



MassDOT-FHWA Pilot Project:

Climate Change and Extreme Weather Vulnerability Assessments and Adaptation Options of the Central Artery

Northeastern Transportation and Wildlife Conference
Lake Placid, NY

September 11-14, 2016







The Central Artery/Tunnel (CA/T) system is a critical link in regional transportation and a vitally important asset in the Boston metropolitan area. It is potentially vulnerable to flooding from an extreme coastal storm under present and future climate.







Tip O'Neill Tunnel Exit & Entrance Ramps

Tip O'Neill Tunnel Exit & Entrance Ramps

Tip O'Neill Tunnel Exit Ramp







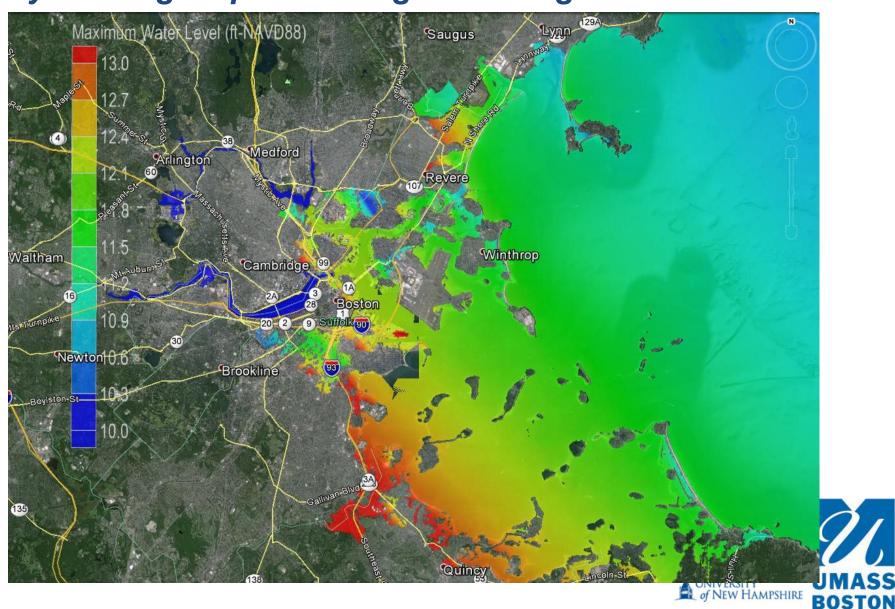


Vent Building 4– Detail of 15KV Electrical Conduit





Why existing maps are not good enough

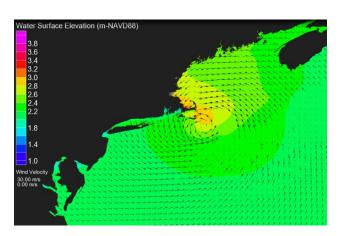




High Resolution Hydrodynamic Modeling

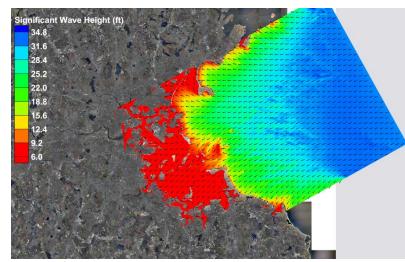
 Includes relevant physical processes (tides, storm surge, wind, waves, wave setup, river discharge, sea level rise, future climate scenarios)





- Currents
- Storm Surge
- Tides
- **Water Levels**
- Winds
- SLR
- Discharge
- Infrastructure





Waves

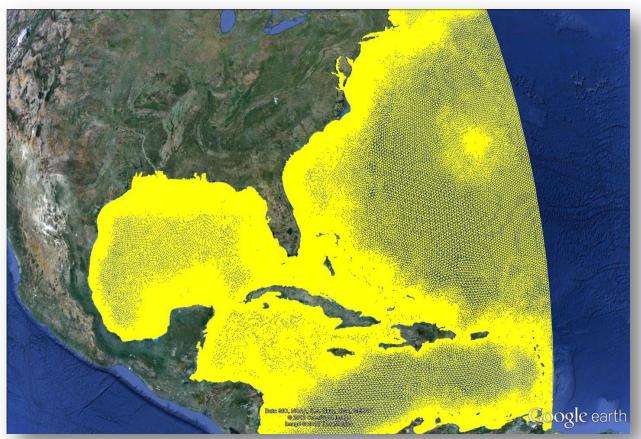
Wave Setup





Grid Development

Grid covers a large regional area (North Atlantic) to capture large-scale storm (hurricane, nor'easter) dynamics.

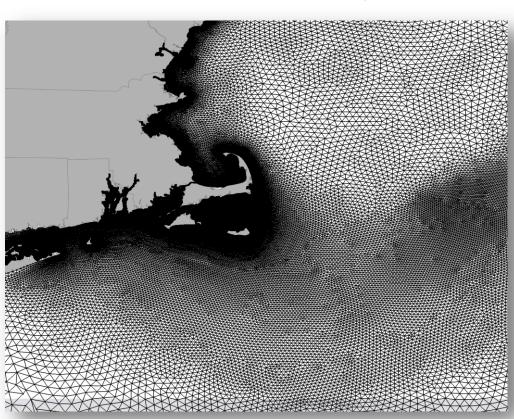


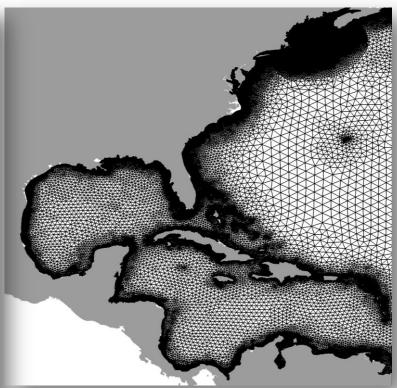




Grid Development

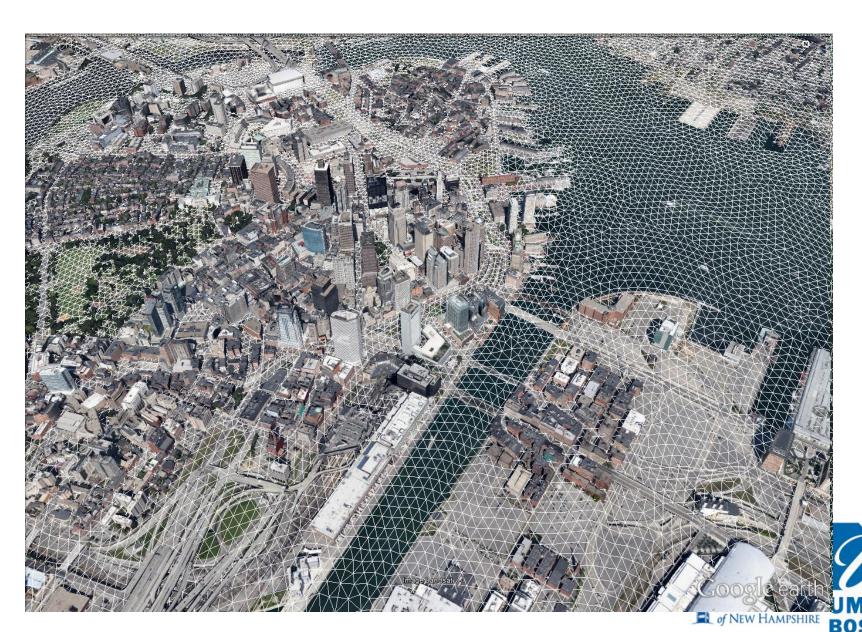
Unstructured grid = varying resolution with high resolution in areas of interest (Central Artery)



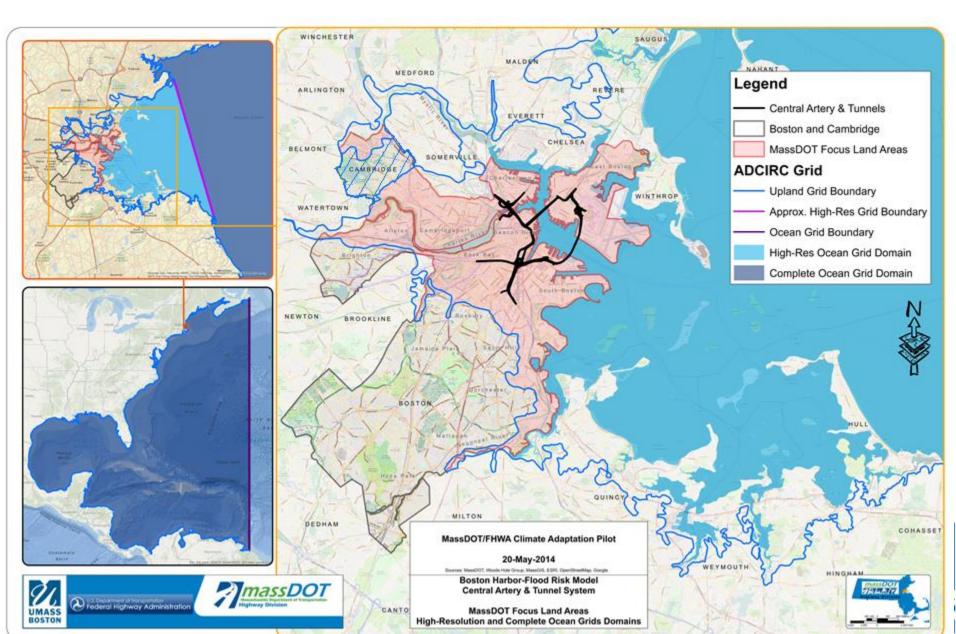






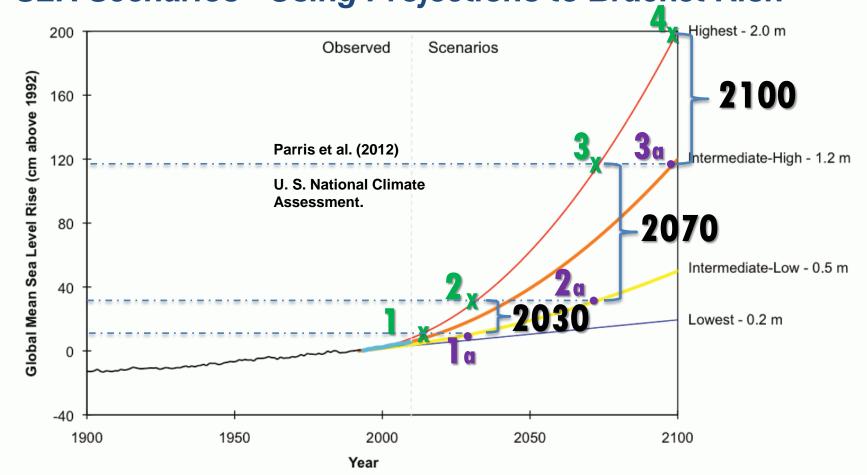








SLR Scenarios - Using Projections to Bracket Risk

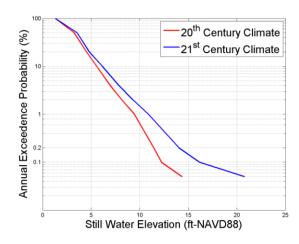




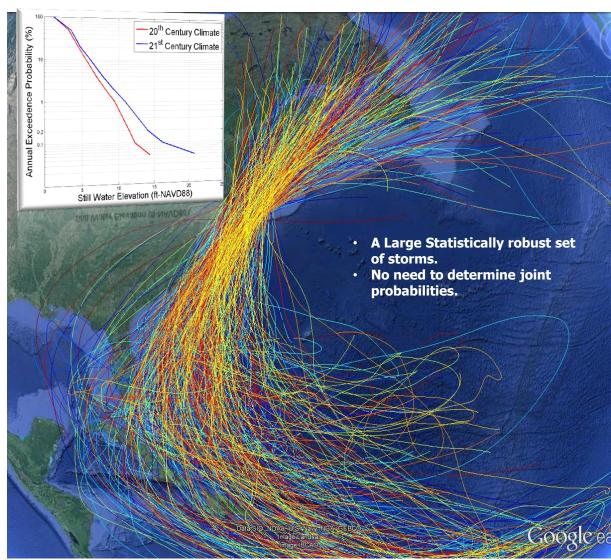


Storm Climatology - Hurricanes

- 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

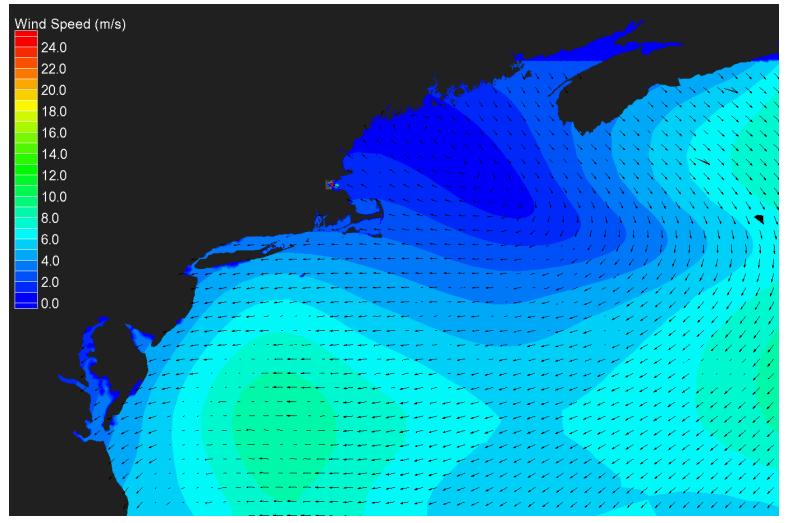


 Simulates storms combined with SLR and precipitation





Model Results - Winds (Nor'easter)

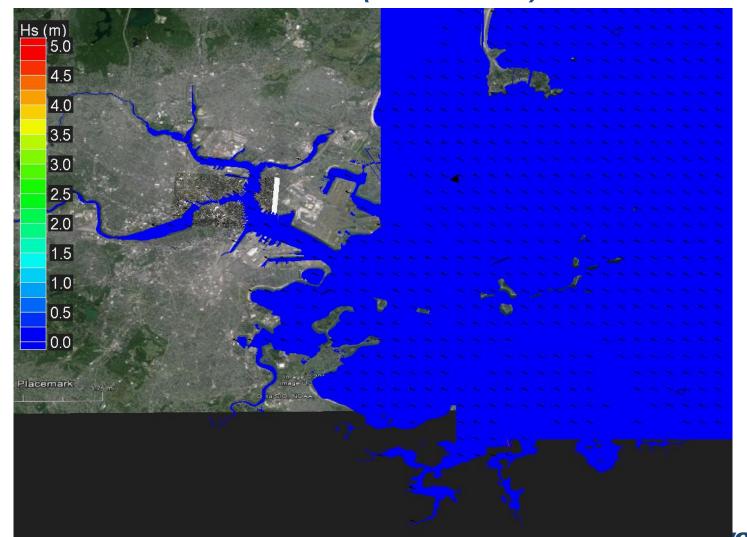






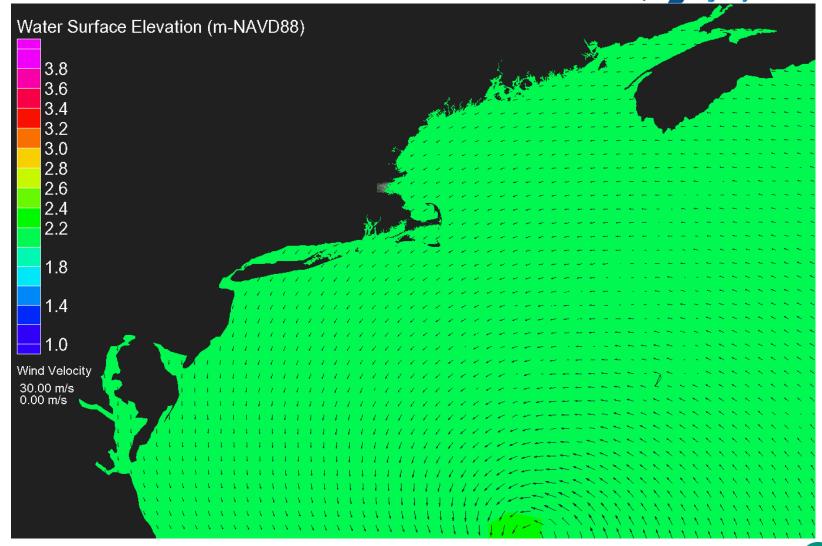


Model Results - Waves (Nor'easter)









Example Model Results – 2070 (Hurricane)







Model Results - Water Surface Elevation (Hurricane)

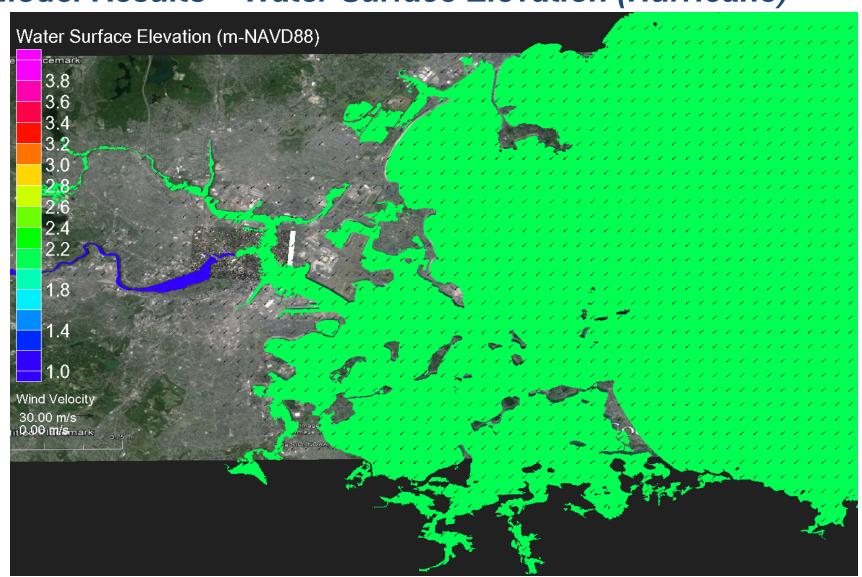




Table 5-3. Flood depths of the at-grade land around Boat Sections with Portals: "2013" indicates present vulnerability, "2013 to 2030" indicates vulnerability over the period from the just past the present to 2030, "2030 to 2070 or to 2100" indicates vulnerability over the period just past 2030 to 2070 under a higher SLR scenario, or over the period just past 2030 to 2100 under a lower SLR scenario.

Notes: * = majority of depth exceeds 0.5 ft around perimeter; when a range of depths is shown, it means that flood

depth varies along the perimeter of the Boat Section.								
Structure_ID	2013 0.1 Depth (ft)	2013 to 2030 0.1 Depth (ft)	2030 to 2070/2100 0.1 Depth (ft)	Ramp Area or Roadway Area and Notes				
BIN5UR -POR	0	0	*0 to 3.2	Ramp CS-SA Central Artery Southbound to Surface Artery				
BIN5VQ-POR	0	<mark>0</mark>	*0 to 1.4	Rose Kennedy Greenway Parcel 18: Ramp A-CN Atlantic Avenue to I-93 Northbound				
BIN5VA-POR	*0 to 1.0	*0 to 1.7	*0 to 4.4	Rose Kennedy Greenway Parcel 12: Ramp CN-SA Central Artery Northbound to Surface Artery				
BIN59Y-POR	0	0	*0 to 2.3	Ramp CN-S Central Artery Northbound to Storrow Drive				
BIN5AF-POR	0	0	*0 to 1.6	Storrow Drive Northbound entrance to Leverett Circle Tunnel				
BIN5K2-POR	0	0	*0 to 1.5	Storrow Drive Northbound exit from Leverett Circle Tunnel				
BIN59K-POR	0	0	*0 to 1.7	Ramp L-CS Leverett Circle to Central Artery Southbound				
BIN7BC-POR	0	0	*0 to 2.8	Ramp B Massport Haul Road to I-90 Westbound				
BIN7BB-POR	0	0	*2.2 to2.8	Ramp D Congress Street to I-93 from Ramp Area F				
BIN7BL-POR BIN7BM	0	0	*0 to 2.8	Ramp L I-93 North Bound to I-90 Eastbound – includes a short underpass from BIN7BM to BIN7BL				
BIN7DE-POR BIN7D5-POR BIN7DX-POR BIN7BN-POR	0	0	*0 to 3.4	I-90 / I-93 Interchange: Ramp D tunnel exit to I-93 Southbound, I-90 West Bound tunnel exit, I-90 East Bound tunnel entrance and Ramp C entrance to I-93 Northbound / Tip O'Neill Tunnel				
BIN7GA-POR BIN7FX-POR BIN7FL-POR	0	0	*0 to 1.9	Sumner Tunnel Exit: Ramp ST-CN to Central Artery Northbound, and Ramp ST-S to Storrow Drive Also, door to D6-SW25-FAC is located in the Boat Section outside (upstream) of BIN7GA-POR				
BIN7HV-POR	0	0	*0 to 3.3	I-93 Northbound entrance to Ted Williams Tunnel				
BIN7EK-POR BIN7E7-POR BIN7F6-POR BIN7FQ-POR BIN7FN-POR	O.	O.	*0 to 3.0	Rose Kennedy Greenway Parcel 6: Ramp SA-CS Surface Artery to Central Artery South, Ramp SA-CN Surface Artery to Central Artery North, Ramp SA-CT Surface Artery to Callahan Tunnel Ramp ST-SA Sumner Tunnel to Surface Artery Ramp ST-CN Sumner Tunnel to Central Artery North				
BIN6HB	0	0	*0 to 3.3	I-93 Southbound exits from Ted Williams Tunnel and I-90 Collector				

CA/T Flood Depths and Parcel 6, 12, 18 **Project**





Massachusetts Department of Transportation Highway Division

Table 6-2. Number of lanes and dimensions, and material and installation costs, for the Portals requiring gates in listed Table 5 -3: "2013" indicates installation recommended now, "<2030" indicates installation recommended during the period from the just past the present to 2030, "<2070 or <2100" indicates installation recommended over the period just past 2030 to 2070 under a higher SLR scenario, or over the period just past 2030 to 2100 under a lower SLR scenario.

portou just pust 200 0 to 2100 un	No. of	Est. Total	Year	Gate Material	Installation	
Portal Locations	Lanes	Width (feet)	Installed	(\$Million)	(\$Million)	Total Cost (\$Million)
BIN5VA	2	<mark>38</mark>	2013	<mark>1.7</mark>	<mark>1.1</mark>	2.8
BIN7J8/7J9/7JD/7JE/7JF/7RX (also need watertight door for D6-SW04-FAC)	4,2,1, 2,2,1	308	2013	14.9	9.7	24.6
BINA07	2	29	<u><</u> 2030	1.5	1.0	2.5
BINC00	2	28	<u><</u> 2030	1.5	1.0	2.5
BIN7UG/BIN7MD/BIN7GC	2,4,5	181	<u><</u> 2030	8.7	5.7	14.4
BIN5UR	2	35	<2070 or ≤2100	1.5	1.0	2.5
BIN5VQ	2	<mark>37</mark>	<2070 or <2100	<mark>1.7</mark>	<mark>1.1</mark>	2.8
BIN59Y	2	52	≤2070 or ≤2100	2.6	1.7	4.3
BIN7DE/7D5/7DX/7BN	1,2,2,1	198	≤2070 or ≤2100	9.8	6.4	16.2
BIN7HV	3	60	≤2070 or ≤2100	3	2.0	5.0
BIN9P8	4	61	<2070 or ≤2100	3	2.0	5.0
BINC01	2	38	<2070 or ≤2100	2	1.3	3.3
BIN7EK/7E7/7F6/7FQ/7FN	1,2,1, 2,1	<mark>196</mark>	<2070 or <2100	<mark>9.1</mark>	<mark>5.9</mark>	<u>15.0</u>
BIN7GA/7FX/7FL	2,1,2	124	<2070 or <2100	6.3	4.1	10.4

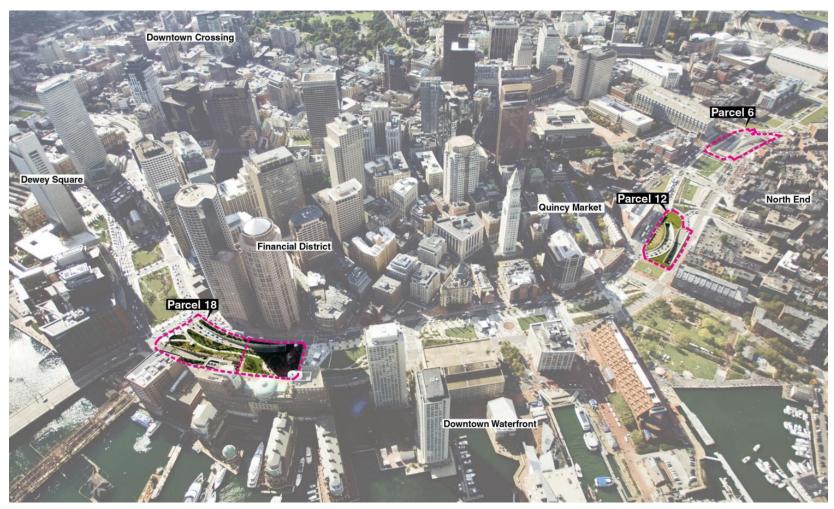
Bin5VA =Parcel 12

Bin5VQ = Parcel 18

Bin7EK/7E7/7F6/7FQ/7FN = Parcel 6











Possible Regional Adaptation Strategies



Figure 6-1. Flood entry point locations that are viable sites for regional adaptations under the 2013 scenario (Milton site not shown).



Figure 6-2. Flood entry point locations that are viable sites for regional adaptations under the 2030 scenario.





Possible Regional Adaptation Strategies

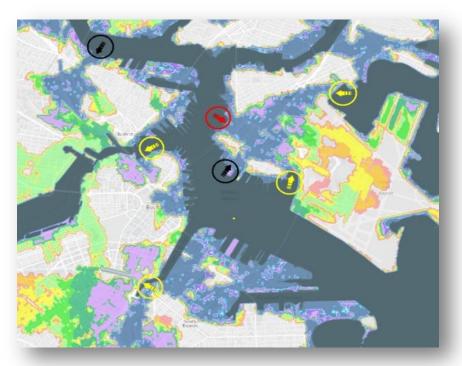


Figure 6-3. Flood entry point locations that are viable sites for regional adaptations under the 2070 scenario.





Municipalities using BH-FRM Data

Organizations using BH-FRM Data

Cambridge

Chelsea

Gloucester

Hull

Oak Bluffs

Quincy

Swampscott

Harvard University

MassPort

Massachusetts Bay Transportation Authority

Boston Water and Sewer Commission

Boston Redevelopment Authority

The Boston Harbor Association

Worcester Polytechnic Institute





MassDOT is Expanding the model to entire coast and islands:

This work will assess the vulnerability of MassDOT's transportation systems (roads, bridges, railways, airports) along the entire Massachusetts coastline. This 2 year project has 3 main phases:

- Phase 1: Pilot-scale analysis to develop methodologies and test modeling schemes.
- Phase 2: Extension and refinement of BH-FRM to the entire coastline. The new model will be called the Massachusetts Coastline Flood Risk Model (MC-FRM) and will be used for the regional analysis.
- Phase 3: Regional scale vulnerability analysis and conceptual adaptation strategies.





Thank you!

Find the full report and appendices here:

http://www.massdot.state.ma.us/highway/Departments/EnvironmentalServices/EMSSustainabilityUnit/Sustainability.aspx

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