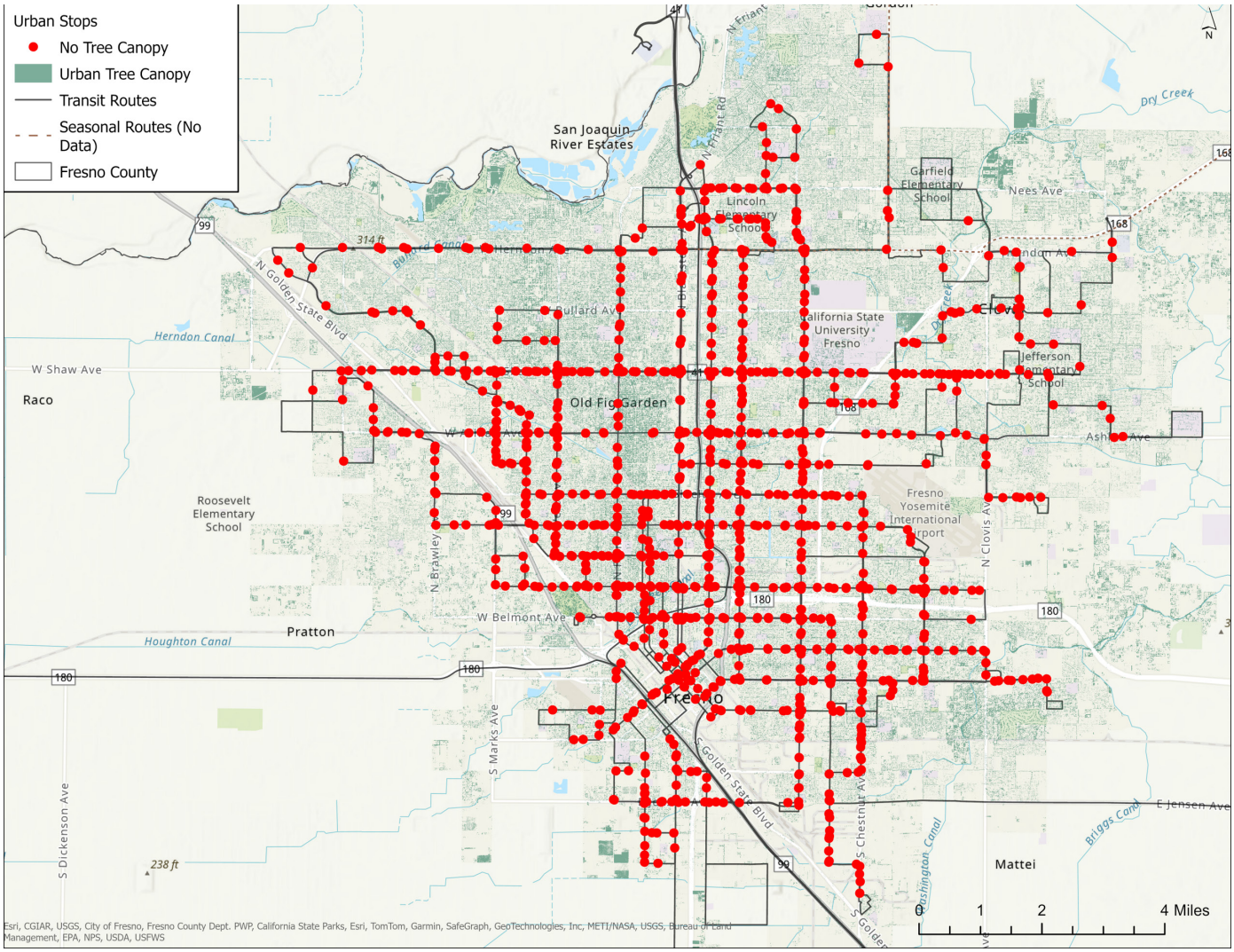
Tree Canopy
Is there adequate tree canopy coverage at this bus stop and surrounding streets?

Bus shelters and seating: Does this bus stop have seating with shade-providing shelter? (This information was not available at the time of writing. An inventory of existing bus shelters is an important next step to determine which stops require shelter installation.)

Ridership
Does this stop have low, medium, or high ridership compared to other transit stops?

Frequency
Does this stop have low, medium, or high frequency of service compared to other transit stops?

Urban Tree Canopy

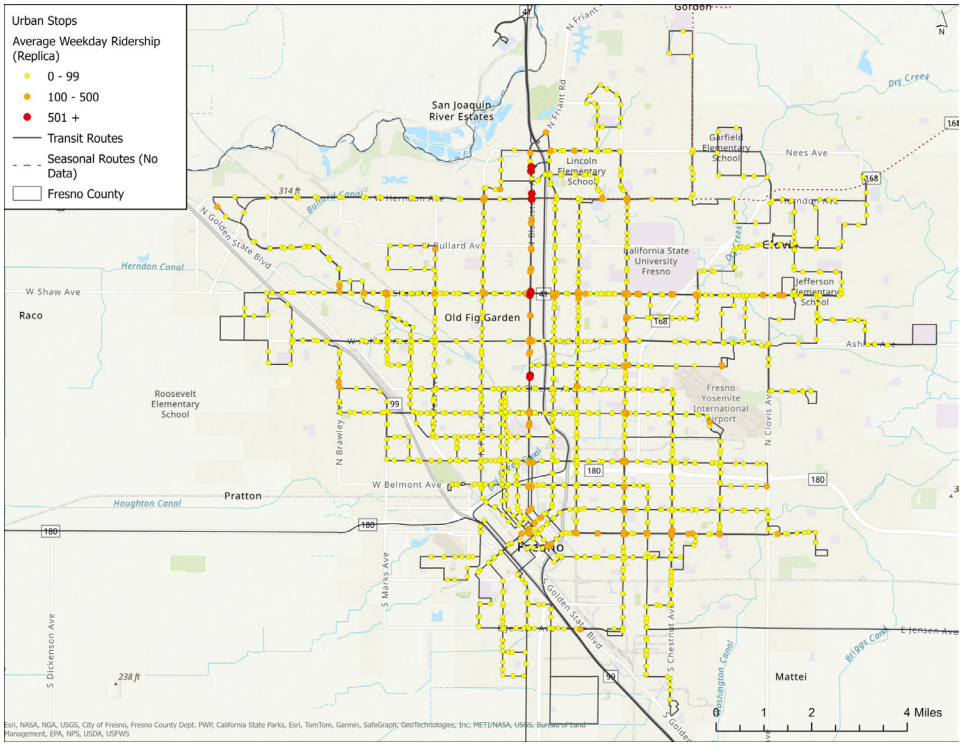


Fresno/Clovis has over 1,500 bus stops served by FAX, Clovis Transit, and FCRTA. Based on data from the USFS, 74 percent of these stops and surrounding areas may be lacking adequate shade from the tree canopy.

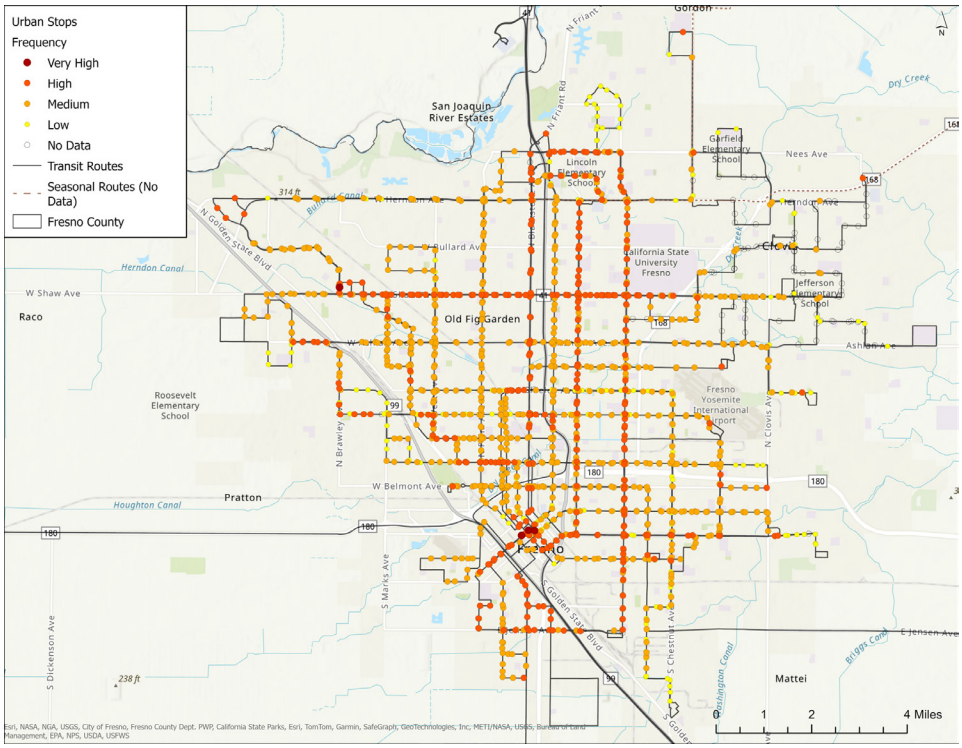
Existing Conditions

The highest ridership lines in Fresno are FAX-01-Q - BRT, FAX-38-Cedar, FAX-09-Shaw, and FAX-34-First Street.

Transit Ridership



Transit Frequency



Recommended Treatments

Recommendations to mitigate extreme heat at transit stops in the City of Fresno fall into high, medium, and longer-term categories. Notably, passive cooling approaches at transit stops can help to maximize thermal comfort. Design solutions include considerations of solar reflectance, albedo, and heat absorption of materials, shade from nearby buildings, solar orientation, mixing and layering shade, and pedestrian routes and connectivity.

High Priority Recommendations

Develop a comprehensive inventory of bus shelters to identify candidate locations for future investment.

Install bus shelters where absent around high frequency/ridership stops.

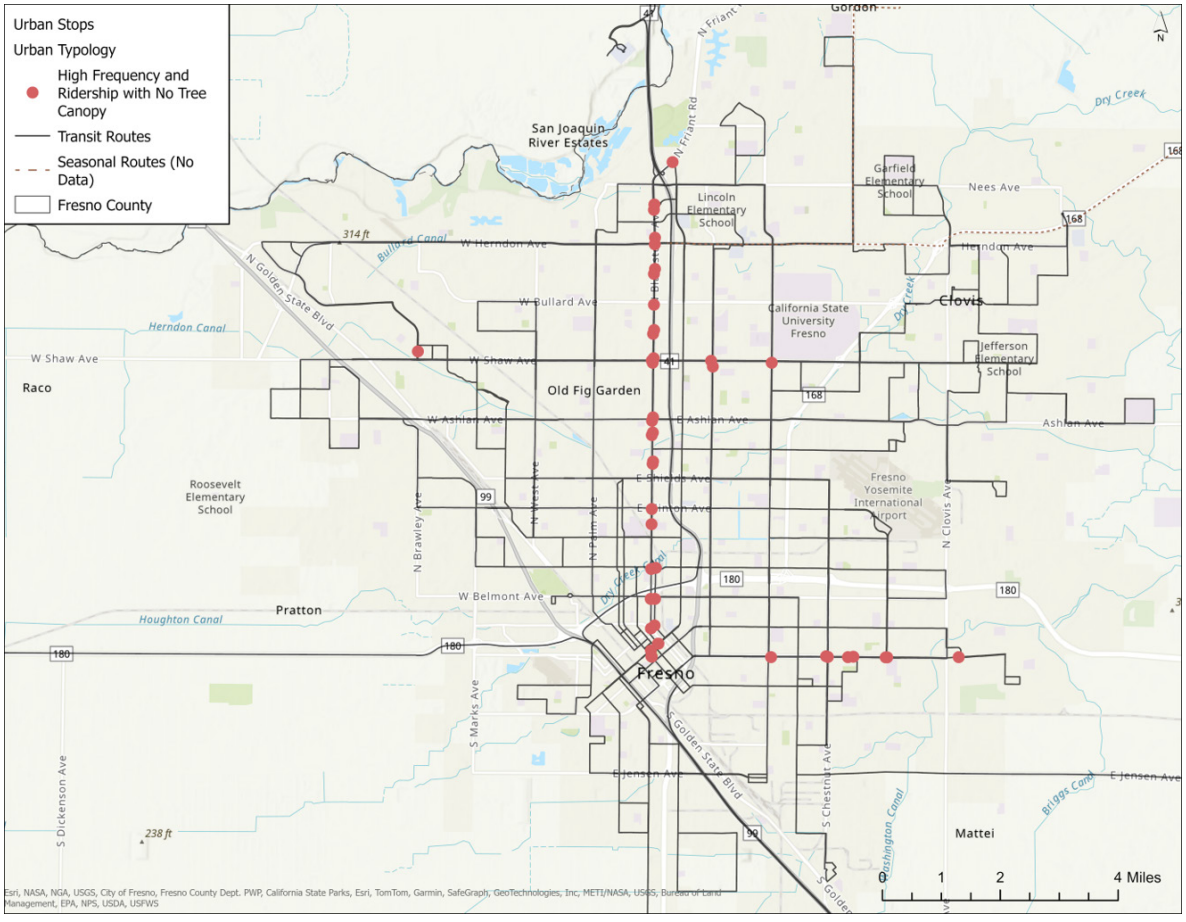
Develop a shade tree and landscaping planting plan for:

- Blackstone Avenue
- Eastern end of the Cesar Chavez/ Kings Canyon Road

Prioritize radiant cooling/air-conditioning at major transit hubs such as:

- Downtown Transit Center
- Manchester Transit Center
- Major stops that serve Cal State Fresno
- Future High Speed Rail Station

High Frequency/Ridership with No Tree Canopy



*Bus stop IDs/locations are available in Appendix 9

Recommended Treatments

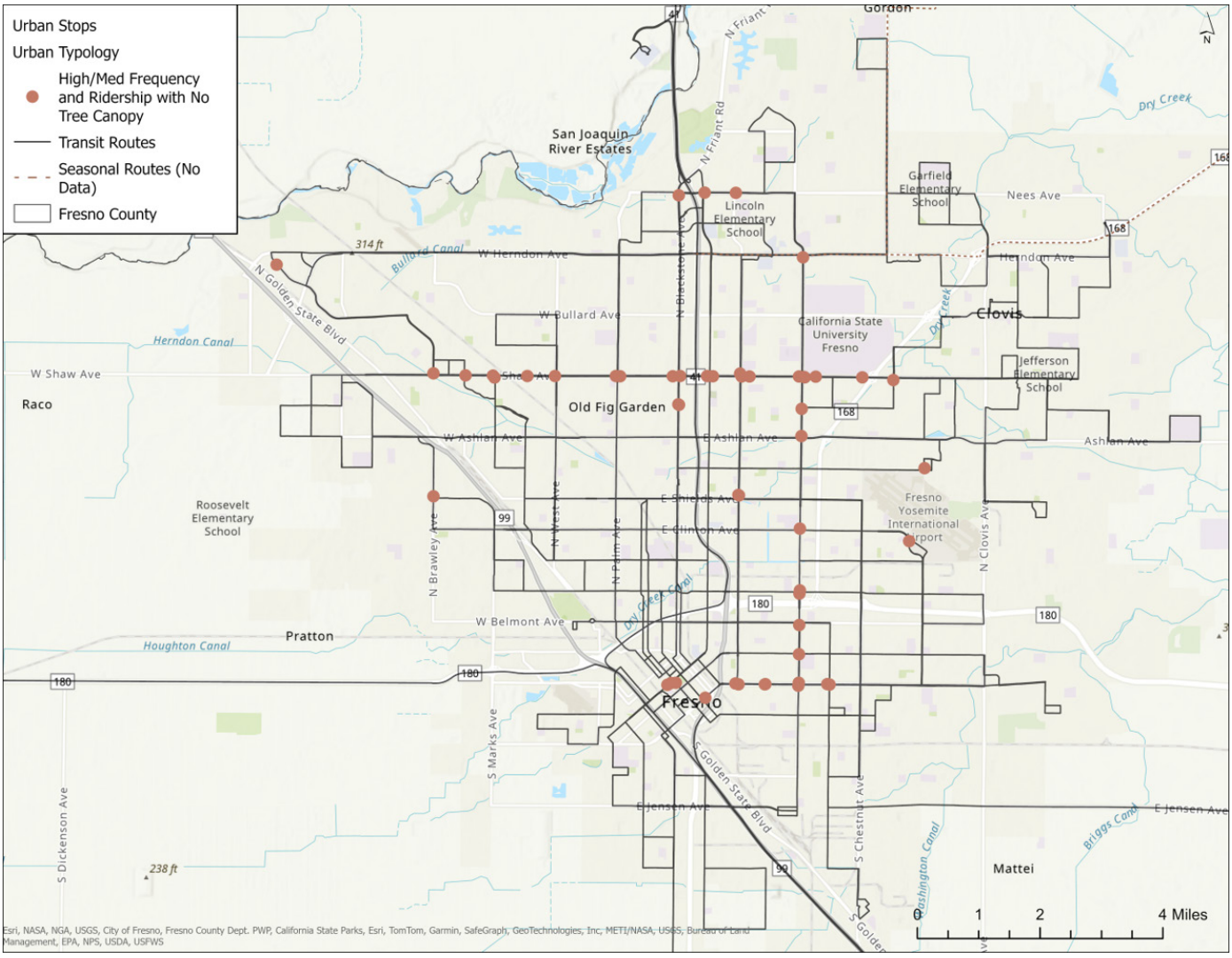
Medium Priority Recommendations

Install bus shelters where absent around medium frequency/ridership stops

Develop a shade tree and landscaping planting plan for:

- Shaw Avenue
- Western end of Cesar Chavez Boulevard
- Cedar Avenue
- Other spot locations as indicated

Medium Frequency/Ridership with No Tree Canopy



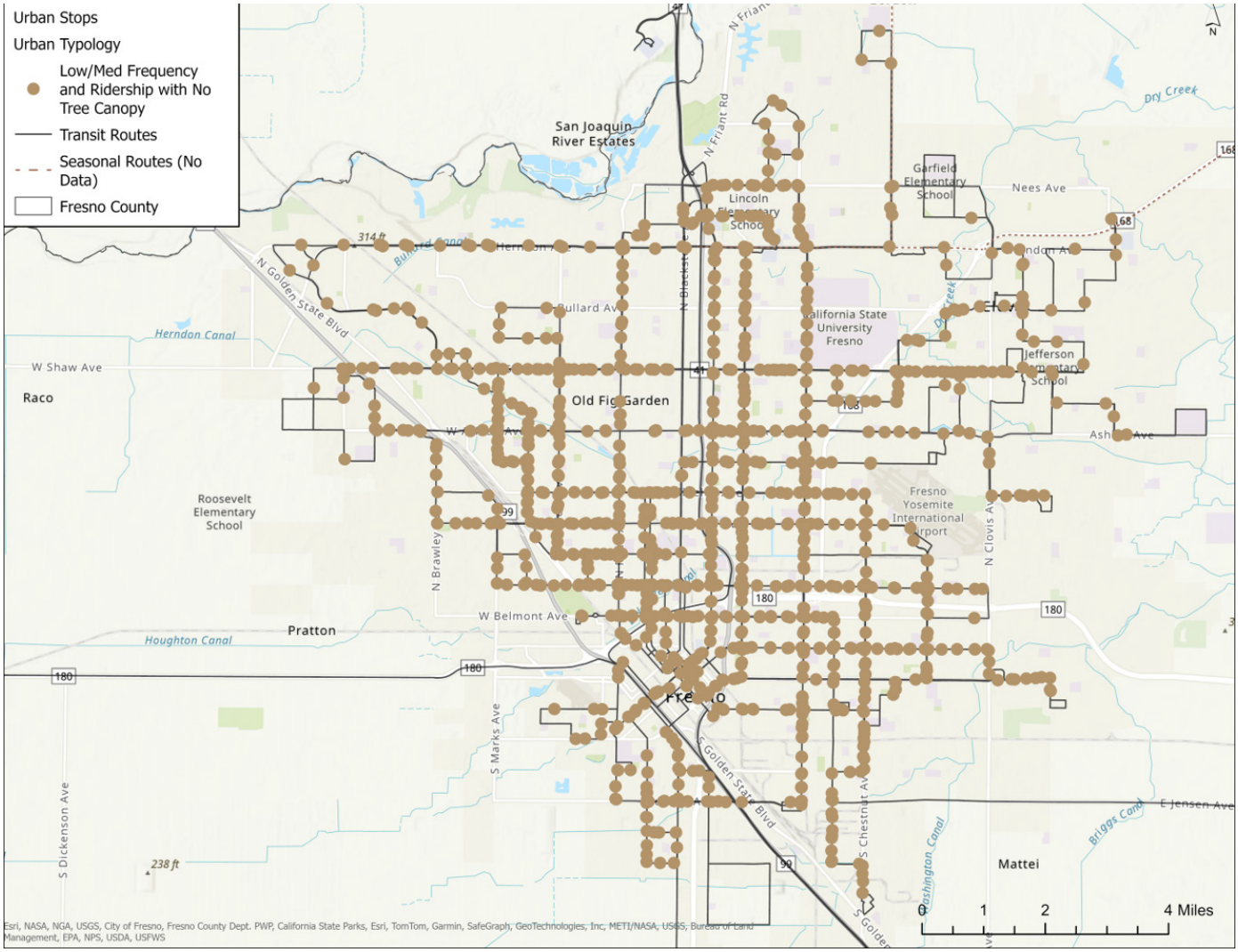
*Bus stop IDs/locations are available in Appendix 9

Recommended Treatments

Opportunistic / Longer Term Recommendations

Install bus shelters where absent around low frequency/ridership stops

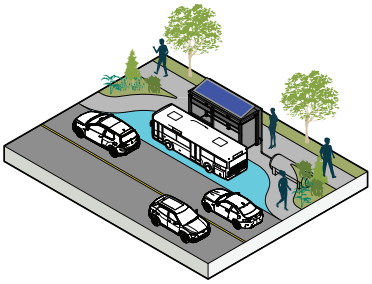
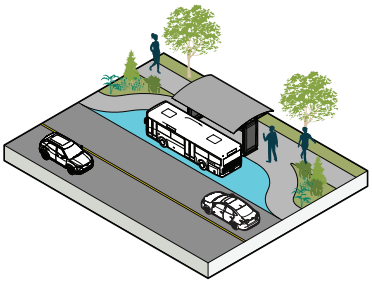
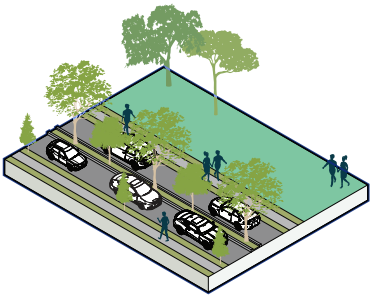
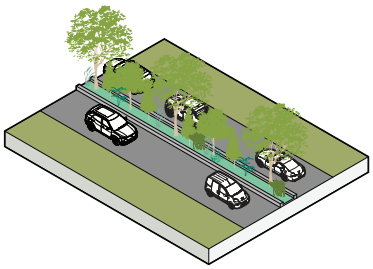
Low Frequency/Ridership with No Tree Canopy



Proposed treatments, including tree and landscaping plans, and radiant cooling/air-conditioning are described further on the next page.

*Bus stop IDs/locations are available in Appendix 9

Recommended Treatments

	Treatment	Description	Application
01	**Radiant cooling / air-conditioned bus shelters** 	Radiant cooling or air-conditioned bus shelters provide the most protection from heat. However, applications should be limited to the highest need locations due to the capital cost, maintenance, and energy requirements.	Major Transit Hubs
02	**Shaded bus shelters / tree canopies** 	Shelters and trees shade passengers waiting for the bus.	Bus stops that lack shelters and/or tree canopy with higher ridership and frequency.
03	**Tree canopies / Water Sensitive Urban Design** 	Planting trees around transit stops and incorporating bioretention basins into the public right-of-way areas.	Bus stops that lack tree canopy with moderate ridership and frequency.
04	**Median Vegetation Strip / Green Corridors** 	Creating shaded, green corridors using a combination of trees, bioretention basins, and vegetation at transit stops, rights of way, and medians along pedestrian routes.	Bus stops that lack tree canopy and areas with high pedestrian activity with low ridership and frequency.

Treatment Co-Benefits

Social / Health

- Provides relief from heat and provides outdoor thermal comfort
- Improves air quality from reduced use of personal vehicles
- Maintains accessibility across Fresno County
- Promotes connectivity

Environmental

- Reduces greenhouse gas from decreased personal vehicle dependence
- Improves air quality from reduced personal vehicle dependence

Economic

- Maintains public transit related jobs and access to jobs

Treatment Costs

Treatment Type	Cost Range	Assumptions*
Radiant Cooling / Air-Conditioned Bus Shelters	$21k-$45k per bus shelter	$18k per bus shelter (direct costs) $12k per bus shelter (indirect costs)
Shaded Bus Shelters / Tree Canopies	$14k-$30k per bus shelter / transit stop	$12k per bus shelter (direct costs) $8k per bus shelter (indirect costs)
Tree Canopies / Water Sensitive Urban Design	$28k-$60k per transit stop	Estimated area is 1000 LF $24k per transit stop (direct costs) $16k per transit stop (indirect costs)
Median Vegetation Strip / Green Corridors	$71k-$151k per transit stop and surrounding median	Includes one bioswale and median vegetation for 600 ft^2 $61k per transit stop/median (direct costs) $40k per transit stop/median (indirect costs)

* All treatment types include equipment pads and standard bus shelters with benches. Excavation costs not included.

Annual O&M

O&M includes weekly cleaning and incidental repairs, electrical maintenance of air conditioner, and tree and vegetation maintenance. O&M costs range from $2k to $4k annually for shade, bioswales, and vegetation at and around transit stops, and between $4k and $8k annually for air-conditioned shelters.

Implementation

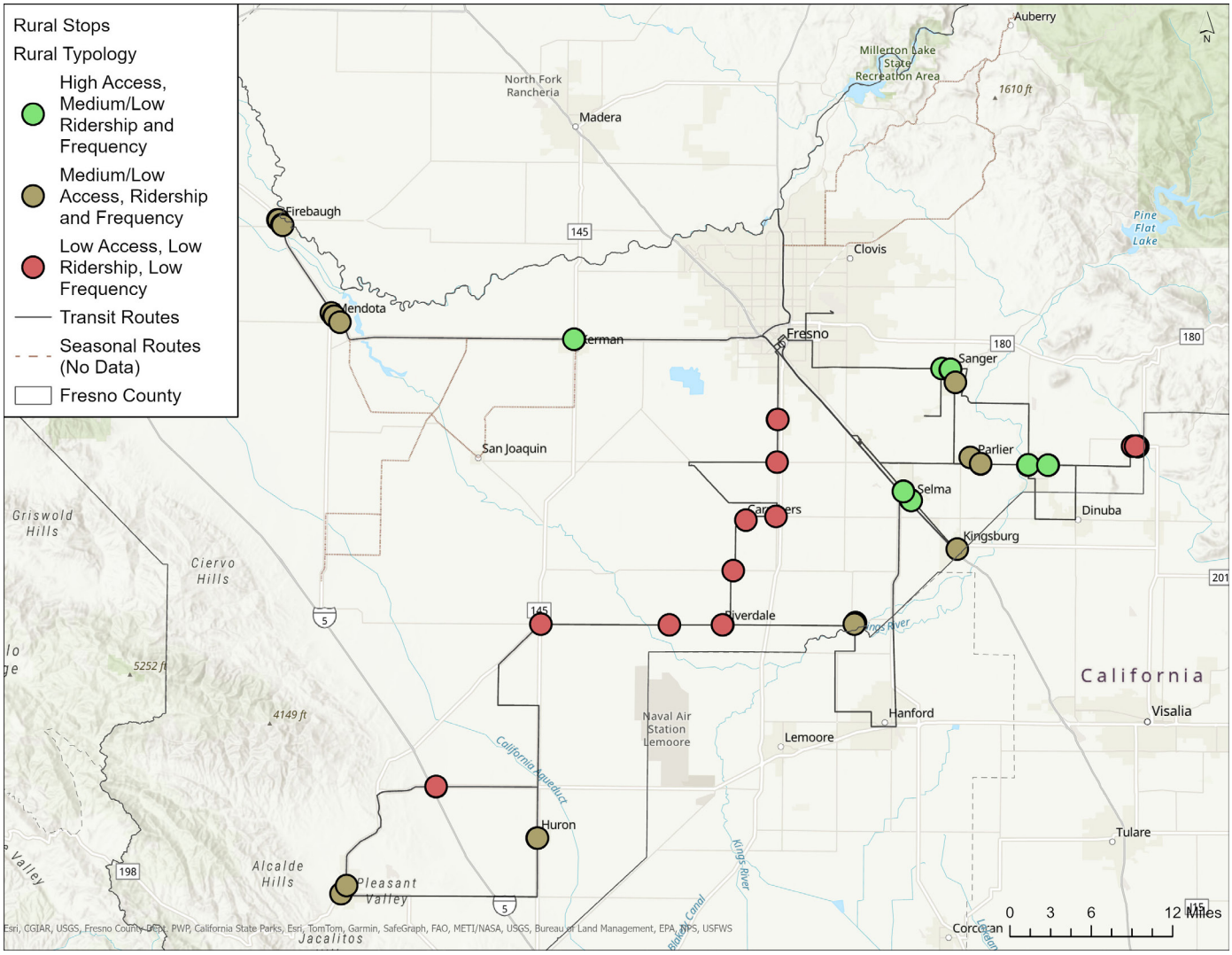
Cost ranges reflect costs for treatment of a single transit stop location. In practice, costs will multiply across prioritized transit stops, phased over time. For 25 high priority stops, implementing shaded bus shelters may cost about $350k to $750k in total.

PRIORITY PROJECT 4

MITIGATE EXTREME HEAT AT FCRTA TRANSIT STOPS

What's At Risk

Rural transit stops based on access, ridership, and frequency



In Fresno County's rural areas, transit riders face long wait times and limited access to essential services, making them especially vulnerable during extreme heat events. Today, summer temperatures can reach up to 116°F during heat waves, and by 2050, the heat index is projected to rise by 5°F, increasing by 11°F by 2085. This means that a 1-in-5-year heat event, which currently averages 99°F, could reach between 104°F and 110°F—dangerous levels for all outdoor travelers.

Priority Project 4 aims to mitigate extreme heat at FCRTA transit stops by adding shelter, shading, and tree canopies to provide relief for transit riders. Investing in these heat-mitigation strategies is essential to protecting the health and safety of those who depend on public transportation in Fresno County's rural communities.

Potential Impacts

Asset Criticality

Fresno's public transit system is an essential component of the countywide transportation network:

It has multiple local and regional transit routes provided by: FAX, Clovis Transit, and FCRTA.

Serves youth, seniors, and others who are unable to drive.

Serves isolated rural communities and multiple Equity Priority Communities.

Potential Consequences

Heat impacts vary depending on severity:

Increased risk of heat-related illnesses including heat exhaustion (103°F to 124°F), and heat stroke (which becomes a serious threat at 125°F and above), posing a risk of hospitalization or death.

Outdoor workers, pregnant women, and individuals with asthma or cardiovascular disease are most impacted by heat-related illness.

Dependence on public transit can further exacerbate these risks, highlighting the need for effective heat mitigation strategies.

Existing Conditions

Given the uniformly high heat risks throughout Fresno/Clovis, Fresno COG analyzed bus stops and their surrounding areas based on the following criteria:

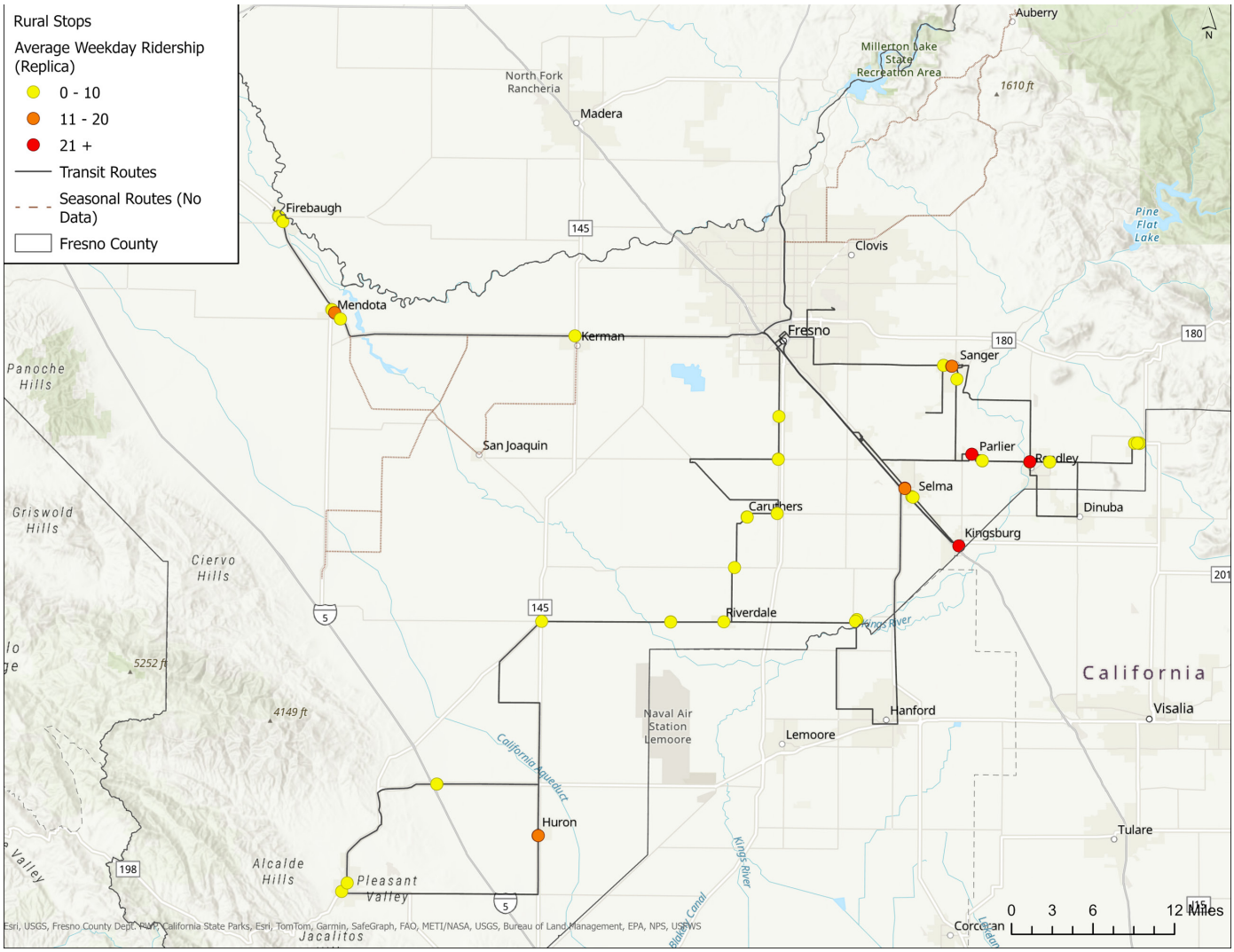
Access to Critical Services: Does this bus stop serve transit routes that provide access to critical services like hospitals, senior centers, and schools? For rural transit riders, transit is essential for accessing critical services.

Ridership
Is this stop along a transit route with low, medium, or high ridership compared to others?

Frequency
Does this stop have low, medium, or high frequency of service compared to other transit stops?

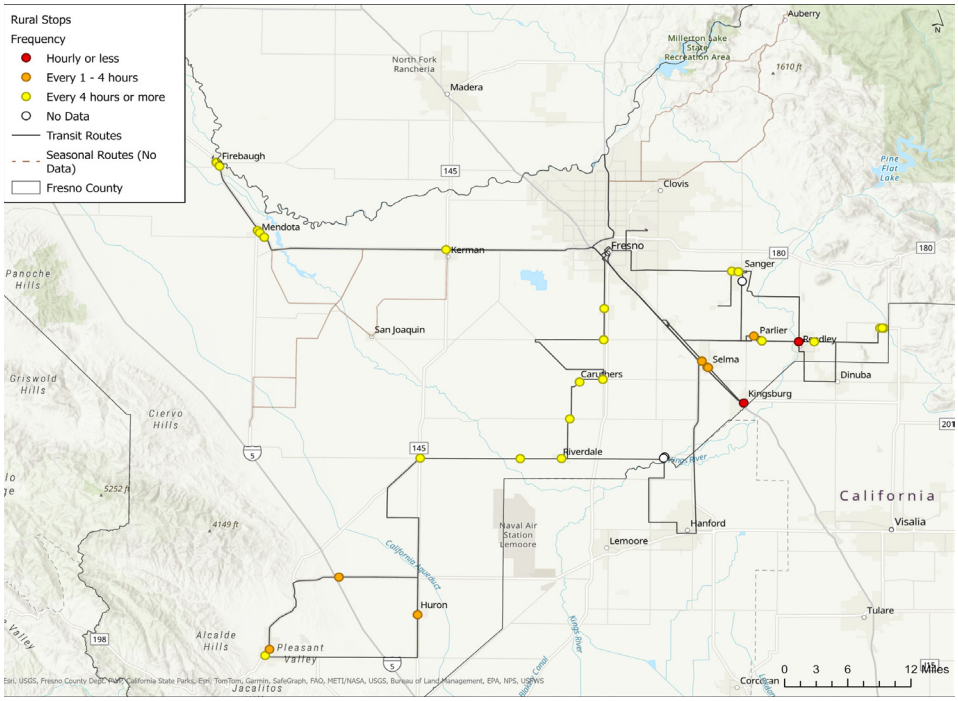
Urban Tree Canopy

Note: Tree canopy data from the USFS is not currently available fo rural areas.

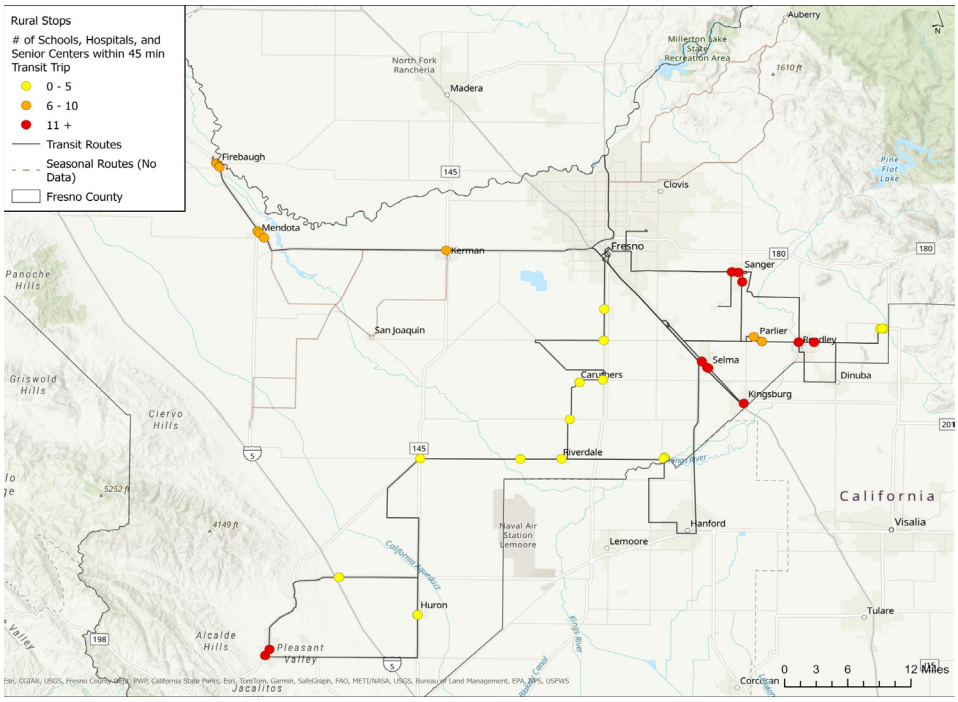


Existing Conditions

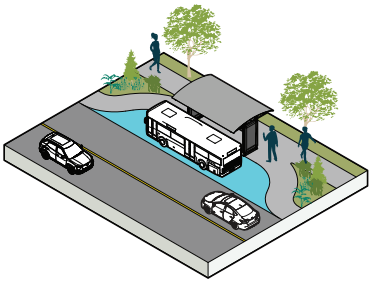
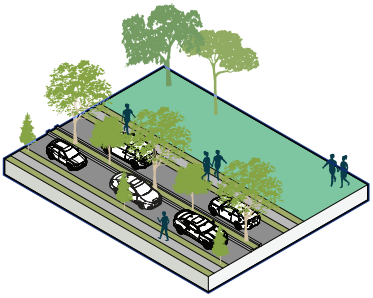
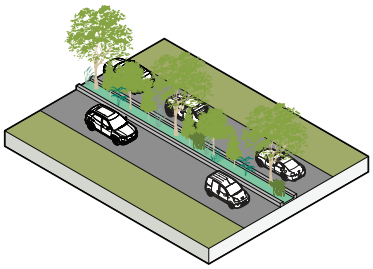
Transit Frequency



Access to Critical Services



Recommended Treatments

	Treatment	Description	Application
01	**Shaded bus shelters / tree canopies** 	Shelters and trees shade passengers waiting for the bus.	Bus stops that lack shelters and/or tree canopy with higher ridership and frequency.
02	**Tree canopies / Water Sensitive Urban Design** 	Planting trees around transit stops and incorporating bioretention basins into the public right-of-way areas.	Bus stops that lack tree canopy with moderate ridership and frequency but provide access to critical services.
03	**Median Vegetation Strip / Green Corridors** 	Creating shaded, green corridors using a combination of trees, bioretention basins, and vegetation at transit stops, rights of way, and medians along pedestrian routes.	Bus stops that lack tree canopy with low ridership and frequency; providing limited access to critical services.

The methodology applied here prioritizes areas of high use and access to services in order to reduce exposure to a greater number of transit riders. However, this is just one framing for prioritization; additional consideration should be given to transit stops that are in more remote locations that may be waiting for long periods of time due to infrequent stops.

Recommended Treatments

Since heat risk is typically uniform across the county, Fresno COG scored and ranked rural transit stops based on level of access to services, ridership, and service frequency. Shelter, shade, and tree canopies are recommended at the following locations, organized by priority.

High Priority Locations

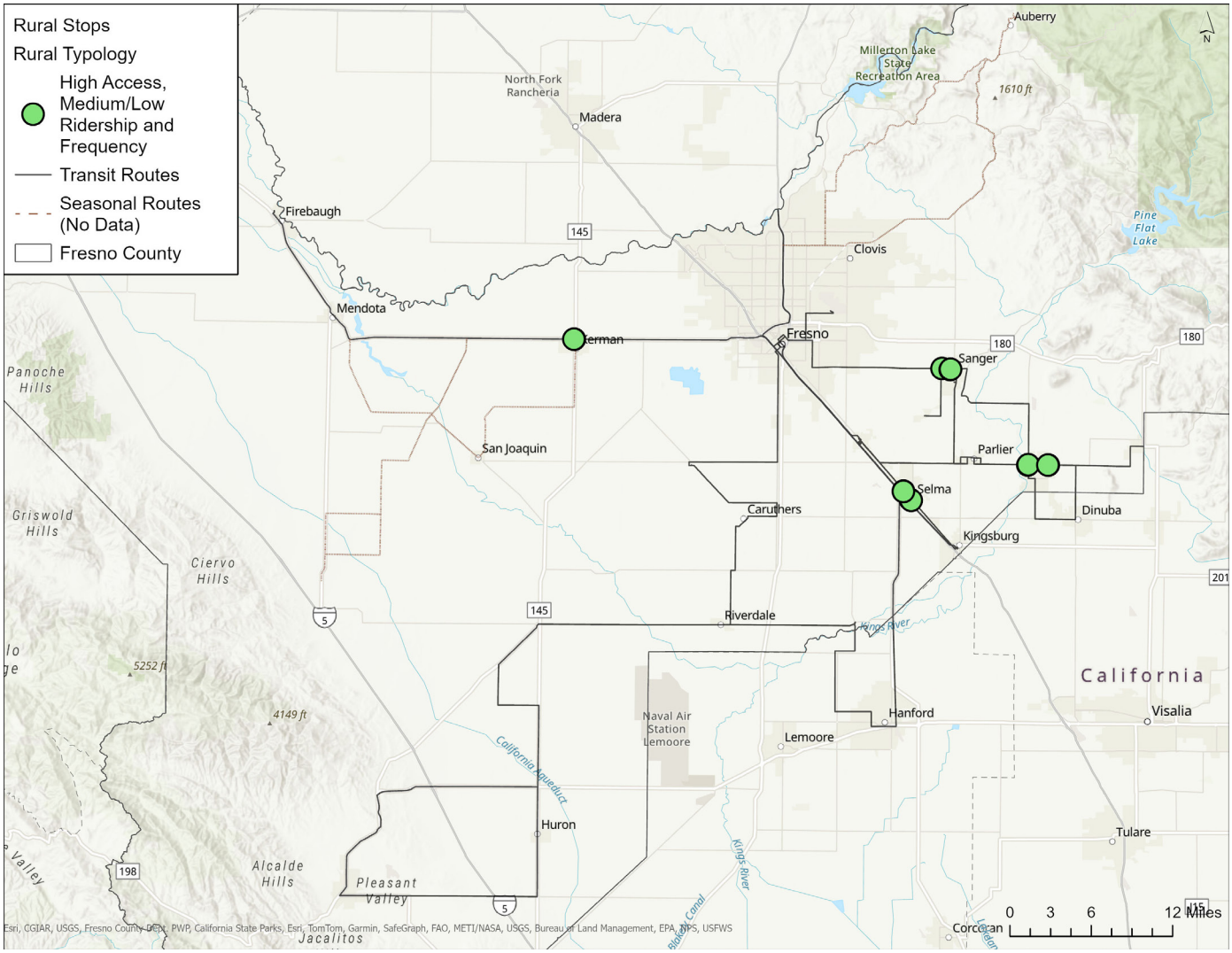
Sanger
- Jensen Ave at S. Bethel Ave
- 7th Street and De Witt Ave

Selma
- Whitson Street

Reedley

Kerman

Routes with the Highest Frequency and Access to Critical Services



*Bus stop IDs/locations are available in Appendix 9

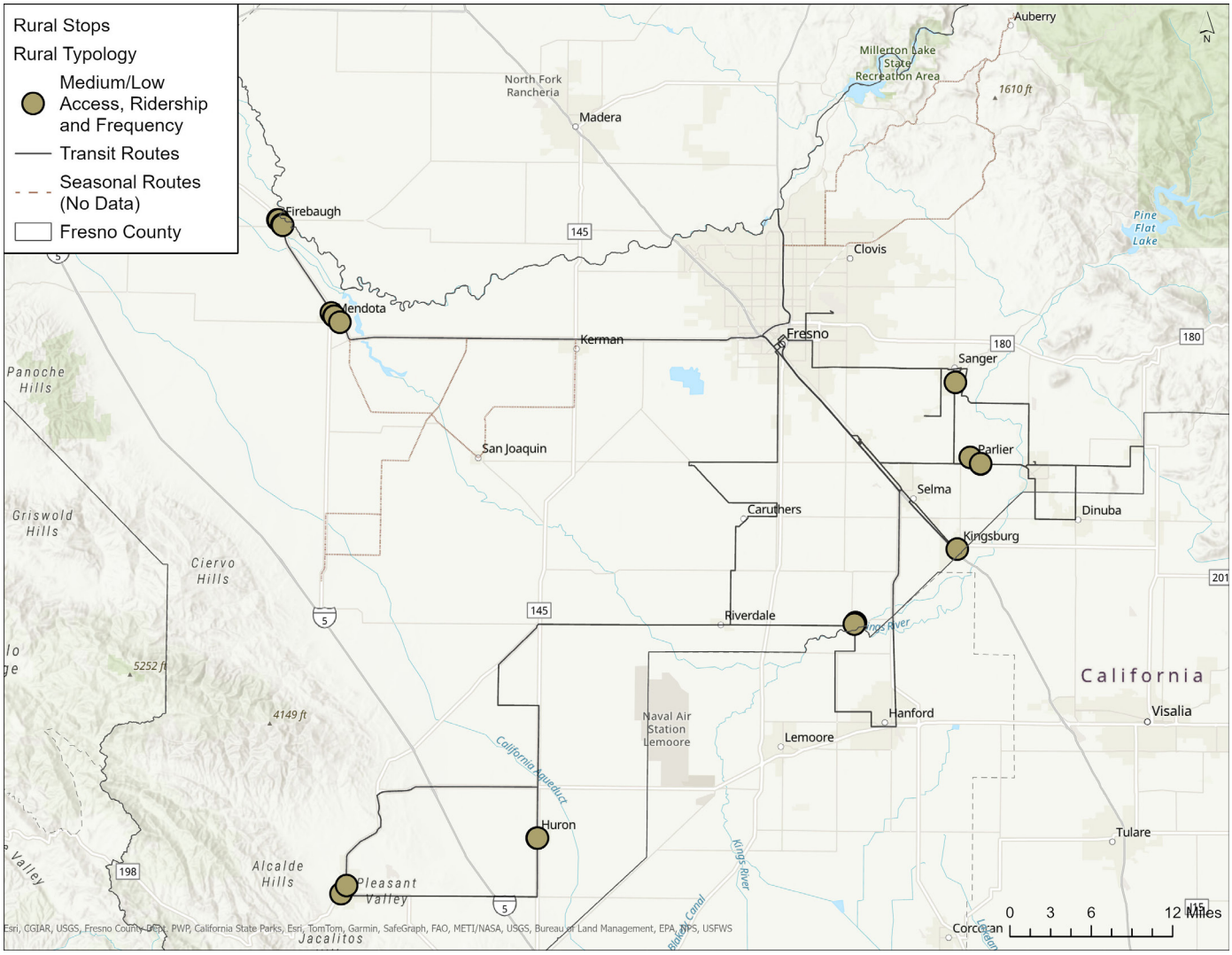
Recommended Treatments

Since heat risk is typically uniform across the county, Fresno COG scored and ranked rural transit stops based on level of access to services, ridership, and service frequency. Shelter, shade, and tree canopies are recommended at the following locations, organized by priority.

Medium Priority Locations

Stops in Firebaugh, Mendota, Kingsburg, Parlier, and Laton

Routes with the Moderate Frequency and Access to Critical Services



*Bus stop IDs/locations are available in Appendix 9

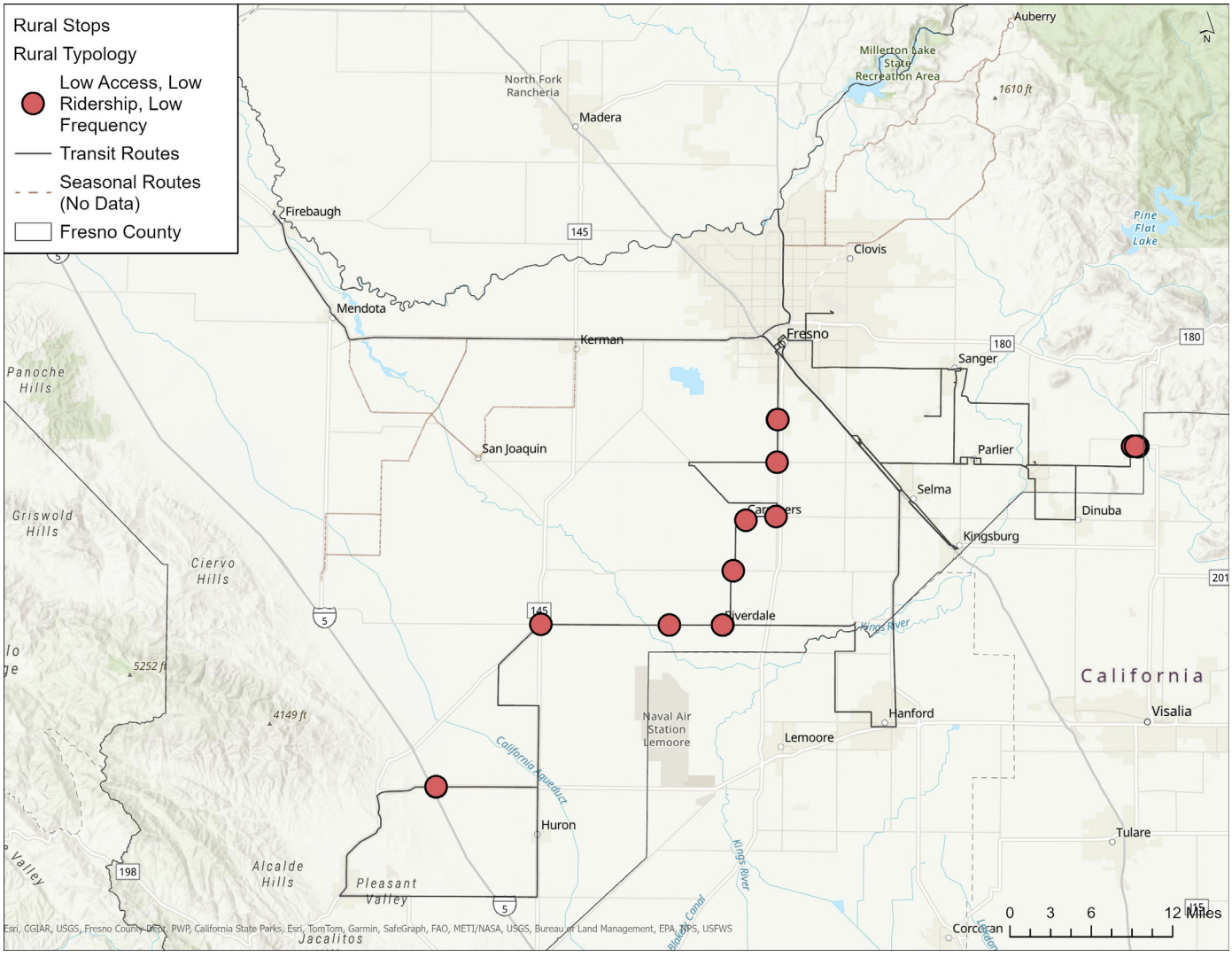
Recommended Treatments

Since heat risk is typically uniform across the county, Fresno COG scored and ranked rural transit stops based on level of access to services, ridership, and service frequency. Shelter, shade, and tree canopies are recommended at the following locations, organized by priority.

Opportunistic/ Longer Term Locations

Stops along Coalinga Intercity Transit

Routes with the Lowest Frequency and Access to Critical Services



Other next steps to support this recommendation include:
Develop a comprehensive inventory of bus shelters to identify candidate locations for future investment.

- Install bus shelters where absent
- Develop a shade tree and landscaping planting plan

*Bus stop IDs/locations are available in Appendix 9

Treatment Co-Benefits

Social / Health

- Provides relief from heat and provides outdoor thermal comfort
- Improves air quality from reduced use of personal vehicles
- Maintains accessibility across Fresno County
- Promotes connectivity
- Serves isolated communities

Environmental

- Reduces greenhouse gas from decreased personal vehicle dependence
- Improves air quality from reduced personal vehicle dependence

Economic

- Maintains public transit related jobs and access to jobs

Treatment Costs

Treatment Type	Cost Range	Assumptions
Shaded Bus Shelters / Tree Canopies	$14k-$30k per bus shelter / transit stop	$12k per bus shelter (direct costs) $8k per bus shelter (indirect costs)
Tree Canopies / Water Sensitive Urban Design	$28k-$60k per transit stop	Estimated area is 1000 LF $24k per transit stop (direct costs) $16k per transit stop (indirect costs)
Median Vegetation Strip / Green Corridors	$71k-$151k per transit stop and surrounding median	Includes one bioswale and median vegetation for 600 ft^2 $61k per transit stop/median (direct costs) $40k per transit stop/median (indirect costs)

* All treatment types include equipment pads and standard bus shelters with benches. Excavation costs not included.

Annual O&M

O&M includes weekly cleaning and incidental repairs, electrical maintenance of air conditioner, and tree and vegetation maintenance. O&M costs range from $2000 to $4000 annually.

Implementation

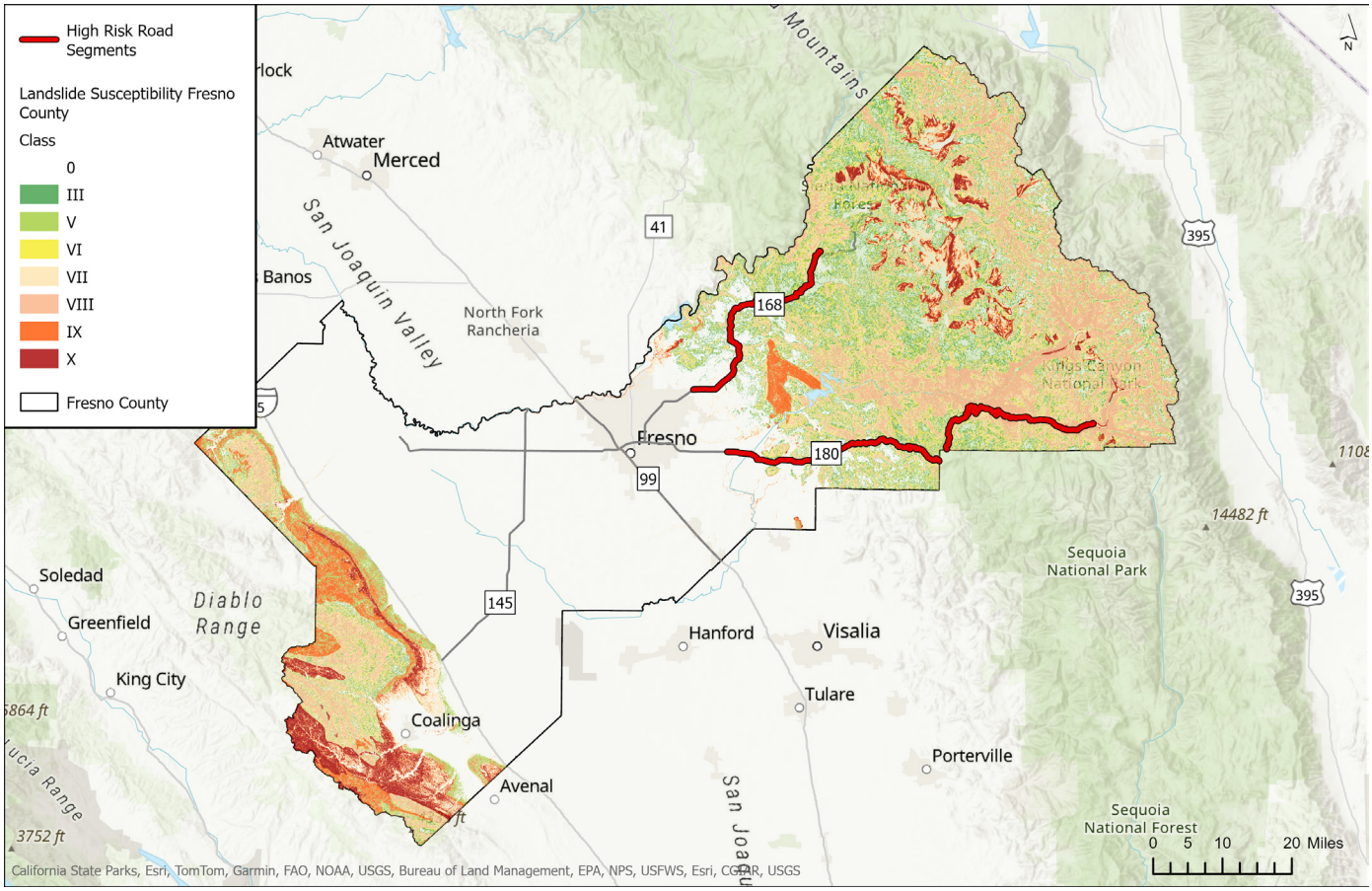
Cost ranges reflect costs for treatment of a single transit stop location. In practice, costs will multiply across prioritized transit stops, phased over time. In the short term, implementing solutions at the 5 high priority transit stops may cost between $70k and $150k for shade and tree canopy improvements. Additional street improvements at all 5 priority stops may cost $140k to $755k in total.

PRIORITY PROJECT 5

MITIGATE LANDSLIDES ALONG STATE ROUTE 168 AND STATE ROUTE 180

What's At Risk

High landslide risk roadside segments identified in Fresno County



Following wildfires, precipitation on burn scars can cause landslides and debris flows. Portions of SR-168 and SR-180 (shown in red) are located in high wildfire risk zones in the mountainous areas that flank the county's east and west side. As a result of combined wildfire risk and slope, these stretches of highway are susceptible to major landslides and slope instability, resulting in road closures and major maintenance needs, cutting off isolated rural communities from basic services. Additionally, disruptions to these roads impact visitors traveling to Kings Canyon National Park, a vital resource for tourism and the local economy.

Priority Project 5 aims to mitigate landslide risk along 112 road miles of SR-168 and SR-180. SR-168 is specifically a priority as it serves as a vital FCRTA transit route serving Auberry and other isolated mountain communities.

ROCK STRENGTH

SLOPE CLASS	1	2	3
1	0	0	0
2	0	V	VII
3	0	V	VII
4	III	VIII	IX
5	VI	IX	X
6	VII	IX	X
7	VIII	IX	X
8	VIII	IX	X

LANDSLIDE SUSCEPTIBILITY CLASSES

(0 III V VI VII VIII IX X → increasing susceptibility)

Potential Impacts

Asset Criticality

SR-168 & SR-180 serve multiple purposes:

Critical emergency access & evacuation routes.

FCRTA Auberry Transit route.

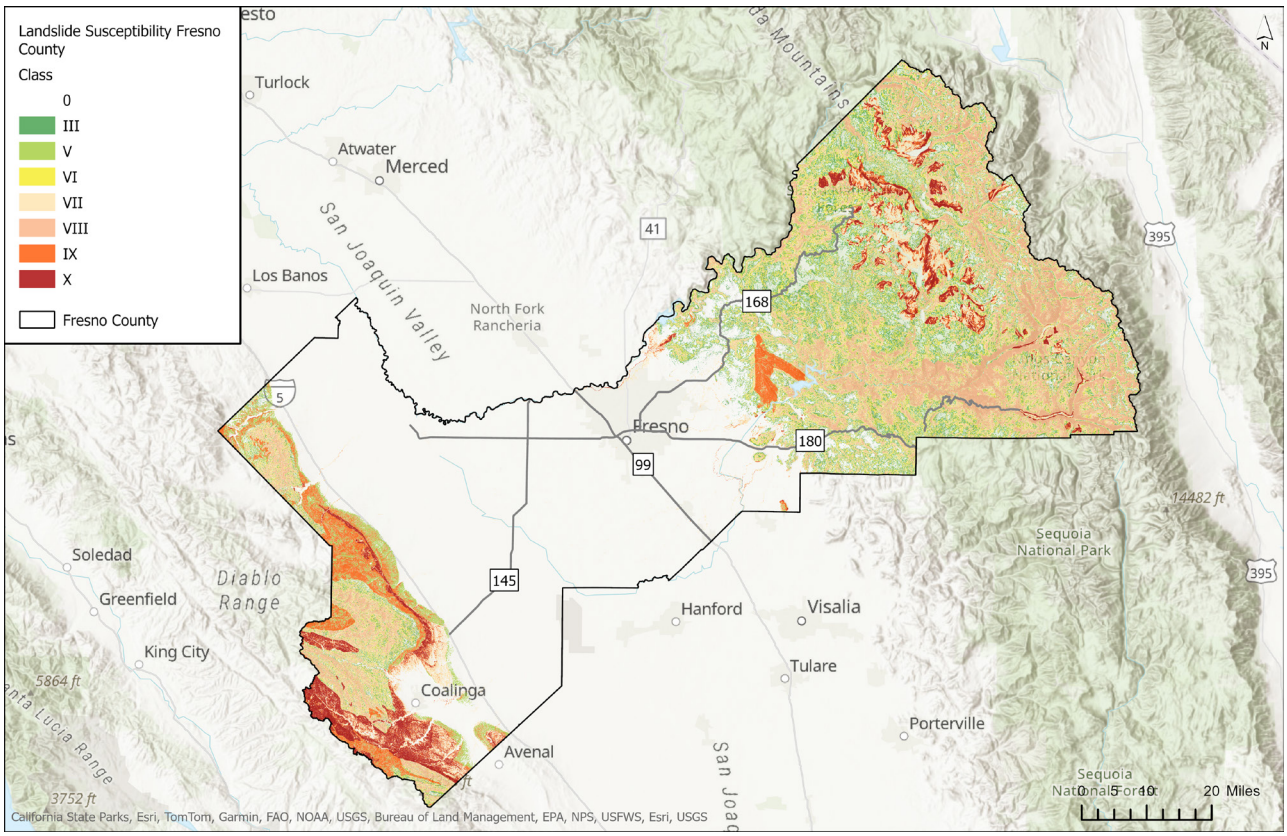
Serves rural, isolated communities and Equity Priority Communities.

Primary access routes to Kings Canyon National Park & Sierra National Forest.

Potential Consequences

Landslide impacts vary depending on severity, described below:

Roads may become inaccessible on the order of weeks to months during repair; past landslide events have led to significant road closures along these routes and even small amounts (e.g., a couple of inches) of soil displacement can cause roads to become impassable.



Fresno County's foothills and mountainous areas have a history of landslides, driven by steep slopes in the Sierra Nevada and erosive soils of the Coast Range. Landslide susceptibility classes can be used as a basis for treatments along high-risk roadway segments. The susceptibility classes indicate areas where landslides are likely to occur based on the locations of past landslides, the location and relative strength of rock units, and the steepness of topographic slope to classify the relative likelihood of deep-seated landsliding (Wilson and Keefer, 1985). Other types of landslides not captured here include events driven by rainfall, earthquakes, and shallow mudslides or debris flows, such as those that follow wildland fires and heavy rain events.

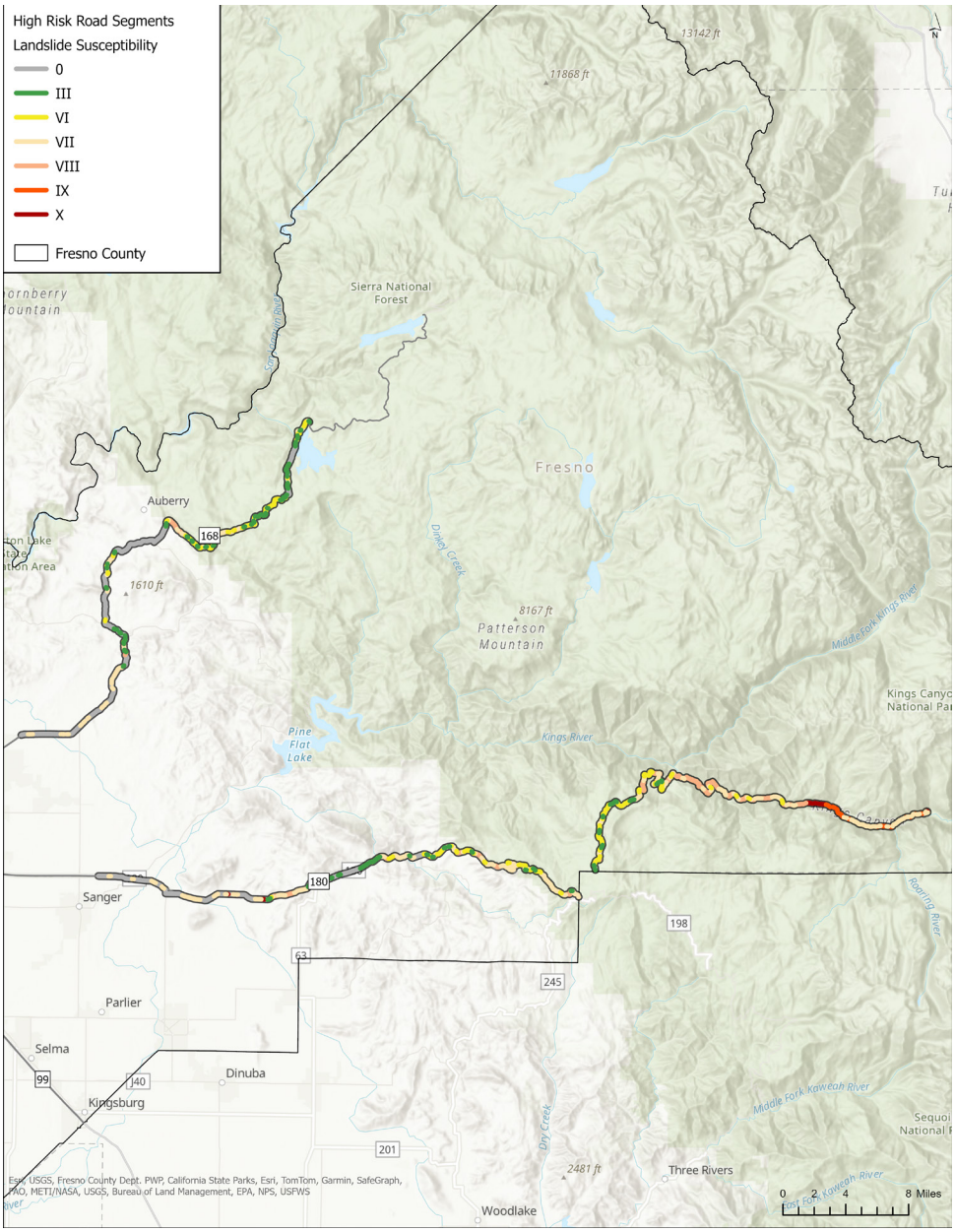
Existing Conditions

Selecting the Appropriate Treatment

Fresno COG identified mountainous segments of SR-168 and SR-180 as high priority due to both landslide susceptibility and other roadway characteristics, including their importance in serving isolated communities. SR-168 serves as a transit route, with Class VIII susceptibility around Auberry. SR-180 includes steep slopes (Class IX and X susceptibility) through Kings Canyon.

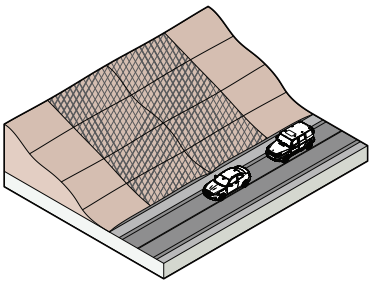
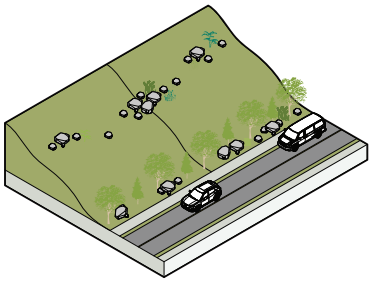
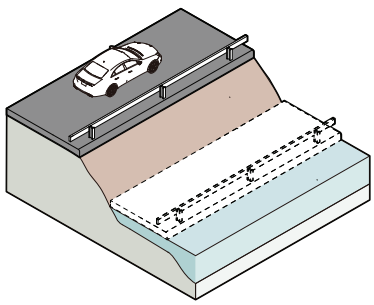
Fresno COG employed the susceptibility classes on the following page to identify the types of suitable mitigation strategies along these priority road segments—for instance, retention measures, like tie backs and rock mesh along steep slopes (especially Classes IX-X) and stabilization measures, like drainage improvements and vegetative controls, along more moderate slopes.

Landslide susceptibility along high landslide risk road segments



Recommended Treatments

Landslide mitigation strategies are based on a variety of factors, including the type of rock present at the slope face, whether the rock has beds (layers) or joints (fractures), the orientation of these features with respect to the slope face, and the position of any road cuts and benches with respect to the slope. The landslide susceptibility categories encompass different types of geology and rock strength that do not map one-to-one with mitigation measures; rather they provide a general framework for assigning appropriate treatments. Fresno COG should apply mitigation strategies in the high landslide susceptibility areas along both of these critical routes. Additionally, Fresno COG can work with Caltrans to monitor high risk landslide areas, including the higher susceptibility segments of the Auberry Transit Line, given its importance for transit-dependent populations.

Treatment	Description	Application
01 **Landalide Retention** 	In-situ stabilization such as rock bolts, rock meshes, and rock catch pits. Taller free-standing rock slopes may be unstable and may require tieback or soil nail walls.	Steep Slopes – Susceptibility Classes VI-X: Landslide susceptibility classes VI-X, such as those along Highway 180 in Kings Canyon.
02 **Erosion Stabilization** 	Vertical/horizontal drains deep within the hill to prevent water buildup in the landslide mass or along the relatively weak failure plane or shear zones; Surficial drainage improvements and vegetation to keep shallow soils in place and prevent formation of slope rills or gullies; or tieback or soil nail walls for taller cut slopes; Appropriate native vegetative cover.	Moderate Slopes – Susceptibility Classes V-X: moderate slopes comprised of soil or weathered rock, such as those along the Highway 168 / Auberry Transit Line.
03 **Realignment** 	Realignment and/or abandonment of current road alignment, with the understanding that the landslide cannot be stopped.	Worst-case scenarios, where maintenance is continuously problematic.

Treatment Co-Benefits

Social / Health

- Promotes connectivity to community services (e.g., healthcare, schools, evacuation)
- Serves isolated communities
- Prioritizes rural areas of Fresno County

Environmental

- Improves water quality from reduced sedimentation
- Enhances or preserves biodiversity

Economic

- Supports continuous access to jobs, tourism, and regional trade routes
- Reduces cost of repair

Treatment Costs

Treatment Type	Cost Range	Assumptions
Landslide Retention	$6.4M-$13.6M per 10,000 ft^2	10,000 ft^2 @ $552/$ft^2$; assumes rock face of 10 ft (direct costs) $350/$ft^2$ (indirect costs)
Erosion Stabilization	$116k-$248k per 10,000 ft^2	10,000 ft^2 @ $10/$ft^2$ (direct costs) $65/$ft^2$ (indirect costs)
Realignment	$15.3M-$33M per mile	$13.3M per mile (direct costs) $8.5M per mile (indirect costs)

Annual O&M

O&M costs for realignment include regular roadway maintenance estimated between $20,000 and $30,000 annually. Erosion stabilization and landslide retention are forms maintenance that may require repeated applications during a 10-15 year design life.

Implementation

In practice, the targeted mitigation areas along 112 road miles will likely vary in size, depending on findings of additional technical studies.

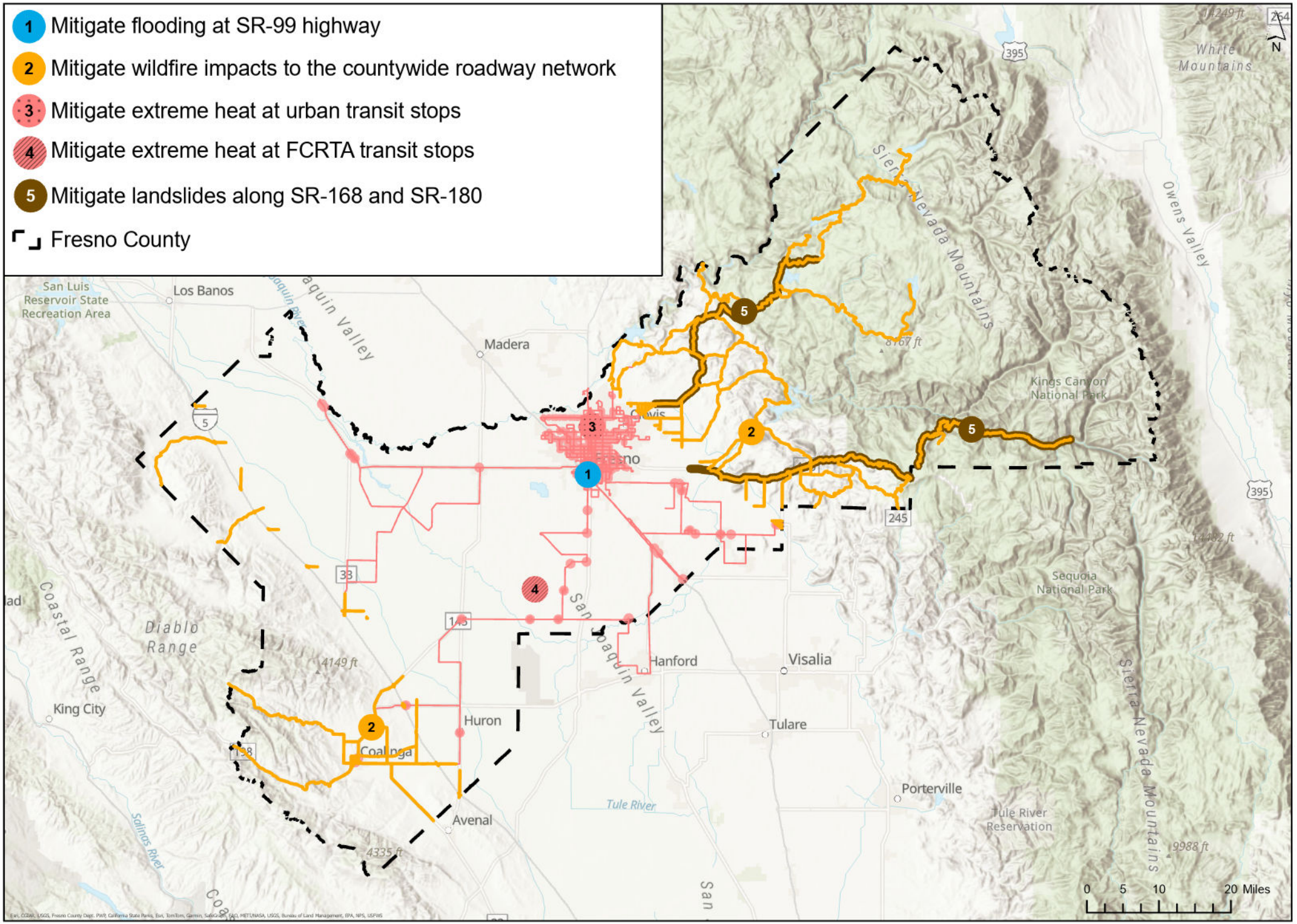
6. Next Steps

The transportation network-wide climate risk assessment and resulting project identification and prioritization marks a significant milestone for Fresno COG, laying the groundwork for a more resilient transportation future. The projects identified here will become candidate projects for the 2026 Regional Transportation Plan/Sustainable Community Strategy. Moving forward, the next steps will focus on securing funding opportunities, fostering partnerships with key stakeholders, and developing detailed implementation strategies for each of the five priority projects. Continued collaboration with local communities, agencies, and policymakers will be essential to ensure these initiatives effectively enhance the county's resilience to climate change. Adaptation and resilience projects should be conceptualized and designed so that they align with – and don't unintentionally conflict with – important local goals such as sustainability, walkability, connectivity, accessibility, and economic development. By advancing these projects, the region takes a critical step toward protecting its natural and built environments while promoting long-term economic and social sustainability.

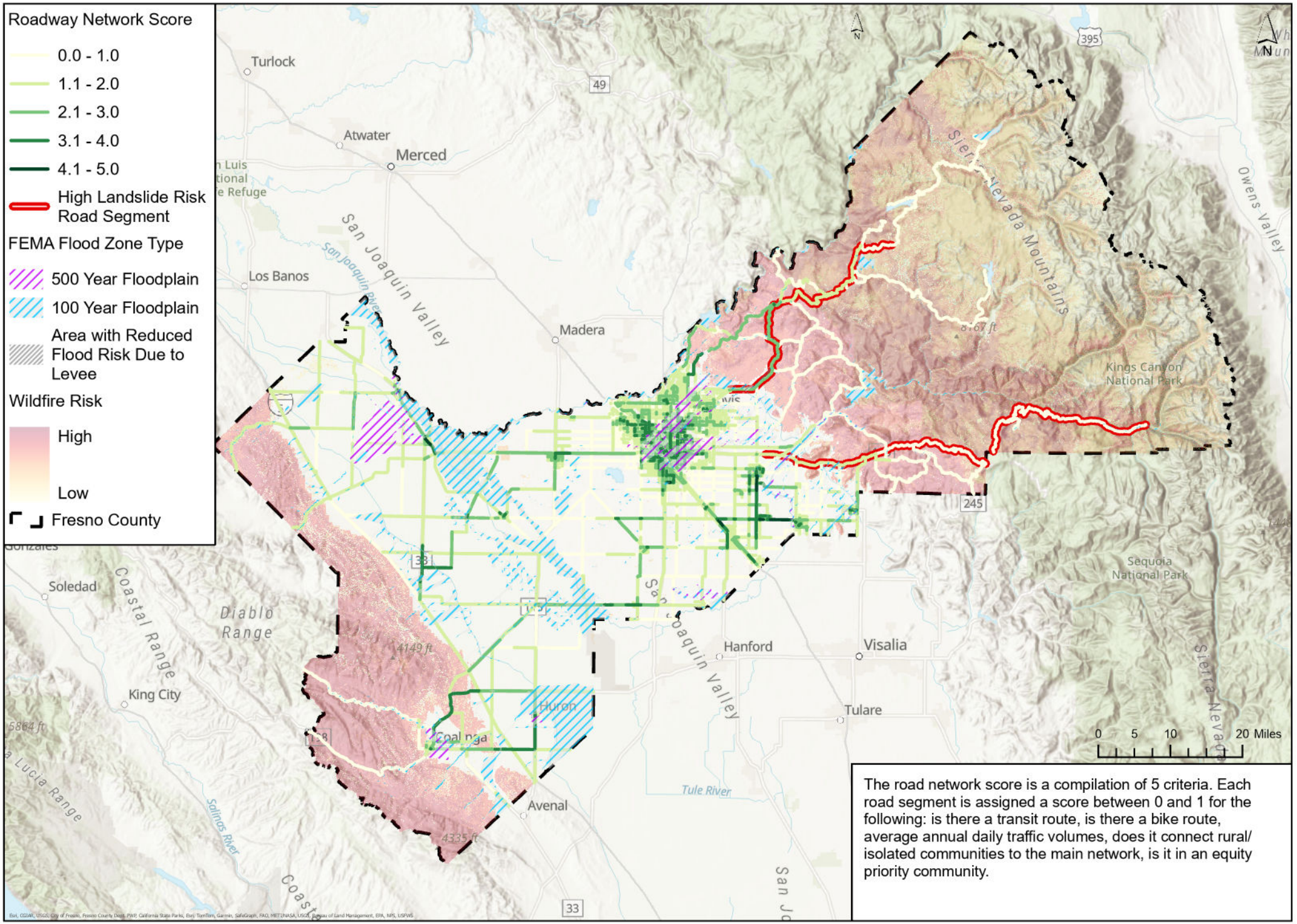
Appendices

A.1 Maps of Priority Projects and Climate Hazards

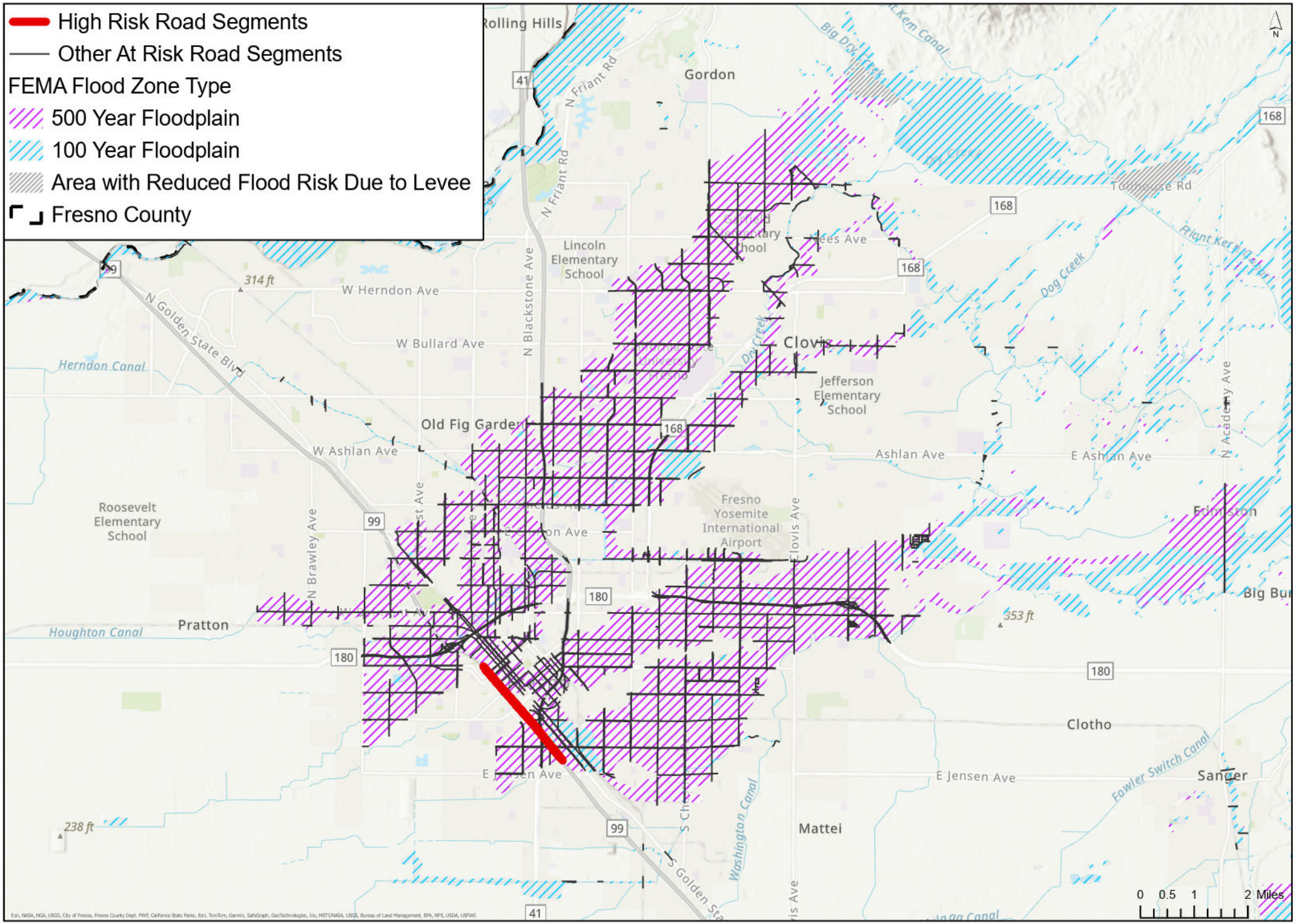
Priority Projects



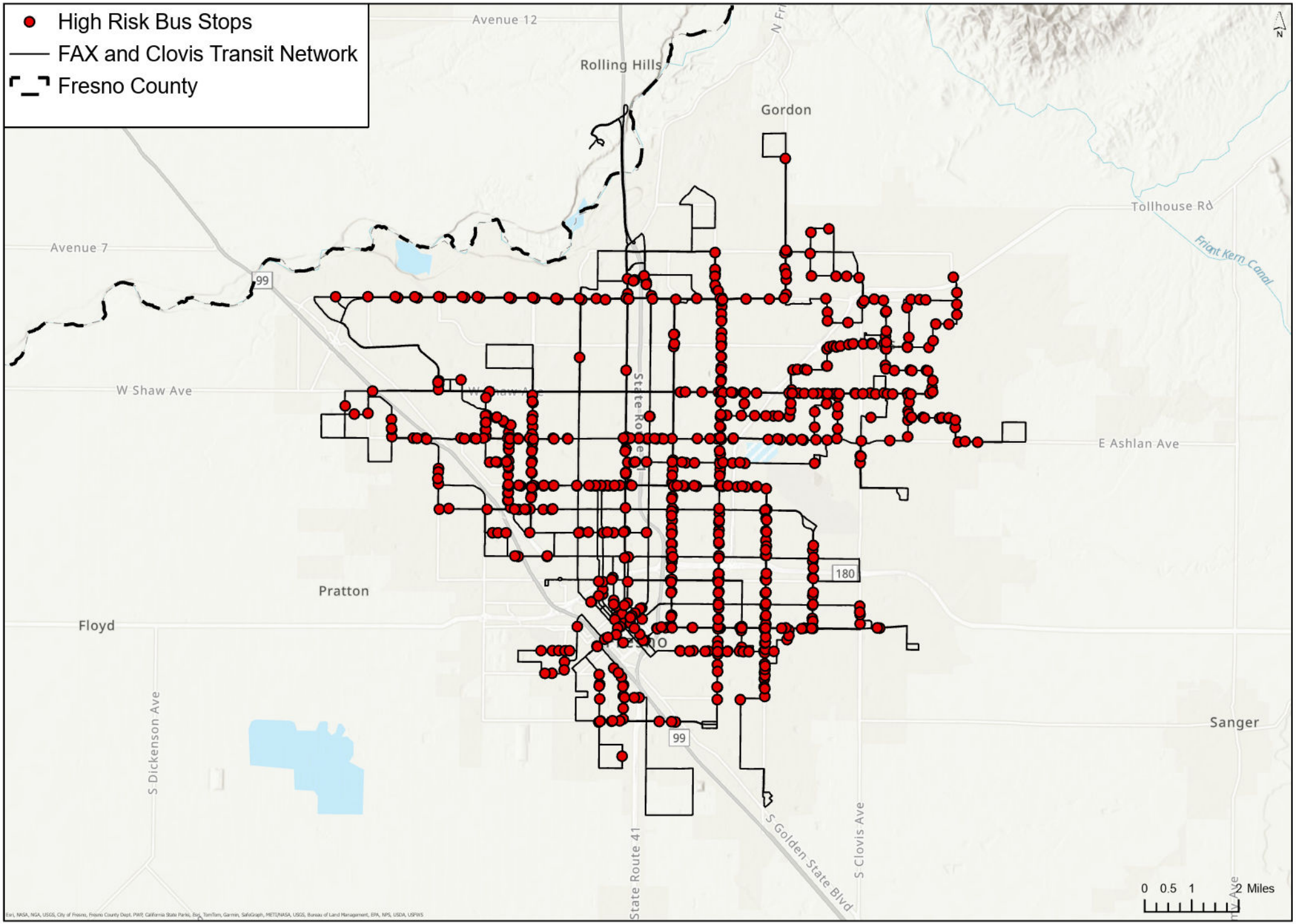
Hazard Impacts to Road Network



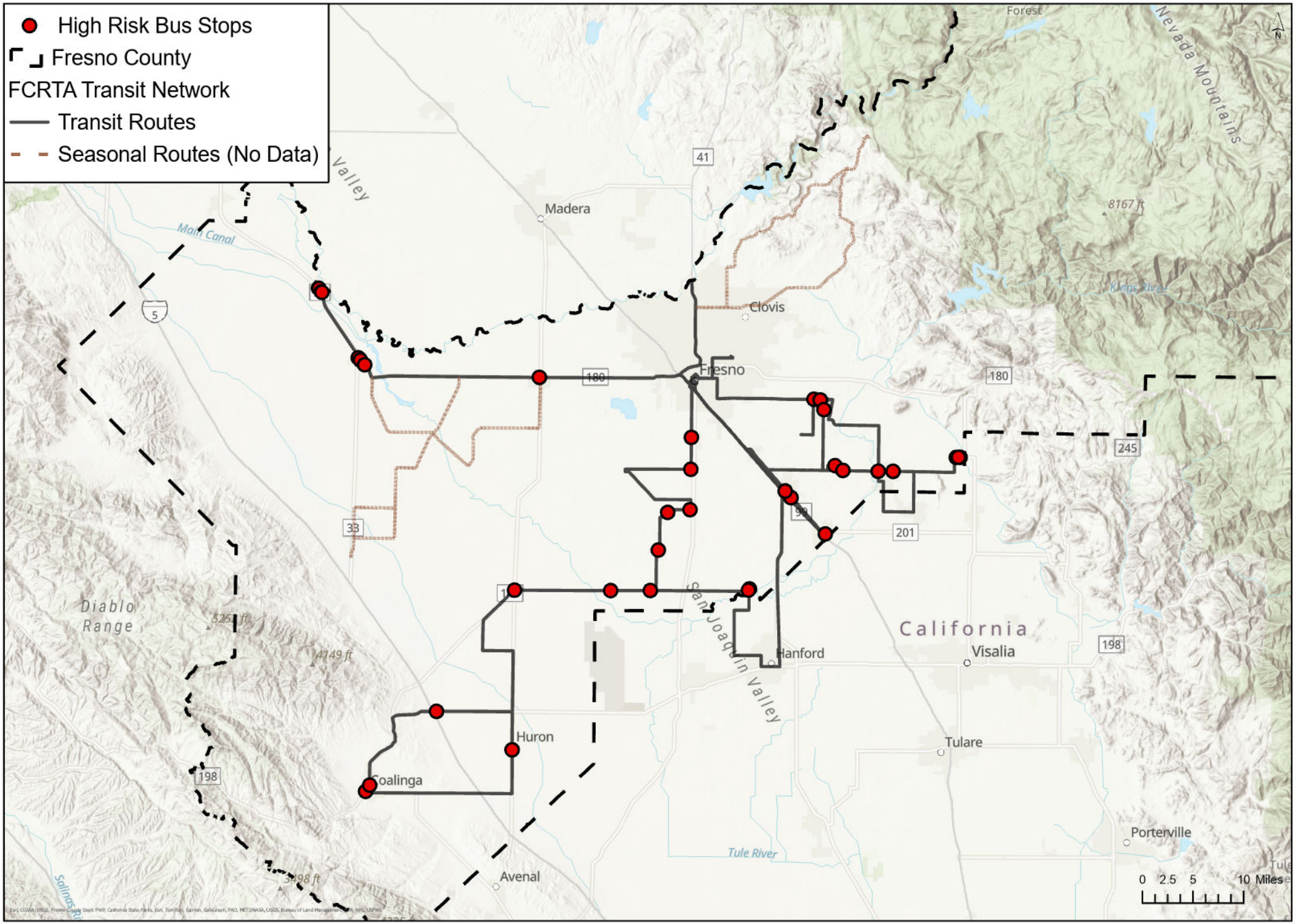
High Risk Urban Flooding in Fresno/Clovis



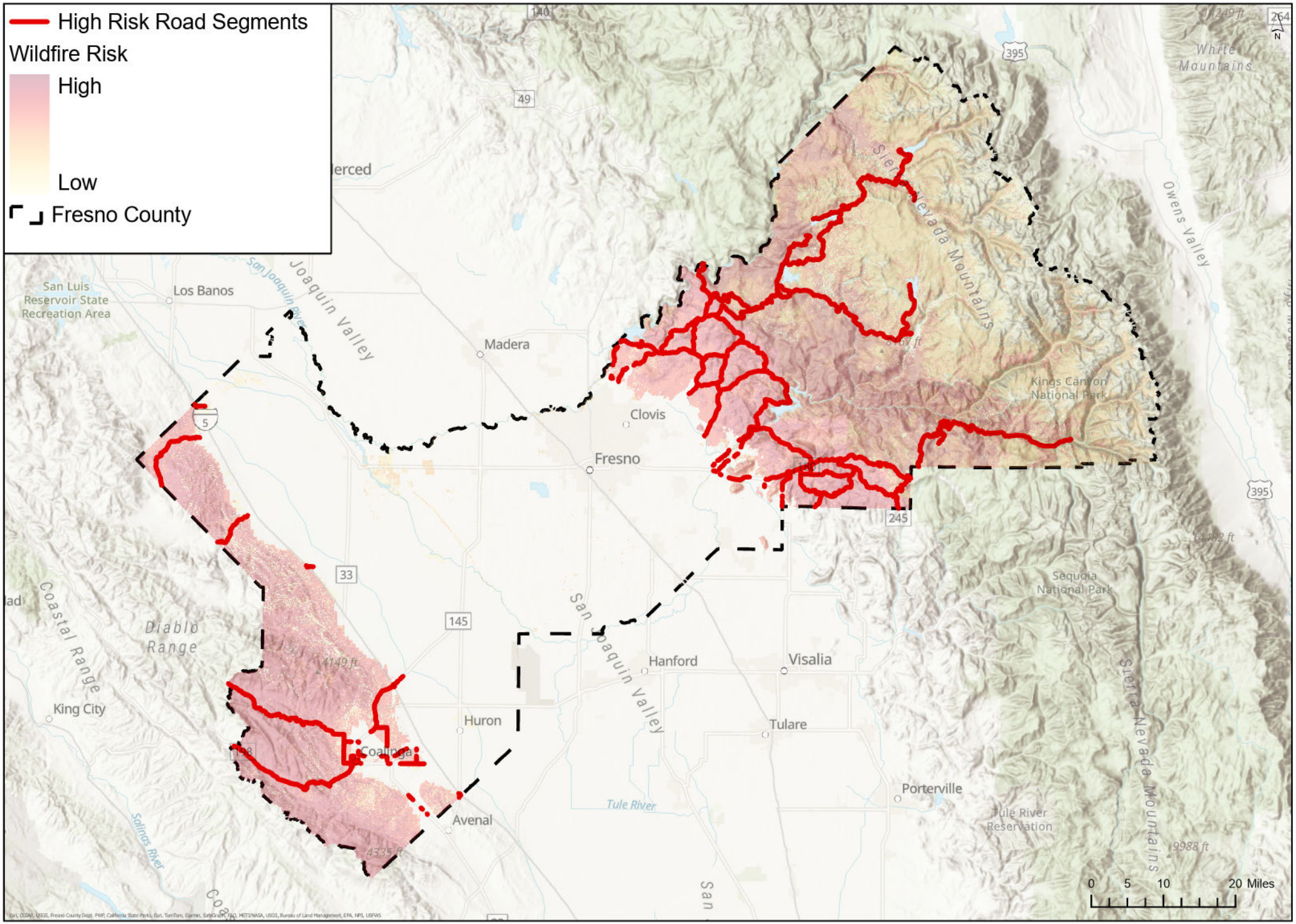
Urban Extreme Heat Impacts to Transit Network



Rural Extreme Heat Impacts to Transit Network



County-wide Wildfire Impacts to Road Network



Landslide Impacts to Road Network

A.2 Agency Outreach and Engagement Summary

Overview

The Technical Working Group was created to engage with institutional stakeholders including the member agencies that will be the main users of this Plan. Arup worked with the Fresno County COG staff to identify and assemble the Technical Working Group, which included representatives from member agencies, local transit agencies, public health departments, conservation districts, County planning and emergency management departments, and others. Four meetings were held in September and November 2024, and January and April 2025. The consultant team worked with the TWG to leverage their networks and to reach the community-based organizations in their respective jurisdictions.

TWG members provided input into the project in the following ways:

- Attended 4 virtual working group meetings of approximately 2 hours each
- Provided data and information on the project's risk assessment
- Provided feedback on the project opportunities and process for selecting priority projects
- Provided input into outreach events and ways to engage with CBOs and the general public
- Invited to review the administrative draft of the Plan

TWG Member Organizations

- CA Department of Transportation
- City of Firebaugh
- City of Selma
- Clovis Transit
- Cultiva la Salud
- Fresno Area Express
- Fresno City Planning and Development
- Fresno County Board of Supervisors
- Fresno County Department of Public Health
- Fresno County Office of Emergency Services
- Fresno County Public Works & Planning
- Fresno County Rural Transit Agency
- Fresno Metropolitan Flood Control District

- Kings River Conservancy
- Leadership Counsel for Justice & Accountability
- League of Women Voters of Fresno
- San Joaquin Valley Air Pollution Control District
- Selma Airport

Meeting Dates and Topics

- TWG Meeting #1 was held September 12th, 2024, and included review of the project process and methodology, and discussion of the engagement plan and climate hazard impacts in Fresno County on residents and transportation assets
- TWG Meeting #2 was held on November 19th, 2024, with a focus on sharing climate risk results and the approach to project prioritization
- TWG Meeting #3 was held on January 30th, 2025, with a focus on sharing the project opportunities, process for selection priority projects, and potential solutions
- TWG Meeting #4 was held on April 23rd, with a focus on reviewing the administrative draft report

Takeaways from the TWG

- Coordination with first responders is essential for reducing impacts to isolated populations
- Road conditions, isolation, and limited access worsen impacts in rural areas
- There are existing challenges with degraded pavement across the county
- Providing shade at transit stops is the number one priority for transit riders
- Bus yards are critical facilities to prioritize investment for transit service
- Project prioritization should consider more than # of people affected, since rural populations face multiple challenges
- Streamlined permitting for proposed projects will help to reduce costs and accelerate implementation

A.3 Community Outreach and Engagement Summary

Community Based Organizations

The project team met with County-wide community-based organizations to refine risk metrics, project evaluation, and identification of effective solutions. Meeting with community-based organizations helped to align the project with community needs and to design engagement activities that capture lived experiences of community members and people who may be disproportionately impacted by climate hazards. One meeting was held in December 2024, and the same organizations and representatives were invited to the fourth Technical Working Group meeting (April 2025) to review the administrative draft of the Plan. The Arup team worked with Fresno COG and the Technical Working Group to identify and engage CBOs across the county.

6.1.1 Community-based Workshop

A community-based workshop was held on December 12, 2-4 pm. During the meeting, the project team provided an overview of the project and led an in-depth discussion of climate hazards and their impacts on the transportation system and residents. The project team sought input on priority areas of concern, the impact of hazards on equity priority communities and populations served by these CBOs, and their preferred solutions.

6.1.2 Combined TWG and Community-Based Administrative Review Meeting

On April 23, 2025, the project team presented this draft report to the TWG and the Community-Based Organizations engaged throughout the project. All organizations were invited to provided written feedback on the administrative draft of the report, and comments [will be] addressed by the project team in the final draft of the report.

Public

The project team also sought input from the general public to improve understanding of climate impacts at prioritized locations and the suitability of solutions for mitigating the priority projects. Events included 6 pop ups at existing community events in the prioritized locations or surrounding areas.

6.1.3 Survey

The project team distributed a survey from November 2024 to January 2025 in conjunction with the Regional Transportation Plan survey. The project team developed questions focused on understanding the public's experience with climate hazards' impacts on transportation. Key findings from the survey questions included the following:

- Continuous access (keeping roads open): Landslides limiting route access are a concern (esp. West Fresno)
- Ingress/egress planning and redundancy during wildfire and flooding, especially Highways 99, 180, 168, and Freeway 41

1. Access out of Fresno foothills and Southwest Fresno
2. Flooding in Metro Fresno

- Managing thermal comfort for pedestrians & transit riders

6.1.4 Pop Ups

Pop ups were held in six locations throughout Fresno County:

- February 28, 2025 – Reedley (Fresno Street Eats)
- March 8, 2025 – Fresno (Community Disaster Preparedness Workshop – Community Housing Council)
- March 15, 2025 – Fresno (Southeast Family Fair)
- March 19, 2025 – Fresno (Hoover High School Regional Family Engagement, Parent University)
- March 26, 2025 – Mendota (Mendota Outdoor Market)
- April 12, 2025 – Auberry (Earth Day Event)

The project team spoke to an estimated 420-475 people during pop up events. During each pop up, the project team representatives shared the priority project needs locations and the corresponding solutions. They spoke to community members about how the hazards have impacted their use of roads and public transit. This information was reviewed during the development of project recommendations, to account for any additional information that may be relevant to reducing risk in priority project locations. Individual pop up summary reports are provided in the following appendix.

Primary takeaways include the following:

- Community concern in Urban Fresno is primarily around flooding and heat
- In West Fresno, flooding along SR-180 disrupts traffic access and farm workers have limited transportation options
- In East Fresno, mountain communities are impacted by wildfire and flooding, but are generally less concerned with transit and heat, as compared to other areas of the County
- In East Fresno, communities are prioritizing wildfire preparedness and Firewise planning

Community members also provided input on their preferred solutions. Their choices for hazard mitigation include expanding the tree canopy and radiant cooling at transit stops; thinning forested areas to reduce the threat of wildfire and improving evacuation communication and early warning systems; landslide retention; right-sizing the drainage system and stormwater retention basins to mitigate flooding.

Community members at Mendota Farmers Market explore climate hazards and potential solutions.

A.4 Pop up Summary Reports

urban diversity design

Memorandum

To: Karen Barns, ARUP

Date: May 1st, 2025
From: Sheila Hakimipour

Project: Fresno County Climate Resiliency Plan

Pages: (3)

Re: Popups Summary (Draft)

CC: Brooke DuBose, Karen Barn, Maggie Messerschmidt (ARUP)

Paul Herman, Matthew Shimizu (FCOG)

The outreach and community engagement for the Fresno County Climate Resiliency Plan focused on public outreach to improve understanding of the consequences of climate hazards on transportation systems in prioritized locations. The outreach events included popups at existing community events in prioritized high-risk locations. Engagement strategies focused on groups that are particularly vulnerable to climate impacts due to socio-economic factors or other factors and that historically have been underrepresented in decision-making processes.

Urban Diversity Design and Fresno Council of Governments staff facilitated six popups in different corners of the county. Popups occurred in late February to early April 2025. The project team solicited feedback and recommendations from the project stakeholder groups on the best locations and events to set up popups. Fresno County residents who visited the popups collected project fact sheets in English and Spanish and reviewed maps that demonstrated technical assessments of climate hazards and their impact on roads and transportation systems. They were also invited to vote for their favorite solution strategies to mitigate the impacts of climate hazards on transportation systems.

Popups Outline:

East Fresno County

1. Reedley: Street Eats; 2/28/25; 40-50 engaged
2. Aubery: Earth Day; 4/12/25; 15-20 engaged

West Fresno County

3. Mendota: Open Market; 3/26/25; 60-65 engaged

Urban Area

4. Fresno: Community Disaster Preparedness Workshop (a Community Housing Council event); 3/8/25; 55 engaged

urban diversity design

5. Fresno: Southeast Fresno Family Fair (hosted by Assemblymember Arambula's Office); 3/15/25; 50-60 engaged
6. Fresno: Hoover High School Regional Family Engagement (hosted by Fresno Unified Parent University); 3/19/25; 200-225 engaged

Total Attendees at the Pop Up: 420-475

What We Heard:

- On the east side of Fresno County in the valley area (Reedley), people did not have many concerns about climate hazards. The majority drive, so most people don't experience the impact of heat on transportation systems and buses. The people we spoke with do not experience a lot of flooding. Some people who stopped by work in the mountain area and experience the effects of wildfires and landslides.

- In Fresno County's eastern mountains, we heard that there are big concerns regarding the impacts of wildfire and landslide on the roads and road closures during climate hazard events. Residents informed the COG team about issues on Peterson Road, Powerhouse Road, and Stump Springs Road between Kaiser Pass and Big Creek Road due to wildfire. They also mentioned the flooding issues at the Old Sierra Elementary site.

- On the west side of Fresno County, many farm workers who live there have limited access to resources and transportation. In Mendota, the project team mainly engaged with Spanish-speaking residents who frequently mentioned the impact of the flooding, both inside the town and on State Route 180. Residents expressed how the areas on the city's east side get flooded with heavy rain and how the wetlands outside the city adjacent to SR 180 rise with rain and can disrupt the traffic access via SR 180. SR 180 is the primary access to Mendota, and if it's closed, folks have to travel a much longer distance through Firebaugh and HWY 99 to go to work or shop, etc.

- In the Fresno urban area, the project team engaged with a large number of residents during three popups. Residents expressed concerns mainly about flood and heat. They recalled flooding in areas on the maps that corresponded to the areas highlighted by the risk assessment. Many specific locations (roads and intersections) were mentioned. The project team collected all the notes (please see summary reports for each popup).

Total Votes on Solution Posters

Note: no votes were collected at the Aubery popup

urban diversity design

Hazard Type	***Solution (votes)***	***Solution (votes)***	***Solution (votes)***	***Solution (votes)***	***Solution (votes)***
Extreme Heat	Shaded Shelters (57)	Radiant cooling (69)	Tree Canopies (69)	Median veg. strip (13)	
Wildfire	Land Use Planning (7)	Thinning of forested areas (17)	Roadside veg. management (11)	Structural hardening (5)	Wildfire resistant bridge design (6)
Wildfire (cont'd)	Evacuation/ Emergency Routes (13)	Early warning systems (17)	Evacuation phone system (19)	Fire-treated wooden utility poles (5)	Routine utility inspections/ maintenance (10)
Landslides	Monitoring high-risk areas (9)	Realignment (4)	Landslide retention (12)	Erosion stabilization (5)	
Flood	Vegetative swales/berms (14)	Erosion control ground cover (12)	Stormwater retention basins (22)	Rain gardens (15)	Tree canopies/ water sensitive urban design (11)
Flood (cont'd)	Median vegetation strip (8)	Flood barriers (10)	Protection against scouring (8)	Right-size drainage systems (58)	

Total votes collected: 506

Fresno COG / UDD CCRP Popup Report

Reedley (Fresno Street Eats) Popup Details

Event Date: February 28, 2025
Event Location: Pioneer Park, 845 F St, Reedley, CA 93654
Timeframe: 4:30pm – 7:15pm
Team: COG (Matthew Shimizu, Sean Nunes)
UDD (Sheila Hakimipour, Karl Gurney)

Summary of Outreach Event:

The team tabled at a "Fresno Street Eats" event in central Reedley, CA (population 25,227 in 2020), a regional nexus for Fresno County's eastern rural communities. While most interactions were brief and revolved around the scope of the project and specific climate hazards, several locals were willing to have in-depth conversations about their experience and potential solutions. A diverse group of participants attended the popup displays, including families with young children, college and university students, small business owners, and employees working in local infrastructure sectors such as utilities and transportation.
The majority of participants communicated in English, while a smaller portion spoke exclusively Spanish. Below are the specific points of feedback gathered:

Estimated Number of Participants:

40-50; 8-10 Spanish language interactions

Setting notes:

The outreach table was located on the northeast side of G Street at the corner of 9th Street in Reedley, alongside other local vendors. Food trucks were located across the street. The street was blocked from vehicular traffic by local law enforcement.

Feedback for Maps (transcribed from notes written by participants on sticky notes):

- Wildfire Map
  - Different soil, veg, fire-risk, dust conditions on the west side of Fresno County mean for greater risks.
  - Crystal Cave Road; Pass Lodgepole; One way/no way out.[i]
  - Sample Road in Tollhouse area fire risk.
- Rural Transit Map
  - Trees missing. Plant more trees.
  - The limited public transportation we have in Reedley has very little to no actual infrastructure to protect transit users if users from the extreme climate conditions eve experience (heat/cold)

    - Bus stop: no bus stop in Reedley
- Landslide Map
    - Morro Rock after Lodgepole[ii]
    - Sample Road gets very bad with fire/rain

Feedback for Climate Solutions (table representing votes for specific solutions):

At-A-Glance:

4-6 votes: Radiant Cooling of bus shelters; Thinning of Forested Areas.

3 votes: Easily Accessible Evacuation/Emergency Routes; Median Vegetation strip; Routine inspection/maintenance of electrical utility lines.

2 votes: Shaded bus shelters; Tree Canopies; Landslide retention.

Table 1: Complete Summary:

Hazard.Type	Solution.(votes)	Solution.(votes)	Solution.(votes)	Solution.(votes)	Solution.(votes)
Extreme Heat	Shaded Shelters (2)	Radiant cooling (6)	Tree Canopies (2)	Median veg. strip (3)	
Wildfire	Land Use Planning (0)	Thinning of forested areas (4)	Roadside veg. management (0)	Structural hardening (0)	Wildfire resistant bridge design
Wildfire (cont'd)	Evacuation/ Emergency Routes (3)	Early warning systems (0)	Evacuation phone system (0)	Fire-treated wooden utility poles (0)	Routine utility inspections/ maintenance (3)
Landslides	Monitoring high-risk areas (0)	Realignment (0)	Landslide retention (2)	Erosion stabilization (0)	

Figure 1: Votes for Solutions – Heat and Landslides

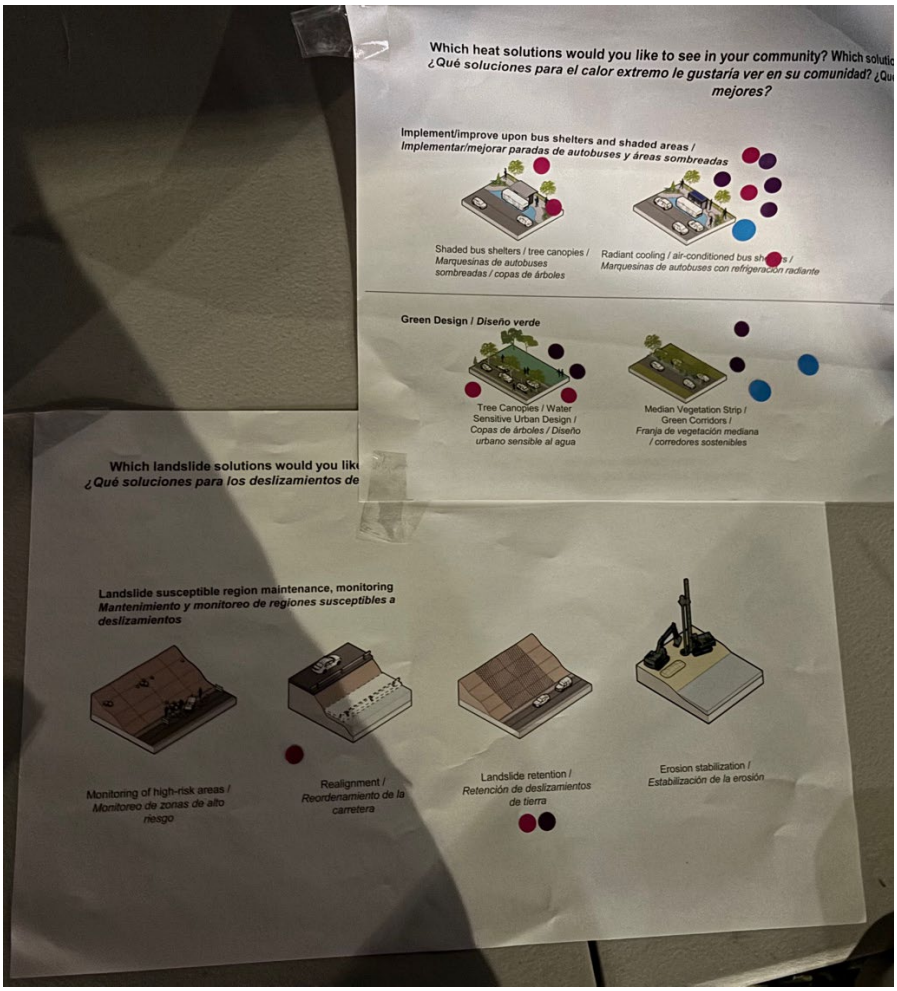
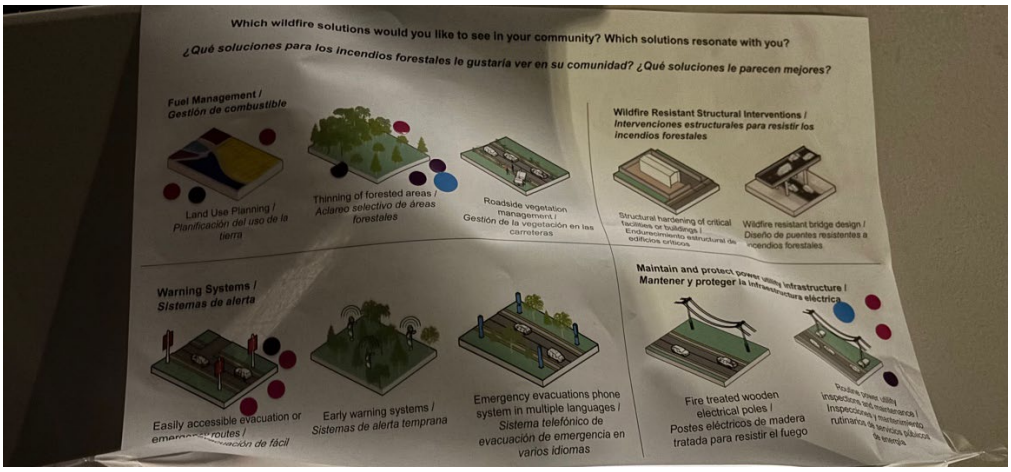


Figure 2: Votes for Solutions—Wildfire



Other public engagement notes:

All participants responded that they drove their own vehicles when asked if they use the public transportation network. One participant indicated that a parent regularly uses the bus. No public transportation vehicles were visible in the vicinity of Pioneer Park during the event.

On the solution boards, people were confused and interpreted some of the thumbnails as traffic solutions instead of climate hazard solutions.

Generally, people interacted with Solution boards more than the maps.

Combo map is a bit confusing to work with because it includes Wildfire and Flood hazards combined with Landslide priority projects/routes.

CBOs that requested to be notified about the project:

Rosa Corcoles; Self help Enterprise (works at Visalia site); rmcorcoles07@outlook.com

Prepared by Karl Gurney, UDD

Reviewed by Sheila Hakimipour, UDD

March 2025

Revised May 2025

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[i] Crystal Cave Road and Lodgepole are in Tulare County, located within Sequoia National Park.
[ii] Morro Rock is in Tulare County within Sequoia National Park.

Fresno COG / UDD CCRP Popup Report

Community Disaster Preparedness Workshop – Community Housing Council

Event Date: March 8, 2025,
Event Location: 205 E River Park Circle, Fresno, CA 93720
Timeframe: 11am-1pm
Team: UDD (Sheila Hakimipour).

Summary of Outreach Event:

The event focused on disaster preparedness. The event sponsor supports Fresno County residents who wish to become homeowners or obtain loans, or who are otherwise served by the Community Housing Council. Supervisor Magsig opened the event. Other vendors such as Red Cross, Clovis Fire Department, Fresno Community Emergency Response were also at the event. Residents also participated in the event's raffle, which encouraged them to come by the table and interact with the solutions posters and project scope maps. Vendors and others who set up tables attended by invitation. There were many families with young children. Following the event, the project team recommended that the Fresno COG team stay in touch and participate in other events hosted by the Community Housing Council, including one in September.

Estimated Number of Participants:

55 (no Spanish interactions)

Setting notes:

The event was inside, with a few displays outside

Feedback for Maps (transcribed from notes written by participants on sticky notes):

- Clinton & Brawley Bushfires
- Flooding areas: Minnewawa and Barstow

Feedback for Climate Solutions (votes for specific solutions):

Top Five solutions:

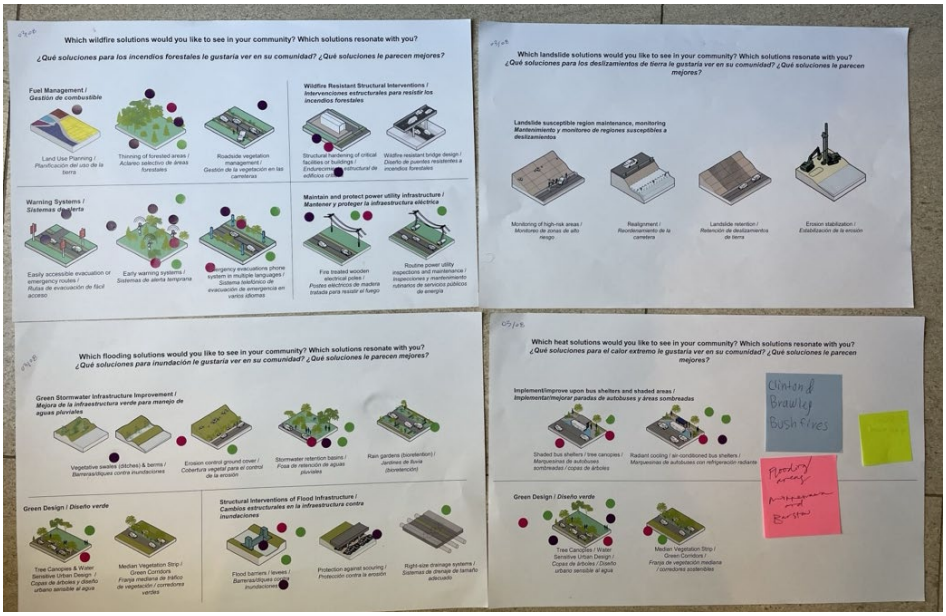
1. Early warning systems (7)

2. Tree Canopies (6)
3. Evacuation phone system (5)
4. Thinning of forested areas (5)
5. Flood barriers (5)

Table 1: Complete Summary

Hazard.Type	Solution.(votes)	Solution.(votes)	Solution.(votes)	Solution.(votes)	Solution.(votes)
Extreme Heat	Shaded Shelters (3)	Radiant cooling (4)	Tree Canopies (6)	Median veg. strip (2)	
Wildfire	Land Use Planning (1)	Thinning of forested areas (5)	Roadside veg. management (1)	Structural hardening (3)	Wildfire resistant bridge design (0)
Wildfire (cont'd)	Evacuation/ Emergency Routes (1)	Early warning systems (7)	Evacuation phone system (5)	Fire-treated wooden utility poles (3)	Routine utility inspections/ maintenance (1)
Landslides	Monitoring high-risk areas (0)	Realignment (0)	Landslide retention (0)	Erosion stabilization (0)	
Flood	Vegetative swales/berms (1)	Erosion control ground cover (2)	Stormwater retention basins (4)	Rain gardens (1)	Tree canopies/ water sensitive urban design (2)
Flood (cont'd)	Median vegetation strip (0)	Flood barriers (5)	Protection against scouring (1)	Right-size drainage systems (1)	

Figure 1: Votes for Solutions



Prepared by Karl Gurney, UDD

Reviewed by Sheila Hakimipour (UDD)

(April 2025)

Fresno COG / UDD CCRP Popup Report

Southeast Family Fair Popup Details

Event Date: March 15, 2025
Event Location: The Fresno Center, 4879 E Cesar Chavez Blvd, Fresno, CA 93727
Timeframe: 8:30am-12:30pm
Team: COG (Matthew Shimizu, Sean Nunes); UDD (Sheila Hakimipour, Karl Gurney)

Summary of Outreach Event:

The team tabled at a public outreach event in Southeast Fresno sponsored by Assemblyman Joaquin Arambula, the Community Health and Resource ("Southeast Family") Fair. The popup was set up alongside several other local service nonprofits, public agencies, a food distribution site, tax filing services, financial literacy training, and a mobile health clinic. Participants were invited to give feedback on the hazard and project maps and especially on the solutions boards, which resulted in more conversation than the maps. The maps were limited to the urban heat map on the transit network, as well as the context map for the whole project throughout Fresno County. The other maps were available for participants as a reference but were not posted on easels. Throughout the four hours the outreach team interacted with individuals, couples, and a few families. The table hosted several Spanish-language conversations, although one person was unable to communicate with the team due to there being no translation available in their language.

Estimated Number of Participants:

50-60; 10-15 Spanish language interactions

Setting notes:

The outreach table was in the parking lot of the shopping center on the north side of Cesar Chavez Blvd about halfway between Chestnut Avenue and Winery Avenue.

Feedback for Maps (transcribed from notes written by participants on sticky notes):

- Flood Map
    - Chestnut/Shepherd
    - Cornelia & Olive / Olive & aa (illegible)

Feedback for Climate Solutions (table representing votes for specific solutions):

Top Five solutions:

1. Tree canopies (22),
2. Radiant cooling (21),
3. Shaded shelters (16),

4. Vegetative swales/berms (10),
5. Stormwater retention basins (9)

Table 1: Complete Summary:

Hazard Type	*Solution (votes)*	*Solution (votes)*	*Solution (votes)*	*Solution (votes)*	*Solution (votes)*
Extreme Heat	Shaded Shelters (16)	Radiant cooling (21)	Tree Canopies (22)	Median veg. strip (2)	
Wildfire	Land Use Planning (6)	Thinning of forested areas (3)	Roadside veg. management (2)	Structural hardening (2)	Wildfire resistant bridge design (2)
Wildfire (cont'd)	Evacuation/ Emergency Routes (6)	Early warning systems (3)	Evacuation phone system (3)	Fire-treated wooden utility poles (1)	Routine utility inspections/ maintenance (4)
Landslides	Monitoring high-risk areas (2)	Realignment (0)	Landslide retention (3)	Erosion stabilization (0)	
Flood	Vegetative swales/berms (10)	Erosion control ground cover (7)	Stormwater retention basins (9)	Rain gardens (4)	Tree canopies/ water sensitive urban design (4)
Flood (cont'd)	Median vegetation strip (2)	Flood barriers (0)	Protection against scouring (2)	Right-size drainage systems (4)	

Figure 1: Votes for Solutions – Extreme Heat

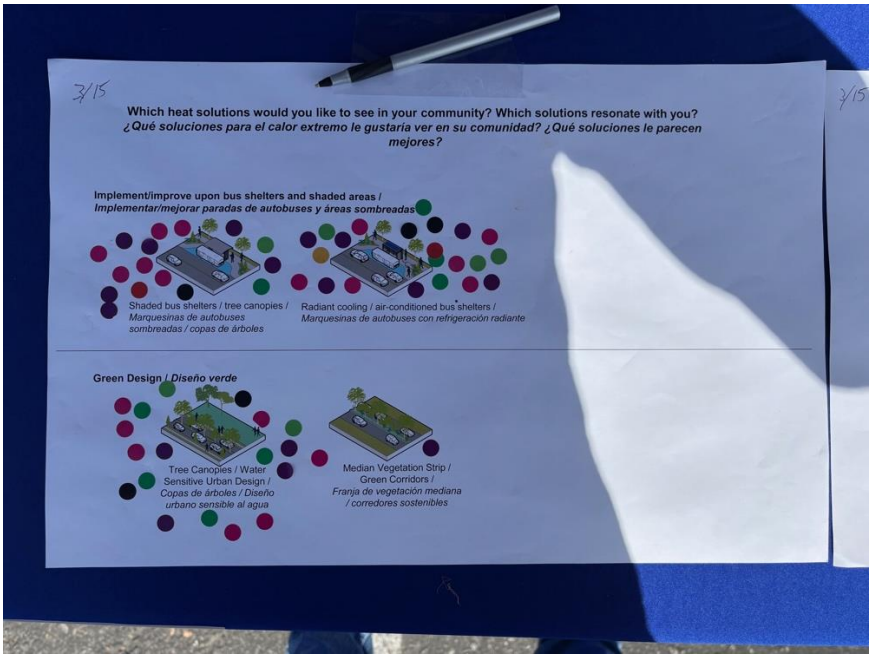


Figure 2: Votes for Solutions—Flooding

Figure 3: Votes for Solutions –Landslides

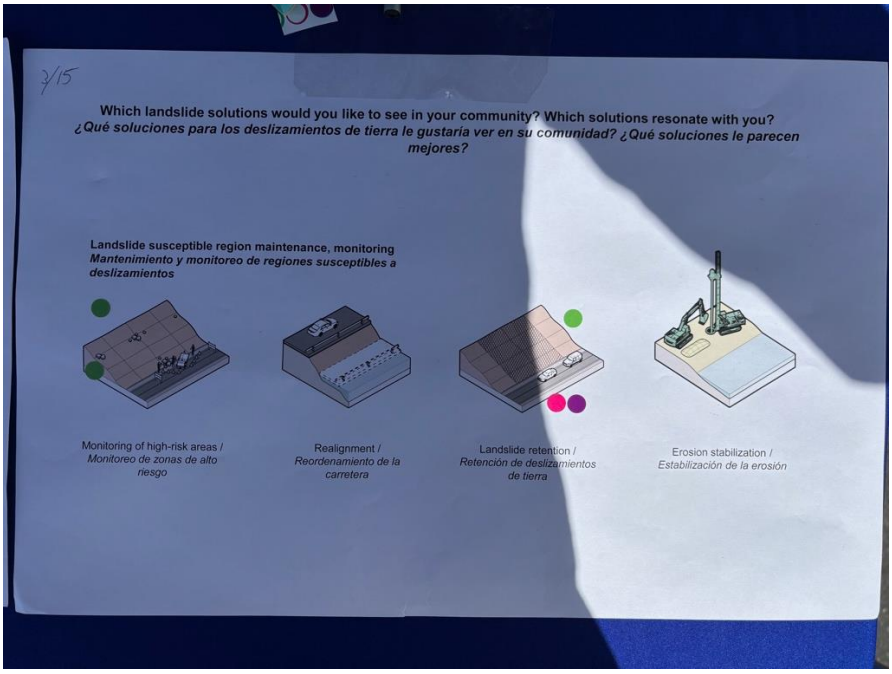
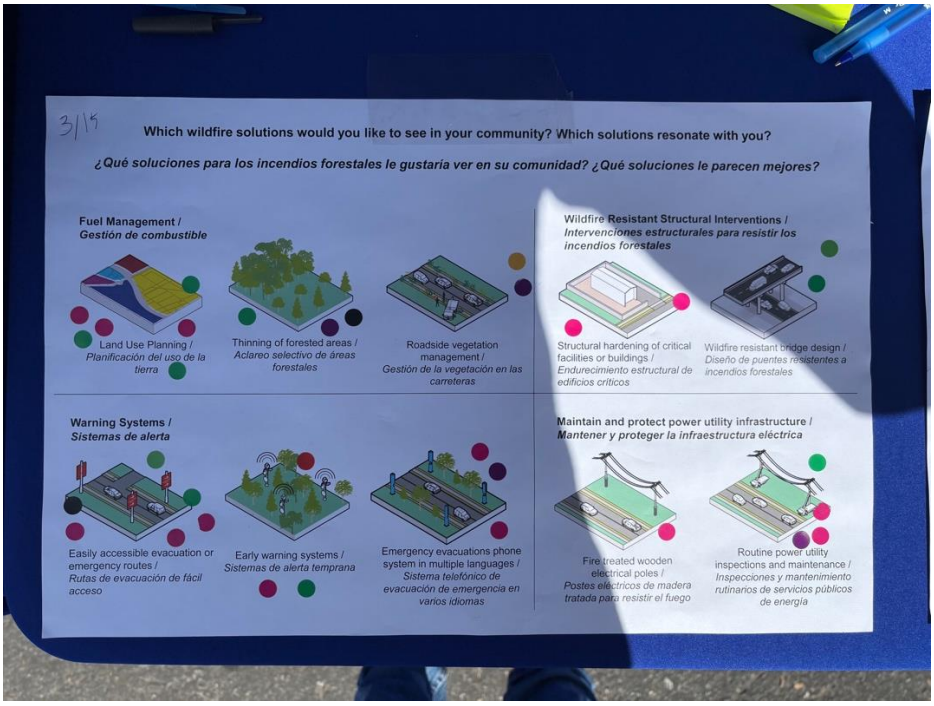


Figure 4: Votes for Solutions –Wildfires



Prepared by Karl Gurney, UDD

Reviewed by Sheila Hakimipour (UDD)

March 2025

Fresno COG / UDD CCRP Popup Report 3.19.25

Hoover High School Regional Family Engagement (Parent University) Popup Details

Event Date: March 19, 2025
Event Location: Hoover High School, 5550 N First St, Fresno, CA 93710
Timeframe: 4:00pm to 7:30pm
Team: COG (Paul Herman); UDD (Sheila Hakimipour); Interpretation by Linguistica (Reyna Rodriguez).

Summary of Outreach Event:

The team tabled at a School-Parent University event for Hoover High School District. Many families from Hoover High School and all the feeding schools participated in the event. An estimated total of 2500 to 3000 people were at the event. An estimated 200-225 people stopped at the table. Many participants brought cards to be stamped at most tables. Engagement for people who came to the table was very high and people responded well to the interactive components of the popup. We estimate that about ninety percent of the people who stopped by stayed and talked with us (instead of moving on after getting a stamp). Three outreach staff were speaking continually with parents/residents for 2.5 hours. Most of the interactions were in English, but about ten or fifteen interactions were in Spanish. The primary focus of most conversations was flooding and extreme heat in urban areas. Engagement primarily involved parents and families with young children from local elementary schools in the Hoover District, although a small number of high school students (fewer than twenty) also participated.

Estimated Number of Participants:

200-225; 10-15 Spanish-language interactions

Setting notes:

The table was located at the northeast corner of the central lawn, along with over fifty other vendors or organization outreach tables.

Feedback for Maps (transcribed from notes written by participants on sticky notes):

- Hazards to Road Network (Combo Map for Fresno County)
    - Mayfair flooding
    - Flooding 99 between Olive & Belmont
    - Flooding near Tenaya School near Bullard
    - First/Dakota bus stops no shelters
    - Flooding Sanger McCall & North

    - By Robinson School flood.
    - Flooding McKinley between Chestnut & Clovis
    - Flooding Ashlan & Chestnut to 180
    - Champlain (flooding) Bullard & Barstow (flooding) Ashlan transit (shelters)
    - Maple/Gettysburg Bus 38 and 9
    - Flooding Sierra & Fresno
    - Millbrook & Gettysburg flooding
    - Vinland Park flooded, Barton Park flood, Fruit/Barstow flood
    - Flooding issue Fruit/McKinley
    - Bus stop Princeton & Clovis tree is giving shade
    - Flooding Ashlan & Clovis county island
    - Fresno between Herndon and Sierra shade structure
    - Gettysburg/Woodrow bus shelter shade / Fresno & Browning
    - Vinland/Santa Ana/Barton flooding
    - Flooding / Potholes/Dry Creek cottonwood Park
    - Blackstone Dollar Tree bus stop, no shelter
    - Quigley Park Lira Park flooding
    - Dakota Millbrook bus shelter
    - Dakota Millbrook/ Cedar bus shelter
    - Dakota Clovis flooded
    - Berhert (?) flooded / Orange
    - Bullard flooded / Kearney Park flooded
    - Flooding Ashlan & Winery by Blackbeard's
    - Fresno/Shaw flooding
    - Bus stop shelter @ Holland/Vinland school
    - Ashlan/Fresno bus 45 / N Angus/Holland
    - 5th/Gettysburg Flooding
    - Flooding Angus/Gettysburg
    - Shaw/Cedar flood / Ashlan block / Fresno/Gettysburg Flooding
    - Vinland Park / Gettysburg/Maple / Crosswalk Barstow between First & Fresno
- Urban Heat Hazards Map
    - Cedar & Shaw (near university)
    - Heat Willow between Gettysburg & Shaw
    - Heat / Trees taken down on California Avenue

Feedback for Climate Solutions (table representing votes for specific solutions):

Top Five solutions:

1. Right-size drainage systems (34)
2. Shaded shelters (28)
3. Radiant Cooling (25)
4. Tree Canopies (18)
5. Evacuation phone systems (11)

Table 1: Complete Summary:

Hazard Type	*Solution (votes)*	*Solution (votes)*	*Solution (votes)*	*Solution (votes)*	*Solution (votes)*
Extreme Heat	Shaded Shelters (28)	Radiant cooling (25)	Tree Canopies (18)	Median veg. strip (2)	
Wildfire	Land Use Planning (0)	Thinning of forested areas (3)	Roadside veg. management (5)	Structural hardening (0)	Wildfire resistant bridge design (4)
Wildfire (cont'd)	Evacuation/ Emergency Routes (2)	Early warning systems (7)	Evacuation phone system (11)	Fire-treated wooden utility poles (1)	Routine utility inspections/ maintenance (2)
Landslides	Monitoring high-risk areas (4)	Realignment (4)	Landslide retention (5)	Erosion stabilization (5)	
Flood	Vegetative swales/berms (3)	Erosion control ground cover (2)	Stormwater retention basins (2)	Rain gardens (7)	Tree canopies/ water sensitive urban design (3)
Flood (cont'd)	Median vegetation strip (5)	Flood barriers (5)	Protection against scouring (3)	Right-size drainage systems (34)	

Figure 1: Votes for Solutions – Extreme Heat, Flooding, Landslides, Wildfires

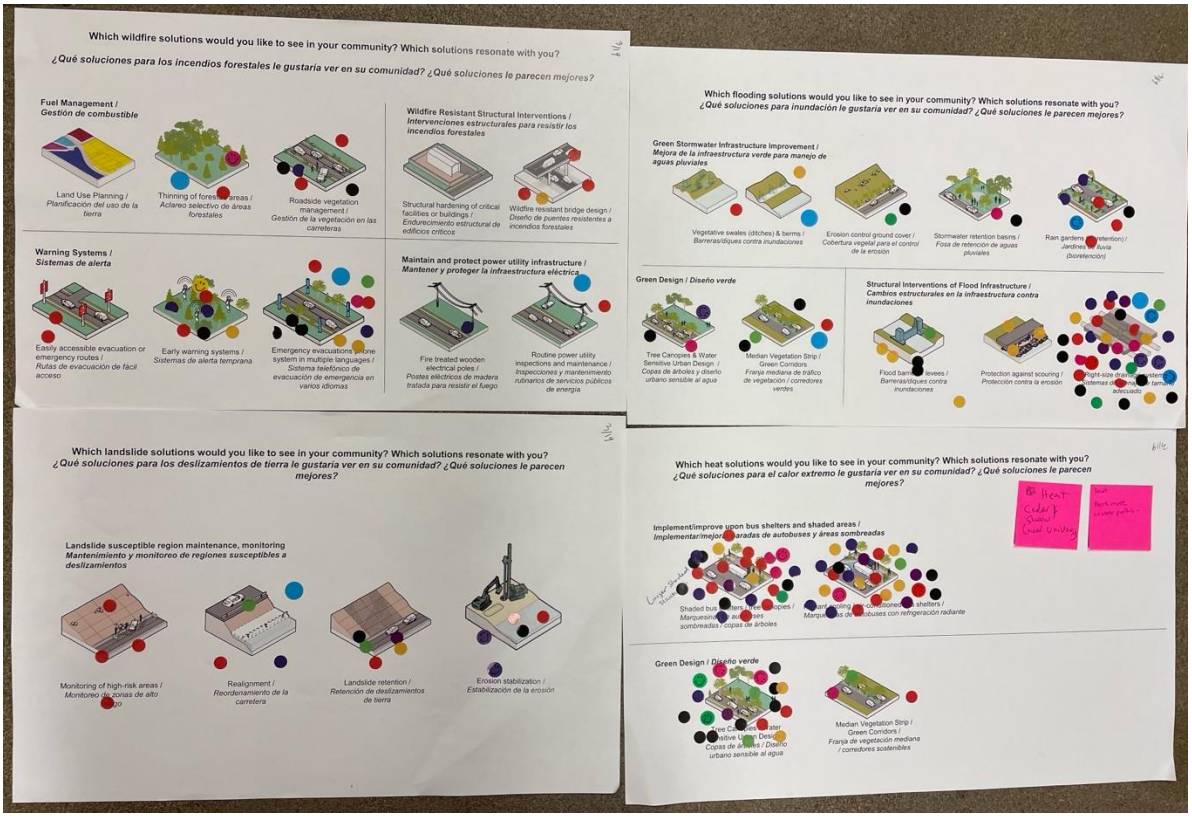
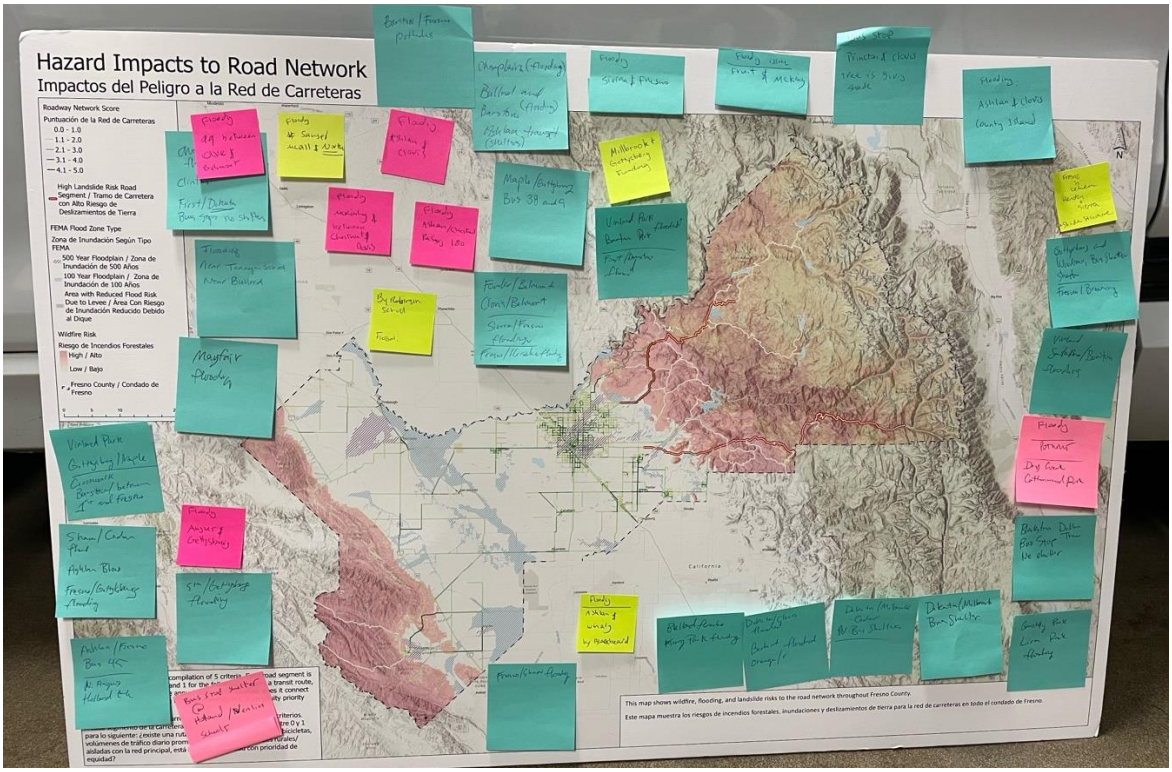


Figure 2: Combo map with comments



Prepared by Karl Gurney, UDD

Reviewed by Sheila Hakimipour (UDD)

(April 2025)

(Revised May 2025)

Fresno COG / UDD CCRP Popup Report 3.26.25

Mendota Outdoor Market Popup Details

Event Date: March 26, 2025
Event Location: Rojas Pierce Park: 297 San Pedro St, Mendota, CA 93640
Timeframe: 4:30pm to 7:00pm
Team: COG (Matthew Shimizu, Sean Nunes); UDD (Sheila Hakimipour); Interpretation by Linguistica (Reyna Rodriguez)

Summary of Outreach Event:

The Outdoor Market, hosted by the Westside Youth Center in Mendota, provided valuable community insights. Community members particularly focused on local flooding concerns. Most participants spoke Spanish and were enthusiastic about engaging, despite language barriers that limited interaction with the entire team. Event organizers offered helpful feedback as well. Young people showed less interest in the presented materials than their adult counterparts. Overall, participant insights were thoughtful and informative.

Estimated Number of Participants:

60-70; 50 -55 Spanish-language interactions.

Setting notes:

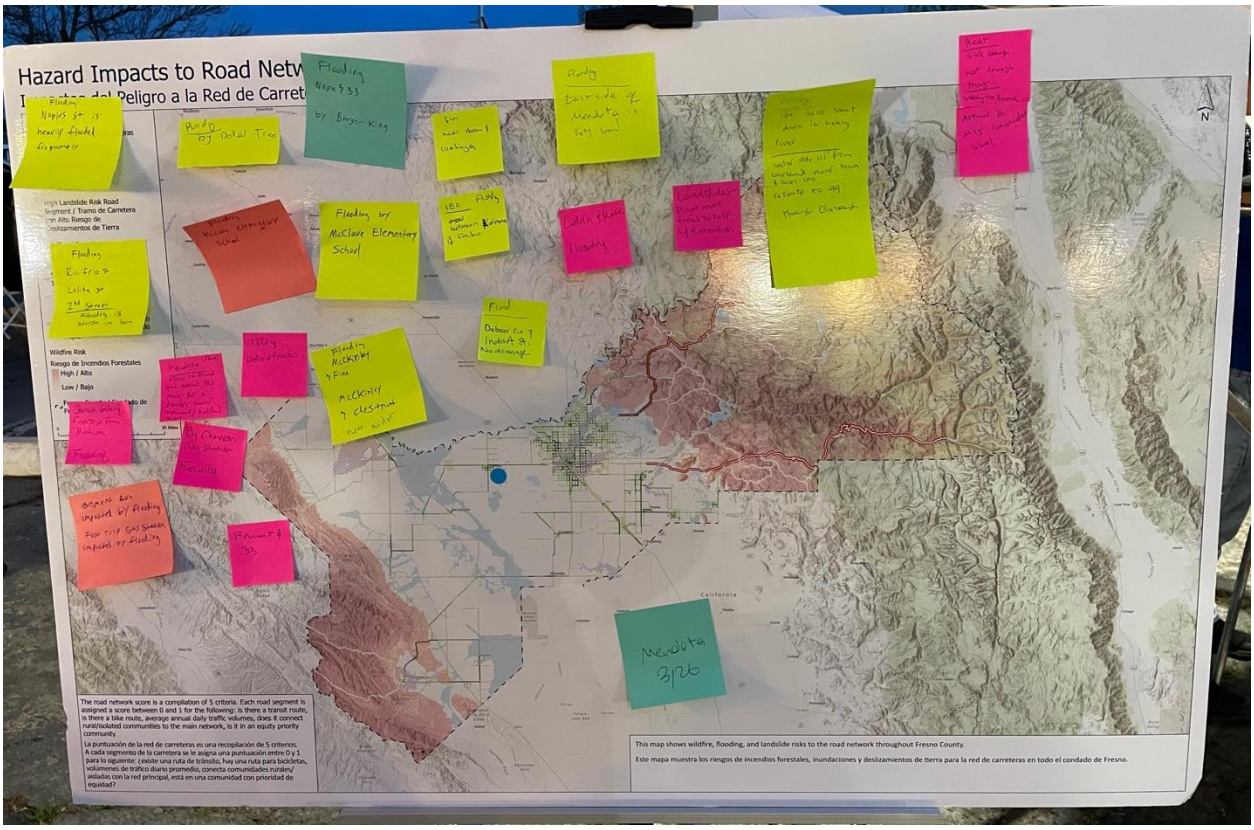
The event was outside, in a local park, and the wind made interactions with the printed materials challenging. Another organizer (Binational) had an event set up next to the outdoor market that provided a stream of participants who were moving back and forth between their popup and the outdoor market.

Feedback for Maps (transcribed from notes written by participants on sticky notes):

- Highway 180 flooded that forces traffic into rural areas of various quality. Drainage improvements in Mendota proper have improved.
- Not much concern for heat. People drive, don't walk around.
- Transportation isn't great. Get stuck in Mendota. Suffering from high food costs, inflation; so lack of transportation hurts. Food desert in a farming community.
- Flooding Naples Street/Heavily Flooded Frequently
- Flooding Rio Frio/Lolita & 2nd street. Flooding worse in town
- Flooding by Dollar Tree
- Flooding McClave Elementary School
- Flooding McClave Elementary School

- 180 by tracks
- By Chevron Gas station
- Belmont Ave Fast trip impacted by flooding
- Belmont & 33
- Flooding Napa & 33 by Burger King
- Flooding McKinley Chestnut
- Flooding McKinley by airport
- Flood near Huron & Coalinga
- Lolita & Kate flooding
- DeBoer circ. Indara street no drainage
- Landslides please more trees to help retention
- Heat in Firebaugh, not enough shade.

Figure 1: Notes placed on Road Network Map



Feedback for Climate Solutions (table representing votes for specific solutions):

Top Five solutions:

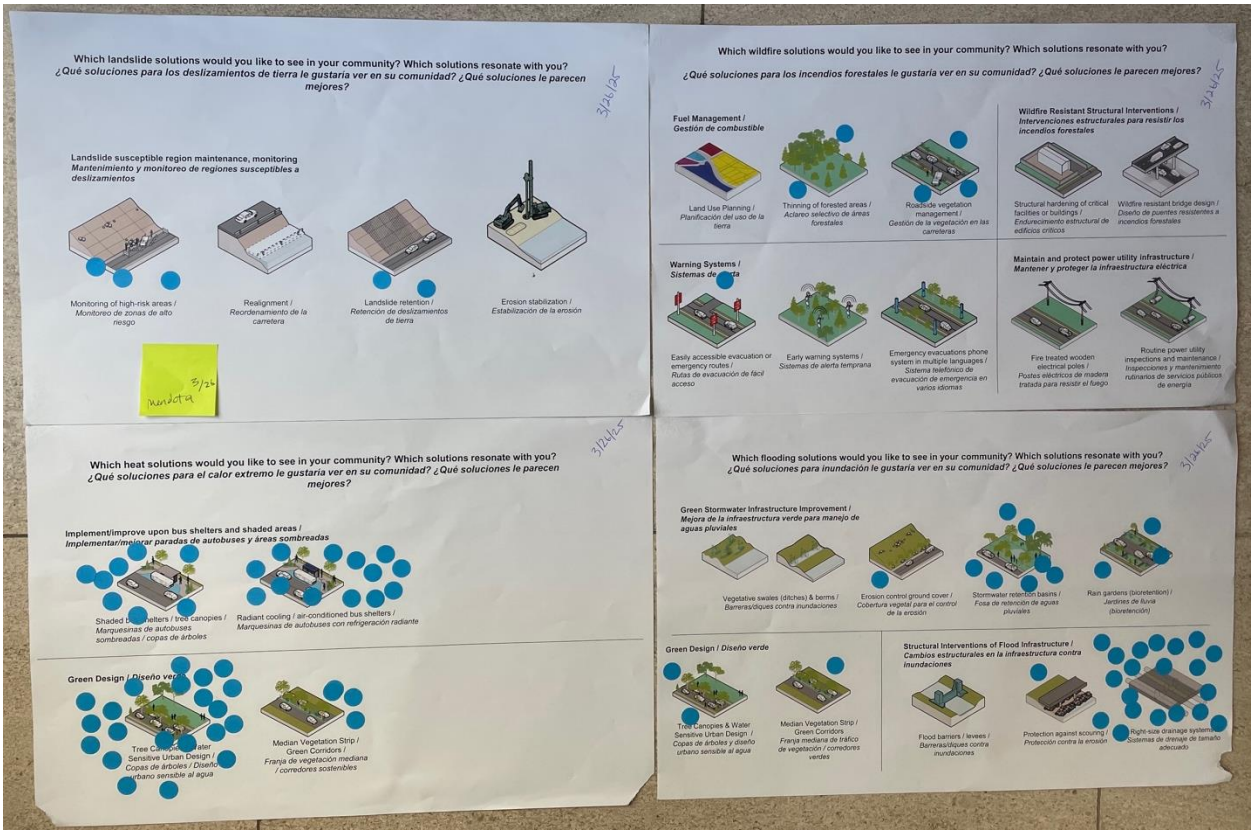
1. Tree Canopies (21)

2. Right-size drainage systems (19)
3. Radiant cooling (13)
4. Shaded Shelters (8)
5. Stormwater retention basins (7)

Table 1: Complete Summary:

Hazard Type	*Solution (votes)*	*Solution (votes)*	*Solution (votes)*	*Solution (votes)*	*Solution (votes)*
Extreme Heat	Shaded Shelters (8)	Radiant cooling (13)	Tree Canopies (21)	Median veg. strip (4)	
Wildfire	Land Use Planning (0)	Thinning of forested areas (2)	Roadside veg. management (3)	Structural hardening (0)	Wildfire resistant bridge design (0)
Wildfire (cont'd)	Evacuation/ Emergency Routes (1)	Early warning systems (0)	Evacuation phone system (0)	Fire-treated wooden utility poles (0)	Routine utility inspections/ maintenance (0)
Landslides	Monitoring high-risk areas (3)	Realignment (0)	Landslide retention (2)	Erosion stabilization (0)	
Flood	Vegetative swales/berms (0)	Erosion control ground cover (1)	Stormwater retention basins (7)	Rain gardens (3)	Tree canopies/ water sensitive urban design (2)
Flood (cont'd)	Median vegetation strip (1)	Flood barriers (0)	Protection against scouring (2)	Right-size drainage systems (19)	

Figure 2: Votes for Solutions



Prepared by Karl Gurney, UDD

(April 2025)

(Revised May 2025)

Fresno COG / UDD CCRP Popup Report

Auberry Earth Day Popup Details:

Event Date: April 12, 2025
Event Location: Auberry Park, 33367 Auberry Rd, Auberry, CA 93602
Timeframe: 10:00am to 3:00pm
Team: COG (Paul Herman, Matthew Shimizu); UDD was not present due to scheduling conflicts

Summary of Outreach Event:

The COG team held between 15-20 conversations with residents in Auberry and Big Creek, who provided comments on road impacts from the Creek Fire in 2020. In addition, a representative from the Sierra Resource Conservation District (SRCD) expressed interest in opportunities for Fresno COG and SRCD to collaborate after the CAP completion on specific Firewise communities' transportation projects, as well as coordinating with Caltrans.

Estimated Number of Participants:

15-20

Setting notes:

The popup was held at Auberry Park, on the north side of the main commercial zone of the mountain community of Auberry, and about 3 miles to the west of the Big Sandy Rancheria (a local Native American Reservation).

Feedback for Maps (transcribed from notes written by participants on sticky notes):

On Combo Map:

- Peterson Road wildfires
- Powerhouse Road wildfires
- Stump Springs Rd between Kaiser Pass & Big Creek Rd.
- Tollhouse – smoke coming down and potential issues
- Lodge & Tollhouse: flooding / Old Sierra Elementary

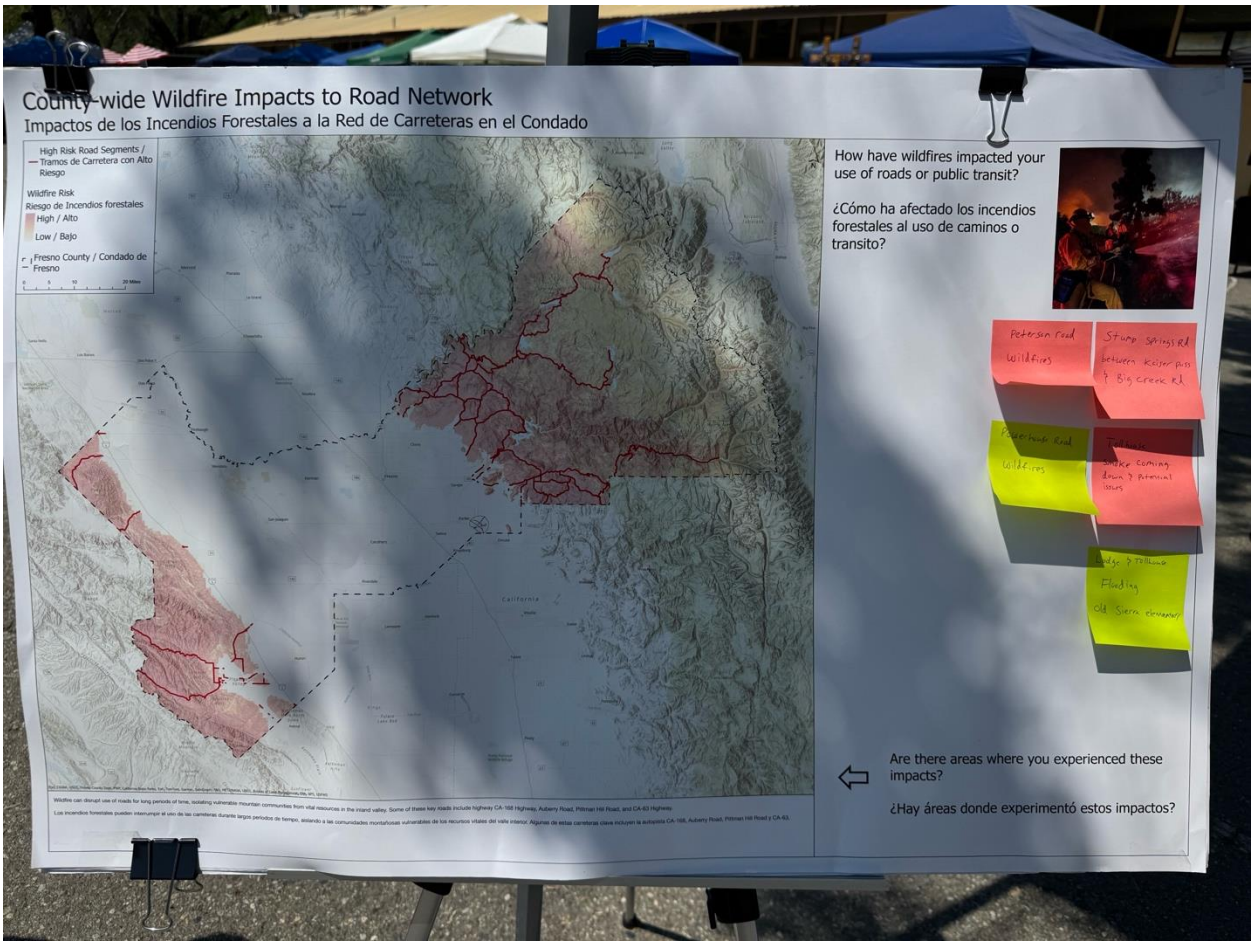


Figure 1: Combo Map and Sticky Notes

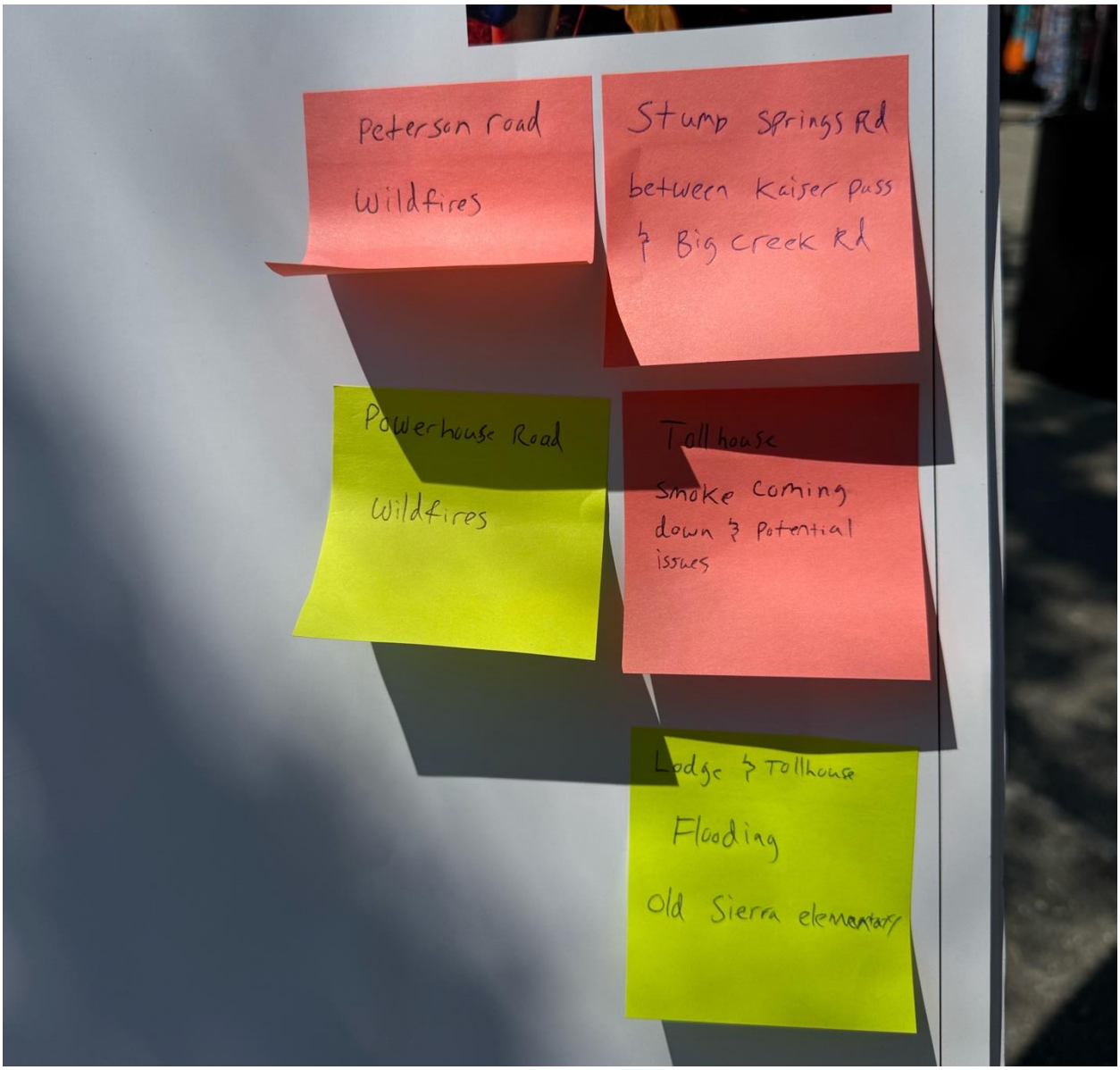


Figure 2: Detail of Combo Map with Sticky Notes text

Feedback for Climate Solutions (table representing votes for specific solutions):

At-A-Glance:

Participants did not provide votes for any solutions.

Prepared by Karl Gurney, UDD

April 2025

A.5 Review of Existing Plans Memo

ARUP

Memorandum

To	Fresno Council of Governments
Date	October 18, 2024
Copies	
Reference number	303440-00
From	Arup
File reference	
Subject	Final summary of existing plans, studies, and policies

1. Overview

As the first task in creating the Fresno County Transportation Climate Resiliency Plan, Arup reviewed a set of existing plans, studies, and data sets (see Table 1) to understand what previous work has been completed on assessing transportation vulnerabilities and developing adaptation solutions and how the previous work can support and inform this ongoing study. We plan to leverage key information extracted from the review of relevant plans to aid in the development of Fresno County's transportation risk assessment and resiliency plan and additionally ensure methods are consistent with Fresno COG's primary goals and governing ideologies including equitable resilience.

Table 1: Plans, studies, and data sets reviewed for this task

Fresno County Regional Transportation Vulnerability Assessment	Blackstone Corridor Transportation + Housing Study
Federal Transportation Improvement Program	Fifth National Climate Assessment
Fresno County Multi-Jurisdictional Hazard Mitigation Plan	California Fifth Climate Assessment
Fresno County Annual Action Plan 2023-24	Cal-Adapt
Fresno County Regional Transportation Plan & Sustainable Communities Strategy	FHWA's Climate Change Adaptation Guide for Transportation Systems
Fresno Priority Climate Action Plan	California Adaptation Planning Guide
Fresno County General Plan Policy Document	U.S. Department of Transportation PROTECT Program
Fresno County Regional Safety Plan	CalEnviroScreen 4.0
Fresno-Madera State Route 41 and Avenue 9 Sustainable Corridors Study	California Public Utilities Commission Disadvantage Communities
Multi-Jurisdictional Pavement Management System	U.S. Department of Transportation Equitable Transportation Community Explorer
Eastside Transportation Corridor Improvement Study	

There have been significant actions taken to understand the hazards facing Fresno County's regional transportation networks, and the previous work showcases a comprehensive understanding of where sensitive communities are located within the county as well as the most pressing hazards seen by Fresno County.

During this review, information was extracted on prioritization criteria, hazard profiling, damage ratings, outreach methods and standards, and indicators of vulnerability and/or disadvantaged communities. In the next phase of work, Arup intends to use this information to build a robust transportation risk assessment methodology. In developing this methodology, Arup will align with best practice, providing a clear and transparent method for assessing risk to Fresno County's regional transportation networks and surrounding communities and prioritizing adaptation solutions

2. Summary of Relevant Plans, Studies, and Data Sets

During this phase, Arup reviewed (1) local plans and guidance for Fresno County, (2) state and national plans and guidance, and (3) equity data sets and indicators. The summary is organized into these three categories.

2.1 Local plans and guidance

2.1.1 Fresno County Regional Transportation Network Vulnerability Assessment

Overview:

The Fresno County Regional Transportation Network Vulnerability Assessment is an assessment of the vulnerability of roads, bridges, transit stops, culverts, and airports to flooding, heat, wildfire, and landslide hazards that was completed in 2020. The goal of this assessment was to assist Fresno COG and member agencies in understanding the potential impacts of climate change on the region's transportation infrastructure. To score the vulnerability of different assets to the various hazards, this assessment used many factors, including historical hazard data and future hazard projections; previous damage; and asset material, condition, and capacity. After completing the vulnerability assessment, this study developed potential adaptation strategies to address the identified vulnerabilities, considering factors such as processes and resources, policy and funding, and co-benefits when evaluating the adaptation solutions. Public feedback, gathered through surveys, stakeholder interviews, workshops, and pop-up events, was used to inform the vulnerability assessment and adaptation strategies.

Key Findings:

Key results from the Fresno County Regional Transportation Network Vulnerability Assessment include:

- Socially vulnerable populations are disproportionately at risk to the impacts of climate change on transportation.
- Wildfire and riverine flooding pose substantial risks to portions of the county without redundant transportation routes.
- Heat, wildfire, and flooding are expected to increase in the future with climate change, which will impact transportation routes and likely increase maintenance requirements for roads and other transportation assets.

- Many bridges are at risk of riverine flooding. While many of these bridges are in low-density areas, many do not have redundant paths.
- Wildfires could isolate communities in the Sierra Nevada and surrounding foothills who have limited redundancy in egress routes.
- Transportation assets in the mountainous regions of Fresno County are vulnerable to landslides triggered by large amounts of precipitation.
- Recommendations to adapt to climate change include: shading bus stops and changing pavement design to protect against heat; elevating infrastructure, increasing scour prevention, and installing tree wells or bioswales to protect against flooding; maintaining defensible spaces sizing infrastructure to account for wildfire exposure to protect against wildfire; and monitoring slope stability to protect against landslides.

Extracted Information:

Based on the literature review of the Fresno County Regional Transportation Network Vulnerability Assessment, the following key components were extracted and are intended to inform the next phase of this work:

- Transportation assets to be assessed for risk to climate hazards (i.e., roads, bridges, transit stops, airports, and culverts).
- Climate data (current and future) that will be updated with the most recent models for flood, wildfire, and heat.
- Potential assets and locations that are most vulnerable to climate hazards that could be studied further during the prioritization phase.
- Factors to include when assessing vulnerability and risk (e.g., hazard intensity, asset material or capacity, previous damage, etc.).
- Stakeholder feedback and outreach methods.

2.1.2 Federal Transportation Improvement Program

Overview:

The Federal Transportation Improvement Program (FTIP) is an incremental implementation (four years) of the long-range Regional Transportation Plan (RTP) (long-range meaning 24 years). The FTIP showcases how to implement the long-range plan by aggregating it into more manageable components to then identify which projects are eligible for federal funding. There are two key components to this process (1) the priority list of projects to be completed in a four-year period and (2) showcasing a financial plan to support this priority list. The preliminary prioritization schema used in selecting projects align with projects that engage both historically underserved populations and federal land management agencies. Additionally, the selection criteria considers whether a proposed project coincides with air quality requirements and the transportation performance management approach. Financial funding is then distributed and planned based on COG's interpretation of the federal prioritization scheme.

Extracted Information:

Based on the literature review of the Federal Transportation Improvement Program, the following key components were extracted and are intended to inform the next phase of this work:

- Methods used in FTIP's financial prioritization criteria.
- List of example projects selected for implementation.

2.1.3 Fresno County Multi-Jurisdictional Hazard Mitigation Plan

Overview:

The Hazard Mitigation Plan details the process used to plan hazard mitigation plans for Fresno County with the primary goal of reducing vulnerability for the County and residents to future hazardous events. The risk assessment used for mitigation planning is separated into the following key steps: (1) identify hazards, (2) profile hazard events to inform vulnerability assessments, (3) inventory assets, and (4) estimate losses (FEMA, 2001). These hazards are then used to assess the vulnerability of primarily building exposure, critical facilities, agricultural assets, and transportation (human-induced hazards). The most significant hazards identified include, flooding, wildfire, sever weather, drought, and agricultural-based hazards. Additionally, this plan details a prioritization process for how to select certain mitigation strategies.

Extracted Information:

Based on the literature review of the Fresno County Multi-Jurisdictional Hazard Mitigation Plan, the following key components were extracted and are intended to inform the next phase of this work:

- Hazard Profile Rating System: In identifying and detailing all physical hazards that are probable in the planning area and then rating them based on likelihood of future occurrence (e.g. Unlikely to High Likely).
- Documentation of all risk assessments performed in the Fresno County Planning Area.
- STAPLEE Prioritization: Process for selection of mitigation strategies based on social, technical, administrative, political, legal, economic, and environmental impacts.

2.1.4 Fresno County Annual Action Plan 2023-24

Overview:

Fresno County details their 2023-24 Annual Action Plan which targets the needs related to the housing crisis. By allocating grant funding from the US Department of Housing to address the needs outlined in the Strategic (Consolidated) Plan the action plan focuses on housing related needs to a variety of communities. This plan outlines the methods used to generate the 2023-24 Annual Action Plan with goals including, but not limited to, improvements to public facilities and infrastructure for Cities and Unincorporated communities, housing rehabilitation efforts and the expansion of affordable housing developments. Additionally, the report outlines hazard identification and mitigation efforts that currently threaten households for Fresno County. The governing hazards that influence risk in households is summarized in this report as increasing temperatures and extreme heat, inland flooding, wildfire, and drought. This report considers the effects of inequitable housing by recognizing that the impacts from these hazards are significantly larger for lower-income households or sensitive communities when compared to higher income households.

Extracted Information:

Based on the literature review of the Fresno County Annual Action Plan 2023-24, the following key components were extracted and are intended to inform the next phase of this work:

- Identification of hazards that cause higher risk to lower-income households and sensitive populations.
- Documentation of outreach methods and actions used in Fresno county's work, primarily with citizen committee groups as well as priority in participation from historically underrepresented communities.
- List of example projects regarding equitable housing.

2.1.5 Regional Transportation Plan & Sustainable Communities Strategy

Overview:

Discusses Fresno Council of Government's (COG) 2022 Regional Transportation Plan's (RTP) long term vision thru 2046. The approach leverages their efforts in establishing Transportation Performance Measures (TPM) targets for all public roads in the COG planning area. These Transportation Performance Measures are applied in routinely to inform and aid decision makers in objectively understanding the investment consequences across different transportation assets or modes. These consequences can then be addressed through project work and prioritized by means of the defined project prioritization criteria. Example future scenarios were modeled addressing the issues related to transportation planning in Fresno County. The RTP's also mentions other options for risk quantification including the ITHIM Modeling Tool and Fresno County Health Priority Index. Additionally outreach methods and examples of equitable planning were detailed regarding environmental justice.

Extracted Information:

Based on the literature review of the Regional Transportation & Sustainable Communities Strategy, the following key components were extracted and are intended to inform the next phase of this work:

- Project Prioritization Criteria categorized into the following modes (a) maintenance, (b) capacity increasing, (c) transit, (d) operations, and (e) bike and pedestrian projects;
- Examples of possible Fresno County Future Scenarios, in particular those regarding Fresno County's climate adaptation and mitigation strategies
- Project Prioritization List from Fresno County

2.1.6 Fresno Priority Climate Action Plan

Overview:

The Fresno Priority Climate Action Plan (PCAP) was an initial effort to understand greenhouse gas (GHG) emissions and impacts to communities in Fresno County as well as priorities for reducing GHG emissions. The study consisted of three main tasks: (1) conducting a GHG inventory, (2) identifying GHG reduction measures, and (3) completing an analysis of benefits to low-income disadvantaged communities. The transportation sector contributes nearly half of Fresno County's GHG emissions, and the plan proposes five transportation-focused strategies for reducing GHG emissions. As a part of this study, a thorough investigation into how climate change, pollution, and GHG impact low-income

disadvantaged communities and how the proposed reduction measures could benefit these communities. The PCAP will be used in the next phase of developing a Comprehensive Climate Action Plan.

Extracted Information:

Based on the literature review of the Fresno Priority Climate Action Plan, the following key components were extracted and are intended to inform the next phase of this work:

- Recommendations for the transportation sector that could possibly be incorporated into the potential projects and project prioritization (e.g., electrical vehicle charging network and well-connected bike and pedestrian system).
- Information about how low-income disadvantaged communities are impacted by climate change that can be used during the project prioritization phase.

2.1.7 Fresno County General Plan Policy Document

Overview:

The Fresno County General Plan Policy is a set of governing guidelines regarding land use and development. Important topics of note include transportation circulation and environmental justice efforts defined by Fresno County. The general plan details a framework to aid in the decision-making process for changing or address countywide transportation issues. This framework separates how to address transportation risk by (1) new development and (2) existing roadways for improvement. For new development of roadways, the Fresno County General Plan Policy uses a roadway functional classification system that defines standards required for new developments by functional class (e.g., local, expressway state route). Regarding existing roadways, technical assessment tools are leveraged including Road and Traffic Evaluation (RATE) and Pavement Management System (PMS) to prioritize roadway improvements. The Fresno County Policy Plan additionally considers issues related to environmental justice by defining the existing conditions of environmental hazards as well as the associated consequences.

Extracted Information:

Based on the literature review of the Fresno County General Plan Policy Document, the following key components were extracted and are intended to inform the next phase of this work:

- Roadway Functional Classification System.
- Road Traffic Evaluation and Pavement Management System.
- Breakdown of environmental hazards and consequences effecting the more vulnerable regions of Fresno County.

2.1.8 Regional Safety Plan

Overview:

To address Fresno County's growing roadway safety risk the COG has worked to develop a Regional Safety Plan to ultimately incorporate transportation-based safety planning into the broader long-term transportation planning for Fresno County. The Regional Safety Plan outlines plans to implement and

bolster roadway safety for Fresno County by aligning itself with the State of California's Strategic Highway Safety Plan.

Extracted Information:

Based on the literature review of the Regional Safety Plan the following key components were extracted and are intended to inform the next phase of this work:

- Guidelines for Authentic Outreach.
- Statistics regarding crash safety for Fresno County.
- Relative Severity Index: a tool used to understand the relative severity of a transportation related incident to aid in prioritization of these risks.
- Example solutions to improve roadway safety for varying types of crashes.

2.1.9 Fresno-Madera State Route 41 and Avenue 9 Sustainable Corridors Study

Overview:

This report summarizes the sustainable corridors case study for Fresno-Madera Route 41 and Avenue 9 Sustainable Corridors Study. The purpose of this study is to explore future improvements to the transportation network for State Route 41 (SR-41) and Avenue 9 corridors in Fresno and Madera. Both routes are integral to the transportation network for the surrounding communities which are primarily identified to be sensitive. This study is broken up into the following phases: (1) identification of existing conditions, (2) planning of transportation improvements, (3) review of improvements through community engagement, and (4) travel forecasts. In following this workflow this case study explores future scenarios that are modeled in detail as well as provides tools to measure the equity considered in transportation solutions.

Extracted Information:

Based on the literature review of the Fresno-Madera State Route 41 and Avenue 9 Sustainable Corridors Study the following key components were extracted and are intended to inform the next phase of this work:

- Outreach guiding questions and methods.
- Equity Assessment Tool: Themes to identify if a proposed transportation solution is considering equity in an adequate manner.
- Building Equitable Projects: Identified factors to generate a project with adequate equitable outcome.
- Future project scenarios.

2.1.10 Multi-jurisdictional Pavement Management System

Overview:

The Multi-jurisdictional Pavement Management System report consists of a series of reports beginning with a technical report explaining the methods of the Pavement Management System. The Pavement Management System offers a methodology to identify roads and transportation networks with pavement

damage and assign a qualitative rating. These ratings are then paired with financial estimates for rehabilitation to model future scenarios. A series of case studies were implemented using the Pavement Management System for the following cites: Coalinga, Firebaugh, Fowler, Huron, Kingsburg, Mendota, Orange Cove, San Joaquin, and Selma.

Extracted Information:

Based on the literature review of the Multi-jurisdictional Pavement Management System the following key components were extracted and are intended to inform the next phase of this work:

- Pavement Management System methodology.
- Case studies for select Fresno County cities showcasing implementation of the Pavement Management System.

2.1.11 Eastside Transportation Corridor Improvement Study

Overview:

The Eastside Transportation Corridor Improvement Study aims to identify projects to improve the transportation mobility and life safety measures for the Academy Avenue and Manning Avenue Corridor. This report summarizes existing transportation conditions and opportunities for improvement through a variety of lenses including climate change preparedness.

Extracted Information:

Based on the literature review of the Eastside Transportation Corridor Improvement Study the following key components were extracted and are intended to inform the next phase of this work:

- Climate Change Preparedness: vulnerability ratings and terminology.
- Climate Change Preparedness: adaptation measures and potential solutions by hazard.

2.1.12 Blackstone Corridor Transportation + Housing Study

Overview:

The Blackstone Corridor Transportation and Housing Study aims to transition the Blackstone Corridor from its current state into a multi-modal transportation hub in Fresno County while maintaining mixed-use livable and affordable building complexes. This framework implements future scenarios to depict potential solutions for the region but does not set a timeline.

Extracted Information:

Based on the literature review of the Blackstone Corridor Transportation + Housing following key components were extracted and are intended to inform the next phase of this work:

- Case Study of future scenarios modeled for the Blackstone Corridor Transportation.

2.2 State and national plans and guidance

2.2.1 Fifth National Climate Assessment

Overview:

The Fifth National Climate Assessment is a report in compliance with The Global Change Research Act of 1990 in which a science-informed assessment of the United States is implemented to support informed policy planning. This report contains the assessment of physical climate science data for current and projected climate scenarios for its risk and impacts on building, infrastructure, and societal impacts. A transportation specific summary is provided linking the relationship between climate hazards and the vulnerability they pose on transportation infrastructure. Climate action and mitigation strategies are then derived from the findings of these assessments, showcasing a variety of sample strategies. The identified climate change related events are summarized by region across the United States.

Extracted Information:

Based on the literature review of Fifth National Climate Assessment the following key components were extracted and are intended to inform the next phase of this work:

- Climate change assessments on regions of the United States.
- Climate hazard data.
- Equitable approaches to adaptation.
- Informed development of adaptation and mitigation strategies.

2.2.2 California Fifth Climate Assessment

Overview:

Historically, the state of California (CA) has endured a variety of climate-change related events including severe drought, wildfire, and extreme heat events as examples. California climate assessment efforts, the most recent being the Fifth Climate Change Assessment were guided from the initiative brought forth from Senate Bill 132. This bill urges the state to engage in climate change assessments on a recurrence interval of at minimum every five years. As a result the Fifth Assessment will offer the most up-to-date climate data for California originally derived from the CMIP6 model. Further context will be collected as a part of the Tribal research program to gain input regarding the impact of climate change from the Indigenous Peoples of California. These efforts aim to further bolster adaptation and resilience strategies for the state of California.

Extracted Information:

Based on the literature review of California Fifth Climate Assessment the following key components were extracted and are intended to inform the next phase of this work:

- Climate Data for projections of future climate scenarios.

2.2.3 Cal-Adapt

Overview:

Cal-Adapt is a tool offering accessible high-resolution downscaled climate data with prioritization to support both (1) California's energy sector and (2) informing the latest developments of climate adaptation measures. Within Cal-Adapt's API offers a variety of credible and detailed climate data for hazards including wildfires, extreme heat, droughts, or precipitation. Despite housing a variety of models, Cal-Adapt includes LOCA Downscaled climate projections which are sourced from the CMIP5 and

CMIP6 models allowing for high-resolution projections for the RCP 4.5 and RCP 8.5 climate scenarios. Cal-Adapt serves as a premier tool in easily accessing climate data on a state led scale.

Extracted Information:

Based on the literature review of Cal-Adapt the following key components were extracted and are intended to inform the next phase of this work:

- Climate data for projections of future climate scenarios.

2.2.4 FHWA's Climate Change Adaptation Guide for Transportation System Management, Operations, and Maintenance

Overview:

The Climate Change Adaptation Guide for Transportation System Management, Operations, and Maintenance provides guidance to the Department of Transportation (DOT) transportation system management and operations (TSMO) and maintenance employees to integrate the risks from climate change and risk reduction measures into ongoing planning efforts. This guidance involves the development of a Climate Change and Extreme Weather Vulnerability Assessment Framework to generate primarily qualitative assessments. From these assessments, can then be derived climate-informed adaptation measures and policy planning.

Extracted Information:

Based on the literature review of the FHWA's Climate Change Adaptation Guide for Transportation System Management, Operations and Maintenance, the following key components were extracted and are intended to inform the next phase of this work:

- Qualitative vulnerability assessment frameworks.
- Sample adaptation measures for a variety of time frames.

2.2.5 California Adaptation Planning Guide

Overview:

The first iteration of the California Adaptation Planning Guide (APG) originated in 2015 under the jurisdiction of the California Office of Emergency Services and California Polytechnic State University, San Luis Obispo among other agencies. In 2020 the planning guide was re-issued to present an updated comprehensive workflow for communities or regions to engage in adaptation planning measures. In using the APG, the Governor's Office of Emergency Services aims to support local regions to prioritize climate-informed actions that address both climate-related hazards and foster building of resilient infrastructure while maintaining equity in their planning efforts. In developing these plans, APG also offers guidance on equitable methods for outreach and engagement to embed trust and transparency in the development of mitigation planning. Additionally, the California APG provides a means to perform a vulnerability assessment based on hazard data and historical performance of infrastructure post disaster.

Extracted Information:

Based on the literature review of the California Adaptation Planning Guide, the following key components were extracted and are intended to inform the next phase of this work:

- Holistic vulnerability information and guidance.
- Equitable outreach methods and approaches.
- Prioritization of adaptation strategies.

2.2.6 U.S. Department of Transportation Promoting Resilient Operations for Transformative, Efficient, and Cost-Saving Transportation Program (PROTECT)

Overview:

As a result of the Bipartisan Infrastructure Law, the U.S. Department of Transportation developed the Promoting Resilient Operations for Transformative, Efficient, and Cost-Saving Transportation (PROTECT) program to provide funding for surface transportation resilience to various natural hazards including climate change. The goal of the funding is to support planning activities, resilience improvements, community resilience, and evacuation routes.

Extracted Information:

The PROTECT program is a possible funding source that could be considered when pursuing funding for the projects developed as a result of this study. The program provides funding for planning activities, resilience improvements, and community resilience, so it would be a benefit to Fresno COG to tailor the projects developed in this study to be eligible for these (and other) funds and to frame these outputs according to the PROTECT program funding selection considerations.[1]

2.3 Equity data sets and indicators

2.3.1 CalEnviroScreen 4.0

Overview:

CalEnviroScreen 4.0 is an interactive tool that can be used to understand the burdens and vulnerabilities of California communities, developed by the Office of Environmental Health Hazard Assessment within the California Environmental Protection Agency. It maps which communities are affected by pollution and social demographic factors that indicate higher vulnerability to pollution. The higher a community's score, the more exposed it is to a particular pollutant or social factor. The tool provides a relative evaluation of pollution burdens and vulnerabilities and uses twenty-one indicators to characterize the pollution burden and population characteristics of a community. A benefit of CalEnviroScreen is that it assesses cumulative impacts to understand how a community is affected simultaneously by many factors.

Extracted Information:

Based on the review of CalEnviroScreen 4.0, the following key components were extracted and are intended to inform the next phase of this work:

- Potential indicators of social vulnerability (e.g., educational attainment, linguistic isolation, unemployment, traffic impacts, exposure to drinking water contaminants, etc.) that can be used during project prioritization.

[1] https://www.fhwa.dot.gov/bipartisan-infrastructure-law/promote.cfm

- Data on the pollution burden and population characteristics of Fresno County by census tract. Fresno County has an average CalEnviroScreen 4.0 percentile of 69.5 out of 100, compared to a state average of 50. The western portion of the county is more exposed to pollutants and/or socially vulnerable, with an average percentile near 80 and a percentile of 100 in the most exposed census tract (located in Fresno city). On the other hand, the eastern half of the county has an average percentile of 30, with a census tract along the border with Madera County having a percentile of only 4 out of 100.

2.3.2 California Public Utilities Commission Disadvantaged Communities

Overview:

The California Public Utilities Commission (CPUC) makes concerted efforts to improve air quality and economic conditions in disadvantaged communities, which they identify as communities that suffer from a combination of economic, health, and environmental burdens, including poverty, high unemployment, air and water pollution, presence of hazardous waste, and high incidence of asthma and heart disease. CPUC uses CalEnviroScreen to help identify disadvantaged communities.

Extracted Information:

Based on the review of CPUC's definition of disadvantaged communities (taken from CalEPA, as determined per SB 535,[2]), the following criteria for defining disadvantaged communities were extracted and are intended to inform the next phase of this work, unless otherwise directed:

- Census tracts receiving the highest 25 percent of overall scores in CalEnviroScreen 4.0 (1,984 tracts).
- Census tracts lacking overall scores in CalEnviroScreen 4.0 due to data gaps, but receiving the highest 5 percent of CalEnviroScreen 4.0 cumulative pollution burden scores (19 tracts).
- Census tracts identified in the 2017 DAC designation as disadvantaged, regardless of their scores in CalEnviroScreen 4.0 (307 tracts).
- Lands under the control of federally recognized tribes.

2.3.3 U.S. Department of Transportation Equitable Transportation Community Explorer

Overview:

The Equitable Transportation Community (ETC) Explorer is a resource developed by the United States Department of Transportation (DOT) to explore the burden communities experience as a result of underinvestment in transportation. One of DOT's goals in collecting and analyzing this data is to ensure that future DOT projects and investments address the disadvantages caused by transportation or the lack thereof. The explorer provides data at the census tract level and uses census data from 2020. Vulnerabilities are expressed in five categories: (1) transportation insecurity, (2) climate and disaster risk burden, (3) environmental burden, (4) health vulnerability, and (5) social vulnerability. Many indicators and variables were used to develop the rankings: the three indicators for the transportation insecurity category were (1) transportation cost burden, (2) transportation access burden, and (3) transportation

[2] https://calepa.ca.gov/envjustice/ghginvest/

safety burden. The climate and disaster risk burden category also included three categories: (1) annualized disaster losses, (2) future climate and disaster risk burden, and (3) impervious surfaces.

Extracted Information:

Based on the review of the DOT Equitable Transportation Community Explorer, the following key components were extracted and are intended to inform the next phase of this work:

- A list of indicators that can be used to assess environmental, health, and social vulnerability and the relative vulnerabilities in these categories across census tracts in Fresno County.
- Data on the vulnerabilities in Fresno County: more than 400,000 people in Fresno County, approximately 40% of the population, were classified as living in disadvantaged census tracts, with health vulnerability, social vulnerability, and transportation insecurity driving the disadvantaged classifications.

3. Conclusion

Arup reviewed the above list of documents that was developed in consultation with Fresno COG. We have extracted information from Fresno COG's guidelines and policies, existing risk assessment methods, existing understanding of hazard and vulnerability, prioritization criteria of projects, mitigation strategies, outreach methods and equitable and sustainable development methods. The risk assessment and resiliency plan to be developed by Arup will build upon this previous work, utilizing established practices and leveraging existing findings in order to best integrate the results of the risk assessment with the strong body of work already completed by Fresno COG

A.6 Climate Hazards Memo

ARUP

Fresno Council of Governments

Fresno County Climate Resiliency Plan for Transportation

Climate Hazard Memo

Prepared by Emma Lambert, Jinal Mehta, Karen Barns

Final | May 16, 2025

Overview

This memo summarizes the climate hazard information sourced for Fresno County and the analyses conducted to understand how flooding, extreme heat, and wildfire hazards will change in the future due to climate change.

This assessment identifies the following overall trends for Fresno County:

- **Flooding** is a regional issue for Fresno County, though certain areas appear to be more prone to extreme flooding such as the cities of Fresno, Clovis & western Fresno County. In the future, extreme precipitation events may become more frequent, which drives the increase in flood risk in this study.
- **Extreme Heat** is an all-encompassing issue for Fresno County. The county is already susceptible to high temperatures and in the future are expected to get even hotter. In Fresno County, the heat index (a measure of temperature that serves as proxy for what high temperature and humidity "feels like" on the human body) can potentially rise on average by 5°F to 11°F by 2050 and 2085 respectively. Similarly, the dry bulb temperature is anticipated to increase as well causing more stress on Fresno County's road network.
- **Wildfires** in Fresno County predominantly impact rural and mountainous regions due to the availability of wildland fuel (trees, brush, etc.). Looking forward, changing climactic conditions can increase the likelihood of a wildfire significantly in certain areas. Some projections show that the chance of a wildfire occurring in heavily forested areas of Fresno County will triple by end of century.

This assessment uses the best available regional public datasets available for all of Fresno County. A summary of all hazard data sources is provided in the appendix. Present-day or "baseline" data for flood and wildfire are used "as is" with minimal adjustment. The post-processing of the future climate indicator data involves translating a climate indicator into a set of defined intensity measures that varies by hazard source. The data presented here will be used as inputs into the Transportation System Risk Assessment (Task 3) and Project-specific Climate Risk Assessments (Task 7).

1. Riverine Flooding

Flooding can be caused by several sources: rivers (fluvial), stormwater (pluvial), coastal (storm surge, wave run up, sea level rise, etc.), emergent groundwater, and more (e.g., dam burst). In riverine flooding, existing banks of rivers or their tributaries overflow and water escapes into the surrounding floodplain. In pluvial flooding, rainwater flows over land and collects in basins or ponds at local low points. In all these cases, flooding can inundate transportation infrastructure and cause damage leading to consequences like financial loss and downtime.

This assessment focuses on riverine flood risk of operational downtime in the present day as well as in the future. The baseline flood hazard dataset used in this study is FEMA's National Flood Hazard Layer (NFHL) that denotes regions where extreme flood events may occur. The climate indicator dataset used is a locally downscaled precipitation dataset that gives daily precipitation totals across North America (derived from LOCA1).

1.1 Present Day

FEMA National Flood Hazard Layer

The FEMA NFHL provides a general understanding of the extents of extreme riverine flood events in Fresno County. FEMA designates zones that may see flooding in extreme rainfall events, specifically the 100-year and 500-year events. The 100-year event is also known as the 1% chance exceedance event, as this event has a 1% chance of occurring or being exceeded each year. Similarly, the 500-year event is also known as the 0.2% chance exceedance event, as this event has a 0.2% chance of occurring or being exceeded each year.

A known limitation of the NFHL is that the flood zone designations do not provide information on flood depths. While base flood elevations (BFEs) are reported for certain areas near major rivers, this information is not available for most mapped flood zones. Some flood zones without an estimated BFE may additionally incur shallow ponding or sheet flow, estimated between 1-3 ft of flooding, which could cause damage to buildings and infrastructure. The FEMA NFHL within the boundaries of Fresno County is shown in Figure 1.

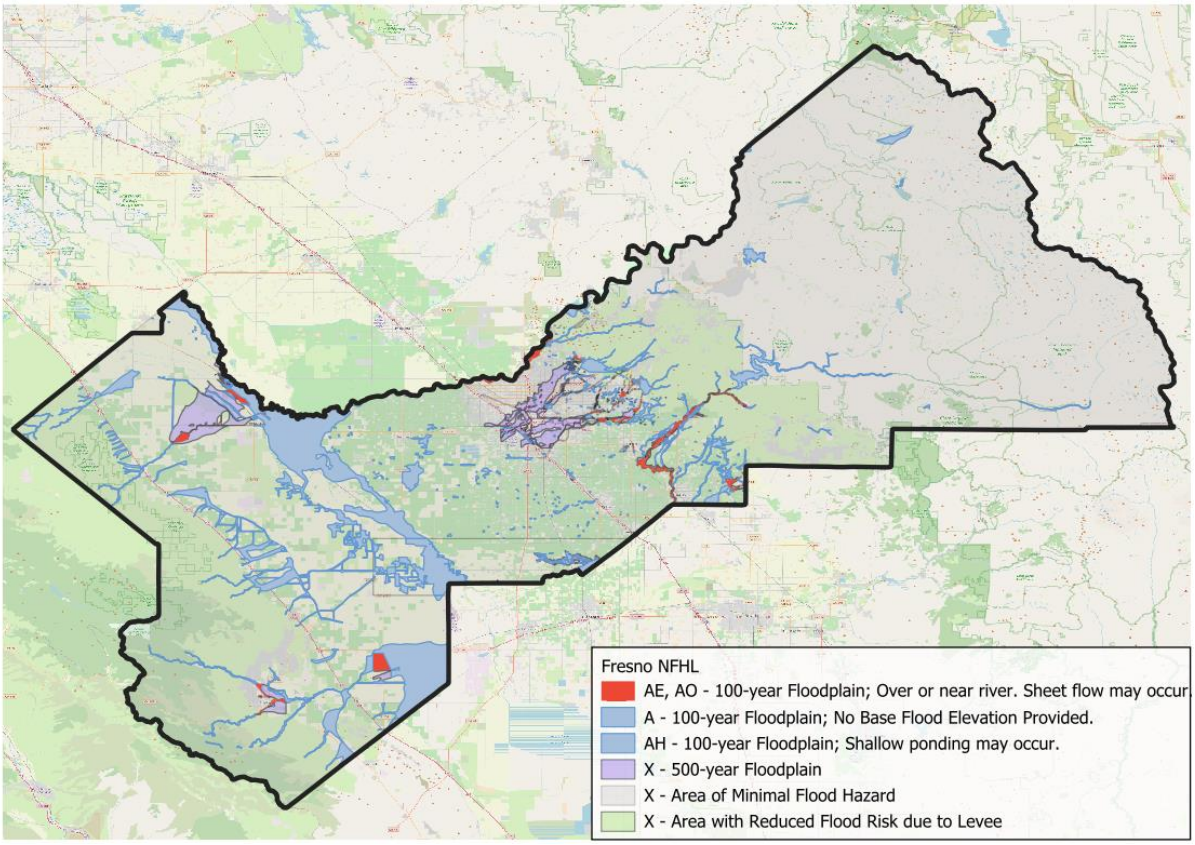
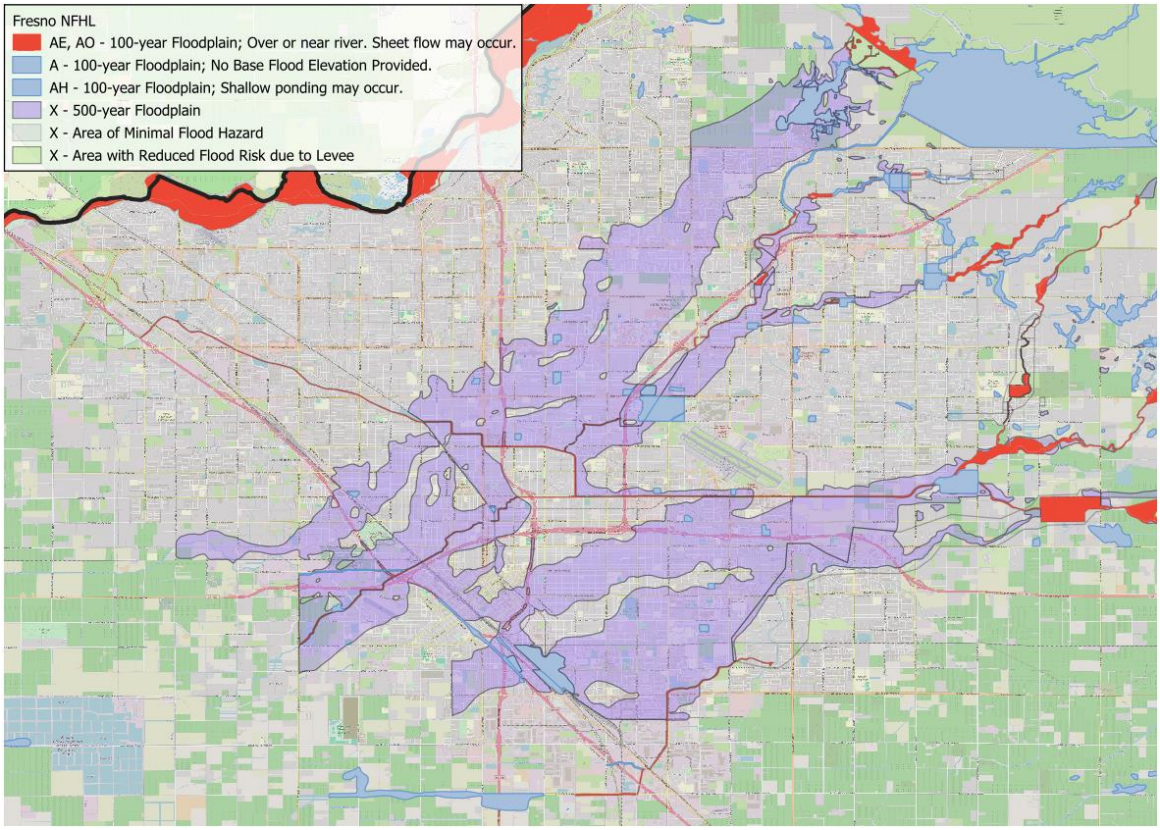


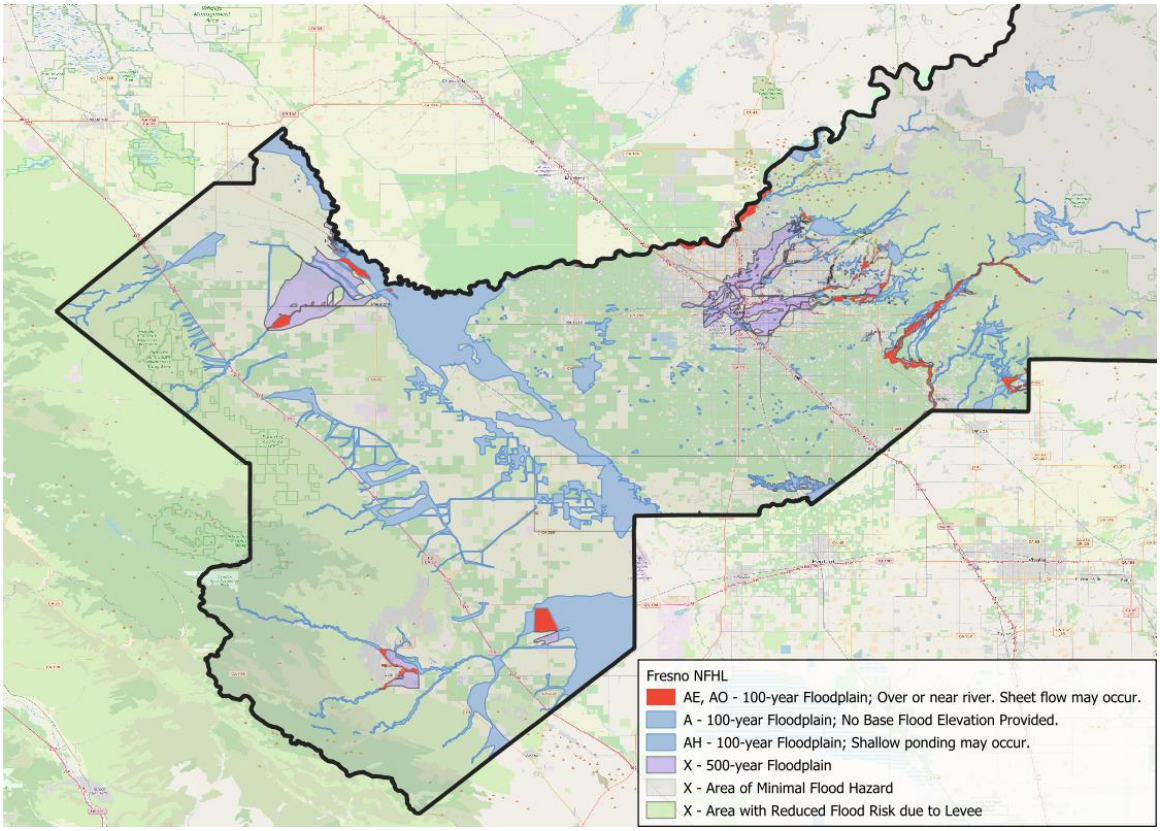
Figure 1. FEMA National Flood Hazard Layer overlayed in Fresno County.

Large portions of Fresno and Clovis fall within the 500-year FEMA flood plain as illustrated in the yellow areas in Figure 2a, in part due to the path of Big Dry Creek as well as a series of canals and waterways through the city. Heavy rain or rapid snowmelt in the Sierra Nevada can cause major rivers such as the San Joaquin and Kings rivers to overflow. A number of smaller rivers, streams, and canals when overtopped can cause flooding in eastern Fresno while much of Western Fresno is in the floodplain of the San Joaquin River, as shown in Figure 2b.

Overall, the FEMA NFHL provides a general sense of the portions of Fresno County that may be susceptible to extreme flooding. More local flood hazard models as well as observations from historic events such as the February 2024 atmospheric rivers can provide additional insights into flood-prone areas of Fresno County. For the purpose of this assessment, the FEMA NFHL is used to identify sections of Fresno County for flood risk evaluation.



(a)



(b)

Figure 2. FEMA National Flood Hazard Layer focused on (a) Fresno and Clovis, and (b) the western portion of Fresno County.

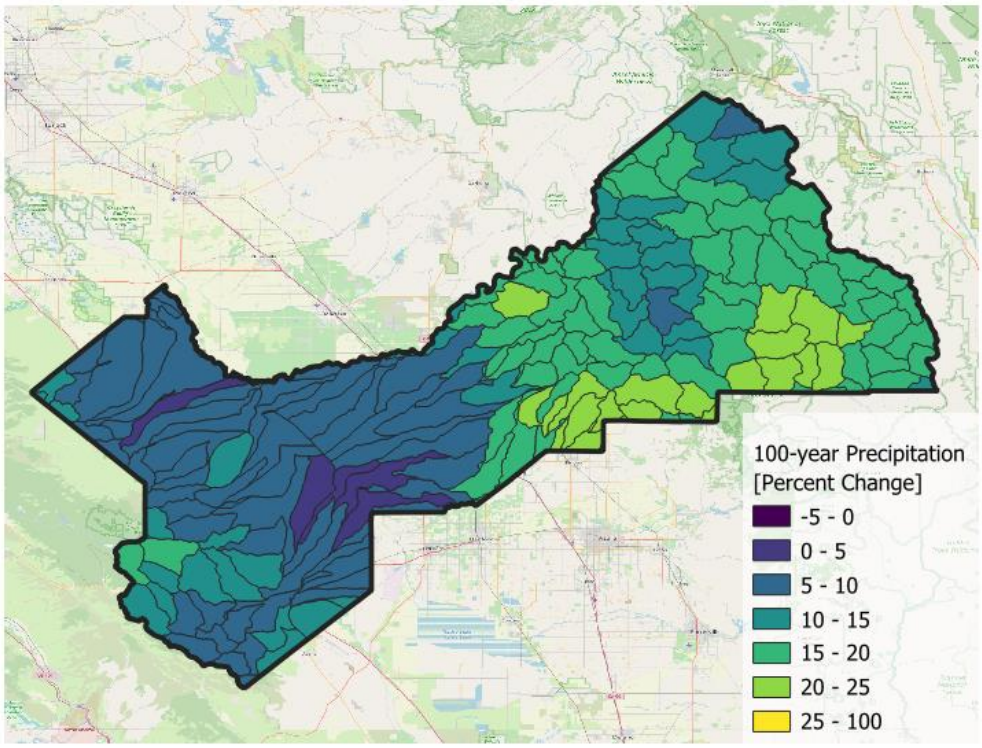
1.2 Future Climate

Climate Indicator: Extreme Precipitation

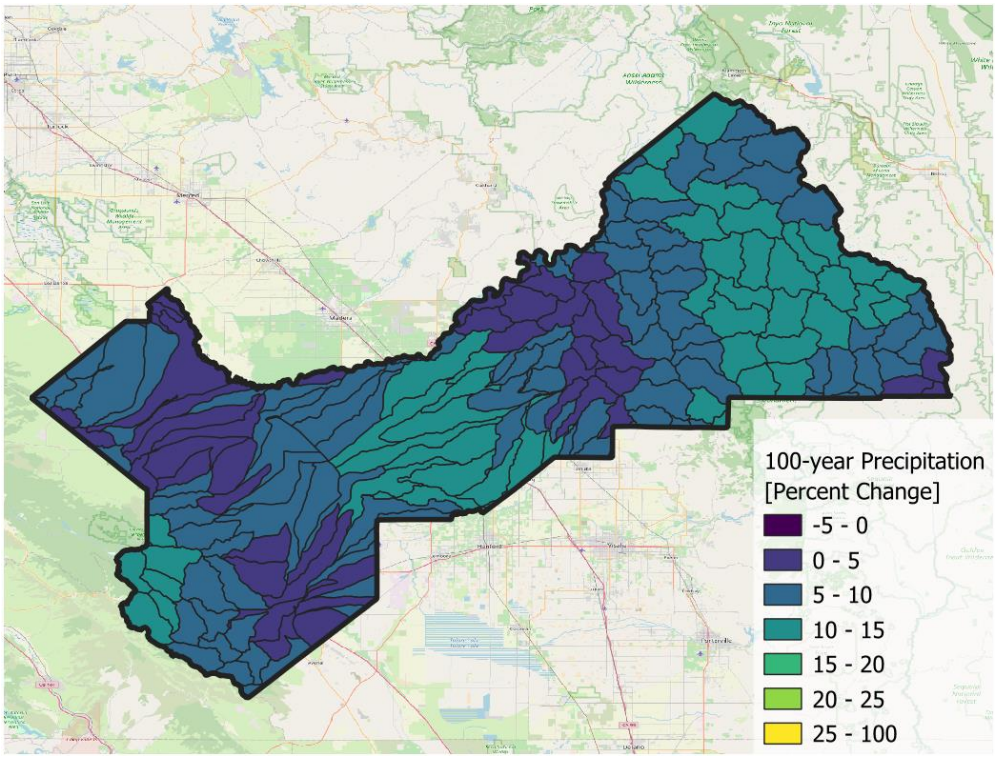
FEMA does not provide projections of how these flood zones or likelihoods may change in the future with a changing climate. As precipitation is the primary driver of riverine flooding, climate model data in the form of downscaled daily precipitation totals from LOCA1 North American Domain can assist in estimating how the likelihood of these extreme flood events may change in the future. With extreme value analysis of the maximum daily precipitation for all years represented in the dataset, we can estimate the likelihood of various intensities of precipitation events. Specifically for this study, the 5-year, 20-year, 50-year and 100-year precipitation intensities (i.e., inches of rain) for each climate scenario and time horizon generate a relationship between the current climate and forecasted climate to scale the likelihood of extreme flood events identified by the FEMA NFHL. Since precipitation impacts on riverine flooding occur at a watershed scale, which is much larger than that of the LOCA1 NAD grid (6km), the precipitation intensities and the scaling factors derived from them were all upscaled to the HUC12 watershed scale (Hydrologic Unit Code).

There are several ways to view and use this data. One view that can help illustrate the increasing intensity in extreme events is the change in extreme precipitation for the 100-year event in Fresno County between the present and future shown in Figure 3 (SSP2-4.5) and 4 (SSP5-8.5) for climate scenarios (a) mid-century and (b) end of century. For mid-century (SSP2-4.5) climate scenario the projected percent increase in the 100-year extreme precipitation ranges from 3% to 22% across the county. Similarly, for end of century (SSP5-8.5) the percent increase in the 100-year precipitation ranges from 10% to 26%. These changes are compared to a baseline, or "present-day" time range as well where the climate models are hindcasted, or run for past years. In this case, the baseline or present-day time range refers to the years before and including 2014 and the mid-century and end-of-century time horizons refer to the years 2035-2065 and 2070-2100.

As shown in Figures 3 and 4, each watershed sees a slightly different % increase, and overall, the watersheds in the southeastern part of Fresno County sees higher increases in precipitation in the 100-year event for both climate scenarios. Most of this region is considered either high or low mountain. Different climate scenarios, such as SSP2-4.5 and SSP5-8.5 embed many assumptions about changing climactic conditions; Figure 3a shows how in the SSP2-4.5 mid-century scenario, some watersheds in Western Fresno County see a slight decrease in the 100-year extreme rainfall. This decrease does not show up in Figure 4b, which shows both the western side of Fresno and pockets in the northeast hold smaller increases in precipitation in the 100-year event under the SSP5-8.5 climate scenario at the end of century. Aside from these nuances, the climate data shows that extreme precipitation events in Fresno County will become more intense across the county in the near and long-term future.

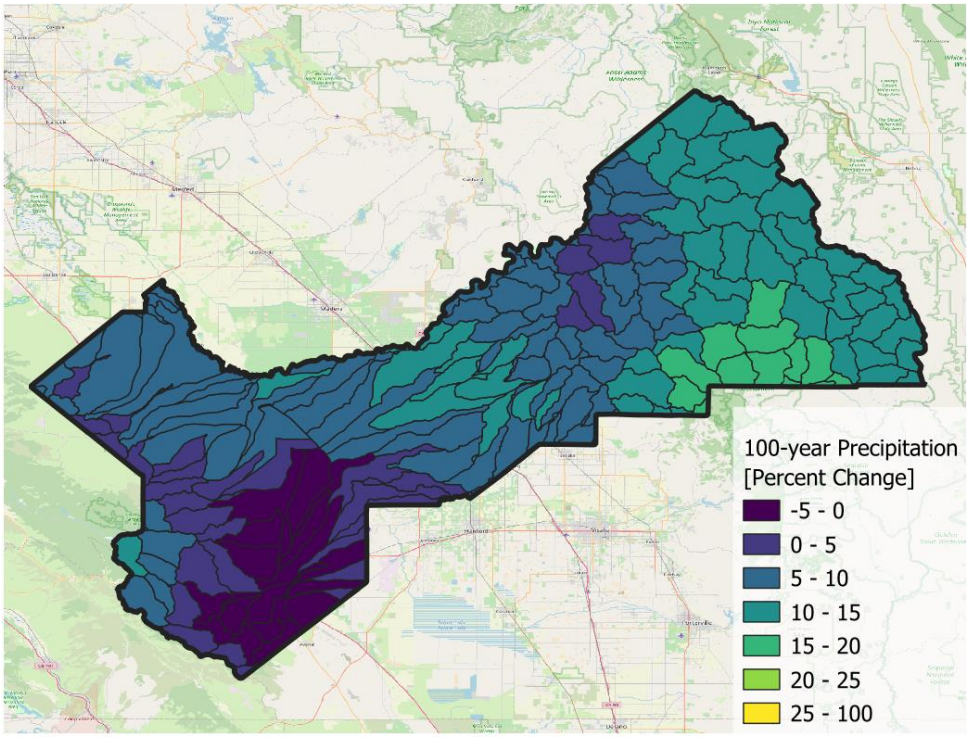


(a)



(b)

Figure 3. Percent change in 100-year precipitation from current climate to future climate scenarios (a) SSP2-4.5 2050 and (b) SSP2-4.5 2085 by HUC-12s watershed scale [LOCAv1 North American Domain].



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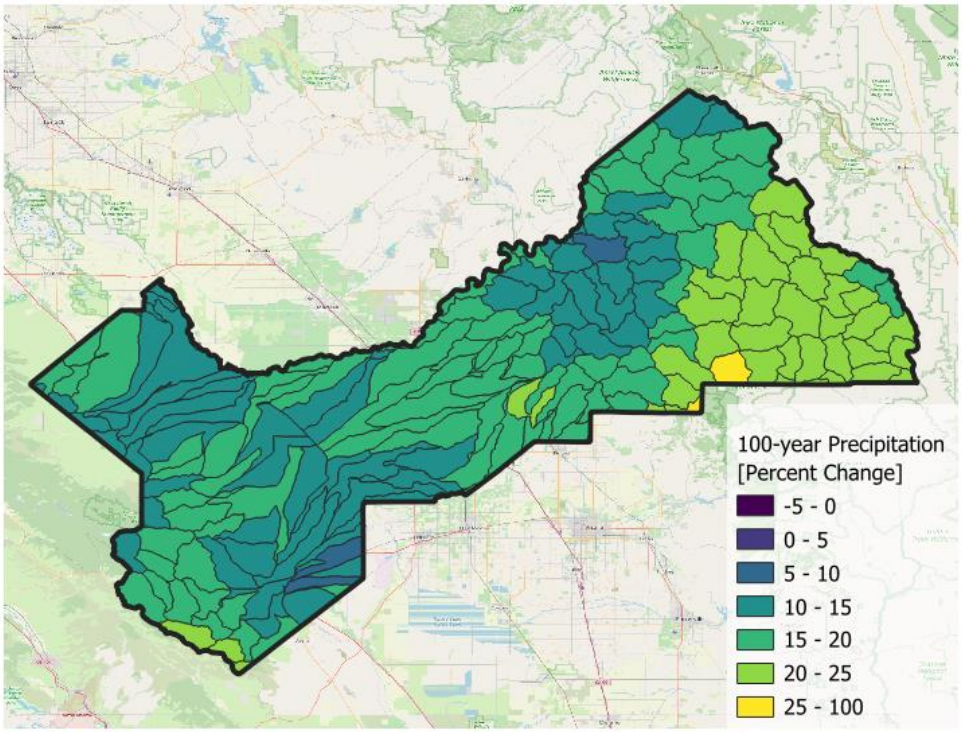


(b)

Figure 4. Percent change in 100-year precipitation from current climate to future climate scenarios (a) SSP5-8.5 2050 and (b) SSP5-8.5 2085 by HUC-12s watershed scale [LOCAv1 North American Domain].

In this study, the projected future changes in extreme precipitation are used in conjunction with the FEMA NFHL flood zones to estimate how the likelihood of inland flooding may change over time. Many factors such as land use and topography are critical in translating a specific increase in precipitation intensity to a change in flood depth and/or extent and require both watershed-level and site-specific flood modelling. Therefore, no assumptions are made in this study regarding future precipitation impacts on FEMA flood extents. Instead, the increase in likelihood of extreme precipitation events is used as a proxy to predict the increase in likelihood of extreme flood events. In other words, if the 100-year rainfall is twice as likely in the future, we estimate the 100-year flood will become twice as likely in the future and become the 50-year flood event. This situation occurs in several watersheds in Fresno County, including one in Fresno encompassing a large 500-year FEMA floodplain. In these cases, future risk is evaluated higher than present-day risk due to the increased frequency of the same type of event. The implications of the estimated change in extreme flooding likelihoods are further discussed in the *Transportation Risk Assessment Analysis and Findings Report*.

2. Extreme Heat

The temperature data collected for use in the extreme heat risk assessments for Fresno County is expressed in two temperature metrics, heat index (a combination of dry bulb temperature and % relative humidity) and the likelihood of a 7-day heatwave above a region's pavement design threshold (a metric purely based on dry bulb temperature). This study utilizes NOAA's observational weather station data (ASOS) for the present-day analysis and the California Domain LOCAv2 climate model data to understand how temperature extremes may change in the future.

2.1 Present Day

Heat Index

Heat index is a metric that combines the effects of dry bulb temperature and relative humidity to serve as a proxy for what high temperature "feels like" on the human body. For each of the 10 weather stations in Fresno County included in the ASOS observational weather station dataset, we calculated the 99th percentile heat index and generated hazard curve for the 1-, 5-, 10-, and 20-year extreme heat events. The current climate 1 in 5-year heat index event is plotted for Fresno County in Figure 5.

Across Fresno County, the maximum and average 1 in 5-year extreme heat index is approximately 116°F and 99°F, respectively. The 5-year return period (or 1 in 5-year heat index) extreme heat event, which is 116°F, corresponds to an event that has a 20% chance of being exceeded in any given year.

In present-day Fresno County the severity of heat is consistent across the inland valley areas and decreases in the mountainous regions. Towards the eastern mountainous region, hot spot lines, or branches of heat, begin to pop up, as these regions are along the Kings River and San Joaquin River. These rivers serve as valleys between the Sierra Mountains, as they are located at significantly lower elevations than their surroundings, and therefore encapsulate higher temperatures.

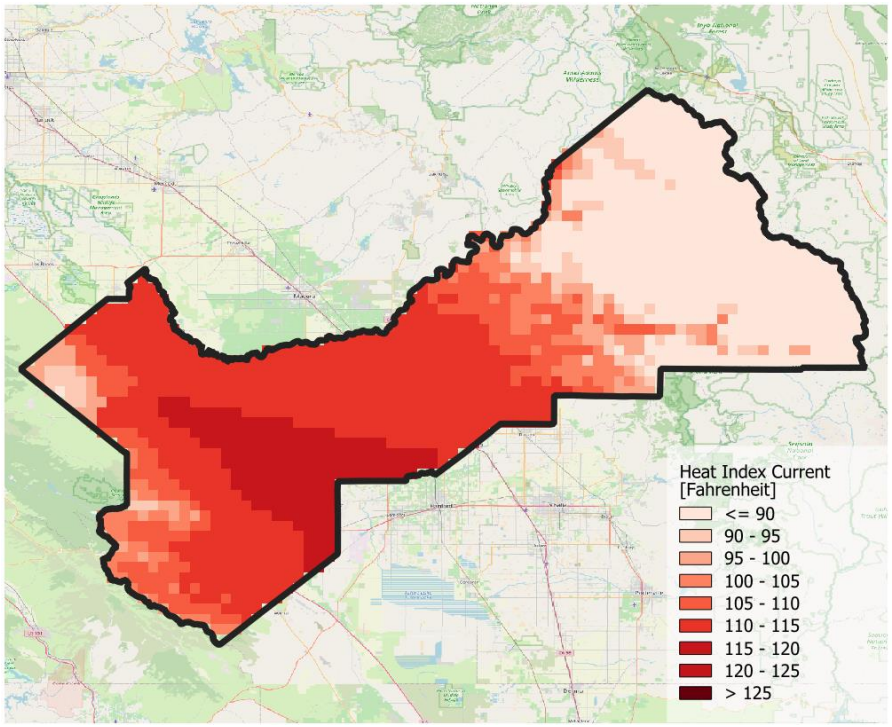


Figure 5. Extreme annual heat index for 1 in 5-year extreme heat event for current climate scenarios [ASOS Observational Weather Station Data].

7-Day Dry Bulb Temperature Above Pavement Design Thresholds

Dry bulb temperature is a metric that measures the outside air temperature using a thermometer that is not impacted by moisture or radiation. This metric, dry bulb temperature, is evaluated for whether it exceeds the pavement design thresholds set for Fresno County's road network. These pavement design temperature thresholds are defined using the Caltrans Pavement Climate Regions. The exact metric used to assess pavement design requires identifying the rate of occurrence in which the outside air temperature exceeds the design threshold on a rolling average maximum seven-day basis. These pavement design thresholds were defined to be 110°F and 120°F. The rate of occurrence in which these temperature thresholds are exceeded by the rolling seven-day average are plotted for current climate for 110°F in Figure 6 and 120°F in Figure 7.

Across Fresno County, the rate of occurrence is almost uniformly zero or considered extremely small. This indicates that across a seven-day period, the average daily maximum temperature does not exceed 110°F and 120°F, frequently if at all for present day climate.

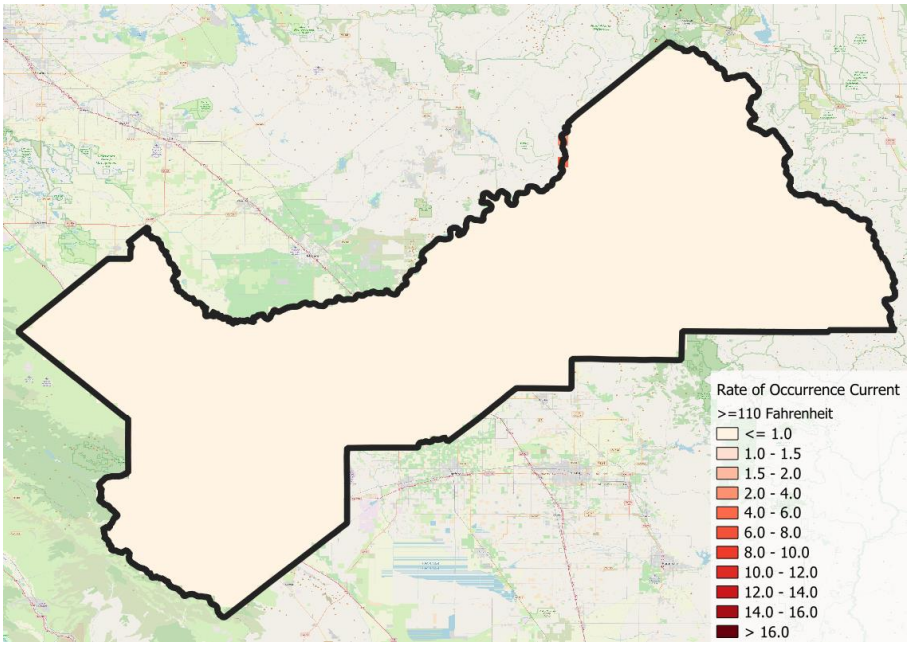


Figure 6. Rate of occurrence for dry bulb temperature exceeding 110°F for current climate scenarios [LOCAv2 California Domain].

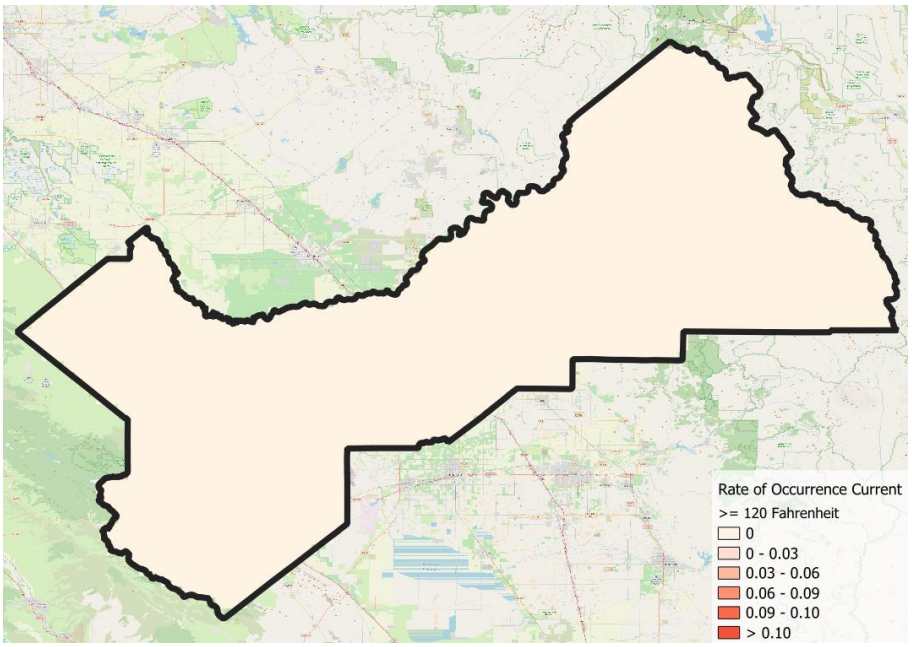
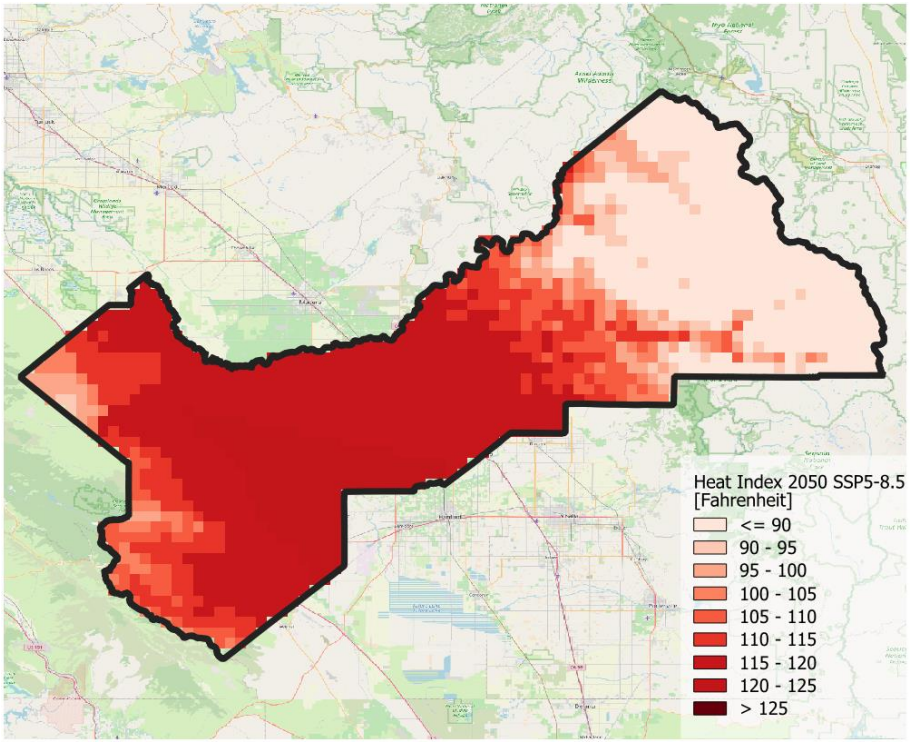


Figure 7. Rate of occurrence for dry bulb temperature exceeding 120°F for current climate scenarios [LOCAv2 California Domain].

2.2 Future Climate

Heat Index

LOCAv2 in the California domain offers a 3-kilometer grid resolution of temperature values at a daily resolution. We utilized these climate projections to calculate future changes in the intensity and likelihood of extreme heat events by projecting observational weather station data forward for the 99th percentile and the same return periods as those selected for present day data. An example of how extreme heat may increase in the future is detailed in Figure 8 for climate scenarios (a) midcentury SSP5-8.5 and (b) end of century SSP5-8.5. These maps indicate the average county heat index could increase by 5 degrees Fahrenheit by mid-century and 12 degrees Fahrenheit by the end of century respectively for the 5-year extreme heat event.



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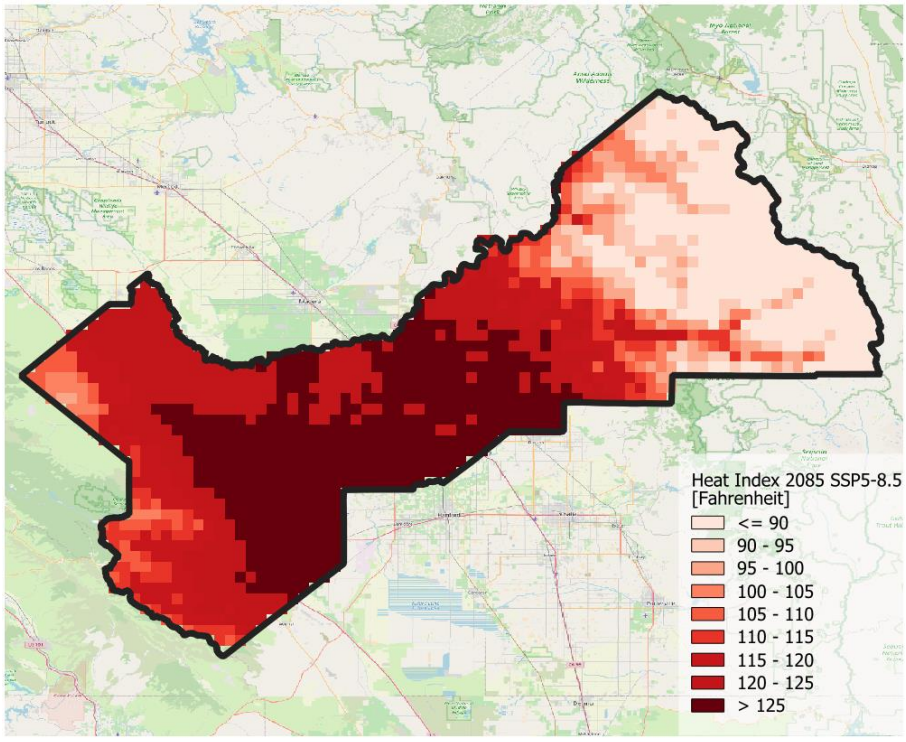
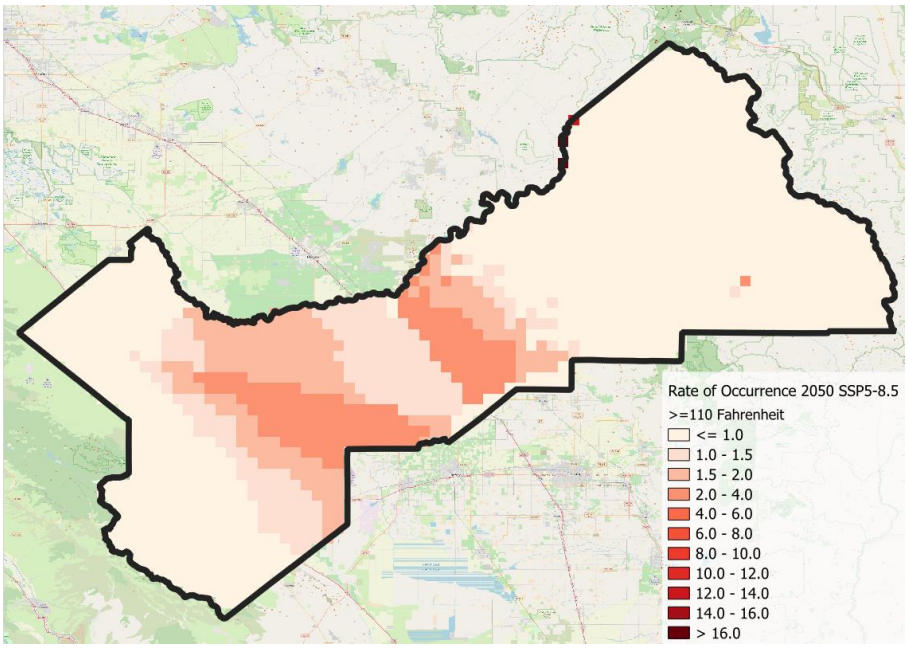


(b)

Figure 8. Extreme annual heat index for 1 in 5-year extreme heat event for future climate scenarios (a) SSP5-8.5 2050 and (b) SSP5-8.5 2085 [LOCAv2 California Domain].

7-Day Dry Bulb Temperature Above Pavement Design Thresholds

The LOCAv2 in the California domain similarly is used to quantify future dry bulb temperature values. We utilized these climate projections to calculate future changes in the intensity and likelihood of extreme heat events by projecting observational weather station data forward for the daily maximum dry bulb temperature. This projection of daily maximum dry bulb temperature is then assessed for whether it exceeds the design threshold on a rolling average maximum seven-day period. An example of how these rates of occurrences may increase in the future for exceeding the 110°F in Figure 8 and 120°F in Figure 7 for climate scenarios (a) midcentury SSP5-8.5 and (b) end of century SSP5-8.5. In Figure 8, we see a concentration in the inland valley near the city of Fresno and in the western county where the frequency of the 110°F threshold being exceeded on an average weekly basis, increases, compared to present day. In Figure 8, we see a concentration in the inland valley near the city of Fresno and in the western county where the frequency of the 110°F threshold being exceeded on an average weekly basis, increases, when compared to present day. In Figure 7, we see a concentration primarily in the western county, where the frequency of the 120°F threshold being exceeded on an average weekly basis, increases, when compared to present day.



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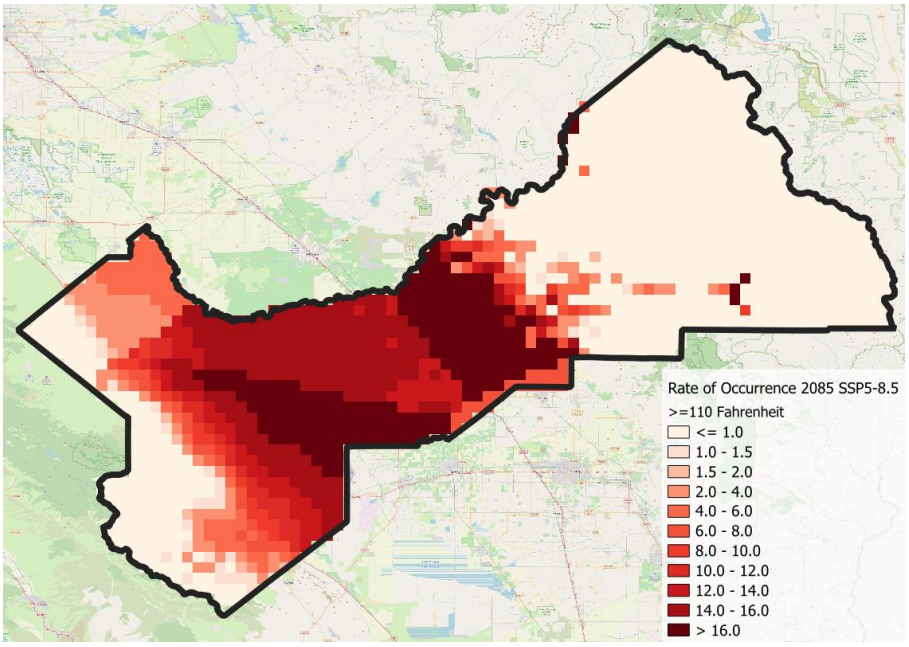
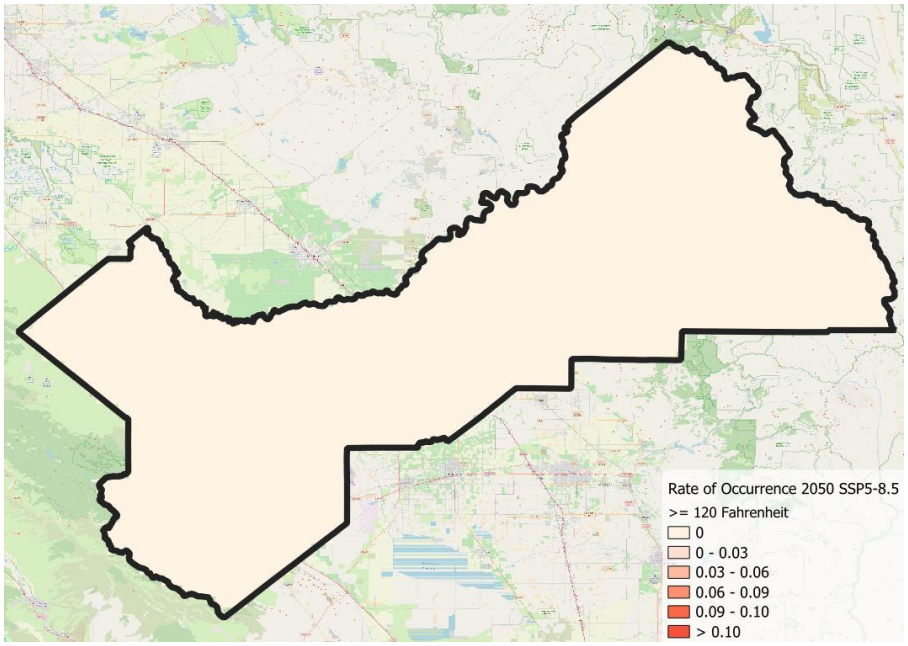


(b)

Figure 9. Rate of occurrence for dry bulb temperature exceeding 110°F for future climate scenarios (a) SSP5-8.5 2050 and (b) SSP5-8.5 2085 [LOCAv2 California Domain].



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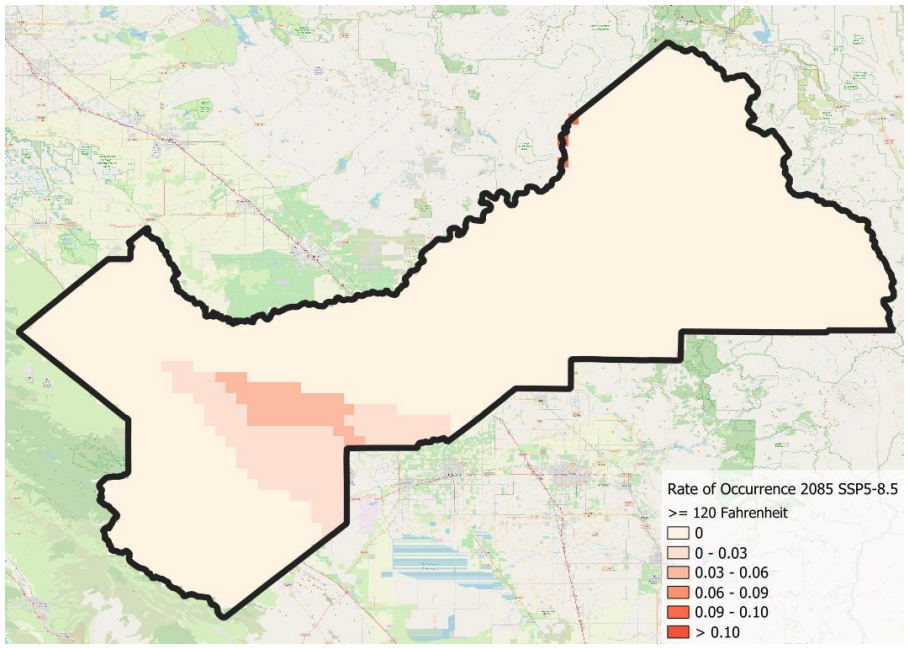


(b)

Figure 10. Rate of occurrence for dry bulb temperature exceeding 120°F for future climate scenarios (a) SSP5-8.5 2050 and (b) SSP5-8.5 2085 [LOCAv2 California Domain].

3. Wildfire

Wildfires represent a growing risk to infrastructure due to climate change and urbanization. Buildings constructed in the wildland-urban interface (WUI) are directly exposed to wildfires because of their proximity to areas with high burnable fuel. This study's wildfire risk assessment is primarily based wildfire threat class and the change in decadal wildfire probability. A summary of the wildfire hazard data sources utilized in this study is provided in the appendix.

3.1 Present Day

Fire Threat Class

Our assessment of present day wildfire risk is based on CAL FIRE's wildfire threat class. Fire threat class provides a measure of fuel conditions and fire potential. Fire threat can be defined as a combination of two factors: 1) fire probability, or the likelihood of a particular area burning, and 2) potential fire behavior. These two factors are combined to create five threat classes ranging from low to extreme such that impacts from wildfire are more likely to occur and/or be of increased severity for higher threat classes. Fire threat class is mapped for Fresno County in Figure 11. The fire threat class in Fresno County is highest in the mountainous regions that are more heavily forested.

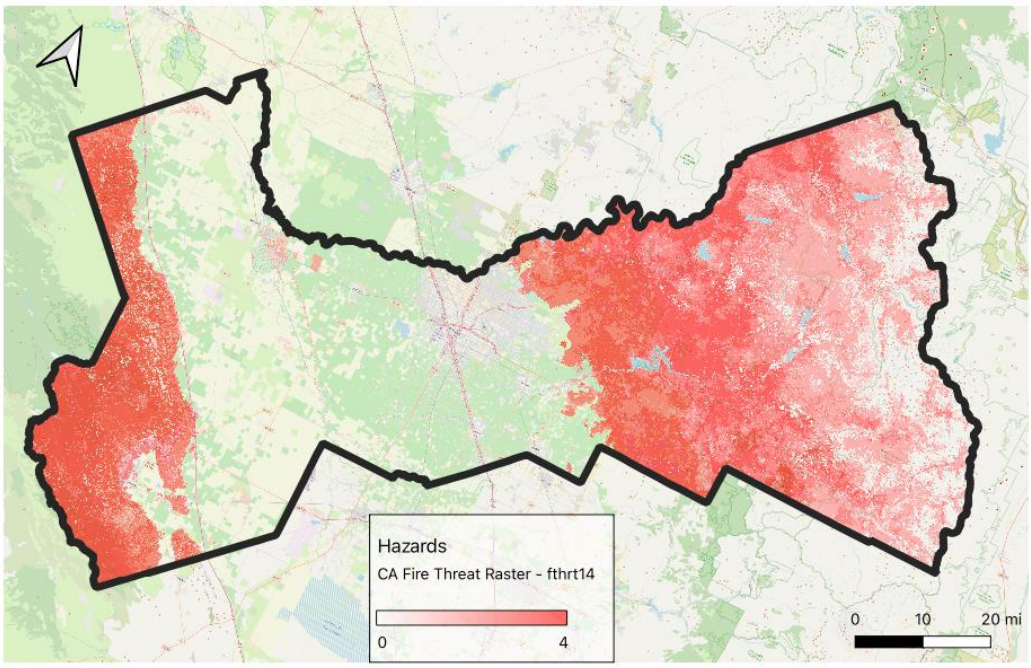


Figure 11. Fire Threat Class.

3.2 Future Climate

Climate Indicator: Wildfire Probability

CAL FIRE does not provide future fire threat data; therefore, we use a climate indicator, the change annual probability of a wildfire occurring, in conjunction with the present-day wildfire

threat class data to estimate how the likelihood of a given intensity of wildfire may change in the future. LOCAv1 provides a metric – the annual probability of a wildfire occurring – per each decade in the past (1950 onwards) and in the future (up to 2100). Similar to the other climate hazards mentioned herein, a future decade's wildfire probability is compared to a baseline, or "present-day" time range where the climate models are hindcasted, or run for past years.

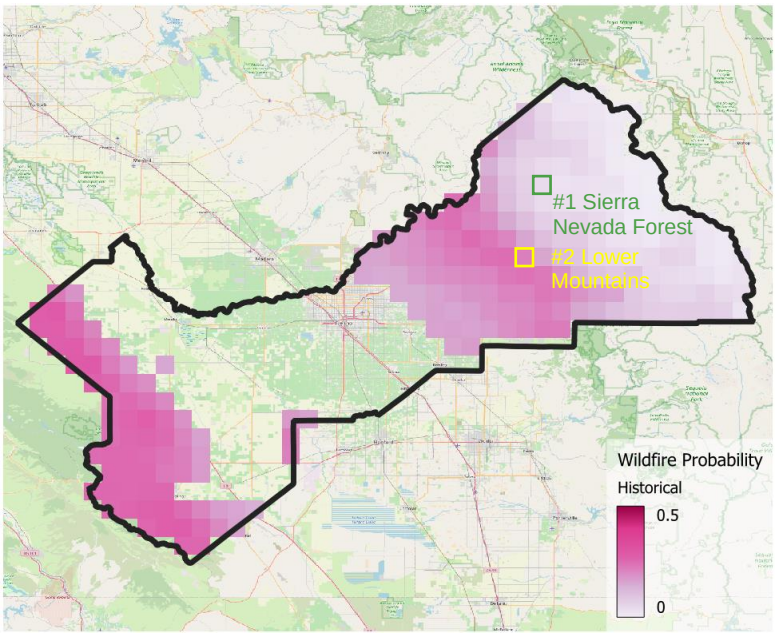
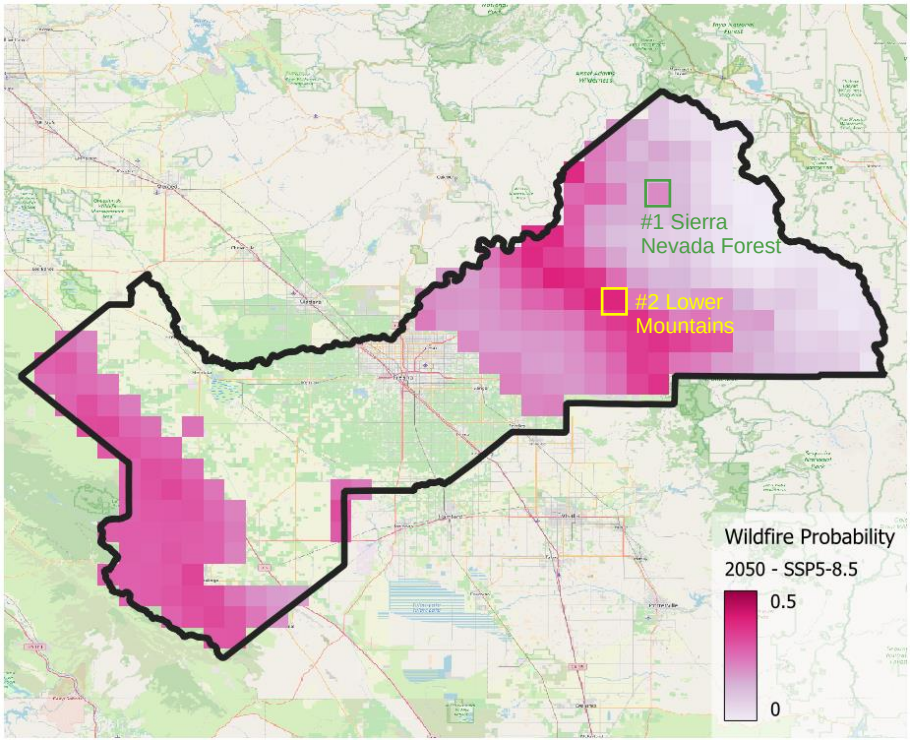
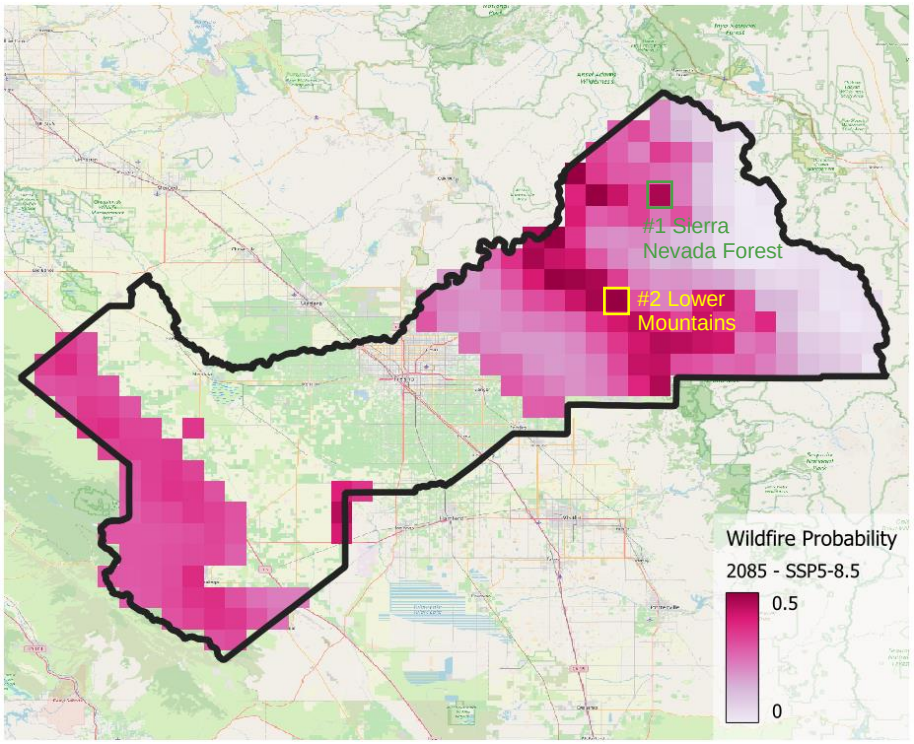


Figure 12. Annual probability of occurrence of a wildfire present day climate.

The annual wildfire probability, given as a decadal average and then averaged again over the aforementioned time horizons, is shown in Figure 13. Notably, wildfire probability increases in the Sierra Nevada mountains towards the eastern part of Fresno County. The maximum wildfire probability increases from 29% in the present-day to 39% by midcentury and 53% by the end of century for the SSP5-8.5 scenario depicted on the maps below.



(a)



(b)

Figure 13. Annual probability of occurrence of a wildfire for future climate scenarios (a) SSP5-8.5 2050 and (b) SSP5-8.5 2085 [LOCAv1].

Two sample locations in Fresno County can illustrate more specifically how the wildfire hazard may change in the future with a changing climate. The two locations, denoted in Figure 12, Figure 13a, and Figure 13b are both in the mountain regions of Fresno, the (1) Sierra Nevada Forest and (2) Lower Mountains. As shown in Table 1, the likelihood of a wildfire in the Sierra Nevada Forest increases first more gradually between the current climate and a mid-century climate. By the end of century, the probability of occurrence more than doubles in the Sierra Nevada Forest. In the lower mountain regions of Fresno, wildfire becomes more significantly likely by mid-century and doubles from mid- to end-of century.

Table 1. Annual probability of occurrence for current and future climate for two locations of Fresno County.

Climate Scenario	Annual Probability of Occurrence	
	#1 Sierra Nevada Forest	#2 Lower Mountains
Current	0.219	0.041
Mid Century	0.383	0.209
End of Century	0.502	0.472

4. Landslide

A deep-seated landslide can be described as a landslide with a failure location that originates deep beneath the earth's surface. A summary of the landslide hazard data source used in these risk assessments is provided in the appendix.

4.1 Present Day

The California Department of Conservation California Geological Survey's map of deep-seated landslide susceptibility is utilized in this study to assess present-day landslide hazard. Landslide susceptibility is classified 0 to 10 in order of increasing susceptibility, based on rock strength and slope steepness. This map is shown for Fresno County in Figure 14. In the eastern and western portions of Fresno County, we see high landslide susceptibility in the high and low mountain areas.

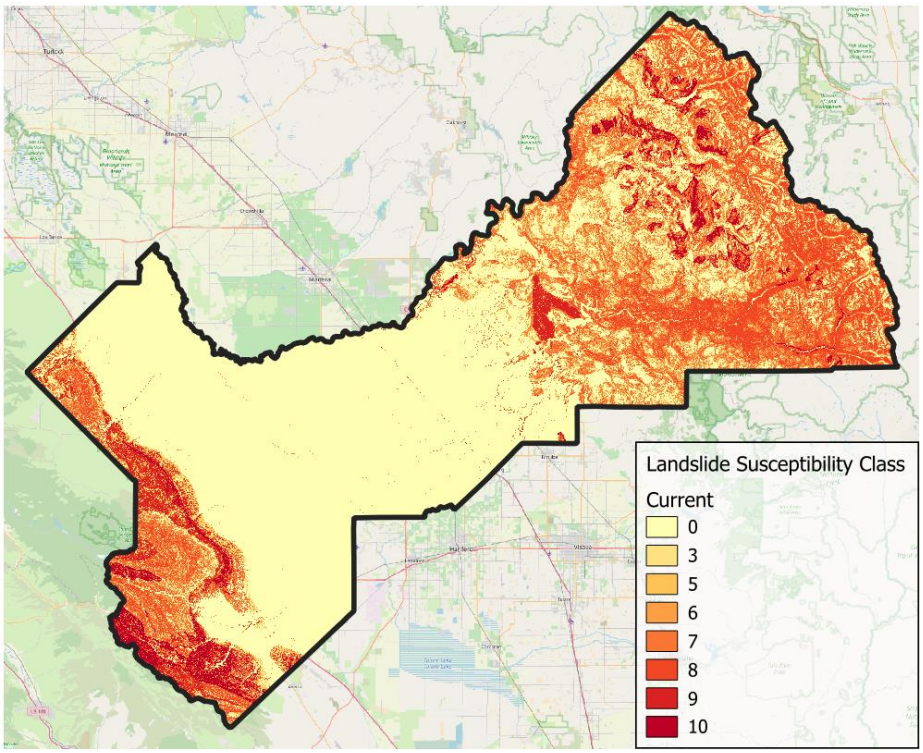


Figure 14. Deep-seated landslide susceptibility class for current climate [California Geological Survey].

Appendix: Data Sources

Table A-1. Summary of climate hazard data sources used for flood risk assessments.

Climate Indicator / Hazards	Epoch(s)	Scenarios	Data Source	Climate Variable	Intensity Measures	Description / Metrics	Link
Pluvial / Fluvial Flooding	Present Day	-	FEMA	Floodplain	1-percent and 0.2-percent-annual-chance floodplain	Temporary flooding from 1-percent and 0.2-percent-annual-chance flooding	https://www.fema.gov/flood-maps/national-flood-hazard-layer
	Future Climate: Hindcast & Forecast	SSP2/RCP4.5 SSP5/RCP8.5	LOCAv1 Climate Model Data	Precipitation	Extreme annual maximum precipitation from the: • 5-year • 20-year • 50-year • 100-year precipitation event	Extreme. annual maximum precipitation (daily)	https://loca.ucsd.edu/loca-version-2-for-north-america-ca-jan-2023/

Table A-2. Summary of climate hazard data sources used for extreme heat risk assessments.

Climate Indicator / Hazards	Epoch(s)	Scenarios	Data Source	Climate Variable	Intensity Measures	Description / Metrics	Link
Extreme Heat	Present Day	-	ASOS Observational Weather Station Data	Dry Bulb Temperature	Annual rate of occurrence	7-day average maximum dry bulb temperature	https://mesonet.agron.iastate.edu/request/download.phtml?network=CA_ASOS
				Heat Index	99th percentile heat index	Median annual 99th percentile heat index	
					Extreme annual maximum heat index from: • 1-year • 5-year • 10-year • 20-year • 50-year extreme temperature event	Extreme annual maximum heat index (daily)	
	Future Climate: Hindcast & Forecast	SSP2/RCP4.5 SSP5/RCP8.5	LOCAv2 Hybrid Climate Model Data	Dry Bulb Temperature	Annual rate of occurrence	7-day average maximum dry bulb temperature	https://analytics.cal-adapt.org/data/catalog/
				Heat Index	99th percentile heat index	Median annual 99th percentile heat index	
					Extreme annual maximum heat index from: • 1-year • 5-year • 10-year • 20-year • 50-year extreme temperature event	Extreme annual maximum heat index (daily)	

Table A-3. Summary of climate hazard data sources used for wildfire risk assessments.

Climate Indicator / Hazards	Epoch(s)	Scenarios	Data Source	Climate Variable	Intensity Measures	Description / Metrics	Link
Wildfire	Historical Climate	-	CAL FIRE	Fire threat class	Threat class	Historical fire threat class	https://www.fire.ca.gov/Home/What-We-Do/Fire-Resource-Assessment-Program/GIS-Mapping-and-Data-Analytics
	Future Climate	SSP2/RCP4.5 SSP5/RCP8.5	UC Merced / Geospatial Innovation Facility (LOCAv1 Climate Model Data Derived)	Wildfire Probability	10-year exceedance probabilities of decadal wildfire	Decadal wildfire probability	https://cal-adapt.org/data/download/

Table A-4. Summary of climate hazard data sources used for landslide risk assessments.

Climate Indicator / Hazards	Epoch(s)	Scenarios	Data Source	Climate Variable	Intensity Measures	Description / Metrics	Link
Landslide	Historical Climate	-	California Department of Conservation/ California Geologic Survey	Landslide susceptibility class	Landslide susceptibility class	Deep-seeded landslide susceptibility based on rock strength and slope steepness	https://data.ca.gov/dataset/cgs-map-sheet-58-deep-seated-landslide-susceptibility

A.7 Risk Assessment Methodology Memo

ARUP

Fresno Council of Governments

Fresno County Climate Resiliency Plan for Transportation

Transportation Risk Assessment Methodology Memo

Prepared by Emma Lambert, Jinal Mehta, Karen Barns

Final | May 16, 2025

1. Introduction

This methodology memo outlines the risk assessment framework used to undertake the multi-hazard transportation system risk assessment for Fresno County. The risk assessment is a key input into the development of the Fresno County Climate Resiliency Plan which will identify priority projects to enhance the resilience of the County's transportation infrastructure. This memo is one in a series that document the approach and findings of the assessment. More detail on the climate hazards is provided in the *Fresno County Climate Hazard* memo and the findings of the risk assessment are documented in the *Fresno County Transportation Risk Analysis Findings* report. The approach presented here generates qualitative risk ratings (e.g., Low, Medium, High) that are underpinned by quantitative metrics and a consistent methodology wherever possible.

2. Scope

The scope of the study includes the following transportation assets:

- Road network
- Bridges
- Bike network
- Transit network and bus yards
- Airports
- Rail network

For each transportation asset, the primary consequence or impact of concern was discussed and agreed upon with Fresno COG at the project inception. Consequently, this study focused on downtime (or operational disruption) and human health and wellness, depending on the specific hazard-asset pairing, as shown in

Table 1.

Table 1. Consequences assessed for each hazard-asset pair in the County's regional transportation network.

Hazard	Road Network	Bridges	Bike Network	Transit Routes and Facilities	Airports	Rail Network	Bus Yards
Flooding	Downtime	Downtime	Downtime	Downtime	Downtime	Downtime	Downtime
Wildfire	Downtime	Downtime	Downtime	Downtime	Downtime	Qualitative	Downtime
Extreme Heat	Downtime	Downtime	Health + Wellness	Health + Wellness	Qualitative	Qualitative	Qualitative

Downtime refers to an estimated amount of time (e.g. hours, days, weeks or months) that an asset is unable to perform its function. For example, a flooded road could result in 1 to 3 days of downtime for waters to recede, debris to be cleared, and any repairs to be conducted during which the road is inaccessible.

Impact to human health and wellness is another consequence that assesses a human's health risk associated with a given hazard. In this study, we assess the health risk of extreme heat impacts on transit riders, as riders commuting to and from a bus stop may face adverse health effects from prolonged exposure to very high temperatures.

For four hazard-asset pairs (heat and airports, heat and rail, heat and bus yards, wildfire and rail) where hazard impacts were deemed to be limited, of lower priority to Fresno COG, or beyond the scope of the study, a qualitative narrative discussion of impacts was undertaken.

3. Risk Assessment Methodology

The goal of a risk assessment is to identify areas where the combination of hazard and asset vulnerability have an impact on a consequence of concern (e.g., downtime to operational functionality). The information gleaned from the county-wide risk assessment conducted in this study will be a key input into the development projects and programs to enhance the resilience of the transportation infrastructure. Taking a holistic, consistent risk-based approach to creating a resilient future requires a method to compare the potential impacts of multiple hazards, each with different likelihoods and intensities, on several types of infrastructure - for example, wildfires may impact roads much less frequently than flooding, but may impact roads more severely. Risk assessments provide a framework to be able to make these comparisons by considering both the likelihood of an event (e.g. a 100-year flood) in combination with its consequence (e.g. the amount of time the road will be closed).

Assessing risk integrates the following three key components: hazard, vulnerability, and exposure.

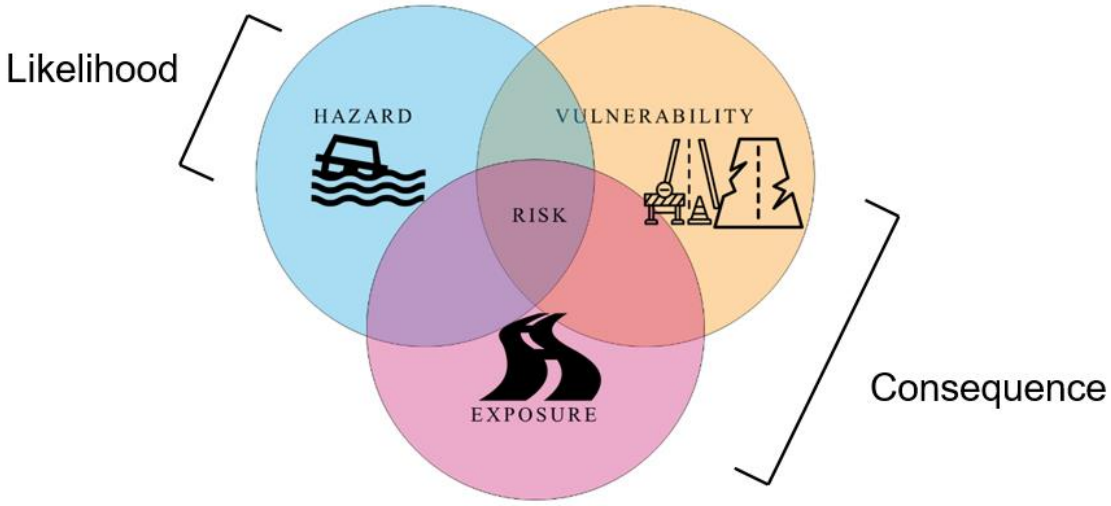


Figure 1. Key components of risk.

- **Hazard and Exposure:** Hazard is assessed by defining the likelihood and intensity measure for a particular location. For example, in a given year a flood map may give a 1% chance of at least 1-3 feet of flooding occurring at a given location. Exposure is assessed by identifying the assets in hazard-prone and understanding their characteristics to see if the hazard may impact them. For example, the elevation of a bridge may impact whether the bridge is in fact exposed to flooding. The characteristics considered in this study focused on asset location due to the number of assets and their geographical spread.
- **Vulnerability and Consequence:** Vulnerability considers how an asset is expected to perform when subjected to a hazard. For example, 6 inches of flooding on a road can inhibit a car's ability to drive safely on the road and therefore result in road closure. One foot of flooding may damage critical maintenance equipment at a bus yard requiring it to close for a month for repair.

A detailed description of the application of these components and how they are applied is presented in Figure 2 using the road network and flooding as an example.

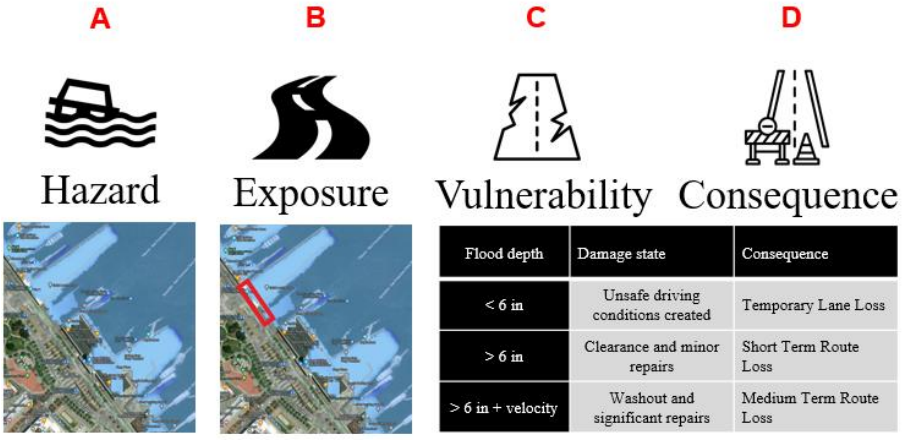


Figure 2. Example flood risk assessment for Fresno County's road network.

3.1 Approach used for flood impacts on roadway downtime

- **Step 1. Assess hazard:** The FEMA National Flood Hazard Layer (NFHL) provides an understanding of the spatial extents of extreme riverine flood events. FEMA designates zones that may see flooding in extreme rainfall events, specifically the 100-year and 500-year events. Using the FEMA NFHL, the 100-year and 500-year floodplains can be identified across Fresno County. For more information on the FEMA NFHL, see Section 1.1 of the *Fresno County Climate Hazard* memo.
- **Step 2. Assess exposure:** Overlaying Fresno County's road network with FEMA's NFHL layer allows for identification of road segments within both the 100-year and 500-year floodplains.
- **Step 3. Assess vulnerability:** The performance of a road subjected to flooding depends on the flood depth and velocity experienced. Depending on the intensity of the flood depth and/or flood velocity, the road may perform differently. In this study, there are three defining damage states that link flood depth to vulnerability: (1) less than six inches of flooding leads unsafe driving conditions, (2) greater than six inches of flooding could lead to road clearance and minor repairs and (3) greater than six inches paired with velocity could lead to washout or significant repairs.
- **Step 4. Assess consequence:** Each of the three damage states described above results in different amounts of downtime for a road. They are: (1) temporary lane closure, (2) short-term route closure, and (3) medium term route closure. These consequences of lane and route closure can then be mapped to a generalized consequence descriptor, such as minimal or moderate, as shown in Table 2.

This process is then repeated for each segment of the road network across the county. To go from multiple consequence assessments to risk, the final step requires integrating multiple likelihoods and consequences to obtain a final risk rating using the risk matrix shown in Table 2. For example, a road within Fresno County falls within the 500-year FEMA flood plain (a flood expected to occur on average every 500-years or with a 0.2% chance of being exceeded each year), and is assigned damage state two (greater than six inches of flooding can lead to road clearance and minor repairs) resulting in a consequence of short-term route closure which maps to a moderate impact for the road. Mapping the likelihood (500-yr which corresponds to unlikely) and moderate consequence within this table would result in a low-medium risk rating for this road.

		Consequence (Impact)					
		Temporary	Minimal	Moderate	Significant	Severe	Catastrophic
Likelihood	Exceptionally Likely	Med-High	High	Very High	Very High	Very High	Very High
	Very Likely	Med	Med-High	High	Very High	Very High	Very High
	Likely	Low-Med	Med	Med-High	High	Very High	Very High
	Possible	Low	Low-Med	Med	Med-High	High	Very High
	Unlikely	Very Low	Low	Low-Med	Med	Med-High	High
	Very Unlikely	Very Low	Very Low	Low	Low-Med	Med	Med-High

Table 2. Example risk matrix with consequence definitions for Fresno County's roadway network.

Tables 3 and 4 show how the likelihood categories map to the hazard data and how the consequence categories map to different amounts of downtime for the transportation assets. The estimation of downtime for each consequence descriptor is intended to benchmark these descriptors for general understanding.

Table 3. Likelihood description by return period.

Likelihood	Return Period [Years]	
	Lower Bound	Upper Bound
Exceptionally Likely	0	2
Very Likely	2	10
Likely	10	50
Possible	50	250
Unlikely	250	1250
Very Unlikely	1250	<

Table 4. Equivalent downtime for each consequence descriptor.

Consequence Descriptor	Equivalent Downtime Benchmark
Temporary	Few hours
Minimal	< 2 days
Moderate	2 - 10 days
Significant	1.5 – 6 weeks
Severe	1.5 – 18 months
Catastrophic	18+ months

3.2 Approach used for health and wellness

Impacts on human health and wellness is also a key consequence in this study. High heat hazard can have significant impacts on health and wellness, particularly the transit ridership experience. As illustrated in Figure 3. Example extreme heat risk assessment for human health and wellness. the logic behind assessing extreme heat impacts on health risk is similar to that of the method described above for downtime and is underpinned by the same components of risk: hazard, exposure, vulnerability, and consequence. As with any multi-consequence assessment, the health and wellness risks will be considered in conjunction with the downtime risks when utilizing the results of this study in further adaptation planning decisions like developing a project priorities list.

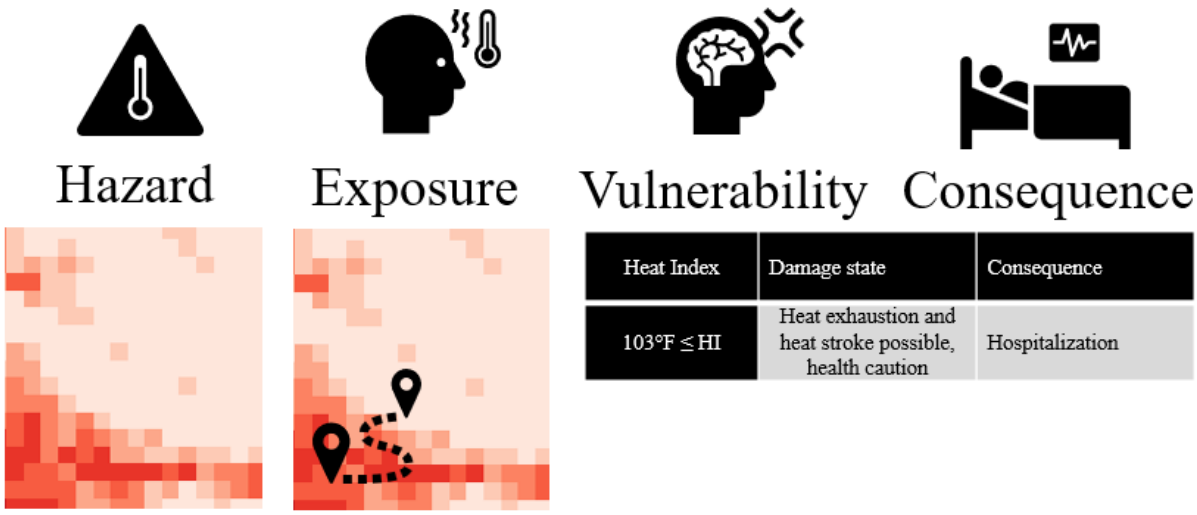


Figure 3. Example extreme heat risk assessment for human health and wellness.

The consequence for human health and wellness is the average annual likelihood of a person being hospitalized. Hospitalization could occur from possible heat exhaustion or heat stroke. This metric assumes an individual has experienced prolonged exposure to heat above a certain temperature threshold.

Hospitalization risk requires a severely high heat event, therefore, to assess this consequence, all potential extreme heat events modelled are evaluated for their consequence using the average annual likelihood of an individual being hospitalized to map to a risk rating. Average annual likelihood accounts for the different events that may occur, each with different likelihoods and probabilities of hospitalization each year. For example, if the same temperature is more frequent in one region but less frequent in another, even though the impacts could be the same (e.g., hospitalization) the region with more high heat index days will have more risk. To anchor the risk ratings, the resulting rates are compared with standard hospitalization rates from all potential hazards, such as an approximate 5% annual hospitalization rate for people ages 1-64 in 2018 (National Center for Health Statistics, 2020-2021).

3.3 Intended Use

This is a high-level risk assessment using the best publicly available hazard and asset data covering all of Fresno county. The results of the implementation of the risk assessment methodology described herein are presented in the *Fresno County Transportation Risk Analysis Findings* report. Overall, the results of this study should be taken relative to each other and augmented with local knowledge and other factors when utilizing them beyond the purposes of this study.

A.8 Risk Assessment Technical Report

ARUP

Fresno Council of Governments

Fresno County
Transportation Risk Analysis Findings Report

Final | May, 2025

Job number 303440-00

Arup US, Inc.
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Contents

1. Introduction

Fresno County has been faced with the impacts of extreme climate events and their related adverse impacts to infrastructure and communities (e.g. roads, transit ridership, public health). From the September 2020 Creek Fire to major flooding in 2023, events like these have driven public and government discourse around the need to prioritize resilient countywide infrastructure. To address these events the Fresno Council of Governments (COG) has commissioned a regional multi-hazard risk assessment of the County's transportation infrastructure as part of the development of the Fresno County Climate Resiliency Plan.

This report summarizes the findings from Fresno County's regional transportation risk assessment study, and includes the following sections:

- An **overview** of the study scope and approach
- An overview of the county's **transportation assets** included in this regional risk assessment
- The present-day and future **flood, wildfire, extreme heat, and landslide** risks for relevant assets.
- A summary of **findings** for the study

2. Study Approach

2.1 Scope

The scope of this study considers the impacts of multiple climate hazards on Fresno County's regional transportation network and infrastructure. The hazards analyzed in this assessment include wildfire, flooding, extreme heat, and landslide. To include the impacts of climate change, either explicit climate model data or climate indicators are used in determining future climate for the climate scenarios 2050 SSP2-4.5, 2085 SSP2-4.5, 2050 SSP5-5.8, and 2085 SSP5-8.5. Further detail regarding the climate hazard data and scenarios is documented in the *Climate Hazards Memo.*

The following assets are assessed for wildfire, flooding, and extreme heat hazards:

- Roads and bridges
- Transit network and bus yards
- Bicycle network
- Airports
- Rail network

For each transportation asset and hazard pair, the primary consequence or impact of concern was discussed and agreed upon with Fresno COG at the project inception. This study focused on downtime (or operational disruption) and human health and wellness, depending on the specific hazard-asset pairing, as shown in Table 1. For some hazard-asset pairs a qualitative discussion of impacts was deemed more appropriate.

Table 1. Consequences assessed for each hazard-asset pair in the County's regional transportation network.

Hazard	Road Network	Bridges	Bike Network	Transit Network	Airports	Rail Network	Bus Yards
Flooding	Downtime	Downtime	Downtime	Downtime	Downtime	Downtime	Downtime
Wildfire	Downtime	Downtime	Downtime	Downtime	Downtime	Qualitative	Downtime
Extreme Heat	Downtime	Downtime	Health + Wellness	Health + Wellness	Qualitative	Qualitative	Qualitative

The scale of the study in terms of geography, hazards, and assets, meant that a deep dive into the condition of each individual asset was not undertaken. The assessment was based primarily on location of assets and any information provided in GIS format.

2.2 Approach

The risk assessment approach incorporates the three key components of risk: hazard, exposure, and vulnerability. In using these key components, all hazard and asset combinations are assessed for their subsequent consequence, downtime or human health and wellness. Within

the scope of this work, a hazard can be described as an intensity measure of either flooding, wildfire, extreme heat, or landslide. For example, the intensity measure used for extreme heat for roadways is the average seven-day heat wave. Assessing vulnerability involves understanding the specific temperature threshold a roadway is designed for, above which damage such as spider cracking can occur. If damage occurs, the downtime resulting from road closures needed to repair the roadway is assessed (i.e. the consequence). This approach then uses the likelihood of an event (e.g. frequency of a heat wave) and the consequence (e.g. minimal downtime) to assign a risk rating using Table 2.

Table 2. Risk matrix used to assign risk ratings based on likelihood and consequence.

		Consequence (Impact)					
		Temporary	Minimal	Moderate	Significant	Severe	Catastrophic
Likelihood	Exceptionally Likely	Med-High	High	Very High	Very High	Very High	Very High
	Very Likely	Med	Med-High	High	Very High	Very High	Very High
	Likely	Low-Med	Med	Med-High	High	Very High	Very High
	Possible	Low	Low-Med	Med	Med-High	High	Very High
	Unlikely	Very Low	Low	Low-Med	Med	Med-High	High
	Very Unlikely	Very Low	Very Low	Low	Low-Med	Med	Med-High

Using a consistent risk-based approach across hazard and asset pairs allows for comparison of the potential impacts of multiple hazards and consequences. For example, wildfires may impact roads much less frequently than flooding but may impact roads more severely. The benefit of this framework is to be able to make these comparisons by considering both the likelihood of an event (e.g. a 100-year flood) in combination with its consequence (e.g. the amount of time the road will be closed). Further detail on the risk assessment methodology can be found in the *Transportation Risk Assessment Methodology Memo*.

Sections 3-7 showcase the assessed assets and respective consequences through risk rating maps. Each of these sections follows the format below:

- **Damage state definitions**. These definitions are provided for the hazard and asset pair being discussed if it differs than a previously defined set of damage states.
- **Hazard data sources**. A description of the hazard data sources used for present-day and future climate hazards if not already introduced. Discussion is provided regarding where the hazard data pops up in Fresno County.
- **Present-day risk**. The results of present-day risk assessment are presented through regional risk rating maps of Fresno County. Key findings for present-day risk are summarized.
- **Future climate risk**. The results of the future climate risk assessments are presented through regional risk rating maps of Fresno County. Key findings of how present-day risk changes as a result of climate change is provided.

Within the main portion of this report only discusses future climate risk as it relates to climate scenarios SSP5-8.5, mid-century, 2050, and end of century, 2085. The SSP5-8.5 climate scenario is selected because it generally represents the most severe impacts of climate change for most hazards and time horizons. The risk maps for the remaining climate scenarios SSP2-4.5 mid-century and end of century are attached in the appendix.

3. Transportation Assets

3.1 Roads and Bridges

For this risk assessment, the road network was discretized into 1/10th mile segments to allow for sufficient granularity in reporting the physical risk results described in the following sections. This resulted in the assessment of 33,880 road segments and 345 bridges. These segments included identification of major collectors, primary arterials, highways, freeways, and local roads with higher traffic volume.

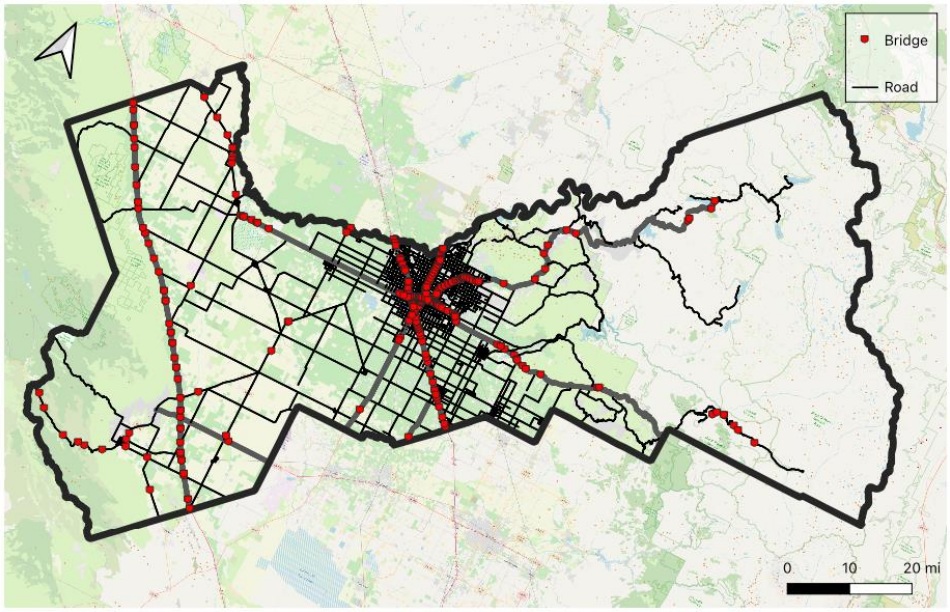

Figure 1. Roads and bridges evaluated in the risk assessment.

3.2 Transit Network and Bus Yards

Fresno County's transit network is comprised of urban and rural bus routes operated by Fresno Area Express (FAX), Clovis Transit, and Fresno County Rural Transit Agency (FCRTA). The transit routes were discretized into 1/10th mile segments, in alignment with the road network. Twenty bus yards were also assessed in the study, where one yard is serviced by FAX, one yard is serviced by Clovis Transit, and the remaining 18 yards are serviced by FCRTA. Figure 2 shows the transit routes and bus yards that were evaluated in this study. The transit routes with the highest average weekday ridership across all transit agencies is summarized in .

Table 3. Ranked routes by highest average weekday ridership across all transit agencies.

Transit agency	Route	Average weekday ridership[1]
FAX	01-Q-BRT	7,400
FAX	38-Cedar	4,000
FAX	09-Shaw	3,350
FAX	FAX-34-First Street	2,500
FAX	28-Dss/Manchester/West Fresno	2,000

[1]Note: Ridership data for FAX are weekday data (excluding holidays) from May 2024 and for Clovis Transit are from the period between October 2023 and February 2024, Ridership data for FCRTA are weekday data (excluding holidays) from the period February 2024.

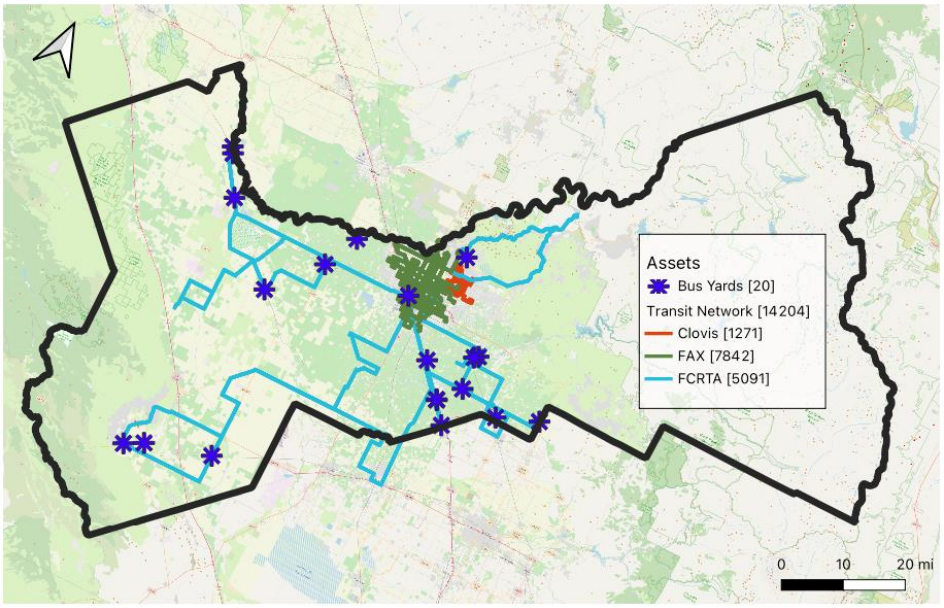

Figure 2. Transit routes and bus yards evaluated in the risk assessment.

3.3 Bicycle Network

The bicycle network evaluated for this assessment includes on-street facilities (e.g. bike lanes), and off-street shared use paths, such as the Lewis Eaton Trail. The bike network segments were discretized into 1/10th mile segments in alignment with the road network.

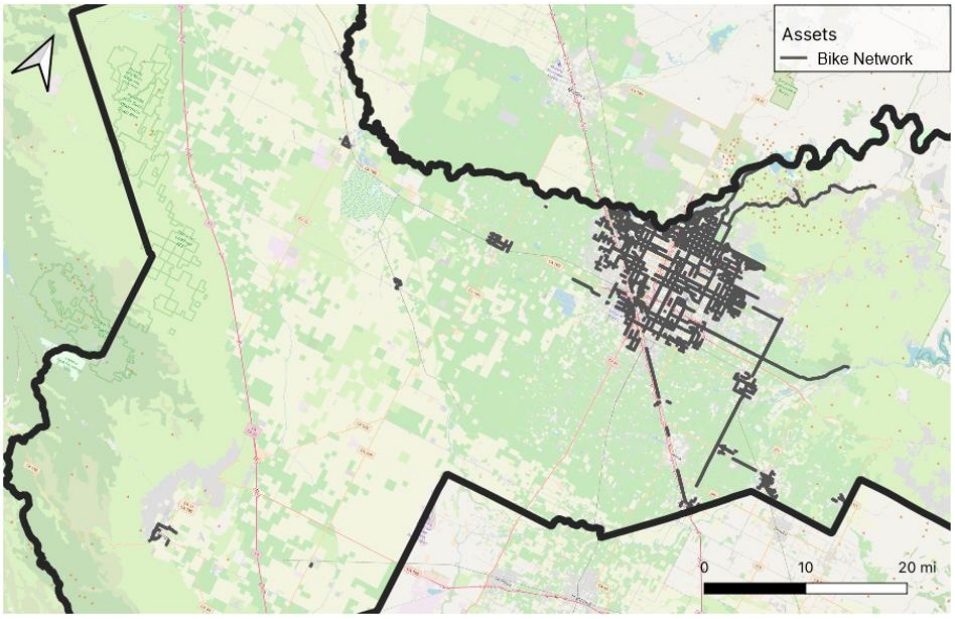

Figure 3. The countywide bike network evaluated in the risk assessment.

3.4 Rail Network

The rail network in Fresno County is comprised of a series of main lines and branch lines, as shown in Figure 4. Eight rail lines were studied and discretized into 1/10th mile segments resulting in the assessment of 2,088 rail assets. Based on the data provided Fresno COG that labels railroads by class, the main lines (Class 1) are Stockton, Fresno, and Bakersfield.

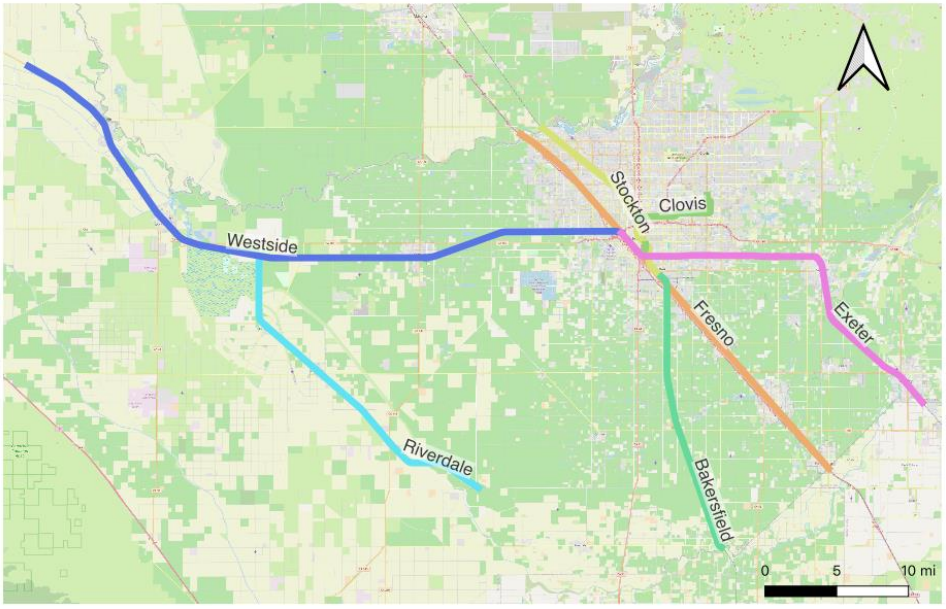

Figure 4. Fresno County's rail network evaluated in the risk assessment.

3.5 Airports

Nine airports were assessed for flood risk in the study and are shown in Figure 5. Among these airports are larger commercial airports (e.g. Fresno Yosemite International Airport) and smaller airports with lesser traffic (e.g. Firebaugh Airport). A footprint, or polygon area, of each of the nine airports was provided by Fresno COG .

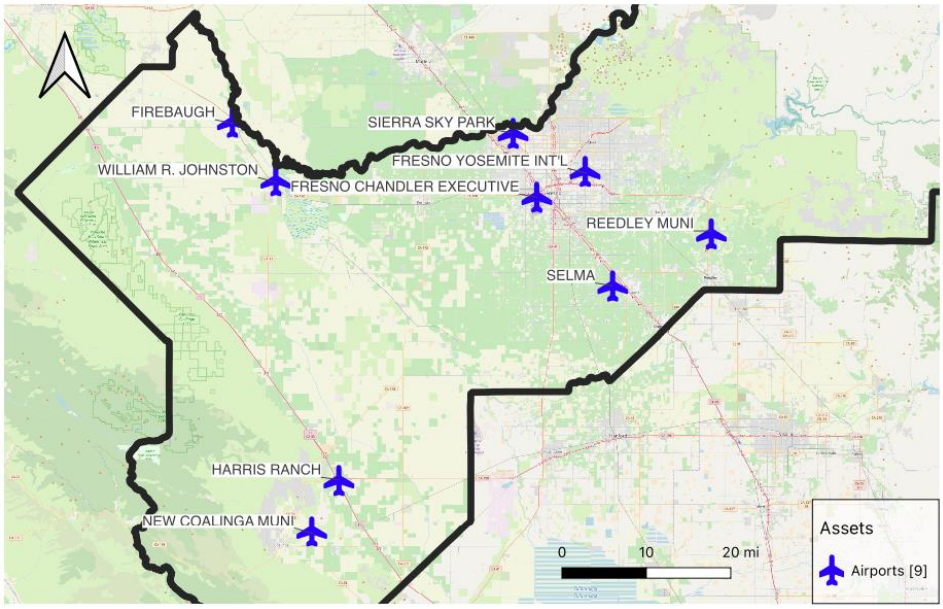

Figure 5. Fresno County's airports evaluated in the risk assessment.

4. Flooding Risk

This section summarizes the findings from the risk assessment of Fresno County's transportation network from flood hazard, what these results mean for Fresno County's regional risk profile, and how they are expected to change considering the effects of climate change.

Certain hazards, including flooding, do not have explicit future hazard datasets. Therefore, future risk ratings are primarily based on present-day hazard data and future climate indicators. In these cases, risk can only be augmented where it already exists (e.g., existing floodplains). Note that climate change could introduce new areas of flooding, but this study does not capture this specific case.

4.1 Flood Risk to Roads and Bridges

The impacts flooding on road operations and damage varies by the severity of the flooding. These impacts may include the following:

- **Unsafe driving conditions** can result from just six inches or less of flooding on a road. These conditions can result in operational disruption or downtime for a few hours or so.
- **Clearance and minor repairs** to roads may be needed after being exposed to six inches or greater flooding. The potential damage caused from this event can result in road closure time resulting in downtime on the order of several days.

Bridges are determined as road assets that intersect with FEMA flood zones AE (floodways) and AO (shallow ponding). Since bridges cross water bodies, they are susceptible to an additional third damage state that considers the potential effects of washout:

- **Washout and significant repairs** of roads can result from a more significant flooding event involving greater than six inches of flooding with velocity. This event results in the worst-case consequence of road closure resulting on the order of weeks of downtime.

The data source used to identify present day flood hazards is the FEMA National Flood Hazard Layer (NFHL), see the *Climate Hazard Memo* for more details. This data identifies where extreme flood events may occur, but do not provide flood depths. As shown in Figure 6, most of Fresno and Clovis are encompassed by a 500-year flood plain. The rural areas of Fresno County predominantly lies within the 100-year flood plain (blue and red extents) which translates to a five times greater chance that those areas flood within a given year compared to the 500-year flood plain. Per the *Climate Hazard Memo,* climate indicators are used to understand how the present-day hazard may shift overtime in its frequency. For flood, extreme precipitation is used which provides us with a proxy of how much more likely a flooding event will be in the future.

The present-day risk ratings are summarized in Figure 7 where all of the roads denoted as grey are considered negligible flood risk as they are not within a FEMA NFHL zone designation. Less than 20% of the roadway network is affected by flood hazard with risk ratings ranging from ***Low-Med*** to ***Med-High***.

Key takeaways from the present-day flood risk assessment are the following:

- Cluster of ***Low-Med*** roads in City of Fresno are in a large 500-year floodplain.
- A number of roads of moderate concern (***Med***) in West Fresno County are all in the 100-year floodplain including major highways such as CA-180 along West Whitebridge Avenue and CA-145 along Fresno Coalinga Road.
- Roads over and near rivers receive a rating of ***Med-High*** due to the potential of significant damage resulting from washout. For example, in Western Fresno County Belmont Avenue crosses multiple creeks including Panoche Creek.

Zooming into Fresno County's more urban areas, the Cities of Fresno and Clovis, Figure 8 details the present-day downtime risk ratings. As previously noted, in the present-day climate the City of Fresno intersects with both the 100-year and 500-year flood plains. Some key takeaways from the present-day flood risk assessment for the urban areas of Fresno and Clovis are the following:

- Swaths of the City's streets are flagged for ***Low-Med*** risk due to their overlap with the 500-year flood plain. The roads of most concern approximately span from the Fresno Chandler Executive Airport to California State University Fresno. Highways CA-180 and CA-41 are also of concern due to their overlay with the 500-year flood plain.
- Flood risk of CA-99 highway that is flagged for ***Med*** risk is due to portions of the highway overlapping with the 100-year flood plain.
- The orange dots, denoted as ***Med-High*** risk ratings, are road assets that cross over or near rivers and therefore are able to trigger the washout damage state.

Under the mid-century, high emissions climate scenario (SSP5-8.5, 2050) (refer to Figure 9 and Figure 10) the road asset risk ratings increase in certain locations. This is because when considering extreme precipitation as a climate indicator the future climate may change the 100-year floodplain to a more likely event like the 50-year floodplain. The risk ratings for the mid-century climate scenario range from ***Low-Med*** to ***High***. Similarly, for the risk ratings in the end of century scenario (SSP5-8.5, 2085) shown in Figure 11 and Figure 12, the range remains the same as mid-century of ***Low-Med*** to ***High***, however the overall distribution of risk becomes more severe (i.e., there are more roads with a ***High*** rating at the end of century compared to mid-century). Some key takeaways from the future flood risk results are the following:

- In the city center of Fresno, the 500-year flood plain is becoming more frequent which elevates the risk rating of roads spanning from Fresno Chandler Executive Airport to California State University Fresno as well as highways CA-180 and CA-41 (***Low-Med*** to ***Med***).
- Flood risk of CA-99 highway increases to ***Med-High*** considering climate change.
- For road assets that are over and near rivers, the risk rating is elevated from ***Med-High*** to ***High***.

In summary, flood risk is an issue regionally for Fresno County's road assets. Due to climate change, impacts to assets will become more severe. The most impacted areas are within the City of Fresno and stretches along western Fresno County's less urbanized roads:

- **City of Fresno.** Fresno and Clovis will experience flood risk concentrated in areas such as highways CA-41, CA-99, and CA-180. Flood risk is primarily of concern among roads between Fresno Chandler Executive Airport and California State University Fresno within the City's road network.
- **Western Fresno County.** Within Western Fresno County, roads that cross water bodies including Belmont Avenue, South Fairfax Avenue, highways CA-33, and CA-269 are of the most concern. Second to roads that cross water bodies, are roads that provide major connections to the rural areas of western Fresno County which include stretches of West Mount Whitney Avenue, highway CA-145, and mountain routes Los Gatos Road and CA-198.

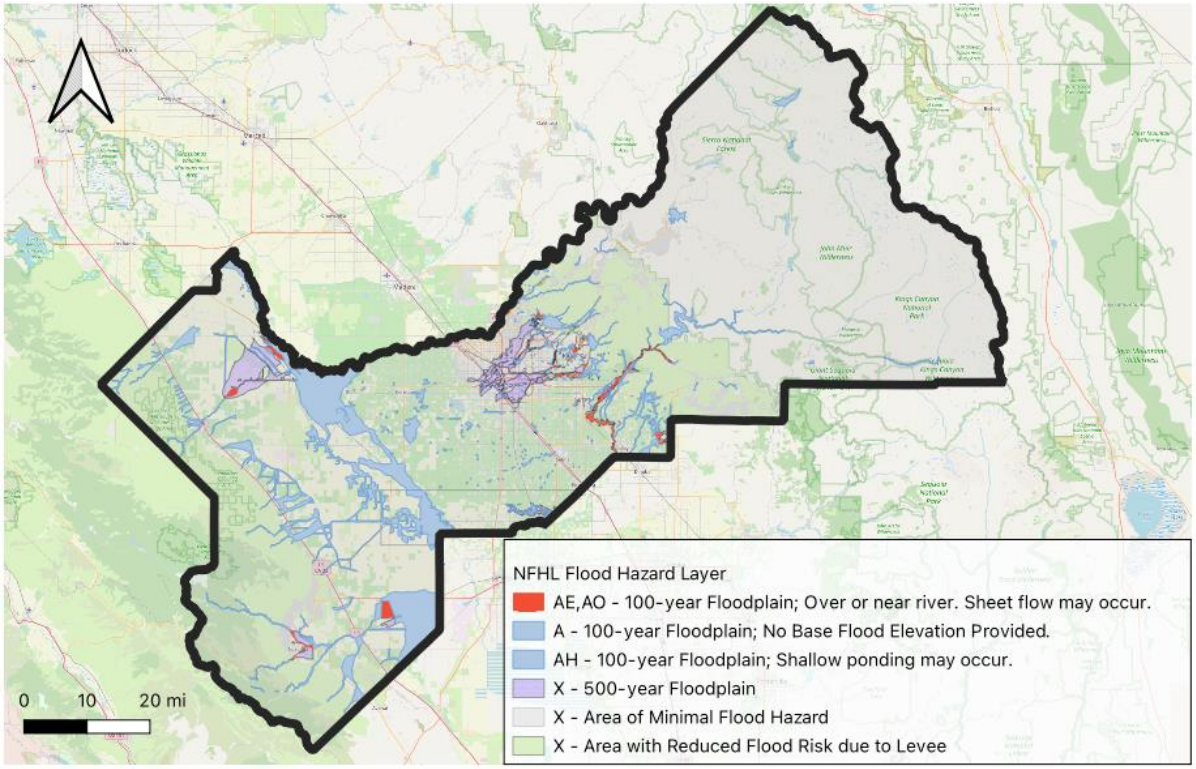

Figure 6. FEMA National Flood Hazard Layer overlayed in Fresno County.

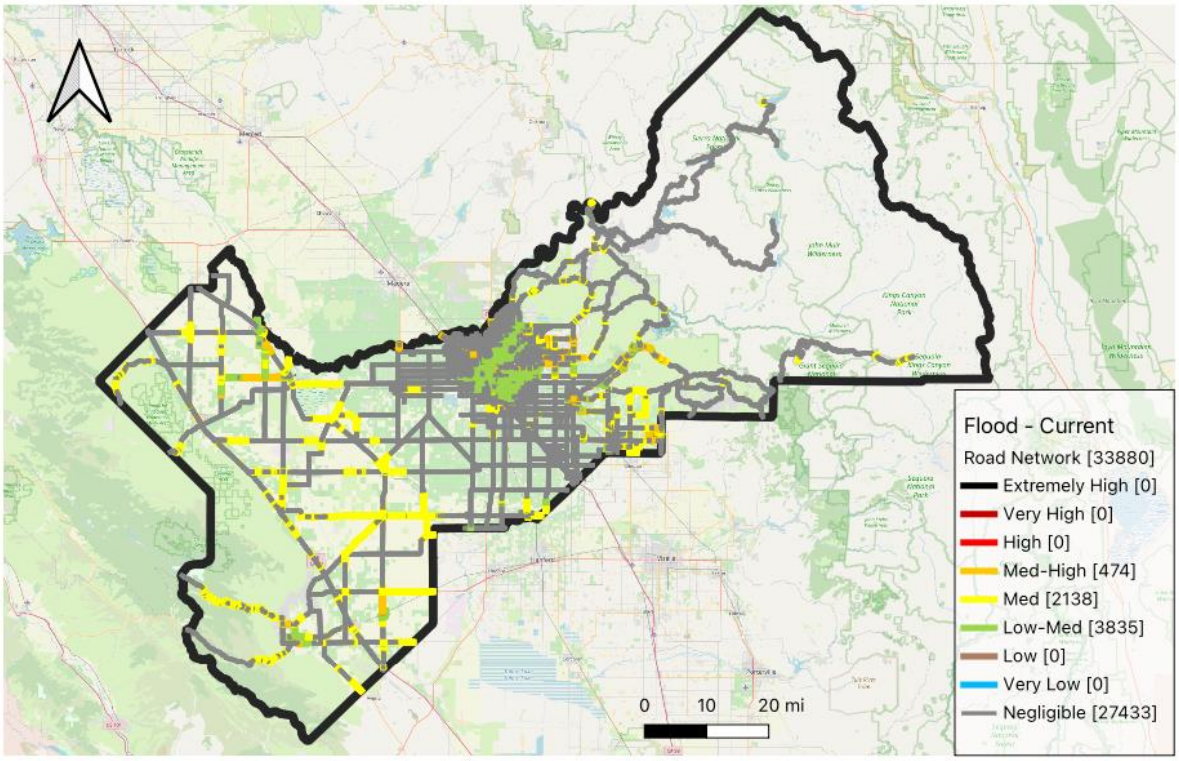

Figure 7. Downtime risk ratings of the road network from present day flood hazard.

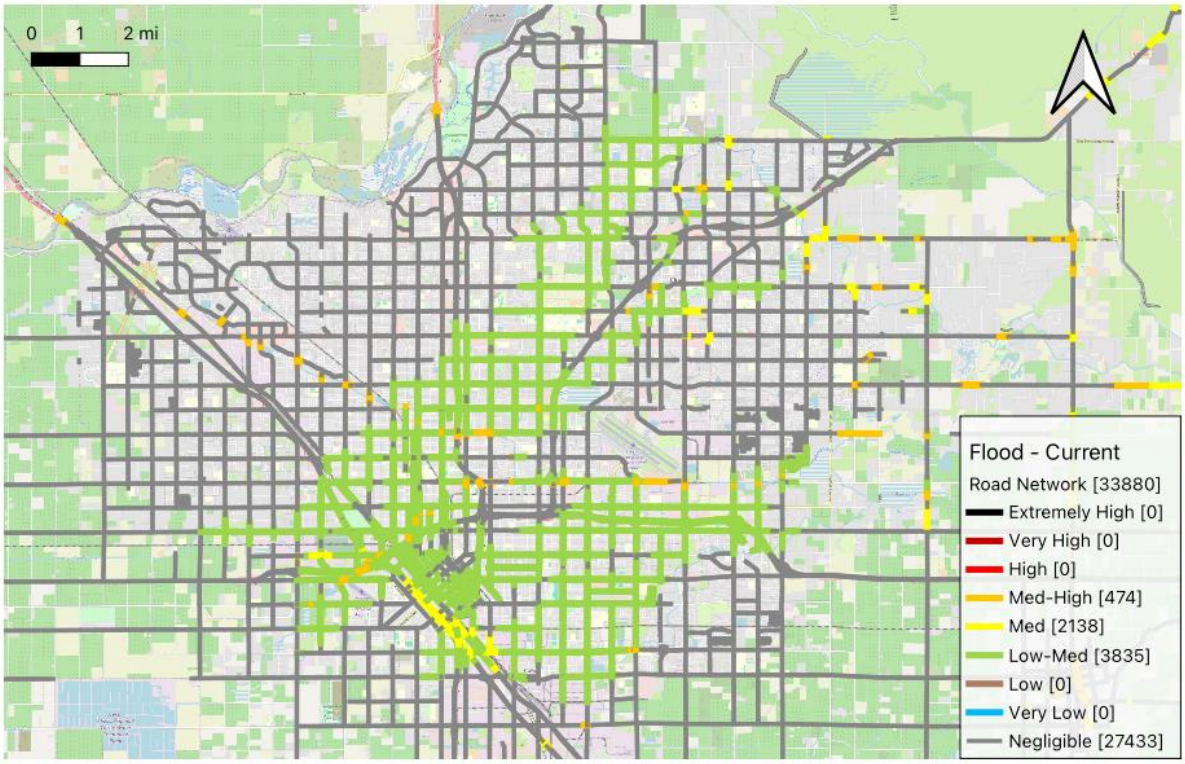

Figure 8. Downtime risk ratings for the cities of Fresno and Clovis' road network from present-day flood hazard.

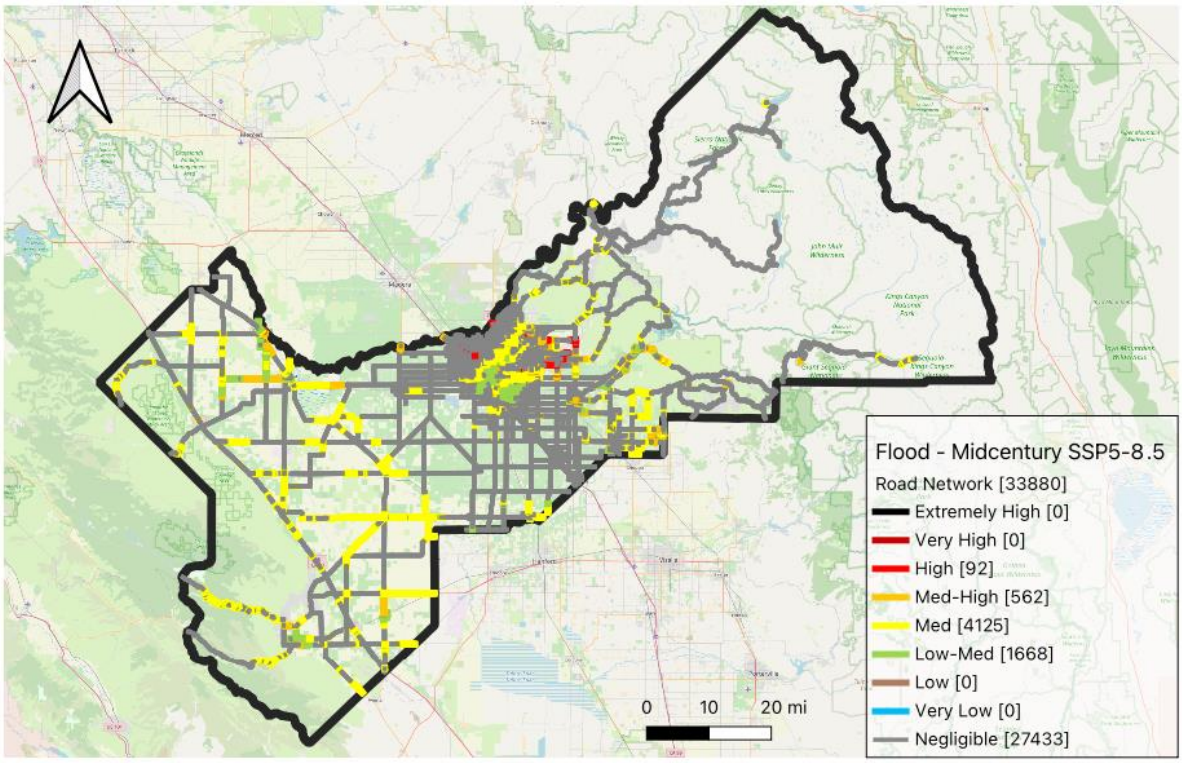

Figure 9. Downtime risk ratings of the road network from mid-century (SSP5-8.5) climate flood hazard.

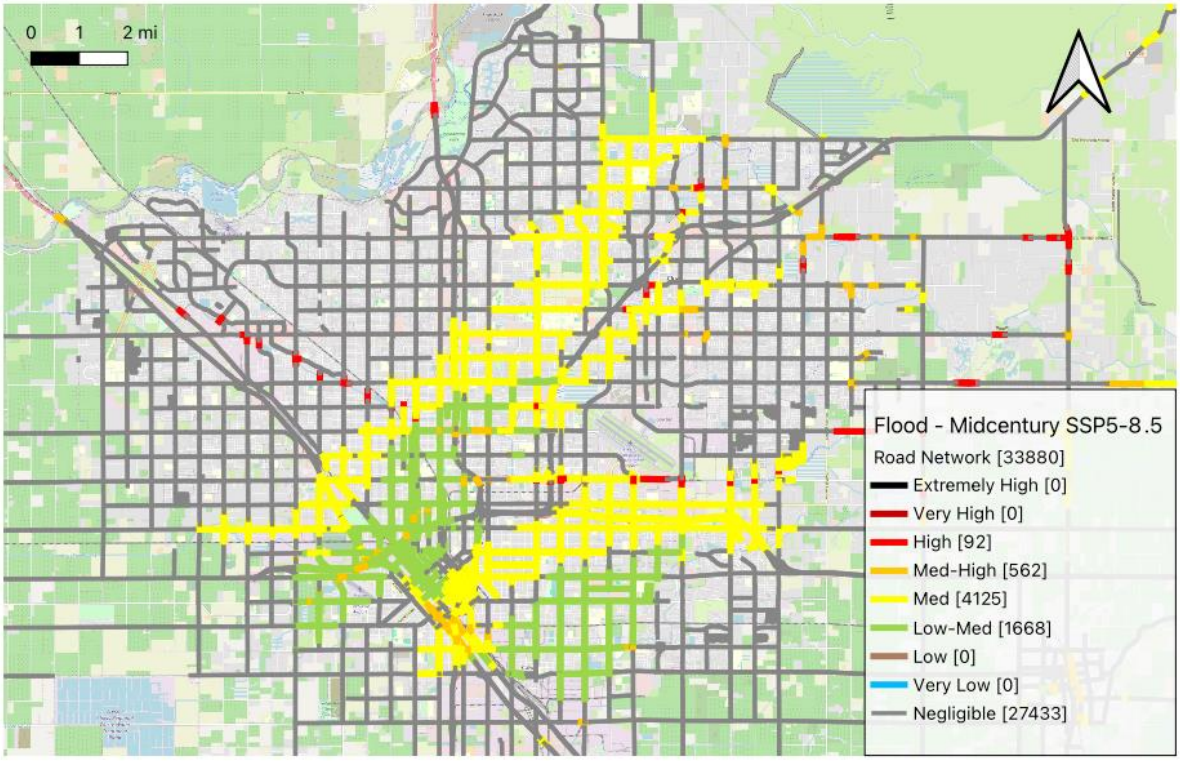

Figure 10. Downtime risk ratings for the cities of Fresno and Clovis' road network, from mid-century climate (SSP5-8.5) flood hazard.

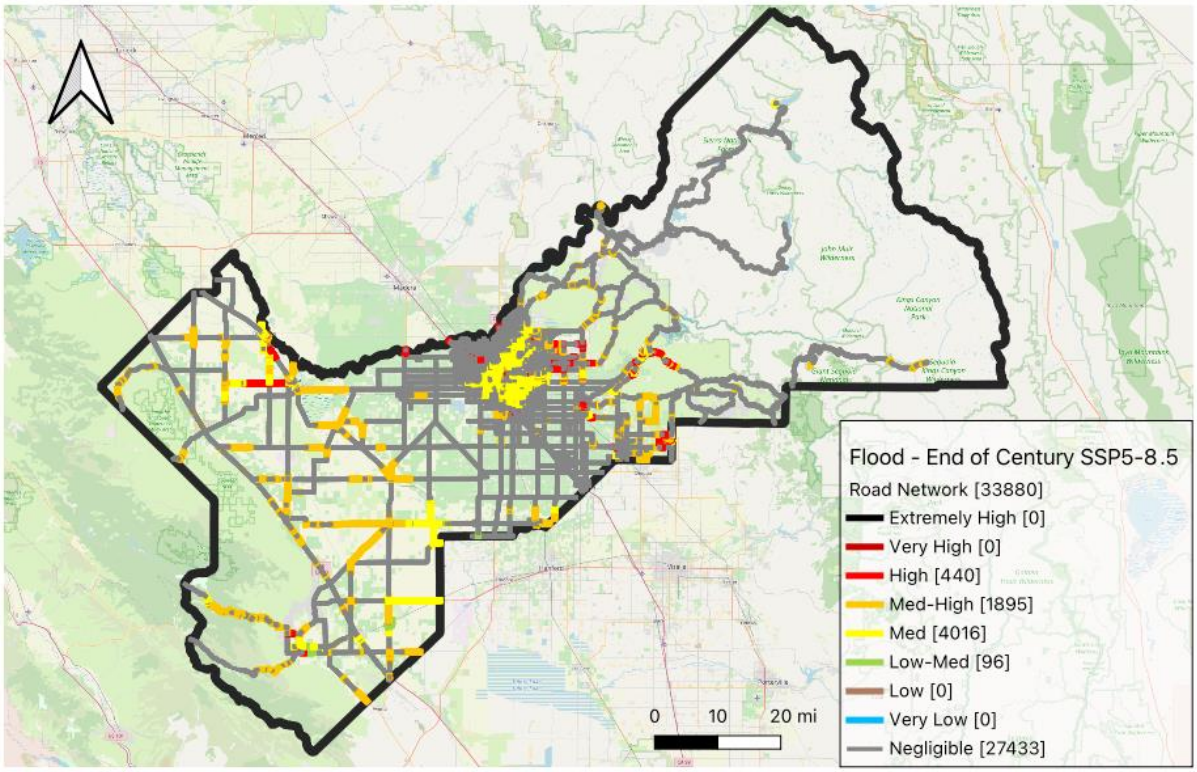

Figure 11. Downtime risk ratings of the road network from end of century (SSP5-8.5) climate flood hazard.

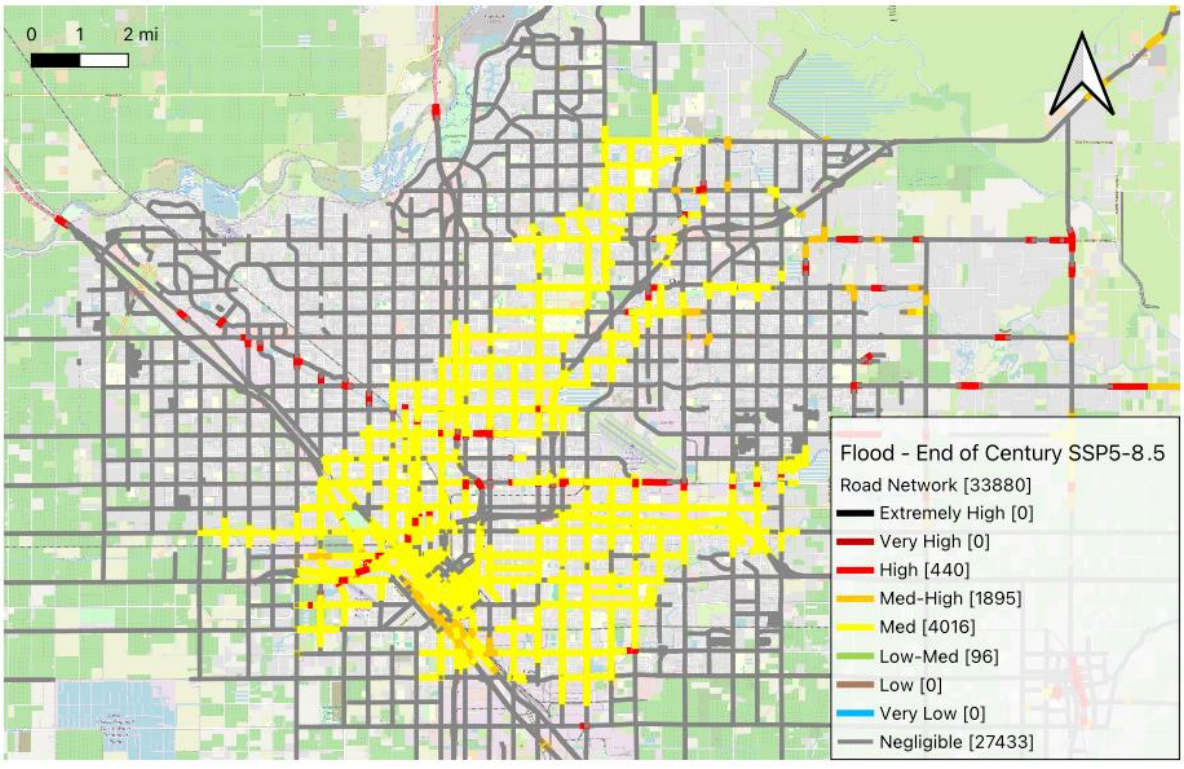

Figure 12. Downtime risk ratings for the cities of Fresno and Clovis' road network, from end of century climate (SSP5-8.5) flood hazard.

4.2 Flood Risk to the Transit Network and Bus Yards

The damage states used to assess the flood risk road network assets are also used in the assessment of Fresno County's transit network. The flood consequences considered for Fresno County's transit infrastructure is as follows:

- Transit routes and bus yards are assessed for the impacts flood may play on **operational downtime**.

4.2.1 Transit Routes

Transit routes were assessed by discretizing the provided transit network data from Fresno COG. Around 35% of transit routes are affected by flooding with varying degrees of severity in Fresno County. Present-day risk ratings range from ***Low-Med*** to ***Med-High*** along the transit routes mapped in Figure 13. For future climate scenarios mid-century (Figure 15) and end of century (Figure 17), the risk ratings range from ***Low-Med*** to ***High***.

The top five routes with the highest average weekly ridership demand are within the City of Fresno (refer to). Therefore a closer look is taken of all routes within the City of Fresno as seen in Figure 14. Some key takeaways from this risk assessment include:

- FAX routes in the center of the city flagged for ***Low-Med*** risk are exposed to the 500-year flood plain.
- Among the routes that have the highest average weekly ridership, three (Routes 1, 38, and 28 (FAX)) out of the top five routes are also within the top five riskiest routes to flood risk in Fresno County. Only portions of each of these routes are exposed to flood risk and are denoted as follows:
    - Flood risk approximately impacts 55% of Routes 1 and 38. Route 38 has more severe flood risk compared to Route 1 despite an equal distribution of areas effected across each route's entire length.
    - Flood risk approximately impacts 70% of Route 28.
- The transit route with the highest flood risk, FAX Route 38 is also the second highest demand route for average weekly ridership.
- Among the regional transit routes (FCRTA), Coalinga Intercity Transit Route and Westside Transit Route have the highest flood risk.
    - Flood risk approximately impacts 25% of the Coalinga Intercity Transit Route. However, the flood risk exposed to this route is more severe than the Westside Transit Route.
    - Flood risk approximately impacts 35% of the Westside Transit Route. Despite more of the route being exposed to flood risk, the severity of the risk is less than that of the Coalinga Intercity Transit Route.

Accounting for the effects of climate change results in an increase in risk to the transit routes. The future risk ratings for mid-century climate and end of century climate are shown in Figure 16 and Figure 18. From these results the following findings can be summarized:

- FAX routes in the center of the city exposed to the 500-year flood plain raise from ***Low-Med*** to ***Med*** risk by end of century due to future extreme precipitation events.
- For routes already flagged with flood risk in the present-day climate, the risk ratings increase by 1-2 ratings by end of century.
- Routes 1, 38 and 28 remain within the top five riskiest routes for flood risk in Fresno County by end of century climate.
- FAX Route 38 increases in risk along most of its length in 1 risk rating by end of century.
- Most of the present-day risk ratings increase by 1 rating by end of century for both Coalinga Intercity Transit Route and Westside Transit Route (FCRTA).

In summary, flood risk is an issue regionally for Fresno County's transit route assets. It is expected that flooding risk increases with climate change which makes transit route assets more vulnerable. The routes of most concern are as follows: urban route with the highest average weekly ridership and rural routes which are critical to many outer lying communities:

- **Urban Routes**. Urban routes with the highest average weekly ridership are among the leaders of concern for flood risk. Some of the most impacted routes from flood risk are along the FAX transit network including Routes 1, 28, and 38. These routes coincidentally are also within the top five most traveled routes for weekly ridership.
- **Rural Routes**. The more rural routes are critical to outer lying communities. Among these routes, the FCRTA Coalinga Intercity Transit and Westside Transit Routes have highest flood risk.

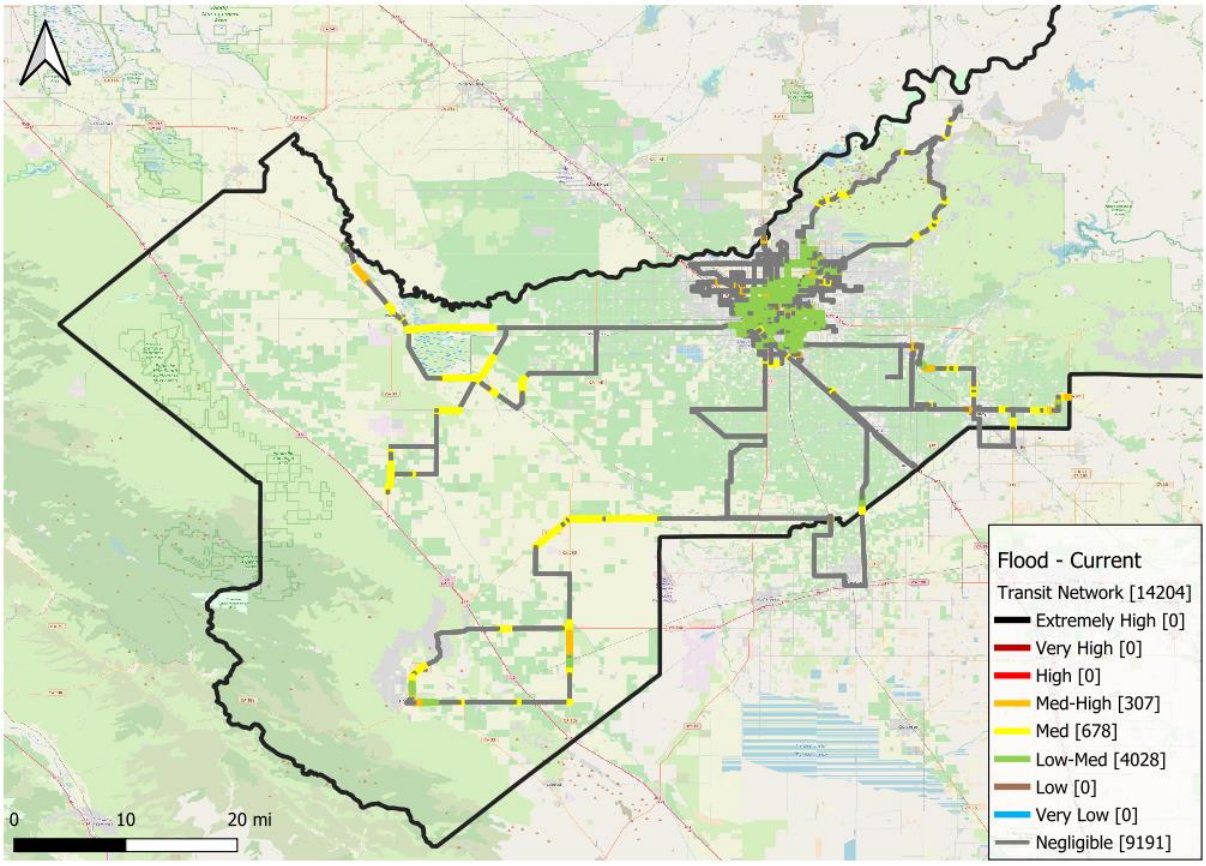

Figure 13. Downtime risk ratings of the transit network from present-day climate flood hazard.

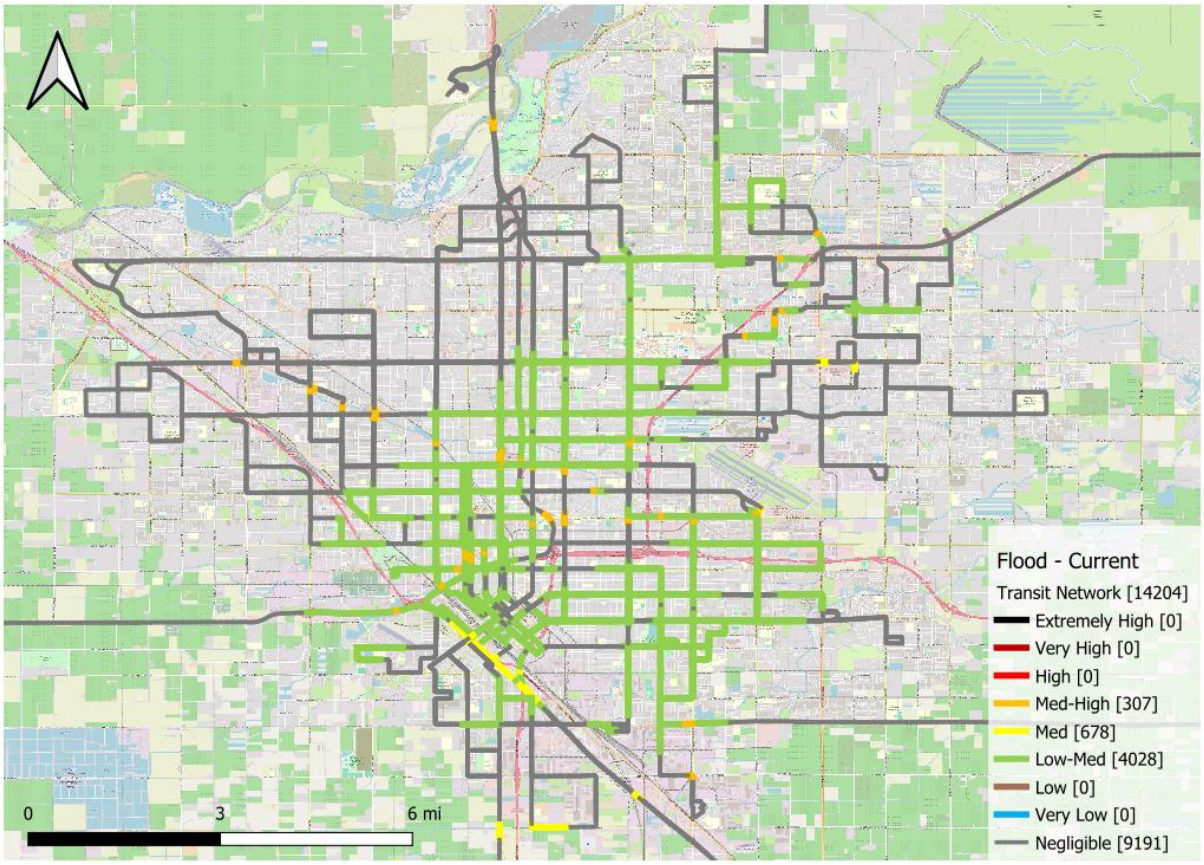

Figure 14. Downtime risk ratings for transit lines serving Fresno and Clovis from present day flooding.

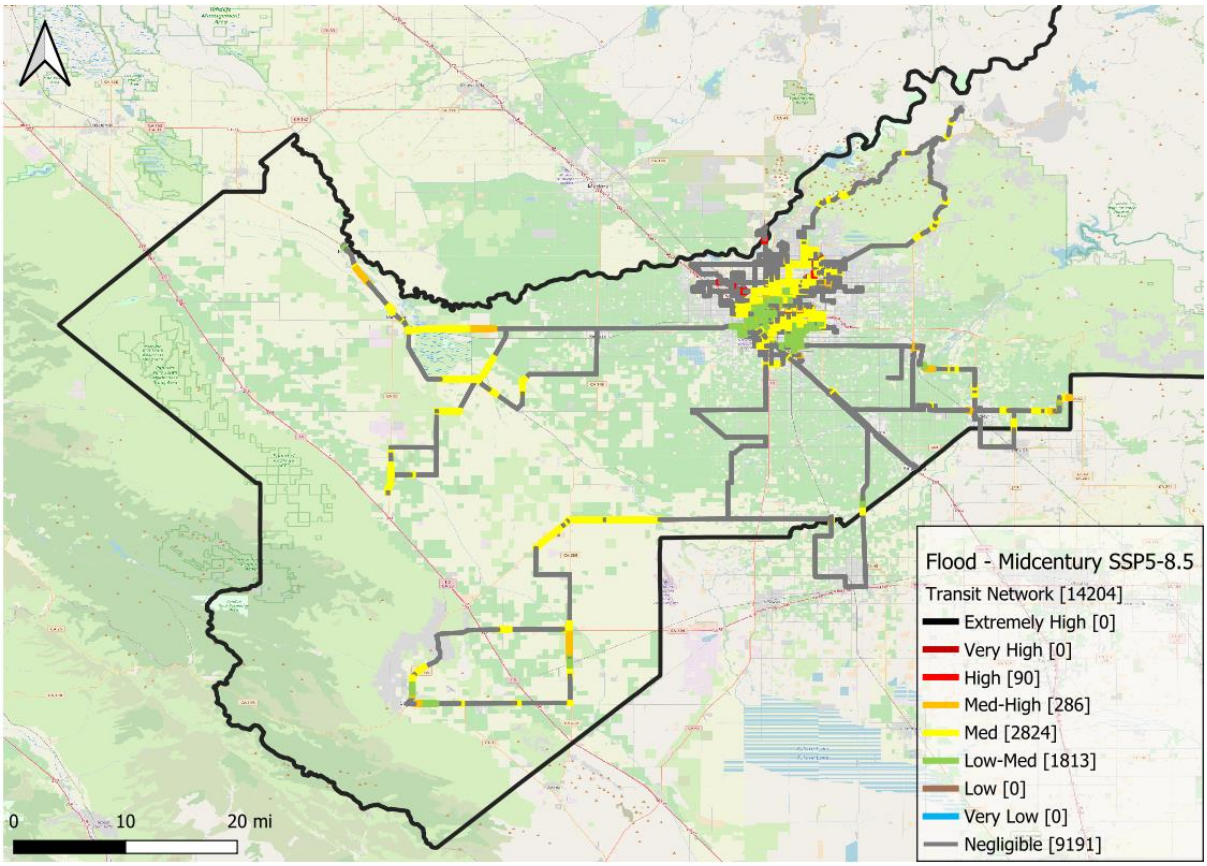

Figure 15. Downtime risk ratings of the transit network from mid-century climate (SSP5-8.5) flood hazard.

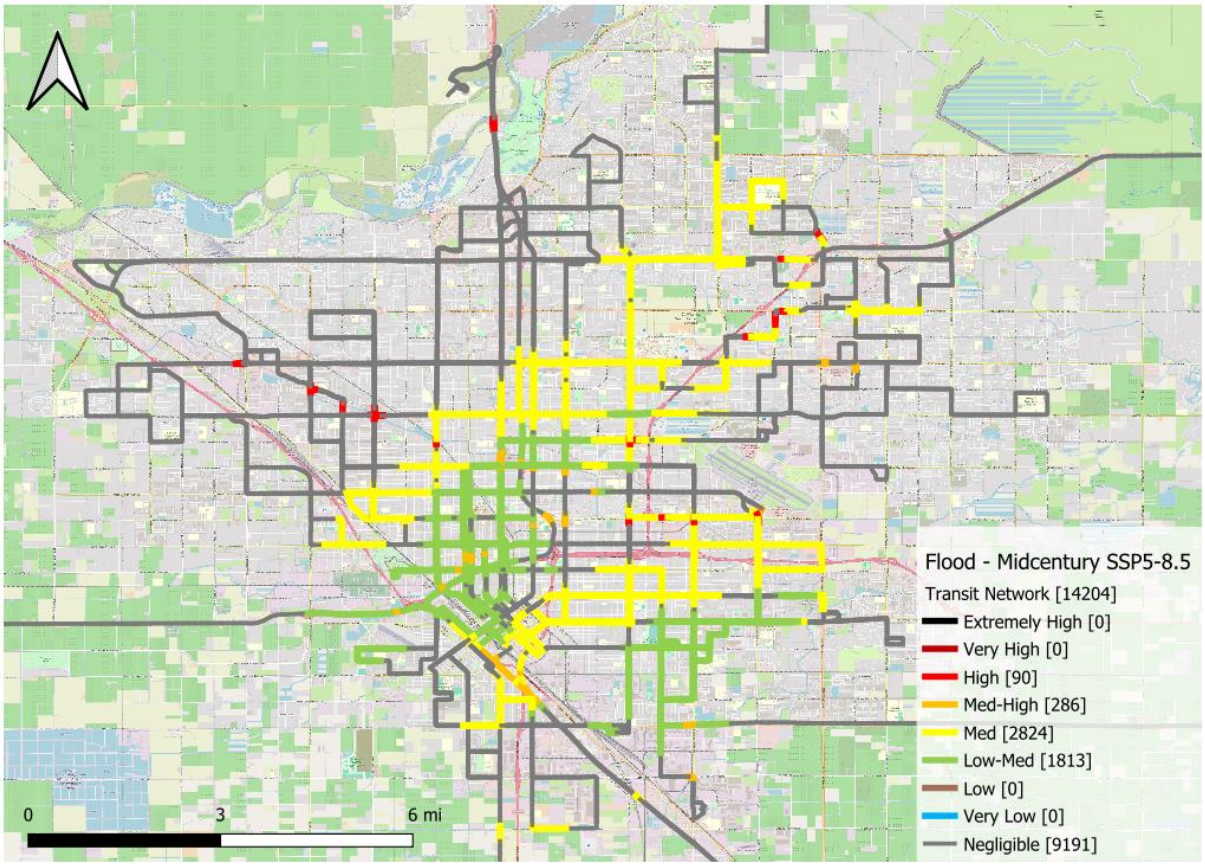

Figure 16. Downtime risk ratings for transit lines serving Fresno and Clovis, from mid-century climate (SSP5-8.5) flood hazard.

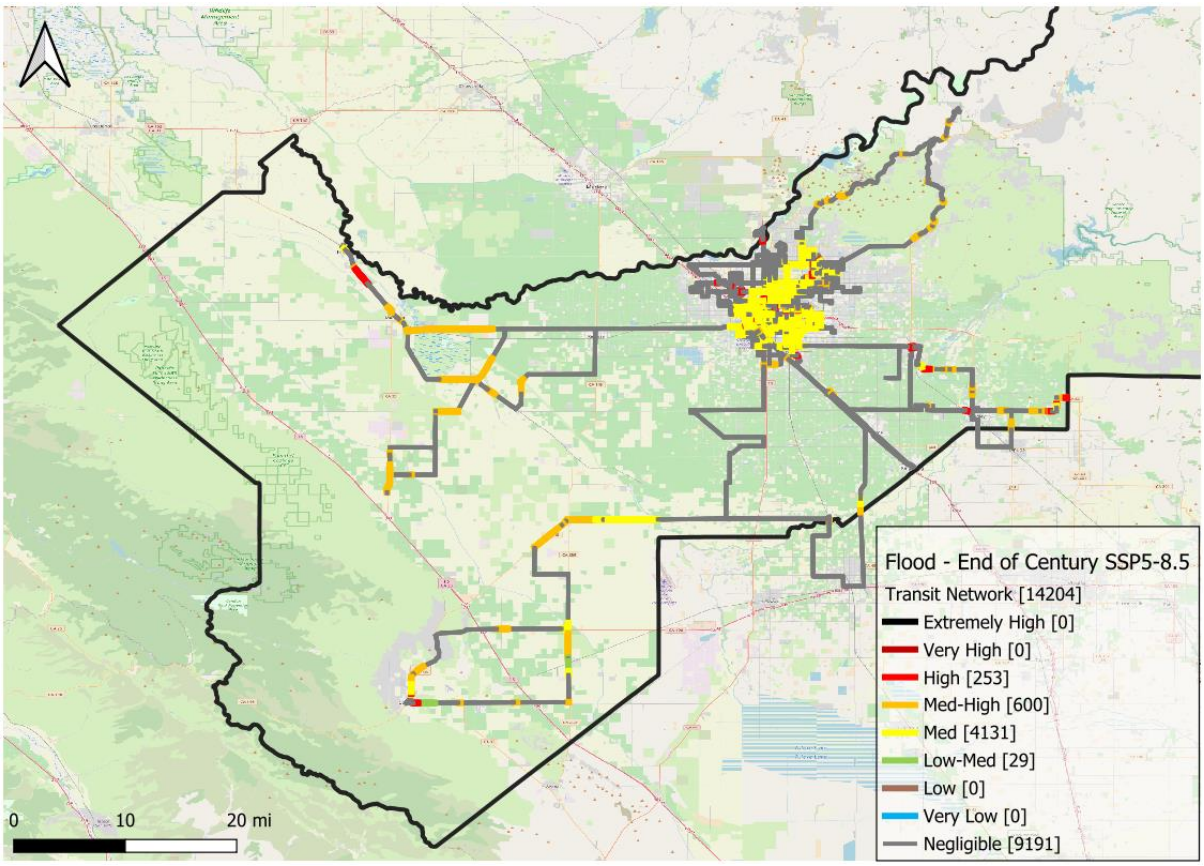

Figure 17. Downtime risk ratings of the transit network from end of century climate (SSP5-8.5) flood hazard.

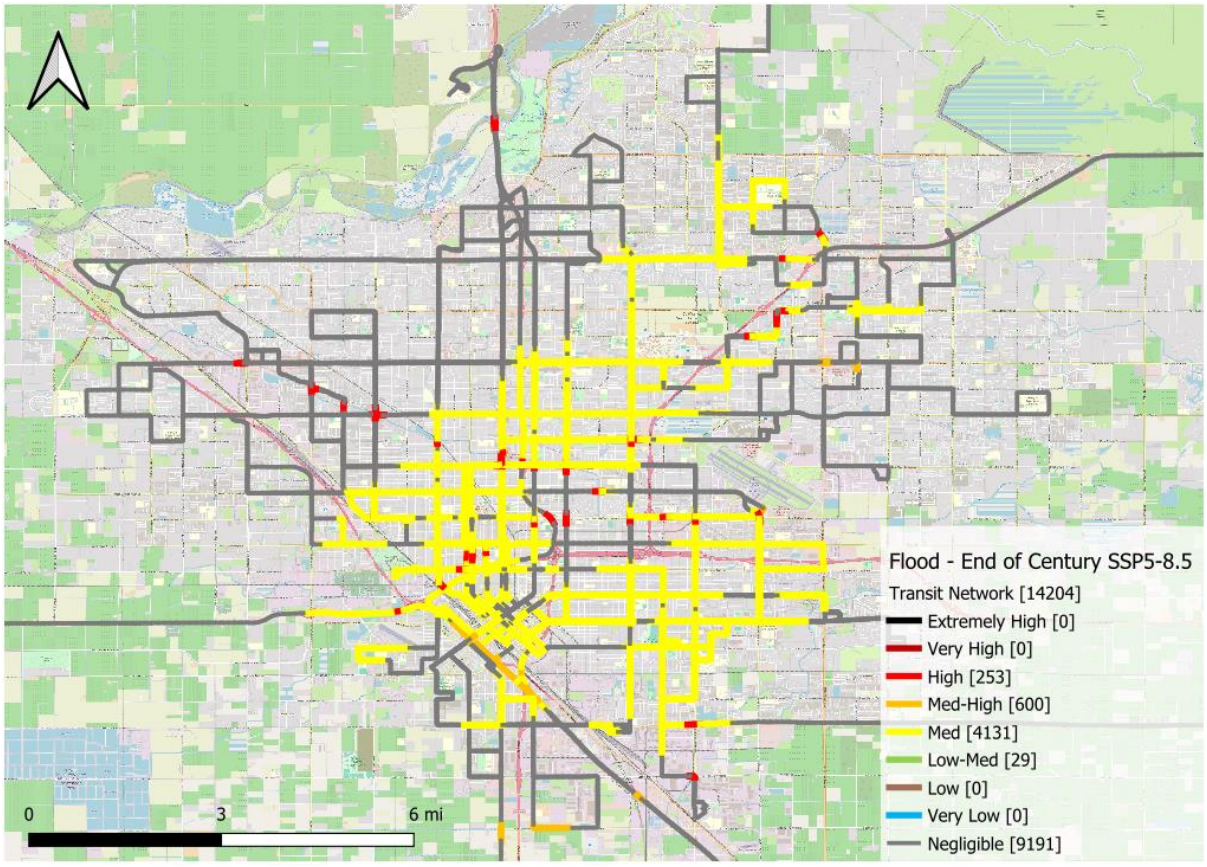

Figure 18. Downtime risk ratings for transit lines serving Fresno and Clovis, from end of century climate (SSP5-8.5) flood hazard.

4.2.2 Bus Yards

Fresno County has 20 bus yards that were assessed for flood risk. Flooding of bus yards can damage critical equipment or buildings with critical infrastructure. This damage may require longer repair/replacement times for both the equipment and the building itself. Although not explicitly assessed, flooding may result in limited access to bus yards in the event that surrounding areas are flooded.

Around 25% of the bus yards assessed are near rivers or within a FEMA flood plain at the confluence of multiple water bodies. Bus yards with onsite infrastructure (e.g. buildings) can experience even worse damage and impacts due to the presence of critical equipment. Present-day risk ratings range from ***Low-Med*** to ***High*** as illustrated Figure 19. Among the bus yards with higher risk ratings are those that neighbor well known water bodies including:

- ***High*** risk bus yards are those that overlap with 100-year FEMA flood plain, interact with neighboring water bodies, and are flagged for having critical infrastructure. These bus yards are owned by FCRTA and noted as follows:
    - Firebaugh Bus Yard 1 which neighbors the San Joquin River.
    - Coalinga Bus Yard which neighbors the Los Gatos Creek.
    - Orange Cove Bus Yard which is at the confluence of a channel and creek.
- The second highest risk rating, ***Medium-High*** risk ratings, are bus yards that overlap with the 500-year FEMA flood plain, interact with neighboring water bodies, and are flagged for having critical infrastructure. These bus yards are noted as follows:
    - Firebaugh Bus Yard 2 (FCRTA) which neighbors the San Joquin River.
    - FAX Bus Yard (FAX) lies at the confluence of multiple creeks and channels.

The impacts of climate change result in higher flood risk ratings for bus yards that range in ***Med*** to ***Very-High*** for mid-century climate scenario (Figure 20) and end of century climate (Figure 21). Among the future climate risk ratings are the following findings:

- By mid-century climate (SSP5-8.5, 2050) only the FCRTA Firebaugh Bus Yard 1 increases in a risk rating level from ***High*** to ***Very-High***. By end of century (SSP5-8.5, 2085) all the originally ***High*** flood risk bus yards increase to ***Very-High*** risk (Firebaugh Bus Yard 1, Orange Cove Bus Yard, and Coalinga Bus Yard).
- By end of century (SSP5-8.5, 2085) the additional FCRTA Firebaugh Bus Yard 2 in Firebaugh and the FAX bus yard increase by one risk rating level from present-day ***Medium-High*** to ***High***.

In summary, flood risk impacts only a small portion of the bus yards assessed. Due to climate change, the conditions of the effected bus yards will only grow more severe. The most impacted areas are distributed among the City of Fresno and far out along the borders of Fresno County:

- **City of Fresno**. The FAX bus yard is most effected by flood risk. The bus yard has onsite critical infrastructure and is at the confluence of multiple creeks and flood plains making the site more vulnerable to flooding.
- **Areas along the border of Fresno County**. In examining flood risk in the more rural areas, the FCRTA bus yards, Firebaugh 1, Firebaugh 2, Orange Cove, and Coalinga are

hot spots. All of these bus yards hold critical infrastructure onsite as well as interact with neighboring bodies of water.

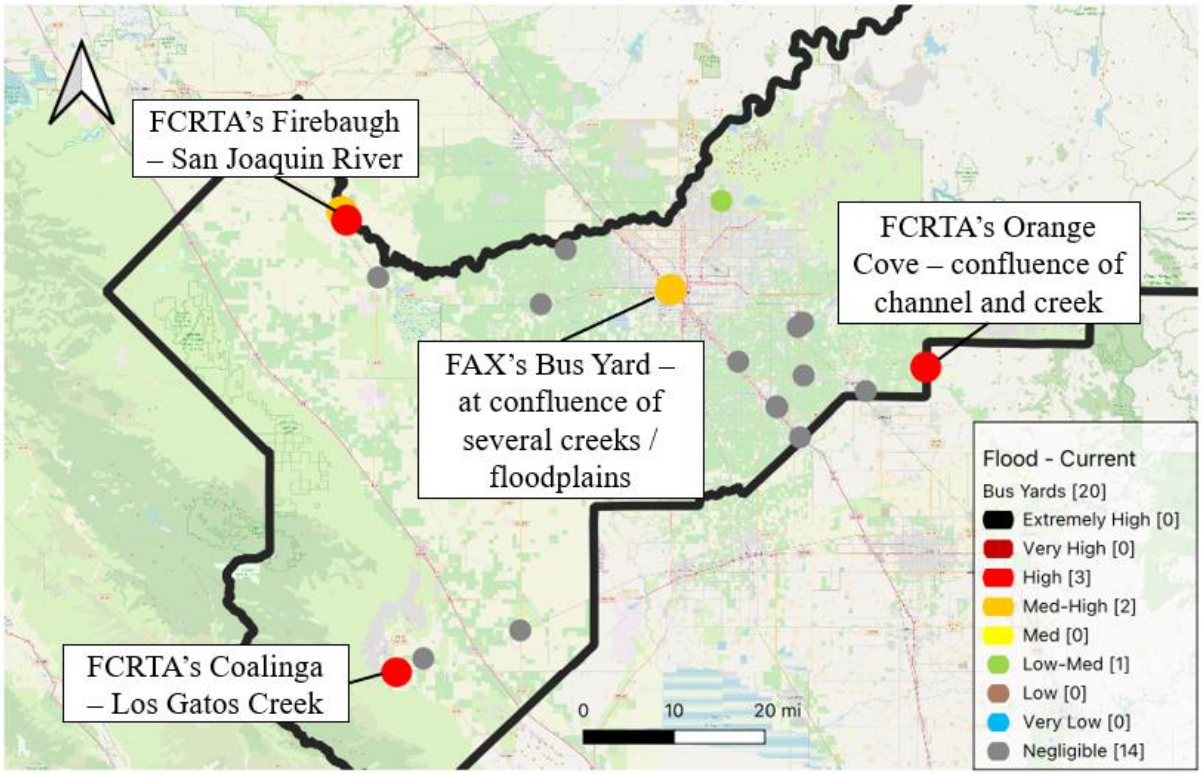

Figure 19. Downtime risk ratings of bus yards from present day flood hazard.

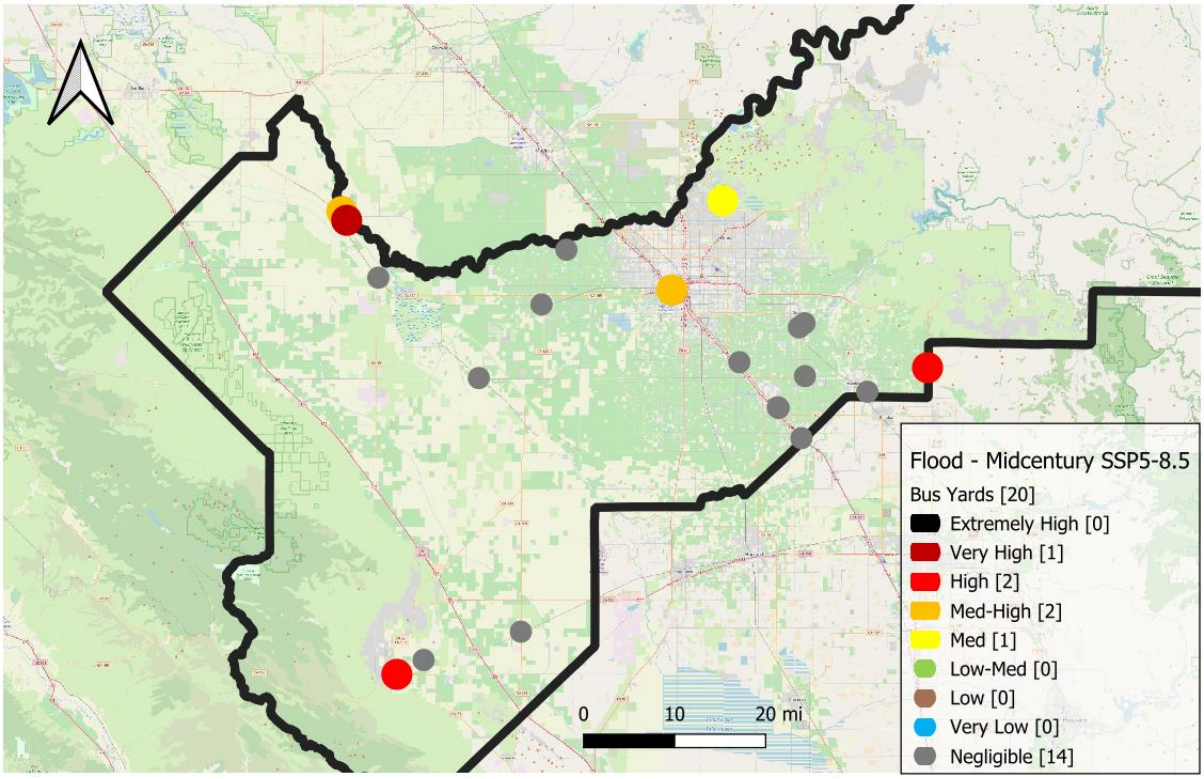

Figure 20. Downtime risk ratings of bus yards from mid-century climate (SSP5-8.5) flood hazard.

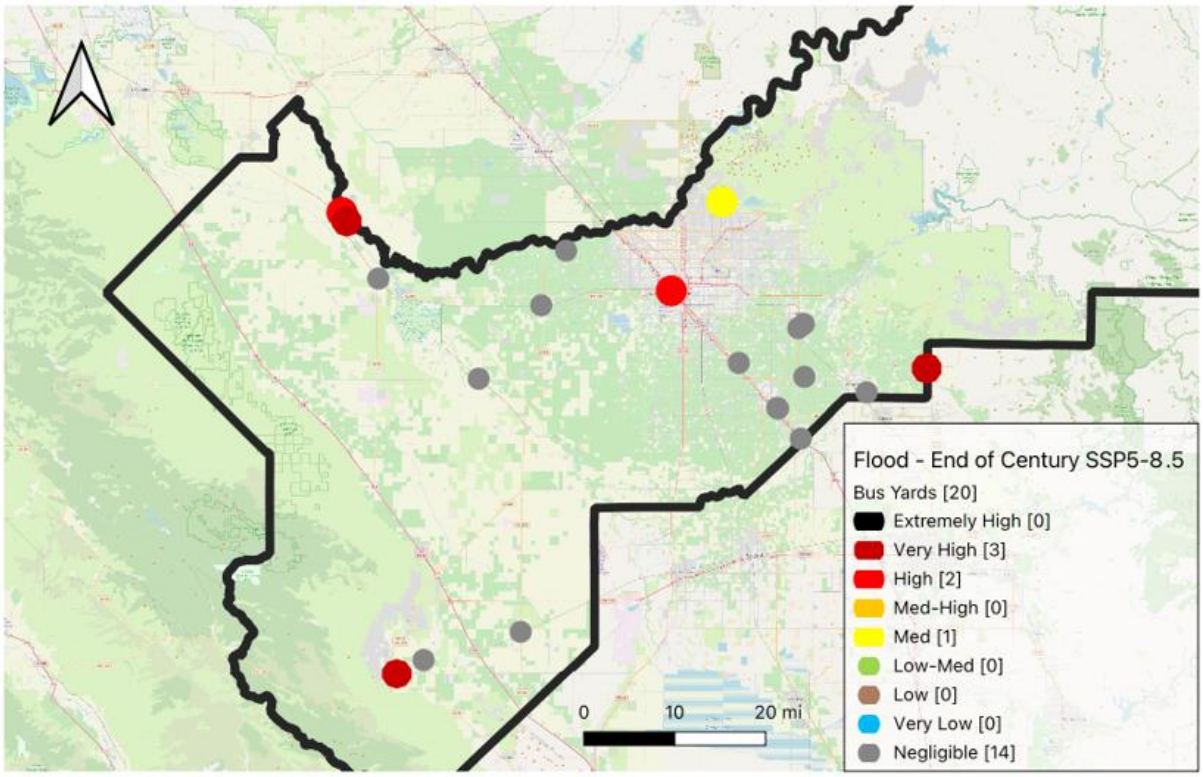

Figure 21. Downtime risk ratings of bus yards from end of century climate (SSP5-8.5) flood hazard.

4.3 Flood Risk to the Bike Network

The assessments of Fresno County's bike network follow the same methods of assessing roads. The bike network was assessed using a dataset provided to Arup from Fresno COG. Of the entire bike network, around 22% of the bike network is impacted by flooding according to the FEMA NFHL. The present-day risk ratings in Figure 22 range from ***Low-Med*** to ***Med-High***. In the future, the mid-century climate scenario (Figure 23) and end of century climate scenario (Figure 24) risk ratings change to range from ***Low-Med*** to ***High***. For the traditional on street paths and facilities, the logic behind the findings of the risk ratings is similar to that of the road network.

Beyond closure of bike facilities, flooding can also contribute to longer term degradation and safety issues. For example, damage such as potholes and deteriorated pavement quality can cause safety hazards, as can debris from storms and flooding in the time after flood waters recede. Additionally, in areas where facilities are flooded bicyclists may be forced into vehicle travel lanes or sidewalks, and frequent occurrence may discourage bicycling entirely.

Majority of bike paths (off-street paths), either border or neighbor a canal or creek in Fresno County. Therefore, a significant portion of Fresno County's bike paths are exposed to flooding. The impacts of flood risk are expected to increase when considering climate change. Among these bike paths are the following hot spots:

- **City of Fresno**:
    - Flood risk is significant at the Fancher Creek Path since the bike path aligns with Central No.23 and Washington Colony No.15 canals (both canals that connect to Francher Creek Canal).
- **City of Clovis**:
    - Dry Creek Path is exposed to flood risk in part due to it spanning along the Big Dry Creek.
    - Enterprise Canal Trail borders the neighboring Enterprise Canal resulting in flood risk.
    - Portions of the Leonard Avenue that cross the neighboring Dog Creek.
- **Areas along the border of Fresno County**:
    - Railroad Avenue Trail is exposed to flood risk due to the trail neighboring the Friant-Kern Canal.
    - The Lewis Eaton Trail and Riverside Trail are exposed to flood risk in part due to both bike paths neighboring the San Joquin River.

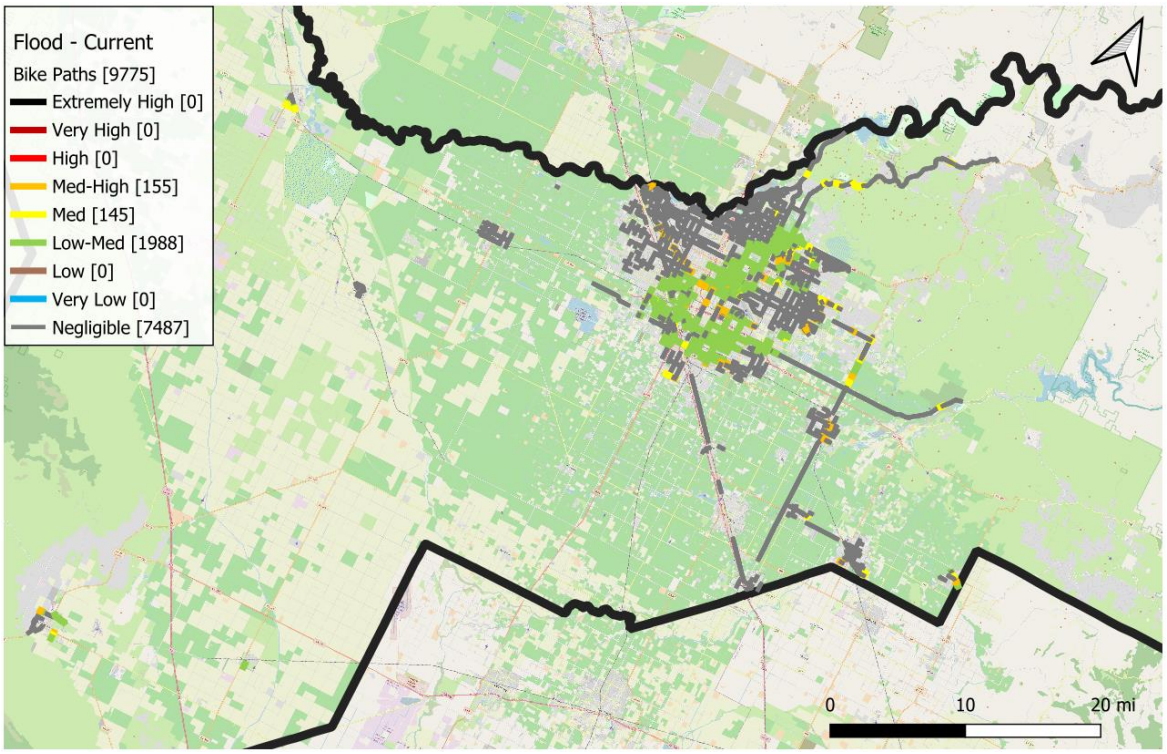

Figure 22. Downtime risk ratings of bike paths from present day flood hazard.

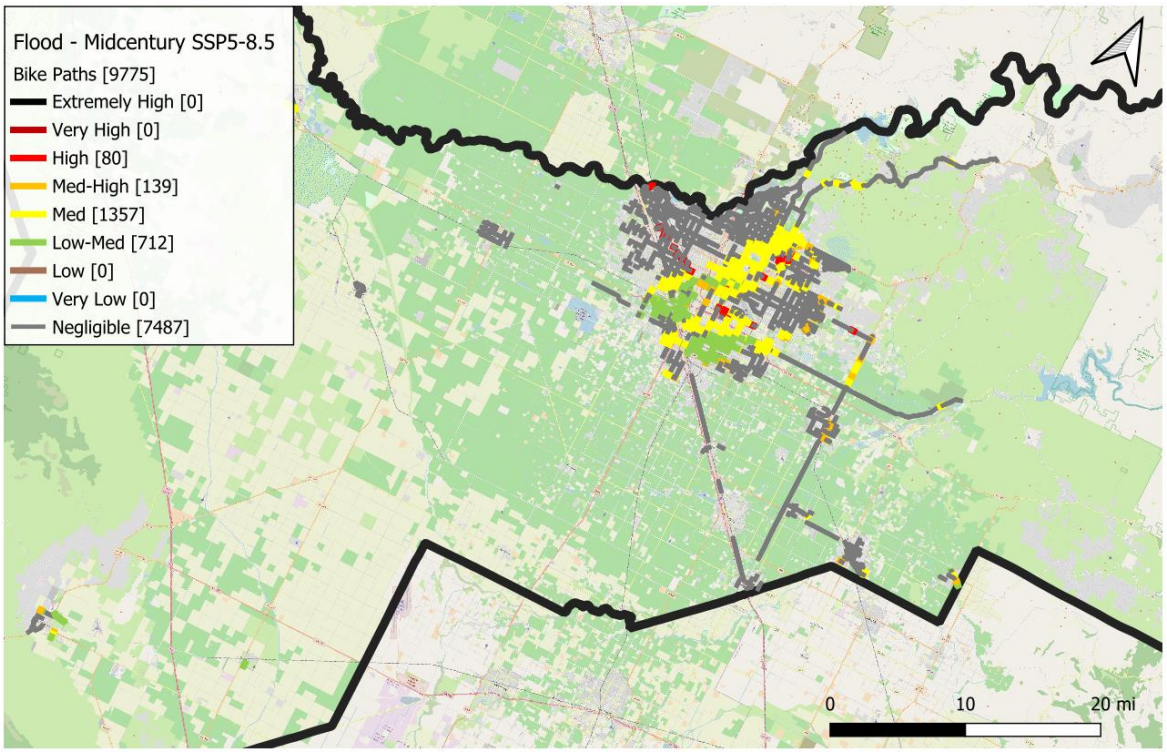

Figure 23. Downtime risk ratings of bike paths from mid-century climate (SSP5-8.5) flood hazard.

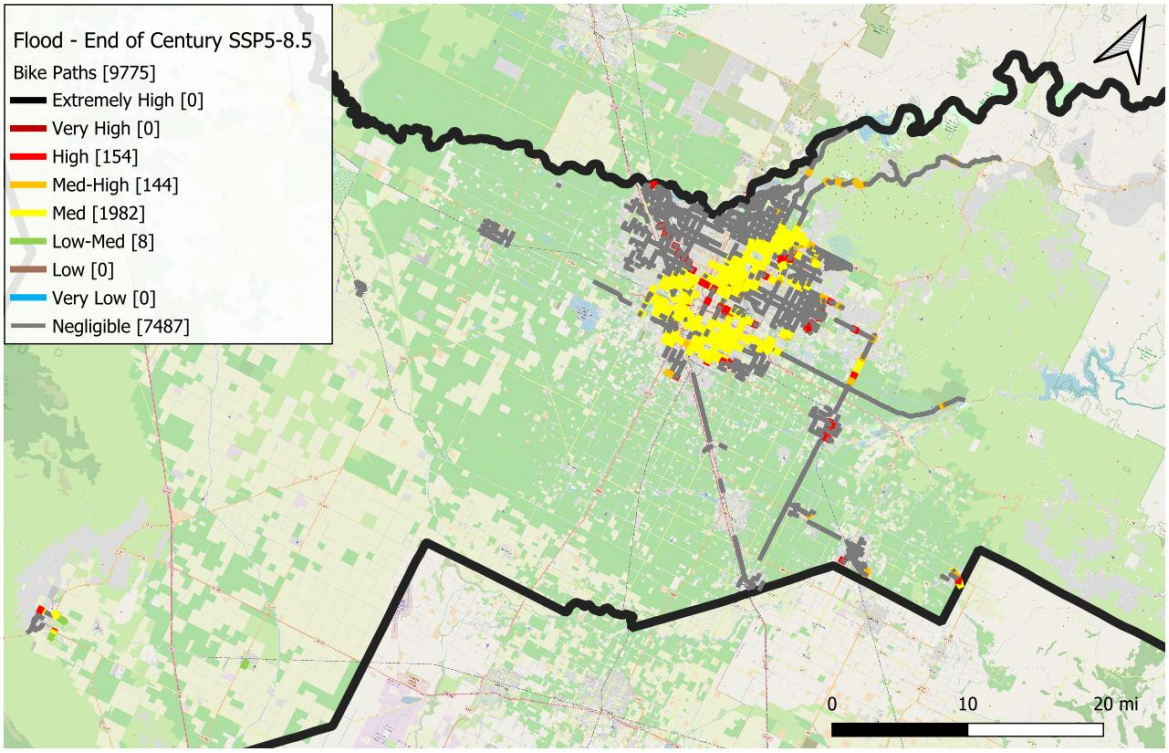

Figure 24. Downtime risk ratings of bike paths from end of century climate (SSP5-8.5) flood hazard.

4.4 Flood Risk to the Rail Network

The impacts of flooding can result in loss of functionality of the rail line and subsequent operational disruption. Depending on the severity, flooding can result in a wide range of impacts to rail lines. These impacts can range from a few days of downtime from events such as overtopping of a rail lines to on the order of months for larger incidents such as embankment erosion that requires significant repair and reconstruction. In the assessment of Fresno's rail infrastructure, we have taken a conservative approach in which if a rail line overlaps with a known flood plain then that would be a significant event with high impacts. These impacts to rail include the following:

- Six inches or less of flooding on a rail asset can result in possible delays, with damage unlikely that can result in downtime on the order of weeks.
- Six inches or greater of flooding on a rail asset, or if flood water reaches ballast / sub-ballast can result in probable damage (e.g. scour) and operational disruption on the order of months.
- Greater than six inches of flooding with velocity can result in likely damage (e.g. scour) and delay is assumed with operational disruption on the order of magnitude of months of downtime.

The present-day risk ratings are summarized in Figure 25 where all of the rail lines denoted as grey are considered negligible flood risk as they are not within a FEMA NFHL zone designation. Approximately 25% of the County's rail network is affected by flood hazard with risk ratings ranging from ***Med-High*** to ***High*** for present-day climate. The key takeaways from this assessment are summarized as follows:

- Both branch and main rail lines are impacted by flood, further reiterating that flooding is a regional issue for Fresno County.
- For present-day climate, the flood risk in the more rural areas of western Fresno County governs relative to rail lines in the city center.
- Flooding can deposit debris on rail tracks. Additionally, if rail lines travel over or near rivers, potential ballast and embankment erosion and scour can occur.

Accounting for the effects of climate change, the risk to rail infrastructure subsequently increases. In the mid-century climate scenario, rail line risk ratings range from ***Med-High*** to ***High*** with more assets skewed towards the higher end of the spectrum compared to present-day risk. By the end of century, the change is more drastic where rail line risk ratings range from ***High*** to ***Very-High***. Most of the flood rail risk ratings are increasing by approximately five times due to the increased frequency and of extreme precipitation events in Fresno County.

In summary, flood risk impacts pockets of Fresno County's rail network. These rail lines become more vulnerable as flood risk is expected to increase with climate change. The rail lines of most concern are as follows:

- **City of Fresno**. Rail lines that run through the city center of Fresno are also considered the county's main rail lines. As such, main lines Stockton, Bakersfield, and Fresno are considered the primary through route that serves the county of Fresno. Among these routes is considerable flood risk that is concentrated in the city center of Fresno.
- **Eastern Fresno County**. The more rural rail lines are considered branch lines amongst Fresno County's rail network that are exposed to western Fresno County's flood hazard. Particular areas of concern are Westside and Riverdale branch lines.

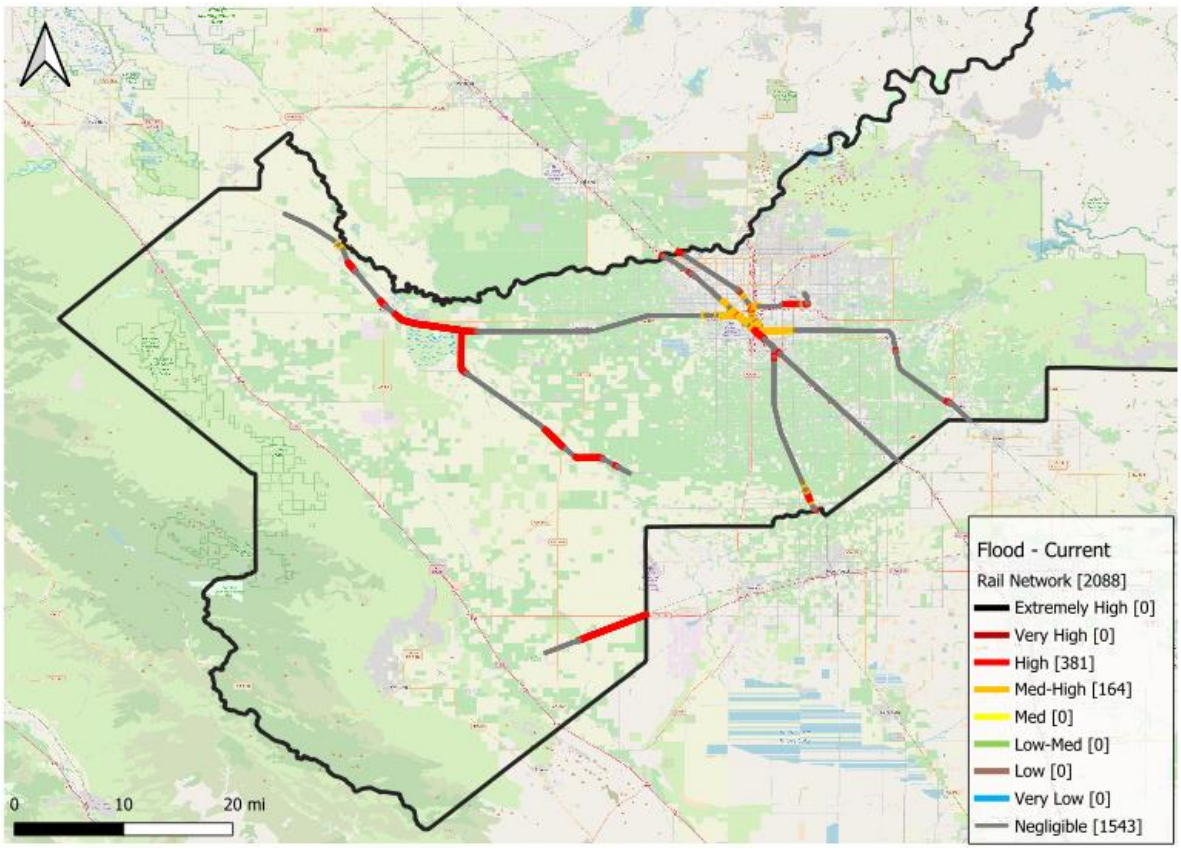

Figure 25. Downtime risk ratings of the rail network from present day flood hazard.

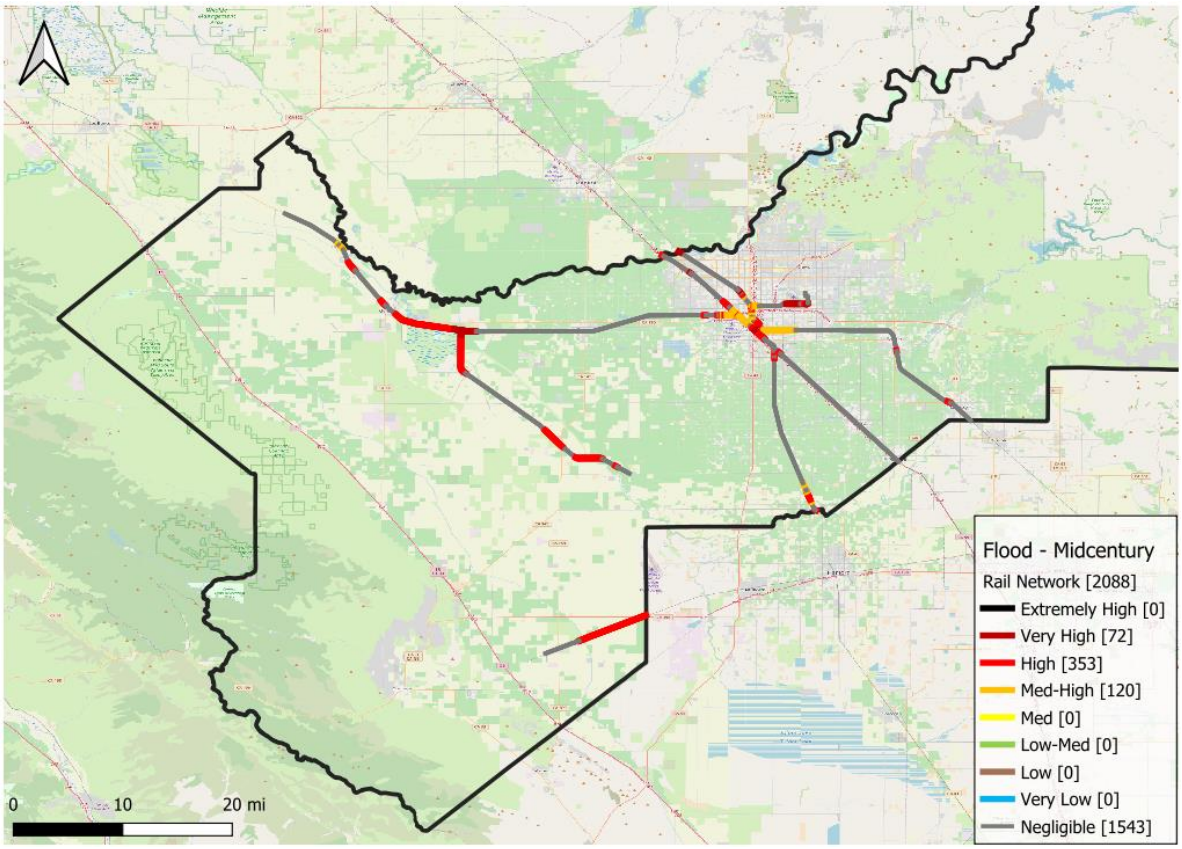

Figure 26. Downtime risk ratings of the rail network from mid-century climate (SSP5-8.5) flood hazard.

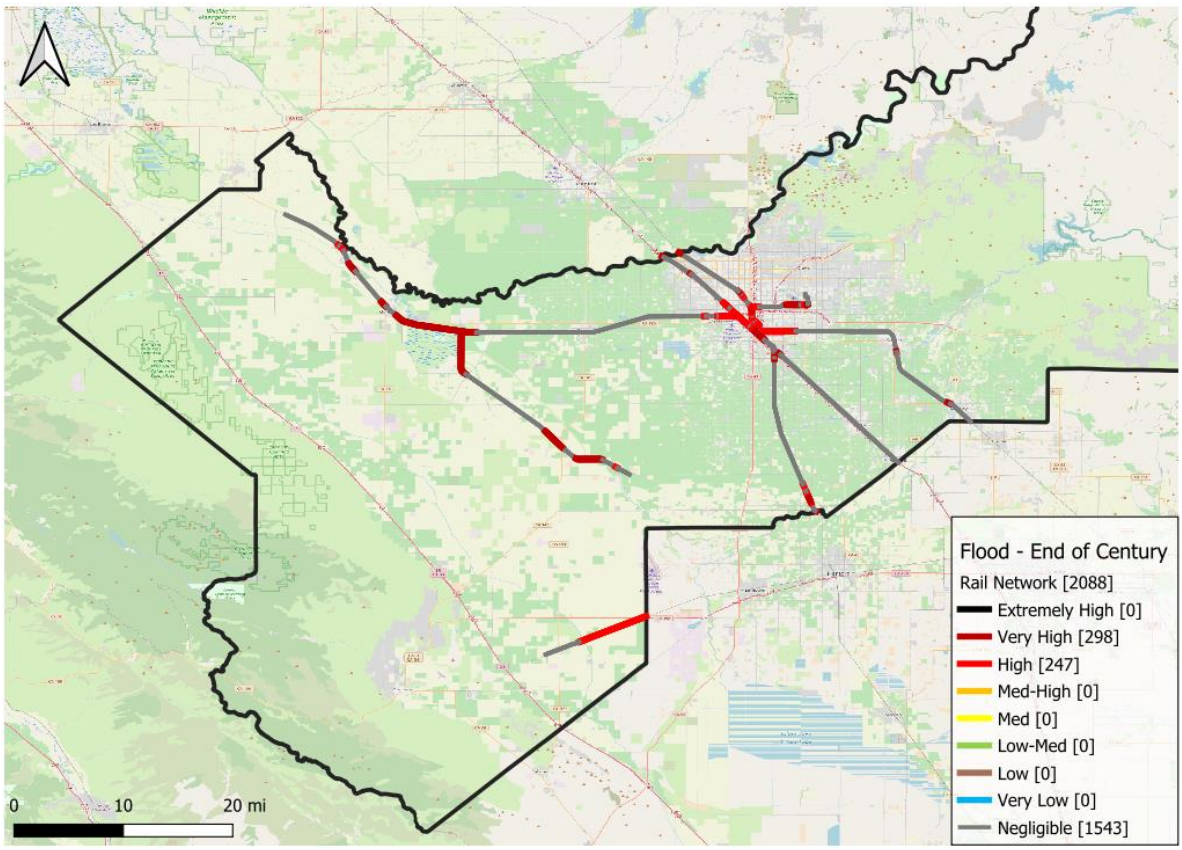

Figure 27. Downtime risk ratings of the rail network from end of century climate (SSP5-8.5) flood hazard.

4.5 Flood Risk to Airports

Flooding can impact airport operations in a variety of ways. For this study, flood risk was measured by if a FEMA flood plain intersected with any location within the broader airport footprint. If this intersection occurred between the hazard and asset, then it was expected that damage to buildings or critical infrastructure (e.g., runways, equipment) could occur and lead to commercial impacts on day-to-day operations. For example, if a runway is flooded this can inhibit an aircraft's ability to safely land and/or takeoff resulting in potential disruptions to operations. Additionally, flooding can damage navigation equipment necessary for landing planes whether that equipment is outside or inside a building (if flood levels get high enough). Therefore, this method takes a conservative approach in assuming that if any airport intersects with a FEMA NFHL flood plain it will then trigger a severe downtime consequence. This consequence can result on the order of magnitude of months of downtime.

Among the nine airports assessed, five of them are exposed to flooding according to the FEMA NFHL. All the airports flagged for flood risk are those that lie near rivers / channels or in a flood plain at the confluence of multiple water bodies. The risk ratings vary in range from present-day to future climate in the following ways:

- Present-day ratings, seen in Figure 28, range from:
    - Firebaugh Airport is flagged for ***Med-High*** risk
    - Fresno Chandler Executive Airport, Fresno Yosemite International Airport, Selma Airport, and William R. Johnston Airport are flagged for ***High*** risk.

- Mid-century ratings, seen in Figure 29, range from:
    - Firebaugh Airport remains ***Med-High*** risk
    - Fresno Chandler Executive Airport, Selma Airport, and William R. Johnston Airport remain ***High*** risk.
    - Fresno Yosemite International Airport is flagged for ***Very-High*** risk.
- End of century ratings, seen in Figure 30, range from:
    - Firebaugh Airport is flagged for ***High*** risk
    - Fresno Chandler Executive Airport, Fresno Yosemite International Airport, Selma Airport, and William R. Johnston Airport are flagged for ***Very-High*** risk.

In summary, flood risk to airports has significant impacts. The impacts of flood risk are expected to increase with the effects of climate change. The airports particularly vulnerable to flooding are the following, Fresno Chandler Executive Airport, Fresno Yosemite International Airport, Selma Airport, William R. Johnston Airport, and Selma Airport.

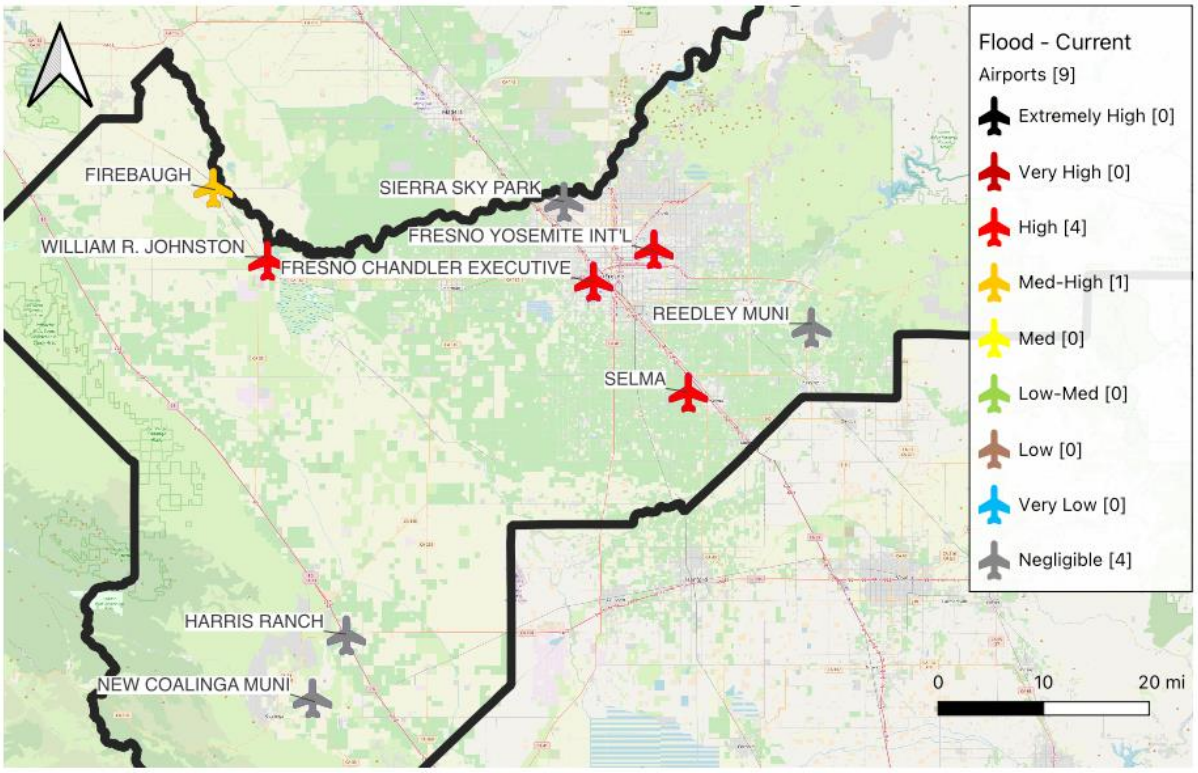

Figure 28. Downtime risk ratings of the airports from present day flood hazard.

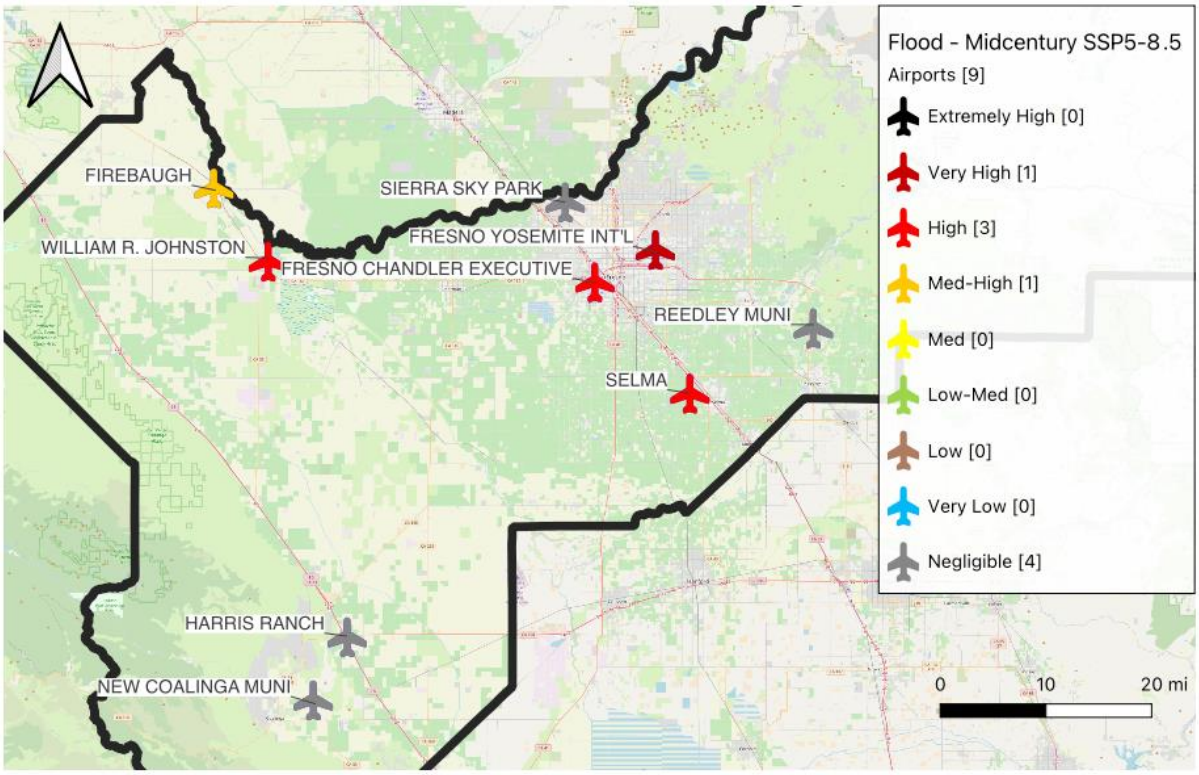

Figure 29. Downtime risk ratings of the airports from mid-century climate (SSP5-8.5) flood hazard.

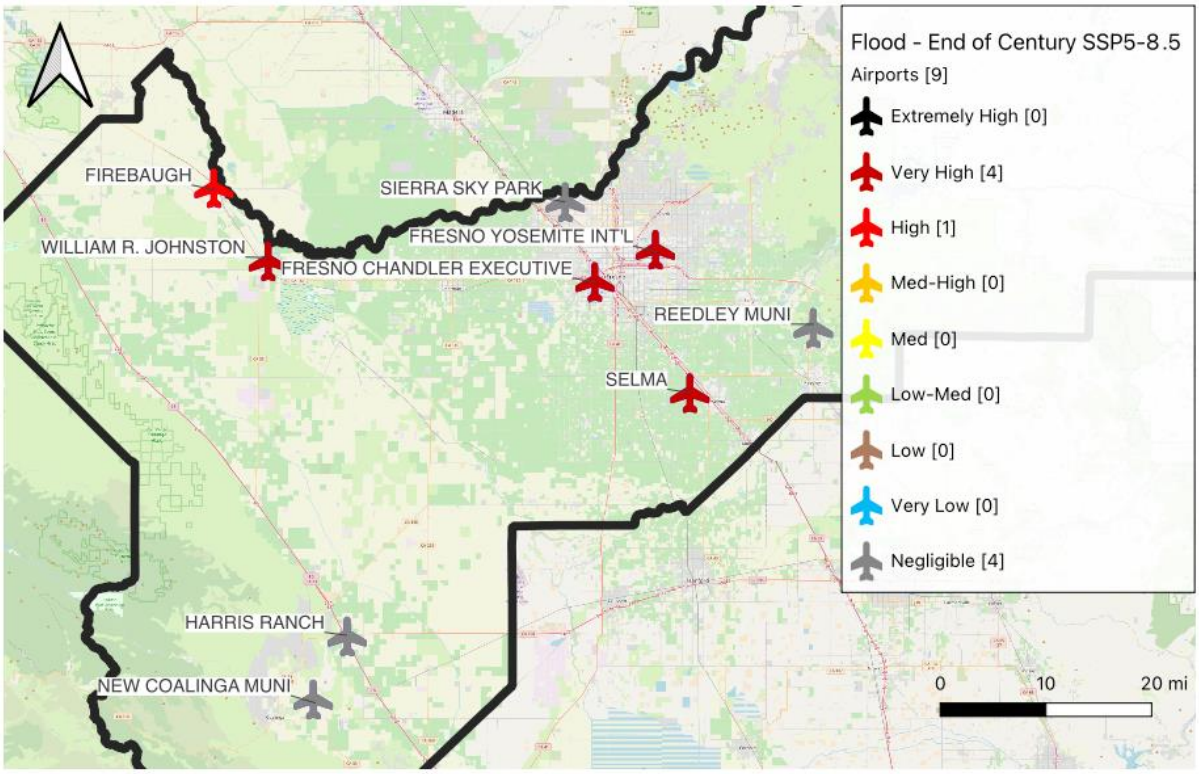

Figure 30. Downtime risk ratings of the airports from end of century climate (SSP5-8.5) flood hazard.

5. Wildfire Risk

This section outlines the findings from the risk assessment of Fresno County's transportation network from wildfire hazard. Within each asset section describes the impacts wildfire risk has on downtime for each type of asset. The section then transitions into what these results mean for Fresno County's regional risk profile and how they are expected to change considering the effects of climate change.

For certain hazards (e.g. wildfire) which do not have explicit future hazard datasets, risk ratings shown are primarily based on present-day hazard data and future climate indicators. In these cases, risk can only be augmented where it already exists (e.g. existing areas with wildfire threat). Note that climate change can introduce new risk where it does not currently exist, but this study does not cover that scenario.

5.1 Wildfire Risk to Roads and Bridges

The impacts of wildfires on roads can range in severity from creating unsafe driving conditions to causing physical damage to roadside facilities. The impacts considered in this study are summarized below:

- **Road closure** from a small grass or brush fire near the road asset. This can result in the order of several days of downtime due to the route being inoperable from wildfire smoke or evacuation precautions.
- **Road closure** from a larger forest fire near the road asset. This higher intensity fire can result in significant loss of operability from potential debris or wildfire smoke leading to on the order of weeks of downtime.
- **Structural damage**, if the asset is a bridge, and neighbors an intense fire. This can lead to months downtime from bridge closure and repairs.

To depict present-day wildfire hazard, this study used CALFIRE's wildfire threat class (shown in Figure 31) as discussed in *Climate Hazard Memo*. The fire threat class map provides pixels indicating the likelihood of a fire burning in a particular area. The fire threat definition is separated into five classes ranging from low fire threat to extreme fire threat. These fire threat class definitions are underpinned by the frequency at which a fire rotates through an area. In Fresno County, the spatial patterns vary from flood hazard to wildfire hazard in that wildfire is more prominent in the mountains compared to flooding which is much more present in the valley and cities. Per the *Climate Hazard Memo,* climate indicators are used to understand how the present-day hazard may shift overtime in its frequency. For wildfire, the indicator is decadal wildfire probability which provides a proxy of how much more likely a wildfire will be in the future.

The present-day risk ratings are summarized in Figure 32 where all of the roads denoted as grey are considered negligible wildfire risk as they are not exposed wildfire hazard or exposed to minimal hazard. Less than 20% of the roadway network is affected by wildfire hazard ranging in ratings from ***Med*** to ***High***. The present-day wildfire risk ratings highlight the following key findings:

- Roads highlighted for wildfire risk are primarily in less urbanized areas, as these areas tend to be near parcels with greater burnable fuel.
- Roads in mountainous regions are generally flagged for the highest risk due to the surrounding forested areas.

In zooming into the mountainous regions of Fresno County, Figure 33 details the present-day, downtime risk ratings. The key highlights from these ratings are the following:

- Majority of integral connection routes between the inland valley and the eastern mountains of Fresno County are flagged for significant wildfire risk. These roads being inoperable due to wildfire could isolate vulnerable mountain communities from vital resources in the inland valley (e.g. certain hospitals). Some of these key roads include highway CA Route 168, Auberry Road, Pittman Hill Road, and highway CA Route 63 (South Hills Valley Road).
- Bridges that are within a high wildfire hazard zones are susceptible to major structural damage from intense forest fires and therefore flagged for ***High*** risk. As such small pockets of ***High*** risk ratings are seen amongst the mountain roads.
- There is some increase in future risk due to increasing wildfire probability, but the regional wildfire risk profile stays relatively constant in this study (majority of risk ratings are ***Med-High*** or become ***Med-High*** across future scenarios).
- Despite some of the assets in the future scenarios not seeing a risk rating shift does not necessarily mean that the road is not affected by climate change; but that relative to other roads, its effect is more muted.

When the impacts of climate change are assessed, the wildfire risk ratings for road assets increases. that the ratings range from ***Med*** to ***High*** for mid-century climate scenario (Figure 34 and Figure 35) and ***Med*** to ***Very-High*** for the end of century climate (Figure 36 and Figure 37). In these future climate scenarios, the eastern mountain's road network sees the majority of it its ***Med*** increasing to ***Med-High*** risk ratings.

In summary, wildfire risk to road assets is governed by the county's mountain road network. The impacts of climate change will increase risk for some of the assets. The road assets most vulnerable to wildfire risk are as follows:

- **Mountain Regions**. Primary roads connecting the inland valley to the western and eastern mountains of Fresno County are very vulnerable to wildfire risk due to being in high wildfire hazard zones.

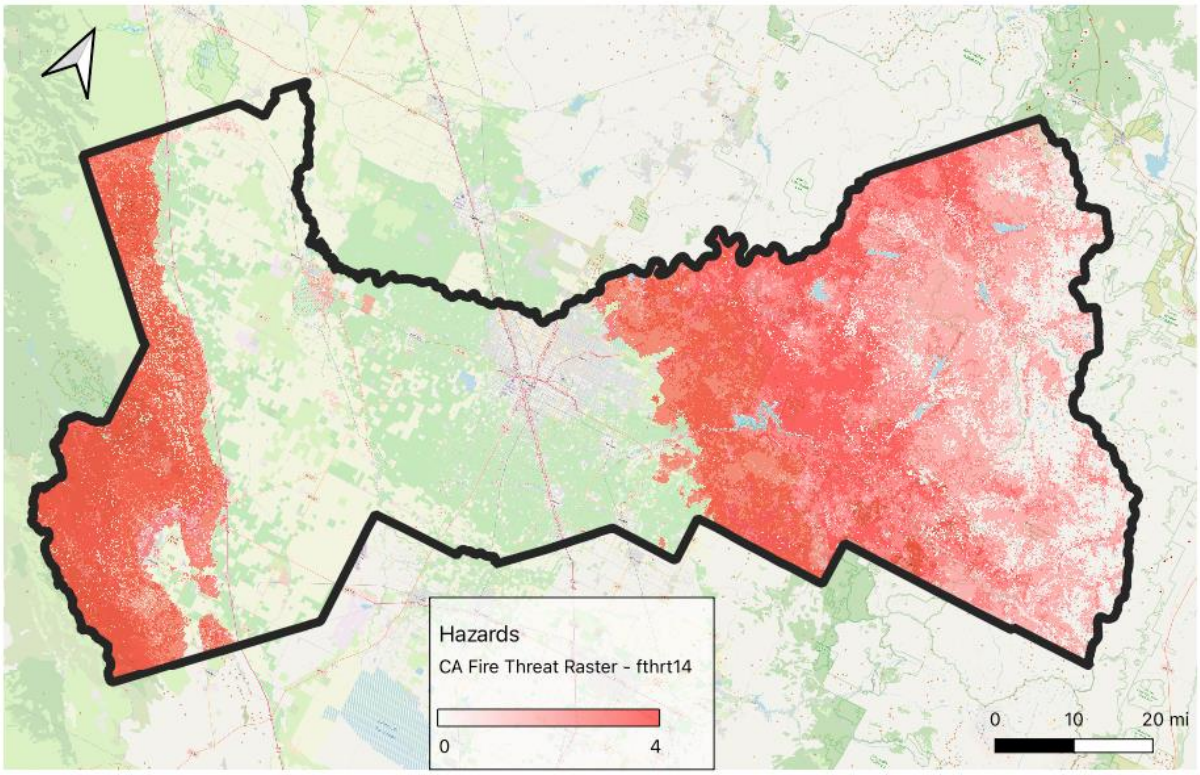

Figure 31. CALFIRE fire threat class overlayed in Fresno County.

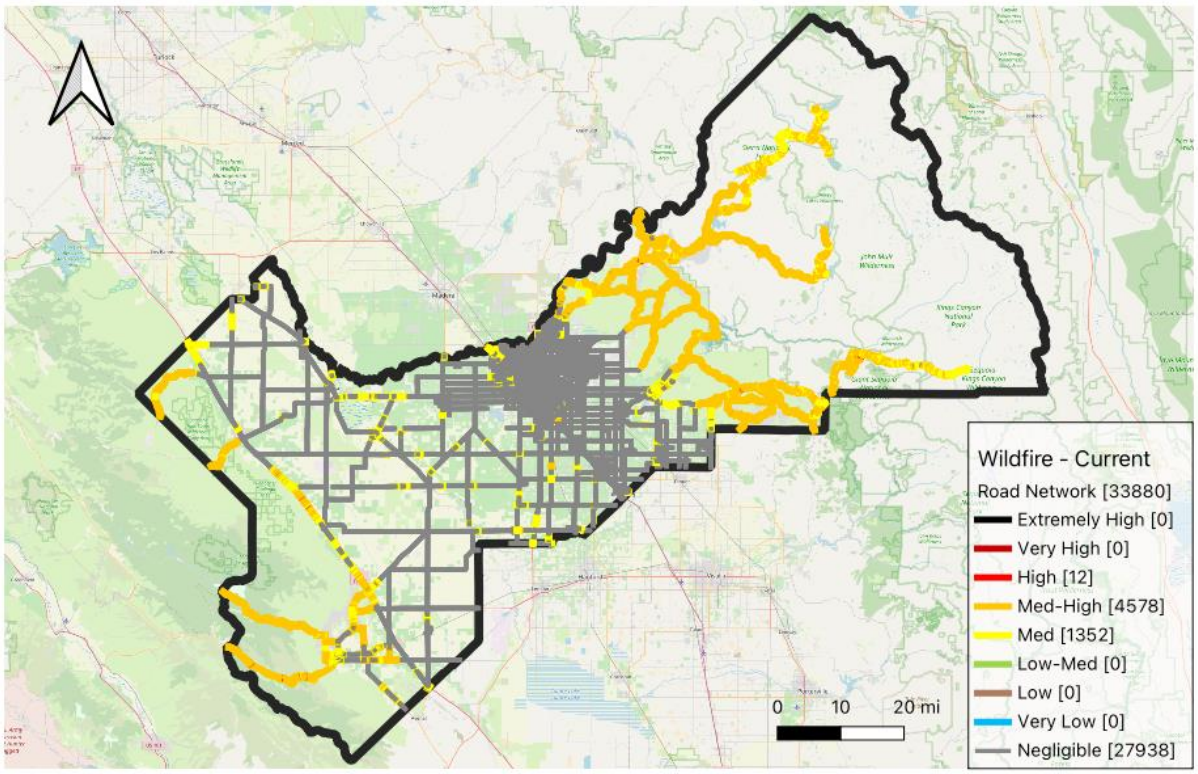

Figure 32. Downtime risk ratings of the road network from present day wildfire hazard.

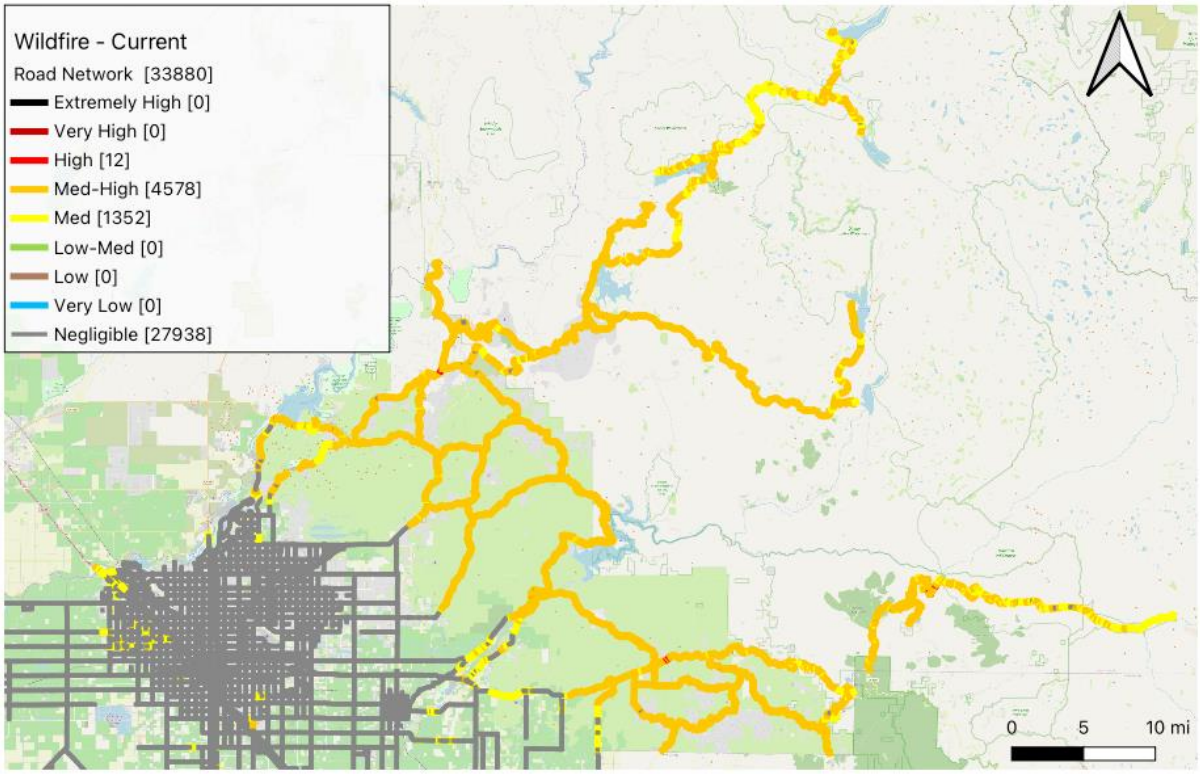

Figure 33. Downtime risk ratings of the road network, focused on the mountains, from present-day wildfire hazard.

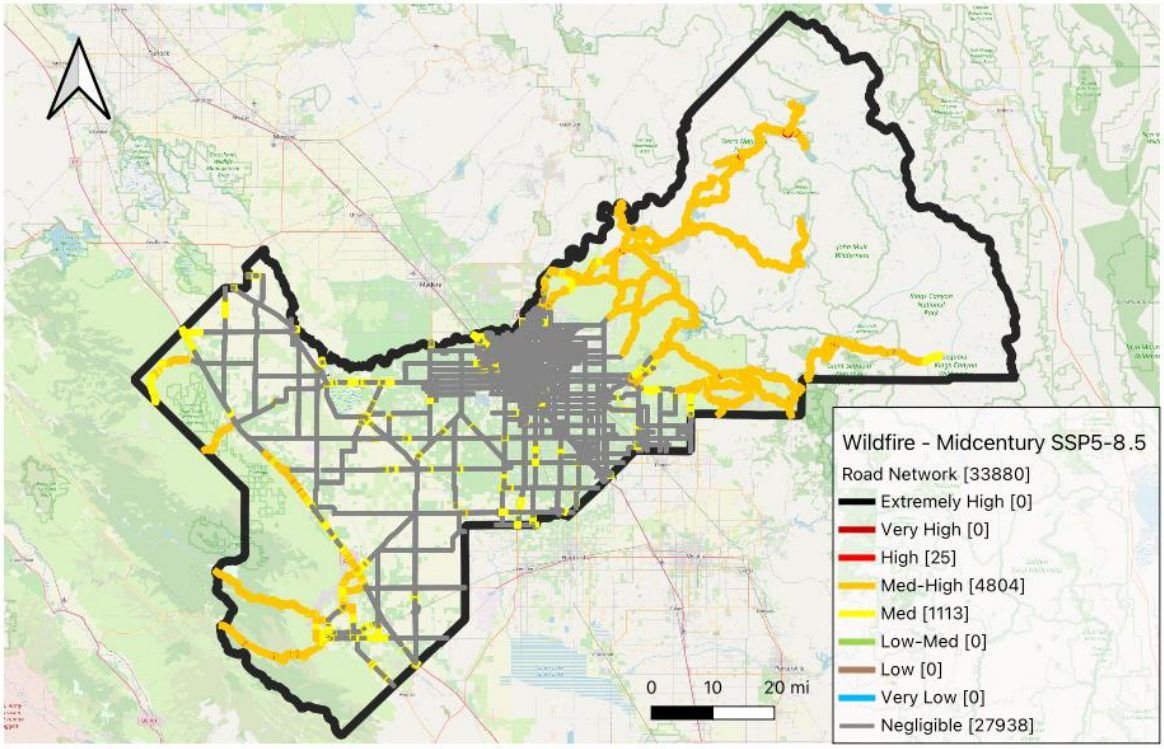

Figure 34. Downtime risk ratings of the road network from mid-century (SSP5-8.5) climate wildfire hazard.

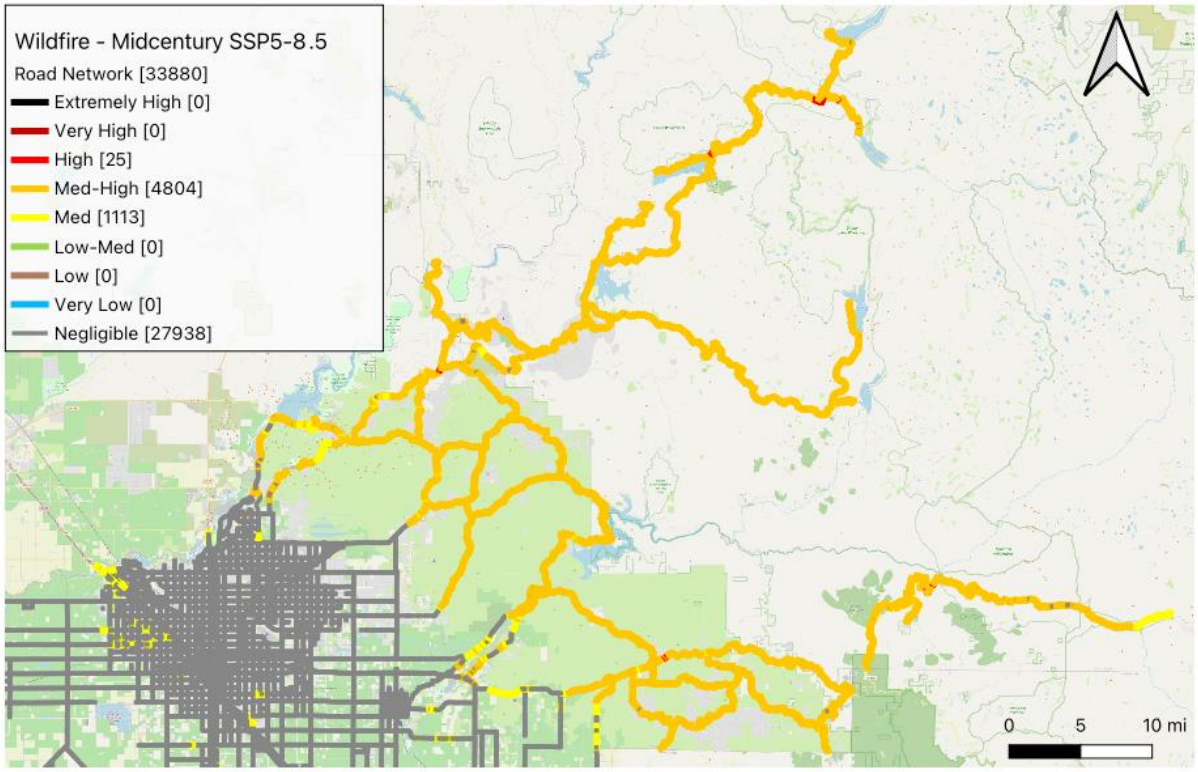

Figure 35. Downtime risk ratings of the road network, focused on the mountains, from mid-century climate (SSP5-8.5) wildfire hazard.

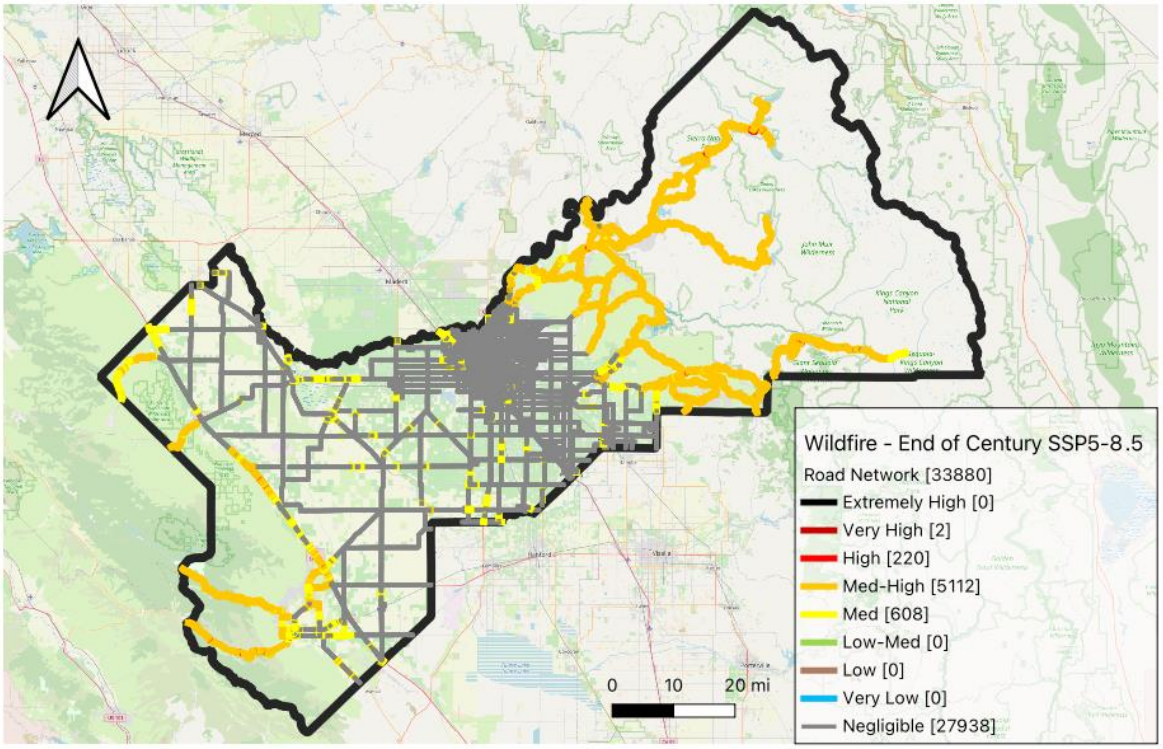

Figure 36. Downtime risk ratings of the road network from end of century (SSP5-8.5) climate wildfire hazard.

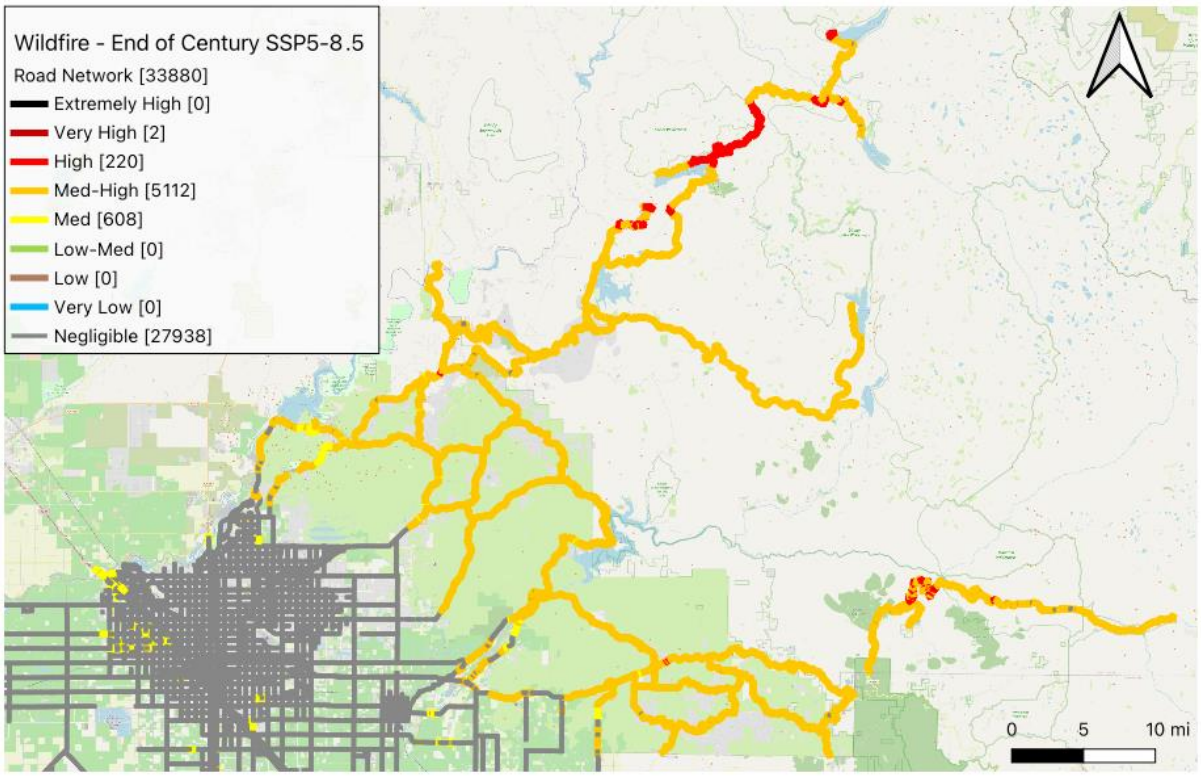

Figure 37. Downtime risk ratings of the road network, focused on the mountains, from end of century climate (SSP5-8.5) wildfire hazard.

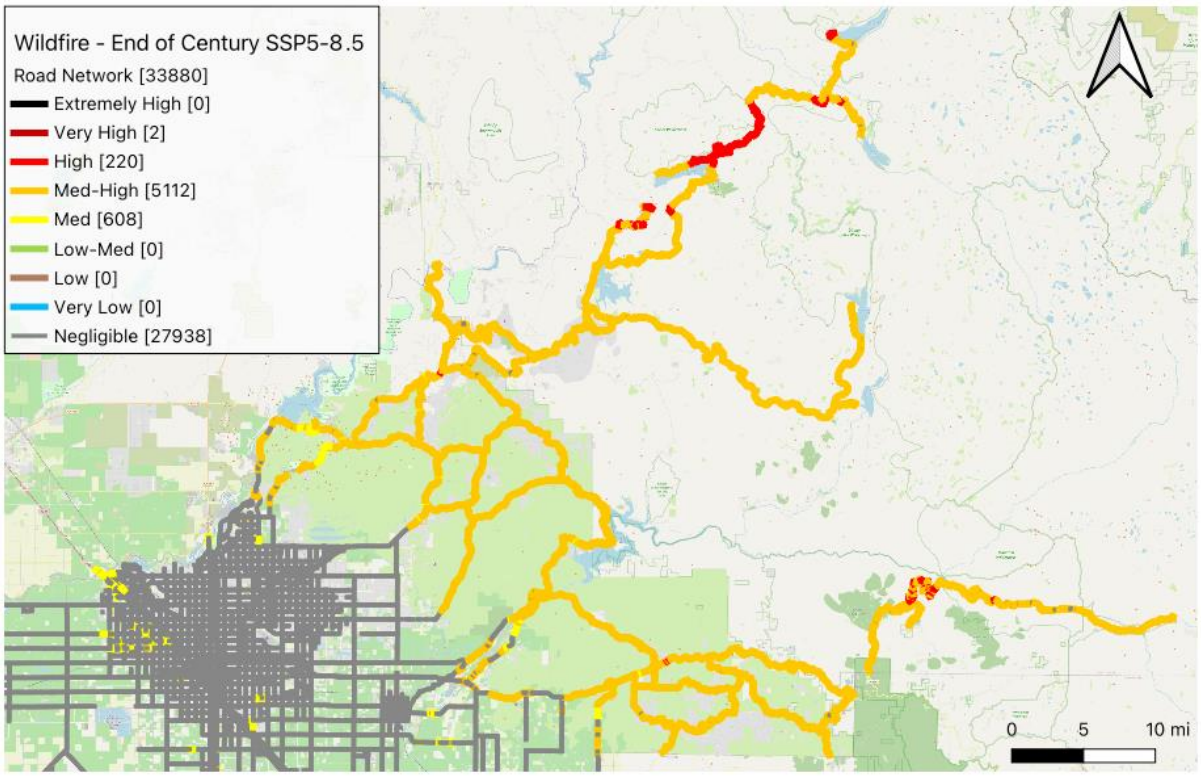

Figure 38. Downtime risk ratings of the road network, focused on the mountains, from end of century climate (SSP5-8.5) wildfire hazard.

5.2 Wildfire Risk to the Transit Network and Bus Yards

5.2.1 Transit Routes

Similar to roads, the transit routes that are affected most by wildfire are those that are within the mountains. Present-day risk ratings range from ***Med*** to ***High*** along the transit routes mapped in Figure 13. The following findings from this risk assessment includes:

- Transit routes in city centers such as the City of Fresno are predominantly negligible for wildfire risk.
- FCRTA transit routes are those that govern the regional risk profile for wildfire due to their service of the smaller, more rural, mountain communities in Fresno County.
- Within a given route not all road segments will necessarily flag as being in an area of wildfire risk, therefore it is important to analyze these results considering the broader route.

None of the top five average weekly ridership transit routes overlap with the top five routes exposed to wildfire risk. The leading riskiest transit routes to wildfire are predominantly those managed by the FCRTA. A zoomed in view of the risk ratings is presented for the route with the highest wildfire risk Fresno County, Auberry Transit. The risk ratings are shown for present-day in Figure 40. Key findings for Auberry Transit line are the following:

- Auberry Transit is the route with this highest wildfire risk across the county. Wildfire risk is present along the majority of the route length, in contrast to other routes that may see high risk in certain pockets. Therefore, most of the road is in an area of high wildfire potential.

Considering future climate scenarios mid-century (Figure 41 and Figure 42) and end of century (Figure 43 and Figure 44), the risk ratings follow the same in range from ***Med*** to ***High***. The following findings from these risk assessments include:

- The furthest stretch of Auberry Transit route that travels into the eastern mountains increases in risk by end of century from ***Med*** to ***Med-High***.
- FCRTA transit routes remains the governing transit agency in future climate scenarios.

In summary, only the Auberry Transit route is exposed to significant wildfire hazard resulting in wildfire risk. Therefore, Auberry Transit is identified as a route of concern for wildfire risk.

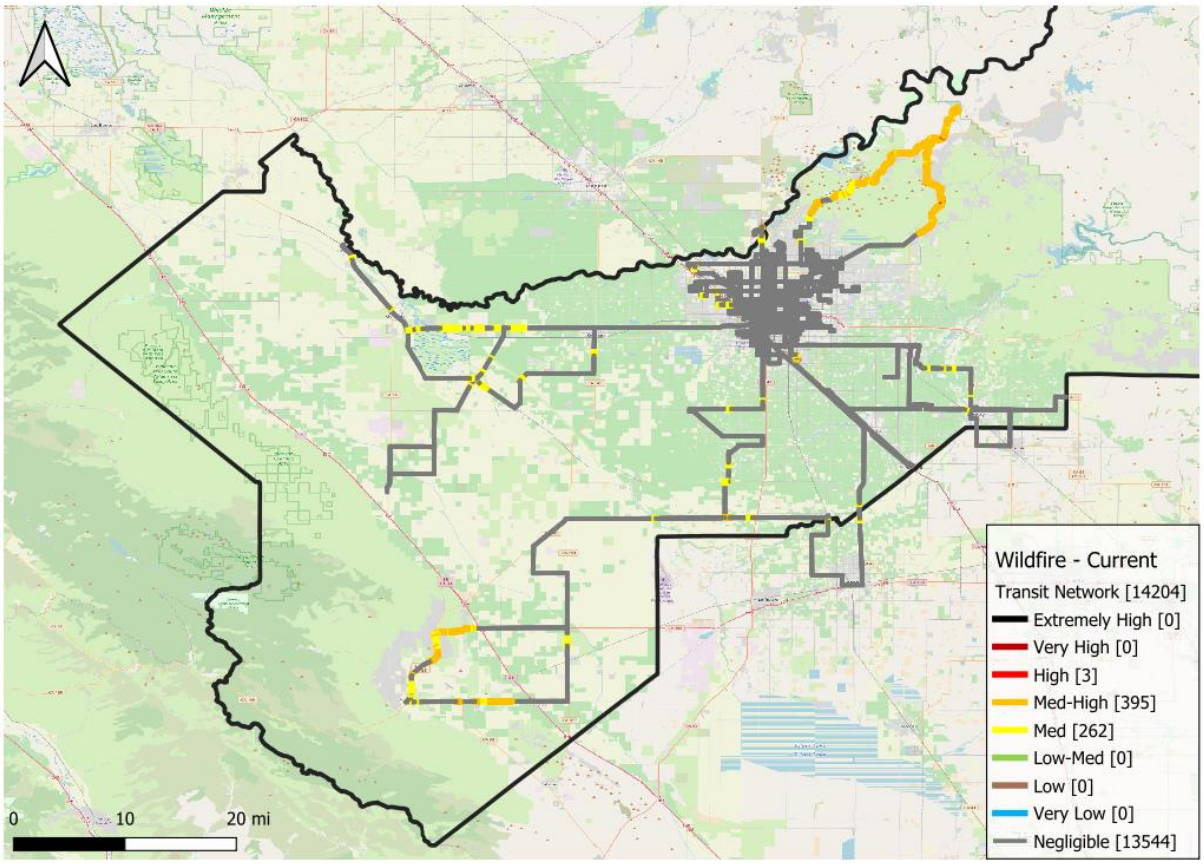

Figure 39. Downtime risk ratings of the transit network from present-day wildfire hazard.

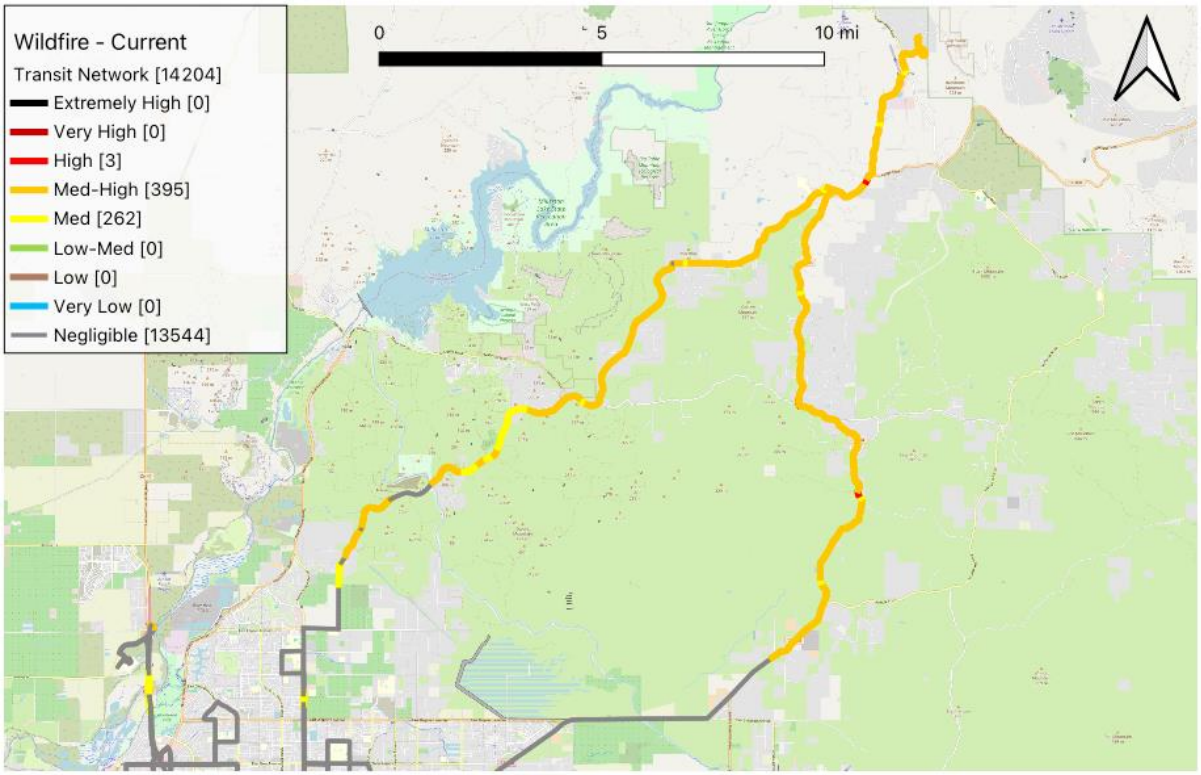

Figure 40. Downtime risk ratings of the transit network, focused on the Auberry Transit line (FCRTA), from present-day wildfire hazard.

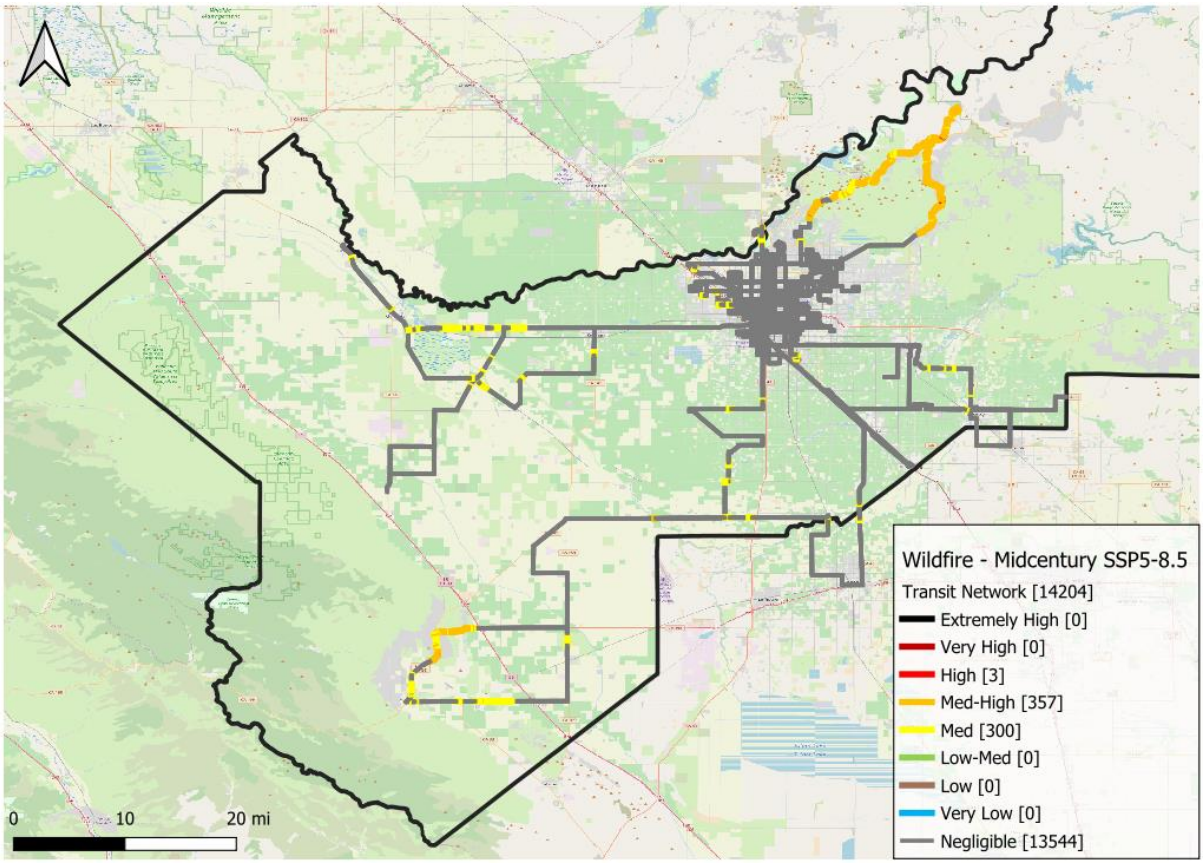

Figure 41. Downtime risk ratings of the transit network from mid-century climate (SSP5-8.5) wildfire hazard.

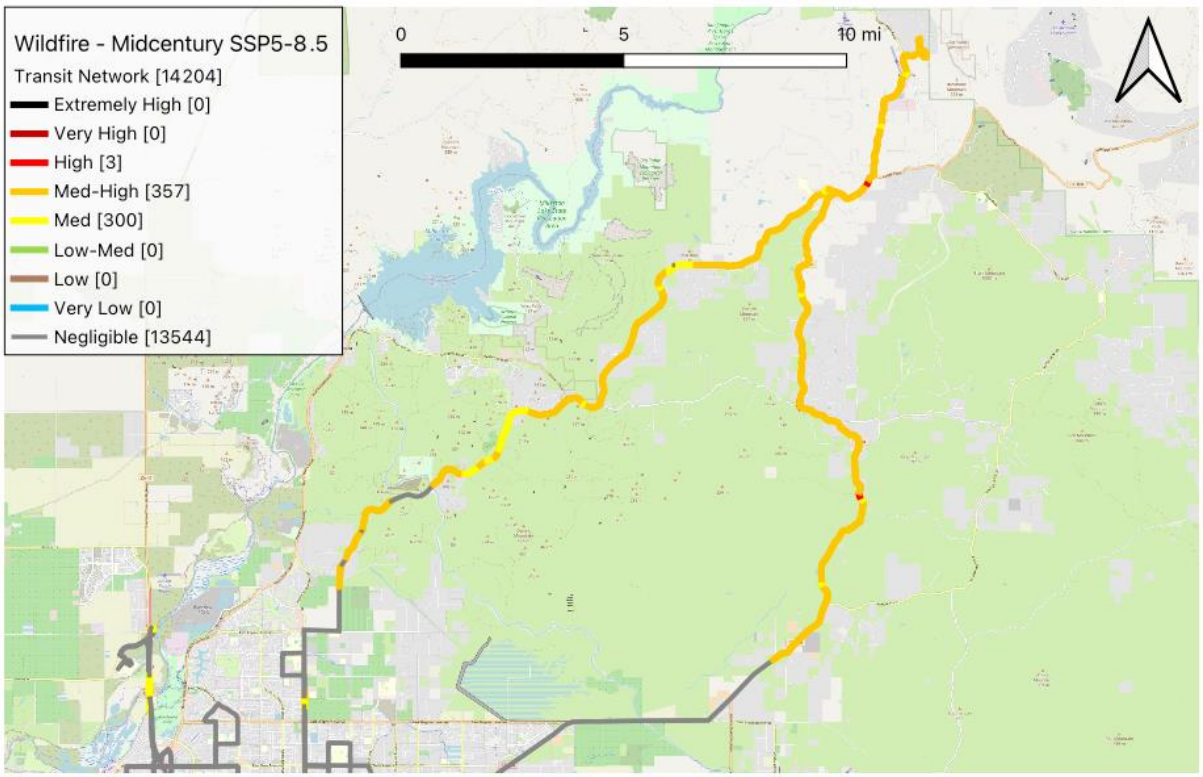

Figure 42. Downtime risk ratings of the road network, focused on Auberry Transit line (FCRTA), from mid-century climate (SSP5-8.5) wildfire hazard.

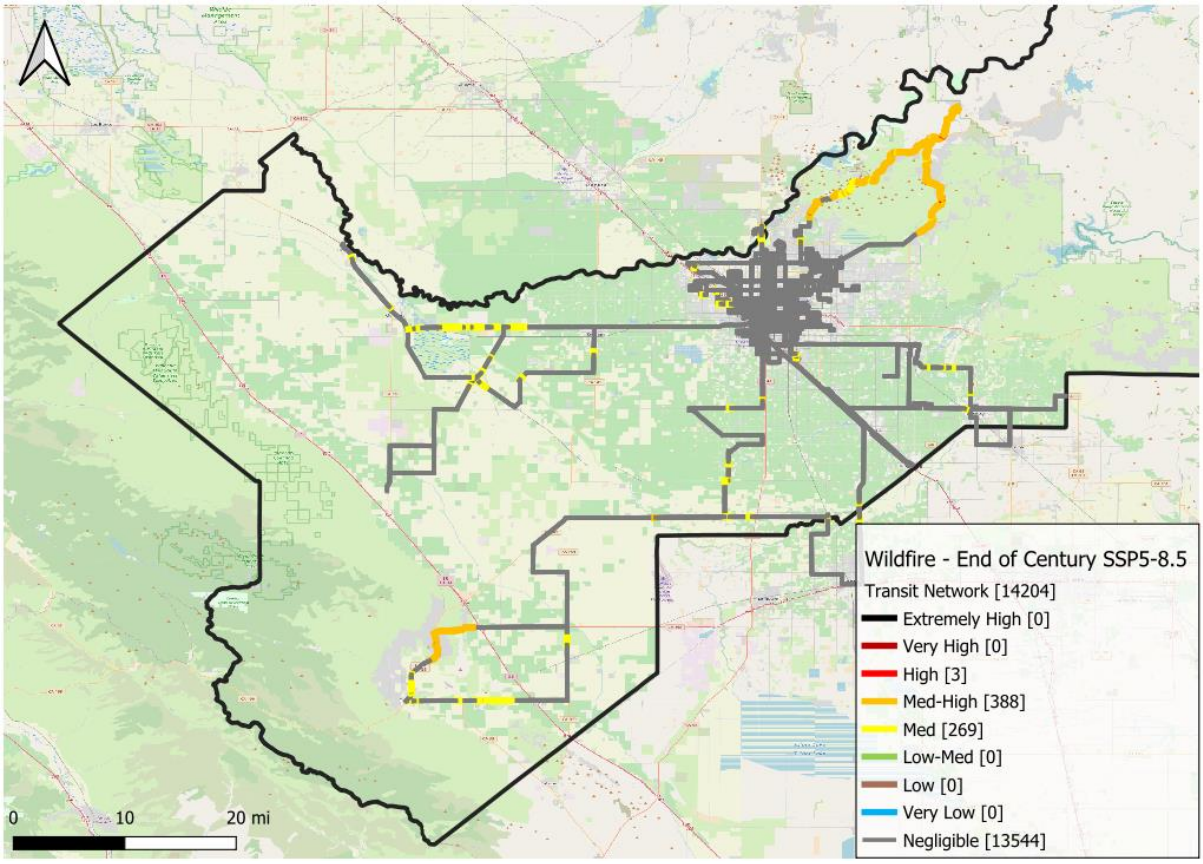

Figure 43. Downtime risk ratings of the transit network from end of century climate (SSP5-8.5) wildfire hazard.

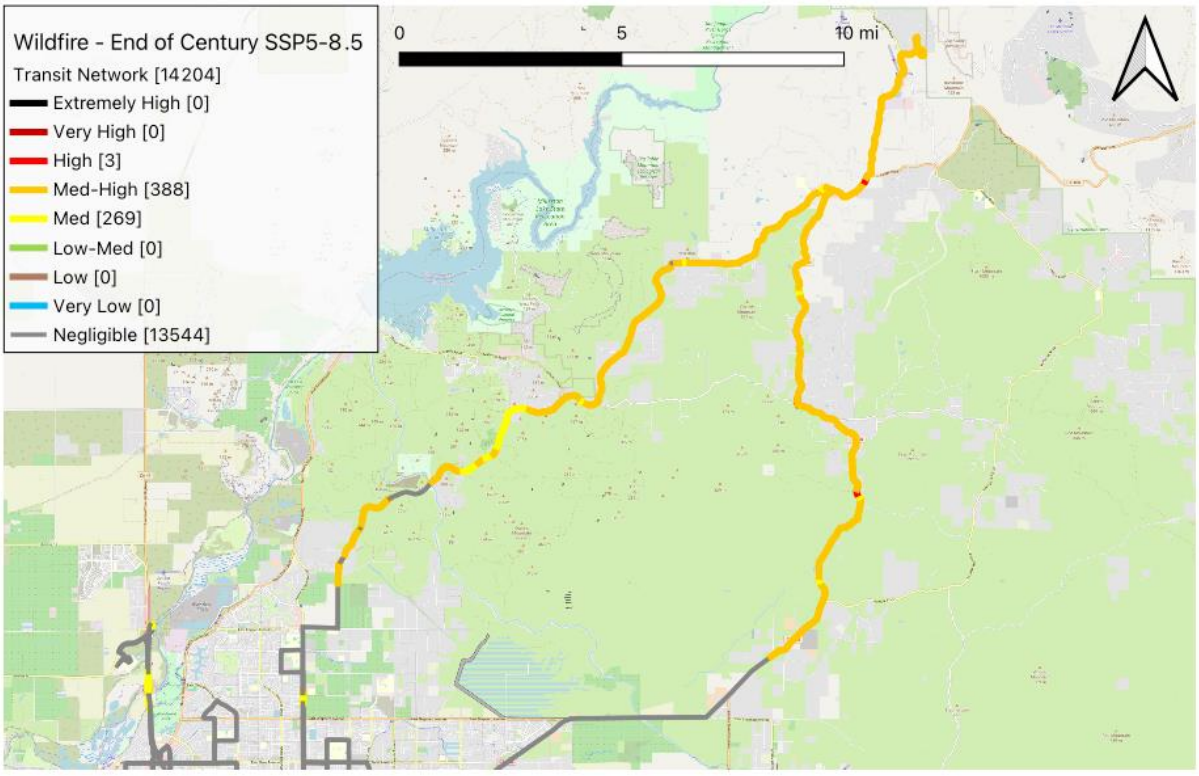

Figure 44. Downtime risk ratings of the road network, focused on Auberry Transit line (FCRTA), from end of century climate (SSP5-8.5) wildfire hazard.

5.2.2 Bus Yards

None of the bus yards assessed intersected with wildfire hazard, therefore all bus yards are found to have negligible wildfire risk. In this study, the projected future changes in wildfire are used in conjunction with the CALFIRE fire threat class to estimate how the likelihood of wildfire may change over time. Therefore, a limitation of this data is that there is no ability to predict future wildfire hazard when an asset does not fall within a fire threat class zone. With this caveat, the future climate scenario ratings remain negligible as well for wildfire risk.

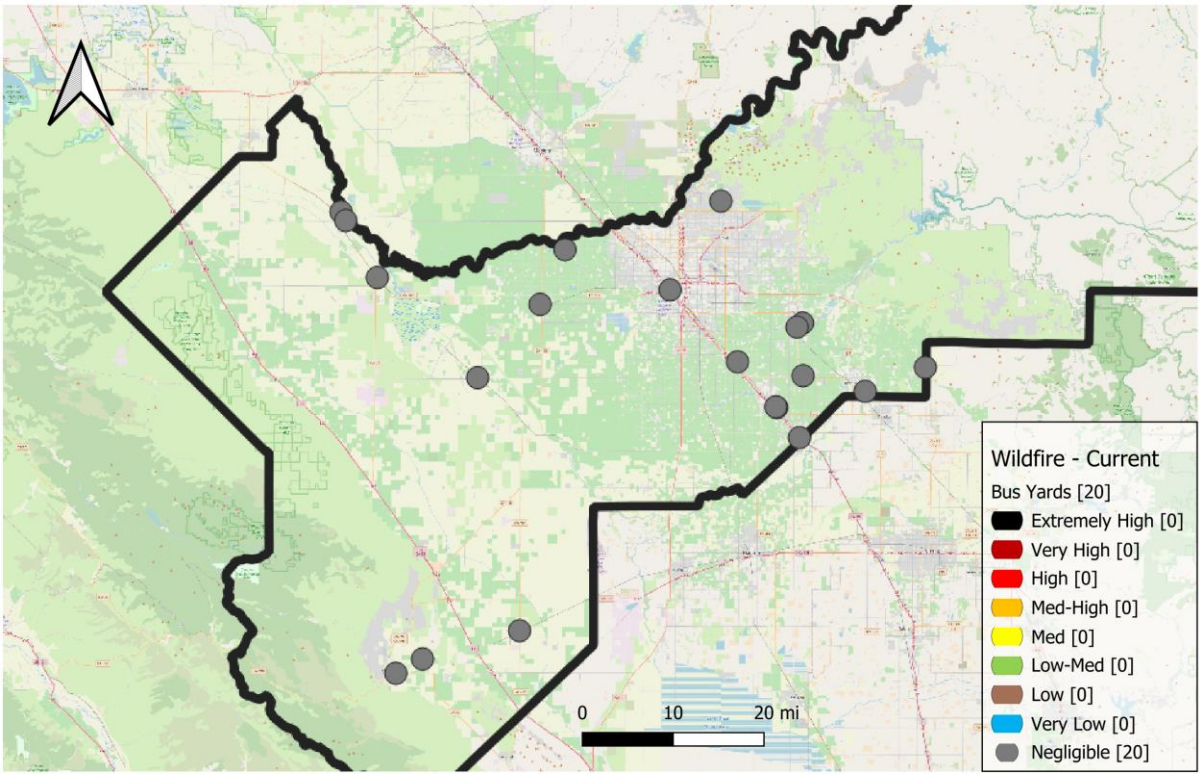

Figure 45. Downtime risk ratings of bus yards from present day wildfire hazard.

5.3 Wildfire Risk to the Bike Network

Of the entire bike network, around 4% of bike paths have the potential to be impacted by wildfire as they are within a wildfire threat class area. This is due to the concentration of the bike network to be within the more urban areas of Fresno County where there is minimal wildfire risk. The bike network with the highest wildfire risk are those that venture into the mountainous regions of Fresno County, namely Auberry Road, North Friant Road, and East Trimmer Springs Road (eastern mountains) and South Monterey Avenue, Elm Avenue, Cambridge Avenue, and West Phelps Avenue (western mountains). The present-day risk ratings in Figure 46 range from ***Med*** to ***Med-High***. In the future, the mid-century climate scenario (Figure 47) and end of century climate scenario (Figure 48) risk ratings remain similar in range from ***Med*** to ***Med-High***.

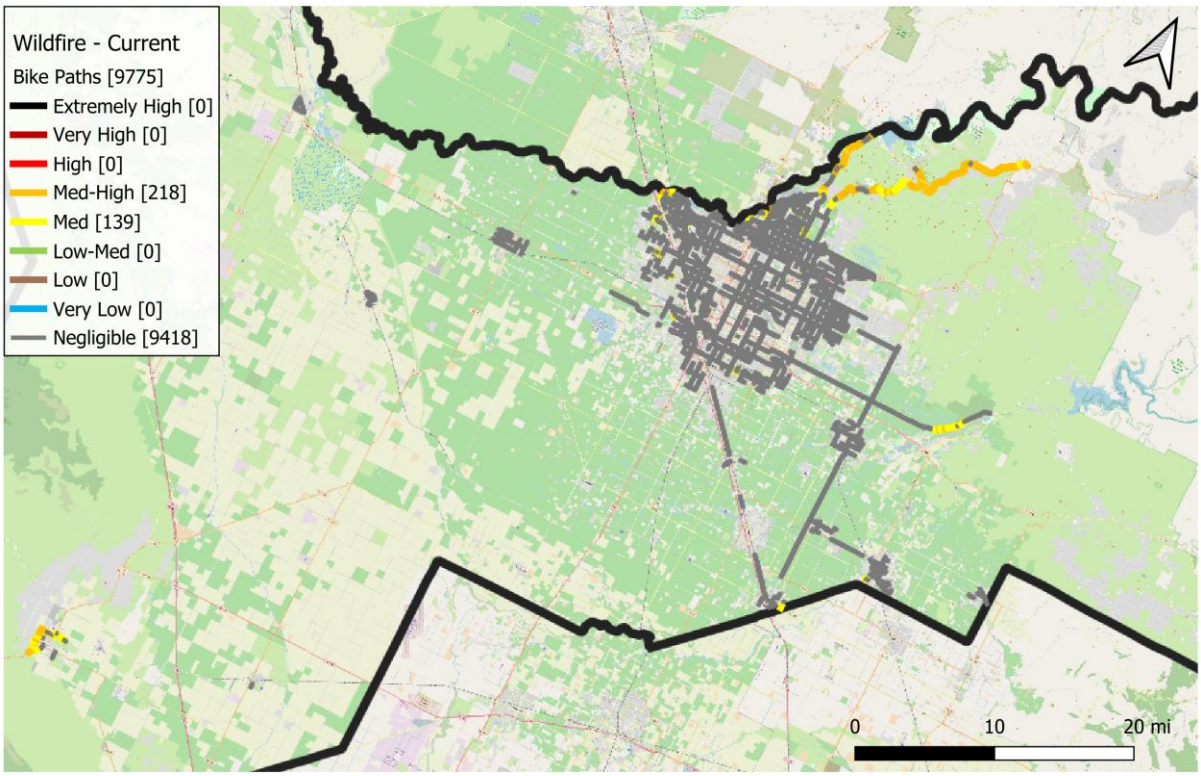

Figure 46. Downtime risk ratings of bike paths from present day wildfire hazard.

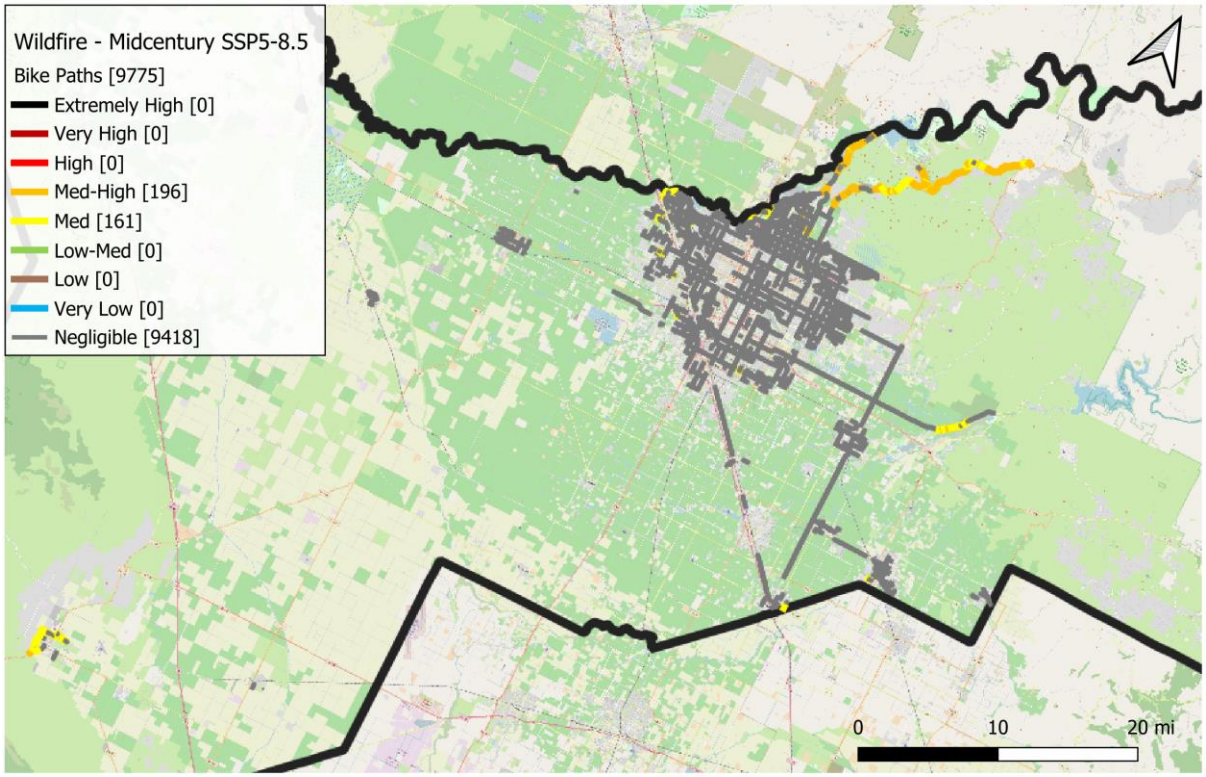

Figure 47. Downtime risk ratings of bike paths from mid-century (SSP5-8.5) wildfire hazard.

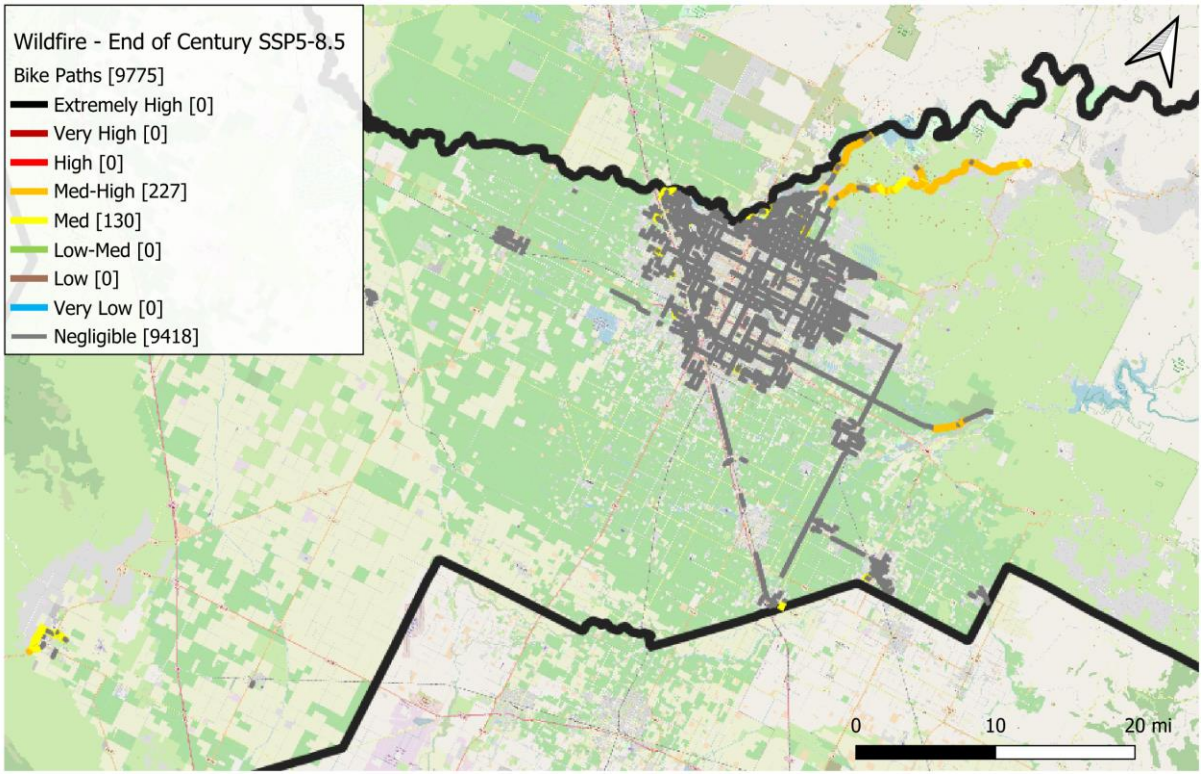

Figure 48. Downtime risk ratings of bike paths from end of century (SSP5-8.5) wildfire hazard.

5.4 Wildfire Risk to the Rail Network

A qualitative description is provided for the impact of wildfire on Fresno County's rail network. Wildfire risk to rail assets increases with high temperatures and wind speeds. According to the U.S. Department of Transportation the governing damage to rail infrastructure and its dependencies from wildfire are the following:

- Wildfires can result in very high temperatures that have the potential to distort rail lines, damage signaling and communications equipment, power connections, as well as larger infrastructure such as stations,
- Depending on the level of damage to equipment and infrastructure, wildfire can result in lengthy operational disruptions and subsequent financial losses,
- Loss of vegetation from wildfire in areas adjacent to the rail right of way can increase the impacts from other correlated hazards including erosion, flooding, and landslides.
- Air quality and heavy smoke can pose a threat to rail worker and passenger health and wellness and visibility for train operators (Federal Railroad Administration, 2024).

5.5 Wildfire Risk to Airports

None of the airports assessed intersected with wildfire hazard, therefore all airports are found to have negligible wildfire risk. In this study, the projected future changes in wildfire are used in conjunction with the CALFIRE fire threat class to estimate how the likelihood of wildfire may change over time. Therefore, a limitation of this data is that there is no ability to predict

future wildfire hazard when an asset does not fall within a fire threat class zone. With this caveat, the future climate scenario ratings remain negligible for wildfire risk.

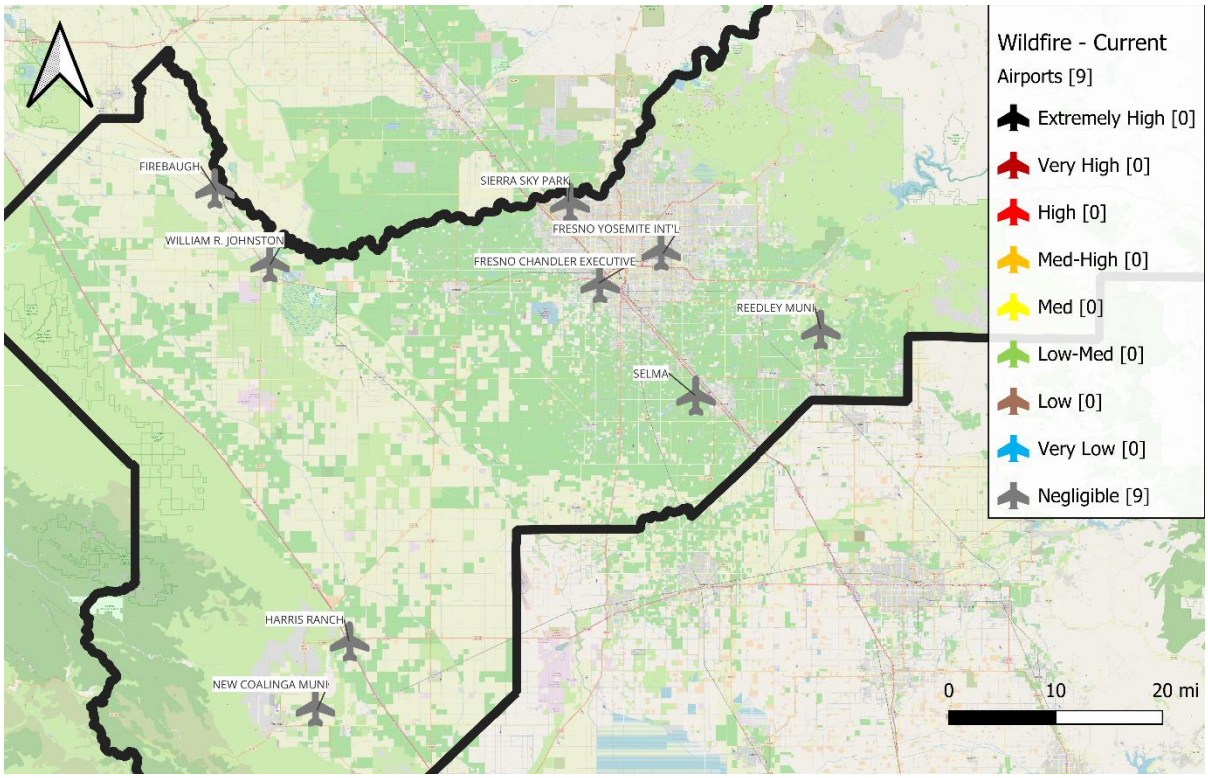

Figure 49. Downtime risk ratings of the airports from present day wildfire hazard.

6. Extreme Heat

This section outlines the findings from the risk assessment of Fresno County's transportation network for extreme heat hazard. Within each asset section describes the impacts extreme heat risk has on each type of asset. The section then transitions into what these results mean for Fresno County's regional risk profile and how they are expected to change considering the effects of climate change. Two classes of consequences were assessed depending on the asset: (1) downtime and (2) human health and wellness. The road network and bridges are assessed for downtime due to damage to the infrastructure while the transit routes and bike network are assessed for human health and wellness impacts to passengers and cyclists. All other asset classes are provided with a qualitative description of risk.

6.1 Extreme Heat Risk to Roads and Bridges

The impacts extreme heat can have on road operations and damage varies by the climate region. Fresno County has three separate climate regions: inland valley, low mountain, and high mountain per the *Caltrans Pavement Climate Regions* (Department of Transportation, 2005). The pavement design thresholds are expressed through performance grades which differ for each climate region. The performance grade can then be used in conjunction with the latitude to derive what the demand outside seven-day average high air temperature must be in order for

the pavement to fail. These demand values were tabulated based on Fresno County's coordinates and are summarized in the table below for each pavement climate region:

Table 4. Caltrans Pavement Design outside air seven-day average high temperature thresholds by climate region.

Low Mountain	High Mountain	Inland Valley
110°F	110°F	121°F

Observational weather station data was used to analyze present day extreme heat hazard. For future climate, the LOCA2 California Domain dry bulb temperature data was used to project forward the observational weather station data. This data was then adapted into a rate of occurrence of when the seven-day average maximum temperature exceeds the pavement design threshold per the *Climate Hazards Memo*.

The impact from exceeding these temperatures during extreme heat events are summarized below:

- **Spider cracking** or **buckling** on a road can result when the pavement design threshold is exceeded. This can cause unsafe driving conditions and can allow water to penetrate the pavement, weakening the subgrade and with the potential to cause further damage. These conditions may require repair to the damaged roads causing short term lane closure that can last on the order of a few hours.

The present-day risk ratings are summarized in Figure 50 where all of the roads denoted as grey are considered negligible heat risk as their respective pavement design thresholds are not exceeded and therefore have a zero rate of occurrence. The risk ratings for present day climate are either ***Very-Low*** or negligible. Some key takeaways from the present-day heat risk assessment are the following:

- Less than 3% of the road network are seeing outside air temperatures that exceed the pavement design temperatures.
- The highest risk ratings are ***Very-Low*** risk for areas in the low-mountain climate region (e.g. east of Clovis) due to their pavement being designed for lower pavement design thresholds (e.g. 110°F).
- The roadways in the inland valley climate region that are flagged as negligible are so due to the pavement design threshold being 121°F, a temperature that has to date never occurred in Fresno County.

Under the mid-century, high emissions climate scenario (SSP5-8.5, 2050), refer to Figure 51, the road asset risk ratings increase in certain places. This is due to the impacts of climate change causing extreme temperatures to become more likely for longer durations of time. The risk ratings for the mid-century climate scenario range from ***Very-Low*** to ***Low***. Some key takeaways from the mid-century heat risk assessment are the following:

- The number of affected road assets to extreme heat hazard that potentially could cause cracking in the pavement rises from 3% present-day to 5% by mid-century.

- Among the roadways that are flagged as ***Very-Low*** risk in present-day increase to ***Low*** due to rising temperatures making the design threshold being exceeded more frequently. Additionally risk that was considered negligible in the present-day in some of the low and high mountain regions transition to ***Very-Low***.
- The roadways in the inland valley climate region that are flagged as negligible remain negligible.

Under the end of century, high emissions climate scenario (SSP5-8.5, 2085), refer to Figure 52, the road asset risk ratings further increase. The risk ratings for the end of century climate scenario range from ***Very-Low*** to ***Low***. Some key takeaways from the end of century heat risk assessment are the following:

- The number of affected road assets to extreme heat hazard that potentially could cause cracking in the pavement rises from 3% present-day to 14% by end of century.
- Among the roadways that are flagged as ***Low*** risk in mid-century increase to ***Very-Low*** due to the low-mountain area further cooling in those parts. Additionally, risk that was considered negligible in the present-day in some of the low and high mountain regions transition to ***Low*** or ***Very-Low***.
- By end of century some of the roadways in the inland valley climate region that are flagged as negligible become flagged for ***Low*** risk which means that dry bulb temperatures are exceeding 121°F.

The pavement design performance grade values align with the pavement climate regions within Fresno County, low mountain, high mountain, and inland valley. Majority of Fresno County falls within the inland valley climate region. There is a pocket in northern middle/east Fresno County denoted as low mountain. Lastly, the eastern mountains in Fresno County are flagged to be in the high mountain climate region.

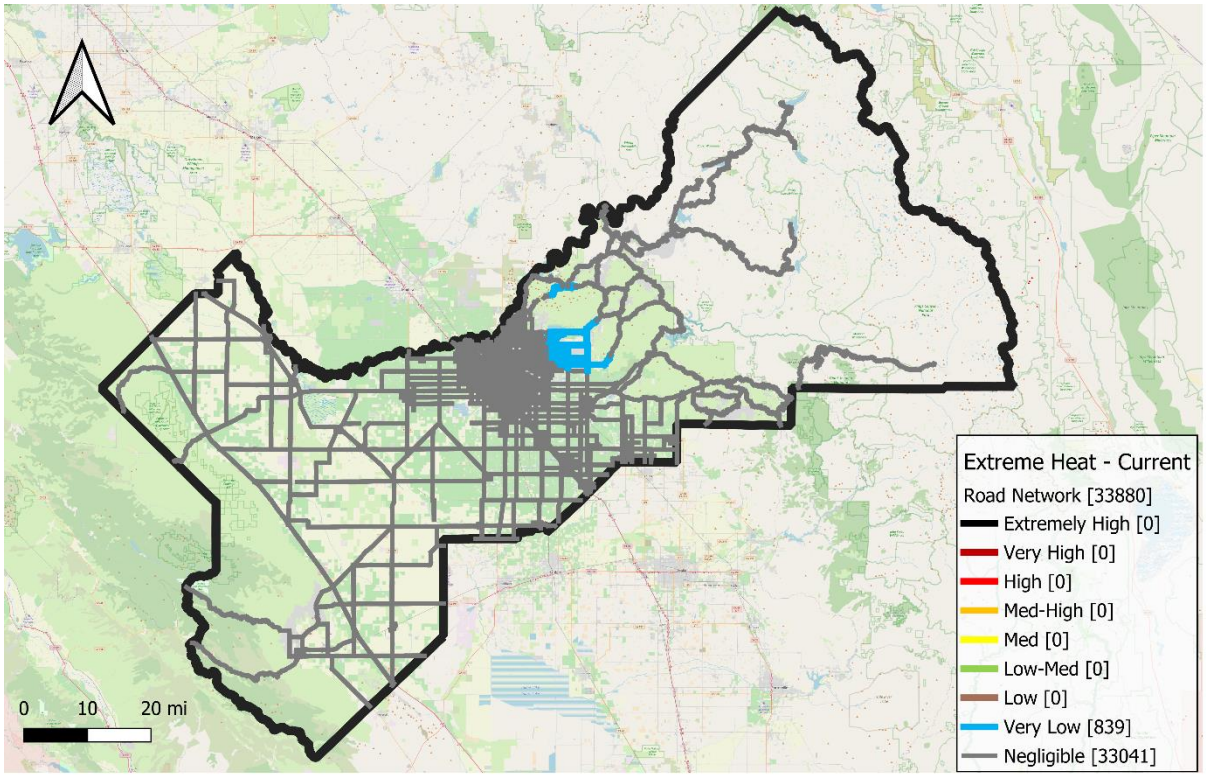

Figure 50. Downtime risk ratings of the road network from present day extreme heat hazard.

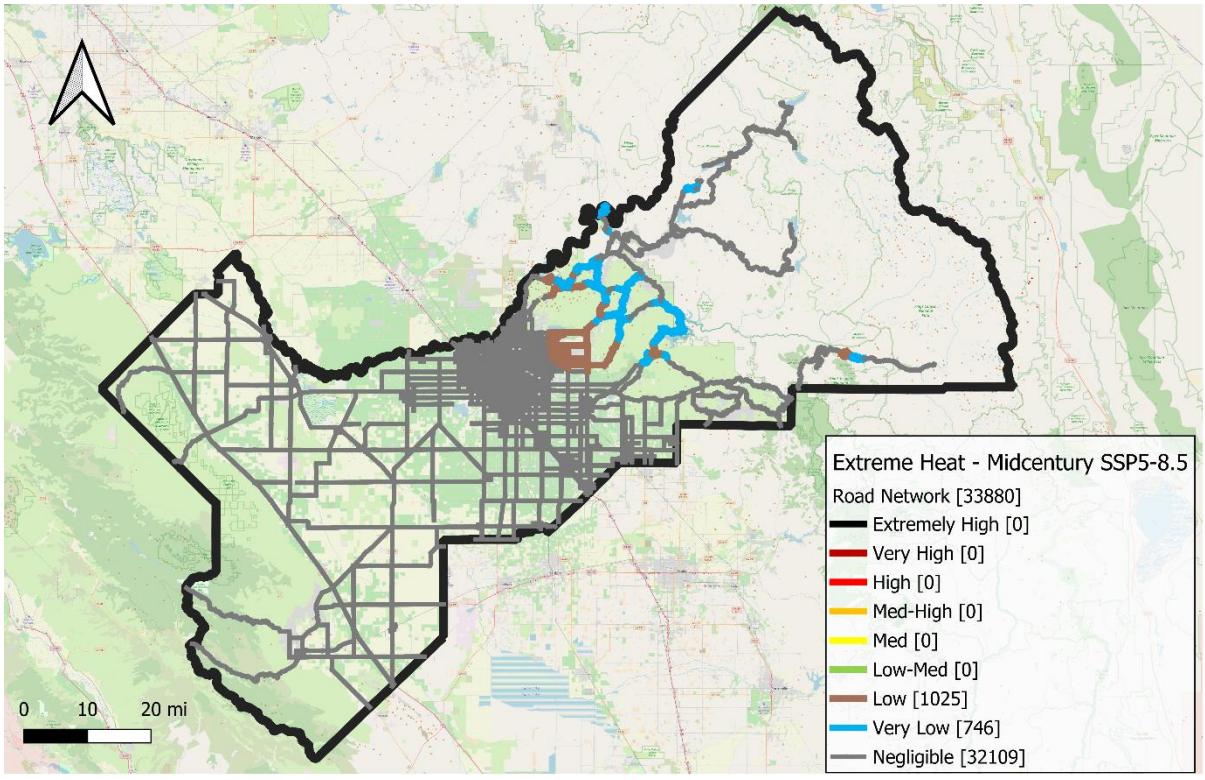

Figure 51. Downtime risk ratings of the road network from mid-century (SSP5-8.5) climate extreme heat hazard.

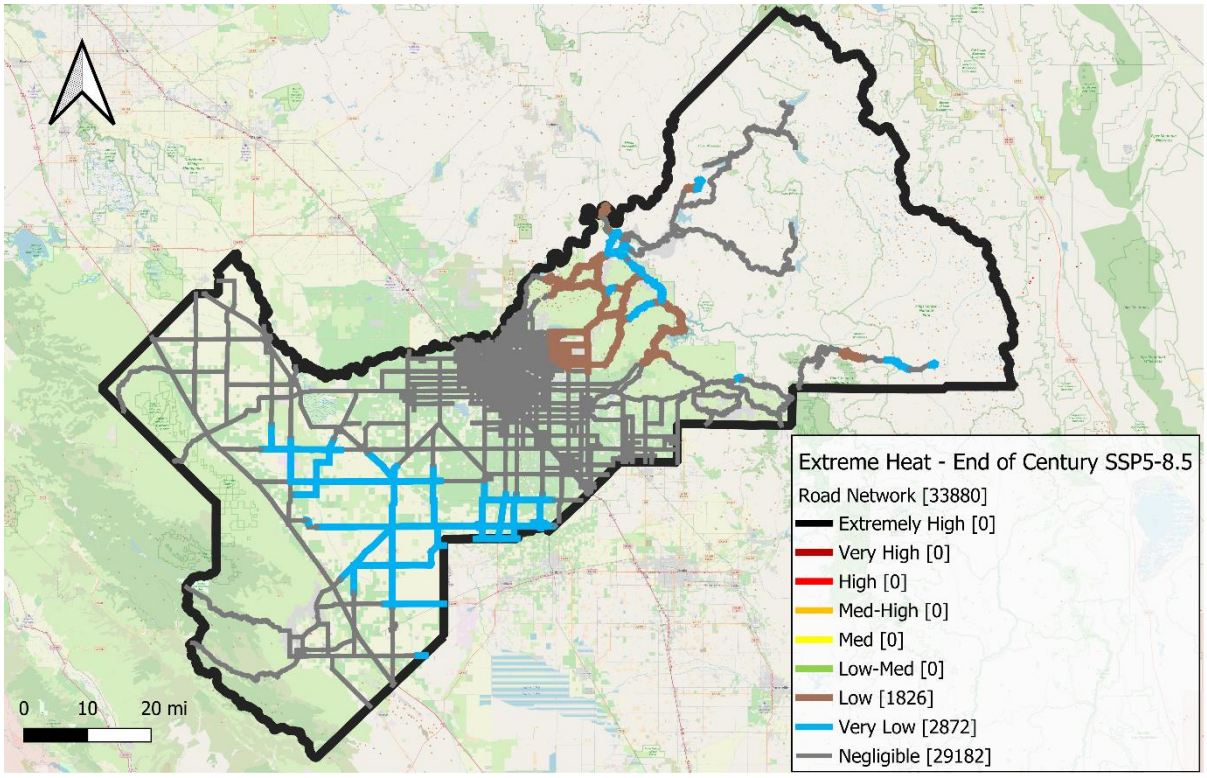

Figure 52. Downtime risk ratings of the road network from end of century (SSP5-8.5) climate extreme heat hazard.

6.2 Extreme Heat Risk to the Transit Network and Bus Yards

6.2.1 Transit Routes

For the impact of extreme heat, Fresno COG was more concerned with the transit ridership experience, or what it is felt like walking to or waiting at bus stops, as opposed to downtime as this is already assessed under roads. Therefore, Arup assessed Fresno County's transportation network for impacts on human health and wellness, in particular the average annual likelihood of a person being hospitalized if exposed to heat for a duration of time. Across the board heat is a regional issue for Fresno County as seen Figure 53.

The extreme heat hazard source used to depict present day heat hazard is sourced from observational weather station data using heat index as presented in Figure 54. Heat index is a temperature metric that better captures what the temperature feels like on the human body. Heat index combines the effects of dry bulb temperature and relative humidity. Due to this combination heat index is traditionally expected to be a higher temperature value that dry bulb temperature. Per the *Climate Hazard Memo*, heat index is a regional issue with less demanding heat in the mountainous regions and intense heat in the inland valley. For future climate, downscaled climate model data is used from LOCA2 California domain to project the observational weather station data forward to mid-century and end of century climate.

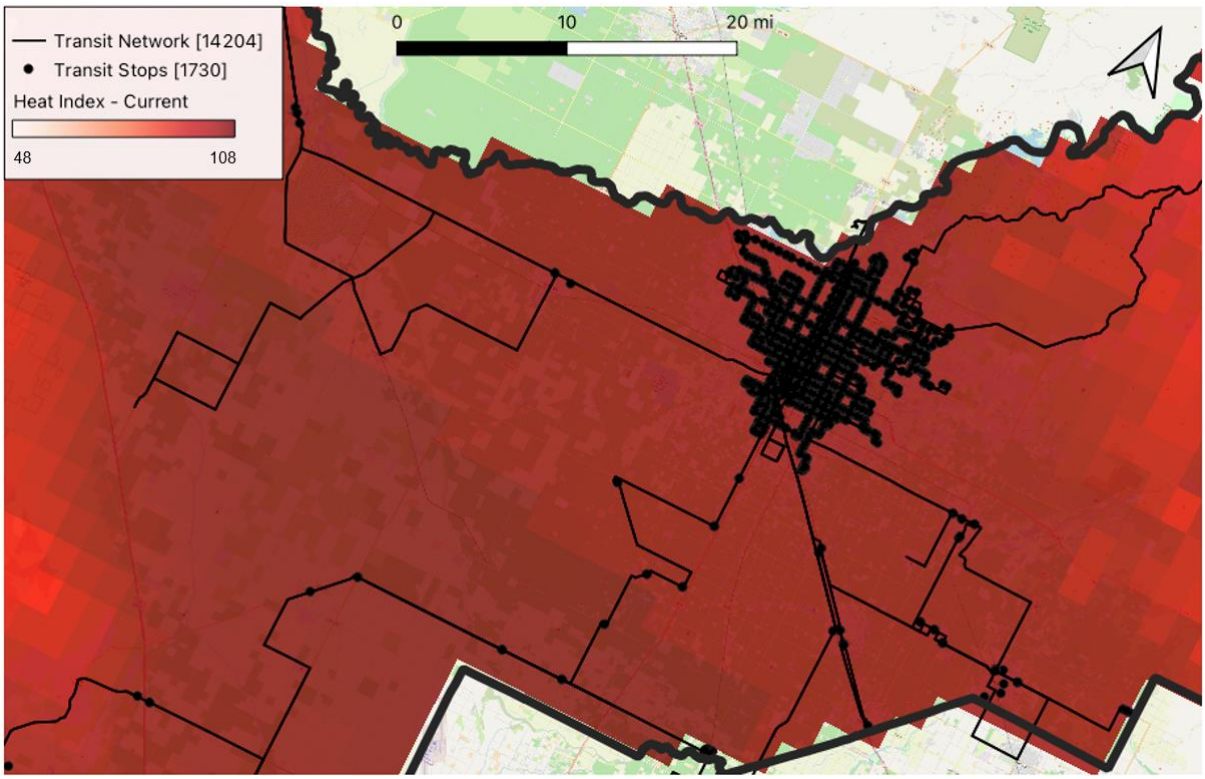

Figure 53. Heat hazard map plotted in Fahrenheit for Fresno County overlayed with the transit network.

Hospitalization

The impacts of extreme heat on human health and wellness, in particular the likelihood of an individual being hospitalized considers many factors about the human body. These impacts are summarized below:

- **Heat exhaustion** for normal populations is likely for prolonged exposure to heat index values that range from 103°F to 124°F. These impacts can result in an individual potentially being hospitalized.
- **Heat stroke** for normal populations is likely for prolonged exposure to heat index values that are 125°F and higher. Heat exhaustion is likely. These impacts can result in an individual potentially being hospitalized.

Since heat is a regional hazard all transit routes are exposed and vulnerable to varying degrees of severity. The transit lines that are riskiest to extreme heat are those that lie within the inland valley portion of Fresno County. The present-day risk ratings in Figure 55 range from ***Med-High*** to ***Very-High***. Some key takeaways from the present-day climate risk assessment are the following:

- The ***Very-High*** hospitalization risk ratings in western Fresno County can be attributed to that concentration of heat on the current climate heat map (Figure 54).
- The likelihood of hospitalization is a regional issue for Fresno County as all areas are exposed to high temperatures.

Extreme heat events already are frequent in Fresno County and considering the effects of climate change, these events will only grow in duration and intensity of temperature. In the

future, the mid-century climate scenario (Figure 57) the risk ratings range from ***High*** to ***Extremely-High***. By end of century climate scenario (Figure 59) risk ratings remain similar in range from ***Very-High*** to ***Extremely-High***. A more specific summary of how risk changes is summarized below:

- The temperatures in western Fresno County grow significantly with climate change. By mid-century the original pocket of ***Very-High*** increases to ***Extremely-High*** hospitalization risk.
- The regional hospitalization risk profile for Fresno County increases fairly uniformly across the region when considering the impacts of climate change.

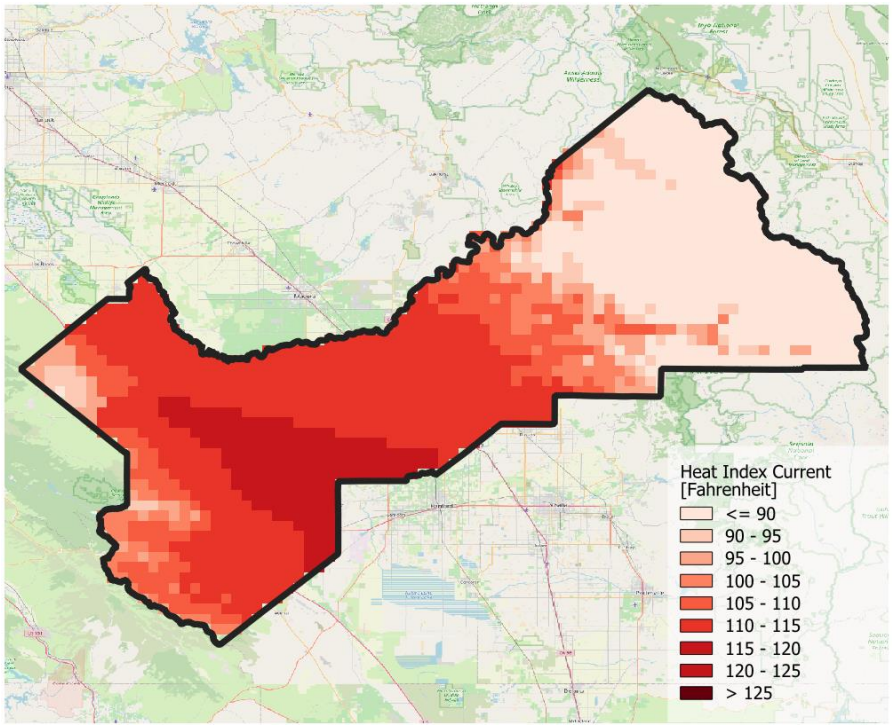

Figure 54. Extreme annual heat index for 1 in 5-year extreme heat event for current climate scenarios [ASOS Observational Weather Station Data].

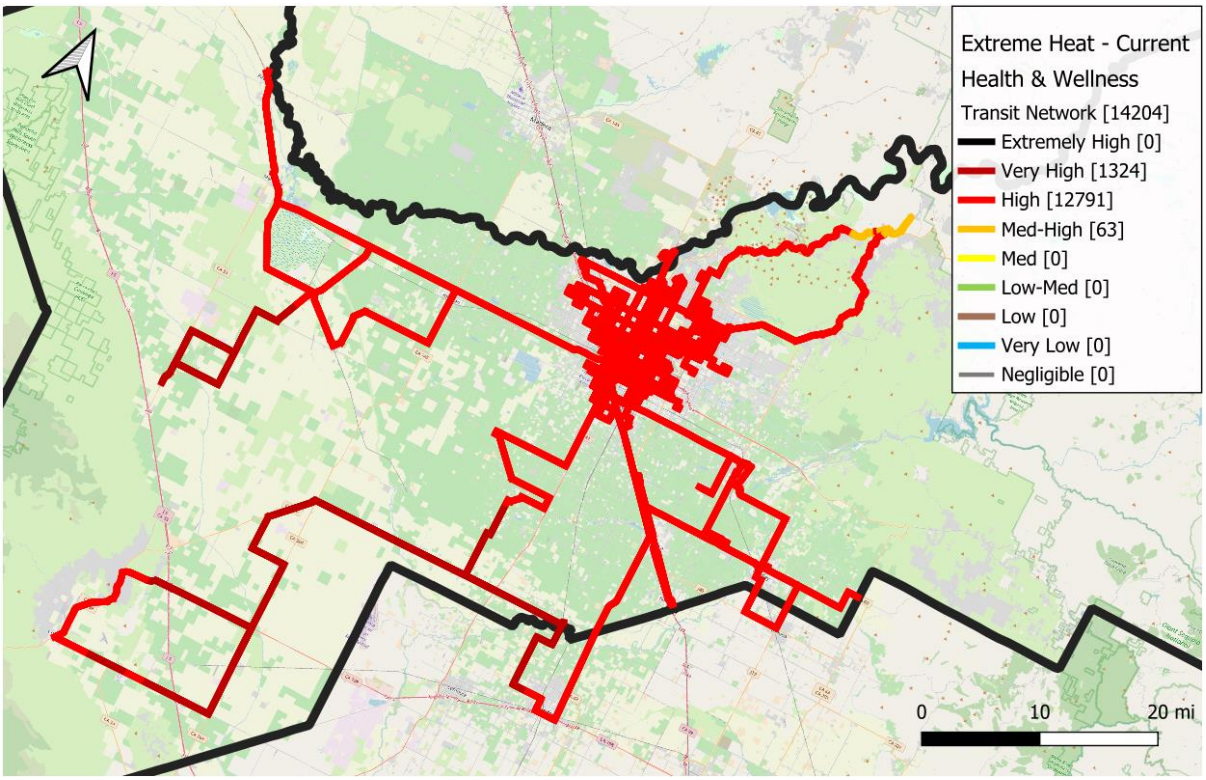

Figure 55. Hospitalization risk ratings of the transit lines from current climate extreme heat hazard.

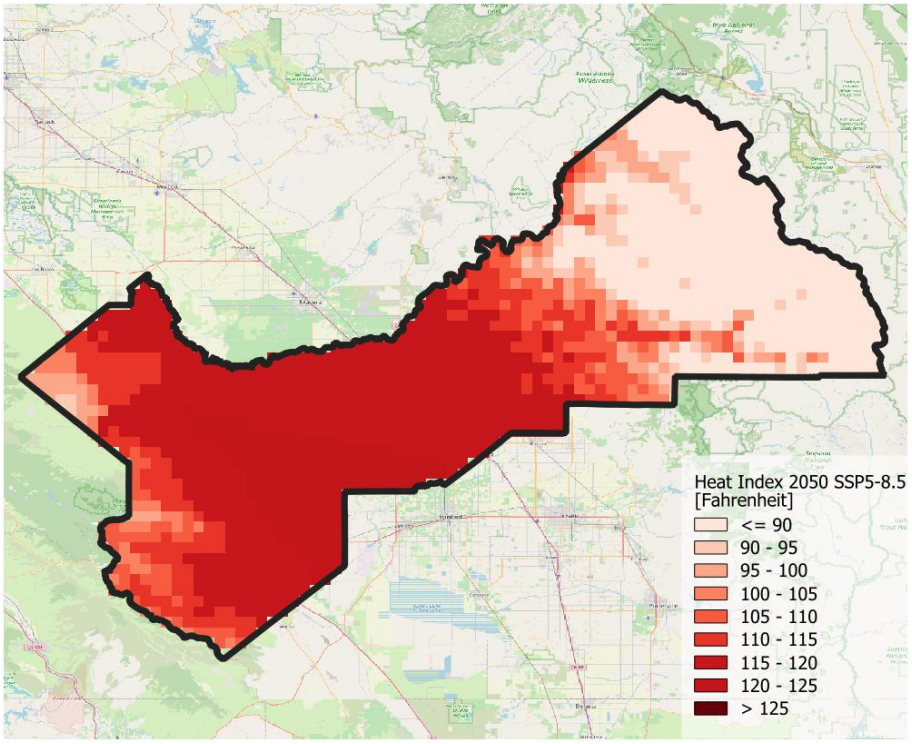

Figure 56. Extreme annual heat index for 1 in 5-year extreme heat event for future climate scenario mid-century SSP5-8.5 [LOCAv2 California Domain].

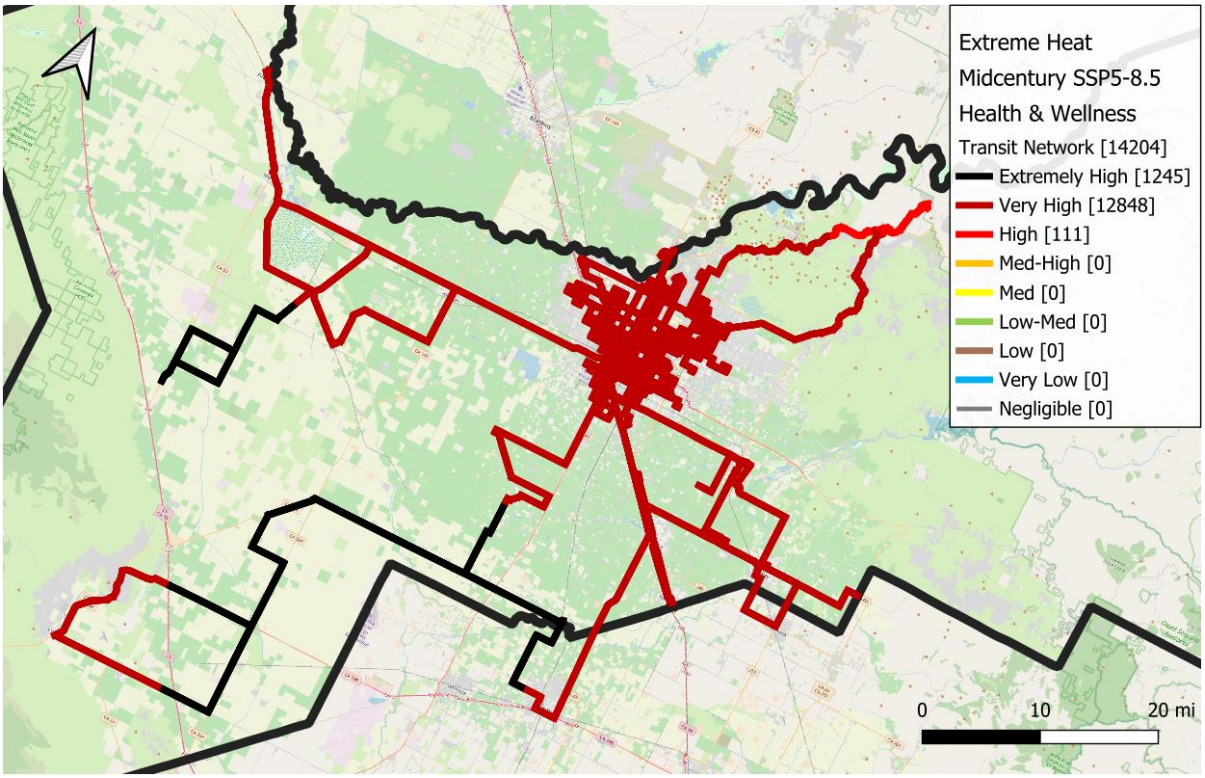

Figure 57. Hospitalization risk ratings of the transit lines from mid-century (SSP5-8.5) climate extreme heat hazard.

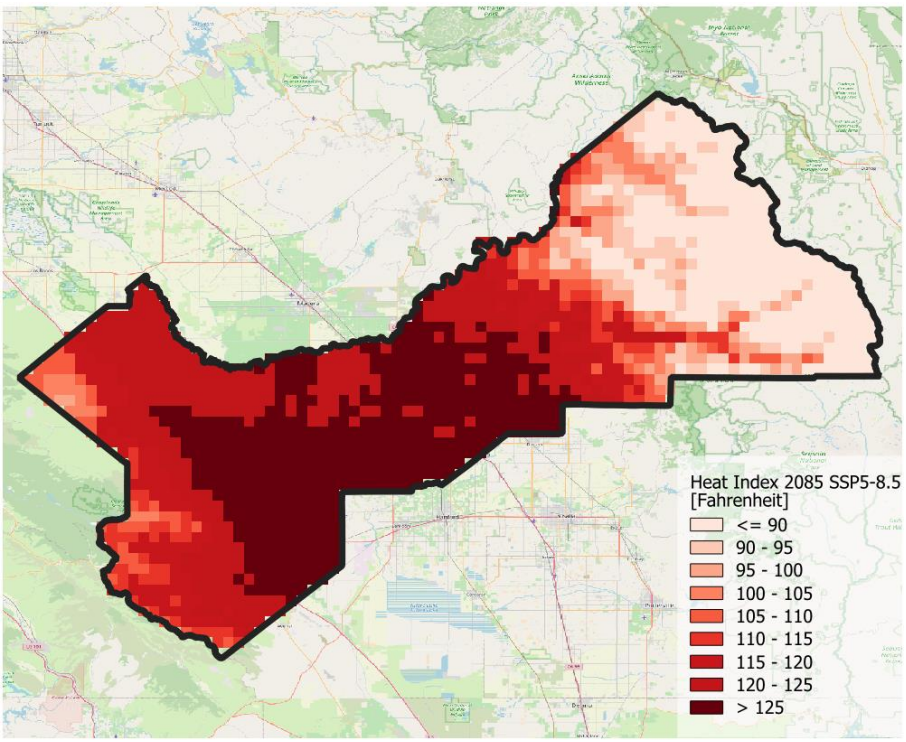

Figure 58. Extreme annual heat index for 1 in 5-year extreme heat event for future climate scenario end of century SSP5-8.5 [LOCAv2 California Domain].

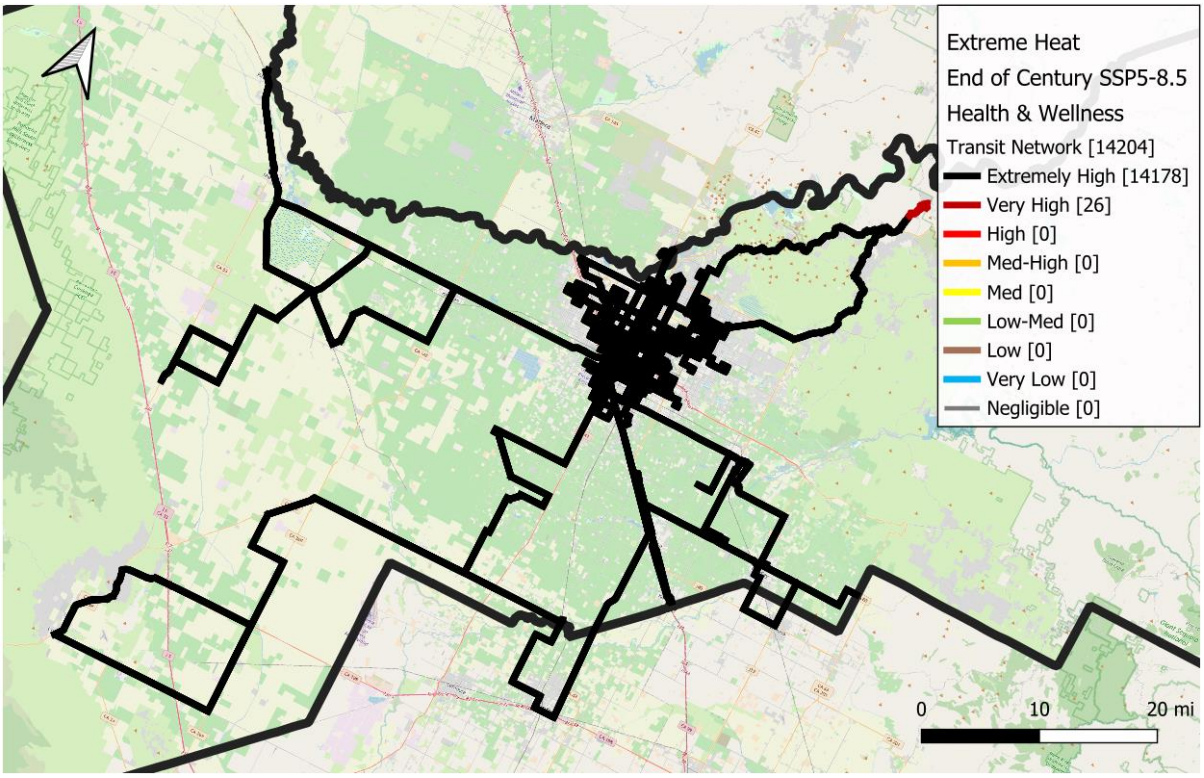

Figure 59. Hospitalization risk ratings of the transit lines from end of century (SSP5-8.5) climate extreme heat hazard.

6.2.2 Bus Yards

A qualitative description is provided for the impact of extreme heat on Fresno County's bus yards. Extreme heat is expected to impact bus yards primarily through the following components:

- **Buses**. The impacts of extreme heat on the buses housed in the bus yards varies depending on the type of vehicle traditional fuel or electric. However, extreme heat consistently can impact a buses ability to operate if faced with mechanical issues such as overheating, battery failure, internal fluid levels, and tire pressure (AAA, 2023) (Environmental Protection Agency, n.d.). Electric buses pose the additional challenge of charging requirements, where extreme heat events can lead to prolonged charging times and impact the distances buses are able to travel (Valley Metro, n.d.).

- **On-site facilities.** The impacts of extreme heat on the buildings, or on-site facilities, within a bus yard pose risks to workers, especially in non-air-conditioned buildings. In those with air conditioning, high temperatures increase the demand on the air conditioning units resulting in inadequate cooling and higher temperatures inside. This can impact worker health and wellness and any temperature sensitive critical equipment.

- **Workers.** Depending on the temperature, prolonged exposure to heat can cause a variety of impacts on the human body ranging from minor impact to cognitive performance all the way to heat stroke. This of particular concern for outdoor workers. All of these effects may impact a workers' health and ability to work under these conditions. One strategy to address this may be to alter worker schedules to avoid the hottest parts of the day which may have operational impacts.

- **Surrounding road network.** Extreme heat can cause spider cracking or buckling on the surrounding road network to each bus yard. As such, repairs of surrounding roads may be required and therefore disrupt a bus operator's ability to exit the yard.

6.3 Extreme Heat Risk to the Bike Network

Hospitalization

Since heat is a regional hazard all bike paths are exposed and vulnerable to varying degrees of severity. The bike paths that are at highest risk of extreme heat are those that lie within the inland valley portion of Fresno County. The present-day risk ratings in Figure 60 range from ***Med-High*** to ***Very-High***. Some key takeaways from the present-day climate risk assessment are the following:

- Majority of Fresno County's bike paths are exposed to ***High*** risk.

- Risk ratings that are flagged for ***Med-High*** risk are those that venture into the mountains, such as Auberry Road.

Extreme heat events already are frequent in Fresno County and considering the effects of climate change, these events will only grow in duration and intensity of temperature. In the future, the mid-century climate scenario (Figure 61) the risk ratings range from ***High*** to ***Extremely-High***. By end of century climate scenario (Figure 62) risk ratings are all flagged as ***Extremely-High***. The following trends for how extreme heat changes over time in Fresno County are summarized as follows:

- The bulk of Fresno County's bike paths change from present-day ***High*** risk to ***Very-High*** by mid-century and ***Extremely High*** by end of century climate.
- By end of century climate, bike paths in the mountains converge with the inland valley risk ratings to all be flagged as ***Extremely-High*** risk.

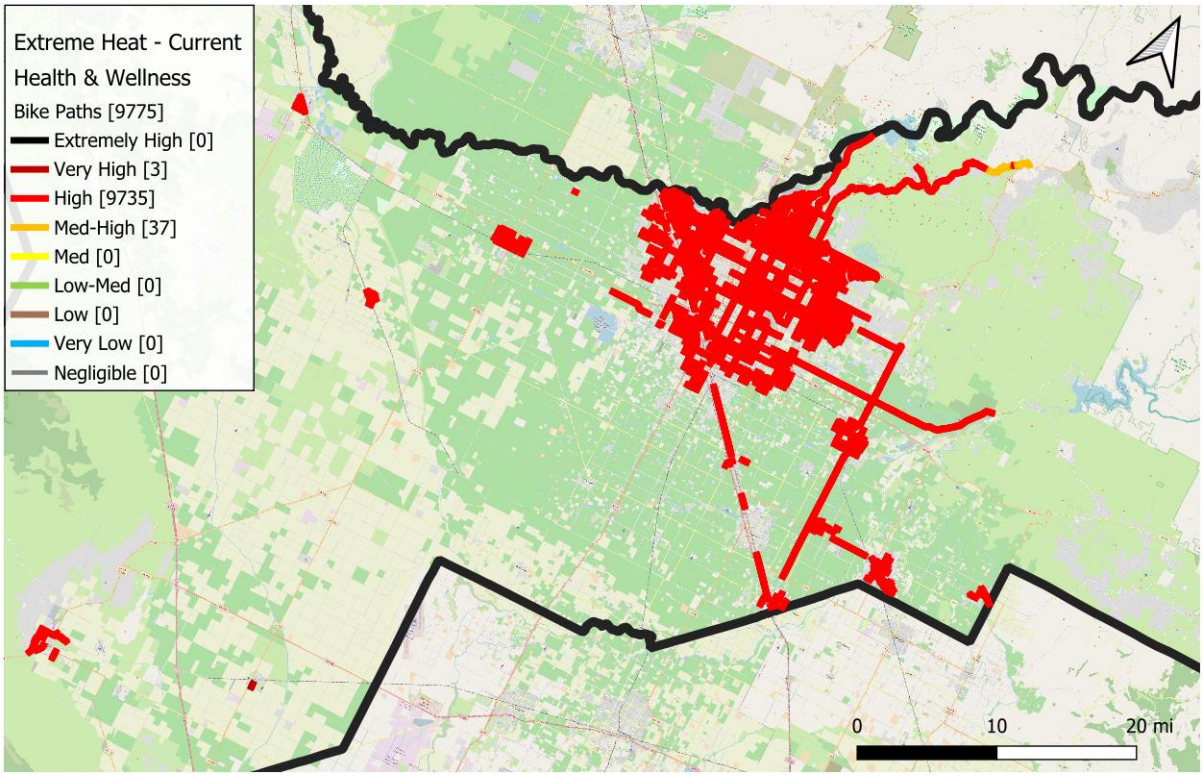

Figure 60. Hospitalization risk ratings of the bike paths from present-day climate extreme heat hazard.

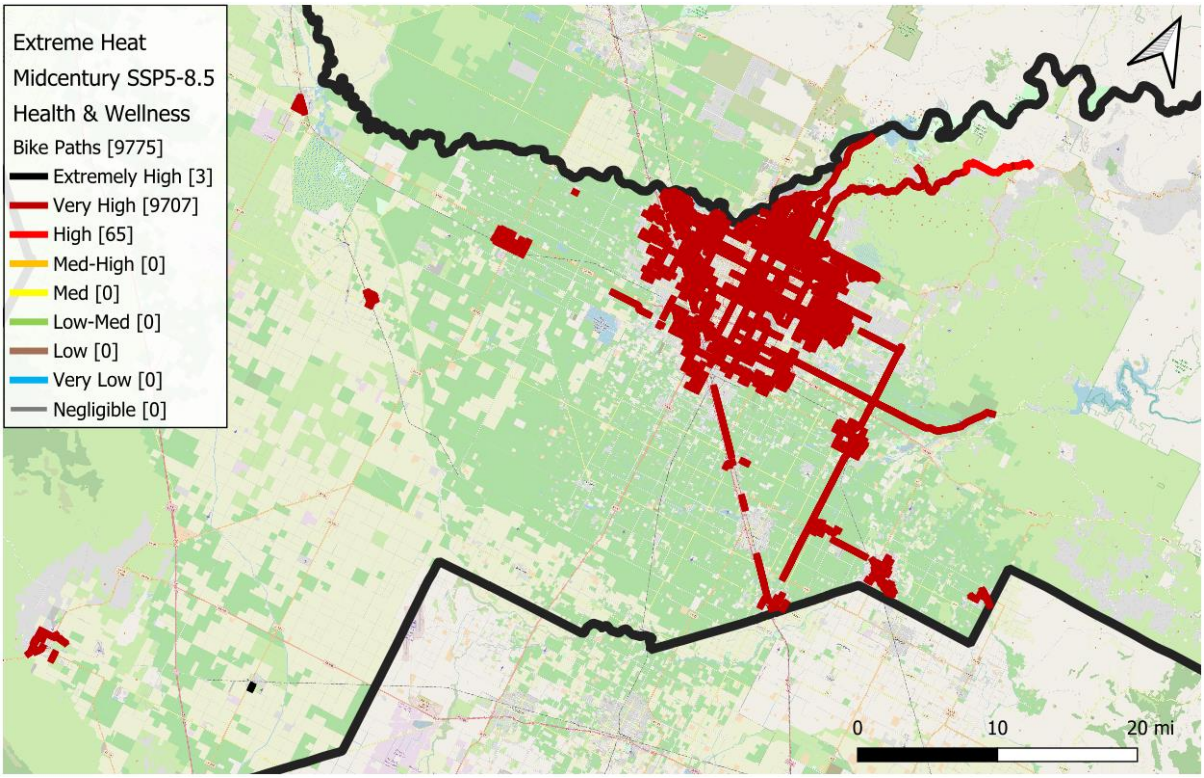

Figure 61. Hospitalization risk ratings of the bike paths from mid-century (SSP5-8.5) climate extreme heat hazard.

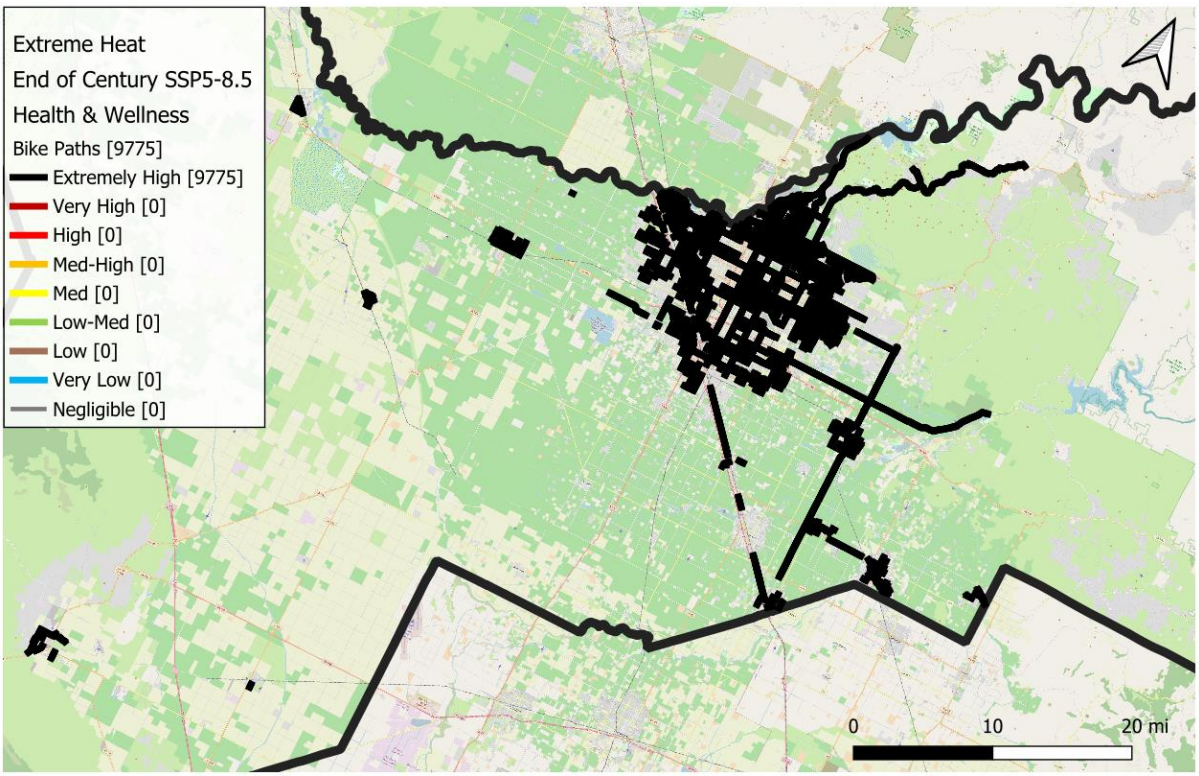

Figure 62. Hospitalization risk ratings of the bike paths from end of century (SSP5-8.5) climate extreme heat hazard.

6.4 Extreme Heat Risk to the Rail Network

A qualitative description is provided for the impact of extreme heat on Fresno County's rail network. The County's main rail network mostly runs through the inland valley climate region which is susceptible to very high temperatures. Extreme heat is expected to impact rail infrastructure primarily through the following components:

- Track expansion that leads to rail buckling,
- Decay of features that support the rail system (e.g. fastening systems, wood rail ties),
- Possible degradation of electronic system performance including rail switches, light signals, or monitoring systems,
- Outdoor railroad workers impact to human health and wellness (Federal Railroad Administration, 2024).

Rising temperatures from climate change can cause operational disruption or even damage to rail lines from the possibility of rail buckling. On very hot days it is standard practice for rail network providers to decrease the speed of their trains to allow operators the ability to locate potential heat-related hazards and alter their course if needed (Lee, 2024). These speed restrictions vary by provider. For Fresno County, their main rail lines are operated by Amtrak. On days the outside air temperature exceeds roughly 95° Fahrenheit, operators will impose speed restrictions for passenger lines at a maximum of 80 mph (Chinowsky, et al., 2019). These speed restrictions can result in minutes to hours delay per day of the temperature threshold

being exceeded. If rail buckling does occur the downtime associated can be significant ranging from hours to days.

6.5 Extreme Heat Risk to Airports

A qualitative description is provided for the potential impacts of extreme heat on Fresno County's airports. Extreme heat can impact an airport's ability to adequately perform day-to-day operations when considering the effects of climate change. A summary of extreme heat impacts airport assets is summarized below:

- **Runway Damage**. Extreme heat can cause buckling of pavement or even melting of the runway. This is seen in London's Luton Airport in which a heatwave forced a section of the runway to lift requiring highly import repair measures to take place (Cotovio & Hardie, 2022). This results in downtime from temporary flight suspension.
- **Worker safety**. Operational disruptions can occur as a function of high heat due to the unsafe working conditions for outdoor workers. This can result in operational disruption resulting in downtime.
- **Airplanes unable to takeoff**. Heat can impact an airplane's ability to takeoff under its standard operating conditions. When both temperature and humidity increase it results in less aerodynamic lift meaning that airplanes may need to take off at higher speeds in order to maintain the same takeoff weight. In instances where higher speeds are not possible, e.g., if limited by the length of the runway, weight penalties (i.e., reductions) may be imposed. Limiting the takeoff weight reduces an airplane's ability to maximize the number of passengers, baggage, or fuel. The impact of these limitations may vary by type of airplane, length of route, or weight of cargo being carried, and may result in financial loss or downtime for Fresno County's airports and the airlines servicing these locations.

7. Landslide

This section outlines the findings from the risk assessment for two primary highways that enter the mountains, CA Route 168 and CA Route 180 for their susceptibility to landslide hazard. The assessment of these routes for landslide were added to the project scope due to particular concern for these sections. Landslide risk was only captured for the current climate scenario.

7.1 Landslide Risk to Roads

Landslides have the potential to cause significant damage and disruption. This impact is summarized below:

- **Damage to roads** from landslide can occur when the land above a road slides over the road and blocks the roadway, or the land below a road gives way and compromises the structural integrity of the road above. This can result in a road becoming inaccessible on the order of weeks to months of downtime while it is repaired.

Present-day landslide hazard is depicted using the California Department of Conservation California Geological Survey's map of deep-seated landslide susceptibility. Landslide susceptibility is classified from 0 to 10 in order of increasing susceptibility, based on rock strength and slope steepness. These landslide susceptibility classes are then mapped to an

equivalent return period. The landslide susceptibility map is shown for Fresno County in Figure 63. The high and low mountain areas of Fresno County are highly susceptible to landslide hazard.

The present-day risk ratings are summarized in which all road assets denoted as grey are considered negligible to landslide risk. Approximately, 35% of CA Routes 168 and 180 are affected by landslide hazard with risk ratings ranging from ***Med*** to ***Very-High*** as presented in Figure 64. Some key takeaways from the present-day landslide risk assessment are the following:

- Both CA Routes 168 and 180 have significant landslide risk due to the roads traveling into Fresno County's eastern mountain regions.
- CA Route 180 has higher landslide risk when compared to CA Route 168.

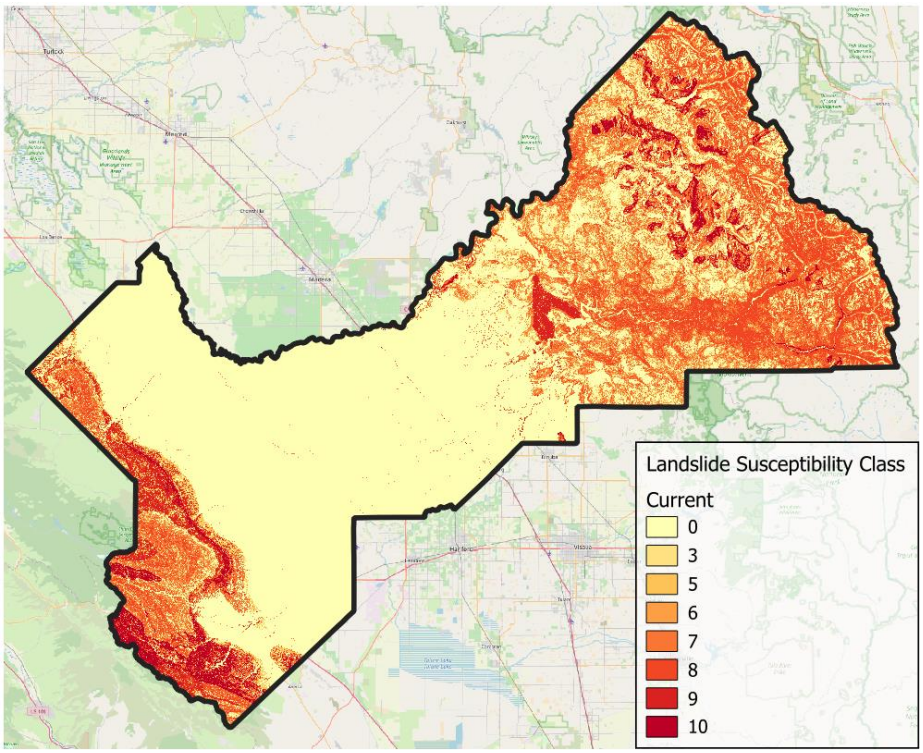

Figure 63. California Geological Survey's deep-seated landslide susceptibility overlayed in Fresno County.

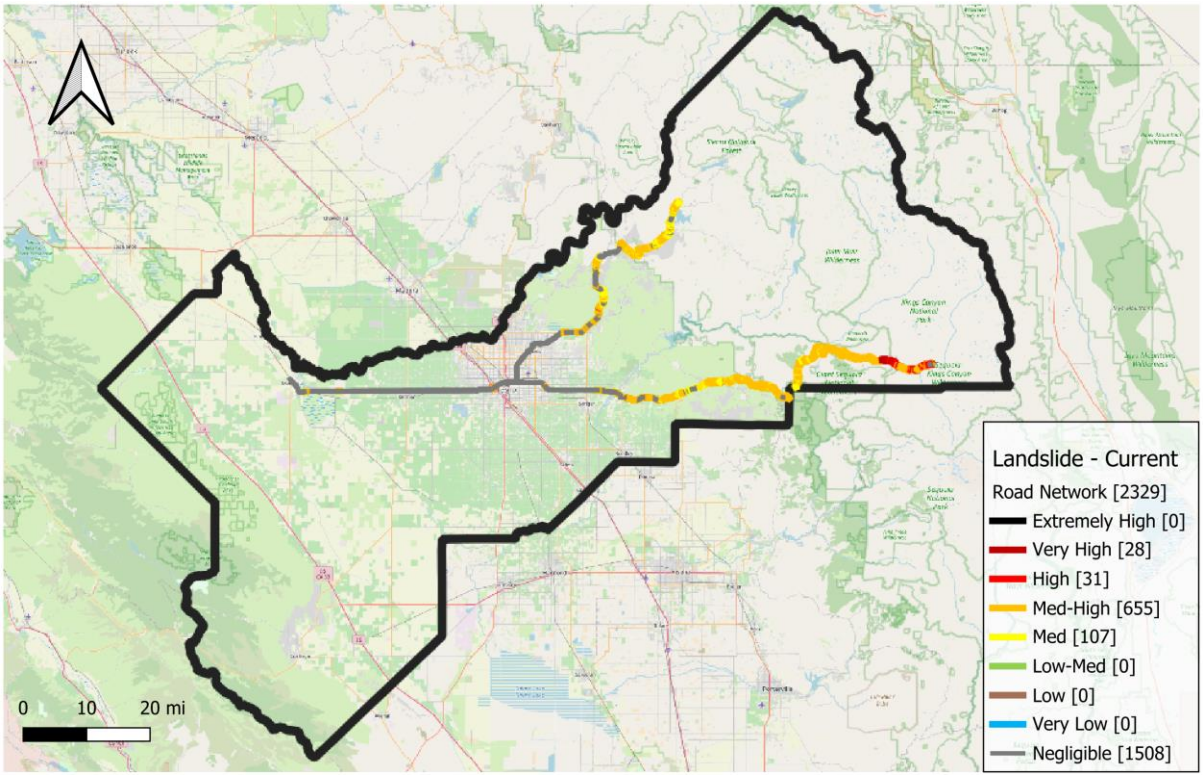

Figure 64. Downtime risk ratings of the CA Route 168 and CA Route 180 from present day landslide hazard.

8. Conclusions

The following are the key findings from Fresno County's regional transportation risk assessment:

Roads and bridges:

- For **roads** and **bridges**, the impacts of flood and wildfire are similar but impact different regions; wildfire impacts mountainous roads more while flood impacts the inland valley.

  Flooding:

  - The problem areas in Fresno County include **roads** and highways that are concentrated in the City of Fresno and Western Fresno County, such as highway CA-99 and Belmont Avenue, respectively.
  - **Bridges**, or roads that travel over water bodies are of the most pressing concerns due to their potential for more significant damage from washout which requires significant road repairs.

  Wildfire:

  - The problem areas in Fresno County are **roads** and highways that are integral to connecting the inland valley communities to the more rural mountain communities (e.g., Pittman Hill Road).
  - Roads can become more vulnerable from wildfire risk if the route is lined with **bridges** (due to the potential structural damage that can occur). As such, mountain roads lined with bridges are of pressing concern.

  Extreme heat:

  - Extreme heat impacts roads in the low-mountain regions. The effects of climate change have caused portions of the high mountain and western inland valley road network to have risk from temperatures beginning to exceed the demand pavement design threshold.

Transit routes and bike network:

- Flooding impacts **transit routes** and the **bike network** more than wildfire (i.e., more of the transit routes are affected by flooding compared to wildfire).

  Flooding:

  - The **transit routes** of concern for flood risk are primarily urban routes, operated by FAX, that also have high weekly ridership (i.e. Routes 1, 28, and 38).
  - The **transit route** with the highest combined ridership and flood risk is Route 38.
  - Rural **transit routes**, operated by FCRTA, typically serve more isolated communities with smaller overall ridership. Among these routes, the FCRTA

Coalinga Intercity Transit and Westside Transit Routes are defined as routes with considerable flood risk.

- Among the **bike network**, bike paths (off-street paths) are considered especially vulnerable to flood risk due to their adjacency to bodies of water. The primary areas of concern for these off-street paths lie within the cities of Fresno and Clovis as well as along the border of Fresno County.

Wildfire:

- The problem **transit routes** in Fresno County include FCRTA's Auberry Transit and Coalinga Intercity Transit Routes.
- Rural **transit routes**, operated by FCRTA, typically serve more isolated communities.
- Among the **bike network**, bike paths that travel into the mountains are of particular concern for wildfire risk. The primary areas of concern for these off-street paths lie within the eastern and western mountains of Fresno County, such as Auberry Road or Elm Avenue.

Extreme heat:

- Extreme heat impacts **riders** of **transit routes** across the county almost uniformly due to extreme heat being a regional hazard.
- Exposed **bus stops** (without shade) to prolonged heat will be of more concern due to the inability of riders to have relief from direct sunlight. Of particular concern is the first and last mile of travel where passengers are exerting themselves by walking to and from or waiting at a bus stop.

Other assets:

- Flood impacts on the **rail network** are concentrated on the main lines in the City of Fresno and the branch lines in Eastern Fresno County.
- Flood impacts about 25% of **bus yards** and 50% of **airports**; wildfire does not impact any bus yards or airports in this study.

9. References

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Appendix: SSP2-4.5 risk results

This section includes the risk ratings for SS2-4.5 where the risk is non-zero. The results focus on mid-century for flooding and end of century for wildfire and extreme heat, to capture the difference in results compared to SSP5-8.5 as presented in the body of the report.

Flooding risk

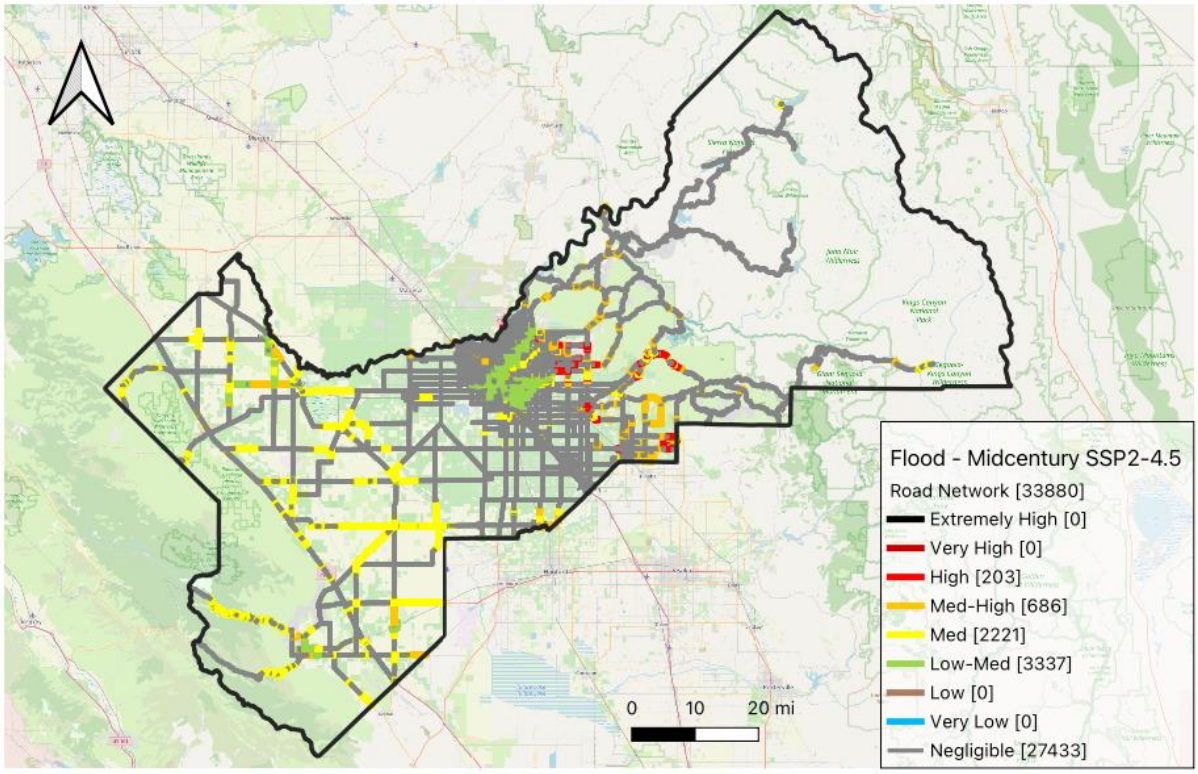

Figure 65. Downtime risk ratings of the road network from mid-century (SSP2-4.5) climate flood hazard.

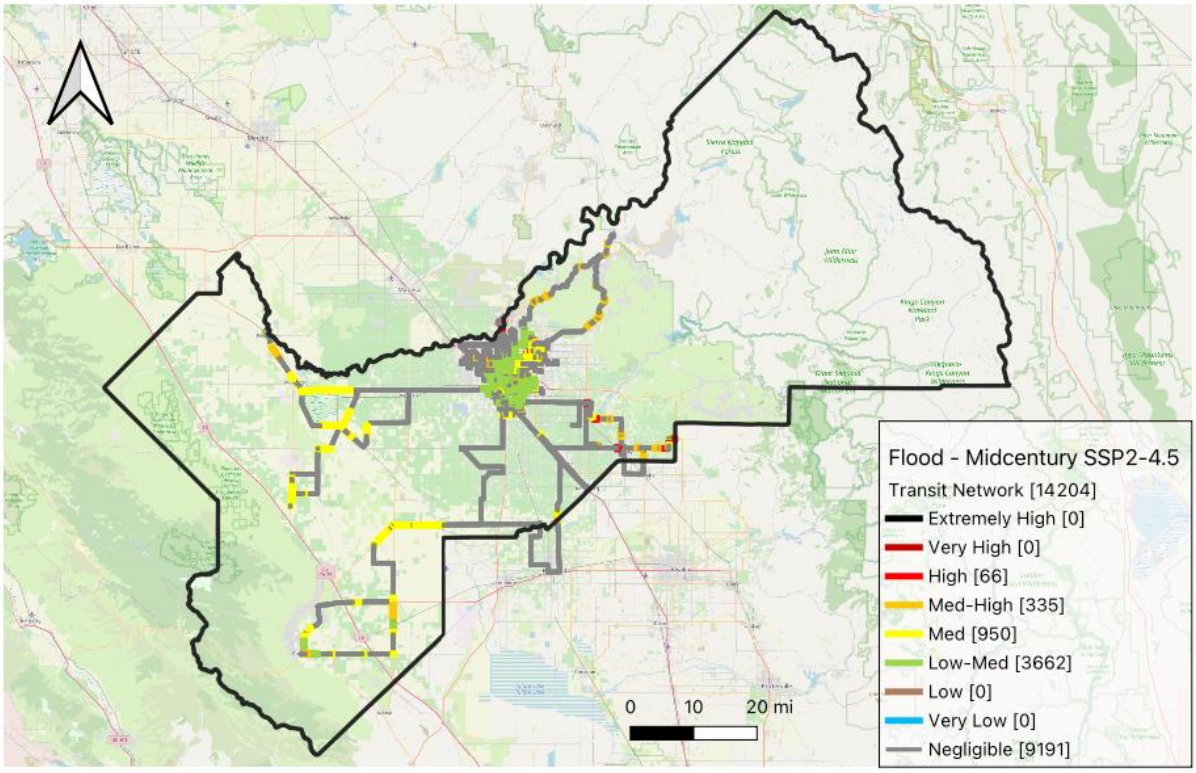

Figure 66. Downtime risk ratings of the transit network from mid-century climate (SSP2-4.5) flood hazard.

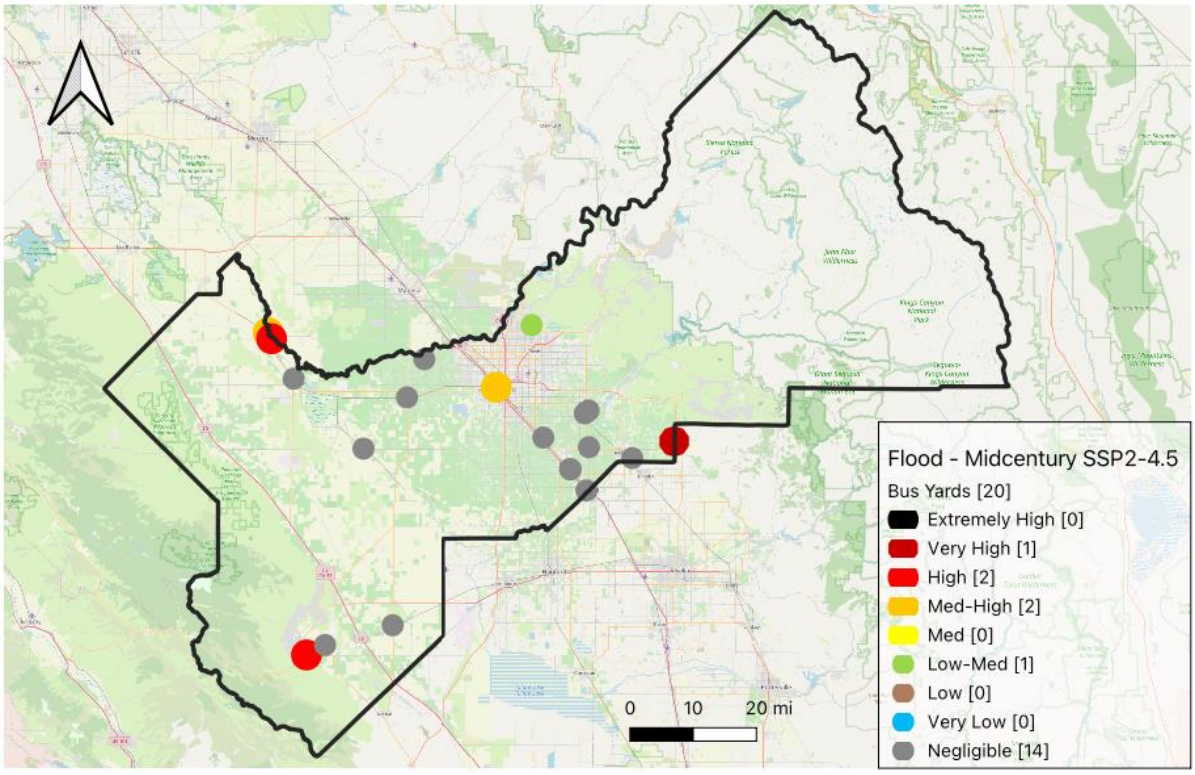

Figure 67. Downtime risk ratings of bus yards from mid-century climate (SSP2-4.5) flood hazard.

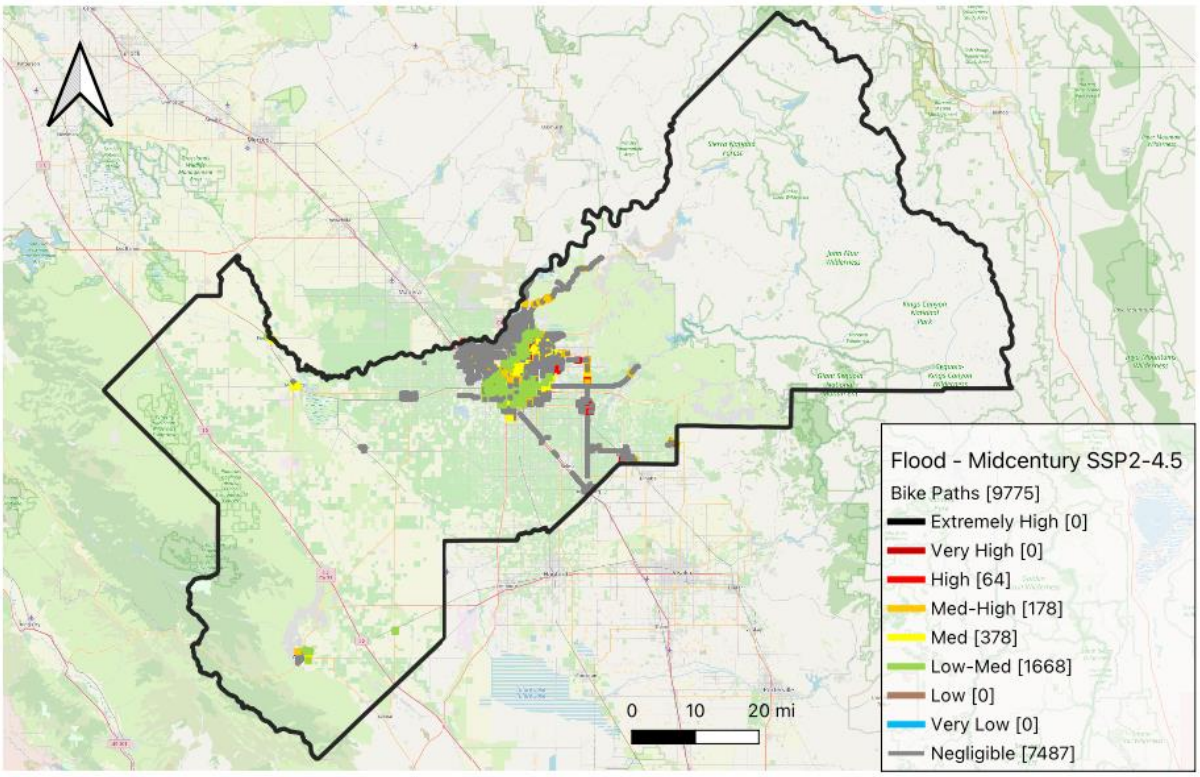

Figure 68. Downtime risk ratings of bike paths from mid-century climate (SSP2-4.5) flood hazard.

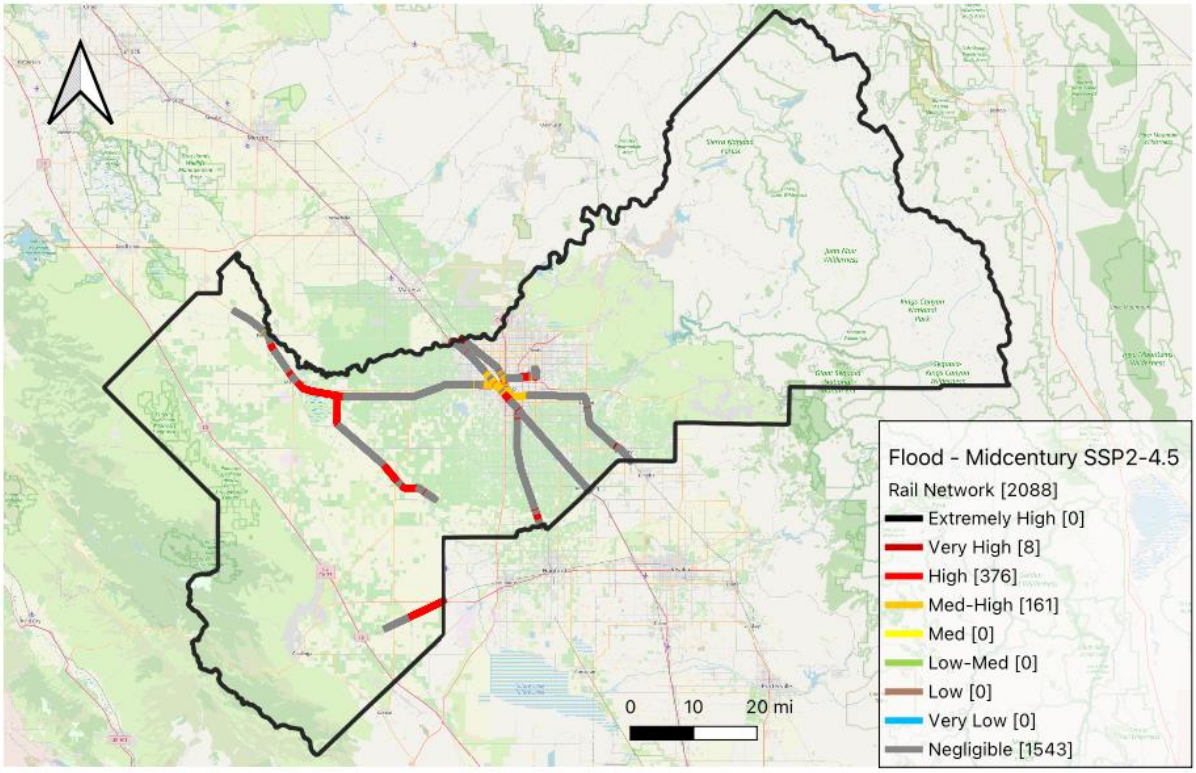

Figure 69. Downtime risk ratings of the rail network from mid-century climate (SSP2-4.5) flood hazard.

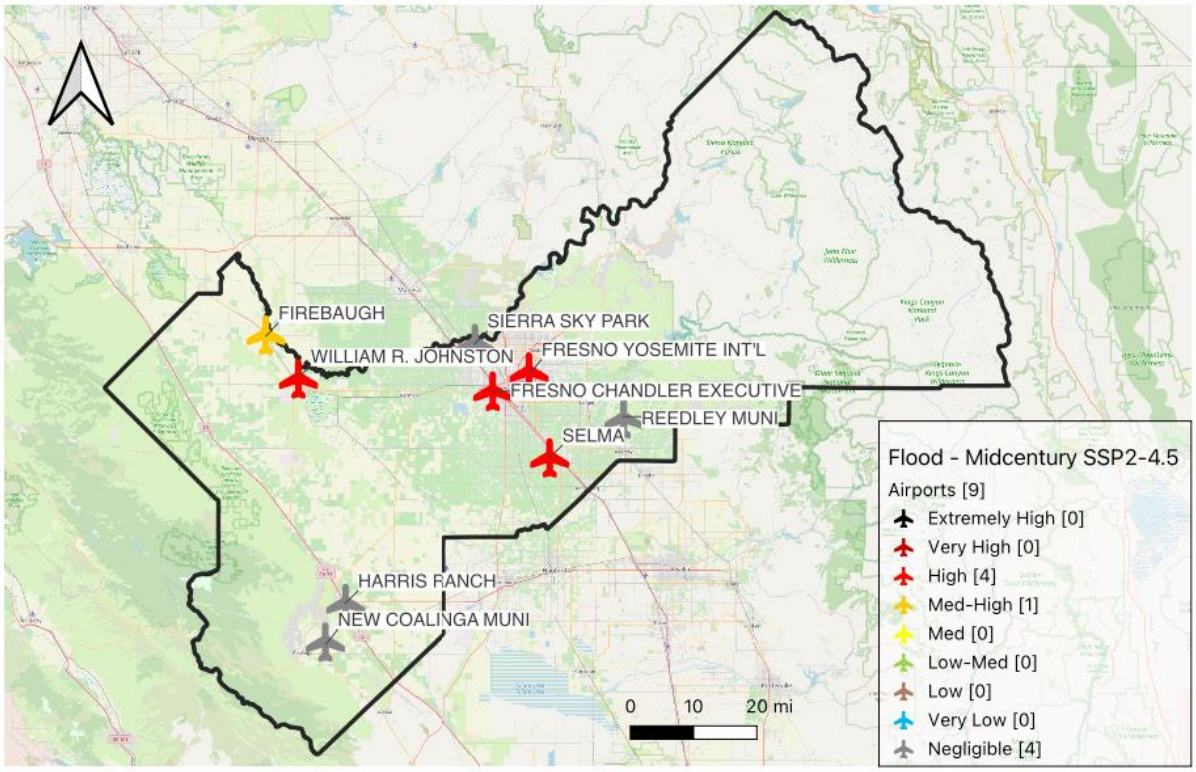

Figure 70. Downtime risk ratings of the airports from mid-century climate (SSP2-4.5) flood hazard.

Wildfire risk

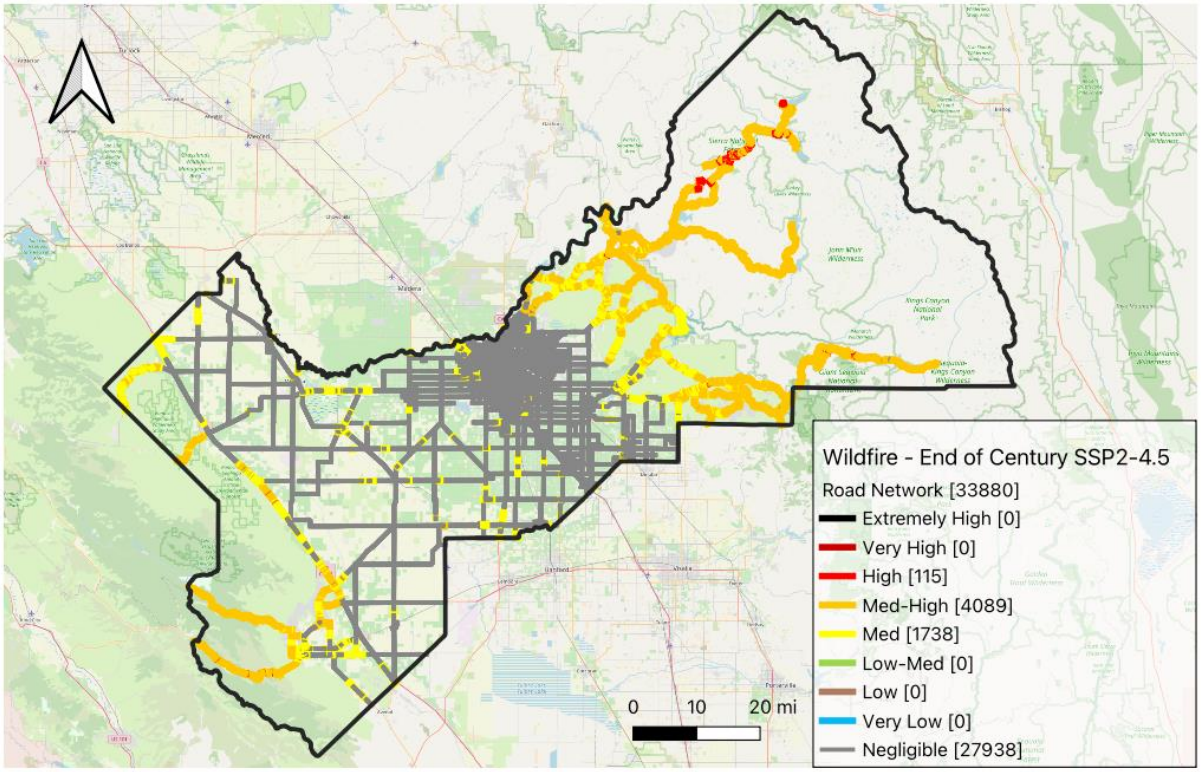

Figure 71. Downtime risk ratings of the road network from end of century (SSP2-4.5) climate wildfire hazard.

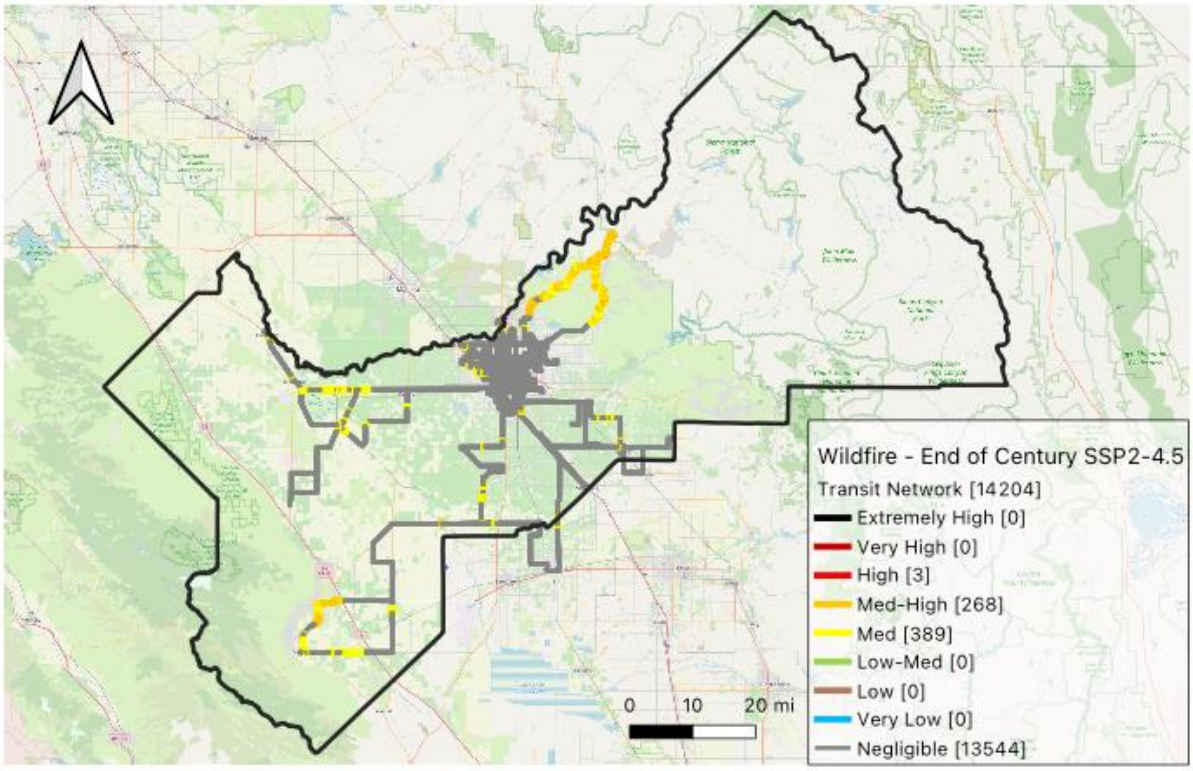

Figure 72. Downtime risk ratings of the transit network from end of century climate (SSP2-4.5) wildfire hazard.

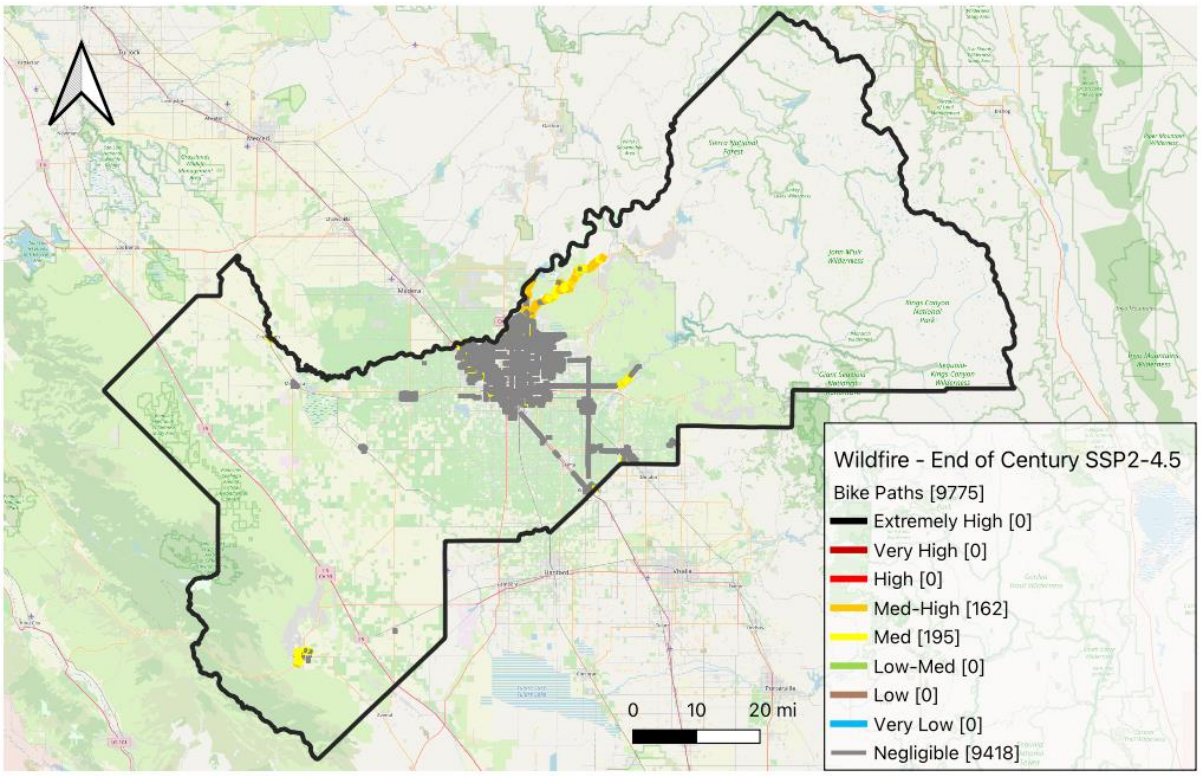

Figure 73. Downtime risk ratings of bike paths from end of century (SSP2-4.5) wildfire hazard.

Extreme heat risk

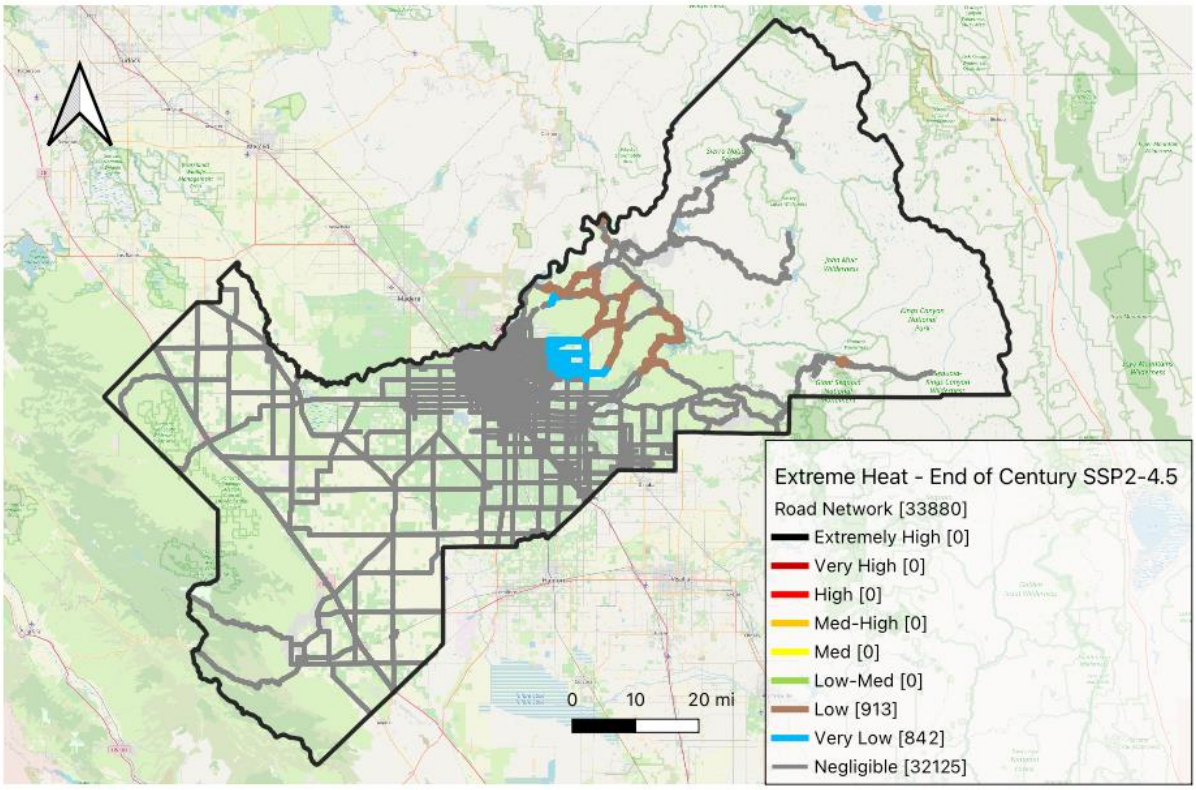

Figure 74. Downtime risk ratings of the road network from end-century (SSP2-4.5) climate extreme heat hazard.

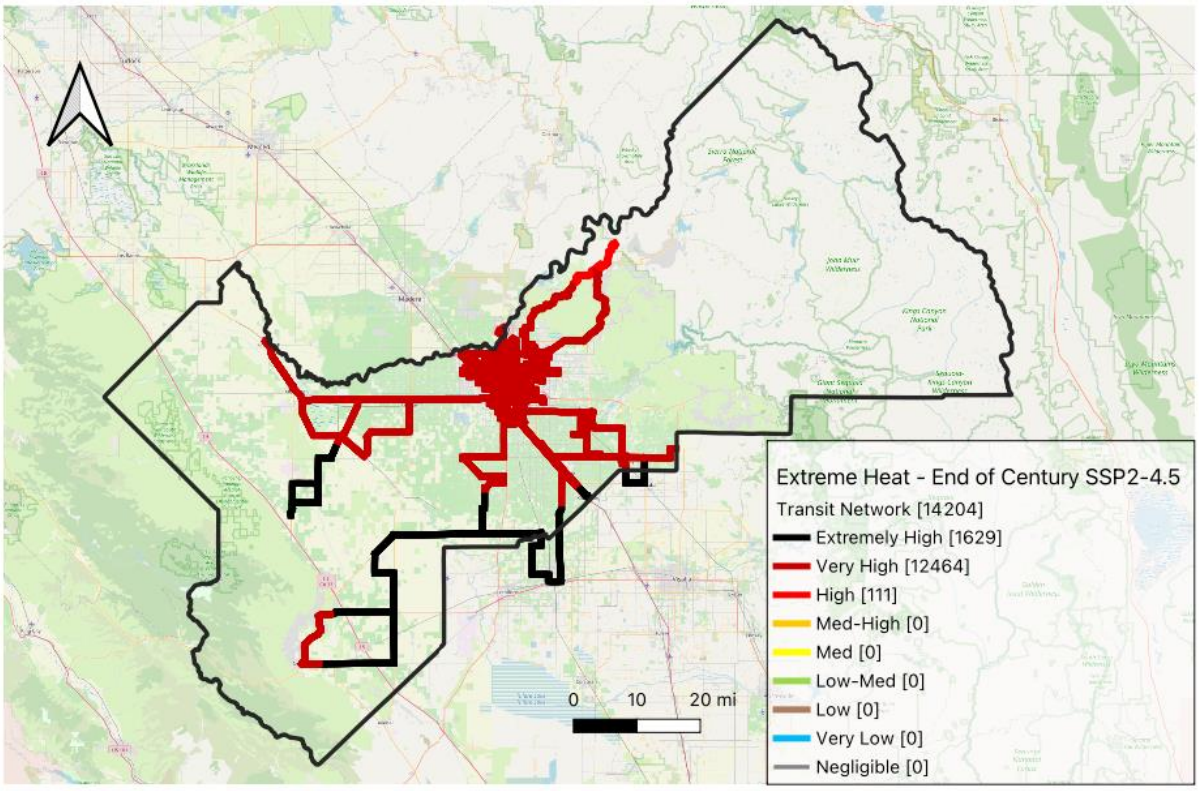

Figure 75. Hospitalization risk ratings of the transit lines from end of century (SSP2-4.5) climate extreme heat hazard.

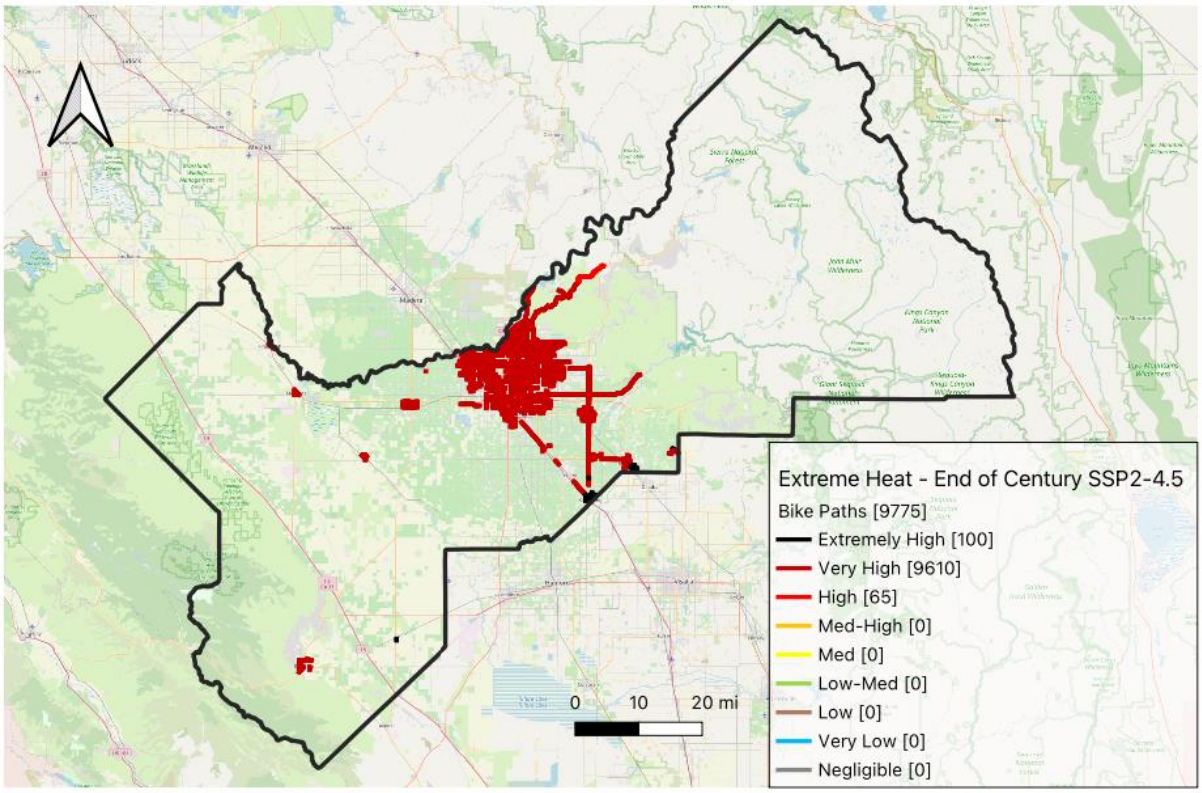

Figure 76. Hospitalization risk ratings of the bike paths from end of century (SSP2-4.5) climate extreme heat hazard.

A.9 Priority Transit Stop Locations & IDs

The following transit stops are recommended priority stops for mitigation, as identified in Priority Projects 3 and 4 to mitigate impacts of extreme heat at urban and FCRTA transit stops.

Urban - High Frequency and Ridership with No Tree Canopy

Transit Agency	Stop ID	Stop Code	Stop Name
FAX	14	14	SHAW - FIRST
FAX	15	15	NW SHAW - BLACKSTONE
FAX	28	28	BRAWLEY - WALMART
FAX	83	83	MANCHESTER TRANSIT CENTER
FAX	84	84	CEDAR STATION
FAX	89	89	MANCHESTER TRANSIT CENTER
FAX	90	90	FIRST - SHAW NB
FAX	95	95	HERNDON STATION
FAX	96	96	SHAW STATION
FAX	167	167	CEDAR - SHAW
FAX	374	374	DIVISADERO STATION
FAX	376	376	BELMONT STATION
FAX	377	377	OLIVE STATION
FAX	744	744	L SHELTER
FAX	851	851	CHESTNUT STATION
FAX	971	971	GRIFFITH STATION
FAX	973	973	ASHLAN STATION
FAX	979	979	SHAW STATION
FAX	982	982	BARSTOW STATION
FAX	987	987	SIERRA STATION
FAX	999	999	EL PASO STATION
FAX	1005	1005	SIERRA STATION
FAX	1009	1009	BARSTOW STATION
FAX	1017	1017	ASHLAN STATION
FAX	1018	1018	GRIFFITH STATION
FAX	1023	1023	WELDON STATION
FAX	1028	1028	BELMONT STATION
FAX	1910	1910	WILLOW STATION
FAX	1917	1917	NE BLACKSTONE - EL PASO
FAX	2222	2222	WOODWARD STATION
FAX	2224	2224	HERNDON STATION
FAX	2225	2225	BULLARD STATION
FAX	2227	2227	CLINTON STATION
FAX	2228	2228	OLIVE STATION

FAX	2229	2229	DIVISADERO STATION
FAX	2231	2231	FRESNO ST STATION
FAX	2232	2232	VAN NESS STATION
FAX	2233	2233	CHESTNUT STATION
FAX	2234	2234	PEACH STATION
FAX	2235	2235	CLOVIS STATION
FAX	2237	2237	PEACH STATION
FAX	2238	2238	FRESNO ST STATION
FAX	2239	2239	VAN NESS STATION
FAX	2240	2240	WILLOW STATION

Urban – High/Med Frequency and Ridership with No Tree Canopy

FAX	5	5	BRAWLEY - SHIELDS
FAX	7	7	SHAW - WEST
FAX	8	8	SE SHAW - BLACKSTONE
FAX	9	9	SHAW - FIRST
FAX	10	10	SHAW - CEDAR
FAX	11	11	WILLOW - SHAW
FAX	13	13	SHAW - CEDAR
FAX	72	72	FRESNO YOSEMITE INTL - EB
FAX	82	82	FIRST/SHAW S/B
FAX	137	137	FIRST - SHIELDS
FAX	144	144	FIRST - SHIELDS
FAX	169	169	CEDAR - VENTURA
FAX	175	175	CEDAR - VENTURA
FAX	181	181	MARKS - SHAW
FAX	251	251	SW SHAW - HUGHES
FAX	259	259	SE SHAW - PALM
FAX	263	263	SE SHAW - GLENN
FAX	265	265	SE SHAW - FRESNO
FAX	287	287	NW SHAW - FRESNO
FAX	293	293	NW SHAW - PALM
FAX	345	345	SE SHAW - VALENTINE
Clovis	2506409		Shaw - Cedar
FAX	405	405	NW SHAW - MARKS
FAX	409	409	NE BRAWLEY - SHAW
FAX	643	643	A SHELTER
FAX	827	827	NW SHAW - BARTON
FAX	846	846	SE SHAW - FISHER
FAX	854	854	MAPLE STATION
FAX	862	862	FIRST ST STATION
FAX	891	891	1ST ST STATION
FAX	912	912	MAPLE STATION
FAX	927	927	SW SHAW - CHESTNUT

FAX	975	975	GETTYSBURG STATION
FAX	1065	1065	SE FRESNO - FULTON MALL
FAX	1141	1141	NE FRESNO - BROADWAY
FAX	1236	1236	M ST STATION
FAX	1307	1307	B SHELTER
FAX	1443	1443	NE CEDAR - OLIVE
FAX	1484	1484	SE BLACKSTONE - NEES
FAX	1485	1485	SE NEES - FRESNO
FAX	1494	1494	SW CEDAR - HERNDON
FAX	1505	1505	SW CEDAR - GETTYSBURG
FAX	1508	1508	NW CEDAR - ASHLAN
FAX	1516	1516	NW CEDAR - CLINTON
FAX	1521	1521	SW CEDAR - OLIVE
FAX	1524	1524	SW CEDAR - BELMONT
FAX	1528	1528	SW CEDAR - TULARE
FAX	1868	1868	SE NEES - FIRST
FAX	1961	1961	SW RIVERSIDE - EL PASEO
FAX	2226	2226	GETTYSBURG STATION
FAX	2236	2236	6TH ST STATION
FAX	2241	2241	SIXTH STREET STATION
FAX	2293	2293	NE PEACH - DAKOTA

FCRTA – High Access, Medium/Low Ridership and Frequency

TCRTA	D4020	Manning Ave and Buttonwillow Ave
FCRTA	2454675	Davita Sanger Dialysis Center
FCRTA	2454679	Auto Dealership
FCRTA	29351	Me N Ed's
FCRTA	29352	Round Table Pizza
FCRTA	29362	Sanger Hospital
FCRTA	29363	Sanger City Hall
FCRTA	29364	Sanger City Hall
FCRTA	29374	McDonald’s
FCRTA	29375	Reedley College
FCRTA	29377	Beauty Supply
FCRTA	29384	Dr. Verma’s
FCRTA	29386	Selma Plaza shopping center/Papa Murphy's Pizza
FCRTA	29388	Selma Plaza shopping center/WIC Bench
FCRTA	29446	Brooks Ranch