Application Checklist

The following documents are required and must be submitted via Smartsheet in one single PDF document, not to exceed 25 MB. The Signature Page may be submitted separately if there are issues combining with the single PDF document. Keep the file name brief, as files are corrupted when file names are too long. Refer to the Grant Application Guide for additional information and/or samples. Failure to include any of the required documents will result in a reduced application score.

PDF documents should be submitted in their fillable PDF formats. The original file formats will be required upon grant award.

Required Application Documents	
(✓)	**Ensure these items are completed prior to submitting to Caltrans via Smartsheet**
✔	Application Cover Sheet (complete in Smartsheet and submit with single PDF document)
✔	Signature Page (Electronic signatures accepted; may submit as a separate file if there are issues with combining with single PDF document)
✔	Application Narrative
✔	Scope of Work
✔	Cost and Schedule
	Third Party In-Kind Valuation Plan (if applicable, required upon award)
✔	Map of Project Area
Supplemental Documentation (not required)	
✔	Graphics of Project Area (when applicable)
✔	Letter(s) of support
✔	Data

Sustainable Transportation Planning Grant Program

GRANT APPLICATION COVER SHEET

PART A. APPLICATION INFORMATION

FY 2025-26

Grant Category (select only one)

Climate Adaptation (MPOs, RTPAs, Transit Agencies, Cities, Counties, Tribes, other Public Transportation Planning Entities)

X	11.47% Local Match requirement (Not Applicable to Native American Tribal Governments)

Sustainable Communities (MPOs with sub-applicant, RTPAs, Transit Agencies, Cities, Counties, Tribes, other Public Transportation Planning Entities)		**Strategic Partnerships** (MPOs & RTPAs only) **Strategic Partnerships Transit** (MPOs, RTPAs & Transit Agencies only)	
	Sustainable Communities Competitive (11.47% Local Match requirement) **Not applicable to Native American Tribal Governments**		Strategic Partnerships (FHWA SPR Part I) (20% Local Match requirement)
	Sustainable Communities Competitive Technical (11.47% Local Match requirement) **Not applicable to Native American Tribal Governments**		Strategic Partnerships Transit (FTA 5304) (11.47% Local Match requirement)

Application Submittal Type (more than one may be selected)

New		**Prior Phases**		**Re-Submittal**	
X	New Application		Continuation of a prior project. If so, list the Grant FY and project title below.		Re-submittal from a prior grant cycle.
					How many times has an application been submitted for this project, including this one?

PART B. PROJECT INFORMATION

Project Title and Location

Project Title	Eastern Fresno County Climate Adaptation Plan		
Project Location (City)	Eastern Fresno County Unincorporated Communities	Project Location (County)	Fresno County

Funding Information

1. Is the applicant proposing to meet the minimum local match requirement or an over-match? Use the Match Calculator to determine the appropriate match. Match Calculator (Posted on STPG Website)

   ☒ Minimum Local Match ☐ Over-Match

2. What is the source of Local Match funds being used?
   (MPOs – Federal Toll Credits, PL, and FTA 5303 cannot be used to match Sustainable Communities Competitive or Adaptation Planning grants)

   ☒ Local Transportation Funds ☐ Local Sales Tax ☐ Special Bond Measures
   ☐ Other, specify:

Grant Funds Requested	Local Match (Cash)	Local Match (In-Kind)	Total Local Match	% Local Match	Total Project Cost
$1,500,000	**$194,341**	**$0.00**	**$194,341**	**11.47%**	**$1,694,341**

Sustainable Transportation Planning Grant Program
GRANT APPLICATION COVER SHEET

Project Description (3-5 Sentences Max.)	
Insert Application Narrative: 1. Project Description	A study of the eastern unincorporated communities (east of Highways 99 and 41 to the County line) and overlapping incorporated communities will be performed to plan for the resilience of transportation infrastructure due to flooding, drought, wildfire, tree mortality, and other climate-related causes. When storm events occur, the roads can flood and impact thousands of residents trying to get to school, work, and access to other vital resources. This area of study was chosen due to its high risk for flash floods, wildfires, road failures, and high concentration of rural communities (see Attachment A). Deliverables include a report with scoping, cost estimates, and a list of priority projects, with feasibility of recommended actions, identified through a scientific and public process that considers cost, equity, long-term resiliency, and potential environmental impact. The study is in alignment with the Fresno County Hazard Mitigation Plan, the California Transportation Plan, the California Climate Adaptation Strategy, and Climate Action Plan for Transportation Infrastructure (CAPTI). The primary goal of the study is to identify the best ways to prepare, respond, manage, adapt, and maintain in the wake of the affects of climate change.

Project Type

Choose the Project Type that best represents the focus of the proposed project. See Grant Application Guide for examples. Select a maximum of two project types.

- ☐ Active Transportation (Bicycle and Pedestrian)
- ☒ Climate Change (Infrastructure Adaptation, Vulnerability and Resiliency)
- ☐ Complete Streets (Multimodal specific type)
- ☐ Corridor (Local Streets or Highways)
- ☐ Freight/Goods Movement
- ☐ General Plan-Related (Circulation Element, Land Use Element, Specific Plan)
- ☐ Multimodal (Motorized and Active Transportation)
- ☐ Safety (Vision Zero, Safe Routes to Schools)
- ☐ Technical (Modeling, VMT Mitigation, ZEV Infrastructure, ZEB Transition, etc.)
- ☐ Transit (Bus, Light Rail, and Commuter Rail Service)
- ☐ Other, specify:

Under-Resourced Community Definitions

PART B. PROJECT INFORMATION (CONTINUED)

If applicable to the project, what tools were used to identify the under-resourced communities in the project area? Choose all that apply.

☒ Rural Communities of 50,000 or less and outside of urbanized areas

☒ Native American Tribal Governments

☐ Regionally/Locally Defined Under-Resourced Communities

☐ At/Below 80% Assembly Bill 1550 (Gomez, Statutes of 2016)

☐ At/Above 75% California Department of Education, Free or Reduced Priced Meals Data

☒ At/Above 75% CalEnviroScreen Version 4.0

☒ At/Below 25% California Healthy Places Index

PART C. CONTACT INFORMATON*

	Primary Applicant	Sub-Applicant	Sub-Applicant
Organization (Legal name)	County of Fresno		
Dept./Division	Public Works and Planning, Design		
Street Address	2220 Tulare Street, 6th Floor		
City	Fresno		
Zip Code	93721		
Phone Number	(559) 600-4109		
Executive Director Name	Steven E. White		
Title	Director		
Executive Director E-mail	stwhite@fresnocountyca.gov		
Financial Manager Name	Lemuel Asprec		
Title	PWP Business Manager		
Financial Manager E-mail	lasprec@fresnocountyca.gov		
Contact Person Name	Erin Haagenson		
Title	Program Manager		
Contact Phone Number	(559) 600-9908		
Contact E-mail	ehaagenson@fresnocountyca,gov		

*Use additional pages if necessary.

PART D. COMPLIANT HOUSING ELEMENT

City/County Primary/Sub-Applicants for Sustainable Communities Grants	Yes	No
Does the City/County have a compliant Housing Element? If No, explain the current status:	X	
Has the City/County submitted Annual Progress Report to the California Department of Housing and Community Development for calendar years 2022 and 2023?	X	

PART E. OTHER FUNDING PROGRAMS

Applicants may leverage other program funds for this planning grant, as long as the activities are eligible.

	Yes	No	N/A
Is the applicant applying for the Governor's Office of Planning and Research (OPR) Climate Adaptation Planning Grant Program? Applicants should not submit the same project application to both funding programs. However, applicants may propose to leverage funds from one funding program to another. For instance, an applicant with a large project may propose to fund one component with Caltrans funds, and another with OPR funds. Applicants may also propose two entirely different projects to each funding program. If yes, identify the differences between each proposal, and briefly summarize the leverage opportunity if awarded both Caltrans and OPR funding:		X	
Is the applicant applying for any other funding programs to complete this project? If yes, list them here:		X	

Sustainable Transportation Planning Grant Program
GRANT APPLICATION COVER SHEET

PART F. LEGISLATIVE INFORMATION

Use the following link to determine the appropriate legislative members in the Project area.

Search by address: http://findyourrep.legislature.ca.gov/

State Senator(s)		Assembly Member(s)	
District	Name	District	Name
12	Shannon Grove	8	David Tangipa
14	Anna Caballero	31	Joaquin Arambula
16	Melissa Hurtado	33	Alexandra Macedo

PART G. LETTERS OF SUPPORT

List all letters of support received for the proposed project. Letters should be addressed to the applicant. Letters received after the final application filing date will not be considered.

Name/Agency	Name/Agency
Vong Mouanoutoua, Mayor, City of Clovis	
Robert Phipps, Executive Director, Fresno Council of Governments	
Alma Beltran, Mayor, City of Parlier	
Matthew Tuttle, Mayor, City of Reedley	
David M. Merritt, General Manager, Kings River Conservation District	

Sustainable Transportation Planning Grant Program

GRANT APPLICATION SIGNATURE PAGE

If selected for funding, the information contained in this application will become the foundation of the contract with Caltrans.

To the best of my knowledge, all information contained in this application is true and correct. If awarded a grant with Caltrans, I agree that I will adhere to the program guidelines.

Applicant			
Authorized Official (Applicant)			
Print Full Name	Mohammad Alimi		
Title	Design Engineer		
Signature		Date	
Sub Applicant(s)*			
Authorized Official (Sub-Applicant)			
Print Full Name			
Title			
Signature		Date	
Authorized Official (Sub-Applicant)			
Print Full Name			
Title			
Signature		Date	
Authorized Official (Sub-Applicant)			
Print Full Name			
Title			
Signature		Date	

*Use additional pages if necessary.

PART G. APPLICATION NARRATIVE

FY 2025-26

Project Information	
Organization (legal name)	County of Fresno
Project Title	Eastern Fresno County Climate Adaptation Plan
Project Area Boundaries	East of Highways 99 and 41 to the County Line
Project Timeframe (Start and End Dates):	November 2025-June 2028

Application Narrative

1. Project Description (5 points) - Do not exceed the space provided (5 sentences maximum)
Briefly summarize project in a clear and concise manner, including why the project is necessary, major deliverables, desired outcomes, parties involved, and alignment with relevant local, regional, and/or State planning efforts.

A study of the eastern unincorporated communities (east of Highways 99 and 41 to the County line) and overlapping incorporated communities will be performed to plan for the resilience of transportation infrastructure due to flooding, drought, wildfire, tree mortality, and other climate-related causes. When storm events occur, the roads can flood and impact thousands of residents trying to get to school, work, and access to other vital resources, including recreational facilities. This area of study was chosen due to its high risk for flash floods, wildfires, road failures, and high concentration of rural communities (see Attachment A). Deliverables include a report with scoping, cost estimates, and a list of priority projects, with feasibility of recommended actions, identified through a scientific and public process that considers cost, equity, long-term resiliency, and potential environmental impact. The study is in alignment with the Fresno County Hazard Mitigation Plan, the California Transportation Plan, the California Climate Adaptation Strategy, and Climate Action Plan for Transportation Infrastructure (CAPTI). The primary goal of the study is to identify the best ways to prepare, respond, manage, adapt, and maintain in the wake of the affects of climate change.

2A. Project Justification (10 points) - Do not exceed the space provided

- Describe the problem or deficiencies the project is attempting to address, including the climate adaptation need and any other priority needs, as well as how the project will address the identified problems or deficiencies
- Describe the impact of not funding the project
- Describe the public benefits

The Sierra Nevada mountains face many challenges from climate change, including snowpack loss, water supply issues, droughts and flooding, vegetation changes, increased wildfires, and streamflow changes. These are also the primary challenges for eastern Fresno County in the Climate Change battle.

This affects rural residents on their daily commutes, as well as trucks moving Central Valley commodities across the region. Some of these roads are the single point of access for residents and major power infrastructure for Southern California Edison. As storm events continue to increase in frequency and intensity, these flash flood occurrences are also expected to increase, and the current network of culverts that is in place needs a detailed evaluation and significant upgrading. Mountain river systems are especially sensitive to and affected by climate change, and cannot compete with our continued human disturbance, including water pollution, hydropower development, and water withdrawals for agriculture & human consumption.

While the Sierra Nevada's snowpack has fluctuated between below normal and above normal over the past several years, multiple climate studies forecast levels to decrease by 48–79% by the end of the century. This is due to warmer temperatures melting snow faster and earlier, and the gradual loss of alpine glaciers to warmer temperatures at those altitudes. Warmer winter temperatures will cause snow to melt sooner and peak spring streamflow to arrive earlier. However, spring precipitation is expected to decrease, which will diminish late spring and summer streamflow.

The Sierra Nevada's snowpack directly impacts California's water supply, including Fresno County's. In fact, it provides a third of California's water supply, so the loss of snowpack will make it harder to store and use water during the dry season. Despite the thousands of dams which make up the network of water storage and hydroelectric facilities in the California Water Reclamation Project, the water supply will take a direct hit from losing the annual snowpack.

As we've seen in recent years, climate change is expected to lead to more variable weather patterns, including longer and more severe droughts and floods. From December 2022 through March 2023, almost all of California and Nevada saw above-normal precipitation, with the most anomalous amounts primarily falling across central California into the Sierra Nevada mountains, causing rockslides, flash flooding, levee breeches, and crop loss. Still, even with the record amounts of rain that had fallen, the storms had only moved the drought status from, "Exceptional," to "Exceptionally dry." Since then, the region of Central California has experienced below normal amounts of rain and snowfall in the mountains, which is how the weather pendulum swings.

Climate change is likely to alter health and longevity of vegetation in the Sierra Nevada. Some trees that

2A. Project Justification (continued)

are icons of the Sierra Nevada forests, such as the noble Giant Sequoia, the Ponderosa Pine, and the Douglas Fir, may become incompatible with the climate. In recent years millions of trees have died due to an insect called the western pine beetle. Most of the trees they colonized were already vulnerable from drought conditions, which contributed to their demise. With warming temperatures, relief is not expected any time soon.

All of these factors put together sets the stage for increased wildfire danger. The Creek Fire, which started in September of 2020 and was the largest single wildfire in Fresno County History, was fueled by dry, unhealthy trees, which had been victims of years of warming, drier conditions. The Creek Fire occurred amid an already quite active wildfire season in California, which until early September had largely been driven by an outbreak of dry thunderstorms in mid-August. Between August 15 and September 9 alone, more than 1.6 million acres had burned in the state, more than five times California's average acreage burned by that date. Over Labor Day weekend of 2020, the state suffered "one of its hottest weekends in memory", leading the National Weather Service to issue widespread heat advisories and red flag warnings. The first two days of the Creek Fire's growth saw abnormally hot and dry conditions for the region (see Attachment F). As climate change persists, we can expect the area of land in the Sierra Nevada mountains burned annually to increase, and increased biodiversity loss and ecosystem changes due to the changing environment.

Using the Environmental Jusitice Screening Tool (EJScreen) (see Attachment B), eastern Fresno County's most pressing vulnerabilities to wildfire, extreme heat, and drought conditions are apparent. These hazards are also represented in Attachments D and E, taken from the Fresno County Hazard Mitigation Plan. A priority goal of the County's Climate Adaptation Plan (Plan) is to reduce wildfire risks, protect lives and property, increase safety for the public and first responders, and provide safer ingress and egress.

The Plan will also ensure that the dams and levees that protect the Valley communities from flood waters are structurally sound and not at risk of failure for the foreseeable future. The 2022-23 Winter storm season was record-breaking for precipitation, both in rainfall and snowfall, and some levees were breached due to the immense volume of water they had to hold back. Some roadways were also affected by washouts and flash flooding. A study into how we can best transform our roadways into safer travelways during these storm events would make a huge difference not only in the way the County carries out its emergency activities but also for the population who relies on the roadways for safe and reliable travel.

If the project doesn't receive funding, these issues will continue to create enormous obstacles for the County. The study is extremely important for the future well-being of the County's rural and mountain communities, both for their everyday lives and for the future resilience of the region.

2B. Under-Resourced Communities Justification (7.5 points) - Do not exceed the space provided

The tools in the Grant Application Guide, Appendix A, are intended to help applicants define an under-resourced community.

- Explain how the project area or portions of the project area benefit under-resourced communities, including Tribal, local, regional, and rural communities as applicable
- Explain how the proposed project addresses the needs of the communities and how they will benefit from the proposed project, including if the communities informed the scope of the project
- Cite data sources, the tools used, and include a comparison to the statewide thresholds that are established in each tool

Using the California Healthy Places index, the County of Fresno has a score of 12.5, meaning that 87.5% of all other counties in the state have healthier conditions (see Attachment C). Under the individual categories, the County has less healthy economic conditions than 73.2% of other California Counties, less healthy transportation conditions than 98.2% of other California Counties, and less healthy clean environment conditions than 96.4% of other California Counties. These numbers reflect a population with economic, social, and environmental conditions far below the state's median levels. In the economic category, the state's percentage above poverty level is 69.1% and the County's is 54.9%. For transportation, the state's active commuting percentage is 8.99% and the County's is 3.32%. In the Environment category, PM2.5 numbers for the state are 10.2 µg/m³ and the County's are 13.2 µg/m³. There's also a drinking water contaminant issue as the state's number is 478 and the County's is 713.

The study will seek out the most vulnerable areas prone to flooding, wildfire, and potential mud/rockslides, as well as identifying and mapping the best evacuation routes and ensuring those routes are maintained and in good condition. The population is spread out over a large area, with small communities clustered throughout the foothills. These communities rely on the County to keep the roadways open in a variety of weather conditions year-round, and the Plan would help identify ways to minimize road closures and/or blocking of essential evacuation routes in case of a emergency.

The three largest Indigenous Tribal Governments within eastern Fresno County are Table Mountain Rancheria, Big Sandy Rancheria, and the Mono Band of Yokut Indians. The County maintains good relationships with the tribes and will work with them to find solutions to roadway challenges adjacent to tribal lands.

2C. Under-Resourced Communities Engagement (7.5 points) - Do not exceed the space provided

See Grant Application Guide, Appendix A. for best practices in community engagement

- Describe how the proposed project will engage under-resourced communities and how the effort was informed by engagement with under-resourced communities, including Tribal, local, regional, and rural communities as applicable
    - Include specific outreach methods for involving under-resourced communities
- Describe how under-resourced communities will continue to be engages during the next phases after the proposed planning project is complete, including implementation

The County will collaborate with its incorporated and unincorporated communities whose roads may be affected by storms, wildfires, and other affects of climate change. We will partner with community-based organizations, including school districts and resource conservation districts, that advocate for and have established relationships with underserved populations. This collaboration will help communication with residents in the foothills and hard to reach areas to address the unique challenges they face. In-person public meetings will be held in the respective communities to ensure the public is informed and can ask questions about the Plan. Outreach will include, but are not limited to, direct mailings, notices in newspapers, online surveys, project website, food distribution lines, pop-up events, radio, churches, and advertising on social media networks, to ensure the widest reach possible. Materials will be tailored to reflect the diversity of each community. All meetings and materials will be available with English, Spanish, Hmong, Punjabi, and other translations as needed per community. Letters of support for this project have already been secured from a number of agencies in the County (Attachment G). Once the Plan is complete, community engagement will be maintained through the project website, social media, community organizations, and future events.

3. Grant Specific Objectives (Total 40 points)

Integrate the following Grant Program Considerations (Grant Application Guide, Chapter 1.2) in the responses for 3A-D below, as applicable:

- Caltrans Strategic Plan
- California Transportation Plan (CTP)
- Modal Plans that Support the CTP
- Strategic Highway Safety Plan
- Title VI and Environmental Justice
- Climate Action Plan for Transportation Infrastructure
- California Adaptation Strategy
- Master Plan for Aging

3A. Grant Specific Objectives; climate risk and adaptation (10 points) - Do not exceed the space provided

- Explain how the project identifies and assesses climate change impact risks to multimodal transportation infrastructure vulnerabilities to climate change impacts in the project area
- Explain how the project will identify adaptation strategies and specific actions to remedy identified climate related vulnerabilities. Projects and plans should describe short-, medium-, and long-term strategies that will address the overall risk for the entire service life of the asset or capital project using the best available science and guidance.
- Articulate how the project will advance the planning of specific climate adaptation projects, such as developing a cost estimate, pursuing a technical feasibility study for adaptation options, or developing a conceptual design (up to 30%)
- When applicable, explain how the project includes economic analysis and/or cost-benefit analysis of identified adaptation strategy or strategies

The proposed Plan will work in tandem with the Fresno County Multi-Jurisdictional Hazard Mitigation Plan, which is a County-wide plan that geographically covers everything within Fresno County's jurisdictional boundaries. The proposed Eastern Fresno County Climate Adaptation Plan, like the plan for Western Fresno County, will focus on the resilience of transportation infrastructure in the eastern half of Fresno County, east of Highways 99 and 41. The majority of eastern Fresno County is geographically mountainous, yet the majority of the population resides in the valley region. Nonetheless, the County is still responsible for thousands of miles of roadway that the entire population relies on every day to be safe and passable in a variety of weather conditions, from snow activities during the winter months to water and camping activities in the hot summer months to escape the extreme heat of the valley floor. The eastern region has been impacted by soil erosion and recent wildfires, such as the Creek Fire of 2020-21, and attack from the Western Pine Beetle due to dry conditions (see Attachment F). Years of drought have led to dramatic rates of tree mortality, which has contributed to more dry vegetation and ground fuels in the area as well as create an unstable base for roadways. Many of the County's bridges and culverts were damaged during the Creek Fire and in recent storms and need to be assessed for safety. Ensuring emergency evacuation routes are passable and in good condition as well as having solid plans in place for the population in case of evacuation emergency is essential to overcoming unforeseen hazards of climate change.

3A. Grant Specific Objectives; climate risk and adaptation (continued)

The flood and wildfire risk have been studied previously in the Fresno County Hazard Mitigation Plan, but specific strategies focused on transportation were not identified. Fresno Council of Governments issued a Transportation Network Vulnerability Assessment in 2020, but the recommended strategies are very general, such as "Elevate infrastructure" and "Enhance drainage capacity." A goal of this Climate Adaptation Plan is to identify specific solutions and alternatives that can be implemented when funding is available for priority projects. In creating a list of solutions, we will look at the projected costs of implementing the solutions versus costs saved that the County would spend cleaning up the areas after events and fixing roads, County staff time, labor, and materials, time saved by roadway users, and other pertinent benefits. The list of implementable solution alternatives should be cost efficient. The final Plan will identify locations that suffer from climate-related events that impact road users, and scope solutions and costs associated with implementing the improvements. The recommended solutions will take in account the short-, medium-, and long-term strategies of capital projects that build resiliency and how to best monitor the infrastructure for ongoing adaptability and review climate change patterns to evaluate the efficiency of the project improvements. Projects in the Plan will also incorporate multi-modal projects, such as bicycle, pedestrian, and transit. The priority projects will be programmed into the Regional Transportation Plan, which will help implement and program the funding to facilitate the recommended improvements.

3B. Grant Specific Objectives; co-benefits (10 points) - Do not exceed the space provided

- Identify co-benefits of the adaptation work, such as benefits to public health, natural ecosystems, air quality, social equity, the economy, or reductions in greenhouse gas (GHG) emissions.
  - If reductions in GHG emissions are identified as a co-benefit, explain how the project advances transportation related GHG emission reductions specifically through different project types/strategies (e.g., mode shift, demand management, accessibility, etc.)
- Describe if and how nature-based solutions will be integrated into the proposed project
- Describe how adaptation needs of environmental resources in proximity to the transportation system such as coastal resources like tidal marsh or beaches, wildlife connectivity, wetlands, or fish passage needs are considered in the proposed project (if applicable)

Nature-based solutions will be explored, such as restoring native habitats, healthy soils, and native plants, will make landscapes less vulnerable to fire and reduce flammable vegetation. This will not just create long-term solutions to resilient transportation infrastructure, but also benefit the ecosystem and thereby improve GHG levels and the health of the population. The 2023 California Hazard Mitigation Plan encourages incorporating nature-based solutions into planning, as they can preserve, enhance, or restore a natural system, and reduce GHGs, and provide health benefits and recreational opportunities to under-invested in communities. Nature-based solutions like planting native vegetation can help absorb excess water, reduce floods, and absorb heat and carbon, thereby reducing affects of extreme heat conditions. Other actions that would improve GHG levels in the eastern Fresno County mountain areas are thinning tree canopies, removing dead wood, and reducing flammable materials, which can reduce the intensity and spread of wildfires. Creating greenspaces can create fuel breaks, provide wildlife habitat and corridors, and improve air and water quality. If foothill ranchers are able to improve soil health on their croplands and grasslands, they can reduce GHG emissions from the soil and build resilience to drought.

3C. Grant Specific Objectives; partnerships and stakeholder process (10 points) - Do not exceed the space provided

- Explain how the project demonstrates on-going collaboration and partnerships between sectors and jurisdictions, and across levels of government at a regional scale
- Explain if the project also includes collaboration and partnerships with diverse external stakeholders such as businesses, non-governmental agencies, federal, state, or local agencies, community-based organizations, and community residents
- Explain how the project includes a multistakeholder process that provides an opportunity for meaningful community engagement from communities potentially impacted by any project identified or developed as part of the planning grant

We will consult with Fresno Council of Governments, who put out a Regional Transportation Vulnerability Assessment in 2020, and was awarded a 23-34 Climate Adaptation Planning Grant. Consultations with regional water, irrigation, and resource agencies, such as Kings River Conservation District, will also be vital to share information and stay current with developments. We will work with the impacted school districts, to help disseminate information to families and invite feedback from the community through surveys and public meetings. With the assistance of community leaders, such as city managers and County Supervisors, we can reach a larger swath of residents. Community-based organizations, such as the Fresno Economic Opportunities Commission, that have established relationships with hard to reach and under-served residents, will be utilized to provide opportunities for meaningful public engagement. We will hold in-person meetings in the communities where projects are being explored to involve more individuals and reduce their burden of attending meetings. Utilizing opportunities at already planned and well attended community events will also help reach more residents, such as food distributions and community block parties and festivals. Outreach will include direct mailing, notices in newspapers, online surveys, project website, and advertising on social media networks, to ensure the widest reach possible. All meetings and materials will be available with English and Spanish translations.

Letters of support have been acquired from the Fresno Council of Governments, the City of Clovis, the City of Parlier, the City of Reedley, and the Kings River Conservation District. Outreach will continue with the unincorporated and incorporated communities and the residents who live within the special districts.

3D. Grant Specific Objectives; alignment with other plans and State Goals (10 points) - Do not exceed the space provided

- Explain how the project is consistent with priorities, goals, and actions of the California State Adaptation Strategy, follows State guidance on adaptation planning, and is consistent with any applicable local/regional resilience planning.
- Articulate if the project will identify ways to incorporate transportation-related climate adaptation needs into existing transportation plans, specifically how the project will lead to the identification and development of capital projects that can be programmed as part of local or regional plans
- Explain how the project is in alignment with or augments existing plans, including climate action/adaptation plans, hazard mitigation plans, safety elements of general plans, resilience improvement plans, and/or Coastal Act/Certified Local Coastal Program plans
- Explain how the proposed project addresses public access and Complete Streets needs

The project is consistent with the priorities of the California State Adaptation Strategy, in that it will strengthen protections for climate vulnerable communities, bolster public health and safety, build a climate resistant economy, explore nature-based solutions, and make decisions based on the best available climate science. It also aligns with the California Transportation Plan 2050 goals of safety, climate, equity, economy, environment, and infrastructure.

One outcome of the study is to build on the Fresno County Hazard Mitigation Plan and the California State Hazard Mitigation Plan, and various regional plans and studies, to develop site-specific solutions in hazardous areas. A priority list of projects will be created that can be programmed into the Regional Transportation Plan. This will make it easier to pursue funding for capital projects in the future.

A goal of the project is to ensure access to the roads for the public, and solutions will include the possibility of augmenting the routes to enhance active transportation options or public transit services. Assessing complete streets needs of the communities will advance social equity in the region, and will be a priority of the Plan.

The Plan will include recommendations for changes to County Design Standards that incorporate sustainable technologies, such as use of recycled materials, green construction standards, permeable pavements, cooling pavements, roadway widths, and bike and pedestrian infrastructure that would contribute to a Complete Streets model.

4. Project Management (Total 30 points) See Scope of Work and Cost and Schedule samples and checklists for requirements (Grant Application Guide, Appendix B), also available on the Caltrans grants website: https://dot.ca.gov/programs/transportation-planning/division-of-transportation-planning/regional-and-community-planning/sustainable-transportation-planning-grants
4A. Scope of Work **(15 points)**
4B. Cost and Schedule **(15 points)**

Scope of Work Checklist

The Scope of Work (SOW) is the official description of the work that is to be completed during the contract. Tasks 1-6 outlined in the SOW are for illustrative purposes only. **Applications with missing components will be at a competitive disadvantage.** Please use this checklist to make sure your Scope of Work is complete.

Scope of Work Checklist	
(✓)	**Ensure these items are completed prior to submitting to Caltrans**
✓	Use the Fiscal Year 2025-26 template provided
✓	Include the activities discussed in the grant application
✓	List all tasks using the same title as stated in the Project Cost and Schedule
✓	Include task numbers in accurate and proper sequencing, consistent with the Cost and Schedule
✓	Exclude sub-task numbers; only include sub-headings
✓	Exclude tasks for project management and/or staff/consultant coordination; these activities should be spread among relevant tasks
✓	Include a thorough Introduction to describe relevant background, related planning efforts, the project and project area demographics, including a description of the under-resourced community involved with the project, if applicable
✓	Include a thorough and accurate narrative description of each task
✓	Task 01 is a required task. It must be titled "Project Administration", it cannot exceed 5% of the grant award amount, and only the grantee and sub-recipient(s) can charge against this Task. This Task must only include the following activities and deliverables: • Caltrans and grantee Project kick-off meeting at the start of the grant • Invoicing and quarterly reporting to Caltrans • DBE Reporting (federal grants only)
✓	Include Task 02 for the procurement of a consultant (if needed). This task is for the grantee and sub-applicant(s) only.
✓	Include detailed public participation and services to diverse communities in the Public Outreach Task (excluding technical projects)
✓	Identify public outreach strategies in a manner that provides flexibility and allows for a diverse range of outreach methods (both in-person and virtual), excluding technical projects
✓	Include a Task(s) for a Draft and Final product. The draft plan must include an opportunity for the public to provide feedback (excluding technical projects).
✓	Include a summary of next steps your agency will take towards implementing the project in the Final Product
✓	List achievable project deliverables for each Task
✓	EXCLUDE environmental, complex design, engineering work, and other ineligible activities outlined in the Grant Application Guide

SCOPE OF WORK

Project Information	
Grant Category	**Climate Adaptation**
Grant Fiscal Year	**FY 2025-26**
Project Title	**Eastern Fresno County Climate Adaptation Plan**
Organization (Legal name)	**County of Fresno, Department of Public Works and Planning**

Disclaimer

Agency commits to the Scope of Work below. Any changes will need to be approved by Caltrans prior to initiating any Scope of Work change or amendment.

Introduction

The eastern half of Fresno County is dominated by the Sierra Nevada mountains, where many rivers and small tributaries flow into the Valley. In the 19th century, before the modern era of agriculture and development of the Central Valley began, the region was a floodplain with a Mediterranean Climate. As the area became populated and agriculture thrived, eventually it became necessary to control the rivers during the rainy seasons to mitigate flood hazards. This prompted the establishment of the California State Water Reclamation Project (CSWRP), a network of canals, pipelines, reservoirs, and hydroelectric power facilities that stretch over 700 miles all the way from the northern Sacramento Valley to the Southern San Joaquin Valley and ensured that the water could be stored and delivered to farmers and at the same time protect the population from annual storm flooding, and generate power in the process.

California has been through its share of droughts, and, along with water conservation efforts, this network has seen us through very dry spans of time. Unfortunately, those times will become more frequent with the changing climate, which means warmer, drier winters where there is less snowpack and, therefore, less water for our use during the drier months. Hotter summers not only impact the conditions of both the soil and pavement, but when it finally rains in the winter, the soil cannot absorb the deluge of water and, consequently, flash flooding risks increase. As reported by the Environmental Protection Agency's climate change impact on transportation, extreme hot weather can lead to cracks in pavement, and water getting into the cracks leads to further deterioration and road washouts. We could see warmer storms move over the region in the winter, which means a greater risk of flash flooding in the mountain areas and no snow, which will affect our water supply. And drier conditions set up the mountain areas for wildfire risk, whether it’s due to summer lightning strikes or careless campers. All of these things take a toll on our roadway infrastructure, including bridges and culverts, and we need to take steps to ensure the public will be safe through the challenging times ahead.

The study will cover the eastern unincorporated communities (east of Highways 99 and 41 to the County line) and overlapping incorporated communities to plan for the resilience of transportation infrastructure due to flooding, drought, wildfire, tree mortality, and other climate-related causes. When storm events occur, the roads can flood and impact thousands of residents trying to get to school, work, and access to other vital resources. This area of study was chosen due to its high risk for flash floods, wildfires, road failures, and high concentration of rural communities. Deliverables include a report with scoping, cost estimates, and a list of priority projects, with feasibility of recommended actions, identified through a scientific and public process that considers cost, equity, long-term resiliency, and potential environmental impact. The study is in alignment with the Fresno County Hazard Mitigation Plan, the California Transportation Plan, the California Climate Adaptation Strategy, and Climate Action Plan for Transportation Infrastructure (CAPTI).

Project Stakeholders

The unincorporated communities include, but are not limited to, Auberry, Dinkey Creek, Dunlap, Friant, Hume, Huntington Lake, Piedra, Prather, Shaver Lake, Tollhouse, and Yokuts Valley. The incorporated cities include Clovis, Selma, Parlier, Reedley, Sanger, Kingsburg, Fowler, and Orange Cove. Each community and city will be kept informed and invited to participate in engagement activities. Community-based organizations will be utilized to increase outreach to underserved groups. The Fresno Council of Governments will be engaging in a separate Countywide assessment of vulnerable transportation locations and will be kept informed about locations the County identifies as priorities. The Fresno County Public Works and Planning Department has extensive documentation on past storm and fire events and will help with providing information about previous road closures and damages. Southern California Edison and Pacific Gas & Electric Company will be contacted as they have utilities and infrastructure throughout eastern Fresno County. A consultant will be working on this project to identify locations that need to build climate resiliency, scoping the potential projects for solutions and alternatives, feasibility, cost estimates, and creating a priority list of projects that can be programmed into the Regional Transportation Plan for future funding consideration. The consultant will also be involved with public engagement activities. The County recently was awarded a $3 million grant from the California Department of Forestry and Fire Protection (CalFire), which will aid in the removal and disposal of hazardous trees and ground fuels along roadsides and habitable structures, as well as widening a number of dedicated fire escape routes through the thinning of ground fuels and vegetation, further strengthening community protection.

Overall Project Objectives

Sustainability
The project will identify transportation infrastructure that requires resilient construction that provide sustainable, reliable mobility for people, goods, and services.

Preservation
Nature-based solutions will be explored as options to preserve or enhance the existing environment and transportation system and reduce GHG emissions.

Accessibility
Improve the accessibility of transportation routes for underserved and rural communities trying to reach critical services.

Safety
Decrease the risk of serious injury or fatalities while using the transportation system, especially during and after serious weather events.

Innovation
Explore innovative designs through the use of nature-based solutions to reduce flood and risk, and innovative technologies to build resilience against wildfires.

Economy
Support the local, regional, and national agricultural economy by keeping access open to essential routes.

Health
Keep access to health services available through reliable transportation routes and support infrastructure that reduces GHG emissions.

Summary of Project Tasks

Task 01: Project Administration

This is an Administrative Task that shall only be charged against by the Grantee for the Administration of this grant project. Costs for this task cannot exceed 5% of the grant award amount.

Grantee will manage and administer the grant project according to the Grant Application Guidelines, Regional Planning Handbook, and the executed grant contract between Caltrans and the grantee.

Task Deliverables
• Kick-off meeting with Caltrans - Meeting Notes • Quarterly invoices and progress reports

Task 02: Consultant Procurement

Grantee will procure a consultant, consistent with state and federal requirements, Local Assistance Procedures Manual for procuring non-Architectural and Engineering consultants, the Grant Application Guide, Regional Planning Handbook, and the executed grant contract between Caltrans and the grantee.

Task Deliverables
• Provide current procurement procedures • Provide copy of the Request for Proposal/Qualifications • Provide copy of the contract between consultant and grantee and copies of all amendments to the consultant contract • Meeting notes from project kick-off with consultant

Task 1: Existing Conditions

The consultant will inventory existing roads and past flood and fire-impacted areas.

Task Deliverables
• Inventory/Baseline infrastructure report.

Task 2: Analysis

The consultant will analyze climate change data and make recommendations on potential resiliency improvements, cost estimates, and develop an initial priority list.

Task Deliverables
• Data collection and Analysis report, including compiled GHG emissions inventory and identified data gaps. Report on target emissions reductions, including proposed targets and rationale. Analysis report shall include recommended actions, reduction strategies, supporting data and rationale.

Task 3: Public Outreach

The consultant will be tasked with developing strategy for public outreach, through use of social media, traditional media, and community-based organizations; Producing surveys, flyers, and advertisements; providing outreach and a minimum of five (5) meetings in multiple languages as needed (combination of in-person and virtual) and present draft plan, priority list, and conceptual drawings to the public and required personnel.

Task Deliverables
• Copies of sign-in sheets/proof of attendance of all public outreach meetings and events, including summary report of outreach and feedback received. Brochures, promotional videos, or websites developed for advertising the Plan.

Task 4: Advisory Committee Meetings

The consultant will be tasked with attending and presenting to advisory groups as needed or requested.

Task Deliverables
• Summary report of feedback received and copies of meeting sign-in sheets/proof of attendance.

Task 5: Draft and Final Plan

The consultant will prepare a Draft plan based on their analysis and feedback from County staff and Cities. The consultant will prepare a final plan based on feedback received from public outreach, the Board of Supervisors, County staff, and Cities.

Task Deliverables
• Draft Plan for County and Cities Review – list of comments • Draft Plan for Public Review – list of comments • Draft Plan for Board of Supervisors Review – list of comments • Final Plan that includes a summary of next steps towards implementation, a starting list of projects and their ranked prioritization based on most efficient use of funds, credits FHWA, FTA, and/or Caltrans on the cover or title page, submitted to Caltrans in an ADA accessible electronic copy

Task 6: Board Review/Approval

The consultant will be tasked with attending and presenting the Draft Plan and Final Plan to the Board of Supervisors, and potentially other oversight groups.

Task Deliverables
• Present Draft and later, Final Plan at the Board of Supervisors meetings • Preparation of Visual Media Presentation of Draft and Final Plans through slideshow or video • Assisting with preparation of advance agenda material • Give presentation and answer questions from the Board, and defend recommendations • Give presentations at up to 2 additional meetings if needed

California Department of Transportation

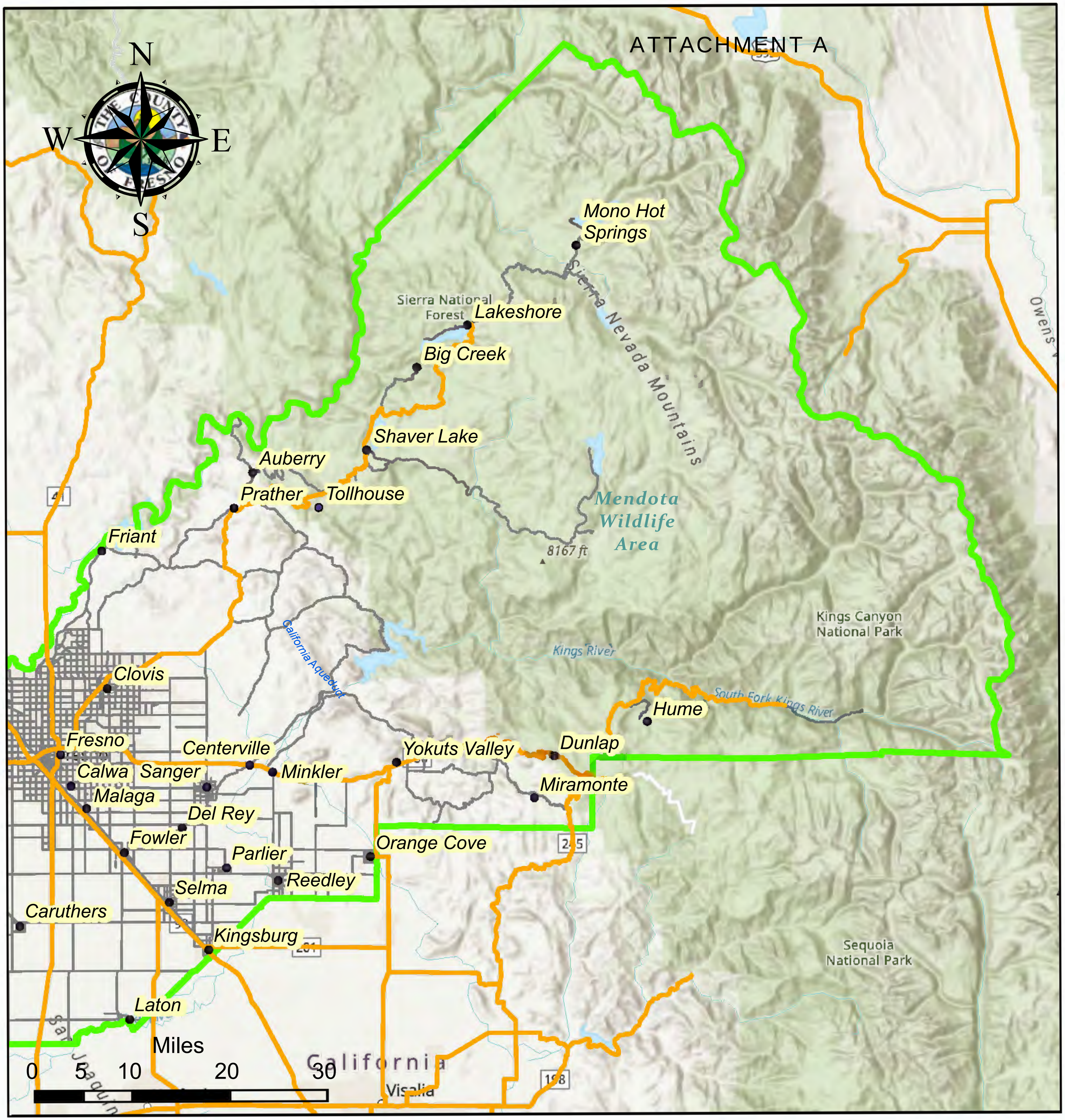
Sustainable Transportation Planning Grant Program

COST AND SCHEDULE

Grant Category	Climate Adaptation
Grant Fiscal Year	FY 2025-26
Project Title	Eastern Fresno County Climate Adaptation Plan
Organization (Legal name)	County of Fresno, Public Works and Planning
Disclaimers	Agency commits to the Cost and Schedule below. Any changes will need to be approved by Caltrans prior to initiating any Cost and Schedule change or amendment. Use only whole dollars in the financial information fields. No rounding up or down and no cents. Use the Local Match Calculator to ensure that grant and local match amounts are correct: Local Match Calculator (posted on-line)
Reimbursements/ Invoicing	Does your agency plan to request reimburesement for indirect costs? ☐ Yes ☑ No If yes, what is the estimated indirect cost rate? ______ Does your agency plan to use the Tapered Match approach for invoicing purposes? ☐ Yes ☑ No

Task #	Task Title	Grant Amount*	Estimated Local Cash Match*	Estimated Local In-Kind Match*	Estimated Total Project Cost*	FY 2025/26												FY 2026/27												FY 2027/28											
						J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J
01	Project Administration (no more than 5% of total grant funds)	$70,000	$9,069	$0	$79,069					X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
02	Consultant Procurement	$50,000	$6,478	$0	$56,478						X	X	X																												
03	Existing Conditions	$150,000	$19,434	$0	$169,434									X	X	X																									
04	Analysis	$900,000	$116,605	$0	$1,016,605											X	X	X																							
05	Public Outreach	$50,000	$6,478	$0	$56,478														X	X	X																				
06	Advisory Committee Meetings	$20,000	$2,591	$0	$22,591									X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X								
07	Draft and Final Plan	$250,000	$32,390	$0	$282,390									X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	
08	Board Review/Approval	$10,000	$1,296	$0	$11,296																																		X	X	
	Totals	**$1,500,000**	**$194,341**	**$0**	**$1,694,341**																																				

Fresno County East Side Climate Adaptation Planning



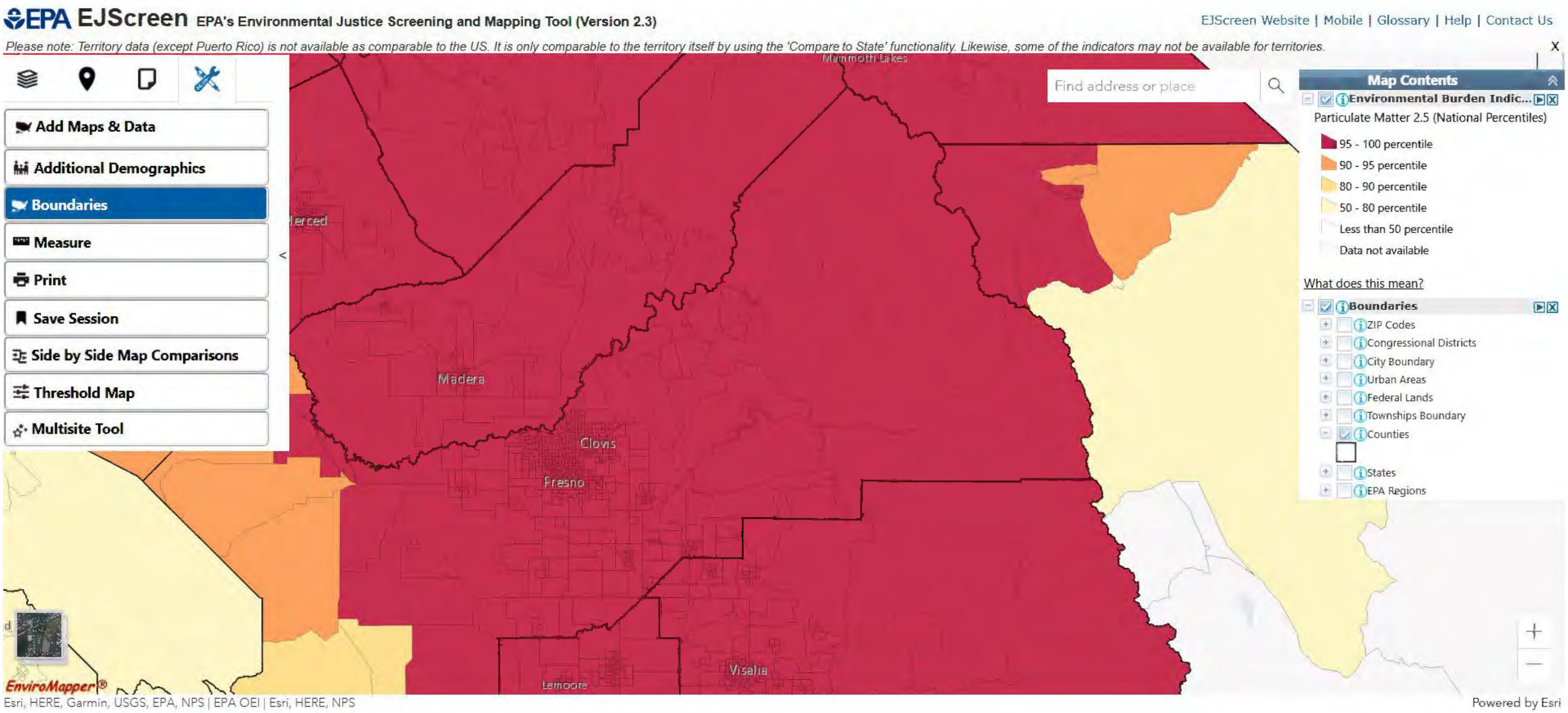
Legend

- Fresno County Boundary
- Highways
- County Roads
- Communities

Prepared by:
Diana Nuttman, Staff Analyst
County of Fresno
Public Works & Planning, Design Division
01/05/2025

EPA EJScreen for Eastern Fresno County – Particlulate Matter 2.5

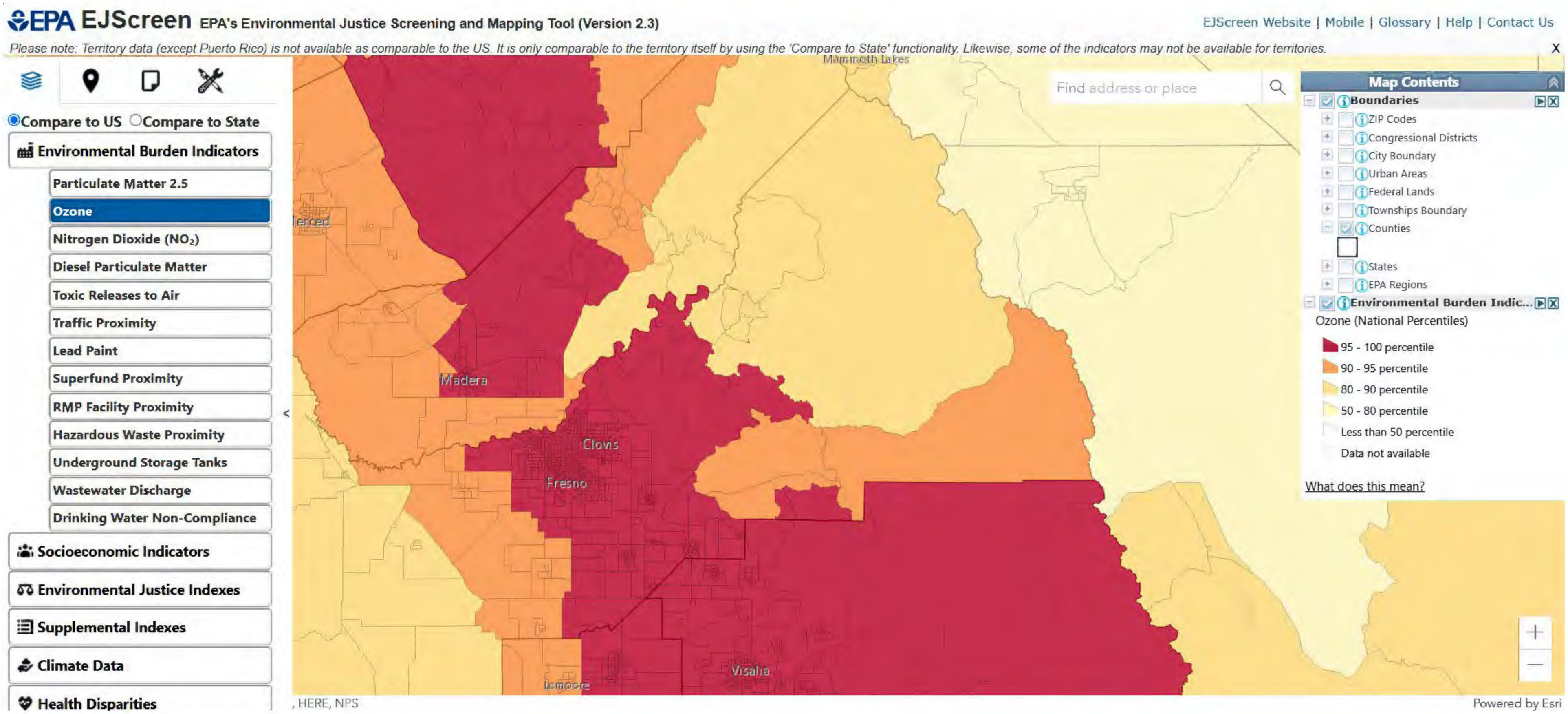
Red portions are in the 95-100 percentile, Orange portions are 90-95 percentile, and Yellow is 80-90 percentile. Notice that the majority of Fresno County is in the 95-100 percentile.



https://ejscreen.epa.gov/mapper/
Accessed on January 13, 2025

EPA EJScreen for Eastern Fresno County – Ozone

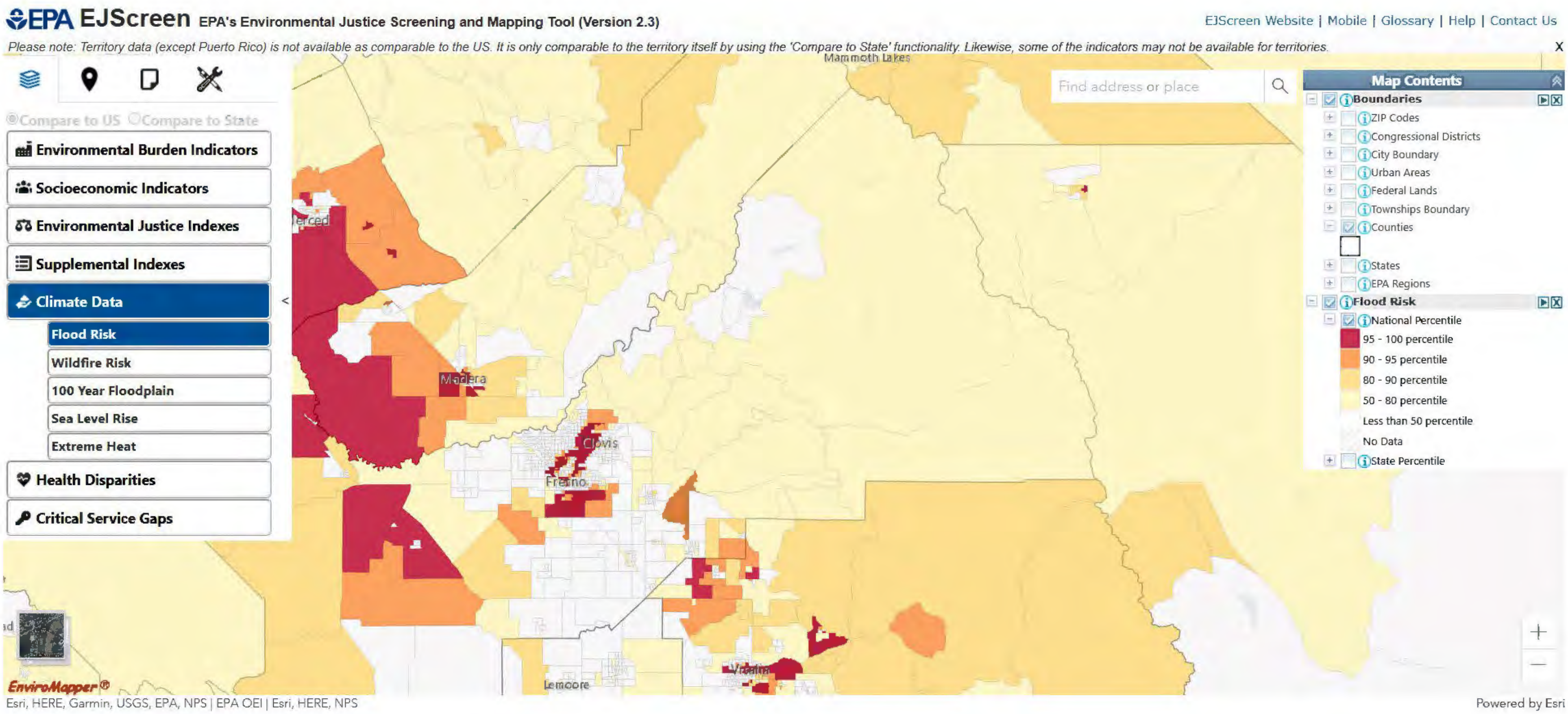
Red portions are in the 95-100 percentile, Orange portions are 90-95 percentile, and Yellow is 80-90 percentile. Most of the Sierra Nevada is above the 50-80 percentile, espectially the foothill and Valley areas which are in the 95-100 percentile.



https://ejscreen.epa.gov/mapper/
Accessed on January 13, 2025

EPA EJScreen for Eastern Fresno County – Flood Risk

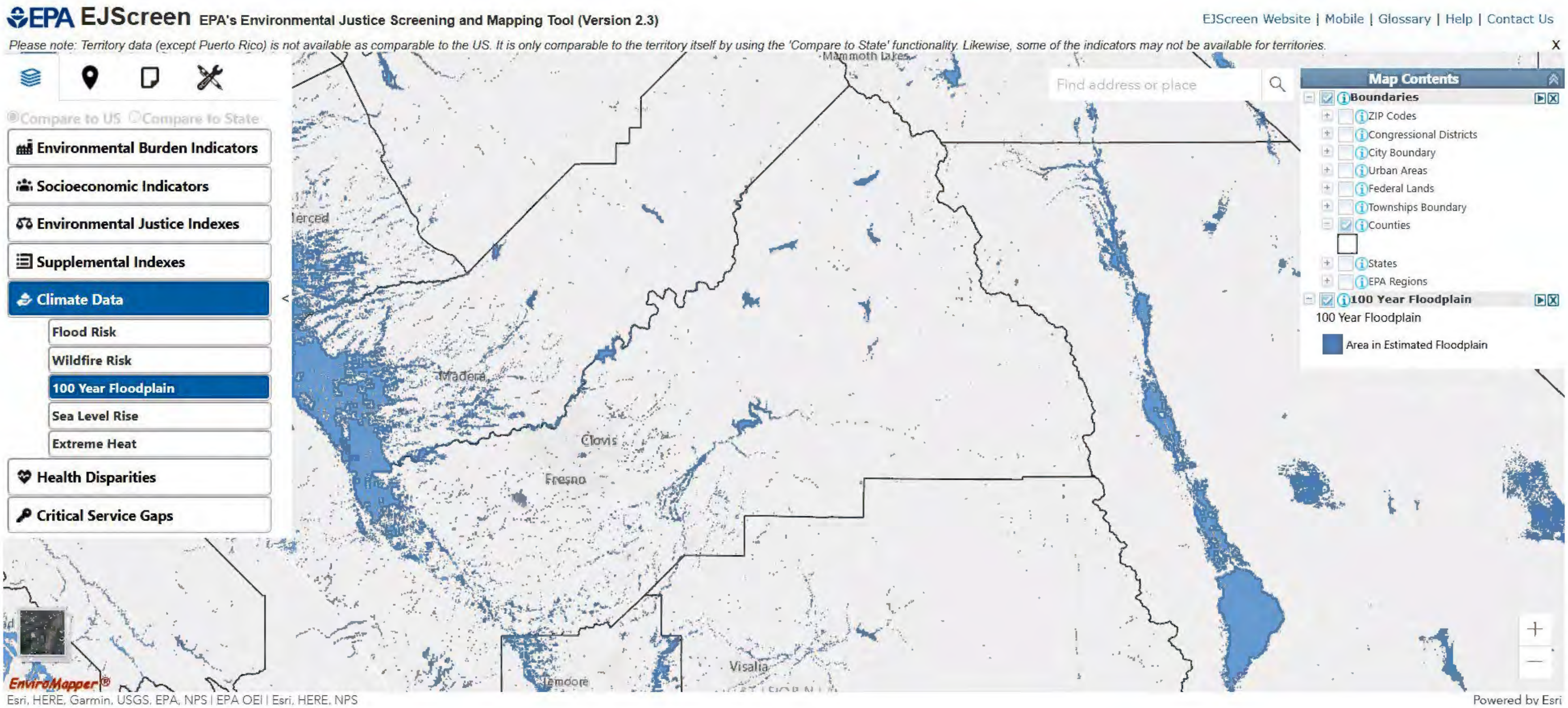
Red portions are in the 95-100 percentile, Orange portions are 90-95 percentile, and Yellow is 80-90 percentile.
Most of the Sierra Nevada is above the 50-80 percentile, although a portion of the Valley floor is at significant flood risk.



https://ejscreen.epa.gov/mapper/
Accessed on January 13, 2025

EPA EJScreen for Eastern Fresno County – 100-year Floodplain

The areas in blue are considered to be in the 100-year floodplain. Many of the larger blue areas in Eastern Fresno County are dammed reservoirs, constructed for hydroelectric power, flood control, and irrigation.

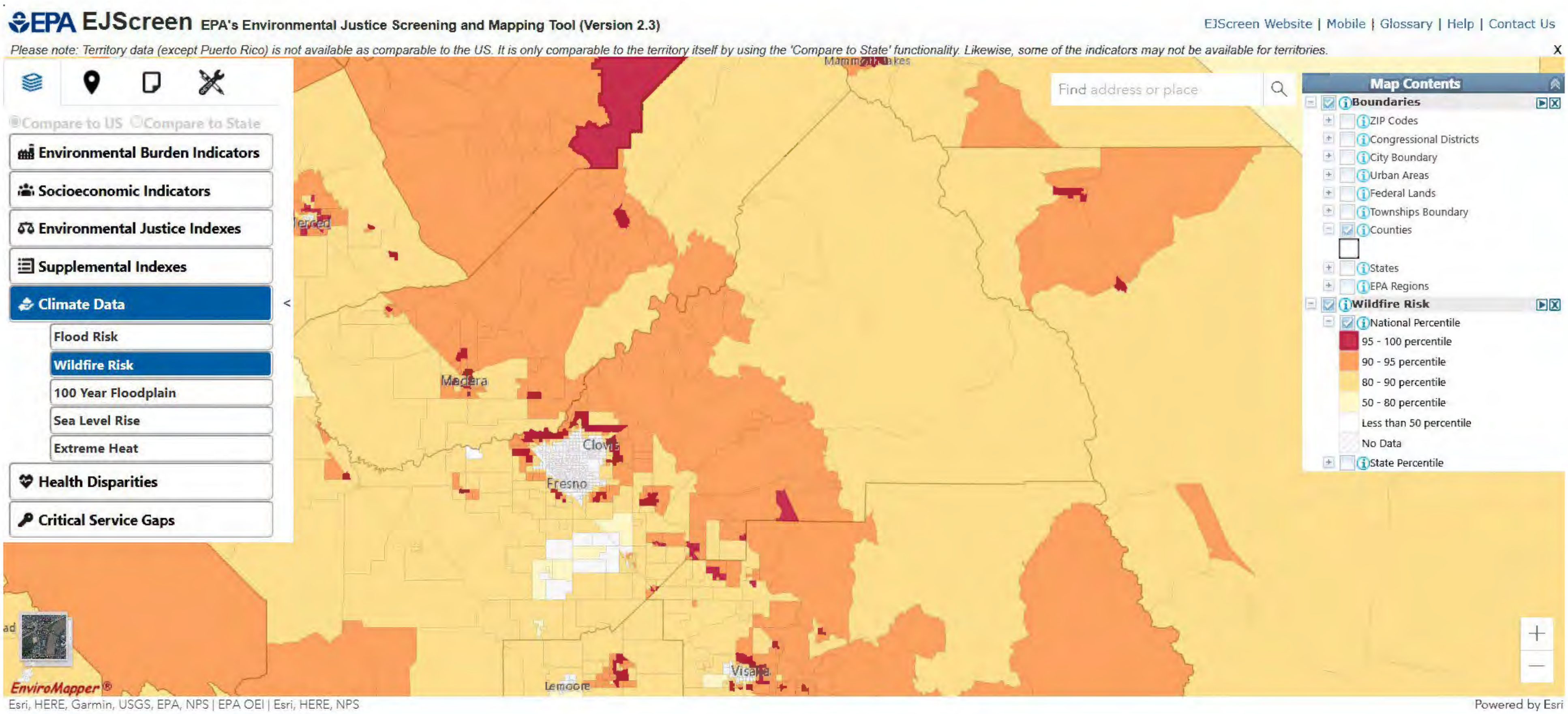


https://ejscreen.epa.gov/mapper/

Accessed on January 13, 2025

EPA EJScreen for Eastern Fresno County – Wildfire Risk

Red portions are in the 95-100 percentile, Orange portions are 90-95 percentile, and Yellow is 80-90 percentile. Most of the Sierra Nevada is above the 80-90 percentile, especially the foothills which are in the 90-95 percentile.

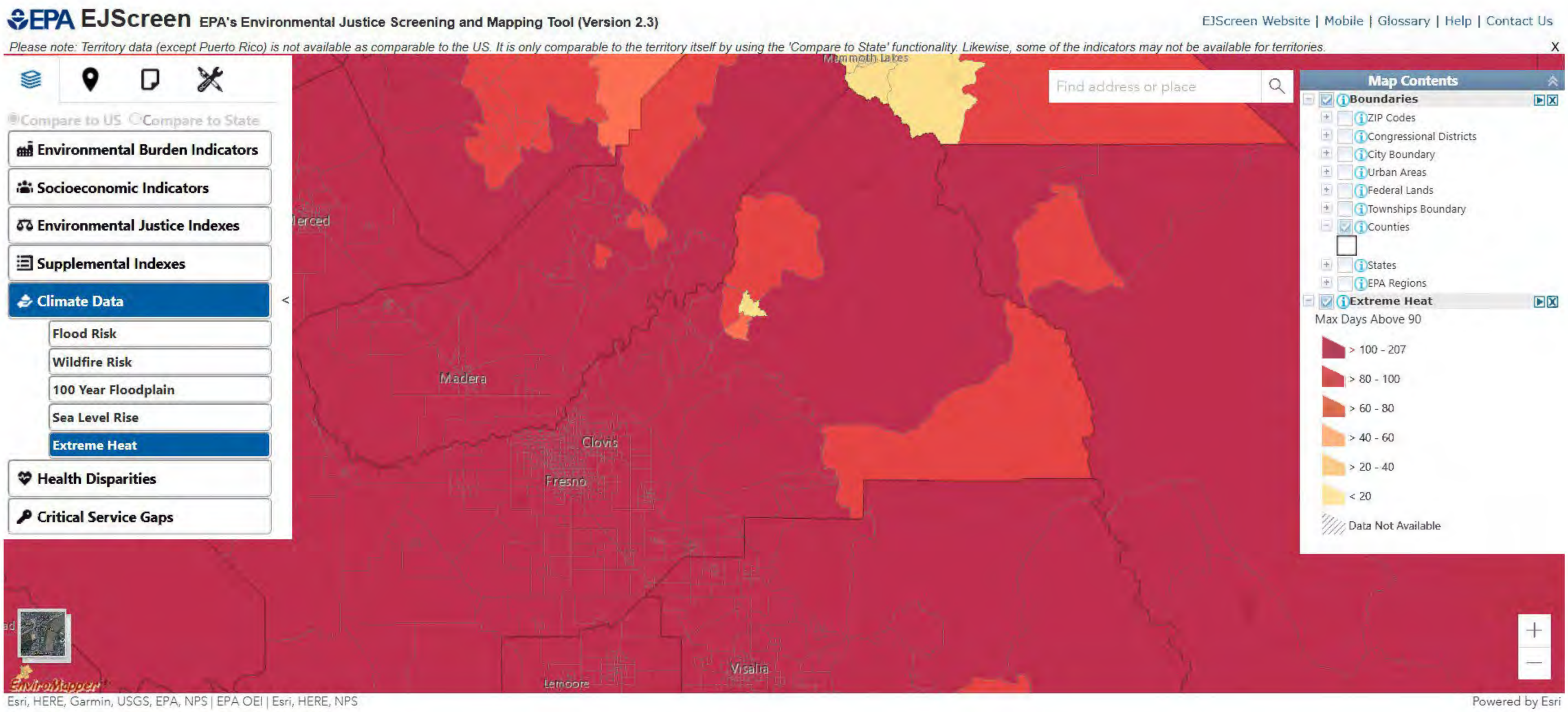


https://ejscreen.epa.gov/mapper/

Accessed on January 13, 2025

EPA EJScreen for Eastern Fresno County – Extreme Heat

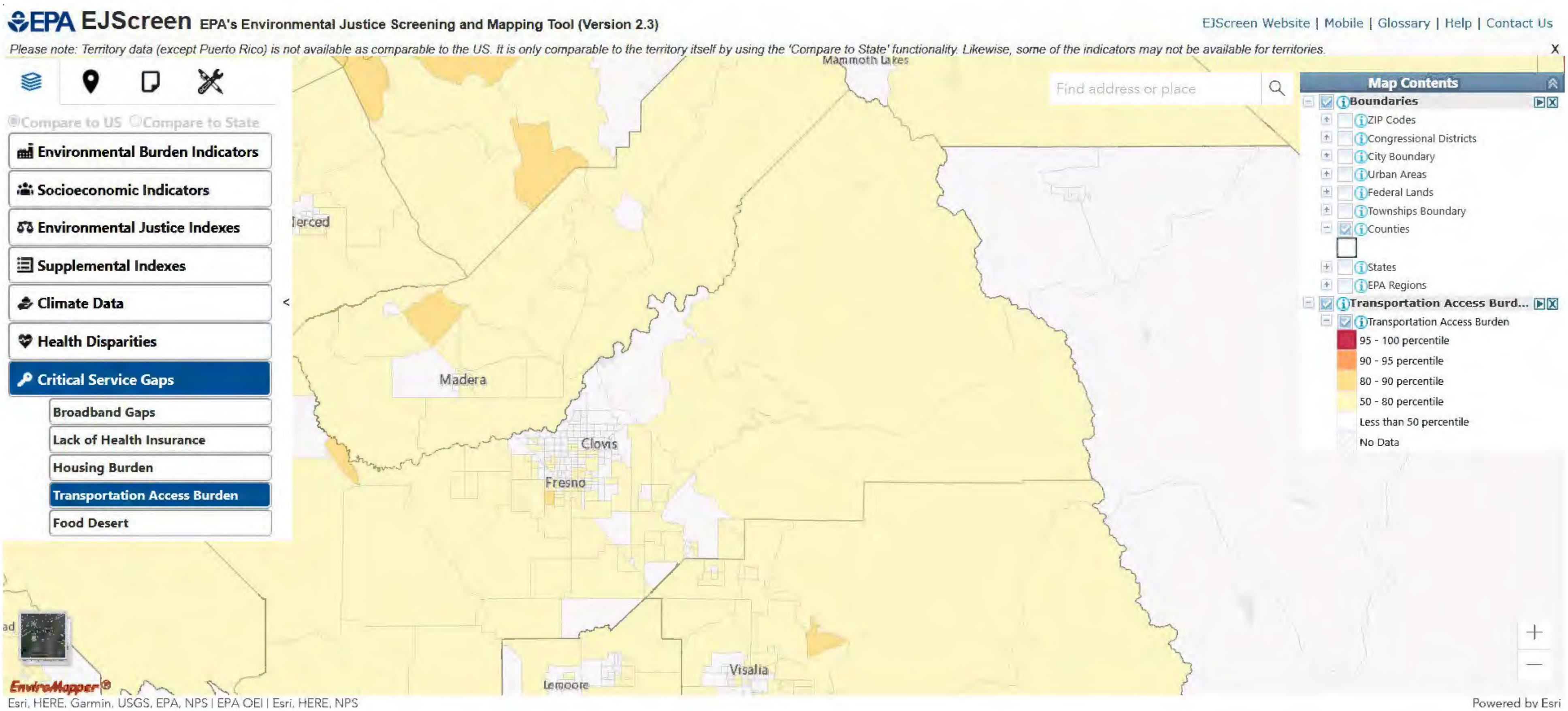
Red portions are 100-207 days per year above 90°F and dark orange portions are 90-100 days per year above 90°F.
The summers in Fresno County frequently stay over 100°F for weeks on end with no rain.



https://ejscreen.epa.gov/mapper/
Accessed on January 13, 2025

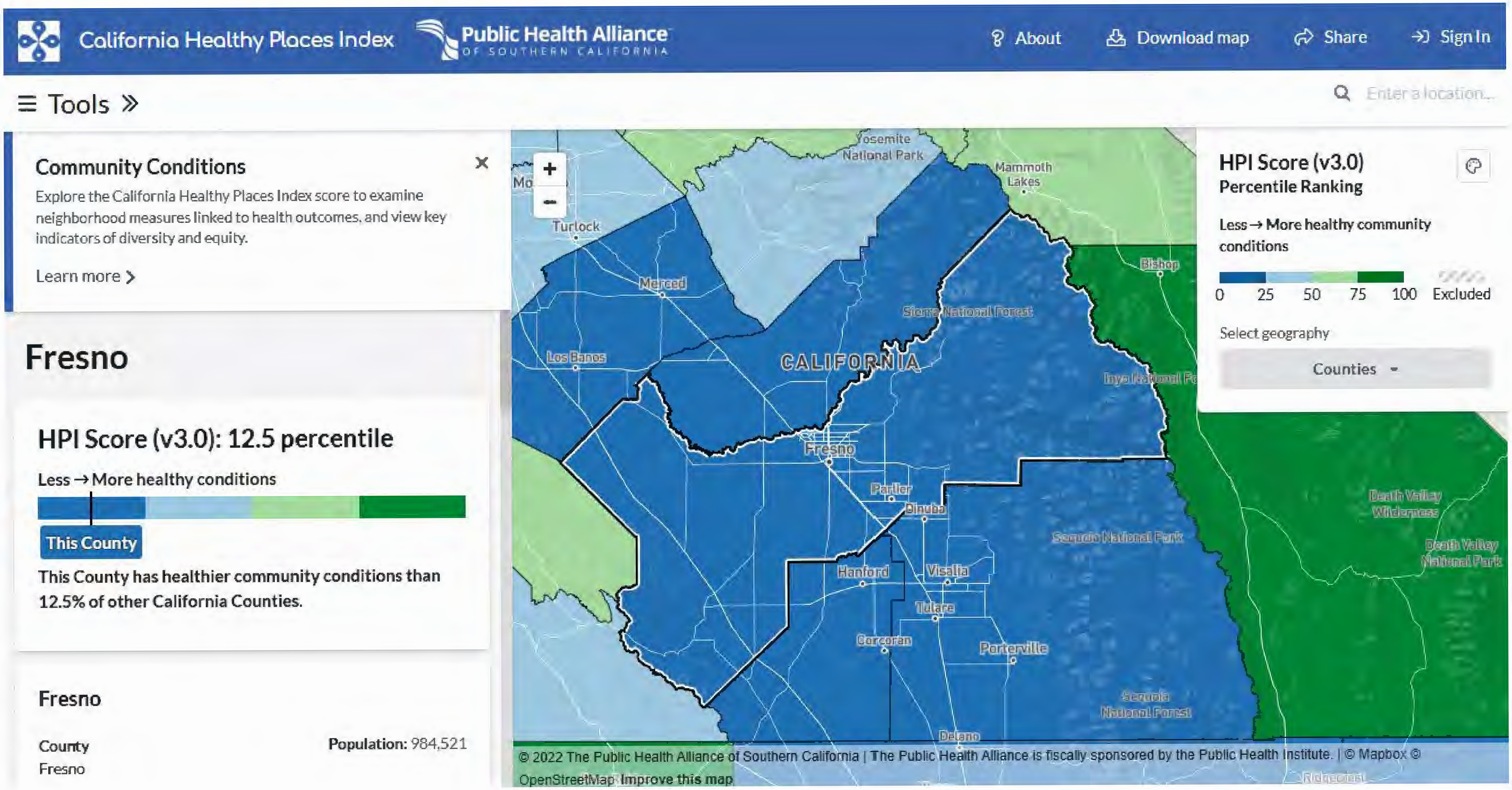
EPA EJScreen for Eastern Fresno County – Transportation Access Burden

Red portions are in the 95-100 percentile, Orange portions are 90-95 percentile, and Yellow is 80-90 percentile. Most of Fresno County falls in the 50-60 percentile. The concern is the condition of transportation infrastructurfe in the event of natural hazards.



https://ejscreen.epa.gov/mapper/
Accessed on January 13, 2025

HEALTHY PLACES INDEX (3.0)
FRESNO COUNTY SCORE: 12.5 PERCENTILE



https://map.healthyplacesindex.org
Accessed on January 4, 2025

HEALTHY PLACES INDEX (3.0)
FRESNO COUNTY SCORE: 12.5 PERCENTILE

Policy Action Areas

Economic

*This County has healthier economic conditions than **26.8%** of other California Counties.*

Indicator	Value	Percentile Ranking
Above Poverty	54.9%	7.1
Employed	68.2%	50.0
Per Capita Income	$24,400	20.7

Education

*This County has healthier education conditions than **33.9%** of other California Counties.*

Indicator	Value	Percentile Ranking
Bachelor's Education or Higher	21.2%	43.1
High School Enrollment	97.5%	41.5
Preschool Enrollment	40.6%	30.4

Social

*This County has healthier social conditions than **28.6%** of other California Counties.*

Indicator	Value	Percentile Ranking
2020 Census Response Rate	68.6%	55.4
Voting	72.6%	8.9

Transportation

*This County has healthier transportation conditions than **1.8%** of other California Counties.*

Indicator	Value	Percentile Ranking
Active Commuting	3.32%	25.0
Automobile Access	91.8%	8.9

Neighborhood

*This County has healthier neighborhood conditions than **14.3%** of other California Counties.*

Indicator	Value	Percentile Ranking
Park Access	60.1%	32.1
Retail Density	3.33 jobs per acre	66.1
Tree Canopy	5.12%	19.6

Healthcare Access

*This County has healthier healthcare access conditions than **21.4%** of other California Counties.*

Indicator	Value	Percentile Ranking
Insured Adults	87.4%	25.9

Housing

*This County has healthier housing conditions than **10.7%** of other California Counties.*

Indicator	Value	Percentile Ranking
Homeownership	53.3%	13.8
Housing Habitability	98.9%	55.4
Low-Income Homeowner Severe Housing Cost Burden	8.90%	85.7
Low-Income Renter Severe Housing Cost Burden	28.4%	10.7
Uncrowded Housing	90.6%	12.1

Clean Environment

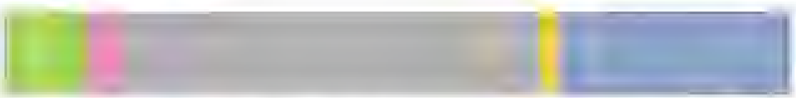
*This County has healthier clean environment conditions than **3.6%** of other California Counties.*

Indicator	Value	Percentile Ranking
Diesel PM	0.179 kg/day	17.9
Drinking Water Contaminants	713	1.8
Ozone	0.0604 ppm	7.1
PM 2.5	13.2 µg/m³	5.4

HEALTHY PLACES INDEX (3.0)
FRESNO COUNTY SCORE: 12.5 PERCENTILE

Racial Justice and Health Equity

Race/Ethnicity



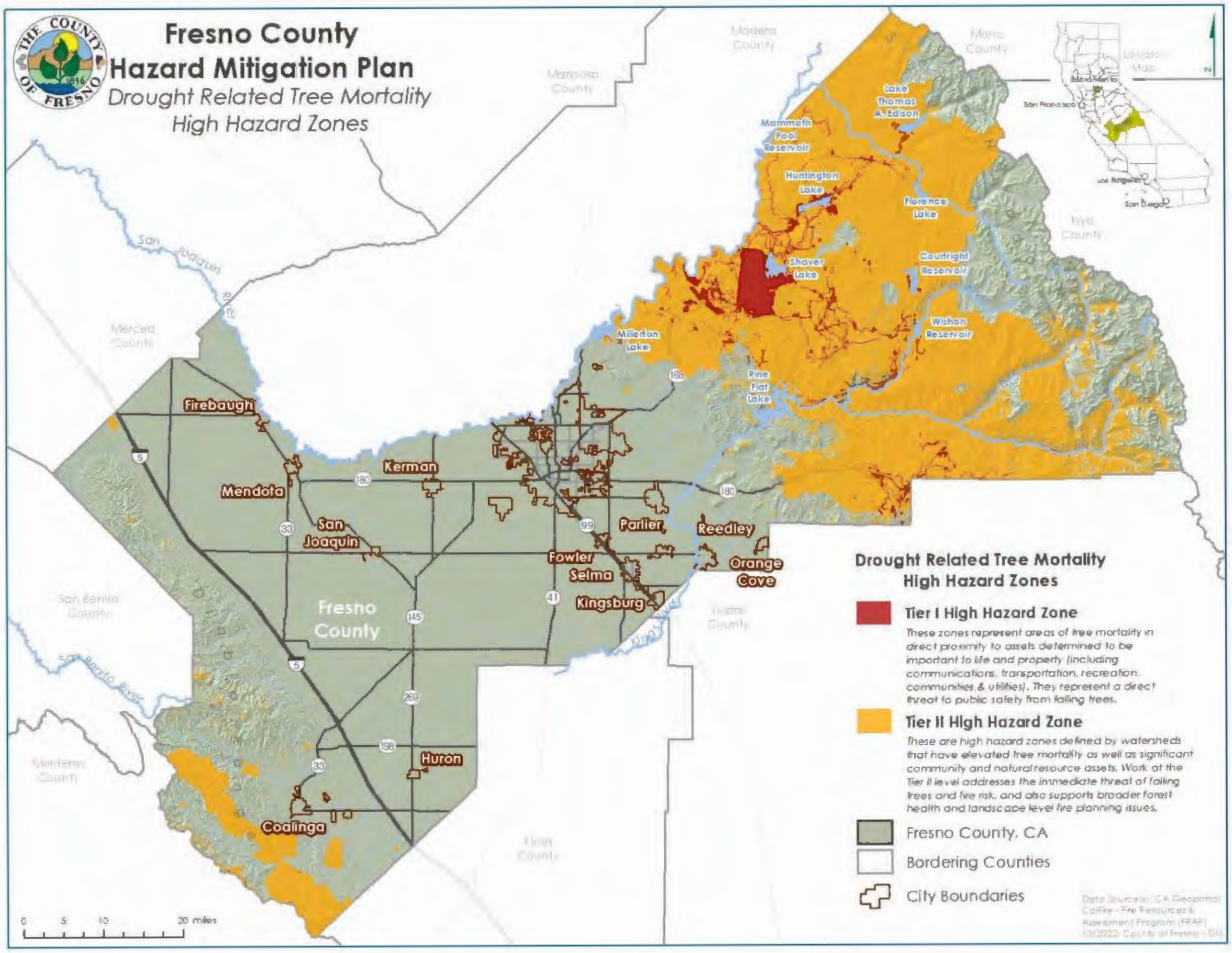
Click to expand groups and show tribal affiliation or ancestry detail.

American Indian or Alaska Native alone	0.5%
Asian alone	10.2%
Black or African American alone	4.5%
Hispanic or Latino of any race	53.0%
Native Hawaiian or other Pacific Islander alone	0.1%
Some other race alone	0.2%
Two or more races	2.1%
White alone	29.4%

Equity

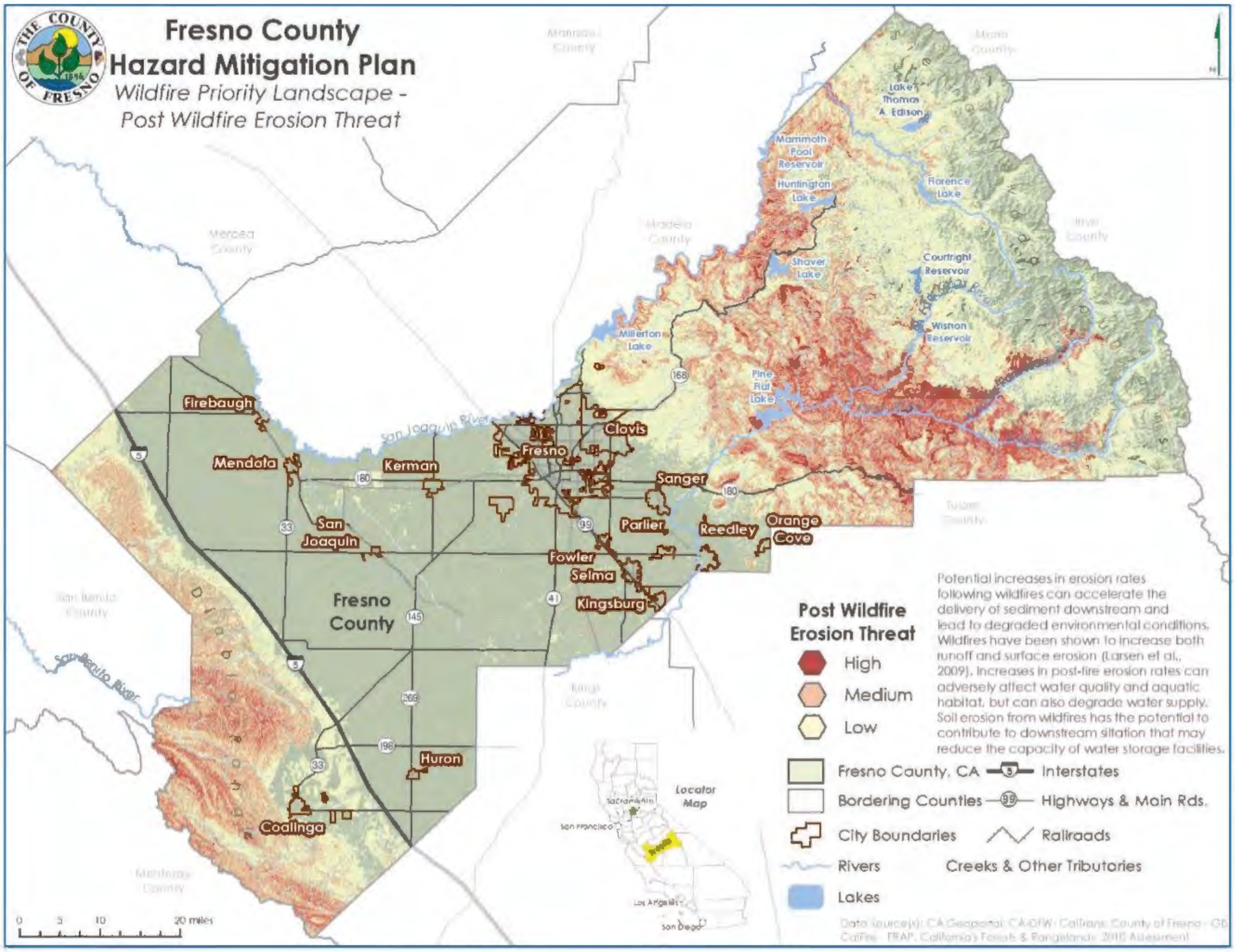
Indicator	Value	Percentile Ranking
Historically Redlined (Tract)	N/A	N/A
Race/Ethnicity Diversity Index	51.8%	66.1
Race/Ethnicity Diversity of Electeds (County)	-43.3%	24.1

Figure 9. Fresno County Drought Related Tree Mortality High Hazard Zones



Source: CA Geoportal; CalFire – Fire Resources & Assessment Program (FRAP), 10/2022; County of Fresno - GIS

Figure 31. Fresno County Wildfire Priority Landscape - Post Wildfire Erosion Threat



Source: CA Geoportal; CA-DFW; CalTrans; County of Fresno – GIS, CalFIRE – FRAP, California's Forests and Rangelands: 2010 Assessment

Capital Weather Gang

California endures record-setting 'kiln-like' heat as fires rage, causing injuries

Creek Fire explodes in size, trapping and injuring campers

September 6, 2020

By Andrew Freedman

California just witnessed one of its hottest weekends in memory, which intensified destructive wildfires that erupted.

The scorching temperatures forced the National Weather Service to issue heat alerts for nearly the entire state. Many areas were also under red-flag warnings for high fire danger as the heat worsened blazes already burning and helped fuel new ones.

Numerous locations in California experienced their hottest September day on record Sunday. A few spots saw their highest temperatures ever observed in any month.

Woodland Hills,just 20 miles from downtown Los Angeles, soared to 121 degrees, the highest temperature ever observed in Los Angeles County. Chino, 32 miles east of Los Angeles, also hit 121 degrees. Both the Chino and Woodland Hills marks were the highest ever recorded west of the mountains in Southern California.

Farther north, the mercury in San Luis Obispo, just 10 miles from the Pacific Ocean, reached a sweltering 120 degrees. This may be the highest temperature ever measured so close to the ocean in the Americas. Even downtown San Francisco touched 100 degrees, breaking a record that stood for more than a century.

The blistering heat helped fuel a serious wildfire situation Saturday when the Creek Fire in the Sierra National Forest erupted, about 290 miles north of Los Angeles. The blaze was first detected Friday night and rapidly grew to at least 45,500 acres by Sunday afternoon.

That fire trapped about 1,000 people near Mammoth Pool reservoir as flames crossed the San Joaquin River, including about 150 people who became stranded at a boat launch, the Associated Press reported.

A backpacking trip cut short by unforeseen thunder, ash rain, and having to drive through literal fire to evacuate #SierraNationalForest in time. Grateful to the SNF ranger who led us down... wish we we got her name. #CreekFire @mercnews @sfchronicle @ABC7 @KTVU pic.twitter.com/37Ys7XGJ2a
— Juliana Park (@julipdoe) September 6, 2020

According to the AP, 200 people were rescued from the Mammoth Pool Campground by military helicopters. Two of them were severely injured, 10 had "moderate injuries" and others had minor or no injuries. According to the California Air National Guard, this was the largest wildfire-related air evacuation in recent memory.

The Fresno Bee reported that at one point, people trapped by the flames were told to jump in the water as a last resort should the flames get too close. However, Sierra National Forest officials said the fire burned around the reservoir and the evacuations took place because the blaze blocked evacuation routes.

The Fresno County Sheriff's Office ordered new evacuations Sunday morning as the fire continued to grow.

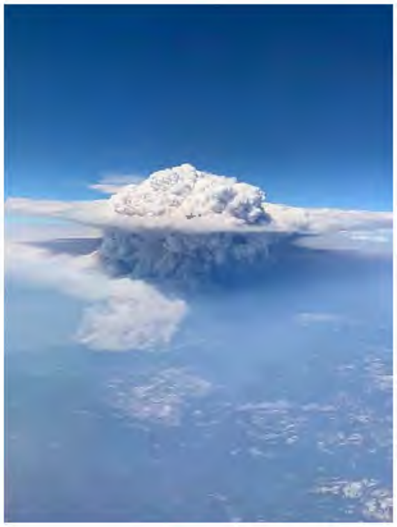
The Creek Fire sent smoke, embers and fine particles 45,000 feet in the air Saturday and Sunday, forming a pyrocumulonimbus cloud. Such clouds, which look like explosions from a distance, are fire-driven weather systems. The one seen Saturday was causing lightning to strike areas downwind along with erratic and gusty surface winds. Ash fell more than 10 miles away from the fire.

Fires this weekend are what are known as plume-dominated blazes, which occur when the environment is favorable for the upward billowing of smoke and vertical transfer of heat.

Smoke from the Creek Fire billows beyond a ridge as seen Sept. 5 from Huntington Lake, Calif. (Eric Paul Zamora/Fresno Bee/AP)

Thalia Dockery
@SweetBrown_Shug · **Follow**

Replying to @wxbrad I took this today from our Southwest flight from San Jose to Las Vegas



8:50 PM · Sep 5, 2020

3.3K Reply Copy link

Read 129 replies

Plume-dominated fires can frequently become firestorms, taking on the structure of a thunderstorm because of their incredible vertical release of heat. Extreme fire behavior, as has been seen with the Creek Fire, is often a characteristic of plume-dominated fires.

The Creek Fire appeared to produce multiple fire tornadoes based on Doppler radar data, which revealed vortices inside the fire and smoke plume that matched the size and shape of tornadoes.

Dr. Daniel Swain
@Weather_West · **Follow**

Serious situation developing in foothills of Fresno County near #Oakhurst. #CreekFire has exploded in size & intensity at a time when 1000s of visitors have crowded area. Massive pyrocumulus cloud indicative of extreme fire behavior, & #pyrotornado may have occurred.#CAwx #CAfire

Watch on X

GIF

4:59 PM · Sep 5, 2020

1.1K Reply Copy link

Read 45 replies

A change of wind speed and direction with height known as wind shear caused the smoke plume to rotate. In an unusual turn of events, the smoke plume's updraft also appeared to repeatedly split, with pairs of spinning rotations repeatedly forming and drifting away from one another.

The Loyalton Fire in Lassen County, Calif., produced five or more fire tornadoes barely three weeks ago, prompting the National Weather Service to issue a first-of-its-kind fire tornado warning.

In addition to the Creek Fire, firefighters are still battling the second-, third- and fourth-largest fires in state history that erupted during a mid-August heat wave and unusual thunderstorms north of San Francisco. Although those fires are better contained, the heat, dry weather and shifting, strong offshore winds are causing an uptick in their activity.

Since Aug. 15, the state has seen more than 1.6 million acres burned and 900 new fires started, along with eight deaths and nearly 3,300 destroyed structures. In an average California fire season to date, about 310,000 acres are burned, according to Cal Fire, the state firefighting agency.

Daniel Swain, a climate researcher at the University of California at Los Angeles, said the state may set a record for the "most acres burned in the modern era" as soon as Monday.

Firefighting operations will continue to be extremely challenging because of the triple-digit heat and extremely low humidity levels, according to the Weather Service.

Forecasters are monitoring two periods for strong, desiccating offshore winds to pick up in strength early this week. The first looks as though it could take place Sunday night through Monday evening, with the next taking shape as a rare early-season Santa Ana wind event in Southern California on Tuesday into Wednesday.

ATTACHMENT F

The Weather Service's forecast office in Los Angeles is predicting "elevated to critical fire danger" through Wednesday.

Dakota Smith
@weatherdak · **Follow**

Hi-res imagery of the Creek Fire's explosive growth today.

Pyrocumulonimbus mania. Wow.

Watch on X

GIF

10:43 PM · Sep 5, 2020

1.7K Reply Copy link

Read 33 replies

Punishing heat

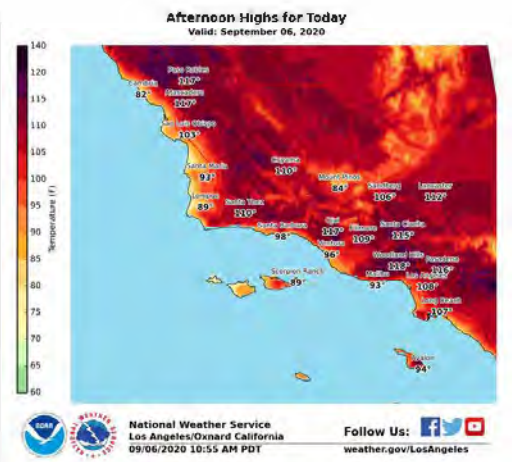
The Weather Service office in Los Angeles described Sunday's heat as "kiln-like," predicting a "dangerous to potentially deadly" extreme heat event.

Ninety-nine percent of the state's population was under an excessive-heat warning or heat advisory, according to the Weather Service office in Sacramento.

In a sign of the heat to come, temperatures did not drop below the 90s on Saturday night and into early Sunday in some locations from the San Fernando Valley to parts of L.A. County. Two temperature stations in the L.A. area were still hovering above the century mark at 3:02 a.m. local time, the Weather Service said.

NWS Los Angeles
@NWSLosAngeles · **Follow**

Dangerous and deadly record breaking heat today across SW Calif. ALL-TIME record highs expected for some locations! Many valley/desert areas expected to hit 110-120°, with portions of the coastal plain soaring over 100°. #LAheat #LAWeather #cawx #Socal



11:12 AM · Sep 6, 2020

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High temperatures in Southern California on Sunday ranged from 105 to 115 degrees near the coast to up to 120 degrees in inland areas, which would edge past all-time-high temperature records in some locations.

Some noteworthy temperature records that have already fallen include:

- Burbank, Calif., tied its all-time-high temperature record of 114 degrees on both Saturday and Sunday.

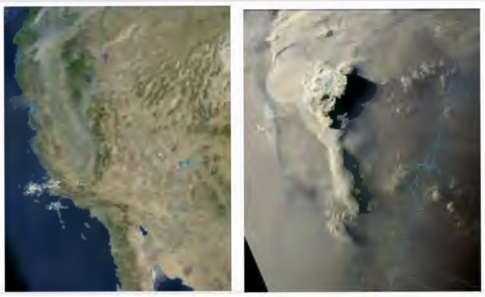
- Palm Springs hit 122 degrees Saturday, breaking its previous September record from 1950.
- Death Valley, Calif., set a September record with a high of 125 degrees, beating the old record of 123, set in 1996. This comes just two weeks after reaching 130 degrees, an August record, and the highest temperature observed globally since at least 1931.
- The 121-degree temperature recorded in Woodland Hills, Calif., on Sunday was both the highest temperature on record there and the highest temperature seen anywhere in Los Angeles, Ventura, Santa Barbara and San Luis Obispo counties, the Weather Service said.

The massive heat dome sprawled over western North America established September records from Mexico to the Colorado Rockies. Mexicali, Mexico, soared to 121.1 degrees Saturday, the country's hottest temperature ever observed during the month. Denver hit 101 degrees Saturday, its highest September temperature and the latest on record it has crossed the century mark. Nearby Boulder hit 99 degrees both Saturday and Sunday, its hottest temperature so late in the year. On Tuesday, Denver and Boulder are expecting snow.

La Junta, Colo., about 60 miles southeast of Pueblo, registered a high of 108 degrees, a state record for the month of September.

Drew Tuma
@DrewTumaABC7 · Follow

On the left, California at 11am this morning from satellite. On the right, the same shot at 7pm this evening. Shows you the enormous amount of smoke sent into the atmosphere from numerous fires that broke out today. #CreekFire #ValleyFire #ElDoradoFire



9:44 PM · Sep 5, 2020

9.4K Reply Copy link

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Temperatures are forecast to cool some by Tuesday but to remain above normal in most of California for much of the week.

Studies show human-caused climate change is tilting the odds in favor of more frequent, severe and longer-lasting heat waves, as well as larger wildfires throughout large parts of the West. Research published last month, for example, shows climate change is tied to more frequent occurrences of extreme-fire-risk days in parts of California during the fall. (Meteorologists define the fall as beginning Sept. 1.)

Michael Wehner, who researches extreme weather events at Lawrence Berkeley National Laboratory, estimates "climate change has caused extreme heat waves to be 3 to 4 degrees Fahrenheit warmer in California." These trends "will continue as the planet continues to warm," he said in an email, noting the amount of warming will depend on future greenhouse gas emissions.

The heat wave has prompted warnings from the operator of California's electricity grid that rolling blackouts may need to be instituted during times of peak power use, and it has asked residents to take steps to reduce electricity use during times of peak demand. A "Stage 2 warning" was issued Saturday and Sunday, indicating all efforts at outage mitigation had been taken, but it was not followed by outages.

The California ISO declared a "Flex Alert" on Sunday, calling for reduced electricity use between 3 p.m. and 9 p.m. local time.

The state utility PG&E has also warned it may institute rolling outages if winds get too strong early this week, because its power infrastructure has been blamed for sparking some of the state's largest and deadliest blazes in recent years.

Extreme heat has been the top weather-related killer in the United States during the past 30 years, and combined with poor air quality from nearby fires as well as the coronavirus pandemic, the health threat is particularly acute. Air conditioning provides the best protection from excessive heat, but because of the possibility of exposure to the virus at cooling shelters, the pandemic may keep people who lack air conditioning at home.

Jason Samenow, Scott Wilson and Matthew Cappucci contributed to this report.

Huntington Lake is seen in the foreground as the Creek Fire burns in the distance Sept. 5, about 35 miles northeast of Fresno. (Eric Paul Zamora/Fresno Bee/AP)

Berkeley Forests

Previous tree mortality and density big factors in the devastating 2020 Creek Fire

May 18, 2022

Wildfires burning in western US Forests have increased in size and severity since the late 20th century, with a number of recent fires exhibiting characteristics that match the criteria for mass fires – or fires that burn with high intensity over large continuous areas for long durations of time. Operational fire behavior models, commonly used by federal and state fire suppression agencies to predict how wildfires will behave, cannot predict mass fire behavior, largely because they do not include the important combustion and fire-atmosphere interactions. The Creek Fire, which exhibited mass fire behavior when it burned through the southern Sierra Nevada in 2020, was analyzed to better understand the mechanisms and forest conditions that contribute to devastating wildfires.

Scott Stephens, Alexis Bernal, and Brandon Collins from the University of California, Berkeley, along with other colleagues used both ground based and remotely sensed data to analyze behavior patterns of the 2020 Creek Fire to determine which variables were important in predicting fire severity. Findings indicated that dead biomass and live tree density were the two most important variables – more so than treatment history (i.e. timber harvesting, fire hazard reduction treatments, etc.), fire history or topography. Areas with the highest amounts of dead biomass and live tree densities were also positively related to high severity fire patch size - indicating that large homogenous swaths of these types of conditions resulted in adverse, landscape-scale fire effects.

"Forest restoration must be increased greatly in California forests, the Creek Fire shows us what will happen if we don't move decisively " said Dr. Stephens, lead author on the work, which is published in a new paper (https://authors.elsevier.com/sd/article/S0378-1127(22)00252-3) in the journal Forest Ecology and Management.

Additional analysis revealed that although the first two days of the Creek Fire were abnormally hot and dry, weather during the days of the greatest fire growth was largely within the normal range for the time of year (late summer). The spatial distribution of fire intensity during those days, however, revealed some notable patterns, with the concentration of heat from the fire being in the opposite location of where it would be expected. Specifically, on the day of the largest growth (September 6th), not only was the greatest heat concentrated away from the fire perimeter (or "flaming front", which is the expected location for heat concentration), but a significant amount of heat was still being generated within the previous day's fire perimeter. This finding is critical to better understanding how traditional fire behavior models may or may not accurately predict fire behavior in forests that have large, contiguous areas of dead trees and high live tree density – an increasingly common forest fuel condition in our Sierra Nevada forests.

The findings of this study have important implications for managers, as they indicate that in certain forest structures (i.e. those with large, homogenous swaths of dead biomass or high densities of live trees) conventional fire models may dramatically under-predict the spread rate and area burned because these models do not correctly capture the physics driving the fire.

The Creek Fire is one of a number of fires that shows us how vulnerable of our current frequent-fire forest conditions are to suffering high tree mortality and offering fuel conditions capable of generating mass fires from which future forest recovery is questionable because of type conversion and probable reoccurring high severity fire.

The study, titled "Mass Fire Behavior Created by Extensive Tree Mortality and High Density Not Predicted by Operational Fire Behavior Models in the Southern Sierra Nevada, (https://authors.elsevier.com/sd/article/S0378-1127(22)00252-3)" was published online on May 16th in the journal Forest Ecology and Management. The authors of the paper are:

- Scott Stephens, Department of Environmental Science, Policy and Management, University of California, Berkeley.
- Alexis Bernal, Department of Environmental Science, Policy and Management, University of California, Berkeley.
- Brandon Collins, Department of Environmental Science, Policy and Management and Center for Fire Research and Outreach, University of California, Berkeley.
- Mark Finney, USDA Forest Service, Rocky Mountain Research Station.
- Chris Lautenberger, Reax Engineering.
- David Saah, Spatial Informatics Group and Geospatial Analysis Lab, University of San Francisco.

Title
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Publication Date
2022-08-01

DOI
10.1016/j.foreco.2022.120258

ATTACHMENT F

Forest Ecology and Management 518 (2022) 120258

Contents lists available at ScienceDirect

Forest Ecology and Management

journal homepage: www.elsevier.com/locate/foreco

Mass fire behavior created by extensive tree mortality and high tree density not predicted by operational fire behavior models in the southern Sierra Nevada

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ARTICLE INFO

Keywords:
Creek fire
Restoration
Mixed conifer forest
Wildfire
Drought
Bark beetles

ABSTRACT

Large, severe wildfires continue to burn in frequent-fire adapted forests but the mechanisms that contribute to them and their predictability are important questions. Using a combination of ground based and remotely sensed data we analyzed the behavior and patterns of the 2020 Creek Fire where drought and bark beetles had previously created substantial levels of tree mortality in the southern Sierra Nevada. We found that dead biomass and live tree densities were the most important variables predicting fire severity; high severity fire encompassed 41% of the area and the largest high severity patch (19,592 ha) comprised 13% of total area burned. Areas with the highest amounts of dead biomass and live tree densities were also positively related to high severity fire patch size indicating that larger, more homogenous conditions of this forest characteristic resulted in adverse, landscape-scale fire effects. The first two days of the Creek Fire were abnormally hot and dry but weather during the days of the greatest fire growth was largely within the normal range of variation for that time of year with one day with lower windspeeds. From September 5 to 8th the fire burned almost 50% of its entire area and fire intensity patterns inferred from remotely sensed brightness-temperature data were typical except on September 6th when heat increased towards the interior of the fire. Not only was the greatest heat concentrated away from the fire perimeter, but a significant amount of heat was still being generated within the fire perimeter from the previous day. This is a classic pattern for a mass fire and the high amount of dead biomass created from the drought and bark beetles along with high live tree densities were critical factors in developing mass fire behavior. Operational fire behavior models were not able to predict this behavior largely because they do not include post-frontal combustion and fire-atmosphere interactions. An important question regarding this mass fire is if the tree mortality event that preceded it could have been avoided or reduced or was it within the natural range of variation for these forests? We found that the mortality episode was outside of historical analogs and was exacerbated by past management decisions. The Creek Fire shows us how vulnerable of our current frequent-fire forest conditions are to suffering high tree mortality and offering fuel conditions capable of generating mass fires from which future forest recovery is questionable because of type conversion and probable reoccurring high severity fire.

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https://doi.org/10.1016/j.foreco.2022.120258
Received 4 March 2022; Received in revised form 21 April 2022; Accepted 26 April 2022
Available online 16 May 2022

1. Introduction

Fire is an integral component of most western US forests but more than a century of logging and attempted fire exclusion has dramatically changed frequent-fire forests (forests that used to burn every 35 years or less) by increasing tree densities, lowering average tree size, increasing the dominance of shade tolerant species, and increasing fuel loads (Safford and Stevens, 2017; Hagmann et al., 2021; Bernal et al., 2022). Wildfires burning in these forest conditions have increased in size and severity since the late 20th century (Miller et al., 2009; Stevens et al., 2017) with climate change also being a factor (Abatzoglou and Williams, 2016; Westerling, 2016). In addition to altered forests and climate change, recent drought/bark beetle induced tree mortality can also be a factor contributing to exacerbated wildfire behavior and effects (Stephens et al., 2018). An important consideration with large-scale tree mortality is the potential to add long-burning, high fuel loads over extensive areas—fuel characteristics that match the criteria for mass fires. Mass fires (Finney and McAllister, 2011) can occur when large, continuous areas (several km^2) are burning with high intensity for long durations (hours) as seen from multiple earthquake-related ignitions in urban areas and by incendiary bombing in war (Pitts, 1991). Mass fire behaviors result from the strong coupling between the fire and induced atmospheric circulations.

Wildland fire behavior concerns the spread and energy release of free-burning vegetation but is complicated to predict. Modeling of fire behavior is traditionally focused on the characteristics of the flaming edge – its spread rate and fireline intensity as a direct function of fuel, weather, and topographic factors. All US operational fire behavior prediction models are empirical, i.e., based on fitting of experimental data, and suffer from two principal limitations. First, feedbacks between the fire and its environment are not explicitly included, and second, heat release from combustion is restricted to only the short-lived flaming phase of fine fuel materials. Both of these limiting factors are interconnected because heat release over extensive areas (not thin flame zones) from all phases of combustion (flaming and non-flaming) can become coupled with atmospheric circulations that in-turn affect broad-scale fire behaviors for long periods.

In most natural fuel configurations, fine fuel materials ($<$7.5 cm thick) have a short flaming time, typically varying from a few seconds for grass to perhaps a minute or two for small woody fuel particles (Nelson, 2003). Once flaming has ceased, burning of residual char (often called solid phase combustion) is not modeled but may constitute 30% of the pre-burn fuel mass (Di Blasi et al., 2001), and even a greater fraction of potential residual heat because of its high carbon content (Babrauskas, 2006). Furthermore, combustion characteristics of large woody fuel (logs) and deep organic layers (duff) are completely neglected by current operational models but burn in widely varying fashion – ranging from little consumption, to long-duration smoldering with slow heat release rates, to flaming at high heat release rates. Environmental conditions at the time of burning, including those induced by the fire itself, have a strong influence on the type of combustion and heat release rates in these fuels. One of the most salient fire-induced influences is local winds that effectively ventilate combustion of the long-burning materials. Thus, disparity between predicted and observed fire growth would be expected in fuel types with large or deep fuel materials that support deep combustion zones and long duration burning, occurring well beyond the passage of the flaming edge.

Fuel conditions across vast areas of western US frequent-fire forests are now characterized by high concentrations of large woody material and deep organic layers on the forest floor because the historical regime of frequent fire has been disrupted by fire suppression and exclusion (Hagmann et al., 2021). Burning of these fuel complexes under wildfire conditions may exhibit many of the fire behaviors that are outside the range of modeling capabilities. Key indicators of such fires would be the deep zones of combustion covering large areas for long durations. Such fires could develop pyrocumulonimbus clouds towering to altitudes of 10,000 m (Peterson et al., 2017) (Fig. 1), associated precipitation and downdrafts, and likely vorticity near the ground that further affects burning behaviors of the fuel complex in ways beyond the assumptions and capabilities of operational fire behavior models (Finney et al., 2021).

The overall goal of this project is to investigate extreme fire behavior and effects for a wildfire that occurred in an area affected by high tree mortality prior to the wildfire. We hypothesized that this pre-fire mortality influenced the burning characteristics of the fire itself, as indicated by Goodwin et al. (2021), which may not be captured by current operational fire spread models. We integrated disparate spatial datasets in a novel analytical approach to address the following objectives: (1) quantify the extent and magnitude of tree mortality that preceded the 2020 Creek Fire, (2) use a network of weather data collected before and during this fire to evaluate fire growth with local weather, and (3) predict the fire behavior and severity of the Creek Fire and compared it to its actual behavior. The overall goal of addressing these objectives is to understand drivers of extreme fire behavior in a relatively unique, but likely increasing, forest fuel condition and to assess the potential for current operational fire spread models to capture this behavior (see Fig. 2).

Fig. 1. Locations (triangles) and names of RAWS stations used to create baseline and Creek Fire weather conditions (top panel). Shaded teal area delineates the Creek Fire footprint and is superimposed on aerial photos provided by United States Department of Agriculture National Agriculture Imagery Program (2020). Bottom panel is a photograph of the plume created by the Creek Fire taken by Thalia Dockery.

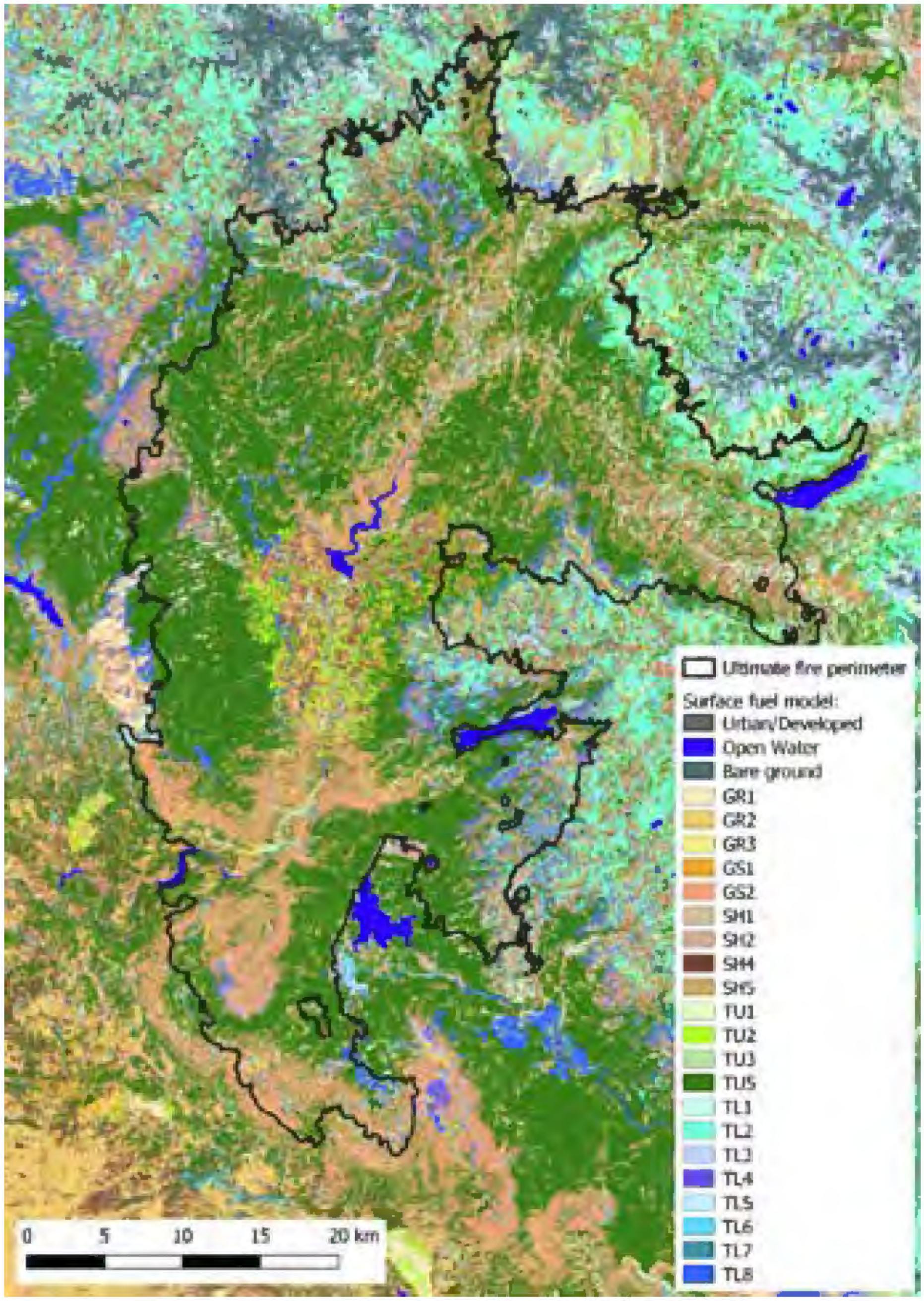

Fig. 2. Map of surface fuel models within the Creek Fire footprint (outlined in black).

2. Materials and methods

2.1. Study site

The Creek Fire burned in the southern Sierra Nevada mostly in the US Forest Service Sierra National Forest (Lat 37° 12′ 4″ Long 119° 16′ 18″). The fire burned 154,000 ha, which began in the early evening on September 4, 2020, in the Big Creek drainage between Shaver Lake and Huntington Lakes, California. The fire burned mostly in mixed conifer forests composed of ponderosa pine (*Pinus ponderosa*), sugar pine (*Pinus lambertiana*), white fir (*Abies concolor*), incense-cedar (*Calocedrus decurrens*), and California black oak (*Quercus kelloggii*). Prior to 1900, low- to moderate-severity fire ignited by lighting and Indigenous communities was common across this area, with mean fire return intervals ranging from 5 to 20 years (Kilgore and Taylor, 1979; Caprio and Swetnam, 1993; Krasnow et al., 2017; Long et al., 2017,2021). This area of the southern Sierra Nevada has varied land-use practices including past wildfires, harvesting operations, recreation, and a limited amount of prescribed fire and other fuel treatments. The Creek Fire is one of the largest forest wildfires in modern California history.

2.2. Fire weather

We collected data from 7 Remote Automated Weather Stations in and around the Creek Fire footprint (Fig. 1) using the Program for Climate, Ecosystem, and Fire Applications and Fire and Aviation Application Information portals. For each station, we collected dry bulb temperature (°C), relative humidity (%), and windspeed (km h^{-1}) from 2000 to 2020, specifically focusing on the common wildfire months of August–October. Station data were then processed within Fire Family Plus to extract hourly weather data for each day as well as hourly fire danger metrics including the energy release component (ERC) and burning index (BI). ERC reflects the available energy per unit area within the flaming front, and by keeping fuel type constant, becomes an index of changing fuel moisture content. BI is related to the flame length (Bradshaw et al., 1983) and thus a product of both ERC and the fire rate of spread which is heavily influenced by wind speed. These indices from the National Fire Danger Rating System are derived from the Rothermel fire spread equation (Rothermel, 1972) for fuel model "G" which contains four fuel size classes but applies only to fire behavior of a thin flaming front. Both metrics are positively related to fire severity (Lydersen et al., 2014, 2017). For each day, we averaged hourly weather data from 18:00 to 1:00 UTC (11:00–18:00 PST), which is when we expect weather to have the greatest influence on fire behavior.

2.3. Fire growth and intensity

To discern how fire spread and intensity varied with weather, we used the Visible Infrared Imaging Radiometer Suite (VIIRS) aboard the Joint Polar Satellite System (JPSS-1), which provides a 375-m resolution active fire product from the Fire Information for Resource Management System. From this point dataset, we interpolated daily Creek Fire perimeters similar to Briones-Herrera et al. (2020). Based on their methods, we aggregated points for each day of the Creek Fire in R (R Core Team 2020) at 1125 m, with a minimum of 3 points to be considered as part of the daily fire perimeter. Daily aggregated points were then applied with a convex hull algorithm using the *sf* package (Pebesma, 2018) to delineate fire perimeters. When two or more interpolated perimeters overlapped spatially and temporally, we combined those perimeters together. We also created maps of daily fire intensity by converting the VIIRS points into a 375-m resolution raster dataset. To do this, we estimated the Normalized Difference Brightness Temperature Index (NDBTI: Eq. (1)):

$$NDBTI = \frac{T4 - T5}{T4 + T5} \tag{1}$$

where T4 and T5 represent the brightness temperature (Kelvin) of the VIIRS I4 and I5 bands, respectively (Waigl et al., 2017). Both bands are used in the active fire detection and characterization algorithm, with I4 used as the predominant band for active fire detection and I5 used to compliment I4 by correcting saturated pixels. Elevated NDBTI values indicate higher fire intensity, which can distinguish active fire fronts from residual fire within a fire perimeter (Waigl et al., 2017). However, cases can arise where I4 $<$ I5, resulting in a negative NDBTI value. This anomalous condition is an artifact of pixel saturation due to the low temperature threshold of the I4 band (367 K). In these cases, pixels were assigned a value equivalent to the maximum NDBTI value for a given day to better represent those pixels displaying high fire intensity.

2.4. Fire severity

Fire severity was estimated according to corrected methods established by Parks et al. (2018), which uses the Google Earth Engine platform to derive Landsat-based fire severity indices. We created a 30 m resolution raster of an extended assessment of the relativized delta normalized burn ratio (RdNBR) using Landsat imagery from the year prior to and after the start date of the Creek Fire (September 4, 2020). We then categorized RdNBR values into four fire severity classes (unchanged, low, moderate, and high) based on thresholds for the composite burn index described by Miller and Thode (2007).

2.5. Forest structure and composition

To quantify forest structure following drought and bark beetle attacks (2012–2016) in the southern Sierra Nevada, we used live tree density (trees ha^{-1}) and live tree basal area (m^2 ha^{-1}) from F3. F3 is a 30-m resolution raster dataset that integrates Forest Inventory and Analysis data and uses the Forest Vegetation Simulator (FVS) to model initial stand conditions and project succession over time (Huang et al., 2018). It then uses Field and Satellite for Ecosystem Mapping to incrorporate remotely-sensed data (Light Detection and Ranging data and Landsat imagery) to simulate spatiotemporal forest patterns across larger scales. Since tree mortality data were not available for F3, we used the change in live basal area from 2011 to 2016 to estimate the amount of snag basal area generated during the drought and bark beetle attacks. However, this approach means that mortality is only detectable if there was a decrease in basal area from 2011 to 2016. Predicted tree mortality between 2011 and 2016 is mainly driven by a stand density index-based mortality model within FVS which applies either background or density-dependent mortality rates when relative stand density index is below or above a minimum threshold, respectively (Dixon et al., 2008). F3 uses regionally-specific mortality models developed for FVS variants (Huang et al., 2018), with the western Sierra Nevada variant accounting for basal area distribution and species to estimate mortality rates for individual trees (Dixon et al., 2008). However, this approach mainly attributes mortality among smaller-sized trees without consideration for the spatially interactive processes that govern the species and size of trees that die following large-scale disturbances (Huang et al., 2019). Given that the region encompassing the Creek Fire footprint suffered the greatest mortality among large ponderosa pine that likely died from bark beetle-associated mortality (Fettig et al., 2019), our estimates of mortality and fuels generated by that mortality may be lower than what existed in this region prior to the Creek Fire.We converted snag basal area to a percent of total basal area within a given pixel. We also converted snag basal area to dead biomass (Mg ha^{-1}) using aboveground biomass allometric equations provided by Knight et al. (2020) to estimate dead fuels that were available to burn during the Creek Fire.

2.6. Previous fire history

Since previous wildfire activity can influence subsequent fire behavior and effects (Lydersen et al., 2019), we accounted for wildfire history within the Creek Fire footprint. Wildfire data from 1984 to 2017 were obtained from Miller (2017), which included all wildfires >81 ha in size. Although this window omits three years prior to the Creek Fire, there were no additional wildfires within the Creek Fire footprint from 2017 to 2020, totaling 23 wildfires prior to the Creek Fire. We converted fire perimeter polygons to a 30-m resolution raster dataset, with pixel values ranging from 0 to 3 indicating the number of times burned.

2.7. Previous treatment history and topography

Fuel reduction and forest restoration treatments can have an impact on fire behavior and effects (Stephens et al., 2009). We accounted for treatment history within the Creek Fire footprint by using the US Forest Service Activity Tracking System (FACTS), which contains a database of polygons delineating various treatments that are planned or completed. These treatments included fire hazard reduction, range improvement, reforestation, timber stand improvement, and timber harvesting. We chose to only include treatments that were completed from 2011 until the start date of the Creek Fire to evaluate how treatments implemented during the drought and bark beetle attacks may have impacted the Creek Fire. We converted polygons to a 30-m resolution raster dataset, with pixel values categorized as 0 or 1 to indicate the absence of presence of treatments, respectively.

Topographic data were acquired from LANDFIRE and included elevation (m), slope (degrees), and aspect (degrees). We converted aspect to a categorical variable with breakpoints at 0°/360°, 90°, 180°, and 270° to correspond to northeast-facing, southeast-facing, southwest-facing, and northwest-facing slopes, respectively. All spatial data including forest structure and composition, previous fire history, previous treatment history, and topography were cropped and aligned with the extent of the fire severity raster we generated (~30 m resolution;

World Geodetic System 84).

2.8. Modeled fire behavior

The operational fire spread model ELMFIRE (Lautenberger, 2013, 2017) was used to model initial progression of the Creek Fire from September 4 to 8, 2020 under conventional modeling assumptions that could have realistically been applied for real-time forecasting. ELMFIRE can be thought of as a gridded ensemble implementation of 2D Rothermel-based fire models such as FARSITE (Finney, 1998) with some differences in how the fire front is tracked and crown fire and spotting are estimated. ELMFIRE is uncoupled to the atmosphere. Although the Creek Fire's specific origin area and time of ignition are not precisely known, (per Inciweb: National Wildfire Coordinating Group, 2020a) the ignition coordinates are taken as (−119.272°, 37.201°) with an ignition time of 18:30 PDT on September 4th. Fire model inputs were specified as follows:

- Topography and surface/canopy fuels: Pyrologix' 2020 California Fuelscape data that are based on LANDFIRE 2016 Remap 2.0.0 (LF Remap). Calibration workshops with interagency fire and fuels personnel were held to develop a calibrated fuelscape that produces locally accurate fire behavior results. Since LF Remap does not included disturbances after 2016, spatial data on fuel disturbances (fire, fuel treatments, mortality, etc.) through early 2020 were then incorporated into the fuelscape to provide a fuelscape suitable for use in California during the 2020 fire season. Additional details are provided in Brough et al. (2020).Wind speed and direction, relative humidity, and temperature: Real Time Mesoscale Analysis (National Oceanic and Atmospheric Administration, 2020) which provides hourly estimates of sensible weather variables on a 2.5 km grid for the Continental US
- Dead fuel moisture: Calculated from gridded Real Time Mesoscale Analysis data using NFDRS procedures (Bradshaw et al., 1983)
- Live fuel moisture: Estimated from national fuel moisture database (United States Forest Service, 2020)

ELMFIRE was run in a 1000-member ensemble with wind speed perturbed at ±3 mph, wind direction perturbed at ±15°, spread rate adjustment factor varied from 0.8 to 1.2, and dead fuel moisture content perturbed by ±0.01%. Fire perimeter snapshots were extracted from the 90th percentile ensemble member. The modeled growth of the Creek Fire was then compared to the actual fire perimeters to evaluate how well ELMFIRE predicted this event.

2.9. Data analysis

To evaluate how weather conditions during the Creek Fire compared to average weather conditions for the region, we measured the departure of weather conditions from the year the Creek Fire burned relative to previous years. To do this, we used the *boot* package in R (Canty and Ripley, 2017) to bootstrap 95% confidence intervals (1000 permutations) for each daily weather metric across all weather stations (Fig. 1) from 2000 to 2019 to establish a baseline of average weather conditions for the region. When then bootstrapped 95% confidence intervals across all weather stations for 2020 and compared if daily weather conditions during the Creek Fire overlapped with our baseline. We then compared fire weather days with the days of greatest fire spread and intensity during the Creek Fire.

To determine if prior forest conditions influenced fire severity, we used the *rpart* package in R (Therneau and Atkinson, 2019) to create a categorical regression tree that identified environmental thresholds that were associated with Creek Fire severity. We extracted values of live tree density, percent basal area of snags, fuels (i.e., dead biomass), previous fire history, previous treatment history, and topography from our raster datasets using a 180-m grid of points across the Creek Fire footprint. A spacing of 180 m was chosen to minimize biases that arise from spatial autocorrelation associated with modeling fire severity (Kane et al., 2015). This resulted in a sample size of 47,680 points. With those extracted values as explanatory variables to predict fire severity, we used a class method for splitting variables and a complexity parameter of 0.01 (the increase in R^2 value at each split that must occur for the split to be accepted).

Since environmental conditions within an individual pixel insufficiently captures the spatial context in the surrounding area, which can be quite influential for fire effects (Povak et al., 2020), we used the *patchwoRk* package in R (Sanchez, 2019) to evaluate whether prior forest conditions at larger scales influenced the fire severity patterns observed during the Creek Fire. To characterize landscape-scale, high severity patterns within the Creek Fire footprint, we delineated patches of high severity using the PatchMorph tool (Girvetz and Greco, 2007; Sánchez Meador, 2019). This algorithm determines the size and shape of patches by specifying minimum patch width and maximum width of gaps within a patch. Similar to studies that used this tool to delineate patches of fire severity, we used a minimum patch width and maximum gap thickness of 90 m (or three 30-m pixels) and a minimum patch size of 0.5 ha (Collins and Stephens, 2010, Stevens et al., 2021). Using our regression tree model, we created a continuous map of pre-fire forest conditions across the entirety of the Creek Fire footprint and used the thresholds identified to aggregate patches of forest conditions (now referred to as forest condition departure classes; FCD) using the PatchMorph tool. We used the same patch constraints delineating high severity fire patches. We extracted the percent area from patches of FCD that intersected with high severity fire patches and used a log-transformed linear model to evaluate how the scale of FCD may have influenced high severity fire patch size.

3. Results

Baseline conditions from 2000 to 2019 from our weather station network (Fig. 1) averaged 19 °C, 38% relative humidity, and 6 km h^{-1} windspeed. Similar conditions were observed in 2020, with average temperature 19 °C, 35% relative humidity, and 5 km h^{-1} windspeed. However, the first two days of the Creek Fire were abnormally hotter and drier (Fig. 3), with temperature 5 °C higher and relative humidity 6% lower than baseline conditions ($p < 0.05$). Windspeed for those same days were within the normal range of variation. Despite initial hotter and drier conditions, we found that all weather metrics during the days of the greatest fire growth (September 6–September 8; Fig. 4) were largely within the normal range of variation for late summer and early autumn except for September 6th that had a lower windspeed. When evaluating metrics of fire danger, we found that the first five days of the Creek Fire, including the period of highest spread, were within the normal range of variation for both ERC and BI ($p < 0.05$; Fig. 5).

From September 5 to September 8, the fire burned almost 50% of the entire Creek Fire footprint. Upon closer examination of these large fire growth days, the spatial distribution of fire intensity revealed some notable patterns (Fig. 6). On September 5th, fire intensity was typical, with heat concentrated on the perimeter of the active flaming front. However, on the largest growth day (September 6), fire intensity was reversed, with heat increasing towards the interior of the fire perimeter. Not only was the greatest heat concentrated away from the fire perimeter, but a significant amount of heat was still being generated within the fire perimeter from the previous day. This pattern reversed back to what we would expect from a typical active flaming front by September 7th, with heat increasing towards the perimeter and heat from previous days subsiding.

Prior to the Creek Fire, we found that the drought and bark beetle attacks from 2012 to 2016 created substantial levels of tree mortality and dead fuels. By 2016, average percent of snag basal area was 37%, with most (63%) of the area characterized by moderate tree mortality (25–75%). Tree mortality translated to an average of 65 Mg ha^{-1} of dead

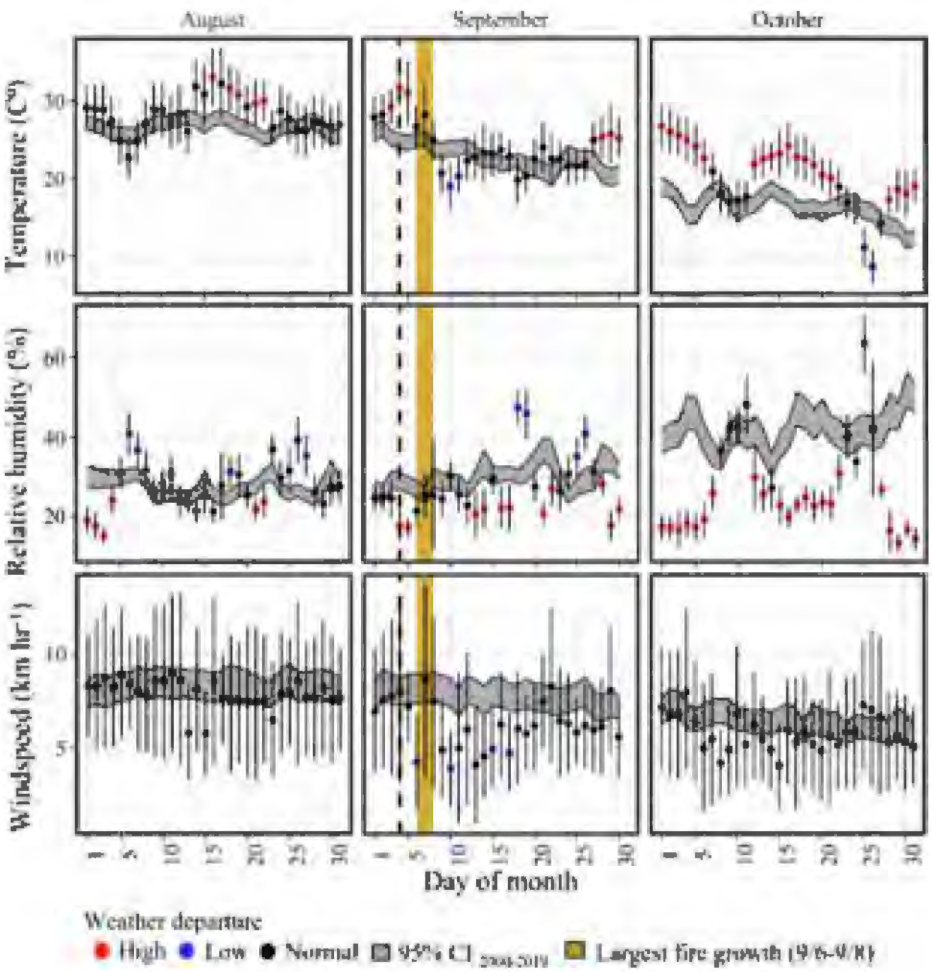

Fig. 3. Creek Fire weather departure from baseline conditions (2000–2019). Gray shaded areas are bootstrapped 95% confidence intervals for baseline weather conditions, while error bars are confidence intervals for 2020. Initiation date of Creek Fire denoted with dashed line and gold shaded area are the days of largest fire spread (September 6–8th). Colored dots represent significant ($p < 0.05$) departure from baseline conditions, with red indicating more severe fire weather, blue indicating lower, and black indicating observation falls within normal range of variation. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

biomass, with the interquartile range spanning 25–92 Mg ha^{-1}. Despite increased levels of tree mortality, live tree density (trees > 2.5 cm diameter-at-breast-height) was still high in 2016, averaging 622 trees ha^{-1}.

Dead biomass and live tree densities were the most important variables in our categorical regression tree analysis predicting fire severity. Dead biomass, in particular, had the strongest influence on pixel-level fire severity (Fig. 7), with > 46 Mg ha^{-1} resulting in high severity. In areas below this level of dead biomass, the lowest tree densities (<232 trees ha^{-1}) were associated with low severity, while the highest tree densities (>693 trees ha^{-1}) at low elevation (<2430 m) were associated with high severity. Intermediate levels of tree density (232–693 trees ha^{-1}) had mixed effects, producing moderate severity at lower elevation (<2430 m) and low severity at higher elevation (>2430 m). Our regression tree did not identify fire history or past forest treatments as factors related to fire severity. We also could not distinguish the contributing factors related to unchanged fire severity due to the small sample size of these observations.

Among fire severity classes, high severity accounted for the greatest proportion of area (41%) burned in the Creek Fire (61,305 ha; Fig. 8), followed by moderate severity (35%; 52,768 ha), low severity (21%; 30,917 ha), and unchanged (3%; 4920 ha). When aggregated as patches ≥ 0.5 ha, we found that that the Creek Fire created very large contiguous areas of high severity, with the largest high severity patch (19,592 ha) comprising 13% of total area burned (Fig. 8). This is a stark contrast compared to the other fire severity strata, where the cumulative area of the largest patches across unchanged, low, and moderate severity only made up 1% of total area burned (245, 699, and 1014 ha, respectively).

We used the thresholds identified in the regression tree analysis to map and analyze three forest condition departure (FCD) classes: FCD-high, FCD-mod, and FCD-low (Table 1). Prior to the Creek Fire, a majority (66%; 99,115 ha) of the landscape was composed of patches in the FCD-high class (dead biomass >46 Mg ha^{-1} and >693 trees ha^{-1}), with the largest patch in this class being 83,645 ha in size. FCD-mod (407–693 trees ha^{-1} and elevation <2430 m or 232–407 trees ha^{-1}) patches accounted for 21% of the landscape, followed by FCD-low (<232 trees ha^{-1} or 407–693 trees ha^{-1} and elevation > 2430 m) patches which represented 9% of the landscape. The distribution of FCD classes within individual patches of high severity (Fig. 9) revealed that FCD-high overwhelmingly burned at high fire severity (91%). While FCD-low and FCD-mod were interspersed in high severity patch areas, they consisted of <31% of total high fire severity area. Our linear model also revealed some notable patterns in the influence of forest conditions on landscape-level, high severity fire effects. Only FCD-high was positively related to high severity fire patch size ($p = 0.029$), indicating that larger, more homogenous conditions of this forest characteristic resulted in adverse, landscape-scale fire effects.

3.1. Fire spread modeling

Modeled fire spread was compared to actual fire growth with cumulative MODIS (National Wildfire Coordinating Group, 2020b), VIIRS (National Wildfire Coordinating Group, 2020c), and IR (National Interagency Fire Center, 2020) fire detections at several discrete times between September 4th and September 8th, 2020 (Fig. 10). Using ELMFIRE, the rapid northward fire growth on September 5th and September 6th was not captured (Fig. 10b and c). The offshore wind event that impacted the region on September 7th and September 8th

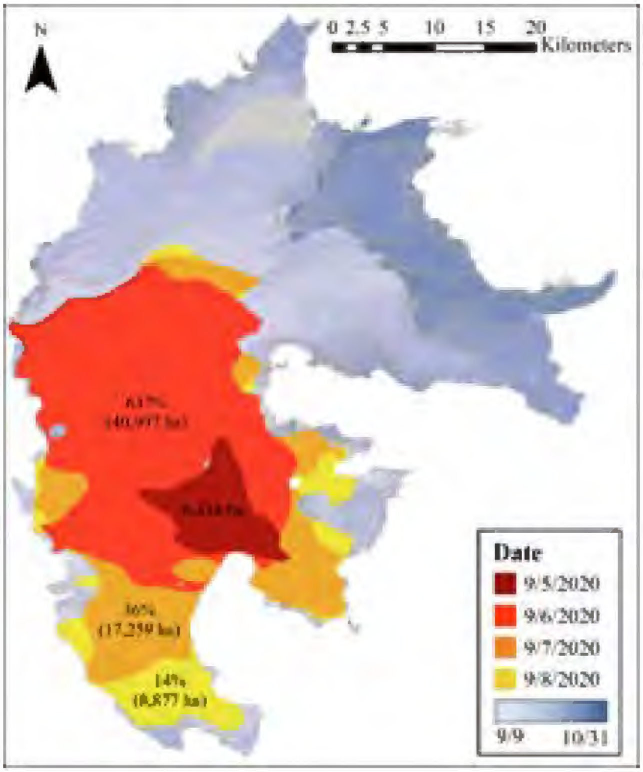

Fig. 4. Creek Fire growth during the days of greatest fire spread. Colored polygons delineate daily fire growth, with percentage of growth relative to previous day indicated. Absolute size of growth (ha) for a given day indicated in parenthesis. The total amount of area burned during the four days of greatest fire spread consisted of almost 50% of the entire Creek Fire footprint. Shaded polygons in blue and outlined in gray delineate fire spread during subsequent days (9/9/2020–10/31/2020). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

drove fire to the southwest. As shown in Fig. 10d and e, this was captured to some degree in the model, with some discrepancies in timing and extent of the run.

4. Discussion

This work identified several factors that contributed to the extreme behavior of the Creek Fire. Before discussing these factors, it should be stressed that the forests within the Creek Fire were already highly altered from fire suppression/exclusion and past harvesting. An extensive 1911 inventory of mixed conifer forests to the southwest of the Creek Fire was compared to contemporary conditions and found drastic differences, particularly in tree density, canopy cover, the density of large trees, and the dominance of white fir that collectively increased fire hazards and reduced forest resilience (Stephens et al., 2015). These conditions alone have led to increased percentages of high severity fire and high severity patch size in the Sierra Nevada (Miller et al., 2009) even without the large-scale tree mortality that happened during the 2012–2016 drought. Increasing burn severity and larger high severity patches is a problem because it can lead to a reduction in frequent-fire forests from type conversion to shrublands or other vegetation types (Coop et al., 2020).

The Creek Fire destroyed at least 853 buildings and cost over $193 million (2020 USD) to suppress (NIFC, 2020). While lightning ignited fires and Indigenous burning have been a part of this landscape for thousands of years (Caprio and Swetnam, 1993; Long et al., 2017,2021; Krasnow et al., 2017), the severity patterns within the Creek Fire are completely outside the historical range of variation of mixed conifer forests (Safford and Stevens, 2017). In similar mixed conifer forests in the Greenhorn Mountains southwest of the Creek Fire, the historic percentage of areas that experienced high severity fire was low and varied from 1% to 3% (Stephens et al., 2015). This is in stark contrast to the Creek Fire that was 41% high severity with the largest single, high severity patch (19,592 ha) comprising 13% of total area burned.

Prior to the Creek Fire, a majority (66%) of the landscape was composed of patches in the FCD-high class. Our analysis revealed that FCD-high areas overwhelmingly burned at high fire severity (91%) during the Creek Fire. Our model also revealed some notable patterns regarding the influence of forest conditions on landscape-level, high

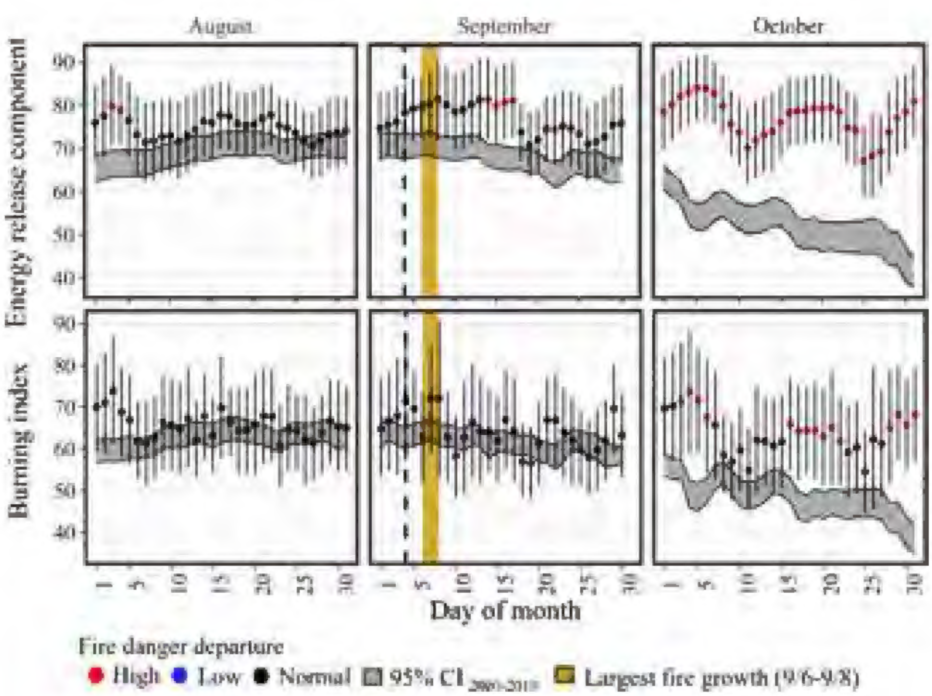

Fig. 5. Creek Fire danger departure from baseline conditions (2000–2019). Gray shaded areas are bootstrapped 95% confidence intervals for baseline fire danger conditions, while error bars are confidence intervals for 2020. Initiation date of Creek Fire denoted with dashed line and gold shaded area are the days of largest fire spread (September 6–8th). Colored dots represent significant ($p < 0.05$) departure from baseline conditions, with red indicating higher fire danger, blue indicating lower, and black indicating observation falls within normal range of variation. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

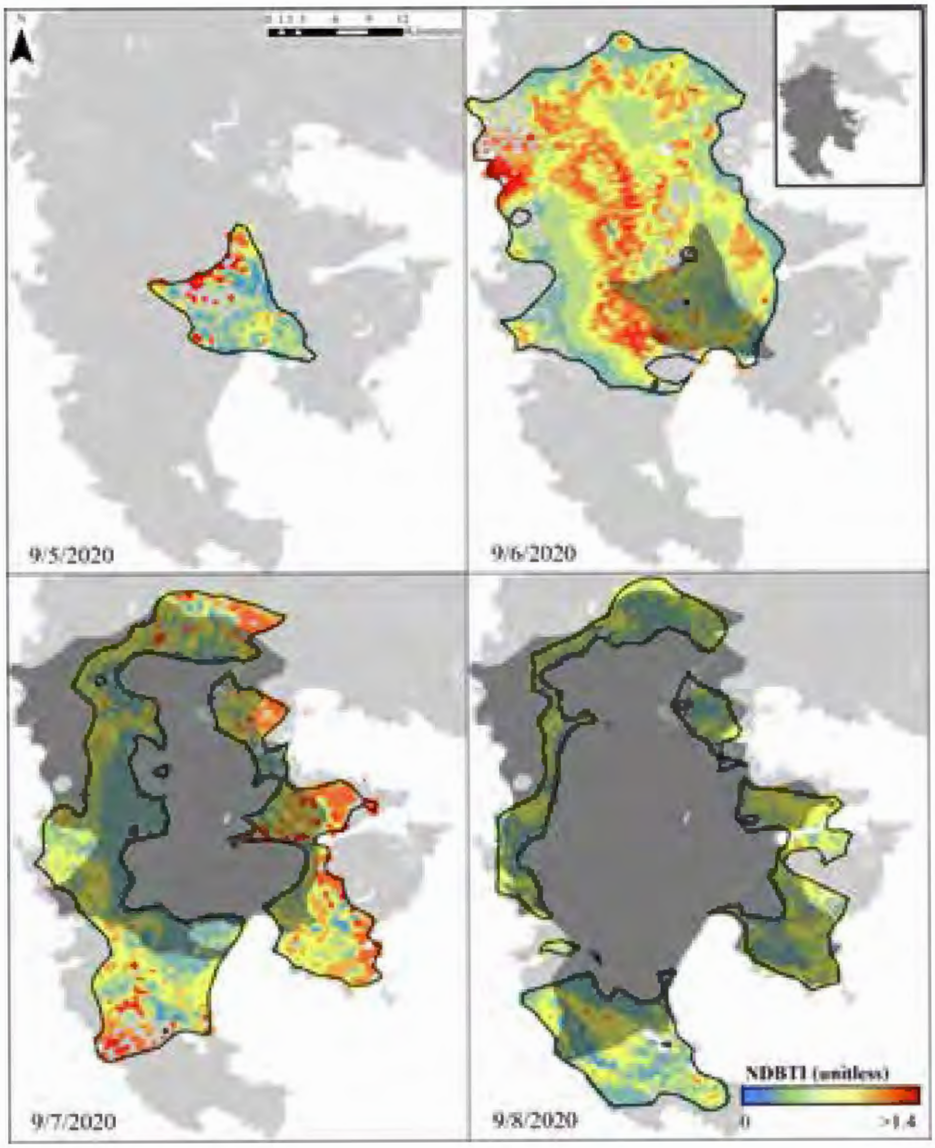

Fig. 6. Distribution of daily fire intensity using the Normalized Difference Brightness Temperature Index (NDBTI), where higher values indicate greater fire intensity. Days that experienced the largest growth relative to the previous day (>10%) are shown. Light gray area delineates the Creek Fire footprint while the dark shaded area delineates the total fire perimeter from previous days. The inset shows the location of the daily fire perimeters relative to the entirety of the Creek Fire footprint.

severity fire effects. Only FCD-high was positively related to high severity fire patch size ($p = 0.029$), indicating that larger, homogenous FCD-high conditions resulted in adverse, landscape-scale fire effects. Indeed, the condition of this forest prior to and after the 2012–2016 drought contributed to the behavior and effects of the Creek Fire. This assertion is also supported by the findings Goodwin et al. (2021), which demonstrated considerably greater potential energy release from wildfire following drought-related tree mortality. If drought and bark beetle induced mortality occurs in other areas of the Sierra Nevada (i.e. the northern Sierra Nevada) or elsewhere, we expect that similar fire effects could be produced.

This research found that the largest factors that contributed to high severity fire within the Creek Fire were dead biomass and live tree densities. Dead biomass, in particular, had the strongest influence on pixel-level fire severity (Fig. 7). Although the first two days of the Creek Fire were abnormally hotter and drier, all weather metrics during the days of the greatest fire growth (September 6–September 8) were largely within normal ranges (except September 6th that had lower windspeeds, the day the fire grew the most). More evidence regarding fire weather is provided by the National Fire Danger indices: on September 6th the fire grew 637% (40,997 ha) relative to the previous day although BI and ERC were within normal range of variation (Figs. 3 and 5). This is an important result that provides further evidence that the fire behavior during its more severe burning periods did not conform to the standard line-fire modeling assumptions but was instead a function of more complex interactions of fuel and fire-induced atmospheric conditions. This strong fuels signal in the severity the Creek Fire was also corroborated by an analysis of all large 2020 wildfires in California (Safford et al., 2022), which also identified the nearby 2020 Castle Fire as having a similar fuels-dominated signal.

High rates of energy release over large areas are the preconditions for fire behaviors called firestorms or mass fires (Carrier et al., 1981,1985) that become dynamically dependent upon strong atmospheric interactions. The strong coupling between the fire and atmosphere means that fire growth and behaviors along any portion of the burning area are themselves a function of large scale fire-induced atmospheric flows such as strong downdrafts, indrafts, and vorticity of the entire plume or lee-side edges. High surface winds and vortices along the fire front loft and transport burning material far from the fire edge and further expand fire growth. Recent analysis of RADAR revealed smoke plumes above the

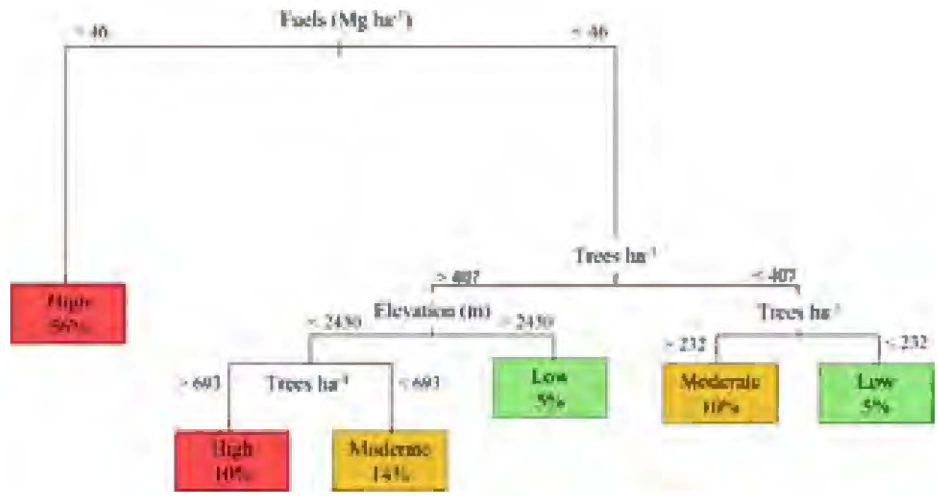

Fig. 7. Regression tree output explaining the influence of environmental conditions on fire severity. Colored boxes at the ends of the regression tree branches contain categories of fire severity (low, moderate, and high) and percentage of observations in each resulting group.

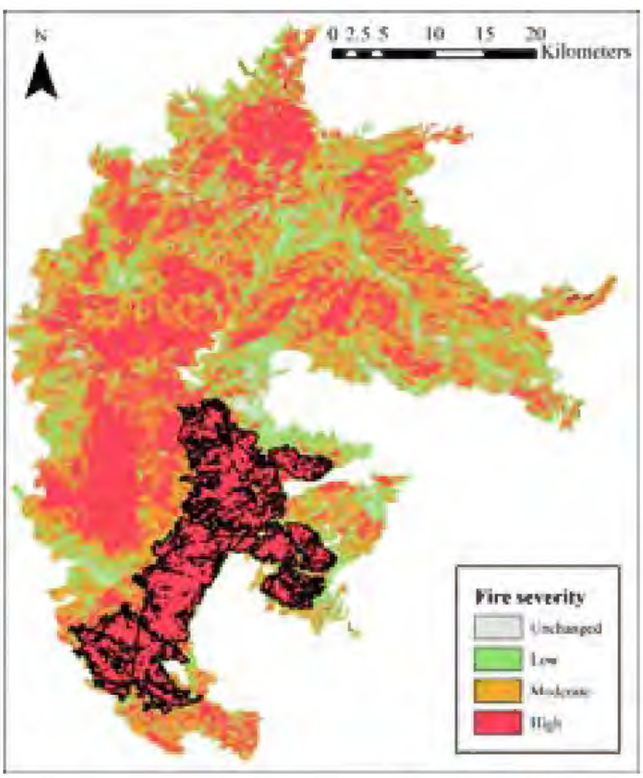

Fig. 8. Map of fire severity according to classes based on composite burn index (CBI) values including unchanged (CBI 0–0.1), low (–0.1-1.25), moderate (1.25–2.25), and high (2.25–3). The high severity patch with black border delineates the largest patch in our dataset (19,592 ha).

Creek Fire and two other large fires in California, contained counter rotating vortex pairs and associated high surface winds along the lee edges of the fire for up to 9 h and 20 km of fire spread (Lareau et al., 2022). Although fuel conditions were not evaluated by Lareau et al. (2022), the observed vorticity would likely have been initiated by prolonged area-wide burning which forces ambient wind flow around the fire front to create vorticity (i.e. Countryman, 1964) rather than a thin flame zone that is penetrated by surface winds. Sustaining the plume and vorticity would then be aided by long-duration heat release from heavy fuels across large areas, some of which would be remote from the outer fire edge as observed here. The high rates of energy release across the burning area are themselves enhanced by the strong fire-induced surface winds that ventilate the combustion of solid fuel materials. Thus, the growth and energy release from any portion of these fires becomes dependent on the atmospheric circulations generated by the heat release from the entire fire.

Table 1
Description of forest condition departure classes (FCD) determined by thresholds found for fuels, tree density, and elevation using categorical regression tree analysis.

Class	Fuels (Mg ha^{-1})	Trees ha^{-1}	Elevation (m)
FCD-low	<46	<232	All elevations
FCD-low	<46	407–693	>2430
FCD-mod	<46	407–693	<2430
FCD-mod	<46	232–407	All elevations
FCD-high	<46	>693	<2430
FCD-high	>46	All tree densities	All elevations

This explanation is consistent with the changes in heat release patterns observed from September 5 to September 8 (Fig. 6). On September 5th, fire intensity was typical for most wildfires with heat concentrated on the fires perimeter. However, on the largest growth day (September 6th), this was pattern was reversed, with heat increasing towards the interior of the fire. Not only was the greatest heat concentrated away from the fire perimeter, but a significant amount of heat was still being generated within the fire perimeter from the previous day (Fig. 6). At the whole-fire scale, prolonged heat release from the interior would sustain the buoyant updrafts in the plume core that interact with the wind, moisture, and temperature profiles of the atmosphere. This is a classic pattern for a mass fire and the high amount of large, dead biomas created from the drought and bark beetle attack along with high tree density (that produced large amounts of crown fuels) were critical factors in developing mass fire behavior as anticipated by Stephens et al. (2018). Severe drought during this period exacerbated by climate change was also a contributing factor because it reduced fuel moistures to even lower levels that further adds to the vulnerability of these forests (Williams et al., 2022).

4.1. Management implications

Fire behavior exhibited by the Creek Fire during its initial progression is well outside the capabilities of current-generation fire models. Modeling initial spread of the Creek Fire with any conventional fire model will result in a dramatic under-prediction in spread rate and area burned because these models do not capture the physics that drove the

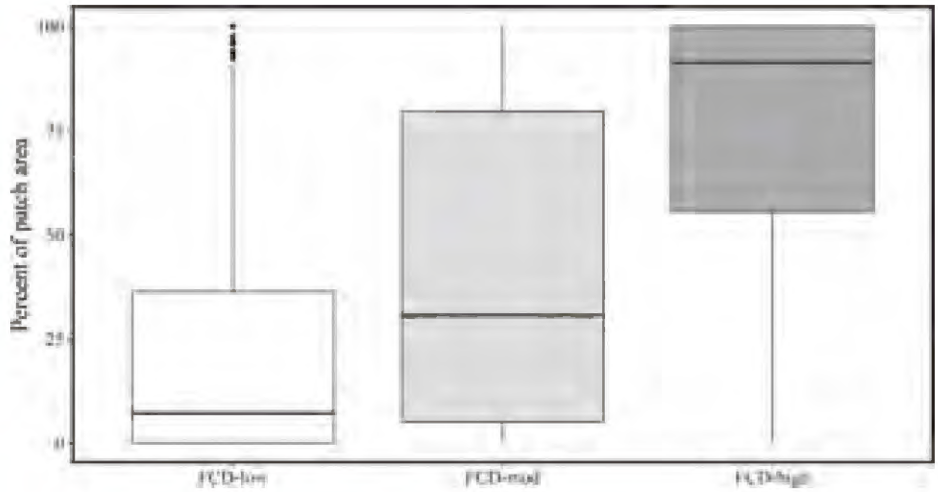

Fig. 9. Percentage of overlap area between forest condition departure classes (FCD) and high severity fire patches.

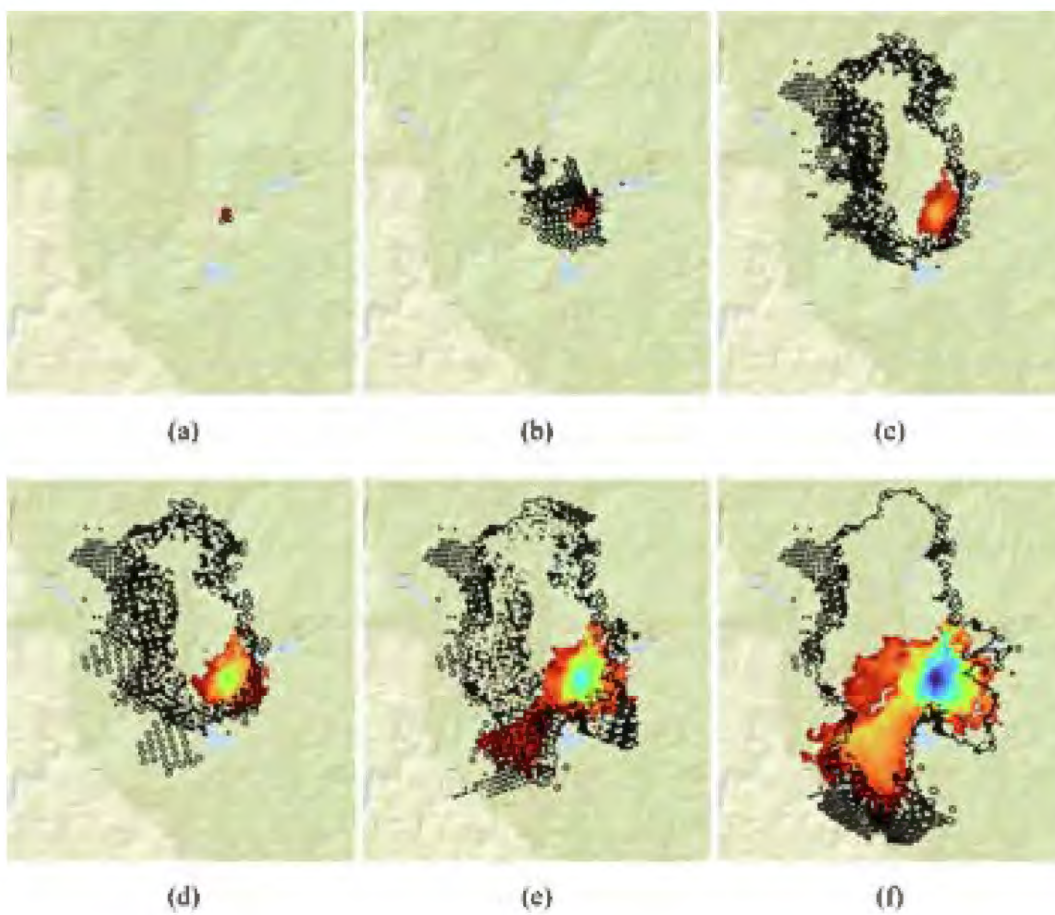

Fig. 10. ELMFIRE modeled progression of the Creek Fire (blue to red contours) compared to observed fire perimeter (black lines) from September 4 to 8, 2020. (a) September 5th 05:50 UTC (b) September 5th 21:42 UTC (c) September 6th 10:50 UTC (d) September 7th 05:33 UTC (e) September 7th 21:36 UTC (f) September 8th 21:40 UTC. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

Creek Fire's initial spread including post-frontal combustion and fire-atmosphere interactions. This outcome is particularly challenging to managers who always prioritize firefighter and public safety. With no operational fire model able to predict such an event, managers can easily underrepresent such events, particularly in areas that experienced considerable tree mortality. It should be noted, however, that extreme fire behavior associated with plume-dominated fire spread is not limited to areas with extensive pre-fire tree mortality (Povak et al., 2020). The potential for extreme fire behavior to cause great harm to human life was demonstrated when the Creek Fire necessitated the rescue of people by National Guard helicopters. The fire trapped visitors at Mammoth Pool Reservoir after it jumped the San Joaquin River and the US National Guard rescued >100 people from this location.

An important question regarding mass fire behavior exhibited by the

Creek Fire is whether the tree mortality event that preceded it could have been avoided or reduced in intensity or was it within the natural range of variation for these forests? To help answer this question we can learn from a severe drought that impacted the forests in southern California and northern Baja California from 1999 to 2002 (Minnich et al., 2016). This severe drought and bark beetle attack killed millions of trees in mixed conifer and pine dominated forests in the San Bernardino and Cleveland National Forests in the US but had a very different impact on Jeffrey pine (*Pinus jeffreyi*)-mixed conifer forests in the Sierra San Pedro Matrir (SSPM) in northern Baja California, Mexico (Stephens and Fule, 2005). Both of these forests are in the Peninsular Mountains with similar soils, topography, climate, past fire frequency, and tree species but the SSPM does not have any ponderosa pine but includes all other mixed conifer tree species (Stephens et al., 2003; Stephens and Gill, 2005; Dunbar-Irwin and Safford, 2016). Although these forests are similar ecologically their management histories are very different with the SSPM never being harvested and fire suppression beginning in 1970, versus on the US side of the border, extensive harvesting occurred along with 120 years of fire exclusion and suppression (Dunbar-Irwin and Safford, 2016; Rivera-Huerta et al., 2016).

In 1932 mixed Jeffrey pine forests in the San Bernardino Mountains had an average density of 95 trees ha^{-1} (trees > 12.5 cm dbh) (Minnich et al., 1995); current tree density from the SSPM for trees > 10 cm dbh is 110 trees ha^{-1} which is similar to that reported in the San Bernardino Mountains before large-scale fire suppression or harvesting (Stephens and Fule, 2005). In 1992, mixed Jeffrey pine forests in the San Bernardino Mountains had tree densities 79% larger than those in the early 1930s mainly because of fire suppression (Minnich et al., 1995). This dramatic change in forest density shaped the drought/bark beetle responses from these areas. Drought and bark beetle mortality (1999–2002) increased snag density in the SSPM by approximately 1.0 snag ha^{-1} to an average of 5 ha^{-1} (Stephens, 2004) but in southern California forests, snag density increased to 125 snags ha^{-1} in many areas (Sims, 2004; Stephens and Fule, 2005).

Past forest management on the US side of the Peninsular Mountains predisposed these forests to a massive tree die-back but on the Mexican side of the border, the forests were able to incorporate these stresses with only modest mortality. Neither Californian tree mortality event (1999–2002 southern California or 2012–2016 southern Sierra Nevada) have historical analogs. Further evidence of the vulnerability of Sierra Nevada mixed conifer forests to severe mortality is provided by a recent study that found historic forests experienced very little competition versus today when 82–95% of mixed conifer forests are in the full occupancy or imminent mortality classes (North et al., 2022). When Sierra Nevada forests were subjected to drought and increased heat stress from climate change, tree defenses were compromised and millions of trees died but the resilient forests in the SSPM persisted (Stephens and Fule, 2005; Stephens and Gill, 2005).

Amazingly, when SSPM Jeffrey pine-mixed conifer forests burned in a wildfire the year after a severe drought ended (2003), the combination of drought/bark beetles and wildfire only killed 20% of the trees and the forest remains in a resilient condition today (Murphy et al., 2021). The good news is California mixed conifer and other frequent-fire adapted forests can become more resilient if we undertake forest restoration (Stephens et al., 2021) at the necessary scales (North et al., 2012; Hessburg et al., 2021; Prichard et al., 2021) and intensity (North et al., 2021,2022). The 2020 Creek Fire shows us how vulnerable our current forest conditions are to suffering high tree mortality and offering fuel conditions capable of generating firestorms and mass fires from which future forest recovery is questionable.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgement

We thank John Battles and Danny Foster for discussions related to this project and Chuck McHugh for assisting with the Fire Danger Rating System analysis. We also thank Zack Steel for helping to generate the fire severity spatial layer for the Creek Fire. This study was funded by the California Energy Commission's Eletrical Program Investment Charge Program (Grant# EPC-18-026). It does not nesessarily represent the views of the Energy Commission, its empoyees, or the State of California.

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CITY of CLOVIS

- MAYOR VONG MOUANOUTOUA -

January 15, 2025

Steven E. White
Director, Fresno County Public Works and Planning
2220 Tulare Street, 8th Floor
Fresno, CA 93721

Subject: Support for Fresno County's Climate Adaptation Planning Grant Application

Dear Mr. White,

I want to express my support for the County of Fresno's application for a Caltrans Climate Adaptation Planning Grant to explore transportation infrastructure resiliency in the communities I represent.

The residents of Clovis are vulnerable to flooding, drought, wildfire, and tree mortality, among other climate related issues. These climate risks can cause roads to close, cutting residents off from essential services such as health care, school, work, food and sanitation, as well as access to the urban areas of Fresno and Clovis which can have more supplies than the more rural communities. These vital services often require long trips to access, meaning that the roads are essential to life in this area. This grant would fund a study to find effective mitigation solutions to the effects of climate change on the region's transportation infrastructure, allowing roads to remain open to residents, commerce, and natural resources.

Not only do increasingly frequent floods, wildfires, and drought impact the daily lives of residents on the front lines of these changing conditions, but also trucks moving commodities across the region. The roads in this area are often the lone point of access for supplies coming in and out of these communities, as well as power infrastructure for Southern California Edison. Climate trends predict earlier snow melts that will dramatically impact the water supply for the entire state of California, impacting agriculture downstream and drinking water for residents statewide. As this is a critical issue for the residents of this region and the well-being of the state, the sooner we can start preparing our infrastructure for future conditions, the better equipped the residents and the state will be to withstand them.

I am committed to working with the County of Fresno to help facilitate public engagement and hear the concerns of residents so that we may find solutions that work best and carry us forward.

Sincerely,

Vong Mouanoutoua
Mayor, City of Clovis

City Hall Administration • 1033 Fifth Street, Clovis, CA 93612 • 559.324.2010 • TTY-711
vongm@cityofclovis.com • www.cityofclovis.com

FRESNO
Council of Governments

2035 Tulare St., Ste. 201 tel 559-233-4148
Fresno, California 93721 fax 559-233-9645
www.fresnocog.org

January 15, 2025

Steven E. White
Director, Fresno County Public Works and Planning
2220 Tulare Street, 8th Floor
Fresno, CA 93721

Subject: Support for Fresno County's Climate Adaptation Planning Grant Application

Mr. White,

Fresno Council of Governments supports the County of Fresno's Caltrans Climate Adaptation Planning Grant application to explore transportation infrastructure resiliency in the county's eastern region.

Fresno County's eastern region is vulnerable to flooding, drought, wildfire, and tree mortality, among other climate-related issues. These climate risks can cause roads to close, cutting residents off from essential services such as health care, school, work, food and sanitation, as well as access to the urban areas of Fresno and Clovis, which have more supplies than the rural communities. These vital services often require long trips to access, meaning that the roads are essential to life in this area. This grant would fund a study to find effective mitigation solutions to the climate change effects on the region's transportation infrastructure, allowing roads to remain open to residents, commerce, and natural resources.

Increasingly frequent floods, wildfires, and drought impact not only impact our residents' daily lives but they also affect trucks moving commodities across the region. The roads in this area are often the lone point of access for supplies coming in and out of these communities, as well as power infrastructure for Southern California Edison. Climate trends predict earlier snow melts that will dramatically impact the water supply for the entire state of California, impacting agriculture downstream and drinking water for residents statewide. As this is a critical issue for our residents and the well-being of the State, the sooner we can start preparing our infrastructure for future conditions, the better equipped our residents and the State will be to withstand them.

I am committed to working with the County of Fresno to help facilitate public engagement and hear the concerns of residents so that we may find solutions that work best and carry us forward.

Sincerely,

Robert Phipps
Executive Direcctor
Fresno Council of Governments

ATTACHMENT G

4886 East Jensen Avenue
Fresno, California 93725

Tel: 559.237.5567
Fax: 559.237.5560

www.krcd.org
@kingsrivercd

January 21, 2025

Steven E. White
Director, Fresno County Public Works and Planning
2220 Tulare Street, 8th Floor
Fresno, CA 93721

Re: Support for Fresno County's Climate Adaptation Planning Grant Application

Dear Mr. White:

On behalf of the Kings River Conservation District, I want to express my support for the County of Fresno's application for a Caltrans Climate Adaptation Planning Grant to explore transportation infrastructure resiliency in the communities I represent.

The service area of the Kings River Conservation District is vulnerable to flooding, drought, wildfire, and tree mortality, among other climate related issues. Flooding is of particular concern for the District, which is entrusted with responsibility for managing water, energy, and environmental resources in this region. This grant would fund a study to find effective mitigation solutions to the effects of climate change on the region's transportation infrastructure, which is directly tied to the goals of the District.

Increasingly intense wet and dry seasons in the Kings River service area have profound impacts on the water supply from the Kings River. Drought exacerbates overdrafting of groundwater resources, and intense rains and snow melts can cause floods that overwhelm the capabilities to recharge these resources. With climate trends predicting intensifying extremes, it is crucial that the infrastructure of this region be prepared to accommodate the realities of the future. Finding effective mitigation solutions can protect natural resources as well as the people and industry that depend on the Kings River, so the sooner we act, the better equipped the region will be to withstand them.

Sincerely,

David M. Merritt
General Manager

DMM/BS/dmr

File: 300.05.02
L25-0010

A thriving Community
Una próspera Comunidad

January 15, 2025

Steven E. White
Director, Fresno County Public Works and Planning
2220 Tulare Street, 8th Floor
Fresno, CA 93721

Subject: Support for Fresno County's Climate Adaptation Planning Grant Application

Dear Mr. White,

On behalf of the city of Parlier, I want to express my support for the County of Fresno's application for a Caltrans Climate Adaptation Planning Grant to explore transportation infrastructure resiliency in the communities I represent.

The residents of Parlier are vulnerable to flooding, drought, wildfire, and tree mortality, among other climate related issues. These climate risks can cause roads to close, cutting residents off from essential services such as health care, school, jobs, food and sanitation, as well as access to the urban areas of Fresno and Clovis which can have more supplies than the more rural communities. Road closures also impact the agricultural economy which is a major concern for the residents of the region. This grant would fund a study to find effective mitigation solutions to the effects of climate change on the region's transportation infrastructure, allowing roads to remain open to residents, commerce, and natural resources.

Not only do increasingly frequent floods, wildfires, and drought impact the daily lives of residents on the front lines of these changing conditions, but also trucks moving commodities across the region. Climate trends predict earlier snow melts that will dramatically impact the water supply for the entire state of California, impacting agriculture downstream and drinking water for residents statewide. As this is a critical issue for the residents of this region and the well-being of the state, the sooner we can start preparing our infrastructure for future conditions, the better equipped the residents and the state will be to withstand them.

1100 E. Parlier Avenue, Parlier, California 93648 • PHONE (559) 646-3545 • FAX (559) 646-0416

I am committed to working with the County of Fresno to help facilitate public engagement and hear the concerns of residents so that we may find solutions that work best and carry us forward.

Sincerely,

Alma Beltran
Mayor

ATTACHMENT G

City of Reedley

OFFICE OF THE MAYOR
1717 Ninth Street
Reedley, Ca. 93654
(559) 637-4200 ext. 212

January 15, 2025

Steven E. White
Director, Fresno County Public Works and Planning
2220 Tulare Street, 8th Floor
Fresno, CA 93721

Subject: Support for Fresno County's Climate Adaptation Planning Grant Application

Dear Mr. White,

I wholeheartedly support the County of Fresno's application for a Caltrans Climate Adaptation Planning Grant to explore transportation infrastructure resiliency in the community I represent.

The residents of Reedley are vulnerable to flooding, drought, wildfire, and tree mortality, among other climate related issues. These climate risks can cause roads to close, cutting residents off from essential services such as health care, school, jobs, food and sanitation, as well as access to the urban areas of Fresno and Clovis which can have more supplies than the more rural communities. Road closures also impact the agricultural economy which is a major concern for the residents of the region. This grant would fund a study to find effective mitigation solutions to the effects of climate change on the region's transportation infrastructure, allowing roads to remain open to residents, commerce, and natural resources.

Not only do increasingly frequent floods, wildfires, and drought impact the daily lives of residents on the front lines of these changing conditions, but also trucks moving commodities across the region. Climate trends predict earlier snow melts that will dramatically impact the water supply for the entire state of California, impacting agriculture downstream and drinking water for residents statewide. As this is a critical issue for the residents of this region and the well-being of the state, the sooner we can start preparing our infrastructure for future conditions, the better equipped the residents and the state will be to withstand them.

I am committed to working with the County of Fresno to help facilitate public engagement and hear the concerns of residents so that we may find solutions that work best and carry us forward.

Sincerely,

Matthew Tuttle
Mayor of Reedley

ATTACHMENT H

PHOTOS OF DAMAGED ROADWAYS IN EASTERN FRESNO COUNTY

Creek Fire in eastern Fresno County, September 2020.

PHOTOS OF DAMAGED ROADWAYS IN EASTERN FRESNO COUNTY

Creek Fire surrounding a bridge under construction in September, 2020

Fire damage on Alder Springs Road near Auberry in Eastern Fresno County.

ATTACHMENT H

PHOTOS OF DAMAGED ROADWAYS IN EASTERN FRESNO COUNTY

***Washout due to flooding on Anchor Ave near Orange Cove in eastern Fresno County*.**

ATTACHMENT H

PHOTOS OF DAMAGED ROADWAYS IN EASTERN FRESNO COUNTY

Flood damage on Dunlap Road in eastern Fresno County.

Flood damage on Ruth Hill Road in eastern Fresno County.

ATTACHMENT H

PHOTOS OF DAMAGED ROADWAYS IN EASTERN FRESNO COUNTY

***Rockslide due to storms on Highway 168 in eastern Fresno County*.**

***Washout due to storms on Italian Bar Road in eastern Fresno County*.**

ATTACHMENT H

PHOTOS OF DAMAGED ROADWAYS IN EASTERN FRESNO COUNTY

***Storm damage on Todd Eymann Road near Miramonte in eastern Fresno County*.**

ATTACHMENT H

PHOTOS OF DAMAGED ROADWAYS IN EASTERN FRESNO COUNTY

***Washout due to flooding on Old Millerton Road in eastern Fresno County*.**

Mudslide on Trimmer Springs Road in eastern Fresno County.

ATTACHMENT H

PHOTOS OF DAMAGED ROADWAYS IN EASTERN FRESNO COUNTY

***Storm damage on Hintington Lake Road in eastern Fresno County*.**

***Storm damage on Hogback Road in eastern Fresno County*.**

ATTACHMENT H

PHOTOS OF DAMAGED ROADWAYS IN EASTERN FRESNO COUNTY

***Flooding due to storms at Cricket Hollow Park near Reedley in eastern Fresno County*.**

***Levee breach due to storms near Sanger in eastern Fresno County*.**