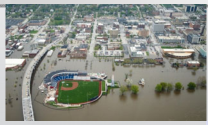
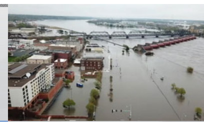




Resiliency Planning and Design for Transportation Systems

Jason Bird - Jacobs
Tammy Nicholson- Iowa DOT

ACEC Conference 9/11/2019

Presenter Introductions

Jason Bird, CFM, Jacobs
- FL Resilience Practice Leader
- US South Water Resources Lead
- UNDRR ARISE US Network Chairman

Tammy Nicholson, Iowa DOT
- Director, Location and Environment Bureau
- Iowa DOT Resiliency Working Group

Resiliency Planning and Design for Transportation Systems, Agenda: 3:20 - 4:00 pm

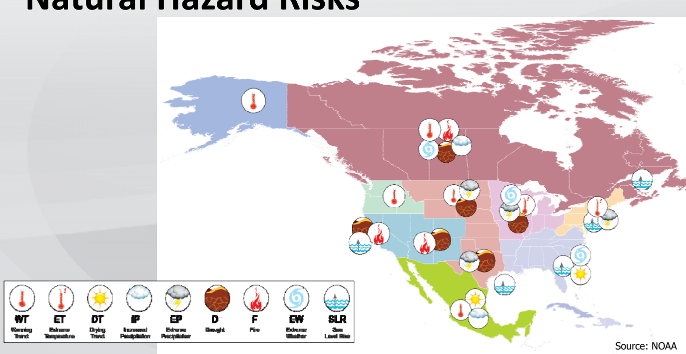
1. **The Resilient Approach**
   - Natural Hazard risks and how they evolve
   - Risk mitigation and adaptation
2. **Industry Trends and Case Studies**
   - Florida DOT Enhanced Standards
   - Southeast Florida Municipal Road Project
   - Tamiami Trail & A1A
   - US 34, Colorado
3. **Resilient Response in Iowa**
   - Pilot Studies and Planning
   - Research and Project Prioritization
   - 2019 Flood Recovery

Natural Hazard Risks

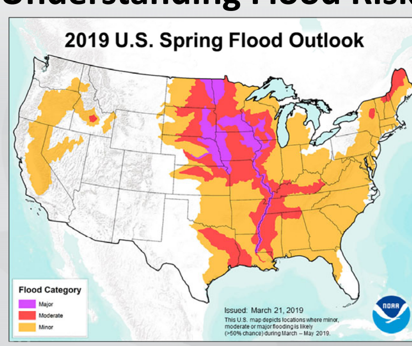
- Severe weather hazards vary by region
  - Exacerbated by climate change.
  - Focus on hazards with most frequent impacts.
  - Flooding is a top priority in Iowa.

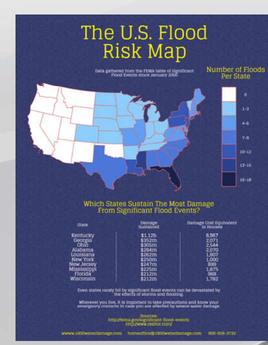
Climate influences many aspects of infrastructure planning, design and operations… in different ways.

Natural Hazard Risks

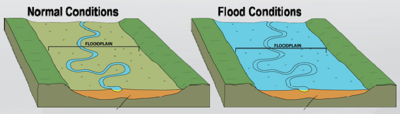


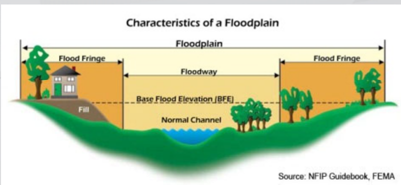
Understanding Flood Risk





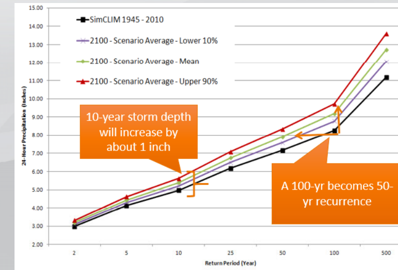
Understanding Flood Risk





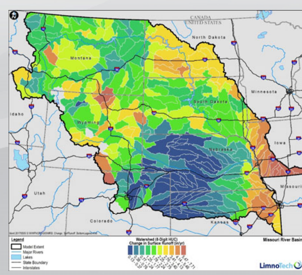
Evolving Natural Hazards

- Climate driven change
  - Increasing event frequency and severity
  - Combined flood mechanisms result in catastrophic events
    - Rainfall, Riverine, Snow Melt, Tidal/Surge Coastal
  - Current 100-year event will become the 50-year event



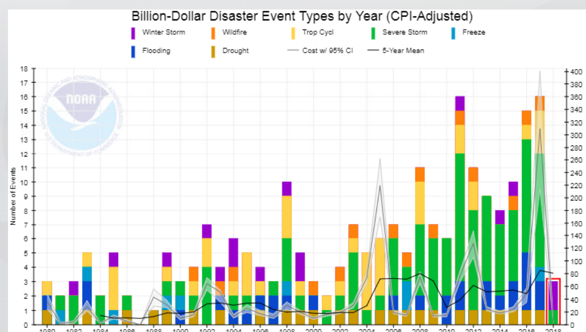
Evolving Natural Hazards

- Development driven change
  - Land use change
  - Increased imperviousness
  - Floodplain encroachments
- Aging infrastructure
  - Based on older design standards
  - Limited capacity and LOS



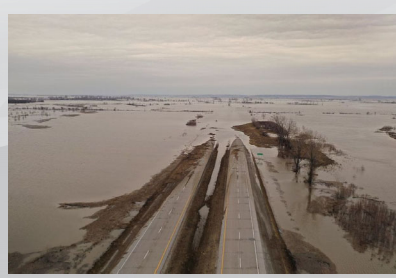
Missouri River watershed map, runoff increases.

Evolving Natural Hazards



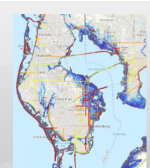
Source: NOAA National Centers for Environmental Information (NCEI) U.S. Billion-Dollar Weather and Climate Disasters. https://www.ncdc.noaa.gov/billions/

Evolving Natural Hazards



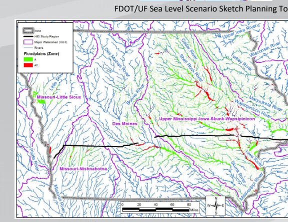
The Resilient Approach

- Identifying & Communicating Current and Future Risk
  - Climate Projections & Scenarios
  - Criticality & Sensitivity Assessments
  - Vulnerability Assessments (FHWA tools)
  - FDOT funded Sketch Planning tool
- State and Federal Guidance
  - Federal guidance and State policies
  - FHWA ERP & MAP-21 programs



FDOT/UF Sea Level Scenario Sketch Planning Tool

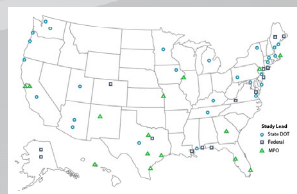
U.S. DOT Vulnerability Assessment Scoring Tool (VAST)



I-DOT, I-80 Vulnerability Study

Risk Mitigation and Adaptation

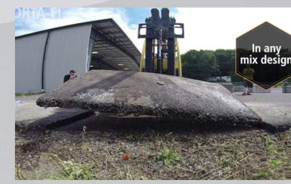
- Adaptation Approach
  - Enhanced standards & policy (build back better)
  - Holistic, adaptable and flexible designs
  - Regional collaboration
- Prioritization and Implementation
  - Asset criticality & vulnerability
  - Remaining service life
  - Alignment with CIP and R&R programs



Transportation Agencies using FHWA Resilience Resources.

Industry Trends to Building Resilience

- Stormwater Management & Erosion Control
  - Design storms used as basis of design (should be forward looking)
- Road Elevation
  - Elevation above seasonal high groundwater (1-3 ft)
  - Storm return frequency based on asset criticality, above 500 year flood stage
- Road Section Hardening
  - Cement stabilized base
  - Geotextile underlayment
  - Black base
  - Fiber reinforced asphalt



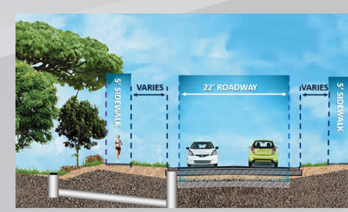
Forta-Fi Fiber Reinforced Asphalt




Case Studies

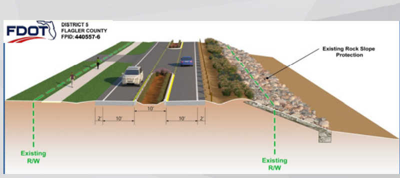
Southeast Florida Municipal Road Project

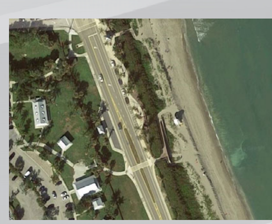
- Road elevation policy based on 30-year planning horizon
- Flexible and adaptable design standards
- Harmonization with adjacent private property
- Increased stormwater LOS
- Complete street approach
  - Maximizes value
  - Minimizes disruption
  - Improves public service performance



Florida Historic A1A Improvements

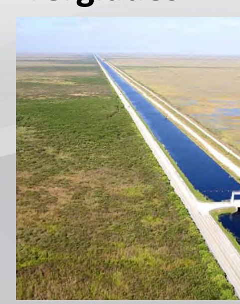
- 350 mile long coastal roadway from Key West to Georgia
- Hybrid armouring includes both hardened and nature based coastal defences, outperformed conventional armouring during Hurricane Matthew





Elevated Roadway across FL Everglades

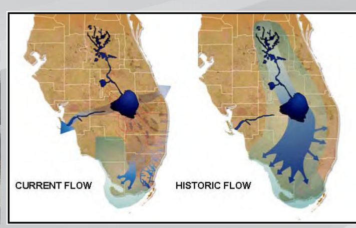
- Tamiami Trail: 100 mile long surface roadway across swamp
- Collaboration with USACE, the National Park Service and FDOT
- Phase 1 project (approx. 10 miles)
- USDOT $20 million TIGER grant



Source: https://flh.fhwa.dot.gov/projects/fl/tamiami/

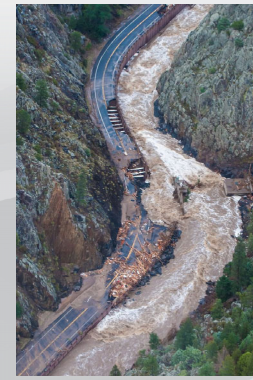
Elevated Roadway across FL Everglades

Purpose: Everglades restoration; protect roadway, historic water flow and wildlife passageways, via road elevation of 13 feet and continuous bridges.



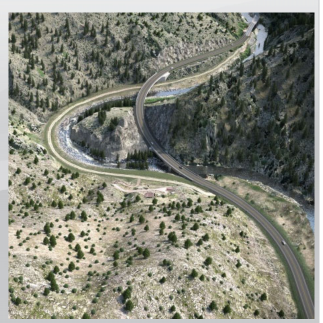
US 34, Colorado

- Severe damage from flooding in 1976 and the fall of 2013 which exceeded the 500-year flood event.
- 400 miles of roadway and 120 bridges damaged from flooding; Presidential disaster declaration was issued.
- 23 mile roadway within Big Thompson River canyon, leading to Rocky Mountain National Park.



US 34, Colorado

- Jacobs designed emergency replacement in 3-months and $280M ultimate roadway realignment.
- Resilient design included use of soil cement base, matrix riprap, moving the roadway onto bedrock and elevating road above flood stage.
- Collaboration with FHWA as Resiliency pilot project considering TBL impacts, use of ERP funding.

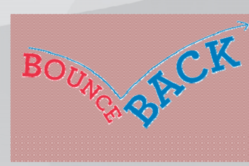


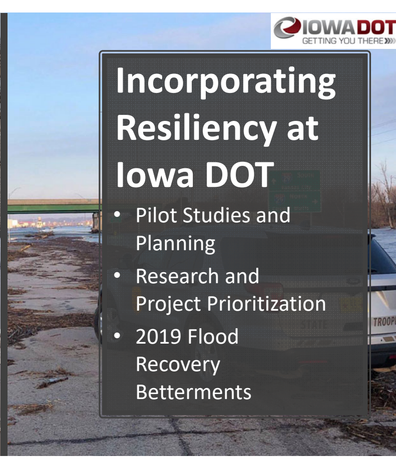
Engineering News-Record named as the 2018 Overall National Best of the Best Project.

Defining Resiliency

As defined by FHWA Order 5520:

Resilience is the ability to anticipate, prepare for, and adapt to changing conditions and withstand, respond to, and recover rapidly from disruptions.





Incorporating Resiliency at Iowa DOT

- Pilot Studies and Planning
- Research and Project Prioritization
- 2019 Flood Recovery Betterments

Iowa's Bridge and Highway Climate Change and Extreme Weather Vulnerability Assessment Pilot

Final Report
March 2015

IOWA STATE UNIVERSITY
Institute for Transportation

Sponsored by
Iowa Department of Transportation
(InTrans Project 13-484)
Federal Highway Administration
(HEPN-707)

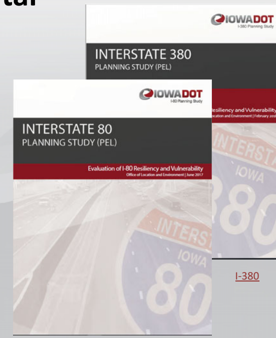
Iowa's Bridge and Highway Climate Change and Extreme Weather Vulnerability Assessment Pilot

I-35 over South Skunk River - 2010

Planning and Environmental Linkages (PEL)

This resiliency study utilized the following methodology:

1. **Assess** threats based on historical climate and projected future climate trends.
2. **Identify** vulnerabilities that may suggest a risk of impact resulting from an extreme weather event.
3. **Indicate** strategies to adapt and minimize the risk of traffic interruption along the corridor as a result of an extreme weather event.
4. **Provide** recommendations for consideration in future studies.

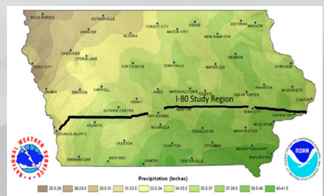


I-80

I-380

Climate and Weather Trends - Precipitation

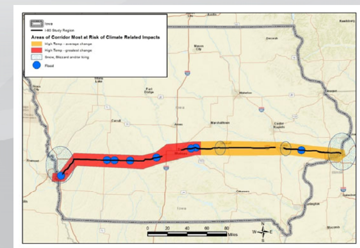
- Increase in high intensity rainfall events (days with more than 1.25" of rain)
- Precipitation Increase in Spring and Summer Months – Decline in Fall Months
- Highest monthly precipitation along I-80 corridor is in June (coincident with timing of flood events)
- Increased precipitation trends expected to continue in future



Iowa Annual Average Precipitation Normal (1981-2010) Provided by NOAA NWS

I-80 Results and Mitigation Strategies

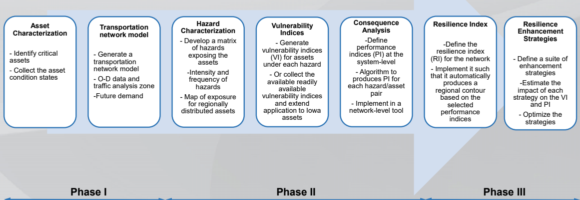
- Pavement compositions/designs considering higher temperatures
- Increase in roadway grades, bridge elevations, culvert size, etc.
- Design for larger design storm based on asset criticality
- Natural windbreaks and additional ROW for snow drift control/storage
- Adjusting maintenance schedules and procedures
- Expansion of asset monitoring programs



Research

IOWADOT IHRB
IOWA STATE UNIVERSITY

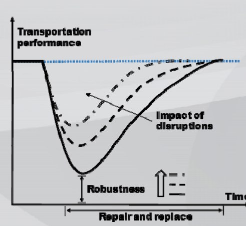
- Assessing and Enhancing the Transportation Resilience for the State of Iowa.
- Extreme Weather, Proxy Indicators, and Asset Management



Proposed procedure for the state-wide resilience assessment and enhancement tool consisting of three main phases

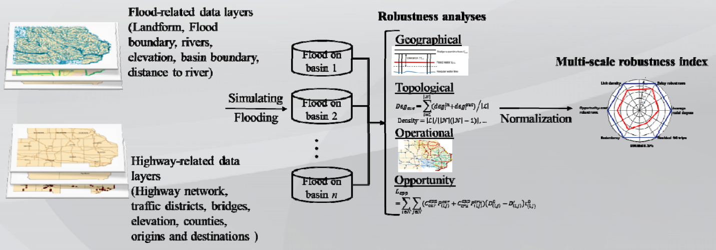
Background

Transportation network performance curve with a disruption



- Impact of disruption: the area between the performance curve and the blue dashed line.
- The higher the network robustness, the smaller effort required for recovery of system functionality.
- High robustness also shortens the network repair time.

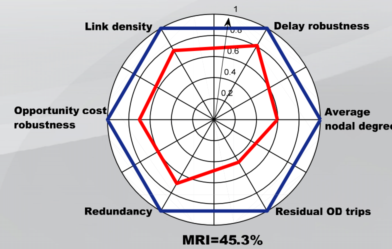
Analysis



Process of transportation network robustness assessment subject to flood hazards based on multi-scale robustness model

Multi-scale resilience index (MRI)

1) Many current approaches use single or double measures for resilience analysis, they fail to consider a full range of multiple parameters associated with damages.
2) The proposed MRI provides a comprehensive expression of network resilience from both the overall viewpoint and the situation of each parameter.



Note: all parameters are normalized in [0,1]

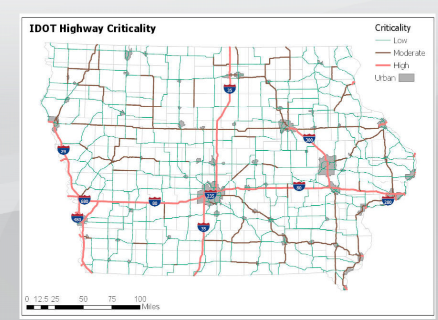
Economic Assessment of Betterments

- As per FHWA 2013 Emergency Relief Manual
  - Betterments can be justified for ER funding by comparing the projected cost to the ER program from potential recurring damage over the design life for the basic repair to the cost of the betterment.
  - The analysis **does not include** other factors often included in highway benefit/cost evaluations, such as traffic delays costs, added user costs, motorist safety, economic impacts, etc.
- This provision limits what can be equated to account for the "benefits" portion of a typical benefit/cost assessment.

Criticality Map

Criteria	Weight
Usage: Functional Class	(30%)
Economic Impact: Truck AADT	(30%)
Social Impact: SoVI	(10%)
System Impact: Redundancy	(30%)

Criticality
- Low (62% of CL Miles)
- Moderate (23% of CL Miles)
- High (15% of CL Miles)



NOTE: Interstate segments and segments connected to bridges near east and west border manually rated "High".

Emergency Repairs and Response

I-680 ER RnR Analysis: Flood Events Overview

Flood Event Description	
September 2011 Flood	
Estimated Frequency	200-yr
Damage Description	Need for full site reconstruction ($2011 estimated Asset Value)= $12,409,915* ER = $17,369,000 (140% of Asset Value), PR= $0
March 2019 Flood	
Estimated Frequency	150-yr
Damage Description	The site suffered **severe** damage consisting of loss of shoulder embankment and pavement on eastbound outside (south) lane in multiple sections of roadway.
Cost of Repairs (Total Repair = ER +PR)	ER= $3,145,531 PR = $223,012 ER+PR = $3,368,543 **(21% of Asset Value)**
Duration of Roadway Closure	Roadway was closed for 22 days during flood and partially closed (1 shoulder plus 1 lane) due to repairs still ongoing.

ER = Emergency Repairs; PR = Permanent Repairs

I-680 ER RnR Analysis: Proposed Betterment

Proposed Betterment	
Estimated Frequency of Flood Event that Betterment can withstand	500-yr
Betterment Description	Permanent side-slope protection (Flexamat)
Cost of Betterment	Total Cost = $1,823,300 PR Cost = $223,012 Cost Above PR Cost = $1,600,288
Design Life	50-yrs

Based on annual reduction of risk
- **Betterment (Flexamat) B/C =4**
- **With Criticality considered: B/C = 12**

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THANK YOU FOR YOUR TIME AND ATTENTION

Questions?