Pivoting to the Future: Resiliency Planning in Virginia Beach

Hampton Roads Sea Level Rise/Flooding Adaptation Forum

February 22, 2019

Steven J. Poe, PE, City of Virginia Beach
Stormwater Engineering Center
Agenda

• Project Overview
• Hazards and Risk
• Adaptation Strategy Approach
• Policy Document Overview
• City-wide Structural Alternatives
• Next Steps
Project Overview
Ongoing Studies

• Comprehensive Sea Level Rise and Recurrent Flooding Study
  • Assessing existing and future flood vulnerabilities across the City’s four unique watersheds
  • Identifying strategies to ensure our city is resilient to future flooding events

• Master Drainage Study
  • Detailed inventory of the City’s stormwater system
  • Assessing the system’s performance
  • Identifying deficiencies or needed improvements

Project Website: http://www.vbgov.com/pwSLR
Study Approach

1. Sea Level Rise/ Recurrent Flooding Impacts
   Defining the problem

2. Adaptation Strategies
   Tailoring the solutions

3. Implementation
   Planning the actions
Timeline of Activities

Planning
- Scenarios
- Conceptual model

Study Progression
- Grant award
- Hazard and risk assessment
- Essential analysis to inform design
- Stormwater coordination
- Policy menu

Strategy Focus
- Structural Alternatives
  - City-wide Concepts
  - Performance
  - Down-selection
- Policy refinement and rankings

Synthesis
- Neighborhood and site alternatives
- Full Draft Adaptation Plan
- Stakeholder outreach and input
Hazards and Risk
## VB SLR Planning Scenarios

<table>
<thead>
<tr>
<th>Life Cycle Alignment</th>
<th>Time Horizon/Time Period</th>
<th>SLR Value</th>
<th>Relevance</th>
<th>Use</th>
</tr>
</thead>
<tbody>
<tr>
<td>Municipal Planning</td>
<td>20-40 years 2035-2055</td>
<td>1.5 ft</td>
<td>Comprehensive Plan &amp; Outcomes</td>
<td>Vulnerability assessment, key planning value</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Commercial and Utility life-cycles</td>
<td>Basis for evaluation of all adaptation strategies</td>
</tr>
<tr>
<td>Critical Infrastructure</td>
<td>50-70 years 2065-2085</td>
<td>3.0 ft</td>
<td>Utility Infrastructure life-cycle</td>
<td>Secondary vulnerability assessment to provide insight into long-term risk</td>
</tr>
<tr>
<td>Long-term awareness</td>
<td></td>
<td></td>
<td>Transportation infrastructure lifecycles</td>
<td>Basis for long-term infrastructure decisions</td>
</tr>
<tr>
<td>Adaptive Capacity</td>
<td></td>
<td></td>
<td>Residential structure lifecycles</td>
<td>Evaluate cost-effectiveness of additional protection for adaptable resilience strategies</td>
</tr>
</tbody>
</table>
Observed Acceleration

Norfolk (Sewells Point), Virginia

RSL Rise Rate: 5.14 mm/year
Acceleration: 0.119 mm/year$^2$

Boon et al. 2018

Figure III-4. Relative sea level trends, Norfolk, Virginia, 1969-2017 series

~1.6 ft
Impacts
Consequences of Future Without Action

Annualized Losses (Millions)

$0 $50 $100 $150 $200 $250 $300

Baseline Scenario 1.5 ft SLR Scenario 3 ft SLR Scenario

Compared to Today: 4x increase 23x increase
Focus Areas for Adaptation

88% of City’s Risk
Adaptation Strategies
Adaptation Strategies

Policy  Design  Protection

Integrated Solution
Policy Document Overview
Policy Process

- Review Policies and Best Practices
- Iterate
- Menu of Adaptation Options
- Incorporate Feedback
- SLR Working Group
- Focus Group Discussions
- Broad Review
- Align with City Council Goals
- New Restructured Draft
- Participatory Ranking
- Prioritize Actions
- Cross-Departmental Meetings
- Current Draft
Policy Document

• What it represents:
  • Guidelines for instilling best practices to reduce long-term flood risk
  • Starting place for evaluation and implementation by City
  • Unique reflection of City staff perspective and priorities
  • Policy goals set up to match City Council goals*

• Not a prescriptive document to be followed “to the letter”

*A Strategic Plan to Achieve City Council’s Vision for the Future and 2017 - 2022 City Council Goals
Implementation Vision

- Administered and monitored by the Deputy City Manager SLR Working Group
- Responsibility will be assigned for action items to City departments/staff
- City staff will interpret and evaluate the action items and implement the action in general reflection of priorities
- Implementation will occur after public comment
Informing Design
Informing Design

- Rainfall/surge correlation
  - >50% of rainfall events occur during elevated water levels

- Joint-probability of rainfall/storm surge
  - Concurrent rainfall/surge design values

- Regional Precipitation Trends
  - Atlas 14 outdated
  - Heavy rainfall increasing, 20% needed over design life cycle

- Probable maximum event precipitation
  - Design “check storm”

- Wind Tides
  - Water level response to wind tide conditions
  - Minimum design tailwaters
Stormwater Design Standard Outputs

Table VIII-0
Design Rainfall Depths for City of Virginia Beach (in.)

<table>
<thead>
<tr>
<th>Design Frequency</th>
<th>NOAA Atlas 14 Rainfall</th>
<th>Design Rainfall (NOAA Atlas 14 + 20%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-YR</td>
<td>3.00</td>
<td>3.60</td>
</tr>
<tr>
<td>2-YR</td>
<td>3.65</td>
<td>4.38</td>
</tr>
<tr>
<td>10-YR</td>
<td>5.64</td>
<td>6.77</td>
</tr>
<tr>
<td>25-YR</td>
<td>6.99</td>
<td>8.39</td>
</tr>
<tr>
<td>50-YR</td>
<td>8.16</td>
<td>9.79</td>
</tr>
<tr>
<td>100-YR</td>
<td>9.45</td>
<td>11.34</td>
</tr>
</tbody>
</table>

Note: NOAA Atlas 14 precipitation depths do not vary significantly across the City (generally < 0.1” difference). The NOAA 14 rainfall values shown above represent the area northeast of Naval Air Station Oceana.

Table VIII-1A
Design Storm/Tide Joint Probability Pairs for Determining Controlling Tailwater Elevation

<table>
<thead>
<tr>
<th>10-YR Design</th>
<th>25-YR Design</th>
<th>50-YR Design</th>
<th>100-YR Design</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tide Rain</td>
<td>1-YR</td>
<td>2-YR</td>
<td>5-YR</td>
</tr>
<tr>
<td>1-YR</td>
<td>10-YR</td>
<td>10-YR</td>
<td>25-YR</td>
</tr>
</tbody>
</table>

Note: Refer to Table J-12 Design Tidal Elevations for Virginia Beach in Appendix J for corresponding tide elevations. Refer to Table VIII-0 Rainfall Depths for City of Virginia Beach for corresponding rainfall depths and Table J-13 24-Hour Rainfall Distributions for Virginia Beach in Appendix J for corresponding rainfall distribution.

Note: Joint probability pairs represent the highest-frequency tide with the lowest-frequency rainfall and the highest-frequency rainfall with the lowest-frequency tide for each design frequency, as informed by joint probability studies undertaken by the City. Please refer to the City of Virginia Beach study titled “Joint Occurrence and Probabilities of Tides and Rainfall,” dated October 2017 (CIP 7-010, PW/CN-15-0014, Work Orders 2 and 5A) for additional information.

Table J-12
Design Tidal Elevations for Virginia Beach
All Elevations in feet relative to the North American Vertical Datum (NAVD) of 1988

<table>
<thead>
<tr>
<th>Location</th>
<th>Design Level</th>
<th>1-YR</th>
<th>2-YR</th>
<th>3-YR</th>
<th>5-YR</th>
<th>10-YR</th>
<th>25-YR</th>
<th>50-YR</th>
<th>100-YR</th>
<th>500-YR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lynnhaven Bay &amp; River,</td>
<td>Existing Condition</td>
<td>3.1</td>
<td>3.6</td>
<td>4.0</td>
<td>4.4</td>
<td>5.2</td>
<td>5.8</td>
<td>6.2</td>
<td>6.7</td>
<td>8.5</td>
</tr>
<tr>
<td>Eastern Branch</td>
<td>1.5 ft SLR</td>
<td>4.6</td>
<td>5.1</td>
<td>5.5</td>
<td>5.9</td>
<td>6.7</td>
<td>7.3</td>
<td>7.7</td>
<td>8.2</td>
<td>10.0</td>
</tr>
<tr>
<td>Lynnhaven Bay &amp; River,</td>
<td>Existing Condition</td>
<td>3.2</td>
<td>3.9</td>
<td>4.3</td>
<td>4.8</td>
<td>5.5</td>
<td>6.3</td>
<td>6.9</td>
<td>7.4</td>
<td>9.3</td>
</tr>
<tr>
<td>Incl. all areas other than</td>
<td>1.5 ft SLR</td>
<td>4.7</td>
<td>5.4</td>
<td>5.8</td>
<td>6.3</td>
<td>7.0</td>
<td>7.8</td>
<td>8.4</td>
<td>9.0</td>
<td>10.8</td>
</tr>
<tr>
<td>Eastern Branch</td>
<td>3.0 ft SLR</td>
<td>6.4</td>
<td>7.2</td>
<td>7.6</td>
<td>8.1</td>
<td>8.8</td>
<td>9.7</td>
<td>10.3</td>
<td>10.8</td>
<td>12.0</td>
</tr>
<tr>
<td>Chesapeake Bay</td>
<td>Existing Condition</td>
<td>3.2</td>
<td>3.8</td>
<td>4.1</td>
<td>4.5</td>
<td>5.2</td>
<td>5.9</td>
<td>6.5</td>
<td>7.1</td>
<td>8.5</td>
</tr>
<tr>
<td>1.5 ft SLR</td>
<td>4.7</td>
<td>5.3</td>
<td>5.6</td>
<td>6.0</td>
<td>6.7</td>
<td>7.4</td>
<td>8.0</td>
<td>8.6</td>
<td>10.0</td>
<td></td>
</tr>
<tr>
<td>3.0 ft SLR</td>
<td>6.4</td>
<td>7.1</td>
<td>7.4</td>
<td>7.8</td>
<td>8.5</td>
<td>9.3</td>
<td>9.9</td>
<td>10.5</td>
<td>12.0</td>
<td></td>
</tr>
<tr>
<td>Atlantic Ocean &amp; Rudee links</td>
<td>Existing Condition</td>
<td>3.6</td>
<td>4.1</td>
<td>4.5</td>
<td>4.9</td>
<td>5.4</td>
<td>6.3</td>
<td>6.8</td>
<td>7.3</td>
<td>8.7</td>
</tr>
<tr>
<td>1.5 ft SLR</td>
<td>5.1</td>
<td>5.6</td>
<td>6.0</td>
<td>6.4</td>
<td>6.9</td>
<td>7.8</td>
<td>8.3</td>
<td>8.8</td>
<td>10.2</td>
<td></td>
</tr>
<tr>
<td>3.0 ft SLR</td>
<td>7.2</td>
<td>7.7</td>
<td>8.2</td>
<td>8.6</td>
<td>9.2</td>
<td>10.1</td>
<td>10.7</td>
<td>11.2</td>
<td>12.8</td>
<td></td>
</tr>
<tr>
<td>Back Bay, North of</td>
<td>Existing Condition</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>2.4</td>
<td>3.4</td>
<td>4.2</td>
<td>6.4</td>
</tr>
<tr>
<td>Beggars Bridge Creek</td>
<td>1.5 ft SLR</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>3.9</td>
<td>4.9</td>
<td>5.7</td>
<td>6.4</td>
</tr>
<tr>
<td>3.0 ft SLR</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>7.6</td>
<td>9.0</td>
<td>10.1</td>
<td>13.2</td>
<td></td>
</tr>
<tr>
<td>Back Bay, South of</td>
<td>Existing Condition</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Beggars Bridge Creek</td>
<td>1.5 ft SLR</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>3.0 ft SLR</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>North Landing River</td>
<td>Existing Condition</td>
<td>2.8</td>
<td>3.6</td>
<td>4.1</td>
<td>4.7</td>
<td>5.8</td>
<td>6.5</td>
<td>7.1</td>
<td>7.9</td>
<td>10.3</td>
</tr>
<tr>
<td>1.5 ft SLR</td>
<td>4.3</td>
<td>5.1</td>
<td>5.6</td>
<td>6.2</td>
<td>7.5</td>
<td>8.0</td>
<td>8.6</td>
<td>9.4</td>
<td>11.1</td>
<td></td>
</tr>
<tr>
<td>3.0 ft SLR</td>
<td>5.9</td>
<td>6.7</td>
<td>7.2</td>
<td>7.8</td>
<td>8.9</td>
<td>10.2</td>
<td>11.0</td>
<td>13.4</td>
<td>17.1</td>
<td></td>
</tr>
</tbody>
</table>

Notes:
1. All elevations sourced from direct sampling and statistical analysis of the distribution of water elevations in each watershed.
2. Lynnhaven, Elizabeth River, and Atlantic Ocean elevations were sourced from the 2015 FEMA Flood Insurance Study.
3. Back Bay and North Landing River elevations were sourced from CIP 7-030, PW/CN-15-0014, WO2A.
4. The values do not represent potential wind-driven water levels in the Back Bay and North Landing River.
5. Back Bay and North Landing River tailwater values have been limited to return periods where tailwater elevations are above recurring wind tides.
6. Conditions related to a 3-ft rise in sea level include non-linear increases derived from numerical modeling completed by the U.S. Army Corps of Engineers and the North Carolina Floodplain Mapping Program.
Structural Protection
Structural Flood Risk Reduction

Key Activities:

• Investigate coastal flood pathways
• Identify locations for flood risk reduction
• Develop flood risk reduction alternatives
• Assess feasibility and performance
• Provide recommendations
Structural Alternative Levels

Protect Most of City
Designed to Future 100-yr flood
Cost: High (Billions)

Protect High Risk Areas
Designed to Future 10- to 50-yr flood
Cost: Moderate (100s Millions)

Address High Risk Properties
Alternative to Structures
Cost: Low to Moderate (Millions)
City-wide Protection Alternatives

• Limitations:
  • High-level concepts
  • Alignments based on desktop analysis
  • Each alignment will have major impacts and concerns which are not captured in detail
    • Drainage, Environmental, Traffic and Circulation, Navigation, Real Estate, Costs, Constructability, etc…
  • Initial results today – final results pending
Coastal Flood Protection Toolkit

Earthen Levee
Floodwalls
Seawalls
In-Water Sector Gates
In-Water Vertical Lift Gates
In-Water Movable Gates
Flood Logs
Inland Rolling Gates
Inland Swing Gates
Putting the Pieces Together

• Collaborative review of possible alignments

• Identifying combinations of alignments

• Culling options
Conceptualized Alignment Locations

1. Lynnhaven Inlet
2. Long Canal
3. Upper West Branch Lynnhaven
4. Lower West Branch Lynnhaven
5. Upper East Branch Lynnhaven
6. Lower East Branch Lynnhaven
7. Rudee Inlet
8. Elizabeth River
9. West Neck Creek Bridge
10. Knotts Island
11. Sandbridge Road
12. Muddy Creek Road
Combinations for Evaluation

Alternative 1  Alternative 2  Alternative 3  Alternative 4  Alternative 5

Alternative 6  Alternative 7  Alternative 8  Alternative 9  Alternative 10
Model Evaluation

- DHI MIKE21
- Stormwater runoff via MIKE FLOOD
- Tidal calibrated, validated
- 10-/100-yr surge forcing with/without 10-yr runoff
- Structure implementation
- Flood depth benefits and adverse impacts
Model Evaluation Benefits and Impacts

Areas of Benefit (reduced flood depth)

Areas of Adverse Impact (increased flood depth)

FOR INFORMATIONAL PURPOSES
Initial values shown, currently under refinement
Conceptual Alignments

1. Lynnhaven Inlet
2. Long Canal
3. Upper West Branch Lynnhaven
4. Lower West Branch Lynnhaven
5. Upper East Branch Lynnhaven
6. Lower East Branch Lynnhaven
7. Rudee Inlet
8. Elizabeth River
9. West Neck Creek Bridge
10. Knotts Island
11. Sandbridge Road
12. Muddy Creek Road
Down-selection of Alternatives

Alternative 1  Alternative 2  Alternative 3  Alternative 4  Alternative 5

Alternative 6  Alternative 7  Alternative 8  Alternative 9  Alternative 10
Down-selected Alternatives
Down-selected Alternatives
Down-selected Alternatives
Renderings – Lynnhaven Inlet

- Existing Bridge
- LuYnnHaven inLett
- Sand Dune with Sheet Pile Reinforcement
- HorIzontal Sector Gate
- Chesapeake Bay
- In-Water Movable Gate

Combination Gate Solution (Enlarged)

LynnHaven InLett
Renderings – Muddy Creek Rd

EXISTING BRIDGE

EXISTING BOAT HOUSE

MUDDY CREEK ROAD

BEGGAR’S BRIDGE CREEK

BACK BAY NATIONAL WILDLIFE REFUGE

EXISTING CONDITIONS (ENLARGED VIEW)

MUDDY CREEK ROAD
Renderings – Muddy Creek Rd
Cost Estimation

- Rough Order of Magnitude*
  - Utilized ArcGIS and AutoCAD
  - Units costs from USACE, PIANC, etc.
  - Average parameters by unit length
  - Contingencies for:
    - Hard Construction Cost
    - Soft Costs
  - Escalation for future date of construction

*Approximate equivalent to Association for the Advancement of Cost Engineering Class 5 estimate for conceptual engineering phase
# Down-Selected Alternative Summary

## SUMMARY OF ALTERNATIVES

<table>
<thead>
<tr>
<th>ITEMS</th>
<th>CITYWIDE ALTERNATIVES</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2</td>
</tr>
<tr>
<td>Approximate Overall Structure Length (miles)</td>
<td>33.8</td>
</tr>
<tr>
<td>Flooded Area Reduction (square miles)</td>
<td>-27</td>
</tr>
<tr>
<td>Mitigated Structures (thousands)</td>
<td>45.5</td>
</tr>
<tr>
<td>Total Design &amp; Construction Cost (Billion USD 2018)</td>
<td>$3.79**</td>
</tr>
<tr>
<td>Adjacent Municipal Areas Affected</td>
<td>North Carolina, Norfolk, Chesapeake</td>
</tr>
</tbody>
</table>

*Values subject to change pending final modeling and cost adjustments for gate types

**Cost includes flood barrier in Norfolk that benefits Virginia Beach, Norfolk, and Chesapeake

***Final count to be determined from model runs

FOR INFORMATIONAL PURPOSES

Initial values shown, currently under refinement
Future With/Without Alternatives

Annualized Losses (Millions)

Baseline Scenario:
- Losses without Project: $12

3 ft SLR Scenario:
- Losses without Project: $271
- Losses with Project Alternatives: $2, $4, $6, $8

Legend:
- Light blue: Losses without Project
- Dark blue: Losses with Project Alternatives
Next Steps

City-wide Projection:
- Finalize evaluation

Site/Parcel Strategies:
- Key opportunities
- Aggregate Benefits over Areas

Neighborhood Protection:
- Complete for 5 locations

Hybrid Alternatives:
- What’s the best mix?

Draft Adaptation Plan

Review & Stakeholder Engagement

Next 3-4 Months
Discussion