A Path to Higher Ground: Building Flood Resiliency

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Maryland Department of Transportation

Maryland Transit Administration

Baltimore, Maryland
Key Takeaways

- Impetus for a vulnerability analysis
- Determining vulnerable locations
- Lessons learned & next steps: implementation & planning updates
Maryland Department of Transportation
### Ridership Share

<table>
<thead>
<tr>
<th>Mode</th>
<th>Share</th>
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<tbody>
<tr>
<td>Bus</td>
<td>68.7%</td>
</tr>
<tr>
<td>Rail</td>
<td>11.1%</td>
</tr>
<tr>
<td>VCG</td>
<td>6.7%</td>
</tr>
<tr>
<td>MARC</td>
<td>8.1%</td>
</tr>
<tr>
<td>STS</td>
<td>3.6%</td>
</tr>
<tr>
<td>Bus</td>
<td>1.8%</td>
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### # of Fixed Routes

<table>
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<tbody>
<tr>
<td>Bus</td>
<td>66</td>
</tr>
<tr>
<td>Rail</td>
<td>1 (2 spurs)</td>
</tr>
<tr>
<td>VCG</td>
<td>1 (1 spur)</td>
</tr>
<tr>
<td>MARC</td>
<td>36</td>
</tr>
<tr>
<td>STS</td>
<td>-</td>
</tr>
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### Track Route Miles

<table>
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<th>Miles</th>
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<td>-</td>
</tr>
<tr>
<td>Rail</td>
<td>34</td>
</tr>
<tr>
<td>VCG</td>
<td>58</td>
</tr>
<tr>
<td>MARC</td>
<td>471</td>
</tr>
<tr>
<td>STS</td>
<td>-</td>
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</table>

### # of Stations

<table>
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<tr>
<td>Rail</td>
<td>14</td>
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<tr>
<td>VCG</td>
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<tr>
<td>MARC</td>
<td>42</td>
</tr>
<tr>
<td>STS</td>
<td>52</td>
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</tbody>
</table>

- Maryland Transit Administration
MDOT MTA Service Area
Impetus No. 1: Hurricane Isabel  
September 18-20, 2003

• Category 2 at landfall  
• Landfall: NC Outer Banks  
• Tides: 8 feet above normal  
• Rain: 1-6 inches  
• Winds: 55 to 65 mph

Isabel’s 8-Foot Storm Surge

St. Michaels, Talbot County

Fells Point, Baltimore City

Annapolis, Anne Arundel County
2016 Metro Flooding Study

12’ Storm Surge Will Flood:

• +7,400 feet of track
• Shot Tower station
• Charles Center station’s mezzanine by 3’

2016 Metro Flooding Study
Impetus No. 2: Sea Level Rise

2100 Projections, Maryland Commission on Climate Change

- Unrestrained emissions: 2.2-4.1 foot rise
- Rapid reductions: 1.4 to 2.8 foot rise

Smith Island, Somerset County

Holland Island, Dorchester County
Impetus No. 3: Track Wash Outs

More Severe Rain Storms & A More Built Environment

- July 2016 and May 2018 Ellicott City flooding
- Infrastructure damage exacerbated by impervious surfaces

Light Rail, Baltimore Highlands

Freight, Townsend-Centreville Line
# 2016 Climate Assessment: Vulnerability Analysis

<table>
<thead>
<tr>
<th>Vulnerability Mapping</th>
<th>Risk Assessment</th>
<th>Adaptation</th>
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<tr>
<td><strong>Purpose</strong></td>
<td><strong>Purpose</strong></td>
<td><strong>Purpose</strong></td>
</tr>
<tr>
<td>Identify At-Risk</td>
<td>Quantify Risk</td>
<td>Mitigate Risk</td>
</tr>
<tr>
<td>Locations</td>
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<td><strong>Inputs</strong></td>
<td><strong>Inputs</strong></td>
<td><strong>Inputs</strong></td>
</tr>
<tr>
<td>• GIS Data</td>
<td>• Probability</td>
<td>• Brainstorming Work Session</td>
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<td>Assessment</td>
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<td>• Consequence</td>
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<td></td>
<td>Assessment</td>
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<td>• Stakeholder Meetings</td>
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<tr>
<td><strong>Outputs</strong></td>
<td><strong>Outputs</strong></td>
<td><strong>Outputs</strong></td>
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<tr>
<td>• Vulnerability Maps</td>
<td>• Risk Ratings</td>
<td>• Final Report</td>
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</table>
# Vulnerability Mapping

## Sea Level Rise

**Scenarios:** 2, 4, & 6 feet  
**Data:** National Oceanic & Atmospheric Administration

## Storm Surge

**Scenarios:** Category 1-4  
**Data:** USACE via NWS’ Sea, Lake, & Overland Surge Hurricane (SLOSH)

## Rainstorm Flooding

**Scenarios:** 100 & 500 year  
**Data:** FEMA National Flood Hazard Layer Floodplain Data
Risk Assessment

Risk

Severity
Categorized Impacts to:
- Finances
- Operations
- Reputation

Probability
Uses yes/no scoring on sensitivity and adaptive capacity measures:
- Alternative routes
- Completed adaption projects
- Natural barriers
<table>
<thead>
<tr>
<th>PROBABILITY</th>
<th>Insignificant</th>
<th>Minor</th>
<th>Moderate</th>
<th>Major</th>
<th>Catastrophic</th>
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<tr>
<td>Rare</td>
<td>Low</td>
<td>Low</td>
<td>Moderate</td>
<td>Moderate</td>
<td>High</td>
</tr>
<tr>
<td>Unlikely</td>
<td>Low</td>
<td>Low</td>
<td>Moderate</td>
<td>High</td>
<td>High</td>
</tr>
<tr>
<td>Possible</td>
<td>Low</td>
<td>Moderate</td>
<td>High</td>
<td>High</td>
<td>Very High</td>
</tr>
<tr>
<td>Likely</td>
<td>Moderate</td>
<td>Moderate</td>
<td>High</td>
<td>Very High</td>
<td>Very High</td>
</tr>
<tr>
<td>Almost Certain</td>
<td>Moderate</td>
<td>High</td>
<td>Very High</td>
<td>Very High</td>
<td>Very High</td>
</tr>
</tbody>
</table>
Risk Ranking

- MARC: Low: 12
- Commuter Bus: Low: 3, Moderate: 4, High: 4
- Light Rail: Very High: 25
- Metro: Low: 2, Moderate: 10, High: 5
- Freight: Low: 3, Moderate: 6, High: 4
Metro’s Shot Tower Station
Metro’s Shot Tower Station
Metro’s Shot Tower Station
MARC’s Brunswick Maintenance Facility & Station
Light Rail’s Nursery Road Station & Bridge

Sea Level Rise
- 2ft Inundation
- 4ft Inundation
- 6ft Inundation

Map showing inundation zones with different colors representing sea level rise scenarios.
Light Rail’s Nursery Road Station & Bridge
Light Rail’s Nursery Road Station & Bridge

Storm Surge
- Category 1
- Category 2
- Category 3
- Category 4
Lessons Learned: Implementation

**Project Specific**
- Benefit-cost ratios that reflect climate risk
- Risk-based communication
- Evolving technologies and products

**Programmatic**
- Risk data to drive project prioritization
- Planning/design/construction criteria
- Maintenance plans
- Continuity of operations
- Staff training & qualifications
Lessons Learned: Vulnerability Analysis

- Explore **mapping** resources that integrate sea level rise into storm surge and floodplain data
- Incorporating **bus routes & operations**
- Consider **critical assets** at high risk locations
- Align exposure **probability** with asset useful life
- Align **severity** definitions with those used by Asset and Safety Management Systems
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