NATIONAL ACADEMIES Sciences Engineering Medicine

TRB TRANSPORTATION RESEARCH BOARD

TRB Webinar: State DOTs Perspective on Pavement Resilience

November 30, 2022

2:00 – 4:00 PM

PDH Certification Information

2.0 Professional Development Hours (PDH) – see follow-up email

You must attend the entire webinar.

Questions? Contact Andie Pitchford at TRBwebinar@nas.edu

The Transportation Research Board has met the standards and requirements of the Registered Continuing Education Providers Program. Credit earned on completion of this program will be reported to RCEP. A certificate of completion will be issued to participants that have registered and attended the entire session. As such, it does not include content that may be deemed or construed to be an approval or endorsement by RCEP.

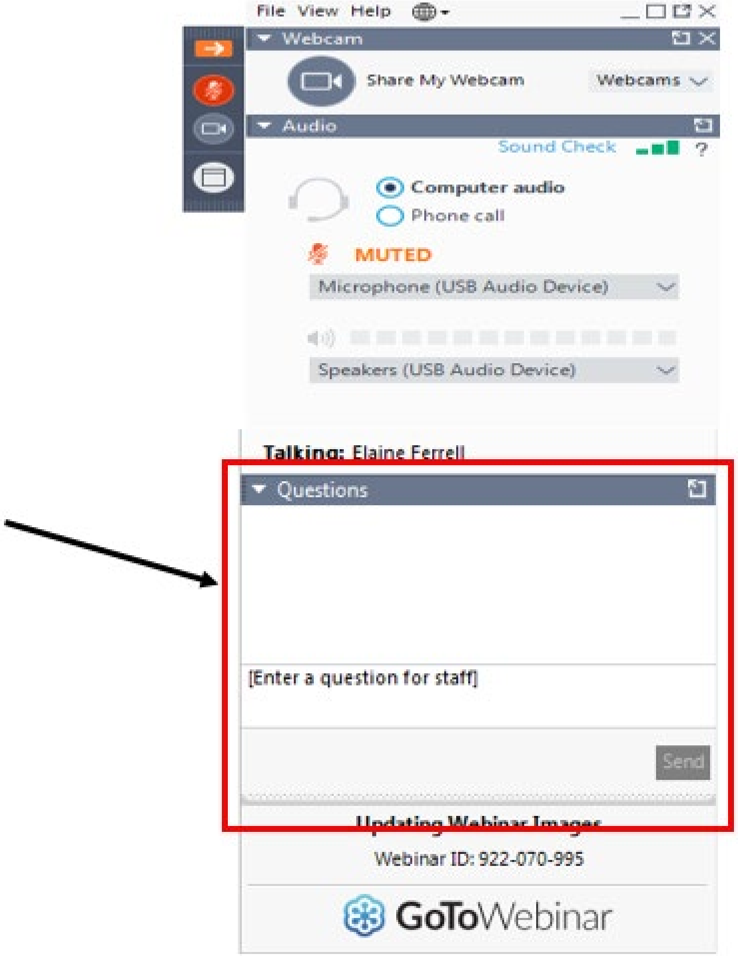
RCEP
REGISTERED CONTINUING EDUCATION PROGRAM

Learning Objectives

- Identify major pavement challenges for state DOTs facing climate change and extreme events
- Prepare for and adapt to changing conditions
- Plan to withstand, respond to, and recover rapidly from climate related disruptions

Questions and Answers

- Please type your questions into your webinar control panel
- We will read your questions out loud, and answer as many as time allows



Today's presenters

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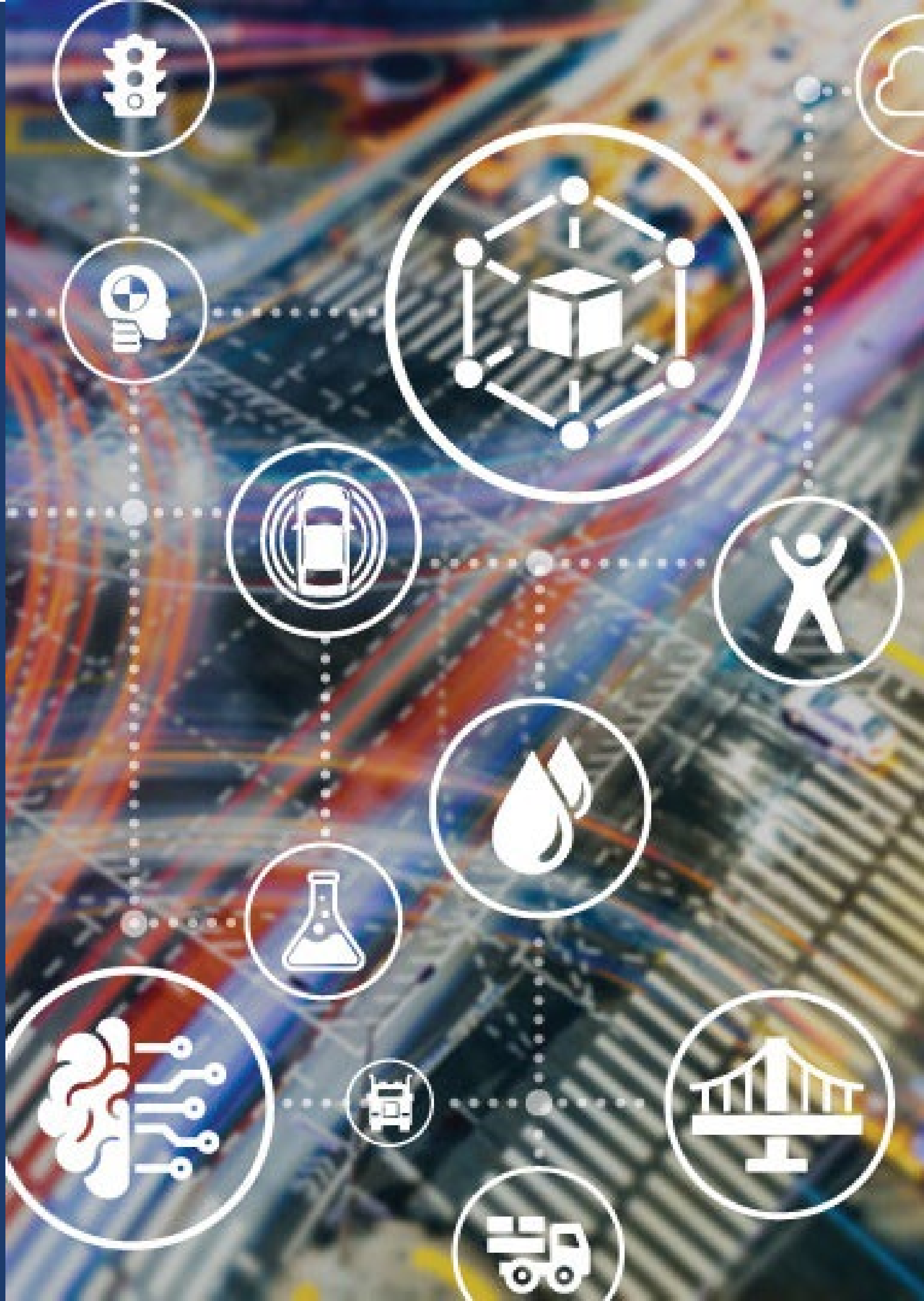
Progress Toward More Resilient Pavements

Amir Golalipour, Ph.D., P.E.
Office of Research, Development, and Technology
Federal Highway Administration (FHWA)

TRB Webinar Series: State DOTs Perspective on Pavement Resilience
November 30th, 2022



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What Is Resilience?

Resilience: The ability to anticipate, prepare for, and adapt to changing conditions and withstand, respond to, and recover rapidly from disruptions, FHWA Order 5520 (FHWA 2014c).

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FHWA Resilience

Transportation Asset Management Plans (TAMP)

Bipartisan Infrastructure Law (BIL)

23 U.S.C. 119(e), requires:

A State shall develop a risk-based asset management plan for the National Highway System to improve or preserve the condition of the assets and the performance of the system.

Consider extreme weather and resiliency in the life cycle cost and risk management analyses of their TAMPs (23 U.S.C. 119(e)(4)(D)).

Resilience in TAMPs in Regulation

23 CFR Part 515.7

State DOTs are required to develop a risk-based asset management plan to include specific minimum processes, including the following section on lifecycle planning identified in subsection (b)*:

> A State DOT shall establish a process for conducting lifecycle planning for an asset class or asset subgroup at the network level (network to be defined by the State DOT). As a State DOT develops its lifecycle planning process, the State DOT should include future changes in demand; information on current and future environmental conditions, including extreme weather events, **climate change**, and seismic activity; and other factors that could impact whole-life costs of assets.

*Similar requirements are in subsection (c), which addresses risk management plans.

* (Office of the Federal Register, National Archives and Records Administration 2018)

Addressing Resilience in TAMP Risk Management Analysis

What can States do to address risks associated with extreme weather and climate change?

Three steps for success:

1. Leverage results from existing (or new) vulnerability and engineering assessments focused on resilience.
2. Identify hazards affecting each asset class.
3. Assess strategies/costs for making each asset class resilient.

State DOT's Perspective on Pavement Resilience

TRB Webinar

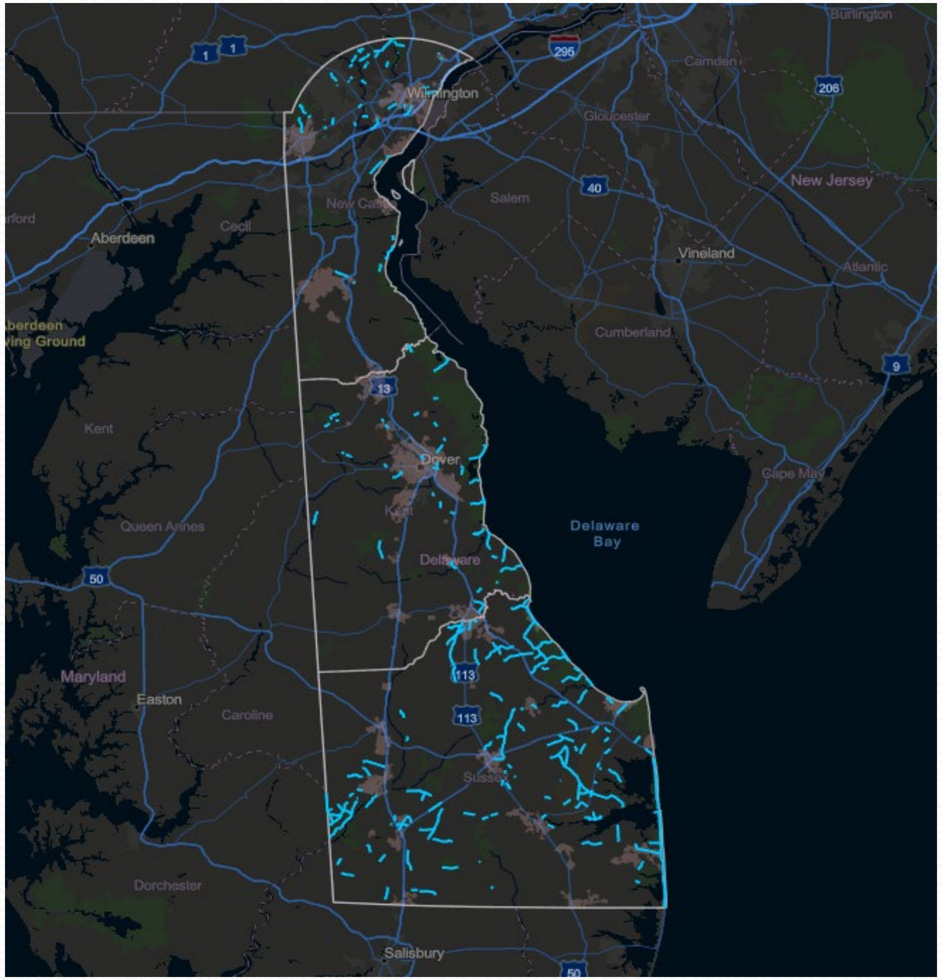
11.30.22

Jim Pappas, P.E.
Director - Transportation Resiliency & Sustainability

Roadway Flooding Challenges

Due to the low-lying topography of the state, creating resilient infrastructure in the face of roadway flooding becomes a challenge. We have been and continue to be challenged by the effects of sea level rise and frequently flooded roadways across the state.

250+ miles identified statewide.



Possible Mitigation Options

- Tolerate
- Relocation/Realignment
- Elevate
- Harden
- New, innovative solutions
- Strategic (Managed) Retreat
  - Abandon
  - Buy-outs

DelDOT Sustainability & Resiliency Basemap - Pennoni Work Space

Roadway Flooding

Sussex County Frequently Flooded Roadways - By Road Rating

COMMENTS

- <Null>
- Level 1 (Good)
- Level 2 (Fair)
- Level 3 (Poor)
- Level 4 (Very Poor)
- <all other values>

Sea Level Rise Inundation

Sea Level Rise Inundation - 2ft Above MHHW

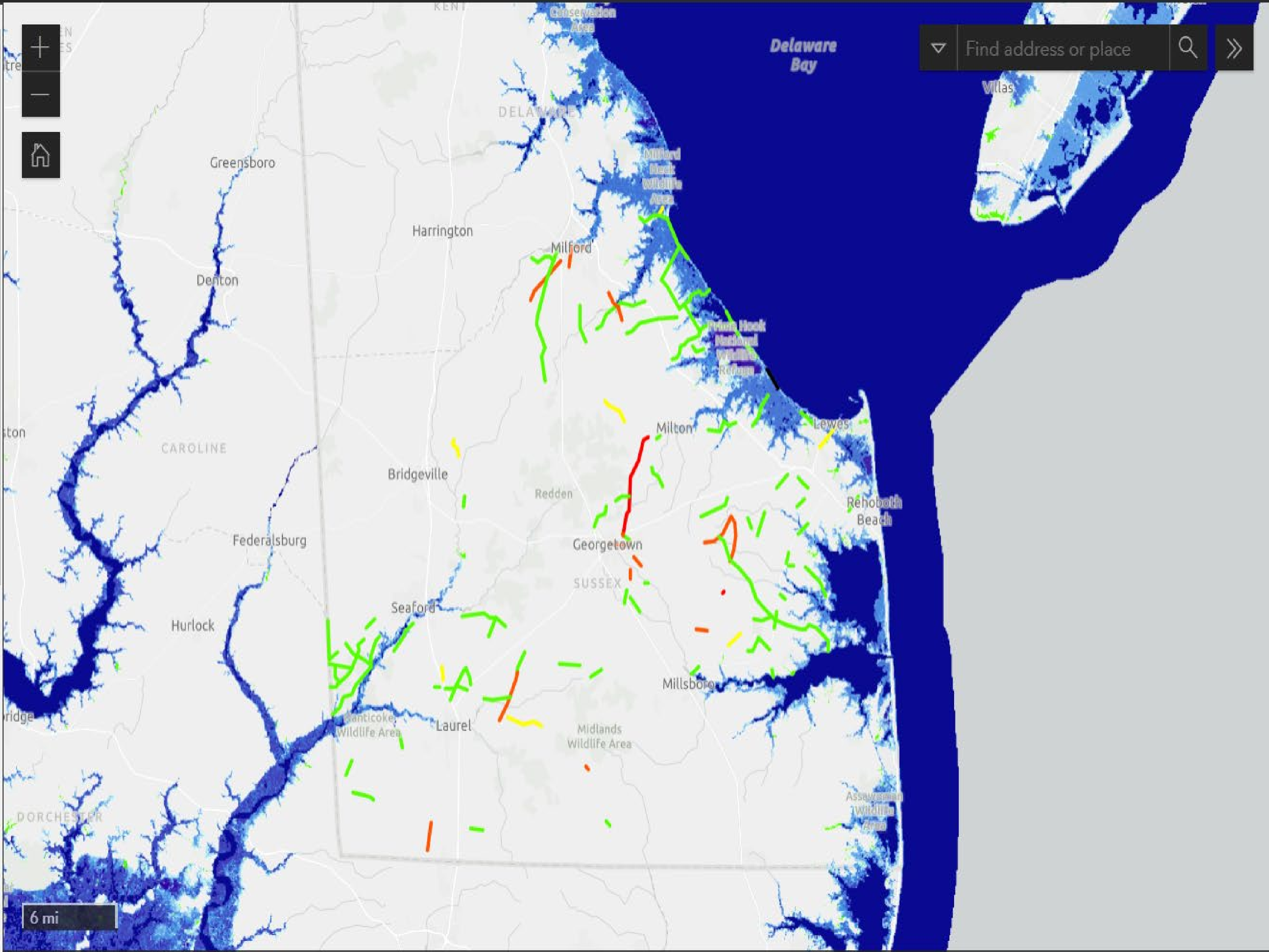
world_countries_webmerc

Census_States_Generalized

No_Data

NJDEPA_AreasNotMapped_webmerc

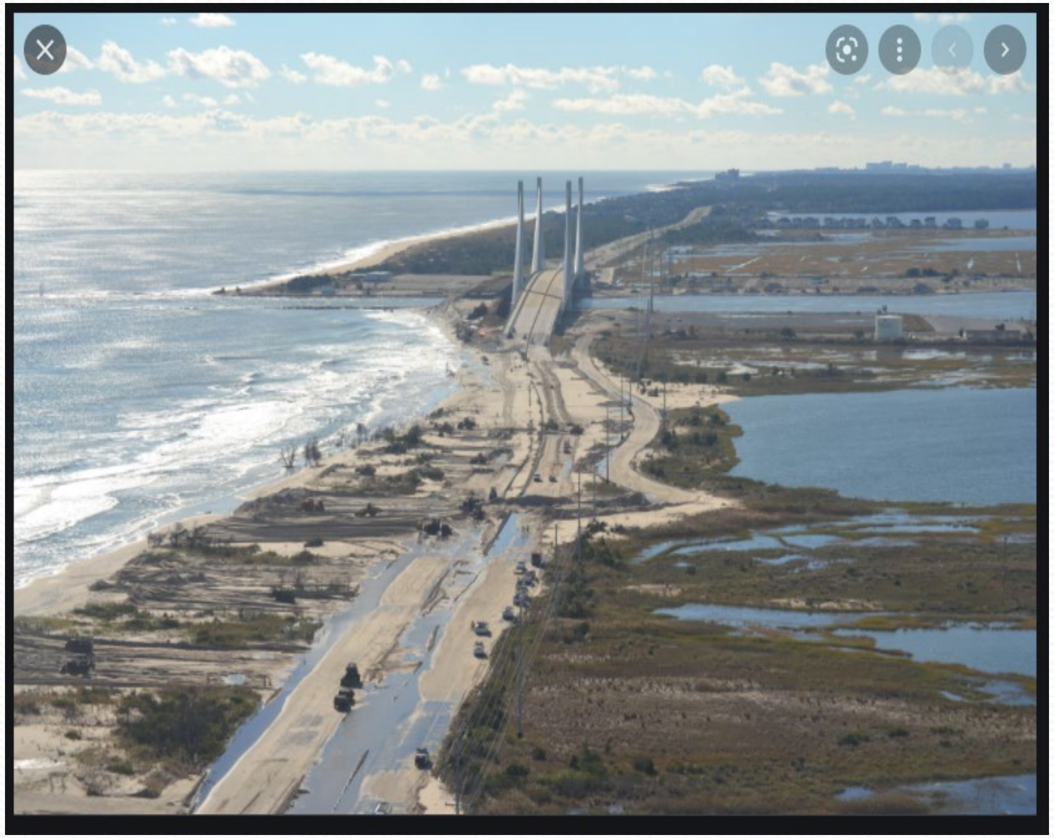
wa_problemarea



County of Sussex, DE, Delaware FirstMap, VGIN, Esri, HERE, Garmin, SafeGraph, FAO, METI/NASA, USGS, EPA, NPS | NOAA Office for Coastal Management (coastal.info@no... Powered by Esri

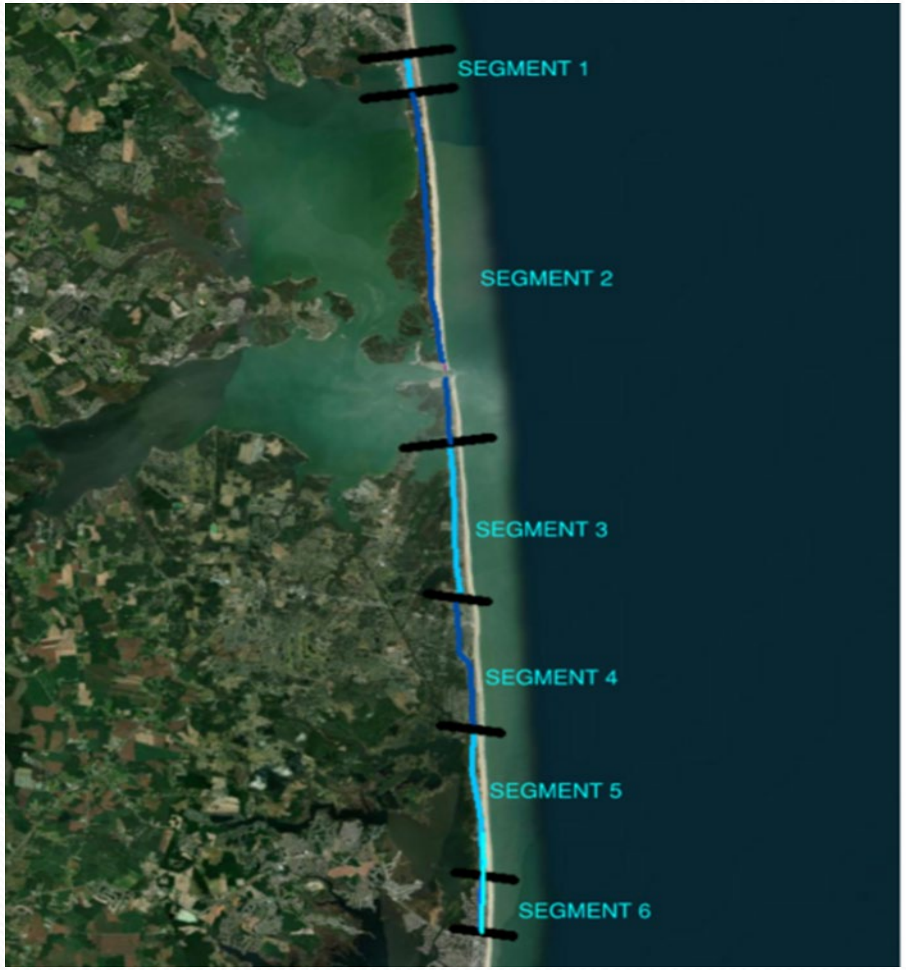
SR 1, Dewey Beach to Fenwick Island

- Critical corridor for the state
- FEMA Planning Study Grant
- Engaged with AECOM for the study
- Data gathering, model generation on going
- Extensive public engagement planned – communities, businesses, legislators
- Deliverable – resilient transportation options for corridor



SR 1 Resiliency Study - Update

- Initial planning work complete
  - Corridor was broken down by risk assessment
  - Ocean and bay modeling performed
- Ready for public outreach
  - Advise public of this study
  - Seek input



Pilottown Road, Lewes

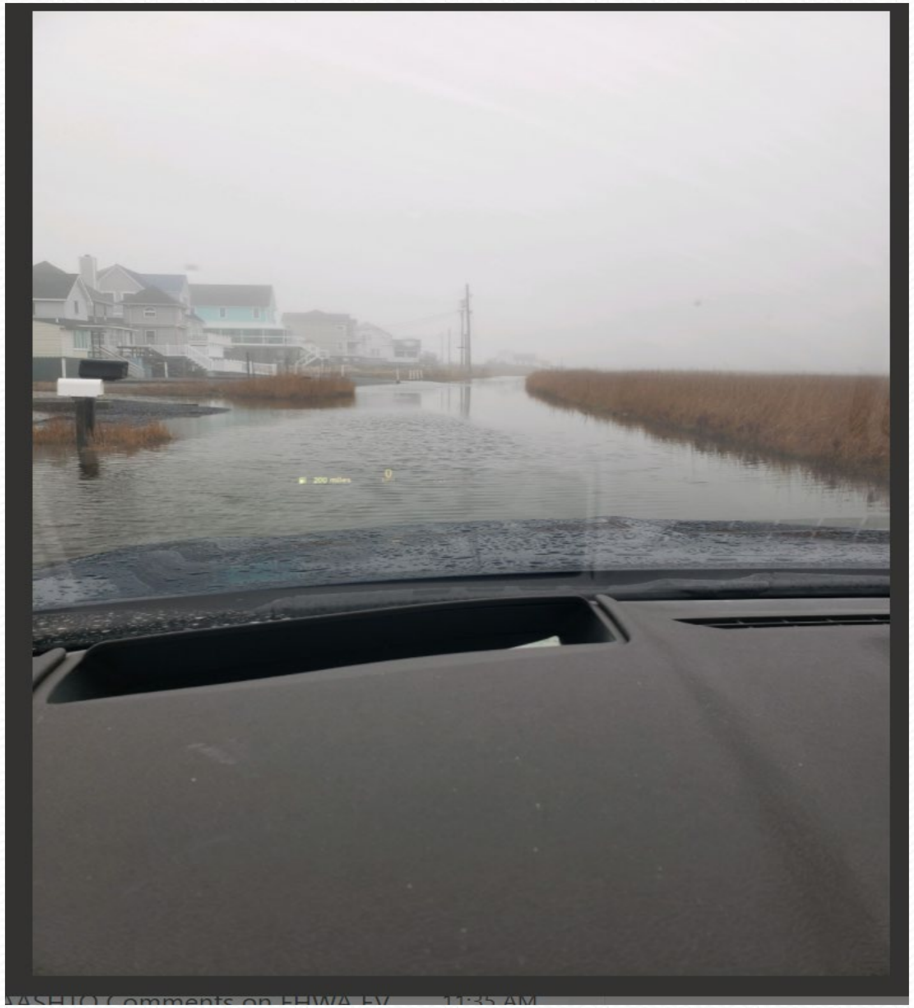
- DNREC is lead agency
- FEMA Planning Study Grant
- Serves UD, DNREC, commercial property, boat ramp
- Looking to possibly raise roadway to minimize roadway flooding occurrences

Pilottown Road - Update

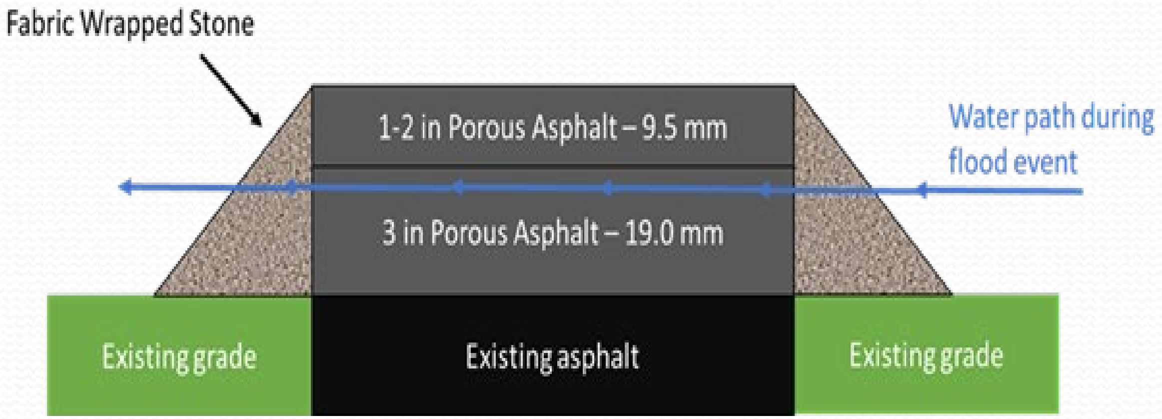
- Planning work completed
- Have met with Mayor, City Manager, City Council, and public
- Next steps:
  - Meet with local businesses directly affected by project for input
  - Apply for a Federal grant for construction

South Bowers Road

- Small, local, one-way-in, one-way out roadway to beach community
- Significant roadway overtopping at times
- Short-term solution is to elevate roadway … by how much?
  - Encroaching wetlands along roadway; limited construction area
  - Build on existing roadway footprint
  - Roadway settlement concerns with additional overlay



South Bowers Road



South Bowers Road

South Bowers Road

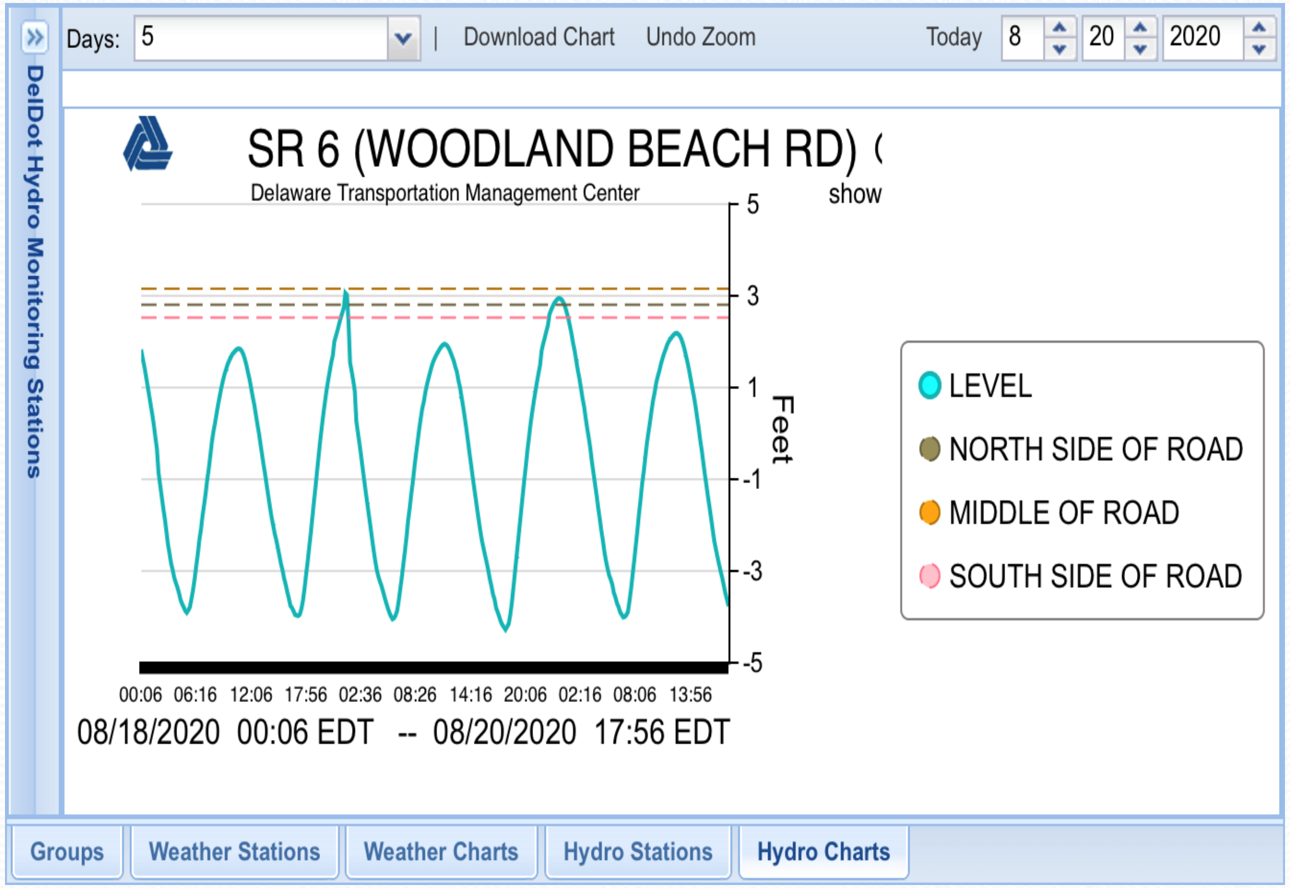
Woodland Beach Road, SR 6, east of Smyrna

- One-way-in, one-way-out access road to beach community
- Roadway sees many overtopping events
- Have been past evacuations of community
- Water on Road warning sign system is active
- Working with UD on low-cost sensor deployment
- Longer term solution sought
  - Underlying soil stabilization
  - Lightweight aggregate fill to raise roadway
  - Pile supported roadway slabs in low lying areas

Woodland Beach Road - Update

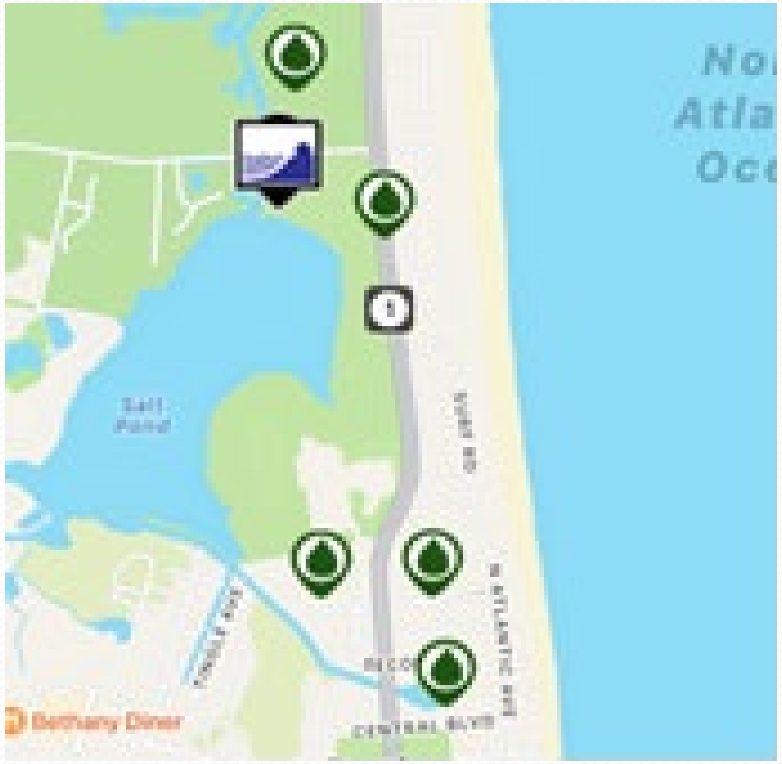
- Pave & Rehab plans complete
- Similar roadway elevation plan as South Bowers Road
- Short-term mitigation project
- Long-term ….TBD

Warning Signage



Warning Signage

- TMC and IT working on app to notify commuters
- Use existing gauge/roadway information
- Link to DelDOT website will be included in notification
- Testing ongoing
- Deployment in the fall



Latest State S&P Bond Rating Report

(Summer 2022)

"We consider the social and governance risks of DelDOT's pledged revenue neutral in our credit rating analysis and consistent with similar obligations secured by motor vehicle fuel and related taxes. However, Delaware is the lowest-lying state, exposing the pledged revenue to potential disruptions from environmental physical risks such as flooding and sea level rise. We believe the department's efforts, including creation of a division of resiliency and sustainability that consolidates existing programs and new organizational priorities under one roof in May 2021, is an important mitigant to offset these acute and chronic risks. In addition, the costs associated with resiliency infrastructure are being incorporated into the proposed fiscal 2023-2028 capital program, as it was expanded by $67 million to include a carbon reduction program and a resiliency and sustainability program."

Thank you for your time and attention

Jim Pappas

james.pappas@delaware.gov

TRB Webinar: State DOTs Perspective on Pavement Resilience

November 30, 2022

Tyson D. Rupnow, Ph.D., P.E.
Associate Director, Research

Outline

- Background
- Summary of major events
- Research efforts
- Discussion points

Background

- Resiliency is a new buzz word for many SHA's
- Encompasses many areas of work
  - Each SHA will have their own particular issues
    - Flooding
    - Subsidence
    - Fires
    - New / alternative roadway use
    - Mudslides, landslides, blizzard, etc.
    - Power outages
- Each of the issues requires a different approach to solve

Summary of Major Events

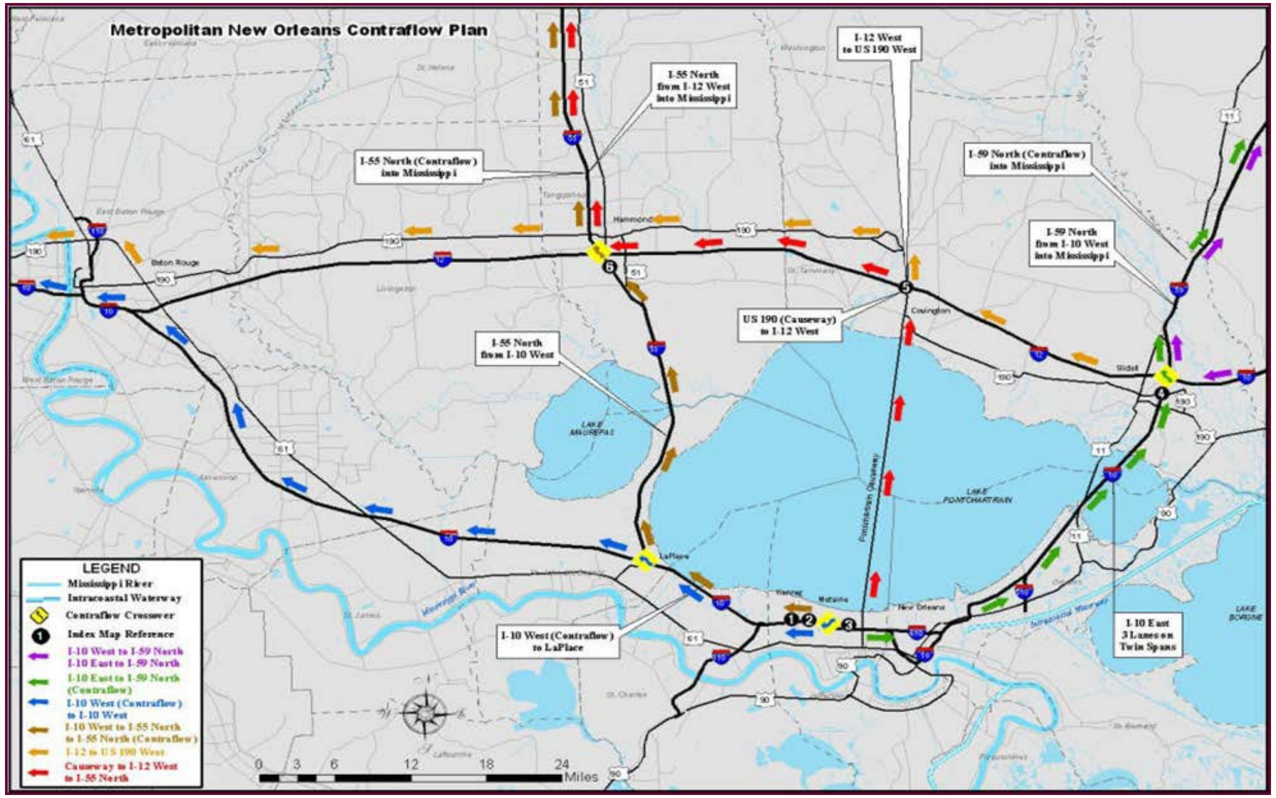
- Katrina
- Rita
- Laura
- 2016 flooding event
- Summary

Katrina

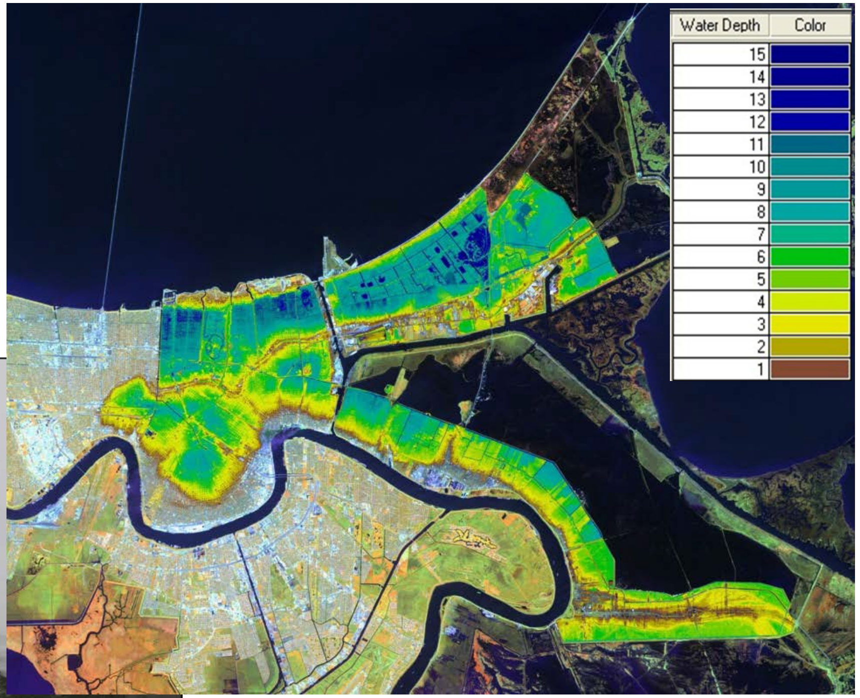
- August 29, 2005
- Until nearly 10 years later was the largest natural disaster in US history

Katrina

- Largest evacuation in the history of America



Katrina



Katrina

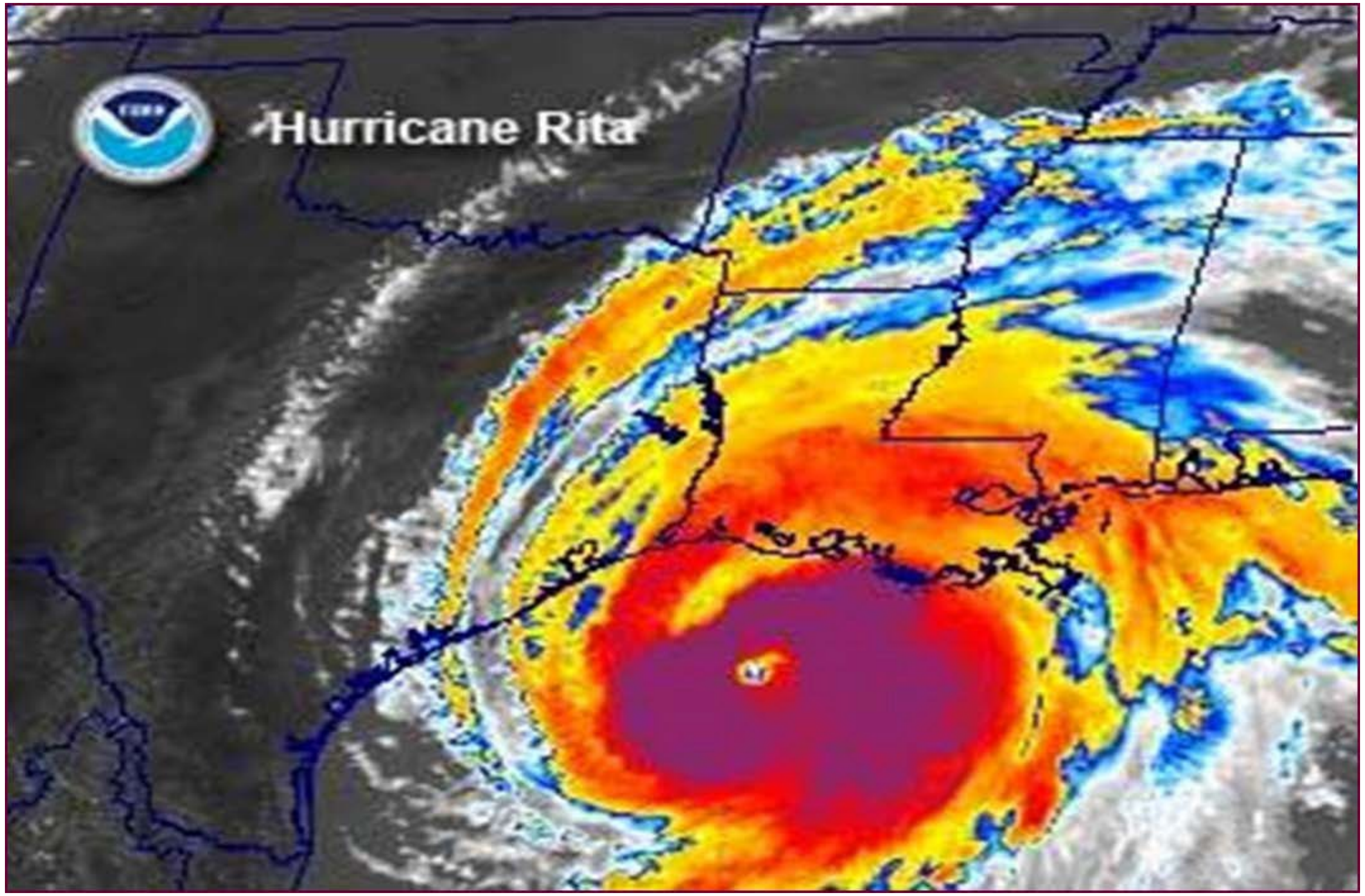
Katrina – Twin Spans

- EB
  - Lost 38 spans
  - 170 spans shifted alignment
  - 130’ barrier rail damaged
- WB
  - 26 spans lost
  - 303 spans shifter alignment
  - 13,910 barrier rail damaged
- Major bearing damage on BOTH directions

Katrina

Rita

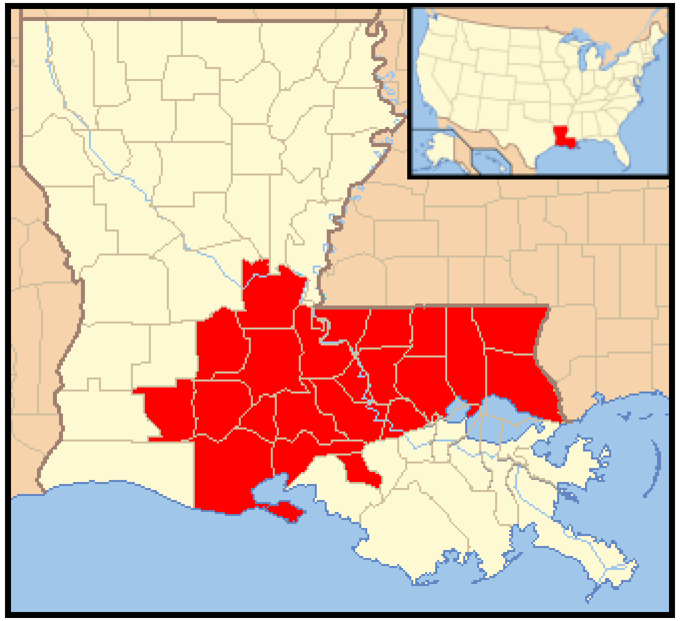
- September 24, 2005



Rita

2016 Flooding Event

- August 11, 2016
- 7.1 trillion gallons of water fell from the sky
  - 31.4 inches of rain in Watson, LA
- 10 rivers at record flood stage
- Livingston Parish
  - 75% of homes and businesses = total loss
- >175,000 homes and businesses affected

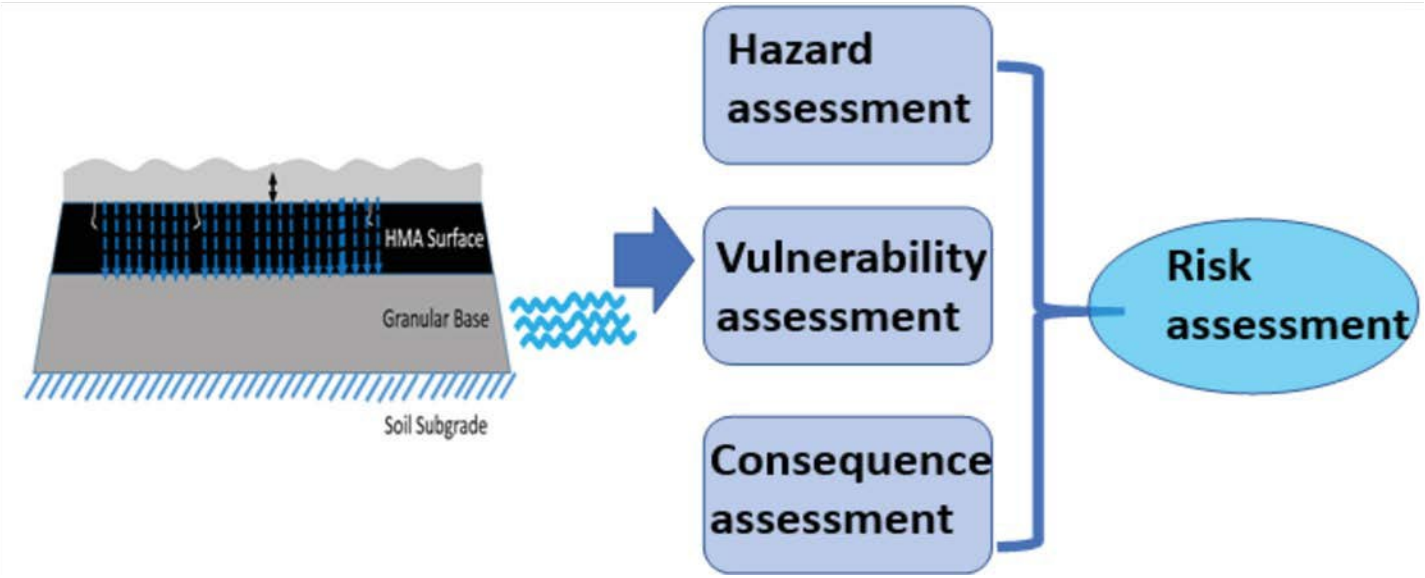


2016 Flooding Event

2016 Flooding Event

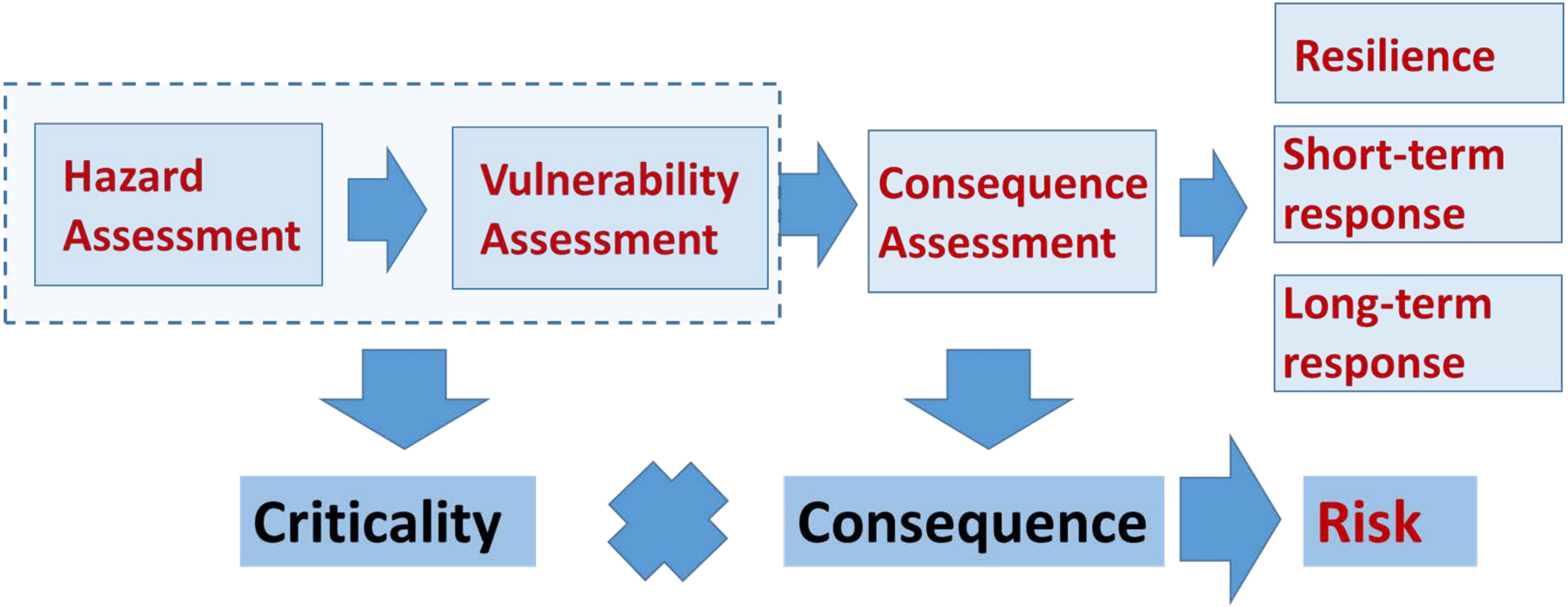
Research

- Best Practices for Assessing Roadway Damages Caused By Flooding
- Developed engineering protocol levels



Research

$$\text{RF}= \boldsymbol{Hazard\ Factor} \times \boldsymbol{Vulnerability\ Factor} \times \boldsymbol{Consequence\ Factor}$$



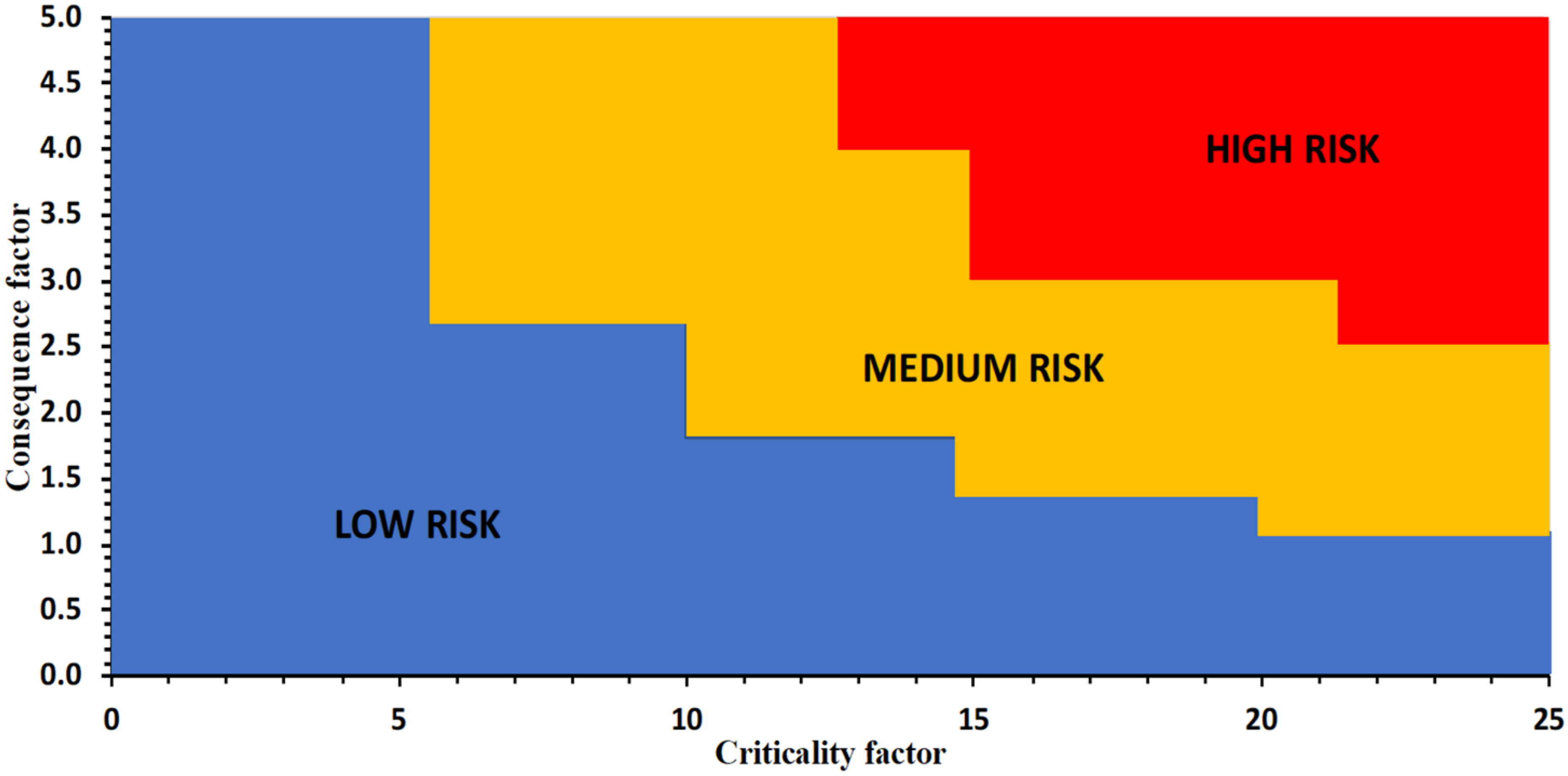
Research

$$CF = w_{RC} * RC + w_{CD} * CD$$

Functional class of roadways	replacement/ repair cost
Interstates & Other Arterials	5
Collectors	3
Local roads	1

Traffic volume (AADT)	cost of service restriction to drivers
>3,000	5
400-3,000	3
<400	1

Research



HIGH RISK
MEDIUM RISK
LOW RISK
Consequence factor
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
0
5
10
15
20
25
Criticality factor

Research

- 3 Levels
  - Level 3 – field reconnaissance
  - Level 2 – field reconnaissance + NDT
  - Level 1 – field reconnaissance + NDT + hydraulic and pavement performance analyses

Research

- DOT's and *local agencies* regularly monitor roadways documenting existing conditions
- Final Report
  - https://www.ltrc.lsu.edu/pdf/2020/FR_615.pdf
- Technical Summary
  - https://www.ltrc.lsu.edu/pdf/2020/ts_615.pdf

Discussion Points

- Who pays for resilience?
- How to prioritize?
- What policy, or policies, need to be changed?
  - Extends to laws, design procedures, etc.
- Local, state, and federal politics ALL play a role


Google Earth
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4.65 ft.

Recent Climate Stressors in Colorado

Craig Wieden – CDOT State Materials Engineer

Presentation Overview

- CDOT's Resiliency Program Overview and Process
- Common Resiliency Stressors in CO that we currently consider
- Recent Stressor Examples
  - 2020 Grizzly Creek Fire - Glenwood Canyon
  - 2021 Glenwood Canyon Post Fire Debris Flows
- Gaps and Needs

Photo courtesy USFS – White River National Forest

Overview of CDOT's Resiliency Program

- Policy Directive 1905.0 – the vision for resilience at CDOT - 2018
  - Works to integrate resilience in CDOT functions in advance
  - Coordinates resilience activities at CDOT
  - Conducts research to support resilience
  - Provides resiliency knowledge and resources to CDOT staff
- Acknowledgment: Lizzie Kemp – CDOT Resiliency Program Manager

COLORADO DEPARTMENT OF TRANSPORTATION			■ POLICY DIRECTIVE ☐ PROCEDURAL DIRECTIVE
Subject **Building Resilience into Transportation Infrastructure and Operations**			Number **1905.0**
Effective **11/15/18**	Supersedes **New**	Originating Office **Division of Transportation Development**	

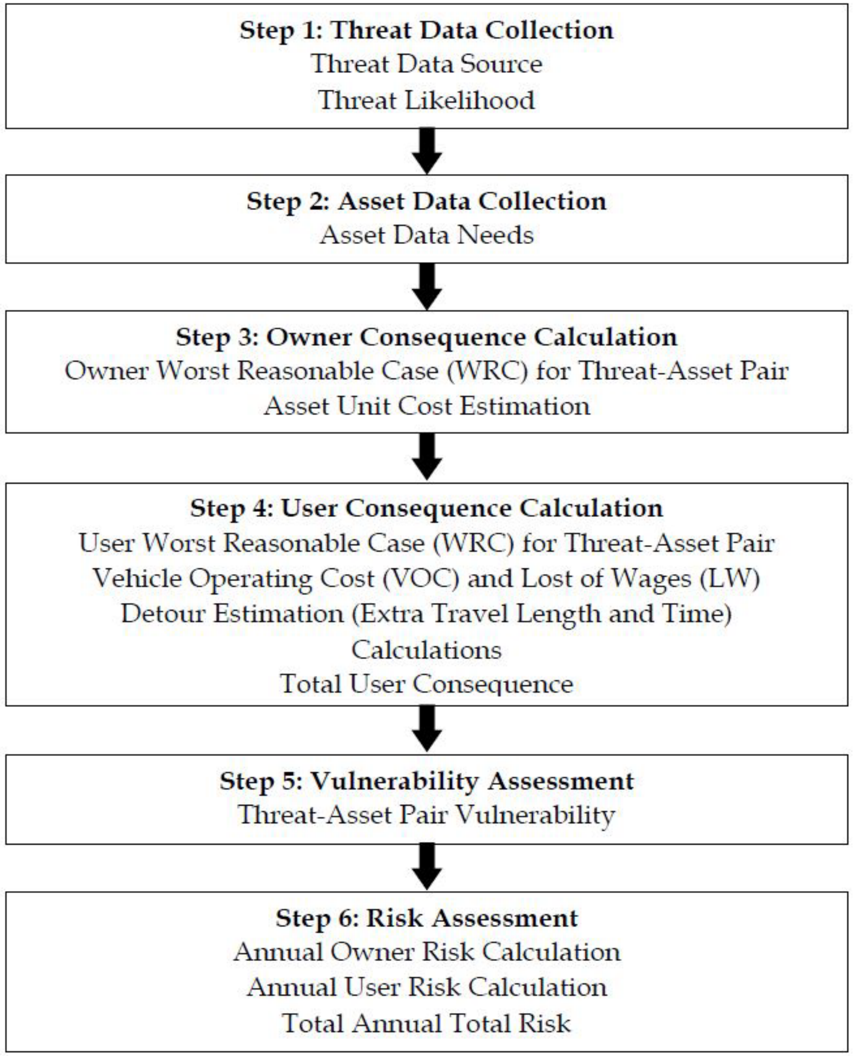
I. PURPOSE

The purpose of this Policy Directive is to implement the principles of resilience into Colorado's transportation system practices. This will enable the Colorado Department of Transportation to proactively manage risks, minimize disruptions and adapt to changing conditions in order to provide continuous transportation service in Colorado. Colorado's transportation infrastructure directly or indirectly affects the lives of all people living in the state, and provides the essential services that underpin the state's economy and the movement of people, goods, and information. Maintaining a secure, functioning, and resilient infrastructure is critical to the state's safety, prosperity, and well-being.

The benefits or resilience are widespread, including fiscal benefits by saving the state money, social and economic benefits, by saving the public time and ensuring timely access to markets for businesses, and safety benefits, by taking action before a disruption becomes disastrous.

Resiliency Analysis Process

- Conduct a Quantitative Risk Assessment estimating:
  - Threat (Stressor) source and likelihood
  - Asset data needs
  - Owner consequences calculation
    - Cost to repair/replace the asset
    - Cleanup costs
  - User consequence calculation
    - Vehicle Operating Cost
    - Value of time associated with detour/delay
  - Vulnerability Assessment
  - Risk Assessment
    - Annual owner risk calculation
    - Annual user risk Calculation
    - Total Annual Risk
  - Perform Benefit/Cost Analysis



Common Stressors in Colorado

- Flooding
- Rockfall
- Landslides
- Sinkholes
- Wildfires
- Post Fire Debris Flows

2020 Grizzly Creek Fire

2020 Grizzly Creek Fire

- Fire began in August of 2020
- 13-day full Interstate Closure

2021 Glenwood Debris Flows

2021 Post Fire Debris Flows

- Relatively minor events June into July
- 1 or 2 day closures in general

2021 Glenwood Debris Flows

2021 Post Fire Debris Flows

- July 29th and 31st Events

2021 Glenwood Debris Flows

2021 Post Fire Debris Flows

- July 29th and 31st Events

2021 Glenwood Debris Flows

Gaps and Needs

R&R Analysis Guidance
- Modeling recurrence interval or magnitude?
- Modeling resolution?
- Cost estimates?
- Ground truth/discrete measurement points
- Annual Risk/Recalibration

Partner Agencies Listing/Roles
Detour routes – location and hardening
Operational planning
Mitigation Timing
Lessons Learned

TRB Webinar
State DOTs Perspective on Pavement Resilience

Steven Olmsted – Arizona Department of Transportation – November 2022

Agency Snapshot

Arizona

- 140,000 maintenance lane miles
- 8,000 bridges
- 1 International border

ADOT

- 30,000 maintenance lane miles connecting those 140,000
- 5,000 bridges
- 7 maintenance/construction districts
- 1,500 facility buildings

Spread over 114,000 square miles
Operating from sea level to 8,000 feet
Temperatures below 0°F to over 120°F

Agency Resilience

Critical Transportation Infrastructure Protection

State

- Arizona State Emergency Response and Recovery Plan (SERRP)
- Planning Branch – AZ Department of Emergency and Military Affairs

ADOT

- Emergency Preparedness Management
- Business Continuity - pandemic - Director's Office revamp
- Roadway - Incident Response Unit
- Physical, chemical, biological – dedicated Emergency Manager
- Road Weather AZ 511 app / ADOT Alerts app
- Cyber - IT Security Risk Management & Compliance team
- Transportation Infrastructure - Weather & Natural Hazard

Transportation Infrastructure Resilience

FHWA 5520 - anticipate, prepare for, and adapt to changing conditions and withstand, respond to, and recover rapidly from disruptions

Program Definition - The management of assets (bridges, culverts, pavement, and roadside vegetation/stabilization) in relation to the extreme weather-climate risks of; intense precipitation, system flooding, wildfires, wildfire-induced floods, drought-related dust storms, rockfall incidents, slope failures, and measurable climate trends (especially as it relates to precipitation and direct effects of increased surface temperatures); by regions or specific segments, emphasized as critical to contribute to the safety of the traveling public, improve weather and natural hazard risk management, and improve the long term life cycle planning of transportation infrastructure.

Eligible Risk Inventory

- Agency - political, financial, reputational
- Environmental - natural hazard, extreme weather, future climate
- Infrastructure - road and bridge failure
    - Intense Precipitation
    - System Flooding
    - Wildfires
    - Wildfire-Induced Floods
    - Drought-Related Dust Storms
    - Rockfall Incidents
    - Slope Failures and Subsidence
    - Increased Surface Temperatures

Eligible Risk Inventory

Eligible Risk Inventory

Eligible Risk Inventory

Eligible Risk Inventory

Eligible Risk Inventory

Eligible Risk Inventory

Asset Management Connection

Risk Category	Risk Event (Risk Owner)	L^*	X	$C^\dagger$	=	$R^\ddagger$	Risk Mitigation	Heat Type
	3. Extreme weather trends (Environmental Planning Resilience Program, Districts, Transportation System Management & Operations [TSMO])	5	x	4	=	20	Implementation of ADOT's Resilience Program 2021/22 Work Plan. Pump station reliability tool implemented. Complete probabilistic risk modeling development for bridge design.	VERY HIGH

1.5 Risk Management

The importance of considering risk in the management of transportation assets is highlighted by the federal requirement to develop a risk-based TAMP. ADOT maintains a risk register that identifies risks, assigns ratings, defines risk ownership, and provides a high-level summary of the recommended risk mitigations. Although this TAMP focuses on bridges and pavements, the risk analysis includes consideration of other assets on the NHS and SHS. There are 33 total risks identified in this TAMP, of which 17 are high and very high priority. Mitigations are recommended for these high priority risks, which include extreme weather, inadequate funding, staff attrition, and flooding damage, among others. Risks directly associated with bridges and pavements were incorporated into the TAMP analysis and included:

Resilience Life Cycle Planning

ADOT

A Climate Engineering Assessment for Transportation Assets (CEA-TA)
Incorporating Probabilistic Analysis into Extreme Weather and Climate Change Design Engineering

Steven Olmsted, Arizona Department of Transportation; Alan O'Connor, Trinity College Dublin; Constantine Samaras, Carnegie Mellon University; Beatriz Martinez-Pastor, Trinity College Dublin; Lauren Cook, Carnegie Mellon University

Abstract

Transportation infrastructure is a complex system of assets required to deliver a myriad of services and functions. As fiscal constraint for the development and rehabilitation of such structures remains; and endless retrofitting continues to be cost prohibitive; new and novel approaches to long term planning and project development, engineering design, and life cycle assessment are paramount. The management of these infrastructure systems has now evolved from a decentralized, project-based focus, to one that now encompasses enterprise wide endeavors – administration, technology adoption, planning, design, construction, operations and maintenance. In addition, the expansion of risk analysis for extreme weather management and climate change adaptation has complicated the long term delivery of these complex transportation systems. At the 2015 Transportation Research Board (TRB) Annual Meeting, Session 197: *Mainstreaming Climate Change and Extreme Weather Resilience into Transportation*, the Arizona Department of Transportation (ADOT) introduced the challenge ahead for public entities to coordinate a host of known and unknown extreme weather and climate change issues. That challenge – Continue considering the balance between predictable asset deterioration curves, the sudden and unpredictable nature of extreme weather events and long term climate trends, new models for risk assessment and life cycle cost analysis, and appropriate adaptation strategies. This multiple part challenge necessitated a new end-to-end engineering approach to incorporate such current and future risks. At the 2016 Annual Meeting ADOT submitted a paper representing the core of that new approach – a Resilience Program and an ADOT/United States Geological Survey Partnership. That paper was graciously recognized as a best paper by the TRB Special Task Force on Climate Change and Energy. In the spirit of continuing that forward progress – this paper presents the remaining parts needed to develop a new end-to-end engineering-based asset adaption process – a structured sequence to incorporate extreme weather and climate change adaptation into the design engineering process. The paper benefits from preeminent researchers in the two integral, and practice ready, remaining parts – probabilistic modeling for engineering design and infrastructure system design life cycle outcomes for extreme weather and climate change in a transportation engineering setting.

Arizona DOT Resilience Program

Transportation infrastructure is a complex system of assets required to deliver a myriad of services and functions. The expansion of risk development for extreme weather management and climate change adaptation has complicated the long term delivery of these complex transportation systems.

In order to develop an innovative approach, the first step was to create a system process that allowed for a shift from a deterministic preset design parameter and/or frequency basis, statistical risk of failure, and historic project and programs budgeting focus – i.e. extreme events not considered – to a probabilistic analysis approach that inputs additional data, vulnerabilities, and considerations not previously considered. In 2015 and 2016 ADOT focused on linking scientific evidence-driven data capture with the design engineering processes through the development of a partnership with the United States Geological Society (USGS). Extensive 2-D/3-D engineered modeling underway.

(CEA-TA) – A Structured Sequence

Identify EX W & CC project and program candidates - *Vulnerability Assessment*

2015 FHWA Pilot Project - The study examined baseline (historical) and potential future extreme weather conditions, focusing on temperature and precipitation variables. Two future analysis periods were selected: 2025 to 2055 (referred to subsequently as 2040, the median year), which reflects the time horizon of ongoing long-range planning efforts, and 2065 to 2095 (2080), roughly associated with the expected design lifespans of some critical infrastructure types, such as bridges. To provide a long term baseline against which to compare the projections, the team also examined temperature and precipitation observations from 1950 through 1999. The report was issued by FHWA in the Spring of 2016.

WHY IS MOVING TO A PROBABILISTIC APPROACH EVEN NEEDED?

This question could cover pages and pages. The short answer is easy. In addition to sustainable transportation attributes, there is growing consensus that if transportation systems are going to incorporate extreme weather and climate change, consideration must be developed that account for hydrometeorology/climatology, hydrology, hydraulics, and hydrodynamics. Since all these areas continue to adopt advanced mathematical modeling approaches, it is therefore logical that transportation systems and projects develop also incorporate these progressions.

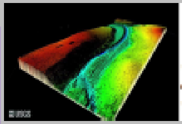
Develop economic analysis process - *Justification*

An economic analysis for the CEA-TA process would consist of using a probabilistic approach to life cycle cost analysis. The life cycle cost of an infrastructure asset such as a roadway or bridge, is the total cost to an agency throughout the asset's useful life. This includes the planning, design, construction, maintenance and decommissioning phases of infrastructure delivery. State DOTs typically initially approach this process without considering risk and uncertainty that future conditions will be different from the past, and assume a uniform distribution of annual maintenance costs and major reinvestment intervals. Long-lived infrastructure must perform under future climate conditions and climate-influenced usage that deviates from the historical data now populating infrastructure economic analysis and asset management models. Climate change impacts, such as sea-level rise, storm surges, changes in precipitation, hotter temperatures, and others are potential vectors of infrastructure failure and should be taken into consideration in infrastructure economic analysis and asset management models.

Resilience Program
Economic Analysis Pilot
US 191 MP 436 to Chinle
PROJECT NO. 191 AP 436 H8676 01 C
FEDERAL AID NO. STP-191-E(214)T
Apache County
Holbrook District

Design probabilistic modeling approach to produce an array of results - *Quality Control*

Optimize operation and maintenance of an increasingly aging stock, which is subjected to evolving loads (e.g. both live loading and climate induced loading). In response to this challenge the past decade has seen increased interest by infrastructure owners and managers in the use of probabilistic methods for the assessment/management of their assets. Employed once a deterministic assessment has rendered a repair/rehabilitate/replace now scenario

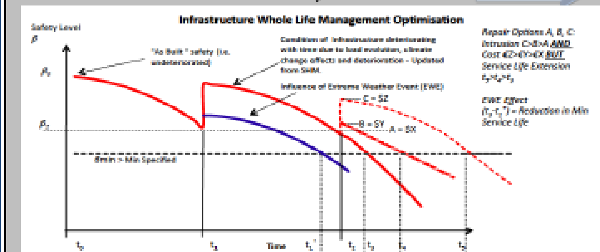


Define limits of simulation runs that incorporates latest science/engineering - *Policy*

Climate models can provide insight into future conditions, projecting air temperature, precipitation, evapotranspiration, and other factors of interest to engineers, at various temporal and spatial resolutions. However, there is a considerable disparity in the outputs provided from climate models for impacts analyses and the inputs needed by engineers for planning and design. These discrepancies include mismatches in temporal and spatial scales, complicated data extraction and preparation requirements, sizeable model, data, and scenario uncertainties, and a lack of direction for the rigorous selection of models for use in different engineering applications.

Innovative change examples:

- Every Day Counts – 4 : Collaborative Hydraulics: Advancing to the Next Generation of Engineering (CHANGE)
- NCHRP 15-61 - Applying Climate Change Information to Hydrologic and Hydraulic Design of Transportation Infrastructure
- NCAR - *The Future Intensification of Hourly Precipitation Extremes* - Andreas F. Prein et al. December 2016
- LiDAR, UAS/UAV, 2-D water modeling, 3-D visualization and animation tools
- Translational organizations to provide rigorous standards for interpretation of climate data, development of a single, simplified user interface that accesses all downscaled data sources, and tools that automatically post-process data based on defined standards



Systematically record location and resilience efforts GIS/TAMP - *Risk Management*

ADOT has been systematically capturing data sets for extreme weather and climate change use through an extensive geographic information system (GIS) effort that will subsequently support ADOT's transportation asset management planning (TAMP). ADOT's studies showed concerns with the climate and extreme weather vulnerability of bridges, culverts, pavement, and roadside vegetation / stabilization. Legislation - Focus in MAP-21 on performance based management and risk-based asset management plans; Inclusion of "resilience" in FAST Act.

Develop life cycle models to monitor investment - *BCA/ROI*

Civil infrastructure systems are among the largest local, state and Federal investments, and these infrastructure systems are critical to U.S. economic, environmental and social outcomes. Yet longstanding underinvestment in infrastructure has resulted in the poor condition of much of U.S. infrastructure, with an estimated $3.6 trillion of re-investment needed by 2020. New methods for benefit cost analysis, return on investment studies, and major rehabilitation timeline analyses are needed that incorporate probabilistic approaches, and minimize regret by DOTs under a changing climate. The results of CEA-TA provides that method.

Acknowledgments

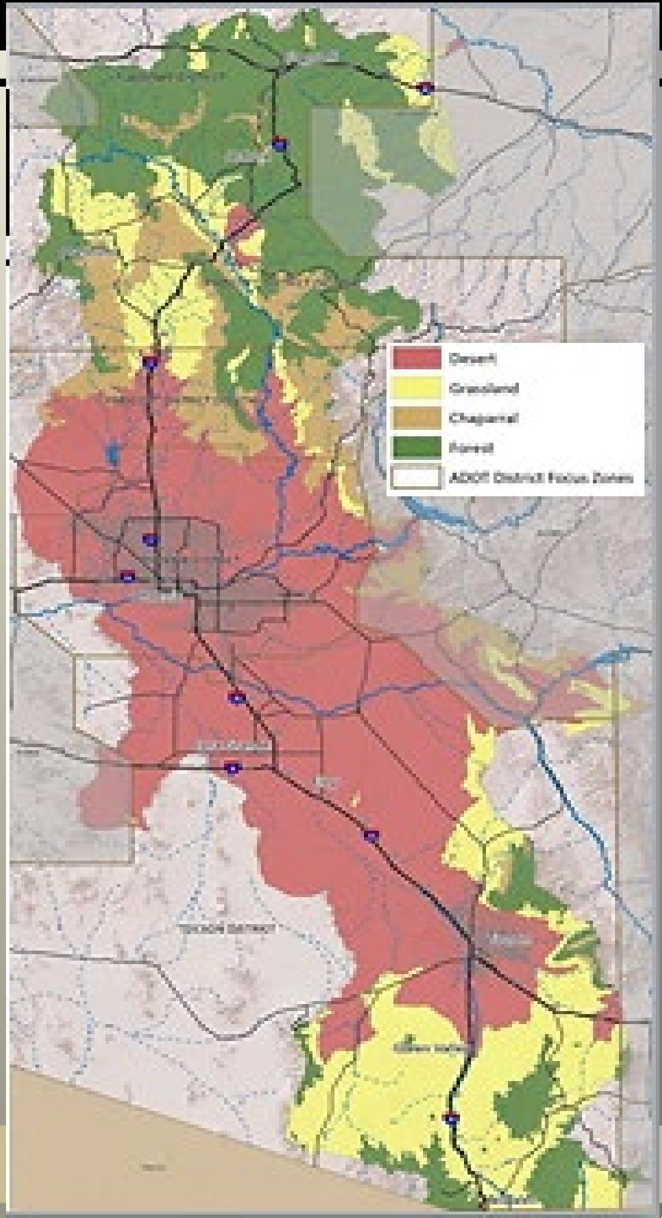
The completion of this project would not have possible without assistance from many stakeholders both within and outside ADOT that contributed to this effort. Specifically, the International Symposium - *Transportation Resilience: Adaptation to Climate Change and Extreme Weather Events*, June 16-17, 2016 at the European Commission in Brussels, Belgium that was the catalyst for the transatlantic partnering. The ADOT author wishes to acknowledge the efforts and support of: ADOT State Engineer's Office and ADOT Environmental Planning.

Resilience Building Example #1

State Route 191 - Mile Post 436 to Chinle – Chinle, AZ – Navajo Nation

Develop Geographic Specific Climate Models

- Large, geographically diverse study area (over 30,000 square miles)
- High spatial resolution climate data desired
- Stressors included both average and extreme temperature and precipitation
- Helpful existing tools (e.g., FHWA CMIP Processer), but customization required
- Modest resources for collection and processing



Climate Data Selection

Parameter	Specification
Projections and Historical Data Source	Downscaled CMIP5 Bias Corrected Constructed Analogs (BCCA) daily projections with accompanying historical data
Emissions Pathway	Representative Concentration Pathway 8.5
Downscaled General Circulation Models (GCM)	NorESM1-M, HadGEM2-ES, CSIRO-MK3.6, CanESM2, MPI-ESM-LR, MPI-ESM-P, GFDL-ESM2M
Horizontal Spatial Resolution	1/8° (~7.5 mile or ~12km)
Temporal Resolution	Daily for 1950-2000 (backcastings from models in addition to historical data), 2025-2055, and 2065-2095
Model Outputs	Temperature (daily maximum and minimum) and precipitation (daily total)

Climate Output Metrics

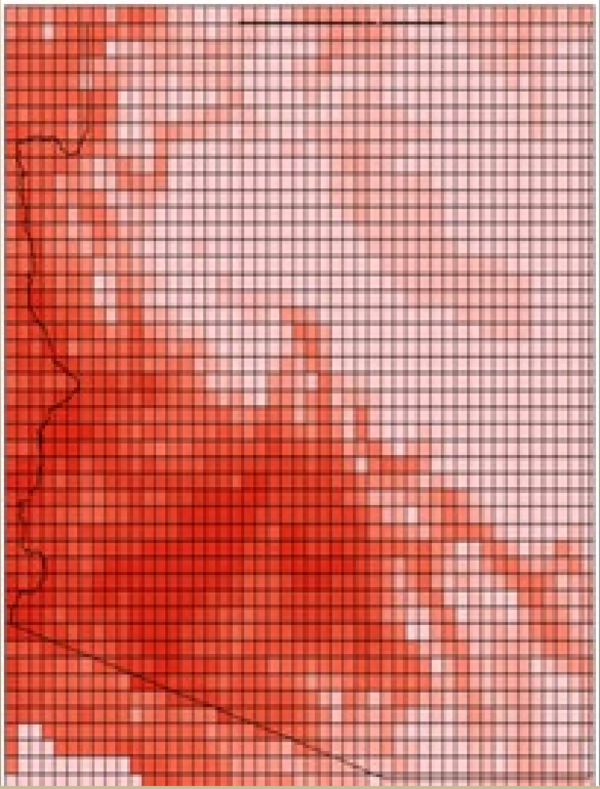
Maximum 1-Day Precipitation Event (by time period)
100-/200-Year Maximum Precipitation Event using Generalized Extreme Value distribution
Minimum Annual Precipitation
Average Annual Precipitation
Average Number of Days Per Year in which Precipitation Exceeds Baseline Period's 99th-Percentile Precipitation Event
Average May-June-July-August Precipitation
Average Daily Maximum Temperature
Average Number of Days Per Year in which Temperature equals or exceeds 100 degrees
Average Number of Days Per Year in which Temperature equals or exceeds 110 degrees
Average Number of Days Per Year in which Temperature falls below or is equal to 32 degrees
Average Daily Minimum Temperature

Climate Models (19 Models x 2 RCP scenarios)

Modeling Center (or Group)	Institute ID	Model Name
Commonwealth Scientific and Industrial Research Organization (CSIRO) and Bureau of Meteorology (BOM), Australia	CSIRO-BOM	ACCESS1.0
Beijing Climate Center, China Meteorological Administration	BCC	BCC-CSM1.1
Canadian Centre for Climate Modeling and Analysis	CCCMA	CanESM2
National Center for Atmospheric Research	NCAR	CCSM4
Community Earth System Model Contributors	NSF-DOE-NCAR	CESM1(BGC)
Centre National de Recherches Météorologiques / Centre Européen de Recherche et Formation Avancée en Calcul Scientifique	CNRM-CERFACS	CNRM-CM5
Commonwealth Scientific and Industrial Research Organization in collaboration with Queensland Climate Change Centre of Excellence	CSIRO-QCCCE	CSIRO-Mk3.6.0
NOAA Geophysical Fluid Dynamics Laboratory	NOAA GFDL	GFDL-ESM2G GFDL-ESM2M
Institute for Numerical Mathematics	INM	INM-CM4
Institute Pierre-Simon Laplace	IPSL	IPSL-CM5A-LR IPSL-CM5A-MR
Japan Agency for Marine-Earth Science and Technology, Atmosphere and Ocean Research Institute, and National Institute for Environmental Studies	MIROC	MIROC-ESM MIROC-ESM-CHEM MIROC5
Max Planck Institute for Meteorology	MPI-M	MPI-ESM-LR MPI-ESM-MR
Meteorological Research Institute	MRI	MRI-CGCM3
Norwegian Climate Centre	NCC	NORESM1-ME

Climate Data Outputs

- Arizona was laid out in 12 km x 12 km grid (total of 2680 grid elements)
- Grids are consistent with format of downscaled climate data
- Nineteen (19) climate models
- Considered two time periods
  - 2025-2055
  - 2065-2095



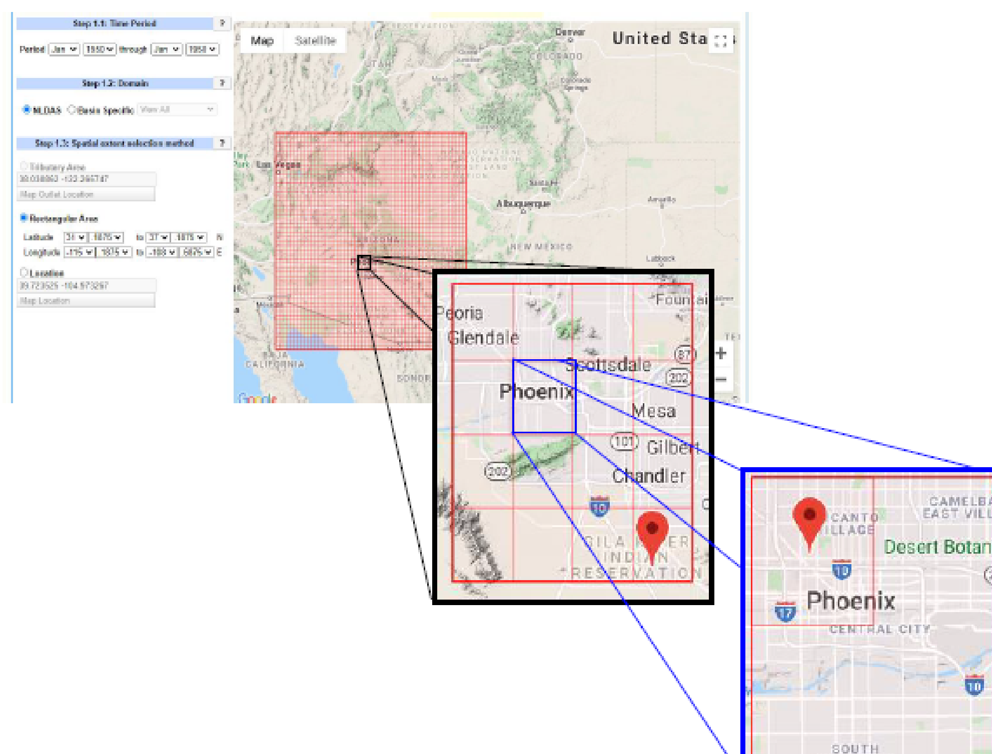
FHWA Pooled Fund Project – Solicitation 1542

Demonstration to Advance New Pavement Technologies

Project - AZ DOT Climate Modeling and Pavement Performance Study
Binder Grade and Freeze Thaw (2022 – '23)

GCM Data Access

- Bulk download from archives for 18 GCMs
  - High resolution ~ 5.9 TB
  - Lower resolution ~ 1.1 TB
- Climate variables
  - Daily maximum temperature
  - Daily minimum temperature
  - Daily precipitation



Resilience and Asset Management Resources

Current resources:

1. Guidance on *Incorporating Risk Management into Transportation Asset Management Plans* (2017) (FHWA 2017b).
2. Guidance on *Using a Life Cycle Planning Process to Support Asset Management* (2017) (FHWA 2017f).
3. Asset Management, Extreme Weather, and Proxy Indicators Pilot Program (2017-2019).
4. **NHI Course**: Addressing Climate Resilience in Highway Project Development and Preliminary Design - NHI 142085 (2022)

Coming soon (under development):

1. *Addressing Resilience to Climate Change and Extreme Weather in Transportation Asset Management.*

NEW: Transportation Pooled Fund on Resilience

New Pooled Fund Project:

Resilience Approaches for Pavements and Geotechnical Assets

TPF TRANSPORTATION POOLED FUND

Solicitations Studies Tools Help

Transportation Pooled Fund - Solicitation Details

Home › Solicitations › Resilience Approaches for Pavements and Geotechnical Assets

Resilience Approaches for Pavements and Geotechnical Assets

Print

General Information

Solicitation Number:	1590
Status:	Solicitation posted
Date Posted:	Nov 23, 2022
Last Updated:	Nov 23, 2022
Solicitation Expires:	Nov 23, 2023
Partners:	VA
Lead Organization:	Virginia Department of Transportation

Financial Summary

Commitment Start Year:	2023
Commitment End Year:	2027
100% SP&R Approval:	Not Requested
Commitments Required:	$500,000.00
Commitments Received:	$50,000.00

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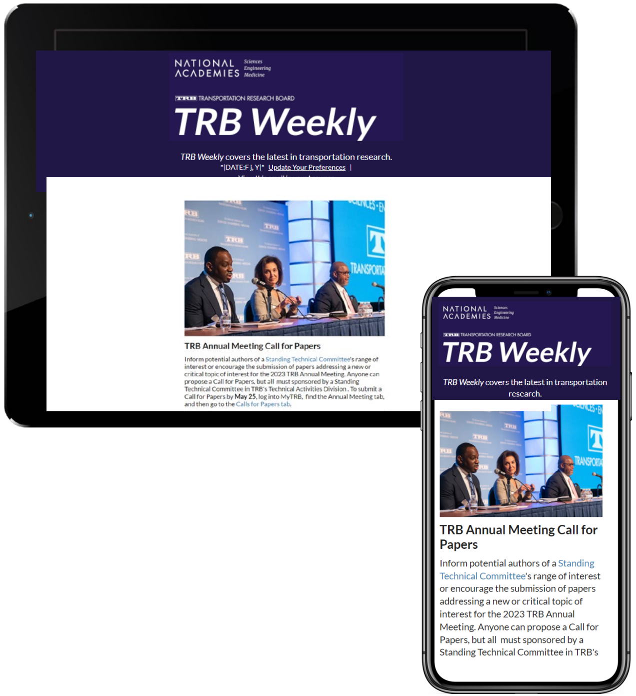

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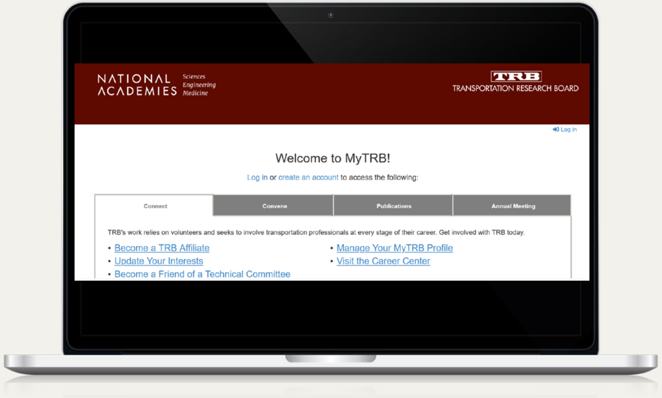

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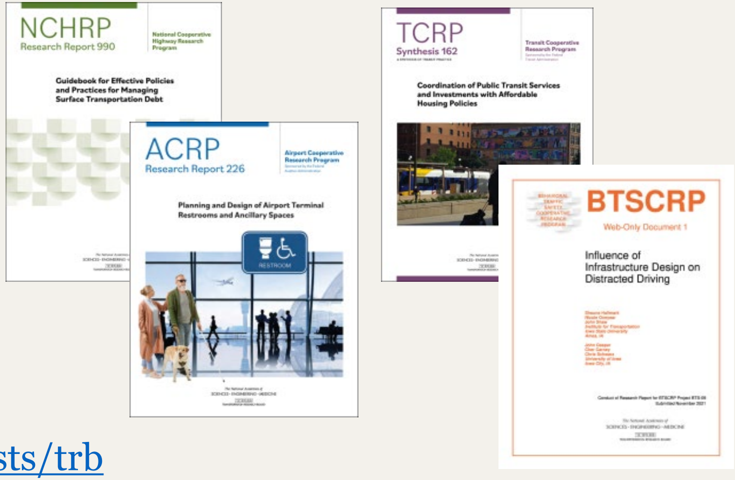

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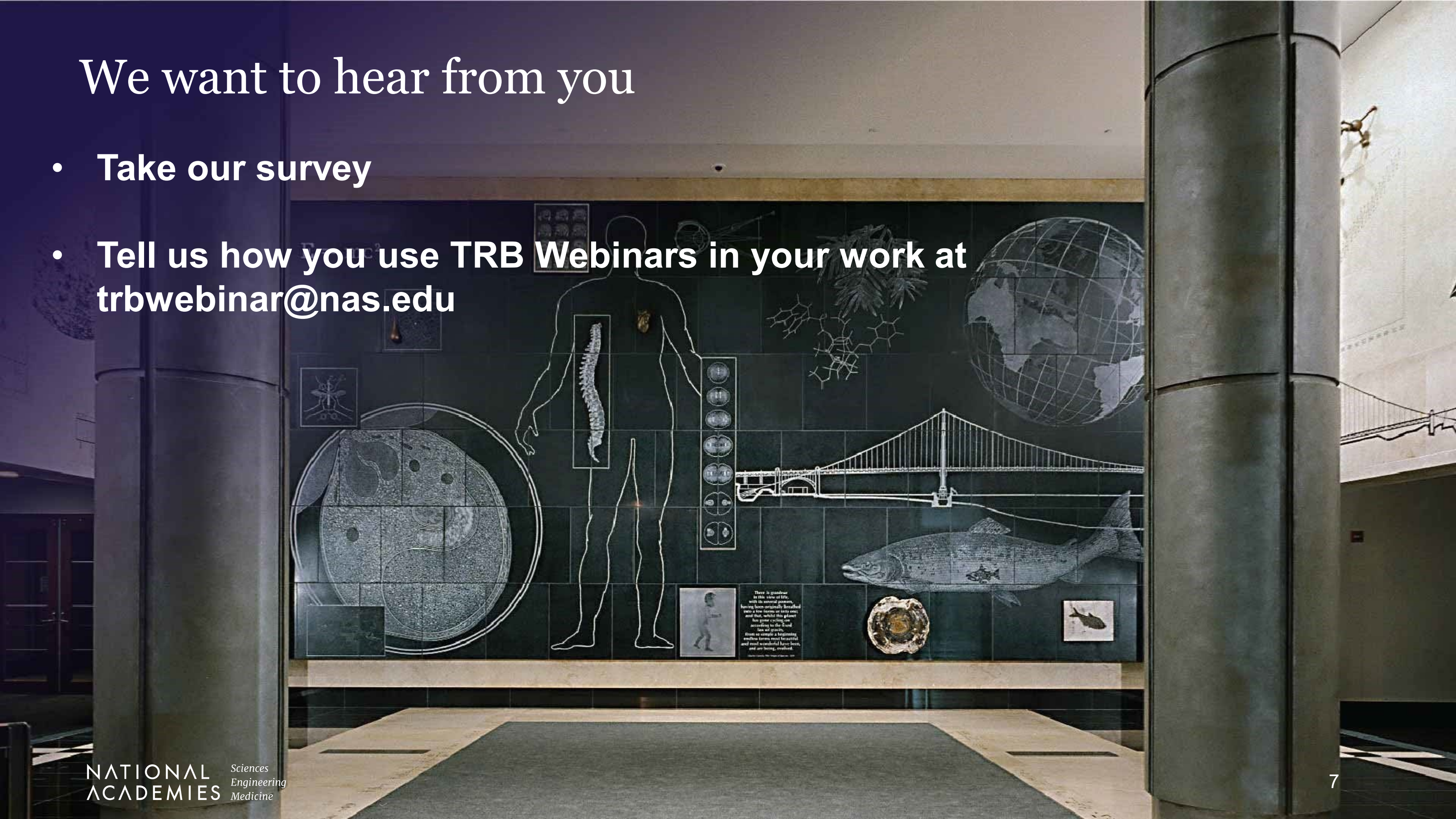

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