Impacts of Wildfires on Pavement Systems

Prashant Ram
Applied Pavement Technology, Inc. (APTech)

Northwest Pavement Management Association Conference

October 26, 2023

Who am I?

- Prashant V. Ram
- Undergrad in Civil Engg. And Masters in Chemistry in India (2001-2006)
- Masters in Civil Engg. at Purdue (2006-2008)
- Pavement Engineer,
  Applied Pavement Technology, Inc. (APTech)
  (2008-present)
- Passionate about sustainability, resilience, pavement/asset management
- I like concrete, have nothing against asphalt
- I like classic rock and heavy metal
- I like riding bikes
- I like lighthouses

Presentation Outline

- Climate Change and Resilience
- Study Objectives
- Wildfire Trends
- Impacts on Pavements & Other Assets
- Assessing Damage to Pavements
- Knowledge Gaps
- Asset Management Considerations
- Next Steps

Climate Change and Resilience

Image Source: Tobias Rademacher on Unsplash

Background

- Long-term shifts in temperature and weather patterns
  - Can be natural
    - Changes in sun's activity
    - Large volcanic eruptions
  - Since 1800s, human activities have been main driver due to burning of fossil fuels like coal, oil, and gas
- Humans are responsible for global warming
  - Supported by historical observation and climate modeling
  - Even most optimistic models predict substantial climate change over the next century

What is Climate Change?

- Burning fossil fuels generates greenhouse gases (GHGs)
  - Acts as a thermal blanket around Earth, traps sun's heat, and raises temperature
- Main GHGs that cause climate change
  - Carbon dioxide
  - Methane
- Climate change doesn't only mean warmer temperatures
  - Earth is a system—everything is connected!
- Climate change impacts include droughts, severe fires, rising sea levels, flooding, melting ice caps, extreme storms, and declining biodiversity

6

What Do We Know for Sure?

"Human activities, principally through emissions of greenhouse gases, have unequivocally caused global warming, with global surface temperature reaching 1.1°C above 1850-1900 in 2011-2020"

IPCC. 2023. "Summary for Policymakers." *Climate Change 2023.* Intergovernmental Panel on Climate Change, Geneva, Switzerland.

Image Source: Kelly Sikkema on Unsplash

Surface Temperature Projections

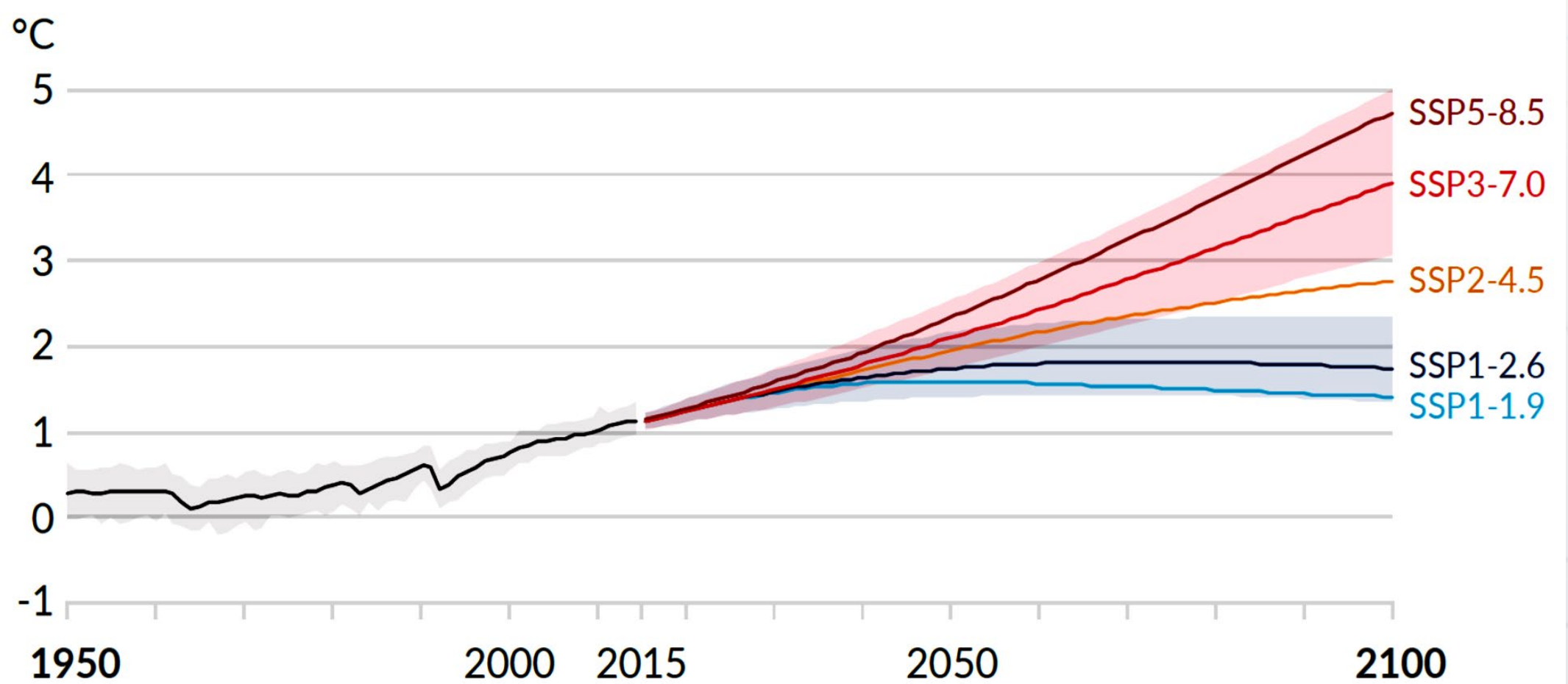


Image Source: IPCC

Turtles are Resilient. Be like them.

- "The Secret of Surviving Anything" – Josh Kaufmann
- "It is not the strongest that survive, nor the most intelligent, but the ones most responsive to change" – Charles Darwin
- Turtles cannot run, don't have sharp teeth or claws, don't look menacing
- But…they do have a lot of protection/adaptation strategies
  - Swim away quickly
  - Camouflage
  - Snap with jaws
  - If everything fails, retract into shell and wait

Maintenance

Preservation

Rehab and Reconstruction

Human Asset Management (HAM) and Transportation Asset Management (TAM) - basically the same

---

You are building resilience by following proper HAM and TAM practices

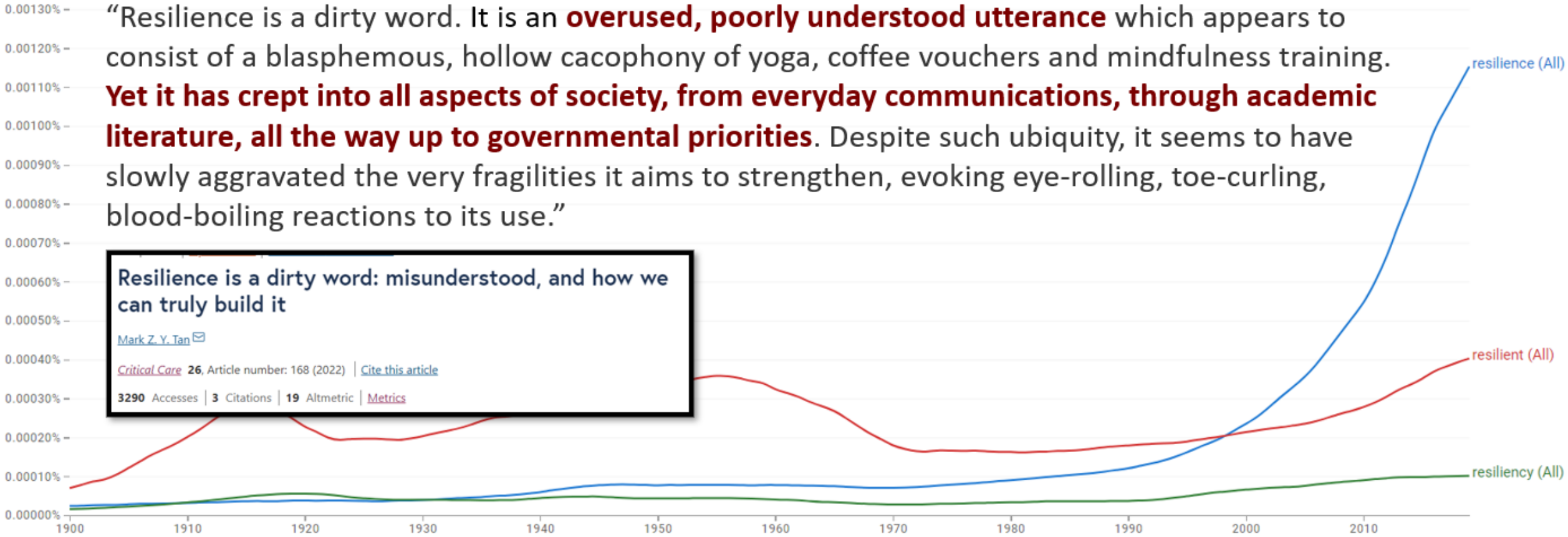
"Resilience is a dirty word. It is an **overused, poorly understood utterance** which appears to consist of a blasphemous, hollow cacophony of yoga, coffee vouchers and mindfulness training. **Yet it has crept into all aspects of society, from everyday communications, through academic literature, all the way up to governmental priorities**. Despite such ubiquity, it seems to have slowly aggravated the very fragilities it aims to strengthen, evoking eye-rolling, toe-curling, blood-boiling reactions to its use."

Resilience is a dirty word: misunderstood, and how we can truly build it

Mark Z. Y. Tan

Critical Care **26**, Article number: 168 (2022) | Cite this article

3290 Accesses | **3** Citations | **19** Altmetric | Metrics



By 2040,every 10th word in each sentence will be: resilience, resilient, or resiliency.

By 2060, resilience, resilient, or resiliency will the only three words in every sentence written in English.

Seriously, What is Resilience?

- Resilience is the practice of implementing strategies to endure impacts that occur
  - Endure events
  - Quickly recover
- FHWA Order 5520 definition

  "…ability to anticipate, prepare for, and adapt to changing conditions and withstand, respond to, and recover rapidly from disruptions."

12

Sustainability and Resilience Relationship

- Sustainability seeks to avoid changes that will impact people and the environment
- Resilience is about enduring and recovering from impacts that could have been prevented or mitigated through sustainable development

FHWA's resilience webpage:
https://www.fhwa.dot.gov/environment/sustainability/resilience/
FHWA's sustainable pavements program webpage:
https://www.fhwa.dot.gov/pavement/sustainability/

Image source: FHWA

13

Key Characteristics of Resilience

- Addresses both climate change adaptation and disaster risk reduction
- Must consider effects of interacting systems
- Goes beyond traditional engineering approaches
- Form of risk management

Image source: Dave Claman, Iowa DOT

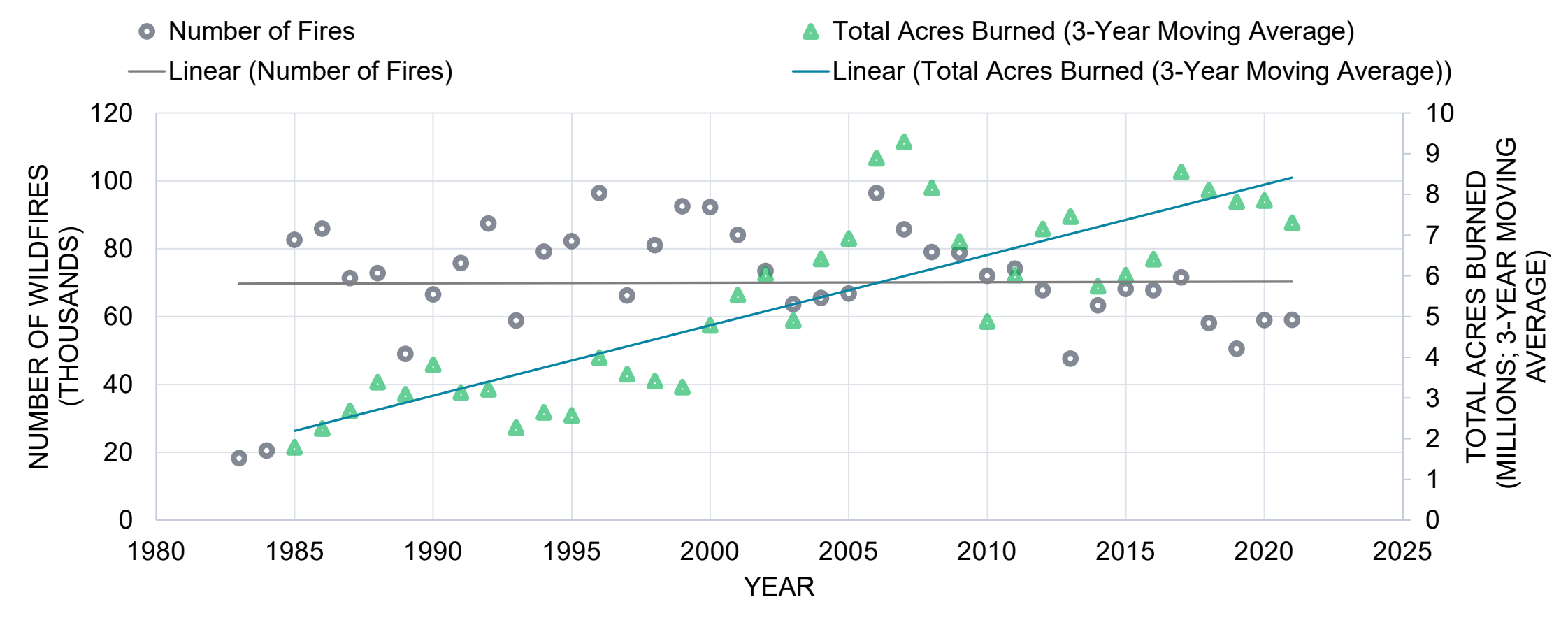
14

Study Background and Wildfire Trends

Project Objectives

- Compile, synthesize, and document the direct and indirect impacts of wildfires on pavement infrastructure through:
  - Literature review
  - Interviews with selected highway agency personnel

Intensity and Size of Wildfires are Increasing



Cost of Fighting Wildfires has Increased Substantially

Average Annual Cost to Fight Wildfires

Source: National Interagency Coordination Center

In cost per fire between 1985 and 2020

Source: National Interagency Coordination Center

Ratio of infrastructure rehab cost to total fire cost

Source: Western Forestry Leadership Coalition (2010)

States at High to Extreme Wildfire Risk (as of 2021)

Rank	State	Estimated Number of Properties at Risk
1	California	2,040,600
2	Texas	717,800
3	Colorado	373,900
4	Arizona	242,200
5	Idaho	175,000
6	Washington	155,500
7	Oklahoma	153,400
8	Oregon	147,500
9	Montana	137,800
10	Utah	136,000
11	New Mexico	131,600
12	Nevada	67,100
13	Wyoming	36,800

Rank	State	Percentage of Properties at Risk
1	Montana	29%
2	Idaho	26%
3	Colorado	17%
4	California	15%
5	New Mexico	15%
6	Utah	14%
7	Wyoming	14%
8	Arizona	9%
9	Oklahoma	9%
10	Oregon	9%
11	Texas	7%
12	Nevada	6%
13	Washington	5%

Source: Verisk (2021)

Wildfire Impacts on Transportation Infrastructure

Impacts on Pavements

- Surface damage: melted pavement, potholes, raveling, delamination
- Structural damage due to increased traffic loadings (number and magnitude) from fire suppression and post-fire cleanup
- Damage due to post-fire flooding (washout and debris flow, reduced structural support, loss of structural capacity)

Timber Haul Traffic

Post-Fire Debris Flow

Trash Rack: To Catch Debris Flow

Washouts

Asphalt Materials

- Asphalt materials can become mechanically unstable and emit harmful gases during a fire event
- Fire damage to asphalt pavements is more prevalent in tunnels
- Asphalt roadways generally do not undergo combustion
- Fires from other sources (e.g., abandoned vehicles) can lead to asphalt pavement damage

Concrete Materials

- Higher fire resistance in comparison to asphalt
- Some studies have looked at heating history of structural concrete: color changes and physical effects
  - Loss in compressive strength around 570 °F
- Wildfire impacts on concrete pavements not well documented

Erosion and Debris Flow

- Wildfires often result in soil erosion and slope instability
  - Can lead to roadway closures, property damage, and loss of human life
  - Can clog drainage systems, potentially leading to flooding issues and long-term road closures
- Extreme wildfires followed by precipitation can cause debris flow that impacts downslope infrastructure
- Burnt areas are more susceptible to flooding

Culverts

- Can be over capacity due to post-fire flooding
- Can be damaged/melted due to fires (depending on type and composition)
- Fire Resistance of pipe types:
  - Concrete: high
  - Corrugated Steel: most coatings used for corrosion are flammable
  - HDPE: flammable
  - PVC: flammable (lower rating than HDPE)
- ASTM standard under development
  - Resilience-Based Design of Culvert and Storm Drain Pipes Exposed to Wildfires

Post-Fire Culvert Designs in Paradise, CA

Clogged Culverts

Other Impacts on Roadway Network

Source: Oregon DOT

Bridges

Assessing Damage to Pavements

Post-Fire Pavement Condition Evaluation
Equivalent Single Axle Load (ESAL) Method

- Does not involve measurement of distresses
- Assess how much life was lost due to fire-related traffic
- Pavement Fire Damage Ratio =
  Ratio of fire-related ESALs to design ESALs
- Damage Value = Fire Damage Ratio x Replacement Cost

- Approach can be variable since precise traffic loadings are rarely known
- Design ESALs for a road may not be known (particularly lower volume roadways)

Post-Fire Pavement Condition Evaluation
Pavement Condition Index (PCI) Method

- Based on visual assessment of pavement condition using the ASTM D 6433 standard
- PCI = Numerical measure of pavement surface condition
  - <40: Reconstruction
  - 40 to 70: Rehabilitation
  - >70: Maintenance and Preservation
- Fire damage cost = difference is cost between pre- and post-fire treatment cost based on PCI

PCI Range	Rating Scale
86-100	Good
85-71	Satisfactory
70-56	Fair
55-41	Poor
40-26	Very Poor
25-11	Serious
0-10	Failed

Damage from Debris Removal Can be Significant

© 2020 Butte County Recovers

© 2020 Karl Mondon Bay Area News Group

Fire-Resistant Materials

- Several studies have investigated the impact of using flame retardant materials in asphalt pavement mixtures:
  - Magnesium Hydroxide
  - Composite Flame Retardants
  - Calcium Hydroxide
  - Aluminum Hydroxide + Calcium Hydroxide
  - Aluminum Hydroxide + Calcium Carbonate
  - Porous Sepiolite
- Cost effectiveness, practicality, long-term performance unknown

Knowledge Gaps

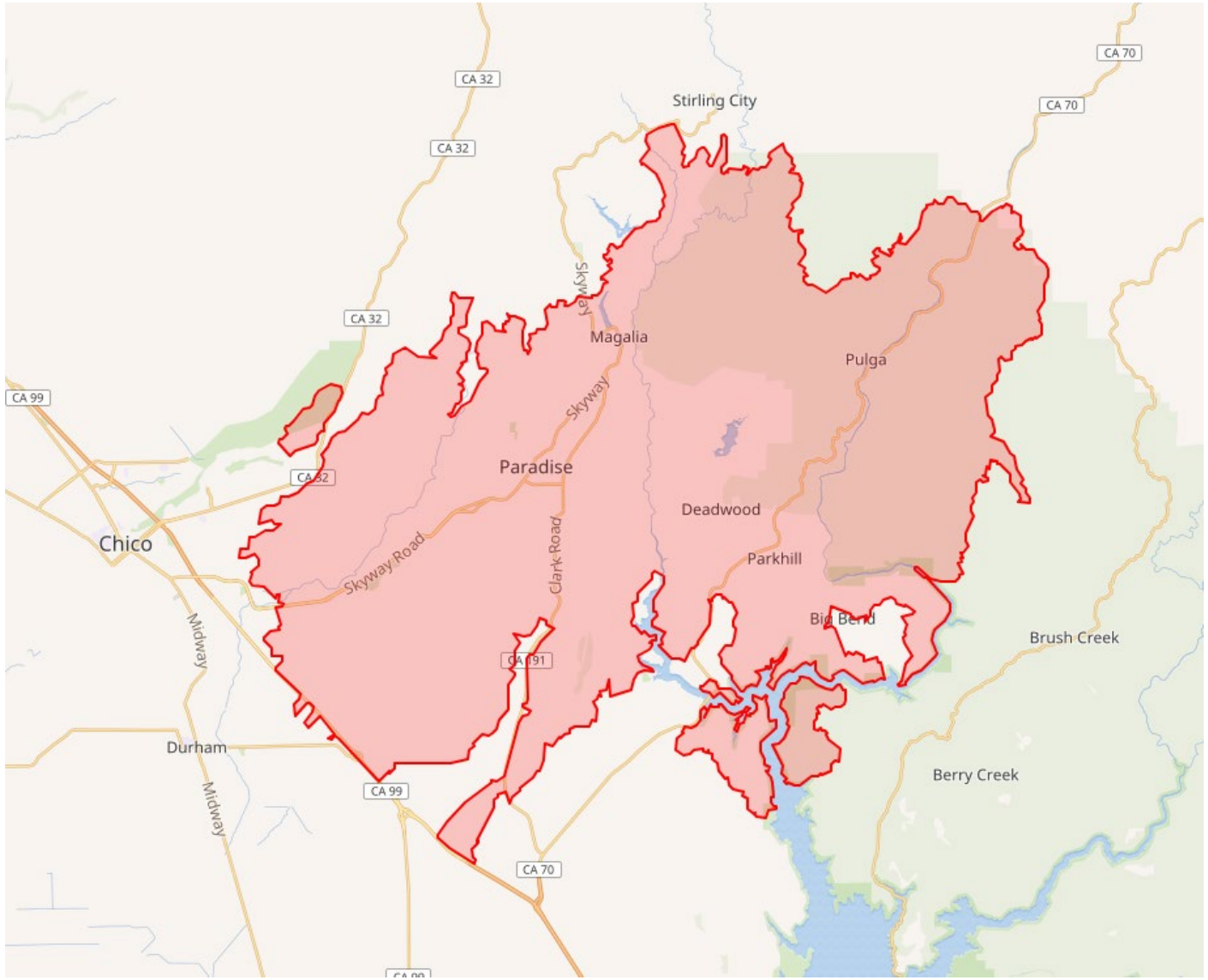
- Guidance on assessing damage after a wildfire event
- Performance of fire-resistant designs and materials
- Suite of treatment strategies in wildfire prone areas
- Impacts of wildfires on concrete pavements

Ongoing Project Activities

- Conduct interviews with state, federal and local agencies to learn about:
  - Primary concerns, challenges and impacts of wildfires
  - Impacts on pavements and other infrastructure assets
  - Approaches to repair damage
  - Strategies to improve resilience
- **Please let us know if you are in interested in participating in the interviews!**
- Project outcomes: Tech Brief, Webinar, Interview Summaries, Report

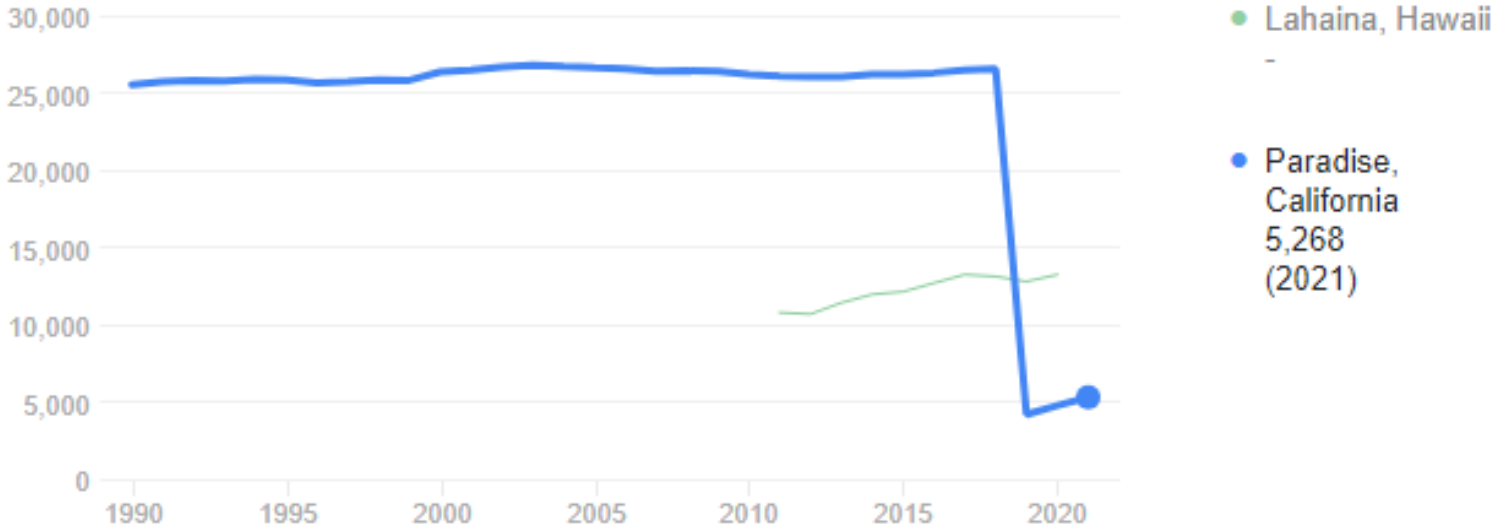
Town of Paradise, CA

Camp Fire- 2018



Town of Paradise, CA

5,268 (2021)

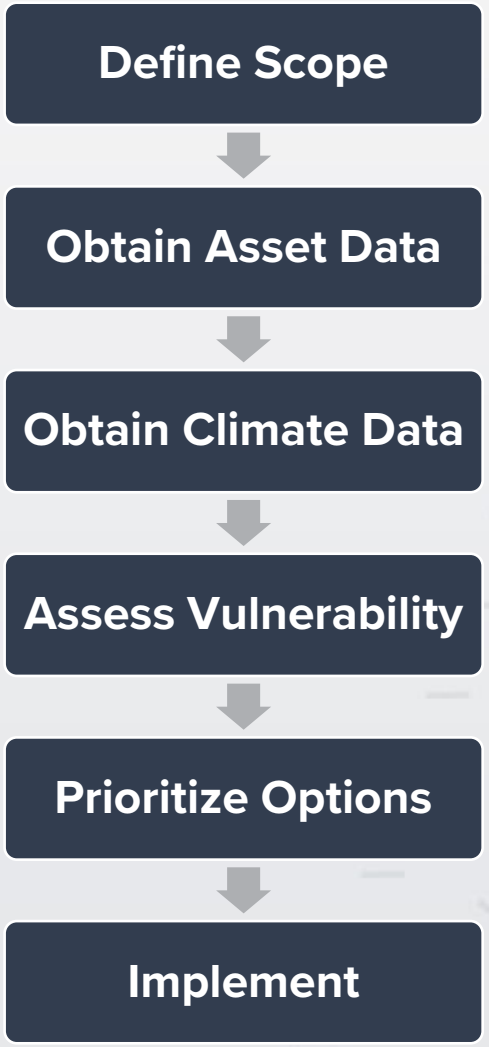


Town of Paradise, CA

Town of Paradise, CA

Asset Management Considerations

General Approach to Resilience



- Which assets are valued? What are the impacts?
- Identify climate impacts that may cause damage to assets
  - Gather appropriate climate data
  - Estimate risk to each asset
  - Consider possible solutions
  - Prioritize and plan for most feasible actions
  - Implement plan and monitor

Opportunities in BIL
PROTECT Formula Program

- PROTECT (*Promoting Resilient Operations for Transformative, Efficient, and Cost-Saving Transportation*) Formula Program
  - Funding to help have surface transportation resilient to natural hazards
  - $7.3 Billion between 2022 and 2026
- Eligible Activities
  - **Planning Grants** (resilience planning, redesign, design, data tools to simulate disruption scenarios, etc.)
  - **Resilience Improvement Grants** (improve ability of existing asset to withstand one or more elements of weather/natural disaster)
  - **Community Resilience and Evacuation Route Grants** (strengthen and protect evacuation routes)
  - **At-Risk Coastal Infrastructure Grants**

47

Opportunities in BIL
PROTECT Discretionary Grant Program

- Competitive grant program
  - $1.4 Billion between 2022 and 2026
- Selection considerations
  - Resilience Improvement Grants
    - Benefits exceed activity cost
    - High risk of failure and associated impacts
  - Community Resilience and Evacuation Route Grants
    - Future occurrence or recurrence is likely
    - Projected change in development, demographics, and extreme weather events

48

Concluding Remarks (1/2)

- Resilience
  - Is a system characteristic
  - Goes beyond traditional engineering qualities
  - Endure and Recover
- The 6-step approach

49

Concluding Remarks (2/2)

- Establish pre-fire baseline conditions and periodically monitor key performance indicators
- Assess conditions as quickly as feasible following a fire event
  - Visual/PCI-based methods
  - Structural condition evaluation

50

Resilience is about Standing the Test of Time

"I'm on the pavement thinking about the government…"

- Bob Dylan thinking about how the government is going to fund pavement resilience improvements


Thank You!
Prashant Ram
pram@appliedpavement.com