AAPA American Association of Port Authorities

Alliance of the Ports of Canada, the Caribbean, Latin America and the United States

Prioritizing Coastal Resilience: Modeling Inundation Risk in a Changing Climate

Kirk F. Bosma, P.E.
kbosma@woodsholegroup.com

WOODS HOLE GROUP
A CLS COMPANY

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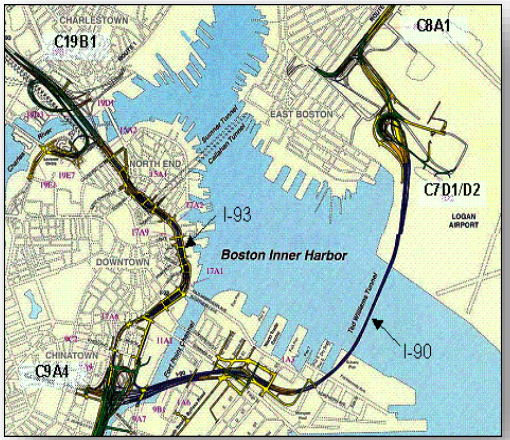
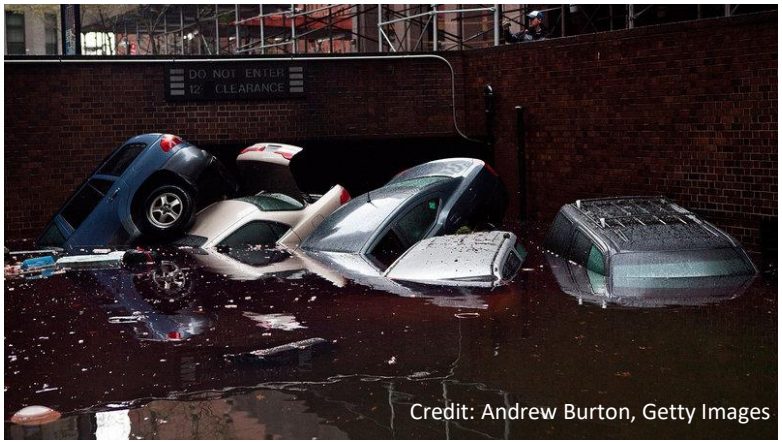
Where it all started…

The **Central Artery** is a critical link in regional transportation and a vitally important asset in the Boston metropolitan area.

1. What is the probability of flooding?
2. What is vulnerable and what is the priority?
3. What interventions are available and what is the plan?

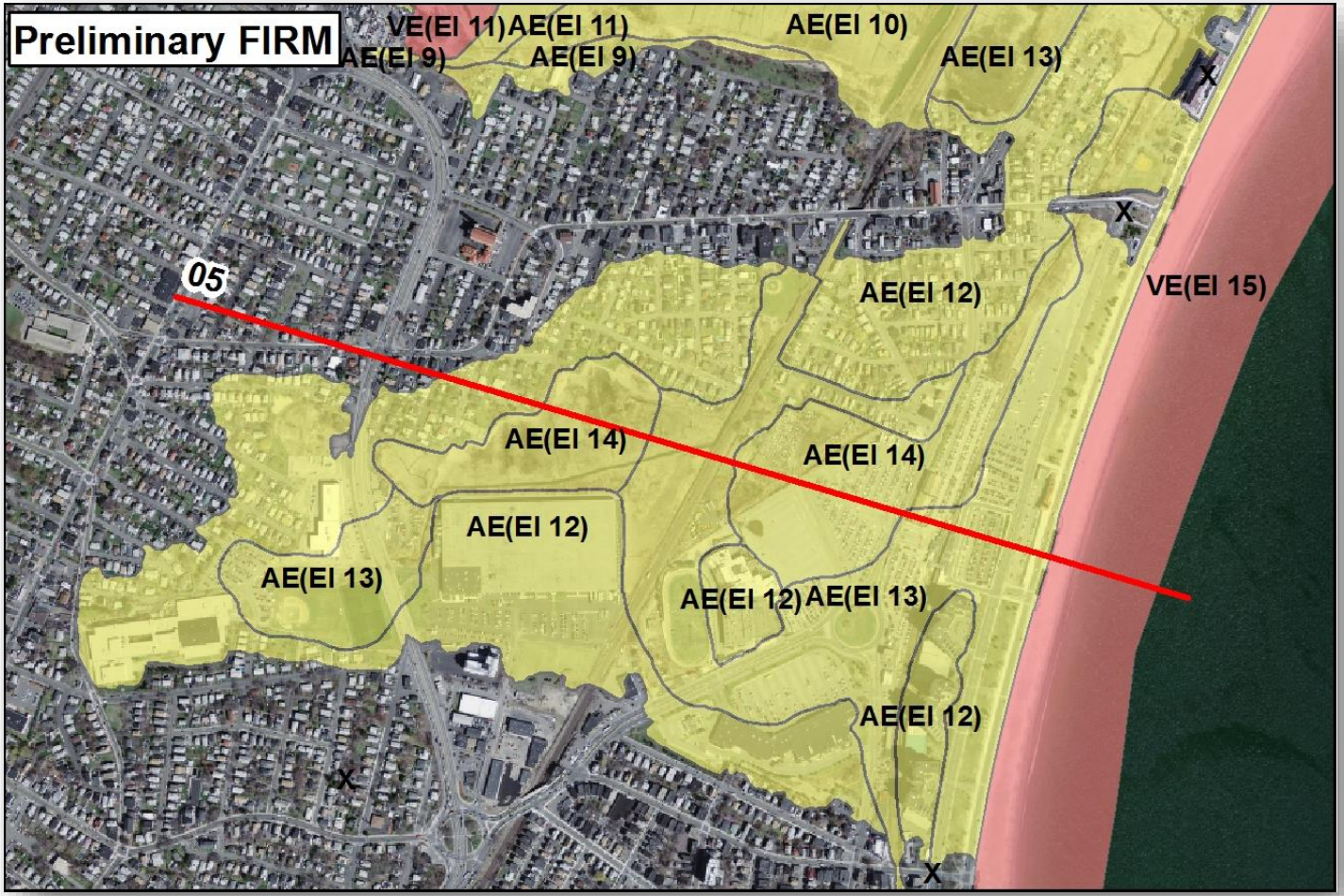




Credit: Andrew Burton, Getty Images

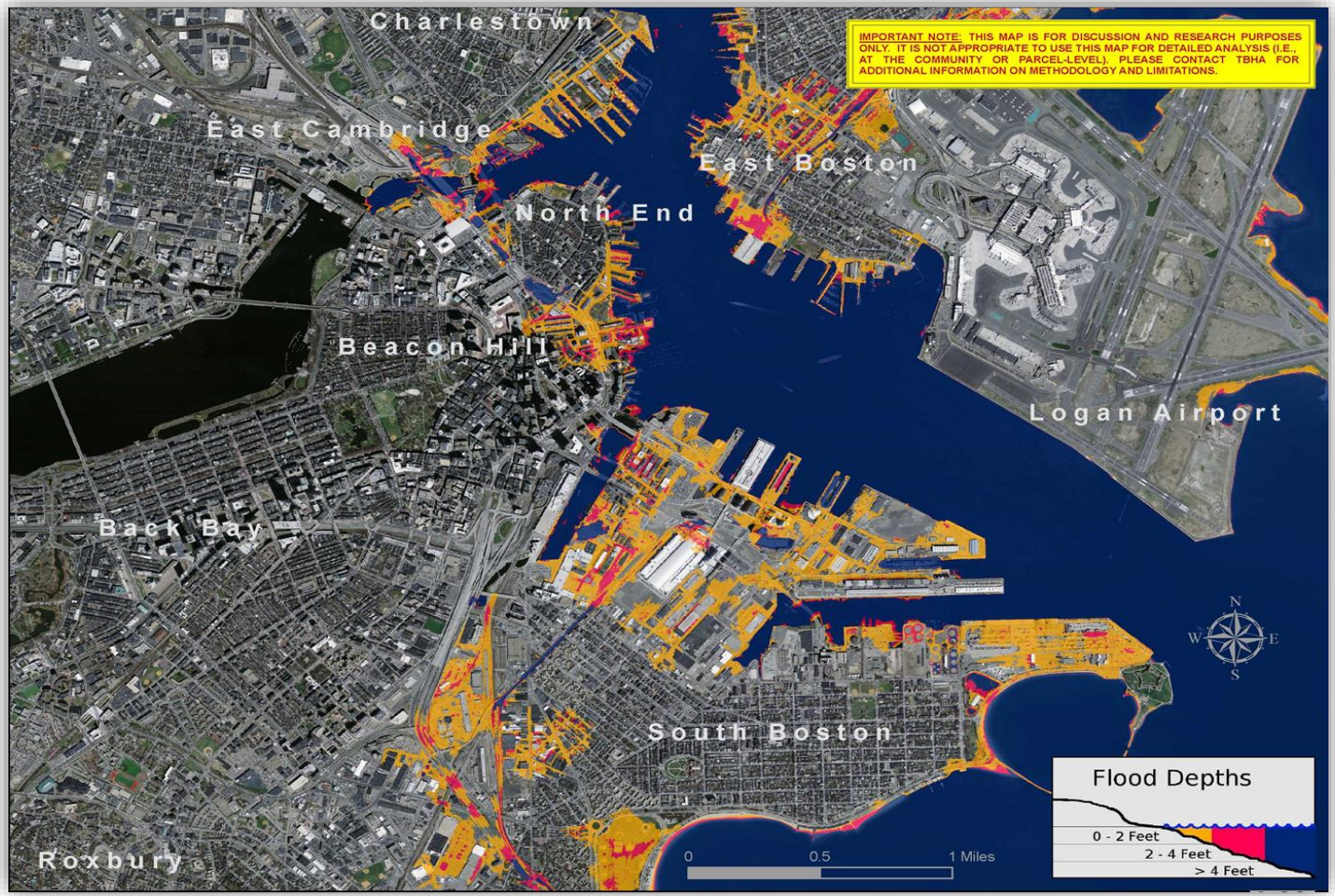
Flood Mapping Types: FEMA

- FEMA is only backward looking
- Only considers “100-year” storm
- Region I does not use dynamic modeling
- Transect based analysis



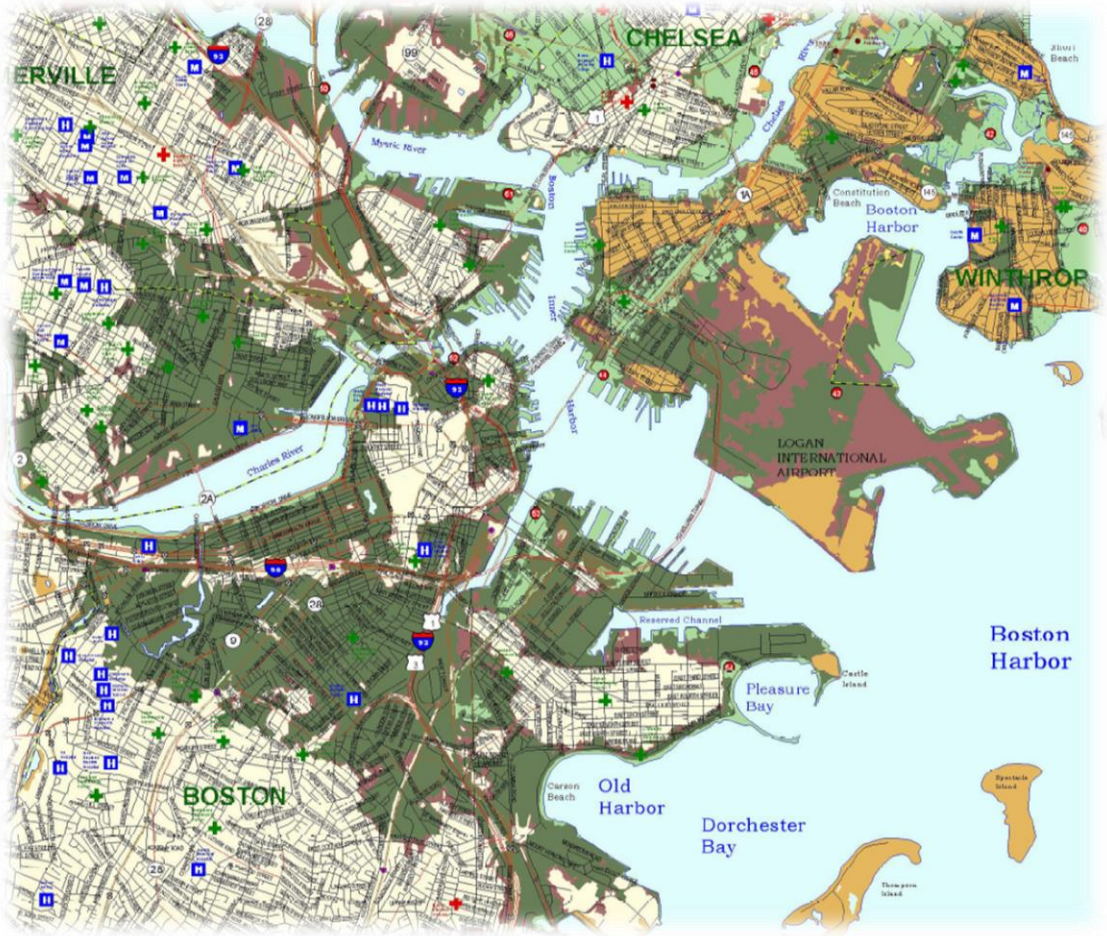
Flood Mapping Types: Bathtub

- Standard “bathtub” models do not reflect dynamic nature of coastal flooding
- No joint flooding conditions
- Limited infrastructure (e.g., dams)
- Does not account for tides

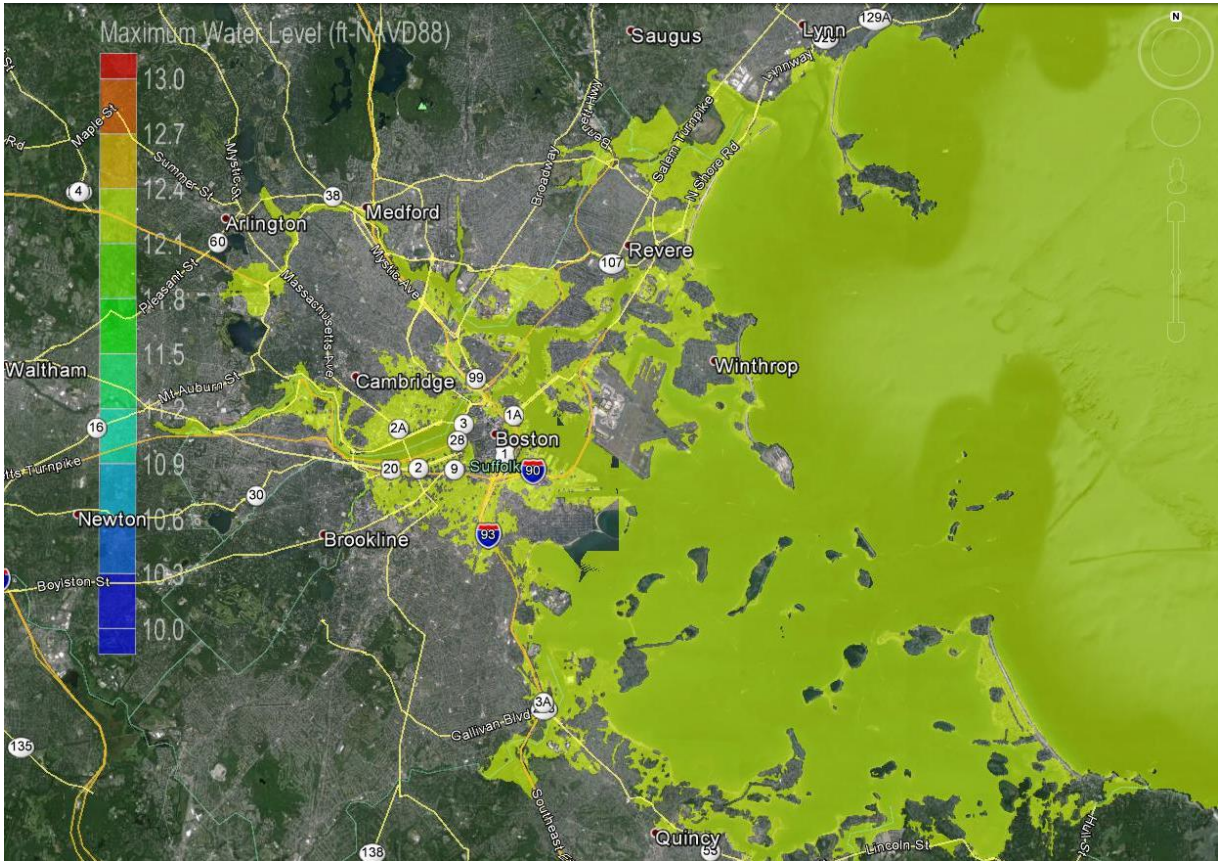


Flood Mapping Types: National Storm Surge Hazard

- Worst possible scenario for emergency planning (at MHW)…no associated risk planning
- Coarse modeling domain results in local inaccuracies
- Does not include impacts of waves
- Errors are relatively large (+/- 20%)
- Just hurricanes



Inadequacy of Existing Mapping



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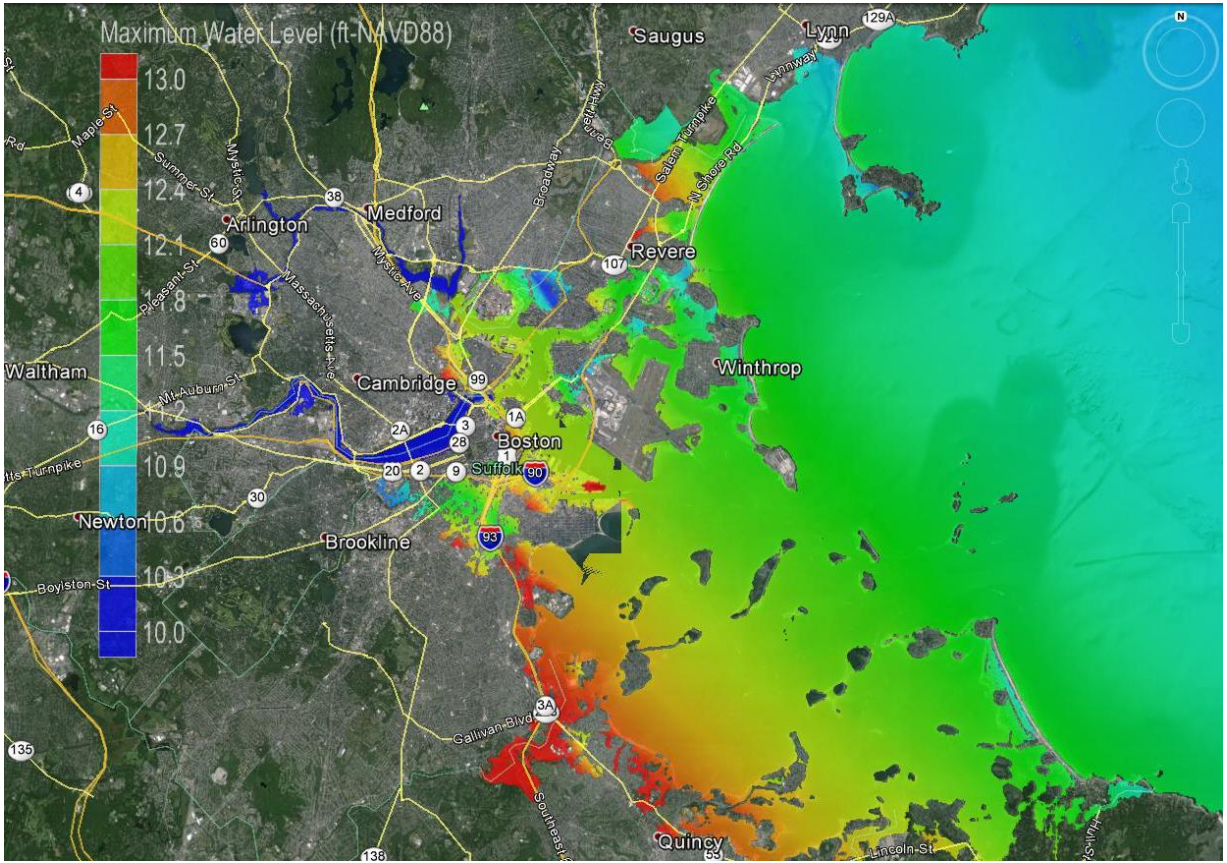
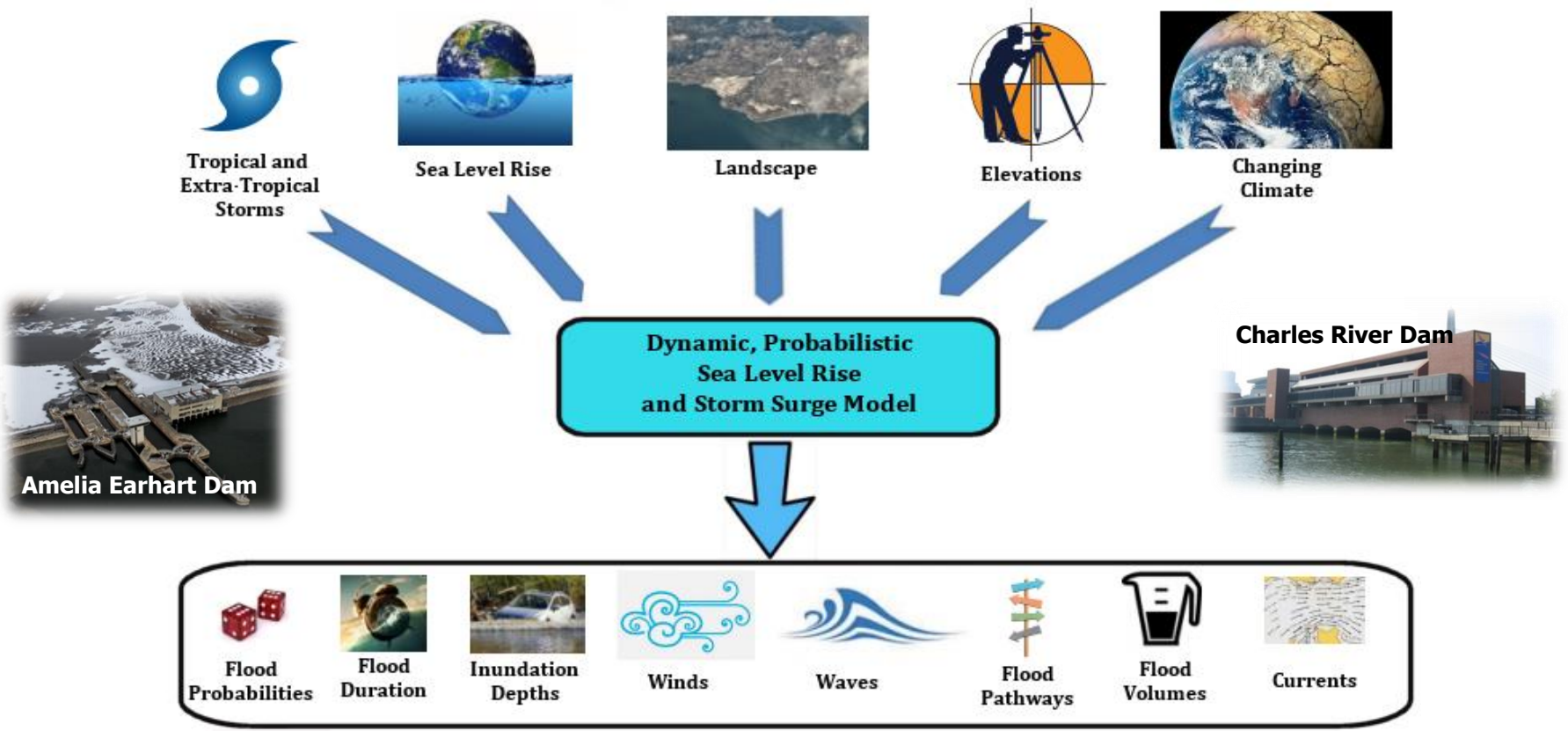
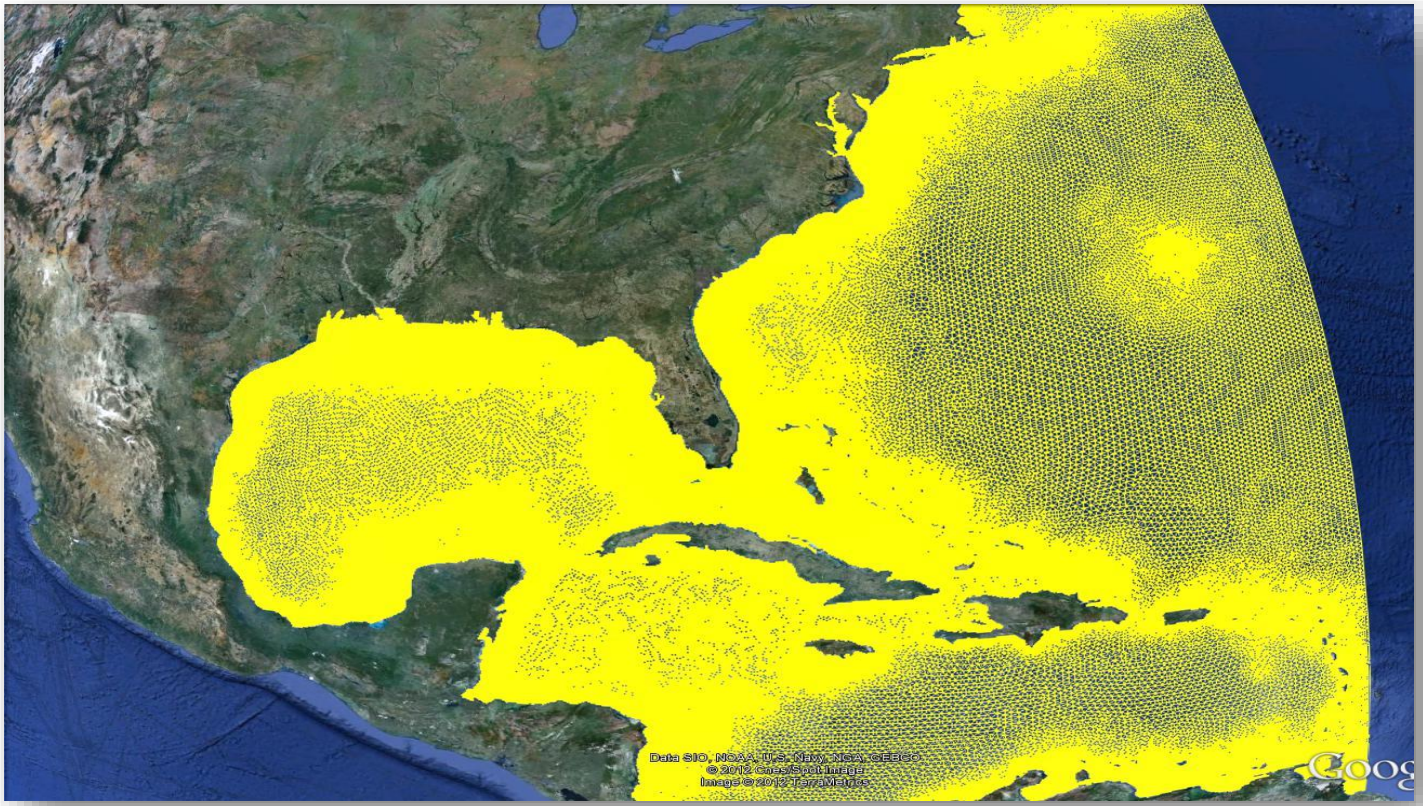


High-Res Probabilistic, Hydrodynamic Modeling

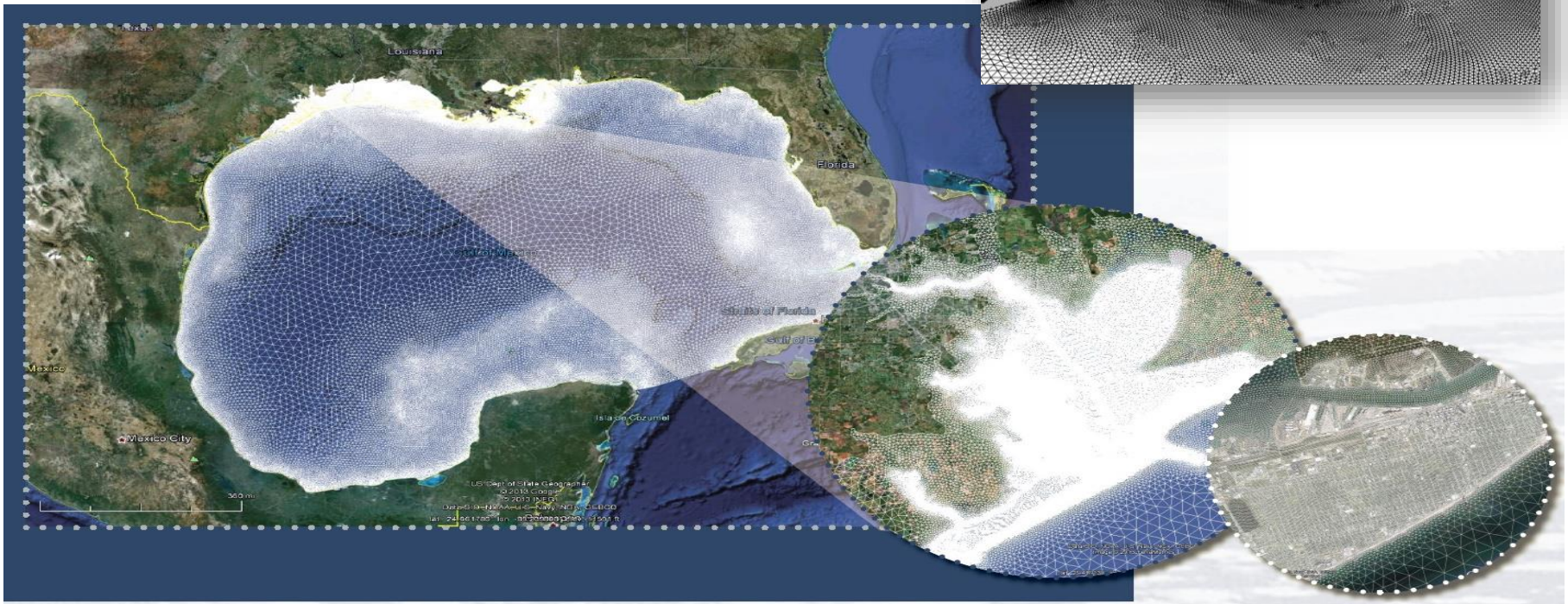


Regional Grid



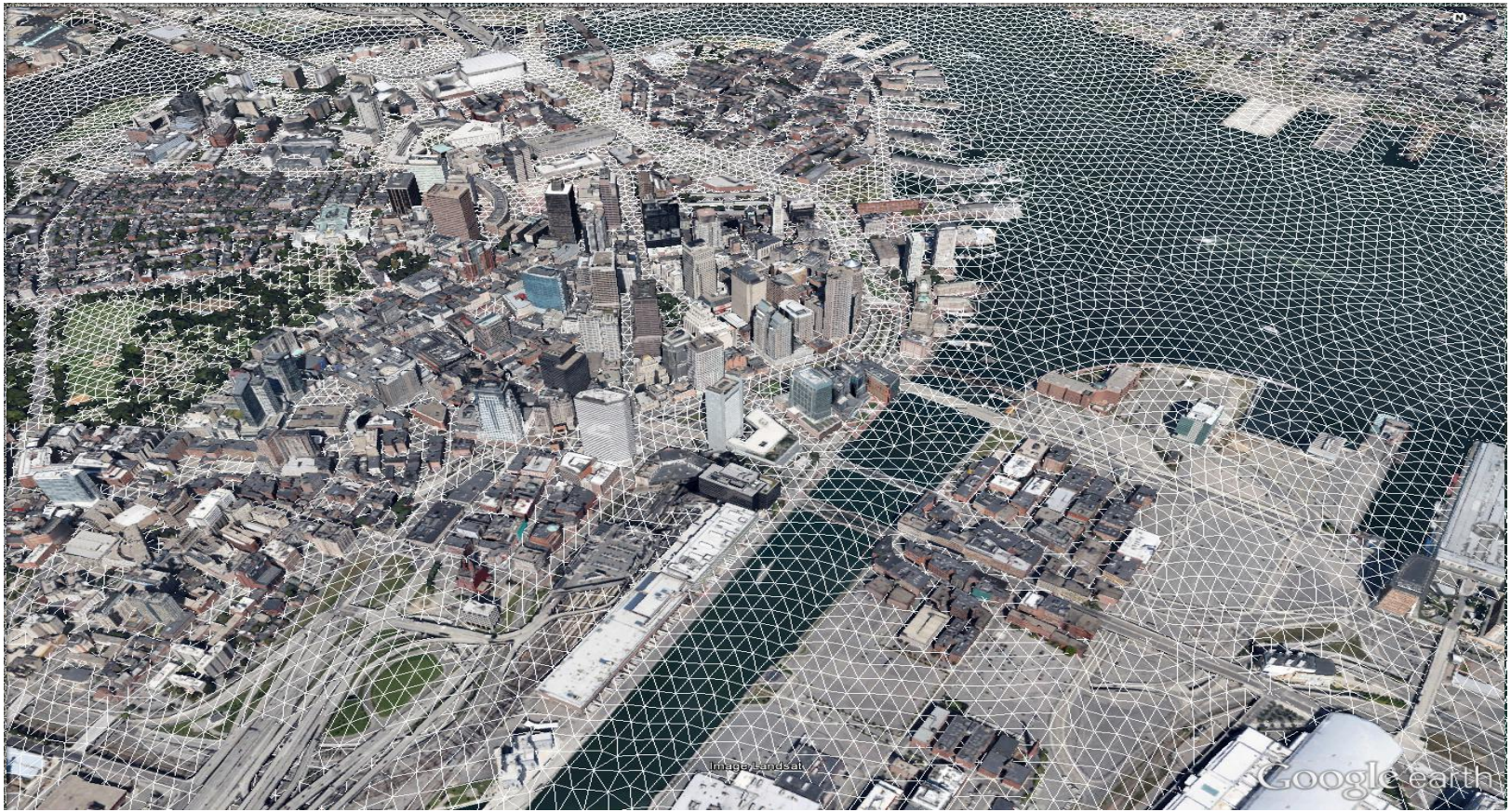
Unstructured Grid

Varying resolution with high resolution in areas of interest

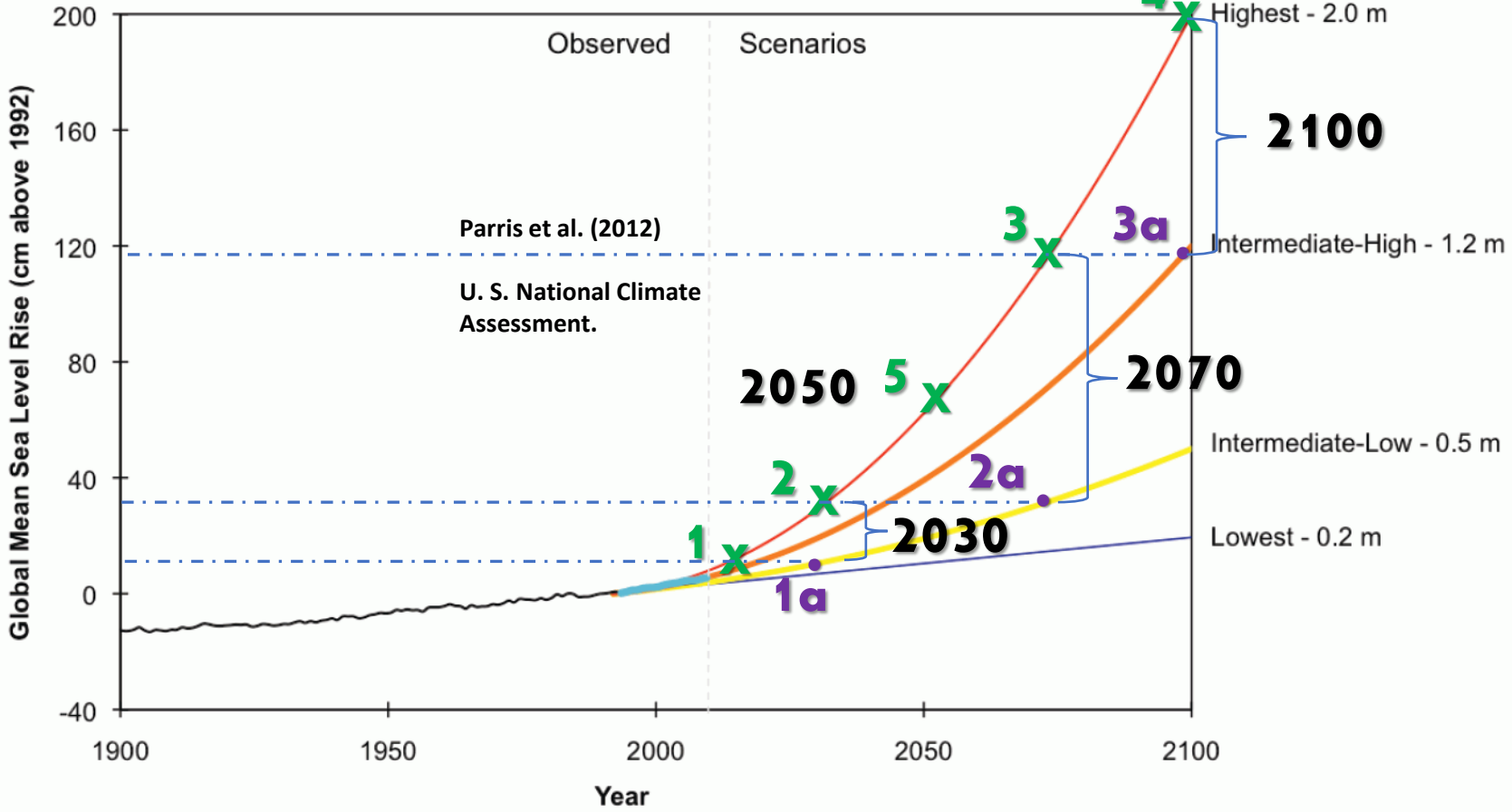


Boston Grid

Boston Grid



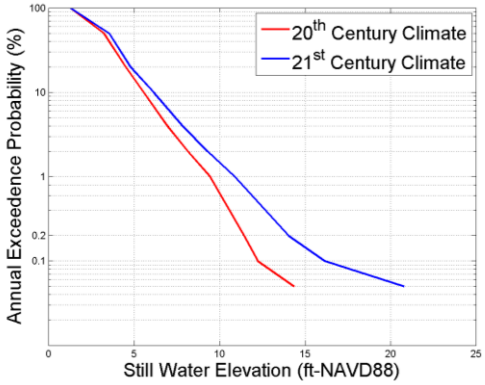
Using Projections to Bracket Risk



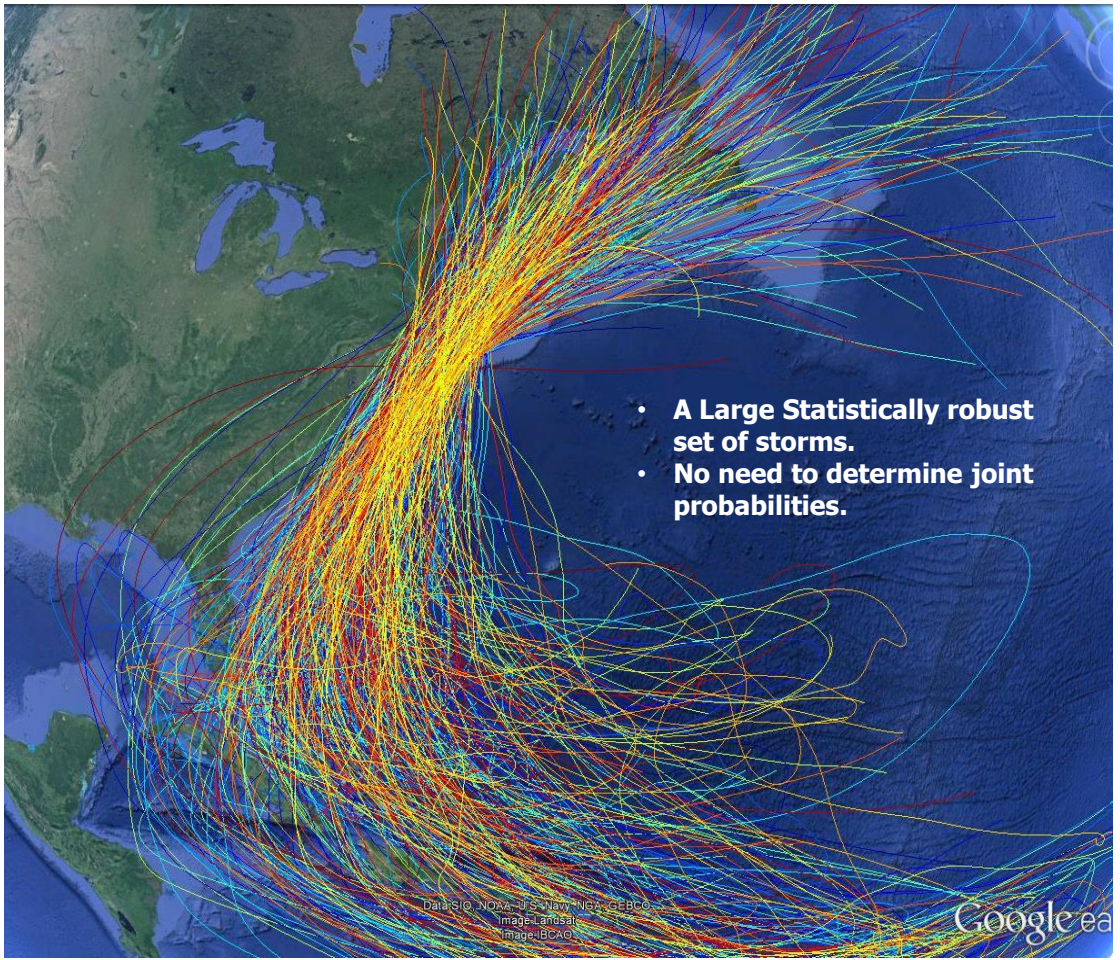
Storm Climatology

- Monte Carlo simulations, using a large statistically robust set of storms (Emanuel, et al., 2006) and a physics based approach

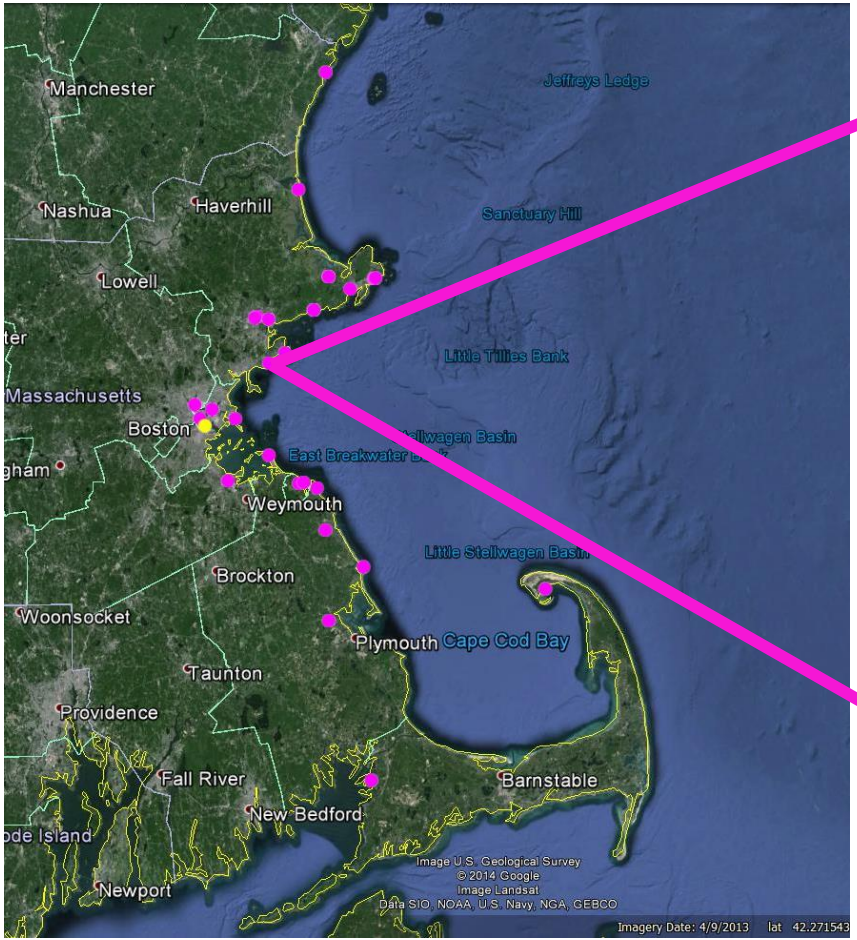
- Present and future climate change scenarios

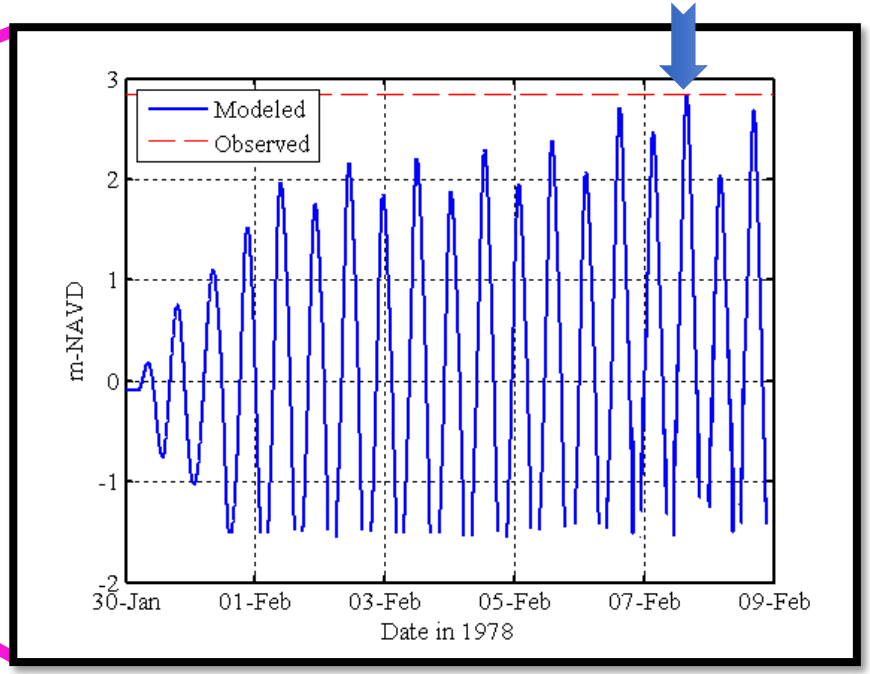


- Simulates storms (both hurricane and nor'easter) combined with SLR and precipitation based river discharge

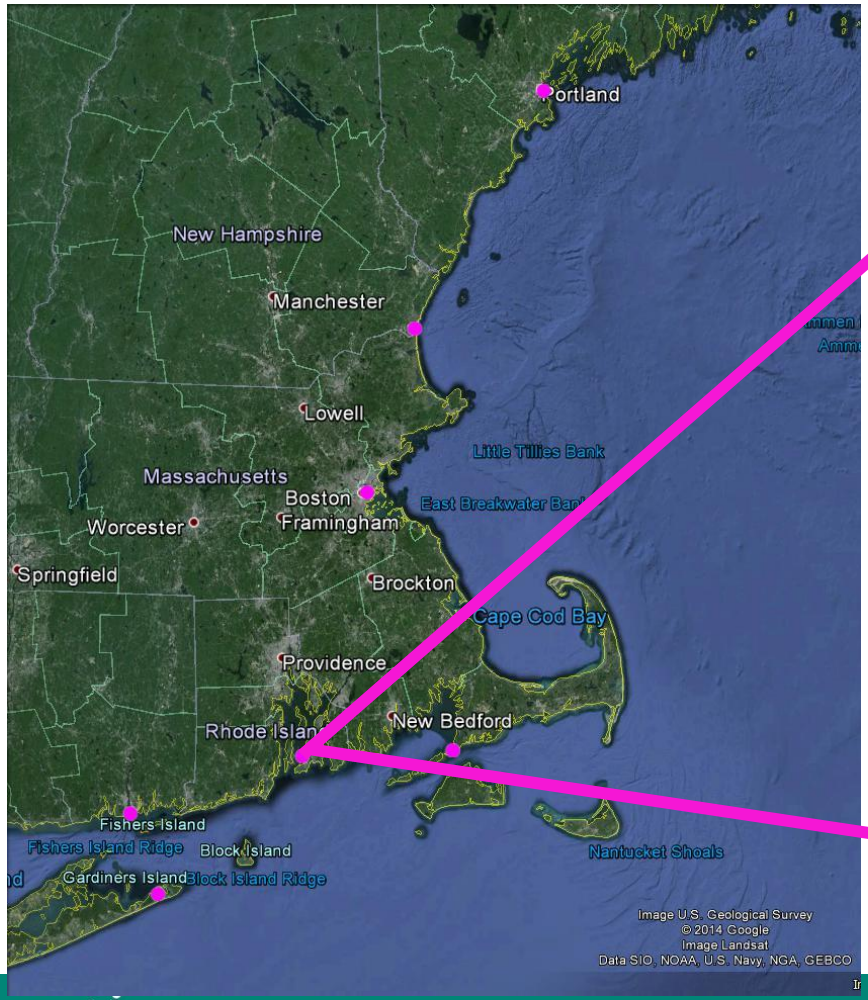


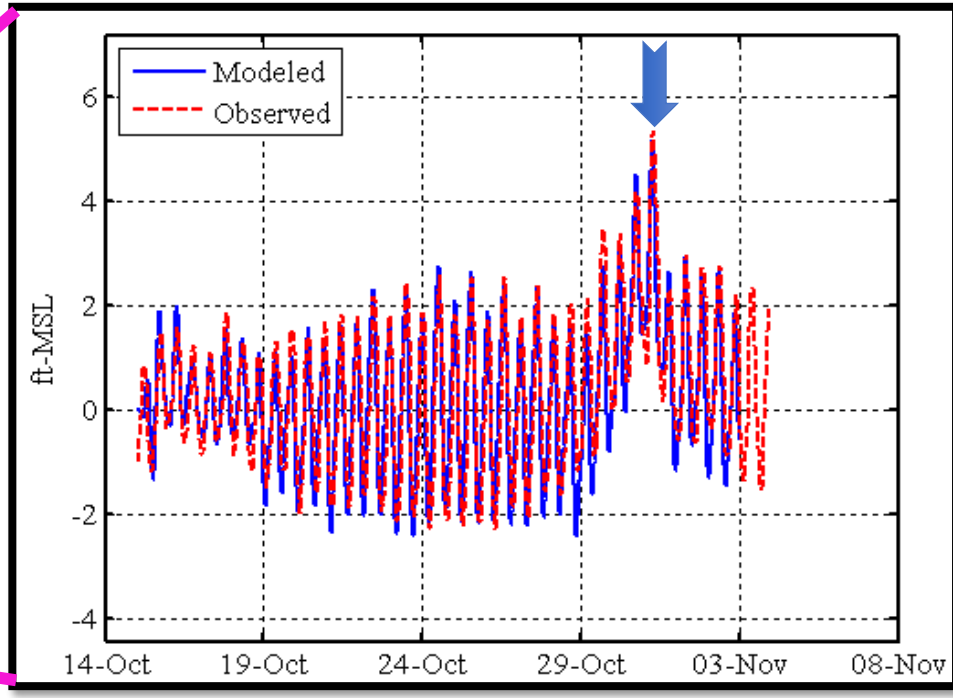
Model Calibration



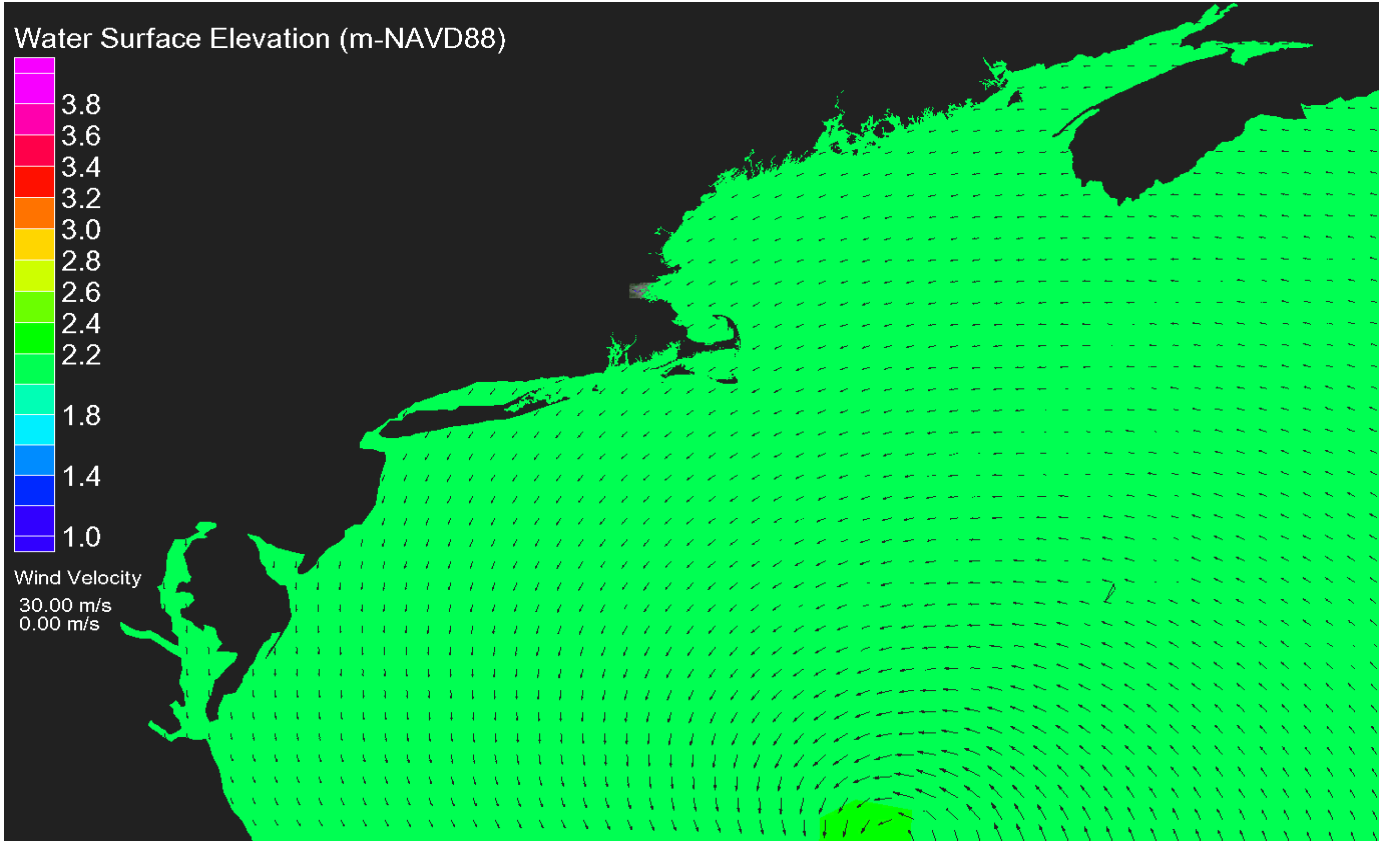


Model Validation





Example – Tropical Cyclone



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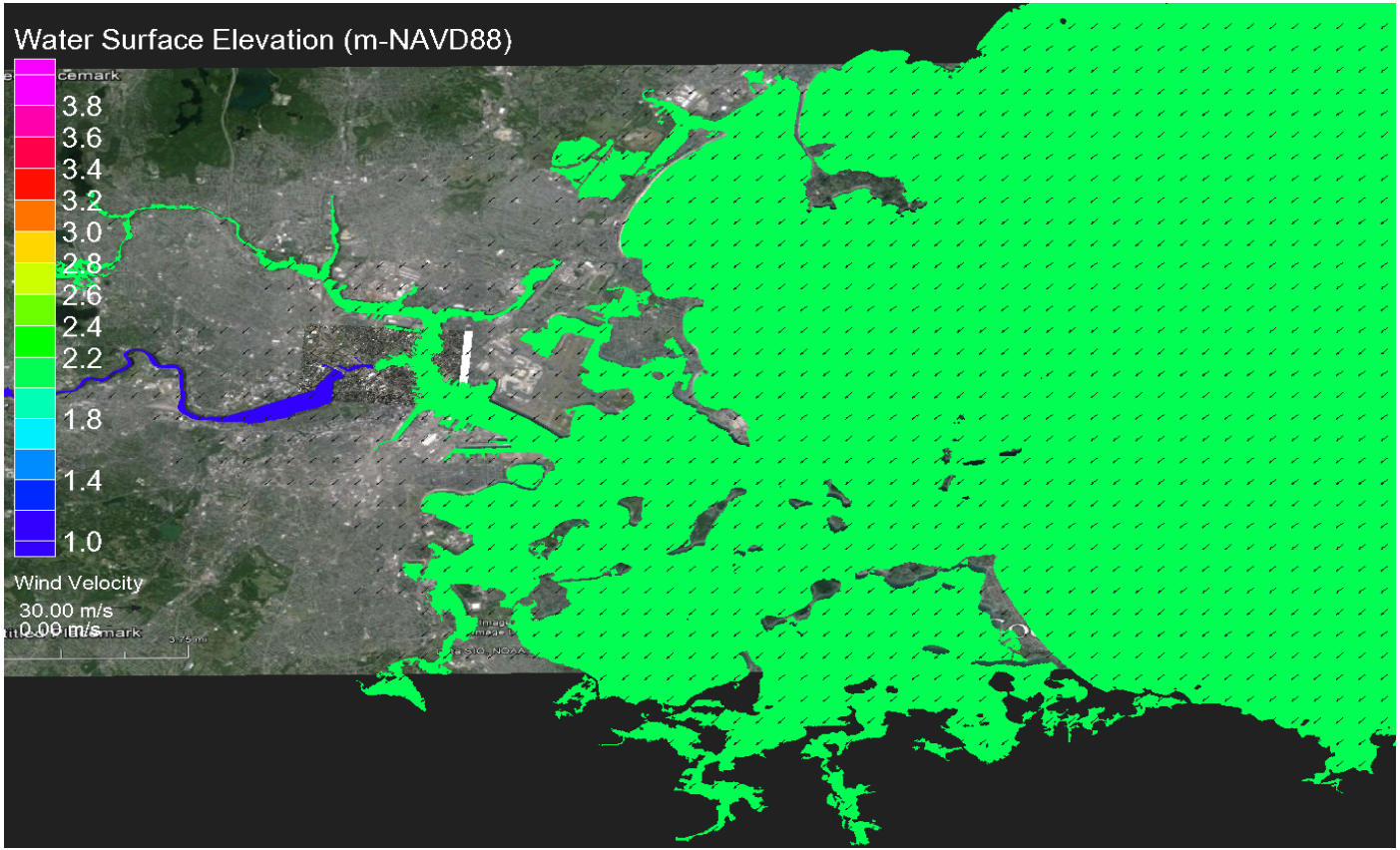
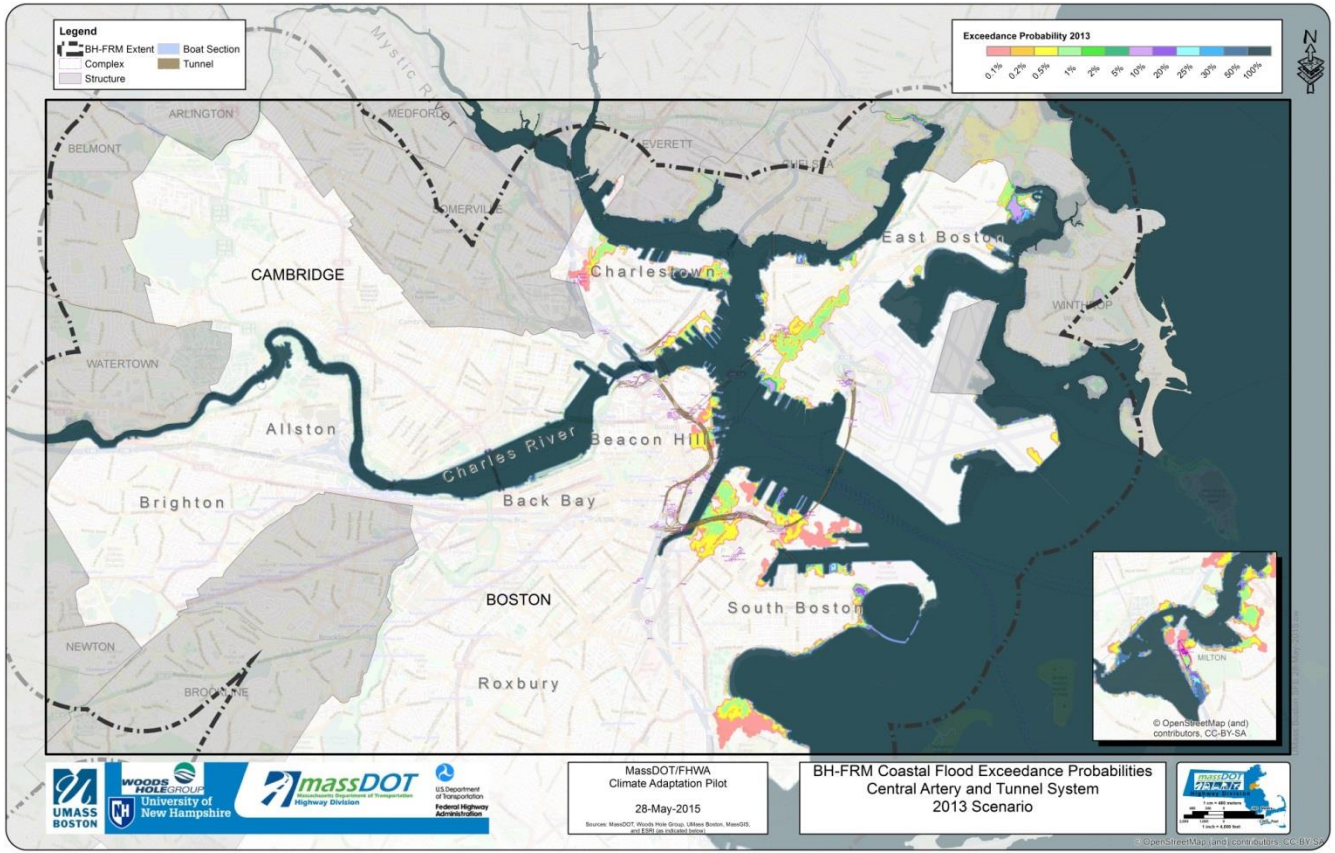


Exceedance Probability Maps

Coastal Flood Exceedance Probability

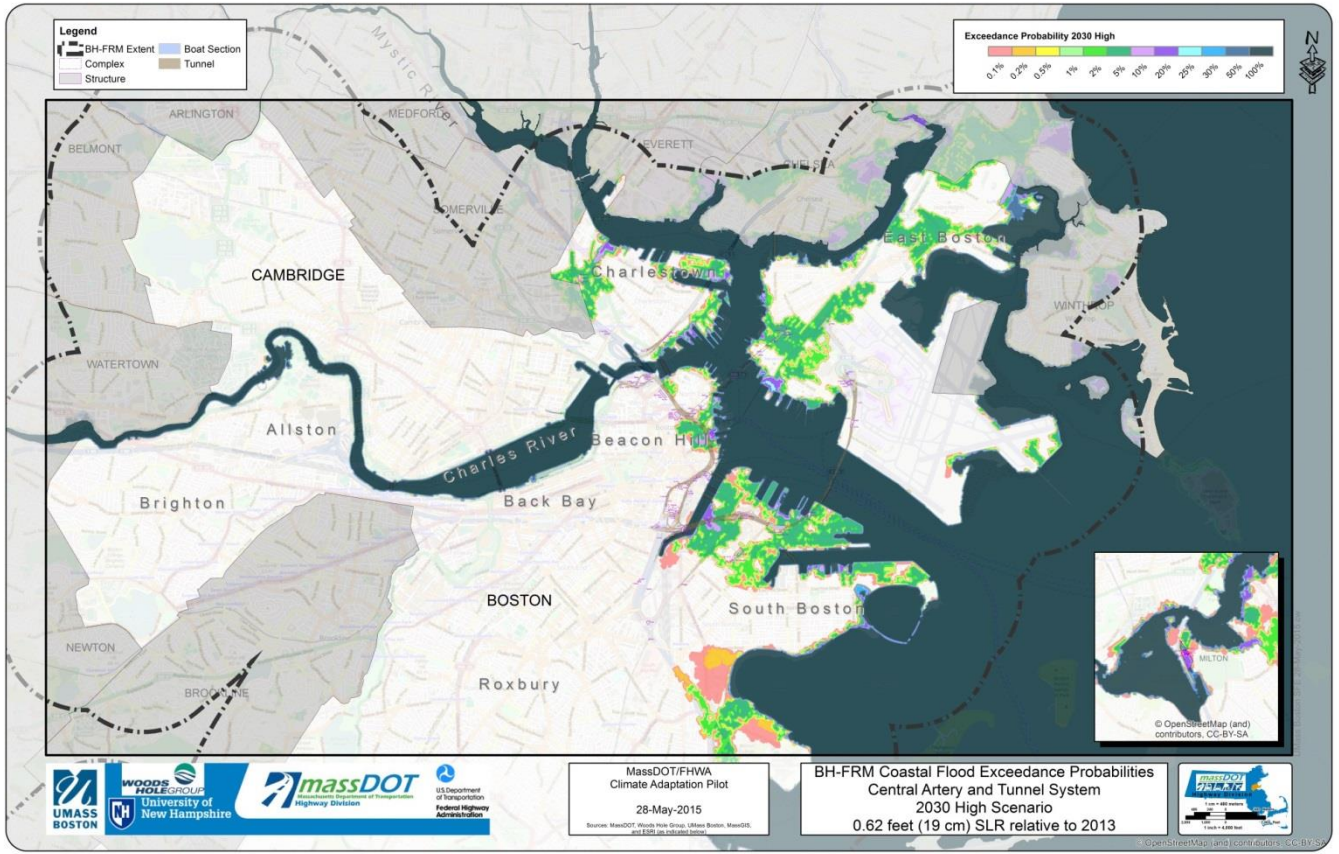


CFEP

- 0.1%
- 0.2%
- 0.5%
- 1%
- 2%
- 5%
- 10%
- 20%
- 25%
- 30%
- 50%
- 100%

Exceedance Probability Maps

Coastal Flood Exceedance Probability



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Exceedance Probability Maps

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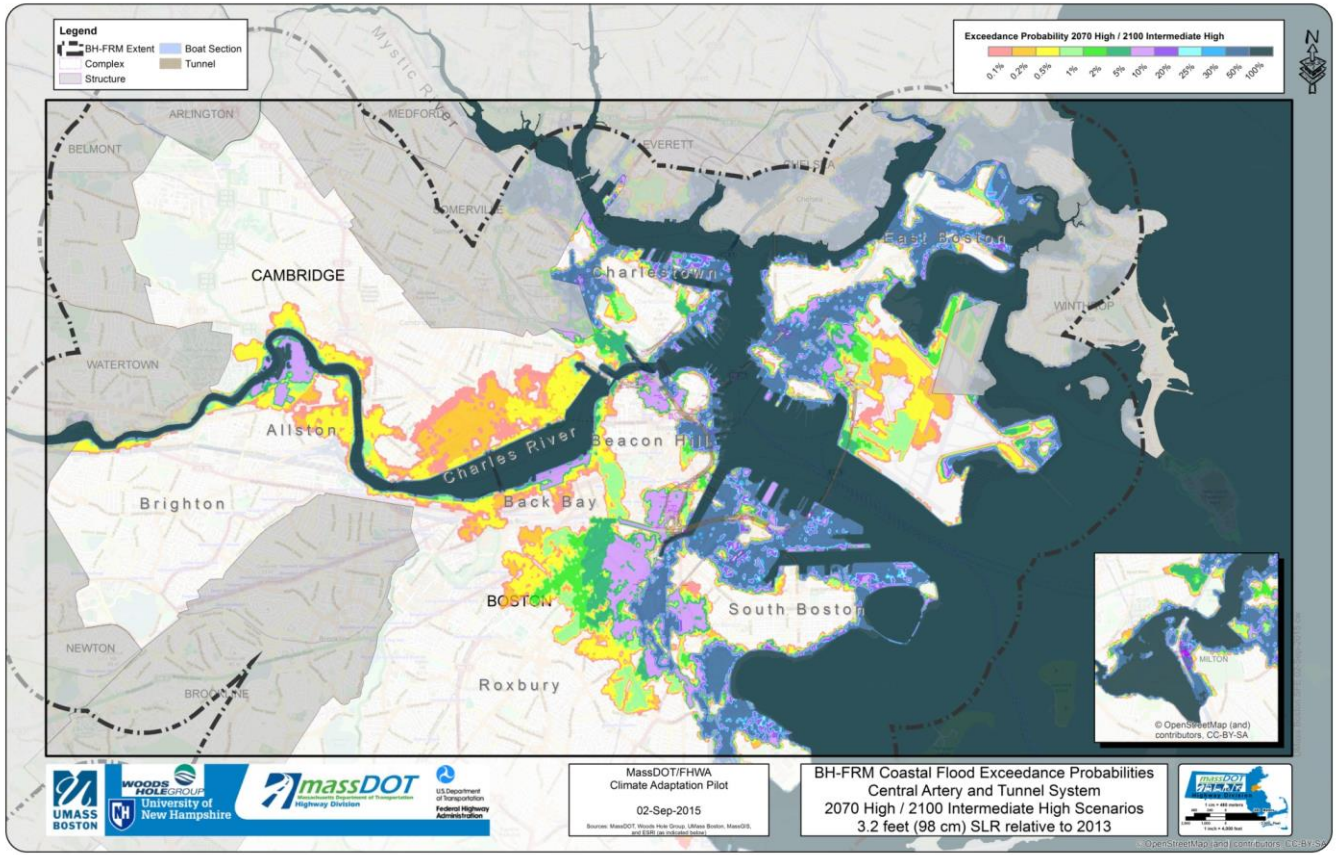

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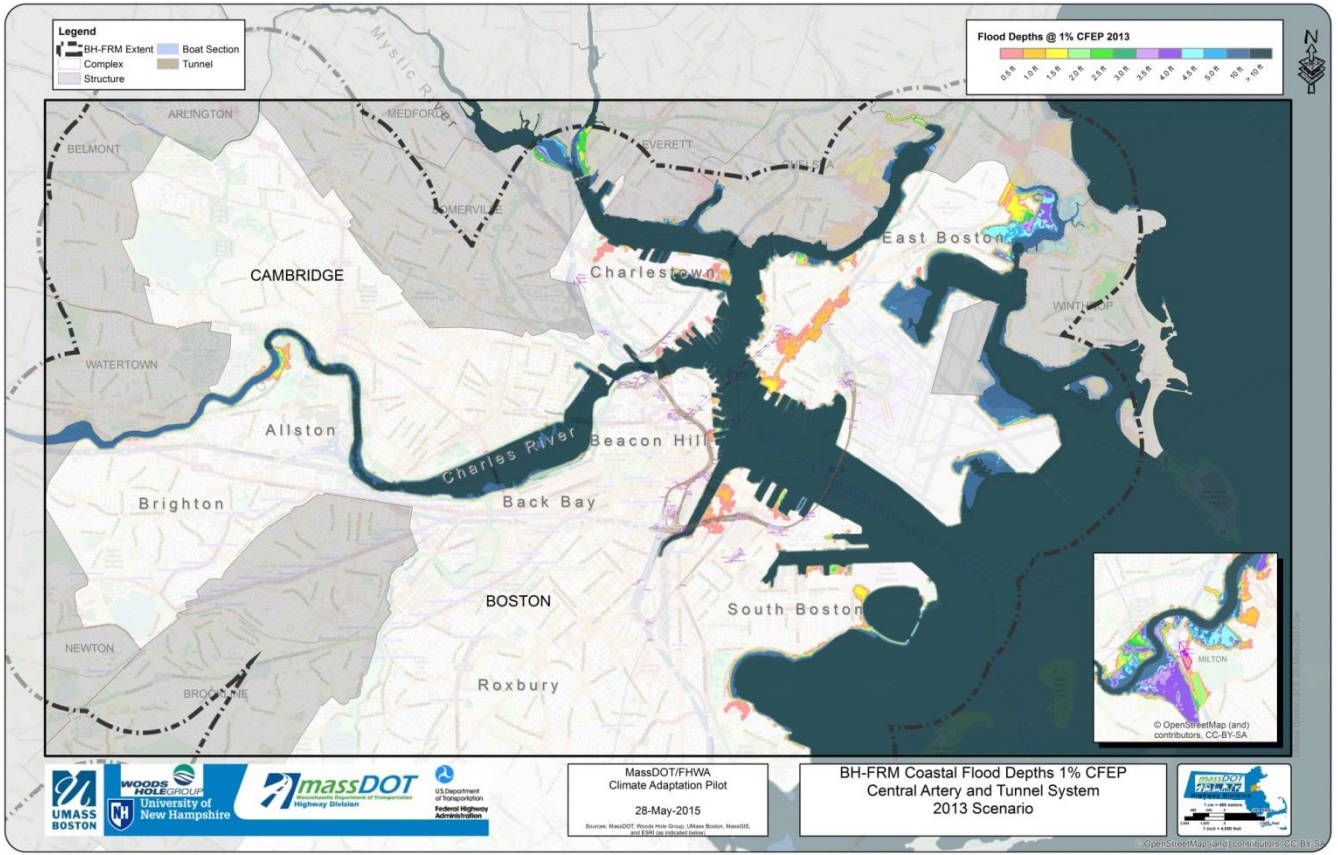
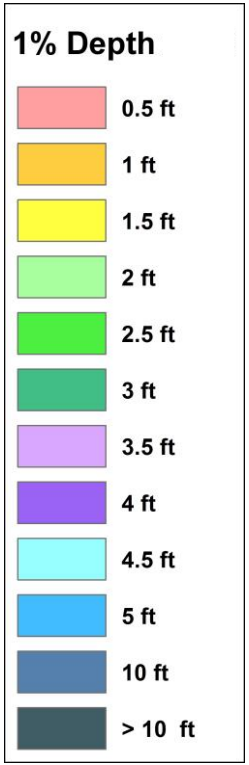
Depth of Inundation Maps





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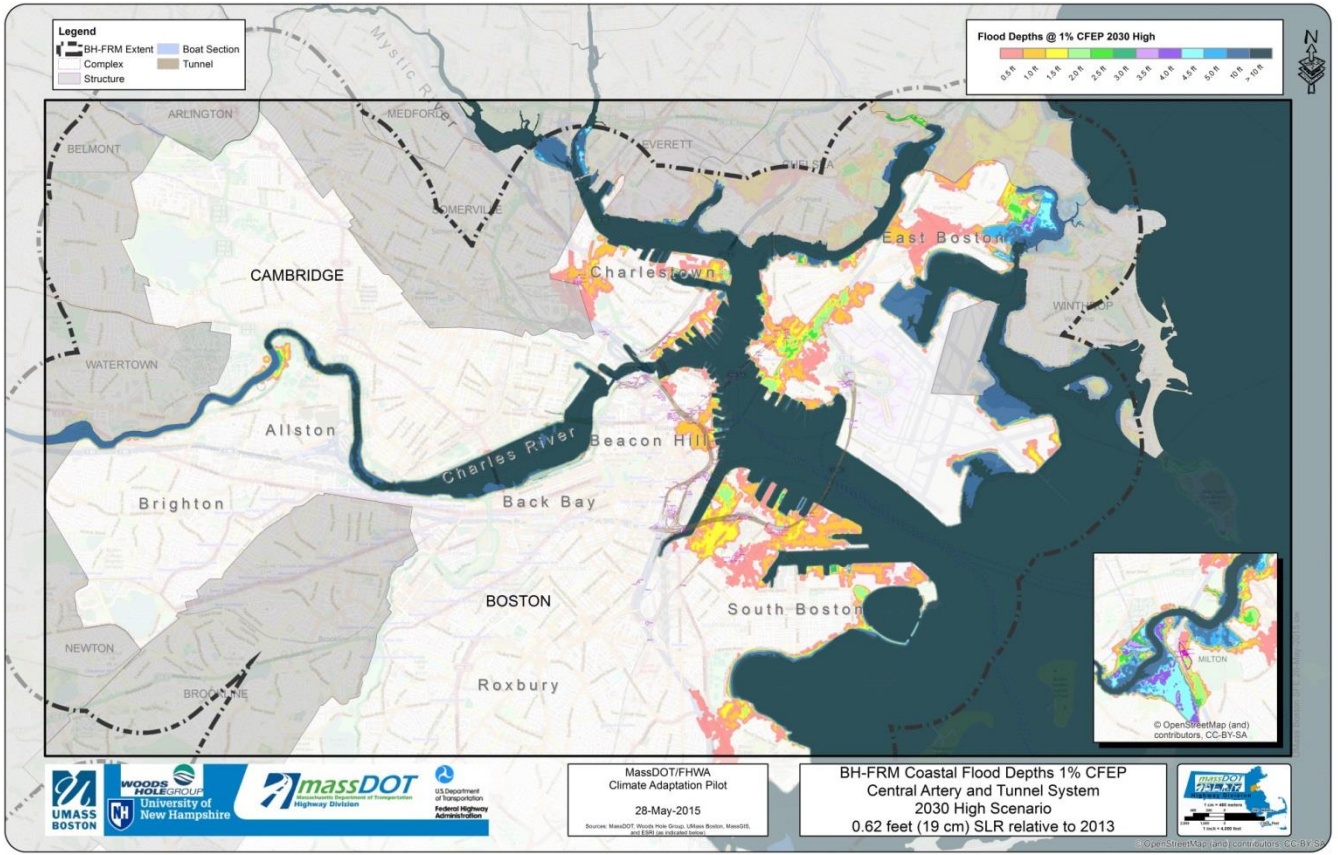

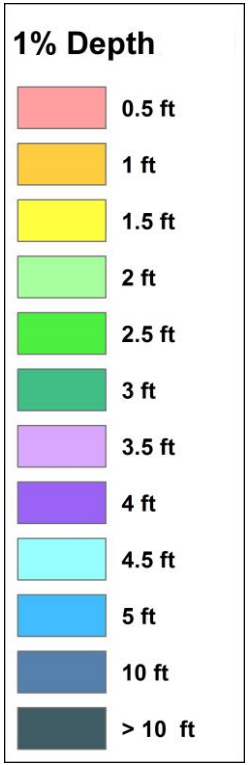

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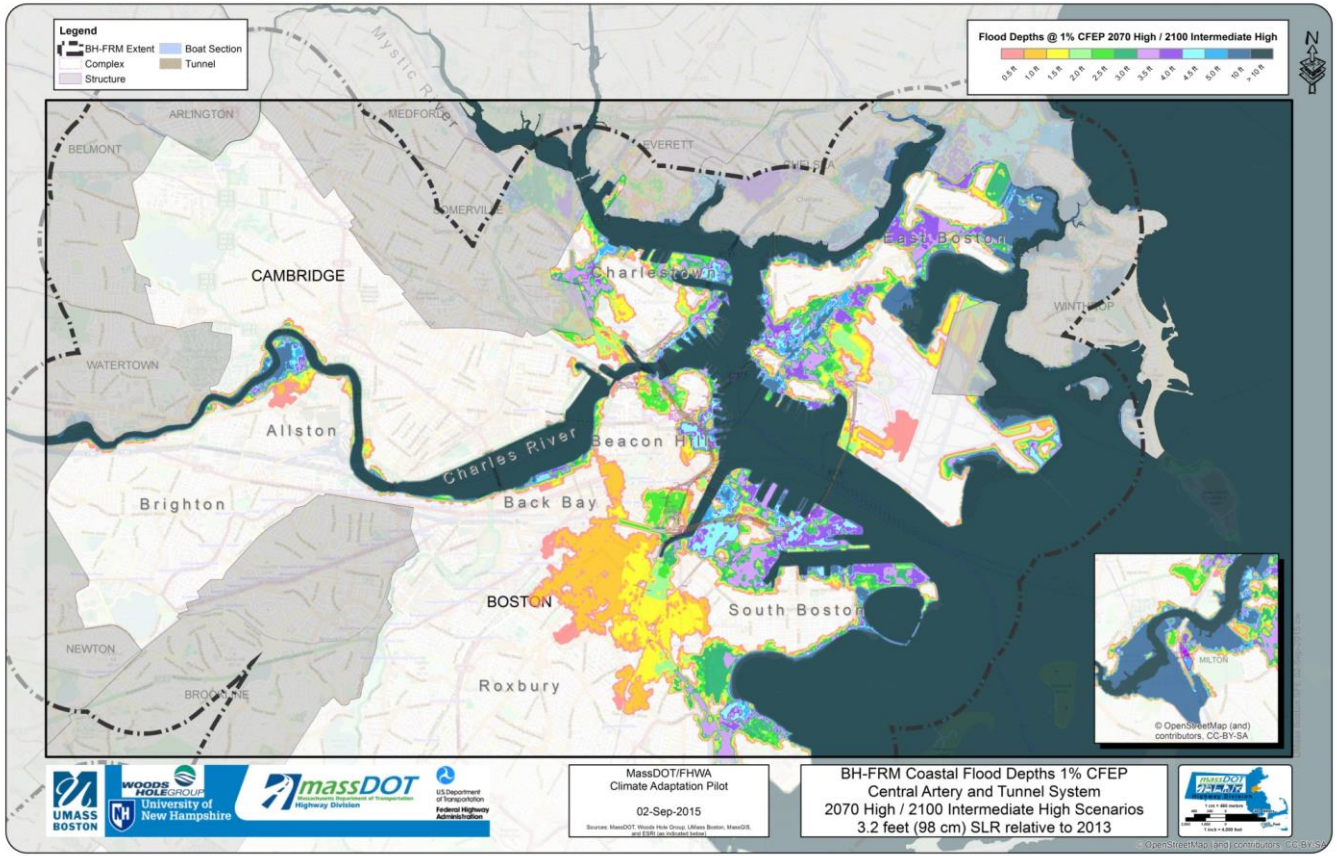
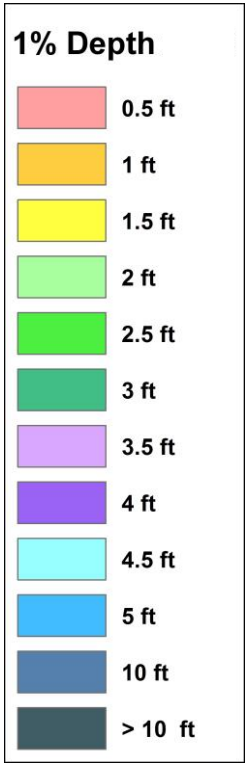
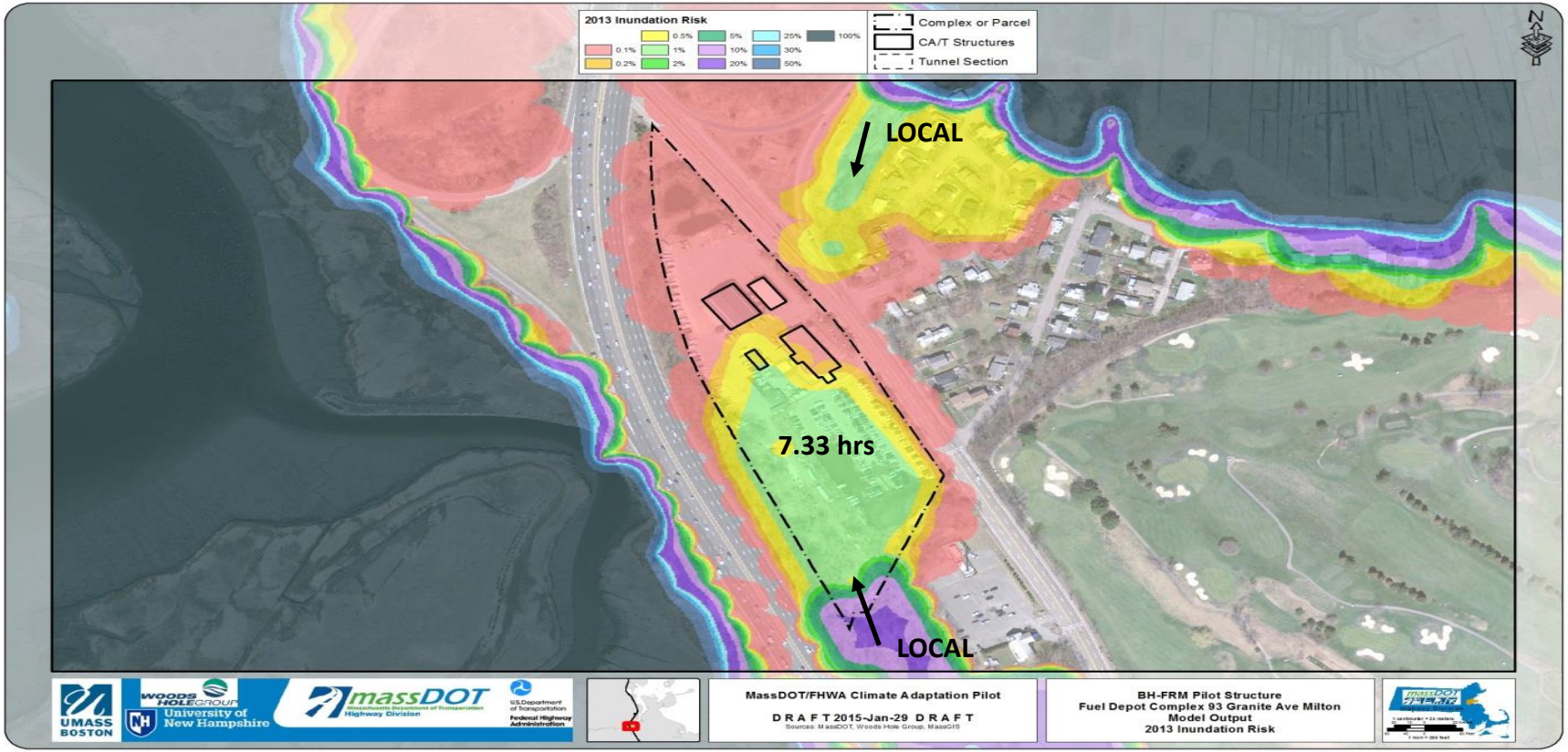




BH-FRM Assessment



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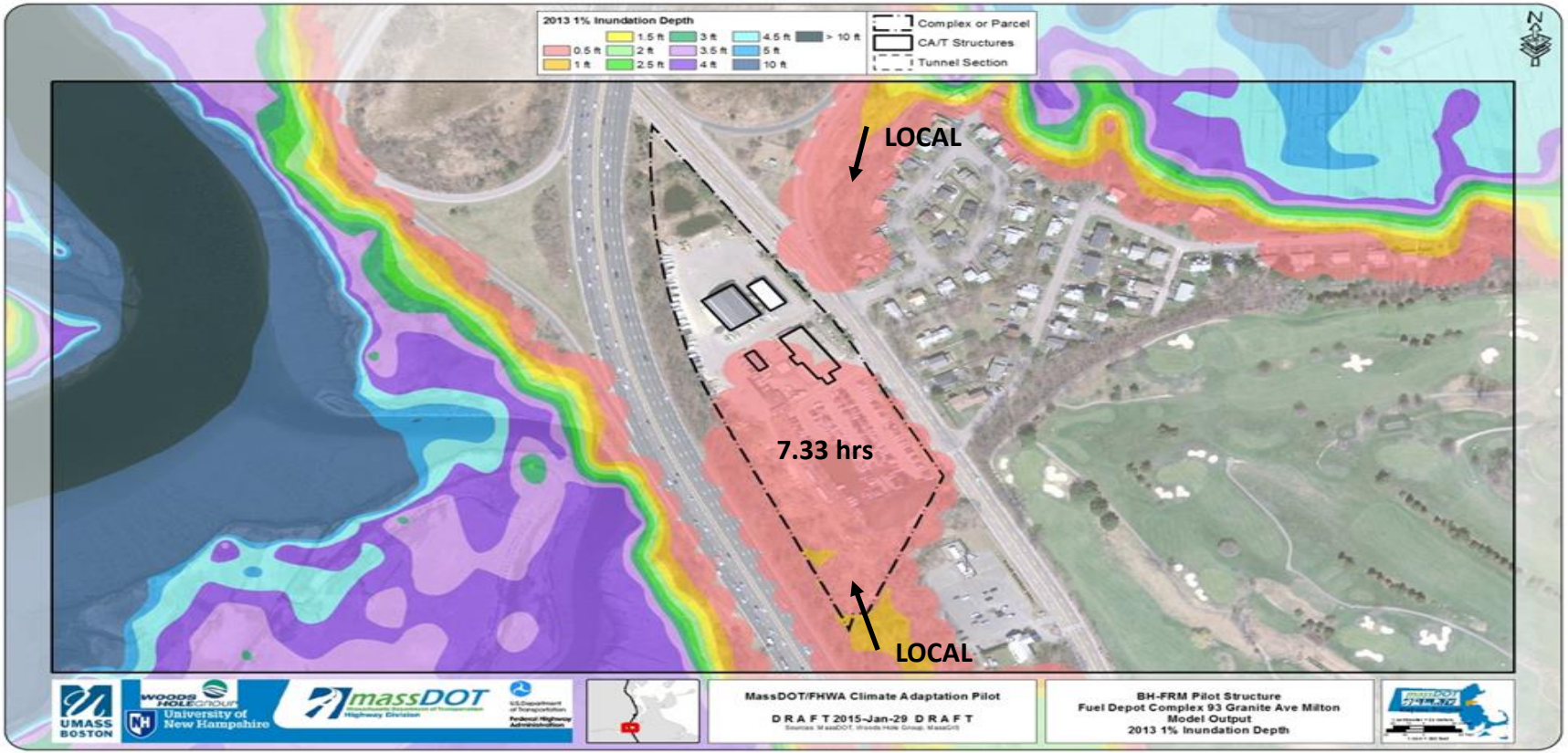

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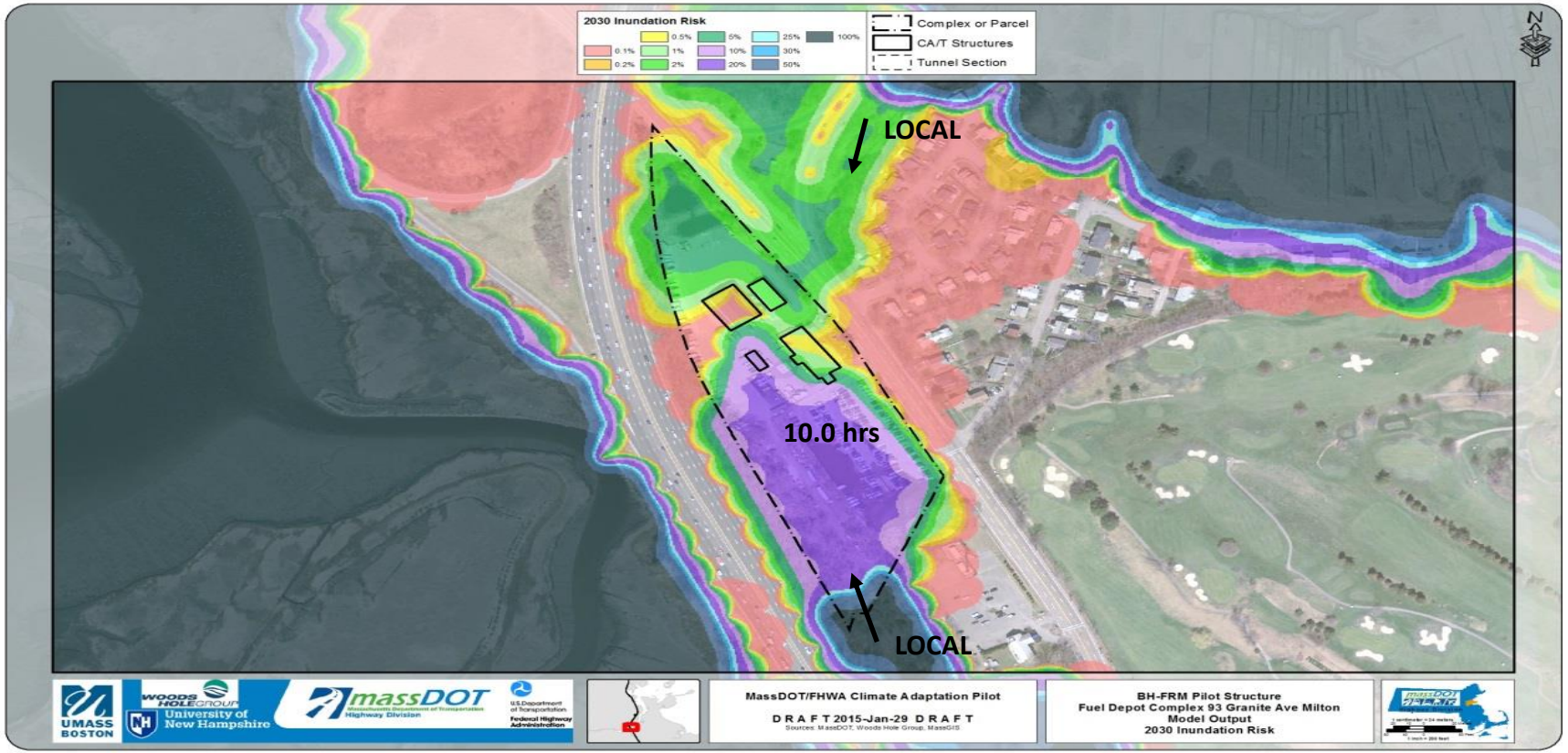

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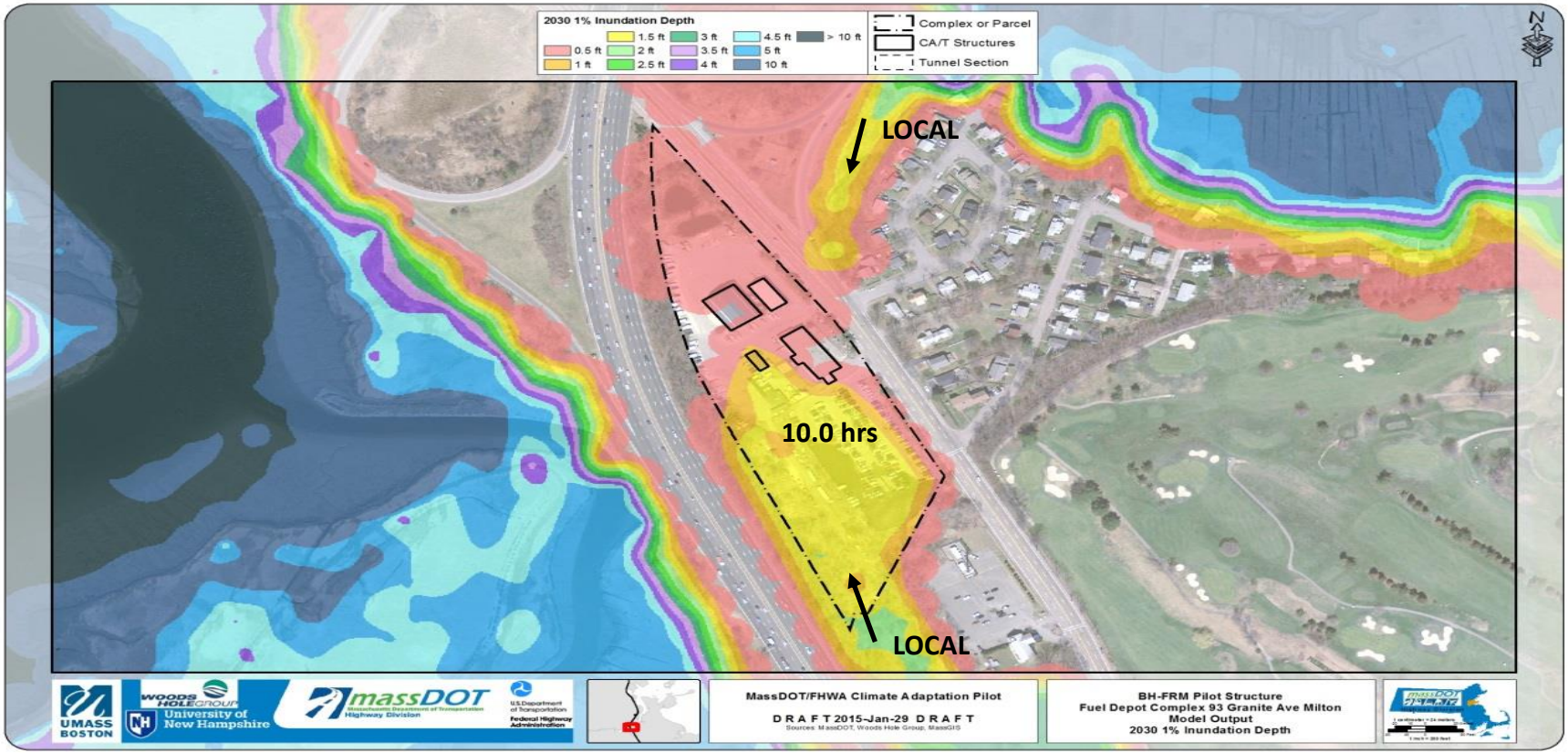
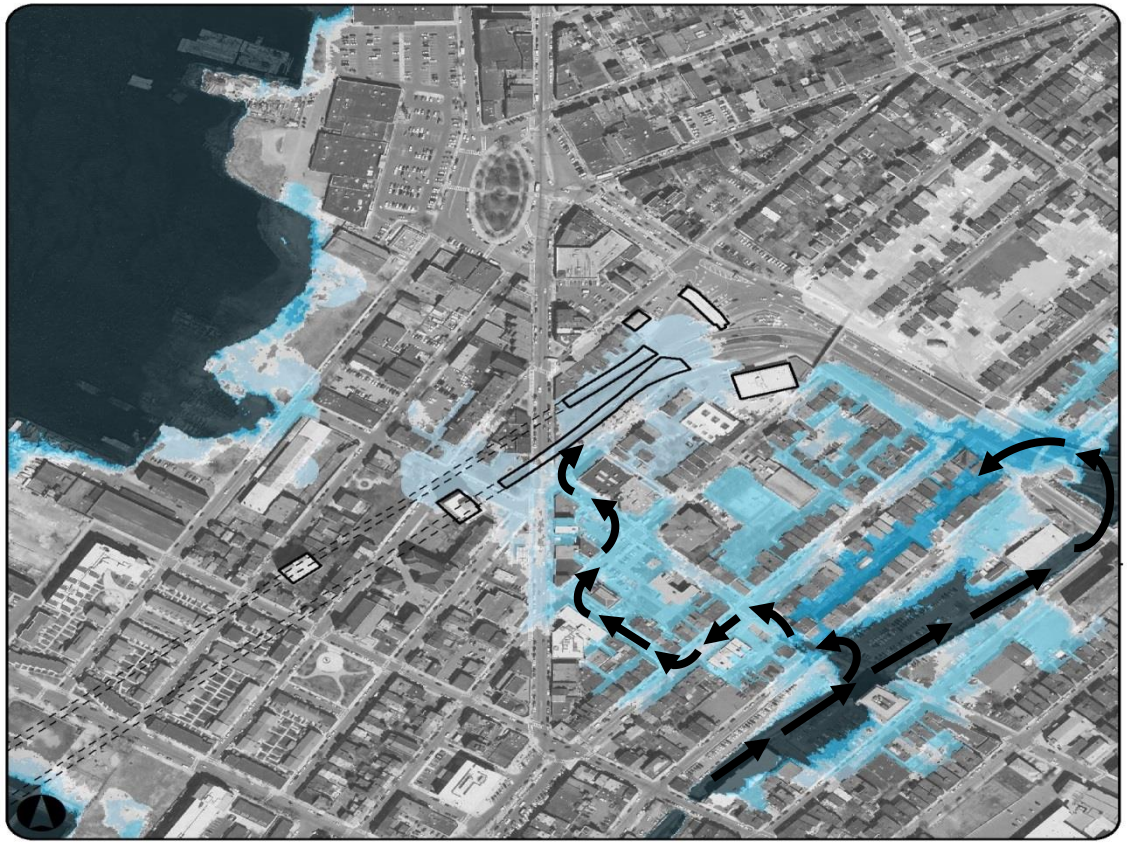


Flood Pathways



MassDOT/FHWA Climate Adaptation Pilot
BH-FRM Flood Pathway Analysis

2013 Regional and Local Flood Pathways

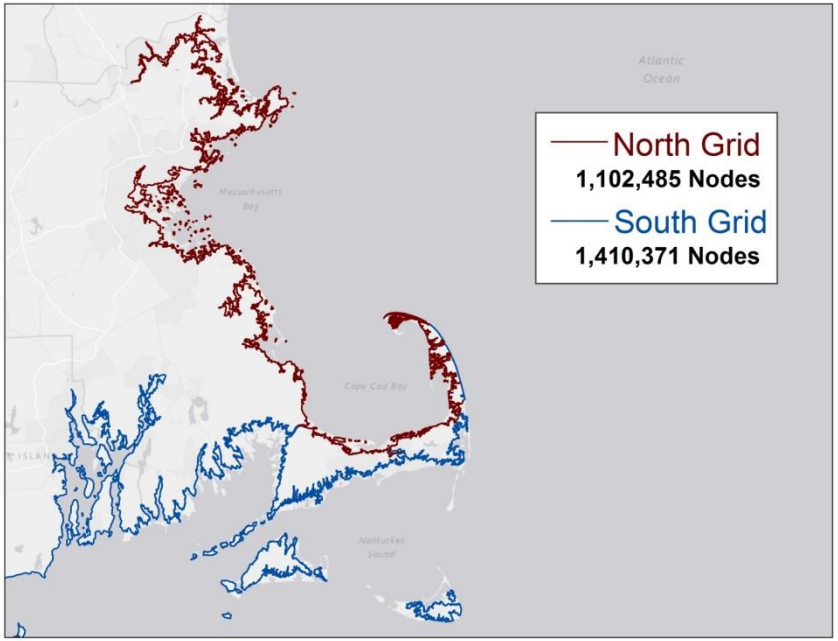
Callahan Tunnel
East Boston, MA

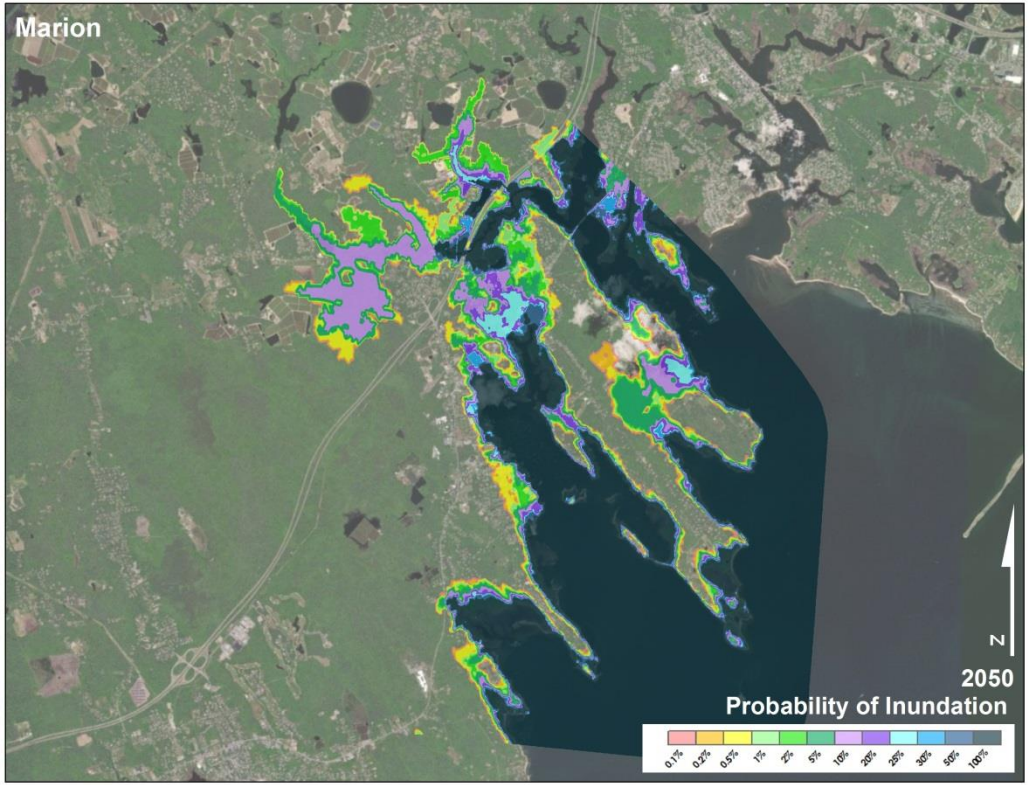
UMASS BOSTON | WOODS HOLE GROUP | University of New Hampshire | massDOT Highway Division | U.S. Department of Transportation Federal Highway Administration

CA/T System

Complex or Parcel | CA/T Structures | Tunnel Section

Statewide Modeling (MC-FRM)



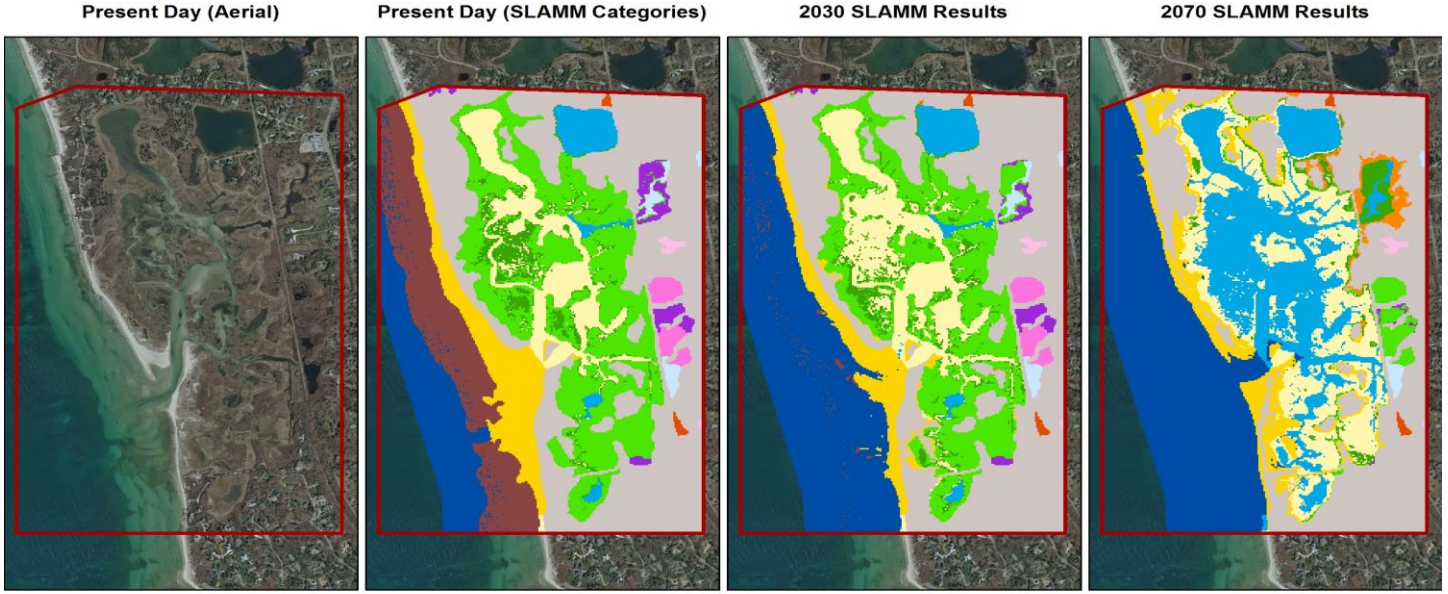


MC-FRM – Run-up and overtopping

Time variably calculated for each storm and every time step through the model simulation

MC-FRM – Run-up and overtopping

Time variably calculated for each storm and every time step through the model simulation



Great Sippewissett Marsh

SLAMM Wetland Categories

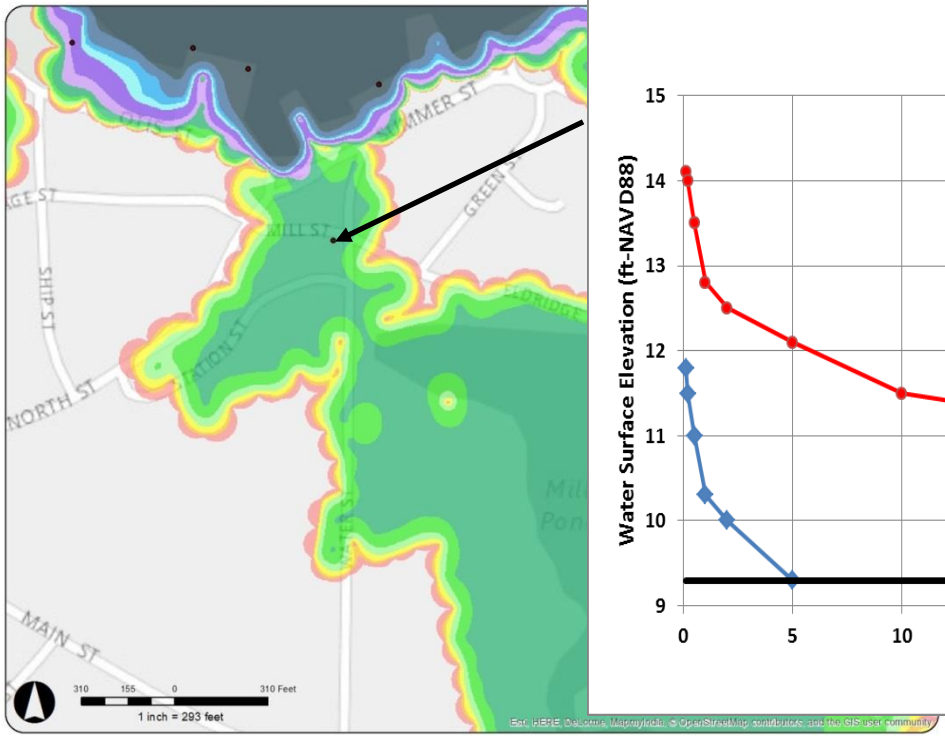
- Upland
- Nontidal Swamp
- Inland Fresh Marsh
- Tidal Fresh Marsh
- Transitional Marsh/Scrub-Shrub
- Regularly Flooded Marsh
- Estuarine Beach/Tidal Flat
- Ocean Beach
- Ocean Flat
- Inland Open Water
- Estuarine Open Water
- Open Ocean
- Irregularly Flooded Marsh
- Tidal Swamp

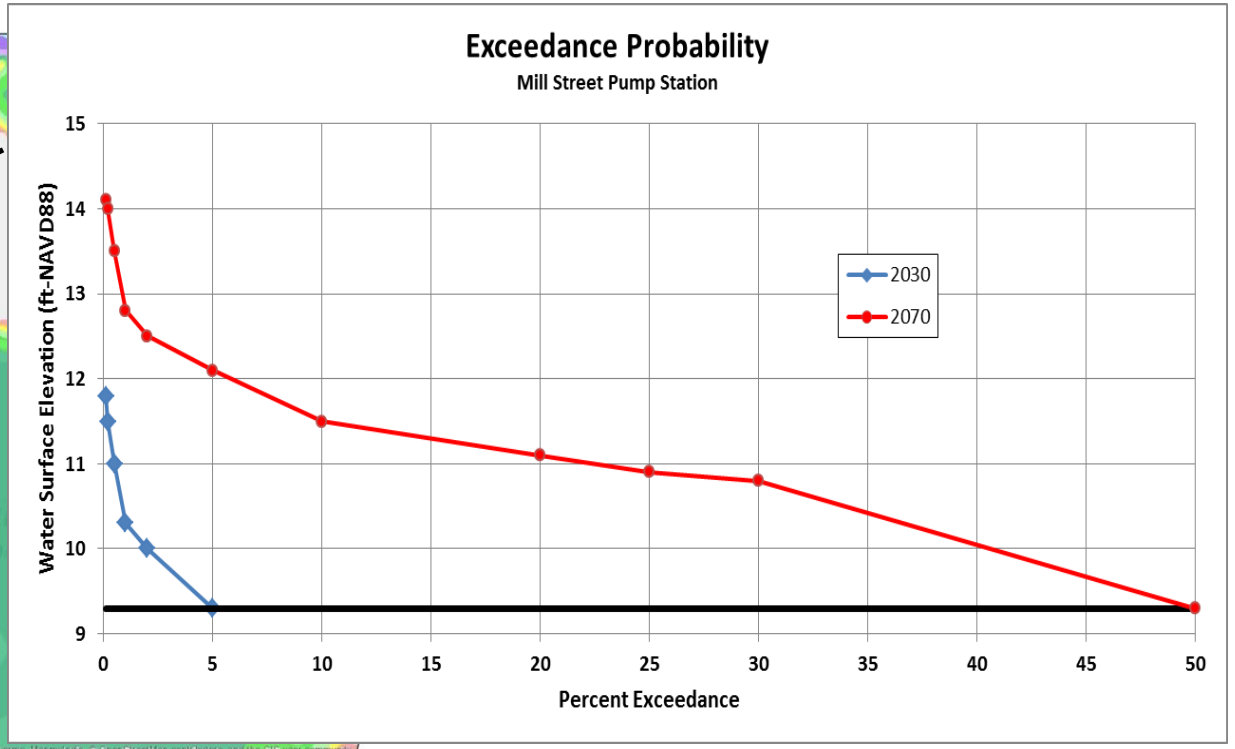
0 1000 2000 4000 Feet

N

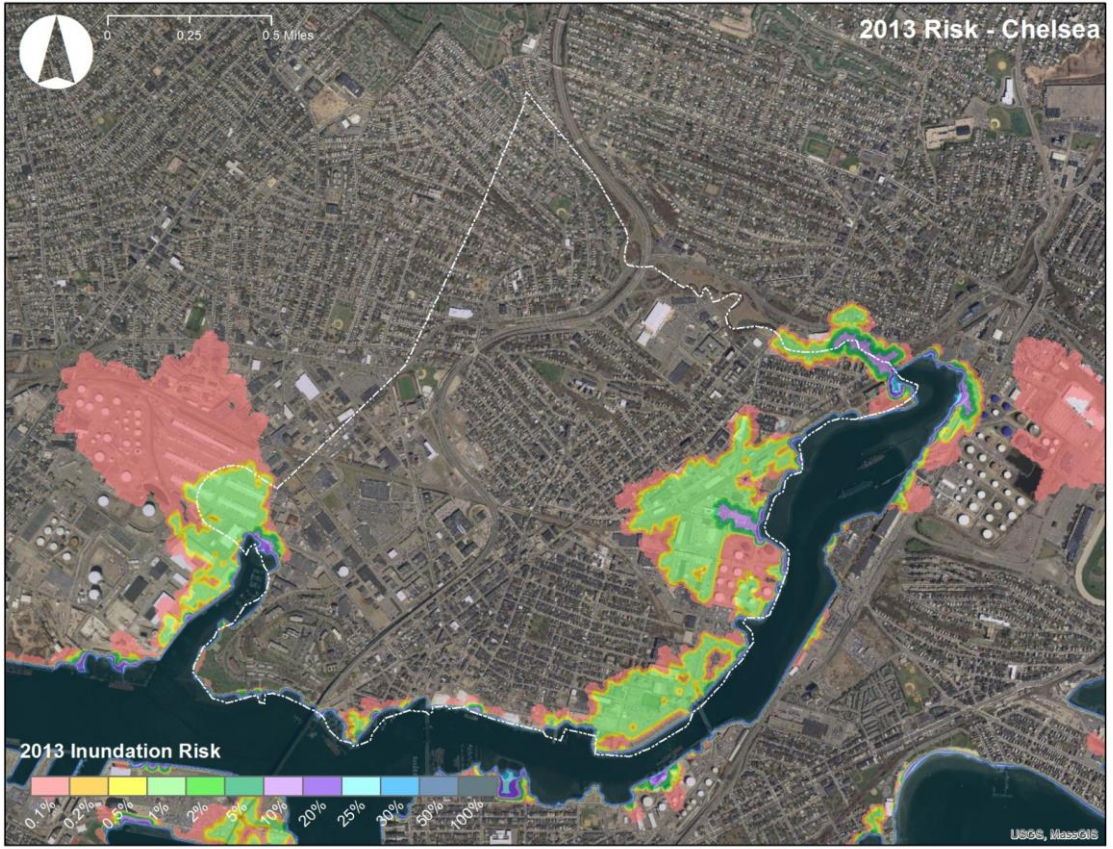
	Area (acres)		
	2011	2030	2070
Upland	142.4	139.3	111.8
Nontidal Swamp	0.8	0.8	0.8
Inland Fresh Marsh	0.9	0.9	0.9
Tidal Fresh Marsh	4.6	4.6	0.0
Transitional Marsh/Scrub-Shrub	0.0	0.1	5.9
Regularly Flooded Marsh	14.9	14.5	9.5
Estuarine Beach/Tidal Flat	31.4	43.6	62.6
Ocean Beach	28.3	22.4	29.1
Ocean Flat	49.0	2.0	0.0
Inland Open Water	3.1	3.1	1.6
Estuarine Open Water	10.2	10.3	73.4
Open Ocean	37.2	92.8	106.1
Irregularly Flooded Marsh	80.9	71.6	7.8
Tidal Swamp	6.2	4.0	0.4

Site Specific Information

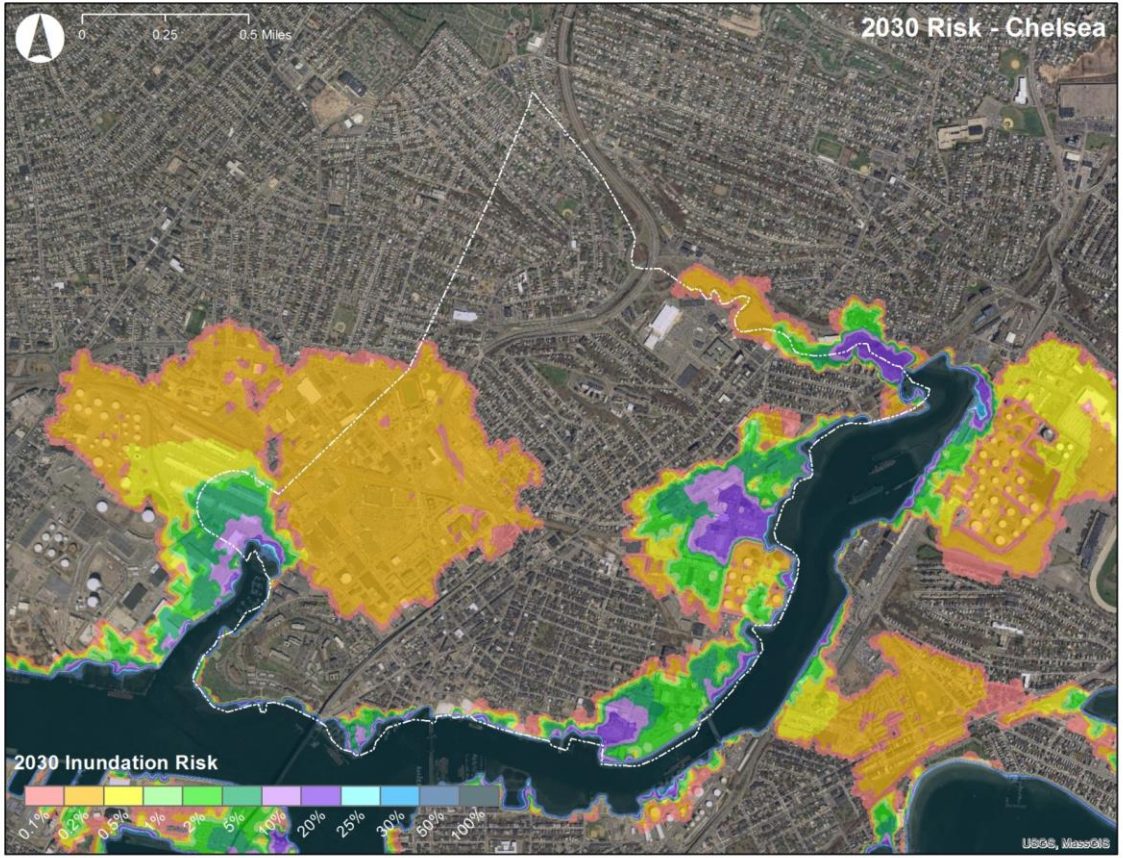




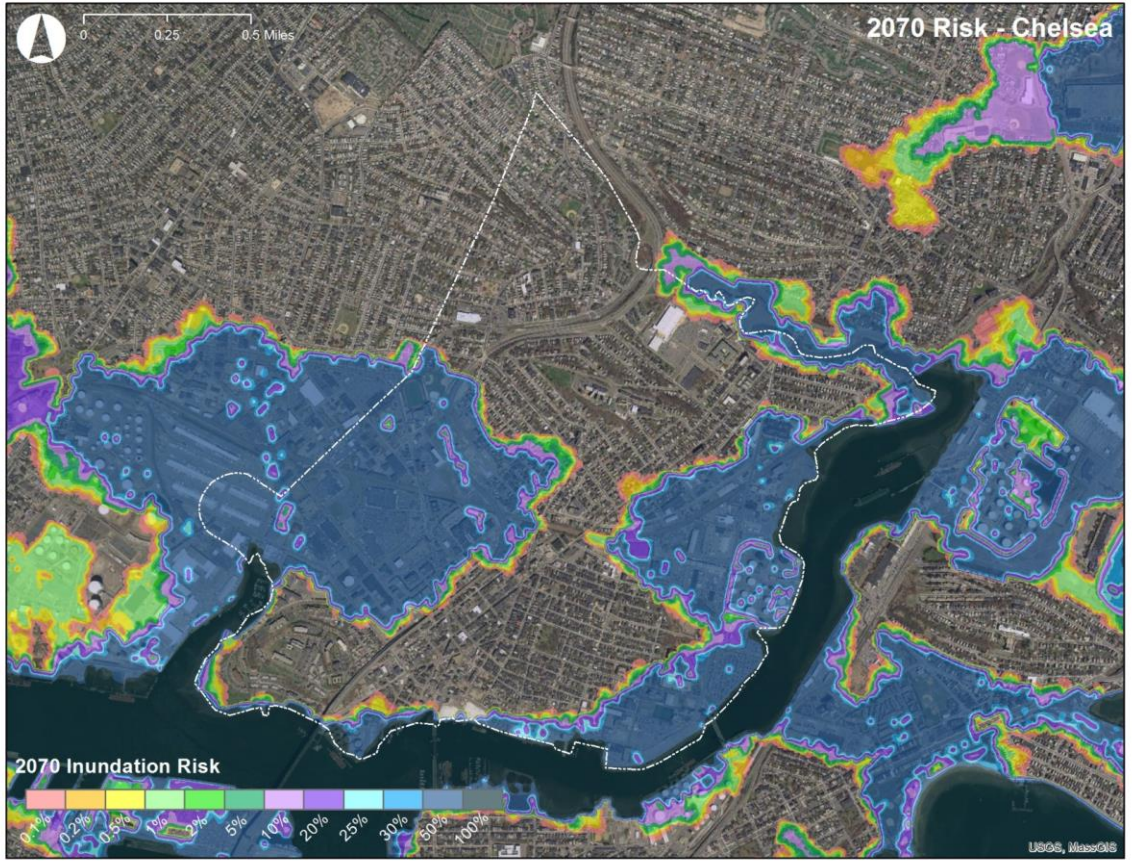
District Level Solutions



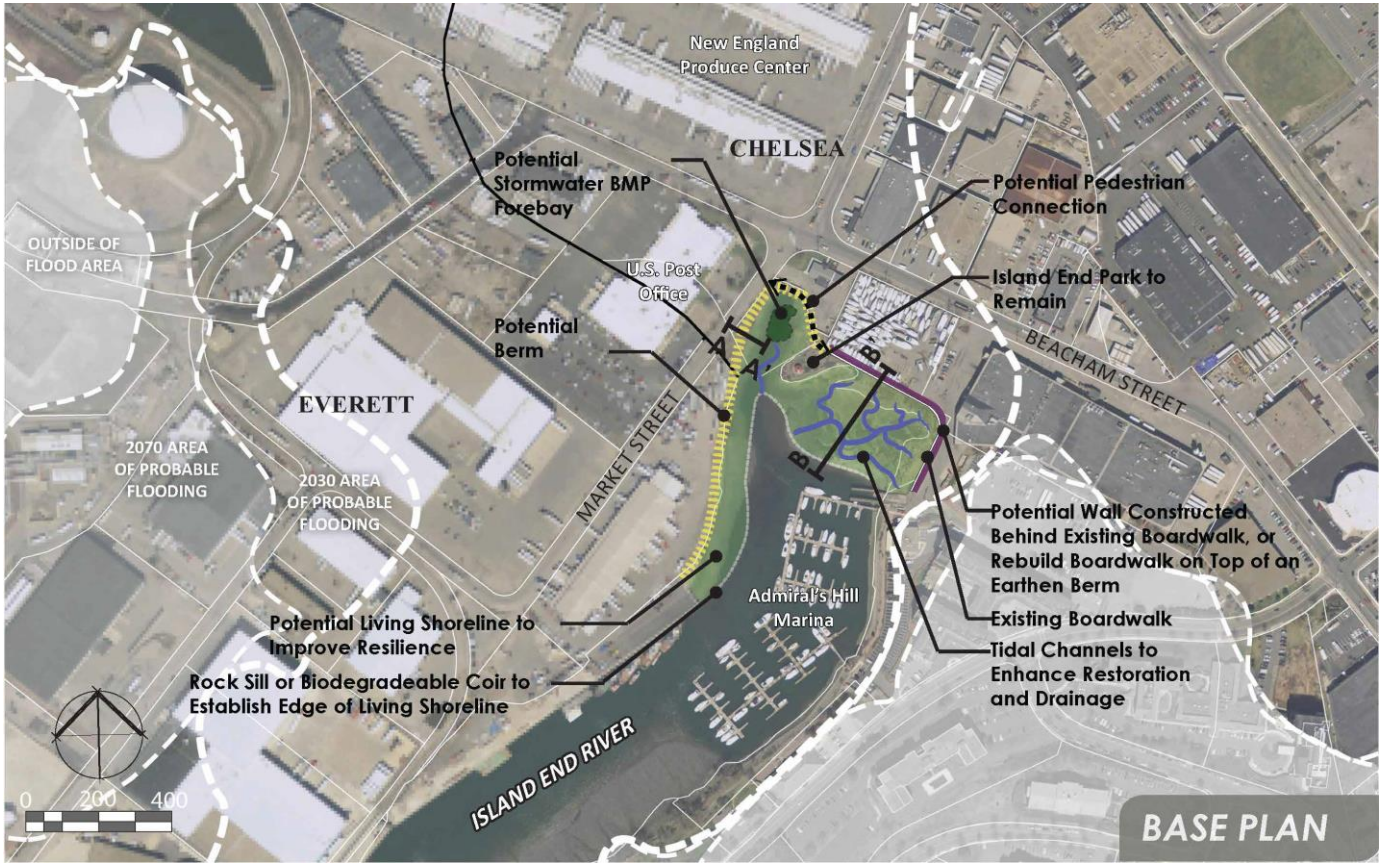
District Level Solutions



District Level Solutions



Hybrid, Urban Resilience Design – Chelsea, MA



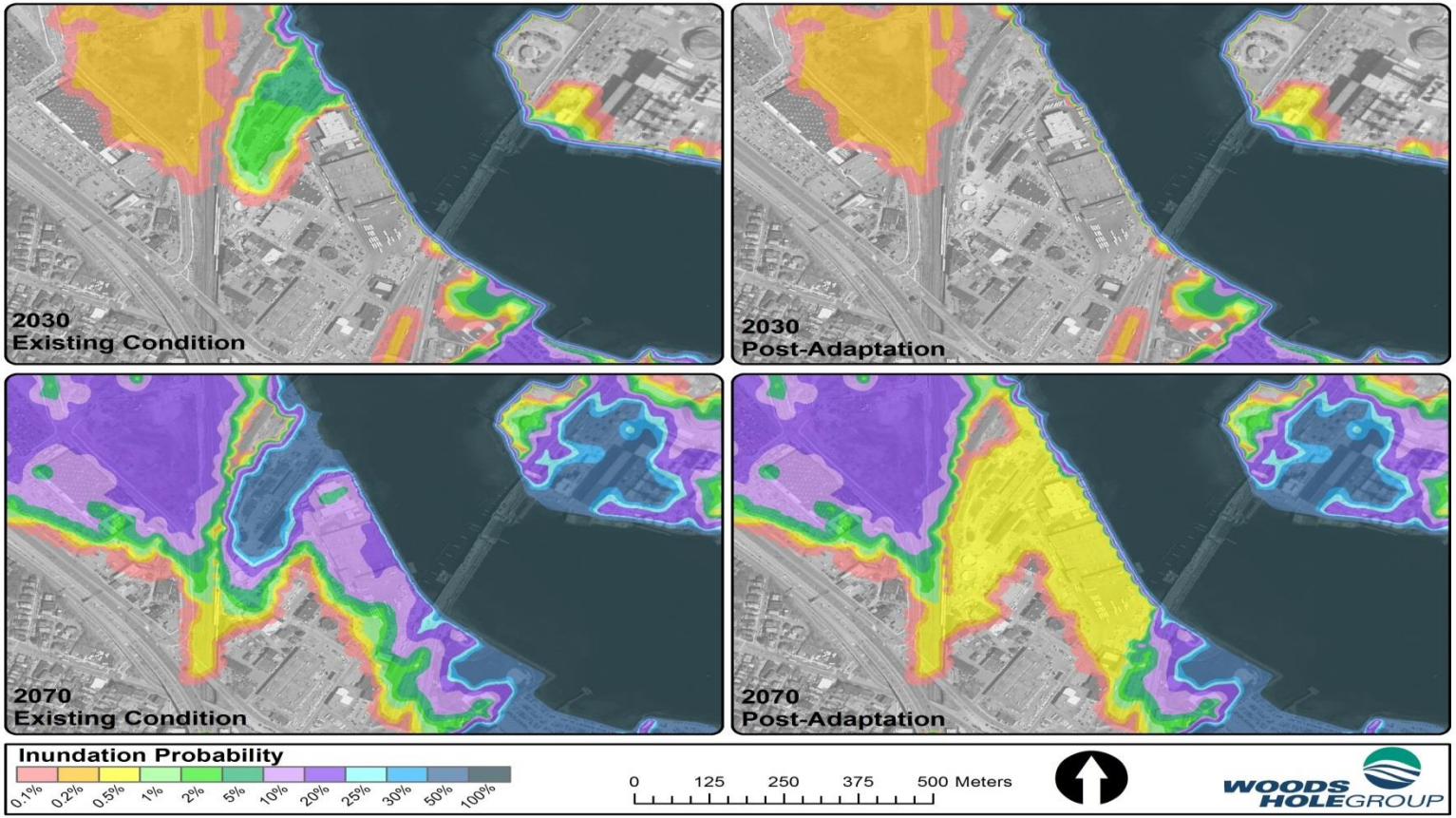
Charlestown MBTA Bus Garage

MBTA's largest Bus Depot housing 208 buses

Before

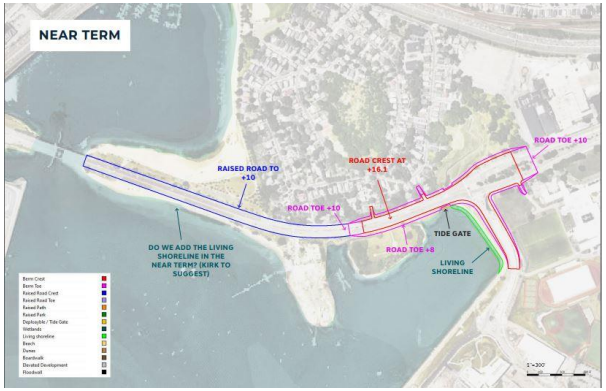
After

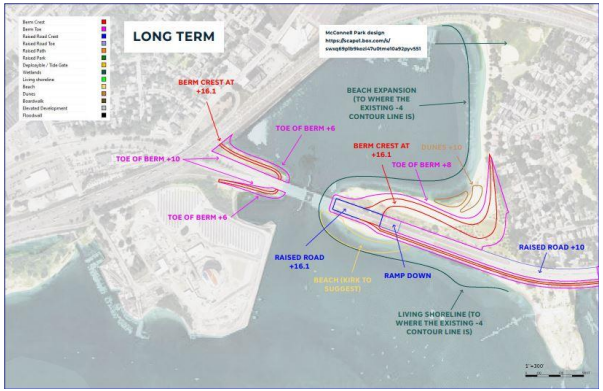
Charlestown MBTA Bus Garage

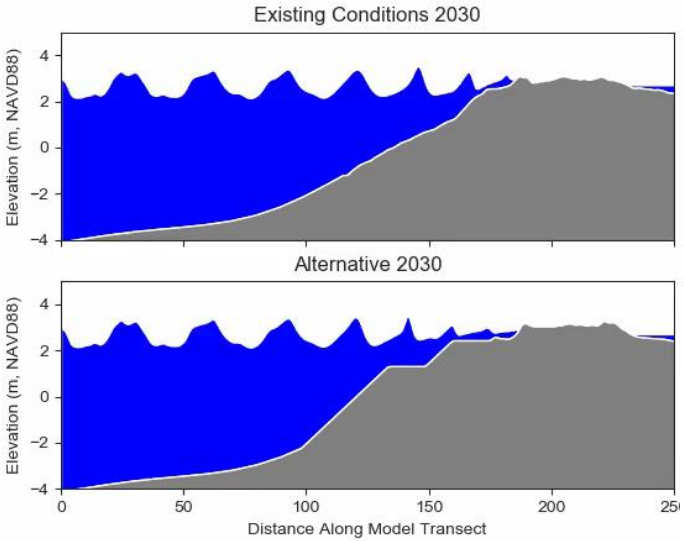


Coastal Resilience Solutions for Dorchester

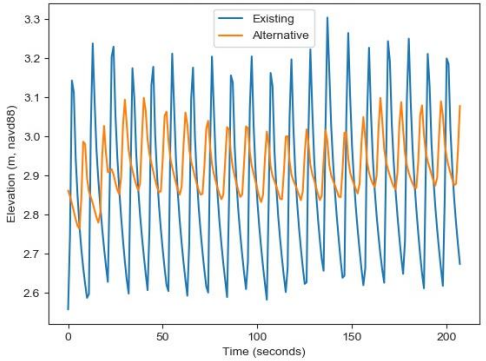
Morrissey Boulevard – Wave Results Summary





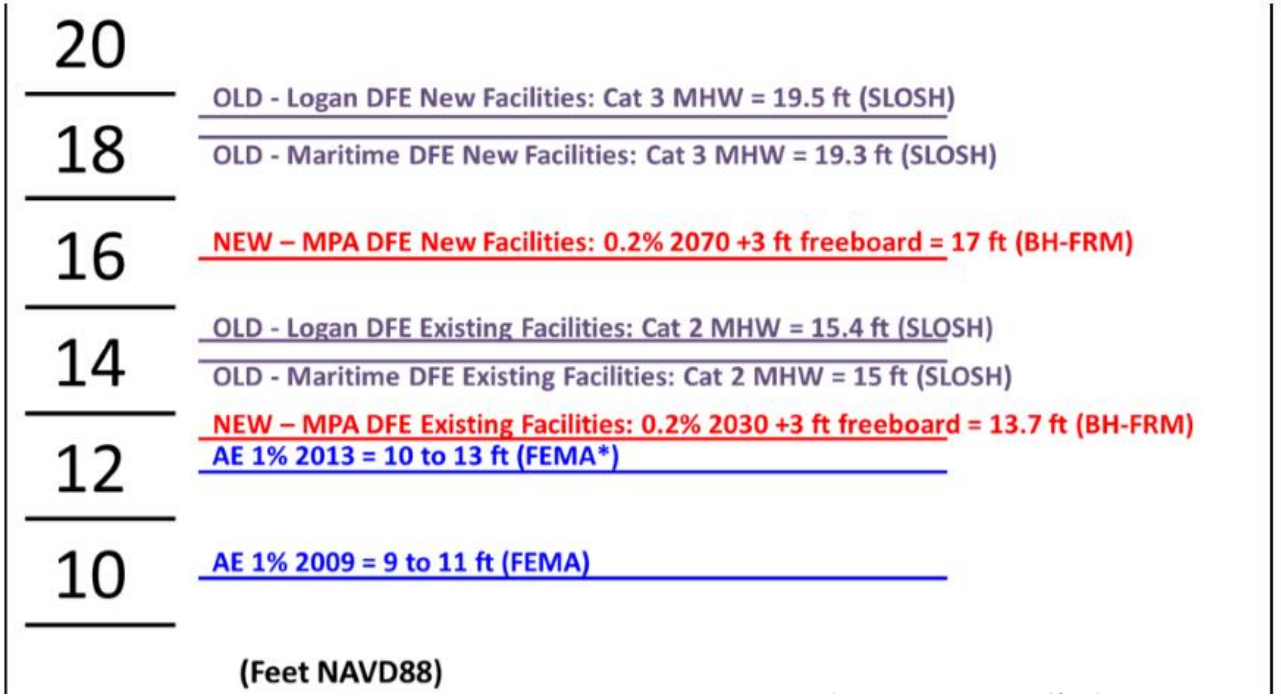


Scenario	Wave Height Reduction
2030 10%	66%
2030 1%	47%
2070 10%	27%
2070 1%	15%

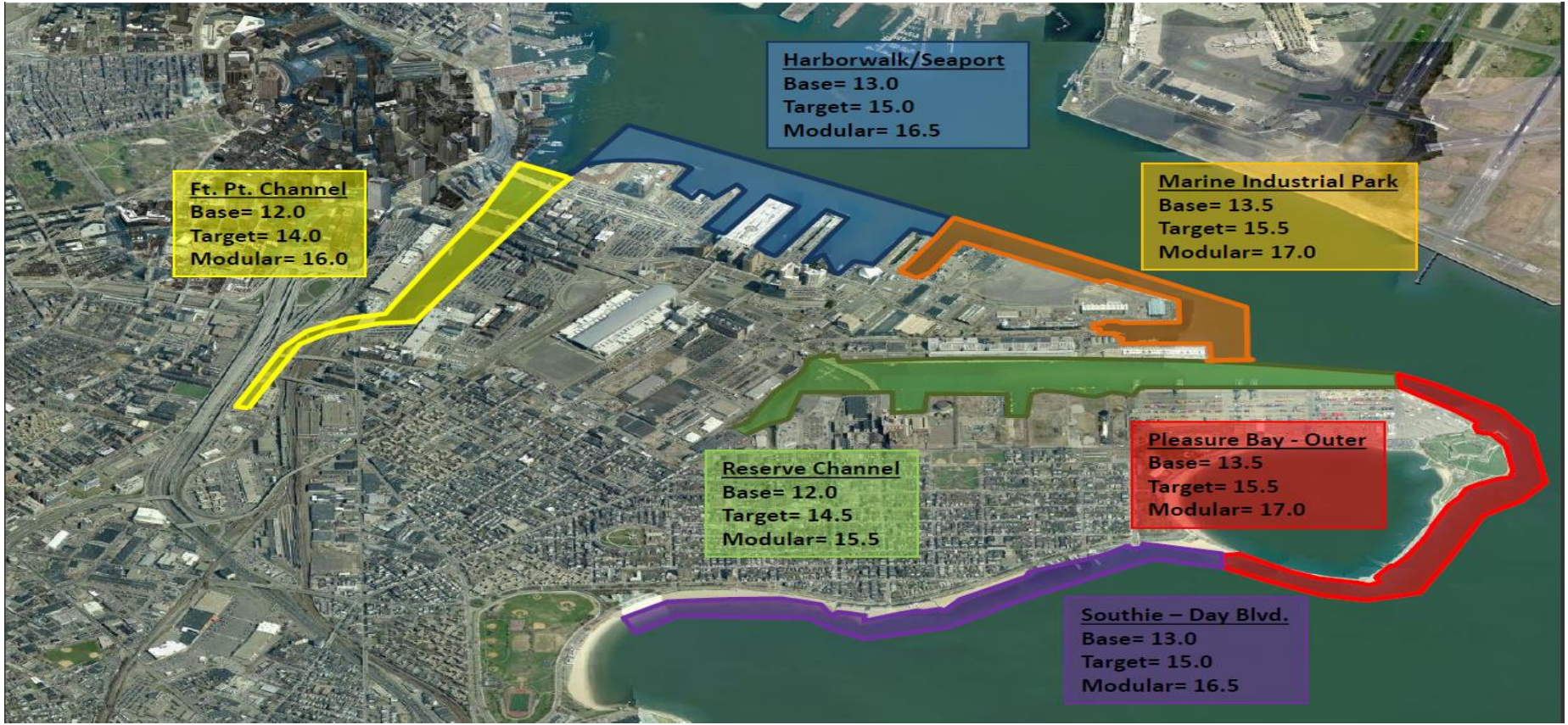


Massport

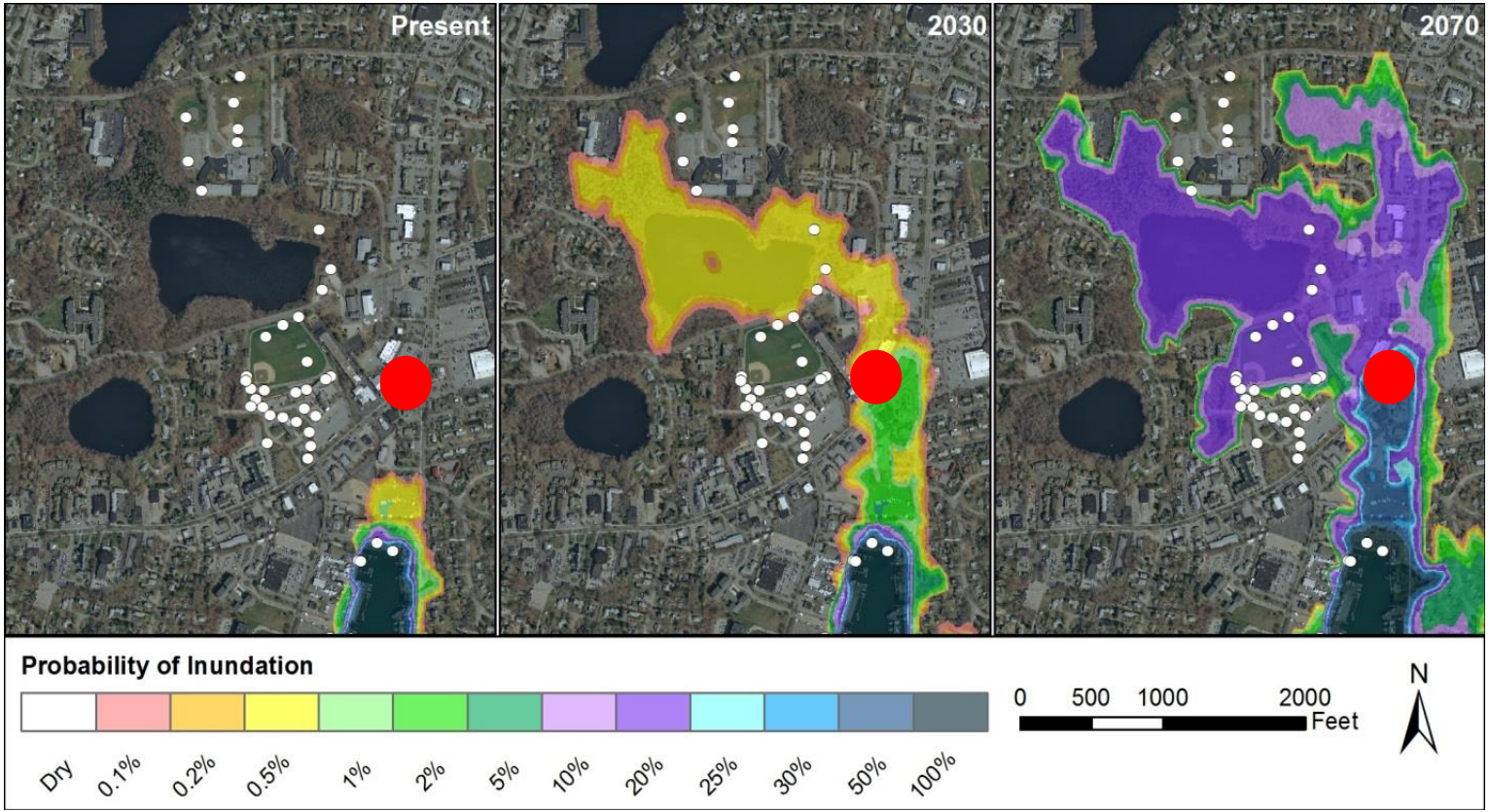
Design Flood Elevations (Probabilistic Model)

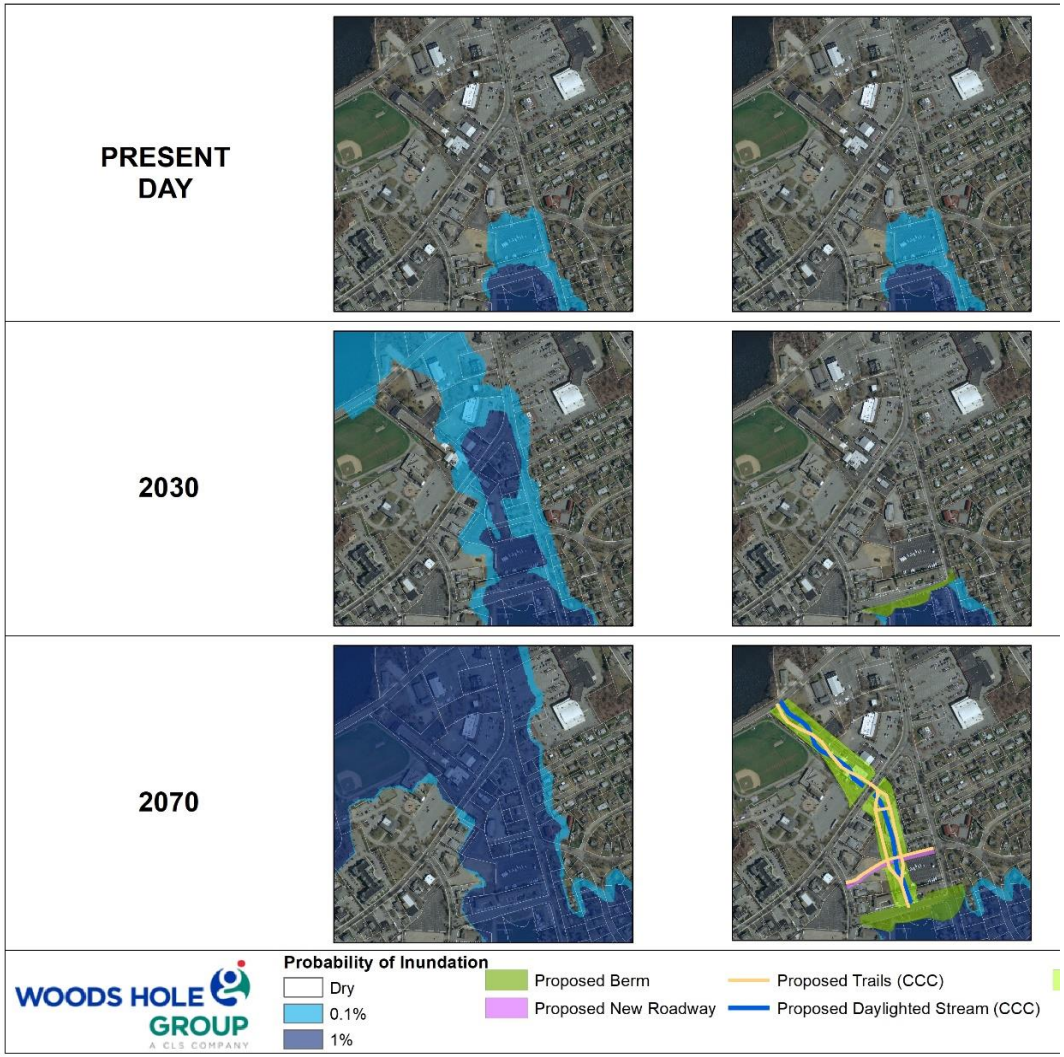


Climate Ready Boston



Example – Design Criteria Output





Design Criteria Output

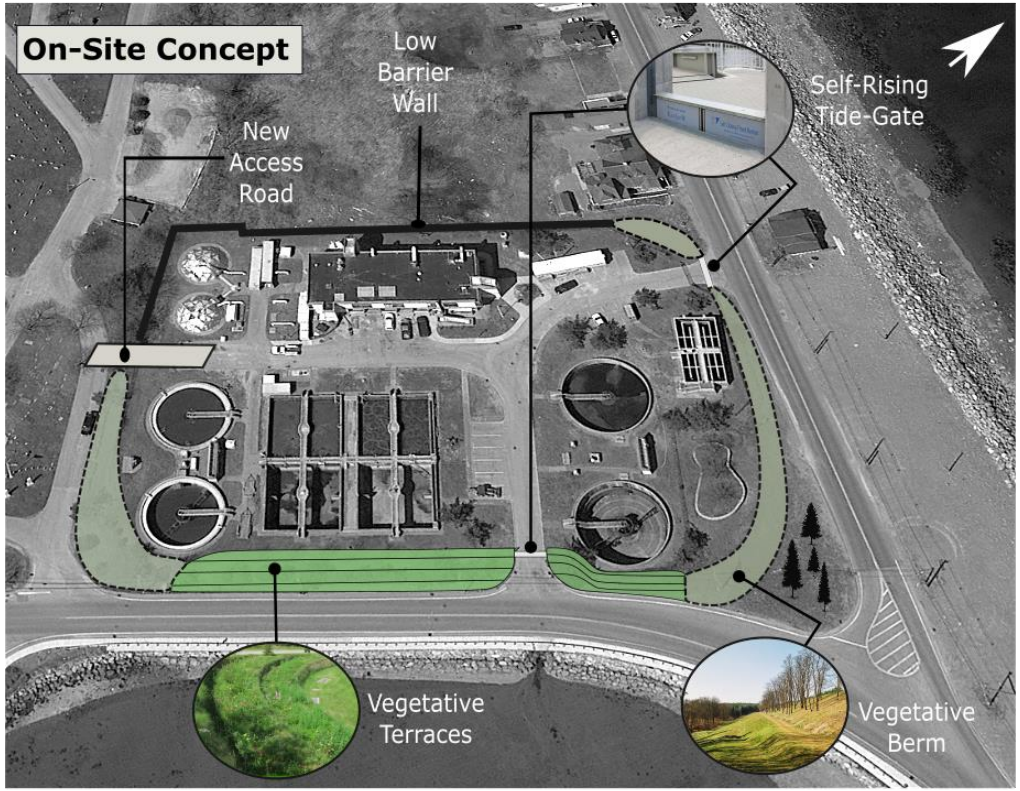
Design Criteria	Intermediate Level (2050, 500-yr)	Target Level (2070, 500-yr)
Stillwater Level	14.4 ft NAVD88	16.3 ft NAVD88
Design Flood Elevation	16.2 ft NAVD88	18.1 ft NAVD88

Woods Hole Oceanographic – Iselin Dock Design

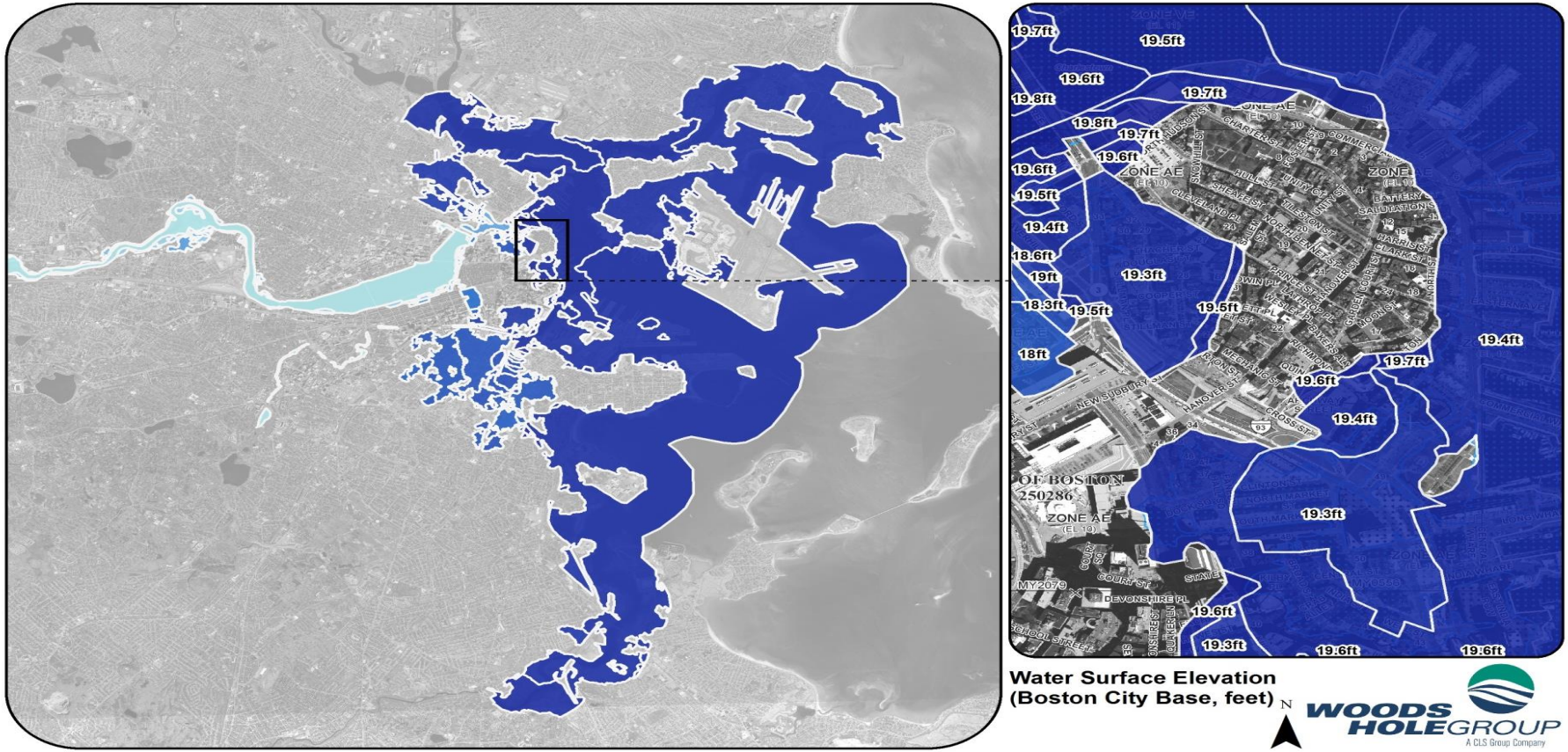
- Episodic and chronic flooding
- Modular design
- Operations vs. service life
- Design to fit within fabric of the surrounding infrastructure

Water Pollution Control Facility – Hull, MA

Asset	Existing Mass State Building Code Requirements (ft, NAVD88)	TR-16 Guides for the Design of Wastewater Treatment Works (ft, NAVD88)	Recommended DFE for Infrastructure (ft, NAVD88)
			50-yr Service Life
Control Building	15	16	18.3
Chlorine Contact Tank	15	16	18.6
Secondary Clarifier No.2	15	16	17.4
Secondary Pump Room	15	16	17.9
Aeration Tanks	15	16	17.2
Primary Clarifier No.2	15	16	16.8
Primary Pump Room	15	16	16.7
New AST Chainwall	15	16	17.1
Gravity Thickener No.1	15	16	16.8
Influent Sewer Line	15	16	18.1
Headworks	15	16	16.7
Sludge AST foundation/pad	15	16	16.7
Effluent Pump Room	15	16	18.6
Driveway (Overall)	15	16	19.4
Ocean side entrance	15	16	19.3
Bay Side entrance	15	16	17.8



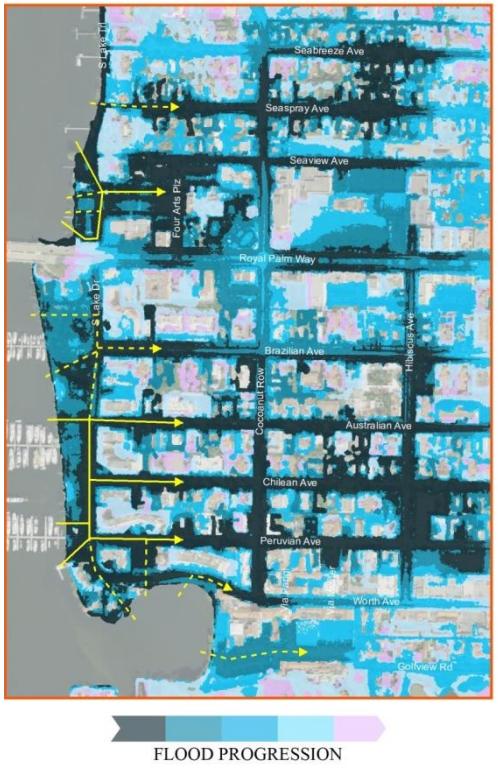
Boston Planning and Development

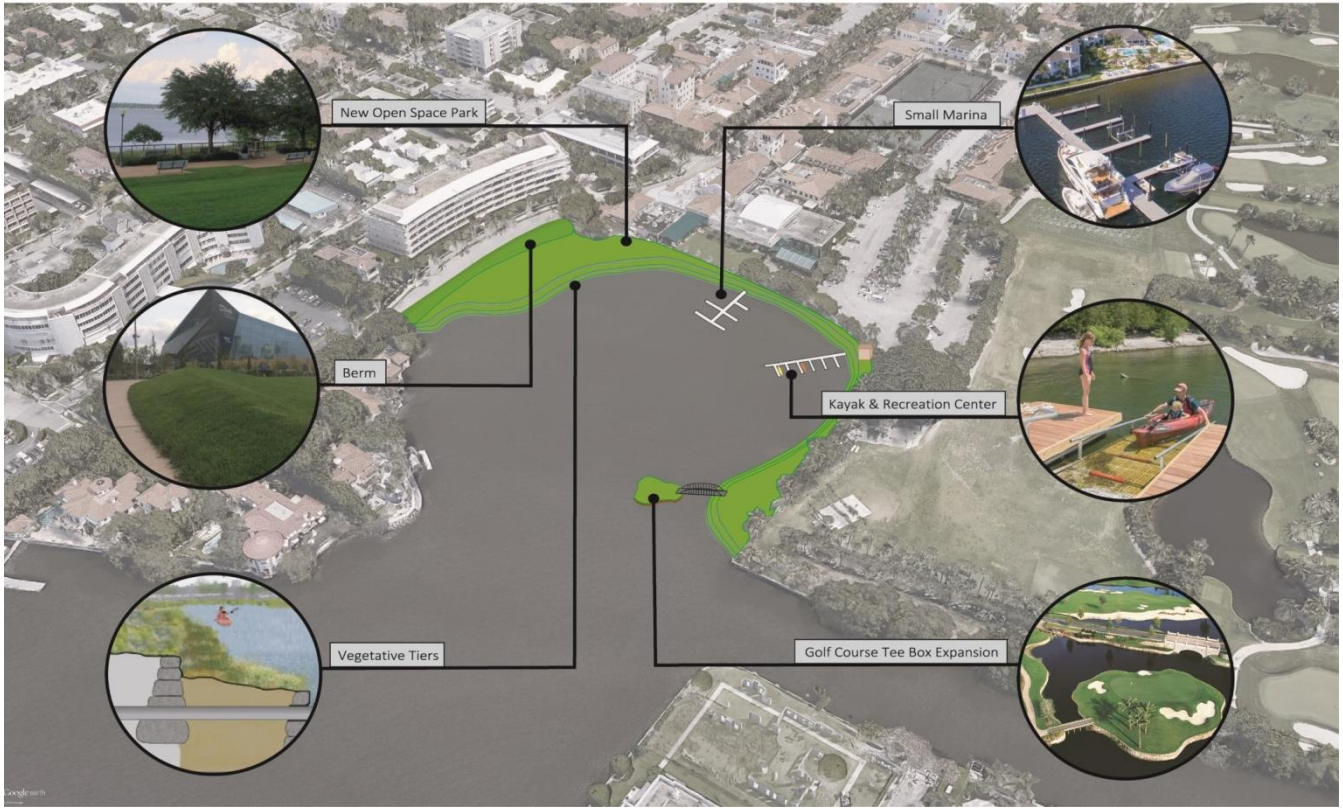


Water Surface Elevation
(Boston City Base, feet)

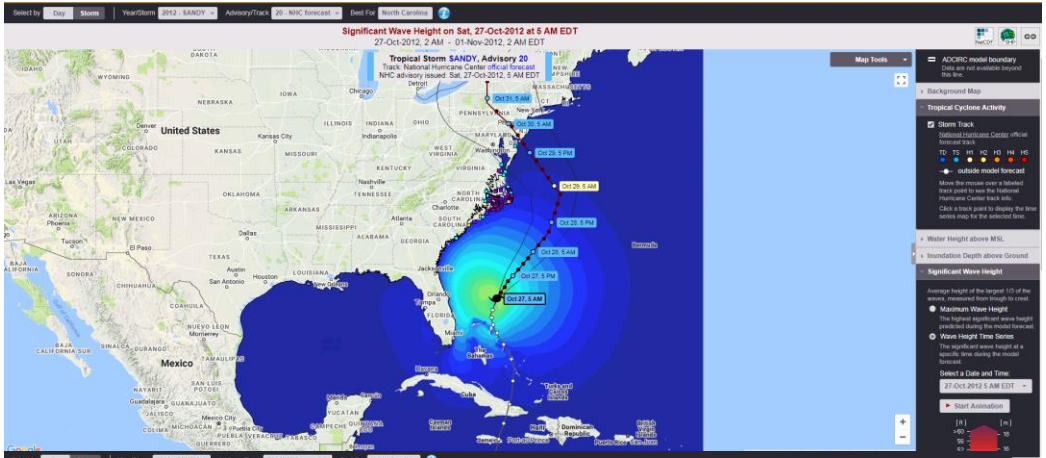
WOODS HOLE GROUP
A CLS Group Company

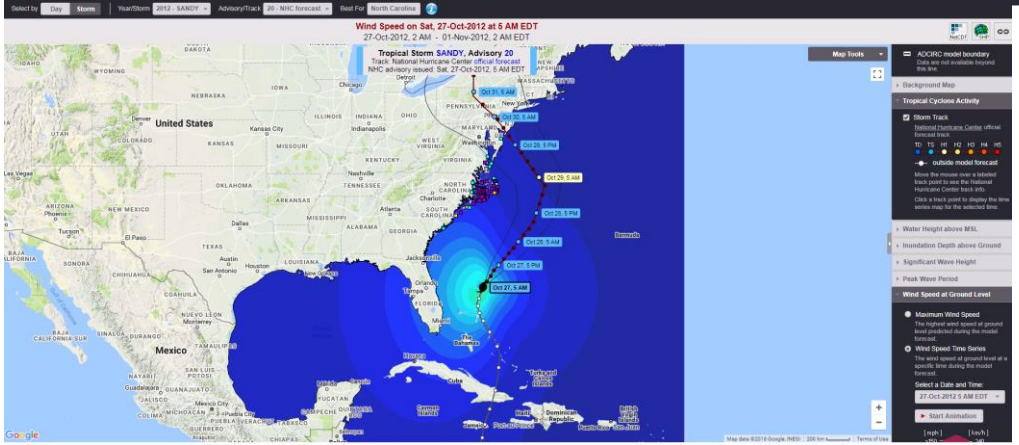
Award-winning approach

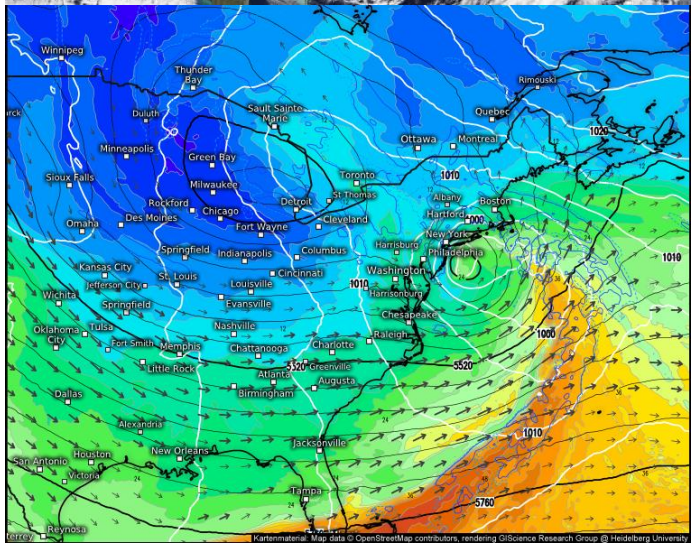




Operational Model







Summary

1. The MassDOT models provide high-resolution flooding results for projected climate change scenarios.
2. Peer-reviewed by Technical Advisory Committee - WHOI, USGS, NOAA, USACE, and USEPA
3. Include relevant processes, storm types, and joint probabilities.
4. The models provide probability based results that can be more effectively used to assess vulnerabilities and prioritize planning.
5. The model can be used to test various adaptation and engineering options, connected to ecological, piped infrastructure, and economic models.
6. Model has been extended and updated for the entire coastline of Massachusetts.