Extreme Weather Vulnerability Studies - Designing for Resilience

Update on PennDOT Efforts

Doug Zimmerman, Bureau of Planning and Research

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Agenda

- **Phase 1:**
  - PennDOT’s Extreme Weather Vulnerability Study
  - FHWA Pilot Project

- **Phase 2:**
  - Designing for Resilience

- **Questions:**
Impetus for Resiliency Efforts

- PennDOT Concern with Number and Intensity of Storms and Damage
- FHWA Order 5520 and Pilot Studies
- Emphasis from DEP / Climate Change Advisory Committee
- Asset Management Requirements
- FAST Act
- CEQ Final Guidance (Rescinded)
- Federal Flood Risk Management Standard
- AASHTO

Emergency Funds Obligated: $140 million spent on Federal Aid System since 2006
Climate and Weather-Related Hazards

Flooding Considered a Primary Issue in Pennsylvania

- Flooding
- Sea-Level Rise
- Fires
- Landslides
- Earthquakes
- High Winds
- High Temperature Days
Extreme Weather Vulnerability Study
Status of Vulnerability Study

- Initial study completed in March 2017
- Distributed to Districts, MPOs, other state agencies for planning purposes
- Updated in Fall 2017
- Additional updates underway
Historic Flooding Vulnerabilities

Sources:
- Road Condition Reporting System (RCRS)
- FEMA Floodplain Maps
- NOAA Weather Data

State Roadway Mileage Vulnerable To Flooding
(By PennDOT District Number)

- 01: 252
- 02: 289
- 03: 467
- 04: 323
- 05: 320
- 06: 219
- 08: 168
- 11: 140
- 12: 170

 Observed Precipitation
- <= 1.5 inch
- 1.5 - 3 inches
- 3 - 5 inches
- 5 - 7 inches
- > 7 inches
Risk Assessment Criteria

Exposure
- Flooding Frequency
- In FEMA Floodplain
- Precipitation Amount

Sensitivity
- Bridge Condition (Scour)
- Pavement Condition (OPI)
- Deficient Pipes

Consequence
- Traffic and Truck Volume
- Functional Class
- Detour Route
Automated the historic risk mapping process to support on-going monitoring
Forecast Climate Impact on Flooding

- Planning level analyses to assess changes to FEMA 1% floodplain maps based on increased rainfall scenarios
- Assessment of global climate model outputs
- Utilized stream gauge, forecast impervious area, and digital elevation data.
- Assessed inundation of PennDOT roads and bridges based on increased stream depths and sea-level rise
- Compare to historic data
Pilot Forecast Analyses [Climate Change Scenarios]

Only Conducted for Allegheny, Delaware and Lycoming Counties

Addressing Sea-Level Rise

- Literature review of available climate science on sea-level rise
  - IPCC
  - NOAA
  - FHWA
  - USACE
  - Historical Tide gage records

- IPCC and NOAA chosen for scenario analyses
- Adjusted for local tide data

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Sea Level Rise by 2050 (m)</th>
<th>Sea level rise by 2100 (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>NOAA Highest</td>
<td>0.7</td>
<td>2.1</td>
</tr>
<tr>
<td>IPCC 2013 Upper Estimate</td>
<td>0.4</td>
<td>1.1</td>
</tr>
</tbody>
</table>
Current Home for Resiliency Data

- PennDOT PennShare Site
  
  http://pennshare.maps.arcgis.com/apps/MapSeries/index.html?appid=29b9f06045f47eb9888193674f8a95

Future Revisions Needed To Support Implementation
FHWA Pilot Study
Project Goals

- Site Selection
- Hydrologic Analysis
- Hydraulic Analysis
- Adaptive Design Options
- Economic Analysis
- Pilot Study Activities
Study Locations and Coordination

1 site location in:
- Allegheny County
- Delaware County
- York County

PennDOT Central Office:
- PennDOT Bureau of Planning & Research
- Planning and Programming
- Highway Design
- Bridge Design

PennDOT District Offices

Metropolitan Planning Organizations (MPOs)
Project Goals

Provide a detailed template for conducting H&H studies that include climate change impacts

Case study in evaluation of adaptation strategies and cost-effectiveness

Evaluating planning-level climate flooding forecasts from PennDOT’s Extreme Weather Vulnerability Study
Pilot Study Next Steps

- Finalize site locations
- Initiate download of projected precipitation data
- Conduct detailed H&H studies incorporating climate projections
- Field visit 3 locations
Designing for Resilience
Workgroup Focus Areas

• Internal Workgroup
  – Focusing on design, construction and maintenance aspects.
  – Traffic Operations separate workgroup

• Multiyear initiative
  – Some items implemented in 6-12 months; others will take longer.

• Short term items
  – Use of geotextiles to prevent loss of approach embankments and to encapsulate pipe backfill.

• Update H & H Manual
  – Incorporate revised USGS regression equations, as well as updates to stream stats database.
Designing for Resilience - preliminary

- Bridge Design
- Opening sized so that design flood/storm to satisfy limitations on backwater increase:
  - Detailed FEMA flood Zone – 0.00” increase in backwater
  - Approximate FEMA flood Zone -1.00’ increase in backwater
- Scour design – evaluates 100yr and 500yr storm events and uses storm with highest velocity (typically the 100yr event)
- Foundation design – 100 year storm event, but check stability of 500 year storm event
Designing for Resilience - *preliminary*

- **Culvert Design**
  - Basic design similar to bridge, size opening for design flood per DM2 Table 10.6.1.

- **Mitigation measures**
  - Check opening for 100 year event
  - Increase opening by 20%?
  - Downstream impacts must be considered
  - Rock the embankment slope, interlocking block (DEP coordination required)
  - Proper construction procedures, flowable fill at inlet
Designing for Resilience

- H&H Design Flood Considerations
  - Changing drainage area characteristics
  - Stream stats is being updated in conjunction with regression equations
  - Other hydrologic methods can evaluate land use changes

Photo Credit: Google Earth, Dallas, PA
## Designing for Resilience – H&H- Current Return Periods

### TABLE 10.6.1
DESIGN FLOOD SELECTION GUIDELINES

<table>
<thead>
<tr>
<th>FUNCTIONAL CLASSIFICATION</th>
<th>MAXIMUM EXCEEDANCE PROBABILITY (%)</th>
<th>MINIMUM RETURN PERIOD (YEARS)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Interstate and Limited Access Highways</td>
<td>2</td>
<td>50</td>
</tr>
<tr>
<td>Principal Arterial System</td>
<td>2</td>
<td>50</td>
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<tr>
<td>Minor Arterial System</td>
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<td>25</td>
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<tr>
<td>Rural Collector System, Major</td>
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<td>25</td>
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<tr>
<td>Other Collector Systems</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>Local Road and Street Systems</td>
<td>10</td>
<td>10</td>
</tr>
</tbody>
</table>

Note: Federal Policy states that the design flood for encroachments by through lanes of Interstate highways shall not be less than the flood with a 2 percent chance of being exceeded in any given year. Interstate highways should be designed to accommodate the 2% (50-year) flood event.