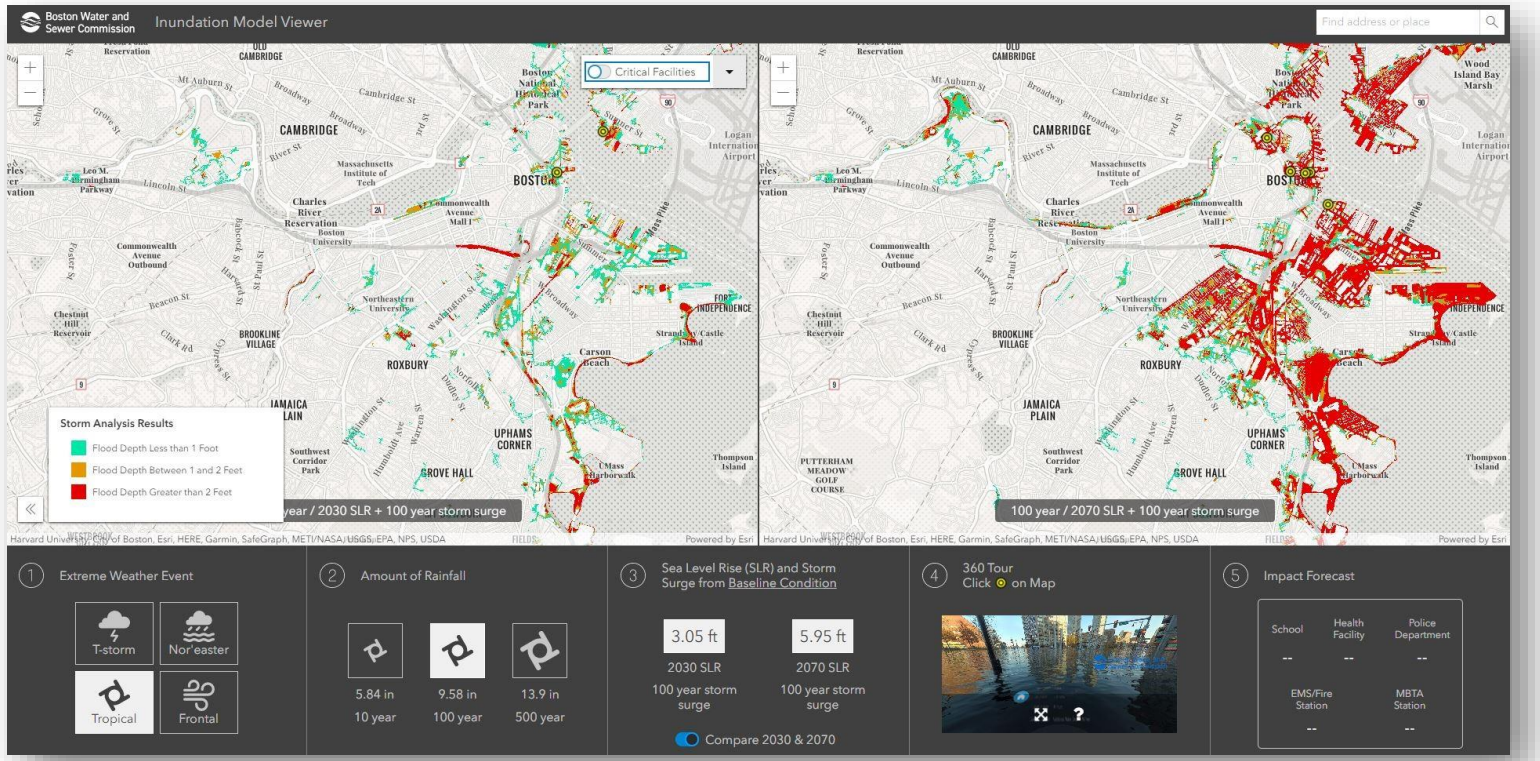
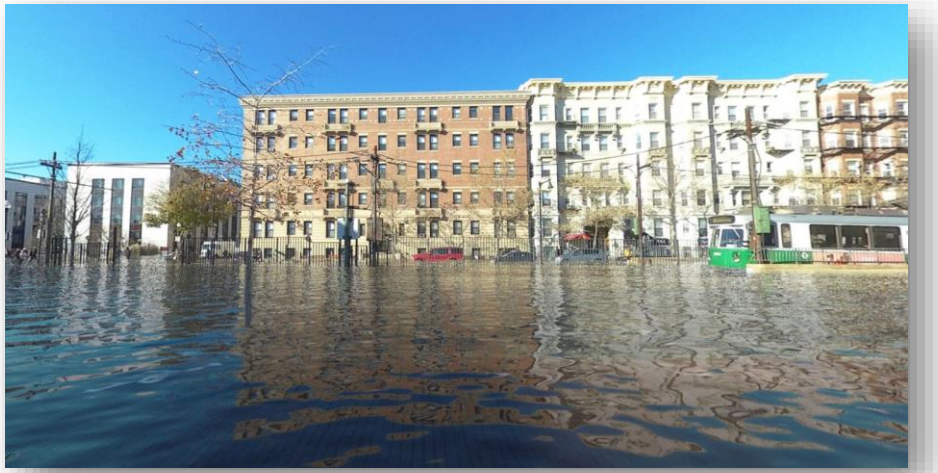
Simulating, Evaluating, and Visualizing Extreme Storm Flooding in Boston Using Spatial Rainfall and 2D Flood Modeling

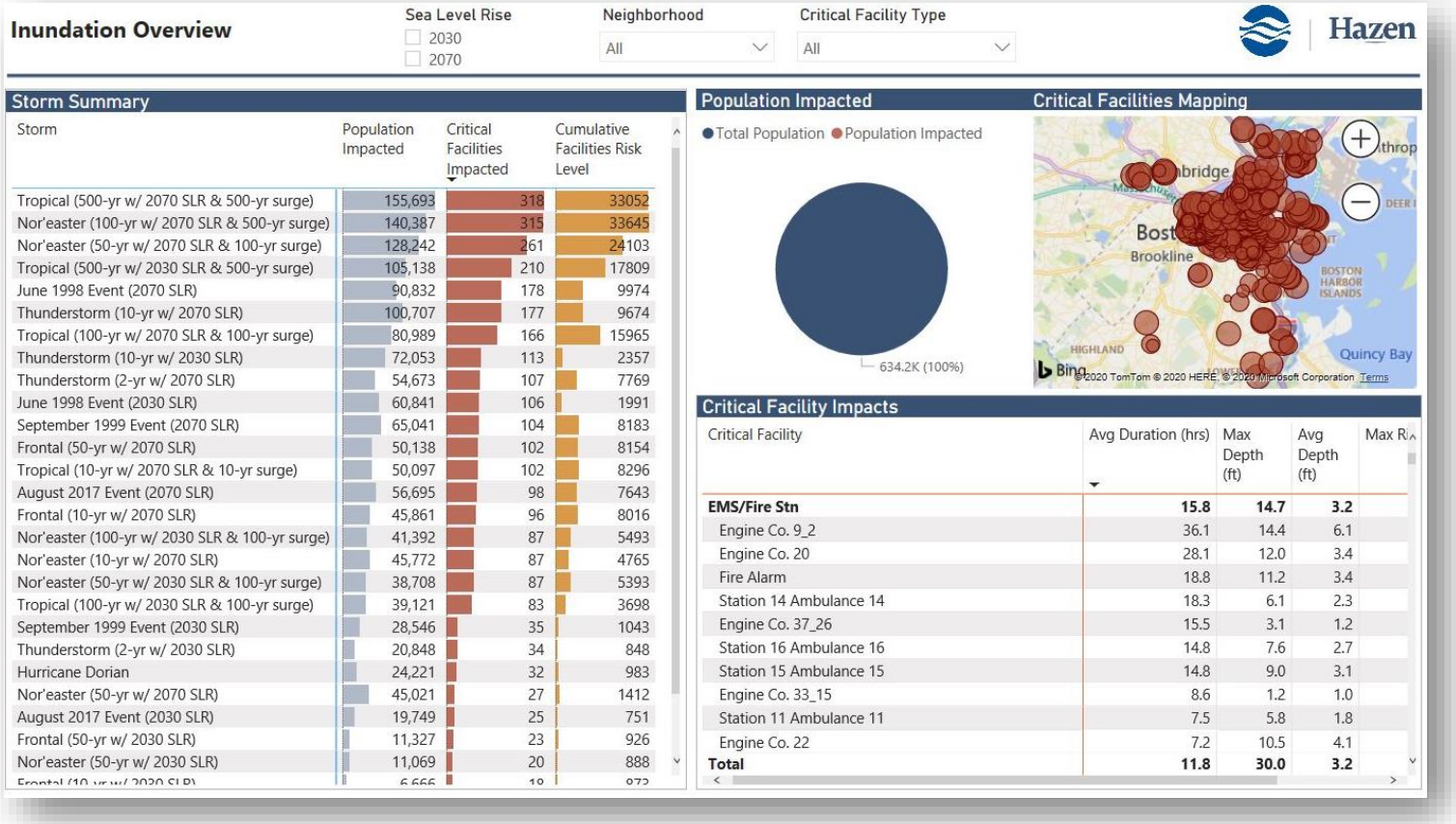




Charlie Jewell – Director of Planning and Sustainability, Boston Water and Sewer Commission
Ben Agrawal, PE – Principal Engineer, Hazen and Sawyer
Charles Wilson, PE – Associate Vice President, Hazen and Sawyer

Agenda

- Background
- Storm event development
- Model development
- Demonstration of visualization tools
- Conclusions



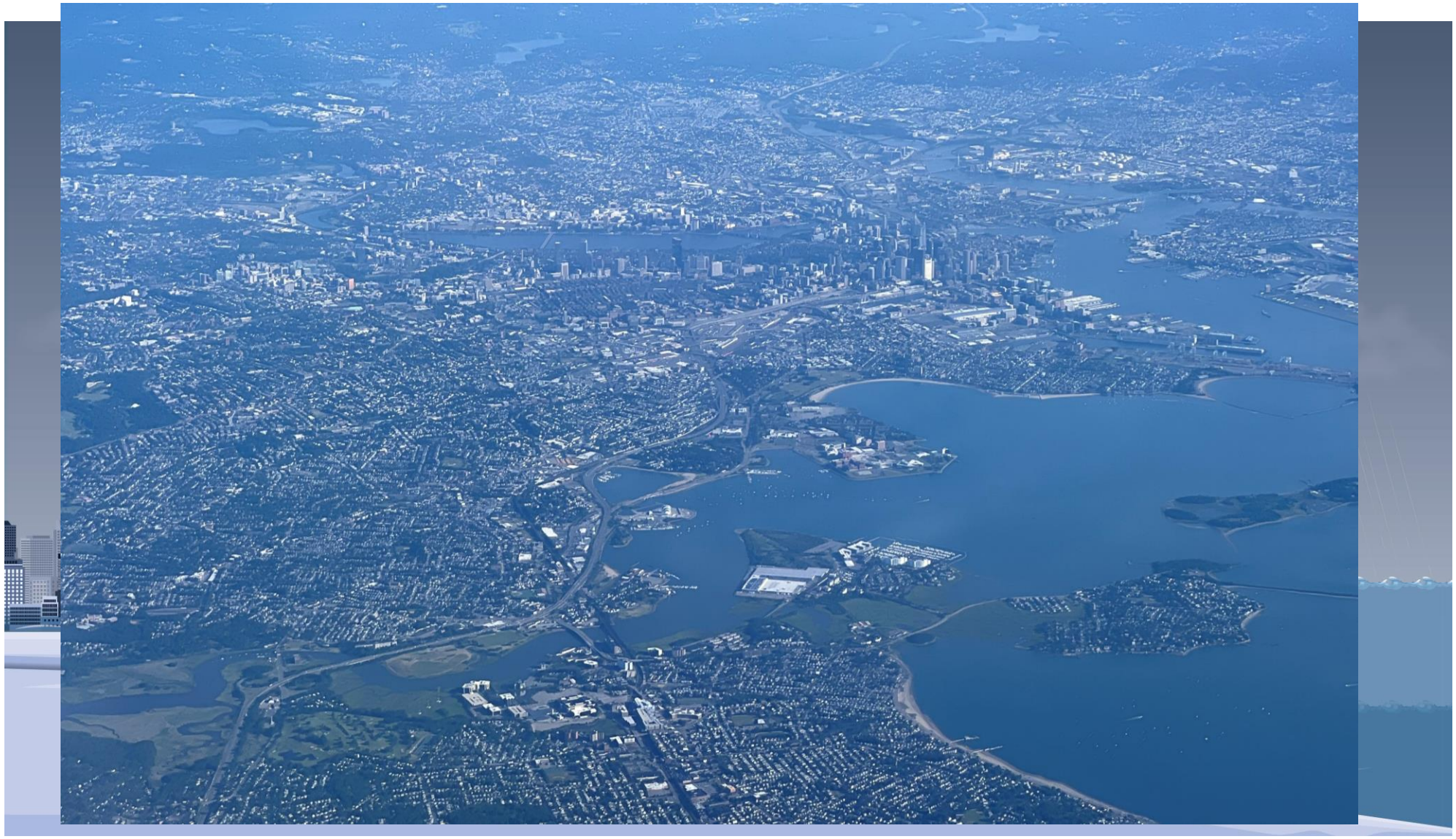
Background

- Hurricane Harvey (Texas, 2017)
- Develop tool and understanding of risks for emergency planning
- **Identify where flooding occurs, how long, and who and what is impacted**
- **Communicate flood impacts to non-technical stakeholders**

Inundation Model - Project Overview

1. Develop 2D model that will estimate and graphically display inundation information using most current projections available.
2. Model will allow identification of land area, buildings and roads impacted by major events.
3. Model can be used as an early warning tool to pre-evacuate potentially impacted areas.
4. Estimate the projected depth and duration of inundation
5. Estimate potential population impacted
6. Identify critical facilities impacted by inundation
7. Utilize model as a collaboration tool with other agencies with data available and accepted by other entities
8. Have the information Peer Reviewed by outside entity.

Boston – Coastal and Stormwater Flooding

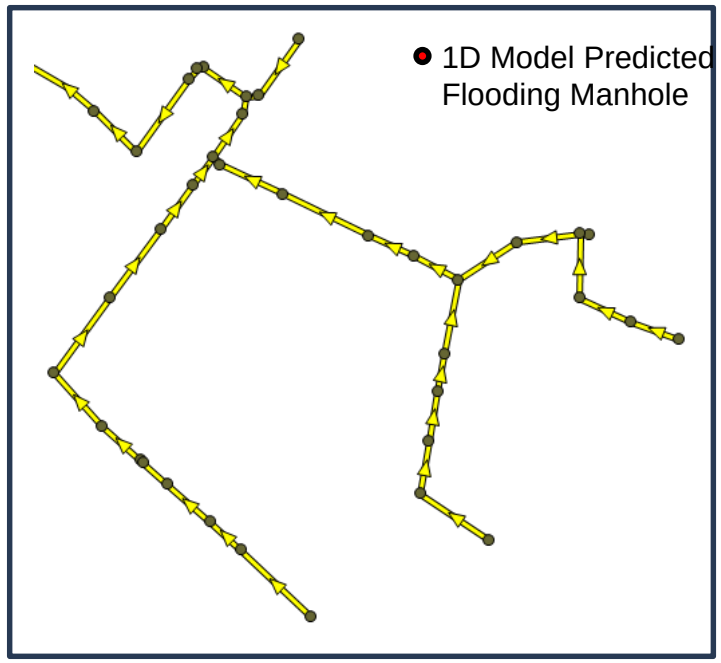


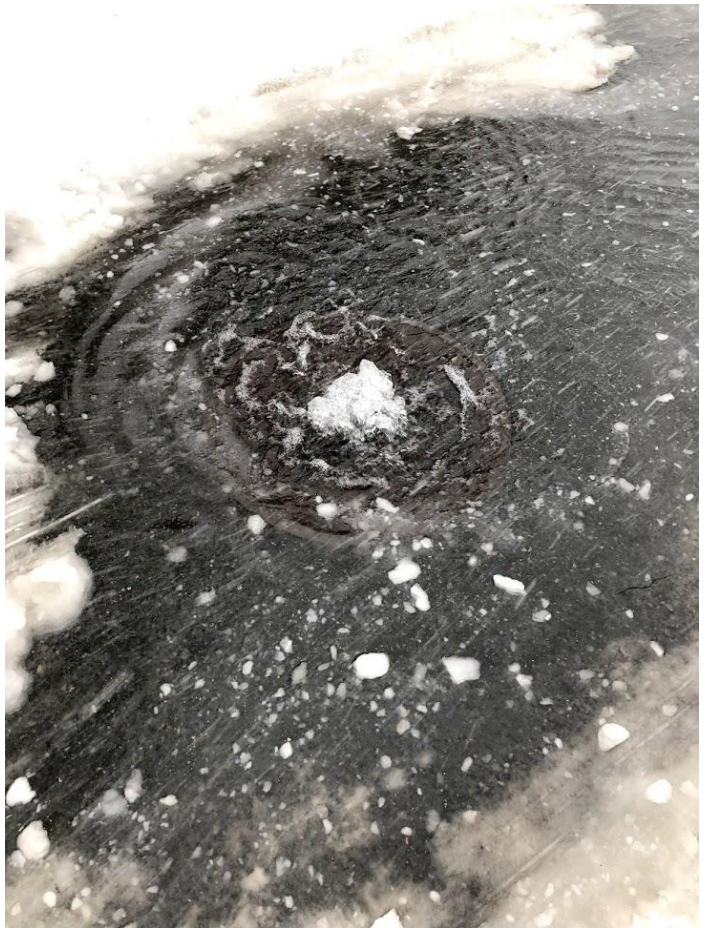
*The Inundation Model considers the impact of coastal flooding **and** inland stormwater flooding*

1D vs. 2D Modeling

1D Modeling

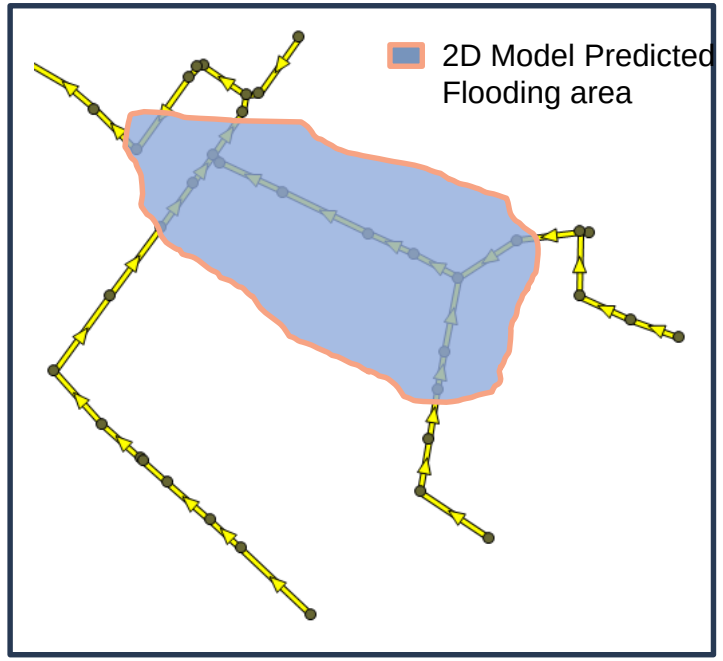
- Flows are limited in pipes
- No predicted flow movement once water leaves piping network





2D Modeling

- 2D mesh for surface flow
- Flow not limited to pipes
- Surface flows are predicted once water leaves piping network or enters from coastal boundary



Wet Weather Events

Rainfall

- Logan Airport Rain Gauge: 3,100 Events
- May 1948 – May 2018
- Develop parameters for characteristic rainfall distributions and motions

Coastal Boundary Conditions

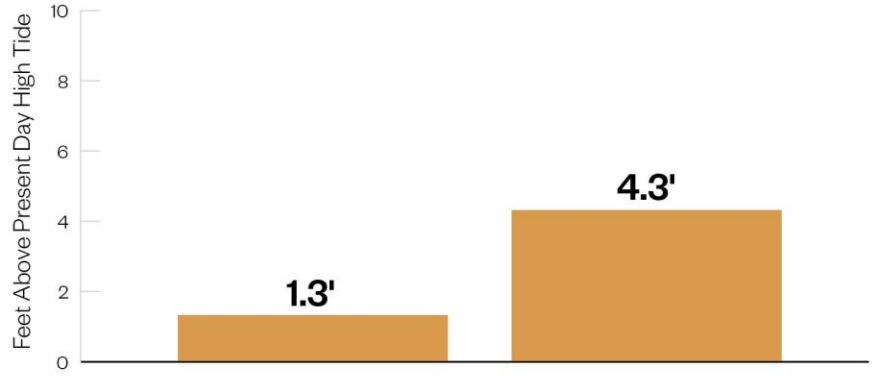
- Massachusetts Coast Flood Risk Model
- Hydrodynamic model
- Sea level rise and storm surge predictions for 2030 and 2070

Thunderstorm

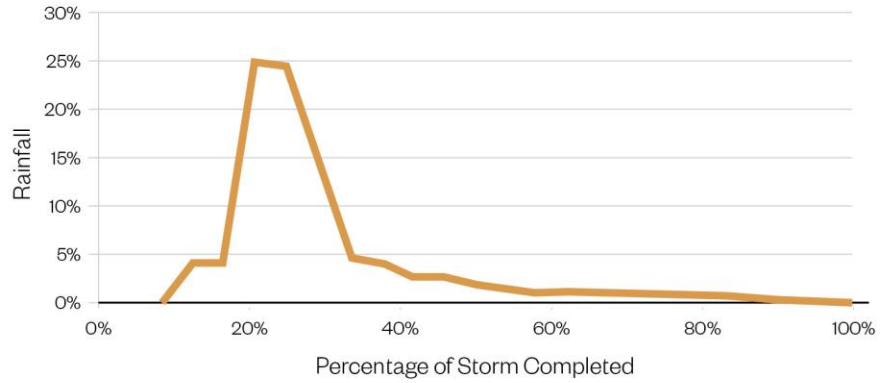
Storm Motion

Storm Direction: **66.0 degrees | Northeast**
Speed: **25 miles per hour**

Sea Level Rise (SLR)



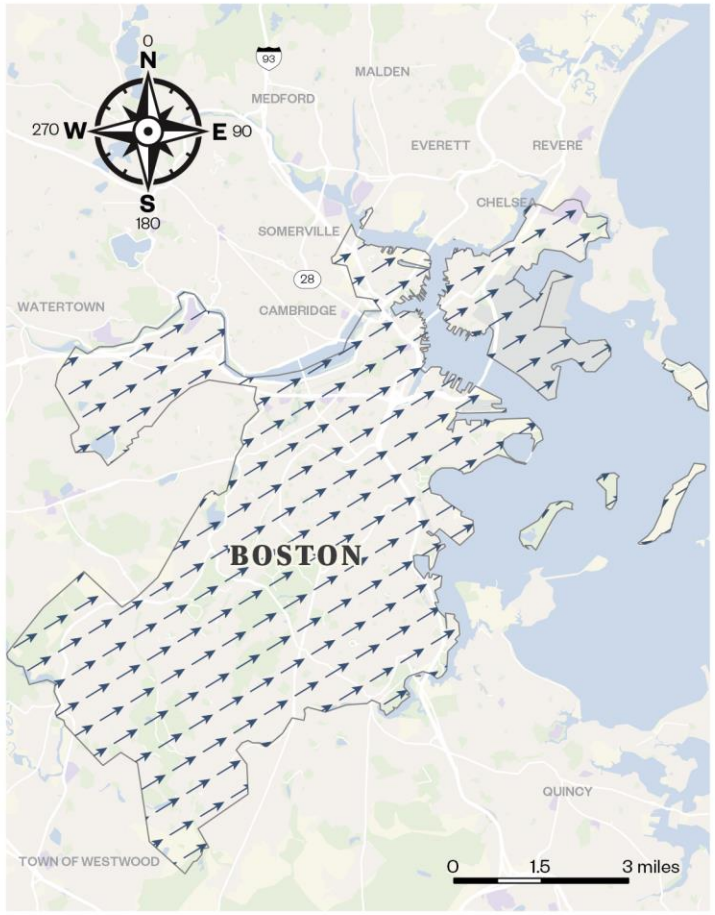
Storm Accumulation



Wet Weather Events

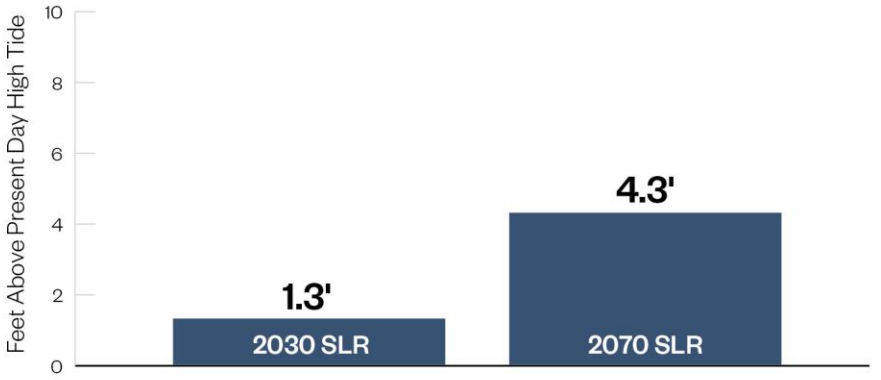
Frontal

Storm Motion

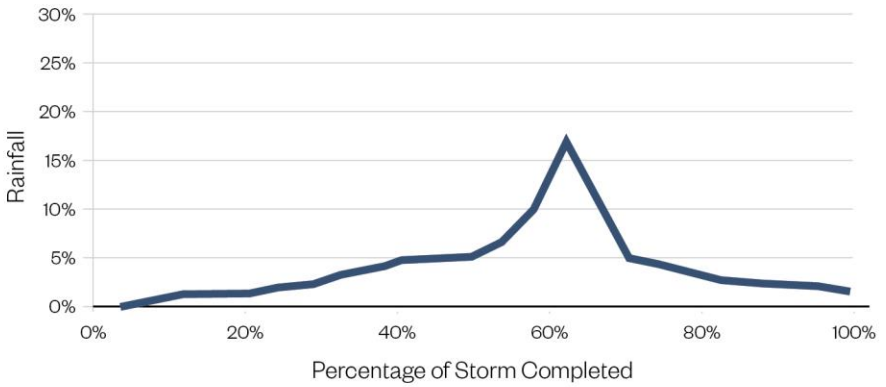


Storm Direction: **56.3 degrees | Northeast**
Speed: **26.4 miles per hour**

Sea Level Rise (SLR)



Storm Accumulation



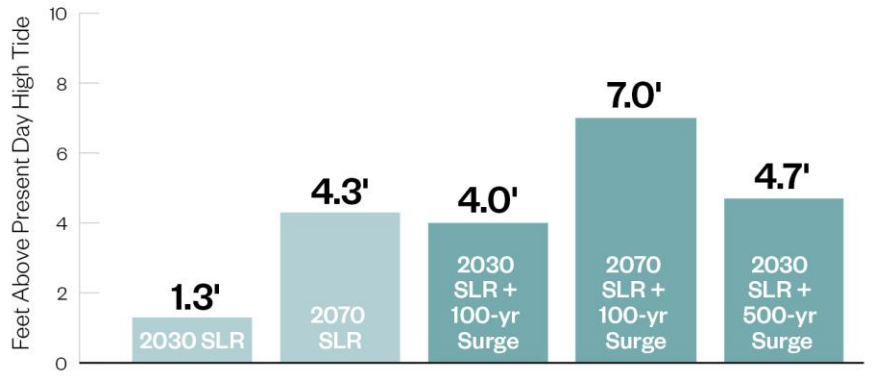
Wet Weather Events

Nor'easter

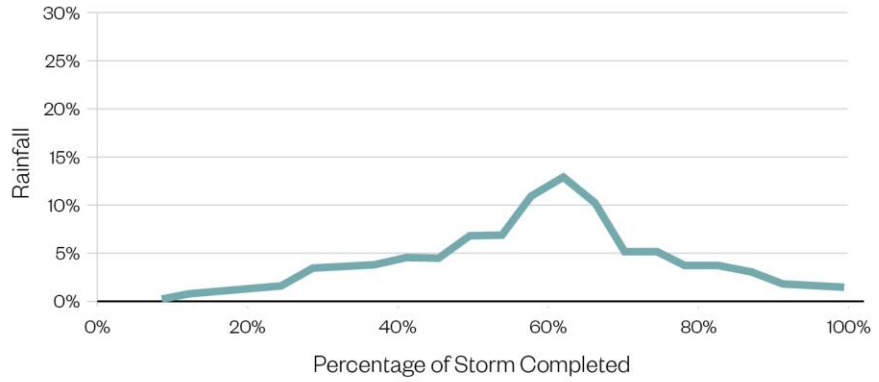
Storm Motion

Storm Direction: **270.0 Degrees | West**
Speed: **21.1 miles per hour**

Sea Level Rise (SLR) and Storm Surge



Storm Accumulation



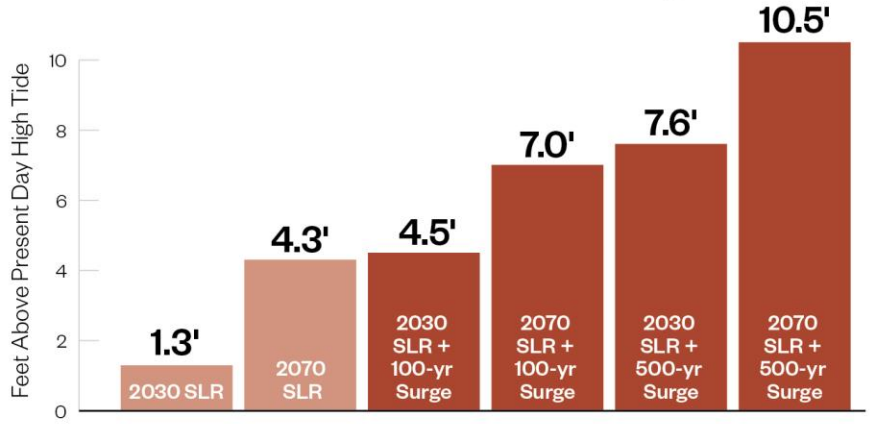
Wet Weather Events

Tropical

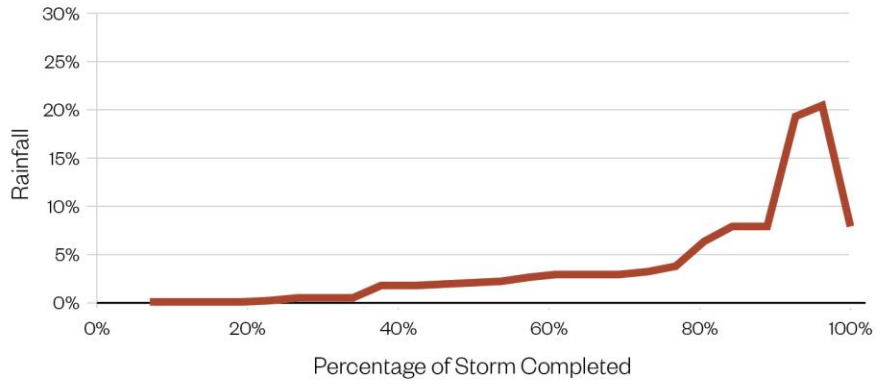
Storm Motion

Storm Direction: **270.0 Degrees | West**
Speed: **24.8 miles per hour**

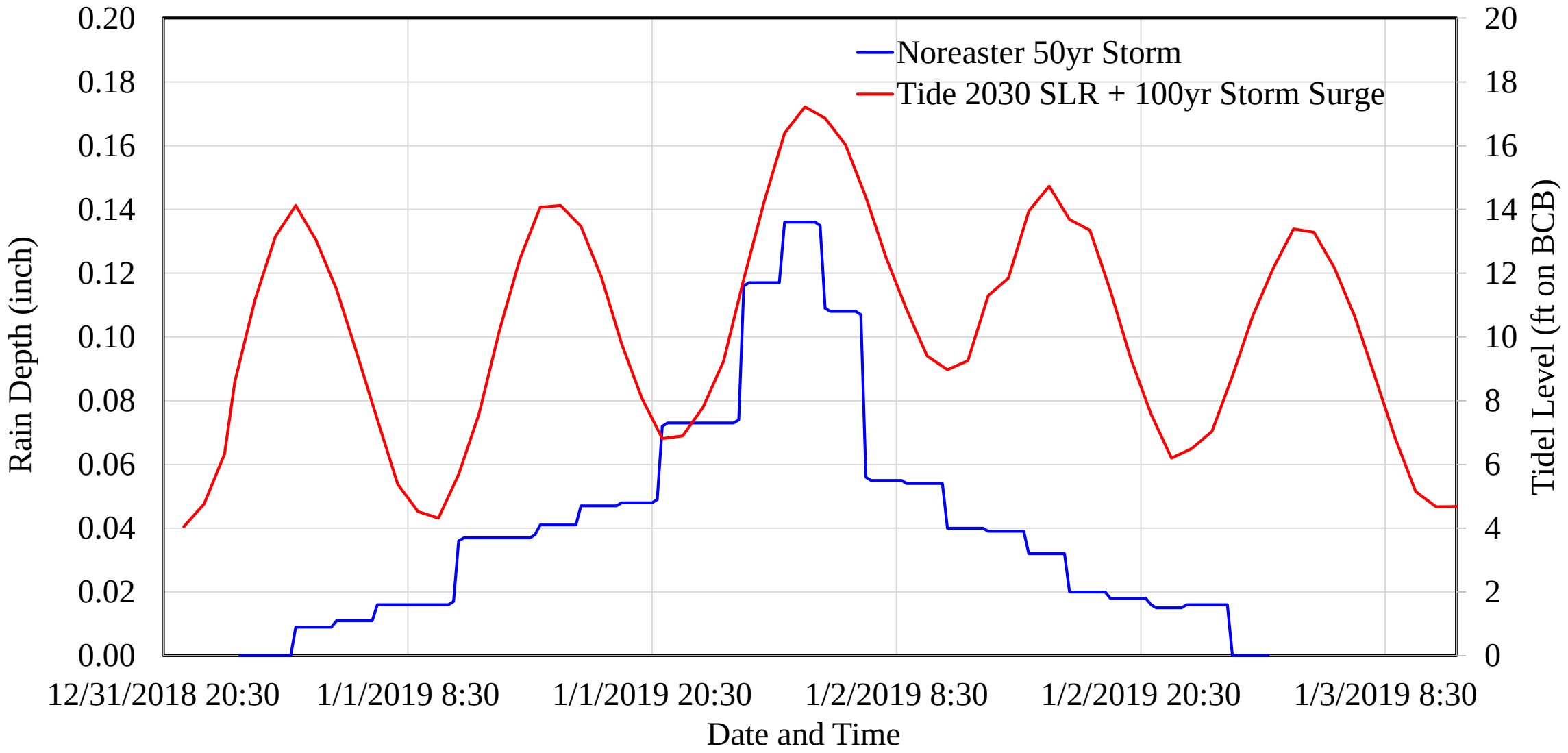
Sea Level Rise (SLR) and Storm Surge



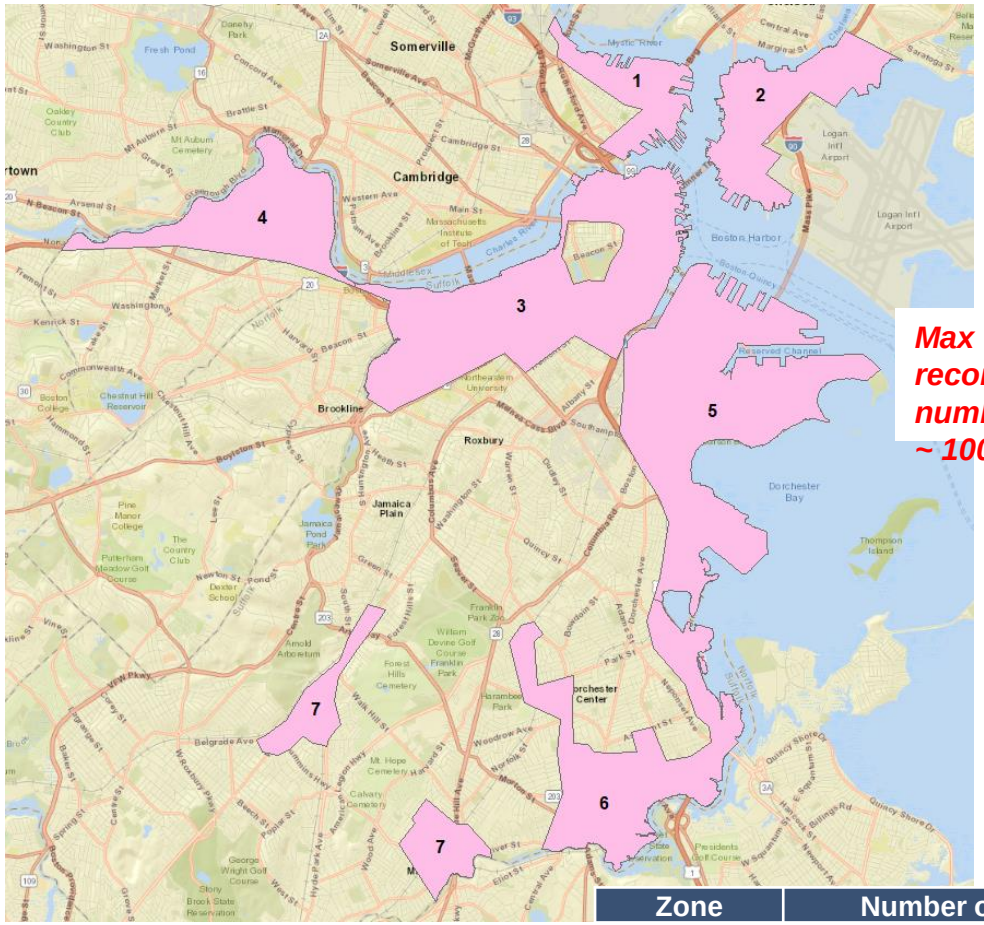
Storm Accumulation



Tide Cycle & Precipitation – Model Example



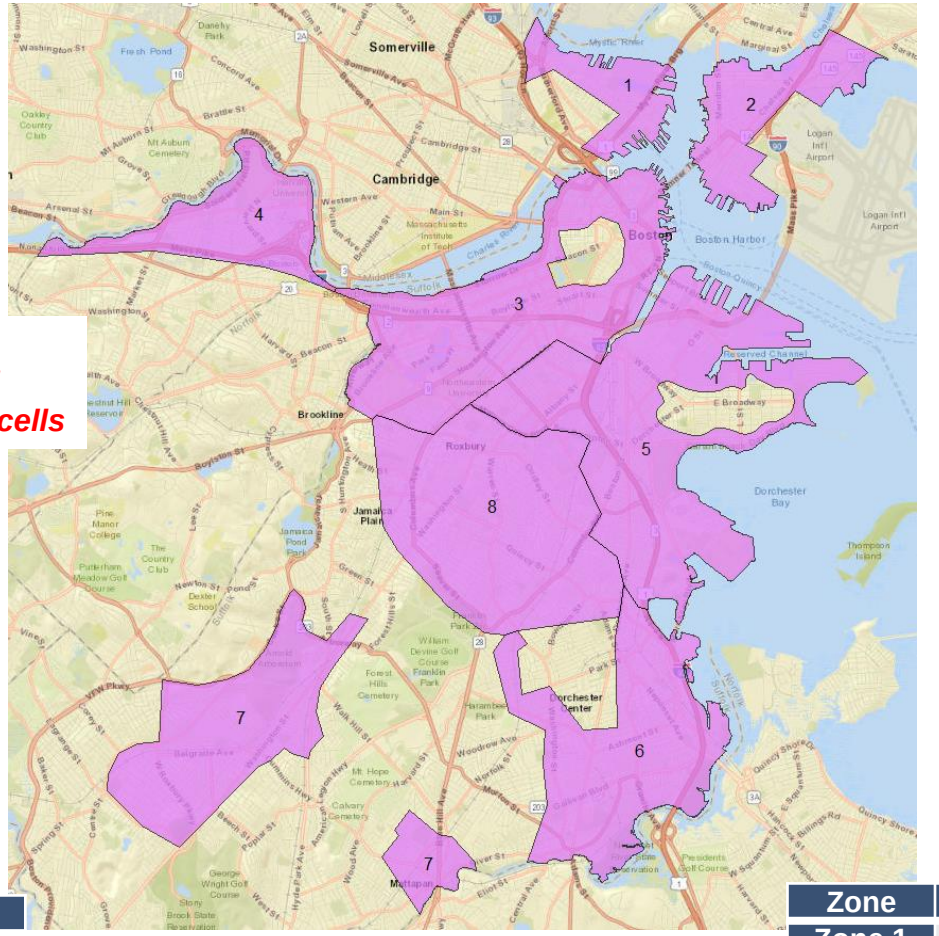
2D Zones – Citywide



Original (initial simulations)

Zone	Number of Cells
Zone 1	22,726
Zone 2	39,910
Zone 3	84,334
Zone 4	45,602
Zone 5	109,877
Zone 6	72,494
Zone 7	29,508

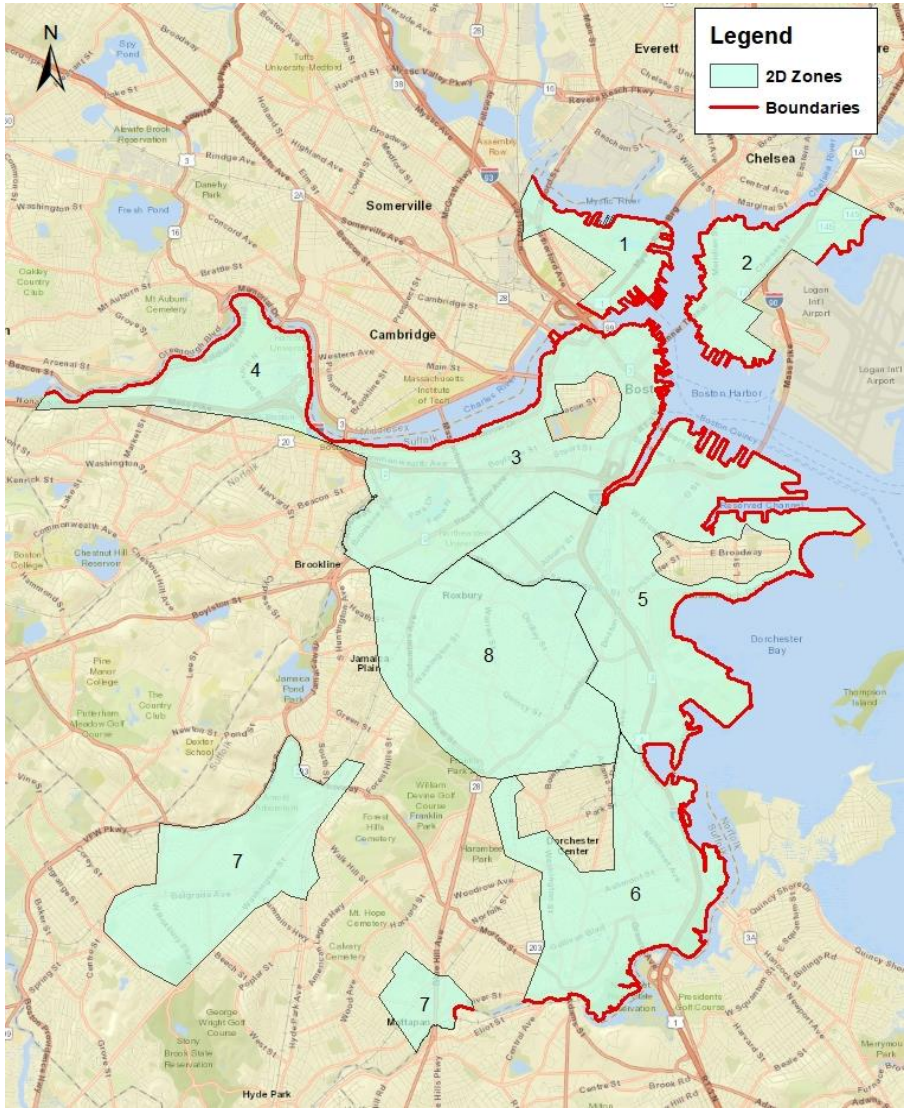
Max recommended number of 2D cells ~ 100,000

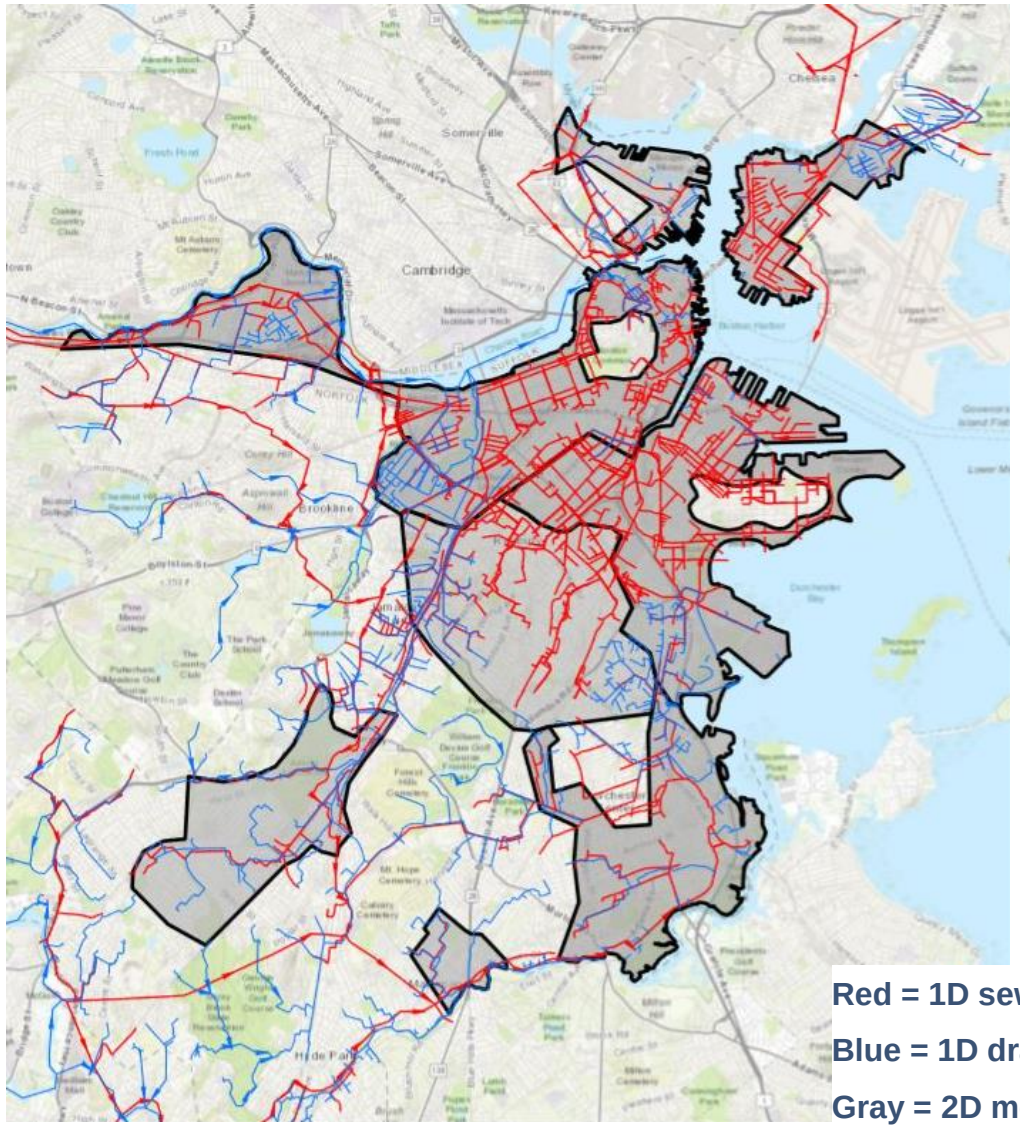


Final (revised simulations)

Zone	Number of Cells
Zone 1	25,290
Zone 2	39,910
Zone 3	93,877
Zone 4	45,602
Zone 5	136,252
Zone 6	99,693
Zone 7	99,965
Zone 8	120,443

Combined Sewer, Drain, and 2D Model





Red = 1D sewer model

Blue = 1D drain model

Gray = 2D model zones

Baseline Simulations Completed

Model Scenario	Dur. (hr)	Depth (in)	Return Period (yr)	Speed (mph)	Hyetograph Shape	Coastal Boundary Condition #1	Coastal Boundary Condition #2
1) Airmass	6	1.83	2	25.0		2030 SLR	2070 SLR
2) Airmass	6	3.20	10	25.0		2030 SLR	2070 SLR
3) Nor'easter	48	5.84	10	21.1		2030 SLR	2070 SLR
4) Nor'easter	48	8.46	50	21.1		2030 SLR	2070 SLR
5) Nor'easter	48	8.46	50	21.1		100-year storm surge + 2030 SLR	100-year storm surge + 2070 SLR
6) Nor'easter	48	9.58	100	21.1		100-year storm surge + 2030 SLR	500-year storm surge + 2070 SLR
7) Frontal	72	6.34	10	26.4		2030 SLR	2070 SLR
8) Frontal	72	9.15	50	26.4		2070 SLR	2070 SLR
9) Tropical	48	5.84	10	24.8		2030 SLR	2070 SLR
10) Tropical	48	9.58	100	24.8		100-year storm surge + 2030 SLR	100-year storm surge + 2070 SLR
11) Tropical	48	13.9	500	24.8		500-year storm surge + 2030 SLR	500-year storm surge + 2070 SLR
12) August 2, 2017	9	3.44	200[2]	N/A[1]		2030 SLR	2070 SLR
13) June 12, 1998	43	6.77	10	N/A[1]		2030 SLR	2070 SLR
14) September 10, 1999	17	4.7	10	N/A[1]		2030 SLR	2070 SLR
15) Dorian	33	10.41				2030 SLR	

240+ 2D simulations completed

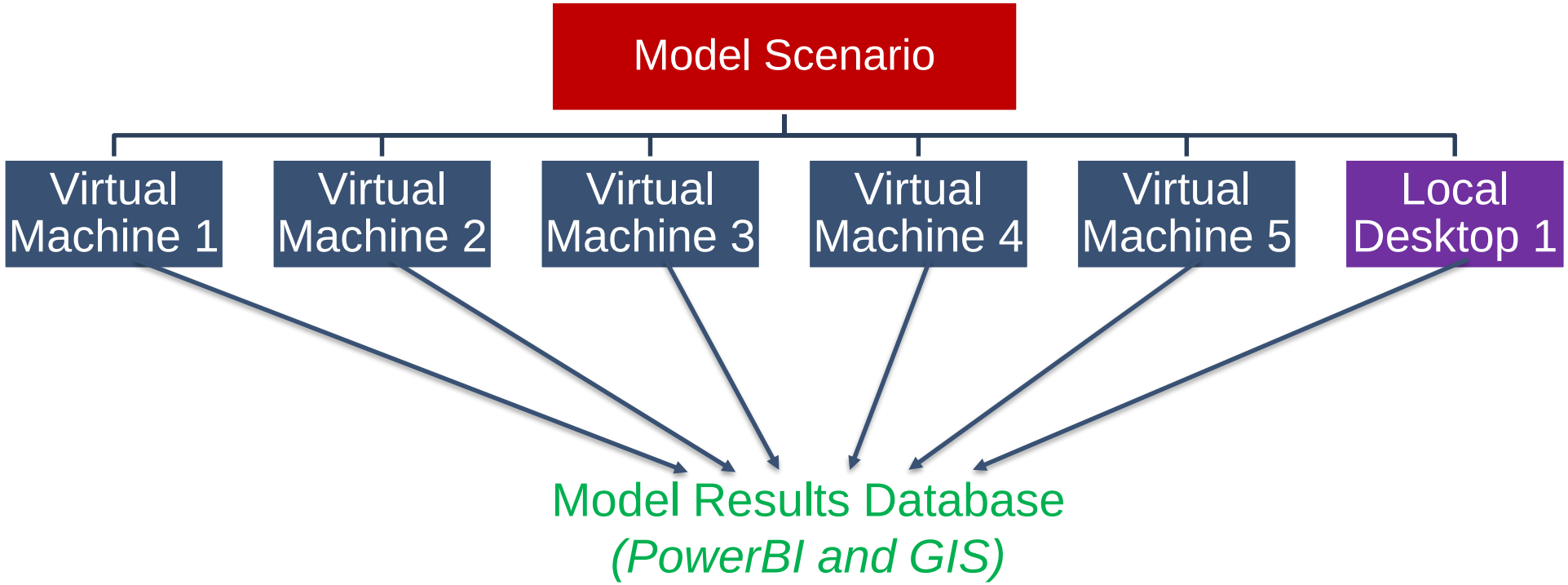
Simulation Strategy

Challenges:

- Model Run Time – Simulating a 48-hour storm requires almost 5 days
- Huge amount of data generated

Solutions:

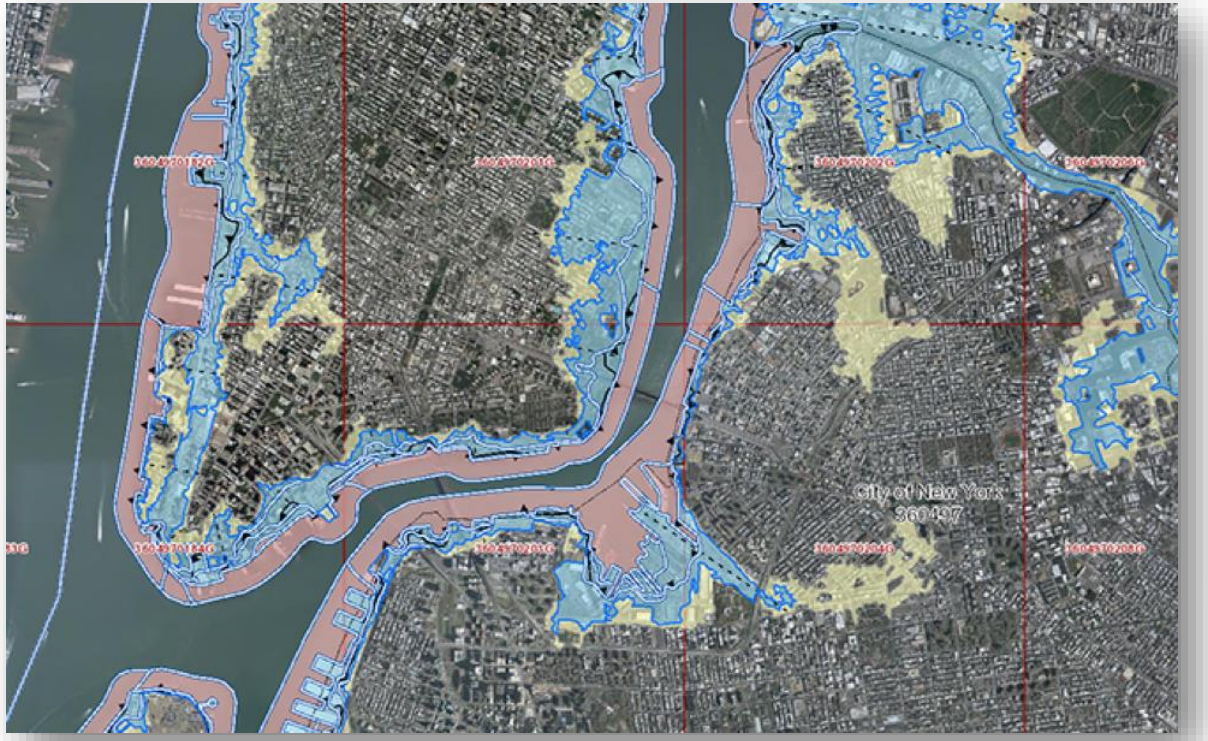
- Utilize multiple virtual machines to run different 2D models simultaneously – avoided over 365 days of continuous model simulation time!
- Develop database for data management



Interpretation of Model Results & Demonstrations

Science News *from research organizations*

New climate modeling predicts increasing occurrences of flash flooding across most of the U.S.



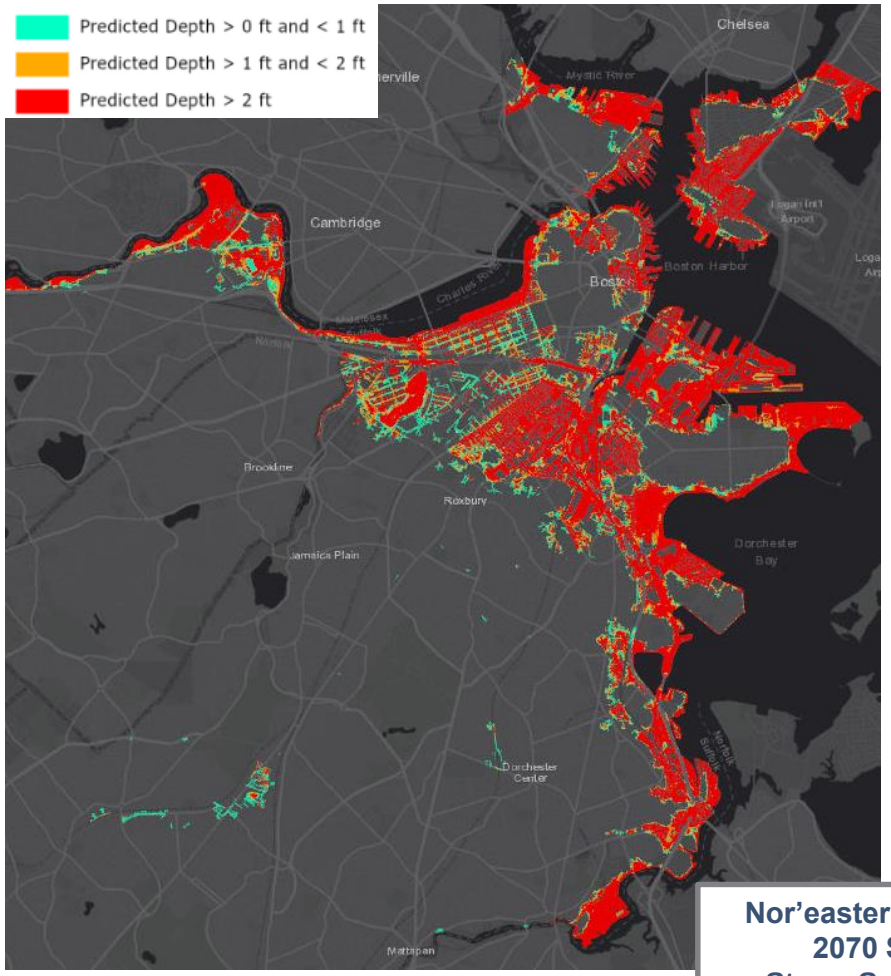
In worst case climate, rain and storm surge combine often for extreme flooding

A study published Thursday found that the changing nature of storms like hurricanes could play a larger part than scientists had expected in worsening floods.

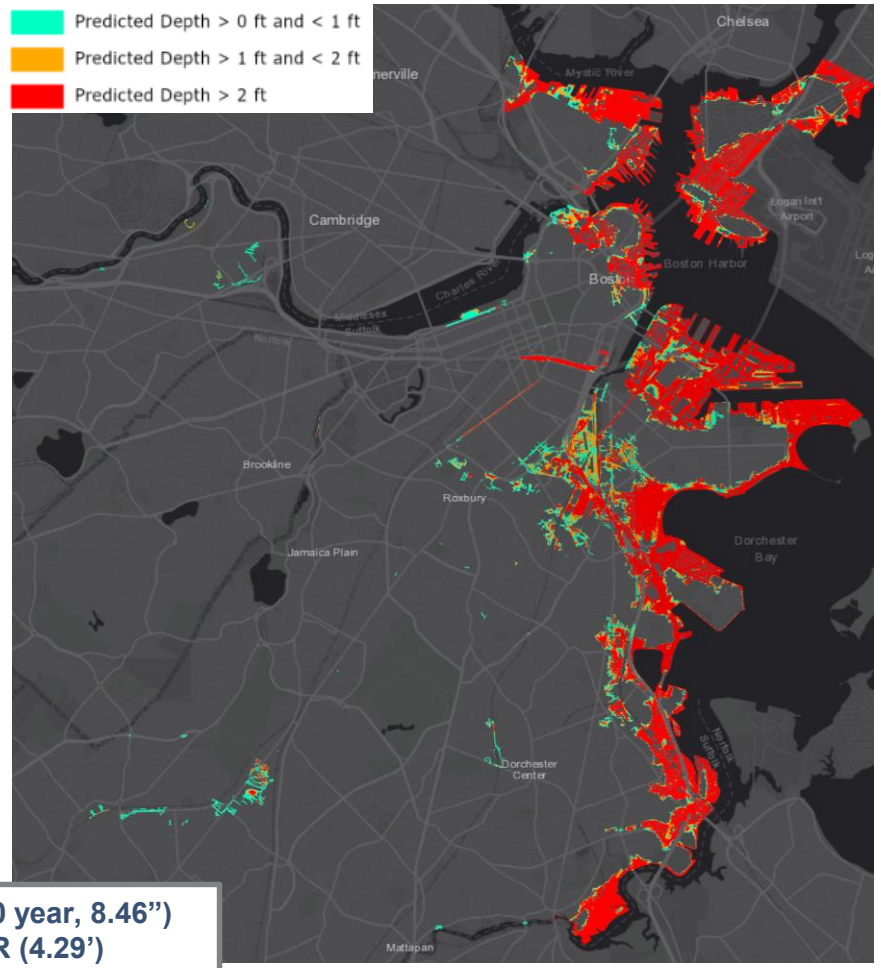
Conclusions

- Identify “citywide” vulnerabilities
- Collaboration
- Plan for continuous improvement/evolvement

No Action Scenario

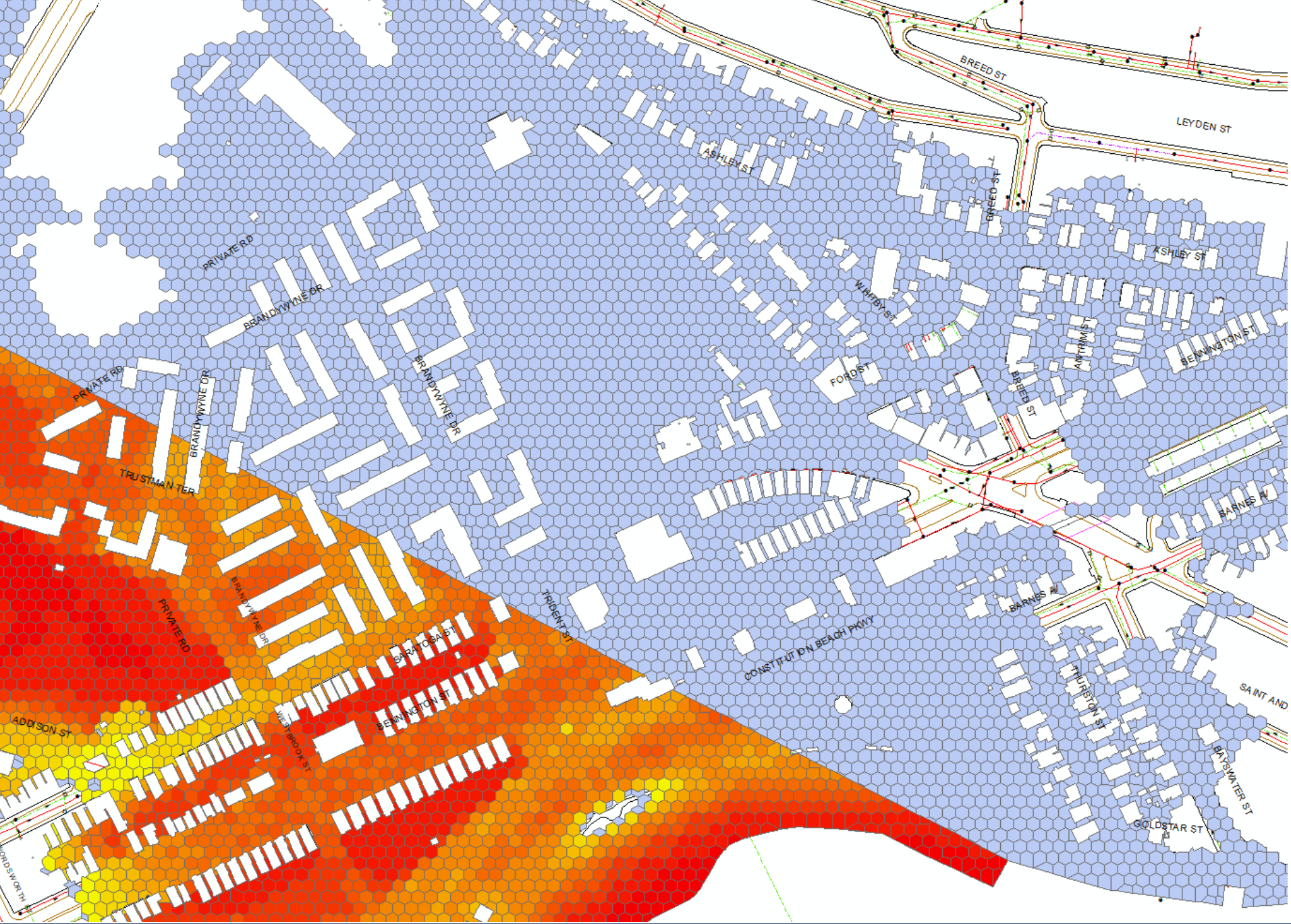


Fort Point Channel & Charles River Dam Protection

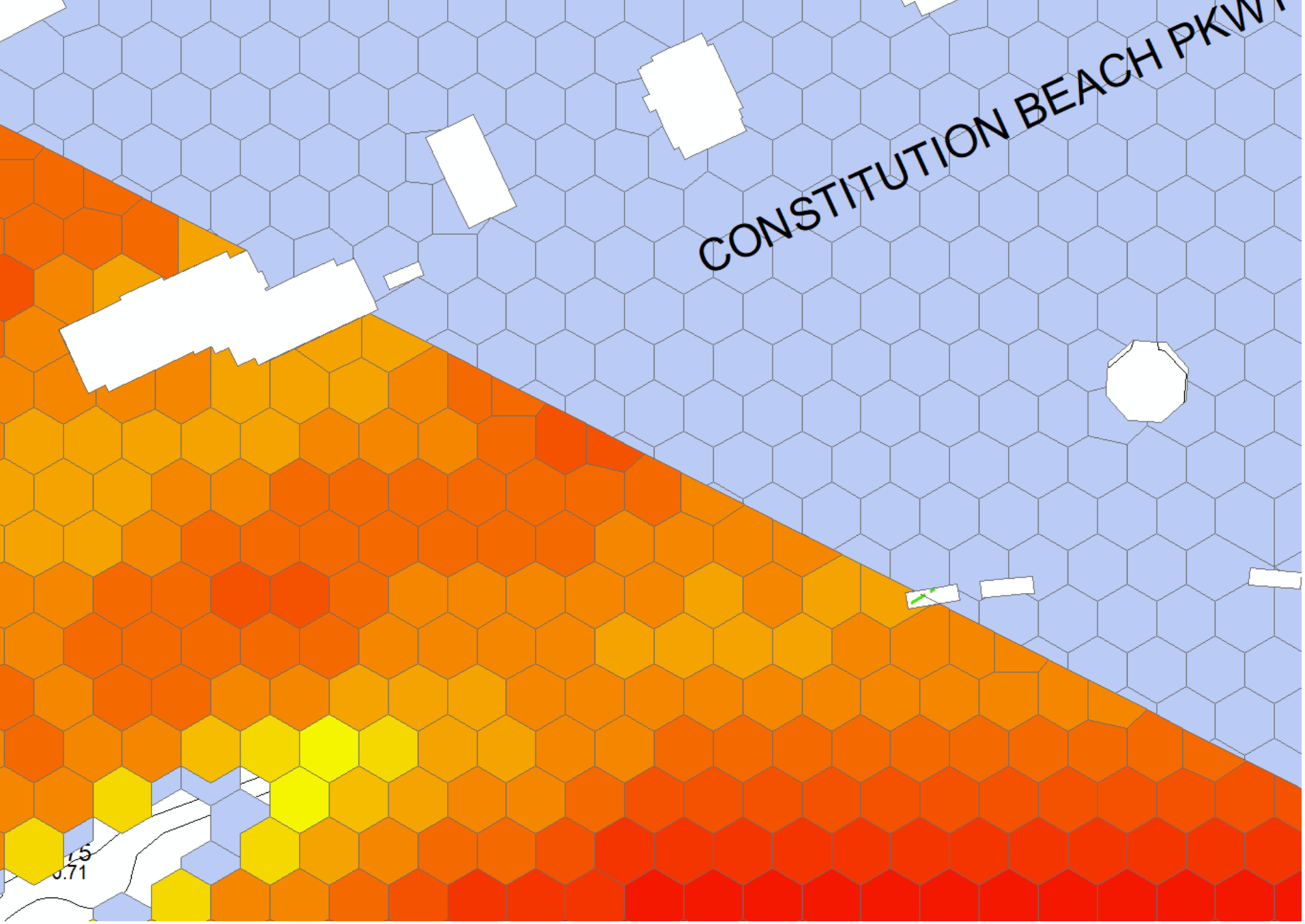


Nor’easter (50 year, 8.46”)
2070 SLR (4.29’)
Storm Surge (100 year)

Nor’easter – 2070 – 100 year storm with Sea Level Rise and Storm Surge



Nor’easter – 2070 – 100 year storm with Sea Level Rise and Storm Surge



Nor’easter – 2070 – 100 year storm with Sea Level Rise and Storm Surge

Acknowledgments and Questions

www.bwscstormviewer.com

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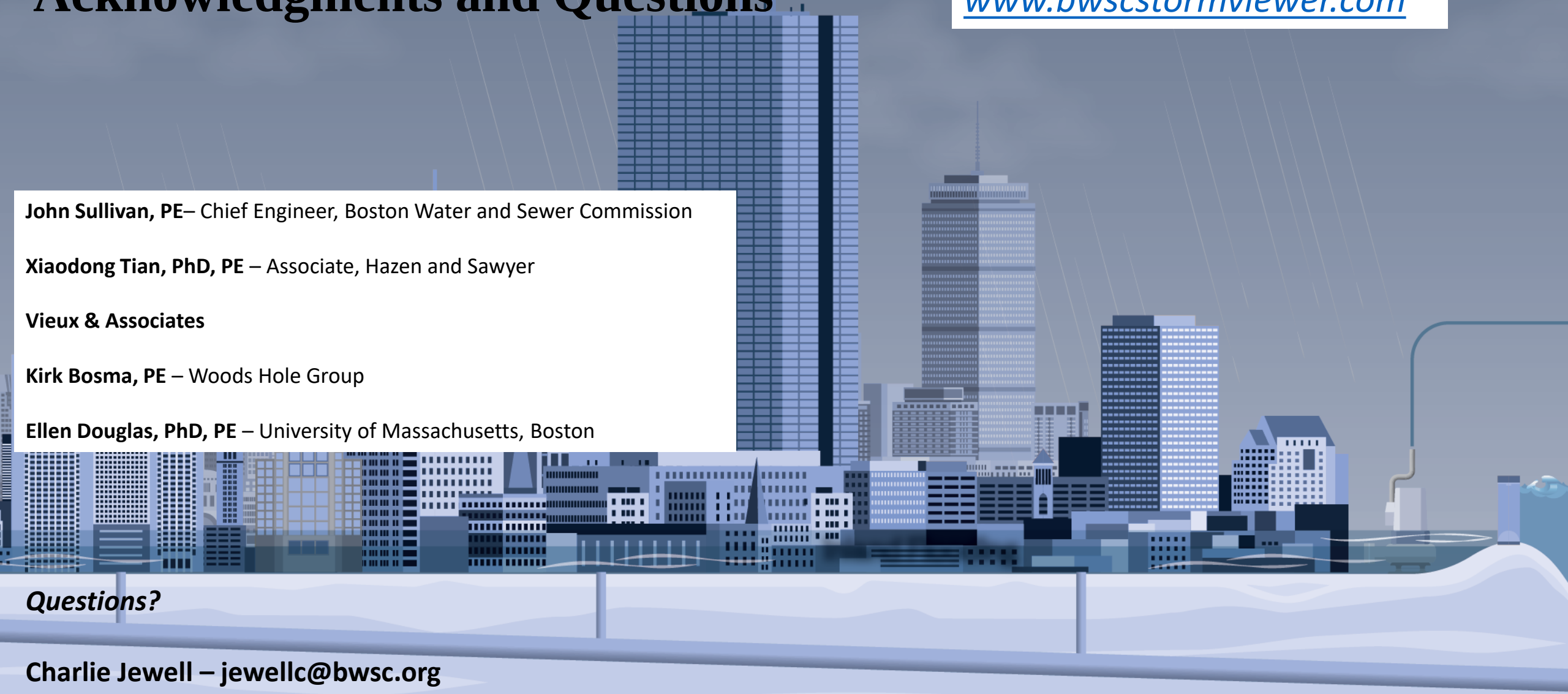
Xiaodong Tian, PhD, PE – Associate, Hazen and Sawyer

Vieux & Associates

Kirk Bosma, PE – Woods Hole Group

Ellen Douglas, PhD, PE – University of Massachusetts, Boston



Questions?

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Boston Water and Sewer Commission

Hazen