City of Norfolk
Coastal Flood Mitigation Program

March 13, 2013

moffatt & nichol

FUGRO

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

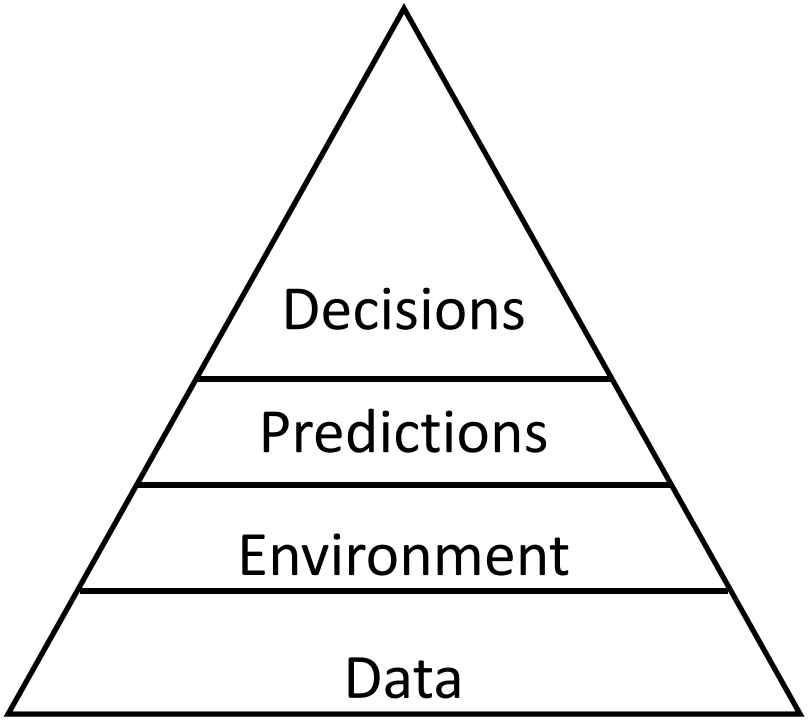
Norfolk City-wide Coastal Flooding Study

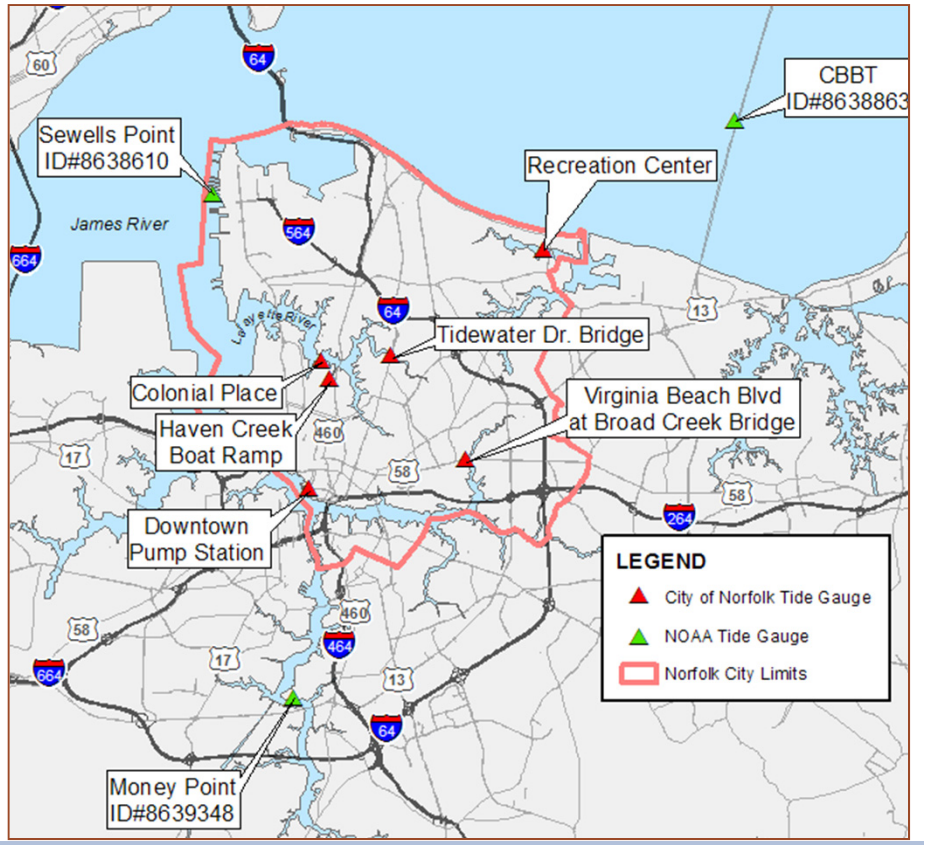
Broad Task Categories

- 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





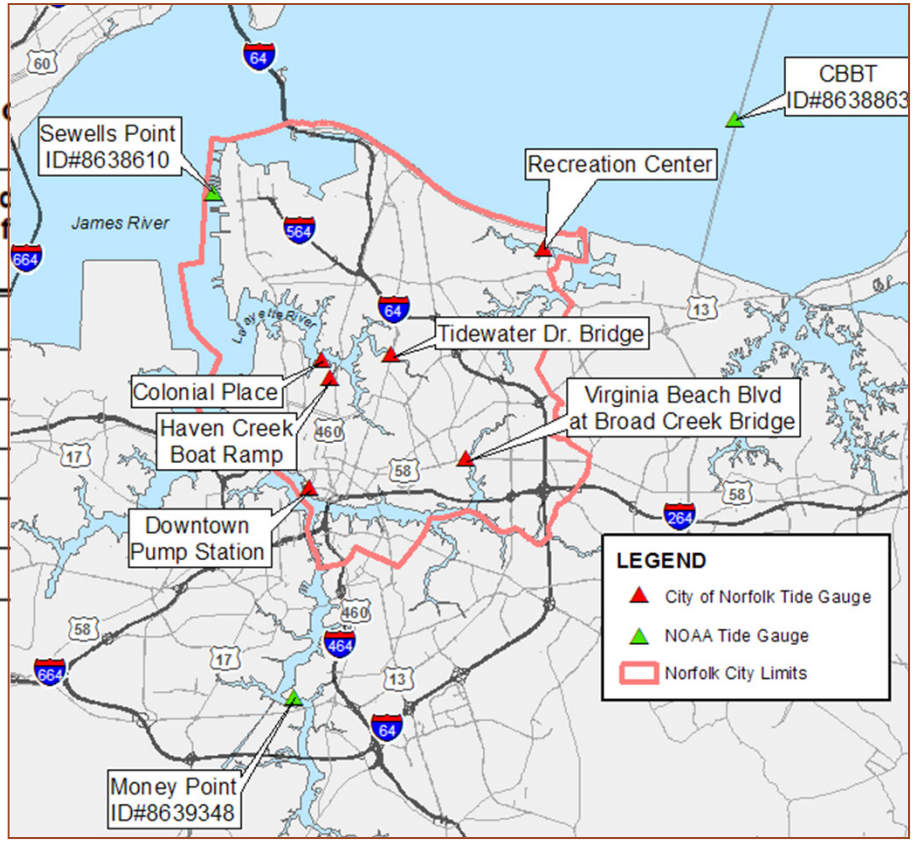
Data-Driven Analysis and Decision Making

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

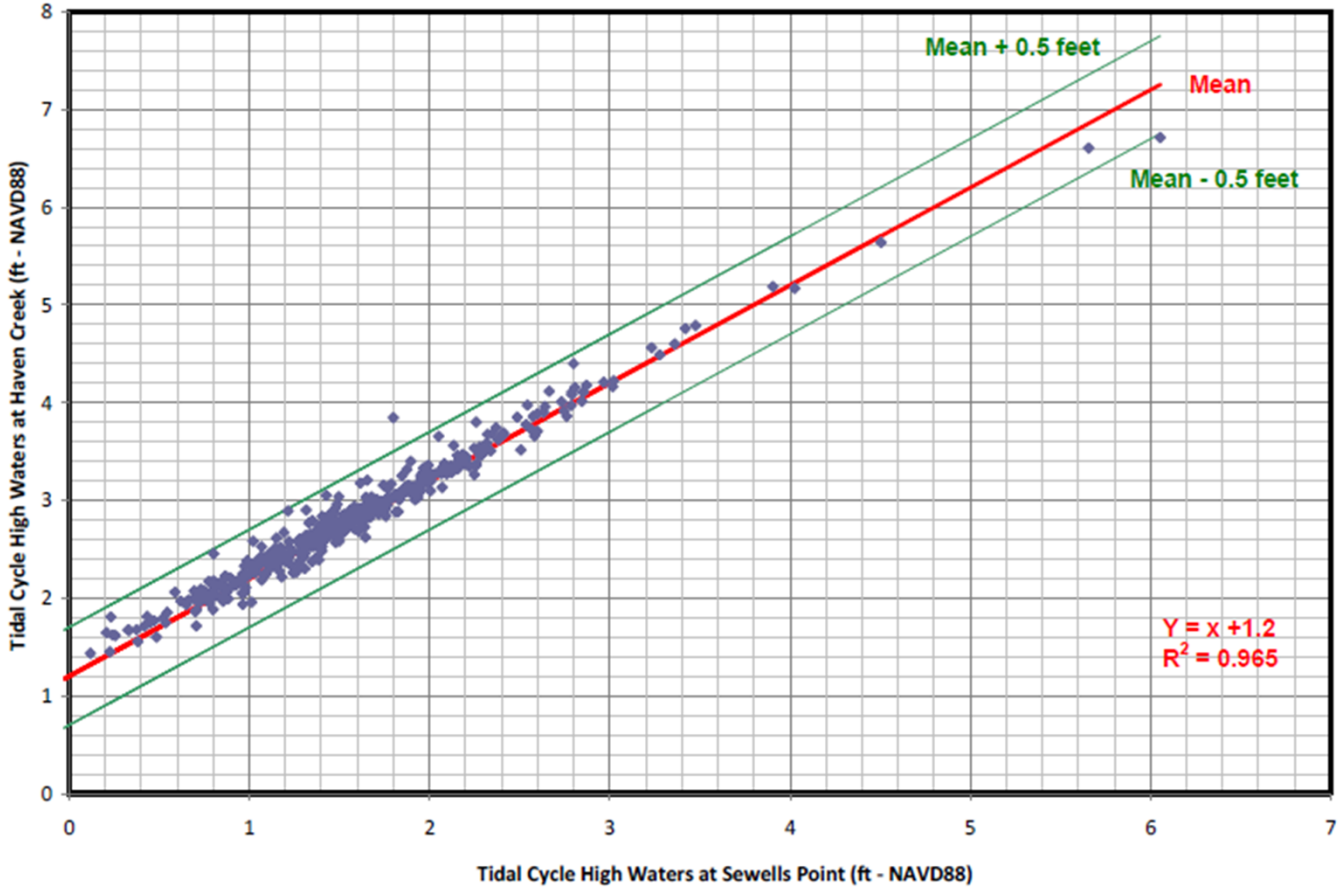
Table 1. Summary of Statistical Water Level Relati

Tide Gauge	Average Water Level, feet	Difference compared to Sewells Point, feet	Ac f
Sewells Point	0.3	--	
Recreation Center	0.3	-0.1	
Havens Creek	1.5	1.2	
Tidewater Bridge	0.9	0.5	
Downtown Pump Station	0.8	0.4	
Broad Creek	0.6	0.2	

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.

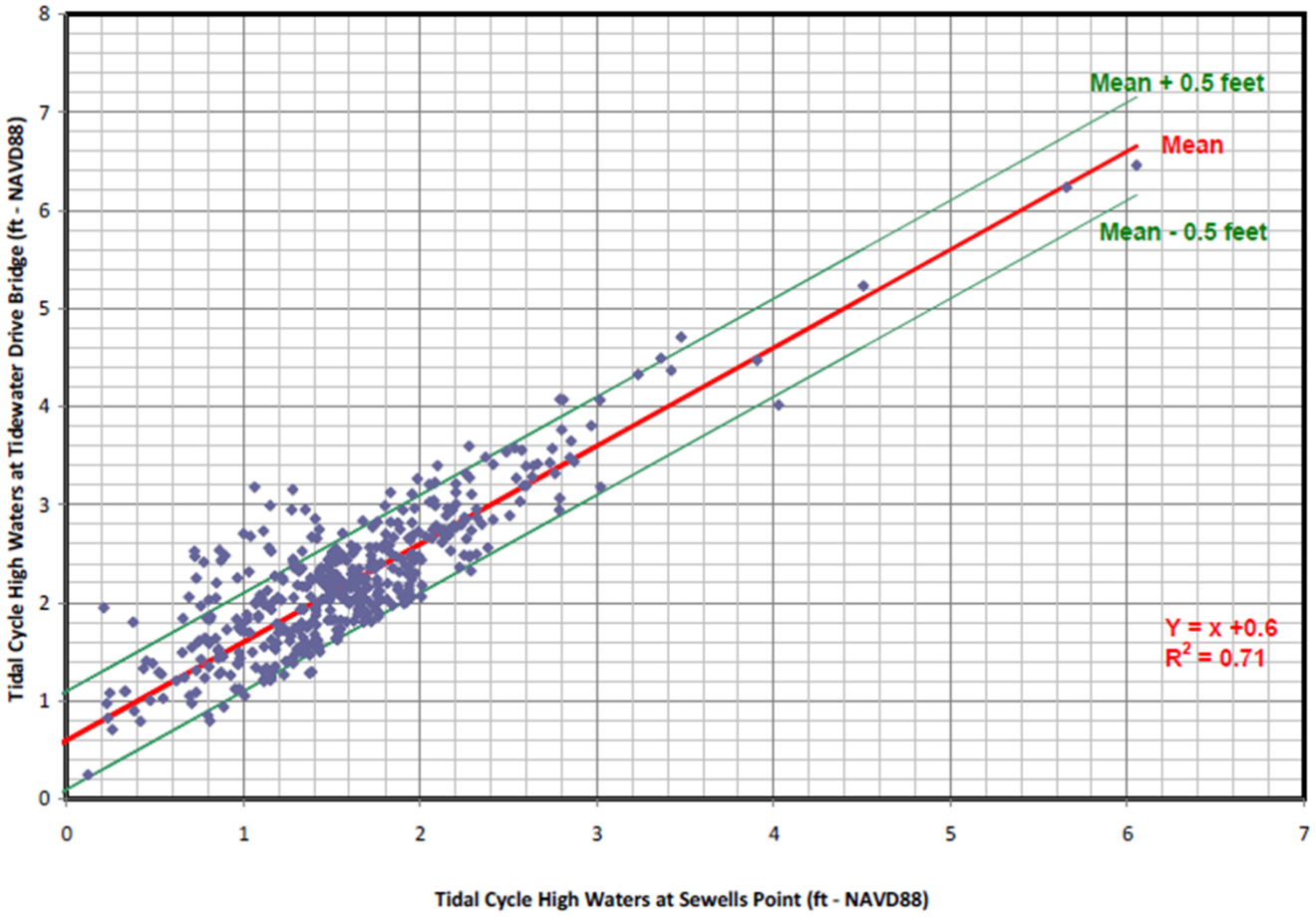


Tide gauges: Haven Creek vs. Sewells Point



COMPARISON OF TIDE GAUGE MEASUREMENTS AND SEWELLS POINT
Lafayette River – Haven Creek Boat Ramp (P13HC)

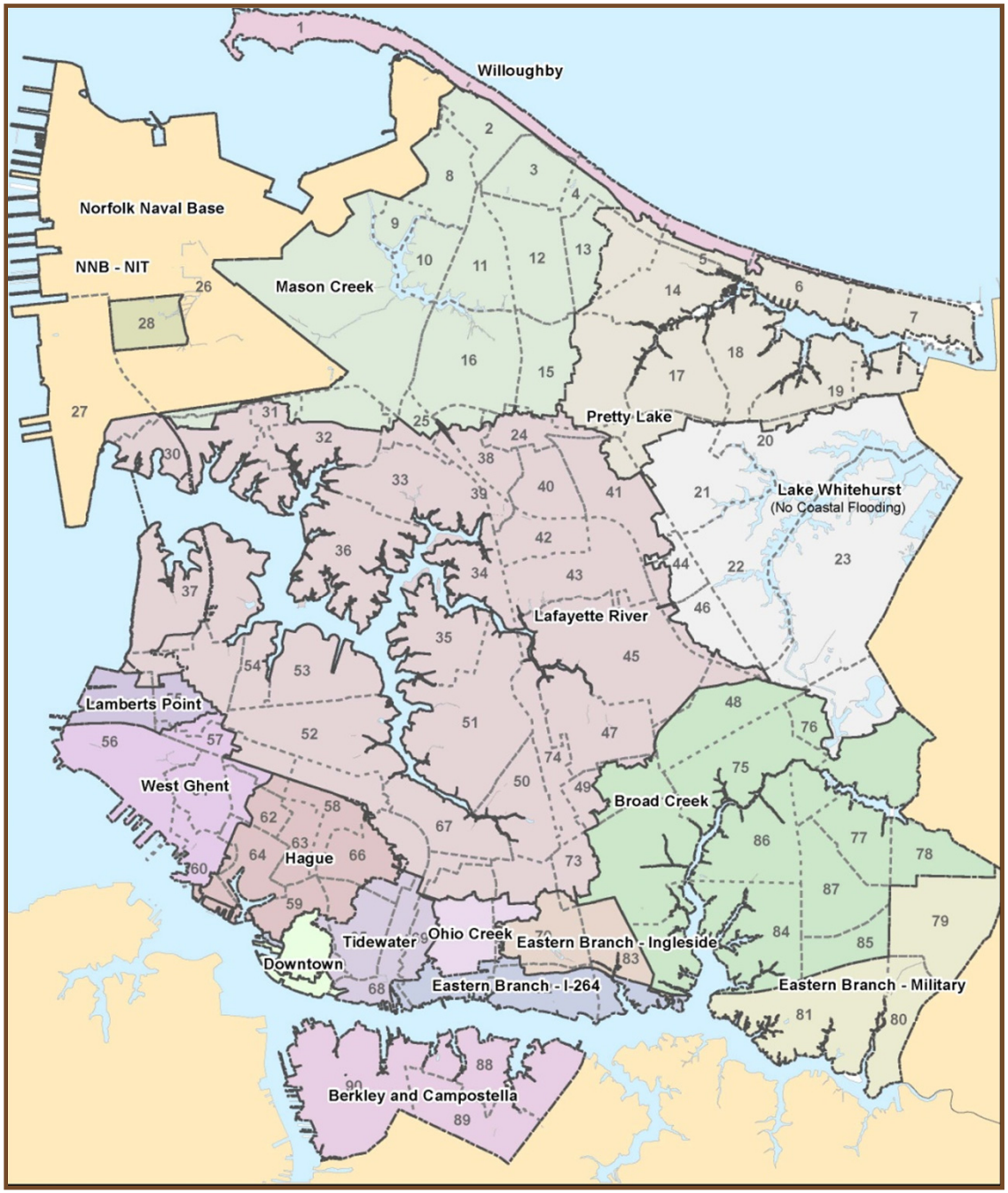
Tide gauges: Tidewater Drive Br. vs. Sewells Point



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

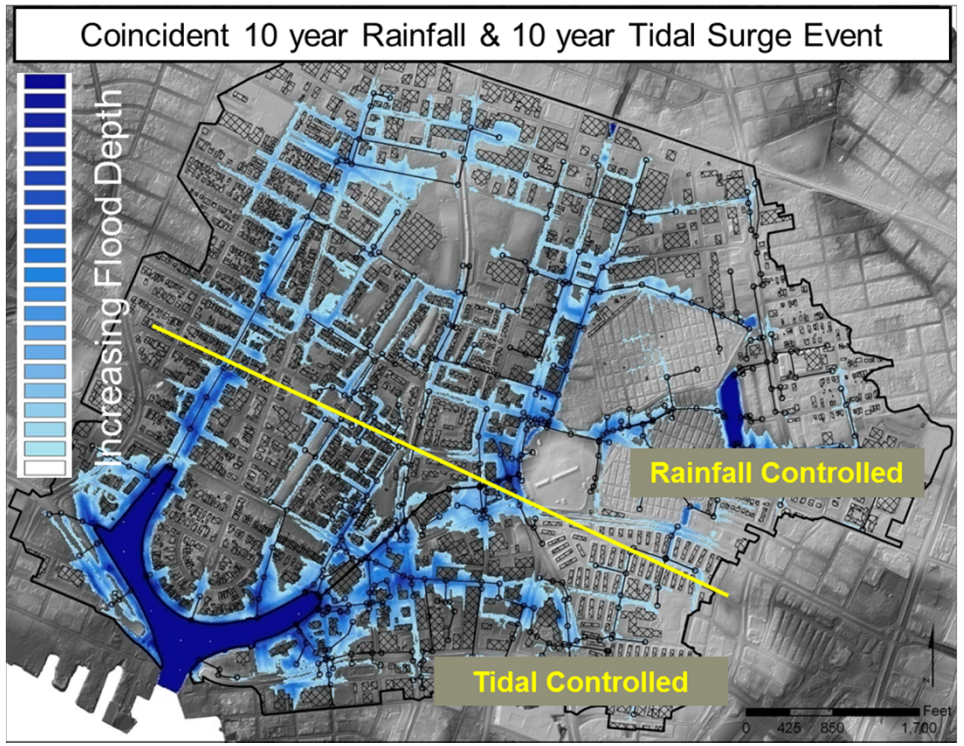
Coastal Flooding Evaluation Methods

- 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


Willoughby
Norfolk Naval Base
NNB - NIT
Mason Creek
Pretty Lake
Lake Whitehurst
(No Coastal Flooding)
Lafayette River
Lamberts Point
West Ghent
Broad Creek
Hague
Tidewater
Ohio Creek
Eastern Branch - Ingleside
Downtown
Eastern Branch - I-264
Eastern Branch - Military
Berkley and Campostella

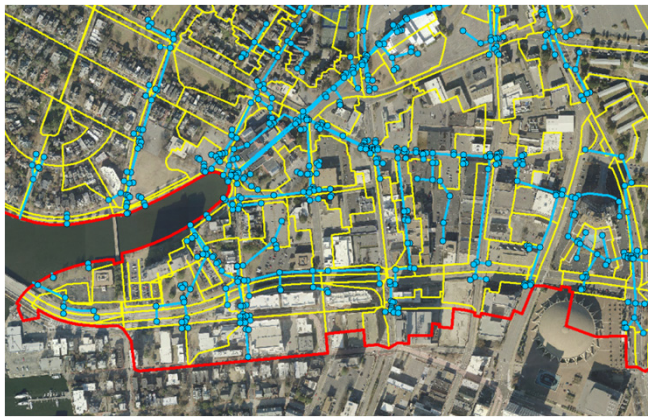
Coastal Flooding Evaluation Methods

- 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



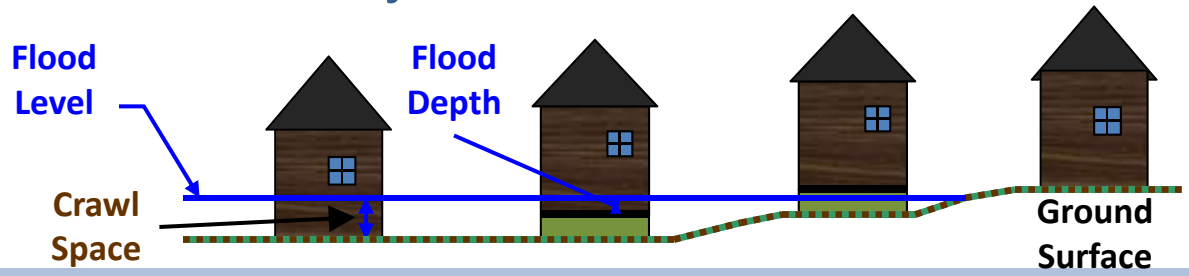
Coastal Flooding Evaluation Methods: Technology

- 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

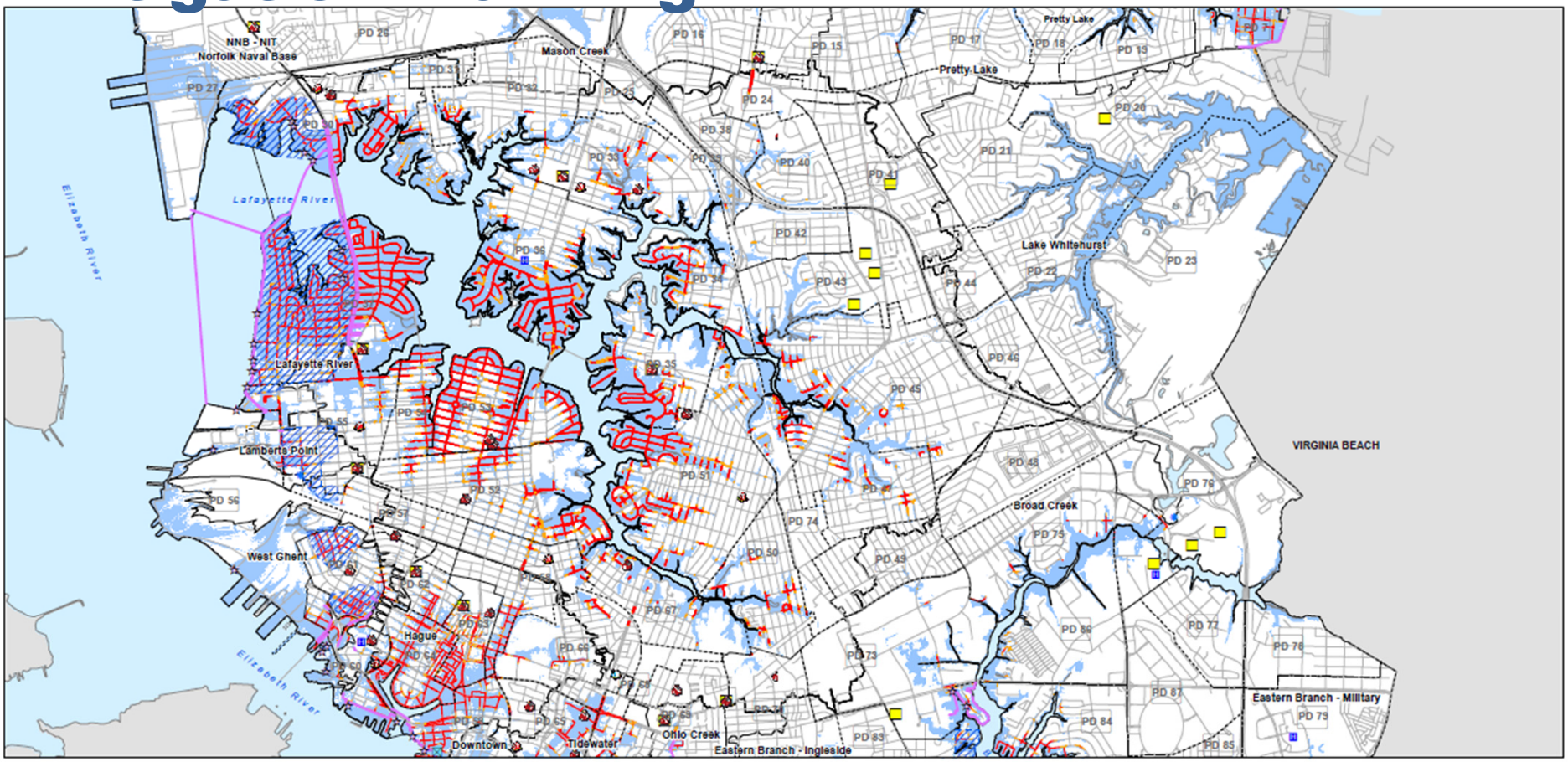


FIGURE 3-12b

City-wide Vulnerability and Mitigation Planning

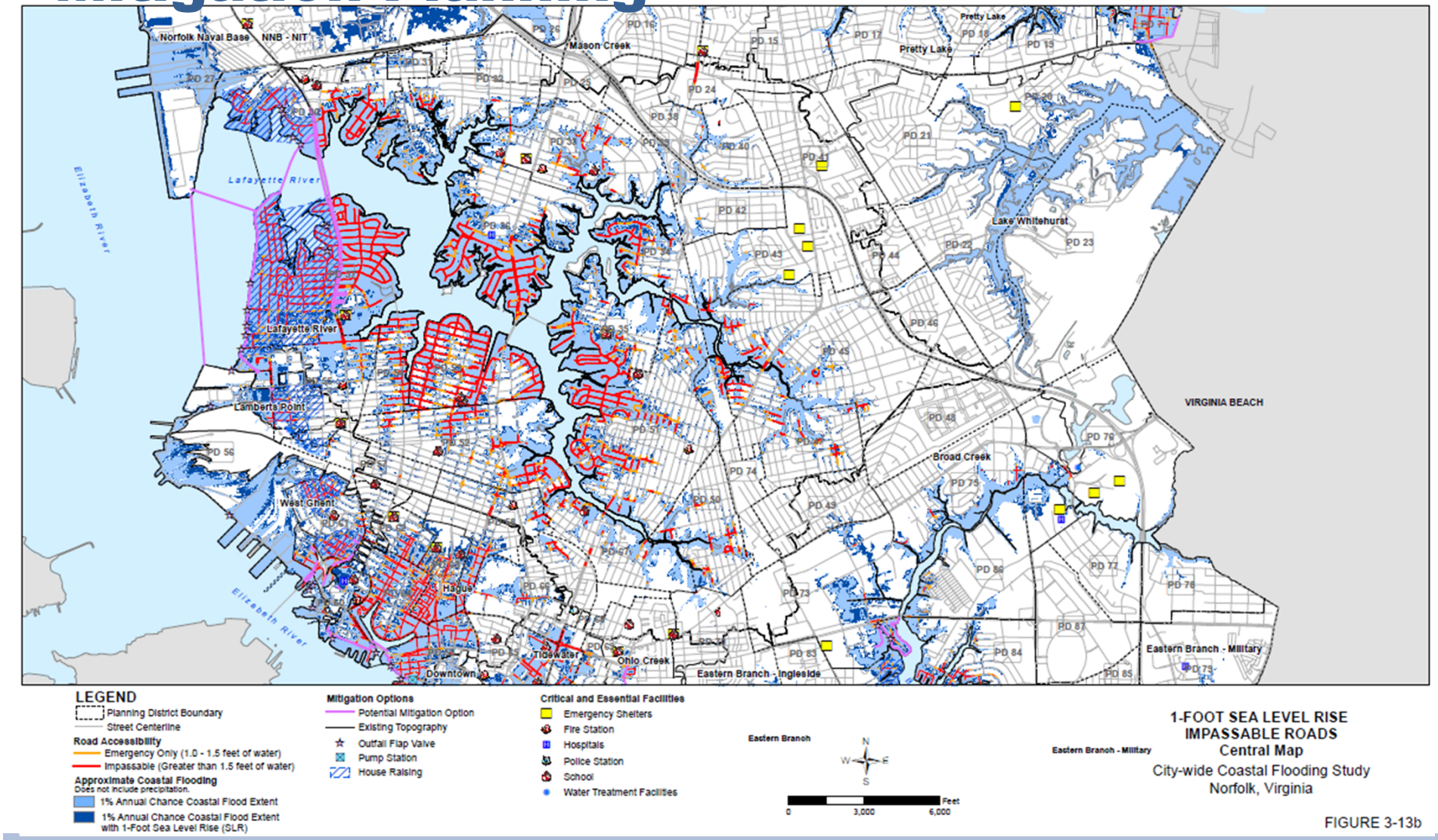
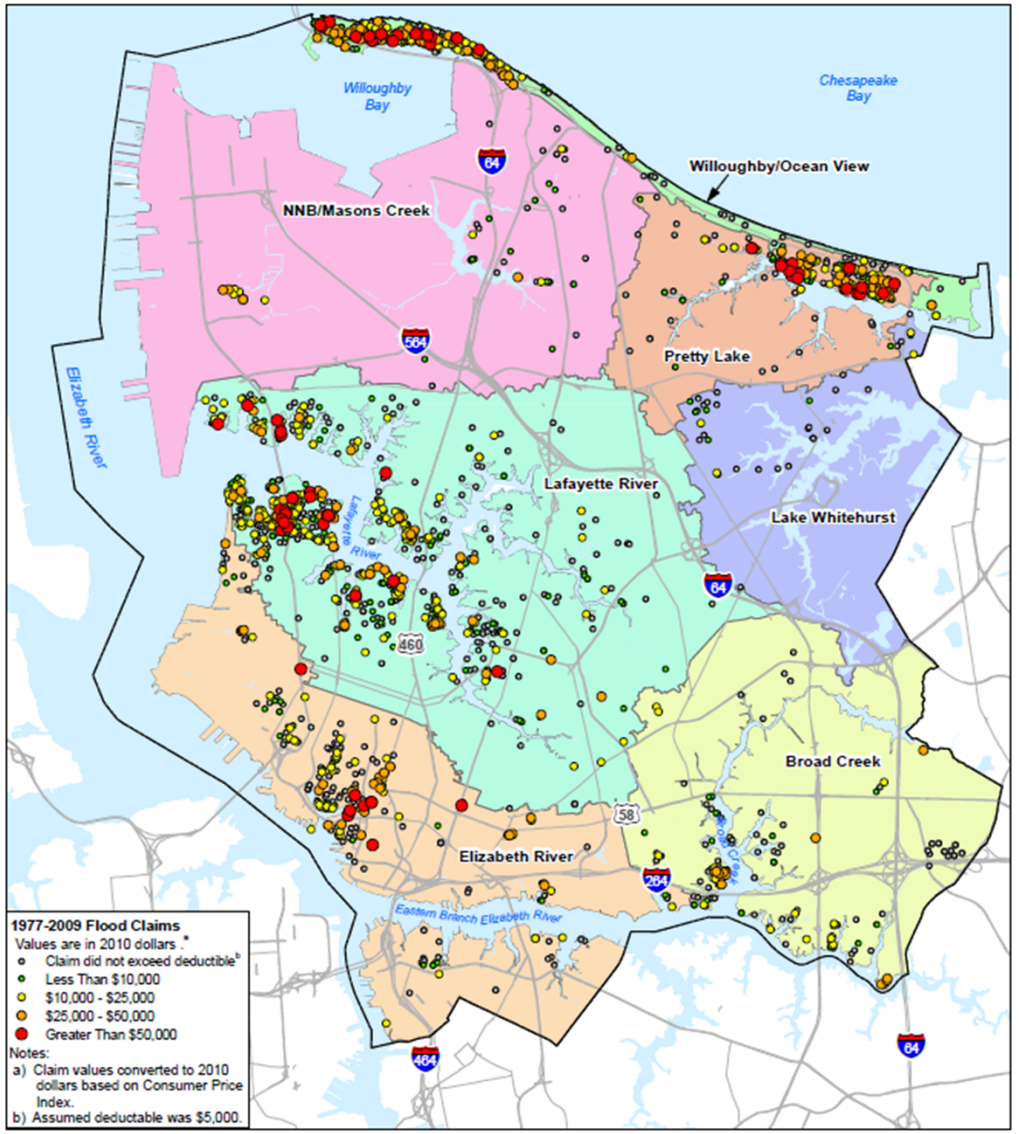
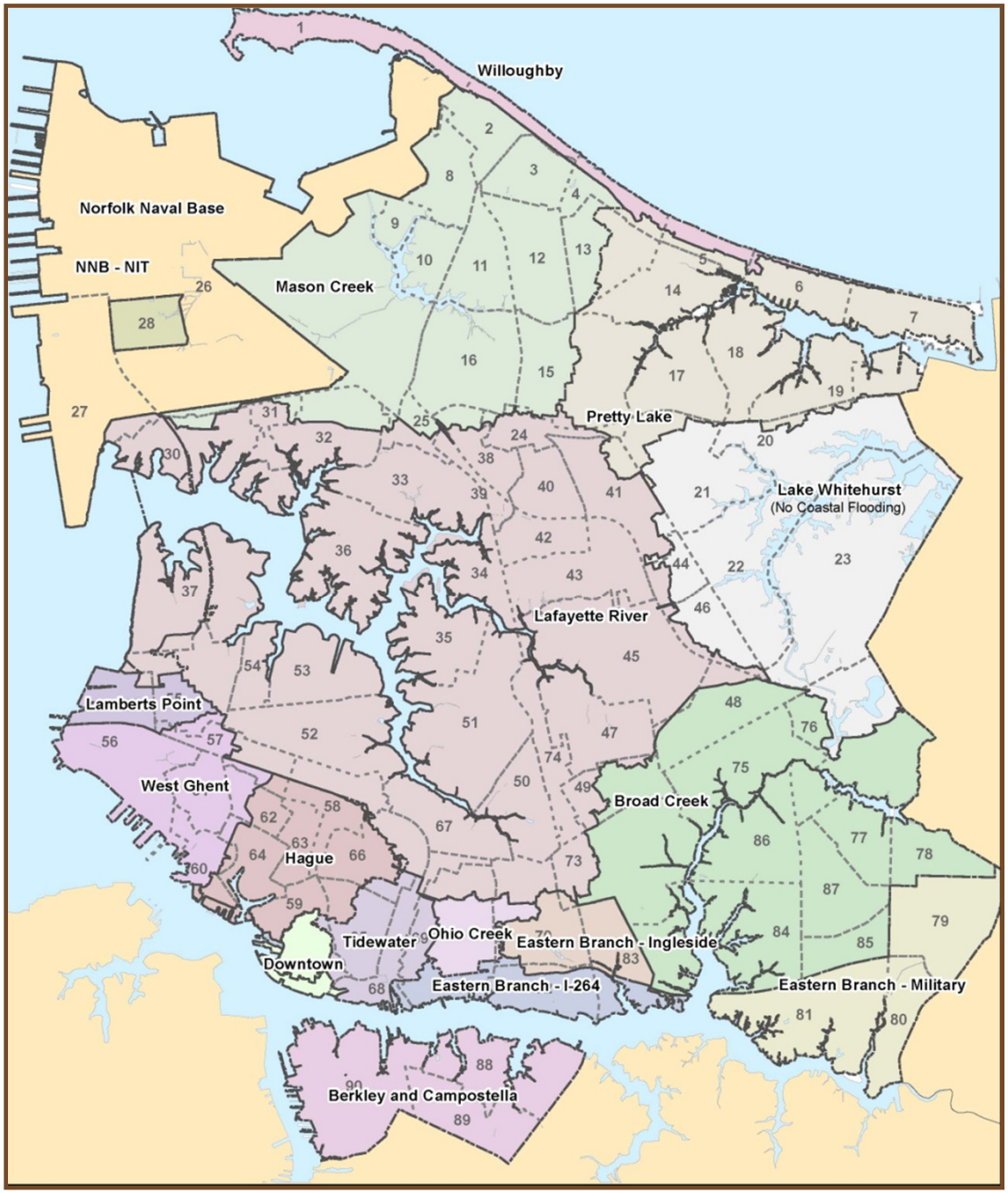


FIGURE 3-13b

City-wide Vulnerability and Mitigation Planning

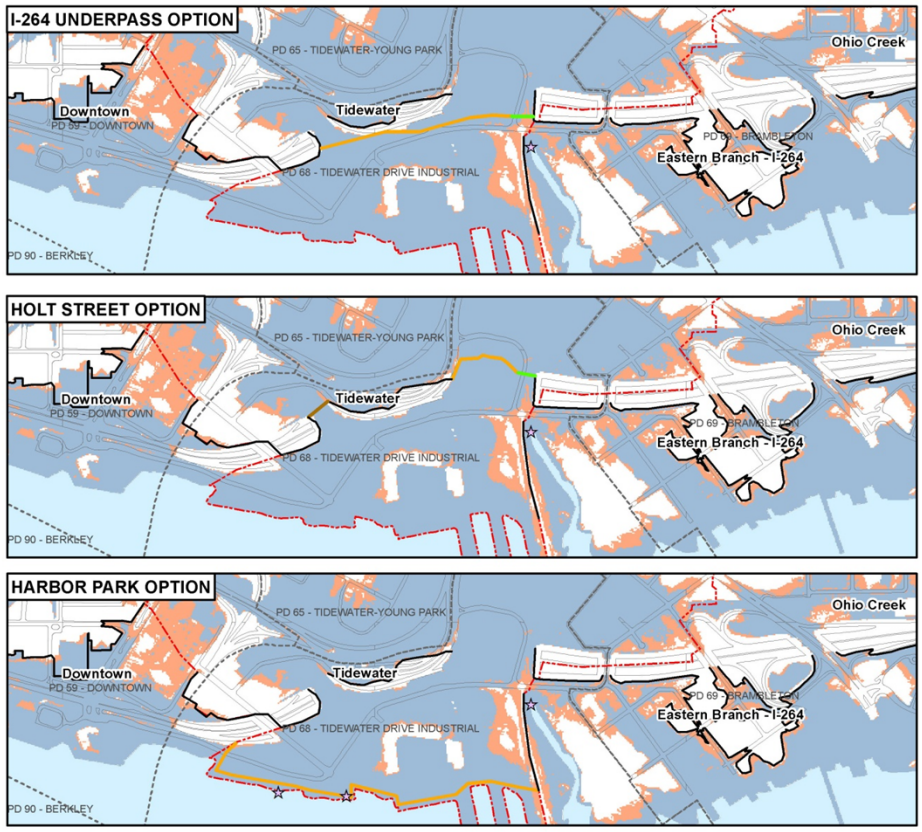
- Infrastructure and property vulnerability
  - FEMA claims
  - Depth-damage curves on GIS-based grid analysis
  - HAZUS-style analysis for detailed looks at local areas




Willoughby
Norfolk Naval Base
NNB - NIT
Mason Creek
Pretty Lake
Lake Whitehurst
(No Coastal Flooding)
Lafayette River
Lamberts Point
West Ghent
Hague
Broad Creek
Tidewater
Ohio Creek
Eastern Branch - Ingleside
Downtown
Eastern Branch - I-264
Eastern Branch - Military
Berkley and Campostella

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

House Raising

Outfall Flap Valve

Pump Station

Critical and Essential Facilities

Emergency Shelters

Fire Station

Hospitals

Police Station

School

Water Treatment Facilities

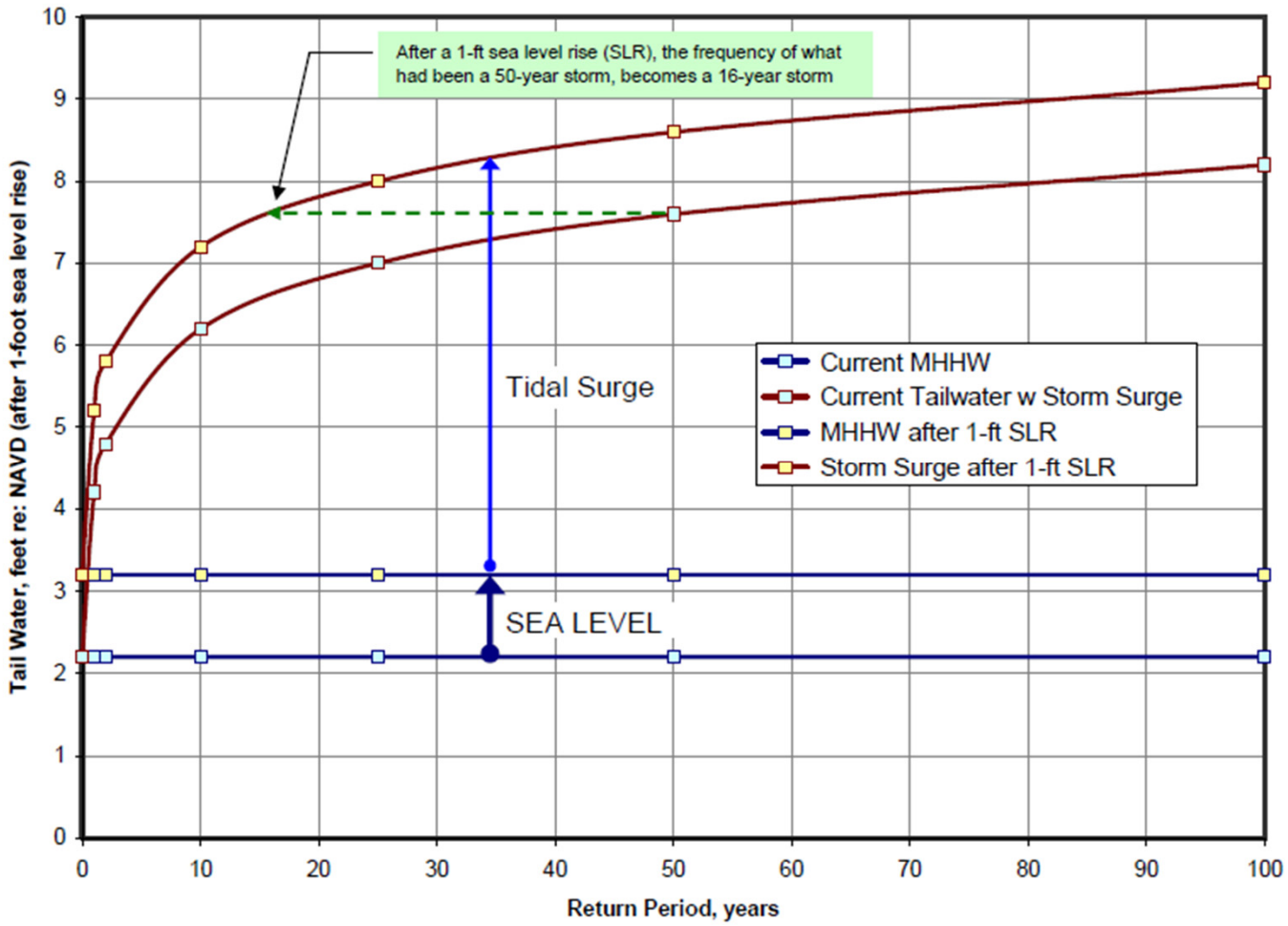
City-wide Vulnerability and Mitigation Planning

- 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 [Score = Reduced Damage / Cost x 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?



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?