Broad approaches to addressing pavement resilience

ASCE Montgomery Branch

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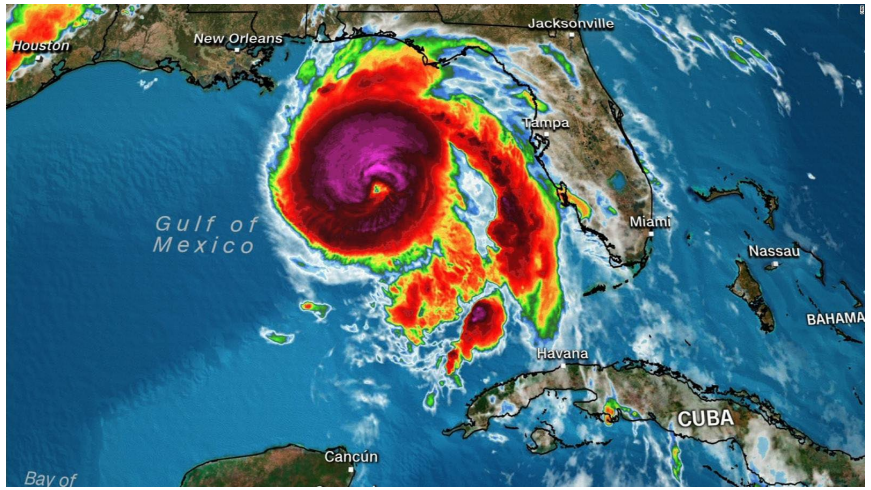
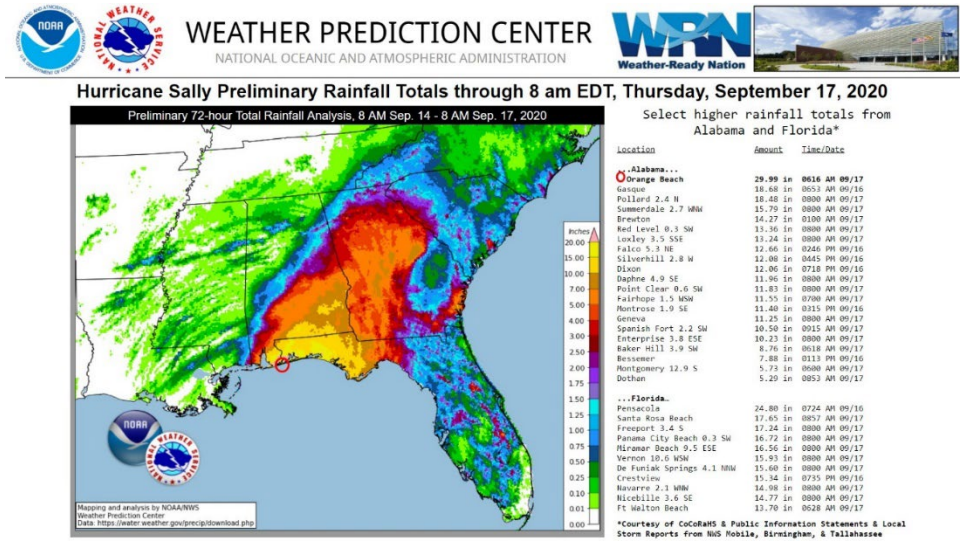
AUBURN UNIVERSITY

The importance of what we're talking about today…





I-40 - https://www.newsobserver.com/news/weather-news/article234964002.html | Hurricane Michael - https://www.cnn.com/2018/10/09/weather/hurricane-michael-stats-superlatives-wxc-trnd/index.html | Bridge - Dr. Jose Vasconcelos, Auburn University
Hurricane Sally – NOAA | Landslide – Dr. Jack Montgomery, Auburn University

[resilience] and [adaptation] defined

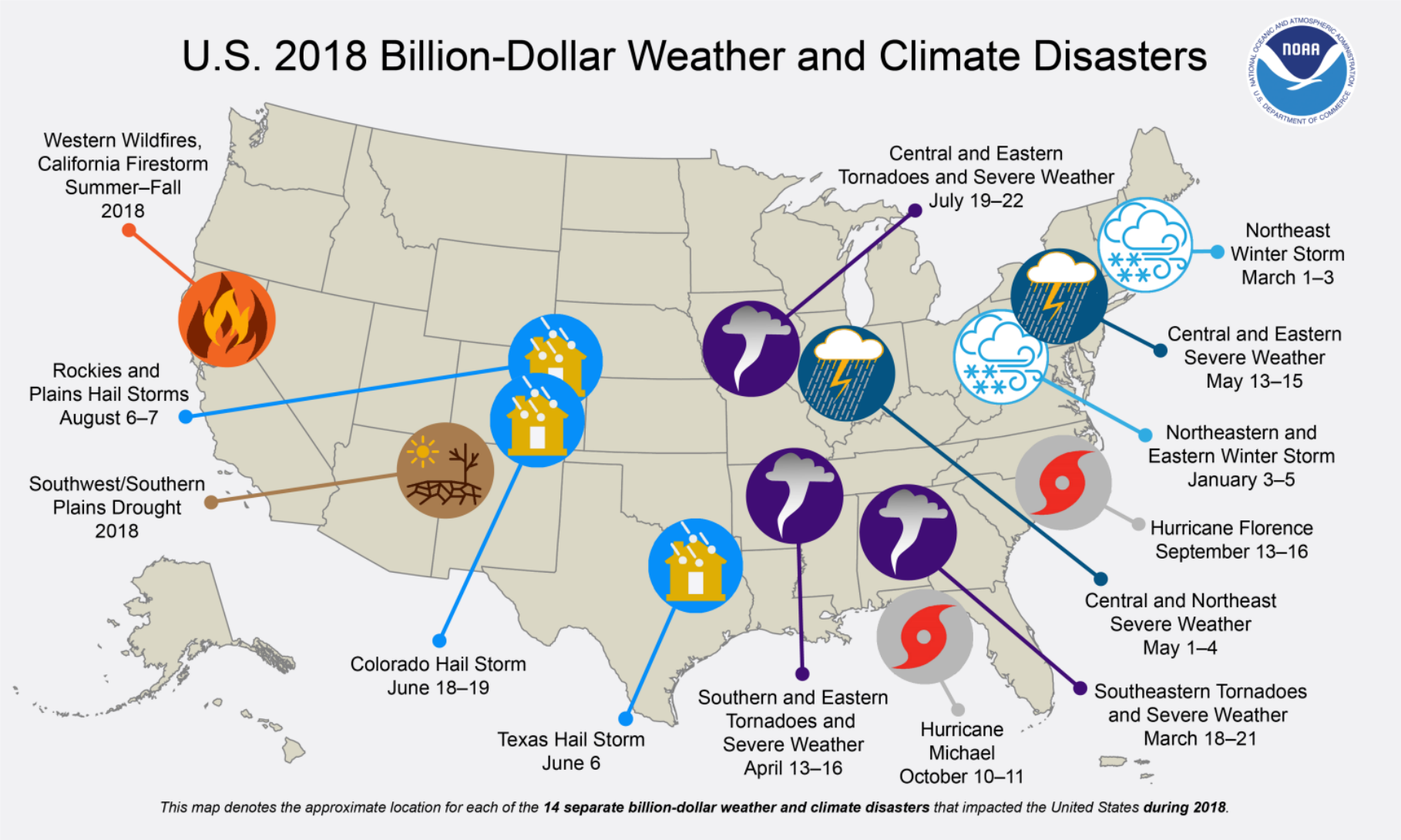
[resilience] “the ability to anticipate, prepare for, and adapt to *changing conditions* and withstand, respond to, and recover rapidly from *disruptions*”

- FHWA Order 5520 (2014)

[adaptation] “Adjustment in natural or human systems in anticipation of or response to a changing environment in a way that effectively uses beneficial opportunities or reduces negative effects.”

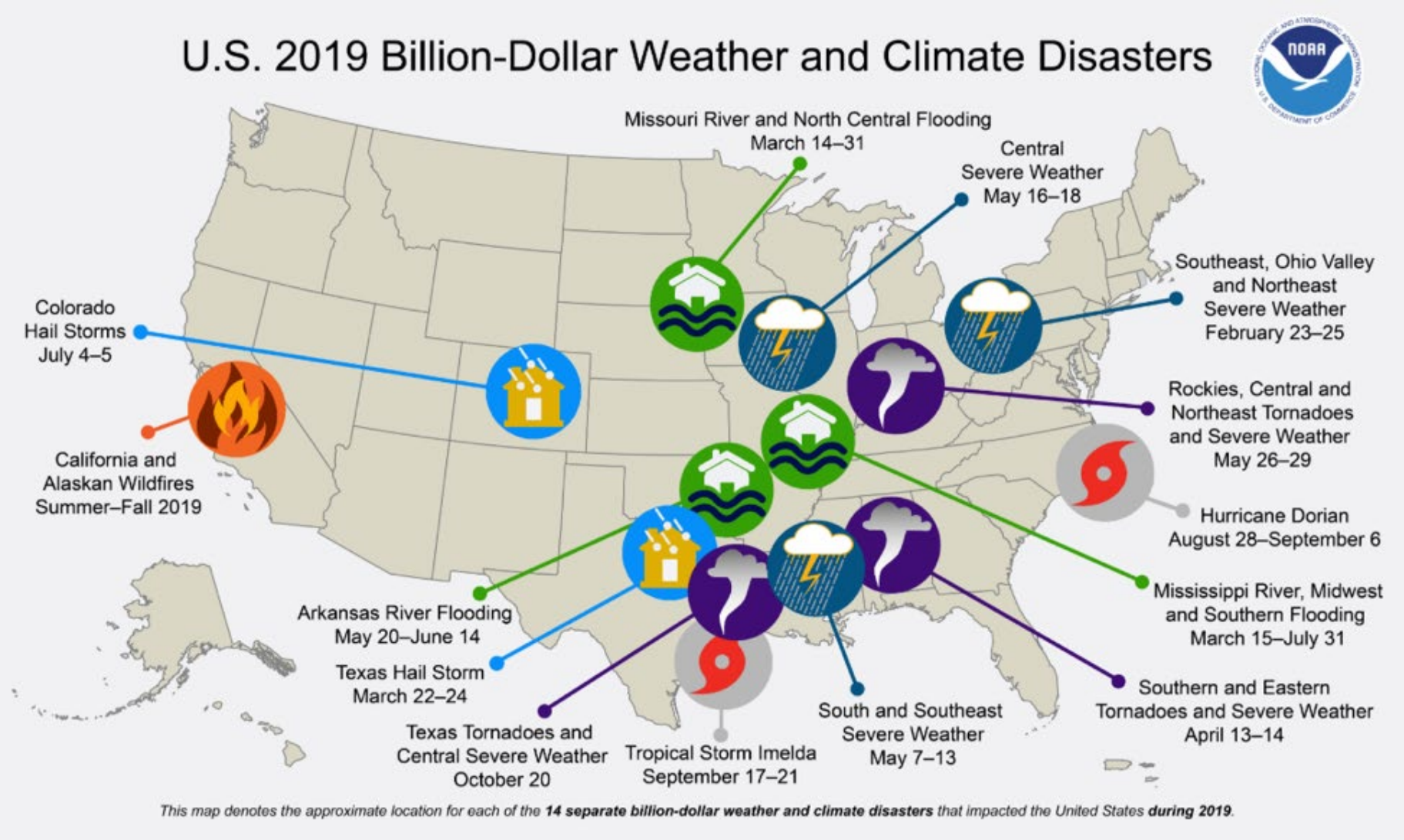
- FHWA Order 5520 (2014)

The need for resilience



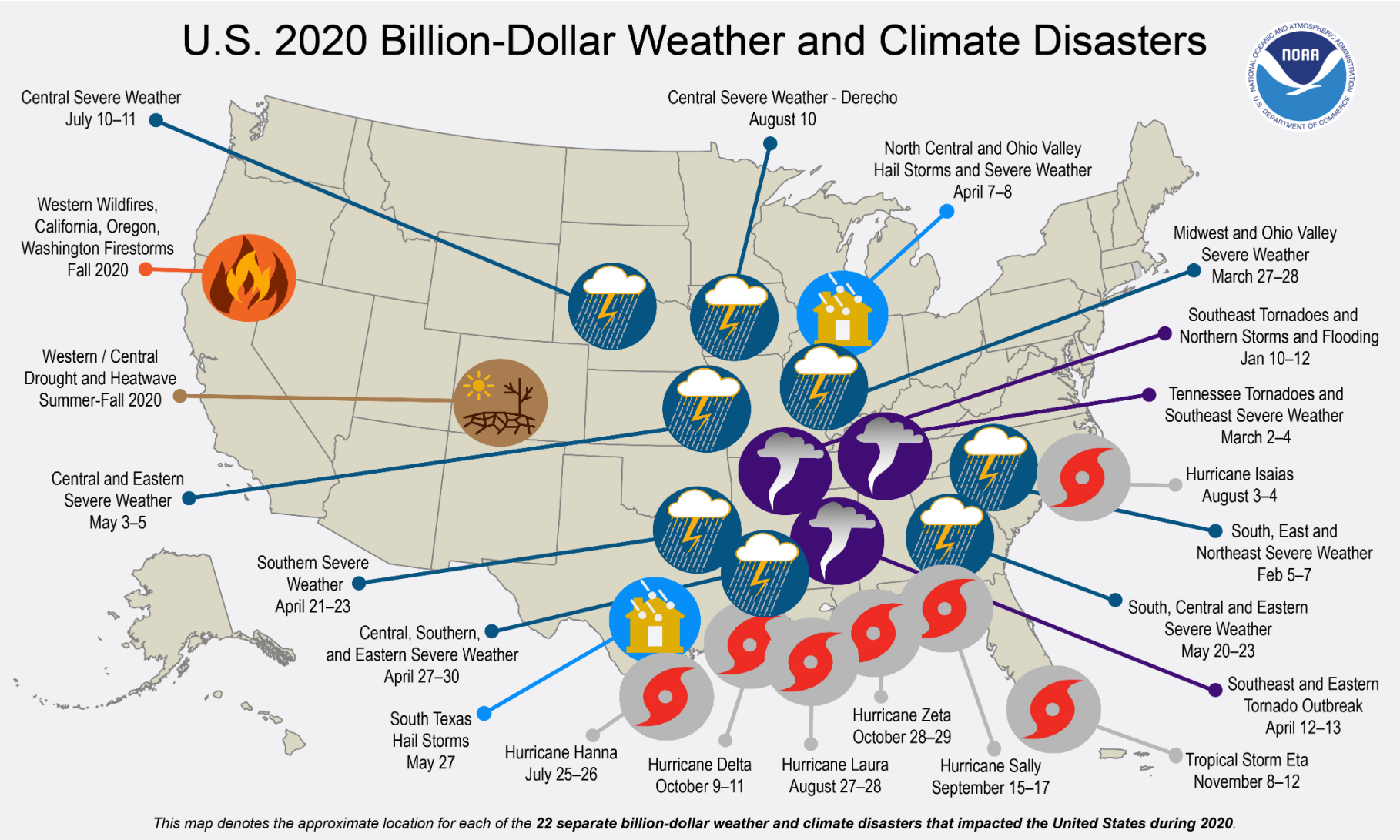
Source: https://www.climate.gov/news-features/blogs/beyond-data/2018s-billion-dollar-disasters-context

The need for resilience



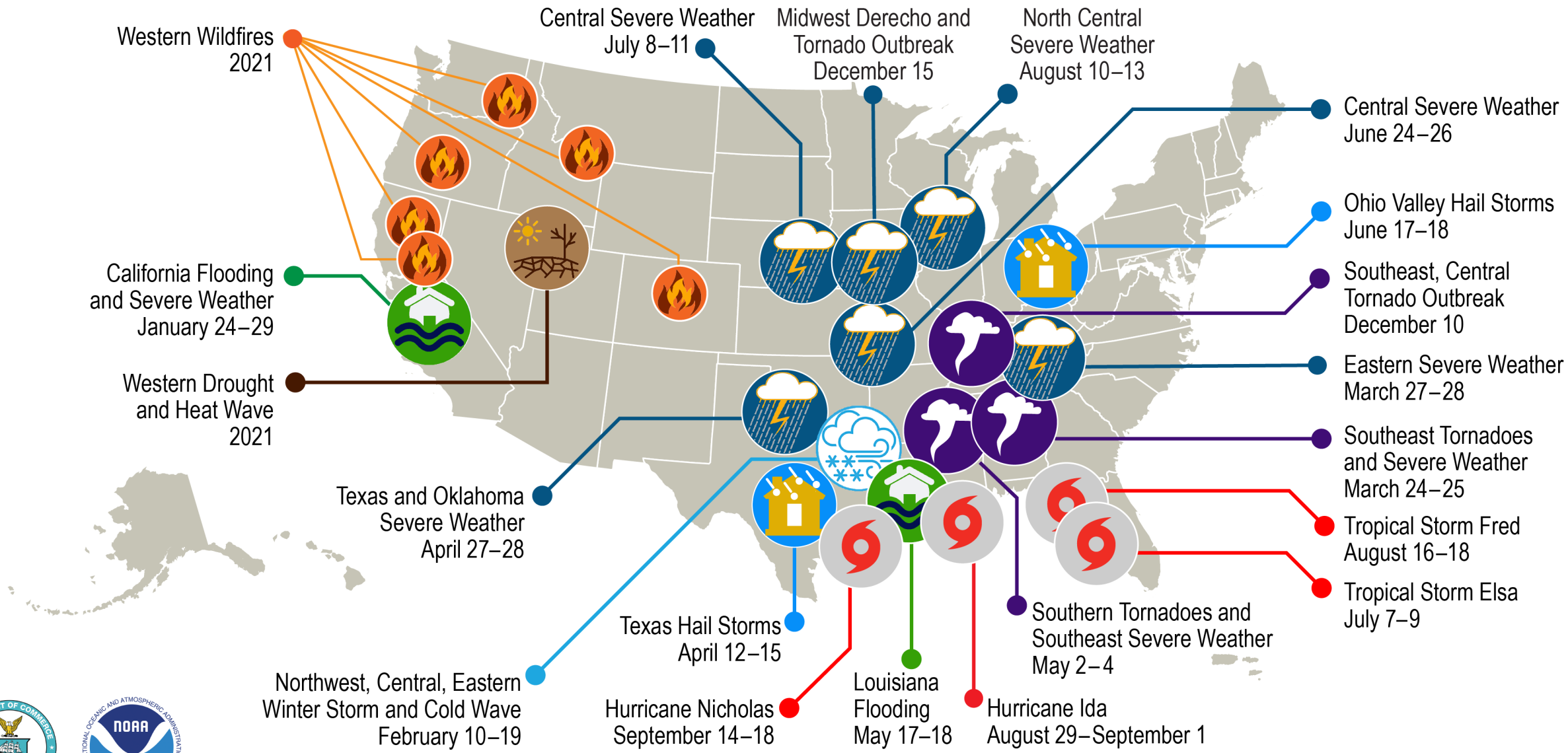
Source: https://www.climate.gov/news-features/blogs/beyond-data/2010-2019-landmark-decade-us-billion-dollar-weather-and-climate

The need for resilience



Graphic: NOAA 2021 https://www.ncdc.noaa.gov/billions/

U.S. 2021 Billion-Dollar Weather and Climate Disasters



*This map denotes the approximate location for each of the **20 separate billion-dollar weather and climate disasters that impacted the United States in 2021***

Graphic: NOAA 2022 https://www.ncdc.noaa.gov/billions/

Difference between sustainability and resilience

*"…**resilience** concerns the capacity of an urban system – including its natural, built, social and economic elements – to manage change, learn from difficult situations and be in a position to rebound after experiencing significant stress or shock, while **sustainability** questions weather or not certain aspects of our daily activities, and the systems in which they operate, can be continued indefinitely into the future, again from a social, economic, and environmental perspective."*

- Newton and Doherty (2014)

Newton and Doherty (2014). "Resilient Sustainable Cities: A Future." Routledge, Taylor & Francis Group, New York, NY.

Resilience is *not* sustainability

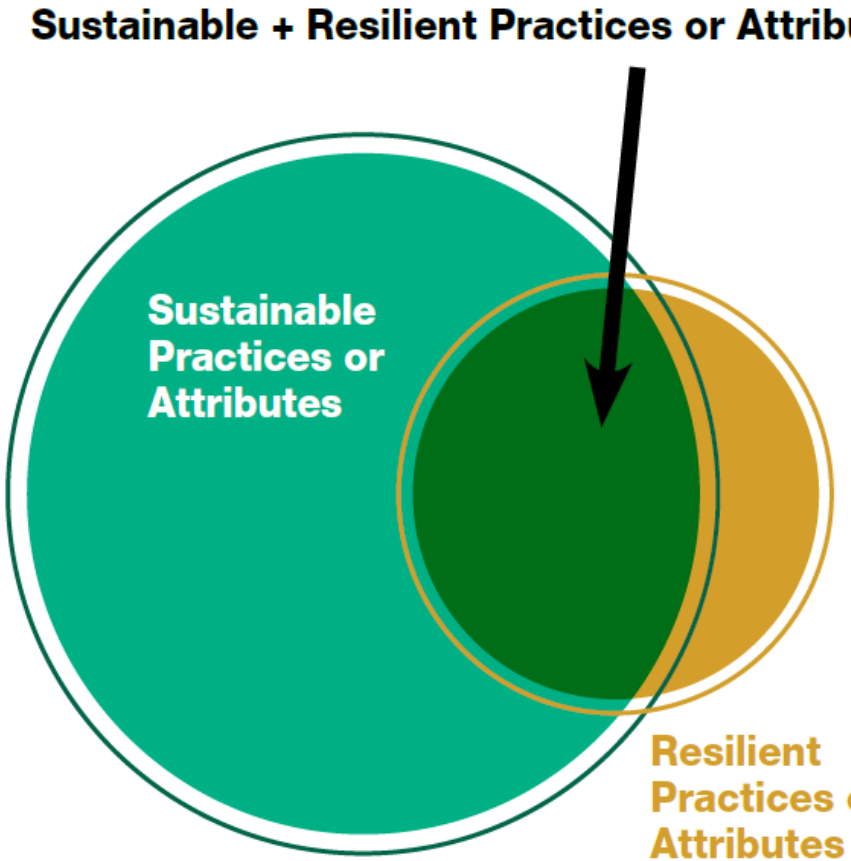


Figure 1. Venn Diagram of Sustainable, Resilient, and Resilient + Sustainable Practices and Attributes for Asphalt Pavements

Sustainable Practices or Attributes

- Use of recycled materials
- Cold Recycled Asphalt
- Asphalt mix and plant optimization

Sustainable + Resilient Practices or Attributes

- Warm Mix Asphalt (low emissions + increase in haul distance)
- Porous pavement systems (stormwater management + nuisance flooding)
- Perpetual Pavement Design
- Deep reconstruction of pavement (increase deep layer moduli)
- Rapid construction
- Ability to adjust pavement design to climate / climatic events to extend pavement life

Resilient Practices or Attributes That Are Not Sustainable

- Use of novel materials with unknown environmental or safety risks
- Use of climate adaptable materials when the social and environmental benefits do not outweigh the costs (e.g., use of polymer modified binders for low volume roads)
- Over-designing for low-risk catastrophic events

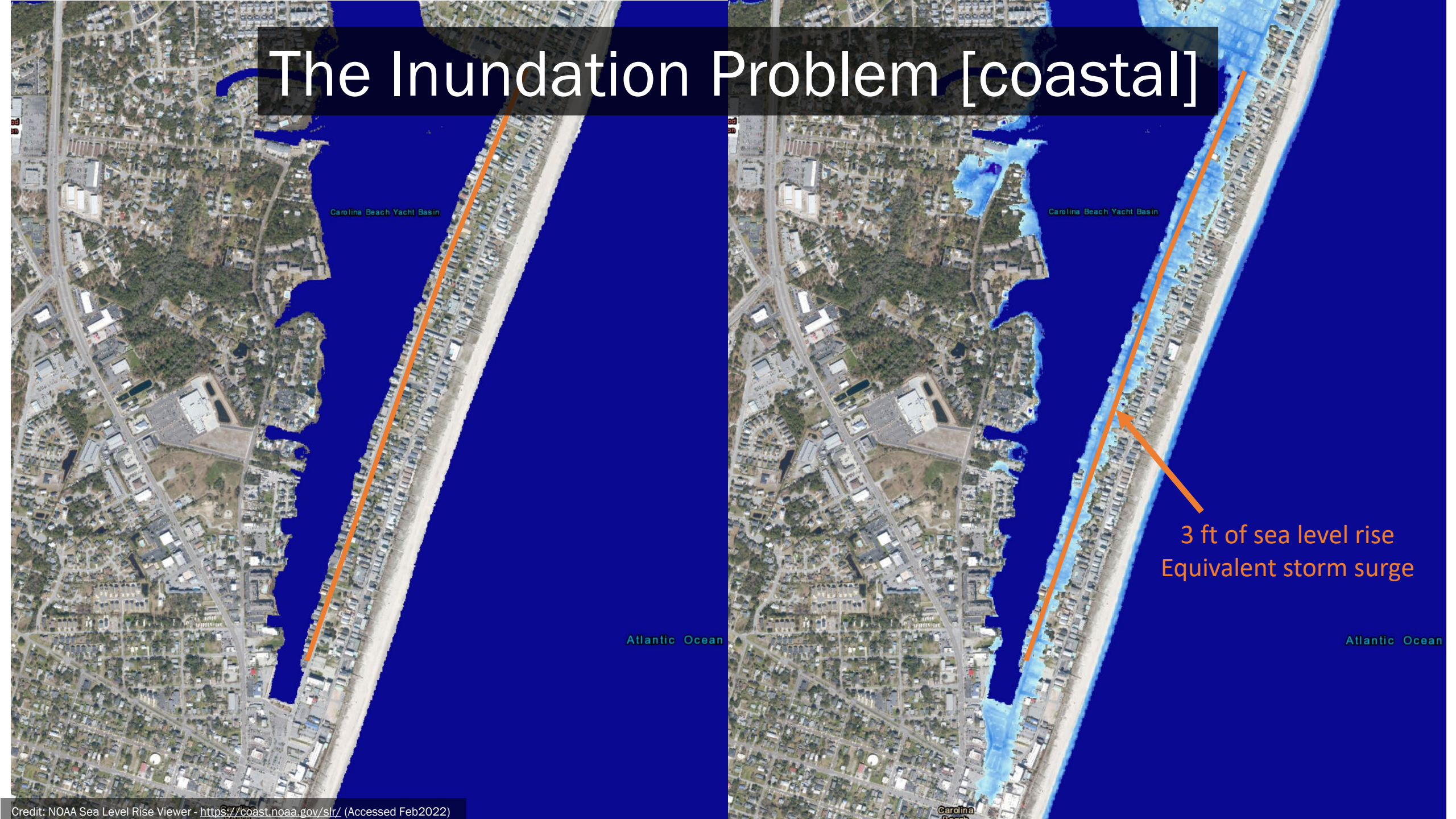
Bowers and Gu (2021) “Resilient Asphalt Pavements: Industry Solutions for the Resilience Goal”, NAPA SIP 105

However...
While resilient solutions may or may not be sustainable... a resilient system contributes to sustainability...

What effect might this have on pavements?

- Flood inundation and rising groundwater tables leading to premature pavement deterioration

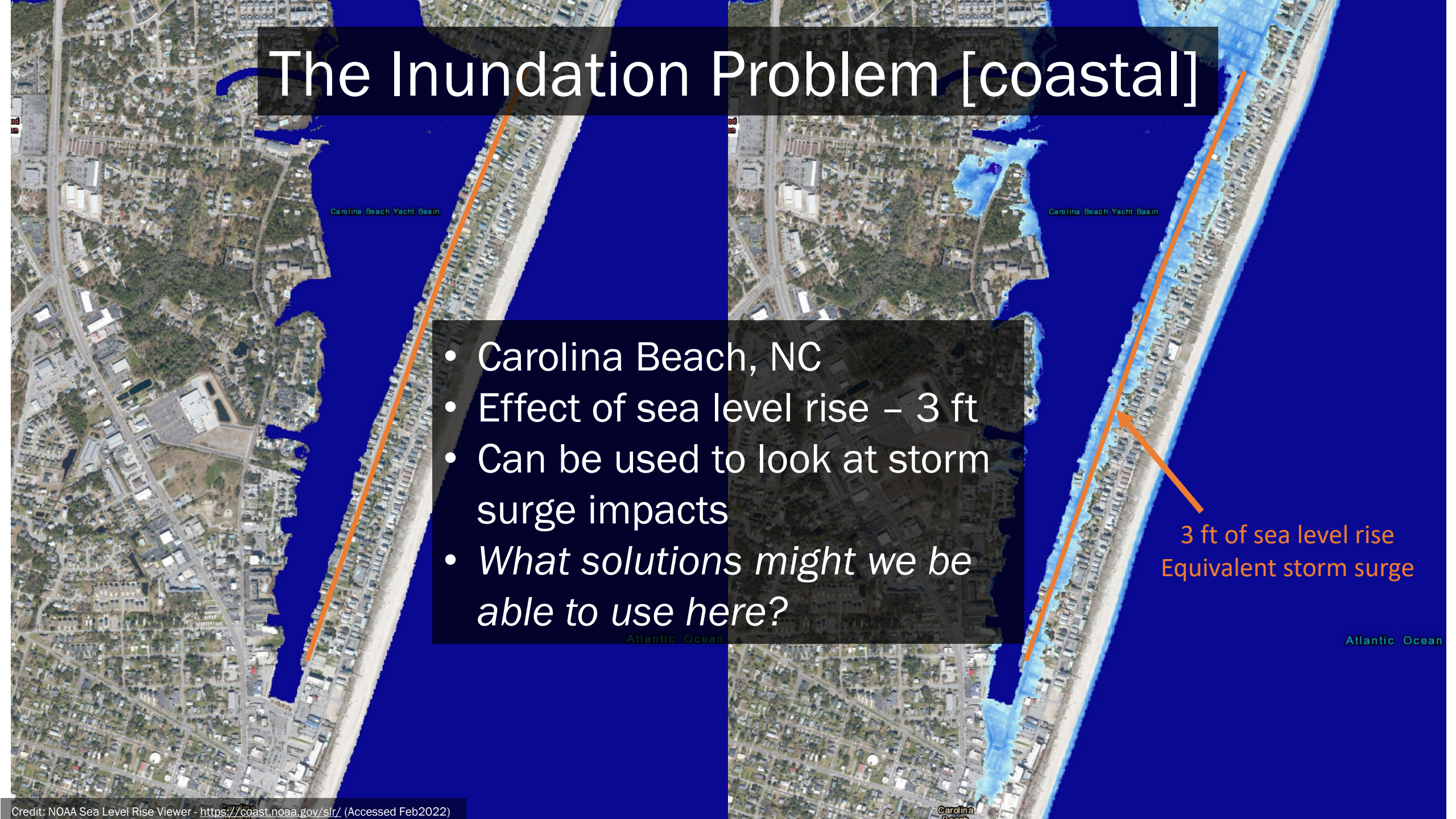
The Inundation Problem [coastal]



Credit: NOAA Sea Level Rise Viewer - https://coast.noaa.gov/slr/ (Accessed Feb2022)

The Inundation Problem [coastal]

- Carolina Beach, NC
- Effect of sea level rise – 3 ft
- Can be used to look at storm surge impacts
- *What solutions might we be able to use here?*



Credit: NOAA Sea Level Rise Viewer - https://coast.noaa.gov/slr/ (Accessed Feb2022)

What effect might this have on pavements?

- Flood inundation and rising groundwater tables leading to premature pavement deterioration
- Extreme temperatures lead to rutting, cracking, buckling
- Destruction of materials production plants due to a climate event/disruption
- Rerouting of trucks or demolition removal damaging pavements after the disruption [cascading event]

Example Tornado Cascading Effect

Potentially vulnerable roads

Vegetation Burn Pit

Path of the Beauregard EF-4 Tornado

Tornado Path, 3/3/2019

LEE COUNTY

Map: Justin Hardee and Patrick Harvill, Lee County Highway Department

To be resilient we need to…

- Understand our vulnerabilities
  - Where are the weak points in your asset or system?
  - How might these be impacted by an event like a natural disaster?
- Assess the risk associated with those vulnerabilities
  - What level of risk can you assume?
  - What are the consequences?
- Adapt
  - Use tools to adapt the system from its original design to account for the resilient needs

[adaptation]

- So we need to adapt to changing conditions
  - Temperature swings [record highs/lows and rapid changes]
  - Wild fires
  - Hurricanes
  - Major non-tropical precipitation events
  - Tornados
  - Sea level rise
  - Drought

...so, what do we do?

Four adaptation “philosophies”

1 Hardening

WHAT IS IT? This is when we strengthen, rebuild, or protect our pavement to withstand any probable event the pavement might subjected to, eliminating or nearly eliminating disruption potential.

2 Adaptation through modification

WHAT IS IT? This is when we make adjustments to our pavement as it is, perhaps not completely hardening the system, but giving it a higher probability of surviving the disruption.

3 Accepting and planning

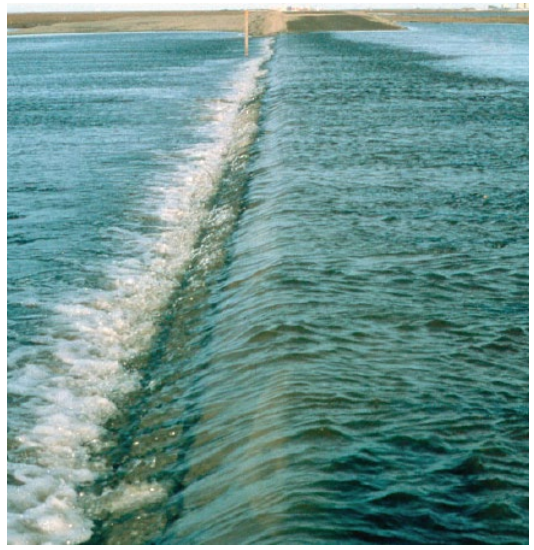
WHAT IS IT? This is when we accept that we will have a complete failure, account for the risk, and plan for funds to be made available to address the problem.

4 Abandonment

WHAT IS IT? This is when we take an honest look at the situation and decide that it makes more financial sense to completely abandon the route.

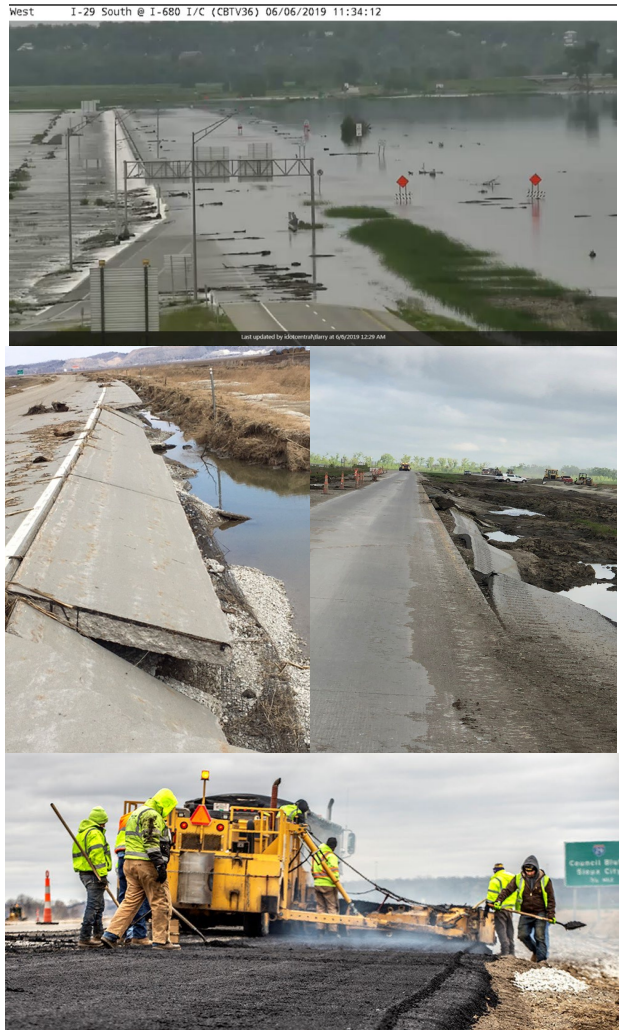
Hardening and *Adaptation Through Modification*

Hardening



You can build infrastructure to withstand almost anything, but at what cost?

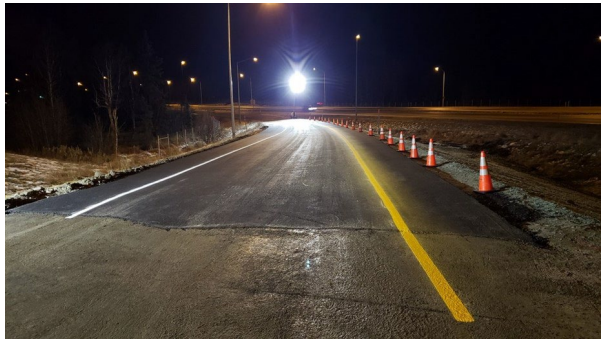
Adaptation Through Modification



What are some creative ways that we can modify current design to adapt it for future challenges in a cost-effective manner?

Credit: Amanda Gilliland, The Transtec Group | Modern Steel Construction, Kuparuk River Submersible Bridge: North Slope of Alaska, Article 2002 | Bill Rosener, Formerly Asphalt Pavement Association of Iowa

Accepting and Planning *or* Abandonment



There are some disruptions you cannot plan for… so how will you respond?

Accepting and Planning

Abandonment

Sometimes abandonment is the only option…

Credit: Amanda Gilliland, The Transtec Group | Mahear Abou Eid, Alaska DOT | Knik Construction | US Climate Resilience Toolkit

Keys to building resilience…

- *Partner* – Agencies and industry need to build partnerships
  - Communication and trust before, during, and after a disruption is crucial
- *Plan* - Come up with solutions *now* for how we adapt and respond
  - Perform a network vulnerability study
  - For various routes, determine the best adaptation "philosophy" to use
  - Build "resilience thinking" into maintenance and rehabilitation schedules
  - Identify alternative routes if an asset is compromised
  - Consider rapid contracting options
  - Consider how we might address materials production facility resilience

Think about the *tools* we *already have*…

Tool	Application
Rapid Construction	Asphalt pavements can be rapidly constructed, a critical part of resilience
Perpetual Pavements	Designed to resist deep distress; ideal for critical corridors; can we build this into maintenance schedules, too?
Climate adaptable materials	Materials designed to handle extreme temperatures
Warm Mix Asphalt	WMA allows for increased haul distances in the case that the asphalt plants are taken offline by a disruptive event
Porous asphalt	Manage stormwater
Recycling	Key when considering supply chain disruption during recovery
Deep reconstruction with Full Depth Reclamation	Cost effective way to strengthen the pavement base with an asphalt overlay
Natural and Nature Based Features	Don’t design against nature, design with nature

What do we need?

- *Funding*
  - Funding to build resilience into the system
  - Funding for emergency response + resilient rebuilding
- Guidance
  - Best practices, methods for building resilience into the system
- Research
  - Incorporating climate models into to design
  - Understanding “new” types of failure so we can design around them
  - Development of new techniques/technologies to help adapt
  - Building resilience into decision making (LCCA or LCA?)

Surface Transportation, Sea Level Rise, and Coastal Storms: A Sustainable Path to Increased Resilience

NOAA Effects of Sea Level Rise Program

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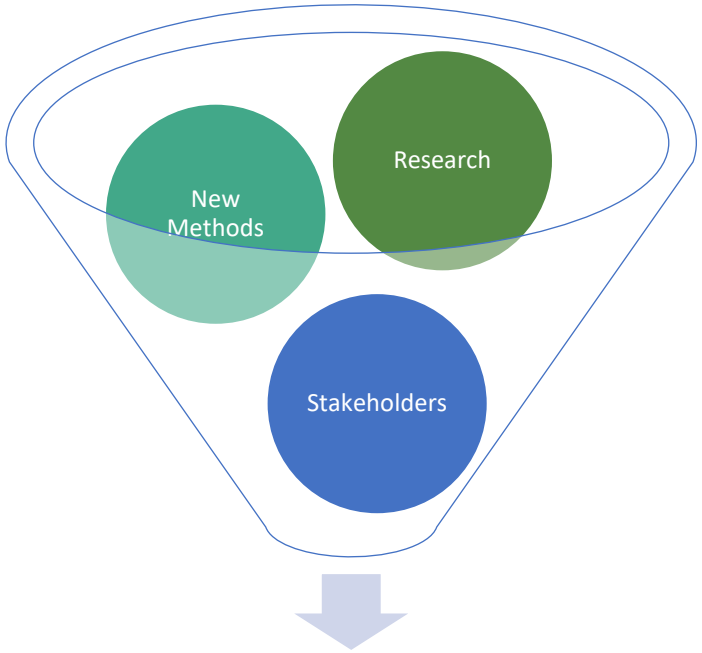
Research Question: How do we make our transportation infrastructure more resilient?

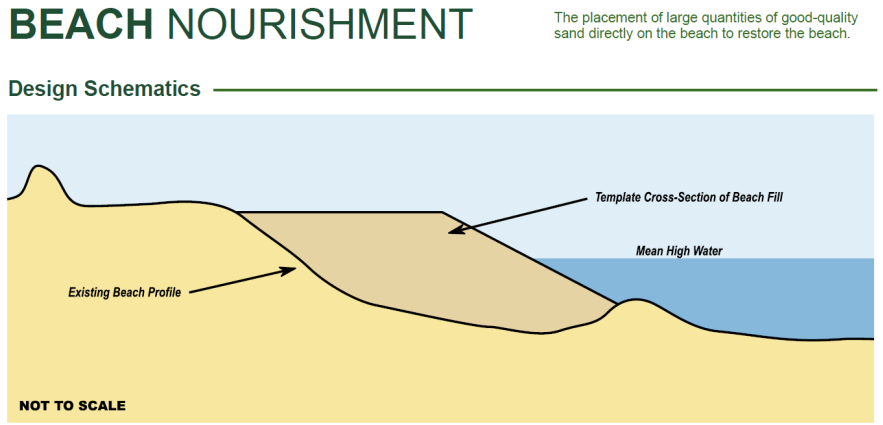
Summary Project Objectives

- **Quantify** vulnerability of coastal communities, infrastructure, and ecosystems to Sea Level Rise and disruptions;
- **Understand** and quantify social, economic, and/or ecological benefits of natural and nature-based features and gray infrastructure;
- **Predict** the effects of SLR and inundation on ecosystems, communities, and infrastructure under varying risk management strategies



What is a “natural or nature-based feature”?

- “Use natural materials and processes to reduce erosion, wave damage, and flood risks”[1]
- Examples include conservation, restoration, or construction of:
  - Beaches
  - Dunes
  - Marsh
  - Mangrove
  - Maritime forests
  - Reefs



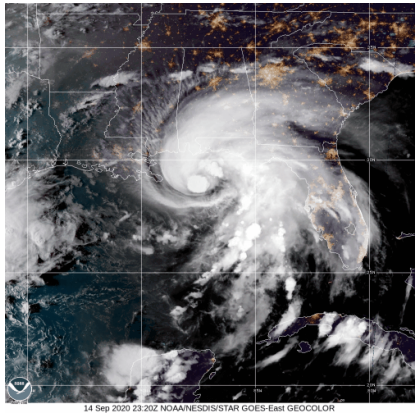
[1]Nature-Based Solutions for Coastal Highway Resilience: An Implementation Guide, Webb et al., FHWA-HEP-19-042 | Living shoreline credit: NOAA https://www.habitatblueprint.noaa.gov/living-shorelines/

Research Site: On and along AL-180, Fort Morgan Road

Our approach: Multi-disciplinary and holistic

Stressor

- Sea Level Rise
- Groundwater
- Coastal Storms

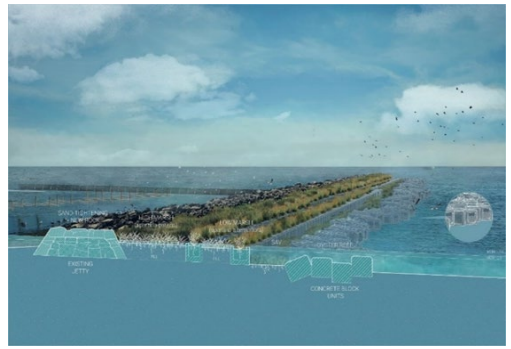


Infrastructure

- Asphalt Pavements
- Coastal Roads
- Multiple Exposures

Socioecological

- Natural and Nature Based Feature Alternatives
- Costs & Benefits
- Resilient Systems

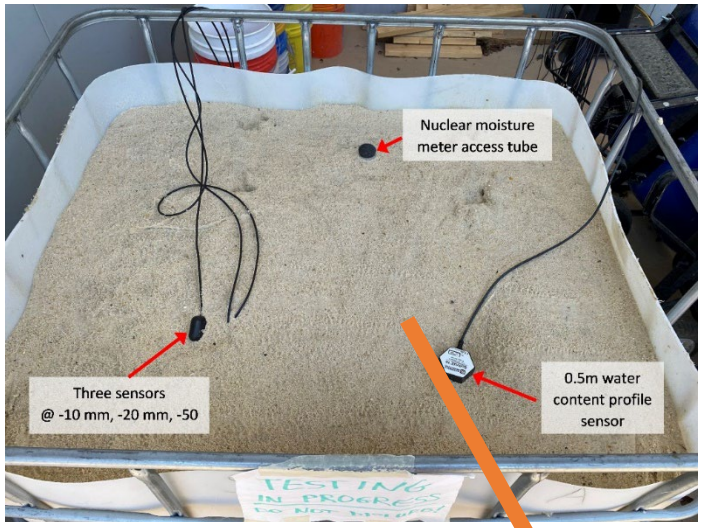


Stressor [SLR and inundation]

- Monitoring will include installations of sensors in the right of way along AL-180
  - Rainfall monitoring with a rain gauge at each site
  - Shallow groundwater level fluctuations with multiple level loggers (~4 to 6 sensors at each site)
  - Surface flow velocities at locations where intermittent streams are identified

Infrastructure [Pavement]

- Place instruments in the pavement at each of the 5 sites for monitoring
  - Run wiring to a pole with a modem, power source, and camera for continuous remote monitoring
- Use Pathways van to record key distress.
  - Rutting, cracking, etc.



Socioecological

- Investigating socioecological context through stakeholder engagement, site characterization, and context analysis
- Predicting how NNBF and hybrid features will change over time
- Assess how adaptation strategies contribute socially and ecologically to their broader context


Study site: Fort Morgan, AL
• AL Route 180 and 182
• Logic: Mobile/Bon Secour Bay to the North, Gulf of Mexico to the South.
• NNBF + Gray Infrastructure
Bon Secour Bay
Bon Secour
Oyster Bay
59
180
135
TW6-well
Option5Outlet1
Gulf Shores
Point2B
The Pines - flooding
Outlet
Mesonet station
Option6Outlet3
Option6Outlet1
Option6Outlet2
Point3B
Gulf Highlands
Fort Morgan

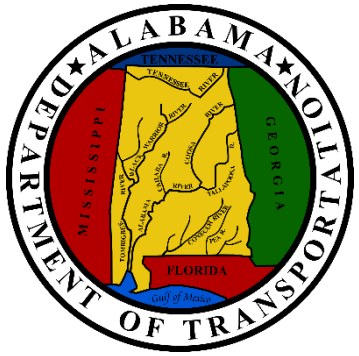
Broad Outcomes

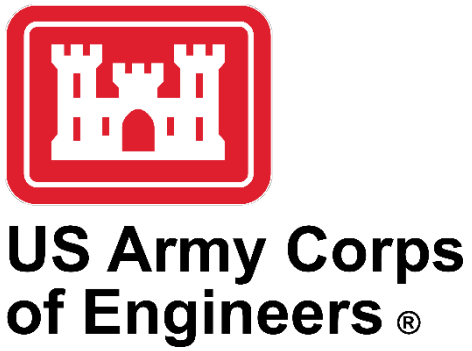
- Enhanced hydrological modeling.
  - Including understanding hydrological impacts of NNBF on the pavement system.
- Pavement deterioration curves.
- Connection between hydrological modeling and pavement design
  - What are the right/wrong ways to consider inundation in design?
- Better understanding and context for the value of NNBF (social, ecological, economic).
- Better guidance and tools for decision makers and designers.

Outcomes, milestones, and partners

- **Goal:** *Science-based, practically grounded, implementable research outcomes and guidance for decision makers to make our coastal infrastructure more resilient.*
- This will save tax dollars, enhance decision making.
- **Partners:**

  Alabama DOT | FHWA | US Army Corps of Engineers | Local Stakeholders





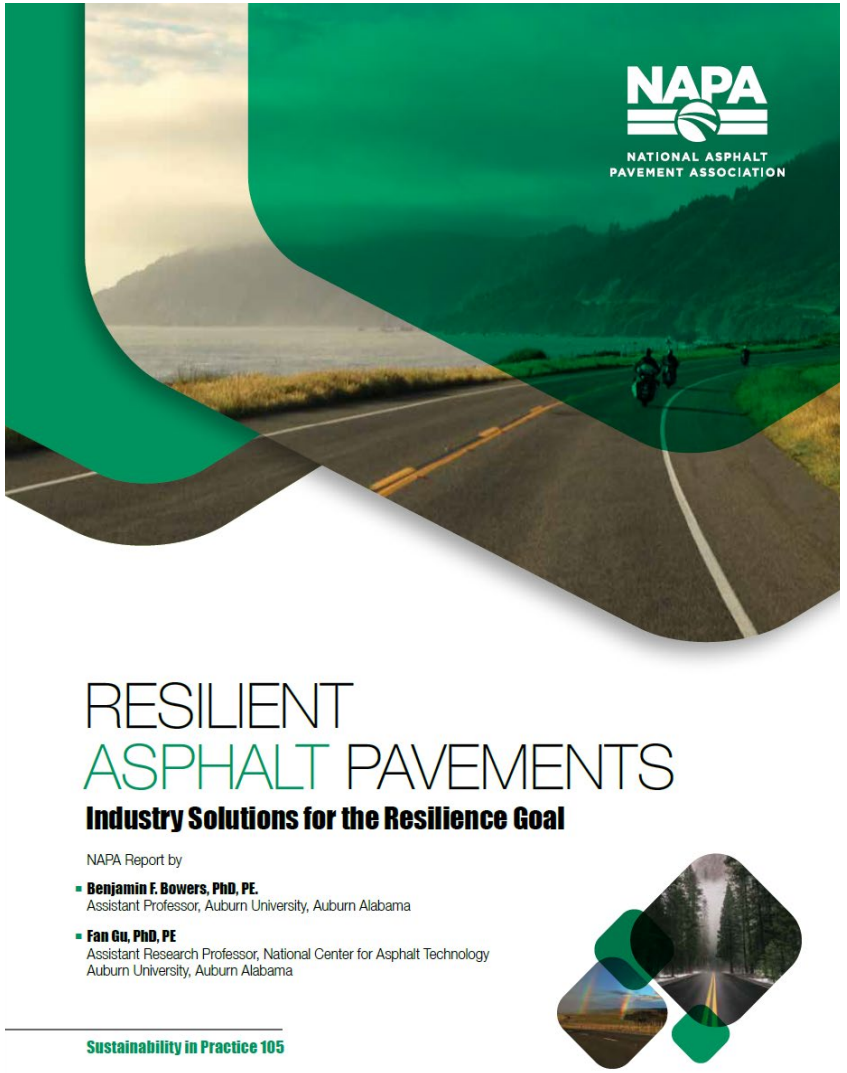
Asphalt Pavement Resilience

- "Resilient Asphalt Pavements – Industry Solutions for Resilience Goal" – NAPA SUP 105

Search online or download here:
https://member.asphaltpavement.org/Shop/Product-Catalog/Product-Details?productid=%7b6399F00E-2392-EB11-B1AC-000D3A9A6645%7d

- NCAT Report 21-02 "Asphalt Pavement: A Critically Important Aspect of Infrastructure Resiliency"

Search online or download here:
https://eng.auburn.edu/research/centers/ncat/files/technical-reports/rep21-02.pdf



Questions?

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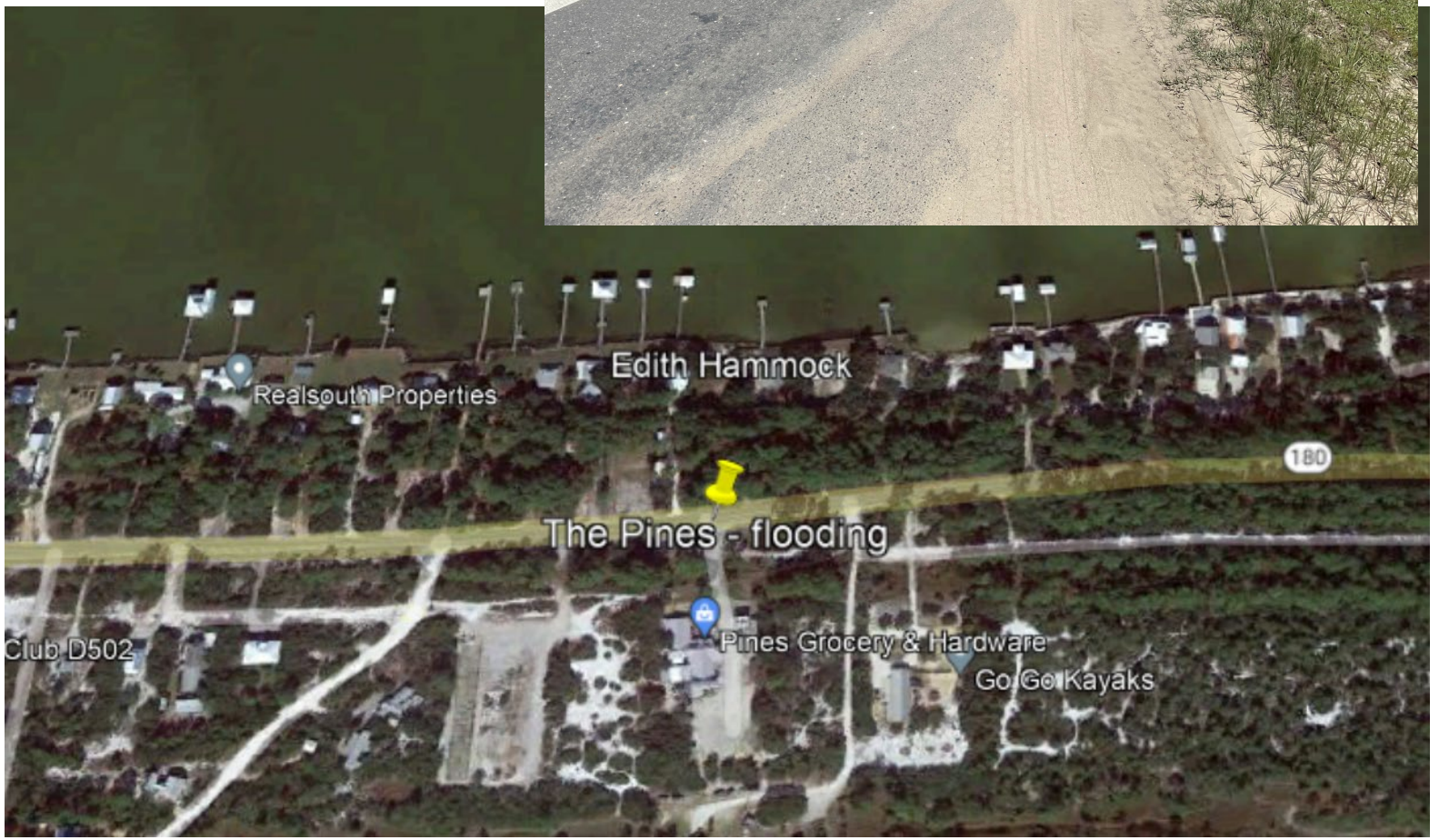
The Pines

- Area of frequent flooding (rain events)
- High GWT, doesn't appear to be caused Bay/Gulf
- Good site to model SLR effects



Public Boat Launch

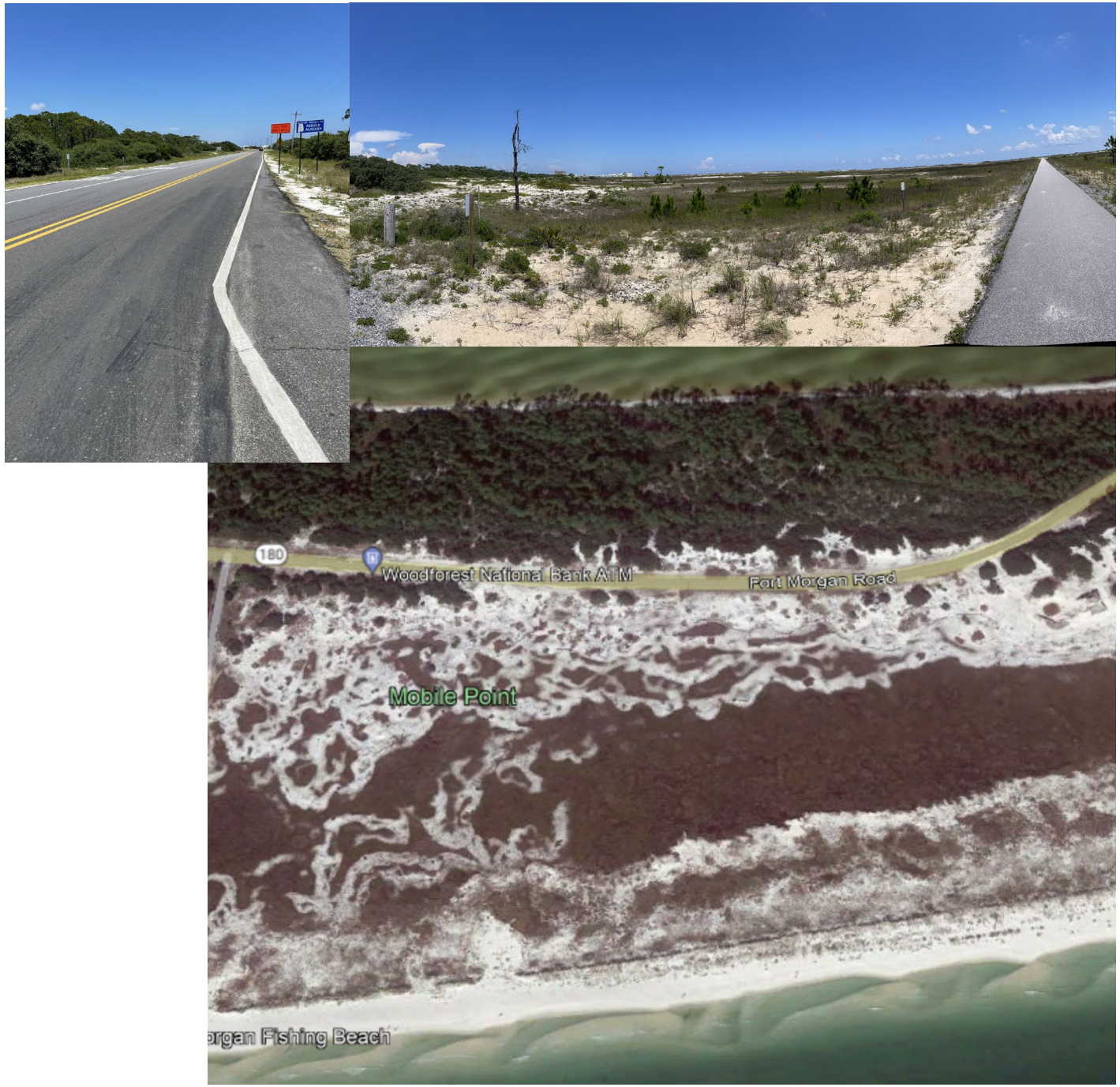
- Bay-side and subject to flooding
- Revetment added to armor
- Good site to model/study traditional grey infrastructure

Navy Cove

- Flood susceptible area, namely in extreme events
- Culvert and *some NNBF*
- Good site to model/study extreme events and model SLR effects

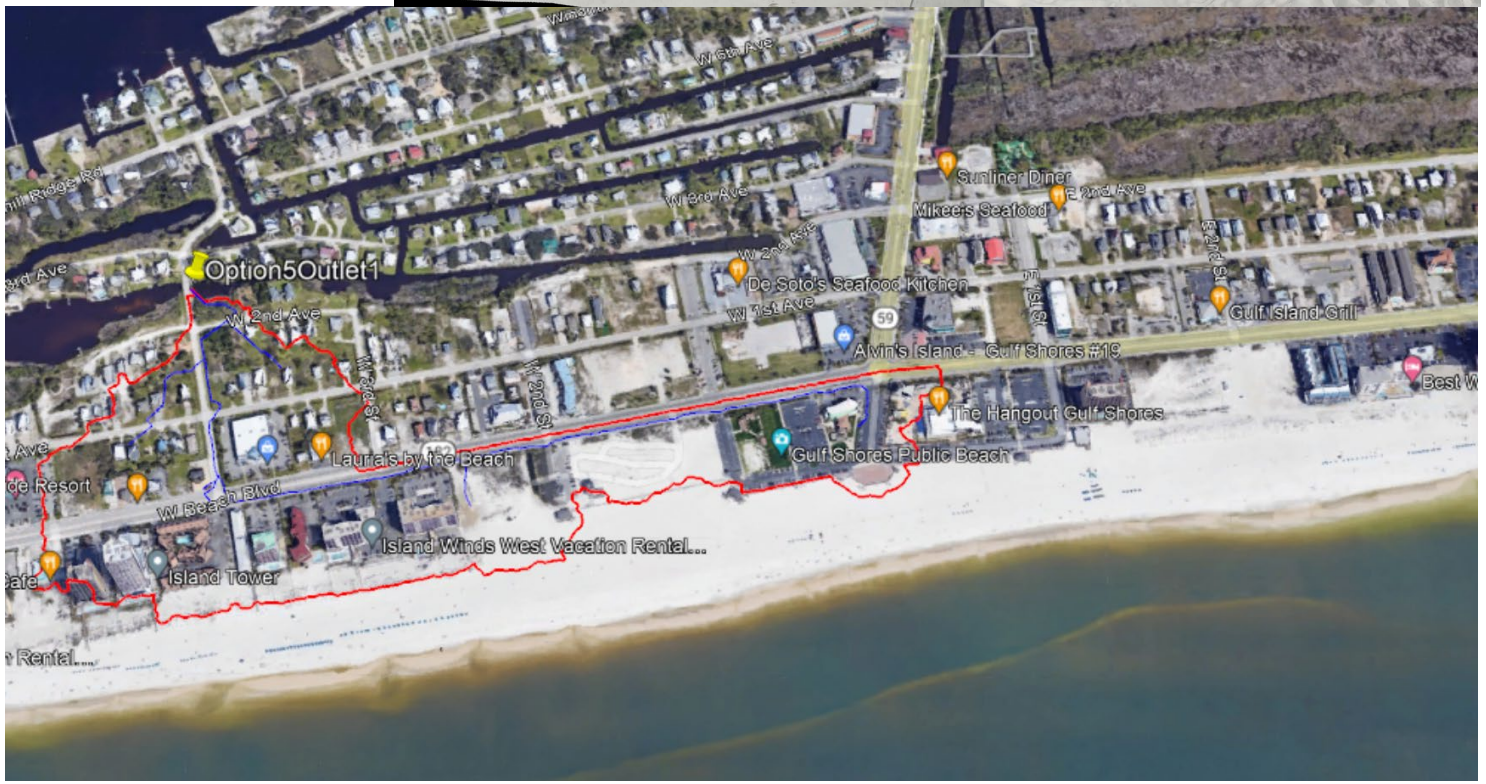
Dune Field

- Roadway protected by dune field
- Opportunity to model/study NNBF, namely from a conservation perspective



Gulf Shores Hangout

- Beach restoration (2005)
- Excellent socioecological site
- Opportunity to model/study NNBF



Ewing Bayou

- High GWT
- Persistent issues
- Interesting SLR effects site
- *Alternative*