Topics

• Brief overview of Norfolk’s Coastal Flood Program

• Data-driven analysis and decision making

• City-wide vulnerability, project concepts, scoring and ranking

• Use of hydrodynamic modeling and GIS technology

• Acknowledgments
Norfolk City-wide Coastal Flooding Study

• Ongoing since 2008; precursors since 1990s
• Prioritize public works expenditures
• Increase ability to communicate risks and decisions to public
• Develop long-term adaptation approach

http://norfolk.gov/flooding
Norfolk City-wide Coastal Flooding Study

Broad Task Categories

- Measurement of tide levels in City, relate to Sewells Point
- Predictive flooding models of tidal/surge flooding, with effects of storm drainage network & rainfall flooding
- Evaluation of design criteria and mitigation alternatives
- Conceptual project design, total design life Benefit-Cost Analysis for selected local projects
- Initial stages of City-wide Coastal Flooding Mitigation Master Plan (with long-term adaptation vision)
Data-Driven Analysis and Decision Making

- 2009-2010 Initial phase of tide gauge program
- Define physical environment and how water levels vary in City, with storm conditions
Data-Driven Analysis and Decision Making

- Variation in high water levels within the City; relationship to Sewells Point for studies and real-time flood information

### Table 1. Summary of Statistical Water Level Relations

<table>
<thead>
<tr>
<th>Tide Gauge</th>
<th>Average Water Level, feet</th>
<th>Difference compared to Sewells Point, feet</th>
<th>Adj. Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sewells Point</td>
<td>0.3</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>Recreation Center</td>
<td>0.3</td>
<td>-0.1</td>
<td></td>
</tr>
<tr>
<td>Havens Creek</td>
<td>1.5</td>
<td>1.2</td>
<td></td>
</tr>
<tr>
<td>Tidewater Bridge</td>
<td>0.9</td>
<td>0.5</td>
<td></td>
</tr>
<tr>
<td>Downtown Pump Station</td>
<td>0.8</td>
<td>0.4</td>
<td></td>
</tr>
<tr>
<td>Broad Creek</td>
<td>0.6</td>
<td>0.2</td>
<td></td>
</tr>
</tbody>
</table>

Notes: Statistical analyses are shown on Figures 2 through 6. All values have been rounded to the nearest tenth of a foot. All elevations are re: NAVD88.
Tide gauges: Haven Creek vs. Sewells Point

COMPARISON OF TIDE GAUGE MEASUREMENTS AND SEWELLS POINT
Lafayette River – Haven Creek Boat Ramp (P13HC)
Tide gauges: Tidewater Drive Br. vs. Sewells Point

COMPARISON OF TIDE GAUGE MEASUREMENTS AND SEWELLS POINT
Lafayette River – Wayne Creek at Tidewater Drive Bridge (P13TW)
Coastal Flooding Evaluation Methods

- High-level City-wide evaluation of tide/surge driven inundation
- For each Planning Districts
  - Number of parcels and buildings
  - Assessed value of improvements
  - Historic losses
  - Miles of roadways
Coastal Flooding Evaluation Methods

• Local project-scale detailed hydrology / hydraulics modeling
  – Based on present topography and storm drain system
  – Detailed, unsteady-state hydraulics of both tide/surge and rainfall-runoff
  – Estimate extent, depth, and duration of flooding for baseline vulnerability, with-project evaluation
  – Compute reduction in flood damage with mitigation projects
Coastal Flooding Evaluation Methods: Technology

• Computer model of present-day flood hydrology / hydraulics

• 1-D/2-D linked model in XP-SWMM
  – More accurate representation of ponding areas and flow along streets
  – Detailed grid of depth in each grid cell, to relate to property within each grid cell
  – Saves on labor costs (for same level of accuracy); prepared for long run times
Coastal Flooding Evaluation Methods: Technology

• GIS-based approach using FEMA and USACE procedures
  – Flood depths at each structure from XP-SWMM models; depth-damage curves applied in GIS
  – Semi-automated setup is scalable from small project areas to City-wide analysis

• Damage analysis includes structures & contents utilizing the City parcel database, with limited field verification

• Additional factors: ancillary structures, vehicles, displacement, loss of use, and City infrastructure considered
City-wide Vulnerability and Mitigation Planning

• May 2012: Preliminary City-wide Coastal Flooding Mitigation Concept Evaluation and Master Plan Development

• Infrastructure and property vulnerability
  – Transportation corridors, routes to critical facilities
City-wide Vulnerability and Mitigation Planning
City-wide Vulnerability and Mitigation Planning

- Infrastructure and property vulnerability
  - FEMA claims
  - Depth-damage curves on GIS-based grid analysis
  - HAZUS-style analysis for detailed looks at local areas
City-wide Vulnerability and Mitigation Planning

- Various mitigation types considered (with and without additional built infrastructure)

LEGEND
- Project Area
- Planning District Boundary
- Approximate Coastal Flooding
  Does not include precipitation.
  - 1% Annual Chance Coastal Flood Extent
  - 1% Annual Chance Coastal Flood Extent with 1-Foot Sea Level Rise

Mitigation Options
- Road Raise
- Berm
- Flood Gate
- Floodwall
- Culvert
- Existing Floodwall
- Existing Topography
- Feature with Yellow Highlight Required for 1-Foot of Sea Level Rise

Critical and Essential Facilities
- Emergency Shelters
- Fire Station
- Hospitals
- Police Station
- School
- Water Treatment Facilities
City-wide Vulnerability and Mitigation Planning

• Project development, scoring and ranking
  – Present and future risk (to property, infrastructure, etc.)
  – Investment (cost) vs. Benefit of mitigation (not just flood damage avoidance); multiple options examined for most project areas  \[ \text{Score} = \frac{\text{Reduced Damage}}{\text{Cost}} \times 100 \]
  – Additional points scored for mitigation risk to critical or essential facilities

• Lafayette River watershed contributes nearly half of the economic damage risk within the City

• City-wide economics for 100-year return period coastal flood magnitude
How Does Sea Level Rise Play Into All This?

• NOAA: relative mean sea level has risen …
  – +3.76 mm/year (1.23 ft/100 yrs) at Portsmouth (shipyard)
  – +4.44 mm/year (1.46 ft/100 yrs) at Sewells Point
  – +6.05 mm/yr (1.98 ft/100 yrs) at Ches. Bay Bridge-Tunnel
  – Acceleration scenarios

• Flooding problems and vulnerabilities exist today

• Relative sea level rise becomes a design parameter, depending on mitigation strategy design life
  – Influences project lateral extents; a couple of feet can make a big difference
  – Modifies “return period” of design water levels
How Does Sea Level Rise Play Into All This?

After a 1-ft sea level rise (SLR), the frequency of what had been a 50-year storm, becomes a 16-year storm.
Next Steps

- Continue to develop tools to inform public
- Bring additional areas of the City to conceptual mitigation design stage
- Promote local and regional benefits of coastal flood mitigation within Norfolk
- Share “what’s worked” for the Norfolk process with other localities and regions
Questions?