Sea Level Rise Adaptation in the Boston Harbor Area

Interactive Qualifying Project

JPH – B112

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Abstract

Over the next 100 years, sea levels are predicted to rise a minimum of approximately 1 foot. With this rise in sea level comes greater storm surge. The Commonwealth of Massachusetts does not currently mandate specific waterproofing techniques to building developers. As a result, developers of new structures on the waterfront have little available to them as far as guidelines to mitigate flood damage and storm surges. The goal of our project was to investigate various sea level rise adaptation techniques that could be used in new construction and major renovations for commercial buildings in Boston. To complete our goal, we used interviews and literary research to gain a wealth of knowledge about different sea level rise adaptation techniques. We provided The Boston Harbor Association (TBHA) with an options paper and a business memo intended for Mayor Thomas Menino recommending different sea level rise adaptation techniques to be used in new construction in Boston's Innovation District.

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Executive Summary

The increase in greenhouse gases and global temperatures over recent years has helped to cause climate change. One of the many dramatic effects this has had on the Earth is a change in sea levels. The change in the Earth's climate is causing water levels to rise approximately 3 mm/year on the eastern coast of the United States (Church, & White 2011). This sea level rise is threatening coastal buildings and other structures that lie close to the ocean. The two major concerns for shore protection are coastal flooding and wave damage (Morang, 2006, chapter V-3, para. 1). Because typical flooding is worsened by heightened sea levels, there is a direct correlation between the severity of floods and the natural rise in sea levels. Although sea level rise will not overtake buildings on its own for hundreds of years, typical flooding is worsened by the slight change in average sea level and increased storm surges, and so buildings will be impacted by this change in the very near future.

The goal of our project was to investigate various sea level rise adaptation techniques that could be used in new construction and major renovations for commercial buildings in Boston. With the completion of our goal, we provided The Boston Harbor Association (TBHA) with an options paper and a business memo intended for Mayor Thomas Menino recommending different sea level rise adaptation techniques (ATs) to be used in new construction in Boston's Innovation District. These recommendations aim to protect both new structures and structures that undergo major renovations from the rising sea levels. We suggested a number of different sea level rise adaptation techniques that varied in cost, type of implementation, and scale. In addition to these

adaptation techniques, we also investigated the legalities involved with implementing these adaptations such as ways to modify building and zoning codes.

To complete our project, we used a number of methods to achieve our objectives and as stepping stones to complete our overall project goal. Our first objective included defining a structured list of ATs that could be considered for use in project sites in the Innovation District. This list considers the relative cost, appropriate use, and ease of implementation for each AT. In order to meet this objective, we interviewed experts who work on the design and construction of buildings such as engineers, and architects. These interviews also helped us with our next objectives: to provide TBHA with a detailed set of alternative ways to make buildings in the Innovation District more flood-resistant in the form of an options paper; and to develop a concise information package including recent disaster costs for the Commonwealth of Massachusetts and a list of globally and successfully used ATs. Speaking with these experts allowed us to gain direct information about general opinions of current ATs as well as proposed ATs, and how these methods might be improved and utilized in a way that is acceptable to the Boston community.

In order to boost public acceptance of the strategies that we proposed, we also identified reasonable incentives for people to adhere to regarding amendments and implementations of the building codes. We also identified general guidelines to follow regarding the legalities of implementing a new standard of ATs. To achieve this objective, we met with officials from the City of Boston. More specifically, the Commissioner of the Environment for Boston, Chief of Staff at City of Boston Office of Environmental and Energy Services, Executive Director of the Air Pollution Control Commission in Boston, and the Director of Energy Policy in Boston. We met informally with these officials to talk about possible incentives for property owners that would be governmentally funded as well as to discuss possibilities for new legislation regarding these issues. From this meeting we gained a better understanding of how incentive programs are set up, and how new legislation is enacted.

We compiled this information into an options paper and a business memo that TBHA could present to Mayor Thomas Menino recommending different sea level rise adaptation techniques to be used in new construction in Boston's Innovation District.

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1 Introduction

An increase in greenhouse gases in the Earth's atmosphere has spawned a phenomenon called global warming. This side effect of an increased burning of fossil fuels over the past few centuries has caused dramatic negative effects on the climate, especially by causing the sea level to rise. Many coastal countries around the world are struggling to protect their land from being lost to rising sea levels. As sea levels change, numerous coastal zones and the infrastructure located in them are being affected, while some others face future damage. With the anticipated rise in sea levels, plans must be made to adapt to higher tides and storm surges in order to protect locations that may be in danger of coastal flooding. Many island and coastal communities such as Venice, Italy have already been forced to undertake precautionary measures to protect themselves against rising waters, as they are continually losing land to the sea. Buildings and other structures on coastlines around the world were not built under the assumption that shorelines would change, and property owners and governments are now facing the need to retrofit existing structures in order to save coastal communities from potential devastation.

With the climate changing due to global warming, numerous sites throughout the world, like Boston Harbor, are being challenged to discover ways to adapt and protect themselves from the dangers of a changing coastline and weather conditions. Officials charged with protecting the Boston Harbor area must consider the risk of losing buildings and undeveloped land to long-term flooding due to sea level rise caused by global climate change. If this is not done, the lives and properties of Boston area residents and businesses will be endangered by higher tides and storm surges, which can cause permanent damage to most buildings, or even injury or death. Damage incurred to waterfront buildings may also result in an economic impact on the city, as many small and large businesses might be either ravaged or completely lost.

Although Massachusetts state building codes account for the potential flooding of buildings as a result of heavy rainfall, they were not designed with the idea of global climate change and permanent sea level rise in mind. Adaptations of buildings to worsened flooding events must be made in the near future because, according to recent studies, sea levels on the east coast of the United States are estimated (by satellite imaging) to be increasing somewhere in the range of 2.8 ± 0.8 to 3.2 ± 0.2 mm/year (Church & White, 2011). This means that, sometime during this century, or possibly even the next few decades, the city of Boston will face damaging water levels to many of its waterfront properties. The scale of a few millimeters every year, though it does not sound like a major change, can be devastating to certain areas that are practically at sea level. George's Island, for example, is a small island in Boston Harbor that holds the historical Fort Warren and reaches only a maximum of about 15 meters above sea level in elevation (Kirshen, Knee, & Ruth, 2008). It is cases like this that call for immediate action to be taken to adapt the Boston Harbor area to changes in sea levels.

While there is ample scholarly literature about sea level rise due to climate change and what its implications are, there is not much currently available that is specifically focused on the Boston Harbor waterfront area. It is of the utmost importance that planners fully understand the issues that the Boston Harbor area now faces so that they can make plans to protect waterfront properties along the harbor. Due to the fact that much of the City of Boston is built upon filled land, many of the structures in the City are only slightly above current sea levels. Additionally, the harbor waterfront is the first line of defense against disasters such as flooding or major storm surges. This means that as long as the waterfront is protected from the rising sea levels, much of the rest of the city of Boston may be protected as a result. In order to properly protect the City of Boston, research must be done using existing flood protection maps and other sources to identify vulnerable areas around Boston Harbor and to formulate revisions to Massachusetts State building codes and building permitting practices to include both new construction and retrofitting methods that should be used to better protect buildings from water damage.

The goal of our project was to investigate various sea level rise adaptation techniques that could be used in new construction and major renovations for commercial buildings in Boston. We also examined past methodologies for sea level rise adaptations used in areas where the consequences of climate change have already begun to affect the community. By analyzing Boston Harbor's most flood-susceptible areas, we were able to make recommendations for ways that buildings that lie in potentially dangerous areas could be accommodated to a reshaping of the coastline. In doing so, the city of Boston will be saved from the preventable catastrophe of damage or loss to buildings and other structures from the rising sea levels and increased storm intensity.

2 Background

Due to an increase in the average temperature of the Earth's atmosphere, the northern and southern ice caps have been melting, causing sea levels to rise in different places around the world. This effect – combined with the historical flooding of New England areas due to storms – causes expected flooding to expand to new heights and areas that have been typically safe, and are thus unprepared for such events. Through its mission to keep Boston Harbor a clean and enjoyable hub of the city, The Boston Harbor Association has recognized the need for an adaptation of the construction of buildings to account for the threat posed by changing sea levels. In this chapter, we will discuss how the climate is changing, how this change is anticipated to impact Boston Harbor area structures, as well as how other cities around the world are adapting to their specific anticipated rise in sea levels. Because research has not yet provided a close look at the role of building and zoning codes in preventing water damage to buildings, we reviewed the current standard code as written by the International Code Council that is now in place in order to suggest adaptations for sea level rise. We also used flood projection maps of The Boston Harbor area to delineate vulnerable structures and areas, and we reviewed the role of The Boston Harbor Association as a driving force for change in the way sea level rise adaptations and safety are currently being addressed.

2.1 – Climate Change

Many societies around the world, from Venice to the low-lying islands of the Maldives, live with the knowledge that sea level rise (SLR) caused by global climate change may soon strip people of the land they live on. In this section, we explain how global climate change has caused a rise in sea levels by looking at historical data on rising sea levels and global climate.

By taking temperature measurements from locations around the globe, researchers have been able to record and track the average change in the Earth's temperature. Over the past century, the "global averaged surface temperature rose by approximately 0.7° C (1.3°F)" (Dahlman, 2009b, para. 4). Government funded organizations such as the National Oceanic and Atmospheric Administration (NOAA) have done research and collected data on the average rate at which the current trend in global temperature change is increasing, which was determined to be about 0.25° Fahrenheit per year[2]. Figure 1, shows the rise on average of the global temperature from 1890 to 2010.

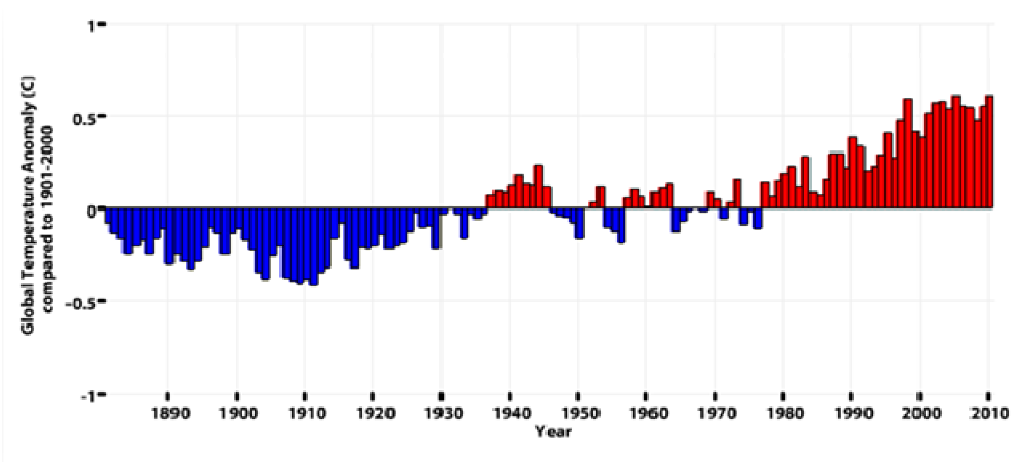


Figure 1: Global Mean Temperature Changes from 1890 – 2010
Note. This image from "Climate Change: Global Temperature" by L. Dahlamn (2009).

Because the oceans take up about 70% of the Earth's surface, most heat energy from the sun is absorbed by the oceans. Heat is absorbed and also transferred between the ocean, atmosphere, and land. Over time, the stored heat energy escapes the ocean by means of "melting ice shelves, evaporating water, or directly reheating the atmosphere" (National Oceanographic Data Center, 2011, para. 3). As time passes, the ocean continues to absorb and release heat energy. Figure 2 shows the change in the ocean's heat content on average from 1955 to 2010. Indicated in red on the graph, it is evident that the yearly average of the ocean's heat content has significantly increased over the past 50 years.

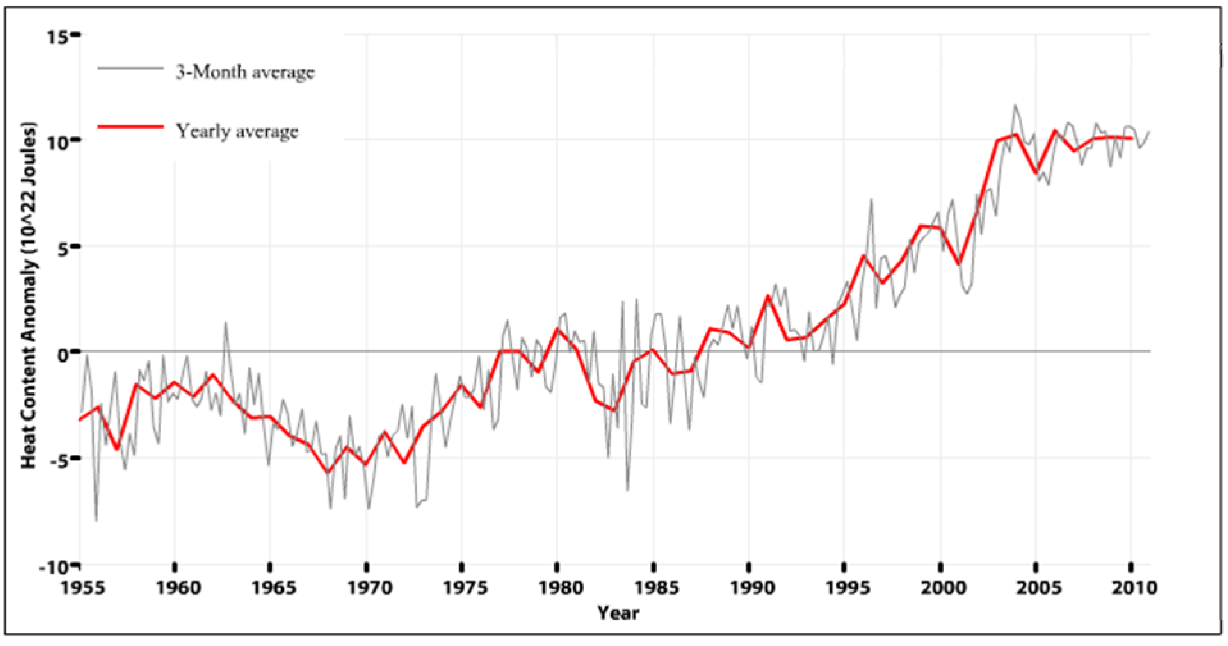


Figure 2: Ocean Heat Content Anomaly from 1955 – 2010
Note. This image from "Climate Change: Ocean Heat Content" by the National Oceanographic Data Center (2009).

The resulting effect of heat being released from the ocean, and the average global temperature increasing, is the rise in the ocean's water level. As the ocean and atmosphere are heated, two phenomena cause sea levels to rise: thermal expansion of ocean waters, and melting of the ice caps (National Oceanographic Data Center, 2011). Neil White (2011) explains that because measurements of sea level at different specific global locations yield incomplete data, satellites have been used to measure the various heights in sea level to determine the overall global rise in water levels. Organizations such as the Commonwealth Scientific and Industrial Research Organisation in Australia (CSIRO) have studied the rising global sea level over the past century. Figure 3 below shows the data CSIRO has collected showing the gradual rise in sea level. Indicated by the dark blue line, the graph shows the increase in sea levels over the past 130 years to be about 205 mm (or about 8 inches), and from the average slope of the graph it is evident that the sea level will continue to rise (para. 1).

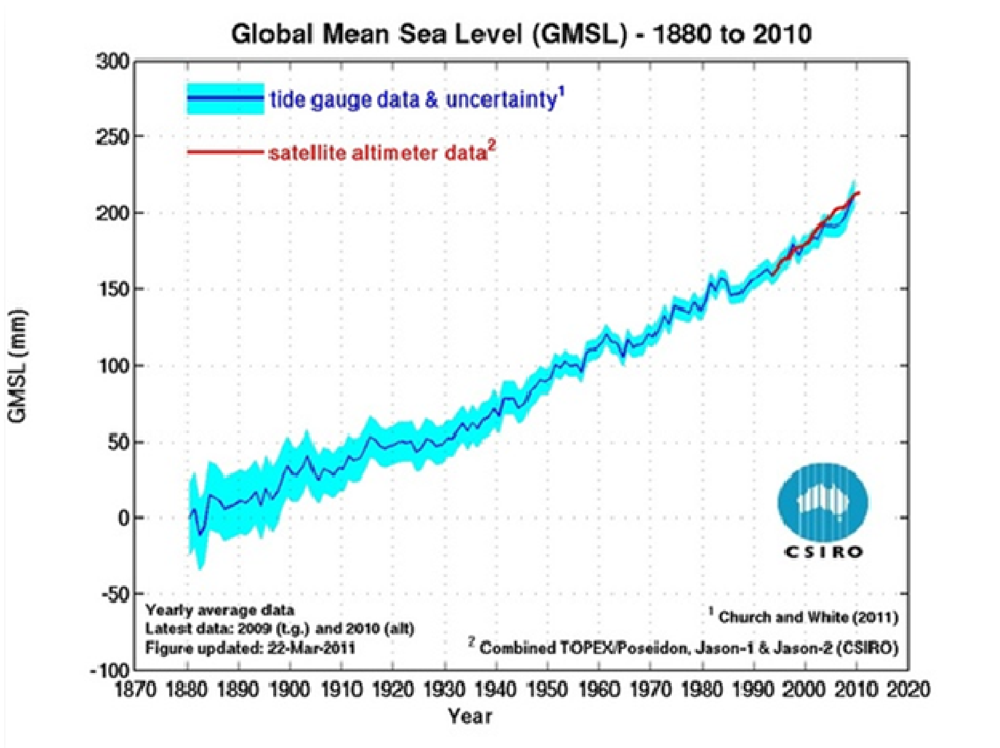


Figure 3: Global Mean Sea Level Rise from 1880 - 2010
Note. This image from "Historical Sea Level Changes" by Neil White (2011).

Based on the data regarding a rise in global temperature and ocean heat levels, these trends suggest that as the average global temperature increases, ocean heat levels – and therefore sea levels – will continue to rise. Scientists believe that if this issue is not addressed promptly, "global sea level would rise 18 to 59 cm (7 to 23 inches) by 2100" (Dahlman, 2009a, para. 5). With the increase in the average global temperature, sea levels have increased and will continue to increase, affecting many coastal and island nations.

2.2 - Effects of Climate Change on Coastal Urban Areas

Many coastal cities utilize their proximity to the sea as an attraction for residents, businesses, and tourists. Coastal cities are also a hub for shipping and transportation that are key to the economic welfare of the region. As a result, areas close to the ocean become highly populated, and waterfront structures are built to accommodate the public. As explained in the previous section, there is a notable change in the Earth's climate that is causing water levels to rise approximately 3 mm/year (Church & White, 2011), which is threatening the existence of these buildings and other structures that lie close to the ocean.

2.2.1 - Urban Buildings

Because of people's natural fascination with the sea, many residential and commercial structures are often built with the added attraction of being "waterfront properties." These buildings face the highest possibility of being damaged by rising sea levels. Recent studies were conducted in the greater New York City area, to estimate the rate of sea level rise for five major areas: The Battery, New York City; Coney Island, Brooklyn; Rockaway Beach, Queens; Long

Beach, Long Island; and Westhampton Beach, Long Island. Gornitz, Couch, and Hartig (2001) explain that for these areas, it has been found that the mean relative sea level rise is 2.7 ± 0.7 mm/year before removal of geological trends (such as long-term glacial isostatic trends) and 1.3 ± 0.7 mm/year after removal. This method of subtracting long-term trends allows for the study of trends that are *only* related to climate change (para. 10). Using only current trends, sea levels for New York City relative to present-day levels were estimated for three different decades as presented in Figure 4.

Decade	Rise in Sea Levels, Relative 2011 Levels (in cm)	Rise (in ft)
2020s	13.7	0.45
2050s	21.8	0.72
2080s	30.0	0.98

Figure 4: Estimated Rise in Sea Levels for New York City by Decade
Note. These data are adapted from "Impacts of Sea Level Rise in the New York City Metropolitan Area" by V. Gornitz, S. Couch, & E.K. Hartig. (2001).

Should the current trend continue according to this projection, there is a great likelihood that the city of New York will experience a considerable loss of land to the ocean during this century. Also, because of SLR, storm surges will become more intrusive and damaging to the city.

Without SLR, damage caused by storm surges has already peaked above what New York City can afford. An article that appeared in the *New York Times* in late August of 2011 used scientific projections of hurricane damage to estimate the costs of various strength hurricanes hitting the New York City area. Figure 5 below shows the costs that would be incurred on Manhattan if a hurricane of any strength was a direct hit, passed over 50 miles from Manhattan, or 100 miles from Manhattan. Note that the category 4 and 5 projections are very rough estimations as there are no known landfalls of hurricanes of that strength in the northeastern U.S. Essentially, no matter where a storm hits with respect to New York City, the cost of the damage will slow economic growth to a standstill, and possibly cause negative economic growth.

Storm Type	Wind Speed (MPH)	Direct Hit to Manhattan	50 Miles from NYC	100 Miles from NYC
Tropical Storm	40	$133,000,000	$35,000,000	$8,000,000
	45	$213,000,000	$55,000,000	$12,000,000
	50	$339,000,000	$88,000,000	$20,000,000
	55	$542,000,000	$141,000,000	$32,000,000
	60	$866,000,000	$226,000,000	$51,000,000
	65	$1,384,000,000	$361,000,000	$81,000,000
	70	$2,210,000,000	$576,000,000	$129,000,000
Category 1 Hurricane	75	$3,530,000,000	$920,000,000	$206,000,000
	80	$5,639,000,000	$1,469,000,000	$330,000,000
	85	$9,007,000,000	$2,347,000,000	$527,000,000
	90	$14,388,000,000	$3,749,000,000	$841,000,000
	95	$22,983,000,000	$5,989,000,000	$1,344,000,000
Category 2 Hurricane	100	$36,712,000,000	$9,556,000,000	$2,147,000,000
	105	$58,643,000,000	$15,281,000,000	$3,429,000,000
	110	$93,674,000,000	$24,409,000,000	$5,478,000,000
Category 3 Hurricane	115	$149,632,000,000	$38,990,000,000	$8,750,000,000
	120	$239,017,000,000	$62,282,000,000	$13,976,000,000
	125	$381,797,000,000	$99,487,000,000	$22,325,000,000
	130	$609,868,000,000	$158,916,000,000	$35,662,000,000
Category 4 Hurricane	135	$974,181,000,000	$253,847,000,000	$56,965,000,000
	140	$1,556,121,000,000	$405,486,000,000	$90,994,000,000
	145	$2,485,692,000,000	$647,709,000,000	$145,350,000,000
	150	$3,970,554,000,000	$1,034,626,000,000	$232,177,000,000
	155	$6,342,418,000,000	$1,652,674,000,000	$370,871,000,000
Category 5 Hurricane	160	$10,131,147,000,000	$2,639,921,000,000	$592,416,000,000
	165	$16,183,125,000,000	$4,216,914,000,000	$946,304,000,000

Figure 5: Estimated Economic Damage of a Tropical Cyclone Hitting NYC
Note. These data are adapted from "A New York Hurricane Could Be a Multibillion-Dollar Catastrophe" by N. Silver (2011).

Coney Island, which is home to a famous amusement park that lies on the southwestern end of Long Island, is situated about one meter (approximately three feet) above sea level (Pickatrail.com, 2011, para. 1). Because it is only slightly elevated as well as close to the shore, Coney Island must constantly deal with flooding and damage to its infrastructure. Figure 5 shows a picture of a flood that occurred in 2011 and caused damage to a shop stand and other areas at Coney Island.

Figure 6: The "Island Shop" at Coney Island, Surrounded by Flood Waters
Note. This image adapted from ConeyIslandCentral.com, image taken by Andy Zerhusen (2011).

This flood of Coney Island was caused primarily by heavy rainfall in a short period of time (Zerhusen, 2011, para.1). With an increase in sea levels, however, flood events such as this will worsen as rainfall will accumulate on top of already dangerous water levels. For this reason, low-lying coastal buildings will be more susceptible not only to long-term flooding, but flash floods as well. Consideration of flash-floods shows the need for immediate action to protect buildings from flood damage and from severe weather that is related to climate change.

2.2.2 - Urban Infrastructure

Some cities, in order to make their waterfront zones more accessible to tourists and residents, have introduced transportation and communication infrastructure in those areas. These systems are just as susceptible to damage due to flooding as buildings and must be considered for protection and upgrading as climate change causes sea levels to rise. As sea levels rise, heavy rainfall can cause more destructive floods in areas that are close to the sea because of an accumulation of high seas and rainfall. In New York City, flooding often causes problems with the subway systems and can also cause power outages. On August 8th, 2007, New York City experienced a devastating flood that crippled much of the subway system and caused major losses of power (Chan, 2007, para. 2). Many subway lines were either delayed or disabled due to the flooding caused by torrential downpours. The Metropolitan Transportation Authority (MTA) concluded afterward that a review should be conducted to determine how the rain was so easily able to interrupt transit services. According to one *New York Times* article, “Governor Spitzer said that it was the third time in seven months that a sudden downpour of rain had led to ‘a total outage of our mass transportation system’” (Chan, 2007, para. 3). In addition, in Boston on August 28, 2011, the Massachusetts Bay Transportation Authority (MBTA) shut down in anticipation of Hurricane Irene. Since it was a Sunday and the hurricane did not hit as hard as expected, the effects of this were not very noticeable. However, if it was a business day and the hurricane hit as hard as expected, this event could have had a catastrophic effect on the City of Boston.

The cause of these flood disasters is believed to be a lack of drainage abilities, which for subway systems caused “flooding of the tracks over the third rail, water pouring through street level vents leading to a smoke condition, and water impacts on the signaling system” (Chan, 2007, para. 8). Inadequate design of systems such as the MTA’s subway and drainage systems have led to considerable problems with the functioning of New York City infrastructure, as many commuters are left stranded and some residents are left without power. According to the same *New York Times* article, “about 1,600 customers were without power in New York City and Westchester County. Earlier… about 4,000 were without power” (para. 16). This is only one example of how easily a city’s infrastructure can be damaged. As sea levels rise, floods such as this will worsen, and entire cities will be damaged.

2.3 – Sea Level Rise Adaptation in Coastal Cities

Throughout the world, many coastal cities are affected by the rising sea level and must adapt to this change to protect buildings along their shores. The two major concerns for shore protection are coastal flooding and wave damage (Morang, 2006, chapter V-3, para. 1). Because typical flooding is worsened by heightened sea levels, there is a direct correlation between the severity of floods and the natural rise in sea levels. Therefore, cities that already face flooding will experience worse floods as sea levels rise. Areas along the Atlantic Ocean and the Gulf of Mexico face hurricanes and storm surges that raise the water level past average heights, and cause coastal property damage. Similarly, along the northeastern coastline, nor’easters create high sea levels and cause flooding damage. After Holland experienced a major flooding incident in 1953, “the Dutch people began the Delta Project to raise the dikes and construct barriers (dams) across the estuarine openings to the North Sea” (Morang, 2006, chapter V-3, para. 1). Figure 6 below shows the movable gates developed to protect against SLR. Gates like this are used to protect cities and heavily settled areas from storm surges and floods.

Figure 7: Movable Gates in Holland
Note. Image is from "Coastal Engineering Manual" by U.S. Army Corps of Engineers (2006).

In addition to Holland, the city of Venice has also attempted to take action against the effects of SLR (Keahey, 2002, para. 10). The solution, proposed in 2002, was similar to that adopted by Holland; the plan consisted of building 79 steel gates that could be raised up in the event of higher than usual sea levels. These structures would help protect against events where storms and SLR cause unusually high water levels along with the tides of the ocean. These gates would essentially be used to form a wall between the city of Venice and the high seas.

The current situation in the City of Boston is not quite as dire as the situation in Holland or Venice, but Boston may eventually find that something similar may need to be erected to protect Boston Harbor from the rising sea levels.

2.3.1 – Types of Adaptation to Sea Level Rise

Recently, adaptation methods have been created by various engineers and architects to address the rising sea level problem, and to protect coastal shores from being destroyed. Some adaptation methods are focused on modifying the surroundings of a building or district, while others use the construction of a building to make an individual building flood-resistant.

The major types of adaption that focus on changing the surroundings of a building are: “armoring, beach stabilization (moderation) structures, beach nourishment, adaptation and retreat, combinations (and new technologies) and the with-no-project (abstention) alternative” (Morang, 2006, chapter V-3, para. 1). Figure 7 below shows a basic diagram of what some of these adaptations would look like with respect to a structure near the shore in a location dealing with the SLR. In Figure 7, the first illustration of a lighthouse on a beach shows the status quo with no adaptation for SLR, and a long vertical line is placed through the structure to indicate a reference line for the later illustrations. One of the adaptations depicted is called “accommodation”, which is simply raising a structure off of the ground. Another adaptation is called “protection”, which consists of building strong wall-type structures to protect against SLR and possible flooding or wave damage. Lastly, “retreat” is another form of adapting to the SLR, in which a structure is moved to a new location that is farther away from the water (Morang, 2006, V-3).

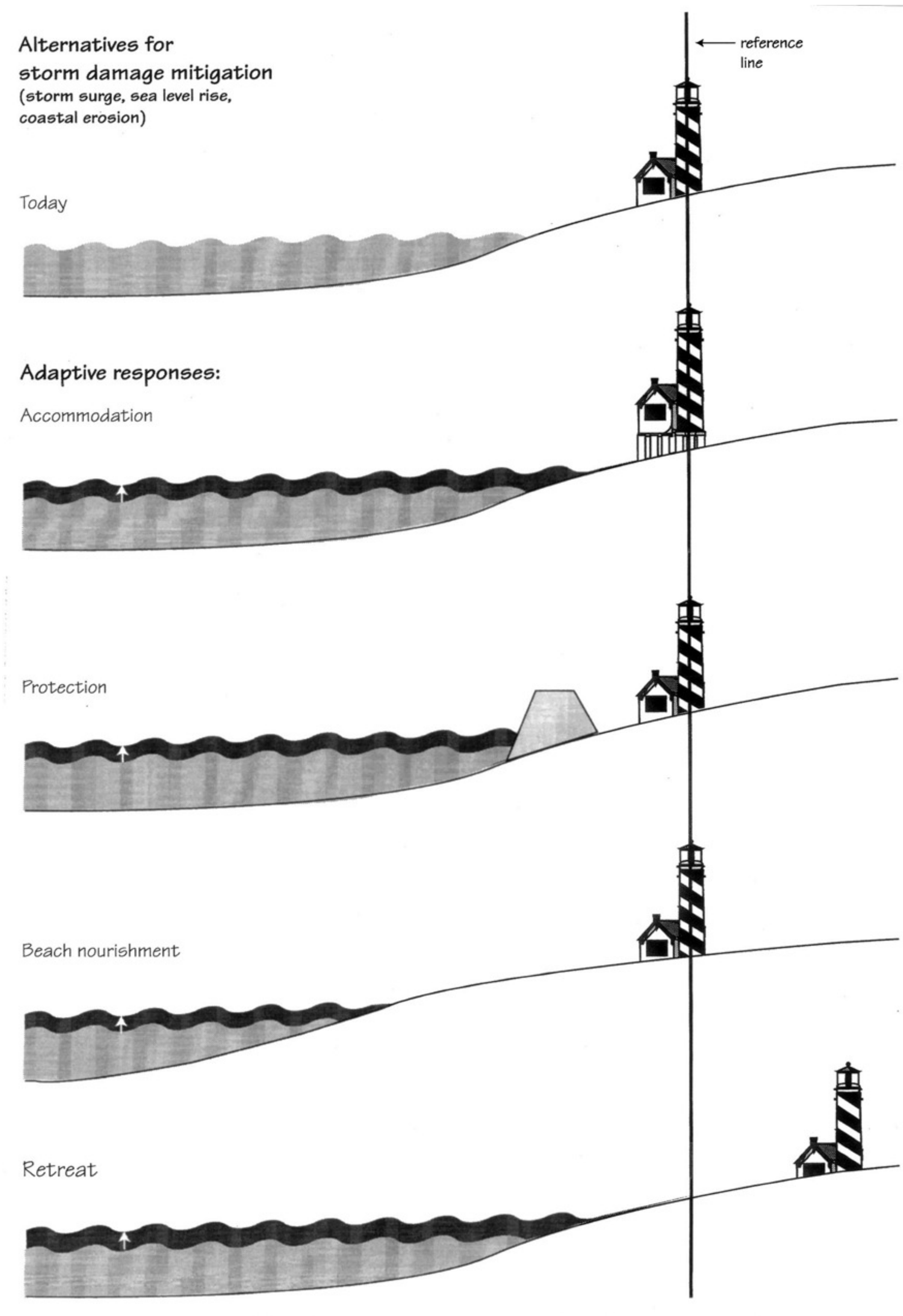


Figure 8: Diagram of Types of Adaptations to SLR
Note. Image is from "Coastal Engineering Manual" by U.S. Army Corps of Engineers (2006).

The types of building modifications that focus on the construction of buildings mainly consist of raising and sealing foundations (Jones, 2009, para. 35). Raising foundations is a process by which either the base of the foundation of a building is raised up on structural support, or it is filled to be higher than the typical foundation height. However, buildings with raised foundations can still experience water leaks, which are best countered by sealing foundations with waterproofing substances. There are many types of substances that can be used for waterproofing a building's foundation; each form of sealant is either sprayed or coated onto the foundation of a building to help prevent water from entering the building. Figure 8 below illustrates the waterproofing effects of sealant used on the exterior of a building. The technique used here is a shield that is temporarily put up on the door when a flood is expected to happen.

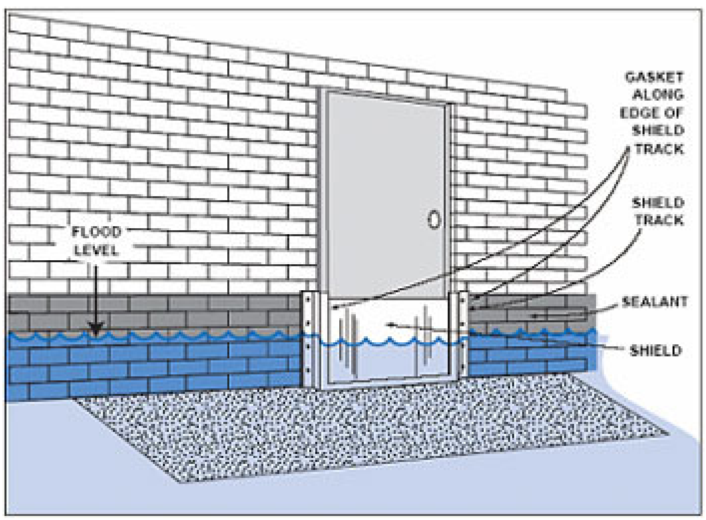


Figure 9: Waterproofing Sealant on a Building
Note. This image from "Flood Resistance of the Building Envelope" by C. Jones (2009).

2.4 - Sea Level Rise in Boston Harbor

Although research on preventing damage caused by sea level rise has been done in many different areas around the world, not much has been done yet in the Boston Harbor area. Sea level rise has recently been recognized as a major issue that the City of Boston (2011, para. 1) will have to deal with in the coming years. Boston Harbor and the surrounding area are an integral part of what makes Boston special. Apart from the risks from SLR that may affect the mainland, there are also consequences for its 30 islands that range in size from less than an acre to 214 acres, with a total of 1600 acres, or over 50 square miles. This section outlines the history of erosion and flood damage in Boston, projections of SLR for the Boston Harbor area, currently used flood precautions in building codes, and information about the focus and mission of The Boston Harbor Association.

2.4.1 – Sea Level Rise in the Boston Harbor Area

Boston's location near the ocean places it in a precarious situation when it comes to flooding and water damage. Also, the fact that Boston is a city that is mostly built on landfill increases its risk to flooding and water damage even more because it lies only slightly above the mean sea level. Some structures in and around the city have already encountered this issue directly, and the rising sea levels may hold in store an unwanted, dangerous future for some of these structures. By looking at and understanding the past patterns of SLR, Boston can be more prepared for what lies in store for this coastal city in the future.

First, we provide the mean historical sea levels in the Boston Harbor area. Figure 9 shows the average sea level trend around Boston. These data show that the mean SLR trend is an increase of 2.63 millimeters per year, with a 5% margin of error (NOAA, 2010, para. 1).

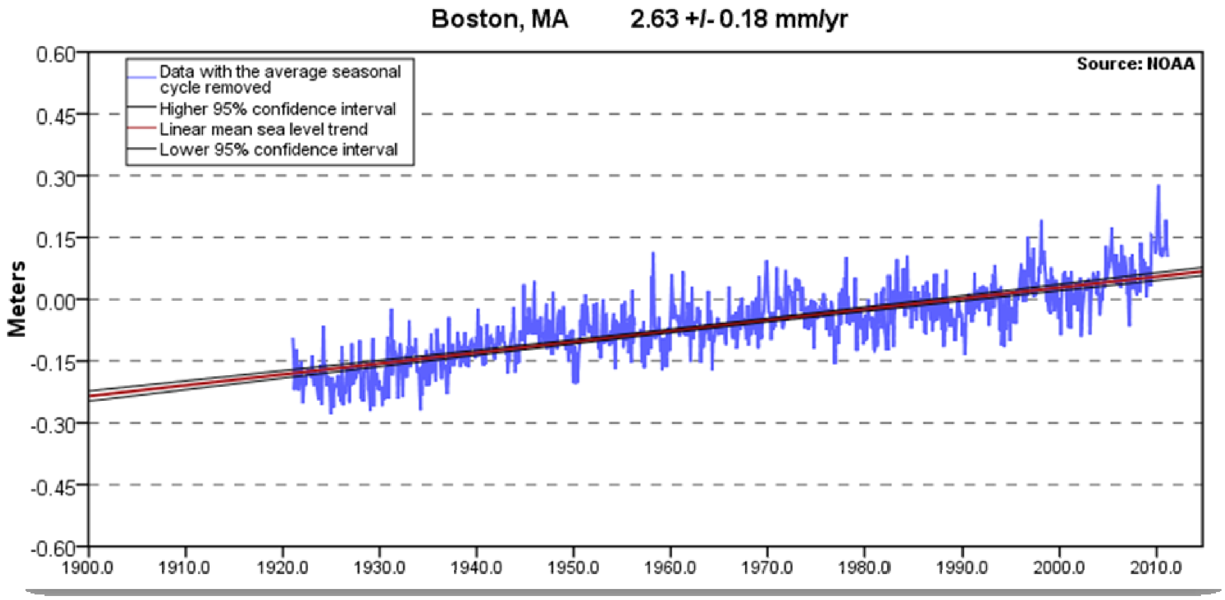


Figure 10: Mean Sea Level Trend of Boston Since 1900
Note. This image from "Mean Sea Level Trend" by NOAA, Tides and Currents (2010).

Since the sea levels are projected to rise, and because this project is about planning for the future, we also provide here projections of future sea levels. If this trend holds, the data in Figure 10 show that the sea levels will continue to rise at an alarming rate and that in turn, many structures will be endangered.

Figure 10 shows the projected yearly sea level in Boston from the year 2000 to 2100 (Kirshen, 2008). The straight bold dotted line denotes the 100-year floodplain, and the straight solid bold line denotes the 500-year floodplain. This is the level of flood water expected to be equaled or exceeded by a flooding event every 100 or 500 years on average, respectively. As the figure shows, the sea level is expected to exceed the 100-year flood level by around the year 2040, and the 500-year flood around the year 2070.

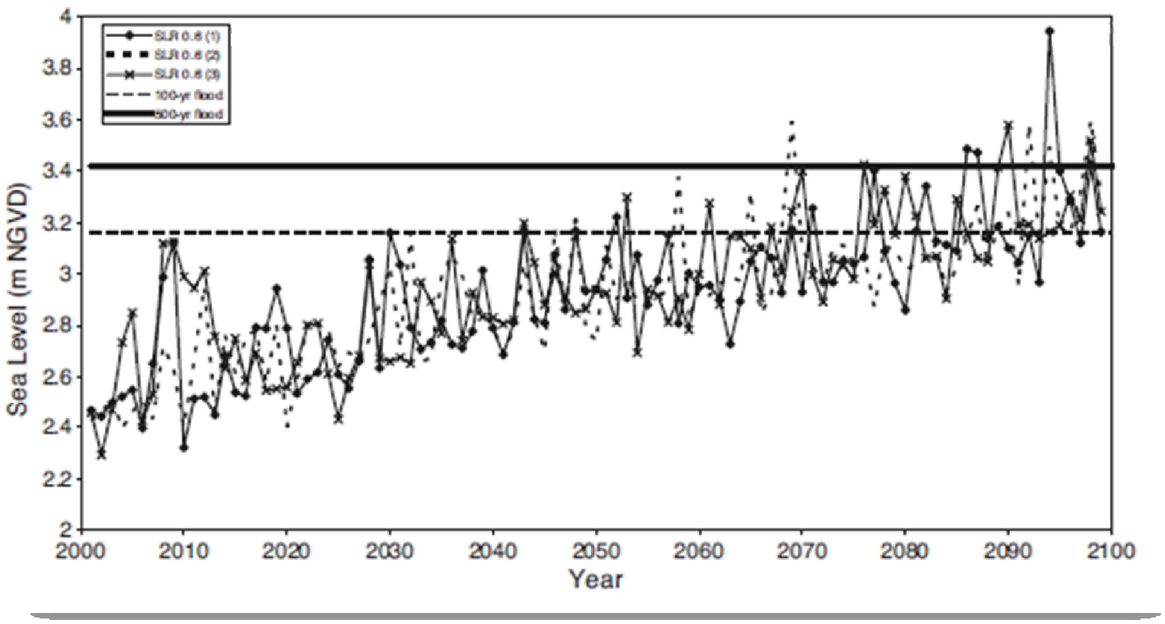


Figure 11: Projected Yearly Sea Levels from 2000 to 2100
Note. This image from "Climate change and coastal flooding in Metro Boston: impacts and adaptation strategies" by P. Kirshen, K. Knee, & M. Ruth (2008).

The City of Boston has published a copious amount of material about climate change and its potential effects on the city. Figure 11 shows both the current 100-year flood zone (indicated by a dark blue crosshatched area, primarily along the waterfront), and a projected 100-year flood zone for the year 2100 (shown in light blue) according to a "Higher Emissions Scenario" that was simulated (Kirshen, 2008). 100-year floods are floods that are expected to occur in an area approximately once every 100 years. Figure 11 also shows the specific areas of Boston (colored light blue) that are projected to be damaged by 100-year flooding in the case that SLR continues according to the trend presented by Figure 10. This map in Figure 11 presents ten landmarks that would be surrounded by or covered by water in the event of a 100-year flood with the projected sea level rise.

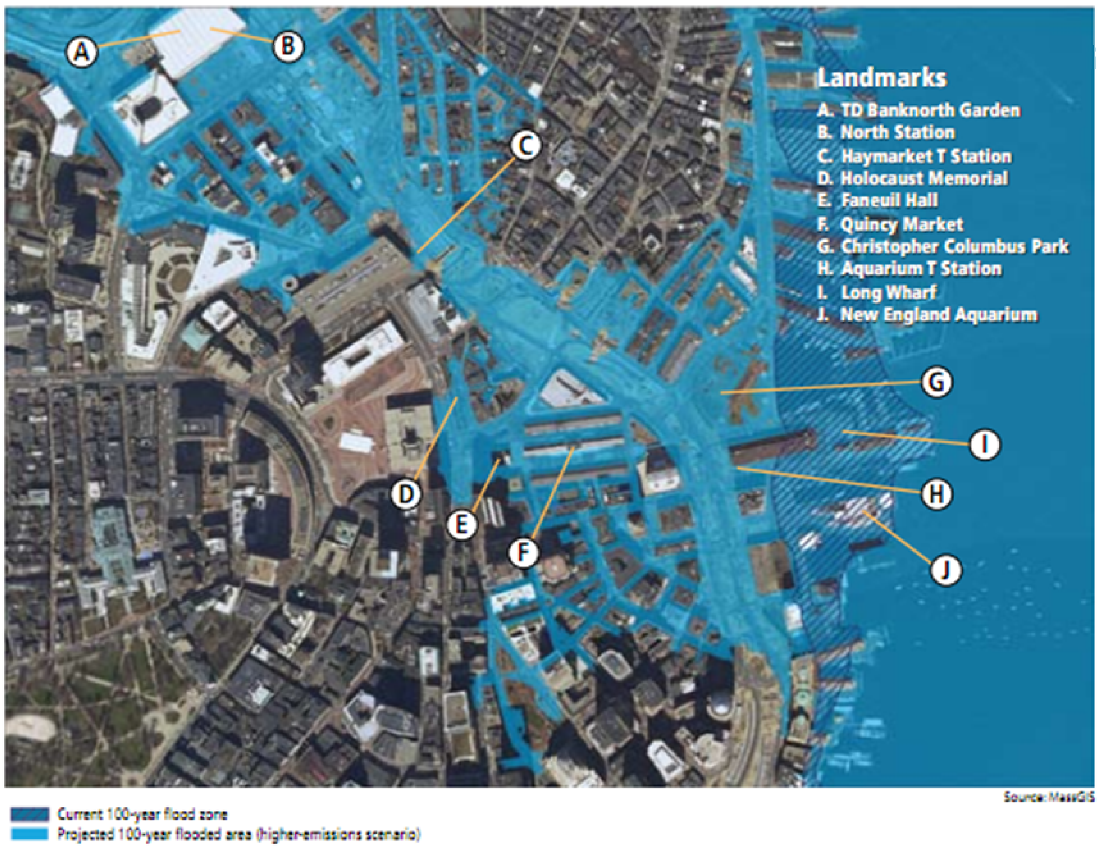


Figure 12: 100-Year flood Zone under "Higher Emissions Scenario"
Note. This image adapted from "Confronting climate change in the U.S. northeast: Massachusetts" by the Union of Concerned Scientists (2007).

One can easily see the urgency for action to be taken to protect buildings from flood damage as SLR will cause not only higher average sea levels, but also higher average flood waters.

2.4.2 – Existing Flood Precautions in Building Codes

The International Building Code (IBC) (2009), which has been adopted in full by the Commonwealth of Massachusetts, contains a minimum set of standards for buildings constructed in the U.S. Of these standards, the most relevant to our project are the flooding regulations contained in section 1612 and Appendix G: Flood-Resistant Construction of the IBC (both are attached as Appendix D in this report). Basically, the IBC's provisions for flood-resistant construction contain rules for administration of the regulations; applicability; powers and duties regarding responsibilities of officials; information about acquiring a building permit in a flood area; various definitions; and other regulations regarding specific types of structures.

Since the IBC's rules and regulations, are only a minimum set of standards that must be met by contractors, engineers and architects, there is much more improvement that could be made to these codes. However, building codes are not the only standard that must be met by professionals who work on the design and construction of buildings. When a structure is going to be built or renovated, for most situations, building permits must be obtained through the city or town in which the construction will take place. During the process of obtaining building permits, property owners or contractors may be presented with stipulations that must be met on an individual basis; these stipulations are items that are not included in building codes. As a result, the process of obtaining building permits can also lead to further requirements – in addition to current building codes – that must be met when building or renovating a building under a building permit.

Massachusetts has adopted the IBC in full for base and commercial codes. The Commonwealth has made significant modifications regarding the codes (Massachusetts Board of

Building Regulations and Standards, 2010, para. 1). These modifications include changes to section 1612 and Appendix G of the IBC.

Even though the Commonwealth has made its own modifications to section 1612 and Appendix G of the IBC, Massachusetts' building codes still do not sufficiently protect against SLR and climate change. Currently, the codes only include very basic protection against flooding (Massachusetts Board of Building Regulations and Standards, 2010, §115). The list of protections that are offered can be found in Appendix D of this report. The Massachusetts version of Appendix G (Flood-Resistant Construction and Construction in Coastal Dunes) of the building code is different from the IBC version because it more clearly defines areas such as coastal dunes, and it also contains many more definitions in the definitions subsection. Even with the modifications to the base IBC code, Massachusetts state codes do not mandate that buildings be adequately protected in any way that accounts for SLR, and so there is much room for addition to the codes as well as improvements to current standards.

2.4.3 – Regulations Set by the Federal Emergency Management Agency (FEMA)

A last source of flood plain regulations for the City of Boston can be found within Article 25 of the Boston Zoning Code, entitled "Flood Hazard Districts". This article outlines requirements that must be met by both commercial and residential construction projects that lay within flood hazard zones. These zones are designated by the Federal Emergency Management Agency (FEMA). FEMA regularly releases Flood Insurance Rate Maps (FIRMs) that delineate flood-prone areas of different counties, including Boston's Suffolk County. There are different levels of flood hazards, and areas are rated according to these levels. The areas are given zone names, with the most prominent for Suffolk County including "A" zones and "V" zones. "A" zones are areas of high risk, and "V" zones are those same areas that lie along a coastline (FEMA, 2009, para. 1).

In March 2009, FEMA released a new set of FIRMs for Suffolk County, as well as regulations for the City of Boston to adhere to in order to remain a part of the agency's National Flood Insurance Program (NFIP). This new set of standards was outlined by FEMA in Paragraph 60.3(e) of the NFIP regulations. On September 25th of 2009, the City of Boston amended Article 25 of the zoning code entitled "Flood Hazard Districts" in accordance with FEMA's requirements. Article 25 of the Boston Zoning Code is attached in Appendix D, and a FIRM for part of Boston is included in Appendix E of this report. Paragraph 60.3(e) of the NFIP regulations is included as Appendix G of this report, as well.

2.4.4 – Development in the Boston Harbor Area

In the Boston Harbor area there are four major development projects in various stages. These are the Spaulding Rehabilitation Hospital at the Charlestown Navy Yard, and the three Innovation District projects; Seaport Square, Pier 4, and Fan Pier. Below these four projects and their significance to our project will be discussed.

2.4.4.1 – Spaulding Rehabilitation Hospital

According to a report done by Partners HealthCare Inc. (2009), owners of the new Spaulding Rehabilitation Hospital on Boston Harbor have already begun anticipating a change in sea levels in the design of their building. To be located at the Charlestown Navy Yard, the new Spaulding Rehabilitation Hospital faces potential flood threats from both the Harbor and the Mystic River.

Because the building has an anticipated life-span of 75 years, and the owners intend to own and operate the buildings throughout its useful life span, the design team reviewed the most recent literature on SLR (at the time of design) to determine a reasonable level at which to set the ground floor and protective walls around the building. Although the cause of SLR is not totally agreed upon, research on the subject shows consistently that within the next century, sea levels should rise between 0.9 to 4.6 feet over existing levels on Boston Harbor. These data helped the design team to choose 2.0 feet of SLR (within the 75-year life of the building) as the basis for their design.

In addition to these data, FEMA maps provided approximate MSL (Mean Sea Level) ratings for the site of the project. The most recent set of maps project the 100-year flood line at +10.0 MSL, and the 500-year flood line at approximately +11.0 MSL. Using a reasonable projection of 2.0 feet of SLR over the lifespan of the building, the design team at Spaulding then augmented FEMA's maps to project future threats. The results showed that the 100-year flood line would then lay at +12.0 MSL and the 500-year flood line at 13.0 MSL.

Taking these data into account along with building restrictions and the surrounding topography, the ground floor was established at +13.35 MSL. All entryways into the building now lay above this level, including the entrance to the basement parking. This adaptation places the building 1.35 feet above the 100-year flood line under 2.0 feet of SLR.

Because of certain limitations in the construction of the building, a full adaptation to the worst-case 4.6 foot SLR was not practical. A restriction of the total building height, along with a restriction on minimum floor-to-floor heights would mean that an adaptation to 4.6 feet of SLR would require the loss of a floor of the Hospital. This alternative was simply not economically feasible. In addition, ground floor access from the streets and sidewalks would be significantly harder to achieve with this increase in the elevation of the ground floor. In addition, raising the building up that much would create more issues meeting the regulations prescribed by the Americans With Disabilities Act (ADA) which is discussed later in this report.

Additional precautions were also taken in order to protect the building from flood damage, should water enter the building despite an increase in elevation of the entryways to the structure. These include locating all essential mechanical and electrical systems on the roof, and locating all user occupiable space above the ground floor (page 2).

2.4.4.2 – Seaport Square

According to a report prepared by Epsilon Associates Inc. (2010), planning for the development of Seaport Square as a new, innovative neighborhood in South Boston has already begun. The Final Environmental Impact Report (FEIR) for this project outlines ways in which this neighborhood will be built in order to make the buildings less vulnerable to floods.

Although detailed plans for the buildings in this area have not yet been developed, basic information on how the developers plan to adapt the neighborhood to SLR is available. In the project's FEIR, the following are listed as preventative measures that can and will be implemented by builders to adapt the area to SLR and flooding:

- Parking garage exhausts will be located at least 10 feet above ground level.
- Parking garage air intakes will be designed to withstand street-level flooding conditions that may arise in the future.
- Building ventilation intake will be located at rooftops or at intermediate levels and will not be in danger of submersion during flooding events.

- Identify specific blocks within project site whose base elevations make them more susceptible to a 500-year flood event.
- Provide guidance to potential third party developers of individual blocks by providing a summary of commitments and potential design strategies in developer's manuals.
- First floor finished building elevations will be set above the 500-year flood level, understood to be at +11 MSL.
- Parking garage entrance ramps will be protected from 500-year flood levels either by permanent design features or by temporary protection measures.
- Electrical switchgear may be located on the second floor of buildings to protect against damage during flood events. Final determination will be made as design progresses on individual blocks.

The adaptations Seaport Square are using are a good start for general ATs to use in Boston, but there should be regulations mandating some of these changes along with additional ATs the Seaport Square team did not decide to use.

2.4.4.3 – Pier 4

According to a FEIR prepared by Arrowstreet Inc. and Goulston & Storrs (2004), the development project at Pier 4 in the Innovation District in South Boston is to be built above accepted levels for the 500-year flood. Like other projects in South Boston, Pier 4 development plans anticipate a minimum elevation that will be just over the 500-year flood level of +11 MSL. Specifically, the site's lowest point – excluding basement space – lies at +11.35 MSL.

2.4.4.4 – Fan Pier

The Fan Pier project at South Boston is currently under construction. The project will take up 21 acres of waterfront property on Boston Harbor. There will be office space, residential space, and retail and restaurant space. Fan Pier will also contain two major parks. The elevation of the parks is +11.85 MSL (+17.5 BCB). In this area, low tide is +1 BCB and high tide is +10.5 BCB. Because planning for this project began in 2001, SLR was not considered during its design.

2.5 – Summary

The climate is changing, and as a consequence the sea level is rising. The rising sea levels are a threat to all buildings that are located on or near the waterfront. One of the most significant problems that could be caused by SLR is flooding. Flooding can be, and has been, a major problem in the world in locations such as Holland and Venice, Italy. In recent years, the SLR has become more of a problem in the Boston Harbor area. By looking at what has been done elsewhere, and by studying the International Building Code as well as the Massachusetts State Building Code, we have formulated recommendations for The Boston Harbor Association on how to cope with the issues presented by the rising sea levels in the Boston Harbor area. These recommendations are discussed in chapters 4 and 5 of this report.

3 Methodology

The goal of our project was to provide The Boston Harbor Association (TBHA) with a detailed analysis of available SLR adaptation techniques (ATs) to be used in the Innovation District in the City of Boston. This analysis – along with a study of projects currently underway – helped us to create a business memo to Boston's Mayor, Thomas Menino, proposing an immediate implementation of ATs in the building of new structures on a building-by-building basis. To do this, we conducted a study of building projects that were still in the planning process in the Innovation District such as the Seaport Square, Pier 4 and Fan Pier projects, and met with the developers, engineers, architects, and other important persons behind the development of the properties around the City of Boston. We also researched ATs that have been used in places around the world where SLR is a growing problem. In addition, we met with City officials for insight into the role of building and zoning codes in the design of the projects. These meetings – along with the study of the Final Environmental Impact Reports (FEIRs) from the Innovation District projects – allowed us to determine the potential for the inclusion of different types of flood-resistant design techniques into the planning of buildings.

In order to accomplish our goal, we completed three objectives. First, we defined a structured list of ATs that could be considered for each of the three project sites of our focus in the Innovation District. This list considers the cost effectiveness, ease of implementation, cost of maintenance, and appropriate use (by building type) of each of these techniques. Next, we provided TBHA with a detailed selection of ways to make building in the Innovation District more flood-resistant in the form of an options paper. Lastly, we developed a concise package of information including: a list of globally and successfully used ATs; recent disaster costs for the Commonwealth of Massachusetts; recent insurance payouts for disaster relief; insurance benefits for building owners who use ATs; and our analysis of the practicality and effectiveness of different ATs. For each of these objectives to be met, we needed to undertake four different types of research while in Boston. The methods that we used to accomplish our goal are described in detail below, and the purpose of each is explained in relation to our objectives.

3.1 – Meetings with City of Boston Officials

In order to better understand the process of implementing amendments to the State Building Code, we met with some of the leaders of the environmental movement in Boston. The goal of Boston's environmental movement is to help reduce the effects of climate change. This common goal is shared by several environmentally conscious groups in Boston. The people we met with represent the City of Boston Office of Environmental and Energy Services and the Air Pollution Control Commission at City of Boston, as well as other environmental programs. The purpose of this informal meeting was to discuss ways by which the City of Boston could alter the process by which buildings are built to include SLR ATs. Additionally, we were able to learn more about the possibility of making changes to the current implementation of building codes in order to account for SLR, as well as the politics behind proposing changes to code. Because these representatives of the City of Boston have been considering the potential problems caused by SLR, they were an excellent source of information about what has and has not already been done relating to SLR adaptation.

3.2 – Researching Adaption Techniques

To be able to understand what types of adaptation techniques (ATs) we should recommend to the Mayor, we conducted a large amount of research on what has been done in various locations worldwide where SLR is a growing problem. In addition to performing literary review on many documents that have been published regarding climate change and sea level rise, we studied what was done at Boston's Spaulding Rehab Hospital in Charlestown. Since there are other locations worldwide that are already dealing with adaptations to SLR, we were able to make a list of recommendations for similar ATs in Boston.

3.3 – Meetings with Developers, Architects and Engineers

Before we were able to make suggestions to improve the protection of buildings from SLR, we needed to better understand flood adaptation methodologies, building codes, and the structural integrity of buildings that are subject to flooding. We were able to meet with building design experts to learn more about how the building codes address the risk of flooding damage. Because TBHA plays a major role in the development of Boston's waterfront, they have relationships with several developers who were in the planning stages for developing commercial sites in this area. Through TBHA, we met with several people involved in the development of buildings in the Innovation District. All interview protocols and specific questions can be found in Appendix C, along with specific names of the people we met with.

By meeting with some of the people involved in development for the Seaport Square, Pier 4 and Fan Pier projects, we were able to discuss possible ATs and their implications. Specifically, these meetings further helped us to refine our list of ATs in terms of cost effectiveness, ease of implementation, and appropriate use. Developers were able to give us insight into their willingness to include each AT in their designs depending on the above qualifiers. We were also able to determine relative budget and time allowances for additions of ATs.

The engineers and architects behind the construction of the buildings were able to collaborate with us on a technical level. With the help of these engineers and architects, we were able to generate a list of ATs as well as complete descriptions of each of these ATs. In some instances, we were able to assess the feasibility of different ATs for various building types. These professionals also brought up various drawbacks to using certain ATs, and were able to inform us about regulations that we were not previously aware of.

Because developers are often interested in selling their properties after completion of the project, they also consider the wants and needs of building owners. For this reason, we had discussions about insurance costs and other factors that would help a building to sell. These discussions allowed us to gather possible benefits to present to developers, such as lowered insurance costs for the owners and their ease of mind as a result of an inclusion of ATs in development plans for their buildings.

3.4 – Summary

By compiling all of the information gathered through research and meetings, we were able to qualitatively analyze the ATs. We considered the practicality of each of the ATs for use with commercial buildings in Boston, and then produced a list of six that are best suited for this city. These six ATs became the basis for the information packet that we submitted to the Office of Mayor Menino.

To complete our goal, we held informal meetings with developers, engineers, and architects to be better able to understand building codes, the structural integrity of buildings, and what types of incentives would make these professionals more willing to adapt structures to the rising sea levels and climate change. To determine the process of putting an AT requirement in place over the base building codes, we spoke with City of Boston representatives who have already been pushing for a change in flood-resistant construction requirements. We also spoke with the developers of the Pier 4 and Seaport Square projects in the Innovation District. We produced a structured list of ATs for use by developers, contractors, and City Officials. Lastly, we presented our work to TBHA who will pass it on to Mayor Menino and the City Officials we met with earlier.

4 Results & Analysis

This chapter of our report covers the material that is to be included in our package of information that will be presented to the City of Boston for consideration.

4.1 – Flood Loss Information

This section covers general information regarding flood damages for Massachusetts, Boston specifically, and other places that have faced major flood losses. To begin this discussion, we have included a table below that outlines all of the hurricanes that have hit New England from the years 1900 to 2000. This table shows that New England has experienced several Category 1 or worse hurricanes. The costs in billions of USD in this table show that these hurricanes have caused major damage to New England, some even causing up to $7 billion (2011 USD). Since climate change is causing more frequent and devastating storms, New England can expect to see similar or worse damages than those caused by the past Category 2 and 3 hurricanes.

Storm	Category		Season	Date of landfall	Cost in Billions USD
	Peak intensity	Intensity at landfall			
New England Hurricane of 1938	Category 5	Category 3	1938	September 21, 1938	4.920
1944 Great Atlantic Hurricane	Category 4	Category 1	1944	September 15, 1944	1.290
Hurricane Able	Category 2	Tropical Depression	1952	September 1, 1952	0.019
Hurricane Carol	Category 3	Category 3	1954	August 31, 1954	3.420
Hurricane Edna	Category 3	Category 1	1954	September 11, 1954	0.337
Hurricane Diane	Category 3	Tropical Storm	1955	August 18–19, 1955	7.030
Hurricane Cindy	Category 1	Tropical Storm	1959	July 11, 1959	0.0006
Hurricane Donna	Category 5	Category 2	1960	September 12, 1960	6.890
Hurricane Esther	Category 4	Tropical Storm	1961	September 26, 1961	0.046
Hurricane Alma	Category 3	Extr. Storm	1966	June 13, 1966	1.470
Tropical Storm Doria	Tropical Storm	Tropical Depression	1971	August 29, 1971	0.826

Hurricane Agnes	Category 1	Tropical Storm	1972	June 22, 1972	16.26
Tropical Storm Carrie	Tropical Storm	Tropical Storm	1972	September 3, 1972	0.009
Subtropical Storm Alfa	Tropical Storm	Subtropical Storm	1973	July 30, 1973	---
Hurricane Belle	Category 3	Category 1	1976	August 10, 1976	0.398
Hurricane Gloria	Category 4	Category 1	1985	September 27, 1985	1.895
Tropical Storm Henri	Tropical Storm	Tropical Depression	1985	September 23, 1985	---
Tropical Storm Chris	Tropical Storm	Tropical Depression	1988	August 29, 1988	0.003
Hurricane Bob	Category 3	Category 2	1991	August 19, 1991	2.495
Hurricane Bertha	Category 3	Tropical Storm	1996	July 13, 1996	0.484
Hurricane Floyd	Category 4	Tropical Storm	1999	September 16–17, 1999	6.119

Figure 13: A List of New England Hurricanes from 1900 to 2000.

Note. This chart taken from http://en.wikipedia.org/wiki/List_of_New_England_hurricanes#Landfalls

4.1.1 - Boston, Massachusetts

The following table shows some basic flood insurance claim information for the Commonwealth of Massachusetts and the City of Boston over a thirty-plus year period. In the table, the total losses are the number of losses that were submitted regardless of status; closed losses are the losses that have been paid; open losses are the losses that have not been paid in full; CWOP losses are losses that have been closed without payment; and total payments are the amount in dollars that were paid (BureauNet, 2011, para. 1).

State/City Name	Total Losses	Closed Losses	Open Losses	CWOP Losses	Total Payments (USD)
Massachusetts	29,467	23,445	31	5,991	$316,277,166.36
Boston	258	162	1	95	$999,647.29

Figure 14: Flood Loss Statistics from 1 January, 1978 through 30 June, 2011

Note. These data are adapted from "Claim information by state" by BureauNet (2009).

This table shows claims made only under the National Flood Insurance Program (NFIP) provided by FEMA. Because information about independent insurance company claims are not included, it can be assumed that the numbers provided in this table are a gross underestimation of how many losses Boston has suffered in the same amount of time due to flooding. This information does show, however, that of Boston's 258 total claims under the NFIP, only about 37% of those have been paid. Therefore, it can be assumed that in the event of a major flood with SLR, many residents and building owners would go without compensation for damage incurred to their buildings. This would put the City of Boston in the situation of having to repair with little help, which would likely lead to a break in the economy. Protected and adapted buildings would result in fewer losses and claims. If the City of Boston is able to reduce the number of annual flood insurance claims by updating buildings, the cost of insurance for buildings in the City will likely decrease. If the cost does not decrease, then the rate at which it increases might instead slow. In either case, a more resilient city would be cost beneficial to residents and building owners in the long run. This is mainly because the costs of adapting buildings to SLR and its adverse effects is relatively low compared to damages that may be suffered in the event that Boston is unprepared for SLR with storm surges.

Additionally, a report was released in 2009, commissioned jointly by Allianz (a leading global finance service provider) and the World Wildlife Foundation (WWF, a leading global environmental non-governmental organization). This report, entitled "Major Tipping Points in the Earth's Climate System and Consequences for the Insurance Sector", included information gathered from other sources by the authors describing estimated asset exposures for four major U.S. harbor cities. These monetary estimations (in billions of dollars) describe the assets at risk in each of these cities under three scenarios: exposure in 2009, no SLR; exposure in 2050, 0.5 meters of SLR; and exposure in 2050, 0.65 meters of SLR (Lenton, Footitt and Dlugolecki, 2009, page 33).

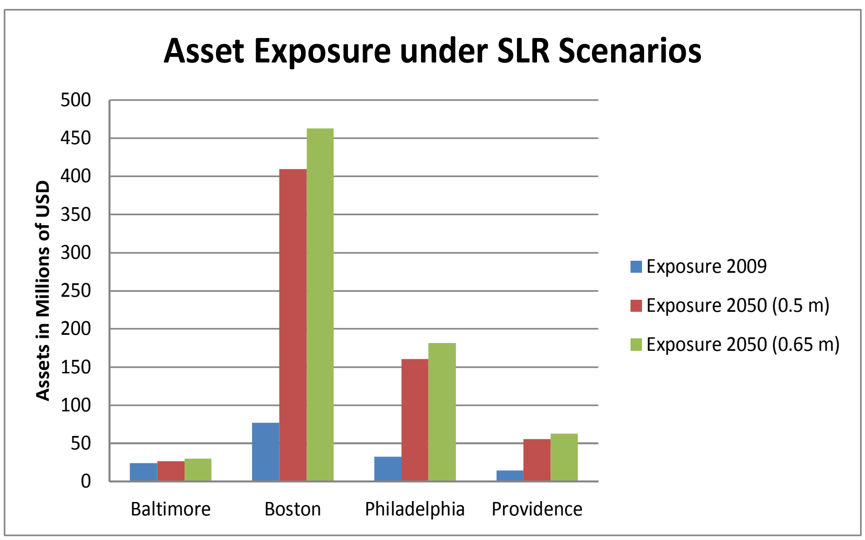


Figure 15: Asset Exposure under Sea Level Rise Scenarios
Note. These data are adapted from "Major tipping points in the earth's climate system and consequences for the insurance sector" by T. Lenton, A. Footitt, & A. Dlugolecki (2009).

Boston is slated to have the highest asset exposure of these four coastal cities. Though "Major Tipping Points" did not give an explanation as to why this is, there are several possible explanations. For one, this could simply be because Boston's net worth is higher than the other presented cities. It could also be because Boston is built closer to or more integrated with the ocean. (This is especially likely, because maps of Baltimore and Providence show much of their land along the water to be undeveloped. Philadelphia appears to be simply further inland, along a river connecting to the ocean.) A third possibility is that because much of Boston was built upon landfill, it lies closer to the MSL in that area than other the other cities. Nevertheless, Boston is expected to have over $400 billion in asset exposure under 0.5 meters of SLR, which is about equivalent to 1.5 feet. This is at the low end of the range of expected SLR for Boston over the next century, and is therefore a very likely situation for the City to be in.

4.1.2 - Mumbai, India

In 2005, many areas of the country of India faced a series of serious floods that led to the deaths of thousands of residents (Hallegatte, S. et al., 2010, page 10). These floods then led to research involving ways to reduce the "clean-up costs" of disasters like this. One particular study was published by the Organisation for Economic Co-Operation and Development (OECD) in 2010. Hallegatte et al. assessed flood damages incurred in 2010 due to the floods, and considering climate change, estimated damages for the 2080s under two different scenarios. The first estimates damages if no structural changes are made to buildings to make them more flood resistant. The second estimates damages if building codes become updated to decrease the vulnerability of structures to floodwaters. Figure 16 shows projected reductions in exposure of nearly 500 million U.S. dollars if action is taken to protect against flood damage.

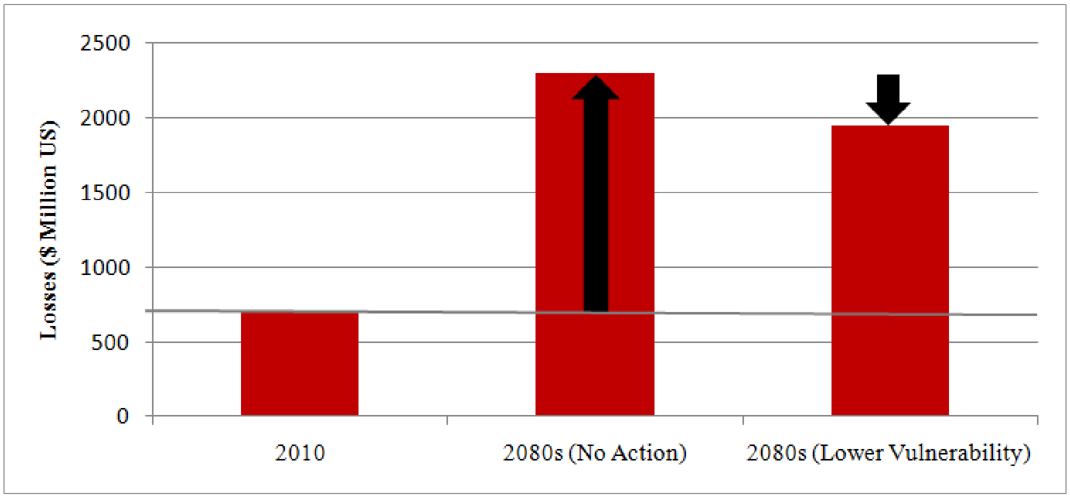


Figure 16: Estimated Total Losses for a 1-in-100 Year Flood Event in Mumbai
Note. These data are adapted from "Flood risks, climate change impacts and adaptation benefits in Mumbai: an initial assessment of socio-economic consequences of present and climate change induced food risks and of possible adaptation options" by S. Hallegatte *et al*. (2010).

Essentially, there will always be long term savings if more money is spent up front on adaptations to protect against flood damage and storm surges.

4.2 – Adaptation Techniques

This section covers SLR adaptation techniques that we have found throughout our research. Some of these ATs are in use, while others generally are not. A list of possible ATs has been included in this section, as well as some places around the world that have used them.

4.2.1 – Adaptation Options

Here we outlined different SLR adaptation options that are available to builders who are concerned with inundation by flooding. This list was compiled through both general research and meetings with civil engineers and architects.

Wet Floodproofing vs. Dry Floodproofing

There are two main types of flood protection that can help structures resist water damage. The first is dry floodproofing, which keeps water out of a structure or an area containing the structure; the second is wet floodproofing, which protects structures in a manner that allows floodwaters to encroach on and even enter a building. Dry floodproofing aims at keeping floodwaters out of a structure, while wet floodproofing aims at making a structure and its contents more flood resilient.

Active vs. Passive

Active adaptations are ones that must be implemented upon notice of a threat of flooding caused by storm surges or other temporary events. The drawback of using active adaptations is that a building's staff must be trained to be able to put the protective barriers in place in the event of a flash flood. There is also the possibility that a building will be unoccupied during one of these events, which would result in a vulnerable structure.

Passive adaptations are ones that are permanently integrated into the design of the building. The benefit of incorporating passive adaptations into the designs of structures is that no man power is needed to put these adaptations into effect. However, these techniques are typically more expensive to incorporate into buildings than active adaptations. Also, passive adaptations usually alter the appearance of buildings in some way, thus leading to aesthetic issues in some situations.

4.2.1.1 – Adaptation Techniques

The following is a list of adaptation techniques along with annotations. Later on in chapter 5, we will pick out six of these adaptation techniques and recommend them to become part of the regulations in the City of Boston.

Salt-resistant building materials

Salt-resistant building materials are currently required for use in flood hazard areas according to ASCE (American Society of Civil Engineers) 24-05: Flood Resistant Design and Construction. Specifically, this document states that "structural steel exposed to direct contact with salt water, salt spray, or other corrosive agents known to be present shall be hot-dipped galvanized after fabrication" (ASCE, 2005, page 21).

Waterproof shields/shutters for doors and windows

Waterproofing shields or shutters for doors and windows would be a temporary solution to be used in the case of a storm or flood. This adaptation would consist of placing shields or shutters in front of the doors and windows of a building prior to a forecasted storm or flood. Because human action is required to implement this adaptation, it is an active adaptation. Shields for doors and windows are already in use around the country (and the world). There are a number of companies that manufacture shields of different sizes.

The advantages of this adaption are that it is a very quick and inexpensive solution. There need be no action taken at time of construction of a building. This means that this method can be utilized on older buildings where the developers never took flood damage mitigation into consideration.

The disadvantages of this are that it is only a temporary solution, and it takes action to be implemented. This means that when a storm is predicted, the shields or shutters must be placed on the doors and windows of a building, and after the storm is over, they must be taken down.

Increase durability of windows and doors

Increasing the durability of windows and doors of a building is a permanent solution that could be regulated for new buildings. For this adaptation, windows and doors must adhere to a specific standard in order to be able to better resist flooding and flood damage.

Current practice is to lock windows or doors with heavy duty latches that form a watertight seal, and construct them with water resistant materials.

The advantages of this adaptation are that a building’s resistance to flood damage will be increased. Along with this, storm surges and high wind speeds will not as easily damage doors and windows which will save money by not having to repair doors and windows. Also, this is a passive adaptation. The disadvantages of this technique include greater expense at the time of construction when purchasing more durable doors and windows.

Raise entrances and windows

Raising building entrances should be one of the first steps towards protecting a building from flooding. The higher the first floor entrance is, the higher the water has to be to get into the first floor. Raising windows up higher also has a similar effect. This adaptation is a passive adaptation.

The advantages of raising entrances and windows include the fact that the higher they are, the higher the water level has to be to get inside the building. For example, if a building’s entrance is 2 feet higher than the sidewalk, it would take flood levels of at least 2 feet to flood the building and cause damage. Essentially, the building will be more resistant to flood damage. This type of adaptation would be passive.

The disadvantages of this include the fact that raised entrances can cause aesthetic problems. For example, buildings by law must be accessible. ADA regulations dictate specific requirements for ramps leading up to an entrance. If an entrance is raised several feet, a long winding ramp leading up to the entrance is not aesthetically pleasing.

Raise foundation

Raising building foundations is a relatively inexpensive adaptation when done at the beginning of construction. In raising foundations, the entrance to the building also gets raised, so these two adaptations go hand in hand. There could be a regulation stating a minimum elevation requirement for foundations to be built. Raising foundations is a somewhat common technique to use on residential buildings, but for commercial buildings it is not as widely adopted.

The advantage of raising foundations is that a building's resistance to flood damage will increase, and with it its lifespan. Also, when done at the time of construction, raising the foundation is relatively inexpensive. This is also a passive technique.

The disadvantages of this adaptation are similar to raising the entrance, in that there may be issues with ADA regulations and aesthetic problems. Since the ADA regulations call for ramps that follow a very shallow incline, there can also be issues with space management on the sidewalk, or the loss of valuable first floor retail space.

Parking garages below grade or on first floor

Placing parking garages below grade and/or on the first floor of a building is an adaptation technique that has already been used in many buildings. This is a passive adaptation, in that after construction of the building and the garage, no action is needed to prepare for a storm. After a large storm or flood however, the garage must be pumped to clear it of floodwater.

This adaptation has several major advantages. One major advantage is that there is added parking space for visitors or tenants. Another advantage is that human life is not at risk when the garage floods. Also, the "habitable" space (areas where there is a high volume of people such as retail or residential space) is not at risk. This is also a passive adaptation.

The major disadvantage of this adaptation is that after the garage floods from a storm or other event, the floodwaters must then be pumped out of the garage. This could also be a somewhat costly adaptation, as digging deep into the ground could prove difficult and time consuming.

Plan for future evacuation of first floor

Planning for the future evacuation of the first floor of a building is a passive adaptation technique that requires no action until waters rise to the floor's level. This adaptation involves using building materials that are resistant to water damage on the lower floors of a building. Essentially, once rising sea levels reach the elevation of the first floor of a building, the floor can be abandoned and the water can be let in. This would also involve other planning, as new entryways would need to be added once the floor is abandoned. There are no major records or information that is gathered regarding places that have applied this adaptation to buildings or structures yet.

The advantages of this adaptation are that human life is not at risk, and there is no effort spent on trying to keep the floodwaters out. This is also a passive adaptation, which means that little to no action is needed to be taken until the sea level rises to the level of the first floor.

The main disadvantages of this adaptation include the fact that once abandoned, the entire floor will be useless. Also, any residents or retail on the first floor would lose their storefront or their homes. Lastly, once flooded and abandoned, new entryways will need to be added and adapted to deal with the water on the first floor.

Lift buildings on piles or "free-board"

Building structures on raised piles or "free-boarding," which is raising a building up on stilts, is a passive adaptation technique. This adaptation involves raising a building either above the flood level or an entire floor on stilts. This creates space under the building which allows room for floodwater to flow so little to no damage is caused to the main part of the building. This method is used for buildings and houses along various coasts throughout the world, but is more suitable for residential houses. This adaptation can be applied to commercial buildings, but this is not typically practiced.

The advantages of this adaptation are that human life will not be at risk. Also some other advantages are that habitable space will not be at risk, and flooding will cause minimal damage to the structure.

The main disadvantages of lifting buildings are that it could be very expensive for larger buildings, create aesthetic problems, and cause problems meeting the entrances to street level.

Amphibious buildings

Building amphibious buildings is a passive adaptation technique that involves allowing buildings to rise with increasing water levels. In this technique, buildings are built on flexible mooring posts that allow the structure to rise off of the ground when water levels increase. Since the building is connected to a foundation by the moorings, it will stay in the same place and lower back to the ground when the waters recede.

The main advantages of this technique is that it is a seamless ground level building during fair weather with the ability to avoid ground level flooding and can accommodate a variety of flood heights.

The disadvantages of this technique are that this can be very expensive. Also, the building will be much more vulnerable to wind damage than if it was built traditionally.

Floating buildings

Constructing floating buildings is a passive adaptation technique that is similar to amphibious buildings in that the structure will rise with the water levels. Examples of this technique can be seen in houseboats, modern water villas, and multiunit communities. This technique involves the use of full-fledged floating foundations, open space, and utility units protected in integrated piping.

The advantages of this technique include that structures can accommodate steady fluctuations in water levels, and can accommodate a variety of flood heights.

The disadvantages are that this is a relatively expensive technique, it may disrupt nearby habitats, and the building is very vulnerable to winds and waves along a high-energy coastline.

4.2.1.2 – Additional Adaptations

There are additional adaptation techniques that are on a larger scale than simply a building-by-building basis. These include the construction of sea walls, creating dune-scapes, and using parks as buffers. We focused on a building-by-building basis for adaptations because we wanted to find alternatives to constructing a wall or dune-scapes. Since Boston Harbor has recently been cleaned up, a sea wall would be very unsightly and would cause many ecological problems as well. However, using parks as a buffer would help to beautify the city, and this strategy is already in use in Boston. The process of placing a park between a building and the waterfront allows floodwaters to seep into the soil and back into the harbor while also providing a civic space for passers-by. TBHA has played a major role in adding the new harbor walk to the perimeter of the harbor. Since this technique is already used on a large scale and is not a building-by-building technique, we do not discuss it further.

4.2.2 – Current Adaptations in Boston, Massachusetts

Current FEMA maps for Suffolk County – which includes the City of Boston – project the 100-year floodline at +10 MSL (+15.65 BCB) and the 500-year floodline at +11 MSL (+16.65 BCB). BCB stands for Boston City Base, and is a datum used by the City of Boston as a measurement of the elevations of buildings in relation to the MSL. The formula for their relationship is as follows: BCB = MSL + 5.56. Predictions of SLR for the next 75 to 100 years vary between 0.9 to 4.6 feet above the current sea level for the City of Boston. Using these data, a new range of sea levels is produced. The following table shows possible outcomes for the City of Boston under SLR and flood events.

Feet of SLR:	0 ft		0.9 ft		4.6 ft	
	MSL	BCB	MSL	BCB	MSL	BCB
100-Year Flood	10.00	15.65	10.90	16.55	14.60	20.25
500-Year Flood	11.00	16.65	11.90	17.55	15.60	21.25

Figure 17: Major Flood Events in Boston, MA, Under Three SLR Scenarios

4.2.2.1 - Spaulding Rehabilitation Hospital

According to a document released by Partners HealthCare Inc. (2009), the new Spaulding Rehabilitation Hospital located in the Charlestown Navy Yard at the edge of Boston Harbor and the Mystic River is currently under construction. At completion, the building will be eight stories tall and provide 221,000 square feet with 132 patient beds. Because the owner of this building is invested in its success, and because the lifespan of the structure is estimated to be around 75 years, designers planned for construction of the building to account for SLR. In order to make the building more flood-resistant, during the planning stage, architects on the project decided to place all of its entryways at or higher than +13.35 MSL (+19.0 BCB). In addition, all major utilities including electrical and HVAC equipment will be located on the top floors of the building protect them from potentially damaging flood waters (page 1).

4.2.2.2 - Seaport Square at South Boston

The Seaport Square development project in South Boston is in its planning stages and is projected to include approximately 6.3 million square feet of new construction. These new buildings will consist of retail, entertainment, residential, and office space. The project will also include a number of climate change adaptations including parking garage air intakes designed to withstand street-level flooding conditions, building ventilation intake located on upper floors, first floor finished building elevations above +11 MSL (+16.65 BCB), and electrical switchgear that may be located on the second floor of buildings to protect against damage during floods, among many other adaptations.

4.2.2.3 - Pier 4 Project at South Boston

The Pier 4 development project in South Boston is slated to begin the construction phases in 2012. The total space will cover 981,700 square feet, not including 20,000 square feet of civic space in the form of parks and walkways. There will be residential, hotel, and office space between the three buildings. Because the buildings are arranged in such a way that they are behind one another before the waterfront, each building has adapted to flood levels to a different degree. Specifically, the building closest to the water is six inches higher than the building behind it, and that building is six inches higher than the one behind it. (Collectively, this results in a one foot difference between the entry-level floors of the first and third buildings.) Also, beneath the three buildings will be a three-story garage space. This space was not designed specifically for floodwaters, but could be adapted so that critical electrical systems and ventilation systems would not be damaged in the case of a flood. Sea walls surround the area on which these structures will be developed, and they reach a maximum height of +11.35 MSL (+17 BCB). The first floor of all of these buildings will not be used as livable space, which also allows for the evacuation of the first floor in the case of a catastrophic flood. Because of its location relative to Logan Airport, these structures also have a height limit of about +263.35 MSL (+269 BCB) set by the Federal Aviation Administration (FAA), which restricts how high the building can be elevated without compromising numbers of floors.

4.2.2.4 – Fan Pier

The Fan Pier project at South Boston is currently under construction. The project will occupy 21 acres of waterfront property on Boston Harbor, including office space, residential space, and retail and restaurant space. Fan Pier will also contain two major parks. The elevation of the parks is +11.85 (+17.5 BCB). In this area, low tide is +1 BCB and high tide is +10.5 BCB. Because planning for this project began in 2001, SLR was not considered during its design and the buildings in this project are not raised up above the flood levels.

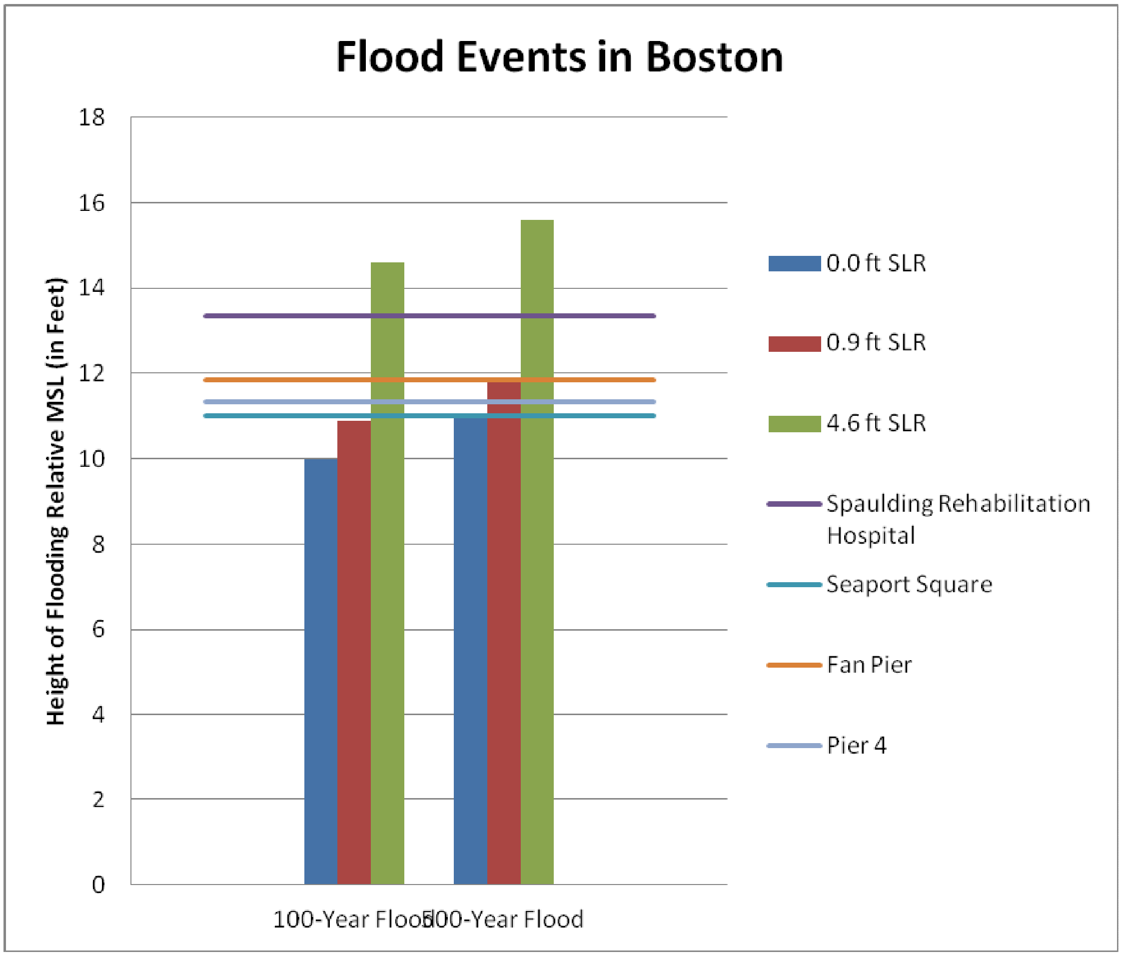


Figure 18: Major Flood Events in Boston, MA, Under Three SLR Scenarios

Figure 18 above shows the levels of the four projects in Boston compared to various 100-year and 500-year flood scenarios relative MSL. In terms of the 100-year flood, all of the projects are safe from the two lesser scenarios, but with the 4.6 feet of SLR all of them will be flooded.

With the 500-year flood, the four projects are only safe if there is no SLR, and will be flooded with any amount of SLR.

4.3 – Regulations

This section outlines the different regulations that must be considered when applying ATs to a building. Building and zoning codes each dictate specific flood resistant construction standards, while the Federal Aviation Administration (FAA) and Americans with Disabilities Act (ADA) have guidelines that must be met for all buildings and can impose additional constraints on the design of a building.

4.3.1 – Building Codes

The International Building Codes and the Commonwealth of Massachusetts' amendments to that code often reference a document by the American Society of Civil Engineers. ASCE 24-05 (2005) provides the standards for building structures that are generally flood resistant. However, this document does not outline many specific steps to be taken to make a structure flood resistant.

For example, "dry floodproofed areas of structures shall be designed and constructed so that any area below the applicable elevation specified [previously], together with attendant utilities and sanitary facilities, is flood resistant with walls that are substantially impermeable to the passage of water" (page 35).

Similarly, "wet floodproofing for flood events up to and including the design flood shall be accomplished by [the] use of techniques that minimize damage to the structure associated with flood loads" (page 36).

Both of these requirements are vague and do not tell builders how they must design and construct a building so as to make it more flood resilient in the face of storm surges or other extreme flood events.

Between Massachusetts's building codes and the ASCE documents, one of the most useful suggestions to builders is to elevate their structures above accepted sea levels. All three code documents (IBC, Massachusetts, and ASCE) state that all livable space must be built above the average sea level determined for the specific area. For example, according to ASCE 24-05, buildings in flood hazard areas other than Coastal High Hazard Areas, Coastal A Zones, and High Risk Flood Hazard Areas, "shall have the lowest floor (including basements) elevated to or above the Design Flood Elevation (DFE) in accordance with the [following] requirements" (page 10). IBC and Massachusetts's building codes also require a minimum elevation in relation to the Mean Sea Level (MSL) and Boston City Base (BCB) respectively, which are linearly related. (The comparative formula states that BCB = MSL + 5.65 feet.) Oftentimes, however, the minimum elevation requirement is set at a height that will not protect a building in the event of a 500-year flood, or even a 100-year flood. If SLR is taken into account, even buildings that are elevated above these flood levels become vulnerable.

Section 24-05 of ASCE's requirements also mentions the design of "pile, post, pier, column, and shear wall foundations" for buildings that are located within a V Zone (Coastal High Hazard) or a Coastal A Zone (page 15). Additionally, there are sections within ASCE 24-05 that discuss other considerations such as "materials, dry and wet flood-proofing, utility installations, building access and miscellaneous construction (decks, porches, patios, garages, chimneys and fireplaces, pools, and above- and below-ground storage tanks)." Both of these sections outline minimum standards, though no specific designs are specified.

4.3.2 – Zoning Codes

Flood plain regulations for the City of Boston can also be found within Article 25 of the Boston Zoning Code, entitled "Flood Hazard Districts". This article outlines requirements that must be met by both commercial and residential construction projects that lay within flood hazard zones set by FEMA in publicly available FIRMs. On September 25, 2009, the City of Boston amended Article 25 of the zoning code entitled "Flood Hazard Districts" in accordance with FEMA's additional requirements.

Like the Commonwealth's building codes, the City of Boston's Article 25 (1982) provides outlines of standards that must be met in order to design a floodproof building without specifying the methods to achieve a floodproof building. For example, the document states that nonresidential construction must "have the lowest floor, including basement, elevated above the highest adjacent grade at least as high as the depth number specified in feet on the FIRM (at least two feet if no depth number is specified)…" In addition, nonresidential construction must: be flood proofed so that below the base flood level the structure is watertight with walls substantially impermeable to the passage of water; have structural components capable of resisting hydrostatic and hydrodynamic flood loads and effects of buoyancy; be certified by a registered professional engineer or architect that the standards of this subsection are satisfied. Such certifications shall be provided to the Building Commissioner (page 3).

Paragraph 60.3(e) of the NFIP regulations, written by FEMA (2009a), states that "the bottom of the lowest horizontal structural member of the lowest floor (excluding the pilings or columns) [of any building] is elevated [on pilings] to or above the base flood level." Additionally, the document mentions the use of "breakaway walls" (page 253).

Article 25 of the Boston Zoning Code is attached in Appendix E, and a FIRM for part of Boston is included in Appendix F of this report. Paragraph 60.3(e) of the NFIP regulations is included as Appendix G of this report, as well.

4.3.3 – FAA Regulations

When considering which ATs can be applied to buildings to account for SLR and storm surges, developers must also take into account various building regulations, more specifically, the regulations from the Federal Aviation Administration (FAA). If developers intend to raise their building foundation, they have to pay close attention to the changes this would cause to the total height of the building. For example, since Boston's Logan Airport is located near most of Boston's large infrastructure, the FAA requires that any tall buildings be under a certain height restriction depending on where the building is located with respect to Logan Airport (Code of Federal Regulations CFR 2011). Figure 19 bellow shows a general height restriction for buildings constructed in Boston based on their location around Logan Airport.

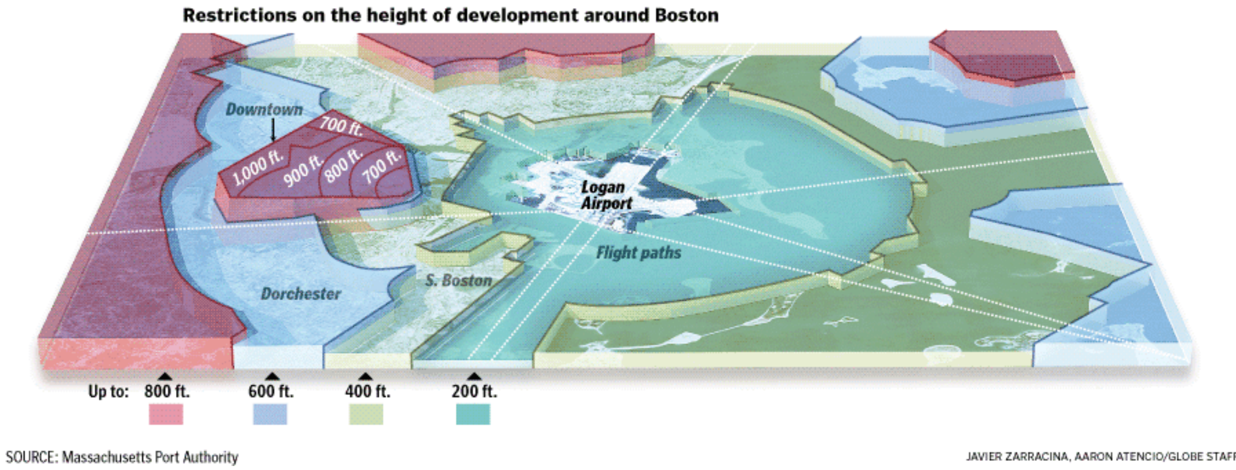


Figure 19: Restrictions on Height for Buildings around Boston
Note: This map was created by the Massachusetts Port Authority (2008)

Due to Logan Airport's layout, some areas within Downtown Boston have a variety of maximum building heights allowed and vary to prevent any obstruction for the airplanes flying to and from the airport. While some sections outside of Downtown Boston have a larger range allowed for buildings heights, certain areas such as Dorchester and South Boston are more restricted to lower building heights. To be more specific, the buildings within the Innovation District in South Boston are mostly restricted to a maximum building height of around 400 feet. Developers who are working within the Innovation District who decide to raise their building foundation by a few feet have to make sure that this change in building height will not exceed the maximum building height in the district and cause an obstruction to airplane paths.

4.3.4 – ADA Regulations

When developers look at what ATs can be applied to buildings, they must also take into account public access to their buildings. More specifically, they must follow the regulations mandated by the Americans with Disabilities Act (ADA) (ADA 2010). One of the most important sections of the ADA is Section 405 that refers to the path of travel (POT). The POT refers to a continuous and unobstructed pedestrian passage. This area may be approached, entered, or exited with respect to the public building. These areas connect with the exterior of the building (public sidewalks, streets, and parking areas), as well as other entrances and parts of the facility. Examples of a POT consist of sidewalks, curb ramps, interior or exterior ramps, clear floor paths through lobbies, corridors, rooms, parking access aisles, elevators or lifts, or any combination of the listed examples (ADA).

If developers decide to raise the foundation as an AT to protect their building, they have to make sure they still meet the ADA regulations regarding the POT, and more specifically, follow the ramp regulations. No matter how elevated a building is, ramps must be constructed to meet ADA regulations. Figure 20 below shows the ratio for a ramp slope and the maximum rise allowed before either an entrance or a landing. Since the ADA has this mandated this regulation, raising a building may result in protecting it against flood hazards, but may also cause problems with the design of the building to account for the length and location of the ramp in addition to adding cost to construction.

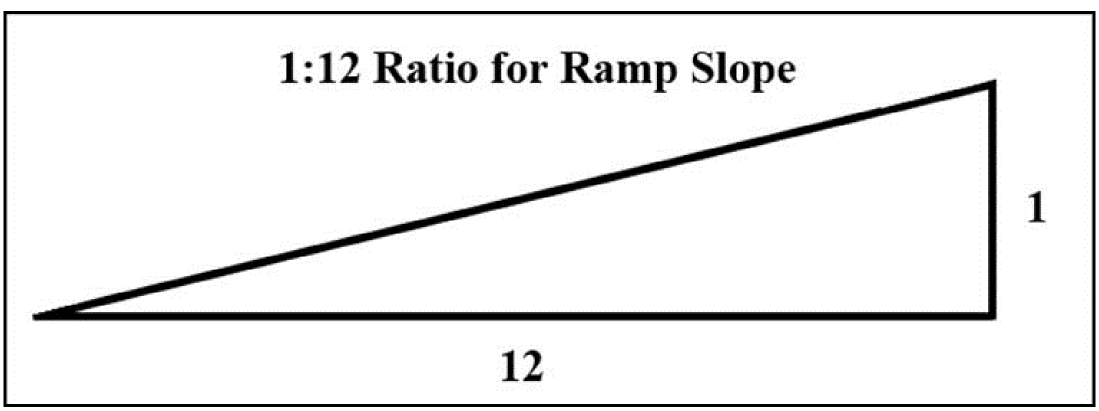


Figure 20: Slope Ratio to Maximum Rise for Ramps
Note: This Figure it not to scale.

4.4 – Legal Options

There are many ways that the City of Boston could require builders to incorporate SLR adaptation techniques into the designs of buildings. A document that was completed late August, 2011 outlines the best legal options for the City. This document, named "Legal Options for Municipal Climate Adaptation in South Boston" by W. Jacobs, L. Cohen, and J. McGrory of Harvard University (2011) should be referenced for more information on these options.

One of the options provided describes "Code Enforcement" as a way for the City to mandate the inclusion of SLR adaptations on a site-by-site basis. According to the authors, "the Boston Commissioner of Inspectional Services has existing authority to abate nuisances that are injurious to the public health, including those caused by unsafe buildings, and to require that existing buildings meet current flood-resistance standards in certain circumstances under the State Sanitary and Building Codes" (page 8).

Another suggestion under the title of "Resilient Building Design" submits that "The City can adopt flood-related performance standards in Article 80 of the Boston Zoning Code, similar to its approach to green building" (page 8). A similar option under the same title is presented as follows: "The City can request that the Board of Building Regulations and Standards pass more stringent flood-resistance standards for Boston or create a flood-resistance stretch code that Boston and other municipalities could adopt" (page 8). Both options would improve the current standard presented in Boston's Building and Zoning codes, which would be a beneficial and long term solution to the issue of SLR. For a complete list of the available options as presented by W. Jacobs, L. Cohen, and J. McGrory, please reference Appendix F of this report.

5 Memo

From the information that we have gathered, we have created a list of building-by-building adaptation techniques to be used in the city of Boston. The following is a memo we created for our agency to distribute to appropriate officials in the City of Boston.

Memorandum

To: Office of Mayor Thomas Menino

From: Danielle Beaulieu, Jeremy Colon, Darius Toussi, Worcester Polytechnic Institute

Date: 10/13/2011

Re: **Storm Surge and Sea Level Rise Design and Construction Recommendations for the City of Boston**

This memo summarizes our recent research on what Boston can do to protect its waterfront buildings from flooding due to climate change-related storm surges and sea level rise. We examined other cities' efforts to protect buildings from flood events and spoke with architects, engineers and developers involved with new buildings on the Boston waterfront to better understand their regulatory and commercial constraints.

In the following sections, we will provide data on expected threats from storm surges to Boston's waterfront, and will show how these threats are not captured in current zoning regulations. Second, we will describe why and how policy makers and developers can implement adaptation measures to make buildings more protected from and resilient to coastal flooding. Finally, we provide additional graphics and resources in appendices.

Background. Boston Mayor Menino and his staff have expressed significant concern and commitment around energy efficiency, green buildings and climate change. One of the mayor's signature achievements, the “Innovation District” of South Boston, is an area especially at risk of flooding due to storm surges and sea level rise.

The waterfront of the Innovation District is undergoing tremendous development. It is expected to be built out within the next ten to 15 years, locking in the type, size and location of major buildings for at least the next 60 to 70 years (P. Kirshen, personal communication, September 12, 2011). According to current projections, the Boston waterfront will be affected by rising sea levels and increased storm surges during this time. Without incorporating adaptive design and construction as new projects are built, the cost of retrofitting and repairing them in the future will be substantially greater.

In Boston, the current standard for flood hazard areas is determined by the Federal Emergency Management System (FEMA) and the Flood Insurance Rate Maps (FIRMs) produced by this agency[1]. In order for the City to retain its membership in the National Flood Insurance Program through FEMA, the areas designated by the appropriate FIRM to be “flood hazard areas” must build according to FEMA’s flood resilient design and construction standards. These regulations are enacted through an amendment of Boston’s Zoning Code, Article 25. However, FEMA’s maps underrepresent actual threats from flood in at least two important ways.

- They are based on 100-year and 500-year flooding due to *rainfall events*, not *hurricanes* (see Appendix A). Between 1900 and 2000, New England saw eight Category 1 or worse hurricanes. Flooding caused by hurricanes is outlined in the Army Corps of Engineers’ “Hurricane Surge Inundation” maps and is depicted as far more frequent and extensive than flooding due to rainfall (see Appendix B).
- The FEMA maps neither account for astronomical high tides (which already leave portions of Boston’s Long Wharf submerged in water 4-6 times per year, see Appendix C) nor an expected one to five feet of sea level rise by 2100, both which exceed FEMA’s projections for possible flooding in the city B. Ris, personal communication, September 2, 2011).

FEMA’s maps provide developers with a false sense of security. Developers in the Innovation District conveyed to us that they are not concerned with flooding at their sites. Because FIRMs are currently the standard for determining flood hazard areas, many developers in areas vulnerable to storm surges do not perceive a need to build strongly flood-resilient buildings.

Recommendations for Builders. Effective methods of preventing extensive flood damage from storm surges fall into three broad categories:

Prevention involves keeping water from entering buildings. Adaptation techniques related to prevention include reinforcing or raising ground-floor doors and windows or creating a buffer between the waterfront and buildings.

[1] For a partial, example FIRM for South Boston, see Appendix A.

Resilience involves using materials that are not destroyed when flooding occurs. Adaptation techniques include locating all mechanicals on upper floors, using materials such as tiles and concrete, not rugs and drywall on the first floor, and making furnishings easily movable if flooding threatens.

Recovery involves adaptation techniques that quickly remove floodwaters from a building to prevent further damage from e.g., mold. Pumps and drainage systems support rapid and less costly cleanups after floods.

Appendix D provides a full list of adaptation techniques we found in our research.

Recommendations for Policy Makers. We perceived a substantial gap in understanding of and concern about storm surges and sea level rise between policy makers and waterfront developers and believe that this is due to the fact that waterfront zoning is based on models that project flooding events due to *rainfall*, not *coastal storm surges*. As a result, developers are substantially underestimating their risk of flooding, and as a result, understandably reluctant to spend money on flood prevention.

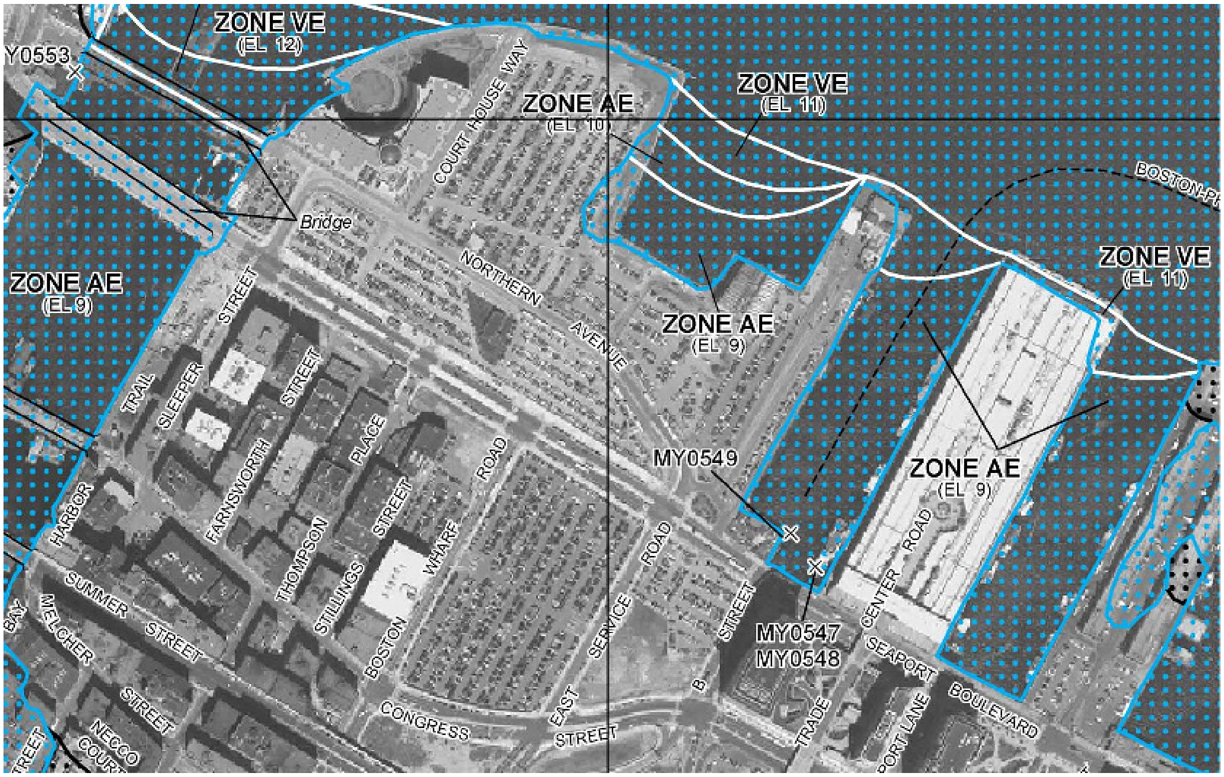
1. We recommend that the City of Boston replace the use of FEMA 100-year and 500-year flood models and maps with the Army Corps of Engineers' "Hurricane Surge Inundation" model and maps as the standard for determining flood hazard districts.

Most cities seeking to prevent flooding use walls and levees to keep water out. Seattle and Charleston, SC instead are developing "floodable zones" that preserve the city's access to its waterfront while minimizing damage when periodic flooding occurs. We believe this model may be more appropriate for Boston than building levees or flood gates.

2. We recommend that the City of Boston include a vision of a "floodable zone" in the Boston Redevelopment Authority's revised Harbor Plan that requires adaptability standards for waterfront development.
3. The City should also require effective performance measures for making buildings less prone to flooding and more readily and inexpensively restored if and when periodic flooding occurs.

Conclusion. New development projects along the South Boston waterfront are currently not being designed to withstand expected storm surges during the lifespan of their buildings. By requiring developers to include up-front adaptation measures to make these structures more protected from and resilient to periodic flooding, the city can prevent extensive damage and expensive repairs and retrofits in the future.

Appendix A. To Mayor Menino.



FIRM

FLOOD INSURANCE RATE MAP

SUFFOLK COUNTY,

MASSACHUSETTS

(ALL JURISDICTIONS)

PANEL 81 OF 151

(SEE MAP INDEX FOR FIRM PANEL LAYOUT)

CONTAINS:

COMMUNITY	NUMBER	PANEL	SUFFIX
BOSTON, CITY OF	250286	0081	G

Notice to User: The **Map Number** shown below should be used when placing map orders; the **Community Number** shown above should be used on insurance applications for the subject community.

MAP NUMBER
25025C0081G

EFFECTIVE DATE
SEPTEMBER 25, 2009

LEGEND

SPECIAL FLOOD HAZARD AREAS (SFHAs) SUBJECT TO INUNDATION BY THE 1% ANNUAL CHANCE FLOOD

The 1% annual chance flood (100-year flood), also known as the base flood, is the flood that has a 1% chance of being equaled or exceeded in any given year. The Special Flood Hazard Area is the area subject to flooding by the 1% annual chance flood. Areas of Special Flood Hazard include Zones A, AE, AH, AO, AR, A99, V and VE. The Base Flood Elevation is the water-surface elevation of the 1% annual chance flood.

ZONE A	No Base Flood Elevations determined.
ZONE AE	Base Flood Elevations determined.
ZONE AH	Flood depths of 1 to 3 feet (usually areas of ponding); Base Flood Elevations determined.
ZONE AO	Flood depths of 1 to 3 feet (usually sheet flow on sloping terrain); average depths determined. For areas of alluvial fan flooding, velocities also determined.
ZONE AR	Special Flood Hazard Area formerly protected from the 1% annual chance flood by a flood control system that was subsequently decertified. Zone AR indicates that the former flood control system is being restored to provide protection from the 1% annual chance or greater flood.
ZONE A99	Area to be protected from 1% annual chance flood by a Federal flood protection system under construction; no Base Flood Elevations determined.
ZONE V	Coastal flood zone with velocity hazard (wave action); no Base Flood Elevations determined.
ZONE VE	Coastal flood zone with velocity hazard (wave action); Base Flood Elevations determined.

FLOODWAY AREAS IN ZONE AE

The floodway is the channel of a stream plus any adjacent floodplain areas that must be kept free of encroachment so that the 1% annual chance flood can be carried without substantial increases in flood heights.

OTHER FLOOD AREAS

ZONE X	Areas of 0.2% annual chance flood; areas of 1% annual chance flood with average depths of less than 1 foot or with drainage areas less than 1 square mile; and areas protected by levees from 1% annual chance flood.

Appendix B. To Mayor Menino.

LEGEND

Hurricane Surge Inundation Areas
(Worst Case Flooding by Hurricane Category)

- Category 1
- Category 2
- Category 3
- Category 4

FEMA 100-Year Flood Zone
(Only those areas beyond the hurricane surge inundation areas are shown)

- FEMA 100-year Flood Zone

Other Map Features

- Wetlands
- Water Bodies
- Non-Flooded Land
- Major Roads
- Other Roads
- Railroads
- Rivers & Streams
- Town Boundaries
- Commuter Rail Stations
- T Stops
- Reference Points
- Red Cross Shelters
- Local Shelters
- Hospitals
- Medical Facilities (Nursing Homes, First Aid Facilities)
- Trailer Parks
- Points of Interest

Notes:

1. Hurricane surge elevations were determined by the National Hurricane Center using the SLOSH model (Sea, Lake and Overland Surge from Hurricanes), and assume peak hurricane surge arrives at mean high water.
2. The hurricane surge inundation areas shown on this map depict the inundation that can be expected to result from a worst case combination of hurricane landfall location, forward speed, and direction for each hurricane category.
3. The FEMA 100-year flood zones are shown for reference to depict those areas beyond the hurricane surge inundation areas where coastal or inland flooding may be expected.
4. Ground elevation data was obtained from MassGIS, and were developed from 1:5000 scale aerial photography. The vertical accuracy is approximately +/- 5 feet, and the horizontal accuracy is approximately +/- 10 feet.
5. The locations of shelters were obtained from local Emergency Management Directors and State and Regional Red Cross Officials.
6. The locations of Hospitals and Medical Facilities were obtained from local Emergency Management Directors and existing mapping sources.
7. Basemap features such as roads and streams were obtained from MassGIS, and most have a source scale of 1:24,000.

Point ID	Ground Elevation	Reference Points Peak Hurricane Surge Elevations Category 1	Category 2	Category 3	Category 4
43	6.2	8.8	12.2	11.8	13.9
44	6.1	9.3	12.7	12.2	14.4
52	9.5	9.1	12.9	12.7	14.0
53	8.4	9.2	12.7	12.0	14.5
54	5.7	9.2	12.7	12.0	14.5

Note:
All elevations are in feet above NGVD (National Geodetic Vertical Datum) of 1929.

US Army Corps of Engineers New England District

MASS GIS

0.25 0 0.25 0.5 Miles

Scale: 1" = 1/4 mile

Sheet 6a of 11

Appendix C. To Mayor Menino.

(Images courtesy of the New England Aquarium)

Appendix D. To Mayor Menino.

Adaptation	Description	Pros	Cons
Salt-resistant building materials	Any portions of a building that are below a certain elevation above mean sea level must be constructed using salt-resistant materials	Inundation with sea water will not easily corrode the structure, thus saving repair costs	May present extra expense in buying more salt-resistance building materials
Waterproof shields/shutters for doors and windows	Waterproof shields and shutters can be placed in front of doors and windows in the case of a storm surge	Inexpensive; quick	Must be actively used
Increase durability of windows and doors	Windows and doors must adhere to a specific standard in order to better resist flooding	Building's resistance to flooding will increase; Storm surges will not easily break windows/doors, thus saving repair costs	May present extra expense in buying more durable windows and doors
Raise entrances and windows	Windows and doors must be placed at a certain elevation above mean sea levels	Building's resistance to flooding will increase	Can cause aesthetic problems; Raising entrances causes ADA issues
Raise foundation	The tops of foundations must meet a certain elevation above mean sea levels	Building's resistance to flooding will increase	Raising entrances causes ADA issues; ADA issues cause spacial issues
Parking garages below grade or on first floor	A parking garage must be the lowest level of a building	Added parking for visitors/tenants; Human life will not be at risk; Habitable space will not be at risk	Floodwaters must then be pumped from garage
Plan for future evacuation of first floor	Buildings are built in such a way that in the event of a permanent flood, the first floor can be filled in to make the second floor at entry level	Human life will not be at risk; Habitable space will not be at risk;	Space will be lost building-wide; Tenants will lose their space; If not included in planning, entryways will need to be retrofitted to new entry level
Lift buildings on piles or "free-board" [2]	The first vertical members of a structure are supported by piles and raised either above the projected flood level or a full story above the ground (to allow for dry-weather use of the ground plane)	Human life will not be at risk; Habitable space will not be at risk; If unused, very minimal damage should be caused by flooding	Relatively expensive for larger buildings; Creates the challenge of being able to meet the street for entrances
Amphibious buildings[5]	Buildings rest on land during low water levels, but have the flexibility to float with rising water levels while staying anchored to flexible mooring posts	Combines the advantage of a seamless ground level building during fair weather with the ability to avoid ground level flooding; can accommodate a variety of flood heights	More expensive at this time than traditional building; remains vulnerable to the force of winds and waves along a high-energy coastline
Floating buildings[5]	From houseboats to modern water villas to multiunit communities with full-fledged floating foundations, open space, and utility units protected in integrated piping	Can use the water sheet as a building plot while allowing structures to accommodate steady fluctuations in water level; can accommodate a variety of flood heights	Still relatively expensive; may disrupt near shore habitats; remains vulnerable to the force of winds and waves along a high-energy coastline

[2] These adaptations and their descriptions taken from "Sea Level Rise in East Boston: Innovative Planning and Design Solutions for Sustainable, Equitable and Creative Redevelopment" by V. Wolff (2011).

Appendix E. To Mayor Menino.

Beaulieu, D., Colon, J., & Toussi, D. (2011). *Sea level rise adaptation in the Boston Harbor area*. An IQP Report at Worcester Polytechnic Institute.

The writers of this memo wrote a full, in depth report regarding sea level rise adaptations in Boston. This report contains information on various wet and dry floodproofing adaptations that can be applied to protect Boston's buildings, as well as research containing damage estimates and claims information against flood insurance in the Commonwealth of Massachusetts. Email bh11@wpi.edu to request for this full report or contact the WPI Gordon Library (Phone: (508) 831-5410 - Fax: (508) 831-5829)

Cohen, L., Jacobs, W., & McGrory, J. (2011). Overview of options & recommended actions. *Legal Options for Municipal Climate Adaptation in South Boston*. Retrieved 30 August, 2011 from http://www.law.harvard.edu/academics/clinical/elpc/publications/climate-adaptation-final_8-25-11.pdf

This document contains different ways that Boston can mandate different flood resilient construction and design techniques into the development of buildings. The report contains an in depth list and process of what can currently be done, what can't be done, and what can be improved to include these adaptation mandating. Some legal methods that this report covers include introducing a stretch code for these adaptations, or expanding the zoning areas in relationship to FEMA maps, or making changes to the building code.

Kirshen, P. (2011, September 12). Personal Interview.

Lenton, T, Footitt, A, & Dlugolecki, A (2009). *Major tipping points in the earth's climate system and consequences for the insurance sector*. Munich, Germany: WWF - World Wide Fund for Nature and Allianz SE. 33-34. Retrieved 8 September, 2011 from http://www.worldwildlife.org/climate/Publications/WWFBinaryitem14354.pdf

This document covers the various expected projections for sea level rise and how they will affect deferent areas of the United States. The authors focus their detail on the economic impacts of sea level rise and coastal flooding, and discuss a change in asset exposure over time for various vulnerable areas.

Partners HealthCare Inc. (2009). Case Study. *Spaulding Rehabilitation Hospital and Projected Sea Level Rise*. 2-7.

This document outlines the steps taken by the designers of the new Spaulding Rehabilitation Hospital on the Charlestown Navy Yard to adapt to sea level rise. Both this document and this project are excellent examples for developers in the City of Boston to follow when adapting to sea level rise. Contact Partners HealthCare Inc. for the full document.

Ris, B. (2011, September 2). Personal Interview.

6 Conclusion

From all of the information that we have gathered, we have come up with three recommendations for the City of Boston. These recommendations will help them to begin to alter regulations regarding flood damage prevention measures used in new construction. Once these regulations have been altered, developers will begin to plan their buildings with more consideration towards sea level rise and flooding.

6.1 – Recommendations

Our recommendations to the City of Boston on behalf of The Boston Harbor Association are geared toward policymakers who can make changes in the zoning codes and the way developers plan their buildings. The following summarizes the recommendations we made to the City of Boston in the memo from the previous chapter.

6.1.1 – Zoning Code Changes

Since waterfront zoning is currently based on the FEMA flood maps which are based on historical data of flooding due to rainfall, developers are not worried about their structures will be susceptible to flooding. These FEMA maps do not show flooding due to coastal storm surges. In contrast, the Army Corps of Engineers' (ACE) "Hurricane Surge Inundation" maps and the "Sea, Lake, and Overland Surge from Hurricanes" (SLOSH) model show flooding due to storm surges and are partially based on both historical data and computer modeling. The ACE maps and SLOSH model should be used for waterfront zoning rather than the FEMA maps for both the

100-year and 500-year flood scenarios. This will help the City of Boston mandate changes for developers to make their buildings more flood resilient.

6.1.2 – Requirements for Upcoming Harbor Plans

Our second recommendation to the City involves the Boston Redevelopment Authority and their upcoming Harbor plans. The City of Boston should require all upcoming Harbor plans utilize the ACE maps and the SLOSH model instead of the FEMA maps when considering flooding, and use effective adaptations. These effective adaptations include the sea level rise adaptation techniques we outlined in chapter 4 of this report. Along with our first recommendation, this would make it so all developers working on new projects or major renovations of buildings in Boston would have to use the ACE maps and SLOSH model when considering how to protect their buildings from flood damage.

6.1.3 – Floodable Zones

Most cities around the world that are seeking adaptation techniques to protect against flood waters have created walls, flood gates, or levees. This is not a viable option for the City of Boston because a great deal of effort was recently spent on beautifying the Harbor and the surrounding area. A wall, flood gate, or levee would take away from the aesthetic value of the Harbor. The City of Boston should seek alternatives instead. These alternatives would include the use of "floodable zones". An example of a "floodable zone" is the Harbor Walk around the perimeter of Boston Harbor. During a storm surge, floodwaters would flood the "floodable zone" which would absorb all off the floodwater in order to protect the surrounding higher value areas from flood damage. These zones should be created in areas that are at a high risk of being flooded during storm surges.

Since Boston is a coastal city and predictions show that the sea levels around the globe are rising, protecting the waterfront buildings should be at the forefront of concerns for the City and developers. Our methods have shown that action must be taken today to protect against the 1 to 5 foot sea level rise by the year 2100. This action, to be taken by the City of Boston, should change the zoning regulations to utilize ACE maps and the SLOSH model instead of FEMA maps, it should mandate developers to utilize the ACE maps and SLOSH model when considering flood damage prevention in their buildings, and "floodable zones" should be created in the most flood-prone areas on the waterfront. Together, with the specific sea level rise adaptations outlined in chapter 4, Boston will become the world leader in preparing for the future sea level rise and protecting its buildings from the dangers of the flooding that comes with it.

Glossary

100-Year Flood

The level of flood water expected to be equaled or exceeded every 100 years on average

500-Year Flood

The level of flood water expected to be equaled or exceeded every 500 years on average

ATs

Adaptation Techniques – construction practices that can be applied to buildings in order to make them more flood resistant

ASCE

American Society of Civil Engineers – organization that provides a library and collective information regarding various civil engineering topics and regulations

BCB

Boston City Base – a datum used by the City of Boston as a measurement of the elevations of buildings in relation to the mean sea level

Dry Floodproofing

A type of floodproofing that keeps water out of a structure or an area containing the structure

DFE

Design Flood Elevation – the minimum height requirement for a specific area above the Base Flood elevation

FAA

Federal Aviation Administration – an organization that determines the regulations for air control in respects to various aircrafts and sounding areas to airports

FEMA

Federal Emergency Management Agency – an agency of the United States Department of Homeland Security, charged with coordinating the response to disasters in the United States that overwhelm the resources of local and state authorities

FEIR

Final Environmental Impact Report – a report and information on the current projects being built in the Innovation District, South Boston (Sea Port Square, Pier 4, Fan Pier)

FIRM

Flood Insurance Rate Map – an official map of a community within the United States that displays the floodplains, more explicitly special hazard areas and risk premium zones, as delineated by the Federal Emergency Management Agency (FEMA)

IBC

International Building Code – a general set of standards in building codes that are used throughout the world (generally adopted for its standard structure but gets altered depending on the location)

MSL

Mean Sea Level – a datum used by the United States as a measurement of the elevations of buildings in relation to the mean sea level

MTA

Metropolitan Transpiration Authority – an organization designed to handle the research and organization regarding the public metropolitan transportation

NOAA

National Oceanic and Atmospheric Administration – a federal agency that focuses their research on the condition of the ocean and atmosphere

NFIP

National Flood Insurance Program – a program created by the Congress of the United States that enables property owners in participating communities to purchase insurance protection from the government against losses from flooding

OECD

Organization for Economic Co-Operation and Development –international organization helping governments tackle the economic, social and governance challenges of a globalized economy

POT

Path of Travel – the path or entry ways in public buildings that society has access to

SLR

Sea Level Rise – a global phenomenon where the mean sea level is rising due to the melting of ice caps, climate change, and the thermal expansion of the ocean

TBHA

The Boston Harbor Association – the leading harbor advocacy group working to promote a clean, alive, and accessible Boston Harbor

Wet Floodproofing

A type of floodproofing that protects structures in a manner that allows floodwaters to encroach on and even enter a building

WWF

World Wildlife Foundation – a leading organization in wildlife conservation and endangered species

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Appendix A – The Boston Harbor Association

The Boston Harbor Association (TBHA) (2011c) is a non-profit organization that focuses on creating an attractive Boston Harbor in order to promote various public activities. TBHA consistently promotes a clean, diverse harbor by adapting to different harbor-front interests such as those of harbor users, environmentalists, developers, waterfront businesses, and the like. The organization also considers Boston Harbor as a recreational and tourist asset and works on restoring the beaches and other public access points. Additionally, TBHA concentrates on improving maritime transportation in Boston Harbor and the conditions of the water quality. Their agenda also includes raising awareness of the dangers of sea-level rise in the Boston Harbor area, and they are leaders in focusing attention on this issue.

As a leader in focusing public attention on SLR in Boston Harbor, the Boston Harbor Association (2011c, para. 1) works to put more attention on how structures are being built with (or without) appropriate water-protective resources. They also focus on retrofitting existing buildings. TBHA (2011a, para. 22) hosts various events regarding the state of the harbor. On November 9-10, 2010, TBHA hosted the "Boston Harbor Sea Level Rise Forum". This event consisted of viewings of maps showing the potential impact of SLR and climate change on Boston Harbor, and "open mike sessions" that allowed the public to offer comments and ask questions regarding SLR and climate change.

TBHA (2011b) is structured such that there are specific officers who maintain the organization, as well as a board of trustees from other organizations who work alongside TBHA to achieve its goals. The board of trustees includes members from such organizations as the Gillette Company, New England Aquarium, UMASS Boston, and the Massachusetts Water Resources Authority. Lastly, there are three staff members, one of which is our team's liaison: President Vivien Li.

Since the Boston Harbor Association (2011c) is not-for-profit, its funding comes from donations, memberships, and revenue from sightseeing activities in and around the harbor. Paid memberships give the member advance notice of events and programs as well as a monthly newsletter. Also, because TBHA only seeks to better Boston Harbor, there are no competitor organizations. Instead, the Boston Harbor Association works with a variety of organizations and sponsors to accomplish their goal. Among the 120 sponsors and supporters, some groups who work alongside TBHA are: Massachusetts Bay Line Inc.; Coastal Marine Management; Boston Autoport; and the Boston Harbor Pilot Association. The Boston Harbor Association also provides a variety of educational programs for groups, classes, and the general public to provide information on Boston Harbor. By doing this, the Boston Harbor Association hopes to generate a greater public understanding and appreciation of Boston Harbor.

Appendix B – Interviews

Over the course of our project, we were able to meet with the following people:

Name	Organization	Title
Bud Ris	New England Aquarium	President and CEO (trustee of TBHA)
Bryan Glascock	City of Boston	Commissioner of Environment for Boston
Jacob Glickel	City of Boston	Chief of Staff, Office of Environmental and Energy Services
Carl Spector	City of Boston	Executive Director, Air Pollution Control Commission
Brad Swing	City of Boston	Director of Energy Policy
Hubert Murray	Partners HealthCare	Manager of Sustainable Initiatives
David Burson	Partners HealthCare	Senior Project Manager
Sandra Brock	Nitsch Engineering	Chief Engineer
Amy Prange	Nitsch Engineering	Project Designer
Shawn Smith	Nitsch Engineering	Project Engineer
Tim McGivern	Nitsch Engineering	Project Engineer
Matthew Kiefer	Goulston & Storrs	Director
Paul Kirshen	Battelle Memorial Institute	Research Leader
Andrew Albers	Gale International	Director of Sustainable Development
David Wamester	Boston Global Investors	Executive VP & Director
John Twohig	Goulston & Storrs	Director
William Cronin	New England Development	Senior VP
Robert Daylor	Tetra Tech	Senior VP
George Tremblay	Arrowstreet	Principal of Pier 4 Development

From these people we learned the following:

- **SLR in Boston**
    - Water is already 11 inches higher than 100 years ago
    - Boston will get between 2 and 6 feet MSL rise in the next 100 years
    - Annual rise is estimated at 1.5 to over 3mm MSL rise per year
- **Flooding in Boston**
    - Long Wharf is under water several times a year from normal tide cycle. AKA "wicked high tide"
- **Buildings in Boston**
    - New Spaulding Rehab Hospital is being built in Charlestown
        - Raised 1 foot to accommodate for a 2-3 foot rise within the building's lifespan
        - Raising the building took it out of the 500-year floodplain
        - Every opening into the building was raised

        - Utilities were placed on top levels
        - Has approximate 80-year lifespan

- **Flooding Elsewhere to Consider**
    - Holland
    - England
    - Venice
    - NYC
    - Nashville, Tennessee
    - New Orleans, Louisiana
    - Norfolk, Virginia
- **Insurance**
    - Travelers insurance deals a lot with insurance coverage dealing with SLR
    - NFIP only applies to cities that choose to adopt FEMA's regulations
- **Building Codes**
    - Flood-resistant construction applies only to certain areas, and requires certain elevations of buildings
    - Code can be changed to allow for ATs if needed
    - Code usually sets a standard, but does not set a guideline
    - Florida updated its building codes in 2004 after Hurricane Charlie, and saw improved building resiliency
    - Code puts height restrictions on buildings in certain zones, causing problems for foundation raising
    - If cost of renovation of a building is more than 50% of the cost of that building, the building must then update according to current building codes
- **Utilities**
    - Aquarium moved utilities to top floors
    - Spaulding had to fight NSTAR to be able to make the utility move possible
        - Utility companies need to have easy access and they have limits to what how high up utilities can be placed
- **Potential ATs**
    - Moving utilities from bottom floors to top floors
    - Parking garages as bottom floors so that they can mitigate flooding
    - Plan on abandoning lower floors – used for retail – over time as the water rises (potential for abandonment)
    - Salt water resistant materials should be used in buildings
    - Raising foundations
        - Inexpensive
    - Sealing buildings past the foundation, possibly to the second floor
        - Windows and doors might raise an issue
    - Require that all glass/windows/holes in a building are located above a certain height
        - Inexpensive, goes into the planning of the building

- **Costs/Issues**
  - Aquarium utility retrofit was a “million-dollar” project
  - Increasing foundation height is not a major cost at the time of construction, but it does cause aesthetic and accessibility problems
    - Accessibility must abide by Americans with Disabilities Act (ADA) requirements
      - Public buildings must have properly graded ramps, which cannot necessarily go out onto the sidewalk, thus taking up building space
      - Meeting ADA requirements with a raised foundation incurs special and aesthetic issues
    - Raised foundations cause aesthetic issues, which raise marketing issues
- **Benefits**
  - Operation costs will go down over the long-term with the use of ATs
  - Insurance rates will go down:
    - At a city-wide level as fewer claims are made on insurance after the implementation of ATs
    - At an individual level as buildings are less vulnerable to damage

The following is a record of out meeting minutes for each interview.

Team Meeting Minutes
Boston Harbor Group
9:30AM August 31, 2011
Boston City Hall Room 805
Chair: Danielle Beaulieu
Secretary: Jeremy Colon

Team Members Present:
Danielle Beaulieu, Jeremy Colon, Darius Toussi

Other Persons Present:
Name: Vivien Li
Title: President of The Boston Harbor Association

Name: Julie Wormser
Title: Executive Director of The Boston Harbor Association

Name: Bryan Glascock
Title: Commissioner of Environment for Boston

Name: Jacob Glickel
Title: Chief of Staff at City of Boston Office of Environmental and Energy Services

Name: Carl Spector
Title: Executive Director, Air Pollution Control Commission at City of Boston

Name: Brad Swing
Title: Director at Renew Boston Program
Member, Board of Directors (Chairman, 2005-2008) at Victory Programs, Inc.
Director of Energy Policy at City of Boston, Office of the Mayor

To begin this meeting, Danielle briefed everybody about the goals of the project. We will be looking into sea level rise adaptations in order to make Boston a more flood-resilient city. We will look into Boston's building and zoning codes in order to determined current flood resilient design regulations to see which standards should be made more stringent.

Brad Swing began discussion by stating that there is a big difference between federal and state law. Massachusetts does not have the ability to create its own building codes, but instead must abide by the International Building Code. There is, however, a Board of Building Regulations and Standards that may make changes to the code standards. The Boston Redevelopment Authority, who is governed by a board and not the state, can approve changes to codes and then pass it on to the Zoning Commission for approval. Mr. Swing then went on to say that zoning code regulates the height, massing, setbacks, and usage of buildings, whereas the building codes determine how a building is built. Zoning codes also sets flood regulations.

Next the Mayor's climate action committee was mentioned. One of their recommendations from them regarding adaptations was that the city should take an in depth look at a small sector and decide what specifically should be done to protect the buildings from SLR. There has been some progress made here by the city.

The option of adding a new stretch code to the building code was mentioned. This would be similar to the stretch energy code that was recently implemented. In this code, the state gave the cities and towns the option of adopting an energy code that is more efficient than the base code. This means that over time, the stretch code will eventually be merged into the base code. The same thing can be done with the building codes. This would create an optional provision unlike any other in the current building code that would be slowly adapted over time.

It was then suggested that we take a small part of the city and use it as a case study to help us create a list of adaptations that would be included in a new stretch building code. The Mayor wants his legacy to be in the Innovation District in South Boston, and it was suggested that that is where we should look. Current projects in the Innovation District are Pier 4, Seaport Square, and Fan Pier. Vivien said that she will help us get into contact with the developers of these projects.

Along with a case study of the Innovation District, everyone agreed that we should study what ATs have been utilized elsewhere in the world. We can take this information and compile a list of specific ATs and give that to the City of Boston.

Danielle asked for more contacts, to which we received the names of Paul Kirshen, the developers of the South Boston projects, insurance companies and re-insurance companies.

Team Meeting Minutes
Boston Harbor Group
10:00AM September 2, 2011
Bud Ris's Office, 177 Milk Street 4th Floor
Chair: Danielle Beaulieu
Secretary: Jeremy Colon

Team Members Present:
Danielle Beaulieu, Jeremy Colon, Darius Toussi

Other Persons Present:
Name: Bud Ris
Title: President and CEO of the New England Aquarium

Bud Ris began the discussion by suggesting that we speak to insurance companies about possible incentives for building owners to upgrade their building's flood resiliency. He suggested speaking to Traveler's Insurance, as they are the leaders in thinking about climate change and its effects. Mr. Ris added that Massachusetts insurance companies can only raise rates if they get permission from the insurance commissioner. He also said that insurance companies would most likely be willing to lower their rates if buildings implemented some adaptations.

When asked about the New England Aquarium's flood resiliency, Mr. Ris responded that the structure was not built under the assumption that SLR would affect it. However, in 2006, all major electrical equipment was moved up from the lower floors of the building to keep it out of the way of possible flood damage. This move was a retrofit, and therefore was extremely expensive; specifically, this upgrade cost the Aquarium over $1 million.

Mr. Ris mentioned that Long Wharf, which is a site not more than a half of a mile away from the Aquarium, is underwater several times a year. This is due to astronomical high tides. He stated that the HarborWalk on Long Wharf is underwater sometimes, as well, through it has been raised on the south and east side of Long Wharf. In addition to this, the Aquarium is developing a plan to make the new sections of the HarborWalk even higher in order to resist flooding.

On the subject of sea level rise, Bud Ris stated that the sea level in Boston Harbor is about eleven inches higher than it was only a century ago. This rise in sea levels causes two issues: a 2 to 6 foot sea level rise in Boston over the next century; and the threat of worsened storm surges. New data shows the annual change has changed from 1.5 to over 3 mm per year.

Bud Ris knew of two projects in Boston that have considered sea level rise in their design; the new Spaulding Rehabilitation Hospital on the Charlestown Navy Yard and the Deer Island Wastewater Treatment Plant. Spaulding chose to put its electrical switchgear on the top floors as well as raise its foundation and entrances one foot above 500-year flood levels. Deer Island increased its elevation by two feet. Other places around the world, such as Denmark and Italy, floodgates have been constructed in order to protect their cities. He had also heard that New York City was working on a project to adapt to sea level rise.

Mr. Ris stated that he believes that Boston should start considering sea level rise adaptations by incorporating them into the building codes. This would ensure that new buildings would be protected from sea level rise and flooding. He does not think that a sea wall would be a good choice, because of the ecological issues that it would create, the unsightliness of such a wall, and problems that it would create with transit into and out of the harbor. Mr. Ris also suggested that another outlet for implementing sea level rise techniques would be to update flood maps of the area that have been set by FEMA. Because the agency does not consider sea level rise in its mappings, they are not accurate for predicting future flood damage.

When asked for additional contacts for our project, Bud Ris suggested that we talk to architects and engineers who work in the Boston Harbor area. He also suggested that we try to talk to Boston Properties, who renovated Atlantic Wharf. Some other contacts included Joe Fallon, a developer in the Innovation District, Ellen Douglas from UMass Boston, and Paul Kirshen from Battelle Institute.

Team Meeting Minutes
Boston Harbor Group
3:30PM September 7, 2011
Hubert Murray's Office, 101 Merrimack Street 8th Floor
Chair: Danielle Beaulieu
Secretary: Jeremy Colon

Team Members Present:
Danielle Beaulieu, Jeremy Colon, Darius Toussi

Others Persons Present:
Name: Hubert Murray
Title: FAIA, RIBA, Manager of Sustainable Initiatives Partners HealthCare

Name: David Burson
Title: AIA, NCARB, Senior Project Manager of Partners HealthCare

Danielle began the meeting by briefing Hubert Murray and David Burson on our project. She told them what the IQP is, how we ended up working with TBHA, and the fact that we're working on SLR ATs for new construction in the Innovation District. Last week we met with city officials about zoning codes and regulations. They told us that we should collect a list of different ATs and compile our own list of practical techniques to use in Boston.

Mr. Murray ad Mr. Burson both had a large part in the techniques that are being used in the new Spaulding Rehab Hospital in the Charlestown Navy Yard. Mr. Burson is a project manager and currently is focused on the new Spaulding Rehab Hospital. Hubert is the manager of sustainable initiatives. They mentioned that Spaulding is located on the waterfront and they are anticipating the effects of global warming and SLR in the future. It is planned to have an 80 year lifespan, and is designed to be able to withstand floods.

Mr. Burson mentioned that we referenced the building codes in our proposal, and he suggested that we look into the Army Corps of Engineers guidelines, as they are more specific than the IBC.

When Mr. Murray was asked about if he knew anything about where ATs have been used on a building-by-building basis, he said he did not know any specific examples. He said that he knows of places such as Amsterdam that have been utilizing community wide techniques. Mr. Murray gave us two potential contacts for what Amsterdam and Venice have done.

Next, Mr. Burson went into more detail about the specifics of why they decided to make Spaulding a sustainable and resilient building. He said that they wanted to be a leader in the field and make a new benchmark for Partners Healthcare. They were prompted by the tragedy of Hurricane Katrina and the floods in Nashville, Tennessee. Mr. Burson stated that they opted to move the primary electrical switch gear up to the penthouse level of the building. They included a 4 day emergency generator as well. He mentioned that they are expecting 2-3 feet of SLR in the next century, and they raised Spaulding a foot to accommodate this. They also only placed critical patient facilities on the upper floors.

Next, Mr Murray went on to say that parking garages are commonly used as the bottom floor of a building because they are non-habitable space and can flood without risk to human life. He also said that in moving utilities to the upper floors, they faced resistance from the fire department and NSTAR. He said they were not willing to embrace the changes and that a code or regulatory requirement would help to cause less resistance.

The discussion went on to FEMA and the FIRMs. Since the FIRMs are only based on historical flood data, and not projections, the requirements set by FEMA do not help to protect against SLR and future flooding. Mr. Murray and Mr. Burson agreed that FEMA's guidelines, along with projections of future sea levels would be helpful to utilize when looking into protecting buildings from SLR. The problem here is that in many parts of the country, SLR is considered more as speculation than fact.

When asked about creating a new stretch building code for SLR adaptations, Mr. Murray said that he thinks the zoning codes would be better to change. The zoning codes would be much easier to change than the building codes.

Next we asked for additional contacts. Mr. Burson said that VHBR civil engineers might be helpful. Mr. Murray also said that we should contact someone in the field of insurance. Specifically, he told us to contact Matthew Kiefer who is a lawyer working with the Seaport Square developers at Goulston & Storrs. Mr. Murray also said that the re-insurance industry is increasingly concerned about SLR. He also said that we should look at a document called "Major Tipping Points" that talks about SLR in Boston. Specifically that by the year 2050, within the bounds of IPCC projections, Boston stands to have $463 billion at risk due to SLR. Lastly, Mr Murray told us to look into the Dutch Delta Commission and a document called "Working with Water".

Team Meeting Minutes
Boston Harbor Group
12:30PM September 9, 2011
Nitsch Engineering 186 Lincoln Street Suite 200
Chair: Danielle Beaulieu
Secretary: Jeremy Colon

Team Members Present:
Danielle Beaulieu, Jeremy Colon, Darius Toussi

Other Persons Present:
Name: Sandra Brock
Title: Chief Engineer at Nitsch Engineering

Name: Amy Prange
Title: Project Designer at Nitsch Engineering

Name: Shawn Smith
Title: Project Enginner at Nitsch Engineering

Name: Tim McGivern
Title: Project Engineer at Nitsch Engineering

Ms. Brock began the discussion by talking about habitable space in the 100-year floodplain. For example, using a garage as the lower floor of a building would be a good use of non-habitable space to mitigate flood damage.

Mr. Smith went on to talk about the insurance industry. He said that insurance companies are constantly trying to raise their rates, and that the political aspect of this is currently at a dead end. Also, FEMA only uses historical date for the FIRMs, which is a problem. Mr. Smith also added that flood insurance is very hard to get if the building to be insured is outside of a floodplain. In addition, there will be a point when re-insurance companies will not be able to pay for the claims for flood damage from insurance companies.

The discussion went on to more specifics about ATs. For example, when considering ATs, it is important to also consider the timeline of a building: how long will it take to build, how long it will be used, and where the habitable vs. non-habitable space will be. Also, the State usually does a lifecycle analysis of 50 years.

We also talked about ATs such as raising foundations. This would not cause much expense if done at the time of construction, but it does cause aesthetic problems as well as problems with meeting ADA regulations. When the building is higher up, it must still be accessible to disabled people. This means that there will need to be ramps and/or elevators into the building.

Another adaptation we discussed was abandonment of the first floor during a flood. This would involve the first floor only being used for retail and not residential, and all of the retail would have to utilize large freight elevators to move their merchandise to upper floors of the building temporarily.

Mr. McGivern informed us of the fact that the City of Seattle had sunken over the years. In sections of the city, the first level had to be filled in, and new roads were constructed on top of the old first level. This is something that could be done in the distant future after SLR has caused waters to take over most of the lower levels of the city.

A huge problem regarding SLR is getting people to "buy in". There has to be some sort of marketing campaign to incentivize people to utilize adaptations in their buildings.

For additional contacts, it was suggested that we contact somebody from the Green Ribbon Commission and that Vivien Li might know some of these people. We were also given the Cambridge city engineer as a possible contact because he is concerned about SLR. Other possible contacts include the Union of Concerned Scientists, Mass Water and Sewer Commission, and someone in the geo tech field.

Team Meeting Minutes
Boston Harbor Group
2:00PM September 12, 2011
1 Cranberry Hill, Lexington MA
Chair: Danielle Beaulieu
Secretary: Jeremy Colon

Team Members Present:
Danielle Beaulieu, Jeremy Colon, Darius Toussi

Others Persons Present:
Name: Paul Kirshen
Title: Research Leader, Battelle Memorial Institute

Paul Kirshen began discussion by stating that a 100-year flood in Boston would cause four feet of storm surge and floodwaters to affected areas. If this flood occurs at high tide, this will add four feet to that surge, making it a total eight feet of high water. Mr. Kirshen predicts that by 2050, we will have about two feet of sea level rise or higher. He also added that there is only one foot of difference between the 10-year flood and 100-year flood, which would make 100-year floods much more frequent should sea levels continue to rise at their current rate. He suggested that some adaptations might include building barriers around specific areas, waterproofing foundations, allowing basements to flood, or allowing the first floor or buildings to be evacuated in the event of a major flood event. Boston might consider flexible sea walls that have room to expand wider and higher, though citizens would probably protest this idea because of the look that it would give to the harbor.

Mr. Kirshen then brought up the point that most developers only want to keep their buildings for a certain amount of time until they are able to sell them. From the moment that a building begins construction, the property is covered by flood insurance. He suggested that we consider recovery after a flood in our analysis of adaptation techniques.

Paul Kirshen also suggested that in order for our work to be more prominent, we will need to consider that some people are still not convinced that climate change is happening. We will need to produce a gathering of evidence that sea level rise is a real problem. We should explain in our report about the melting ice caps and the warming global climate. We also need to provide a full range of possible outcomes for the amount of sea level rise over the next century, because modern science cannot accurately predict the correct amount. Mr. Kirshen also said that we can safely say that it is much more expensive to retrofit or rebuild after flood damage than it would be to include adaptations into the designs of buildings, so we should state this in our report as well.

When asked for additional contacts for our report, Mr. Kirshen suggested that we contact the Boston Redevelopment Authority and the Boston Water and Sewer Commission. To get information about infrastructure, he suggested that we contact the Chamber of Commerce, the Metropolitan Planning Council, the Boston Public Health Department, and electricity providers.

Team Meeting Minutes
Boston Harbor Group
2:00PM September 16, 2011
TBHA Office
Chair: Danielle Beaulieu
Secretary: Jeremy Colon

Team Members Present:
Danielle Beaulieu, Jeremy Colon, Darius Toussi

Others Persons Present:
Name: Matthew Kiefer
Title: Director at Goulston & Storrs

To begin discussion, Matthew Kiefer briefed us on what he does. He is a land use lawyer, and he represents project components in getting projects approved. He focuses on the environment in his work. Mr. Kiefer explained to us that the goal of most construction is very basic flood proofing. Standard practices call for builders to pick the maximum flood elevation to plan for during construction. However, the reason builders find it hard to adapt to sea level rise is because the levels of sea level rise will be very hard to predict.

Mr. Kiefer informed us that Seaport Square is a mixed use project. There is one master developer for this project; a joint venture of Boston Global Investors and Morgan Stanley. This project has included a section about climate change adaptation in their Final Environmental Impact Report, and we should look into the specifics in that document. In addition to Seaport Square, Mr. Kiefer suggested that we look into the new Spaulding Rehabilitation Hospital in the Charlestown Navy Yard. He said that they plan to include garages on the lower levels, and that they will put all of their electrical equipment on the top floors.

We then asked Mr. Kiefer what he could tell us about flood insurance. He went on to say that insurance is required for all buildings, and some large corporations like Harvard are self-insured because they have enough property to spread the risk and cover losses themselves. However, most private development has to have insurance. Private companies do not like to provide insurance to flood prone areas, and that is why the government got into the flood insurance business through FEMA. Mr. Kiefer went on to tell us that re-insurance companies are companies that insure insurance companies, and they are becoming increasingly concerned with climate change because their payout is increasing as a result of it. Basically, the more severe the climate change is, the more re-insurance companies may have to pay, because these companies buy huge amounts of policies. Because of this climate change, premiums are going up, and coverage is getting harder to obtain. We asked Mr. Kiefer how insurance worked during the construction phases of a project, and he told us that developers cannot get a loan for the project without having insurance. This is called Builder's Risk insurance, which is purchased prior to construction. There is no federal program for this insurance.

When asked for additional contacts for our project, Mr. Kiefer suggested that we speak to an insurance agent about discounts that they might offer for including flood adaptation techniques. We might also be interested in talking to representatives from MassPort.

Team Meeting Minutes
Boston Harbor Group
2:00PM September 26, 2011
1 Post Office Square Suite 3150
Chair: Danielle Beaulieu
Secretary: Jeremy Colon

Team Members Present:
Danielle Beaulieu, Jeremy Colon, Darius Toussi

Others Present:
Name: Andrew Albers
Title: Director of Sustainable Development, Gale International

Name: David Wamester
Title: Executive VP & Director, Boston Global Investors

To begin discussion, Andrew Albers mentioned that the new Spaulding Rehabilitation Hospital and Joe Fallon's Fan Pier would be places of interest for our project. He went on to explain that there are no requirements for designing for a 100-year flood event. Mr. Albers believes that developers should design not only for the 100-year flood, but for the 500-year flood as well. This would be a challenge, he said, because developers are concerned with the money being spent on construction more than climate change.

In terms of Seaport Square, we learned that all of the parking will be underground. The groundwater at that project is around +11-12 BCB, which restricts how far down they are able to dig to construct their garages, and they will probably be two or three levels. The development team is facing issues with ventilating the garages above the ground without allowing flood waters through these vents. They have considered using the first floor for ventilation, but this creates problems with losing sidewalk space, or rented space for offices, retail, or residential areas. Mr. Albers went on to state that the garage entrances will be kept at a certain level above flood levels. Pedestrian entrances are planned to be above a certain level as well. Developers of the project will use ramps and stairs to place the entrances two to three feet above the minimum required elevation. This would be at least +18 BCB.

Some adaptations that Mr. Albers suggested looking into included temporary sea walls that could be raised in the event of a flood. These countermeasures would need to be deployed prior to a storm surge, and they would cause a loss of access to the building while they are deployed. Raising the foundations of buildings create problems with ADA regulations, however, because a one foot rise would then require twenty feet of ramps at a 5% incline. These ramps would either cut into sidewalk space, or space inside of the building. Mr. Albers also mentioned that the FAA puts height restrictions on buildings in the Innovation District because of its location relative to Logan Airport. This is to make sure that in the event of an unusually low take off, planes will not see interference from buildings in South Boston.

Team Meeting Minutes
Boston Harbor Group
1:00PM October 5, 2011
Goulston & Storrs, 400 Atlantic Ave, Boston
Chair: Danielle Beaulieu
Secretary: Jeremy Colon

Team Members Present:
Danielle Beaulieu, Jeremy Colon, Darius Toussi

Others Present:

Name: William Cronin
Title: Senior VP, New England Development

Name: Robert Daylor
Title: Senior VP, Tetra Tech

Name: Vivien Li
Title: President, The Boston Harbor Association

Name: George Tremblay
Title: Principal of Pier 4 Development

Name: John Twohig
Title: Director at Goulston & Storrs

Vivien led off the meeting introducing our project and what we have done so far. Mayor Menino is very interested in development in the Innovation District. It would be useful to us to talk to the actual developers working on some of the projects in South BOston.

John Twohig gave an overview of the Pier 4 project. We saw the project plans and the stages of construction they will do. There are 3 buildings and a park. He talked about all of the reviews and regulations they had to go through to get the project approved for construction. They are finalizing the preparatory stage and are hoping to start construction in early 2012.

George Tremblay talked a little bit about the adapations they are taking into account. The biggest of which is that the buildings are being raised in 6 inch increments as they get closer to the water. Each building will have 3 levels of underground parking as well. On the topic of parking, it is 10 times more expensive to build parking in a garage than on the surface. Also, the main concerns of the project are the FAA regulations and water coming into the buildings from the pier.

Next he discussion moved to considerations when building on the waterfront. The two major techniques are to either rive pile down to bedrock and build up, or drive sheeting down into the clay and excavate everything out which creates essentially a "bathtub". The physical characteristics of the underlying soils need to be taken into account too so the building won't just sink into the ground. For example, when the John Hancock Tower was built, the construction de-watered the area which caused the Trinity church to begin to crumble.

FOr the most part, developers are not concerned with the use of their buildings out to the year 2100. This is because they are more concerned with what the buildings will be used for today rather than in the future. Also, the financing goes out to 40 years on some projects.

When asked about implementing ATs such as raising the foundation and planning for first floor abandonment, a strong argument against them was made. A building must be related to the street, and must conform to other buildings in the are as well as regulations such as FAA and ADA regulations. Essentially, developers are given a box in which to build a building, and they must maximize profit in this box. If retail is not at street level, peoplewill be much less likely to visit the shops. Also, nobody would want to rent first floor space if they had to plan on temporarily abandoning it when floods came.They said that for the most part, buildings today are built to sustain the 100 year flood anyway.

Appendix B – Building Codes

The following pages of this appendix contain scanned copies of sections from the International Building Code (2009) and the Massachusetts State Building Code (2010). In order, the sections included are the following:

1. IBC Section 1612: Flood Loads
2. MA State Codes Section 1612: Flood Loads
3. IBC Appendix G: Flood-Resistant Construction
4. MA State Codes Appendix G: Flood-Resistant Construction and Construction in Coastal Dunes

International Building Code (2009)

Section 1612: Flood Loads

1612.1 General. Within *flood hazard areas* as established in Section 1612.3, all new construction of buildings, structures and portions of buildings and structures, including substantial improvement and restoration of substantial damage to buildings and structures, shall be designed and constructed to resist the effects of flood hazards and flood loads. For buildings that are located in more than one *flood hazard area,* the provisions associated with the most restrictive *flood hazard area* shall apply.

1612.2 Definitions. The following words and terms shall, for the purposes of this section, have the meanings shown herein.

BASE FLOOD. The flood having a 1-percent chance of being equaled or exceeded in any given year.

BASE FLOOD ELEVATION. The elevation of the *base flood,* including wave height, relative to the National Geodetic Vertical Datum (NGVD), North American Vertical Datum (NAVD) or other datum specified on the Flood Insurance Rate Map (FIRM). **BASEMENT.** The portion of a building having its floor subgrade (below ground level) on all sides.

This definition of "Basement" is limited in application to the provisions of Section 1612 (see "Basement" in Section 502.1).

DESIGN FLOOD. The flood associated with the greater of the following two areas:

1. Area with a flood plain subject to a 1-percent or greater chance of flooding in any year; or
2. Area designated as a *flood hazard area* on a community's flood hazard map, or otherwise legally designated.

DESIGN FLOOD ELEVATION. The elevation of the *"design flood,"* including wave height, relative to the datum specified on the community's legally designated flood hazard map. In areas designated as Zone AO, the design flood elevation shall be the elevation of the highest existing grade of the building's perimeter plus the depth number (in feet) specified on the flood hazard map. In areas designated as Zone AO where a depth number is not specified on the map, the depth number shall be taken as being equal to 2 feet (610 mm).

DRY FLOODPROOFING. A combination of design modifications that results in a building or structure, including the attendant utility and sanitary facilities, being water tight with walls substantially impermeable to the passage of water and with structural components having the capacity to resist loads as identified in ASCE 7.

EXISTING CONSTRUCTION. Any buildings and structures for which the "start of construction" commenced before the effective date of the community's first flood plain management code, ordinance or standard. "Existing construction" is also referred to as "existing structures."

EXISTING STRUCTURE. See "Existing construction."

FLOOD or FLOODING. A general and temporary condition of partial or complete inundation of normally dry land from:

1. The overflow of inland or tidal waters.
2. The unusual and rapid accumulation or runoff of surface waters from any source.

FLOOD DAMAGE-RESISTANT MATERIALS. Any construction material capable of withstanding direct and prolonged contact with floodwaters without sustaining any damage that requires more than cosmetic repair.

FLOOD HAZARD AREA. The greater of the following two areas:

1. The area within a flood plain subject to a 1-percent or greater chance of flooding in any year.
2. The area designated as a *flood hazard area* on a community's flood hazard map, or otherwise legally designated.

FLOOD HAZARD AREA SUBJECT TO HIGH-VELOCITY WAVE ACTION. Area within the *flood hazard area* that is subject to high-velocity wave action, and shown on a Flood Insurance Rate Map (FIRM) or other flood hazard map as Zone V, VO, VE or V1-30.

FLOOD INSURANCE RATE MAP (FIRM). An official map of a community on which the Federal Emergency Management Agency (FEMA) has delineated both the special flood hazard areas and the risk premium zones applicable to the community.

FLOOD INSURANCE STUDY. The official report provided by the Federal Emergency Management Agency containing the Flood Insurance Rate Map (FIRM), the Flood Boundary and Floodway Map (FBFM), the water surface elevation of the *base flood* and supporting technical data.

FLOODWAY. The channel of the river, creek or other watercourse and the adjacent land areas that must be reserved in order to discharge the *base flood* without cumulatively increasing the water surface elevation more than a designated height.

LOWEST FLOOR. The floor of the lowest enclosed area, including basement, but excluding any unfinished or flood-resistant enclosure, usable solely for vehicle parking, building access or limited storage provided that such enclosure is not built so as to render the structure in violation of this section.

SPECIAL FLOOD HAZARD AREA. The land area subject to flood hazards and shown on a Flood Insurance Rate Map or other flood hazard map as Zone A, AE, A1-30, A99, AR, AO, AH, V, VO, VE or V1-30.

START OF CONSTRUCTION. The date of issuance for new construction and substantial improvements to existing structures, provided the actual start of construction, repair, reconstruction, rehabilitation, *addition,* placement or other improvement is within 180 days after the date of issuance. The actual start of construction means the first placement of permanent construction of a building (including a manufactured home) on a site, such as the pouring of a slab or footings, installation of pilings or construction of columns.

Permanent construction does not include land preparation (such as clearing, excavation, grading or filling), the installation of streets or walkways, excavation for a basement, footings, piers or foundations, the erection of temporary forms or the installation of accessory buildings such as garages or sheds not occupied as *dwelling units* or not part of the main building. For a substantial improvement, the actual "start of construction" means the first *alteration* of any wall, ceiling, floor or other structural part of a building, whether or not that *alteration* affects the external dimensions of the building.

SUBSTANTIAL DAMAGE. Damage of any origin sustained by a structure whereby the cost of restoring the structure to its before-damaged condition would equal or exceed 50 percent of the market value of the structure before the damage occurred.

SUBSTANTIAL IMPROVEMENT. Any repair, reconstruction, rehabilitation, *addition* or improvement of a building or structure, the cost of which equals or exceeds 50 percent of the market value of the structure before the improvement or repair is started. If the structure has sustained substantial damage, any repairs are considered substantial improvement regardless of the actual repair work performed. The term does not, however, include either:

1. Any project for improvement of a building required to correct existing health, sanitary or safety code violations identified by the *building official* and that are the minimum necessary to assure safe living conditions.
2. Any *alteration* of a historic structure provided that the *alteration* will not preclude the structure's continued designation as a historic structure.

1612.3 Establishment of flood hazard areas. To establish *flood hazard areas,* the applicable governing authority shall adopt a flood hazard map and supporting data. The flood hazard map shall include, at a minimum, areas of special flood hazard as identified by the Federal Emergency Management Agency in an engineering report entitled "The Flood Insurance Study for [INSERT NAME OF JURISDICTION]," dated [INSERT DATE OF ISSUANCE], as amended or revised with the accompanying Flood Insurance Rate Map (FIRM) and Flood Boundary and Floodway Map (FBFM) and related supporting data along with any revisions thereto. The adopted flood hazard map and supporting data are hereby adopted by reference and declared to be part of this section.

1612.3.1 Design flood elevations. Where design flood elevations are not included in the *flood hazard areas* established in Section 1612.3, or where floodways are not designated, the *building official* is authorized to require the applicant to:

1. Obtain and reasonably utilize any design flood elevation and floodway data available from a federal, state or other source; or
2. Determine the design flood elevation and/or floodway in accordance with accepted hydrologic and hydraulic engineering practices used to define special flood hazard areas.

Determinations shall be undertaken by a *registered design professional* who shall document that the technical methods used reflect currently accepted engineering practice.

1612.3.2 Determination of impacts. In riverine *flood hazard areas* where design flood elevations are specified but floodways have not been designated, the applicant shall provide a floodway analysis that demonstrates that the proposed work will not increase the design flood elevation more than 1 foot (305 mm) at any point within the jurisdiction of the applicable governing authority.

1612.4 Design and construction. The design and construction of buildings and structures located in *flood hazard areas,* including flood hazard areas subject to high-velocity wave action, shall be in accordance with Chapter 5 of ASCE 7 and with ASCE 24.

1612.5 Flood hazard documentation. The following documentation shall be prepared and sealed by a *registered design professional* and submitted to the *building official:*

1. For construction in *flood hazard areas* not subject to high-velocity wave action:
   1.1. The elevation of the lowest floor, including the basement, as required by the lowest floor elevation inspection in Section 110.3.3.
   1.2. For fully enclosed areas below the design flood elevation where provisions to allow for the automatic entry and exit of floodwaters do not meet the minimum requirements in Section 2.6.2.1 of ASCE 24, *construction documents* shall include a statement that the design will provide for equalization of hydrostatic flood forces in accordance with Section 2.6.2.2 of ASCE 24.
   1.3. For dry flood proofed nonresidential buildings, *construction documents* shall include a statement that the dry flood proofing is designed in accordance with ASCE 24.
2. For construction in flood hazard areas subject to high-velocity wave action:
   2.1. The elevation of the bottom of the lowest horizontal structural member as required by the lowest floor elevation inspection in Section 110.3.3.
   2.2. *Construction documents* shall include a statement that the building is designed in accordance with ASCE 24, including that the pile or column foundation and building or structure to be attached thereto is designed to be anchored to resist flotation, collapse and lateral movement due to the effects of wind and flood loads acting simultaneously on all building components, and other load requirements of Chapter 16. For breakaway walls designed to resist a nominal load of less than 10 psf
   2.3. 2 2 (0.48 kN/m) or more than 20 psf (0.96 kN/m), construction documents shall
   2.4. include a statement that the breakaway wall is designed in accordance with ASCE 24.

International Building Code (2009)
Section 1612: Flood Loads
Amendments unique to the Commonwealth of Massachusetts

1612.1 General. Flood loads shall be determined in accordance with ASCE 7, Section 5.3. Design and construction in flood zones shall be in accordance with ASCE 24 and 780 CMR 120.G and the more stringent design and construction requirements of ASCE 24 or 780 CMR 120.G, as applicable ("right to construct and structure allowed/required elevations shall be governed by the last sentence of 780 CMR 1612.1), shall be expressly identified at the building permit application stage and the more stringent requirements of either reference shall govern, except that flood loads shall be in accordance with the issue of ASCE 7 cited in 780 CMR 35.00 and "right-to construct" and structure-allowed elevations shall be governed by 780 CMR 120.G, M.G.L. c. 131, § 40 and any bylaws ordinances that have legal standing in a community.

International Building Code (2009)
Appendix G: Flood Resistant Construction

The provisions contained in this appendix are not mandatory unless specifically referenced in the adopting ordinance.

SECTION G101
ADMINISTRATION

G1Ol.l Purpose. The purpose of this appendix is to promote the public health, safety and general welfare and to minimize public and private losses due to *flood* conditions in specific *flood hazard* areas through the establishment of comprehensive regulations for management of *flood hazard areas* designed to:

1. Prevent unnecessary disruption of commerce, access and public service during times of *flooding,*
2. Manage the alteration of natural *flood* plains, stream channels and shorelines;
3. Manage filling, grading, dredging and other development which may increase *flood* damage or erosion potential;
4. Prevent or regulate the construction of *flood* barriers which will divert floodwaters or which can increase flood hazards; and
5. Contribute to improved construction techniques in the flood plain.

G 101.2 Objectives. The objectives of this appendix are to protect human life, minimize the expenditure of public money for *flood* control projects, minimize the need for rescue and relief efforts associated with *flooding,* minimize prolonged business interruption, minimize damage to public facilities and utilities, help maintain a stable tax base by providing for the sound use and development of flood-prone areas, contribute to improved construction techniques in the flood plain and ensure that potential owners and occupants are notified that property is within flood hazard areas.

G101.3 Scope. The provisions of this appendix shall apply to all proposed development in a flood hazard area established in Section 1612 of this code, including certain building work exempt from permit under Section 105.2.

G101.4 Violations. Any violation of a provision of this appendix, or failure to comply with a permit or variance issued pursuant to this appendix or any requirement of this appendix, shall be handled in accordance with Section 114.

SECTION G102
APPLICABILITY

G102.1 General. This appendix, in conjunction with the *International Building Code,* provides minimum requirements for development located in flood hazard areas, including the subdivision of land; installation of utilities; placement and replacement of manufactured homes; new construction and repair, reconstruction, rehabilitation or additions to new construction;
substantial improvement of existing buildings and structures, including restoration after damage, temporary structures, and temporary or permanent storage, utility and miscellaneous Group U buildings and structures, and certain building work exempt from permit under Section 105.2.

G102.2 Establishment of flood hazard areas. *Flood hazard areas* are established in Section 1612.3 of the *International Building Code,* adopted by the applicable governing authority on [INSERT DATE].

SECTION G103
POWERS AND DUTIES

G103.1 Permit applications. The *building official* shall review all *permit* applications to determine whether proposed development sites will be reasonably safe from flooding. If a proposed development site is in a flood hazard area, all site development activities (including grading, filling, utility installation and drainage modification), all new construction and substantial improvements (including the placement of prefabricated buildings and manufactured homes) and certain building work exempt from *permit under* Section 105.2 shall be designed and constructed with methods, practices and materials that minimize flood damage and that are in accordance with this code and ASCE 24.

G103.2 Other permits. It shall be the responsibility of the *building official* assure that approval of a proposed development shall not be given until proof that necessary permits have been granted by federal or state agencies having jurisdiction over such development.

G103.3 Determination of design flood elevations. If design flood elevations are not specified, the *building officials* authorized to require the applicant to:

1. Obtain, review and reasonably utilize data available from a federal, state or other source, or
2. Determine the *design flood elevation* in accordance with accepted hydrologic and hydraulic engineering techniques. Such analyses shall be performed and sealed by a *registered design professional.* Studies, analyses and computations shall be submitted in sufficient detail to allow review and approval by the *building official.* The accuracy of data submitted for such determination shall be the responsibility of the applicant.

G 103.4 Activities in riverine flood hazard areas. In riverine *flood hazard areas* where *design flood elevations* are specified but *floodways* have not been designated, the *building official* shall not permit any new construction, substantial improvement or other development, including fill, unless the applicant demonstrates that the cumulative effect of the proposed development, when combined with all other existing and anticipated flood hazard area encroachment, will not increase the design flood elevation more than 1 foot (305 mm) at any point within the community.

G103.5 Floodway encroachment. Prior to issuing a *permit for* any *floodway encroachment,* including fill, new construction, substantial improvements and other development or land-disturbing activity, the *building official* shall require submission of a certification, along with supporting technical data, that demonstrates that such development will not cause any increase of the level of the base *flood.*

G103.5.1 Floodway revisions. A *floodway encroachment* that increases the level of the base *flood* is authorized if the applicant has applied for a conditional Flood Insurance Rate Map (FIRM) revision and has received the approval of the Federal Emergency Management Agency (FEMA).

G103.6 Watercourse alteration. Prior to issuing a permit for any alteration or relocation of any watercourse, the *building official shall* require the applicant to provide notification of the proposal to the appropriate authorities of all affected adjacent government jurisdictions, as well as appropriate state agencies. A copy of the notification shall be maintained in the permit records and submitted to FEMA.

G103.6.1 Engineering analysis. The *building official shall* require submission of an engineering analysis which demonstrates that the flood-carrying capacity of the altered or relocated portion of the watercourse will not be decreased. Such watercourses shall be maintained in a manner which preserves the channel's flood-carrying capacity.

G103.7 Alterations in coastal areas. Prior to issuing a permit for any alteration of sand dunes and mangrove stands in flood hazard areas subject to high velocity wave action, the *building official* shall require submission of an engineering analysis which demonstrates that the proposed alteration will not increase the potential for flood damage.

G103.8 Records. The *building official* shall maintain a permanent record of all *permits* issued in *flood hazard areas,* including copies of inspection reports and certifications required in Section 1612.

SECTION G104 PERMITS

G104.1 Required. Any person, owner or authorized agent who intends to conduct any development in a flood hazard area shall first make application to the *building official* and shall obtain the required *permit.*

G104.2 Application for permit. The applicant shall file an application in writing on a form furnished by the *building official.* Such application shall:

1. Identify and describe the development to be covered by the permit.
2. Describe the land on which the proposed development is to be conducted by legal description, street address or similar description that will readily identify and definitely locate the site.
3. Include a site plan showing the delineation of flood hazard areas, floodway boundaries, flood zones, design flood elevations, ground elevations, proposed fill and excavation and drainage patterns and facilities.
4. Indicate the use and occupancy for which the proposed development is intended.
5. Be accompanied by construction documents, grading and filling plans and other information deemed appropriate by the building official.
6. State the valuation of the proposed work.
7. Be signed by the applicant or the applicant's authorized agent.

G104.3 Validity of permit. The issuance of a *permit under* this appendix shall not be construed to be a permit for, or approval of, any violation of this appendix or any other ordinance of the jurisdiction. The issuance of a *permit based* on submitted documents and information shall not prevent the *building official* from requiring the correction of errors. The *building official* is authorized to prevent occupancy or use of a structure or site which is in violation of this appendix or other ordinances of this jurisdiction.

G104.4 Expiration. A *permit* shall become invalid if the proposed development is not commenced within 180 days after its issuance, or if the work authorized is suspended or abandoned for a period of 180 days after the work commences. Extensions shall be requested in writing and justifiable cause demonstrated. The *building official* is authorized to grant, in writing, one or more extensions of time, for periods not more than 180 days each.

G104.5 Suspension or revocation. The building official is authorized to suspend or revoke a *permit* issued under this appendix wherever the permit is issued in error or on the basis of incorrect, inaccurate or incomplete information, or in violation of any ordinance or code of this jurisdiction.

SECTION G105 VARIANCES

G **105.1 General.** The *board of appeals* established pursuant to Section 112 shall hear and decide requests for variances. The *board of appeals* shall base its determination on technical justifications, and has the right to attach such conditions to variances as it deems necessary to further the purposes and objectives of this appendix and Section 1612.

G105.2 Records. The building official shall maintain a permanent record of all variance actions, including justification for their issuance.

G105.3 Historic structures. A variance is authorized to be issued for the repair or rehabilitation of a historic structure upon a determination that the proposed repair or rehabilitation will not preclude the structure's continued designation as a historic structure, and the variance is the minimum necessary to preserve the historic character and design of the structure.

Exception: Within *flood hazard areas, historic structures* that are not:

1. Listed or preliminarily determined to be eligible for listing in the National Registry of Historic Places; or
2. Determined by the Secretary of the U.S. Department of Interior as contributing to the historical significance of a registered historic district or a district preliminarily determined to qualify as an historic district; or
3. Designated as *historic* under a state or local historic preservation program that is approved by the Department of Interior.

G105.4 Functionally dependent facilities. A variance is authorized to be issued for the construction or substantial improvement of a functionally dependent facility provided the criteria in Section 1612.1 are met and the variance is the minimum necessary to allow the construction or substantial improvement, and that all due consideration has been given to methods and materials that minimize flood damages during the design flood and create no additional threats to public safety.

G105.5 Restrictions. The *board of appeals* shall not issue a variance for any proposed development in a floodway if any increase in flood levels would result during the base flood discharge.

G105.6 Considerations. In reviewing applications for variances, the *board of appeals* shall consider all technical evaluations, all relevant factors, all other portions of this appendix and the following:

1. The danger that materials and debris may be swept onto other lands resulting in further injury or damage;
2. The danger to life and property due to flooding or erosion damage;
3. The susceptibility of the proposed development, including contents, to flood damage and the effect of such damage on current and future owners;
4. The importance of the services provided by the proposed development to the community;
5. The availability of alternate locations for the proposed development that are not subject to flooding or erosion;
6. The compatibility of the proposed development with existing and anticipated development;
7. The relationship of the proposed development to the comprehensive plan and flood plain management program for that area;
8. The safety of access to the property in

times of flood for ordinary and emergency vehicles;

9. The expected heights, velocity, duration, rate of rise and debris and sediment transport of the floodwaters and the effects of wave action, inapplicable, expected at the site; and

10. The costs of providing governmental services during and after flood conditions including maintenance and repair of public utilities and facilities such as sewer, gas, electrical and water systems, streets and bridges.

G105.7 Conditions for issuance. Variances shall only be issued by the *board of appeals* upon:

1. A technical showing of good and sufficient cause that the unique characteristics of the size, configuration or topography of the site renders the elevation standards inappropriate;
2. A determination that failure to grant the variance would result in exceptional hardship by rendering the lot undevelopable;
3. A determination that the granting of a variance will not result in increased flood heights, additional threats to public safety, extraordinary public expense, nor create nuisances, cause fraud on or victimization of the public or conflict with existing local laws or ordinances;
4. A determination that the variance is the minimum necessary, considering the flood hazard, to afford relief; and
5. Notification to the applicant in writing over the signature of the building official that the issuance of a variance to construct a structure below the base flood level will result in increased premium rates for flood insurance up to amounts as high as $25 for $100 of insurance coverage, and that such construction below the base flood level increases risks to life and property.

SECTION G201 DEFINITIONS

G201.1 General. The following words and terms shall, for the purposes of this appendix, have the meanings shown herein. Refer to Chapter 2 for general definitions.

G201.2 Definitions.

DEVELOPMENT. Any manmade change to improved or unimproved real estate, including but not limited to, buildings or other structures, temporary structures, temporary or permanent storage of materials, mining, dredging, filling, grading, paving, excavations, operations and other land-disturbing activities.

FUNCTIONALLY DEPENDENT FACILITY. A facility which cannot be used for its intended purpose unless it is located or carried out in close proximity to water, such as a docking or port facility necessary for the loading or unloading of cargo or passengers, shipbuilding or ship repair. The term does not include long-term storage, manufacture, sales or service facilities.

MANUFACTURED HOME. A structure that is transportable in one or more sections, built on a permanent chassis, designed for use with or without a permanent foundation when attached to the required utilities, and constructed to the Federal Mobile Home Construction and Safety Standards and rules and regulations promulgated by the U.S. Department of Housing and Urban Development. The term also includes mobile homes, park trailers, travel trailers and similar transportable structures that are placed on a site for 180 consecutive days or longer.

MANUFACTURED HOME PARK OR SUBDIVISION. A parcel (or contiguous parcels) of land divided into two or more manufactured home lots for rent or sale.

RECREATIONAL VEHICLE. A vehicle that is built on a single chassis, 400 square feet (37.16 m^2) or less when measured at the largest horizontal projection, designed to be self-propelled or permanently towable by a light-duty truck, and designed primarily not for use as a permanent dwelling but as temporary living quarters for recreational, camping, travel or seasonal use. A recreational vehicle is ready for highway use if it is on its wheels or jacking system, is attached to the site only by quick disconnect-type utilities and security devices and has no permanently attached additions.

VARIANCE. A grant of relief from the requirements of this section which permits construction in a manner otherwise prohibited by this section where specific enforcement would result in unnecessary hardship.

VIOLATION. A development that is not fully compliant with this appendix or Section 1612, as applicable.

SECTION G301
SUBDIVISIONS

G301.1 General. Any subdivision proposal, including proposals for manufactured home parks and subdivisions, or other proposed new development in a flood hazard area shall be reviewed to assure that:

1. All such proposals are consistent with the need to minimize flood damage;
2. All public utilities and facilities, such as sewer, gas, electric and water systems are located and constructed to minimize or eliminate flood damage; and
3. Adequate drainage is provided to reduce exposure to flood hazards.

G301.2 Subdivision requirements. The following requirements shall apply in the case of any proposed subdivision, including proposals for manufactured home parks and subdivisions, any portion of which lies within a flood hazard area:

1. The flood hazard area, including floodways and areas subject to high velocity wave action, as appropriate, shall be delineated on tentative and final subdivision plats;
2. Design flood elevations shall be shown on tentative and final subdivision plats;
3. Residential building lots shall be provided with adequate buildable area outside the floodway; and
4. The design criteria for utilities and facilities set forth in this appendix and appropriate *International Codes* shall be met.

SECTION G401
SITE IMPROVEMENT

G401.1 Development in floodways. Development or land disturbing activity shall not be authorized in the *floodway unless* it has been demonstrated through hydrologic and hydraulic analyses performed in accordance with standard engineering practice that the proposed encroachment will not result in any increase in the level of the base *flood.*

G401.2 Flood hazard areas subject to high-velocity wave action. In flood hazard areas subject to high-velocity wave action:

1. New buildings and buildings that are substantially improved shall only be authorized landward of the reach of mean high tide.
2. The use of fill for structural support of buildings is prohibited.

G401.3 Sewer facilities. All new or replaced sanitary sewer facilities, private sewage treatment plants (including all pumping stations and collector systems) and on-site waste disposal systems shall be designed in accordance with Chapter 8, ASCE 24, to minimize or eliminate infiltration of floodwaters into the facilities and discharge from the facilities into floodwaters, or impairment of the facilities and systems.

G401.4 Water facilities. All new or replacement water facilities shall be designed in accordance with the provisions of Chapter 8, ASCE 24, to minimize or eliminate infiltration of floodwaters into the systems.

G401.5 Storm drainage. Storm drainage shall be designed to convey the flow of surface waters to minimize or eliminate damage to persons or property.

G401.6 Streets and sidewalks. Streets and sidewalks shall be designed to minimize potential for increasing or aggravating flood levels.

SECTION G501 MANUFACTURED HOMES

G501.1 Elevation. All new and replacement manufactured homes to be placed or substantially improved in a *flood hazard area* shall be elevated such that the lowest floor of the manufactured home is elevated to or above the design flood elevation.

G501.2 Foundations. All new and replacement manufactured homes, including substantial improvement of existing manufactured homes, shall be placed on a permanent, reinforced foundation that is designed in accordance with Section 1612.

G501.3 Anchoring. All new and replacement manufactured homes to be placed or substantially improved in a *flood hazard area* shall be installed using methods and practices which minimize flood damage. Manufactured homes shall be securely anchored to an adequately anchored foundation system to resist flotation, collapse and lateral movement. Methods of anchoring are authorized to include, but are not limited to, use of over-the-top or frame ties to ground anchors. This requirement is in addition to applicable state and local anchoring requirements for resisting wind forces.

SECTION G601 RECREATIONAL VEHICLES

G601.1 Placement prohibited. The placement of recreational vehicles shall not be authorized in *flood hazard areas* subject to high velocity wave action and in *floodways.*

G601.2 Temporary placement. Recreational vehicles in *flood hazard areas* shall be fully licensed and ready for highway use, and shall be placed on a site for less than 180 consecutive days.

G601.3 Permanent placement. Recreational vehicles that are not fully licensed and ready for highway use, or that are to be placed on a site for more than 180 consecutive days, shall meet the requirements of Section G501 for manufactured homes.

SECTION G701 TANKS

G701.1 Underground tanks. Underground tanks in *flood hazard areas* shall be anchored to prevent flotation, collapse or lateral movement resulting from hydrostatic loads, including the effects of buoyancy, during conditions of the design *flood.*

G701.2 Above-ground tanks. Above-ground tanks in flood hazard areas shall be elevated to or above the design *flood* elevation or shall be anchored or otherwise designed and constructed to prevent flotation, collapse or lateral movement resulting from hydrodynamic and hydrostatic loads, including the effects of buoyancy, during conditions of the design *flood.*

G701.3 Tank inlets and vents. In *flood hazard areas,* tank inlets, fill openings, outlets and vents shall be:

1. At or above the design flood elevation or fitted with covers designed to prevent the inflow of floodwater or outflow of the contents of the tanks during conditions of the design *flood.*
2. Anchored to prevent lateral movement resulting from hydrodynamic and hydrostatic loads, including the effects of buoyancy, during conditions of the design *flood.*

SECTION G801
OTHER BUILDING WORK

G801.1 Detached accessory structures. Detached accessory structures shall be anchored to prevent flotation, collapse or lateral movement resulting from hydrostatic loads, including the effects of buoyancy, during conditions of the design *flood.* Fully enclosed accessory structures shall have flood openings to allow for the automatic entry and exit of *flood* waters.

G801.2 Fences. Fences in floodways that may block the passage of floodwaters, such as stockade fences and wire mesh fences, shall meet the requirement of Section G103.5.

G801.3 Oil derricks. Oil derricks located in *flood hazard areas* shall be designed in conformance with the flood loads in Sections 1603.1.7 and 1612.

G801.4 Retaining walls, sidewalks and driveways. Retaining walls, sidewalks and driveways shall meet the requirements of Section 1803.4.

G801.5 Prefabricated swimming pools. Prefabricated swimming pools in *floodways* shall meet the requirements of Section GI03.5.

SECTION G901
TEMPORARY STRUCTURES AND TEMPORARY STORAGE

G901.1 Temporary structures. Temporary structures shall be erected for a period of less than 180 days. Temporary structures shall be anchored to prevent flotation, collapse or lateral movement resulting from hydrostatic loads, including the effects of buoyancy, during conditions of the design *flood.* Fully enclosed temporary structures shall have flood openings to allow for the automatic entry and exit of floodwaters.

G901.2 Temporary storage. Temporary storage includes storage of goods and materials for a period of less than 180 days. Stored materials shall not include hazardous materials.

G901.3 Floodway encroachment. Temporary structures and temporary storage in floodways shall meet the requirements of GI03.5.

SECTION G100
UTILITY AND MISCELLANEOUS GROUP U

G1001.1 Utility and miscellaneous Group U. Utility and miscellaneous Group U includes buildings that are accessory in character and miscellaneous structures not classified in any specific occupancy in the *International Building Code,* including, but not limited to, agricultural buildings, aircraft hangars (accessory to a one- or two-family residence), barns, carports, fences more than 6 feet (1829 mm) high, grain silos (accessory to a residential occupancy), greenhouses, livestock shelters, private garages, retaining walls, sheds, stables and towers.

G1001.2 Flood loads. Utility and miscellaneous Group U buildings and structures, including substantial improvement of such buildings and structures, shall be anchored to prevent flotation, collapse or lateral movement resulting from flood loads, including the effects of buoyancy, during conditions of the design *flood.*

G 1001.3 Elevation. Utility and miscellaneous Group U buildings and structures, including substantial improvement of such buildings and structures, shall be elevated such that the lowest floor, including basement, is elevated to or above the design *flood* elevation in accordance with Section 1612 of the *International Building Code.*

G1001.4 Enclosures below design flood elevation. Fully enclosed areas below the design flood elevation shall be at or above grade on all sides and conform to the following:

1. In *flood hazard areas* not subject to high-velocity wave action, enclosed areas shall have flood openings to allow for the automatic inflow and outflow of floodwaters.
2. In *flood hazard areas* subject to high-velocity wave action, enclosed areas shall have walls below the design flood elevation that are designed to break away or collapse from a water load less than that which would occur during the design flood, without causing collapse, displacement or other structural damage to the building or structure.

G1001.5 Flood-damage-resistant materials. Flood-damage-resistant materials shall be used below the design *flood ele*vation.

G1001.6 Protection of mechanical, plumbing and electrical systems. Mechanical, plumbing and electrical systems, including plumbing fixtures, shall be elevated to or above the design *flood* elevation.

Exception: Electrical systems, equipment and components, and heating, ventilating, air conditioning, and plumbing appliances, plumbing fixtures, duct systems and other service equipment shall be permitted to be located below the design *flood* elevation provided that they are designed and installed to prevent water from entering or accumulating within the components and to resist hydrostatic and hydrodynamic loads and stresses, including the effects of buoyancy, during the occurrence of flooding to the design flood elevation in compliance with the flood-resistant construction requirements of this code. Electrical wiring systems shall be permitted to be located below the design flood elevation provided they conform to the provisions of NFPA 70.

SECTION G1101
REFERENCED STANDARDS

ASCE 24-05	Flood Resistance Design and Construction	G103.1, G401.3, G401.4
HUD 24 CFR Part 3280 (1994)	Manufactured Home Construction and Safety Standards	G201
IBC-06	International Building Code	G102.2
INFPA 70-08 Part 3280	National Electric Code Construction and Safety	G1001.6

This section is unique to the Commonwealth of Massachusetts

780 CMR 120.G101 GENERAL

120.G101.1 General: All buildings and structures erected in areas prone to flooding and/or coastal dunes shall **be** constructed and elevated as required **by** the provisions of 780 CMR 120.G.

780 CMR 120.G201 DEFINITIONS

120.G201.1 Definitions. The following words and terms shall, for the purposes of 780 CMR 120.G, and as used elsewhere in 780 CMR, have the meanings shown in 780 CMR 120.G201.

A-Zones: A Zones are synonymous with Flood-Hazard Zones.

Base Flood Elevation: The flood having a 1% chance of being equaled or exceeded in any given year and shall be used to define areas prone to flooding, and describe at a minimum, the depth or peak elevation of flooding.

Basement/Cellar: Any area of the building having its floor subgrade (below ground level) on all sides.

Breakaway Wall: A wall that is not part of the structural support of the building and intended, through its design and construction, to collapse under specific lateral loading forces, without causing damage to the elevated portion of the building or supporting foundation system.

Coastal Dune: Any natural hill, mound or ridge of sediment landward of a coastal beach deposited by wind action or storm overwash. Coastal Dune also means sediment deposited by artificial means and serving the purpose of storm damage prevention or flood control.

Coastal Wetland Resource Area: Any coastal wetland resource area subject to protection under M.G.L. c. 131, § 40 (the Wetlands Protection Act), and310CMR 10.21 through 10.35: *Coastal Wetlands.* Coastal Wetland Resource Areas include barrier beaches, coastal beaches, coastal dunes, rocky intertidal shores, tidal flats, land subject to 100 year coastal storm flowage, coastal banks, land containing shellfish, lands subject to tidal action, and lands under an estuary, salt pond or certain streams, ponds, rivers, lakes or creeks within the coastal zone that are anadromous/ catadromous fish runs.

Conservation Commission: Body comprised of members lawfully appointed pursuant to M.G.L. c. 40, § **8C.** It shall also mean a mayor or board of selectmen, where no conservation commission has been established pursuant to M.G.L. c. 40, § 8C.

Determination of Applicability: A written finding by the issuing authority under M.G.L. c. 131, § 40 (the Wetlands Protection Act), as to whether a site or the work proposed therein is subject to jurisdiction under M.G.L. c, 131, § 40.

Elevation: The placement of a structure above flood level to minimize or prevent flood damages or to preserve the flood control and storm damage prevention functions of a coastal dune.

Failure of a Foundation: a foundation that is no longer supporting the building or foundation or is determined by the building official to be unsafe or incapable of continuing to support the building. For example, failure of a foundation occurs when a building or structure or portion thereof falls off the foundation or when the building official determines there is a risk that the building or structure may fall off the foundation.

Flood* Hazard Zones: Areas subject to a 1%

or greater chance of flooding in any given year and that are not subject to wave heights in excess of three feet. (A ZONES).

Floodproofing: Any combination of structural and non-structural additions, changes or adjustments to structures which reduce or eliminate flood damage to new or substantially improved structures.

F.E.M.A.: Federal Emergency Management Agency.

Flood Insurance Rate Map: Flood insurance rate map (FIRM) means an official map of a community, which delineates both the special hazard zones and the risk premium zones applicable to the community.

High-hazard Zones (V **Zones):** Areas of tidal influence which have been determined to be subject to wave run heights in excess of three feet or subject to high-velocity wave run-up or wave- induced erosion (V Zones).

Highest Adjacent Grade: The highest natural elevation of the ground surface, prior to construction, adjoining the proposed foundation walls of a structure.

Impact Loads: Loads induced by the collision of solid objects on a structure carried by floodwater.

Interests Identified in M.G.L. c. 131, § 40 (the Wetlands Protection Act),: Public or private ground water supply, flood control, storm damage prevention, prevention of pollution, protection of land containing shellfish, protection of fisheries, and protection of wildlife habitat.

Issuing Authority under M.G.L. c. 131, § 40 (the Wetlands Protection Act): a conservation commission, mayor, the selectmen or the Department of Environmental Protection.

Lateral Addition: an addition that expands the footprint of a building or structure including a manufactured home.

Lowest Floor: The lowest floor of the lowest enclosed area (including basement/cellar). An unfinished or flood resistant enclosure, usable solely for parking of vehicles, building access, or incidental storage in an area other than a basement/cellar with appropriate hydrostatic openings as required in 780 CMR 120.G501.4 is not considered a building's lowest floor.

Manufactured Home: A structure that is transportable in one or more sections, built on a permanent chassis, designed for use with or without a permanent foundation when attached to the required utilities, and constructed to the Federal Mobile Home Construction and Safety Standards and rules and regulations promulgated by the U.S. Department of Housing and Urban Development. The term also includes mobile homes, park trailers, travel trailers and similar transportable structures that are placed on a site for 180 days or longer. The term " manufactured home" does not include a "recreational vehicle".

Manufactured Housing: Manufactured Housing is synonymous with Manufactured Home.

Notification of Non-significance: A written finding by the issuing authority under M.G.L. c. 131, § 40 (the Wetlands Protection Act), that the area on which the proposed work is to be done or which the proposed work will alter is not significant to any of the interests identified in M.G.L. c. 131, §40.

Order of Conditions: Written requirements by the issuing authority under M.G.L. c. 131, § 40 (the Wetlands Protection Act) establishing the manner in which work shall be done for work proposed within areas subject to jurisdiction under M.G.L. c. 131, §40.

Order of Resource Area Delineation: Written findings by the issuing authority under M.G.L. c. 131, § 40 (the Wetlands Protection Act) identifying the boundaries of the area(s) subject to jurisdiction under M.G.L. c. 131, § 40.

Recreational Vehicle: A vehicle that is built on a single chassis 400 square feet or less when measured at the largest horizontal projection, designed to be self-propelled or permanently towable by a light duty truck, and designed primarily not for use as a permanent dwelling, but as temporary living quarters for recreational, camping, travel or seasonal use. A recreational vehicle is ready for highway use, if it is on wheels or a jacking system, is attached to the site only by quick disconnect type utilities and security devices, and has no permanently attached additions.

Scouring: The erosion or washing away of slopes or soil by velocity waters.

Special Hazard Zones: An area having special flood, and/or flood-related erosion hazards and shown on Flood Hazard Boundary Map or FIRM as Zone A, AO, Al-30, AE, A99, AH, VO, VI- 30, VE, V.

Start of Construction: The date the building permit was issued, provided the actual start of construction, repair, reconstruction, placement, or other improvement was within 180 days of the permit date. The actual start means the first placement of permanent construction of a structure on a site, such as the pouring of slab or footings, the installation of piles, the construction of columns, or any work beyond the stage of excavation or the placement of a manufactured home on a foundation.

Structure (this definition is intended utilized with this 780 CMR 120.G): A walled and roofed building, including a gas or liquid storage tank, that is principally above ground and affixed to a permanent site, as well as a manufactured home.

Substantial Damage: Damage of any origin sustained by a building or structure including a manufactured home whereby the cost or restoring the building or structure to its before damaged condition would equal or exceed 50% of the market value of the building or structure before the damage occurred.

Substantia] Improvements: Substantial improvement means any reconstruction, rehabilitation, addition, repair or improvement of a structure, the cost of which equals or exceeds 50% of the market value of the structure before the "start of construction" of the improvement. This term includes structures which have incurred "Substantial damage", regardless of the actual repair work performed. Substantial improvement does not, however, include either:

1. any project for improvement of a structure to conect existing violations of state or local health, sanitary, or safety codes which have been identified by the local code enforcement official and which are the minimum necessary to assure safe living conditions or
2. any alteration of a "Historic structure", provided that the alteration will not preclude the structure's continued designation as a "historic structure."

> **Note 1:** The following items can be excluded from the cost of improvement or repair: plans, specifications, survey, permits, and other items which are separate from or incidental to the repair of the damaged or improved building, *i.e.* debris removal/ cartage.
>
> **Note 2:** The latest Assessors'structure value may be used, provided that the Assessors certify that said value is based on 100% valuation, less depreciation.

Substantial Repair of a Foundation: Work to repair and/or replace a foundation that results in the repair or replacement of the portion of the foundation walls with a perimeter along the base of the foundation that equals or exceeds 50% of the perimeter of the base of the entire foundation measured in linear feet. The term "substantial repair of a foundation" also includes a building or structure including a manufactured home that has incurred a failure of a foundation regardless of the actual work done to repair or replace the foundation.

V Zones: V Zones are synonymous with High- Hazard Zones.

Variance: A grant of relief by a community and the Commonwealth, via the Boards of Appeal, from the terms of the Floodplain Management Regulations.

Venting: A system designed to allow flood waters to enter an enclosure, usually the interior of foundations walls, so that the rising water does not create a dangerous differential in hydrostatic pressure; usually achieved through openings in the walls. Vents may be installed in garage doors to satisfy this requirement, provided such vents are installed consistent with 780 CMR 120.G. The necessity of human intervention, such as opening garage doors, does not satisfy this requirement.

780 CMR 120.G301 BASE FLOOD ELEVATION

120.G301.1 Base Flood Elevation. The base flood elevation shall be used to define areas prone to flooding, and shall describe, at a minimum, the depth or peak elevation of flooding (including wave height) which has a 1% (100-year flood) or greater chance of occurring in any given year The 100-year flood elevation shall be determined as follows:

1. In Al-30, AH, AE, Vl-30 and VE, the Base Flood Elevation is provided on the community's Flood Insurance Study and the Flood Insurance Rate Map (FIRM).
2. In AO zones, add the depth provided on the Flood Insurance Rate Map to the highest adjacent grade. If no depth is provided, add at least two feet to the highest adjacent grade.
3. In A, A99 and V zones, the building official, design professional, or surveyor shall obtain, review and reasonably utilize any Base Flood Elevation Data available from a federal, state or other reliable sources.

780 CMR 120.G401 HAZARD ZONES

120.G401.1 Hazard Zones. Areas which have been determined to have a 1% or greater chance of flooding in any given year shall be classified as either flood-hazard zones (A Zones) or high-hazard zones (V Zones) in accordance with 780 CMR 120.G501 and 120.G601.

780 CMR 120.G501 FLOOD HAZARD ZONES

120.G501.1 Construction in Flood-hazard zones (A Zones). All areas which have a 1% or greater chance of flooding in any given year but are not subject to wave heights in excess of three feet shall be designated as flood-hazard zones. Flood- hazard zones shall include all areas shown as A Zones on the most recent Flood Hazard Boundary Map or FIRM. All buildings and structures as defined in 780 CMR 120.G201 including new or replacement manufactured homes erected or substantially improved in flood-hazard zones shall be designed and constructed in accordance with 780 CMR 120.G501.

Plans for the construction or substantial improvement of a building or structure, including a new or replacement manufactured home, in a flood- hazard zone shall be prepared by a qualified registered professional engineer or architect to ensure the compliance with 780 CMR 120.G501. **Exception:** If a substantial improvement consists exclusively of a lateral addition that does not rely on the support of the existing structure, only the lateral addition must be erected in accordance with the applicable provisions of 780 CMR 120.G501. In that event, the existing structure is not required to come into compliance with 780 CMR 120.G501.

Note: If located in a coastal dune that is significant to flood control and/or storm damage prevention, a building or structure, including a new or replacement manufactured home, in a flood-hazard zone shall be designed and constructed in accordance with the applicable provisions of 780 CMR 120.G701,and 120.G801 as well as 780 CMR 120.G501.

120.G501.2 Elevation in a Flood-hazard Zone.
Except as otherwise provided in 120.G501, all buildings or structures, including new or replacement manufactured homes, erected or substantially improved within a flood-hazard zone shall be elevated so that the lowest floor is located at or above the base flood elevation. All basement/
cellar floor surfaces shall be located at or above the base flood elevations.

Exception: Floors of occupancy in any use group, other than use group **R,** below the base flood elevation shall conform to 780 **CMR** 120.G501.5.2. Floors of occupancies in any use group which are utilized solely for structure means of egress, incidental storage garages and parking, and which are located below the base flood elevation, shall conform to 780 **CMR** 120.G501.4.

120.G501.3 Anchorage in a Flood-hazard Zone. The structural systems of all buildings or structures, including new or replacement manufactured homes, shall be designed, connected and anchored to resist flotation, collapse or permanent lateral movement due to structural loads and stresses from flooding equal to the base flood elevation and shall be designed in accordance with 780 **CMR** 1615.2 and 1615.3.

120.G501.4 Enclosures below Base Flood Elevation in a Flood-hazard Zone. Enclosed spaces below the base flood elevation shall not be used for human occupancy with the exception of structural means of egress, entrance foyers, stairways and incidental storage. Fully enclosed spaces shall be designed to equalize automatically hydrostatic forces on exterior walls by allowing for the entry and exit of floodwaters. Designs for meeting this requirement shall either be certified by a registered design professional in accordance with 780 **CMR** 120.G501.11 through 120.G501.13 or conform to the following minimum criterion: a minimum of two openings having a total net area of not less than one square inch (645 mm^2) for every one square foot (0.1 m^2) of enclosed area subject to flooding shall be provided. The bottom of all openings shall not be higher than 12 inches (305 mm) above grade immediately adjacent to the location of the opening. Openings shall not be equipped with screens, louvers, valves or other coverings or devices unless such devices permit the automatic entry and discharge of floodwaters.

120.G501.5 Water-resistant Construction in a Flood-hazard Zone. Occupancies in any use group other than Use Group **R** may, in lieu of meeting the elevation provisions of 780 **CMR** 120.G501.2 be erected with floors usable for human occupancy below the base flood elevation provided that the following conditions are met:

1. All space below the base flood elevation shall be constructed with walls and floors that are substantially impermeable to the passage of water.
2. All structural components subject to hydrostatic and hydrodynamic loads and stresses during the occurrence of flooding to the base flood elevation shall be capable of resisting such forces, including the effects of buoyancy.
3. All openings below the base flood

elevation shall be provided with water-tight closures and shall have adequate structural capacity to support all flood loads acting upon the closure surfaces.

4. All floor and wall penetrations for plumbing, mechanical and electrical systems shall be made water tight to prevent floodwater seepage through spaces between the penetration and wall construction materials. Sanitary sewer and storm drainage systems that have openings below the base flood elevation shall be provided with shutoff valves or closure devices to prevent backwater flow during conditions of flooding.

120.G501.6 Repair or Replacement of Existing Foundations in a Flood-hazard Zone. Existing foundations in a flood-hazard zone may be repaired without further compliance with 780 CMR 120.G501, unless the work replaces the foundation in total, replaces the foundation so as to constitute new construction or constitutes a substantial repair of a foundation as defined in 780 CMR 120.G201. In such events, the foundation shall be brought into compliance with the applicable provisions of 780 CMR 120.G501.

See Note 780 CMR 120.G501.1.

120.G501.7 Protection of Mechanical and Electrical Systems in a Flood-hazard Zone. New and replacement electrical, heating, ventilating, air conditioning and other service equipment in a flood- hazard zone shall either be placed above the base flood elevation or protected so as to prevent water from entering or accumulating within the system components during floods up to the base flood elevation in accordance with the mechanical code listed in 780 CMR 100.0 Installation of electrical wiring and outlets, switches, junction boxes and panels below the base flood elevation shall conform to the provisions of 527 CMR 12.00 listed in 780 CMR 100.0 for location of such items in wet locations. Duct insulation subject to water damage shall not be installed below the base flood elevation.

120.G501.8 Construction Materials, Methods, and Practices in a Flood-hazard Zone. All buildings or structures, including new or replacement manufactured homes, erected in a flood- hazard zone shall be constructed with materials resistant to flood damage and be constructed by methods and practices that minimize flood damage. Construction materials shall be resistant to water damage in accordance with the provisions of 780 CMR 1808.0, 1810.2, 1813.4, 2307.2, 2309.1, 2311.4, 2311.6, and 2503.4.

120.G501.9 Recreational Vehicles in a Flood- hazard Zone. All recreational vehicles placed in a flood-hazard zone and that are not fully licensed and ready for highway use or that are to be placed on a site for more than 180 consecutive days shall comply with the provisions of 780 CMR 120.G501 applicable to buildings or structures, including new or replacement manufactured homes.

120.G501.10 Alterations, Renovation and Repairs in a Flood-hazard Zone. Alterations, renovations and repairs to existing buildings and structures including new or replacement manufactured homes located in a flood-hazard zone shall comply with applicable provisions of 780 CMR. Compliance with 780 CMR 120.G501 is required whenever such alteration, renovation or repair constitutes a substantial repair of a foundation as defined in 780 CMR 120.G201, repair or replacement of a foundation that requires compliance with 780 CMR

120.G501, or a substantial improvement as defined in 780 CMR 120.G201.

120.G501.11 Certifications and Plans for Construction in a Flood-hazard Zone. Certifications and plans shall be submitted in accordance with 780 CMR 120.G501.12 and 120.G501.13 for a substantial repair of a foundation as defined in 780 CMR 120.G201, repair or replacement of a foundation that requires compliance with 780 CMR 120.G501, a substantial improvement as defined in 780 CMR 120.G201, or a building or structure as defined in 780 CMR 120.G201, including a new or replacement manufactured home.

120.G501.12 As-built Elevation Certification for Construction in a Flood-hazard Zone. For all substantial repairs of a foundation as defined in 780 CMR 120.G201, all repairs or replacement of a foundation that trigger the requirement to comply with 780 CMR 120.G501, all substantial improvements as defined in 780 CMR 120.G201, and all buildings or structures including new and replacement manufactured homes, a licensed land surveyor or registered design professional shall certify the actual elevation in relation to the base flood elevation of the lowest floor required to be elevated by the provisions of 780 CMR 120.G501.2. The certification required shall be submitted to the building official after the construction of the foundation is complete and before the commencement of any other work on the building or structure or, if there is no other work, the occupancy of the building or structure.

120.G501.13 Documentation -Water Resistant Construction in a Flood-hazard Zone Where buildings or structures including new or replacement manufactured homes are to be constructed in accordance with 780 **CMR** 120.G501.5, the building official shall require that a registered design professional provide construction documents showing proposed details of floor, wall, foundation support components, loading computations, and other essential technical data used in meeting the conditions of 780 **CMR** 120.G501.5. The construction documents shall be accompanied by a statement bearing the signature of the registered design professional indicating that the design and proposed methods of construction are in accordance with applicable provisions of780 CMR 120.G501.5.

780 CMR 120.G601 HIGH HAZARD ZONES

120.G601.1. Construction in High-hazard Zones (V Zones). Areas of tidal influence which have been determined to be subject to wave heights in excess of three feet (914 mm) or subject to high- velocity wave run-up or wave-induced erosion shall be classified as high- hazard zones. High-hazard zones shall include all areas shown as V Zones on the most recent Flood Hazard Boundary Map or FIRM. All buildings or structures as defined in 780 CMR 120.G201, including new or replacement manufactured homes, erected or substantially improved in a high-hazard zone shall be designed and constructed in accordance with 780 CMR 120.G601. All lateral additions of a building or structure in a high-hazard zone shall also be designed and constructed in accordance with 780 CMR 120.G601 whether or not the lateral addition constitutes a substantial improvement. Plans for a building, structure, substantial improvement, or lateral addition in a high-hazard zone shall be prepared by a registered professional engineer or architect to ensure compliance with 780 CMR 120.G601.

Note: If located in a coastal dune significant to flood control and/or storm damage prevention and a high-hazard zone, a building, structure, including a new or replacement manufactured home, a lateral addition, and a substantial improvement of a building or structure that has suffered substantial damage as a result of flooding or storms shall be designed and constructed in accordance with 780 CMR 120.G701 and 120.G801 as well as 120.G601.

120.G601.1.1 High-hazard Zone Construction Documents Requirements. Where buildings or structures are to be constructed in accordance with 780 CMR 120.G601, the building official shall require that a registered design professional provide construction documents showing proposed details of foundation support and connection components which are used in meeting the requirements of 780 CMR 120.G601.4. Where solid walls or partitions are proposed that are less than two feet above the base flood elevations, wall, framing and connection details of such walls shall be provided, including loading computations for the wall and foundation system used in meeting the conditions of 780 CMR 120.G601.3. The construction documents shall be accompanied by a statement bearing the signature of the registered design professional indicating that the design and proposed methods of construction are in accordance with all applicable provisions of 780 CMR 120.G601.

120.G601.2 Elevation in a High-hazard Zone. All buildings or structures including new and replacement manufactured homes erected or substantially improved within a high-hazard zone shall be elevated so that the bottom of the lowest horizontal structural member supporting the lowest floor, with the exception of mat or raft foundations, piling, pile caps, columns, grade beams and bracing, is located at an elevation that is at least two feet above the base flood elevation. All lateral additions erected in a high- hazard zone shall also be elevated so that the lowest portion of all structural members supporting the lowest floor of the lateral addition with the exception of mat or raft foundations, pilings, pile caps, columns, grade beams and bracing shall also be located at an elevation that is at least two feet above the base flood elevation.

120.G601.3 Enclosures below Base Flood Elevation in a High-hazard Zone. All spaces that are less than two feet above the base flood elevation in a high-hazard zone shall not be used for human occupancy and shall be free of obstruction except as permitted in 780 CMR 120.G601.3:

1. Mat or raft foundations, piling, pile caps, bracing, grade beams and columns which provide structural support for the building.
2. Entrances and exits which are necessary for required ingress and means of egress.
3. Incidental storage of portable or mobile items readily moved in the event of a storm.
4. Walls and partitions are permitted to enclose all or part of the space below the elevated floor provided that such walls and partitions are not part of the structural support of the building and are constructed with insect screening, open wood lattice, or nonsupporting walls designed to break away or collapse without causing collapse, displacement or other structural damage to the elevated portion of the building or supporting foundation system due to the effect of wind loads as specified in 780 CMR 1611.0 and water loads as specified in 780 CMR 1615.0 acting simultaneously. Any such nonsupporting solid wall shall be certified as specified in 780 CMR 120.G601.10 and

120.G601.il.

120.G601.4 Foundations in a High-hazard Zone.
All buildings or structures, including new and replacement manufactured homes, erected or substantially improved in high-hazard zones shall be supported on pilings or columns and shall be adequately anchored to such pilings or columns. All lateral additions in high-hazard zones shall also be supported on pilings or columns and shall be adequately anchored to such pilings or columns. The piling shall have adequate soil penetrations to resist the combined wave and wind loads (lateral and uplift) to which such piles are likely to be subjected during a flood to the base flood elevation. Pile embedment shall include consideration of decreased resistance capacity caused by scour of soil strata surrounding the piling. Pile system design and installation shall also be made in accordance with the provisions of 780 CMR 1816.0 and 1817.0. Mat or raft foundations which support columns shall not be permitted where soil investigations required in accordance with 780 CMR 1802.1 indicate that soil materia] under the mat or raft is subject to scour or erosion from wave-velocity flow conditions.

120.G601.5 Repair or Replacement of Existing Foundations in a High-hazard Zone. Existing foundations may **be** repaired in a high-hazard zone without further compliance with 780 CMR 120.G. unless the work replaces the foundation in total, replaces the foundation so as to constitute new construction, or constitutes a substantia] repair of a foundation as defined in 780 CMR 120.G201. In such events, the foundation shall be brought into compliance with the applicable provisions of 780 CMR 120.G601.

See Note to 780 CMR I20.G601.1.

120.G601.6. Protection of Mechanical and Electrical Systems in a High-hazard Zone. New and replacement electrical equipment and heating, ventilating, air conditioning and other service equipment in a high- hazard zone shall be either placed at least two feet above the base flood elevation or protected so as to prevent water from entering or accumulating within the system components during floods in accordance with the mechanical code listed in 780 CMR 100.0. Installation of electrical wiring and outlets, switches, junction boxes and panels that are less than two feet above the base flood elevation shall conform to the provisions of 527 CMR 12.00 listed in 780 CMR 100.0 for location of such items in wet locations. Duct insulation subject to water damage shall be installed at least two feet above the base flood elevation.

120.G601.7. Construction Materials, Methods and Practices in a High-hazard Zone. All buildings or structures including new or replacement manufactured homes erected in high-hazard zones (V Zones) shall be constructed with materials resistant to flood damage and be constructed by methods and practices that minimize flood damage Construction materials shall be resistant to water damage in accordance with the provisions of 780 CMR 1808.0, 1810.2, 1813.4, 2307.2, 2309.1, 2311.4, 2311.6 and 2503.4.

120.G601.8 Recreational Vehicles in a High- hazard Zone. Recreational vehicles placed in a high-hazard zone and that are not fully licensed and ready for highway use or that are to be placed on a site for more than 180 consecutive days shall comply with the provisions of 780 CMR 120.G601 applicable to buildings or structures including new or replacement manufactured homes.

120.G601.9 Alterations, Renovations and Repairs in a High-hazard Zone. Alterations, renovations and repairs to existing buildings, including manufactured homes, located in a high-hazard zone shall comply with all applicable provisions of 780 CMR. Compliance with 780 CMR 120.G. is required whenever such alteration, renovation or repair constitutes substantial repair of a foundation as defined in 780 CMR 120.G201, the repair or replacement of a foundation that requires compliance with 780 CMR 120.G601. as set forth in 780 CMR 120.G601.5, a substantial improvement as defined in 780 CMR 120.G201, or a lateral addition as defined in 780 CMR 120.G201.

120.G601.10 Certifications and Plans for Construction in a High-hazard Zone. Certifications and plans shall be submitted in accordance with 780 CMR 120.G601.10 and 120.G601.11 for a substantial repair of a foundation as defined in 780 CMR 120.G201, a repair or replacement of a foundation that requires compliance with 780 CMR 120.G601, a substantial improvement as defined in 780 CMR 120.G201, a lateral addition as defined in 780 CMR 120.G201, or a building, or structure, including a new and replacement manufactured home.

120.G601.11 As-built Elevation Certifications for Construction in a High-hazard Zone. For all substantial repairs of a foundation as defined 780 CMR 120.G201, all repairs or replacements of a foundation that trigger the requirement to comply with 780 CMR 120.G601, all substantial improvements as defined in 78Q CMR 120.G201, all lateral additions as defined in 780 CMR 120.G201, and all buildings and structures, including new and replacement manufactured homes, a licensed land surveyor or registered design professional shall certify the actual elevation (in relation to the base flood elevation) of the lowest horizontal structural member required to be elevated by the provisions of 780 CMR 120.G601.2. The certification required herein shall be submitted to the building official after the construction of the foundation is complete and before the commencement of any other work on the building or structure or, if there is no other work, the occupancy of the building or structure.

Appendix C – Zoning Codes

The following pages of this appendix contain copies of sections from Article 25 of the Boston Zoning Code (2009) and Paragraph 60.3(e) of the NFIP Regulations (2009). In order, the sections included are the following:

1. Boston Zoning Code Article 25 [3]
2. Paragraph 60.3(e) of the NFIP Regulations

[3] The pages in this section have been taken from the National Flood Insurance Program's Regulations in the Code of Federal Regulations, Edition 10-1-02.

^ARTICLE 25

FLOOD HAZARD DISTRICTS

(^Article inserted on March 26, 1982*)

SECTION 25-1. **Statement of Purpose**. The purpose of this article is to promote the health and safety of the occupants of land against the hazards of flooding, to preserve and protect the streams and other water courses in the city and their adjoining lands, to protect the community against detrimental use and development, and to minimize flood losses, by provisions designed to:

1. Restrict or prohibit uses and structures which are dangerous to health, safety or property because of water hazards or which cause damaging increases in flood heights or flood velocities.
2. Consider flood plain management in neighboring areas.

SECTION 25-2. **Warning and Disclaimer of Liability**. The degree of flood protection required by this article is considered reasonable for regulatory purposes and is based on scientific and engineering considerations. Larger floods may occur. This article does not imply that areas outside designated flood hazard districts or land uses permitted within such districts will be free from flooding or flood damages. This article shall not create liability on the part of the City of Boston or any officer or employee thereof for any flood damages that may result from reliance on this article or from any administrative decision lawfully made thereunder.

^SECTION 25-3. **Definition and Location of Districts**. Flood hazard districts, also called special flood hazard areas, are defined as lands in a flood plain that are subject to a one percent probability of flooding in any given year. Such flooding is known as the base or 100-year flood. Flood hazard districts are a type of special overlay district established pursuant to Section 3-1A of the Code. These districts include all special flood hazard areas within the City of Boston designated as Zone A, AE, AH, AO, A99, V or VE and are shown on a series of map panels of the Suffolk County Flood Insurance Rate Map (FIRM), effective September 25, 2009, issued by the Federal Emergency Management Agency (FEMA) for the administration of the National Flood Insurance Program. The exact boundaries of the flood hazard districts may be defined by the 100- year base flood elevations shown on the FIRM and further defined by the Suffolk County Flood Insurance Study (FIS) report, effective September 25, 2009. The map identifies special flood hazard areas as A and V zones. V zones are certain coastal areas that are subject to additional hazard because of water velocity and waves. The maps also give the elevations of the base flood in feet above mean sea level (National American Vertical Datum of 1988).

A floodway is defined as the channel of a river or other waterway plus overbank areas that must be kept open in order to discharge the 100-year flood without increasing flood heights. One floodway, for Mother Brook in Hyde Park, is identified by FEMA on a map entitled "Flood Insurance Rate Map, Suffolk County, Massachusetts, City of Boston", effective September 25, 2009, on map panels 0069, 0088 and 0157.

The maps are based on a scientific and engineering study by FEMA entitled "Flood Insurance Study, Suffolk County, Massachusetts, All Jurisdictions" and preliminarily dated October 14, 2008.

Said study and the FIRM and Floodway maps and all maps which, by amendment by the Federal Emergency Management Agency, may be substituted therefore or made supplemental thereto shall be deemed to be, and are hereby made, a part of this code. Said maps and study are on file in the offices of the Building Department, the Conservation Commission, the Zoning Commission and the Engineering Division of the Public Works Department.

(^As amended on December 6, 1990, and September 10, 2009.)

SECTION 25-4. **Interpretation of Maps**. The Building Commissioner shall make interpretations, where needed, as to the exact boundaries of flood hazard districts or floodways. If the map information does not reflect actual site conditions in relation to the base flood elevation, said Commissioner may determine that a location is within or outside a flood hazard district, based on actual elevations provided by a registered professional surveyor or registered professional engineer. Such determination may be appealed to the Board of Appeal under the provisions of Section 5-2 of this code.

The City or an individual may appeal to the Federal Emergency Management Agency to amend the FIRM or Floodway maps or the Flood Insurance Study.

^SECTION 25-5. **Regulations**. Development in flood hazard districts, including structural and non-structural activities and any manmade change to improved or unimproved real estate, such as buildings or other structures, dredging, filling, driving of piles, grading, paving, excavation or drilling operations, shall be subject to the following regulations, as well as to all applicable local, state, and federal regulations:

1. **Residential Construction**. New residential construction shall have the lowest floor, including basement, elevated to or above the base flood elevation.

2. **Nonresidential Construction**. New construction of any commercial, industrial or other nonresidential structure either shall have the lowest floor, including basement, elevated above the highest adjacent grade at least as high as the depth number specified in feet on the FIRM (at least two feet if no depth number is specified); or, together with attendant utility and sanitary facilities, shall:

    (1) be floodproofed so that below the base flood level the structure is watertight with walls substantially impermeable to the passage of water; and

    (2) have structural components capable of resisting hydrostatic and hydrodynamic loads and effects of buoyancy; and

    (3) be certified by a registered professional engineer or architect that the standards of this subsection are satisfied. Such certifications shall be provided to the Building Commissioner.

3. **Pre-existing Structures**. In the case of a building or structure that lawfully exists or for which a building permit has been lawfully issued prior to the effective date of this article, the Board of Appeal may grant permission for reconstruction, structural change or extension thereof under the provisions of Section 9-1, provided that any nonconformity with items 1 and 2 above is not increased.

4. **Storage of Materials and Equipment**. Storage or processing of materials that are flammable, explosive or injurious to water quality or to human, animal or plant life is forbidden in any flood hazard district. Storage of other material or equipment shall be firmly anchored to prevent flotation or be readily removable from the area.

5. **Grading, Filling, Excavating, Dredging, Driving of Piles**. No building permit shall be issued for any work that involves grading, filling, excavating, dredging, driving of piles, paving or other activity that is subject to Chapter 131, Section 40, as amended, of the Massachusetts General Laws unless such work complies with a final order of conditions issued by the Boston Conservation Commission.

6. **Mobile Homes**. No mobile home shall be placed in a flood hazard district.

7. **Floodways**. In a designated floodway there shall be no encroachment, in the form of fill, new construction, substantial improvements, or other development, unless a technical evaluation demonstrates that such encroachment will not result in any increase in flood levels during the base flood discharge.

8. **High Hazard Coastal Districts**. In any V zone, any structure or substantial improvement of any existing structure shall be located landward of the reach of mean high tide.

9. **Drainage Paths**. Within Zones AH and AO on the FIRM, adequate drainage paths must be provided around structures on slopes to guide floodwaters around and away from proposed structures.

(^As amended on September 10, 2009.)

^SECTION 25-6. **Variances**. Subject to the provisions of Sections 7-2, 7- 3, and 7-4, the Board of Appeal may, in a specific case and after public notice and hearing, grant a variance from the provisions of this article provided that the Board of Appeal finds that the proposed use or structure (a) will not derogate from the purpose of this article, (b) will comply with the provisions of the underlying subdistrict or subdistricts, (c) will not overload any public water, drainage or sewer system to such an extent that the proposed use or any developed use in the area or in any other area will be unduly subjected to hazards affecting health, safety or the general welfare, and (d) will not be located within a floodway unless it is demonstrated to the satisfaction of the Board of Appeal that there will be no increase in flood levels during the base flood discharge

Such variances shall lapse and become null and void unless used within two years after the record of said Board's proceedings pertaining thereto is filed with the Building Commissioner pursuant to Section 8 of Chapter 665 of the Acts of 1956 as amended.

Factors to be Considered. In considering a petition for a variance from the provisions of this article, the Board of Appeal shall consider all technical evaluations, standards in other sections of the article and:

a. the danger that materials may be swept onto other lands to the injury of others;
b. the danger to life and property due to flooding;
c. the susceptibility of the proposed facility and its contents to flood damage and the effect of such damage on the individual owner;
d. the importance of the services provided by the proposed facility to the community;
e. the necessity to the facility of a waterfront location, where applicable;
f. the availability of alternative locations for the proposed use which are not subject to flood damage;
g. the compatibility of the proposed use with existing and anticipated development;
h. the relationship of the proposed use to the comprehensive plan and flood plain management program of the area;

i. the safety of access to the property in times of flood for ordinary and emergency vehicles;
j. the expected heights, velocity, duration, rate of rise, and sediment transport of the flood waters and the effects of wave action, if applicable, expected at the site; and
k. the costs of providing governmental services during and after flood conditions, including maintenance and repair of public utilities and facilities such as sewer, gas, electrical, and water systems, and streets and bridges.

Procedures. At the time a variance from item 1 or item 2 of Section 25-5 is issued, the Executive Secretary of the Board of Appeal shall notify the petitioner in writing that (1) construction permitted by said variance will be subject to increased flood insurance rates commensurate with the degree of nonconformity, and (2) construction below the base flood elevation increases risks to life and property.

The Board of Appeal shall maintain a record of all variances granted from Section 25-5, including justification for their issuance. Such variances shall be reported to the Federal Emergency Management Agency in such annual or periodic report as may be requested by the Agency.

Historic Structures. A variance from the provisions of this article may be granted by the Board of Appeal, after due notice and hearing, for the reconstruction or restoration of a structure, or of a structure in a district, which is listed in the National Register of Historic Places or which has been designated by the Boston Landmarks Commission under the provisions of Chapter 772 of the Acts of 1975, even though the requirements of this section are not met.

(^As amended on December 6, 1990)

^SECTION 25-6A. **Exceptions**. Subject to the provisions of Article 6A, the Board of Appeal may, in a specific case and after public notice and hearing, grant an exception to the requirement in Section 25-5.8, provided that the project for fill, new construction, substantial improvement, or other development has received a Conditional Letter of Map Revision (CLOMR) from the Federal Emergency Management Agency.

(^Inserted on December 6, 1990)

SECTION 25-7. **Application**. The provisions of this article are not intended to repeal, amend, abrogate, annual, or interfere with any lawfully adopted statutes, ordinances, covenants, regulations or rules. However, where this article imposes greater restrictions, the provisions of this article shall govern. (Note: The jurisdiction of the Boston Conservation Commission under Chapter 131, Section 40, of the Massachusetts General Laws includes areas not shown on the FIRM and Floodway maps.)

(*Article 25 was originally inserted on March 24, 1977 and was replaced in its entirety on March 26, 1982.)

Paragraph 60.3(e) of the NFIP Regulations

When the Administrator has provided a notice of final base flood elevations within Zones A1–30 and/or AE on the community's FIRM and, if appropriate, has designated AH zones, AO zones, A99 zones, and A zones on the community's FIRM, and has identified on the community's FIRM coastal high hazard areas by designating Zones V1– 30, VE, and/or V, the community shall:

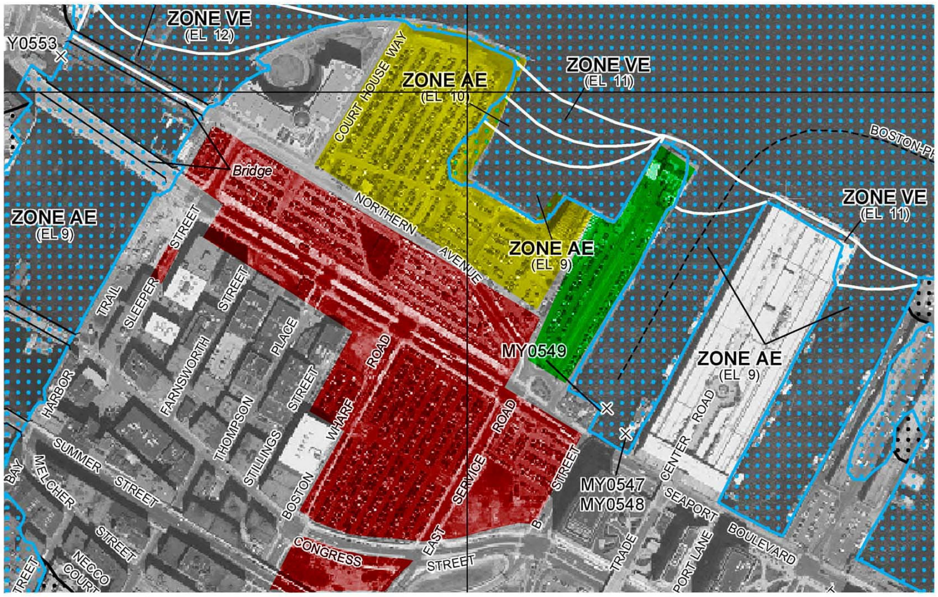
1. Meet the requirements of paragraphs (c)(1) through (14) of this section;
2. Within Zones V1–30, VE, and V on a community's FIRM,
    i. obtain the elevation (in relation to mean sea level) of the bottom of the lowest structural member of the lowest floor (excluding pilings and columns) of all new and substantially improved structures, and whether or not such structures contain a basement, and
    ii. maintain a record of all such information with the official designated by the community under § 59.22(a)(9)(iii);
3. Provide that all new construction within Zones V1–30, VE, and V on the community's FIRM is located landward of the reach of mean high tide;
4. Provide that all new construction and substantial improvements in Zones V1–30 and VE, and also Zone V if base flood elevation data is available, on the community's FIRM, are elevated on pilings and columns so that
    i. the bottom of the lowest horizontal structural member of the lowest floor (excluding the pilings or columns) is elevated to or above the base flood level; and
    ii. the pile or column foundation and structure attached thereto is anchored to resist flotation, collapse and lateral movement due to the effects of wind and water loads acting simultaneously on all building components. Water loading values used shall be those associated with the base flood. Wind loading values used shall be those required by applicable State or local building standards. A registered professional engineer or architect shall develop or review the structural design, specifications and plans for the construction, and shall certify that the design and methods of construction to be used are in accordance with accepted standards of practice for meeting the provisions of paragraphs (e)(4) (i) and (ii) of this section.
5. Provide that all new construction and substantial improvements within Zones V1–30, VE, and V on the community's FIRM have the space below the lowest floor either free of obstruction or constructed with non-supporting breakaway walls, open wood latticework, or insect screening intended to collapse under wind and water loads without causing collapse, displacement, or other structural damage to the elevated portion of the building or supporting foundation system. For the purposes of this section, a breakway wall shall have a design safe loading resistance of not less than 10 and no more than 20 pounds per square foot. Use of breakway walls which exceed a design safe loading resistance of 20 pounds per square foot (either by design or when so required by local or State codes) may be permitted only if a registered professional engineer or architect certifies that the designs proposed meet the following conditions:

i. Breakaway wall collapse shall result from a water load less than that which would occur during the base flood; and,
ii. The elevated portion of the building and supporting foundation system shall not be subject to collapse, displacement, or other structural damage due to the effects of wind and water loads acting simultaneously on all building components (structural and non-structural). Water loading values used shall be those associated with the base flood. Wind loading values used shall be those required by applicable State or local building standards. Such enclosed space shall be useable solely for parking of vehicles, building access, or storage.

6. Prohibit the use of fill for structural support of buildings within Zones V1–30, VE, and V on the community's FIRM;
7. Prohibit man-made alteration of sand dunes and mangrove stands within Zones V1–30, VE, and V on the community's FIRM which would increase potential flood damage.
8. Require that manufactured homes placed or substantially improved within Zones V1–30, V, and VE on the community's FIRM on sites
   i. Outside of a manufactured home park or subdivision,
   ii. In a new manufactured home park or subdivision,
   iii. In an expansion to an existing manufactured home park or subdivision, or
   iv. In an existing manufactured home park or subdivision on which a manufactured home has incurred ''substantial damage'' as the result of a flood, meet the standards of paragraphs (e)(2) through (7) of this section and that manufactured homes placed or substantially improved on other sites in an existing manufactured home park or subdivision within Zones VI–30, V, and VE on the community's FIRM meet the requirements of paragraph (c)(12) of this section.
9. Require that recreational vehicles placed on sites within Zones V1–30, V, and VE on the community's FIRM either
   i. Be on the site for fewer than 180 consecutive days,
   ii. Be fully licensed and ready for highway use, or
   iii. Meet the requirements in paragraphs (b)(1) and (e) (2) through (7) of this section. A recreational vehicle is ready for highway use if it is on its wheels or jacking system, is attached to the site only by quick disconnect type utilities and security devices, and has no permanently attached additions.

Appendix D –Boston Flood Maps

The map below shows an overlay of the FEMA Flood Maps with respect to the new projects that will be constructed in the Innovation District in South Boston. The legend and note for the FEMA map are shown below on another page.



Seaport Square

Fan Pier

Pier 4

NFIP

NATIONAL FLOOD INSURANCE PROGRAM

PANEL 0081G

FIRM

FLOOD INSURANCE RATE MAP

SUFFOLK COUNTY, MASSACHUSETTS

(ALL JURISDICTIONS)

PANEL 81 OF 151

(SEE MAP INDEX FOR FIRM PANEL LAYOUT)

CONTAINS:

COMMUNITY	NUMBER	PANEL	SUFFIX
BOSTON, CITY OF	250286	0081	G

Notice to User: The **Map Number** shown below should be used when placing map orders; the **Community Number** shown above should be used on insurance applications for the subject community.

MAP NUMBER
25025C0081G

EFFECTIVE DATE
SEPTEMBER 25, 2009

Federal Emergency Management Agency

NOTES TO USERS

This map is for use in administering the National Flood Insurance Program. It does not necessarily identify all areas subject to flooding, particularly from local drainage sources of small size. The **community map repository** should be consulted for possible updated or additional flood hazard information.

To obtain more detailed information in areas where **Base Flood Elevations** (BFEs) and/or **floodways** have been determined, users are encouraged to consult the Flood Profiles and Floodway Data and/or Summary of Stillwater Elevations tables contained within the Flood Insurance Study (FIS) report that accompanies this FIRM. Users should be aware that BFEs shown on the FIRM represent rounded whole-foot elevations. These BFEs are intended for flood insurance rating purposes only and should not be used as the sole source of flood elevation information. Accordingly, flood elevation data presented in the FIS report should be utilized in conjunction with the FIRM for purposes of construction and/or floodplain management.

Coastal Base Flood Elevations shown on this map apply only landward of 0.0' North American Vertical Datum of 1988 (NAVD 88). Users of this FIRM should be aware that coastal flood elevations are also provided in the Summary of Stillwater Elevations table in the Flood Insurance Study report for this jurisdiction. Elevations shown in the Summary of Stillwater Elevations table should be used for construction and/or floodplain management purposes when they are higher than the elevations shown on this FIRM.

Boundaries of the **floodways** were computed at cross sections and interpolated between cross sections. The floodways were based on hydraulic considerations with regard to requirements of the National Flood Insurance Program. Floodway widths and other pertinent floodway data are provided in the Flood Insurance Study report for this jurisdiction.

Certain areas not in Special Flood Hazard Areas may be protected by **flood control structures.** Refer to Section 2.4 "Flood Protection Measures" of the Flood Insurance Study report for information on flood control structures for this jurisdiction.

The **projection** used in the preparation of this map was Massachusetts State Plane mainland zone (FIPSZONE 2001). The **horizontal datum** was NAD83, GRS1980 spheroid. Differences in datum, spheroid, projection or State Plane zones used in the production of FIRMs for adjacent jurisdictions may result in slight positional differences in map features across jurisdiction boundaries. These differences do not affect the accuracy of the FIRM.

Flood elevations on this map are referenced to the North American Vertical Datum of 1988. These flood elevations must be compared to structure and ground elevations referenced to the same **vertical datum.** For information regarding conversion between the National Geodetic Vertical Datum of 1929 and the North American Vertical Datum of 1988, visit the National Geodetic Survey website at http://www.ngs.noaa.gov/ or contact the National Geodetic Survey at the following address:

NGS Information Services
NOAA, N/NGS12
National Geodetic Survey
SSMC-3, #9202
1315 East-West Highway
Silver Spring, MD 20910-3282

To obtain current elevation, description, and/or location information for **bench marks** shown on this map, please contact the Information Services Branch of the National Geodetic Survey at **(301) 713-3242,** or visit its website at http://www.ngs.noaa.gov/.

Base map information shown on this FIRM was derived from digital orthophotography. Base map files were provided in digital form by Massachusetts Geographic Information System (MassGIS). Ortho imagery was produced at a scale of 1:5,000. Aerial photography is dated April 2005.

This map reflects more detailed and up-to-date **stream channel configurations** than those shown on the previous FIRM for this jurisdiction. The floodplains and floodways that were transferred from the previous FIRM may have been adjusted to conform to these new stream channel configurations. As a result, the Flood Profiles and Floodway Data tables *in the Flood Insurance Study report (which contains authoritative hydraulic data)* may reflect stream channel distances that differ from what is shown on this map.

Corporate limits shown on this map are based on the best data available at the time of publication. Because changes due to annexations or de-annexations may have occurred after this map was published, map users should contact appropriate community officials to verify current corporate limit locations.

Please refer to the separately printed **Map Index** for an overview map of the county showing the layout of map panels; community map repository addresses; and a Listing of Communities table containing National Flood Insurance Program dates for each community as well as a listing of the panels on which each community is located.

Contact the **FEMA Map Service Center** at 1-800-358-9616 for information on available products associated with this FIRM. Available products may include previously issued Letters of Map Change, *a Flood Insurance Study report,* and/or digital versions of this map. The FEMA Map Service Center may also be reached by Fax at 1-800-358-9620 and its website at http://www.msc.fema.gov/.

If you have **questions about this map** or questions concerning the National Flood Insurance Program in general, please call **1-877-FEMA MAP** (1-877-336-2627) or visit the FEMA website at http://www.fema.gov/.

LEGEND

SPECIAL FLOOD HAZARD AREAS (SFHAs) SUBJECT TO INUNDATION BY THE 1% ANNUAL CHANCE FLOOD

The 1% annual chance flood (100-year flood), also known as the base flood, is the flood that has a 1% chance of being equaled or exceeded in any given year. The Special Flood Hazard Area is the area subject to flooding by the 1% annual chance flood. Areas of Special Flood Hazard include Zones A, AE, AH, AO, AR, A99, V and VE. The Base Flood Elevation is the water-surface elevation of the 1% annual chance flood.

ZONE A	No Base Flood Elevations determined.
ZONE AE	Base Flood Elevations determined.
ZONE AH	Flood depths of 1 to 3 feet (usually areas of ponding); Base Flood Elevations determined.
ZONE AO	Flood depths of 1 to 3 feet (usually sheet flow on sloping terrain); average depths determined. For areas of alluvial fan flooding, velocities also determined.
ZONE AR	Special Flood Hazard Area formerly protected from the 1% annual chance flood by a flood control system that was subsequently decertified. Zone AR indicates that the former flood control system is being restored to provide protection from the 1% annual chance or greater flood.
ZONE A99	Area to be protected from 1% annual chance flood by a Federal flood protection system under construction; no Base Flood Elevations determined.
ZONE V	Coastal flood zone with velocity hazard (wave action); no Base Flood Elevations determined.
ZONE VE	Coastal flood zone with velocity hazard (wave action); Base Flood Elevations determined.

FLOODWAY AREAS IN ZONE AE

The floodway is the channel of a stream plus any adjacent floodplain areas that must be kept free of encroachment so that the 1% annual chance flood can be carried without substantial increases in flood heights.

OTHER FLOOD AREAS

ZONE X	Areas of 0.2% annual chance flood; areas of 1% annual chance flood with average depths of less than 1 foot or with drainage areas less than 1 square mile; and areas protected by levees from 1% annual chance flood.

OTHER AREAS

ZONE X	Areas determined to be outside the 0.2% annual chance floodplain.
ZONE D	Areas in which flood hazards are undetermined, but possible.

COASTAL BARRIER RESOURCES SYSTEM (CBRS) AREAS

OTHERWISE PROTECTED AREAS (OPAs)

CBRS areas and OPAs are normally located within or adjacent to Special Flood Hazard Areas.

1% annual chance floodplain boundary
0.2% annual chance floodplain boundary
Floodway boundary
Zone D boundary
CBRS and OPA boundary
Boundary dividing Special Flood Hazard Areas of different Base Flood Elevations, flood depths or flood velocities.

~~ 513 ~~~~	Base Flood Elevation line and value; elevation in feet*
(EL 987)	Base Flood Elevation value where uniform within zone; elevation in feet*

* Referenced to the North American Vertical Datum of 1988 (NAVD 88)

(A)———(A)	Cross section line
(23)- - - - - - - -(23)	Transect line
97°07'30", 32°22'30"	Geographic coordinates referenced to the North American Datum of 1983 (NAD 83)
$^{42}75^{000m}$N	1000-meter Universal Transverse Mercator grid, zone 19
6000000 M	5000-foot grid : Massachusetts State Plane coordinate system, mainland zone (FIPSZONE 2001), Lambert Conformal Conic
DX5510 ×	Bench mark (see explanation in Notes to Users section of this FIRM panel)
• M1.5	River Mile

MAP REPOSITORIES
Refer to Map Repositories list on Map Index

EFFECTIVE DATE OF COUNTYWIDE
FLOOD INSURANCE RATE MAP
September 25, 2009
EFFECTIVE DATE(S) OF REVISION(S) TO THIS PANEL

For community map revision history prior to countywide mapping, refer to the Community Map History table located in the Flood Insurance Study report for this jurisdiction.

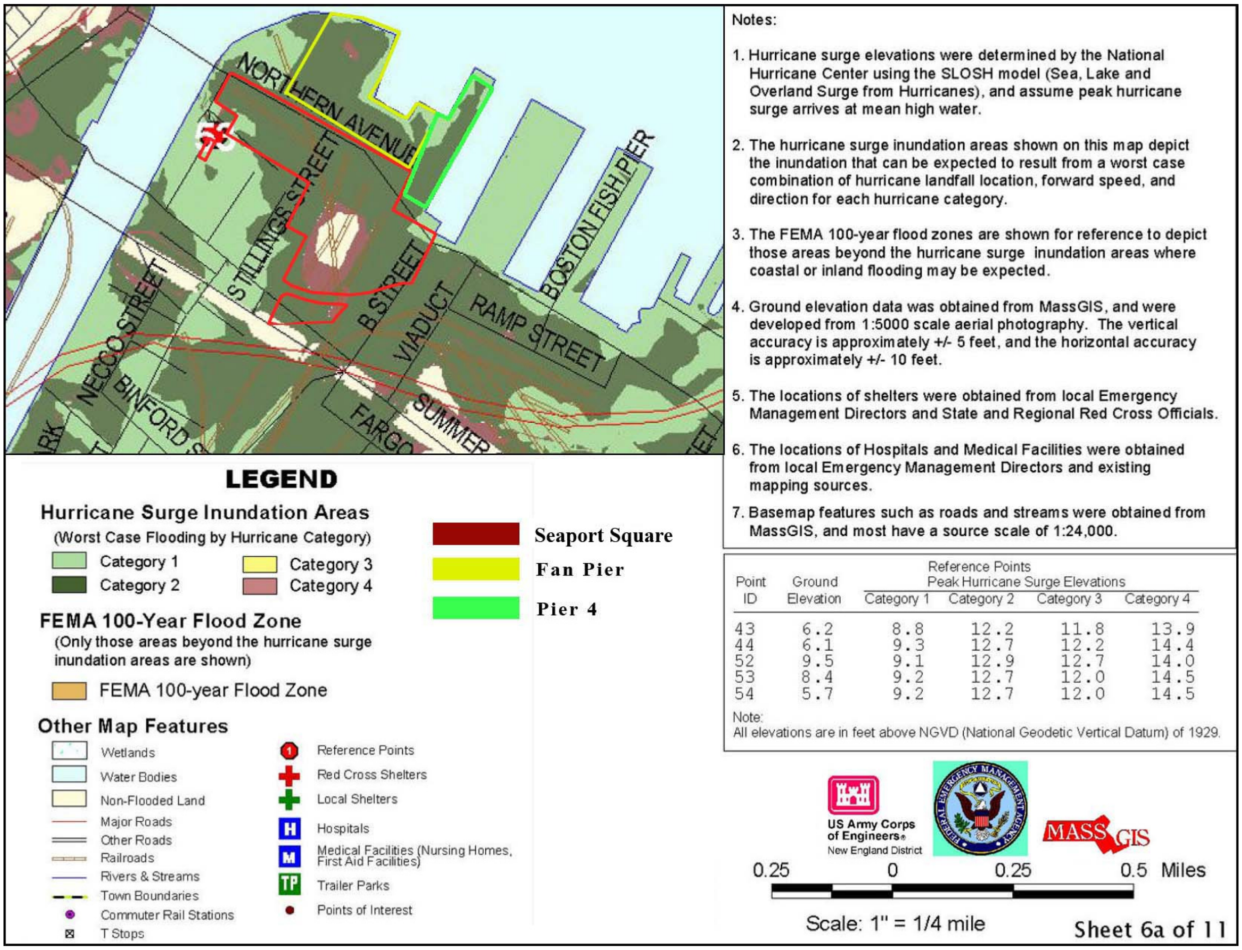
To determine if flood insurance is available in this community, contact your insurance agent or call the National Flood Insurance Program at 1-800-638-6620.

MAP SCALE 1" = 500'

250 0 500 1000 FEET

150 0 150 300 METERS

The last map shows an overlay of the Army Corps of Engineer's Hurricane Storm Surge map with respect to the new projects that will be constructed in the Innovation District in South Boston.



Appendix E – Legal Options for the City

1. Project and Environmental Reviews	
A. Project Impact Review	The City can consider the impacts of climate change on projects, and vice versa, through Article 80 of the Zoning Code.
B. Environmental Impact Review	The City can include adaptation considerations in its comments on the scoping and environmental review of projects under the Massachusetts Environmental Protection Act ("MEPA"). The City can work with the state MEPA Office to ensure that MEPA's guidance for considering the impacts of climate change in environmental review is consistent with the City's approach.
2. Legislation & Regulations	
A. Code Enforcement	The Boston Commissioner of Inspectional Services has existing authority to abate nuisances that are injurious to the public health, including those caused by unsafe buildings, and to require that existing buildings meet current flood-resistance standards in certain circumstances under the State Sanitary and Building Codes. The City's Public Health Commission and the Commissioner of Inspectional Services can pass regulations that build on the minimums set forth in the state sanitary code and the State Board of Building Regulations and Standards ("BBRS") can broaden the situations in which flood-resistance standards apply to existing buildings.
B. Chapter 91 Licenses	The City can consider sea level rise during new Chapter 91 licensing proceedings. The City can request that the Massachusetts Department of Environmental Protection ("DEP") use its authority to renew, amend, revoke, or nullify licenses to ensure continuing compliance with public access requirements.
C. Overlay Zones	The City can amend its Groundwater Conservation Overlay Zone to improve stormwater management and increase onsite retention.

D. Wetlands Ordinance	The City can enact a wetlands ordinance to improve stormwater management and protect coastal resources.
E. Floodplain Regulations	The City can use maps identifying the future 100-year floodplain as a basis for delineating Flood Hazard Districts under Article 25 of the Boston Zoning Code. The City can also restrict vulnerable ground floor uses within these Districts.
F. Resilient Building Design	The City can adopt flood-related performance standards in Article 80 of the Boston Zoning Code, similar to its approach to green building. The City can request that the BBRS pass more stringent flood-resistance standards for Boston or create a flood-resistance stretch code that Boston and other municipalities could adopt.
3. Public Investment	
A. Procurement	The City can use its procurement policies to mandate use of materials that will aid adaptation, such as use of flood-resistant materials in public buildings subject to future flooding.
B. Capital Planning	The City can use its capital planning process to identify and prioritize investments to maintain, renovate, and upgrade public infrastructure to reduce vulnerability to the impacts of climate change.
C. Regional Cooperation	The Boston Water and Sewer Commission ("BWSC") can develop a rate system to charge other municipalities for inflows to the City, work with other municipalities to reduce inflows to Boston, and/or co-finance stormwater management projects in other municipalities to increase Boston's reserve capacity and reduce combined sewer overflows ("CSOs"). The City can encourage the Massachusetts Water Resources Authority ("MWRA") to improve Boston's stormwater flow through its capital improvement program.

4. **Funding for Specific Adaptation Measures**	
A. FEMA Funding for Hazard Mitigation	The City can use Federal Emergency Management Agency ("FEMA") Hazard Mitigation Grant Program planning funds to assess its vulnerability to climate change-related hazards as part of its Hazard Mitigation Plan update. The City can use this plan to access further federal grant funding to reduce its vulnerability to climate change-related natural hazards.
B. Community Development Block Grant (CDBG) Funding	The City can utilize Community Development Block Grants to fund projects that help reduce vulnerability to climate change in low-income neighborhoods.
C. BWSC User Fees	The BWSC can co-finance maintenance of green infrastructure with the City through its user fees.

Note. This table taken from "Legal Options for Municipal Climate Adaptation in South Boston" by W. Jacobs, L. Cohen, & J. McGrory (2011).