Flash Flood Vulnerability and Adaptation Assessment in NE and SE Minnesota

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We all have a stake in A → B
Presentation Overview

- Project background
  - Climate Change
  - FHWA
- Objectives
- Vulnerability assessment
- Facility-level analysis
- Next steps
From 1958 to 2011, the Midwest has seen a 45% increase in very heavy precipitation (NOAA).

Minnesota GO Vision & Statewide Multimodal Transportation Plan identified the risk of flash flooding as a result of changing precipitation patterns due to climate change.
Significant flood events in 2007, 2010 and 2012 highlighted the need to better understand the risk of flash flooding.
District 1 in 2010
Trunk Highway 210 – Thomson

Trunk Highway 210 East Park Entrance
Jay Cooke State Park
Climate Change & Extreme Weather Vulnerability Assessment Framework

A guide for transportation agencies to assess vulnerability to climate change and extreme weather events

3 key steps:
1. Define study assets and climate variables
2. Assess vulnerability
3. Incorporate results into decision making
Project Objectives

- Better understand the trunk highway network’s risk from flash flooding
- Identify cost–effect options to improve the network’s resiliency
- Support future Transportation Asset Management Plan efforts
- Provide feedback to FHWA on the Draft Framework
Key partners and stakeholders

- MnDOT Districts, Counties, MPOs, RDCs, FHWA, other state agencies (Health, Natural Resources and Pollution Control)
- MnDOT Bridge Office, Maintenance Office and Office of Environmental Stewardship
- Engineering firm Parsons Brinkerhoff
Defining Vulnerability

“Climate change *vulnerability* in the transportation context is a function of a transportation system’s *exposure* to climate effects, *sensitivity* to climate effects, and *adaptive capacity.*” (FHWA Vulnerability Framework)

- **Exposure**– whether the asset or system is located in an area experiencing direct impacts of climate change
- **Sensitivity** – how the asset or system fares when exposed to an impact
- **Adaptive capacity** – the systems’ ability to adjust or cope with existing climate variability or future climate impacts
Phase 1: System-wide Vulnerability Assessment

- High-level screen of trunk highway network in District 1 and District 6

- Identify assets at risk from flash flooding
  - Asset condition and features
  - Climate projection changes
  - Rank and prioritize assets based on resiliency and projected climate changes (risk score)
  - Assets will be mapped according to risk score for each District

- Example method to screen for risks in other parts of the state
Proposed Approach to Flood Vulnerability Analysis

1. Identify Assets of Interest:
   - Bridges
   - Large culverts
   - Pipes
   - Roads paralleling floodplains

2. Calculate the Vulnerability Scores for Each Asset:
   - **Sensitivity**
     - Capacity to handle higher flows
     - % change in peak design flow required for overtopping (based on StreamStats)
     - Asset condition
       - Pavement type (roads)
       - Scour rating (bridges)
       - Substructure condition (bridges)
       - Channel condition (bridges and large culverts)
       - Culvert condition (large culverts)
     - Pipe condition (pipes)
   - **Exposure**
     - Stream velocity
     - Previous flooding issues
     - Belt width to span length ratio (bridges, large culverts, pipes)
     - Median stream belt width (roads)
     - # of potential stream bank erosion locations (roads)
     - % forest land cover in drainage area (bridges, large culverts, pipes)
     - % of drainage area covered by lakes & wetlands (storage capacity proxy)
   - **Adaptive Capacity**
     - Average annual daily traffic (AADT)
     - Heavy commercial average daily traffic (HCADT)
     - Detour length
     - Flow control regime (bridges, large culverts, and pipes)

3. Rank Flood Vulnerabilities by District
Proposed Approach to Flood Vulnerability Analysis

Identify Assets of Interest
- Bridges
- Large culverts
- Pipes
- Roads paralleling floodplains

Calculate the Vulnerability Scores for Each Asset

Sensitivity
- Capacity to handle higher flows
  - % change in peak design flow required for overtopping (based on StreamStats)
- Asset condition
  - Pavement type (roads)
  - Scour rating (bridges)
  - Substructure condition (bridges)
  - Channel condition (bridges)
  - Culvert condition (large culverts)
  - Pipe condition (pipes)

Exposure
- % change in the 24-hr 100-yr storm precipitation depth in 2100 (by drainage area)
- % slope of the stream in the vicinity (velocity proxy)
- Previous flooding issues
- Belt width to span length ratio (bridges, large culverts, pipes)
- Median stream belt width (roads)
- # of potential stream bank erosion locations (roads)
- % forest land cover in drainage area (bridges, large culverts, pipes)
- % of drainage area covered by lakes & wetlands (storage capacity proxy)

Adaptive Capacity
- Average annual daily traffic (AADT)
- Heavy commercial average daily traffic (HCADT)
- Detour length

Rank Flood Vulnerabilities by District
Climate Projections

- Select weather stations in watersheds based on available data in SimClim
  - Present-day 100-year 24-hr storm precipitation depths for each station
  - Year 2100 projected 100-year 24-hr storm precipitation depths for each station

- Assign weights to each watershed based on the projected % change in the 100-year 24-hr storm
  - Assets in watersheds where the percentage change in precipitation is higher should be considered at higher risk
Proposed Approach to Slope Vulnerability Analysis

Identify Assets of Interest
- Slopes > 2:1 within 100 ft. of road

Calculate The Vulnerability Scores for Each Slope

**Sensitivity**
- Potential debris material index
- Impermeable substrate index
- Land cover index
- Maximum steepness of slope

**Exposure**
- % change in the 24-hr 100-yr storm precipitation depth in 2100
- Previous slope failures

**Adaptive Capacity**
- Average Annual Daily Traffic (AADT)
- Heavy Commercial Average Daily Traffic (HCADT)
- Detour length

Rank Slope Vulnerabilities by District
Phase 2: Facility-Level Assessments

- One high-risk asset per District (2 total)
  - Whether & which adaptive actions are economically justified
- Three climate scenarios to test asset resilience
  - Hydrology/hydraulic analysis for each climate scenario
- Adaptation options (i.e. design alternatives)
- Analysis of cumulative benefit/cost values from adaption options
District 1: Silver Creek Culvert 5648
(MN 61 north of Two Harbors)
District 6: Spring Valley Crk Culvert 5722
(US 63 in Spring Valley)

Waterway Adequacy Rating 3 “Occasional (every 3 – 10 yrs) overtopping of roadway approaches with significant traffic delays”
Facility Level Assessment Steps

1. Describe the site context
2. Describe the proposed facility
3. Identify climate stressors
4. Develop climate scenarios
5. Assess performance of the proposed facility
6. Develop adaptation options
7. Assess adaptation option performance
8. Conduct an economic analysis
9. Evaluate additional considerations
10. Select a course of action
11. Plan and conduct ongoing activities
Climate Scenarios

- Scenarios: test and measure asset resiliency
- Three climate model scenarios (AR5)
  - High – 90\textsuperscript{th} percentile of projections across all emissions scenarios and models
  - Medium – 50\textsuperscript{th} percentile value
  - Low – 10\textsuperscript{th} percentile value
- And Atlas 14 scenario: 90\% upper confidence interval limit (NOAA Atlas 14)
Project outcomes

- Identify potential changes and make recommendations to FHWA re “framework”
- System-wide vulnerability assessment *(MnDOT)*
  - Methodology: replicable in different parts of MN
  - Maps: examples of risk screening
- Facility-level asset analysis *(MnDOT)*
  - Mitigation or adaptation strategies and design detail recommendations in final report
  - Adaptive design changes: process and cumulative benefit/cost values; inform planning, programming
- “Pilot study” to be used as example in next MnDOT Transport Asset Mgmt Plan (TAMP)
Project Challenges

- Flash floods don’t follow District boundaries
- Data availability and inconsistency
- Modeling software, computing power needs
- “Bleeding edge”
- Confidence in climate science
  - Downscaling, scenarios
- Project scale and replicability
- Institutional awareness and acceptance
- Use in Asset Management
Questions
Asset Management

- Pilot study to be used as example in next TAMP
- Example of incorporating climate into risk assessments
  - System-level vulnerability assessment maps (inventory of assets)
  - Facility-level Engineering analysis and solutions
- Identify reasonable goals and level of service during events
  - Develop performance measures
- Understand direct and indirect weather outcomes
  - Cost to MnDOT and society
- Develop triggers for action