# Preparing for the Rising Tide

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# Executive Summary

The Boston Harbor Association

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## Introduction

On October 29, 2012, one of the largest Atlantic basin storms in recorded history hit the East Coast. Although Superstorm Sandy centered around New Jersey and New York when it made landfall, the massive storm system spanned 1,000 miles north to south, over three times the size of a typical hurricane.

Luckily for Boston, Sandy's storm surge hit the city near low tide, causing relatively minor coastal flooding. Had the storm hit 5½ hours earlier, 6.6 percent of the city could have been flooded, with floodwaters reaching City Hall.

Events such as Superstorm Sandy highlight the growing relevance of climate change and draw attention to the importance of taking steps today to be prepared for the likely events of tomorrow. *Preparing for the Rising Tide* provides policy makers, planners and property owners with site-specific examples of how to assess vulnerability and increase resilience to coastal flooding over time.

The United Nations Intergovernmental Panel on Climate Change (IPCC) defines vulnerability as "the degree to which a system is susceptible to, and unable to cope with, adverse effects of climate change, including climate variability and extremes." Vulnerability assessments focus action on highly sensitive populations, locations and infrastructure.

Preparedness plans need to be robust enough to handle any future condition, and/or flexible enough change over time to meet needs as they arise. Ideally they include "no-regret" and co-benefit" solutions that extend beyond flood control goals. Cost-effective preparedness plans will result in both "here and now" and "prepare and monitor" actions based on threshold triggers such as sea level rise.

Previous reports have described a range of large-scale adaptation strategies. This report takes those recommendations and applies them to specific properties in Boston. Some cities such as Seattle, WA and Charleston, SC are developing "floodable zones" that preserve the city's access to its waterfront while minimizing damage when periodic flooding occurs. This concept of "living with water" is an option to consider in Boston as well.

## Climate Change in New England

Across New England, average annual temperatures have increased by 2 $^0$F since the late 1800s, with even higher increases in average winter temperatures. Most of this warming has occurred within the last few decades. For coastal communities, one of the most alarming impacts of accelerated warming has been an increase in sea levels and coastal flooding due to melting land-based ice and thermal expansion of the ocean.

As a global average, we can expect approximately one to two feet of sea level rise by 2050 and three to six feet by 2100. Sea level in the Northeastern US is expected to be even higher. Higher sea levels will allow waves and storm surges to reach further inland than in the past. There is also growing evidence that climate change is increasing the intensity of hurricanes and other extreme precipitation events.

As a result, coastal residents and business owners are increasingly vulnerable to both intermittent (storm-related) and chronic (tidal) flooding. Planners worry about the potential for storm events to cause massive disruption to transportation and other infrastructure with consequent disruption of business activity and personal lives. Vulnerable populations may be disproportionately harmed by coastal flooding due to their reduced capacities to prepare for or recover from its damage.

## Climate Change Preparedness in Boston

Although Boston has been considering climate change impacts since the early 1990s, these efforts accelerated in 2009 when Mayor Thomas Menino convened the Climate Action Leadership Committee. Their recommendations (adopted by the Mayor in 2011) can be summarized as:

- Climate adaptation is as important as climate mitigation.
- Information on the effects of climate change is sufficient to start planning now, but flexibility and openness to new information are essential.
- Climate adaptation must be thoroughly integrated into all planning and project review conducted by the City.
- Climate adaptation is a responsibility of all members of the community and that special attention must be given to its most vulnerable members.

These broad policy statements set in motion multiple planning processes and other concrete actions across City agencies, including the Boston Water and Sewer Commission, Boston Redevelopment Authority, Office of Emergency Management, Boston Conservation Commission, Parks and Recreation Department, Boston Transportation Department, Boston Public Health Commission and other municipal offices with policy or programmatic responsibilities not directly related to climate change. The City is also partnering with other state agencies and private and non-profit sector leaders in forums such as the Green Ribbon Commission, convened to implement the mayor's Climate Action Plan.

Although Boston is recognized as one of the country's more climate-aware cities, more work is needed to prepare this historic city for current and future risks of coastal flooding. Existing and proposed policies must be integrated with each other and expand to include existing buildings and infrastructure. Increasing Boston's resilience to coastal flooding will take a strong public-private partnership that optimizes the resources and expertise of all sectors.

***How to read the sample plans:***

*These plans recommend actions to take over time to deal with flooding from 1) twice-daily high tides, 2) average annual storms and 3) a "100-year" flood event.*

*For example, Table 7 notes that the entrance to the Aquarium MBTA station floods at 7.5 ft NAVD. At today's sea level, the station would be high and dry at high tide, barely flooded by the annual storm surge and 2.5 feet under water during a "100-year" flood.*

*In 2050, the station entrance is likely to still be dry at high tide, but flooded during annual and 100-year storm surges. By 2100, the station entrance could be flooded at high tide.*

*Thus, while the MBTA today does not have to do anything in the near term to prepare for tidal flooding, it does need plan today to manage both today's severe storms and increased flooding over time.*

## Assessing Boston's Vulnerability to Coastal Flooding

We examined Boston's vulnerability to coastal flooding at two sea levels: five feet above current average high tide (MHHW+5) and 7.5 feet above current average high tide (MHHW+7.5), corresponding to, respectively, the current 100-year storm surge, and the estimated 100-year storm surge, possibly as soon as just after 2050 (see Figures 8 and 9).

We identified and mapped the total footprint and largest ten properties in Boston that would experience flooding at these two flood levels, and analyzed these results by land use, neighborhood, historical district and presence of known hazardous waste sites.

Our analysis found that 6.6 percent of Boston could be flooded at MHHW+5. All of Boston's coastal neighborhoods and the Harbor Islands would flood at this sea level, along with over 65% of the Fort Point historic district and the proposed Blackstone Block district.

At MHHW+7.5, just over 30 percent of Boston could be flooded. This represents 35 to 40 percent of all exempt, industrial, commercial and mixed use lands in Boston. More than 50 percent of 12 Boston neighborhoods would be flooded; East Boston would have the largest flooded area (>140 million sq. ft.).

## Case Studies

We developed vulnerability analyses and sample preparedness plans for two sites in Boston: Long and Central Wharves in downtown Boston and the University of Massachusetts Boston (UMass Boston) on Columbia Point in Dorchester. We are in the process of completing a vulnerability assessment in East Boston.

We found that the buildings considered on Long and Central Wharves already have individual plans in place to manage current flooding threats, but will have to eventually take action on a wharf-wide basis to protect against future flood levels. Table 7 provides a sample preparedness plan for the Marriott Long Wharf Hotel.

The entrances to UMass Boston are not yet adequately protected from current 100-year floods. Effective short term adaptation plans can be developed for these areas; adaptation activities for 2100 will require significant new planning and investment. Table 12 shows a sample preparedness plan for a portion of the UMass Boston campus.

We found that in all cases, property owners should start or continue taking feasible actions now and be prepared to undertake additional actions in the future in order for these properties to continue to serve their present purposes.

Low-income, Spanish-speaking Latino renters in East Boston preferred preparedness actions that enhance their present environment and that do not require temporary or permanent evacuation. They wanted more information on climate change, how it will impact them, and what resources are available to assist them. Once these community members engaged in the issue they wanted to become a part of the decision making process.

## Recommendations

Preparing for the climate of the future will require coordinated efforts among all sectors of the Boston community, because no one entity has the resources, knowledge, and authority to complete the task. The City of Boston's existing Climate Action Plan establishes a framework for climate change preparedness. Now, using this framework, the Boston community needs to accelerate the development of concrete actions such as creating a robust public-private partnership to prepare Boston's waterfront and neighborhoods for the expected rise in sea level.

### Private Sector Actions

1. All property owners in Boston on or near the coastal floodplain should take cost-effective action to reduce their vulnerability to higher and more frequent flooding. In particular, they should:

- Ensure that existing and proposed properties and the people who use them are adequately prepared for the current 100-year flood.
- Determine how levels of future flooding will affect their properties, by, for example, comparing existing site plans to maps of projected flooding depths.
- Identify critical elevations, such as door or vent openings, that indicate levels at which flooding could cause significant damage.
- Evaluate ways to make properties more flood-resistant or resilient.
- Based on potential damages, cost of action, and financial needs, take or plan actions that correspond to change in the actual sea level over time.

2. Because adjacent properties are likely to face similar risks from sea-level rise, property owners should look for opportunities to collaborate with their neighbors

on preparedness projects. This may help to reduce costs or reduce vulnerabilities that could not be addressed individually.

3. Property owners should identify the obstacles to and limits of private action such as restricted resources, lack of technical knowledge, market disincentives, or overwhelming scale. They should also evaluate how the flooding of major infrastructure (transportation, energy) could affect their properties, and communicate both sets of information to public officials.

4. Property owners should participate in city, regional, state, and other planning processes addressing climate preparedness to ensure that their concerns are included.

## Public Sector Actions

1. As outlined above, the City of Boston should also take cost-effective actions to reduce the vulnerability to higher and more frequent flooding of municipally owned facilities on or near the coastal floodplain.

2. The City should establish a range of planning levels for different future time periods for all public and private property owners to use when evaluating the risks of sea-level rise for existing and proposed buildings and other projects. Once the ranges are initially set, they should be periodically re-evaluated to incorporate new scientific understanding.

3. Because sea-level rise will increase the vulnerability of most neighborhoods of Boston, the City should strengthen its efforts to involve all segments of the Boston community in the climate planning process.

4. The City should host a robust discussion of the concept of "living with water" and its potential applicability to Boston.

5. The City, other levels of government, and the private sector should work together to identify and remove obstacles and disincentives to preparedness action by private property owners. They should further work together to identify and implement reasonable steps to encourage, incentivize, and, if necessary, mandate such action. Measures could involve, for example, building, public health, and zoning codes and insurance requirements.

6. Because the City lacks jurisdiction over important elements of Boston's infrastructure (e.g., public transit, the electrical grid, and highway tunnels), the City should work closely with state, regional, and federal agencies to protect these critical components.

7. Notwithstanding this report's focus on sea-level rise and coastal flooding, the City of Boston should ensure that other important effects of climate change, particularly increasing frequency and intensity of heat waves and storms, are included in climate preparedness plans.

## Research Needs

Although there is much knowledge and many tools available to use in evaluating and preparing for the risks of climate change and sea-level rise, more is needed. Boston's academic community, as well as government agencies and private companies, are playing important roles in filling this need. We have identified the following areas as needing attention:

1. Flood preparedness strategies. Property owners and government agencies need a readily available—and expanding—toolkit of cost-effective ways to identify and reduce the vulnerability of buildings, neighborhoods, and infrastructure to sea-level rise and other consequences of climate change.
2. Complexity. Boston needs climate vulnerability assessments that examine the dense interconnectedness of the urban environment, and include consideration of the full economic, environmental, cultural, and public health impacts, and their interaction. Such assessments should compare the costs of doing nothing versus preparing for future flood events.
3. Flood models. Boston needs better, dynamic flood projections that combine the effects of relative sea-level rise with the effects of storm surges, waves, river discharges, precipitation, and the details of local topography.

## Conclusion

We hope that readers of this report will take away the following lessons learned. First, that climate change-related coastal flooding is already a reality we need to manage for, and that such flooding is predicted to increase over time, possibly reaching 6 feet by 2100 and continuing past that for centuries.

Second, that preparing for increased coastal flooding involves implementing phased plans over time. Assessing a property's vulnerability to flooding is relatively straightforward and inexpensive, and preparedness actions may be integrated into maintenance plans to lower overall costs.

Finally, neither the public sector nor the private sector alone has the resources and influence necessary to prepare Boston for increased coastal flooding over time. We need a robust public-private partnership with clear benchmarks and engagement from all sectors to prepare this extraordinary historic city for the rising tide.

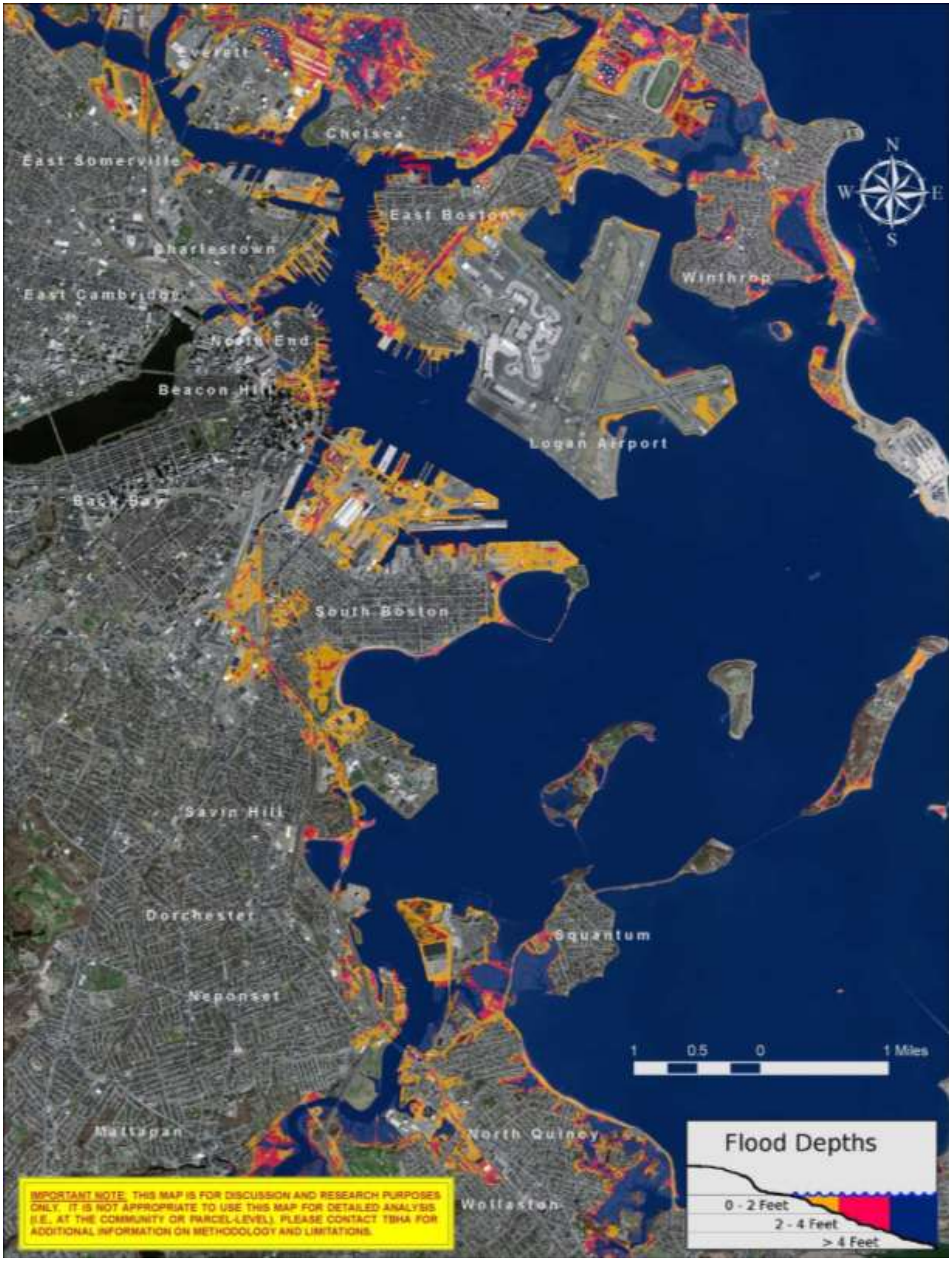


**Figure 1. Expected flooding in Boston at a sea level of MHHW+5/9.8 ft NAVD (TBHA, 2010).**

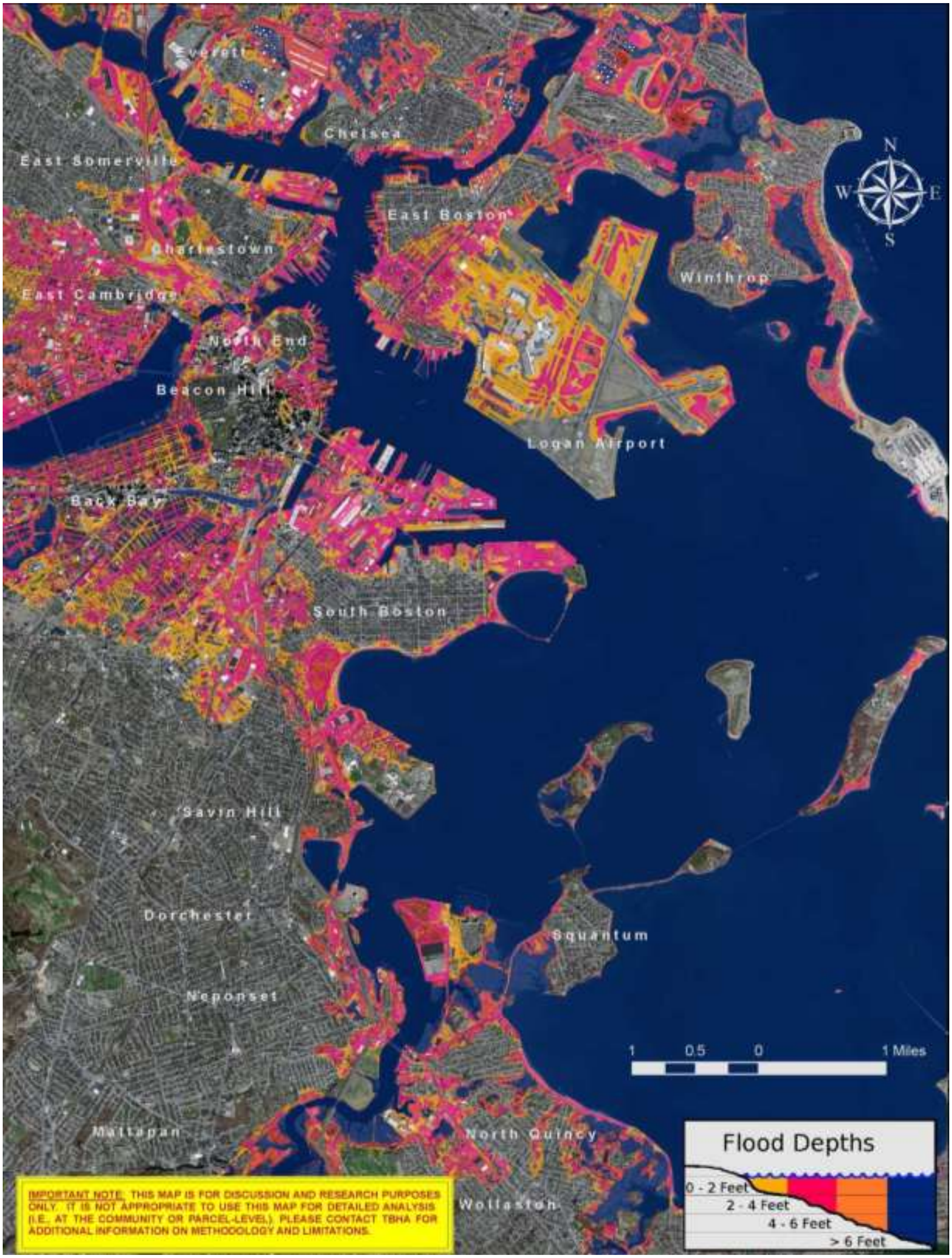


**Figure 2. Expected flooding in Boston at a sea level of MHHW+7.5/12.3 ft NAVD (TBHA, 2010).**

## Table 7. Sample adaptation plan for Long Wharf Marriott/Aquarium MBTA

| Long and Central Wharves - Coastal Climate Change Adaptation Planning | Marriott Hotel and MBTA Aquarium Station |
|---|---|
| **General Description** | The Boston Marriott parcel, residing at the landward end of Long Wharf, becomes flooded when the stillwater elevations exceed approximately 9.5 ft NAVD. Stillwater elevations less than 9.5 ft NAVD do create access issues, as areas around the Marriott parcel become flooded. The MBTA station entrance, west of the Marriot, floods at 7.5 Ft NAVD. |


| Mean Higher High Water (MHHW) Timeline | Annual (1-year) Storm Surge Timeline | 100-year Storm Surge Timeline | Approximate Maximum Water Surface Elevation (ft, NAVD88) | Upland Flooding Potential | Recommended Engineering Adaptations | Estimated Adaptation Cost* |
|---|---|---|---|---|---|---|
| | | | 4.0 | No Flooding Expected | No Action Required | N/A |
| 2010 | | | | | | |
| | | | 5.0 | | | |
| 2050 | | | 6.0 | | | |
| | 2010 | | 7.0 | | | |
| 2100 | 2050 | | 8.0 | Flooding of surrounding area and 7.5 ft NAVD entrances to below-ground garage and MBTA station. | Develop alternate access route plans. Minor flood proofing. | Minimal |
| | | | 9.0 | | | |
| | 2100 | 2010 | 10.0 | Flooding of Marriott infrastructure and entire Long Wharf region. | See Regional Adaptations | See Regional Adaptations |
| | | 2050 | 11.0 | | | |
| | | | 12.0 | Widespread flooding of entire area during storm events. Water arriving into Long Wharf area from other regional sources in addition to local flooding. | In addition to adaptations above, additional flood proofing and elevation of critical infrastructure.<br><br>Evacuate during storm event and return. | *Capital Cost: $20 per square foot of building for wet flood proofing |
| | | 2100 | 13.0 | | | |
| | | | 14.0 | | | |
| | | | 15.0 | | | |
| | | | 16.0 | | | |

* = Initial Capital Costs and Operational and Maintenance costs provided are estimates based on costs from similar types of projects. More detailed and accurate costs would be required for actual engineering and construction. Estimated costs are based on 2010 dollar value.

## Table 12. Sample preparedness strategies for Morrissey Blvd and Bayside Expo.

| UMASS BOSTON - Coastal Climate Change Adaptation Planning | | | | Vulnerable Flood Risk Areas: Morrissey Blvd. Entrance | | | Vulnerable Flood Risk Areas: Bayside Expo Center | | |
|---|---|---|---|---|---|---|---|---|---|
| General Description | | | | The Morrissey Blvd. Entrance is currently the primary entrance to the UMASS-Boston campus. A significant portion of this street, especially south of the campus entrance, is low-lying and is prone to flooding even under present day conditions (storm surge or heavy rainfall events). Once the water surface elevation overtops higher elevations along the coastline, most of Morrissey Blvd. will become flooded. At the campus entrance specifically, as shown in the aerial view, storm surge flooding initially may occur from the Patten's Cove side and subsequently the Savin Hill Cove side when water surface elevations reach between approximately 9.5-10.0 feet NAVD88. | | | Bayside Expo center region, recently purchased by UMASS-Boston, is slated to undergo redevelopment. Currently, the area is prone to potential flooding, especially the low-lying parking lot regions (one of the lowest elevations in the region). There is potential for poor drainage and flooding of this area (approximately 30 acres) even during contemporary rainfall storm events. As sea level increases, there are also lower areas along the Dorchester Bay shoreline that will become susceptible to the higher water surface elevations during storm events, resulting in significant overtopping and widespread flooding of the area. Specifically, areas along the Harbor walk area shown in aerial view. | | |
| | | | |  | | |  | | |
| **Mean Higher High Water (MHHW) Timeline** | **Annual (1-year) Storm Surge Timeline** | **100-year Storm Surge Timeline** | **Approximate Maximum Water Surface Elevation (ft, NAVD88)** | **Upland Flooding Potential** | **Engineering Adaptations** | **Estimated Adaptation Cost*** | **Upland Flooding Potential** | **Engineering Adaptations** | **Estimated Adaptation Cost*** |
| | | | 4.0 | No Flooding Expected | No Action Required | N/A | Poor Drainage of Bayside Expo Parking areas during heavy rainfall events.<br><br>No Flooding of areas from Dorchester Bay waters. | Minor flood proofing of structures<br><br>Installation of a pump house and pumped based-drainage system for parking area+ | Capital Cost: $ 2.0 Million<br><br>Annual Maintenance Costs: $ 10,000 |
| 2010 | | | 5.0 | | | | | | |
| 2050 | | | 6.0 | | | | | | |
| | 2010 | | 7.0 | Flooding of Morrissey Blvd. approx 1/4 mile south of campus entrance.<br>No flooding of campus entrance or facilities | | | | | |
| | 2050 | | 8.0 | | | | | | |
| 2100 | | | 9.0 | | | | | | |
| | | 2010 | 10.0 | Flooding of campus entrance. Initially from Patten's Cove (tidal pond to the west of entrance), and subsequently from Savin Hill Cove. | Tidal control structure at entrance to Patten's Cove. Soft solution (beach nourishment and vegetation enhancement) along Savin Hill Cove. | Capital Cost: $500-750,000<br>Annual Maintenance Costs: $10,000 | Flooding of Bayside Expo areas from Dorchester Bay. Water overtops harbor walk in places. | Modular seawall installation at critical locations along Harbor walk.<br>Seawall extension along Harbor walk as needed. | Capital Cost#: $1.0-1.5 million (1,000 foot length)<br>Annual Maintenance Costs: $15,000 |
| | | 2050 | 11.0 | | | | | | |
| | 2100 | | 12.0 | | | | | | |
| | | | 13.0 | Widespread flooding of UMASS Boston Campus, Morrisey Blvd. and surrounding areas | In addition to adaptations above, additional flood proofing and elevation of critical infrastructure.<br>Evacuate during storm event and return. | Capital Cost: $20 per square foot of building for wet flood proofing. | Widespread flooding of UMASS Boston Campus, Morrisey Blvd. and surrounding areas | In addition to adaptations above, additional flood proofing and elevation of critical infrastructure.<br>Evacuate during storm event and return. | Capital Cost: $20 per square foot of building for wet flood proofing. |
| | | 2100 | 14.0 | | | | | | |
| | | | 15.0 | | | | | | |
| | | | 16.0 | | | | | | |

* = Initial Capital Costs and Operational and Maintenance costs provided are estimates based on costs from similar types of projects. More detailed and accurate costs would be required for actual engineering and construction. Estimated costs are based on 2010 dollar value.

\# - Depends on length of seawall installed.

\+ = Based on a 30 acre area with a peak intensity rainfall of 5 in/hr (average of 0.3 inches/hr over a 24 hour period)

## For more information:


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