

CALTRANS CLIMATE CHANGE

VULNERABILITY ASSESSMENT SUMMARY REPORT

DISTRICT 8

2019



RESILIENCE: THE ABILITY TO PREPARE AND PLAN FOR, ABSORB, RECOVER FROM, OR MORE SUCCESSFULLY ADAPT TO ADVERSE EVENTS.¹

This Summary Report and its associated Technical Report outline climate change effects in District 8. This document provides a high-level review of potential climate impacts in the district's portion of the State Highway System, while the Technical Report presents detail on the technical processes used to identify these impacts. Similar reports are being prepared for each of Caltrans' 12 districts.

A database containing climate stressor geospatial data indicating changes in climate over time (e.g. temperature rise and increased likelihood of wildfires) was developed as part of this study. The maps included in this report and the Technical Report use data from this database, and it is expected to be a valuable resource for ongoing Caltrans resiliency planning efforts and coordination with stakeholders. Caltrans will use this data to evaluate the vulnerability of the State Highway System and other Caltrans assets, and inform future decision-making.

In California and District 8, these general climate trends are expected²:

- **More severe droughts, less snowpack, and changes in water availability**
- **More severe storm impacts and volatile precipitation**
- **Increased temperatures and more frequent, longer heat waves**
- **Longer and more severe wildfire seasons**

¹ - American Association of State Highway and Transportation Officials (AASHTO resilience definition)

² - "Global Warming in the Western United States," Union of Concerned Scientists,

http://www.ucsusa.org/global_warming/regional_information/ca-and-western-states.html#.WMwOFm_yvIU

DISTRICT 8 CONSISTS OF SAN BERNARDINO AND RIVERSIDE COUNTIES WHICH FEATURES DESERTS, MOUNTAINOUS TERRAIN, FORESTS, AGRICULTURE, AS WELL AS URBAN AND RURAL BUILT ENVIRONMENTS.

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OVERVIEW OF METHODOLOGY

The data analysis presented in this report is largely based on global climate data compiled by the Intergovernmental Panel on Climate Change (IPCC) and California research institutions like the Scripps Institution of Oceanography. This data was developed to estimate the earth's natural response to increasing carbon emissions. Research institutions represent these physical processes through Global Climate Models (GCMs). Thirty-two different GCMs have been downscaled to a regional level and refined so they can be used specifically for California. Of those, ten were identified by California state agencies to be the most applicable to California. This analysis used all ten of these representative GCMs, but only the median model is reported in this Summary Report (and the associated Technical Report) due to space limitations.

The IPCC represents future emissions conditions through a set of representative concentration pathways (RCPs) that reflect four scenarios for greenhouse gas (GHG) emission concentrations under varying global economic forces and government policies. The four scenarios are RCP 2.6, RCP 4.5, RCP 6.0, and RCP 8.5. This analysis considered RCP 4.5, which assumes that carbon emissions will peak by mid-century, and RCP 8.5, which assumes a continuation of current emission trends until end of century. This Summary Report presents only results from the RCP 8.5 analysis—the RCP 4.5 analysis is summarized in the associated Technical Report, and the full dataset is compiled in a GIS database.

EVACUATION PLANNING

Among the things that Caltrans must consider when planning for climate change is the role of the State Highway System (SHS) when disaster strikes. The State Highway System is the backbone of most county-level evacuation plans and often provides the only high-capacity evacuation routes from rural communities. In addition, state highways also serve as the main access routes for emergency responders, and may serve as a physical line of defense (a firebreak, an embankment against floodwaters, etc.). As climate-related disasters become more frequent and more severe, this aspect of State Highway System usage will assume a greater importance that may need to be reflected in design. The upcoming studies of climate change adaptation measures will take these factors into account when identifying measures appropriate to each situation.




BACKGROUND AND APPROACH

Caltrans is making a concerted effort to identify the potential climate change vulnerabilities of the State Highway System. The information presented in this report is the latest phase of this effort focusing on District 8. It identifies portions of the State Highway System that could be vulnerable to different climate stressors and Caltrans processes that may need to change as a result.

This report involved applying available climate data to refine the understanding of potential climate risks, and Caltrans coordinated with various state and federal agencies and academic institutions on how to best use the most recent data. Discussions with professionals from various engineering disciplines helped identify the measures presented in this report.

The information in this Summary Report outlines the potential vulnerabilities to Caltrans' District 8 portion of the State Highway System. It illustrates the types of climate stressors that may affect how highways are planned, designed, built, operated, and maintained. This effort is needed to add clarity regarding climate change in the region served by District 8 and begin to define a subset of assets on the State Highway System on which to focus future studies and adaptation efforts. This report does not identify projects to be implemented, nor does it present the cost associated with such projects. These items will be addressed in future work performed by Caltrans.



THE STATE HIGHWAY SYSTEM IN DISTRICT 8 WILL NEED TO ACCOMMODATE INCREASES IN LOCAL AND INTRA-REGIONAL TRAFFIC AS A RESULT OF CONTINUED POPULATION GROWTH AND DEVELOPMENT, WHILE ALSO ADDRESSING THE CHALLENGES ASSOCIATED WITH A CHANGING CLIMATE.

DISTRICT 8 CHARACTERISTICS

Many of the district's major state highways are severely congested during peak periods due to the high number of commuters to and from Los Angeles, Orange, and San Diego Counties. In addition to weekday congestion during morning and afternoon peak hours, Interstate 10 is heavily used for long distance recreational and goods movement to Arizona and beyond—as is Interstate 15 to Nevada and beyond. Interstate 215 is another major goods movement corridor and is heavily used during commute peak hours. State routes 91 and 210 are heavily used for commuter and recreational destination travel, and State Route 58 and Interstate 40 carry substantial volumes of goods movement traffic and intraregional and interregional travelers. Interstate 15 is heavily used to facilitate tourism to and from Nevada and to facilitate the transportation of commodities from Mexico and San Diego in the south. This congestion is expected to increase due to population and employment growth. The Southern California Association of Governments (SCAG) found that the regional

transportation plan for this area does not meet the plan's minimum Level of Service (LOS) "D" operating condition, nor the district's desired system-wide route concept on much of the urban highway system, and some very significant portions of rural interstates.

High winds are prevalent in sections of all four of the interstates and are of particular concern in the Palm Springs area of Interstate 10 and the Cajon Pass area of Interstate 15, from which high-profile vehicles must be diverted when gusts reach 55 miles per hour. The Santa Ana winds are especially strong in autumn in San Bernardino where they funnel through Cajon Pass and increase wildfire risk in the foothills. Portions of District 8 get much colder than other regions in Southern California, and in the winter, the district needs to clear the highways of snow to keep the San Bernardino and San Gabriel Mountains open for recreation. Additionally, the portion of the district located in desert regions is subject to infrequent, but sometimes intense, rainfall.

KEY STATE POLICIES ON CLIMATE CHANGE

There are multiple California state climate change adaptation policies that apply to Caltrans decision-making. Some of the major policies relevant to Caltrans include:

Executive Order (EO) B-30-15 – requires the consideration of climate change in all state investment decisions through the use of full life cycle cost accounting, the prioritization of adaptation actions which also mitigate GHGs, the consideration of the state's most vulnerable populations, the prioritization of natural infrastructure solutions, and the use of flexible approaches where possible. The Governor's Office of Planning and Research (OPR) have since released guidance for implementing EO B-30-15 titled *Planning and Investing for a Resilient California*. The document provides high level guidance on how state agencies should consider and plan for future conditions. Caltrans supported the development of this guidance by serving on a Technical Advisory Group convened by OPR.³

Assembly Bill 1482 – requires all state agencies and departments to prepare for climate change impacts with efforts including: continued collection of climate data, considering climate in state investments, and the promotion of reliable transportation strategies.⁴

Assembly Bill 2800 – requires state agencies to take into account potential climate impacts during planning, design, building, operations, maintenance, and investments in infrastructure. It also requires the formation of a Climate-Safe Infrastructure Working Group consisting of engineers with relevant experience from multiple state agencies, including Caltrans.⁵ The Working Group has since completed *Paying it Forward: The Path Toward Climate-Safe Infrastructure in California*, which recommends strategies for legislators, engineers, architects, scientists, consultants, and other key stakeholders to develop climate ready, resilient infrastructure for California.⁶

3 - California Governor's Office of Planning and Research, "Planning and Investing for a Resilient California," March 13, 2018, <http://opr.ca.gov/planning/icarp/resilient-ca.html>

4 - "Assembly Bill No. 1482," California Legislative Information, October 8, 2015, https://leginfo.legislature.ca.gov/faces/billTextClient.xhtml?bill_id=201520160AB1482

5 - "Assembly Bill No. 2800," California Legislative Information, September 24, 2016, http://leginfo.legislature.ca.gov/faces/billNavClient.xhtml?bill_id=201520160AB2800

6 - Climate-Safe Infrastructure Working Group, *Paying it Forward: The Path Toward Climate-Safe Infrastructure in California*, September 2018, <http://resources.ca.gov/climate/climate-safe-infrastructure-working-group/>

RECENT EXTREME WEATHER IMPACTS IN DISTRICT 8

Extreme weather events already disrupt and damage District 8 infrastructure. The Caltrans State Highway Operations Protection Program (SHOPP) addresses regular wear and tear to Caltrans assets. The SHOPP also addresses extreme weather impacts through its Emergency Damage Repair, which focuses on repairing infrastructure damaged by catastrophic events, Permanent Restoration which restores facilities to their original condition after such events, and Roadway Protective Betterment programs which extend the useful life of facilities through preventative measures. The following examples include a variety of issues and events that Caltrans District 8 has addressed in the past through their SHOPP programs, which may become more prevalent as climate changes.

Temperature – District 8 includes a broad geography with urban areas, desert wilderness such as Joshua Tree National Park, and the San Bernardino Mountains. Temperatures are expected to rise in these areas in the future and have different effects on each. The mountainous regions may face a higher risk of tree mortality due to drought and heat, but desert vegetation could also be negatively affected. Both situations could increase fire potential in District 8. In 2017, a brush fire on Highway 91 in Riverside County damaged the side slope, landscape area, and the metal beam guard rail. These types of impacts may become more frequent as temperatures rise, droughts become more severe, and vegetation dries out.

Precipitation – In December of 2010, multiple subtropical storms hit District 8. These storms continued for a week and delivered between seven and 17 inches of rain, depending on location. These sudden and extreme rain events exceeded the capacities of multiple

District 8 culverts, including one at Willow Creek Road and others along State Route 18. Overflow from the culverts flooded nearby roadways, washed out berms and slopes, and undermined roadbeds. As the climate changes, heavy and extreme precipitation is expected to increase in California and these types of events may become more commonplace in District 8.

Wildfire – Area burned by wildfire has increased in parallel with rising air temperatures, which have increased by 1° to 3°F across the state since the first half of last century. These rising temperatures combined with volatile precipitation, modified vegetation characteristics, changes to wind patterns, and frequency of drought, could have serious influence on wildfire risk in California.⁷ Recent studies have found that the droughts of the last 15 years were “more intense than early- to mid-20th century droughts, with greater temperature and precipitation extremes,” which could contribute to more severe fires and widespread tree mortality in drought-affected areas.⁸

There were many severe wildfires during and following the drought (2011 to 2017), one of the most notable in District 8 being the 2016 Blue Cut Fire in Cajon Pass. The Blue Cut Fire jumped I-15 due to high winds and extremely dry vegetation and destroyed 105 homes, 213 outbuildings, over 200 vehicles, and pieces of highway infrastructure. The San Bernardino National Forest Service, San Bernardino County Fire officials and the County Sheriff’s Department have yet to determine the cause of the fire. The fire burned 36,274 acres off I-15 and Highway 138 north of San Bernardino before it was contained.⁹

⁷ Louise Bedsworth, Dan Cayan, Guido Franco, Leah Fisher, Sonya Ziaja. (California Governor’s Office of Planning and Research, Scripps Institution of Oceanography, California Energy Commission, California Public Utilities Commission), 2018, “Statewide Summary Report,” California’s Fourth Climate Change Assessment, Publication number: SUMCCCA4-2018-013, <http://www.climateassessment.ca.gov/>

⁸ Joseph Crockett, Leroy Westerling, 2018, Greater Temperature and Precipitation Extremes Intensify Western US Droughts, Wildfire Severity, and Sierra Nevada Tree Mortality, *Journal of Climate* 31(1):341-354, doi:10.1175/JCLI-D-17-0254.1, <https://cloudfront.escholarship.org/dist/prd/content/qt3t39d8jq/qt3t39d8jq.pdf?i=osfbdf&v=lg>

⁹ Paola Baker, “A Year Later, Officials Continue Probing Bluecut Fire,” *Daily Press*, August 5, 2017, <http://www.vvdailypress.com/news/20170805/year-later-officials-continue-probing-bluecut-fire>





STATE ROUTE 18 | MARCH 2018 | ROCKFALL CLOSES SR-18 IN THE SAN BERNARDINO MOUNTAINS



STATE ROUTE 91 | SEPTEMBER 2017 | BRUSH FIRE DAMAGE TO LANDSCAPING AND DRAINAGE INFRASTRUCTURE



STATE ROUTE 18 | DECEMBER 2010 | FLOODING AND WASHOUTS FROM SUBTROPICAL STORMS



STATE ROUTE 18 | DECEMBER 2010 | FLOODING AND WASHOUTS FROM SUBTROPICAL STORMS



INFRASTRUCTURE IMPACT EXAMPLE

As the climate changes, California will be affected by more frequent, extreme weather events. In recent years, California has experienced a severe drought (2011 – 2017), a series of extreme storm events that caused flash flooding and landslides across the state (2017 – 2018), the most destructive and deadly wildfire season on record (2018), and deadly mudslides in Southern California (2018). These emergencies demonstrate what could become more commonplace for California in the future, as droughts, storm events, and wildfires become more frequent and severe. It is important to learn from these events, take actions to prevent them wherever possible, and increase the resiliency of transportation infrastructure for near- and long-term threats. This section provides an example of a district-level weather-related event and the district's response.

I-10 TEX WASH BRIDGE WASHOUT

On July 19, 2015, the eastbound Highway 10 Tex Wash Bridge collapsed after a flash flood brought water, mud, and debris through a previously dry riverbed (the Tex Wash). The US National Weather Service found the heavy storm event to be caused by Hurricane Dolores' remaining moisture and circulation, which created perfect conditions for flooding in southeast California. Seventeen centimeters of rain fell in six hours and the flood was determined to be a 1,000-year storm event.¹⁰

A failure analysis of the collapse found that it was caused by a combination of weather factors and bridge design flaws. The main factors that contributed to the bridge failure were:

- The shape of the wash, which caused a bottleneck in the path of the flood
- Flood waters which made an "S" curve due to the shape of the wash and directed flow at, and washed soil out from under, the east abutment
- The erosion of the fill soil on which the east abutment was supported
- The abutment wing walls were perpendicular in alignment to the flood waters which exposed more surface area to the water's force
- The combination of the above effects which knocked over the abutment and caused the deck to collapse.¹¹

Approximately 4,480 trucks cross the bridge daily¹² so its collapse resulted in severe traffic delays. Caltrans responded quickly to the initial event and reopened the bridge to traffic just three days later. Subsequent actions included the complete demolition of the collapsed bridge, replacement of rock slope protection in the wash, and the design of a new bridge that used piles instead of spread footing to make the structure more resilient to similar events. The new bridge was built through accelerated bridge construction (ABC) and was reopened just two months after the collapse.¹³

10 - Maryam Tabbakhha, Abolhassan Astaneh-Asl, Daniel Christian Setioso, "Failure Analysis of Flood Collapse of the Tex Wash Bridge," University of California at Berkeley, Proceedings of the World Congress on Civil, Structural, and Environmental Engineering, Paper No. ICSENM 118 (2016): DOI: 10.11159/icsenm16.118, https://avestia.com/CSEE2016_Proceedings/files/paper/ICSENM/118.pdf

11 - Ibid.

12 - Ibid.

13 - Mike Keat, "Precast Concrete Speeds California Bridge Replacement," American City & County, July 26, 2016, <https://www.americacityandcounty.com/2016/07/26/precast-concrete-speeds-california-bridge-replacement/>





HEAVY WATER FLOW THROUGH TEX WASH CAUSED EAST BOUND COLLAPSE AND ABUTMENT, WING WALL, AND FOOTING DAMAGE

VULNERABILITY AND THE STATE HIGHWAY SYSTEM

CALTRANS EFFORTS

Caltrans has been addressing concerns associated with climate change over the last decade, since the establishment of its Climate Change Branch. Caltrans has since developed guidance on how climate change considerations can be incorporated into project design and other functional Caltrans responsibilities. Activities to respond to climate change and develop guidance documents include:

- The release of *Guidance on Incorporating Sea Level Rise* (2011) to inform effective design and programmatic considerations that incorporate projections of sea level rise.
- *The issuance of Addressing Climate Change Adaptation in Regional Transportation Plans (2013) which serves as a how-to guide for California Metropolitan Planning Organizations (MPOs) and Regional Transportation Planning Agencies (RTPAs).*
- The report out of adaptation goals and progress to OPR through the State Sustainability Roadmaps, Adaptation Chapters, the last of which was submitted in October, 2018.¹⁴

Caltrans' ongoing efforts include developing a more detailed understanding of the risks to the state's transportation system through this study. Next Caltrans is exploring the actions that need to be taken internally to ensure the resiliency of the State Highway System long into the future.

ADDRESSING CONCERNS IN DISTRICT 8

Caltrans District 8's portion of the State Highway System serves critical functions for local communities and the national commerce. Given the importance of this system, understanding the potential impacts of climate change and extreme weather on system performance is a key step in creating a resilient highway system.

The term "vulnerability" is often used to describe the degree to which assets, facilities, and even the entire transportation system, might be subject to disruption due to weather and climate-related hazards. Caltrans' approach focuses on the vulnerability of the transportation system to climate change impacts such as temperature rise and extreme weather impacts, like increased heavy precipitation events.

The approach outlined on this page and the next describes an assessment process consistent with Caltrans practices and is focused on the assessment of likely impacts of climate change-related stressors on the State Highway System. The approach focuses on three issues:

- **Exposure** – identifying Caltrans assets that could be affected by expected future weather and climate-related climate hazards.
- **Consequence** – determining what damage might occur to system assets – in terms of loss of use, costs of repair, and increased maintenance needs.
- **Prioritization** – determining which assets to prioritize for more detailed assessment and capital investments to address identified risks.

Implementing this approach requires the participation of a wide range of Caltrans professionals from planning, asset management, operations/maintenance, design, emergency response, and project accounting, and will require coordination with environmental and social resource agencies. It will take an agency-wide effort to implement successfully.

ENSURING SYSTEM RESILIENCY

Once system vulnerabilities are identified, Caltrans will begin including enhanced system resiliency when choosing projects and project designs. In District 8, this will require implementing projects that help to address the wildfire, precipitation, and increased temperature effects that are expected to occur. The following are some general strategies that District 8 could employ to address precipitation, wildfire, and temperature change.

- While projected precipitation changes are not as extreme in District 8 as they are in other Caltrans districts, a 5–20% change in 100-year storm precipitation depth could still have significant flash flooding impacts. To mitigate this risk, District 8 may need to factor higher storm magnitudes into bridge design to more effectively mitigate scour and abutment erosion.
- Wildfire threats will be most prominent in the forested, mountainous region of District 8 rather than the less-vegetated high desert regions. District 8 can mitigate wildfire risk by preparing Caltrans facilities with ignition resistant materials, covering building openings with metal mesh, and using Class A fire-rated roofing. Resiliency criteria such as those identified in [LEED, Fortified Commercial™](#), or [RELi](#) provide guidance on fire- and weather-resistant building design.
- Temperature changes in already dry, arid environments could affect the health of District 8 maintenance employees. Work schedules may need to be adjusted to help employees avoid high heat and direct sunlight.

These efforts will require Caltrans to be proactive and invest in the long-term viability of the transportation system.

¹⁴ - Governor's Office of Planning and Research, "Tracking Progress Over Time: State Sustainability Roadmaps," October, 2018, http://opr.ca.gov/meetings/tac/2018-10-12/docs/20181012-4_Tracking_Progress_Over_Time.pdf



THE CALTRANS APPROACH TO VULNERABILITY OUTLINED BELOW WAS DEVELOPED TO HELP GUIDE FUTURE PLANNING AND PROGRAMMING PROCESSES. IT DESCRIBES ACTIONS TO ACHIEVE LONG-TERM HIGHWAY SYSTEM RESILIENCY.

THE APPROACH INCLUDES THE FOLLOWING KEY ELEMENTS:



EXPOSURE

Define the components and locations of the highway system (roads, bridges, culverts, etc.) that may be exposed to changing conditions caused by the effects of climate change such as sea level rise, storm surge, wildfire, landslides, and more. Key indicators for this measure include the potential timing of expected changes – e.g., what year could you expect these conditions to occur.

CONSEQUENCE

Identify the implications of extreme weather or climate change on Caltrans assets. Key variables include estimates of cost of damage and the length of closure to repair or replace the asset and measures of environmental or social impacts. The consequence of failure from climate change include (among others):

- Sea level rise and storm surge inundating roadways and bridges forcing their closure, which could lead to delays and detours.
- Wildfire primary and secondary effects (debris loads/ landslides) on roadways, bridges and culverts.
- Precipitation changes, and other effects such as changing land use, that combined, could increase the level of runoff and flooding.
- Impacts to the safety of the traveling public from flash flooding, loss of guardrails and signage from wildfires, debris on the roadway from flooding, wildfire, and landslide events, and limited visibility from poor air quality.

PRIORITIZATION

Develop a method to support investment decision-making from among multiple options related to future climate risk, with elements including:

- Timing – how soon can the impacts be expected?
- Impacts – what are the projected costs to repair/replace? What is the likely time of outage? What are the likely impacts on travel/goods movement?
- Safety – who will be directly or indirectly affected? How can impacts to vulnerable populations be avoided? How will worker safety be affected?

BY USING THIS APPROACH, CALTRANS CAN CAPITALIZE ON ITS INTERNAL CAPABILITIES TO IDENTIFY PROJECTS THAT INCREASE STATE HIGHWAY SYSTEM RESILIENCY.

OTHER EFFORTS IN DISTRICT 8 TO ADDRESS CLIMATE CHANGE

In addition to Caltrans' efforts, there are other climate change planning and preparation efforts underway in District 8. Both of the district's counties have developed reports and adopted plans designed to reduce the impacts of climate change in local communities and build resilience to climate change. Ongoing coordination with local governments and stakeholders will be critical to ensure that methodologies and adaptation strategies are not redundant with other efforts.

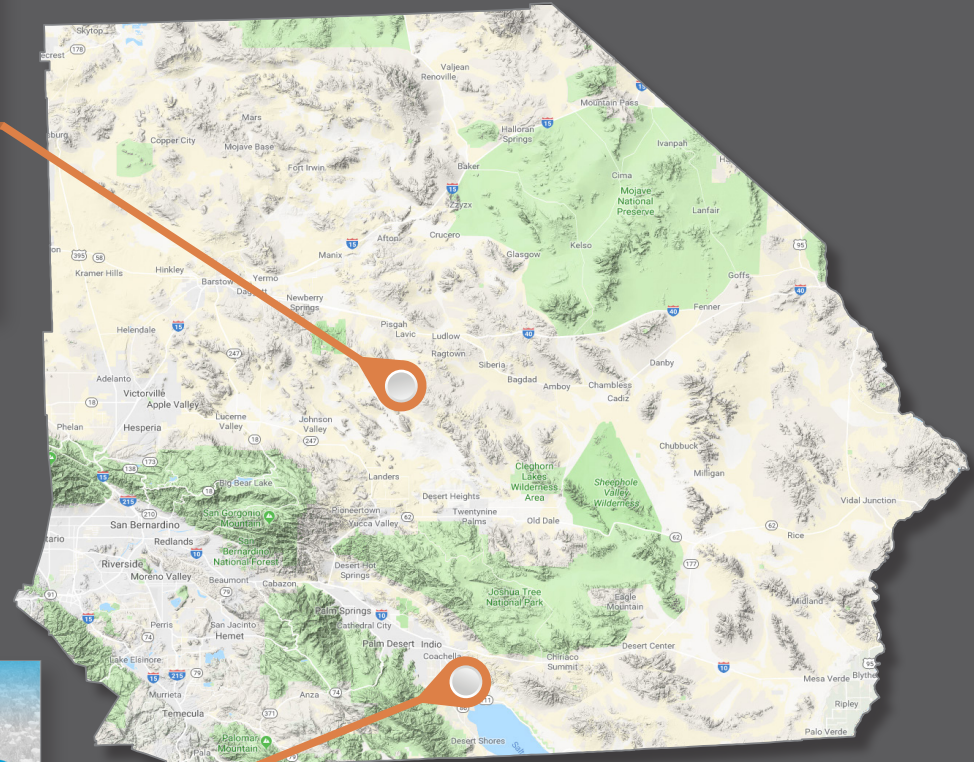
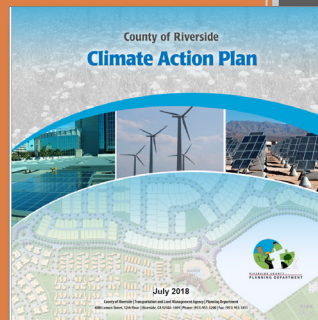
SAN BERNARDINO COUNTY REGIONAL GREENHOUSE GAS REDUCTION PLAN

The San Bernardino County Regional GHG Reduction Plan summarizes actions that each city in the county can take to reduce their GHG emissions and estimate local progress. The plan helps the county assess GHG sources, streamline project approvals, evaluate strategy effectiveness and cost, be involved in local GHG reduction efforts, and give cities credit for past efforts. The plan is useful for cities to reference in their work and to incorporate into a local Climate Action Plan (CAP) if desired.¹⁵



THE RIVERSIDE COUNTY CLIMATE ACTION PLAN

Riverside County updated their CAP in 2018. The CAP focuses on strategies to reduce GHGs, preserve local air quality, conserve energy, and ensure that county decisions meet state legislative requirements. Following the state's adopted AB 32 GHG reduction target, Riverside County set a goal to reduce emissions back to 1990 levels by the year 2020. This target was calculated as a 15% decrease from 2008 levels, as recommended in the AB 32 Scoping Plan. A community-wide emissions inventory was also calculated for the horizon year of 2035. Since the development of the CAP coincided with Riverside County's General Plan Update, the socioeconomic growth rates from the General Plan Update were used to estimate the 2035 emissions. Some of the strategies Riverside County will use to meet this greenhouse gas reduction goals include: the development of a energy efficient design program, anti-idling enforcement, promoting mixed use development and public transit, and increasing reclaimed water use.¹⁶



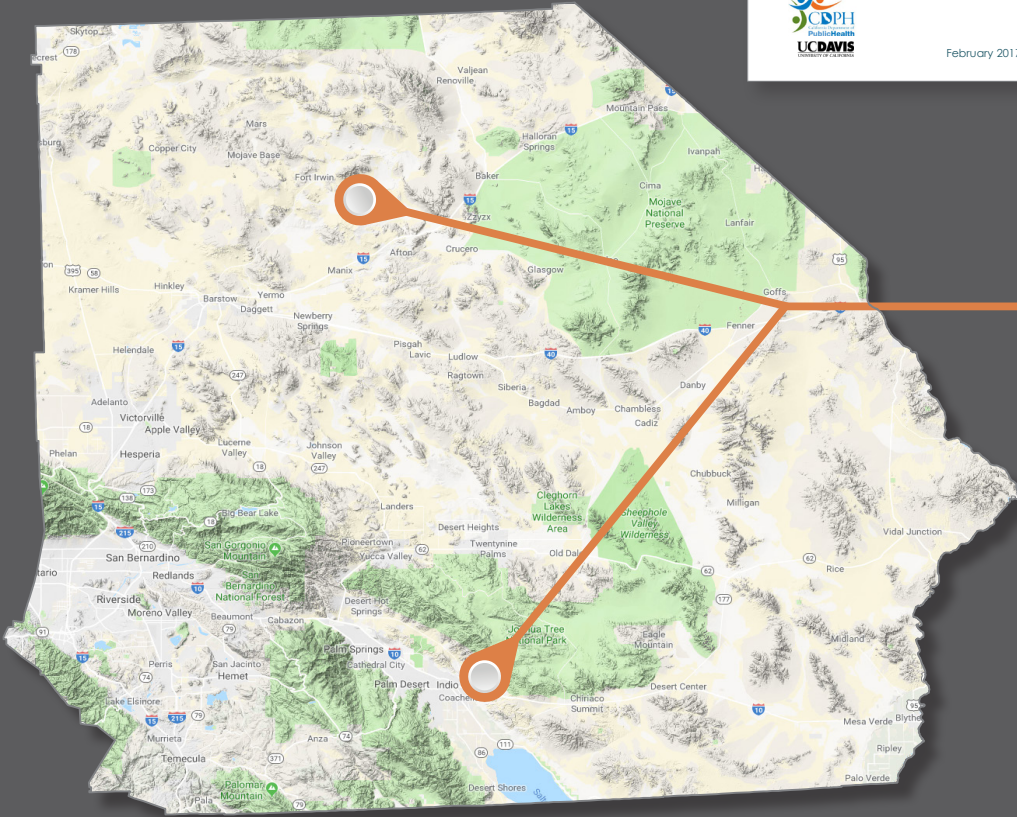
15 – San Bernardino Associated Governments, "San Bernardino County Regional Greenhouse Gas Reduction Plan," March 2014, <http://www.gosbcta.com/plans-projects/plans/greenhouse-gas/SBC-RegionalGreenHouseGasReduction-Final.pdf>

16 – Riverside County, "Riverside County Climate Action Plan," July 2018, <https://planning.rcilma.org/CAP>

Climate Change and Health Profile Report
Riverside County



February 2017



CLIMATE CHANGE AND HEALTH PROFILE REPORTS FOR SAN BERNARDINO AND RIVERSIDE COUNTIES

Reports on climate change and the resulting potential future health impacts to county residents were written for both San Bernardino and Riverside Counties. Both reports provide climate projections for temperature, heat waves, fire, precipitation, and snow pack, and detail on how

these changes could affect public health. Poor water and air quality, extreme weather, and environmental degradation can lead to disease, injuries, malnutrition, and mental health challenges—and vulnerable populations such as the young, elderly, disabled, low income, or those with health conditions may be disproportionately affected. Both county reports provide current local population profiles to identify the size of the population groups that may be at highest risk from climate change impacts, such as:

- 49% of San Bernardino and 47% of Riverside residents have multiple chronic conditions, compared to 44% statewide.
- 16% of San Bernardino residents have been diagnosed with asthma. This compares to 13% in Riverside and 14% statewide.
- 11% of individuals in each county report they live with a disability.
- 7% of San Bernardino and 9% of Riverside residents work outdoors.
- 15% of San Bernardino residents and 13% of Riverside residents are below the poverty line.

Each report suggests actions the counties can take to protect their most vulnerable residents and promote public health in the face of a changing climate. Some suggestions are for the near-term, such as starting public outreach campaigns, improving heat warning systems, and continuing research on the nexus between climate change and health. Others are for the long-term, such as developing resiliency funding opportunities, reducing urban heat islands, and promoting access to health care, to establish community resiliency to climate change health impacts.^{17,18}

17 – Neil Maizlish, Dorette English, Jacqueline Chan, Kathy Dervin, Paul English, “Climate Change and Health Profile Report: Riverside County,” Office of Health Equity, California Department of Public Health, February 2017, https://www.cdph.ca.gov/Programs/OHE/CDPH%20Document%20Library/CHPRs/CHPR065Riverside_County2-23-17.pdf

18 – Neil Maizlish, Dorette English, Jacqueline Chan, Kathy Dervin, Paul English, “Climate Change and Health Profile Report: San Bernardino County,” Office of Health Equity, California Department of Public Health, 2017, https://www.cdph.ca.gov/Programs/OHE/CDPH%20Document%20Library/CHPRs/CHPR071SanBernardino_County2-23-17.pdf

PHASES FOR ACHIEVING RESILIENCY

California has been a national leader in responding to extreme climatic conditions, particularly in regards to Executive Order B-30-15. Successful adaptation to climate change includes a structured approach that anticipates likely disruptions and institutes effective changes in agency operating procedures. The steps shown below outline the approach to achieve resiliency at Caltrans and show how work performed on this study fits within that framework.

PREDICT CLIMATE CHANGE EFFECTS:

Climate change projections suggest that temperatures will be warmer, that precipitation patterns will change, sea levels will rise, and that a combination of these stressors could lead to other types of disruptions, such as those associated with wildfires.

COORDINATE WITH FEDERAL/STATE RESOURCE AGENCIES ON APPLICABLE CLIMATE DATA:

Many state agencies have been actively engaged in projecting specific future climate conditions for purposes such as water supply, energy impacts, and environmental impacts. Federal agencies have also been studying change for other purposes such as anticipating coastal erosion and wildfires.

IDENTIFY EXPOSURE OF CALTRANS HIGHWAYS TO POSSIBLE CLIMATE CHANGE DISRUPTIONS:

Identifying locations where Caltrans' assets might be exposed to extreme weather-related disruptions provides an important foundation for decisions to protect and minimize potential damage. The exposure assessment examines climate stressors such as extreme temperatures, heavy precipitation, sea level rise, and more, and relates the likely consequences of these stresses to disruptions to the State Highway System.

UNDERSTAND POSSIBLE TRANSPORTATION IMPACTS:

Higher precipitation levels could cause more flooding and landslides. Sea level rise and/or storm surge could inundate or damage low-lying coastal roads and bridges. Higher temperatures could affect state highway maintenance and their risk due to wildfires. Understanding these potential impacts provides an impetus to study ways to enhance the resiliency of the State Highway System.

INITIATE VULNERABILITY ASSESSMENT:

Alternative climate futures will have varying impacts on the State Highway System. This step includes an examination of the range of climatic stressors and where, due to terrain or climatic region, portions of the State Highway System might be vulnerable to future disruptions.

IDENTIFY PRIORITIZATION METHOD FOR CALTRANS INVESTMENTS:

This step identifies the process that Caltrans can use to prioritize projects and actions based on their likely system resiliency benefits, through reduced impacts to system users.

This process will focus on resiliency benefits and the timeframe of potential impacts, and could guide the timing of investment actions.

SCOPE OF THIS STUDY

INCORPORATE RESILIENCY PRACTICES THROUGHOUT CALTRANS:

Each Caltrans functional area will be responsible for incorporating those actions that are outlined in their Action Plan, while reporting progress regularly to agency leadership.

PRIORITIZE A SET OF PROJECTS/ACTIONS FOR ENGINEERING ASSESSMENTS:

The prioritization method will help Caltrans identify those projects and actions with the most benefit in terms of enhancing system resiliency. Prioritization could focus on those projects with primary benefits related to system resiliency, or on other projects with benefits that could go beyond resiliency.

MONITOR EFFECTS OF PROJECTS/ACTIONS AND MODIFY GUIDANCE AS APPROPRIATE:

This step is the traditional “feedback” into the decisions that started a particular initiative. In this case, the monitoring of the effects of resiliency-oriented projects and actions adopted by Caltrans is needed to assess if resiliency efforts have been effective over time. This monitoring is a long-term effort, and one that will vary by functional responsibility within Caltrans.

DEVELOP ACTION PLANS FOR EACH CALTRANS FUNCTIONAL AREA

(including planning and modal programs, project delivery, and maintenance & operations):

Each of the functional areas in Caltrans would develop an Action Plan for furthering resiliency-oriented projects and processes in their area of responsibility. These action plans would define specific action steps, the estimated benefits to the State of California related to these steps, a timeline and staff responsibility.

DEVELOP AND IMPLEMENT PILOT STUDIES FOR PLANNING AND PROJECT DEVELOPMENT AND MORE:

Pilot studies could be developed specific to each functional area and provide a “typical” experience for that function. Each pilot study would be assessed from the perspective of lessons learned and how the experience can guide project implementation, and actions similar to those in the pilot studies.

ADVANCE PROJECTS/ACTIONS TO APPROPRIATE INVESTMENT PROGRAMS:

Implementing resiliency-oriented actions and projects will require funding and other agency resources. This step advances those actions, and projects prioritized above, into the final decisions relating to funding and agency support, whether it is the capital program or other budget programs.



TEMPERATURE

Temperatures across California have been steadily rising over the last century. On average, present day (1986 to 2016) temperatures in California have warmed above those recorded during 1901 to 1960 by 1 to 2.9 °F, depending upon location.¹⁹ There is very high confidence that this trend of increasing temperature will continue, leading to higher temperatures, longer heat waves, and potentially more severe drought events.

The figure on the following page shows the change in the average maximum temperature over seven consecutive days (which is an important element in determining the right pavement mix for long-term performance) for three time periods compared to a historical backcasted period from 1975 to 2004. In general, other studies in the US have found that increasing temperatures could impact the transportation system by affecting:

DESIGN

- Ground conditions and water saturation levels can affect foundations and retaining walls.
- Materials exposed to high temperatures over long periods of time can crack, heave, or otherwise become deformed (e.g. pavement heave or track buckling). High temperatures are considered in the design of pavements in particular to mitigate future deterioration.

OPERATIONS AND MAINTENANCE

- Extreme heat events could affect employee health and safety, especially for those that work long hours outdoors.

- Right-of-way landscaping and vegetation must be able to survive longer periods of high temperatures.
- Extended periods of high temperatures could increase the need for protected transit facilities along roadways.
- Higher temperatures could deteriorate bridge joint seals due to expansion, which could accelerate replacement schedules and even affect bridge superstructure.

EFFECTS OF TEMPERATURE RISE IN DISTRICT 8

Under the high emissions scenario (RCP 8.5), the seven-day average maximum temperature in District 8 is projected to increase through the end of the century. In 2025 the increase ranges from 0 to 4 degrees, in 2055 it increases to 4 to 8 degrees, and by 2100 it increases to 6 to 12 degrees. These values represent the increase on top of the historical, modeled average maximum temperature. In San Bernardino and Riverside Counties, the historical average annual high is around 80 degrees. This average could increase to around 84 or 92 degrees given projected changes in seven-day average maximum temperature, which does not factor in any temperature increase that has happened between the historical period and current temperatures.^{20,21} Rising temperatures could affect District 8 materials, maintenance schedules, and landscaping. Longer and more severe periods of drought can lead to tree die-off and increased wildfire risk, as was observed in the last drought period from 2011 to 2017. The areas of District 8 projected to experience the greatest increase in average maximum temperature are the urban centers in the west and the desert regions to the east, including within and south of Mojave National Preserve.

19 - Bedsworth, Louise; Cayan, Dan; Franco, Guido; Fisher, Leah; Ziija, Sonya. (California Governor’s Office of Planning and Research, Scripps Institution of Oceanography, California Energy Commission, California Public Utilities Commission). 2018. Statewide Summary Report. California’s Fourth Climate Change Assessment. Publication number: SUMCCCA4-2018-013.
 20 - “Climate Riverside – California,” US Climate Data, last accessed May 8, 2019, <https://www.usclimatedata.com/climate/riverside/california/united-states/usca1695>
 21 - “Climate San Bernardino - California,” US Climate Data, last accessed May 8, 2019, <https://www.usclimatedata.com/climate/san-bernardino/california/united-states/usca0978>



HIGHER TEMPERATURES COULD LEAD TO MORE FREQUENT PAVEMENT MAINTENANCE AND RE-PAVING

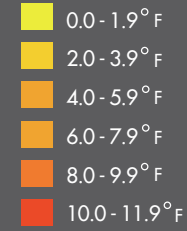


STATE ROUTE 18 | OCTOBER 2007 | WILDFIRES PROMPTED THE REMOVAL OF 18,330 DEAD TREES IN DISTRICT 8 RIGHT-OF-WAY TO MITIGATE FURTHER FIRE RISK

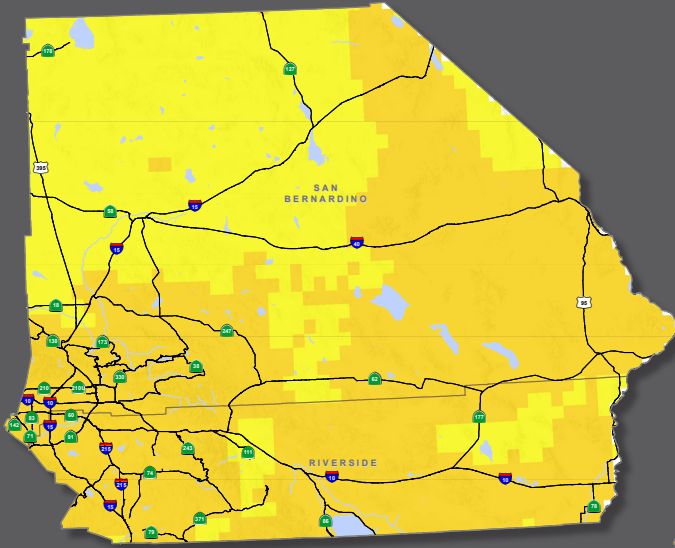
Fig.1

CHANGE IN THE AVERAGE MAXIMUM TEMPERATURE OVER SEVEN CONSECUTIVE DAYS

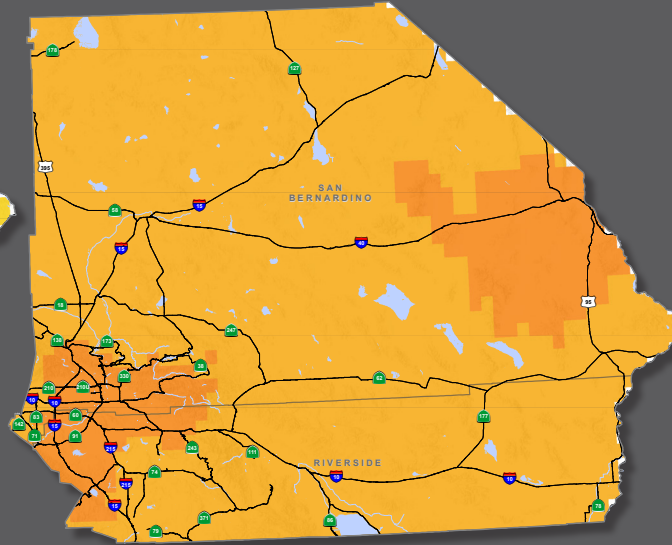
A REQUIRED MEASURE FOR PAVEMENT DESIGN



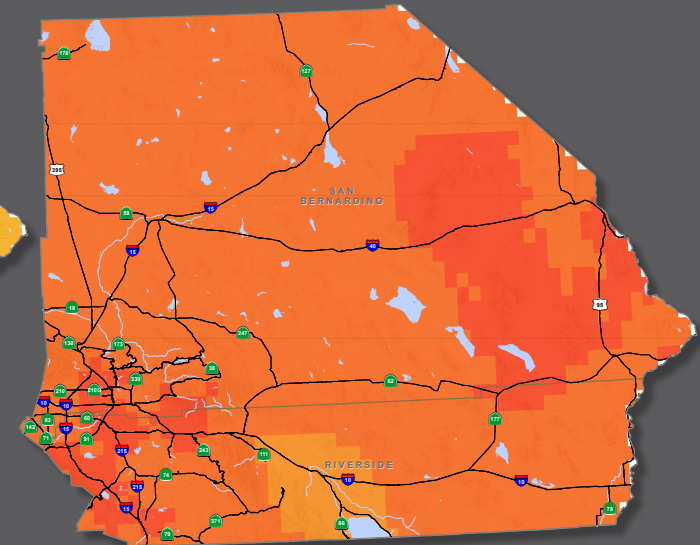
Median Climate Model for CA (CMCC-CMS)



2025 REPRESENTATIVE CONCENTRATION PATHWAYS (RCP) 8.5, 50TH PERCENTILE



2055 REPRESENTATIVE CONCENTRATION PATHWAYS (RCP) 8.5, 50TH PERCENTILE



2085 REPRESENTATIVE CONCENTRATION PATHWAYS (RCP) 8.5, 50TH PERCENTILE

Future Change in the Average Maximum Temperature over Seven Consecutive Days within District 8, Based on the RCP 8.5 Emissions Scenario

Caltrans Transportation Asset Vulnerability Study, District 8. Caltrans No. 74A0737. Climate data provided by the Scripps Institution of Oceanography. The data shown was generated by downscaling global climate outputs using the Localized Constructed Analogs (LOCA) technique.

PAVEMENT DESIGN

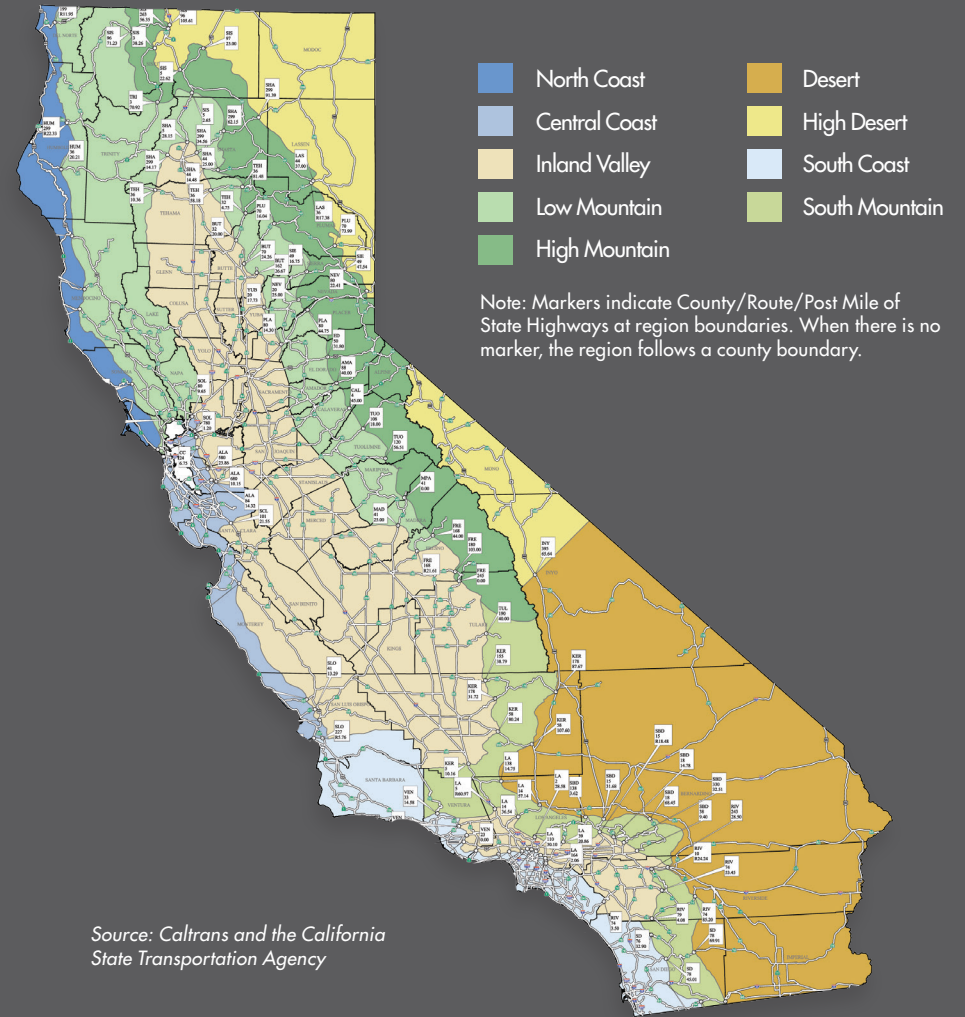
Pavement condition is related to how pavement is designed and is an important component of Caltrans' highway asset management strategy. Ensuring that highway pavements remain durable and maintain good ride quality when exposed to various conditions is an important Caltrans responsibility. Highway pavement can be either concrete or asphalt mix, with the choice dependent on various conditions. One element of asphalt pavement design is the selection of the pavement binder, a decision based in part on temperature conditions in the project area.

Caltrans has divided the state into nine pavement climate regions (as shown in Figure 2) to determine the types of pavement recommended for each area. Pavement design considers two primary criteria: average maximum temperature over seven consecutive days and the change in absolute minimum air temperature. As mentioned in the previous section, the temperature projections for this assessment have been formatted to fit these metrics. An important consideration for Caltrans and its pavement design engineers will be whether the boundaries of these climate regions could shift over time as climate changes, or whether pavement design parameters might need to change due to climatic changes across the state.

The timing of impacts from climate change is different for pavement than other State Highway System assets. Many of Caltrans' assets, including roadways, bridges, and culverts, will be in place for a long time. Decisions made for these assets today may remain in effect until the end of the century. This is not necessarily the case for asphalt pavement, which is replaced approximately every 20-40 years depending on the pavement's purpose. Given the shorter lifespan of asphalt pavements, designs will only need to incorporate nearer term temperature projections.

Fig. 2

CALTRANS PAVEMENT REGIONS



POTHOLES FORMING FROM FREEZE & THAW IMPACTS ON PAVEMENT, ILLUSTRATING PAVEMENT QUALITY CONCERNS

TIMEFRAMES AND ASSET DECISION-MAKING

Decision-making for transportation assets requires consideration of many factors, including how long an asset will be in place. This is often referred to as the design life, or useful life, of an asset. Some assets managed by Caltrans, like asphalt pavement, are replaced around every 20-40 years while others, like bridges, are built with the expectation of a useful life of 50 years or longer. A road alignment may be in place for a century or longer—a reality highlighted by the fact that alignment of the first national highway (as it was defined then), built to connect settlers to the Ohio Valley and the west, is still in existence today.

The two graphics included on this page highlight how design life considerations are a critical part of planning for transportation investment. The figure below shows how future temperature scenarios vary widely depending on emission levels and global response. One thing to note is that the conditions are somewhat consistent through around 2050, after which they begin to diverge more significantly. This means that decisions made on investments nearing the end of century need to include a much wider range of temperature uncertainty for future conditions.

Fig. 3 IPCC - CLIMATE CHANGE 2013: THE PHYSICAL SCIENCE BASIS FAQ 12.1

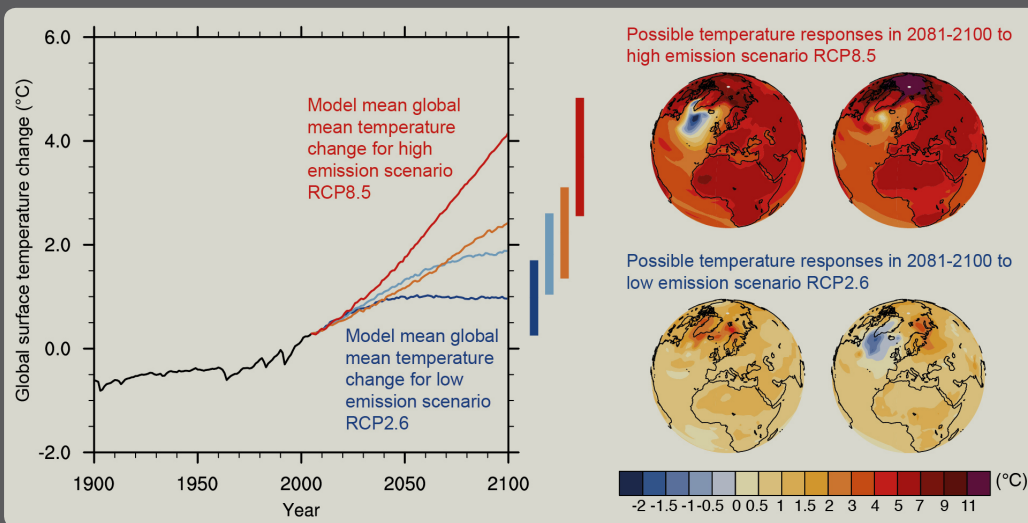
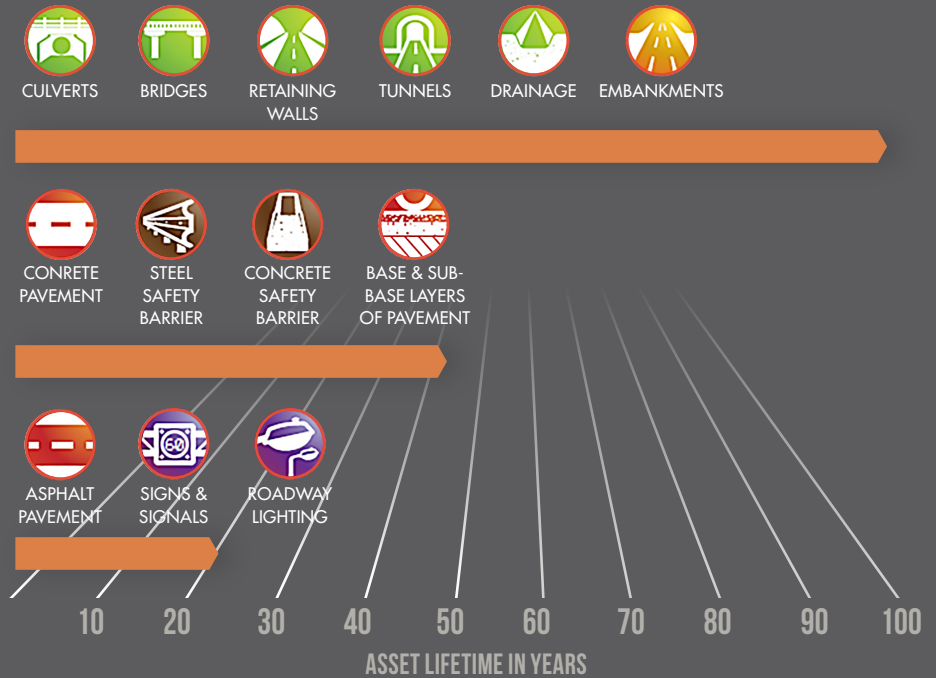


Fig. 4

TRANSPORTATION INFRASTRUCTURE ASSETS



The graphic above was prepared to show how assets maintained by Caltrans will require different considerations for planning and design. All decisions should be forward-looking instead of based on historic trends, because all future scenarios show changing conditions. These future conditions must be considered when designing new transportation assets to ensure that they achieve their full design life.

Source: [UK Highways Agency](#)

Source: [IPCC](#)



PRECIPITATION

Increasing temperatures are expected to increase the volatility of precipitation, due to an increase in energy and moisture in the atmosphere. More intense storm events, combined with other changes in land use and land cover, can increase the risk of damage or loss from flooding. Transportation assets in California are affected by precipitation in a variety of ways, including flooding, landslides, washouts, erosion, and structural damage from heavy rainfall. The primary concern regarding transportation assets is not the overall volume of rainfall over an extended period, but rather more frequent and larger storm events and their potential for damaging the State Highway System.

The Scripps Institution of Oceanography at the University of California, San Diego has generated projected future rainfall data to the year 2100 using RCP 4.5 and 8.5, and a variety of models. One way for Caltrans to use this data is to assess changes to the 100-year storm event over time. The 100-year storm event has a likelihood of occurring once every 100 years—in other words, it has a 1% chance of happening in any given year. A storm of this magnitude could cause significant damage and is therefore a design standard for infrastructure projects, based upon historical conditions. Understanding how the 100-year storm may change in the future can help Caltrans to build more resilient infrastructure, designed to

accommodate heavier storm events. See the figure on the following page for the percentage increase in the 100-year storm depth across District 8.

Indications of increased precipitation in District 8 means that Caltrans must assume higher rainfall and associated flooding, and plan improvements to the State Highway System accordingly. This situation can be exacerbated by increased development, which reduces the natural absorption capacity of the land in drainage areas. Complex conditions like these require a longer-term view be considered for design and flood response for facilities in these areas to ensure that they remain operational to the end of their design lives. Improving long-term resiliency will require that Caltrans conduct a comprehensive assessment of future conditions, and incorporate new values for precipitation in design.

PRECIPITATION CHANGE IN DISTRICT 8

As shown in Figure 5, the 100-year storm depth is projected to increase by anywhere from 0–20% in District 8 depending on the timeframe and location. The high desert regions show lower precipitation increases, while the more urban, western regions closer to the coast show precipitation increases of up to 20%. These changes could increase flash flood frequency. There are several mitigation strategies the district can use to reduce flooding and landslide risk, including changing drainage design requirements, using vegetation to reduce runoff, and building barriers to protect roadways from land or rock slides.



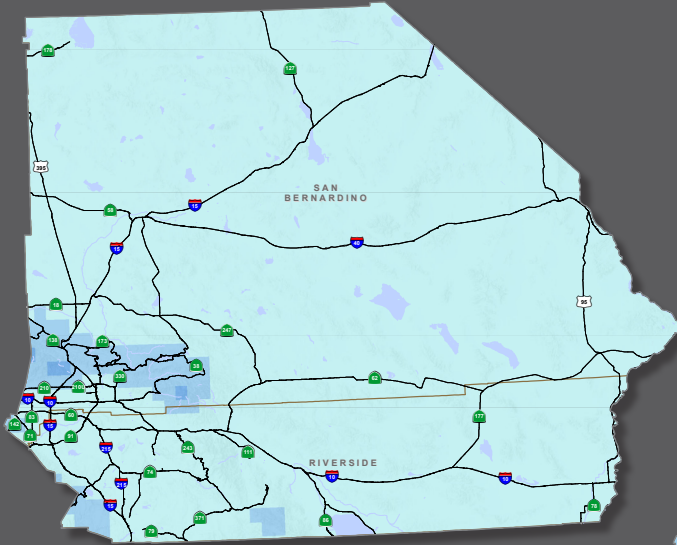
US 396 | DECEMBER 2010 | HEAVY RAIN UNDERMINES ROADWAY



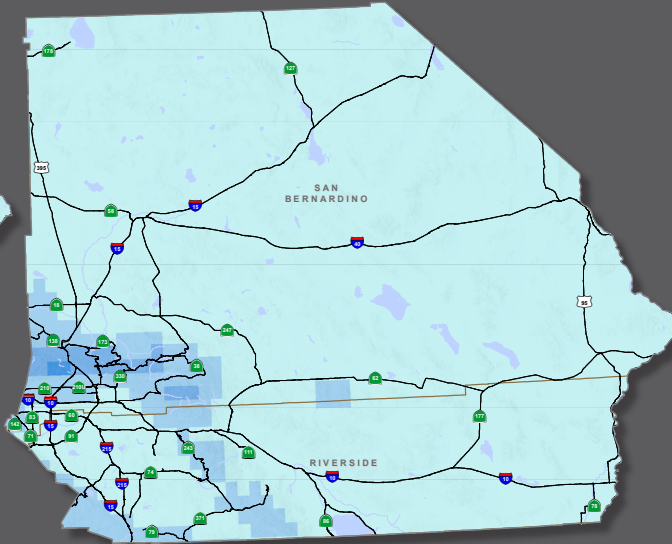
STATE ROUTE 18 | DECEMBER 2010 | ROCKFALL FROM HEAVY RAIN

Fig. 5

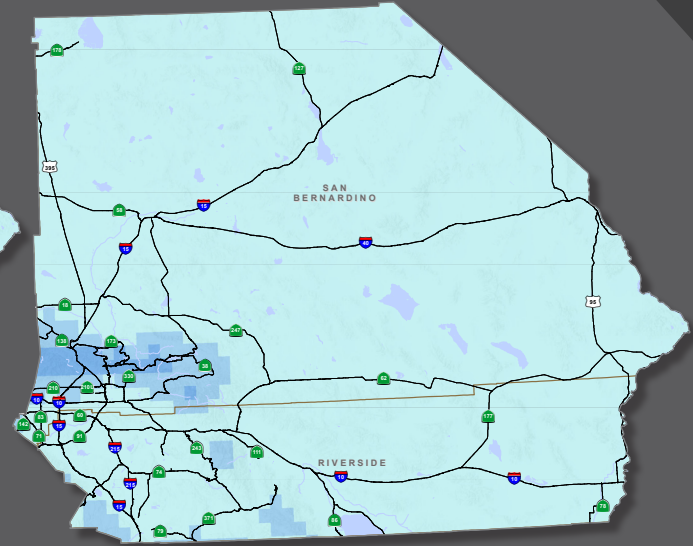
PERCENT CHANGE IN 100-YEAR STORM PRECIPITATION DEPTH



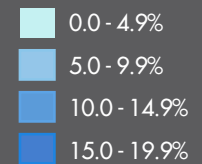
2025 RCP 8.5, 50TH PERCENTILE



2055 RCP 8.5, 50TH PERCENTILE



2085 RCP 8.5, 50TH PERCENTILE



Future Percent Change in 100-year Storm Precipitation Depth within District 8, Based on the RCP 8.5 Emissions Scenario

Caltrans Transportation Asset Vulnerability Study, District 8. Caltrans No. 74A0737. Climate data provided by the Scripps Institution of Oceanography. The data shown was generated by downscaling global climate outputs using the Localized Constructed Analogs (LOCA) technique.

Median Climate Model for CA (HadGEM2-CC)



WILDFIRE

Higher temperatures are expected to influence both the intensity and scale of wildfires by drying out soils and vegetation. Wildfires can contribute to landslide and flooding exposure by burning off protective land cover and reducing the capacity of the soils to absorb rainfall. California is already prone to serious wildfires, and the results of future climate forecasts suggests that the vulnerability will get worse. The need to address these concerns led Governor Jerry Brown to announce a new fund to help forest management and reduce wildfire risk in May 2018.

Figure 6 shows increased likelihood of wildfires in District 8 based upon projected percentages of area burned over time. These projections are from data generated by the MC2 – EPA (from the United States Forest Service), MC2- Applied Climate Science Lab (University of Idaho), and the Cal-Adapt 2.0 (UC Merced) wildfire models. Each model was paired with three downscaled Global Climate Models to produce nine future scenarios. Starting with three different wildfire models was a conservative methodology, as final data shows the highest wildfire risk categorization of all model results. The results for RCP 8.5, the high emissions scenario, are provided in Figure 6 and Table 1. See the associated Technical Report for results processed for RCP 4.5

WILDFIRE EFFECTS IN DISTRICT 8

Wildfire risk is the greatest in the district’s more-densely forested areas, while there is no projected change in wildfire risk for the eastern region (the model still shows a risk, but that risk doesn’t increase due to the region’s less-dense vegetation). The greatest wildfire risk areas border Los Angeles, Orange, and San Diego Counties, where Angeles National Forest meets the San Bernardino Mountains and National Forest. District 8 can mitigate wildfire risk in these areas by using fire-resistant materials, maintaining defensible space, and using fire-safe landscaping. The district can also limit wildfire concern by actively reducing fuel through dead or diseased tree removal and thinning practices.

Table 1: Centerline Miles of Roadways in Moderate to Very High Wildfire Exposure Areas for the RCP 8.5 Scenario

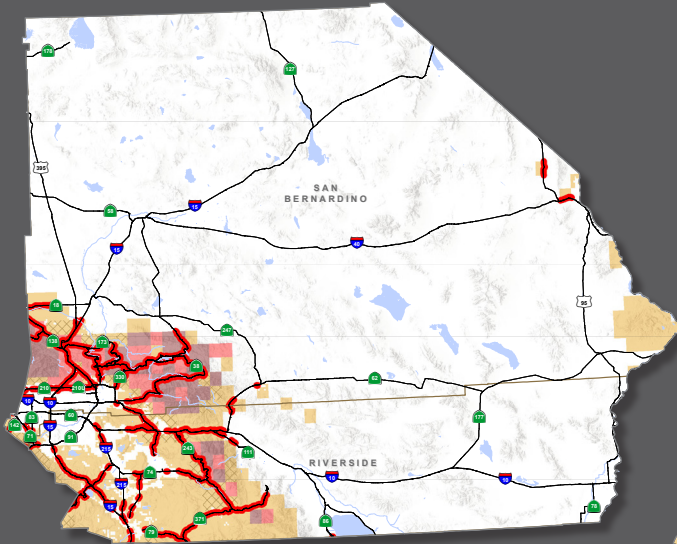
County	Miles		
Riverside	205.1	227.3	240.7
San Bernardino	282.7	333.6	422.7

2025
2055
2085

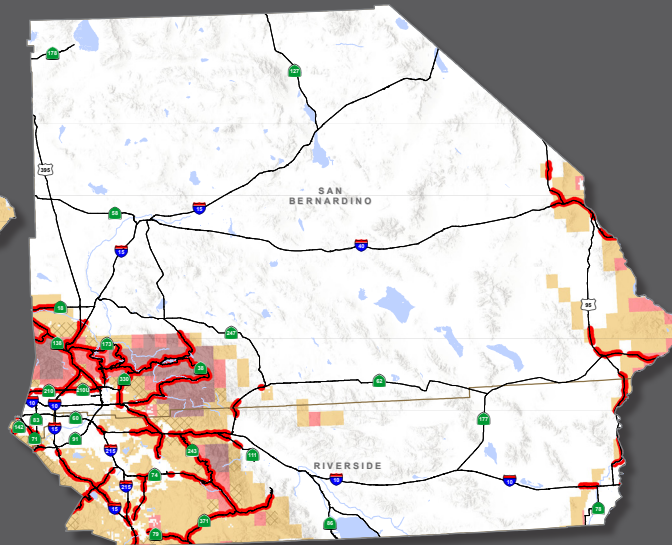


Fig. 6

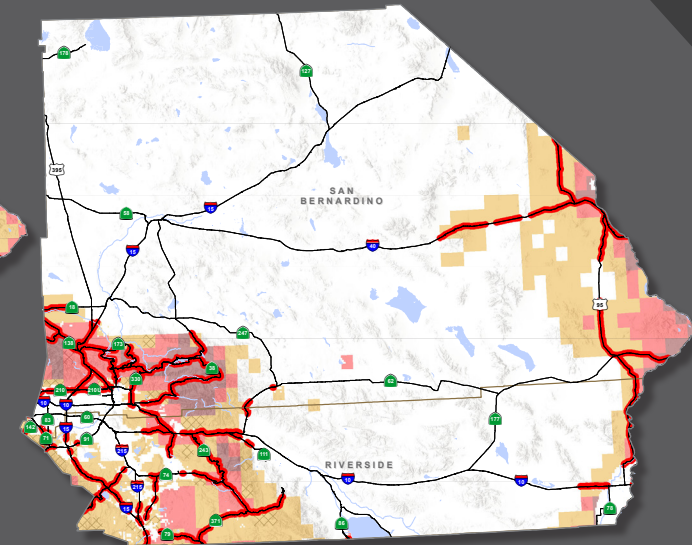
LEVEL OF WILDFIRE CONCERN



2025 RCP 8.5, MULTI-MODEL MAXIMUM



2055 RCP 8.5, MULTI-MODEL MAXIMUM



2085 RCP 8.5, MULTI-MODEL MAXIMUM

Future Level of Wildfire Concern for the Caltrans State Highway System within District 8, Based on the RCP 8.5 Emissions Scenario

The fire model composite summaries shown are based on wildfire projections from three models: (1) MC2 - EPA Climate Impacts Risk Assessment, developed by John Kim, USFS; (2) MC2 - Applied Climate Science Lab at the University of Idaho, developed by Dominique Bachelet, University of Idaho; and (3) University of California Merced model, developed by Leroy Westerling, University of California Merced. For each of these wildfire models, climate inputs were used from three GCMs: (1) CAN ESM2; (2) HAD-GEM2-ES; and (3) MIROC5. The maps show the multi-model maxima for each grid cell across the nine combinations of the three fire models and the three GCMs.

* The hashing shows areas where 5 or more of the 9 models fall under the same cumulative % burn classification as the one shown on the map.

Levels of Concern

- VERY HIGH
- HIGH
- MEDIUM
- HIGH MODEL AGREEMENT*
- EXPOSED ROADWAY

BEFORE WILDFIRE



Fig. 7

**FOREST/TREE COVER
MODERATES RAINFALL EFFECTS
ON THE GROUND, LIMITING
EROSION OF THE SOILS**

**GROUND COVER OF TREES,
SHRUBS AND GRASSES
STABILIZE AND SLOW SURFACE
FLOWS AND FACILITATE
RAINFALL INFILTRATION
INTO THE SOIL**

**INSTALLED SIGNS AND
GUARDRAILS IMPROVE SAFETY
FOR ROADWAY USERS**

**CLEAR CULVERTS ALLOW WATER
TO PASS UNDER THE ROADWAY
AND PROVIDE WILDLIFE
CROSSINGS**

Healthy, vegetated areas provide various ecosystem benefits including precipitation infiltration and soil stabilization. These natural systems help prevent potential damage to roadways, bridges, and culverts by mitigating excessive flood water and preventing erosion.

**LOSS OF FOREST COVER
RESULTS IN MORE EROSION
OF SOILS**

**BURNED SOILS ARE UNABLE
TO FACILITATE THE
INFILTRATION OF RAINFALL,
INCREASING RUNOFF**

**LOSS OF STABILIZING
GROUND COVER RESULTS IN
LOOSER SOILS AND INCREASED
LANDSLIDE POTENTIAL**

**BURNED GROUND COVER LEADS
TO MORE DEBRIS THAT CAN
CLOG CULVERTS/BRIDGES
DURING RAINFALL EVENTS**

**DESTROYED SIGNS AND
GUARDRAILS REDUCE
DRIVER SAFETY**

**DAMAGED OR CLOGGED
CULVERTS INCREASE RISK OF
ROAD OVERWASHING, DAMAGE,
AND ELIMINATES OPTIONS FOR
WILDLIFE CROSSING**



Fig. 8

After wildfires have occurred, new risks are posed to transportation assets in the area. Immediately after a fire, the loss of signs and guardrails presents a danger to travelers and require an immediate response. Other impacts noted in the graphic above can exist as a potential risk to Caltrans assets for years after a wildfire event occurs.

ADAPTIVE DESIGN, RESPONSE, AND RISK MANAGEMENT

Risk-based design strategies are one way of developing an effective adaptation response to climate stressors and dealing with the uncertainties of future climate conditions. A risk-based decision approach considers the broader implications of damage and loss in determining the design approach. The Federal Highway Administration has developed a framework for making design decisions that incorporates climate change: the Adaptation Decision-Making Assessment Process (ADAP)²² process.

At its core, the ADAP process is a risk-based, scenario-driven design process. It incorporates broader economic and social costs, as well as projected future climate conditions, into design decision-making. It can be considered a type of sensitivity test for Caltrans assets and it incorporates an understanding of the implications of failure on Caltrans system users, and the agency's repair costs. The ADAP flowchart shows the basic elements of climate change assessment for existing and future roadways.

The following section highlights the district's response to a wildfire and multiple landslides. While not an example of adaptive design as applied through ADAP, the events demonstrate some of the ways the district currently responds to these events and the mitigation measures used to restore slope stability. These efforts may also be used in the future to prepare for and respond to more frequent and severe wildfires and landslides.

CRANSTON LANDSLIDE AND MITIGATION MEASURES

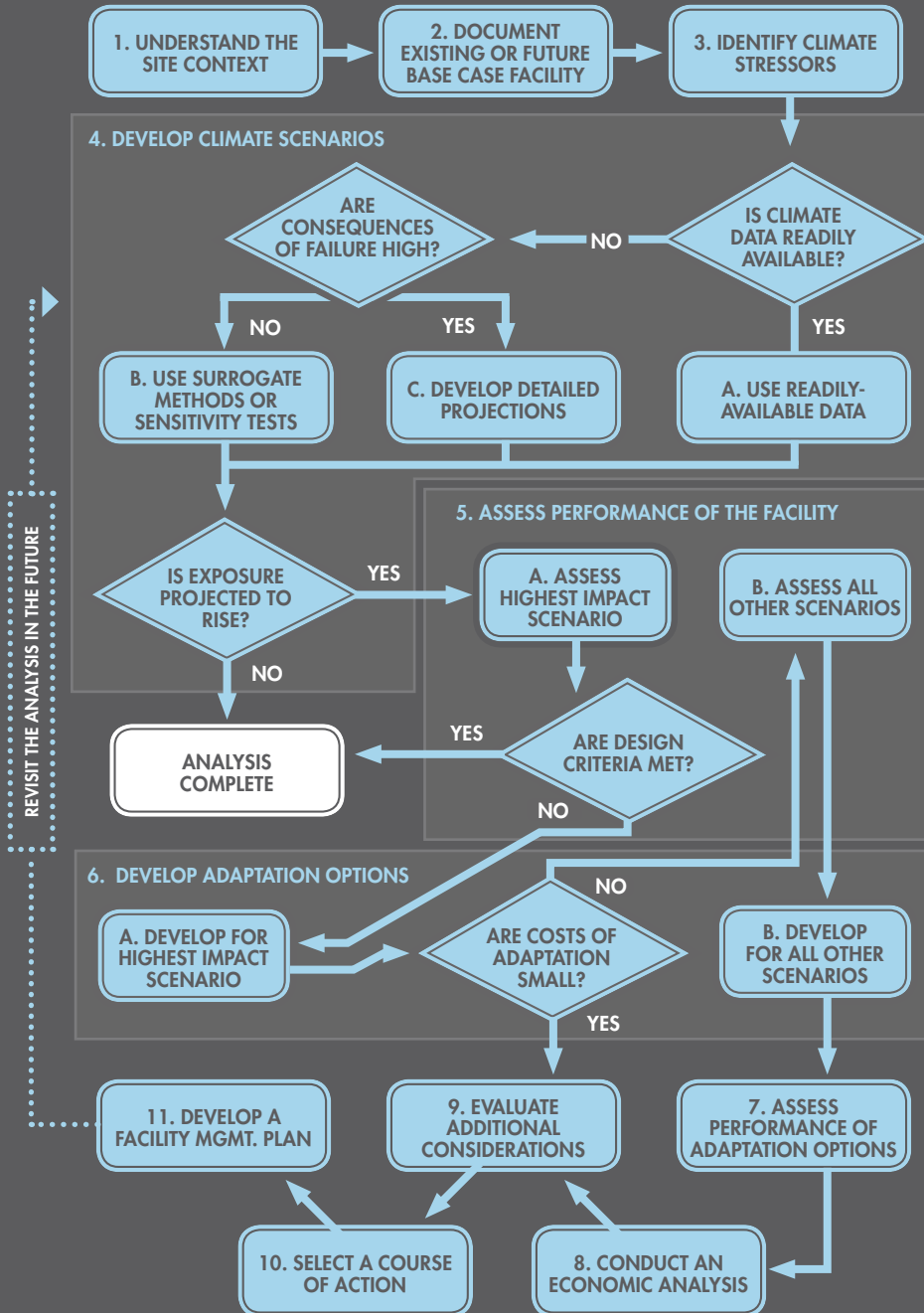
In August 2009, the Cottonwood Fire burned for four days along both sides of Highway 74 in Riverside County between Hemet and Idyllwild.²³ The road was only closed for a few days in 2009, but landslides and mudslides in the same location forced its closure again in 2014.²⁴ Caltrans responded with landslide mitigation measures to stabilize the slope and control water flow, but in 2017 another storm event triggered the Cranston Landslide which compromised these measures. Again, Caltrans responded by repairing culverts, identifying separations in the drainage systems, repairing surficial erosion such as gullies, and installing straw wattles and sandbags to control surface runoff. While this example does not incorporate risk-based design, it demonstrates the persistence required to maintain and stabilize high risk areas.

-
- 22 - "Adaptation Decision-Making Assessment Process," FHWA, last modified January 12, 2018.
https://www.fhwa.dot.gov/environment/sustainability/resilience/ongoing_and_current_research/teacr/adap/index.cfm
- 23 - "Crews Gain Ground on Cottonwood Fire," NBC Los Angeles, August 30, 2009,
<https://www.nbclosangeles.com/news/local/Crews-Gain-Ground-on-Cottonwood-Fire-56226382.html>
- 24 - "Highway 74 Reopens After Landslide," KESQ, last modified August 28, 2016,
<https://www.kesq.com/home/hwy-74-reopens-after-landslide/62498>



Fig. 10

FHWA'S ADAP DESIGN PROCESS



BETWEEN JANUARY 21-23, 2017 THE SAN BERNARDINO MOUNTAINS EXPERIENCED A SIGNIFICANT PRECIPITATION EVENT. THE STORMS PRODUCED ROCK FLOWS THAT WERE STOPPED BY THE EXISTING ROCK BARRIER.



STATE ROUTE 18 | 2017 | ROCKFALL BARRIER STOPS FALLING ROCKS AND DEBRIS



WHAT DOES THIS MEAN TO CALTRANS?

GENERAL CONCLUSIONS

Recent extreme weather events in District 8 provide an opportunity to address many of the potential climate change impacts outlined in this report. Some conclusions that can be reached from the perspective of Caltrans include:

1. New and repaired District 8 facilities should include considerations of the future, rather than relying on historical conditions (page 4 – state policies)
2. Consequence costs should be a determinant in redesign—assessing broader economic measures and the potential cost savings from adaptation (page 10 – vulnerability approach)
3. The development of updated design approaches, which includes best available climate data from state resource agencies, should be a part of the response to these events (page 13– phases for achieving resiliency)
4. The assessment of precipitation effects should include estimated higher rainfall totals derived (page 19 – Precipitation section)
5. FHWA’s ADAP process should be applied in any planning or design of a facility/asset to incorporate uncertainties in climate data and utilize a benefit-cost assessment methodology that considers long-term costs to guide decisions (pages 25-26 – Adaptive Design, Response, and Risk Management)

The State Highway System is at risk from a range of climate stressors, as outlined in this report. Effective management of these risks will require a prioritized response, focusing on the system’s most vulnerable and critical assets first. Taking steps to address these climate concerns will also require the following:

FULLY DEFINING RISKS

This report does not provide a full accounting of risks from changing climate conditions. Additional work will be required to identify risk at an asset-by-asset level from the full range of potential impacts by using the ADAP process. To fully assess and address risks, assets

outside of normal DOT control, but which could affect state highway operation if they failed (e.g., dams and levees), should also be evaluated.

INTEGRATION INTO CALTRANS PROGRAM DELIVERY

Caltrans programs including policies, planning, design, operations, and maintenance, should be redesigned to include the consideration of long-term climate risks. Uncertainties inherent in climate data should be accounted for by adopting a climate scenario-based decision-making process, which involves considering the full range of climate predictions. Caltrans is currently evaluating internal processes to understand how to best incorporate climate change into decision-making.

LEADERSHIP

Leadership will be required at both the state government and transportation agency level. Transportation systems are often undervalued by not considering the broader economic implications of damage, loss, or failure. Avoiding the possible impacts of extreme weather events and climate change on the State Highway System should be made a policy and capital programming priority.

COMMUNICATION AND COLLABORATION

Adapting to the challenges posed by climate change will require a proactive and collaborative approach. Caltrans recognizes that stakeholder input and coordination will be necessary to develop analyses and adaptation strategies that build upon and support the body of work underway by the state. Working with other state agencies and local communities on adaptation strategies can also lead to better decisions and a collective response, and prevents the possibility of working in silos.

A STATE HIGHWAY SYSTEM RESILIENT TO CLIMATE CHANGE

The end result of considering climate change in a systematic and comprehensive way, with the efforts defined by this report being the first steps, will be a State Highway System more resilient to extreme events and climate change.



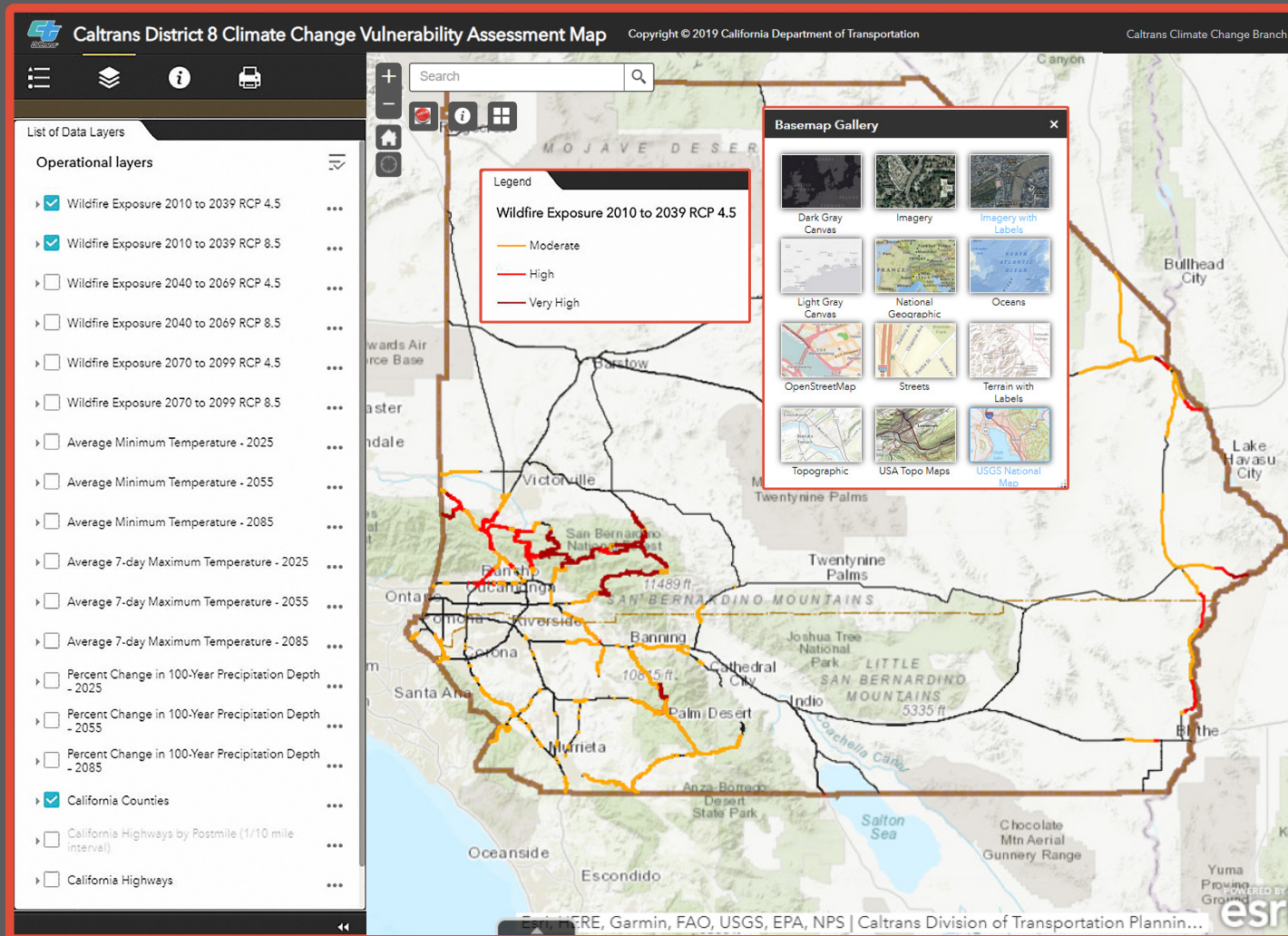
ON-LINE MAPPING TOOL FOR DECISION-MAKING

Caltrans has created an online mapping program to provide information for users across the state, using data assembled for this project. The Caltrans Climate Change Vulnerability Assessment Map can be accessed [here](#).²⁵

This tool enables Caltrans staff, policy-makers, residents and others to identify areas along the State Highway System where vulnerabilities may exist, or how temperature and precipitation may change over time.

The map viewer will be dynamic, incorporating new data as it is developed from various projects undertaken by Caltrans and will be maintained to serve as a resource for all users. The tool will be updated with data for each district as vulnerability assessments are developed.

²⁵ - Caltrans makes no representation about the suitability, reliability, availability, timeliness, or accuracy of its GIS data for any purpose. The GIS data and information are provided "as is" without warranty of any kind. See the map tool for more information.



Complex geospatial analyses were required to develop an understanding of Caltrans assets exposed to sea level rise, storm surge, cliff retreat, temperature, and wildfire. The general approach for each stressor's geospatial analysis went as follows:

- **Obtain/conduct stressor mapping:** The first step in each GIS analysis was to obtain or create maps showing the presence and value of a given climate stressor at various future time periods.
- **Determine critical thresholds:** To highlight areas affected by climate change, the geospatial analyses for certain stressors defined the critical thresholds for which the value of a hazard would be a concern to Caltrans.
- **Overlay the stressor layers with Caltrans State Highway System to determine exposure:** Once high hazard areas had been mapped, the next step was to overlay the Caltrans State Highway System centerlines with the data to identify the segments of roadway exposed.
- **Summarize the miles of roadway affected:** The final step in the geospatial analyses involved running the segments of roadway exposed to a stressor through Caltrans' linear referencing system, which provides an output GIS file indicating the centerline miles of roadway affected by a given hazard.

Upon completion of the geospatial analyses, GIS data for each step was saved to a database that was supplied to Caltrans. This GIS data will be valuable for future Caltrans efforts and is provided on the Caltrans online map viewer shown here.

