ResilientShasta Extreme Climate Event Mobility and Adaptation Plan

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Executive Summary

Extreme weather – including wildfires, floods, heatwaves, extreme storms, and landslides – threaten the transportation infrastructure of the Shasta Region and the mobility of its residents. Extreme weather poses a growing threat as the warming climate intensifies existing hazards and introduces new ones. Rising temperatures and changing precipitation patterns are interacting with local weather, hydrology, forests, and geology to create a changing set of circumstances for the infrastructure systems that the Shasta Region relies on.

This report focuses on the mobility infrastructure of the Shasta Region, including the cities of Shasta Lake, Redding, and Anderson, as well as Shasta County. It is the culmination of the Resilient**Shasta** effort undertaken by the Shasta Regional Transportation Agency (SRTA) to understand the vulnerabilities of the Shasta Region's mobility infrastructure to climate change and extreme weather, identify adaptation actions that will respond to those vulnerabilities, and integrate those actions into a long-term transportation network planning effort for the Region. This report consists of two components: a Shasta Regional Mobility Vulnerability Assessment (vulnerability assessment) that comprehensively investigates, evaluates, and summarizes the Region's

What is Mobility Infrastructure?

Rather than focusing just on the region's transportation infrastructure, this study focuses on the Shasta region's mobility, a concept that includes ***all of the systems that enable the residents of the Shasta region to move around freely and easily, including during emergencies***. Mobility includes both the necessary built infrastructure, as well as the organizations such as RABA, SRTA, Caltrans, Amtrak, and beyond.

Figure ES-1 The Carr Fire burned extremely close to downtown Redding. The extent of the Carr Fire's burn scar in Lake Redding Estates, with central Redding in the distance. Source: City of Redding 2018.

key vulnerabilities to climate change and extreme weather, and the Shasta Regional Mobility Adaptation Plan that explores and recommends adaptation strategies that the Region's state and local agencies should consider to improve the region's resilience to climate impacts.

The vulnerability assessment addresses historical and projected future weather and climate conditions in the Shasta Region and identifies expected changes over the coming century. The vulnerability assessment also evaluates the exposure of the Region's transportation infrastructure and systems to climate and extreme weather hazards and assesses their vulnerability, identifying the Region's highest priority exposure to climate change. The adaptation plan follows the vulnerability assessment, outlining 25 strategies for municipal, county, and state agencies to address climate vulnerabilities. The strategies are designed to leverage existing processes where possible, expand on existing opportunities, and promote cooperation and communication among agencies that conduct similar programs.

Both the vulnerability assessment and the adaptation plan are informed by input from the region's governments and stakeholders, as well as through extensive public input gathered through two surveys and two public meetings.

Key Findings

The Shasta Region is extremely vulnerable to climate and extreme weather hazards, especially wildfires, threatening mobility

Exposure to extreme temperatures, extreme precipitation, and floods all threaten the mobility of Shasta residents, but wildfire poses the greatest challenge. The Shasta Region's forests are already experiencing weather conditions which threaten severe and dangerous fires every summer. Projected changes to weather in the region will intensify the threat, making fires both more likely and more severe. Likewise, projected changes to extreme temperatures and extreme precipitation threaten increased costs associated with faster road and vehicle degradation, flooding/ponding, erosion, and more frequent disruptions to road, bus, train, and active transportation services. Collectively the Region's exposure to these hazards severely threatens the mobility of Shasta residents.

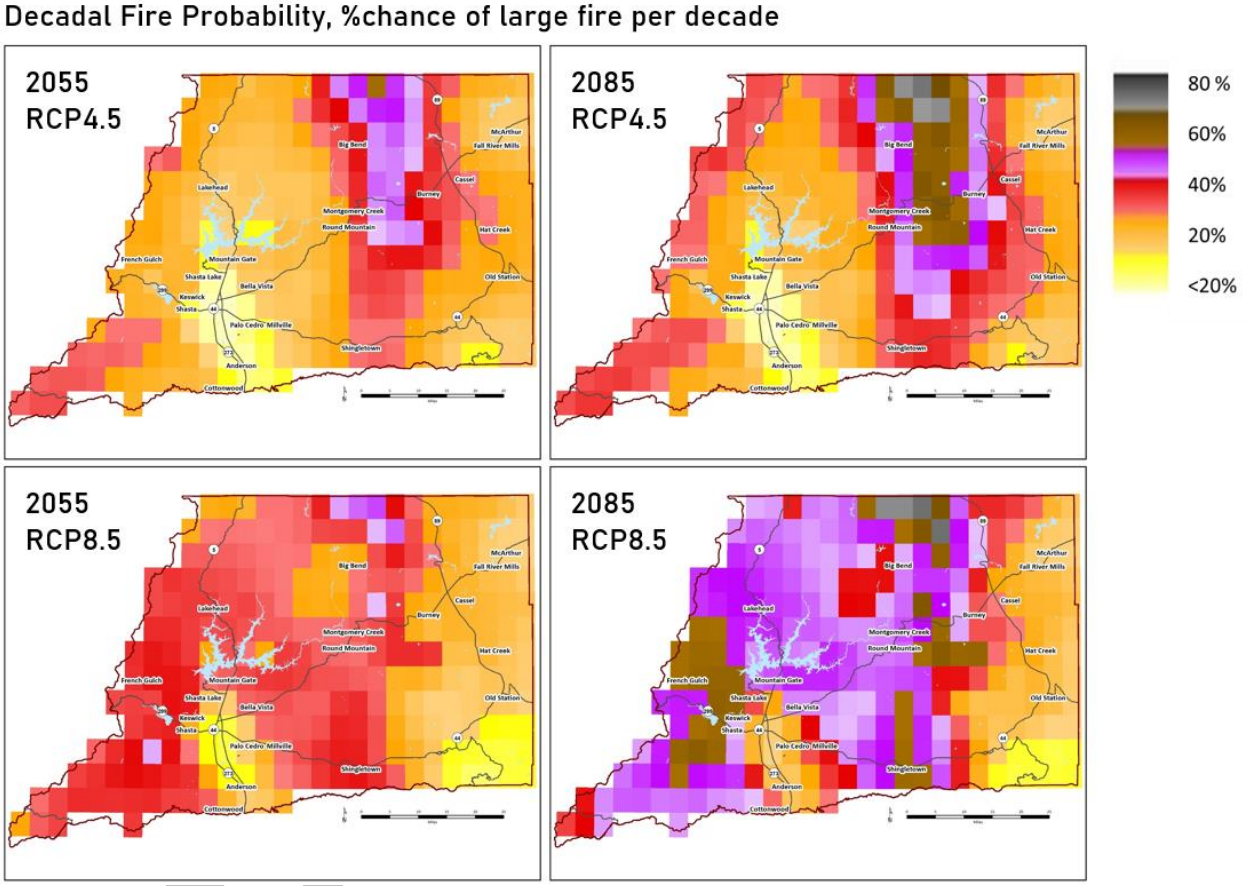
This study identified six key vulnerabilities, including:

- Projections show extreme increases in both **wildfire probability** and **severity** over the coming century, including in areas with key transportation infrastructure
- All-cause evacuation planning does not address **key mobility gaps**, including those for **vulnerable populations**, and rural areas with limited transportation options
- Increases in extreme temperature are likely to accelerate wear & tear on roads and vehicles, impair use of pedestrian, cyclist, and transit systems
- Projected increases to **extreme precipitation** are likely to intensify current hazards related to **localized flooding** and **road delays/closures** due to snow
- **Flood hazards** are likely to increase with **extreme precipitation**, particularly on **uncontrolled streams**, and with **unknown implications for dams**
- Increases in extreme precipitation and wildfire hazards increase the risk of **landslide activity on burned slopes**, especially during **extreme precipitation events**

Mitigating emissions can reduce long-term impacts, but mid-century impacts are baked in

In most cases, the biggest differences between projected climate hazards in the 'best case' reduced emissions scenario (RCP4.5) and the 'worst case' unconstrained emissions scenario (RCP8.5) occur toward the end of the century in the 2085 projections. By comparison, mid-century (2055) projections show much smaller differences between reduced emissions and unconstrained emissions scenarios. Figure ES-2 shows how reduced global emissions may help the region avoid the worst projections for wildfire hazards.

Figure ES-2. Significant increases in wildfire probability are likely to occur by 2055, regardless of emissions scenario. But emissions reductions may reduce extreme hazards by the end of the century.



For Shasta residents and planners, the implication is clear: emissions mitigation actions are an important step to avoid the worst long-term effects of climate change, but will not be sufficient to avoid mid-century projections of climate hazards. Instead, the Shasta Region should plan to adapt its transportation systems to function under the climate and weather conditions projected in this report.

Managing extreme climate and weather hazards like fire is becoming essential to maintaining good condition transportation infrastructure

As the Shasta Region's climate becomes warmer and more extreme, design and maintenance of the region's built infrastructure must also adjust. Built infrastructure that was designed for past climates will likely face accelerated degradation as harsh operating conditions increase wear and tear. New

infrastructure should be built with the climate of the future in mind. A paradigm shift towards addressing climate hazards is necessary as well: ensuring that roads are in good condition should include actions to prevent fires from igniting and spreading along roadsides, as well as protecting roads from fires. Similarly, maintaining vehicles/roads/infrastructure for heat means maintaining them for extreme heat.

Evacuations are inevitable, so transportation investments should seek to make them faster, equitable, and more effective – all without compromising other mobility goals

While evacuation is not traditionally considered a core element of mobility, the fire hazards facing the Shasta Region compel public safety and transportation agencies to consider evacuations in all transportation planning. Evacuation should be considered from every perspective, including planning, design, infrastructure operations, and maintenance. Government, private, and non-profit stakeholders in the region should also work together to improve information sharing about mobility-challenged residents, accelerate evacuation warnings, and assign responsibilities for evacuations.

Changing conditions mean that new hazards are likely to emerge, including from co-dependent infrastructure systems

As transportation systems – along with other critical infrastructure systems like energy, telecommunications, and water – become more integrated and interdependent upon external services, mobility will be increasingly vulnerable to disruptions to interconnected systems. For example, electrification of vehicles exposes much of the Region's transportation infrastructure to vulnerabilities associated with extended power outages. Likewise, automation of signals and an increasing reliance on digital and connected systems to control transportation infrastructure leaves system operators reliant on power, internet, and cellular services. During emergencies, failures in energy or telecommunications systems can cascade, leading to disruptions in transportation services. Disruptions in transportation can likewise exacerbate emergencies or delay restoration of critical infrastructure systems – damaged or destroyed roads can prevent repair crews from reaching downed power lines or damaged communications equipment.

Shasta Regional Mobility Adaptation Plan

The warming climate is already affecting extreme weather in the Shasta Region, across California, and around the world. However, the changes are happening gradually, and day-to-day, seasonal, and annual changes in weather are often enough to make the gradual increase in temperature or fire hazard imperceptible.

Adaptation strategies are actions or sets of actions designed to integrate an awareness of climate hazards into transportation and mobility planning, operations, and management decision-making processes at every level. When full information about projected future hazards is available, many adaptation strategies are simply common-sense efforts to build systems today that will be able to withstand future conditions. However, due to incomplete information or uncertainty, it is not always possible to plan precisely for future conditions. Furthermore, extreme weather events like wildfires and floods occur randomly, even when the warming climate makes their occurrence more likely and more severe.

What is Adaptation?

Climate change *adaptation* refers to any action to prepare for and adjust to changing conditions. Adaptation measures are typically designed with the goal of preventing or reducing damage or disruption, but can also include actions that take advantage of new opportunities, or that create co-benefits for communities and the environment. Adaptation planning is occurring in the public and private sectors and at all levels of government. Presently, adaptation actions are rare, and much more work is necessary to protect the both the Region's and the nation's infrastructure, but agencies like SRTA are taking steps to begin adapting to climate change.

Types of Hazards

Adaptation strategies must address two different types of climate hazards:

- **Acute hazards**: wildfires, floods, and extreme precipitation events (and to a lesser extent landsides) constitute acute hazards that materialize quickly (in a matter of minutes, hours, or days), disrupt regional mobility, and threaten severe costs (including lives)
- **Chronic hazards**: hotter summers, warmer winters, and changes to regional precipitation patterns affect infrastructure systems slowly, gradually increasing the wear and tear on built systems, machines, or increasing demand from users

Figure 1. Acute and chronic hazards can result from the same underlying change: rising temperatures are expected to result in both acute hazards like heat waves as well as chronic hazards like drought. Image Sources: NEHS 2017, NOAA 2019.

Acute hazards often draw the attention due to the dramatic nature of natural disasters; however chronic hazards play a major role in setting the stage: hotter, dryer summers increase the risk of wildfires, and more frequent and severe extreme precipitation events increase the risks of regional flooding. Strategies to address these different types of hazards must take different approaches.

Components of Resilient Mobility

Resilient mobility requires implementing multiple facets of resilience. These include:

- **Resistance**: the ability to handle shocks while minimizing disruption or damage
- **Recovery**: the ability to repair infrastructure and restore service quickly and at a minimum cost
- **Adaptive capacity**: the ability to integrate new information and experience into adaptive processes

Combined, resilient mobility means mobility that maintains acceptable service during acute hazards, that recovers quickly and effectively from disruptions, and that retains the ability to adapt to changing conditions based on future lessons learned. In the Shasta Region, resilient mobility means a transportation system that provides clear and reliable evacuation directions and routes during acute hazards, that ensures detours are clear and well-planned, and that ensures all Shasta residents are provided the means of a safe and effective evacuation to the best ability of the region's transportation agencies.

Types of Adaptation Strategies

This strategy discusses several different types of adaptation strategies:

- **Planning strategies**: Planning strategies include actions taken to ensure that future investments are designed and built-in anticipation of future conditions. These may include research efforts, plans and reports, design standards, or even simply policies
- **Operational strategies**: Operational strategies are actions taken to change the current operations of one or more agencies in order to improve resilience to an extreme weather hazard.
- **Hardening strategies**: Hardening strategies involve investments in physical capital for existing infrastructure.
- **Replacement strategies**: Replacement strategies involve abandoning an existing system and replacing it with a new one (also called relocation). This report does not recommend any replacement strategies.

For some strategies, the line between types may blur – for example, many hardening strategies can be framed as planning strategies, where the vulnerable infrastructure is substituted for hardened infrastructure, but only after the existing infrastructure has worn out past its useful lifetime.

Wildfire

Throughout virtually all the Shasta Region, wildfire hazards are projected to grow more extreme in coming decades.

Projections show extreme increases in both wildfire probability and severity over the coming century, including in areas with key transportation infrastructure

Multiple approaches to reduce wildfire hazards statewide are being researched, and proactive clearing of dangerous biomass, alternative forest management strategies, and approaches to reduce risk of ignition such as enhanced vegetation management on transmission line rights-of-way are all important tools to reduce the hazards presented by wildfire from the top.

This plan is focused on strategies to mitigate the threats of wildfire to the mobility of Shasta residents. Rather than reducing the frequency or size of wildfires in general, these strategies are oriented toward protecting and enhancing the transportation infrastructure of the Shasta region and the mobility of its residents. However, because roadside fires are often initiated by vehicles or drivers, reducing the risk of fire ignition within road rights of way (ROW) is a key goal of these strategies.

W.1: Prioritize fire safety and road protection projects through the Regional Transportation Plan

In order to ensure mobility in the Shasta Region under changing climate conditions, there is no more pressing goal than reducing the threat of wildfire on the region's network of roads and highways. SRTA should consider this goal a key objective of updates to the 2022 Regional Transportation Plan (RTP). Using the RTP, SRTA should set out two new long-term maintenance goals: roadside fire safety and road protection.

W.1 strategy roles & Responsibilities	
Type of strategy	Planning
Proposed lead agency	SRTA
Additional agencies/ roles	State and local public works agencies, utilities
SRTA role	Lead
Possible funding	N/A

Roadside fire safety includes activities that reduce the risk of roadside fire ignition. These primarily include thinning trees and shrubs and clearing hazardous fuels within the ROW of high traffic roads and roads that transit areas of elevated wildfire hazard, but can also include public messaging campaigns**.** Reducing the buildup of hazardous fuels is addressed in other strategies (see **W.2: Convene stakeholder Hazardous Fuels Reduction Working Group**), however SRTA should explore updates to regional transportation policy that provide permanent funding for prioritized vegetation management.

Road protection includes activities that reduce the damage to roads and disruption to mobility caused by fires. When intense wildfires burn over roads, they do damage in several ways, some obvious and some less obvious. Road furniture (including signs, poles, guard rails, and other stationary equipment), communications and utility equipment, bridges, culverts, and pavements can all be damaged by heat, flames, and smoke. Following a fire, the condition of bridge piers, decks, and culverts must all be inspected, and damaged road furniture replaced. In circumstances where utilities have located

important equipment in the ROW (e.g., power transformers, communications hubs/switches, etc.), utilities should consider enclosing it in fire resistant cases.

SRTA's ability to dedicate funding for fire safety and road protection through existing funding sources is limited, however SRTA should explore mechanisms to prioritize funding for projects which achieve these goals, especially where the vulnerability is greatest. SRTA should also provide analytical assistance to agencies where necessary.

W.2: Convene stakeholder Hazardous Fuels Reduction Working Group

W.2 strategy roles & responsibilities	
Type of strategy	Planning, Hardening
Proposed lead agency	Cal Fire, local fire districts
Additional agencies/ roles	Public works agencies, Cal Fire, U.S. Forest Service, electric utilities, municipal fire agencies, additional regional partners
SRTA role	Advisory
Possible funding	Calfire Fire Prevention Grants

The most important step to protect road corridors from wildfire is to reduce the density of hazardous fuels along the region's roadsides. In order to prevent future fires, roadside fuels reduction must become a regular component of road maintenance. In support of creating road corridors that minimize the risk of roadside fire ignition and protect evacuating residents, the agencies responsible for planning, coordinating, and executing both hazardous fuels reduction projects and road protection and maintenance projects should convene a working group of stakeholders for the goal of identifying and clearing or mitigating hazardous fuels within and along the right of ways of highways and major arterials. The intended outcome of this working group would be to achieve defensible spaces along the region's major corridors and in areas subject to greater wildfire threats. Figure 2 demonstrates the concept of defensible spaces as areas alongside a road's right of way where combustible biomass is cleared, shredded, or prescribed-burned.

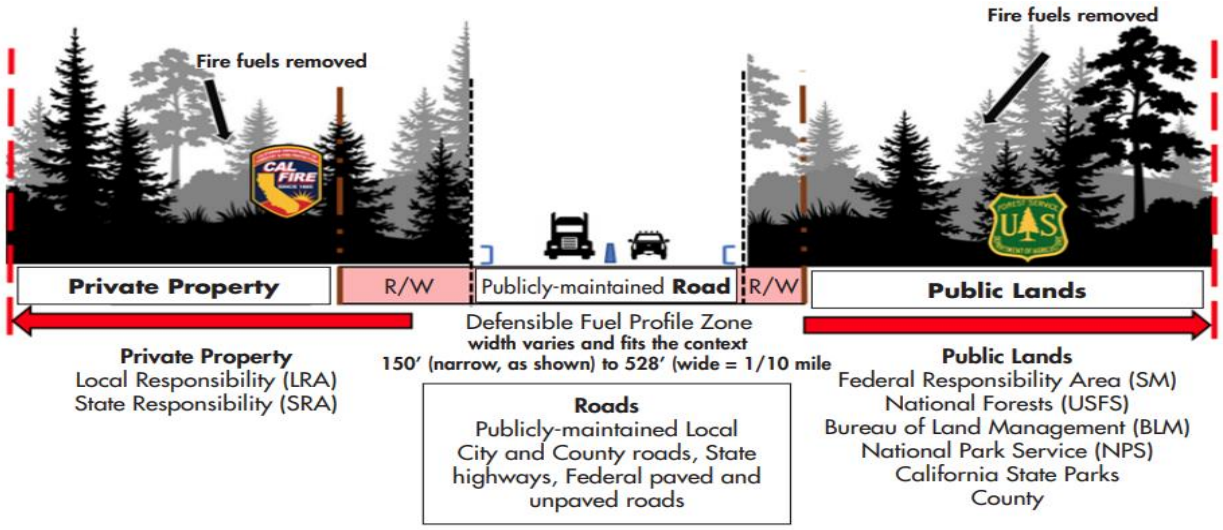


Figure 2. Diagram showing the "defensible fuel profile zone" surrounding a roadway. Responsibilities depend on type of land which public right-of-way transits. Source: California Forest Management Task Force 2021

The purpose of the Hazardous Fuels Reduction Working Group would be to act as a clearinghouse for fuel reduction projects among the various stakeholders, enabling agencies to share plans, coordinate efforts where possible, and ensure that boundaries between local, county, and state jurisdiction do not lead to areas of hazardous fuel buildup. The working group should include at a minimum any agencies conducting fuel mitigation within the Region, including Cal Fire, Caltrans, and County and municipal public works agencies and fire protection agencies.

The working group should first prioritize cooperation and communication, establishing a means for sharing the timing and scope of scheduled mitigation projects, as well as the internal methods agencies use for planning mitigation projects. Over a longer timeframe, the working group should collectively set goals for clearing high-to-severe hazards within an achievable timeframe and set subsequent goals for maintaining fire safe road corridors along the region's highways. The working group could further share best practices (including for clearance methods and tools), lessons learned, and opportunities for funding, and provide additional contact points for improved emergency response. The working group should meet at least twice per year – once at the beginning of the year when projects are being planned, and again at the beginning of the summer. Ideally more frequent meetings should be held in order to ensure that the critical work maintains a high priority within agencies.

As a planning agency, SRTA's role in this working group would be functionally limited, but SRTA can provide long-term planning perspectives, especially related to the prioritization of defensible space clearing near critical routes for secondary access (see adaptation strategy **E.2: Evaluate evacuation bottlenecks and secondary access constraints**). SRTA should seek to be able to provide analysis on current and expected future changes to road usage to facilitate prioritization of working group projects. Additionally, as a part of the ResilientShasta project, SRTA should act as a facilitator to convene stakeholders at the outset and ensure that the working group has commitments from county and city DPWs. This goal may also benefit from use of a new Caltrans collaborative fuels reduction framework (currently under development). As a facilitator, SRTA is also in a prime position to involve additional local stakeholders with relevant input. The Shasta Region has a rich cultural history that can provide important perspectives such as local tribes who may provide indigenous ecological knowledge about

forest management. SRTA can also balance inputs from different user groups, for example by working to clear hazardous vegetation without disrupting shade cover essential to alternative transportation user groups such as hikers, pedestrians, cyclists, and others not using automobiles. Finally, SRTA can play an important role in identifying sources of funding to facilitate this working group.

W.3: Convene private landowners for collaborative hazardous fuels reduction

Following establishment of the Hazardous Fuels Working Group, stakeholders (including public works agencies) should seek ways to integrate key private landowners into a new group focused on hazardous fuel clearing efforts on private lands adjacent to public roads. While critical evacuation corridors often have sufficiently wide rights of way (the land on either side of the road owned by a public agency), many county and local roads have far narrower ROWs. State highways often have ROWs of 150' or wider, while county and local roads can be 60' or narrower. When hazardous fuels accumulate on private lands directly adjacent to county roads that serve as essential access roads to subdivisions or for rural communities, clearing vegetation requires complex arrangements between private landowners, public agencies, and potentially regulators. Additionally, even roads which do not serve any critical evacuation role may be good targets for collaborative fuel clearing efforts. Fires can be sparked on small roads that quickly spread to wider areas.

W.3 strategy roles & responsibilities	
Type of strategy	Planning, Hardening
Proposed lead agency	Cal Fire, fire districts
Additional agencies/ roles	Hazardous Fuels Reduction Working Group, private landowners
SRTA role	Advisory
Possible funding	California Fire Foundation Fire Prevention and Preparedness Grants

The goal of convening select private landowners would be to facilitate cooperative fuel clearing efforts, educate landowners about their important role in mitigating fire hazards, and share resources and lessons learned from the Hazardous Fuels Reduction Working Group. While formal engagement with private landowners may require action from Regional governments to overcome legal or political barriers, the work of the working group would comprise an important element of a Regional response to mitigating fire hazards. The group would focus on the largest landowners with the highest-priority lands (i.e., lands with very high to severe fire hazard adjacent to critical evacuation corridors). The group should also serve as a resource for landowners seeking information on means to commercialize hazardous fuels on their property.

As with the Hazardous Fuels Reduction Working Group, SRTA's role in this group would be limited to advising participants with data and analysis (including current and projected traffic on road segments, road conditions). SRTA's efforts to identify critical secondary access routes and evacuation bottlenecks (see adaptation strategy **E.2: Evaluate evacuation bottlenecks and secondary access constraints**) will also be essential input for these efforts. SRTA should also seek an ongoing dialogue with local landowners and local foundations dedicated to finding funding and revenue sources for hazardous fuel clearing. In the long-term, roadside fuel clearing will need to become a cohesive element of SRTA's prioritization of transportation projects in the region. For example, recent efforts by the McConnell

Foundation to reduce hazardous fuel buildup along roadways from Redding to French Gulch has been delayed by administrative barriers between FEMA, Cal Fire, Shasta County, and the foundation.[1] SRTA should explore using future versions of the RTP to secure funding for fuels reduction and defensible space on the region's roads.

W.4: Proactively plan road resurfacing following heavy fire-fighting activity as part of recovery grants

W.4 strategy roles & responsibilities	
Type of strategy	Operational
Proposed lead agency	SRTA
Additional agencies/ roles	State and local public works agencies
SRTA role	Analytical, advisory
Potential funding	FEMA BRIC Grants

Following a fire, accelerated degradation of road surfaces and subgrades often occurs, especially on low-traffic and low-capacity roads in rural locations (or serving as secondary access routes to subdivisions). During a fire, some roads will experience a sudden increase in use by heavy firefighting and support equipment. Water trucks, bulldozers, and other types of heavy loads will use roads designed to carry much smaller loads. Additionally, in the weeks and months after a fire trucks of equipment and supplies to support recovery and reconstruction may cause further damage. When this heavy traffic gets concentrated on individual road segments, rapid wear and tear can occur, significantly shortening the useful lifetime of the pavement and subgrade.[2] While this can be difficult to detect in the immediate aftermath of a fire, symptoms of deeper damage to the road structure (such as alligator cracking or rutting) may begin to appear soon after.

Along with the relevant transportation agencies in the county, SRTA should work to ensure that these potentially damaged areas receive appropriate recovery funding and repair. Although SRTA cannot lead these efforts, SRTA can provide necessary monitoring, data, and analysis as well as play an important role convening stakeholders in the region to share experiences and best practices. For example, the City of Redding currently has an extensive process for utilizing emergency funds for resurfacing and repair and could share and compare this process with the Region's other public works agencies. When disaster declarations enable state and local agencies to apply for recovery grants, the Shasta Region's applications must specify the areas damage and the necessary repairs.

Damage to road pavements can be evaluated using metrics like the Pavement Condition Index (PCI) or other observation-based measures. By comparing pre- to post-fire conditions, agencies can plan maintenance approaches accordingly (anything from resealing to reconstruction). Assessment of pavement condition is essential as damage may go unnoticed until after recovery funding is no longer available. PCI (or alternative measures of pavement condition) are likely to be an important component of federal performance measures required for interstate and national highways in the 2022 RTP.

[1] Arthur 2021

[2] https://www.cacities.org/Resources-Documents/Education-and-Events-Section/Public-Works-Officers-Institute/2020-Session-Materials/The-Unseen-Impact-of-California-Wildfires-on-Affec

Whether the lead agency for a recovery grant is Caltrans District 2, Shasta County DPW, or another municipal agency, SRTA should seek to ensure this data is available for post-disaster grant applications.

SRTA can further advise lead agencies by providing the primary analysis to identify potentially damaged segments. In some cases, heavy traffic on roads already known to be under-built for large vehicles, or already in fair to poor condition should indicate that recovery grants should be considered even before signs of deterioration emerge. By proactively planning these projects – especially on rural state and county roads – the mobility of rural residents will not need to be impaired by failed road surfaces before repairs can be scheduled.

Evacuation Planning

All-cause evacuation planning does not address key mobility gaps, including those for vulnerable populations, and rural areas with limited transportation options

Evacuation planning and execution poses a critical challenge to the Shasta Region's mobility. Without an effective system to ensure rapid, and universal evacuations, the growing fire hazards in the region will become deadlier. But while evacuation planning can be a useful tool for increasing response times and accelerating evacuations, plans are useless unless they provide workable, flexible frameworks and help develop relevant knowledge and skillsets among the public servants charged with implementing them.

Recommended improvements to evacuation planning in the Shasta Region are focused predominantly on operational and planning measures, but also include a focus on building infrastructure to facilitate all-cause evacuations.

E.1: Plan for the evacuation of mobility-challenged populations

E.1 strategy roles & responsibilities	
Type of strategy	Operational
Proposed lead agency	Public health agency
Additional agencies/ roles	Shasta County OES, Shasta County Sheriff's Office, private hospital networks/housing providers, RABA
SRTA role	Advisory
Possible funding	FTA Section 5310 Grants

Currently, the Shasta County Office of Emergency Services (OES) Emergency Operations Plan (EOP) assigns the primary responsibility for the evacuation of "Access and Functional Needs populations" (including individuals with physical disabilities, no access to vehicles, children and the elderly, limited English speakers, the deaf and hard of hearing, and those with special dietary needs) to the individual. The EOP states the county will assist these mobility-challenged by providing "preparedness information, emergency public information, and critical public services in an accessible manner."

Given projected increases in wildfire probability and intensity across the region, it is essential that the Shasta Region establish formal procedures to ensure that mobility-challenged are able to evacuate. Although some of these goals are already achieved through agreements between RABA, the Shasta County Sheriff's Office (SCSO), and other agencies, these agreements do not achieve the goal of ensuring comprehensive outreach and evacuation of mobility-challenged populations. Public safety, health, and transportation agencies and stakeholders in the Shasta Region should seek to achieve this goal. One approach would be to convene a working group to solve this problem and establish a workable plan. The Shasta County Health and Human Services Agency is the proposed lead agency for this effort, although several agencies could lead this effort, and any effort will require multiple agencies and institutions to effectuate any evacuation. These include Shasta County OES, SCSO, and private/non-profit healthcare networks and providers (including Mercy Medical, Dignity Health, Hill Country Community Clinic), assisted living, nursing care, and palliative/hospice care providers, and organizations dedicated to seniors and residents living with disabilities (e.g., Disability Action Center, Far Northern Regional Center, etc.).

Currently, the county plan only indicates that transportation is available for residents with some level of mobility. The EOP's transportation element identifies three conditions required to transport mobility-challenged residents:

- Evacuees can be accommodated at both embarkation points and at destination general population shelters
- Evacuees can travel on commercial long-haul buses, aircraft, passenger trains, or lift-equipped buses
- Evacuees do not have medical needs indicating they should be transported by specialized medical transport

The goals of the working group should be to identify the mobility-challenged residents in each community, and to understand their mobility challenges, the available assets, where gaps in capacity exist, and which measures would be most productive for assisting in their evacuation. The working group should seek to determine a policy for the rapid and comprehensive evacuation of mobility-challenged residents and explore paths forward toward implementing the policy. The working group should also define the roles and responsibilities of agencies and organizations that are involved. The working group should consider several approaches, including:

- An expansive rapid telephone or text notification system for outpatient clients with significant disabilities or other known mobility challenges, ideally run by healthcare providers with access to patient data and assisted by Shasta County OES for the development of language and advisories
- A county-level official tasked with managing evacuations of mobility-challenged residents during an evacuation, and charged with coordinating evacuations with SCSO, OES, and healthcare/housing providers, as well as an update to the EOP articulating the mobility coordinator's place in the chain of command
- A targeted messaging campaign through healthcare and housing providers for mobility-challenged residents (including non-English and non-native English speakers) informing them of their responsibilities during an evacuation under the updated policy, how to plan ahead for an evacuation, and resources available for evacuation assistance
- An opt-in directory of qualified chronically mobility-challenged residents who will rely on assistance for evacuation

SRTA's role in the working group will necessarily be limited, but should include an articulation of the system's vulnerabilities identified in the Transportation Vulnerability Assessment as well as an ongoing evaluation of the distribution and transportation capabilities of mobility-challenged populations in the region. SRTA should seek to collect data on mobility-challenged populations as part of its ongoing efforts to understand the distribution of disadvantaged and vulnerable communities in the Shasta Region. Over the long-term, SRTA's involvement should also include relevant updates to planned transportation projects and planning documents in accordance with projects resulting from this working group.

E.2: Evaluate evacuation bottlenecks and secondary access constraints

E.2 strategy roles & responsibilities	
Type of strategy	Operational
Proposed lead agency	SRTA
Additional agencies	State and local public works agencies, SCSO, CHP
SRTA role	Lead, Planning
Potential funding	FEMA Building Resilient Infrastructure and Communities (BRIC) Grants

Across the Shasta Region, subdivisions (in both urban and rural areas) and rural communities are served by road networks with limited access routes or with access routes that pose potential bottlenecks during a mass evacuation. For example, the community of Burney is served by only one highway (299) that provides evacuation routes east and west (Figure 3). However, both routes cross areas of very high to severe fire threat, and in an area projected to see significant increases in fire probability and severity. The only other road out of town is an unpaved rural road.

As the region's transportation planning agency, SRTA should seek means to complete an evaluation of the availability, adequacy, and vulnerability of the region's secondary access routes, and to correct these evacuation inadequacies through future road network investments or technological solutions. In subdivisions (which are currently required to have secondary access routes), the emphasis should be on the adequacy of secondary access routes for evacuation of the served population (e.g., including the current condition and capacity of the route), and the exposure of the route to fire hazards (using the Fire Threat Index, satellite imagery, and ground truthing when necessary). This effort should also seek to identify any subdivisions or communities which do not have a required secondary access route.

Figure 3. Highway 299 in the mountains between Montgomery Creek and Burney. Highway 299 is two lanes, with some three-lane passing sections, and is the only viable evacuation route out of communities like Burney, Montgomery Creek, and Round Mountain. Source: Caltrans 2021b.

For rural communities (outside subdivisions), evacuation corridors are typically highways capable of carrying larger capacities of traffic, but served by access roads that are maintained by the county. SRTA's evacuation adequacy evaluation should address whether rural highways have sufficient capacity for evacuation of the communities they serve, keeping in mind that multiple communities may face the same evacuation order at the same time. This evaluation should consider the appropriateness and capacity of roads when contraflow traffic management strategies are implemented. SRTA should also screen these corridors for potential bottlenecks for the entire distance along the road connecting a community and the extended road network. Bottlenecks could include high traffic intersections, bridges/overpasses with weight/height constraints, lane reductions/merges, or even tight turns that cause vehicles to slow. Even insufficient shoulder/turnout capacity can pose a bottleneck

hazard during evacuations due to disabled vehicles. Bottlenecks can also result from a fire (or flood) interacting with the road, for example roads with narrow rights of way and large accumulations of hazardous fuel may cause traffic to slow or stop if fire burns too close. During a flood emergency, undersized culverts may cause overtopping of road surfaces, creating traffic jams.

Where bottlenecks are identified, SRTA should evaluate options to mitigate them. Options may include road upgrades or improvements such as widening or intersection redesigns, as well as technological solutions such as trip-to-green signalization[3] or contraflow traffic management that can be automatically activated during evacuations. Prioritization of mitigation actions in the RTP can be informed by projected changes to fire probability and severity, known inadequacies, and the expected volume of traffic during an evacuation order.

E.3: Promote pooling of fleet transportation assets among public, private, and non-profit entities in the region

E.3 strategy roles & responsibilities	
Type of strategy	Planning
Proposed lead agency	SRTA
Additional agencies	RABA, school districts/colleges, churches, regional public and private fleet owners
SRTA role	Lead, facilitation
Potential funding	N/A

As part of its transportation system data collection efforts, SRTA should create and maintain a directory of fleet transportation managers and an inventory (or approximate inventory) of transit vehicles owned or held by public agencies (incl. RABA, SRTA, regional school districts, etc.), private companies, and other institutions (including churches, colleges, etc.) located in and near the region.[4] The list should be an internal resource maintained and updated by SRTA staff for the sole purpose of providing SCSO, Shasta County OES, and Shasta County DPW with up-to-date information about the number, location, and contact information of fleets in the region during an emergency. The list should include the contact information for two responsible parties in the event of an evacuation. The list should not be considered an agreement or contract, but simply an informational resource that can be called on when needed.

The purpose of maintaining the inventory of fleet transportation assets is not only to assist in increasing evacuation capacity, but also to avoid unnecessary delays associated with calling resources from other parts of the region during an evacuation. While obtaining buy-in across all agencies for future evacuations may face challenges, accelerating response times of transportation fleets is an important response to recent fires with evacuation orders giving residents mere minutes to evacuate. By facilitating access to fleet transportation assets distributed across the Shasta Region, the list will increase the flexibility and resilience of mass evacuation actions, especially in rural parts of the region. In the future, SRTA should seek to build on this initiative by formalizing relationships with fleet owners and SCSO/Shasta County OES (e.g., similar to the current arrangement for fleet sharing between RABA and SCSO).

[3] Trip-to-green signalization is a traffic management approach where all signals are set to green in the dominant direction of traffic flow, effectively blocking cross traffic or making small feeder roads right turn only.
[4] This effort should generally not seek to include specialized medical transports or fleets dedicated for serving vulnerable populations that would likely be needed for such purposes during any emergency.

E.4: Plan evacuation corridor network and install CMS signage

In collaboration with SCSO, Shasta County OES, California OES, and local governments, a public works agency should plan an evacuation corridor network that includes the following elements:

- **Defines regional evacuation zones and** the major evacuation routes for each zone (e.g., Burney and Highway 299)
- Identifies essential evacuation corridors across the region, specifically including the major highways
- Acknowledge the need for agility and flexibility in real world evacuation orders and route selection

E.4 strategy roles & responsibilities	
Type of strategy	Planning
Proposed lead agency	State and local public works agencies
Additional agencies	State and local public works agencies, SCSO, California OES, Shasta County OES
SRTA role	Analysis
Potential funding	FEMA BRIC Grants

Using fire hazard, population, and road network capacity, identify evacuation zones, designate primary and secondary evacuation routes, and plan segments for contraflow traffic in the event of mass evacuation. The plan should identify which evacuation corridors are likely to see evacuation loads greater than road capacity. Caltrans, along with the region's departments of public works, should identify locations for a permanent signage and traffic control system for facilitating evacuations. Permanent signage should include customizable message signage (CMS) and fixed signage, including reverse-directional signage for use during contraflow traffic management. Traffic control devices should include reversible lane lighting and cameras at key junctions.

SRTA should support this effort by providing traffic data and analysis in support of public works' zone and route planning, and data on the locations and types of projected hazards. SRTA should also use the evacuation planning efforts to complement the analysis in strategy E.2: Evaluate evacuation bottlenecks and secondary access constraints, especially for future capacity upgrades and bottleneck mitigation.

Where possible, improvements to evacuation routes should be designed to serve multiple purposes. For example, CMS signage and other ITS infrastructure on I-5 and Highway 299 should be designed to allow use for notifying drivers of I-5 closures and chain requirements and directing drivers to detour routes or off-highway staging areas during extreme snowfall events.

E.5: Conduct evacuation drills (including contraflow traffic management) on key corridors

E.5 strategy roles & responsibilities	
Type of strategy	Planning
Proposed lead agency	SCSO
Additional agencies	Caltrans District 2, State and local public works agencies, SCSO, Shasta County Fire Department, California OES, Shasta County OES, SHASCOM, and city FDs and PDs
SRTA role	Analysis
Potential funding	N/A

Evacuation drills are an essential tool to build and reinforce interagency contacts, identify potential barriers or bottlenecks, and test new ideas – particularly related to evacuation of mobility-challenged individuals. While evacuation drills represent a major investment of time and resources, and local agencies may resist participating, SRTA should use its role as a transportation planning agency to encourage state and regional agencies to coordinate annual evacuation planning drills along the routes most likely to be used in future evacuations. The goals of the drills will be to test emergency communications equipment and systems (including radio interoperability) and ensure that crews and officers from the various agencies know how to communicate, coordinate checkpoints and road closures, implement contraflow traffic, clear stuck vehicles, and prevent congestion.

Establishing temporary contraflow traffic on a highway can be an effective tool for increasing road capacity during an evacuation, but can also create dangerous conditions if executed poorly. Experience across the country has found that establishing a contraflow traffic corridor during an evacuation typically requires significant forward notice to implement safely.[5] If communications or coordination failures occur during a real evacuation, the results can be deadly. For example, in Paradise, a 2016 evacuation drill ensured that when the Camp fire struck in 2018, congestion was minimized, but tragically not eliminated.[6]

Figure 4. Colorado Springs, CO conducts annual community wildfire drills, rotating communities each year. Members of the Colorado Springs Fire Department are pictured in the 2016 drill. Source: FEMA 2016.

Because the goals of evacuation drills are focused on coordination of agency systems, assets, and staff (rather than specific routes), drills should be conducted in different locations each year, following the county emergency operations plan. Drills can be coordinated with local Fire Safety Councils such as those in Shingletown, Whitmore, and Cottonwood, or

[5] FHWA 2006
[6] Arthur 2019

with other community groups, tribes, or local institutions. Drills can also include testing emergency notification systems, including through media channels.

While SRTA is not directly involved in evacuation drills, it can play an important role in encouraging regional partners to conduct drills. SRTA should explore means of encouraging evacuation planning and drills along key corridors by seeking funding for projects based on their public safety priority for evacuations, and base prioritization on metrics established in evacuation drills.

E.6 strategy roles & responsibilities	
Type of strategy	Operational
Proposed lead agency	Public works agencies
Additional agencies	Caltrans District 2
SRTA role	Analysis
Potential funding	N/A

E.6: Pre-stage evacuation resources

Following establishment of evacuation zones, corridors, and a program of evacuation drills, additional reductions in response time can be found by staging necessary evacuation resources throughout the region. Pre-staging traffic management resources can reduce the time necessary to implement evacuation routes, especially if they require coordinated signage as in a contraflow traffic situation. While local governments play a role, the primary responsibility for managing transportation over the Shasta Region's expansive rural areas is carried by Caltrans and Shasta County DPW. Public works agencies should seek to distribute county equipment – including portable generators/lights, radio equipment, ITS equipment (incl. remote sensors and cameras), and movable electronic signs – to multiple locations throughout the region, ideally located to minimize travel times to establish and manage evacuation corridors. Evacuation drills are likely to be especially informative for identifying optimal locations for storing resources.

E.7: Explore advanced evacuation notification and information systems

Presently, Shasta Region residents rely on a wide array of sources for information on evacuations. From text alerts and Code Red to local news and social media, residents report that while evacuation information is often prompt, it is often difficult to evaluate if rapidly changing evacuation orders are current or accurate. Furthermore, text-based evacuation orders can be confusing, leading some residents outside of evacuation zones to begin evacuating (clogging roads) or residents inside evacuation zones to fail to evacuate. Residents also report lacking confidence in the currency of evacuation orders, particularly when signs of fire may be near.

To address resident concerns and ensure that evacuation orders are easy to understand and up to date, SHASCOM should explore working with SRTA, SCSO, and Regional governments to invest in a Shasta Region Evacuation Map tool that can be hosted on the Shasta Ready website and be updated by SHASCOM staff during emergencies. The map would show a clear overlay of evacuation order areas over an easy-to-read online street map, allowing

E.7 strategy roles & responsibilities	
Type of strategy	Planning
Proposed lead agency	SHASCOM
Additional agencies	SCSO, SRTA, county government, municipal governments
SRTA role	Evaluation, Implementation
Potential funding	N/A

users to fully understand the extent of evacuation zones. Further, the map will be updated directly by SHASCOM, avoiding potential confusion resulting from 3rd party maps (e.g., from local news).

Additionally, Shasta Region public safety agencies should continue to explore and evaluate new technologies to inform and update the public during emergencies, potentially including technologies like the Alert FM emergency broadcast system. SRTA should support this effort by facilitating meetings, evaluating technologies, and supplying geospatial data where available.

Average & Extreme Temperatures

Temperatures are increasing and are projected to continue increasing across the Shasta Region. By 2085, the average summer day in Redding will be as hot the average heat wave under current conditions.

Increases in extreme temperature are likely to accelerate wear & tear on roads and vehicles, impair use of pedestrian, cyclist, and transit systems

Extreme temperatures pose few acute hazards but create long-term operating and maintenance costs associated with accelerated degradation of roads and vehicles and impair the mobility of residents who travel without a vehicle. These recommendations are focused on reducing the long-term costs of extreme temperatures by investing in adaptation early.

T.1: Integrate extreme temperature hazards into complete streets planning

Complete streets are streets designed to meet the mobility needs of all users, including mobility-challenged users, as well as pedestrians, cyclists, and transit users. Complete streets can address extreme heat hazards through general strategies to reduce the urban heat island (UHI) effect – the phenomenon where the dark surfaces of roads, rooftops, and other built infrastructure trap and re-emit heat. Approaches to mitigate UHI impacts on transportation include provision of shade, cooling, and hydration facilities along key routes, as well as general strategies to combat UHI. Protecting and enhancing the urban forests in the Shasta Region is an important first step: increased shade tree cover – in particular the use of trees to create continuous shade along the highest traffic bicycle and pedestrian routes and around transit stops – will improve the utility of these facilities on extreme heat days. For transit users, SRTA should promote bus shelters designed to maximize cooling, and advocate to RABA that bus stops without adequate shade should be prioritized for installation of bus shelters or other shade (Figure 5).

Strategy roles & responsibilities	
Type of strategy	Operational
Proposed lead agency	SRTA
Additional agencies	State and local public works agencies, RABA
SRTA role	Lead
Potential funding	Calfire Urban and Community Forestry Grants (with partner), CalEPA Environmental Justice Small Grants, California ReLeaf Treecovery Grants

Although not explicitly directed at mobility resilience, strategies to combat UHI generally may be another component of protecting pedestrian, cyclist, and transit users during extreme heat events. Use of reflective surfaces (such as silvered roof coatings), reflective pavements, and increasing urban forest cover are all practical strategies for combatting UHI.

Increasing public drinking water access is another way to enable mobility disconnected from vehicles. Providing public drinking water facilities enables non-vehicle transportation users to avoid heat stress without relying on vehicles.

Figure 5. Top: The RABA bus stop at Lincoln St. and S. Market St. lacks shade trees or a bus shelter to provide riders with relief during extreme temperatures. Middle: The RABA bus stop at Placer St. and East St. features street trees which provide ample shade, albeit no seating. Bottom: The RABA bus shelter at East St. and Butte St. provides shade both shade and seating, as well as shelter from rain.

Another consideration of extreme heat for pedestrians and cyclists are the elevated safety hazards resulting from heat stress. Drivers, pedestrians, and cyclists alike are more likely to be involved in crashes during heat waves, indicating the increased need to design streets with all users' safety in mind.[7] Complete streets design principles focused on deconflicting pedestrians, bicycles, and motor vehicles should be pursued in order to reduce the increasing risk of heat-related crashes. An overall strategy of designing streets for all users will improve the resilience of non-vehicle transportation in the Shasta Region.

T.2: Ensure fleet investments and management are designed for future extreme temperatures

SRTA should adopt an initiative to promote resilient fleet management among the Shasta Region's state, regional, and local agencies responsible for fleet purchasing and management. Using the projections in this study, SRTA should work to provide agencies with large fleets (particularly emergency response and transit fleets) with the information necessary to make resilient investment and management decisions.

Fleet managers investing in new rolling stock for the Shasta Region's fleets should ensure that the vehicles are capable of operating in extreme temperatures, including those projected for the Shasta Region (and particularly the upper Sacramento River Valley) over the lifetime of the vehicle. For fleet vehicles, this typically means investing in extended-life coolants and—if available—vehicles with upsized cooling systems. For new technologies such as battery

[7] Basagana et al. 2015

electric vehicles and hydrogen electric vehicles, fleet purchasers should work with OEMs to ensure that vehicles are designed to operate in the Shasta Region's projected extreme temperatures.

T.2 Strategy roles & responsibilities	
Type of strategy	Operational
Proposed lead agency	SRTA
Additional agencies	State and local public works agencies, RABA
SRTA role	Analysis, outreach
Potential funding	N/A

Fleet operations should also be adjusted to ensure that cooling systems are well maintained prior to each summer. Coolant levels, hoses, clamps, and radiators are of primary importance, as are parts subject to accelerated wear during extreme heat, including belts and tires, as well as fluids like automatic transmission fluid, brake fluid, and engine oil.

T.3: Promote proactive seasonal fleet management to prepare for hot summers

T.3 Strategy roles and responsibilities	
Type of strategy	Operational
Proposed lead agency	SRTA
Additional agencies	RABA, public and private fleet owners (e.g., CARE-A-VAN, etc.)
SRTA role	Outreach
Potential funding	N/A

Multiple agencies – each with unique fleet management challenges – are required to work together in the event of an evacuation order. During extreme heat events (which can occur simultaneously with major fires), essential fleet vehicles can break down in numerous ways. In order to prepare for these emergencies, fleet maintenance should focus on proactively mitigating common modes of heat failure (e.g., coolant levels & leaks, aged belts, tires, and batteries, fluids condition, etc.) in their essential fleets during the cool season.

As part of its initiative to ensure mobility during extreme heat events, SRTA should conduct outreach and communicate heat hazards and design principles to the region's transit fleet operators, including RABA, as well as private operators like CARE-A-VAN. In addition to vehicle resilience, this initiative should encourage transit operators to prepare, monitor, and quickly repair failing air conditioning systems in fleet vehicles. While air conditioning is ubiquitous, delayed maintenance and unexpected outages can take inconvenient or uncomfortable heat waves and turn them into dangerous extreme heat events that impair the mobility of transit-dependent residents. SRTA's efforts to communicate the importance of heat health to the region's transit operators can support a culture of heat health awareness and impress the importance of proactive maintenance for extreme heat upon Regional fleet operators.

T.4: Convene Caltrans, county, and city public works departments to set upgraded design temperatures for roads

Using the temperature projections in this assessment (and Caltrans D2 Assessment), the state and local public works agencies in the Shasta Region should explore ways to work together to discuss and agree upon temperature specifications for road segments. Ideally, Caltrans D2 would lead a working group, and membership could include additional county and municipal agencies from the across District 2. The goal of the group would be to disseminate information, coordinate planning, and ensure best practices

are available to road crews. Caltrans has already identified the highest priority asphalt upgrades required on state highways in the northern state, and the most vulnerable roads are centered in the Shasta Region, including most of I-5 and highway 273 and major sections of Highways 299 and 44 in the Sacramento River Valley.[8] Additionally, as a larger regional transportation authority, Caltrans has the capacity to assess and disseminate technical advice to the region's local governments.

T.4 strategy roles & responsibilities	
Type of strategy	Hardening
Proposed lead agency	Caltrans D2
Additional agencies	County and local public works agencies, additional regional partners
SRTA role	Advisory, planning
Potential funding	N/A

The goal of the meetings should be to review projected temperatures across the Shasta Region and determine the performance grade binder specification(s) optimal for road resurfacing projects across the region. The design temperatures should address the projected shift in temperature regimes away from freeze thaw cycles in lower-lying areas, and towards higher extreme summer temperatures. Design temperatures should reflect the large spatial variation in projected extreme temperatures across the region, and several specifications are likely to be necessary for different parts of the region. The group should share information and expertise on identifying alternative asphalt mixtures and suppliers, as well as lessons learned in upgrading road pavements.

Although SRTA's role in this strategy is limited to advisory and planning tasks, SRTA should actively participate by promoting the working group concept, seeking participation from Shasta Region participants, providing historical and projected future temperature data for the Shasta Region, and by seeking means to incorporate upgraded binders into future resurfacing projects across the region through the RTP.

[8] Caltrans 2021a

Extreme Precipitation

Projected increases to extreme precipitation are likely to intensify current hazards related to localized flooding and road delays/closures due to snow

Extreme precipitation events are projected to grow in both frequency and intensity. While flooding is the primary hazard associated with extreme precipitation events, the Shasta Region's major rivers and streams are all controlled by dams and reservoirs designed to mitigate large-scale floodplain flooding.

The primary mobility hazards associated with extreme precipitation events are extreme snow events that can cause major roads (especially I-5) to back up, localized flooding (including inundation and erosion) that can disrupt and damage traffic on highways and arterial roads, small ponding that can disrupt pedestrian and cyclist traffic.

P.1 strategy roles & responsibilities	
Type of strategy	Operational
Proposed lead agency	State and local public works agencies
Additional agencies	State and local public works agencies
SRTA role	Advisory, planning
Potential funding	FEMA Flood Mitigation Assistance

P.1: Convene Public Works stakeholders to identify and accelerate clearing of priority culverts

Caltrans has identified several high priority culverts on state highways that are most likely to face localized flooding in excess of their capacity (Table 1 and Table 2). In the Shasta Region, multiple state and local public works agencies already administer culverts with increased flood risk, often based just on historical experience (i.e., 'problem culverts') without conducting comprehensive flood hazard assessments. SRTA should work with the local agency staff to advance a regional goal of monitoring major culverts outside of Caltrans' responsibility areas, especially where these culverts have the potential to obstruct roads if culverts flood.

SRTA should work to convene a culvert flooding working group comprised of all state and local agencies with maintenance responsibilities for culverts. As a first step, the group should pool information on known problem culverts and develop a regionally-focused awareness of flooding hazards. The working group should include opportunities to share experiences, lessons learned, and best practices, as well as advance the awareness among Regional transportation and emergency planners about the projected increases in extreme precipitation events throughout the Region.

As a long-term goal, the working group should contribute to the development of a Regional prioritization of culvert upgrades for flooding prevention. The effort should focus on areas with large projected increases of extreme precipitation, including:

- The Sacramento River Canyon
- Central mountainous areas from Big Bend to Round Mountain
- The southern portion of the Upper Sacramento River Valley around Palo Cedro and Anderson
- The southeastern mountainous areas around Lassen National Volcanic Park

As a technical adviser to the effort, SRTA should work with working group members to collect and centralize data on ongoing culvert clearing projects, problem culverts, and culvert-related flooding (especially after major precipitation events) in order to help identify potentially undersized culverts and prioritize upgrade projects for mobility-critical roads.

Table 1 and Table 2 show priority culverts identified by Caltrans D2's Adaptation Priorities Report. SRTA should encourage a working group of Regional agencies to work toward producing a similar effort.

Table 1. Highest priority large culverts (facing greatest flood hazards) under Caltrans jurisdiction in the Shasta Region. Source: Caltrans 2021a.

Route	Crossing	Postmile
Highway 273	China Gulch	11
Highway 299	Little Hatchet Creek	65
Highway 44	A.C.I.D. Canal	L7
Highway 44	W.Branch Churn Creek	R0
Highway 44	Clover Creek	R2
I-5	W. Fork Stillwater Creek	R25
I-5	Boulder Creek	R17
I-5	Spring Branch Creek	R25
I-5	Salt Creek	R21

Table 2. Highest priority small culverts (facing greatest flood hazards) under Caltrans jurisdiction in the Shasta Region. Source: Caltrans 2021a.

Route	Postmile
Highway 36	4
Highway 36	4
Highway 36	6
Highway 44	26
I-5	26
I-5	30
I-5	30
I-5	30
I-5	30
I-5	31
I-5	31
I-5	32
I-5	33
I-5	44
I-5	48

P.2: Prepare I-5 Shutdown Traffic Management Plan

P.2 strategy roles & responsibilities	
Type of strategy	Planning
Proposed lead agency	State and local public works agencies
Additional agencies	Caltrans D2, CHP, SCSO, Shasta Lake PD, Redding PD, Anderson PD
SRTA role	Analysis, planning
Potential funding	US DOT RAISE Grant

Regional stakeholders (including state and local public works agencies, CHP, SCSO, and private sector partners) should agree to a common goal of developing a plan to manage traffic shutdowns on I-5. One approach could be a comprehensive I-5 Shutdown Traffic Management Plan (STMP). A STMP would seek the dual goals of 1) reducing the number of weather-related shutdowns on I-5 and, 2) managing and mitigating congestion when shutdowns are inevitable. The STMP would focus on management strategies and potential capital upgrades as well as operations plans for both goals.

Keeping I-5 clear and open during extreme precipitation/snowfall events should be the first emphasis of an STMP. The plan should balance the region's competing demands for snow clearing resources against the economic and human costs of significant delays and congestion on I-5, as well as the capital costs of shutdown-related upgrades. Caltrans and CHP should work with Shasta Region agencies as well as the cities of Shasta Lake, Redding, and Anderson to develop a snow clearing element of the plan, incorporating lessons learned from similar snow bottlenecks such as "Operation Snowflake," the management plan for clearing snow from the Grapevine in Los Angeles.[9]

When shutdowns are inevitable, the plan should explore and select new strategies for managing traffic and avoiding congestion/blockages to the south. The STMP operations plan would specify traffic management policies during shutdowns and delegate shared tasks to partner agencies during a shutdown. Ideally, the STMP's operational element would explore and consider several traffic management strategies, including:

- Use of CMS and static signage alerting northbound drivers to upcoming chain checkpoints or road closures well south of potential congestion, likely into Tehama County
- Use of CMS signage along I-5 in the Sacramento River Canyon to alert drivers to incoming inclement weather that may impose chain requirements or closures
- Staging delayed truck traffic in the left shoulder and left lane during extended closures
- Closing the right lane (using lighted signs) to all traffic except emergency vehicles and buses
- Establishing multiple snow closure detour routes (299/44 to 89 or 299 to 3), including emergency use improvements for these routes[10]
- Establishing partnerships with large shopping centers with hardened drives and lots for chain installation/truck staging off of I-5 (e.g., Mt. Shasta Mall) during extended closures
- Deployment and coordination of local PD and SCSO resources for traffic management off of I-5, including for staging truck traffic and managing detour routes

[9] Caltrans 2020

[10] Both detour options would impose significant limitations: Highway 299 currently has only limited operating hours due to repairs following the Monument fire; Highway 3 has large truck limitations south of Callahan

- Deployment and coordination of CHP units on I-5 for targeted enforcement of right lane closure and clearing blocked on/offramps
- Use of CMS and static signage to identify off-highway staging and chain installation locations
- Use of static signage to identify snow closure detour routes
- Use of CMS and static signage to implement right-lane closures and warn drivers not to block on/offramps
- Deployment of and novel communication methods to alert residents and drivers to potential or effected closures, potentially including radio, text, social media, push notifications, or IOT communications technologies

The STMP would also explore and prioritize capital projects to enable selected strategies, including those recommended in the Fix 5 Cascade Gateway project, as well as strategies to improve communications with drivers, create space for designated lanes, and facilitating access for emergency vehicles.[11] The STMP should explore capital improvements to the I-5 Corridor including:

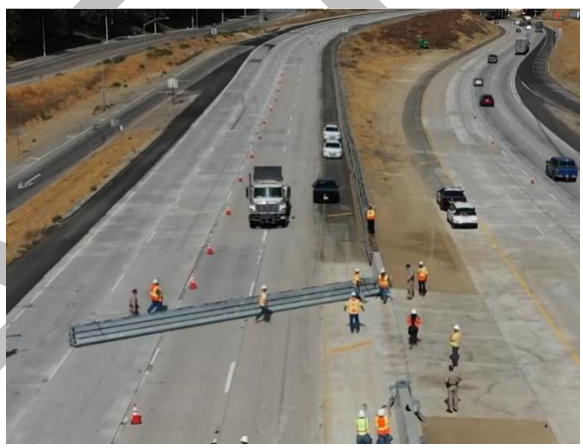


Figure 6. A median turnaround gate installed on the I-5 Grapevine at the Tejon Pass in Los Angeles. The gate allows Caltrans to create a turnaround for vehicles, including large trucks, when snow closes the pass. Alongside "Operation Snowflake" the gate is part of a coordinated strategy to reduce closures and avoid congestion when closures occur. Source: Caltrans 2020.

- Permanent CMS & static signage south of the Fawndale Rd. exit, the junctions with Highway 299, Highway 44, and Highway 273, and Highway 36 for notification of chain check requirements, closures, alternative routes, and traffic management strategies
- Large, movable median turnaround gate for NB traffic at the Fawndale Rd. exit, allowing stranded trucks and vehicles to enter the SB lanes and seek a detour route (a similar gate would likely be appropriate for SB traffic in Siskiyou County)
- Expanded and hardened shoulders for use of staging delayed trucks
- Designated pull outs at multiple locations south of Fawndale Rd. for chain installation
- SRTA should ensure that any capital upgrades to I-5 through Shasta Lake, Redding, and Anderson are implemented with other adaptation strategies in mind. For example, CMS and static signage should be installed to enable use for additional I-5 evacuation planning goals, including usability for contraflow traffic management strategies.

SRTA should ensure that any capital upgrades to I-5 through Shasta Lake, Redding, and Anderson are implemented with other adaptation strategies in mind. For example, CMS and static signage should be installed to enable use for additional I-5 evacuation planning goals, including usability for contraflow traffic management strategies.

[11] SRTA 2020

Additional considerations for discussion in the STMP may include projected reductions in the likelihood of extreme snow events, the projected increase in likelihood of extreme rain events, and the eventuality of wildfire closures.

P.3: Improve I-5 management with resource sharing

P.3 strategy roles & responsibilities	
Type of strategy	Operational
Proposed lead agency	State public works agency
Additional agencies	Local public works agencies
SRTA role	Facilitation
Potential funding	N/A

Backups on I-5 occur when rates of snow accumulation outpace the ability of Caltrans operations crews to clear snow. Hardening I-5 between Shasta Lake and Mt. Shasta against extreme precipitation should include an evaluation of operational needs (See strategy **P.2: Prepare I-5 Shutdown Traffic Management Plan**), and investment in equipment, facilities, and road construction upgrades that increase snow clearing capacity, reduce snowplow travel time, reduce the accumulation of snow, and enhance drainage.

In order to increase the snow clearing capacity of snowplow crews on I-5, SRTA should convene Caltrans Operations staff with County DPW staff to discuss resource capacity, the potential for sharing resources, and the potential need for additional snowplows and snowplow crews. Snowplow response time could be improved through investments in additional snowplow staging sites/salt stockpiles closer to the Sacramento River Canyon.

P.4: Optimize complete streets for extreme precipitation impacts

P.4 strategy roles & responsibilities	
Type of strategy	Planning
Proposed lead agency	SRTA
Additional agencies	State and local public works agencies
SRTA role	Analysis, planning
Potential funding	N/A

A common impact of extreme precipitation is localized flooding caused by excessive runoff and insufficient drainage. While localized flooding rarely leads to catastrophic impacts, the immediate disruption to the mobility of pedestrians, cyclists, transit-dependent, and mobility-challenged individuals can be significant. This is especially problematic in cities where simple drainage options are not always available. Flooding of sidewalks, trails, curb cuts, parking lots, or intersections can create substantial barriers to mobility, especially for mobility-challenged residents.

SRTA should take a lead in evaluating the scope of the problem and recommending solutions which can remedy ponding as a part of future streets projects. SRTA should work with city and county DPWs to identify problem areas on sidewalks and trails in the Shasta Region. This effort could include soliciting feedback from the public about known problem areas.

Measures to mitigate problematic ponding could include:

- Construction of drainage for sidewalks and trails – in built environments, new drainage is often cost prohibitive to construct, however streets and sidewalks can be regraded to direct

stormwater to existing drainage; for unpaved trails new drainage can be as little as a water diversion built into the trail

- Construction of runoff reduction including permeable pavements, detention basins, etc. – Where larger areas of ponding pose a threat, runoff reduction methods can reduce the flow rate of water into low-lying spaces. Use of permeable pavements can remove runoff, and detention basis can hold large volumes of runoff to reduce the peak rate entering sewers
- Promotion of street designs that resist flooding – In areas with persistent ponding issues, SRTA should identify and promote best practices (e.g., curb cut designs) that minimize the opportunity for ponding

Flooding

Flood hazards are likely to increase with extreme precipitation, particularly on uncontrolled streams, and with unknown implications for dams

Flood hazards in the Shasta Region include both damage and direct disruption of roads and highways, rail, transit, and pedestrian and cyclist infrastructure due to inundation and erosion. Based on the limited FEMA hazard modeling available in the region, existing flood hazards pose a significant threat, and are likely to be present in areas not modeled by FEMA. In the Upper Sacramento River Valley, particularly between Redding and Anderson, flooding along the riverbanks is associated with a 100-year streamflow event, including inundation of several important roads such as Highway 273, Highway 299, Park Marina Drive, Churn Creek Road, Girvan Road, and Eastside Road, and potentially shallow flooding on I-5, as well as Highway 151 in Shasta Lake and several locations on the Union Pacific railroad.

If projected increases in extreme precipitation result in a flood stage associated with a 500-year streamflow event, widespread inundation would threaten many more roads, including large segments of I-5, the Highway 44 junction in Redding, several areas of Highway 273, as well as other arterials like North Street, Riverside Avenue, Ox Yoke Road, McMurray Drive, and South Balls Ferry Road in Anderson. Many river crossings throughout the Upper Sacramento River Valley would be threatened as well. In Palo Cedro and Millville, a 500-year streamflow event could lead to flooding of Highway 44, as well as extensive flooding along Old 44 Drive.

Approaches to adapt to flood hazards should rely on FEMA hazard assessments as a starting point, however planners should be aware of the limited perspective supplied by these projections.

F.1: Harden road segments subject to inundation hazards

F.1 strategy roles & responsibilities	
Type of strategy	Planning
Proposed lead agency	State and local public works agencies
Additional agencies	N/A
SRTA role	Analysis, planning
Potential funding	FEMA BRIC Grants, FEMA Flood Mitigation Assistance

Inundation of road surfaces can reduce the load-bearing capacity of the road base, sub-base, and subgrade. Depending on the type of soils, road subgrades can lose 20 – 40% of their strength for months following just four days of inundation.[12] Because inundation of roads occurs simultaneous to emergency response, evacuation, and eventually recovery activities, inundated roads are often most heavily loaded when they are at their weakest, accelerating wear and tear.

Inundation of roads in the Shasta Region is a predictable outcome where 100- and 500-year floodplains have been mapped. Known flood hazards threaten to inundate several areas with high traffic roads in Redding and the upper Sacramento River Valley where flooding would likely result in heavy traffic related to response, evacuation, or recovery.

[12] Sathawara and Patel 2013

There are two approaches to hardening roads against inundation: replacement of asphalt roads with stronger materials that are less susceptible to weakening like reinforced concrete, and elevation of roads above the base flood elevation (BFE). Elevation of roads is typically more costly than replacement with concrete, but has the advantage that hardened roads remain accessible during flooding events. For highways and arterial roads with high potential to be used during evacuation, selective elevation can be an appropriate investment. For example, the eastern approach to the Highway 44 bridge in downtown Redding is located within the 500-year floodplain where Highway 44 passes underneath Sundial Bridge Drive. A 500-year flood would cut off this river crossing, but only at one point. Selective elevation could reduce this hazard, especially since a 500-year flood would also affect the abutments and approaches of the Market Street/Highway 299/273 Bridge. Caltrans has similarly identified six priority 1 bridges that may make good candidates for elevation: [13]

- Highway 299 crossing the Pit River east of Four Corners
- Highway 299 crossing Hat Creek east of Four Corners
- Highway 299 crossing Dry Gulch in Bella Vista
- I-5 crossing Castle Creek in Castella
- Highway 273 crossing Spring Gulch in Anderson
- Highway 36 crossing Begum Creek at the southwestern corner of the region

Hardening high traffic roads in the 100-year floodplain by upgrading asphalt to concrete can reduce the damage from emergency response, evacuation, and recovery, leading to long-term reductions in cost and improvements to mobility. Targeted hardening of road segments subject to flood hazards could be incorporated into road maintenance programs, although hardening will require more substantial reconstruction of the road surface and subgrade.

SRTA does not have a direct role in individual hardening projects; each project is the prerogative of the managing road agency. However, SRTA has an important role as a facilitator of information necessary to prioritize hardening projects. Although flood hardening should be considered a lower priority than fire hardening projects, SRTA should use the RTP process to highlight the need for flood hardening on specific routes.

F.2: Evaluate unknown flood risks

Much of the Shasta Region's mobility is served by a small number of highways that connect rural communities over large distances. These roads constitute critical transportation corridors (including Highway 299, Highway 44, Highway 36, and Highway 89), but many face flood hazards which have never been evaluated or mapped.

SRTA should pursue updated region-wide understanding of flood hazards affecting regional mobility, either by seeking FEMA

F.2 strategy roles & responsibilities	
Type of strategy	Planning
Proposed lead agency	SRTA
Additional agencies	N/A
SRTA role	Analysis
Potential funding	FEMA Flood Mitigation Assistance (through a partner), CalEPA Environmental Justice Small Grants

[13] Caltrans 2021a

analysis of the region's rural streams, or by seeking alternative grant funding for an independent flood hazard analysis. While each approach has advantages, FEMA assessments cannot incorporate projected future change, but are provided as a public good at no cost to regional agencies. However FEMA assessments affect Flood Insurance Rate Maps (FIRMs) which can impose significantly higher insurance costs on the insured in the Region.

Seeking an independent evaluation of flood hazards on uncontrolled streams would require separate funding, but doing so provides the significant advantage that projected changes to extreme precipitation can be integrated into streamflow models. In areas where unknown flood hazards or outdated flood hazard assessments may pose threats to both mobility and public safety, awareness of flood hazards is essential.

F.3: Upgrade undersized culverts

F.3 strategy roles & responsibilities	
Type of strategy	Hardening
Proposed lead agency	Public works agencies
Additional agencies	State and local public works agencies
SRTA role	Analysis
Potential funding	FEMA BRIC Grants, FEMA Flood Mitigation Assistance Grants

Most of the rivers and streams in the Shasta Region are controlled by dams which effectively minimize flooding hazards in all but extreme cases. However, many smaller streams – some of which only flow intermittently – are not dammed and can pose hazards associated with uncontrolled flow following extreme precipitation events, or during especially wet periods. Complicating matters, many of these streams are located in rural areas of the region and have not previously been evaluated for flooding hazards by FEMA. Where these streams cross major roads and highways, they may pose overtopping or erosion risks during flood conditions.

Building on the efforts to identify and accelerate clearing of problem culverts (see strategy **P.1: Convene Public Works stakeholders to identify and accelerate clearing of culverts**) and efforts to map additional flood hazards in the region (see strategy **F.2: Evaluate unknown flood risks**) SRTA should work with the relevant local agency to seek funding opportunities to replace and upgrade the capacity of problem culverts. This effort should ensure that planned culvert capacity accounts for projected increases in extreme precipitation. County and city DPWs should be especially proactive in cases where a road crosses an uncontrolled stream channel, or where the FEMA flood hazard has not been evaluated.

Where culvert capacity cannot be upgraded (or where funding is not sufficient), SRTA should promote projects to harden problem culverts. Hardening roadways can include the use of riprap, vegetation, or other soil stabilization techniques to harden embankments, as well as reconstruction of segments subject to inundation with concrete surfaces which can withstand heavy traffic after inundation.

F.4: Access dam flood hazard maps and integrate them into regional evacuation planning

F.4 strategy roles & responsibilities	
Type of strategy	Planning
Proposed lead agency	SRTA
Additional agencies	Shasta County, Redding, Shasta Lake, Anderson
SRTA role	Policy, planning
Potential funding	N/A

The Shasta Region's flood control infrastructure provides safe and predictable streamflow through the controlled rivers and streams in most circumstances. However, in the event of dam failure, serious to catastrophic flooding could result, necessitating mass evacuations, likely with very short warning. Problematically, the flood maps associated with modeled dam failure scenarios are not publicly available, nor are they currently available to regional planning agencies. As a result, regional evacuation planning efforts cannot anticipate which evacuation routes would be subject to dangerous flooding hazards, and which would be safe. In a worst-case scenario, county officials could conceivably direct evacuating residents to unsafe routes, increasing the risk of fatalities.

Figure 7. Shasta Dam and the Keswick Dam downstream power the region and protect downstream communities from flooding. Key regional agencies do not know how a dam failure would affect communities and infrastructure. Source: USBR 2021.

As part of its efforts to promote mobility in evacuation planning, SRTA should seek to convene stakeholders from the U.S. Bureau of Reclamation, California Office of Emergency Services, and Caltrans, along with SCSO and county and city DPWs to discuss dam safety and flood hazards, evacuation protocols, and identify how projected increases to seasonal and extreme precipitation will affect dam operations. The goals of such meetings should be to identify the roles and responsibilities of various agencies in the event of a dam-related emergency, identify which roads and bridges should not be used, and ensure that evacuation plans account for alternative routes. At a minimum, SCSO should be granted access to dam failure scenario flooding maps so that officials charged with managing evacuations are aware of the overall hazard and the specific corridors expected to be safe. Additionally, sharing information with county and city DPWs could allow hardening of river crossings and key corridors in the Upper Sacramento River Valley against dam-related emergencies. Convening stakeholders also provides evacuation planning officials with contacts which can be relied upon in a real-world evacuation.

Landslides

Increases in extreme precipitation and wildfire hazards increase the risk of landslide activity on burned slopes, especially during extreme precipitation events

Landslide hazards are not typically a major threat to highways and roads in the Shasta Region, but can affect mobility in the region when landslides occur on roads connecting the region with surrounding counties. With projected changes to extreme precipitation and wildfire activity, The Shasta Region may also see land sliding that threatens the region's roads. Landslides can include a wide range of incidents that involve rocks, soil, or debris (such as dead or living vegetation) sliding down a slope, as well as major deep-seated failures of slopes resulting in hundreds or thousands of tons of soil and rock crashing down on infrastructure below. Small rockfalls can pose an acute hazard to drivers, but can be cleared relatively quickly by Caltrans maintenance crews. Larger landslides and debris flows can create significant blockages that take days or weeks to clear. The largest landslides can sweep roads clear off the sides of slopes, requiring extended periods to realign, cut, and reconstruct the road to fit on the new slope geometry.

Figure 8. Following the Carr Fire, accelerated erosion of burned slopes on Shasta Bally began depositing large amounts of debris on Mill Creek Road in the Whiskeytown National Recreation Area. Source: NPS 2021.

Because there are not currently any known landslide hazards in the region, the recommendations in this section are to increase the monitoring of minor landslide activity, and to study the region's slopes in order to gain a better understanding of landslide hazard.

L.1: Enhanced monitoring of potentially hazardous landslide slopes following wildfires

L.1 strategy roles & responsibilities	
Type of strategy	Operational
Proposed lead agency	State and local public works agencies
Additional agencies	N/A
SRTA role	Facilitation
Potential funding	N/A

Currently, landslide monitoring along Caltrans roads is conducted by maintenance crews who observe and report rocks, soils, or debris which slide down slopes onto state highways. In the three corridors identified by the Transportation Vulnerability Assessment's potentially hazardous landslide slope zone screening analysis (including Highway 299 along and west of Whiskeytown Lake, Highway 299 between Buena Vista and Round Mountain, and along I-5 in the Sacramento River Canyon), the primary concern for landslide hazard is not historical landslides, but the

risk of a severe wildfire that destroys slope-side vegetation, followed by an extreme precipitation event that triggers anything from increased sedimentation, rockfall, or debris flows, up to and including large, deep-seated landslides and rockslides.

Enhanced monitoring should be initiated after a major wildfire and would include anything from proactive observations of slope conditions up to conducting landslide hazard assessments of slope soils and hydrology. SRTA's role in this strategy could be as simple as facilitation and data collection for state and county agencies. While minimal effort, observation of slopes is the optimal approach to identifying potential landslide hazards before they occur.

L.2: Highway 299 Corridor Landslide Hazard Assessment

If a funding opportunity becomes available, SRTA should seek funding for a more comprehensive landslide hazard assessment across the entire Highway 299 corridor. Ideally, this assessment would survey hillsides above Highway 299 across the northern state, both within the Shasta Region and in Trinity and Humboldt Counties to the west. Beginning with the 2006 California Geological Survey study of landslide hazards along Highway 299 in Humboldt County and incorporating findings from the 2016 Big French Creek landslides in Trinity County, the study would focus on collecting slope data (including high resolution DEMs, soils and bedrock data, and historical hydrological conditions), categorizing slope features throughout the corridor, identifying the factors that led to past slope failures, and identifying those same features in slopes throughout the corridor.[14]

Figure 9. Landslide on Highway 299 near Big French Creek in Trinity County. Highway 299 was closed for several weeks to repair the road and construct a new catchment for future landslides (area between the slope and the road). Source: Caltrans 2018b.

In addition to supplying Caltrans with critical data for planning slope stabilization projects in the face of projected increases to extreme precipitation, the study would also provide SRTA and county DPWs with a baseline of information necessary to identify hazardous slopes elsewhere in the region, including above local and county roads.

L.2 strategy roles & responsibilities	
Type of strategy	Operational
Proposed lead agency	State and local public works agencies
Additional agencies	N/A
SRTA role	Facilitation
Potential funding	N/A

[14] California Geological Survey 2006

Crosscutting Strategies

Several adaptation strategies apply to multiple hazard categories. These crosscutting strategies target the process of planning and the interdependency of infrastructure systems on one another.

C.1: Integrate resilient approaches into all recovery/reconstruction projects

C.1 strategy roles & responsibilities	
Type of strategy	Planning
Proposed lead agency	SRTA
Additional agencies	N/A
SRTA role	Facilitation, data collection, analysis
Potential funding	N/A

When disasters strike, agencies are frequently able to access funds to rebuild essential infrastructure. Two strategies recommend the integration of mobility resilience principles into recovery (**W.4: Proactively plan road resurfacing following heavy fire-fighting activity as part of recovery grants** and **F.1: Harden road segments subject to inundation hazards**). The common theme of these strategies is that when funding is available to rebuild infrastructure, lessons about past and expected future hazard exposure should be integrated into the design.

SRTA should embrace a role as a regional clearinghouse of resilient development practices and ensure that any future recovery/reconstruction grants implement adaptation strategies for all potential hazards. For example, in the event of a road reconstruction following a fire, segments subject to flood hazards should also be hardened against these hazards. SRTA should use its contacts with local and regional transportation infrastructure agencies to share information about ongoing and planned projects, success implementing adaptation strategies, and resources for additional information.

Another important way to coordinate recovery & restoration efforts with adaptation goals is to ensure that the region's many agency partners work together to inform each other about ongoing or planned projects. For example, the Western Shasta Resource Conservation District (WSRCD) implemented slope revegetation projects following the Carr Fire with resources provided by the California State Water Resources Control Board.[15] The goal of this project was to stabilize soils on slopes with grades less than 40% in order to prevent increased sediment loading in key Sacramento River watersheds. While the primary goal of the project was improving water quality, any transportation resilience co-benefits were not accounted for. In this example, potential coordination between WSRCD and transportation agencies would enable similar projects to adjust scope in order to target key slopes above threatened culverts, drainage systems, or even directly above roadways.

[15] WSRCD 2019

C.2: Plan for interdependencies with vulnerable interconnected infrastructure systems

C.2 strategy roles & responsibilities	
Type of strategy	Planning
Proposed lead agency	SRTA
Additional agencies	State and local public works agencies, Shasta County Fire Department, California OES, Shasta County OES, SHASCOM, city FDs and PDs
SRTA role	Facilitation
Potential funding	N/A

Fires, floods, and other extreme weather hazards never affect just one infrastructure system in isolation. Electricity, fuel, communications, and water infrastructure systems are all subject to sudden disruption in the event of an emergency, and first responders must consider the risk of loss of service when responding to an emergency. These hazards are extremely relevant in areas where disruptions to service are regular occurrences, such as rural areas with poor radio or cellular signal, or in communities experiencing public safety power shutoff (PSPS) events. Since PSPS events occur during periods of elevated fire hazard, the risk of a major fire occurring during a PSPS event should be considered.

In general, agencies responding to emergencies should plan to operate with power, fuel, water, and communications independent from vulnerable infrastructure systems and hardened to the threats of extreme weather hazards. In the Shasta Region, that likely means that portable generators, radio repeaters, and alternative water sources should be components of evacuation plans. The importance of service continuity to evacuating residents should also play into evacuation planning and drills, with simulated shortages of fuel, disruptions to power, and communications outages considered.

Funding Opportunities

Many of the adaptation strategies outlined here could be aided or funded by grant opportunities that are currently or recurrently available from federal and state government agencies.

Funding Opportunities Available to RPOs

California Agencies

State of Good Repair, Caltrans

This Caltrans program can provide additional revenues for transit infrastructure repair and service improvements. Annual funding is approximately $105 million and is made available for eligible transit maintenance, rehabilitation, and capital projects. Eligible applications include transportation planning agency, county transportation commission, and Metropolitan Transit System. SRTA has policies in place for the use of State of Good Repair grants.

State Transportation Improvement Program (STIP), Caltrans

STIP is a multi-year capital improvement program of transportation projects on and off the State Highway System. Caltrans and regional planning agencies prepare transportation improvement plans after amount of funding is decided. Local agencies work through their Regional Transportation Planning Agency, County Transportation Commission, or Metropolitan Planning Organization to nominate projects.

FTA Section 5310- Enhanced Mobility of Seniors and Individuals with Disabilities Program, Caltrans

The goal of this program is to improve the mobility of seniors and individuals with disabilities by removing barriers to transportation services and expanding mobility options available. It provides grant funds for capital (vehicles and related equipment such as cameras, radios, scheduling software), mobility management (travel training, one stop call center) and operating expenses. Eligible public agencies include agencies where no private non-profits are readily available to provide service and agencies that have been approved by the State to coordinate transportation services.

Local Streets and Roads Program (LSRP), California Transportation Commission

This funding is for basic road maintenance, rehabilitation, critical safety projects, traffic control devices, drainage and stormwater capture, etc. Funding could be used for installing permanent signage and traffic control devices to enable contraflow traffic. Eligible applicants include cities and counties, funding is awarded annually.

Prop 84 Wildfire Resiliency & Recovery Planning Grants, California Strategic Growth Council

This past opportunity was advertised by the California Strategic Growth Council (CSGC), the Governor's Office of Planning and Research, and the California Dept. of Conservation. Proposition 84 funded projects that protected natural resources, but concluded with about $720,000 in unused funding. CSGC dedicated the leftover funds to help CA communities affected by wildfire with recovery and adaptation planning. Eligible organizations included local and regional governments (cities, counties, tribes, and metropolitan planning organizations) representing California areas affected by wildfires between 2017-2019.

Federal Agencies

Federal funding programs with relevance to the Adaptation Plan's goals include:

Rebuilding American Infrastructure with Sustainability and Equity, or RAISE Discretionary Grant program, Department of Transportation

The RAISE Discretionary Grant program provides an opportunity for US DOT to invest in road, rail, transit and port projects that promise to achieve national objectives. The grant program is a competitive discretionary fund for multi-modal, multi-jurisdictional projects that are more difficult to support through traditional DOT programs. State, local, and regional agencies are eligible. Recent infrastructure legislation has added $1 billion in funding.

Other Relevant Funding Opportunities (not directly available to RPOs)

California Agencies

Urban & Community Forestry Grants, Calfire

Grant program offers up to $23 million available for urban forestry programs (including forest expansion, maintenance, and workforce development). Grants focused on disadvantaged communities in urban areas. Benefits of the projects include reduced greenhouse gas (GHG) emissions, increased water supply, clean air and water, reduced energy use, flood and storm water management, recreation, urban revitalization, improved public health, and producing useful products such as bio-fuel, clean energy, high quality wood and job creation. These grants are designed for projects that have multiple of the listed benefits and must not be used for mitigation measures. Eligible applicants include a city, a county, a qualifying district or non-profit, but partnering with other organizations is allowed.

Environmental Justice Small Grants, CalEPA

This program offers funding opportunities to assist non-profit community organizations and federally recognized Tribal governments address environmental justice issues in areas disproportionately affected by environmental pollution and hazards.

Relevance to this project: example projects include enhancing local capacity to respond, adapt, and prepare for climate change impacts, developing emergency management plans, etc. – several concepts could be relevant to Shasta Region adaptation strategies.

Building Resilient Infrastructure and Communities (BRIC), FEMA via CalOES

BRIC is a new FEMA pre-disaster hazard mitigation program for hazard mitigation projects that reduce risks from disasters and natural hazards. BRIC is targeted at innovative projects and funding mechanisms to prevent impacts prior to hazards occurring.

Flood Mitigation Assistance (FMA), FEMA via CalOES

The goal of FMA is to reduce or eliminate claims under the National Flood Insurance Program (NFIP), so FMA covers a broad array of investments and activities (including technical assistance) related to flood mitigation. Eligibility is limited to federal disaster areas, but applicants include states, local communities, tribes, and territories, and some private non-profits.

Fire Prevention Grants Program, Calfire

The goal of this Calfire program is to reduce the risk of wildland fires to habitable structures and communities and maximize carbon sequestration. Project categories include Hazardous Fuel Reduction and Fire Prevention Planning, Fire Prevention Education.

2021 Treecovery Grant Program, California ReLeaf

This program is funded by a grant from CalFire, projects must reduce GHG and focus on disadvantaged and low-income communities. Eligible organizations include incorporated non-profits, non-incorporated community-based groups (with fiscal sponsor). Public entities may serve as a fiscal sponsor for an organization but can't apply for funds directly.

Urban Greening, CA Natural Resources Agency

Urban Greening projects result in the conversion of an existing built environment into green space that uses natural and green infrastructure approaches to create sustainable and vibrant communities. Eligible applicants include a city, county, special district, or non-profit, or agency/entity formed pursuant to the Joint Exercise of Powers Act.

Federal

FEMA Hazard Mitigation Grant Program, FEMA

Provides funding to state, local, tribal, and territorial governments so they can rebuild in a way that reduces, or mitigates, future disaster losses in their communities. This grant funding is available after a presidentially declared disaster. Includes "Post-Fire Assistance" for hazard mitigation measures that substantially reduce the risk of future damage, hardship, loss, or suffering in any area affected by a major disaster, or any area affected by a fire for which assistance was provided under Section 420 Fire Management Assistance Grant (FMAG)

Non-Profit Community Organizations

Fire Prevention & Preparedness, CA Fire Foundation

The goal of these grants is to prevent, prepare, and or respond to major events in California, including wildfires, floods, and climate-caused disasters. Eligible applications include fire departments, firefighter associations, fire safe councils, and other community organizations.

2021 County Coordinators Grant, California Fire Safe Council (Info Coming Soon, Opens in Aug.)

The California Fire Safe Council administers U.S. Forest Service State Fire Assistance grant programs and offers a variety of other federal, state and private funding opportunities. Eligible organizations include nonprofits, Native American tribes, municipalities (towns, cities), special districts, state agencies, counties, and for-profit companies.

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Appendix B: Vulnerability Assessment Methodology

This appendix describes the sources and methodologies for the ResilientShasta Extreme Climate Event Mobility and Adaptation Plan: Transportation Vulnerability Assessment.

Scenario Definitions

Describing future outcomes requires some assumptions about the future. By using well-documented scenarios considered to be the industry standard, the projections in this study can be compared with similar efforts such as the Caltrans District 2 vulnerability assessment.[16]

Emissions scenarios

Scenarios used in this study are based on the Intergovernmental Panel on Climate Change's (IPCC) scenarios for the Fifth Assessment Report (AR5).[17] The two scenarios used in this study are the "reduced emissions scenario" (RCP4.5) and the "unconstrained emissions scenario (RCP8.5). These scenarios address the uncertainty of climate change outcomes associated with the amount of greenhouse gas emissions added to the atmosphere between now and the end of the 21st century by human activities. The reduced emissions scenario assumes that global greenhouse gas emissions peak in 2040 and decline afterwards, resulting in an elevated but stable amount of warming by 2100. By contrast the unconstrained emissions scenario corresponds to a world where global greenhouse gas emissions continue to rise throughout the century, leading to rapid and escalating warming by 2100. While neither scenario portrays a future that is the most likely path for human emissions, together these two scenarios 'bookend' the range of outcomes considered most likely.

Time Periods

Climate parameters such as temperature and precipitation can vary year to year, so descriptions of historical or projected future conditions are described in terms of 30-year climate averages. This study uses the same period definitions as the Caltrans District 2 Vulnerability Assessment.[18] For each period, the central year is used to describe the overall period.

Historical:

- 1990 (1975 – 2004)[19]

Projections:

- 2025 (2010 – 2039)[20]
- 2055 (2040 – 2069)

[16] Caltrans 2018a
[17] IPCC 2014
[18] Caltrans 2018a
[19] Historical wildfire probability metrics differ from others, as wildfire probability is only defined by decade. Historical wildfire probability metrics are given for the period 1970 – 2019.
[20] 2025 projection period includes data for the period 2010 – 2020; because the projections were completed in 2015, these projections cover years which have already happened; for purposes of methodological consistency, we use the historical period within the projection file, although the difference between these 'historical projections' and real historical data is very small

- 2085 (2070 – 2099)

Hazard Projections

Climate Change Projections

Future climate projections (including temperature and precipitation) are sourced from the Scripps Institute's Local constructed-analogs (LOCA) downscaled global climate model (GCM) data,[21] which uses global-scale climate change projections from the Climate Model Intercomparison Project 5 (CMIP5) and enhances the resolution of these projections using localized geography and weather data. These are the same downscaled climate projections used by the California climate change assessments, and by Caltrans in its district vulnerability assessments.

The CMIP5 project includes over 30 different GCMs, however only four are used in this analysis. This analysis uses the same four models identified by California's Climate Action Team for California's Fourth Climate Change Assessment.[22] These are:

- HadGEM2-ES, producing a warm/dry simulation
- CNRM-CM5, producing a cooler/wetter simulation
- CanESM2, producing an average simulation, and
- MIROC5, the model simulation that is most unlike the first three for the best coverage of different possibilities[23]

Temperature

Temperature projections in the LOCA downscaled GCM data are used to generate several temperature metrics.

Average annual high temperature

The annual average high temperature is calculated by first by averaging together the daily high temperature (tasmax) for every day in the 30-year climate period, and then by averaging together the temperatures of all four models.

Average seasonal high temperature

Because summer temperatures are more indicative of heat stress, a similar average high temperature metric is generated for just the months of June, July, and August. The daily temperature for every day in the three-month period is averaged together across all 30-years and across the four GCMs.

Heat Wave Temperature

The heat wave temperature is generated by first calculating the rolling seven-day average high temperature, and then identifying the hottest seven-day period in each year. Each annual heat wave temperature is then averaged across all 30 years and all four models.

[21] Bracken et al. 2016
[22] Pierce et al. 2018
[23] Cal Adapt 2021a

Freeze-Thaw Cycles

Diurnal freeze-thaw cycles are defined as the number of days in which the daily high temperature is above 32°F, and daily low temperature (tasmin) is equal-to or lower-than 32°F. The number of FTCs is calculated for each year in each model, and then the annual number of FTCs is averaged across all 30 years and all four models.

Precipitation

Precipitation projections in the LOCA downscaled GCM data are used to generate several precipitation metrics.

Average annual precipitation

The annual average precipitation is calculated using the precipitation metric (pr), and averaging the daily precipitation for every day in the 30-year period and across all four models. Percent changes in precipitation are generated by comparing the projected seasonal precipitation to the same metric calculated using historical data.

Average seasonal precipitation

Because the projected changes to precipitation diverge seasonally, precipitation projections are generated for both the wet season (November – April) and the dry season (May – October). These are generated in the same way as annual averages, but only for the relevant six-month period. Daily precipitation totals (pr) are averaged across each day in the six-month period, over the 30-year timeframe, and across four models.

Percent changes in precipitation are generated by comparing the projected seasonal precipitation to the same metric calculated using historical data.

Extreme precipitation

Extreme precipitation metrics are generated by using the projected daily precipitation totals, and generating three-day rolling totals. Each three-day total shows the total precipitation of the preceding three days. Within each 30-year period and across four models, the top 4%, 1%, and 0.2% of rolling precipitation totals are identified. The lowest value at the threshold of the top 4%, 1%, and 0.2% of values is considered the exceedance threshold for the 25, 100, or 500-year extreme precipitation events, respectively. Comparison of the projected exceedance thresholds to the historical period gives the percent change in exceedance threshold for each type of extreme precipitation event.

Wildfire

Wildfire projections rely on hazard analyses conducted with specialized models for evaluating the effects of climate on wildfire conditions. Two wildfire projections are used, as well as one high-resolution model of current wildfire hazard conditions.

Wildfire Area Burned

The area burned by wildfires has been modeled by Dr. LeRoy Westerling at the University of California, Merced.[24] The UC Merced model evaluated historical wildfires to identify relationships between key

[24] Westerling 2018

climate parameters and wildfire severity. Future wildfire severity was modeled for each grid cell using projected future climate conditions, resulting in an "area burned" metric for large wildfires that corresponds to the intensity of resulting fires. Area burned is measured in hectares per grid cell. Importantly the model is restricted only to "large wildfires" (i.e., fires greater than 1,000 acres in size), so these findings should not be interpreted to include the cumulative area burned of many small fires.

Wildfire area burned projections are hosted on Cal Adapt, and this study uses only the central growth scenario.[25]

Decadal Wildfire Probability

Wildfire probability is also modeled using the UC Merced model, but adapted with a unique methodology described in Dale et al. 2018.[26] This approach produces a percent likelihood of the occurrence of a large wildfire within an individual grid cell over the course of a decade (as opposed to an annual probability). One consequence of using decadal probabilities is that the historical period is expanded to include 1970 – 2019 (as opposed to the 1975 – 2004 historical period used in other comparisons). Similar to area burned, the model results only address large wildfires, although the size of "large" wildfires differs from the area burned metric, with fires over 400 acres in size included.

Decadal wildfire probability projections are hosted on Cal Adapt, and this study uses only the central growth scenario.[27]

Fire Threat Index

Both projections of wildfire intensity and probability are limited in resolution to the 1/16th degree grid cells used by the LOCA downscaled climate projection data. In order to provide high-resolution characterization of fire hazards near and along critical transportation infrastructure, the West-wide Wildfire Assessment Fire Threat Index is used.[28] FTI provides a high-resolution (30m x 30m grid cell) characterization of the combustibility of biomass at the surface, given historical weather conditions. Rankings in the FTI are relative, and serve to provide an indication of the specific locations where fire probability and severity could be highest, near the wildland urban interface.

Flooding

Flood hazards are mapped exclusively using FEMA FIRMs from the National Flood Hazard Layer (NFHL). FEMA FIRMs provide a combined source for modeled flood hazards, although the flood hazards are only retrospective. FIRMs provide both a 100-year floodplain (showing areas of flooding and base flood elevation for flooding associated with streamflow with a 1% annual chance of occurring), and in some areas a 500-year floodplain (associated with streamflow with a 0.2% annual chance of occurring). Because FIRM floodplains are based on historical flood conditions, these probabilistic characterizations of flood hazard are likely underestimates. FIRMs are not mapped comprehensively throughout the Shasta Region, so the absence of flood hazard layers should not be interpreted as an absence of flood hazards.

[25] Cal Adapt 2021b
[26] Dale et al. 2018
[27] Cal Adapt 2021b
[28] Oregon Department of Forestry 2013

FIRMs are hosted on the FEMA NFHL Viewer.[29]

Flood Zones

FEMA designates flood zones based on the probability of experiencing a flood, as well as characteristics about flooding, should it occur. In general, zones designated as or starting with "A" are expected to experience flooding during a 100-year flood event (based on historical data). Zones A, AE, AH, AO, and AR are considered 100-year floodplains. Zone X is considered the 500-year floodplain.

Landslides

No comprehensive or detailed landslide hazard assessments have been conducted in the Shasta Region, so this study relies on a multi-step process to identify one key component of potential landslide hazard: slope angles. The approach used in this assessment is based on evaluation of similar nearby landslide inventories, and application of similar slope characteristics to slopes in the Shasta Region. In this case, the 1997 inventory of landslides in the American River Valley was selected, and analysis of the landslide starting areas identified an average start zone slope of 24.7° with a standard deviation of 12.6°.[30] Slopes in the range 18.4° – 31.0° are considered "potentially hazardous."

Areas of potentially hazardous landslide slope zone are mapped across the entire Shasta Region, and detailed attention is paid to areas with large potential hazard transited by major roads and highways. These potentially hazardous slope zones are cataloged in the landslide section of this report.

Finally, a visual inspection satellite imagery was conducted to identify any historical landslide scars on potentially hazardous slopes above major roads and highways. This survey did not locate any large landslide scars, corroborating the Shasta County Hazard Mitigation Plan's exclusion of landslides.[31]

[29] FEMA 2021
[30] California Dept. of Conservation 1997
[31] Shasta County 2017