Virginia Beach Comprehensive Sea Level Rise and Recurrent Flooding Planning Study

Policy Recommendations and City-wide Flood Protection Strategies

January 15, 2019
Agenda

• Project Overview
• Hazards and Risk Recap
• 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
Goal:
Produce information and strategies that will enable Virginia Beach to establish long-term resilience to sea level rise and associated recurrent flooding

Objectives:

• Establish a full understanding of flood risk and anticipated changes over planning and infrastructure time horizons

• Develop risk-informed strategies, including engineered protection and policy to reduce short and long-term impacts

• Produce City-wide and watershed “action plans” for strategy implementation

• Engage in public outreach process to advance resilience initiatives
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

2015

Planning
- Scenarios
- Conceptual model

2016

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

2017

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

2018

Synthesis
- Neighborhood and site alternatives
- Full Draft Adaptation Plan
- Stakeholder outreach and input

2019
Hazards and Risk Recap
## 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 Commercial and Utility life-cycles</td>
<td>Vulnerability assessment Key planning value 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 Transportation infrastructure lifecycles Residential structure lifecycles</td>
<td>Secondary vulnerability assessment to provide insight into long-term risk Basis for long-term infrastructure decisions Evaluate cost-effectiveness of additional protection for adaptable resilience strategies</td>
</tr>
</tbody>
</table>
“Projections”

Relative Sea Level Change Projections - Gauge: 8638610, Sewells Point, VA (05/01/2014)

- USACE/NOAA Low Rate
- USACE Int, NOAA Int Low
- NOAA Int High Rate
- USACE High Rate
- NOAA High Rate

RSLC in feet (LMSL)

<table>
<thead>
<tr>
<th>Year</th>
<th>USACE/NOAA Low Rate</th>
<th>USACE Int, NOAA Int Low</th>
<th>NOAA Int High Rate</th>
<th>USACE High Rate</th>
<th>NOAA High Rate</th>
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<tbody>
<tr>
<td>2000</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
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<tr>
<td>2010</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
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<tr>
<td>2020</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
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<td>2030</td>
<td>3</td>
<td>3</td>
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<tr>
<td>2040</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>4</td>
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<td>2050</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>2060</td>
<td>6</td>
<td>6</td>
<td>6</td>
<td>6</td>
<td>6</td>
</tr>
<tr>
<td>2070</td>
<td>7</td>
<td>7</td>
<td>7</td>
<td>7</td>
<td>7</td>
</tr>
<tr>
<td>2080</td>
<td>8</td>
<td>8</td>
<td>8</td>
<td>8</td>
<td>8</td>
</tr>
</tbody>
</table>

3 ft
1.5 ft
Observed Acceleration

Norfolk (Sewells Point), Virginia

Boon et al. 2018

RSL Rise Rate: 5.14 mm/year
Acceleration: 0.119 mm/year²

~1.6 ft

Figure III-4. Relative sea level trends, Norfolk, Virginia, 1969-2017 series
Impacts
Consequences of Future Without Action

Annualized Losses ( Millions )

Compared to Today:  
- Baseline Scenario: $12
- 1.5 ft SLR Scenario: $50
- 3 ft SLR Scenario: $271

- 4x increase
- 23x increase
Spatial Distribution of Risk
Focus Areas for Adaptation

Annualized Losses
- Low
- Mild
- Moderate
- High
- Severe

88% of City’s Risk
Adaptation Strategies
Adaptation Strategies

Policy  Design  Protection

Integrated Solution
Policy Document Overview
Policy Process

1. Review Policies and Best Practices
2. Iterate
3. Menu of Adaptation Options
4. Incorporate Feedback
5. Focus Group Discussions
6. SLR Working Group
7. Broad Review
8. Align with City Council Goals
9. Participatory Ranking
10. Prioritize Actions
11. Cross-Departmental Meetings
12. New Restructured Draft
13. SLR Working Group
14. 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

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

1. Plan for a future with more frequent and intense flooding
2. Enhance the flood resilience of critical infrastructure and invest in capital improvements to reduce community flood risk
3. Enhance the flood resilience of buildings and neighborhoods
4. Protect and enhance the local economy
5. Preserve and enhance natural flood buffers and open space
6. Improve City coordination and responsiveness to community flood concerns
7. Advocate for changes in state and federal law and policy to incentivize, support, and fund local resilience implementation

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

• Content:
  • 7 goals
  • 29 objectives
  • 175 action items

• Structure for Goals:
  • Overview
  • Objectives
    • Actions and Priority
    • Benefits and Considerations
      • Community Rating System opportunities

• Implementation Examples
Qualitative Ranking of Policy Actions

Menu of Actions

Evaluation Variables

Technical Feasibility
Project Effectiveness
Administrative Needs
Political Support
Legal Concerns
Cost
Cost-Effectiveness
Environmental Impacts
Social Vulnerability Impacts

Participatory Scoring

Aggregated Rankings

Prioritized Actions
Ranking Responses:

• Group rankings by:
  • Public Works, Planning, Public Utilities, Emergency Management, Parks and Recreation, Legal

• Guidance was for input on items related to responsibilities and expertise

• Over 2,400 inputs provided across the categories

• Relative Rankings:

<table>
<thead>
<tr>
<th>Ranking</th>
<th>Count</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low</td>
<td>1</td>
<td>1%</td>
</tr>
<tr>
<td>Med-Low</td>
<td>40</td>
<td>22%</td>
</tr>
<tr>
<td>Medium</td>
<td>38</td>
<td>20%</td>
</tr>
<tr>
<td>Med-High</td>
<td>57</td>
<td>31%</td>
</tr>
<tr>
<td>High</td>
<td>50</td>
<td>27%</td>
</tr>
</tbody>
</table>
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**

<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 |
|-------------------------------------------|-------------------------------------------|
| 10-YR Design | 25-YR Design | 50-YR Design | 100-YR Design |
| Tide | Rain | Tide | Rain | Tide | Rain | Tide | Rain |
| 16-YR | 1-YR | 25-YR | 1-YR | 50-YR | 1-YR | 100-YR | 1-YR |
| 1-YR | 16-YR | 25-YR | 2-YR | 50-YR | 2-YR | 100-YR | 3-YR |

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.

### Table J-12

<table>
<thead>
<tr>
<th>Design Tidal Elevations for Virginia Beach in feet relative to the North American Vertical Datum (NAVD) of 1988</th>
</tr>
</thead>
<tbody>
<tr>
<td>Location</td>
</tr>
<tr>
<td>----------</td>
</tr>
<tr>
<td>Lynnhaven Bay &amp; River, Eastern Branch</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>Lynnhaven Bay &amp; River, Incl. all areas other than Eastern Branch</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>Chesapeake Bay</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>Atlantic Ocean &amp; Rudee Inlet</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>Back Bay, North of Beggars Bridge Creek</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>Back Bay, South of Beggars Bridge Creek</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>North Landing River</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>Elizabeth River</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<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, PWCN-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
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)

TODAY’S PRESENTATION
IN PROGRESS
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
Conceptual Process

**COORDINATION WITH CITY**

**Existing Data Collection and Site Assessment**
- Site Characterization
- Identify Site Constraints
- Site Specific Base Maps in CAD and GIS

**Development of Ten Citywide Alternatives**
- Design Criteria
- Framework to Evaluate Alternatives
- Hydrodynamic Modeling
- Multi-Disciplinary Evaluation

**Hydrodynamic Modeling of Alternatives**
- Model Mesh Development
- Model Calibration / Validation
- Model simulation of alternatives

**Concept Design for Top Three & Preferred Alternative**
- Concept Design
- Develop High Level Costs and Renders
- Identify and Discuss Preferred Alternative
- Provide Final Recommendation for Preferred Alternative

**USE OF FEMA, USACE, STATE AND LOCAL STANDARDS AND REGULATIONS**
Lynnhaven Inlet Beachfront (East)

Site Conditions

- Area is located in FEMA coastal VE zone with a BFE of 10’ NAVD
- Estuarine and marine wetlands located along the beachfront
- Military property to the northeast and numerous private properties along the beachfront
- Outfalls in vicinity of beach
- Limited width for coastal dune levees
- Maximum high ground elevation limited to ~18’ NAVD
Lynnhaven Inlet Beachfront (West)

Site Conditions

- Area is located in FEMA coastal VE zone with a BFE of 11’ NAVD
- Presence of Little Creek Channel along Va Beach/Norfolk border
- Estuarine and marine wetlands located along the beachfront
- Military property to the west and numerous private properties along the beachfront
- Outfalls in vicinity of beach
- Limited width for coastal levees
- Maximum high ground elevation limited to ~18’ NAVD
Lynnhaven Inlet Beachfront (East)
Identification of Tie-In Locations for Alignment Development

- Extension point high ground
- Crossover at 14.5' NAVD
- Crossover at 11' NAVD
- Tie-in Location up to 14.5' NAVD
- Tie-in Location up to 18' NAVD
- Lynnhaven Inlet
- Wolfsnare Creek
- Broad Bay

Maximum High Ground – 14.5' NAVD
Lynnhaven Inlet
Identification of Tie-In Locations for Alignment Development

Maximum High Ground – 18’ NAVD
Lynnhaven Inlet Beachfront (West)
Identification of Tie-In Locations for Alternative Development

- High-point viable only with additional flood protection to the west
- Potential intervention location along highway median and gated barrier at Lake Pleasure House
- Tie-in Location up to 18' NAVD
- Crosses highway at 15' NAVD
- Large Culvert Connection

Maximum High Ground – 14.5’ NAVD
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
Lynnhaven Inlet
Comparison of 2 Potential Alignments

<table>
<thead>
<tr>
<th>Option 2 - Alignment Comparison (Relative)</th>
<th>DFE Criteria (ft-NAVD)</th>
<th>Approx. Length (ft)</th>
<th>Cost</th>
<th>Real Estate Impact</th>
<th>Constructability</th>
</tr>
</thead>
<tbody>
<tr>
<td>DFE A</td>
<td>14.5</td>
<td>24,674</td>
<td>Lowest</td>
<td>Minimal</td>
<td>Easy</td>
</tr>
<tr>
<td>DFE B</td>
<td>16.0</td>
<td>37,254</td>
<td>Moderate</td>
<td>Moderate w/ few acquisitions</td>
<td>More challenging to elevate by fill</td>
</tr>
</tbody>
</table>
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 of Flood Reduction

Areas where flooding completely removed

Areas of flood reduction (flood depth decreased)

FOR INFORMATIONAL PURPOSES
Initial values shown, currently under refinement
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
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

Citywide Coastal Risk Reduction
Alternative Locations

Location 1 - Lynnhaven Inlet
Location 7 - Rudee Inlet
Location 7* - Sandbridge Beach
Location 9 - West Neck Creek Bridge
Location 11 - Sandbridge Rd
Location 12 - Muddy Creek Rd
Municipal Boundaries

Location 2 - Long Canal
Location 3 - Upper West Branch Lynnhaven
Location 5 - Upper East Branch Lynnhaven
Location 7 - Rudee Inlet
Location 7* - Sandbridge Beach
Location 9 - West Neck Creek Bridge
Location 11 - Sandbridge Rd
Location 12 - Muddy Creek Rd
Municipal Boundaries
Down-selected Alternatives

Citywide Coastal Risk Reduction

Alternative Locations

- Location 1 - Lynnhaven Inlet
- Location 7 - Rudee Inlet
- Location 7* - Sandbridge Beach
- Location 8 - Elizabeth River
- Location 9 - West Neck Creek Bridge
- Location 11 - Sandbridge Rd
- Location 12 - Muddy Creek Rd
- Municipal Boundaries
Renderings – Lynnhaven Inlet
Renderings – Lynnhaven Inlet
Renderings – Muddy Creek Rd
Renderings – Muddy Creek Rd

Muddy Creek Road

Raised Bridge

Raised Road

Miter Gate

Beggar’s Bridge Creek

Gate Levee

Service Access

Gate House

Back Bay National Wildlife Refuge

Miter Gate (Enlarged View)

Muddy Creek Road
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>
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<tbody>
<tr>
<td></td>
<td>2</td>
</tr>
<tr>
<td>Approximate Overall Structure Length (miles)</td>
<td>33.8</td>
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<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>

*FOR INFORMATIONAL PURPOSES
Initial values shown, currently under refinement*

*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*
Future With/Without Alternatives

Annualized Losses (Millions)

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Losses without Project</th>
<th>Losses with Project Alternatives</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline Scenario</td>
<td>$12</td>
<td></td>
</tr>
<tr>
<td>3 ft SLR Scenario</td>
<td>$271</td>
<td>2 4 6 8</td>
</tr>
</tbody>
</table>
USACE Engagement

• **Goal**: Federal cost share

• How will work to date help?
  • Catalyst and justification
  • Allow deeper, broader study

• Federal feasibility and environmental impact study needed
  • Debriefed alignment options to USACE in December
  • Formal request letter for study start provided January 11, 2019
Next Steps

- Finalize evaluation
- Key opportunities
- Aggregate Benefits over Areas
- Complete for 5 locations
- What’s the best mix?
- Study Synthesis
- Review & Stakeholder Engagement

City-wide Projection
Site/Parcel Strategies
Neighborhood Protection
Hybrid Alternatives
Draft Adaptation Plan
Review & Stakeholder Engagement
Questions