Climate Change and the State Highway System

CATC Transportation Policy Forum

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Presented by:

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SR-35 near Santa Cruz, February 2017

Disclaimer

This presentation expresses my personal opinions as a transportation professional. Although it draws on materials developed for Caltrans it does not represent an official position by Caltrans or WSP. These thoughts are my own.

Agenda

- Background to the Current Work
- Vulnerability Assessments
- Climate Action Report
- Lessons Learned
- Recommendations for the Long-Term

Background to the Current Work

SR-70 Landslide

Why State Infrastructure Agencies are Interested in Climate Change

- **Executive Order B-30-15** – requires the consideration of climate change in all state investment decisions
- **Assembly Bill 2800 (2016)** – requires that state agencies account for climate impacts during all phases of infrastructure development
- **Senate Bill 1** – raises funds for road maintenance and rehabilitation and included elements of climate adaptation to ensure effective investment
- Plus, it just **good management practice**

I-15 Washout, February 2017
District 8

Why State Infrastructure Agencies are Interested in Climate Change

- Climate change is already impacting Caltrans' facilities. The wet 2016–17 winter caused flooding, washouts and landslides across the state ($1.2 billion in repairs)

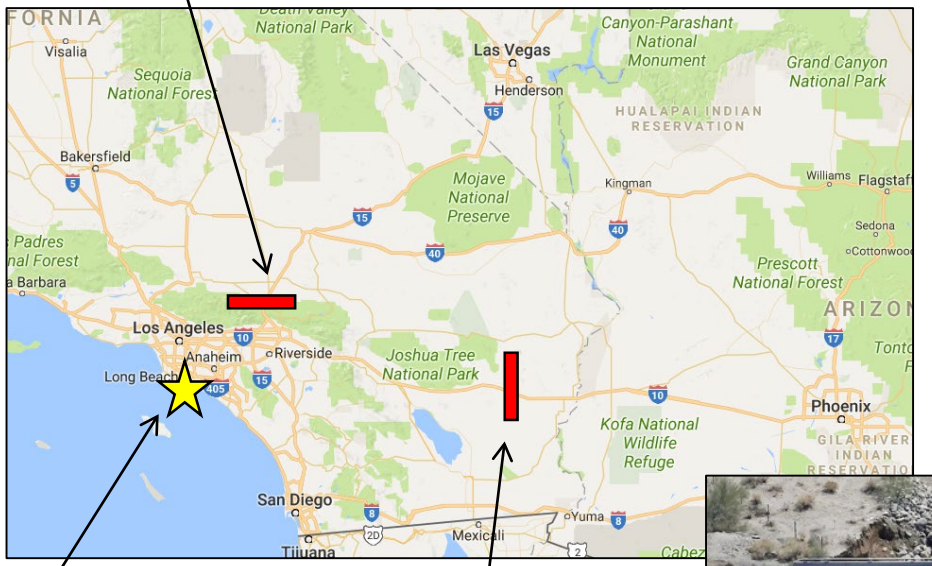
- The State Highway System is the always the backbone of the transportation system, but especially during emergencies
  - Main evacuation routes
  - Main access routes for emergency personnel and supplies
  - May serve as a physical barrier (fire break)

Highway 1, Mud Creek landslide, June 2017

Economic Effects

- A facility can be affected even if it is not directly exposed to a climate stressor
- Example: 40% of the foreign trade of the Unites States goes through the ports of Los Angeles and Long Beach
- In the summer of 2015, 2 separate incidents shut down the main truck routes between the ports and rest of the U.S.

I-15 Cajon Pass Fire
(July 2015)

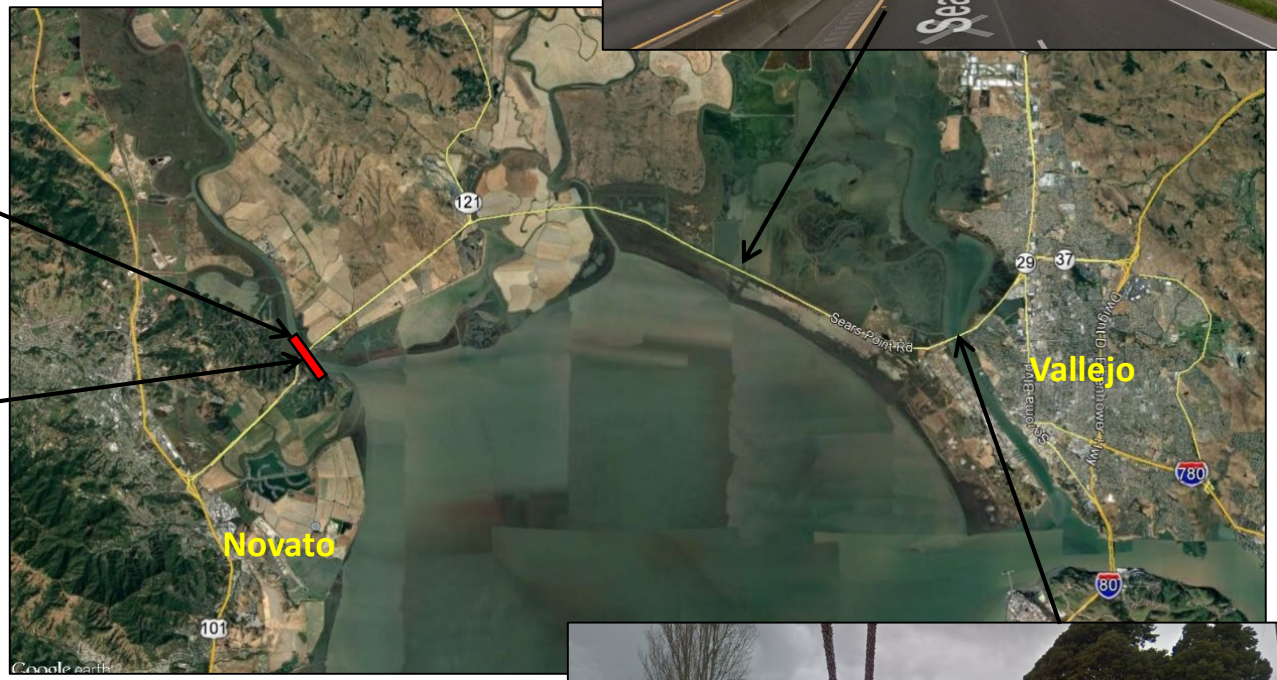


Ports of Los Angeles
& Long Beach

I-10 flooding &
bridge collapse
(July-Sept 2015)

The Weakest Link …

San Pablo Bay National Wildlife Refuge



Novato Creek

Mare Island Bridge

Actions taken by Caltrans

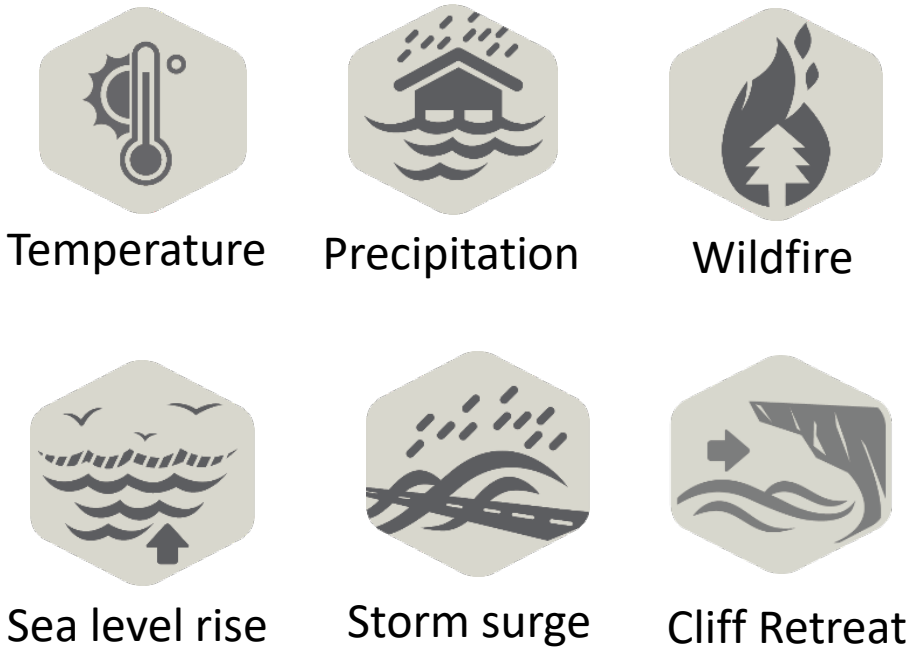
- Climate Change Branch Established 2007
- *Guidance on Incorporating Sea Level Rise* document (2011)
- Report on *Caltrans Activities to Address Climate Change* (2013)
- Pilot vulnerability assessment (District 1, 2014)
- Vulnerability assessments for all 12 Districts (2015-2019)
- Climate Action Report (2017-2020)

Vulnerability Assessments

Route 3 washout, Trinity County

Climate Change Vulnerability Assessments

- Assessing the vulnerability of the State Highway System to 6 climate stressors
- Determine impacts / potential changes to processes
- Identify facilities that were exposed for each stressor where possible
- 10 Districts completed; last 2 will finish this summer



Collaborative Efforts

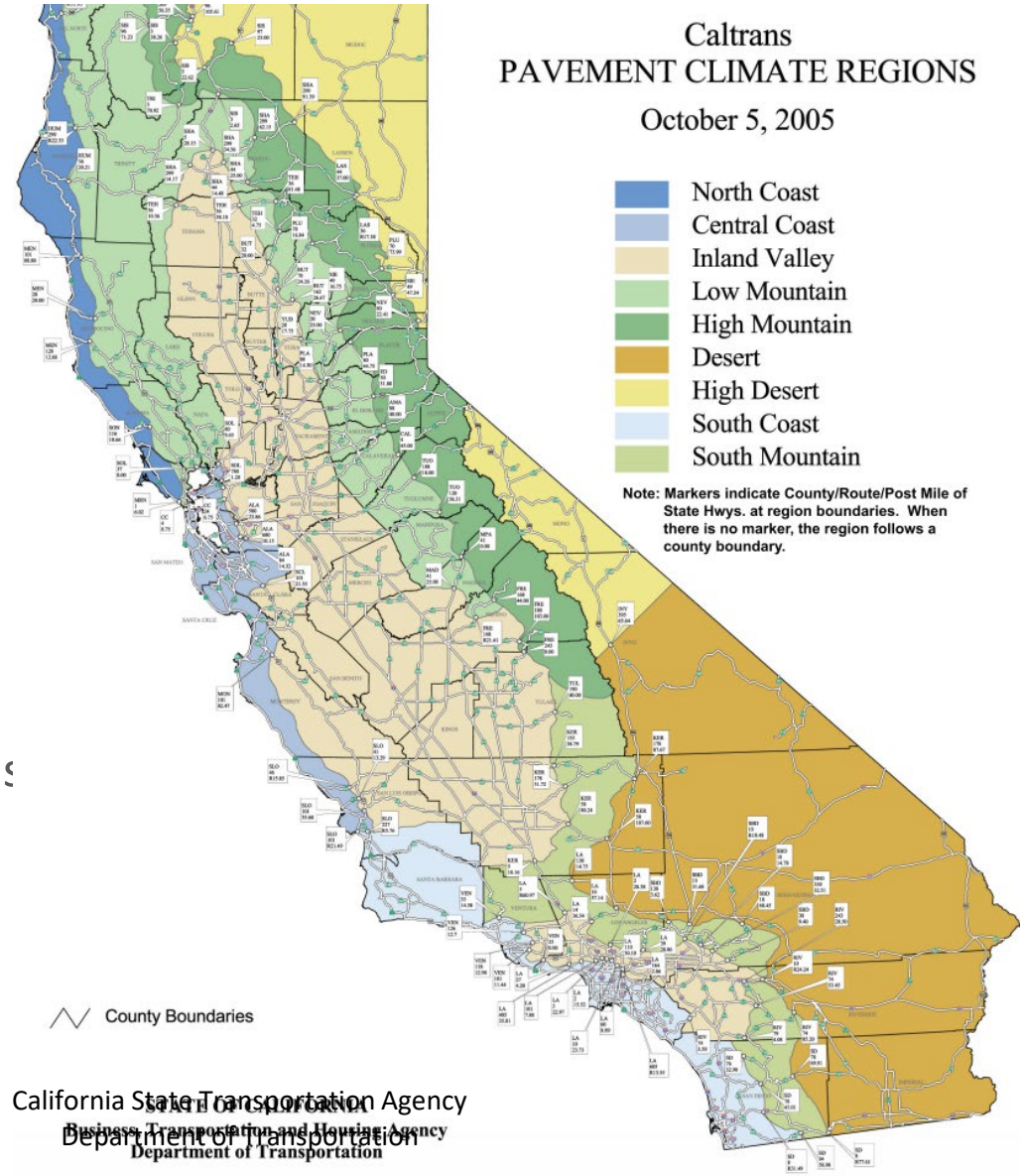
Applied best available data from a wide variety of sources and collaborated with others:

- Caltrans
- NOAA
- USGS
- CalFire
- UC Berkeley
- UC Davis
- BCDC

- California Department of Water Resources
- **California Energy Commission**
- California Geological Survey
- Federal Emergency Management Agency
- **Scripps Institute of Oceanography**
- Point Blue Institute
- U.S. Army Corps of Engineers

Temperature

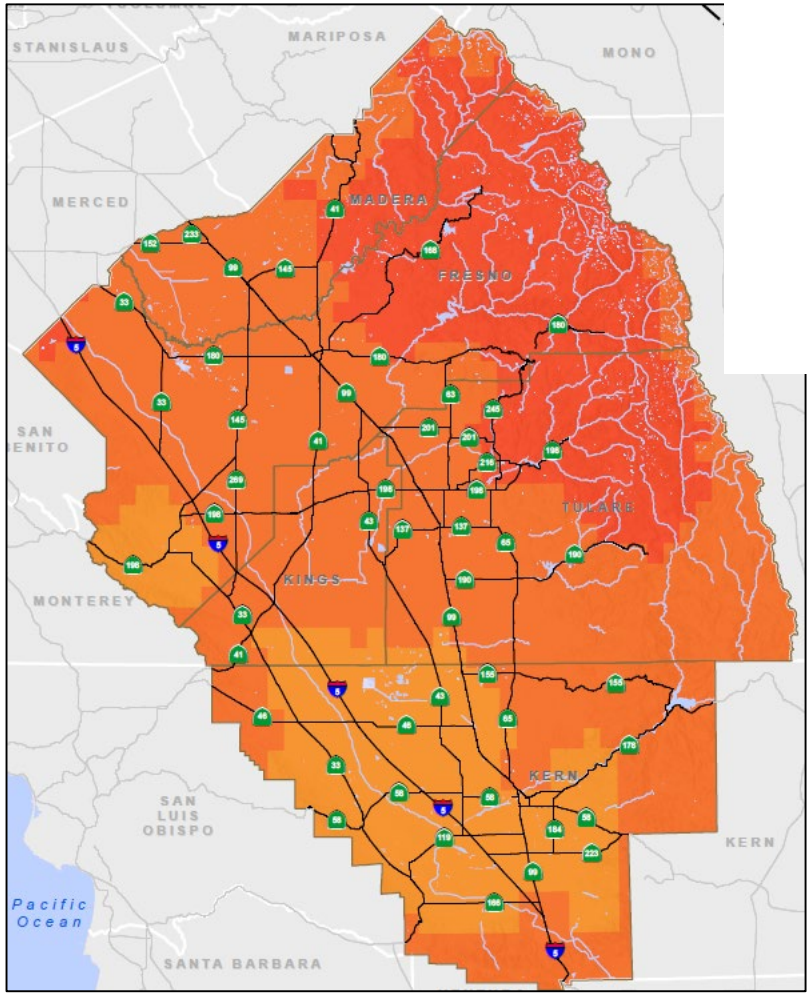
- A factor used in pavement design
  - Low temperature measure
  - High temperature measure
- Used downscaled geospatial data from the California 4th Assessment
  - Median temperature change from models
  - Years: 2025, 2055, 2085



California State Transportation Agency
Department of Transportation

Temperature

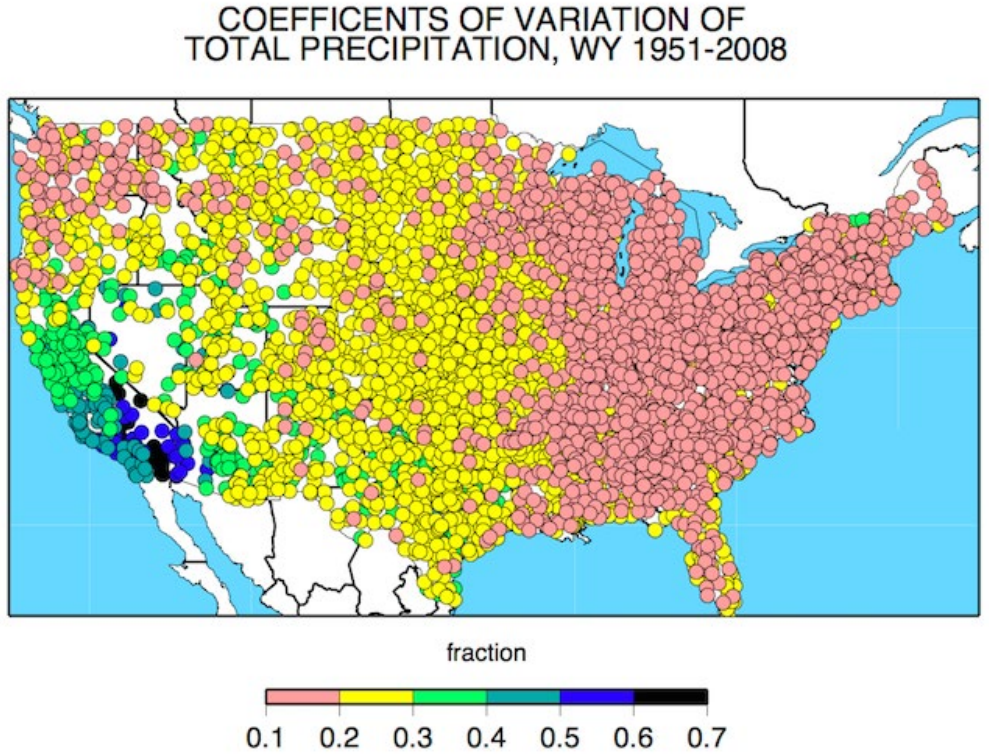
- Expect changes in the freeze/thaw cycle in the Sierra Nevada mountains
- May soften asphalt if pavement mix not changed
- Likely to affect work schedules for road crews



District 6, change in maximum temperature by 2085

Precipitation

- Used to design bridges, culverts, drains, etc.
- Designs usually based on historical data
- Considered whether 100-year storm value is expected to change
- Median precipitation value from all 10 Cal-Adapt models

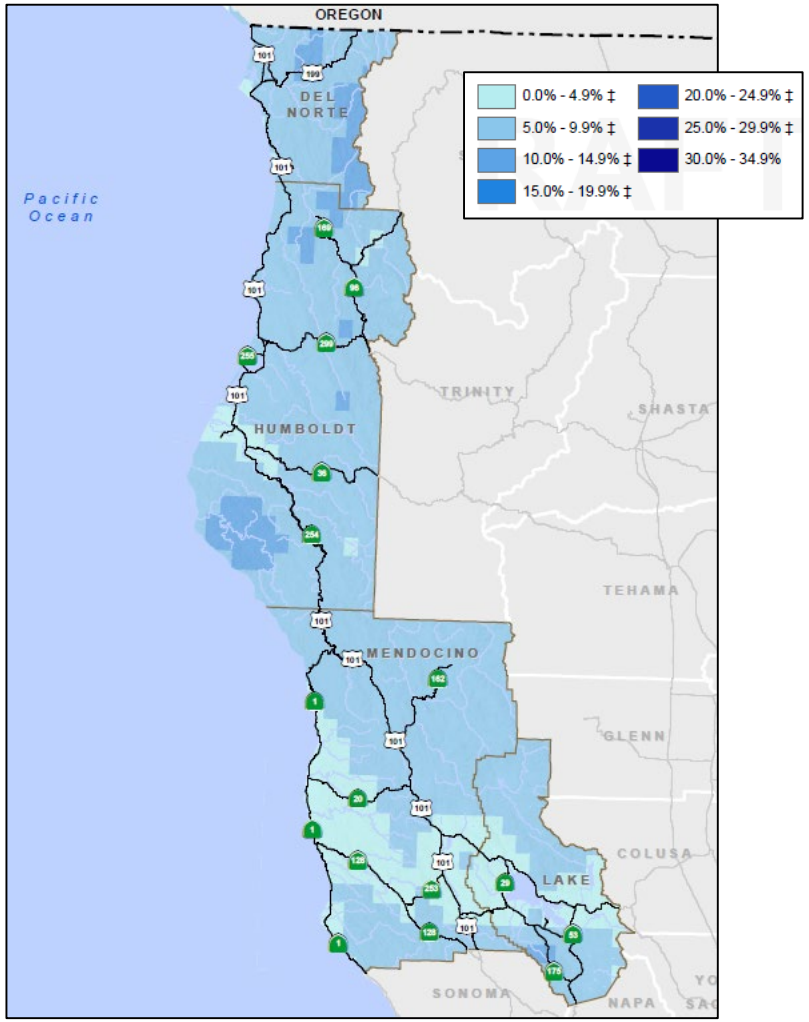


*California has **by far** the most variation in precipitation of any part of the U.S.*

From the California 4th Climate Change Assessment. Source: Dettinger et al, 2011.

Precipitation

- Will need to change the definition of a 100-year flood
- Needs to be considered in combination with other factors, such as the effect:
  - Of wildfires on runoff
  - Of soaked conditions on slope stability
  - Debris flows



District 1, change in 100-year storm by 2085

I-15 Washout, February 2017
District 8

Wildfire

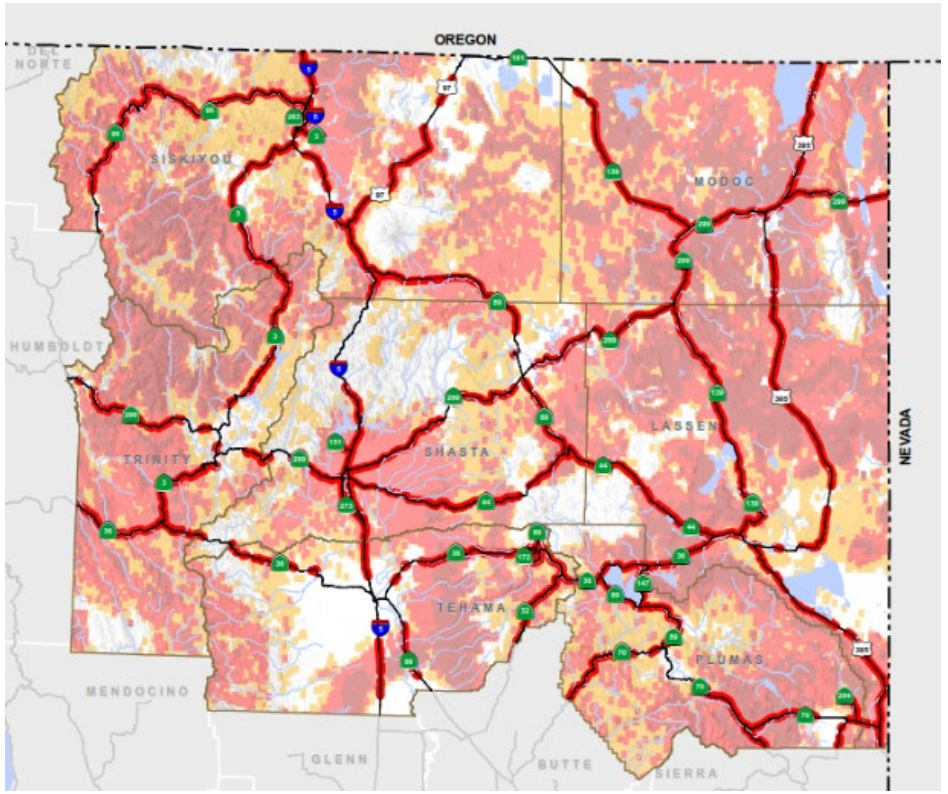
- Examined increasing wildfire likelihood by number expected in geographic areas
  - Very high
  - High
  - Medium
- Data are from the UC Irvine and MC wildfire models developed by the U.S. Forest Service
  - Reflects inputs for changing ground cover associated with climate change

I-15 Cajon Pass, July 2015

Wildfire

In parts of the state, much of the SHS may be subject to wildfire

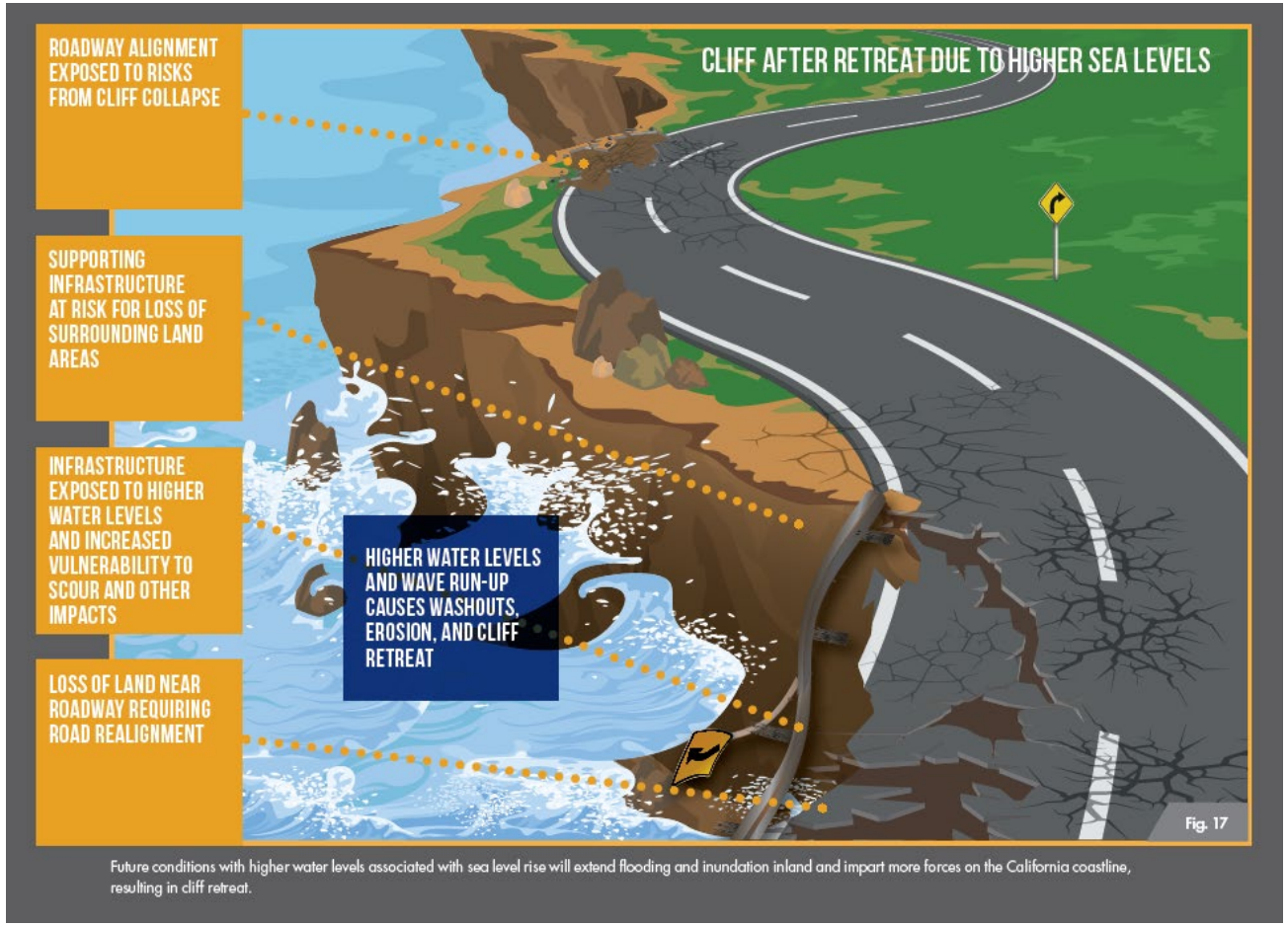
SR-299 Helena Fire



Wildfire Projections for District 2, by 2055

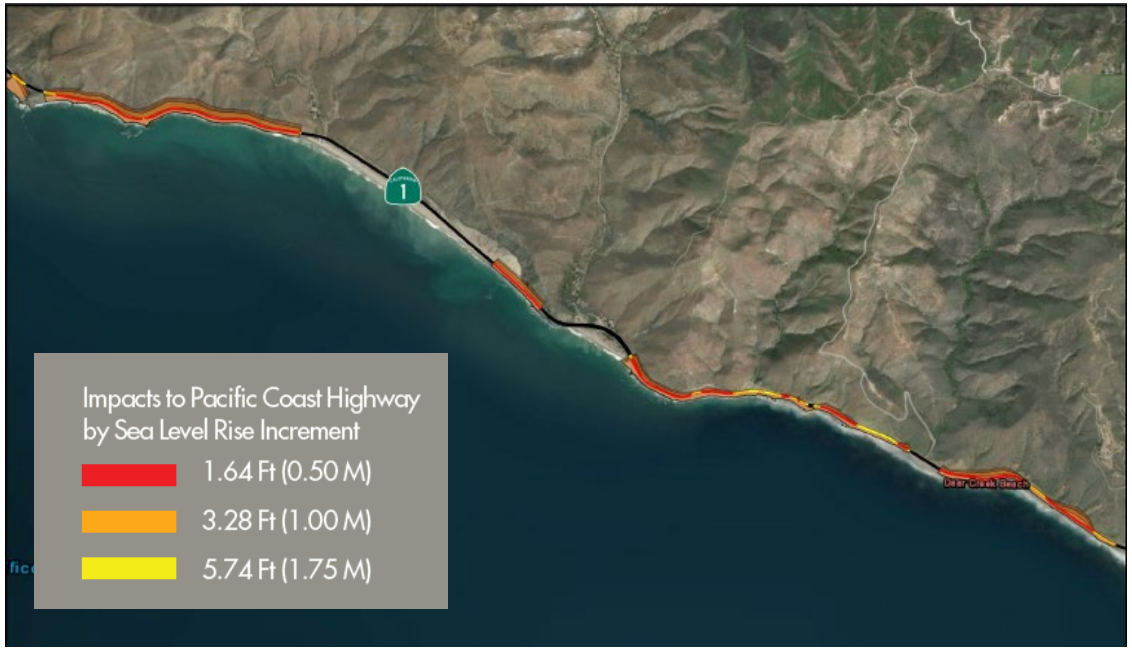
Cliff Retreat and Coastal Erosion

- Affects on a small portion of the highway system, but the cost of treatment can be very high
- Used updated CoSMoS data for So Cal to assess cliff retreat



Cliff Retreat and Coastal Erosion

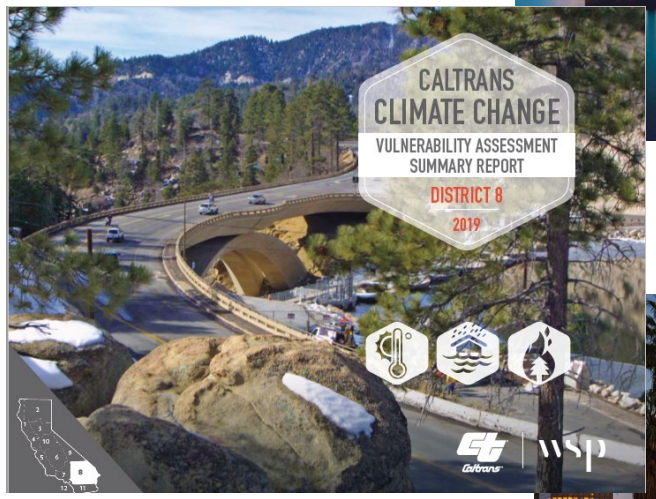
- Red, orange, and yellow roadway on the map indicate state highway exposed to cliff retreat under three sea level rise scenarios



Pacific Coast Highway slide damage

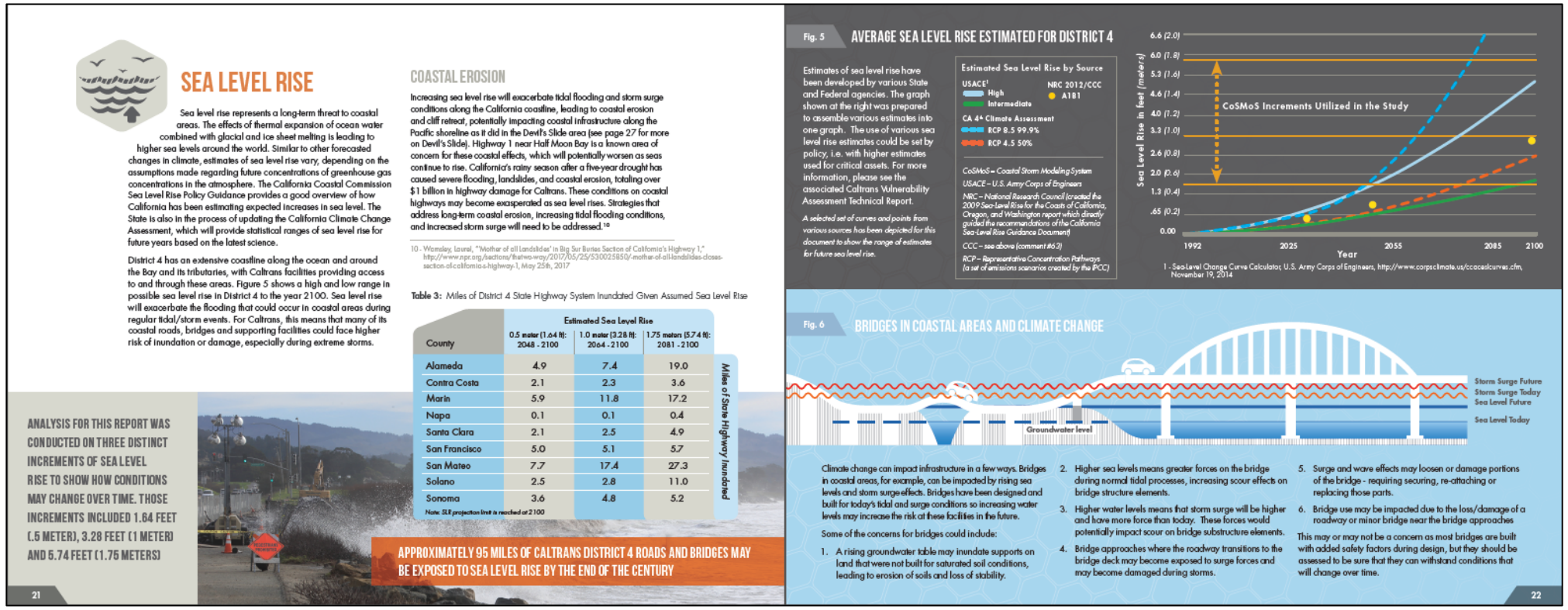
Summary Report

- Discovered that we had to address several different audiences:
  - Technical staff
  - Policy-level staff
  - External audiences
- Produced glossy summary reports in addition to the detailed technical reports



Summary Report - Sample Page

Information made accessible to all California residents



SEA LEVEL RISE

Sea level rise represents a long-term threat to coastal areas. The effects of thermal expansion of ocean water combined with glacial and ice sheet melting is leading to higher sea levels around the world. Similar to other forecasted changes in climate, estimates of sea level rise vary, depending on the assumptions made regarding future concentrations of greenhouse gas concentrations in the atmosphere. The California Coastal Commission Sea Level Rise Policy Guidance provides a good overview of how California has been estimating expected increases in sea level. The State is also in the process of updating the California Climate Change Assessment, which will provide statistical ranges of sea level rise for future years based on the latest science.

District 4 has an extensive coastline along the ocean and around the Bay and its tributaries, with Caltrans facilities providing access to and through these areas. Figure 5 shows a high and low range in possible sea level rise in District 4 to the year 2100. Sea level rise will exacerbate the flooding that could occur in coastal areas during regular tidal/storm events. For Caltrans, this means that many of its coastal roads, bridges and supporting facilities could face higher risk of inundation or damage, especially during extreme storms.

COASTAL EROSION

Increasing sea level rise will exacerbate tidal flooding and storm surge conditions along the California coastline, leading to coastal erosion and cliff retreat, potentially impacting coastal infrastructure along the Pacific shoreline as it did in the Devil's Slide area (see page 27 for more on Devil's Slide). Highway 1 near Half Moon Bay is a known area of concern for these coastal effects, which will potentially worsen as seas continue to rise. California's rainy season after a five-year drought has caused severe flooding, landslides, and coastal erosion, totaling over $1 billion in highway damage for Caltrans. These conditions on coastal highways may become exasperated as sea level rises. Strategies that address long-term coastal erosion, increasing tidal flooding conditions, and increased storm surge will need to be addressed.[10]

10 - Wamsley, Laurel, "Mother of all Landslides' in Big Sur Buries Section of California's Highway 1," http://www.npr.org/sections/thetwo-way/2017/05/25/530025850/-mother-of-all-landslides-closes-section-of-california-s-highway-1, May 25th, 2017

Table 3: Miles of District 4 State Highway System Inundated Given Assumed Sea Level Rise

County	Estimated Sea Level Rise: 0.5 meter (1.64 ft): 2048 - 2100	1.0 meter (3.28 ft): 2064 - 2100	1.75 meters (5.74 ft): 2081 - 2100
Alameda	4.9	7.4	19.0
Contra Costa	2.1	2.3	3.6
Marin	5.9	11.8	17.2
Napa	0.1	0.1	0.4
Santa Clara	2.1	2.5	4.9
San Francisco	5.0	5.1	5.7
San Mateo	7.7	17.4	27.3
Solano	2.5	2.8	11.0
Sonoma	3.6	4.8	5.2

Note: SLR projection limit is reached at 2100

Miles of State Highway Inundated

ANALYSIS FOR THIS REPORT WAS CONDUCTED ON THREE DISTINCT INCREMENTS OF SEA LEVEL RISE TO SHOW HOW CONDITIONS MAY CHANGE OVER TIME. THOSE INCREMENTS INCLUDED 1.64 FEET (.5 METER), 3.28 FEET (1 METER) AND 5.74 FEET (1.75 METERS)

APPROXIMATELY 95 MILES OF CALTRANS DISTRICT 4 ROADS AND BRIDGES MAY BE EXPOSED TO SEA LEVEL RISE BY THE END OF THE CENTURY

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Fig. 5 AVERAGE SEA LEVEL RISE ESTIMATED FOR DISTRICT 4

Estimates of sea level rise have been developed by various State and Federal agencies. The graph shown at the right was prepared to assemble various estimates into one graph. The use of various sea level rise estimates could be set by policy, i.e. with higher estimates used for critical assets. For more information, please see the associated Caltrans Vulnerability Assessment Technical Report.

A selected set of curves and points from various sources has been depicted for this document to show the range of estimates for future sea level rise.

Estimated Sea Level Rise by Source

USACE[1]: High, Intermediate
NRC 2012/CCC: A1B1
CA 4th Climate Assessment: RCP 8.5 99.9%, RCP 4.5 50%

CoSMoS – Coastal Storm Modeling System
USACE – U.S. Army Corps of Engineers
NRC – National Research Council (created the 2009 Sea-Level Rise for the Coasts of California, Oregon, and Washington report which directly guided the recommendations of the California Sea-Level Rise Guidance Document)
CCC – see above (comment #63)
RCP – Representative Concentration Pathways (a set of emissions scenarios created by the IPCC)

1 - Sea-Level Change Curve Calculator, U.S. Army Corps of Engineers, http://www.corpsclimate.us/ccacalcurves.cfm, November 19, 2014

Fig. 6 BRIDGES IN COASTAL AREAS AND CLIMATE CHANGE

Climate change can impact infrastructure in a few ways. Bridges in coastal areas, for example, can be impacted by rising sea levels and storm surge effects. Bridges have been designed and built for today's tidal and surge conditions so increasing water levels may increase the risk at these facilities in the future.

Some of the concerns for bridges could include:

1. A rising groundwater table may inundate supports on land that were not built for saturated soil conditions, leading to erosion of soils and loss of stability.
2. Higher sea levels means greater forces on the bridge during normal tidal processes, increasing scour effects on bridge structure elements.
3. Higher water levels means that storm surge will be higher and have more force than today. These forces would potentially impact scour on bridge substructure elements.
4. Bridge approaches where the roadway transitions to the bridge deck may become exposed to surge forces and may become damaged during storms.
5. Surge and wave effects may loosen or damage portions of the bridge - requiring securing, re-attaching or replacing those parts.
6. Bridge use may be impacted due to the loss/damage of a roadway or minor bridge near the bridge approaches

This may or may not be a concern as most bridges are built with added safety factors during design, but they should be assessed to be sure that they can withstand conditions that will change over time.

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Climate Action Report

US-1 Pfeiffer Canyon Bridge, April 2017

Climate Action Report Project

Follows on the Climate Change Vulnerability Assessments

1) **Greenhouse Gas Emissions & Mitigations Report** - updates the 2013 report on the carbon footprint of Caltrans operations. New report will add a discussion of GHG emissions from users of the SHS
2) **Climate Change Adaptation Recommendations & Strategy Report** - An in-depth look at Caltrans policies & procedures to identify changes to help Caltrans adapt the agency to climate stressors
3) **District-level Adaptation Assessment and Strategy Reports** - Uses a weighted scoring system to prioritize projects within each district in terms of the climate-related threats & the consequences of inaction

Lessons Learned

Lessons Learned

- **California is (mostly) on its own** - Climate change is playing out differently in different places. So the scope for different states to help each other on technical issues is limited (analogy is seismic issues)
- **Need to get comfortable with uncertainty** - Most design work going forward will be based on projections rather than historical data. Need to move towards risk-based, adaptive design
- **Don’t assume consensus** - People are at different stages of climate change knowledge and acceptance
- **The biggest limitation is people** - We face a severe shortage of people with training in climate science and adaptive design
- **Better Data is a Good Investment** - Data is cheap compared to infrastructure. Narrowing the range of uncertainty will avoid over-building or, even worse, unexpected failure

Recommendations for the Long-Term

SR-18, January 2017. Debris stopped by rock barrier

Recommendations - Training

- California needs a large-scale effort to train people in adaptive design and natural infrastructure
- Mainly directed at mid-career technical staff: Caltrans, city and county staff, consultants, developers, construction crew, etc.
- Staff development has a long lead time. We need to start now or people won't be ready when we need them
- The Climate-Safe Infrastructure Working Group had a chapter and a recommendation (#8) on this

Recommendations - Data

- We are in the early stages of adaptation but are already encountering problems with data availability and modeling. If we can no longer rely on historical data then we need something to replace it with; forecasts we have confidence in
- The State needs to accelerate the development of databases and modeling to support design-level analyses
  - Update flood plains and hydrologic modeling
  - Update data on existing assets (elevation, etc.)
  - Improved modeling for combined effects (wildfire & slope stability)
- We can’t wish the data and models into existence; the State needs to invest in their development

Recommendations - Legal Protection

- The legislature needs to grant some sort of protection for people who act reasonably based on the best information available at the time.
    - Everywhere we go we hear engineers' concerns about lawsuits as a reason not to try new things. Fear of litigation could lead to paralysis.
    - The general view is that design immunity is not strong enough. For example, it can be lost due to "changed conditions". The effects of climate change will be widespread and continually changing conditions.
    - If we want people to change the way infrastructure is built then we will need to protect them when they do as we ask