DRAFT

Natural Hazards: Hurricanes, Floods, and Sea Level Rise in the Metro Bay Region Special Area Management Plan

Analysis of Issues and Recommendations for Action

CRMC Draft - January 2009

Natural Hazards: Hurricanes, Floods, and Sea Level Rise in the Metro Bay Region Special Area Management Plan

Analysis of Issues and Recommendations for Action

EXECUTIVE SUMMARY

Rhode Island's coastal communities and the Metro Bay Special Area Management Plan (SAMP) region in particular, are faced with the challenges of proactive planning for anticipated sea level rise and damage resulting from hurricanes and other storm events. The CRMC amended its coastal program in January of 2008 with Section 145 – Climate Change and Sea-level Rise (http://www.crmc.ri.gov/regulations/programs/redbook.pdf), which anticipates 3 to 5 feet of sea-level rise by 2100. This range of increased sea level rise was determined from the best available scientific sources. In a recent paper published in *Science* this past September by Pfeffer et al., (2008), the authors refine earlier findings for predicted sea-level rise and project heights of between 0.8 and 2.0 meters (2.6 – 6.6 feet) by the end of this century. These new findings confirm and are consistent with the figures adopted by CRMC. Obviously, these increased elevations of mean sea level will have dramatic effects on Rhode Island's shoreline, physically affecting coastal infrastructure, residential and commercial buildings, and coastal habitats, especially salt marshes. Further, the economic consequences from flood and storm damage will negatively impact our local and state economies.

Our region has experienced numerous hurricane events in the past and will experience more in the future. The last two major hurricanes to strike Rhode Island were in 1938 and 1954. Since that time, significant development has occurred and new projects are currently planned within the flood hazard areas of the Metro Bay SAMP region. These projects are and will be susceptible to increased risks of flooding and storm damage as a result of sea level rise. Additionally, coastal flooding risks and storm-induced damage will be felt farther inland as sea levels rise and flood zones expand inland. This Metro Bay SAMP chapter details the hazard issues of concern and defines a series of recommendations to minimize the risk from hurricane damage and flooding, both now and in the future, as a result of climate change and sea level rise.

Recommended policy and regulation changes include:

- Develop standards and regulations to address sea level rise and climate change (statewide)
- Adopt freeboard standards that will increase the required first floor elevation above the base flood elevation for new or substantially improved structures in high hazard areas (statewide)
- Implement the Coastal A-zone policy and coordinated implementation approach, where structures within A-zones subject to wave activity of 1.5 to 3 feet are designed to V-zone standards (statewide)
- Develop a review procedure for proposals that include filling in Coastal A-zone and V-zones (Metro Bay), tracking CLOMA-F and LOMA-F to assure that fill is not used as structural support in existing and potential V zones.
- Incorporate provisions into design and permitting of water-based projects to address preparedness, response and recovery of hazards related to hurricanes and sea level rise (statewide)

Recommended actions include:

- Develop and implement a model floodplain ordinance (statewide)

- Evaluate the effectiveness of the hurricane barrier and building standards used behind the barrier based on current and future projected conditions (Metro Bay)
- Inventory hazardous material, including household hazardous material and potential debris within the Metro Bay SAMP. Establish a marine debris removal plan for post-hazard cleanup (Metro Bay). Establish an outreach program to educate home owners about household hazardous waste.
- Prioritize property acquisition strategies that focus on UCG Areas of Particular Concern and flood mitigation (Metro Bay)
- Develop an ongoing outreach program for coastal developers, engineers, small businesses, banks, and home owners on the best ways to safeguard lives and property against coastal hazards (statewide)
- Coordinate state and local aspects of floodplain management across the Metro Bay region (Metro Bay) to include a central website for easy information access and exchange
- Develop and implement training programs (statewide)

Major research needs to accomplish recommended actions

- Obtain LIDAR and multi-beam data to create a seamless topographic and bathymetric digital elevation model for accurate shoreline mapping and to model inundation scenarios for current and future conditions.
- Develop maps depicting current Coastal A zones.
- Develop maps of future flood zones with anticipated sea level rise.
- Develop a build-out analysis for the entire coastal flood plain within the Metro Bay SAMP

1. INTRODUCTION

1.1. The Metro Bay SAMP in the Face of Climate Change

The most recent findings of the Intergovernmental Panel on Climate Change (IPCC, 2007) clearly demonstrate the global air and ocean temperatures are rising due to recent anthropogenic forcing. As global temperatures continue to increase, thermal expansion of seawater and accelerated melting of glacial ice leads to an increase in the total volume of global ocean waters. Over the last 100 years, sea levels have risen 6.7 inches globally. By 2100, greenhouse gas concentrations are predicted to reach levels greater than or equal to those observed during the last interglacial period when sea levels were between 13.1 and 19.7 feet higher than present levels (Overpeck, et al., 2006). Moreover, it has been reported that the occurrence of severe storm events is increasing almost everywhere in the contiguous United States (Madsen and Figdor, 2007). Climate change may increase both the frequency and the severity of these events. Finally, as sea temperatures increase, the associated changes in species composition and ecosystem dynamics will alter our estuaries, fisheries and wetlands, with the potential to increase the presence of invasive species.

In the northeastern United States, signs of our planet's changing climate have become increasingly apparent. Over the past 30 years, average winter temperatures in the region have risen 3.8 degrees Fahrenheit (Union of Concerned Scientists, 2006). The Northeast has experienced the largest increase in extreme precipitation events in the country. New England as a whole has experienced a 61 percent increase in such storm events over the past 59 years, while Rhode Island in particular has witnessed an 88 percent rise over the same period (Madsen and Figdor, 2007). Additionally, data from the Newport tide gauge (1930-2006) suggests a relative rate of sea level rise equal to 10.2 inches (± 0.75 inches) over the last century in Rhode Island, with the last 19 years (1989-2007) showing an even higher average rate of sea level rise: approximately 0.157-inches per year (National Oceanic and Atmospheric Administration (NOAA[1], 2007). If this linear trend continues, Newport's sea level in 2100 will be 15 inches higher than today. However, most model predictions are non-linear; these models anticipate sea levels to be approximately 1.6 to 4.6 feet higher by 2100. Higher sea levels will mean that coastal flood zones will move inland, encroaching on areas that currently are not in high risk flood zones.

Thus, as the frequency of intense storm events increases alongside rising global water temperatures, the people, resources, and facilities located along the upper reaches of Narragansett Bay face ever-greater risks from hurricanes and floods. The Metro Bay region, comprising the coastal portions of the cities of Cranston, Providence, Pawtucket, and East Providence, has served as an urban working waterfront of national and international significance for over 200 years. The region has a population of approximately 379,000 (nearly one-third of the State population of 1.1 million) and a population density eight times greater than the remainder of Rhode Island. The Metro Bay region is a prominent regional storage and distribution site for energy sources (coal, oil, natural and liquefied gas, electricity), and is characterized by transportation access (ship, road, rail), medical and education institutions, a surprising amount of natural habitat. Additionally, the Metro Bay Region is in close proximity to

[1] This value was determined by linear regression of plots of monthly average tide data taken from the Newport Tide Gauges, provided by NOAA's "Tides and Currents" data website (NOAA, 2007)

other urban centers, particularly Boston (40 miles) and New York City (150 miles). Critical regional facilities include a port, oil and gas storage tanks, four state sewage treatment plants, five hospitals, several bridges, and commercial and commuter rails. A major transportation project is also underway to relocate a part of Interstate 195 that spans the Providence and Seekonk rivers.

Parts of this densely settled and developed coastal area is located within a 100-year floodplain that has endured significant losses of both life and property from natural hazards such as the Hurricane of 1938 and Hurricane Carol in 1954. The cities are only just beginning to work together on evacuation issues and thus serious potential public safety problems exist. The Federal Emergency Management Agency (FEMA) has already identified the region as the Achilles' heel of the Northeast due to its vulnerability to flooding (Vanderschmidt, 2005). According to existing models, storm surges as high as 21-feet NGVD29 (22.7-feet MLLW) could cover this urban environment, crippling public and private activity as well as threatening lives, the economy, and the environment. As an additional point, USGS models show that this same scale of flooding may be experienced in the unlikely event of an Atlantic Ocean tsunami tidal wave as well. Therefore, significant public education, prevention, and preparation processes are needed to ensure that this region is able to withstand the effects of a major storm. Adaptation measures will need to be implemented to retrofit infrastructure to be effective with increased sea level rise, given that some facilities are already seeing impacts from spring tides, particularly in the case of strong onshore wind.

Through the Metro Bay SAMP process, major stakeholders and local and national experts (listed in the reference section) have identified specific issues and findings of fact, and proposed solutions to natural hazard threats. Their work, along with additional research, forms the basis for this chapter. This SAMP chapter addresses the impacts of natural hazards and climate change on development in the Metro Bay. Additionally, some of the larger issues, potential impacts, and adaptation measures related to coastal ecosystem functions and services affecting specific resource areas (e.g., wetlands) and policy initiatives (e.g., Urban Coastal Greenway) should be reviewed and addressed by the CRMC and associated state and municipal authorities in the near future.

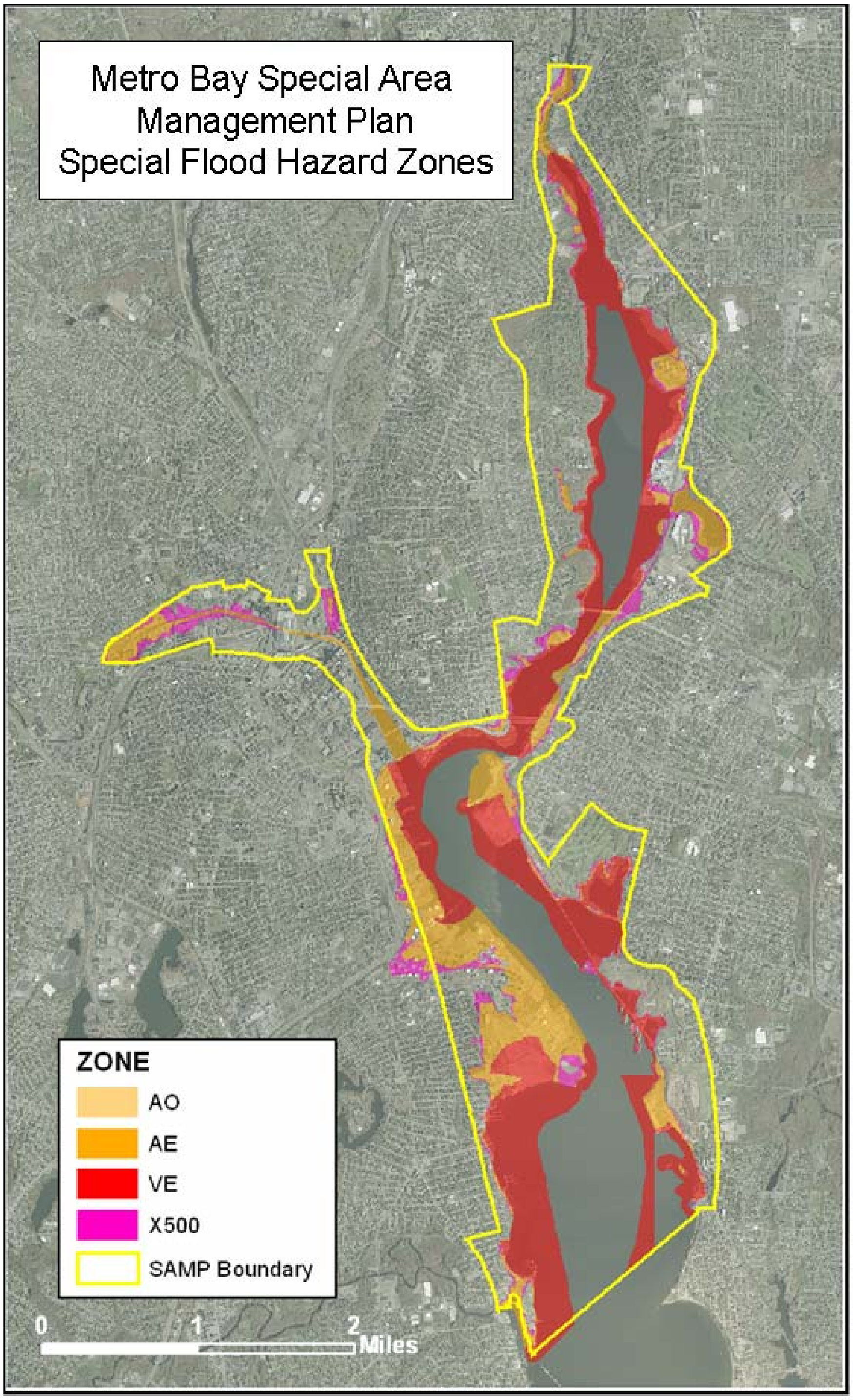


Figure 1. Flood Hazard Zones in the Metro Bay (Providence Plan, 2006).

Zone AO - Subject to 100-year shallow flooding with average depth of 1 to 3 feet. Base flood elevation undetermined.

Zone AE - Represent areas subject to 100-year flood with base flood elevation determined.

Zone VE - Represent areas subject to 100-year flood and additional velocity hazard (wave action). Base flood elevation determined.

X 500 - Areas outside the 100-year flood plain and inside the 500-year flood plain with less than 0.2 percent annual probability of flooding.

Zones based RIGIS overlays, developed from Flood Insurance Rate Maps effective prior to the year 2000, utilizing Flood Hazard Base Maps developed in 1970-71. This figure does not depict the revised maps, currently being produced by FEMA for Providence County.

1.2. Definitions

The discussion of natural hazards and coastal impacts relies on a body of knowledge for which terminology and the consistent use of data is critical when developing models, identifying risks, and permitting projects. Several terms related to floodplain mapping and tidal datums are presented below to help insure that decision-makers are clear about the meaning and use of these terms, as they are presented in this Special Area Management Plan.

Floodplain Mapping

A-zone: Areas susceptible to flooding from tidal waters or riverine systems during the 100-year storm event (1% annual chance of occurrence). Breaking wave heights in A Zones adjacent to V Zone or Coastal A Zones will be less than 1.5 feet.

Base Flood Elevation (BFE): Flood level of the 100-year flood waters (1% annual chance of occurrence), including wave height, in relation to a specified vertical datum

Coastal A-zone: The area landward of a V Zone or landward of an open coast without a mapped V Zone that is within a Special Flood Hazard Area and subject to tidal and storm surge flooding resulting from the 100-year storm event (1% annual chance of occurrence). During base flood conditions the potential breaking wave height is greater than or equal to 1.5 feet, but less than 3.0 feet.

Special Flood Hazard Area: Land located in the floodplain subject to flooding during the 100-year storm event (1% annual chance of occurrence) and delineated on the Flood Insurance Rate Map as V and A zones.

Flood Insurance Rate Map (FIRM): The official map of a community that delineates flood hazard areas. The Federal Emergency Management Agency (FEMA) is responsible for the flood zone delineations, modifications, and updates to the FIRMs as part of the National Flood Insurance Program (NFIP).

Storm surge: The elevation of the ocean surface above the normal tide elevation due to the action of wind stress and reduced atmospheric pressure associated with coastal storms. Storm surge is measured as the difference between actual sea-surface elevation during a storm and the predicted sea-surface elevation associated with the astronomical tide at the time.

V-zone: An area along the coast within a Special Flood Hazard Area and subject to high velocity wave action with tidal and storm surge flooding resulting from the 100-year storm event (1% annual chance of occurrence). During base flood conditions the potential breaking wave height will be 3 feet or greater.

Datums - Tidal and Geodetic (NOAA, 2007) - See Figure 6, p. 15

A tidal datum: is a vertical datum defined by a certain phase of the tide. Tidal datums are local datums and should not be extended into areas which have differing hydrographic characteristics. Tidal datums are calculated from direct observations at a primary tide station over a nineteen year period which is known as a tidal epoch. Tidal datums can be derived from a comparison of simultaneous observations at the primary and a secondary tide station to calculate an equivalent of a 19-year value.

Mean Higher High Water (MHHW): The average of the higher high water height of each tidal day observed over the National Tidal Datum Epoch.

Mean High Water (MHW): A tidal datum determined by the average of all the high water heights observed over the National Tidal Datum Epoch or the Rhode Island Modified Epoch (http://www.crmc.ri.gov/pubs/pdfs/methods_meanhighwater.pdf).

Mean Low Water (MLW): The average of all the low water heights observed over the National Tidal Datum Epoch.

Mean Lower Low Water (MLLW): A tidal datum determined by the average of the lower low water height of each tidal day observed over the National Tidal Datum Epoch.

Mean Sea Level (MSL): A tidal datum determined by the arithmetic mean of hourly tide heights at a given tide station over a 19-year National Tidal Datum Epoch. It pertains to local mean sea level and should not be confused with a fixed vertical datum such as NAVD88.

Mean tide level (MTL): A tidal datum corresponding to the arithmetic mean of mean high water and mean low water.

National Tidal Datum Epoch: The specific l9-year period adopted by the National Ocean Service as the time segment over which tide observations are taken and calculated to obtain mean values (e.g., MLLW, etc.) for tidal datums. The present National Tidal Datum Epoch is 1983-2001. The effective Rhode Island Modified Epoch uses the local sea level trend line from the 1930 -1999 time period for the Newport tide gage published by NOAA at http://tidesandcurrents.noaa.gov/sltrends/sltrends.shtml to estimate a tidal datum epoch value for MSL centered on the current year.

Geodetic datums are fixed reference points that define the size and shape of the earth. A horizontal datum is used to define the location of a point on the earth's surface within a coordinate system. A vertical datum is used to measure the elevation of points on the Earth's surface.

The North American Datum of 1983 (NAD 83) is the official horizontal datum for the United States based on a geocentric origin and the Geodetic Reference System 1980.

NGVD 29 is a vertical datum based on the local mean sea level in 1929, which has changed over time.

NAVD 88 is now the official civilian vertical datum for surveying and mapping activities in the United States. NAVD 88 is not synonymous with mean sea level nor does it correct for sea level changes that have occurred since the establishment of NGVD 29. The conversion to NAVD 88 should be accomplished on a project-by-project basis.
Conversions between datums can be made at www.tidesandcurrents.noaa.gov or calculated through the US Army Corps of Engineers CORPSCON at http://crunch.tec.army.mil/software/corpscon/corpscon.html.

Table 1: Tidal Datum References

Elevations of Tidal Data (Providence)	Feet above MLLW	Meter above MLLW
Mean Higher High Water (MHHW)	4.84	1.48
Mean High Water (MHW)	4.60	1.40
North American Vertical Datum-1988 (NAVD88)	2.47	0.75
Mean Tide Level (MTL)	2.39	0.73
Mean Sea Level (MSL)	2.25	0.69
National Geodetic Vertical Datum-1929 (NGVD29)	1.68	0.51
Mean Low Water (MLW)	0.18	0.06
Mean Lower Low Water (MLLW)	0.00	0.00
Max Observed	17.52	5.34

Source: Providence tide gauge, 1983-2001 epoch, NOAA, 2003; Spaulding, 2005

2. PAST HAZARD EVENTS AND FUTURE EXPOSURE

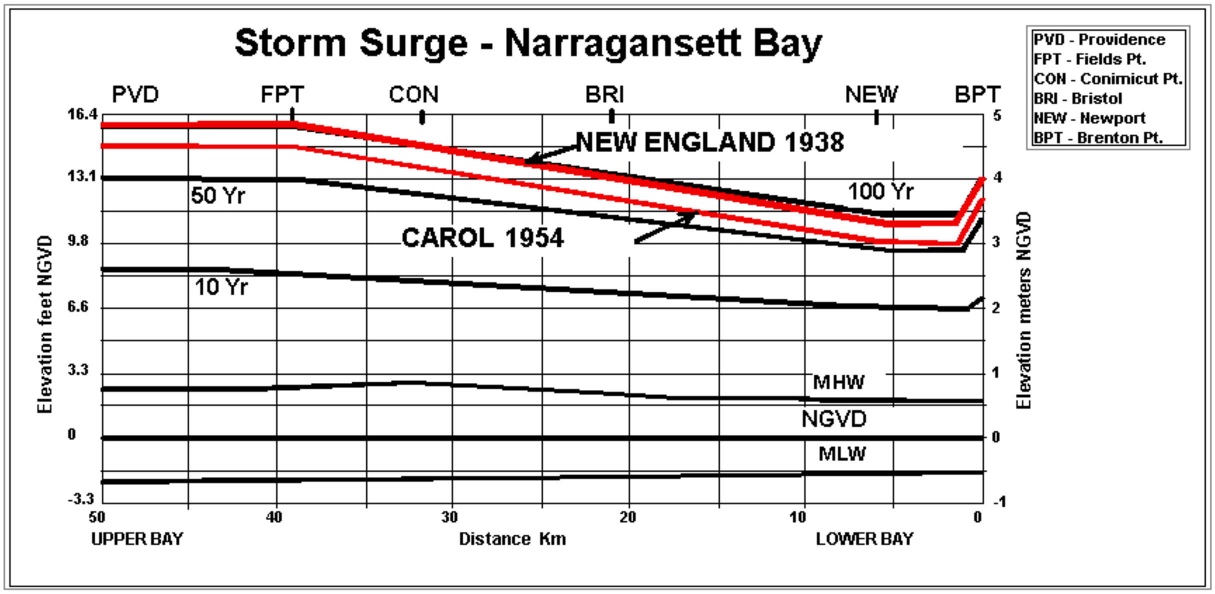
2.1. Coastal Storm History

To appreciate the threats and to evaluate the risks and benefits of future development within the Metro Bay SAMP, it is important to understand the history of the area. Natural and manmade changes that both have occurred and are projected, the geology and topography of the land area and bathymetry of the Bay and rivers, and the limited amount of hazard planning that has been undertaken are critical components for assessing vulnerability of future development. To forge solutions that will protect lives and property, it is also important to address the challenges that decision-makers face; a lack of technical knowledge, limited financial resources, opposition to more stringent regulations, and accelerated climate change. This situation requires managers and citizens to adapt new strategies.

Flooding in Rhode Island results from weather events such as spring snow melt combined with heavy rains, coastal storms (nor'easters), significant rainstorms, tropical storms, and hurricanes. Two major hurricanes hit the Metro Bay area in the 20th century: the Hurricane of '38 and Hurricane Carol in 1954. The impacts of the two storms were different due to the variable factors (e.g., wind speed, forward speed of the storm, storm track and angle of approach, bathymetry, rainfall, tides, and topography) that contributed to the storms' damage.

In terms of wave height and storm surge, the Hurricane of 1938 was of the magnitude of the 100-year storm of record for Rhode Island (RIEMA, 2005). The severity of flooding during that storm was due in part to its coming onshore approximately at spring high tide with wind speeds of 121 to 150 miles per hour (mph), which created a storm surge of 15 feet above mean tide level in the upper Bay (17.5-feet above MLLW or 15.8-feet above NGVD29). Two hundred sixty-two people were killed in Rhode Island alone, with a total death toll of over 682 people in New England from the storm. Statewide damage amounted to $100 million. Hurricane Carol in 1954 is considered greater than a 50-year storm and less than a 100-year storm, as seen in Figure 2.

Figure 2. Storm-surge elevations for Narragansett Bay for various storm events. (CRMC, 2005. *Adapted from U.S. Army Corps of Engineers, 1988*).



While these were the most significant hurricanes to hit the area, other storms also have inflicted serious damage. The Metro Bay area is vulnerable to riverine flooding caused by hurricane rains, as well as by other storms and snowmelt. The flood of March 1968 is considered the record event for most of the State, except for the Blackstone, Pawtuxet, and Pawtucket river basins. Tropical Storm Diane in August 1955 was the record event for the Blackstone River, where 19.76-inches of rain fell during the storm and caused catastrophic flooding, which reached a water level of 21.8-feet at the Woonsocket gauge. For the Pawtuxet River, the flooding in July of 1938 was the flood of record for the main channel of the river. This flooding was due to a coastal storm that dropped seven inches of rain over the river basin at a time when connected reservoirs were already full (FEMA, 2007b). In recent memory, the October 2005 rainfall was the second highest recorded river flood stage at the Woonsocket gauge, where the river crested at 15.34-feet and caused localized flooding in Woonsocket and Pawtucket, as well as localized flooding throughout the Metro Bay region (Advanced Hydrologic Prediction Service, 2005).

The October 2005 storm was estimated as a 25- to 50-year flood event depending on the locale. Governor Carcieri's Disaster Assistance Request estimated the damage at $38 million (Billington, 2006). Also, in the worst flooding since the Hurricane of 1938, upwards of 20 inches of rain fell in parts of Massachusetts and New Hampshire between May 11 and May 18, 2006 (FEMA, 2006b). Rhode Island experienced further severe storms and coastal flooding in mid-April, 2007. Similar to coastal storm surge, riverine flooding is anticipated to increase in the future as a result of accelerated climate change. The impacts reported here will likely increase under such scenarios, since infrastructure, such as stormwater and flood walls, may be undersized to accommodate higher peak flows.

2.1.1 East Providence

The worst coastal flooding in East Providence occurred in the 1938 and 1954 hurricanes, severely impacting the City's waterfront infrastructure. On two occasions the dock of the Gulf Oil Corporation was completely destroyed along with the connecting railroad. Large ships in the Providence River were torn from their moorings and tossed onto shore. For several days, debris blocked roads, railways, and waterways, creating hazardous conditions that hampered emergency and repair crews. Residential structures located along the waterfront were severely damaged or destroyed, while homes inland along the rivers were flooded (East Providence, 2002). The City also has experienced recurring inland flooding in areas such as the Runnins River, where homeowners weathered three floods from 2004 to 2006.

2.1.2 Providence

Providence's vulnerability to flooding stems from two main geographic features: its location at the head of Narragansett Bay and its low elevation downtown and along the port. During the Hurricane of 1938, Providence experienced a storm surge of more than 15 feet above MTL, with waves measuring 10 feet above the surge level (CRMC, 2007a). The hurricane flood waters inundated parts of downtown, which damaged buildings and other infrastructure, destroyed cars, and demolished the wharves of the inner harbor. Transportation, water, and other utilities were not operational for over a week after the storm. In Providence, damage amounted to $16.3 million, equivalent to about $225 million in today's dollars. In 1954, the downtown area was flooded by 12 feet of water (Vallee and Dion, 1996). Damage is estimated to have been $25.1 million, about $134 million in today's dollars (Providence, 2000). Further, these damage estimates do not take into account the increased development in the City over the past half-century; they are simply updated dollar losses of the monetary losses of 1938 and 1954. One can surmise that the havoc wreaked on the City of Providence by storms of these magnitudes would have losses totaling much more than the amounts given above.

Also, in March 1968, riverine flow of record occurred on both the Woonasquatucket and Moshassuck rivers, with extensive flooding in low-lying areas, most of which are outside the SAMP boundary.

2.1.3 Cranston

Hurricane Carol produced a storm surge14.1 feet above NGVD29 near the mouth of the Pawtuxet River (USACE, 1988), causing millions of dollars in damages to yacht clubs, marinas, and boats. The stretch of shoreline from Fields Point to Pawtuxet Neck was the hardest hit; of the 150 craft moored in this area, 75 were sunk and 26 were damaged (Cranston, 2005). Today, the potential loss of marina facilities (excluding vessels) is valued at $1.7 million.

2.1.4 Pawtucket

Torrential rainfall accompanying Tropical Storm Diane in August 1955 caused $28 million in flood damages statewide and triggered record flooding in Pawtucket and other communities along the Blackstone River, which rose 15 feet above flood stage. Estimates made in 1998 indicated that such a flood would cause damage estimated at more than $26 million in Pawtucket alone (Watson, et al., 1998). Subsequently, flood protection projects were constructed in Rhode Island and Massachusetts for the Blackstone River basin, and have since prevented some damages from riverine flooding (RIEMA, 2005).

2.2. Scientific Knowledge

2.2.1. Hurricane Trends

Since 1938, Rhode Island has been impacted by a number of major storms. Given the current and historical trends, it is likely that there will be above-normal Atlantic hurricane activity over the next several years. When viewed historically, a Category 3 hurricane has a 60-year expected return rate for the Northeast region (statistically occurring every 60 years) (Ginis, 2006). According to the National Weather Service, it is no coincidence that the 1930s to1950s were decades of high hurricane activity; analysis of tropical Atlantic sea surface temperature data starting in the early 1950s (Figure 3 below) indicates that this also was a time of warmer tropical Atlantic temperatures (Vallee, 2006). Since 1995, similar trends in sea temperature can be associated with above-normal Atlantic hurricane activity. Hurricanes impacting Rhode Island can be characterized based on past experience and the science of the storms. They commonly travel through the Bahamas and then rapidly accelerate up the east coast, with an average forward speed of 33 mph (Vallee, 2006), the strongest winds focused to the east of the hurricane's eye. Conversely, the heaviest rainfall is usually focused along the storm track and to the west. Nearly half of the hurricanes having hit New England in the past produced riverine and small stream flooding.

Figure 3: Standard Sea Surface Temperature in the tropical Atlantic water (Vallee, 2006).

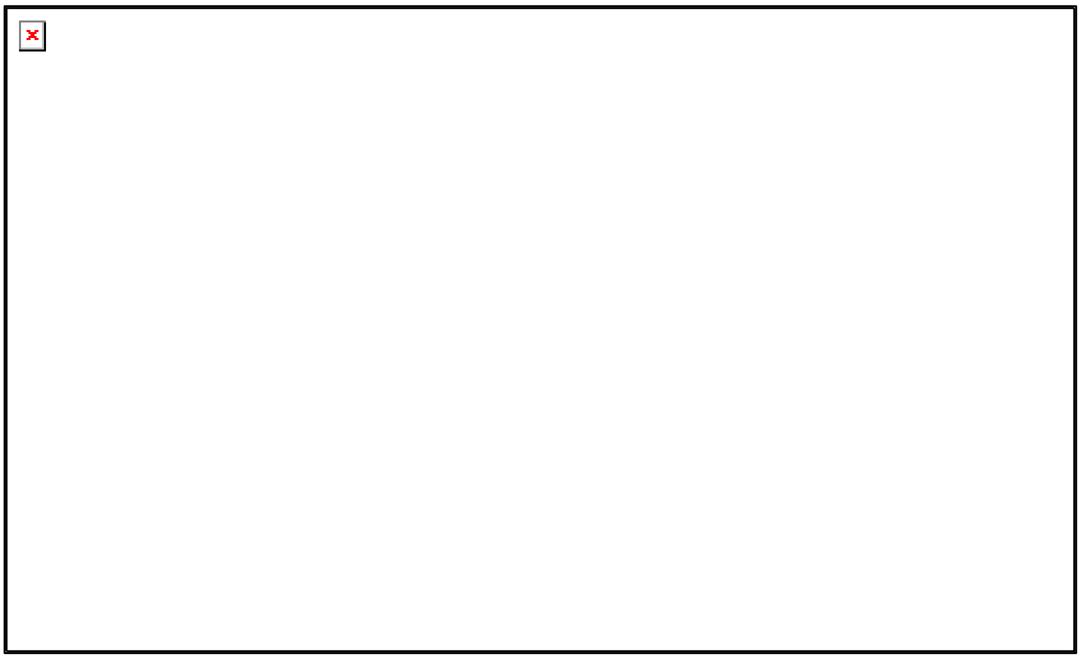


Table 2 Metro Bay Significant Hurricane and Storm Impacts to Rhode Island 1635 - 2007

Storm Name	Date Impacting Narragansett Bay	Category	Statewide Property Damage ($ millions)	Surge Height at Providence Tide Gauge		
				MLLW (ft)	NGVD29 (ft) = (MLLW-1.68’)	MTL(ft) = (MLLW-2.39’)
No Name 1635	25-Aug-1635	*	*	*	*	*
No Name 1815	23-Sept-1815	*	*	*	*	*
No Name 1869	8-Sept-1869	3	*	*	*	*
No Name 1938	21-Sep-38	4[a]	100	17.5	15.8	15.1
No Name 1944	14-Sep-44	*	2	11.7	10.0	9.3
Carol	31-Aug-54	3	90	16.5	14.8	14.1
Edna	11-Sep-54	2	0.1	*	*	*
Diane	19-Aug-55	*	170	*	*	*
Donna	12-Sep-60	2	2.1	*	*	*
Esther	21-Sep-61	3	*	*	*	*
Gloria	27-Sep-85	2	19.8	9.0	7.3	6.6
Bob	19-Aug-91	2	115	10.0	8.3	7.6
Floyd	17-Sep-99	Tropical storm	*	5.6	3.9	3.2
Tammy Subtropical Depression	8-Oct-05 to 15-Oct-2005	Tropical storm	1.65	6.4	4.7	4.0

*No available data. For storm surge heights, this indicates that data was not recorded for NOAA Providence Tide Gauge for these events
Sources: NOAA, 2007; Statewide Property Damage, RIEMA, 2005; Spaulding, 2007; USDOT, 2006; MEMA, 2007; FEMA, 2007b.
a – Most sources classify this hurricane as a Category 3 event when it hit New England

Note: NGVD29 and MTL values are calculated from MLLW values (Spaulding, 2007), (NOAA, 2007)

2.2.2. Climate Change and Sea Level Rise

In recent years, the effects of global climate change have become increasingly clear. In addition to its influence related to hurricane intensity, rising temperatures may also contribute to changes in species behavior and ecology of Narragansett Bay. During the 1990s, mean annual water temperatures averaged approximately 1.1°C (almost 2°F) warmer than they had been between 1890 and 1970 (Nixon, et al., 2007). Over the course of the twentieth century, sea-surface temperatures along the Northeast’s coast have risen more than 1°F (Frumhoff et al., 2007). Future projections for temperature increases show associated changes to circulation patterns, stratification, nutrient distribution, plankton productivity, the transport of lobster and other species in their larval stages, and ultimately the Northeast’s fisheries.

Since changes in global temperature directly influence sea level, global warming brings with it increased rates of sea level rise. Sea level change refers to the change in mean sea level throughout time in response to global climate and local tectonic changes. Sea level is the height of the sea with respect to some benchmark and averaged over a period of time sufficient to smooth out fluctuations caused by waves and tides. Factors contributing to sea level rise include local factors (e.g., local lithosphere dynamics, subsidence, etc.) as well as more global factors (e.g., thermal expansion of sea water, glacial melting, etc.). Globally, sea levels have risen at an average rate of 6.7 inches over the past century, a rate greater than that of the preceding eight centuries (IPCC, 2007). Between 1961 and 2003, global sea level rose at an average rate of 0.07 inches per year and between 1993 and 2003 this rate almost doubled to 0.12 inches per year. These rates are equivalent to sea level rise rates of 7-inches and 12-inches per century, respectively. Contemporary projections give an even higher value for global sea rise over the next century of between 1.6 and 4.6 feet above the 1990 level (Rahmstorf, 2007). Further, both the climate change models used in the IPCC Fourth Assessment Report (IPCC, 2007) and actual tide data indicate that sea level rise rates are accelerating. Contemporary research has determined that there has been a significant acceleration in sea level rise equal to 0.00051 in/yr^2 (± 0.00023 in/yr^2) between 1870 and 2004 (Church and White, 2006).

Taking into account the State's annual local subsidence rate of 0.059 inches per year (Douglas, 1991) (equivalent to approximately 6-inches per century), the historical rate of relative sea level rise in Rhode Island —10.1 inches per century (or 0.10 inches per year) as calculated from the Newport tide gauge (Spaulding, 2005)— is greater than the global average. The Newport gauge is often referred to when looking at statewide trends, since it has the longest and most consistent data of the gauges in Rhode Island. Similarly, over the years 1970 to 2007, the mean rate of sea level rise as recorded by the NOAA tide gauge in Providence shows a relative rate of sea level rise of 0.08 inches per year (NOAA, 2008). Additionally, it should be noted that over the past 18 years (1989-2007), mean relative sea level rise rates in both Providence and Newport have increased significantly to 0.15 inches per year and 0.16 inches per year, respectively (NOAA, 2008). Thus, similar to trends world wide, recent historical tide gauge data suggests that rates of sea level rise are accelerating in Rhode Island.

Table 3[2] Tide Data from the Newport and Providence Tide Gauges showing Mean Monthly Tidal Levels

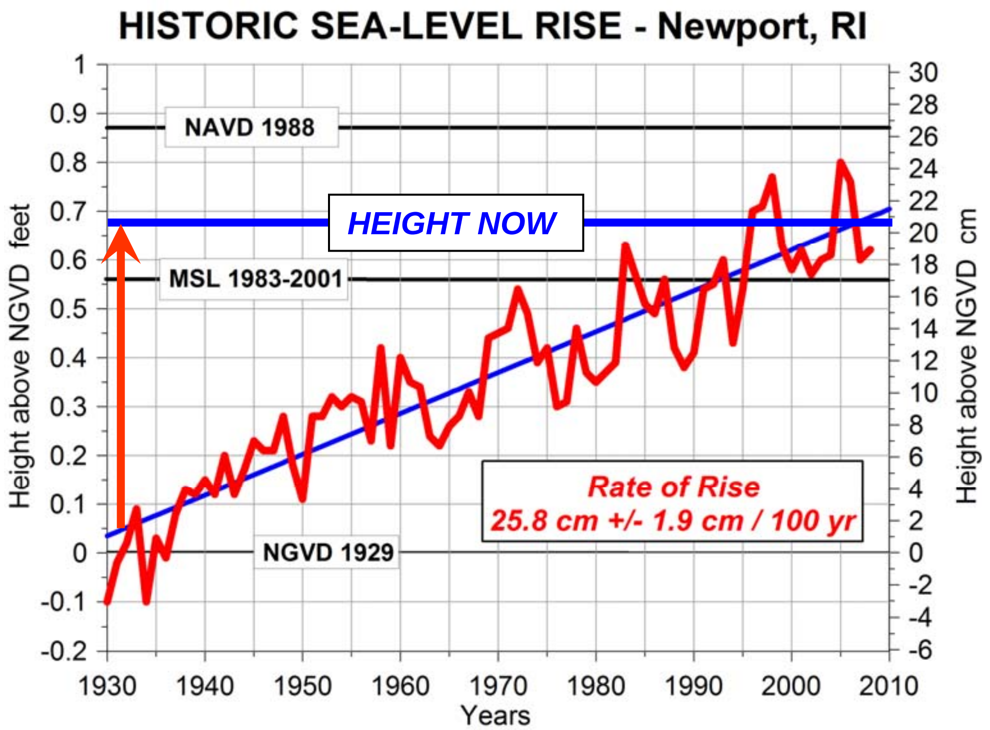
Tide Gauge	Mean Relative Sea Level Change (1970-2007)	Mean Relative Sea Level Change (1970-1988)	Mean Relative Sea Level Change (1989-2007)
Providence	+0.08 in/yr	-0.01 in/yr	+0.15 in/yr
Newport	+0.10 in/yr	+0.05 in/yr	+0.16 in/yr

Source: NOAA, 2007 & 2008

The most recent science (Rahmstorf, 2007) uses a semi-empirical relationship to correlate global sea level rise to global mean surface temperature, which is a good approximation for observations of the 20th century. When this relationship is applied to 21st century warming scenarios and regional isostatic effects are considered, estimates suggest that, by 2100, sea level in Rhode Island could rise approximately two to five feet. According to Titus and Richmond (2001), Rhode Island has 47.1 square miles (mi^2) of land lying within 4.9 vertical feet of sea level with an additional 24 mi^2 between 4.9 and 11.5 feet. This 4.9-foot contour roughly represents the area that would be inundated during spring high water with a 2.3-foot rise in sea level. It appears very probable that such a rise will occur within the next 120 years.

[2] These data were determined by linear regression of plots of monthly average tide data taken from the Newport and Providence Tide Gauges, provided by NOAA's "Tides and Currents" data website (NOAA, 2007; NOAA, 2008)

Figure 4: Newport Tide Gauge data for Historic Sea level Rise in Rhode Island (Boothroyd, 2008)

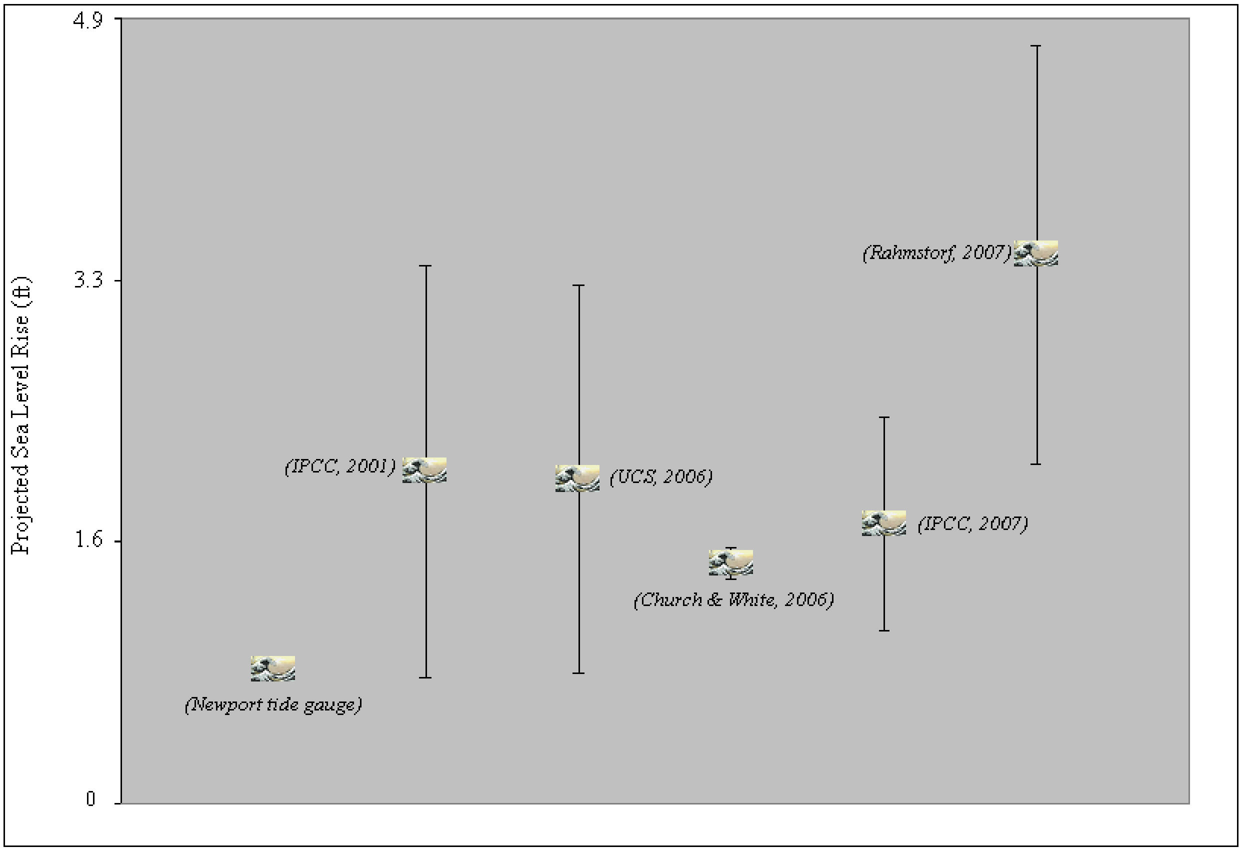


Adapted from: http://tidesandcurrents.noaa.gov/sltrends/sltrends_station.shtml?stnid=8452660%20Newport,%20RI

Boothroyd 2008

This rise in relative sea level will increase the extent of flood damage over time, with lower elevation areas more susceptible to flooding. Any given storm event will surge higher on land because the relative sea level is higher than in the past. Erosion will continue and may increase, due to the increased frequency of severe storms resulting from climate change. Other risks associated with sea level rise include salt intrusion into aquifers and higher water tables. In terms of the impact on the National Flood Insurance Program, “the increase in the expected annual flood damage by the year 2100 for a representative National Flood Insurance Program (NFIP) insured property subject to sea level rises is estimated to increase by 36 to 58 percent for a one-foot rise" (FEMA, 1991). Sea level rise will also reduce the effectiveness of existing coastal structures such as seawalls and revetments, roads, bridges, and residential and commercial buildings. Low-lying areas adjacent to these structures will be subject to increased flooding during storms. Sea level rise of the magnitude predicted could also potentially lead to the compromising of onsite wastewater treatment systems, municipal sewage treatment plants and stormwater infrastructure.

Figure 5: Projected change in relative sea level by 2100 (mean projections with upper and lower values indicated by error bars).



Climate change and sea level rise studies conducted for Boston, New York City, and New Jersey estimate that by 2100, storm events causing 100-year flood levels, as indicated by FEMA Flood Insurance Rate Maps (FIRM), could occur from 3 to 20 times more frequently than at present; this would effectively make a 100-year flood event more like a 30-year flood event (Milligan, 2005). Further, it is likely that both precipitation amount and storm frequency have increased each decade of the 20th century (IPCC, 2001), by as much as 10 to 25 percent. This creates the potential for more catastrophic riverine flooding such as that occurring in October 2005.

2.2.3. Inland Migration of Coastal Flood Zones

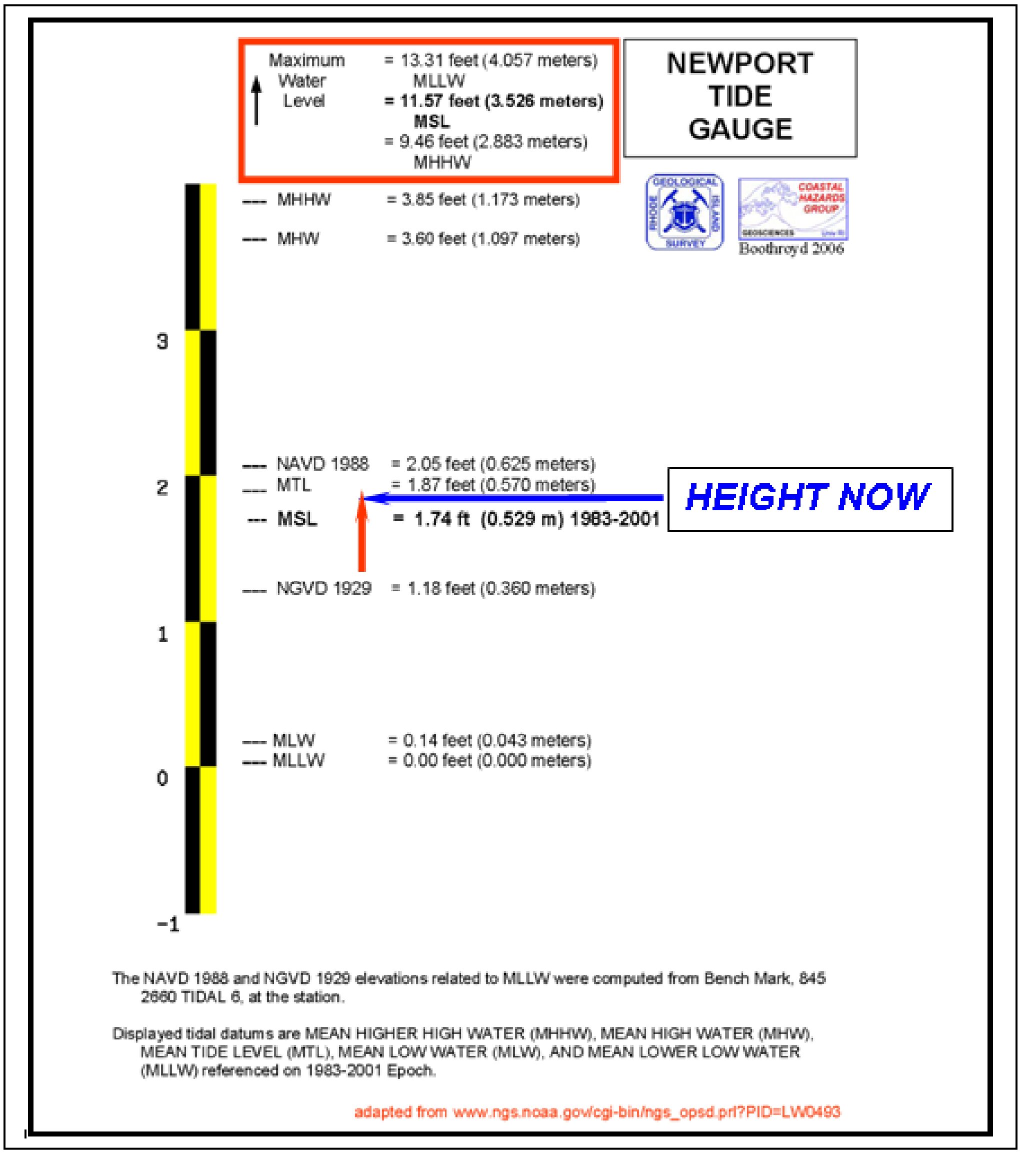
Table 4 depicts increased storm surge elevations for the Boston tide station using different sea level rise scenarios. As a result of higher storm surge levels, some inland areas may flood. Accordingly, the A-zone will move into areas currently not designated as special flood hazard areas. Coastal A zones will migrate into A zones and V-zones will migrate into existing A-zones. This is referred to as flood zone creep.

Table 4. Increased Storm Surge Elevations as Projected with Sea Level Rise

Boston Tide Station	**100-yr Storm Surge Elevation at MHHW (feet NAVD)**		
Sea Level Rise Scenario	*2005*	*2050*	*2100*
Extrapolating 1961-2003 observed trend	9.7	10.5	11.5
IPCC low emissions	9.7	10.7	11.8
IPCC high emissions	9.7	10.7	12.3
Rahmstorf (mid-range)	9.7	11.2	14.1

Source: Frumhoff et al., 2007

Figure 6: Comparison of tidal and fixed vertical datums at the Newport Tide Gage. Note that sea levels are approximately eight inches higher than NGVD 1929 (Boothroyd, 2007).



3. RISKS AND LIABILITIES

A significant portion of the region's critical facilities and coastal infrastructure located in the floodplain is not protected or was built before the current building standards were adopted in the 1970s. Similarly, the region has a high population density, with a diversity of residents and mixed incomes. The series of images below (Figures 7, 8, and 9) illustrates the risks to the State, with the metropolitan area highlighted for its high exposure. As noted above, current floodplain maps and vulnerability assessments *do not* incorporate potential impacts to property or life from increased sea level rise.

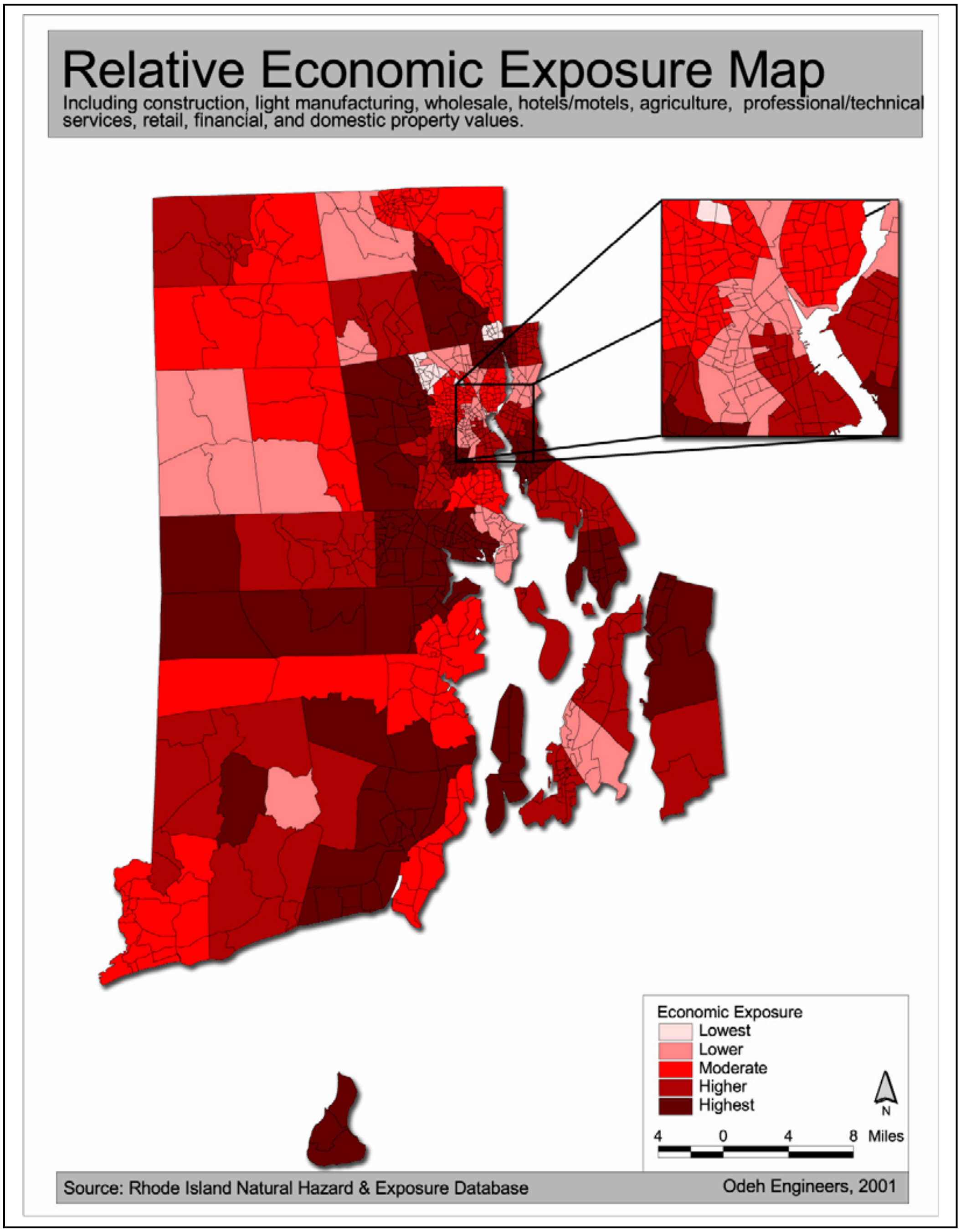
There is an estimated $382 million to $1.6 billion worth of property within the Metro Bay region (Providence Plan, 2006). Nine hundred residents are located directly within the high-risk floodplain. While the entire SAMP shoreline is considered to be in the special flood hazard area, 10 percent (320 acres) of the land within the SAMP is located in the V-zone and 17 percent (570 acres) in the A-zone. Structures located in these areas have a 26 percent chance of suffering flood damage during a 30-year mortgage period (RIEMA, 2005). Depending on the type of storm, floodwaters come from coastal storm surge traveling 20 miles up the Bay or from the overflow of five major rivers—the Woonasquatucket, Moshassuck, Ten Mile, Pawtuxet, and Blackstone/Seekonk rivers.

Table 5 Estimated Land-based Risks in the SAMP Special Flood Hazard Area

	SAMP floodplain	A-zone*	V-zone
SAMP area within floodplain	27 percent SAMP area (901 acres) and 100 percent SAMP shoreline	17 percent (570 acres)	10 percent (320 acres)
Businesses in SAMP floodplain	175 businesses 4,629 employees in SAMP flood zone (1,751 businesses / 24,177 employees in SAMP area)	168 businesses (4,529 employees)	7 businesses (100 employees)
Residents in SAMP floodplain	59 Census Blocks 904 people 263 Households	403 people 39 Census Blocks 108 Households	501 people 20 Census Blocks 155 Households
Range of property assessments in flood zones, parcels with *center* in flood zone to parcels that *intersect* the flood zone (larger value)**	326 to 551 parcels in SAMP flood zone $1.643.572,345 (2,417 to 2,473 parcels in SAMP area)	$91,088,120 to $788,061,055 building assessment $269,546,100 to $1,193,880,735 total assessment (land & building)	$54,506,880 to $170,113,510 building assessment $112,383,270 to $449,691,610 total assessment (land & building)

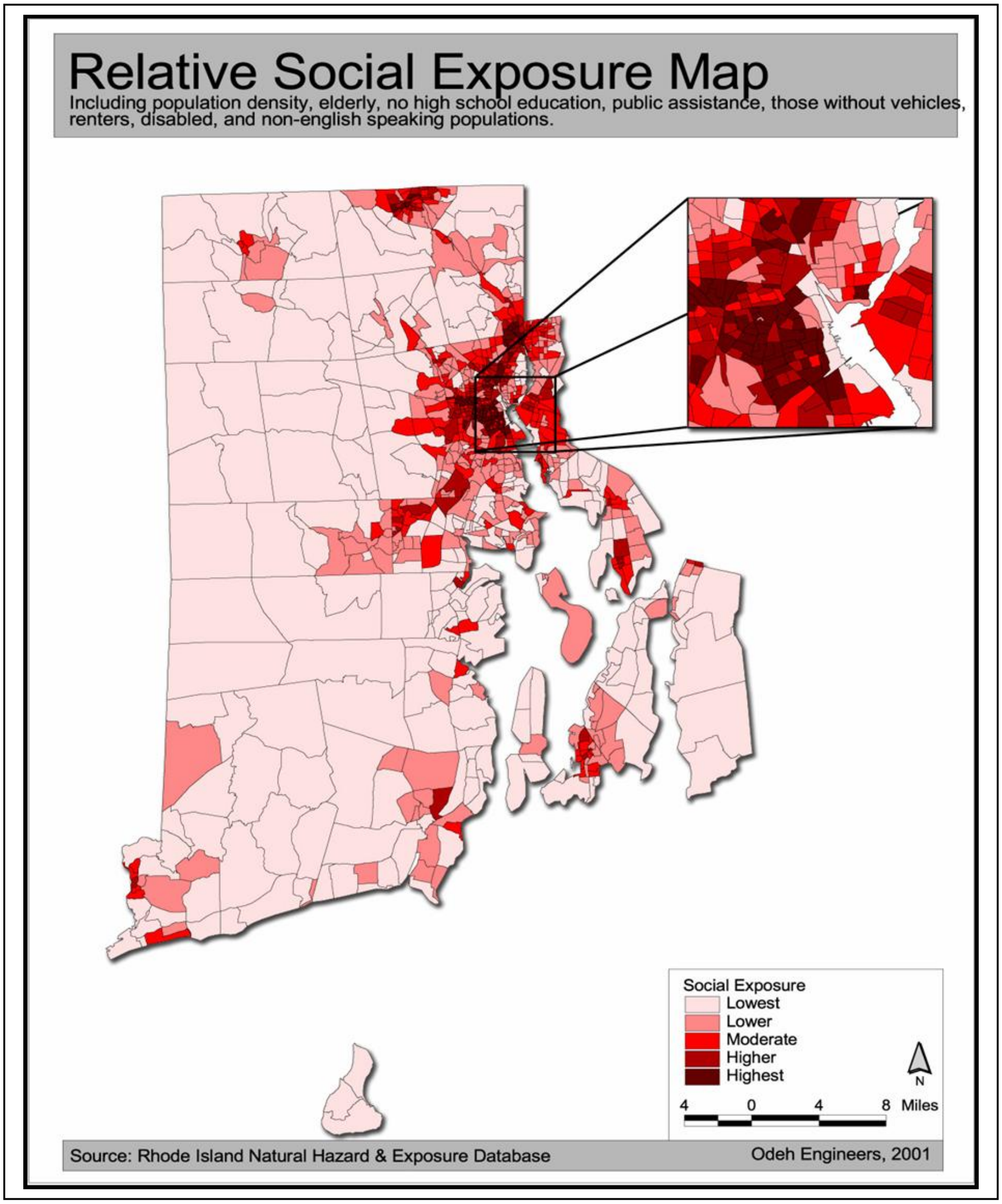
These should be used as estimates only.
*The floodplain includes the area within A- and V-zone boundaries as seen in Figure 1, which does not include updates to floodplain maps or the impacts of A-zone creep, where new properties will be floodplain, as sea level and storm surges rise. Analysis is based on parcels with their center in the flood zone, unless otherwise noted. Information obtained from the 2000 Census.
** Property assessments are from 2004 municipal tax roll data. Pawtucket assessment information was not available in this format, and therefore, was not included (Providence Plan, 2006).

Figure 7: Relative Economic Exposure.



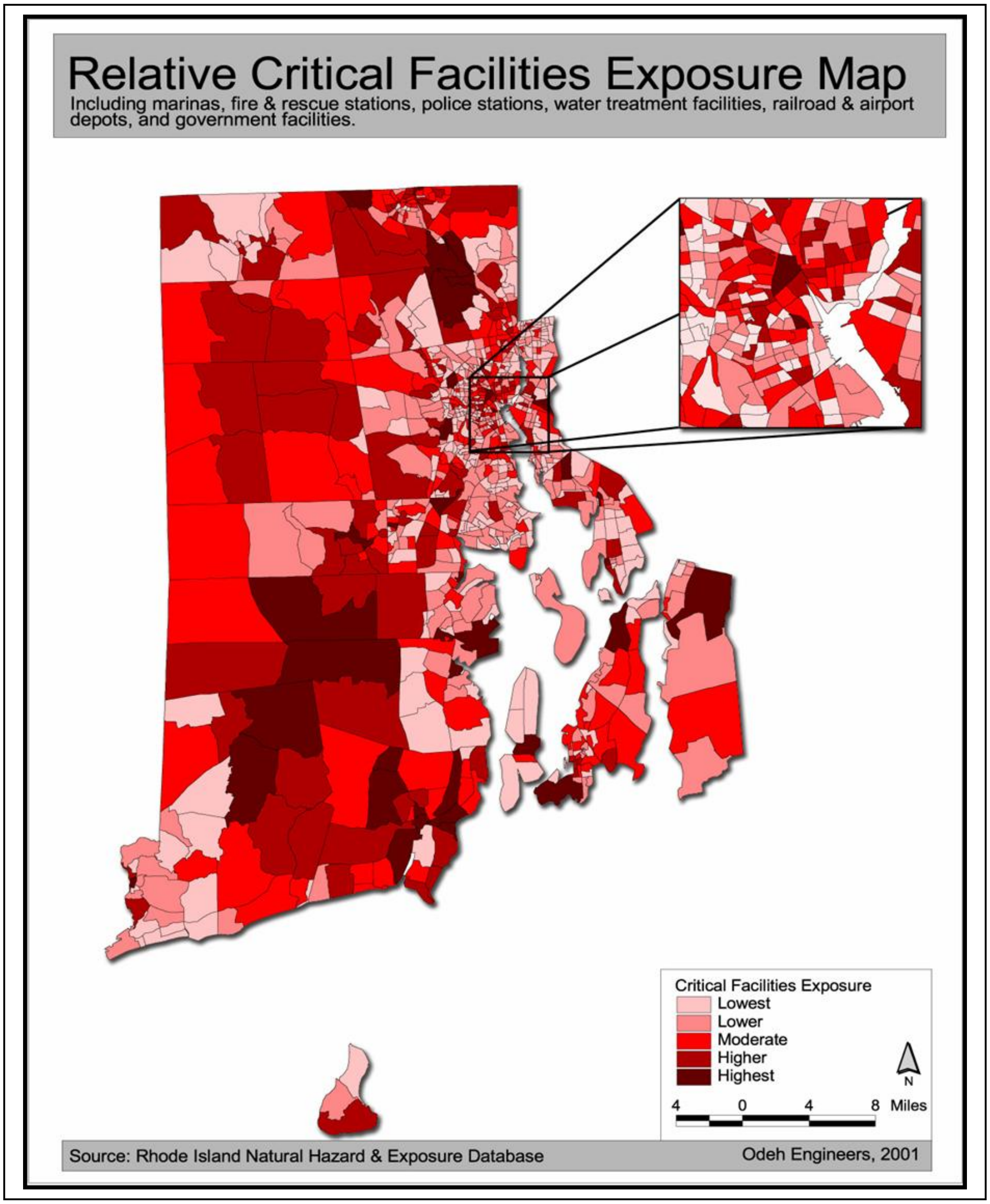
This figure shows the areas in the State that will experience the greatest economic difficulty in the case of an extreme storm event or other natural disaster.

Figure 8: The Populations at Risk in the Event of a Natural Disaster as of the 2000 Census.



The inset provided is of Providence Where the Greatest Levels of Vulnerability are Throughout the State (RIEMA, 2005). This figure does not include new or proposed waterfront revitalization development, which is focused in vulnerable areas.

Figure 9: Statewide Vulnerability of Critical Facilities to Natural Hazards (RIEMA, 2005)



The inset map depicts the scoring results of statewide vulnerability of critical facilities to natural hazards. The darkest hue of red represents the highest risk for facilities such as firehouses, public shelters or hospitals, among others located in special flood hazard areas (RIEMA, 2005).

3.1. Critical Facilities

Critical facilities located in the current designated floodplain include the Narragansett Bay Commission's (NBC) Fields Point municipal wastewater treatment facility (MWTF) in Providence and the Bucklin Point MWTF in East Providence, the National Grid Electric Plant, liquefied natural gas (LNG) and fuel storage tanks, two sewage pump stations along Pawtuxet Neck, the port district in East Providence and Providence, and the National Grid Electric Substation and City Hall in Pawtucket. While these facilities have emergency operation plans and have mitigated many direct flood impacts, it is not known how they would perform with increased storm surge heights or sea level rise. Additional facilities inland of the A-zone may be impacted in the future by A-zone creep. These factors should be evaluated for each facility. NBC indicates that its sewage treatment facilities have been designed to withstand high-risk flooding associated with a 100-year storm (one percent chance), with specific procedures undertaken in coordination with the City of Providence to avoid back-flow flooding of the Bay into the City through the sewage system in the event of a high-hazard storm. (Uva, personal communication, February 9, 2006)

After the Providence River dredging project was completed in December 2005, the United States Army Corps of Engineers (USACE) reopened the shipping channel to fully loaded tankers. These larger vessels will require dockage that can withstand the increased berthing energies. CRMC has the authority to certify that docks can handle certain levels of berthing forces. Since most coastal storm events are tracked in advance, it is unlikely that any oil or gas transfers will occur during a storm; this, however, is not a prohibited activity. There are established oil spill disaster plans in place for Narragansett Bay should a vessel or tank leak its contents.

3.2. Fox Point Hurricane Barrier

The hurricane barrier that protects over 300 acres and $2 billion in property in downtown Providence has yet to perform in a major hurricane, having been constructed after the last major event in 1954. There is a present need to review combined riverine and coastal flood potential under current conditions to determine how the barrier would function during a severe flooding event, such as when a storm surge coincides with extensive riverine flooding from watershed runoff (Boothroyd, personal communication, February 8, 2006). Given both historic and projected sea level rise, there will be less elevation between the high water level and the top of the barrier, and therefore a greater potential for overtopping the barrier with a significant coastal storm surge in the future. It should be noted, however, that while the hurricane barrier is designed to protect downtown Providence, the infill development behind it may cause localized flooding along the Woonasquatucket and Moshassuck rivers.[3]

In 2007, the City received $3 million for repairs to be done to the barrier's pumps and gates (Barbarisi, 2007). Maintenance and operation of the Fox Point Hurricane Barrier was recently transferred from the City of Providence to the US Army Corps of Engineers.

[3] The pumping capacity of the hurricane barrier exceeds the recorded peak flow of these two rivers by 2,900 cubic feet per second, according to figures from the U.S. Geological Survey and USACE.

Table 6: Elevation Heights for Design

Design considerations for the Hurricane Barrier	Feet above MLLW	Meters above MLLW
Providence Flood Insurance Study	17.68	5.39
Providence FIS w/sea level (3 ft)	20.70	6.31
Providence FIS w/sea level (5 ft)	22.66	6.91
Hurricane Barrier Top	26.68	8.13
Hurricane Barrier Design Storm	22.18	6.76
1938 hurricane	17.52	5.34
NAVD88	2.47	0.75
NGVD29	1.68	0.51
MLLW	0.00	0.00

Spaulding, 2007; Providence tide gauge, 1983-2001 epoch. (NOAA, 2003)

3.3. Dams

Another issue is potential dam failure. While dam inundation maps have not been developed for Rhode Island, it is likely that dam failure could severely impact the four Metro Bay cities; furthermore, the 2005 State Hazard Mitigation Plan recommends that inundation maps be prepared (RIEMA, 2005). There are several dams upstream of the Metro Bay floodplain along the Blackstone, Woonasquatucket, Ten Mile, and Pawtuxet rivers. In Rhode Island, the Department of Environmental Management (DEM) is responsible for inspecting dams and requiring repairs or other actions as needed.[4] While DEM's 2000 visual inspection rated the condition of Woonsocket's Thundermist Dam as "good," its Dam Safety Report lists the dam, on the Blackstone, as a "significant hazard," since its failure could result in loss of life and appreciable property damage. A new DEM regulation established in 2006 puts a greater onus on dam owners for maintenance.

3.4. Development in the Four Cities

Since at least the 1930s, there has been extensive development in the Metro Bay coastal area (and redevelopment after coastal storm events) that has reshaped the pre-existing floodplain. The coastline of the Metro Bay area has changed significantly since the earliest aerial photos of the area were taken in 1938 (Boothroyd and Hehre, 2006). The coastline of Providence was filled to develop the Port of Providence and parts of the downtown area. In East Providence, large areas have been filled for industrial use. There has also been significant fill material placed within the floodplain behind the Fox Point Hurricane Barrier. (Boothroyd and McCandless, 2003)

The waterfront is now going through another redevelopment phase that will add additional property and assets to the vulnerable floodplain. Most of this waterfront is subject to flooding and extreme storm surge in a 100-year storm event. According to a November 2007 listing provided by the Economic Development Corporation, it is estimated that approximately $1.35 billion in development is in progress with numerous development projects underway within the SAMP boundary in East Providence, Pawtucket, and Providence. (See Appendix 1)

---

[4] General Laws of RI Chapter 46-19

3.4.1. East Providence Waterfront Redevelopment Plan

The East Providence Waterfront Special Development District Plan provides a framework to transform over 300 acres of the city's currently underutilized industrial waterfront along the Providence and Seekonk rivers into a mix of commercial and residential land uses.

Much of this area is located within the floodplain. Bold Point Park and Pier Road have very low elevations and have been severely impacted by high-hazard flood events in the past (flood elevations are mapped as 18 feet NGVD29 (19.7 ft MLLW)). The plan for this area is to expand the park system, which supports an open-space strategy in flood-prone areas as proposed in the City's hazard mitigation plan.

The City is encouraging the use of recent advances in construction materials and engineering techniques for the planning, siting, design, and construction of the targeted waterfront areas. The plan proposes final grading and elevations for development sites and roads to mitigate flooding impacts. The City plans to construct roadways that are capable of serving as emergency evacuation routes in the event of a natural disaster. The properties within these districts were rezoned by the City in March 2004 to prohibit heavy industrial and heavy commercial uses and to permit a mix of residential, commercial, office, retail, and recreational uses.

Additional major development in the city that lies within the jurisdiction of the Metro Bay SAMP includes the development of Phillipsdale Landing, the former Chevron Property, Aspen Aerogels, and Ross Commons, as well as the East Pointe/GeoNova mixed-use development.

3.4.2. Providence: Narragansett Bayfront and Downcity

The main thrust of Providence's potential waterfront redevelopment is in the Narragansett Bayfront, an area south of the hurricane barrier and north of Thurbers Avenue along Allens Avenue. City planners envision a mixed-use area with parks, offices, hotels, residences, and entertainment. The Comprehensive Plan update supporting this vision has been recently challenged by several local land owners in a filing with the State Comprehensive Plan Appeals Board dated October 6, 2008. Currently, most of the waterfront is occupied by existing heavy industrial uses, some of which are related to the marine trades sector. The Narragansett Bayfront area is located in the special flood hazard area (both A- and V-zones) with base flood elevations of 16 to 19-feet NGVD29 (17.7 ft to 20.7 ft MLLW). Development projects underway or recently completed in the downcity area that lies within the SAMP boundary include educational facilities, hotels, the Dynamo House at Providence Point. They also include large-scale residential projects near the confluence of the Woonasquatucket and Moshassuck rivers. The relocation of Interstate 195 will open up additional land downtown and on both sides of the river within the SAMP area for development and parkland.

3.4.3. Pawtucket: Tidewater

The City of Pawtucket produced a waterfront redevelopment plan that is a combination of parks, industry, and condominiums in areas subject to significant flooding. Recently, city leaders expressed concern about redevelopment where potential floods could damage businesses, residences, and public amenities, such as was the case with the new recreational dock that was destroyed in October 2005 flooding (Billington, 2006). The School Street pier and boat ramp area, seen as a focal public access point, is within a V-zone with potential flooding to 18-feet above NGVD29 (19.7 ft MLLW). The City is planning the redevelopment of this area as well as the Taft Street boat ramp area, and is taking flood zone elevations into consideration. In addition, there are several commercial and residential developments in various stages of planning and construction.

Many of the existing riverfront buildings above the Main Street dam are built below the base flood elevation and would need to be updated to current flood standards if rehabilitated. Additionally, many of these are historic buildings that may qualify for some variances to floodplain building standards. Flooding from the overflow of storm sewer systems and inadequate drainage has proven to be a recurring problem after heavy rains. In addition, the City has suffered property damage from the last few hurricanes due to flooded sewer lines that are not covered by flood or homeowners insurance.

3.4.4. Cranston Waterfront

Cranston's waterfront is considered fully built out. However, the City's building inspector has observed that many of the smaller houses sold are being rebuilt as larger structures (Case, personal communication, August 2, 2005). Many new buyers are unaware that they need to update the homes to meet current state building code flood standards if they apply for a permit to undertake substantial improvement (50 percent of the replacement value of the building). Condominiums are also being built in some locations and marinas are planned. Expansion at the Johnson & Wales University Harbor Campus is vulnerable to flood impacts where lands are within both the V- and A-zones. Based on the 2003 tax assessors database, the coastal property improvements for Edgewood and Pawtuxet Village were assessed at $36.5 million. Within this relatively short coastline there are five marinas containing 383 slips and 121 moorings, valued at $1.7 million in potential property damages (Cranston, 2005).

3.5. Coastal Brownfields

The extent of sites classified as brownfields is not definitive, since thorough tests and evaluations have not been made on all sites in the region to date. According to DEM, many brownfield sites in the Metro Bay area have had their hazardous materials removed (Hellested, personal communication, September 21, 2005). There are, however, a few sites along Allens Avenue in Providence where hazardous materials remain. Those sites, which contain contaminated sediment, have amended property deeds that stipulate sediments must remain covered with a cap. Brownfield sites—unmitigated sites and those with caps—in special flood hazard areas potentially pose a risk of dispersing contaminated soils if directly impacted by waves or massive flooding from storm surge. While maps are now available depicting these brownfield sites, there have not been any studies to quantitatively assess the: 1) cumulative impacts on development within high hazard flood zones; and 2) the potential impact of wave forces on undeveloped brownfield sites or the structural integrity of the redeveloped sites with caps under such wave conditions. While CRMC permitting actions typically look at the wave forces on shoreline structures and evaluate riprap and other capping materials, it is currently not explicit in other state design standards for brownfield sites.

3.6. Marina Development

The number of recreational boats in the Metro Bay region has been steadily rising and is projected to increase significantly in the future as new marinas are developed as integral parts of the renewed waterfront vision (D. Goulet, personal communication, September 7, 2005). Many of these marinas may not be full service marinas (i.e., without boat lifts or ramps) and therefore will have limited capability to assist clients during a hurricane. The boating season coincides with an active hurricane season in New England and most docks and dry racks adjacent to shore are not able to protect boats in strong hurricane conditions. The best solution is to take boats out of the water and away from V-zones. Some marina contracts require mandatory haul out of clients' boats in the event of hurricane warnings. They must be stored outside of the flood hazard area or they will be entrained in the storm surge and become debris with the potential to cause damage to other structures. It should be noted that boat removals are not recommended during the actual storm event due to human safety risks (FEMA, 2002). At present, there are no designated areas or plans for boats to be evacuated to areas outside of the flood hazard zone within the Metro Bay region.

3.7. Repetitive Losses

The number and value of repetitive losses in an area is a measure of vulnerability (Table 7). Most of the losses in the Metro Bay region are the result of stormwater runoff and urban flooding, which are directly proportional to the amount of filling of wetlands, floodways, and floodplains (RIEMA, 2005). Providence has the second highest number of repetitive loss claims in the State and the greatest value of claims paid in the State since 1978 (RIEMA, 2005). Cranston has the fourth highest number of repetitive loss claims and the fifth highest value of claims.

Table 7. National Floodplain Insurance Information in Metro Bay SAMP Cities

City	Flood-plain Policies	Policies in A-zone and V-zone	Property value of policies	Claims since 1978	Repetitive Loss Claims for Property Damage[5] 1978 - 2003	
					Number of claims for repetitive loss	*Claims paid for repetitive loss*
Cranston	366	N/A	N/A	N/A	30 claims for 10 properties	$368,597
East Providence	182	112 A-zone 2 V-zone	$28,227,300	38	3 claims for 1 property	$8,520
Pawtucket	96	7 A-zone 0 V-zone	$7,430,300	20	7 claims for 3 properties	$165,013
Providence	157	72 A-zone 2 V-zone	$36,771,100	200	65 claims for 17 properties	$3,312,849
*State Total	11,520 NFIP policies statewide that insure $8,666,306 worth of property. Since 1978, $19,339,947 NFIP payouts have been made				167 properties 76 currently insured	$9,869,855 $5,067,871
Policies and property values were obtained from individual Hazard Mitigation Plans approved by FEMA for each city. Repetitive loss and claims information is from RI State Mitigation Plan (RIEMA, 2005). *State total refers to data from 1978-2003: http://www.gao.gov/new.items/d04401t.pdf and May 22, 2006 press release by Armand Randolph, RIEMA at http://www.ri.gov/press/view.php?id=1990						

[5] Repetitive loss is significant damage to an insured structure which has sustained a minimum of 2 events since 1978 and where NFIP has paid greater than or equal to $1000. Data represents information from Jan 1978 to Dec 31, 2003. Most of the repetitive loss properties are the result of stormwater runoff and urban flooding (RIEMA, 2005).

3.8. Insurance Risks

According to the Insurance Information Institute, catastrophe losses in the U.S. totaled $61.2 billion in 2005 (Salvatore, 2007). Over a 20 year period from 1986 to 2005, hurricanes and tropical storms constituted 47.5 percent of all catastrophe losses in the United States. During the same 20 year period, two of the four largest catastrophes were hurricanes. Also, eight of the eleven most expensive disasters in U.S. history have occurred since 2001. Historically, Rhode Island has incurred damage from seven hurricanes of Category 2 or higher over the past 100 years (Spaulding, 2007), including the hurricane of 1938, which caused $308 million in losses. As of 2004, Rhode Island had $43.8 billion in insured coastal exposure.

Catastrophe modelers currently predict that catastrophe losses will double every decade due to increasing residential and commercial development, as well as more expensive buildings. In 2003, 53 percent of the nation's population – 153 million people – lived in coastal counties, which make up 17 percent of the country's land mass. Between 1980 and 2003, the populations of coastal counties grew 28 percent. Currently Rhode Island has the highest coastal population density in New England and it is projected that the State's population will rise ten percent by 2030 (Salvatore, 2007).

3.9. Vulnerabilities caused by Future Accelerated Sea Level Rise

With the predicted and observed acceleration of sea level rise rates in Rhode Island, the Metro Bay region will face new problems and dangers determined by the effect of the rising seas on shoreline projects and infrastructure. Table 8 provides a list of the potential effects of sea level rise on CRMC-regulated waterfront activities. Though the list pertains to the State as a whole and not the Metro Bay area specifically, it provides vivid examples of impacts to those regulated activities that are found in the SAMP area.

Table 8. Potential Impacts of Sea Level Rise Related to the RI Coastal Resources Management Program

Regulated Activities Section 100.4 Table 4	Potential Impacts of Sea level Rise
✓ Filling, Removal, and Grading of Shoreline Features	◆ Filling – need to design for increased Stillwater level ◆ Exposing the shoreline to increased vulnerability
✓ Residential Structures ✓ Commercial/Industrial Structures ✓ Recreational Structures ✓ Marinas ✓ Energy-related Activities/Structures	◆ Increased flooding of shorefront facilities as BFE increases ◆ Flood zones expand farther inland ◆ Impact on design and function of utilities (e.g., petroleum storage tanks, municipal wastewater facilities, stormwater outfalls, onsite septic systems, etc.)
✓ Recreational Mooring Areas ✓ Launching Ramps ✓ Residential Docks, Piers, & Floats ✓ Mooring of Houseboats ✓ Mooring of Floating Businesses	◆ Larger waves and still water design height ◆ Overtopping of existing facilities ◆ Reduced effectiveness of existing launch ramps
✓ Municipal Sewage Treatment Facilities	◆ Increased flooding ◆ Discharge pipe hydraulics
✓ Individual Sewage Disposal	◆ Higher coastal groundwater levels

Table 8. Potential Impacts of Sea Level Rise Related to the RI Coastal Resources Management Program

	Regulated Activities Section 100.4 Table 4	Potential Impacts of Sea level Rise
	Systems	◆ Saltwater lens likely to move inland - affects siting and design
✓ ✓	Point Discharges - Runoff Point Discharges - Other	◆ Higher sea level could impact hydraulics of discharge elevation ◆ Backwards flow could become an issue
✓	Non-Structural Shoreline Protection	◆ Larger waves and still water design height ◆ Existing protection may not be as effective ◆ MHW migrates inland from present position
✓	Structural Shoreline Protection	◆ Higher waves and still water design height ◆ Overtopping of existing facilities ◆ Need for redesign (i.e. larger riprap, different slopes) ◆ Demand for structural protection may increase for specific properties, with greater cumulative impacts
✓ ✓	Dredging - Improvement Dredging - Maintenance	◆ Deeper water could reduce need for dredging maintenance ◆ Potential for greater deposition from accelerated shoreline erosion
✓	Beach Nourishment	◆ Larger waves and still water design height ◆ Higher for nourishment due to accelerated shoreline erosion
✓	Filling in Tidal Waters	◆ Larger waves and still water design height
✓	Aquaculture	◆ Limits of the inter-tidal zone changes significantly
✓	Mosquito Control Ditching	◆ Increased coastal groundwater levels
✓	Construction of Public Roads, Bridges, Parking Lots, Railroad Lines, Airports	◆ Increased flooding of shorefront facilities ◆ Increase in wash over events ◆ Increased wave heights affect design ◆ Reduced clearance on bridges

Source: R.I. Sea Grant, 2007a

3.10. Vulnerabilities Caused by Shoreline Debris and Coastal Structures

In addition to vulnerabilities caused by rising sea levels in the Metro Bay area, coastal structures are put at further risk during a storm event by preexisting and storm-generated shoreline debris. Coastal structures designed to withstand flood level waters and historic storm surge (e.g., protective containment rings for hazardous material storage tanks) may not be able to withstand the impact of debris during a storm. The Metro Bay SAMP shoreline is characterized by a wide variety of potential debris including boats, floating docks, construction equipment and industrial scrap, wooden pilings and piling fenders, stone beams, railcars, automotive junkyard refuse, and dock remnants. Locations of shoreline construction, such as Narragansett Bayfront, and poorly maintained coastal infrastructure (e.g., seawalls, revetments, docks, and piers, along the Edgewood Marina in Cranston, and Kettle Point, Squantum Point and south of the Wilkes Barre Pier in East Providence) are areas in which the danger posed by debris is greatly increased. Further, studies have observed that of, “all of the potentially hazardous debris present along the bay the overwhelming majority is privately owned. This private debris consists of small to medium sized recreational boats that are located in and out of the water.” (URI OCE, 2007). An exhaustive list of shoreline debris located along the SAMP shoreline is contained in a report prepared by University of Rhode Island Ocean Engineering students for the R.I. CRMC (URI OCE, 2007).

4. HAZARD PREPAREDNESS PROGRAMS

4.1. Storm Surge Models

Federal agencies assess the potential for storm surge by using the Sea, Lake, and Overland Surges from Hurricanes (SLOSH) model. The National Hurricane Center, along with USACE, developed and issued a SLOSH model for Rhode Island in 1995. This model used the bathymetry of Narragansett Bay and the topography of coastal Rhode Island to predict coastal inundation effects from potential hurricanes. Because of its shape, Narragansett Bay serves as a funnel, which produces larger storm surges farther up the Bay. The SLOSH model for the Metro Bay area predicts storm surges of about 12-feet NGVD29 or 13.7-feet MLLW (category 1 or 2 hurricane) to 21-feet NGVD29 or 22.7-feet MLLW (category 4 to 5 hurricane) (USACE, 1995a,b). Areas at highest risk for coastal flooding from storm surge include the School Street/Pond Street area and the state pier in Pawtucket; the Edgewood neighborhood in Cranston; India Point to Fields Point, including Allens Avenue in Providence; Sabin Point, Kettle Point, Watchemoket Cove, the Gulf Oil area, and the Providence & Worcester Railroad property area in East Providence; and along the eastern shore of the Seekonk River.

SLOSH evacuation maps are general and for informational purposes only. They use the SLOSH model to generate the worst case scenario storm and map areas that will be inundated. There are no regulations or insurance implications to these maps, and therefore they are moderately understood by local officials and updates are rare (NOAA Coastal Services Center, 2005). These models are known for being general estimates for large areas and lack detail for specific locations along the coast. Linked to these storm surge inundation models are estimates of the number of people that need to be evacuated (Table 9) and suggested evacuation areas for each municipality. The SLOSH evacuation area maps do not address how to evacuate nor do they integrate across municipal and state boundaries. As discussed below, RIEMA and the Department of Transportation (DOT) have worked with local communities to address this issue. The Army Corps of Engineers has recently initiated a project to update the SLOSH Inundation Maps for hurricane impacts.

Table 9. Estimates of Vulnerable Population within City Evacuation Zones (as defined by the SLOSH maps) for Severe Hurricane Scenario

City	Total Vulnerable Population in Evacuation Zones by City
Cranston	763
East Providence	408
Pawtucket	213
Providence	1,163
Total estimated	**2,547**

Source: Census 2000; Analysis: Providence Plan, 2006.

4.2. Emergency Evacuation Routes and Plans

In 2004 and 2005, The Rhode Island Emergency Management Agency and the R.I. Department of Transportation (RIDOT) designated evacuation routes, traffic control points and sign locations in coastal communities. The onus then rested on the communities for reviewing and approving the information as well as posting signage. These maps are available in paper copy from the community, as well as online at http://www.riema.ri.gov/evacuation/hurricane_evac.php (RIEMA, 2006). Initially there was concern that the maps ended at municipal boundaries; therefore in 2006 RIEMA and RIDOT coordinated efforts among the municipalities and added signage where needed.

4.3. Flood Maps and the National Flood Insurance Program

All of Rhode Island's 39 cities and towns participate in the National Flood Insurance Program (NFIP). The first communities to join were Newport and Providence in 1970, 20 more communities joined by 1973 and the last Rhode Island community joined in 1986. In all, Rhode Island presently has 15,000 NFIP policies in effect that insure $3,475,527,400 worth of property. Since 1978, $34,378,392 in claims have been paid to NFIP policy holders. According to the Insurance Services Organization (ISO) Rhode Island has the highest NFIP insurance policy retention rate in the country at 92 percent. However, Rhode Island also has the lowest number of policies given its high exposure to both coastal and riverine flooding (Rhode Island Government Online, 2006).

Previously, FEMA surveyed and developed Flood Insurance Rate Maps (FIRMs) for each city, each of which identified the special flood hazard areas, which is itself broken down into two major zones (A- and V-zones), and is further subdivided base flood elevation and flood hazard factors. These are illustrated on Figure 1. The entire coastline of the Metro Bay SAMP area is designated as either A-zone or V-zone. Historically, many of the V-zones were used for industrial uses, but mixed-use urban developments are planned for the future. Within the Metro Bay SAMP boundary, 17 percent of the land area (570 acres) is located in the A-zone, while 10 percent (320 acres) is in the V-zone. Flood Insurance Rate Maps also identify those land areas at potential risk from a 0.2 percent chance flood event (often referred to as the 500-year event). FEMA statistics show that about 25 percent of all flood claims nationwide are for properties located in these areas. Regardless, NFIP's current procedures do not require specific regulations or flood insurance for these properties (Association of State Floodplain Managers (ASFPM), 2003). These FIRMs were originally developed in the 1970s and 1980s and used generalized topography, obsolete land use, and a mean sea level datum from 1929 (NGVD29). Some spot elevations and base flood information updates were made periodically. Therefore the potential flooding of the region may be of greater magnitude than indicated on these maps.

Currently, RIEMA is engaged in the Map Modernization Project and is in the process of updating its FIRMs through this program. The Project uses state-of-the-art technology to increase the quality, reliability, and availability of flood hazard maps and data. The Map Modernization Project is a long term effort, however, and may take up to 10 years to complete the entire state. Recently, a revised FEMA Flood Insurance Study (FIS) was completed for Providence County (FEMA, 2007b) along with updated FIRMs, which are under review as of February, 2008. The maps are expected to be issued in the spring of 2009. The study and the maps use NAVD88 as a mean sea level datum, and utilize hydraulic and hydrologic analyses conducted in the Metro Bay area in the 1980s and '90s, in addition to a 2007 study on the

Blackstone River. While these new maps have been superimposed on 1997 orthophotos, the models themselves were not revised, and therefore the flood elevations have not been changed. They do not incorporate erosion, sea level rise or coastal A-zone designations, which limits their applicability to depict a full picture of flood risks. [refer to new name as “DFIRMS” – Digital FIRMS]

As part of the NFIP, the voluntary Community Rating System (CRS) allows residents to gain credit points that result in discounts on NFIP premiums. When communities go beyond the minimum standards for floodplain management, the CRS can provide discounts in flood insurance premiums to policyholders in that community. Class 1 entitles a policy holder to a 45 percent discount while class 10 is considered not participating in the CRS, thereby receiving no discount. Currently there are only 3 communities in Rhode Island receiving CRS-provided discounts on premiums, none of which are in the Metro Bay region. Pawtucket formerly participated, but its program has been rescinded and residents are not currently eligible for insurance premium discounts. The Metro Bay communities attended a training sponsored by RIEMA in May, 2006 to understand the process and benefits of participating in the CRS.

Table 10. Metro Bay High-Water/Flooding Elevations (given in feet MLLW)

Location	Hurricane of 1938	Hurricane of 1944	Hurricane Carol
Bullock Point	17.5	*	16.5
Crescent Park	17.8	*	*
Squantum Point	17.6	*	17.9
Seekonk River	17.8	*	16.6
Point Street Bridge	18.3	*	17.0
USC&GS Tide Gauge	17.5	11.7	16.5
*No available data. Source: FEMA, 2007b.			

4.4. Municipal Hazard Mitigation Plans

The Federal Disaster Mitigation Act of 2000 and subsequent rules require states and communities to develop natural hazard mitigation plans (RIEMA, 2005). These planning efforts are intended to facilitate cooperation and to better articulate needs for mitigation, resulting in faster allocation of funding and more effective risk-reduction projects. All four Metro Bay cities have FEMA–approved natural hazard mitigation plans, enabling them to be eligible for the NFIP and for federal funding for natural hazard mitigation and disaster recovery. These plans identify natural hazards, determine the community’s vulnerability, and develop targeted mitigation activities. More specific information on these plans can be found in Appendix 1. Given the data gaps related to mapping and modeling, these mitigation plans do not address the potential impacts of sea level rise, A-zone creep, or the increased recurrence of high hazard storm events.

All of the cities have recognized that they lack human and financial resources to implement their mitigation actions. The City of Pawtucket, unlike the other communities, has identified potential mitigation opportunities that could be implemented following a disaster when funds may be available, including resizing culverts, improving drainage of roads, and acquiring lands prone to flooding for open space. Cranston’s mitigation activities include the recent installation of 800 feet of rock riprap revetment for Stillhouse Cove, part of which will prevent the erosion of the evacuation routes for Pawtuxet Neck. The City is seeking funding to flood-proof the sewage pump station facilities located on Pawtuxet Neck.

The City of Pawtucket is considering building a seawall for the Blackstone Valley Electric Substation and repairing the dams along the Blackstone. The City is also reviewing riverfront development plans to ensure that the floodway is left undeveloped and that homes are elevated above the base flood elevation. Having identified property tax incentives to flood-proof buildings, the City will work with NBC to ensure that all backflow-prevention flapper valves for combined sewer overflow systems in flood prone areas are functional.

Providence's plan focuses on protecting open space and educating the public about the building standards for A- and V-zones, and hiring a coordinator for participation in the Community Rating System. The City is no longer responsible for maintenance and operation of the Fox point Hurricane barrier, as those duties were recently transferred to the Army Corps of Engineers.

East Providence's hazard mitigation plan includes exploring financial incentives for conservation easements on vulnerable properties and educating builders, engineers, and small businesses. The City plans to encourage developers to use best practices in siting and flood-proofing coastal infrastructure.

4.5. Municipal Harbor Management Plans

Natural hazards can impact both land-based and water-based activities. None of the Metro Bay area cities currently have CRMC–approved Harbor Management Plans. Furthermore, the existing documents (either outdated or in draft form) do not adequately address or link to other plans to address hazard issues on the waterfront. This is problematic because of unique hazards present in the port districts of Providence and East Providence, for example. The port areas of both cities carry major infrastructure and supply the region with critical goods, in both post- and pre-hazard conditions. Guidance could include evacuation of shore side facilities, structural mitigation of shoreline structures, safe harbor recommendations, and boat pull-out procedures and priorities, as well as address other concern issues such as spills, contamination caused by inundation, and facility closures. It should be noted additionally that new requirements for facility evacuation, import of supplies, emergency transport, etc. may be placed on this infrastructure in the case of a hazard scenario. The East Providence draft plan does not mention hazard issues and the Providence Harbor draft plan addresses this point only in a minor way.

4.6. Business Continuity Planning

Business continuity planning is a structured approach for business owners to examine their businesses, identify vulnerabilities to risk, and establish plans to reduce those vulnerabilities. Small businesses - which represent over 95 percent of employer businesses in Rhode Island (Small Business Administration, 2004) - are most at risk. They have a higher probability of being impacted by a disaster, fewer recovery resources, and a lower tolerance for losses (Institute for Business and Home Safety (IBHS), 2005). As seen in Table 11 below, the floodplain has a broad spectrum of small and large businesses vulnerable to potential flood disasters. Rhode Island–based Code Red, a company devoted to pre-disaster planning, has recently initiated partnerships with several chambers of commerce to provide training in business continuity planning. One tool being used, Open for Business, was developed by IBHS, a national nonprofit insurance industry association that focuses on reducing the social and economic effects of natural disasters.

Table 11. Number of businesses in SAMP floodplain

Annual Sales	V-zone	A-zone
No annual sales	1	26
Less than $500,000	3	39
$.5 - $1 million	1	29
$1.0 - $2.5 million	1	30
$2.5 - $5.0 million	1	20
$5.0 - $20 million		17
$20 - $50 million		7
Total	7 businesses	168 businesses

Source: Providence Plan, 2006

5. EXISTING PLANS AND REGULATIONS

5.1. Existing Building Standards for Floodplains

Rhode Island's statewide building code, based on the 2006 International Building Code (IBC), complements the NFIP minimum standards for building in the 100-year floodplain[6]. The 2006 IBC includes provisions for incorporating a freeboard as well as utilizing a coastal A-zone, in which buildings in specified A-zones that are vulnerable to high wave activity would require V-zone standards (International Code Council (ICC), 2006). State legislation passed in 2007 authorized the CRMC to collaborate with the State Building Commissioner and adopt freeboard calculations (a factor of added safety above the anticipated flood level) to accommodate sea level rise and minimize storm-induced impacts to structures, in accordance with R.I.G.L. § 23-27.3-100.1.5.5.

The cities of Pawtucket and East Providence, and the state CRMC in some cases, have adopted stronger codes, while Providence and Cranston have adopted standards similar to the State Building Code and NFIP. Examples of stronger codes currently adopted within the Metro Bay region include:

a) Height requirements for new or substantially improved nonresidential structures in the floodplain:

- Minimum requirements: The lowest floor level (including basement) of any nonresidential structure shall be elevated or flood-proofed to or above the base flood (100-year flood) elevation. No freeboard required.
- Enhanced requirements: The lowest floor, including basement, be elevated or flood-proofed *one foot above* the base flood elevation. This extra foot is considered the freeboard. (Pawtucket, 2005)

b) Siting requirement for new construction

- Minimum requirements: All new construction shall be located landward of the mean high tide in the velocity zone[7].
- Enhanced requirement: Areas subject to hurricane tidal floods, lying 10 feet or less above mean sea level (or NGVD29 in this case), *shall be limited.* The ordinance includes a list of allowed uses including parks, non-building uses, outdoor storage, marinas, docks, and sea walls. (East Providence, 2003)

c) Requirements related to use of space below base flood elevation

- Minimum requirements: area is allowed for parking, building access and storage.
- Enhanced requirements: Storage or processing of materials that in time of flooding are flammable or explosive or could be injurious to *human, animal or plant life* is prohibited. (Pawtucket, 2005)

---

[6] Flood maps developed by the FEMA identify flood-prone properties and expected flood levels. The maps show the areas that will be inundated during a flood with a severity level that has a one (1) percent chance of occurring or being exceeded in any given year, often called the 100-year flood (Association of State Floodplain Managers, 2003).

[7] The CRMC regulations have a 50-ft minimum setback requirement from coastal shoreline features. The new Urban Coastal Greenway policy defines specific requirements for the shoreline of Metro Bay communities.

5.2. State Plans and Policies

Several state agencies have developed guidance and regulations related to preservation of natural resources, floodplain management, and mitigation of impacts.

Land Use 2025 (R.I. Statewide Planning, 2006), developed by Statewide Planning and approved in May 2006, acknowledges that climate change and sea level rise could impact coastal development. The plan states that, "land use measures to address coastal hazards include special structural design and construction standards, setbacks and buffer areas, limits on shoreline modifications, restrictions on rebuilding after storm damage, and acquisition of vulnerable areas for conservation uses" (R.I. Statewide Planning, 2006). In terms of policies, Land Use LU-16, states "Direct development away from areas subject to flooding."

Rhode Island Comprehensive Planning and Land Use Act has eight required elements. The natural and cultural resources element requires an inventory of the significant natural resource areas and policies for their protection and management. These resource areas include wetlands, coastal features, and flood plains.

The 2005 Urban Environmental Design Manual (DEM, 2005) encourages:

- Post-development flood storage within a floodplain should be, at a minimum, equal to pre-development conditions (for new development)
- The lowest floor elevation should be at least one foot higher than the 100-year floodplain elevation (for new development)
- Net improvement: In addition to improved protection from flood hazards for life and property, any proposed redevelopment or expansion of a site within the 100-year floodplain should demonstrate that post-development conditions will improve the capacity of the area to provide storage or conveyance of flood waters (for redevelopment)

The Coastal Resources Management Program (CRMP) (CRMC, 2007a) has policies related to development and activities within the State's coastal zone (e.g., within the Metro Bay SAMP boundary). Building and construction setbacks and buffer zones are determined by the type of project and its location based on water type, coastal shoreline feature, and coastal erosion rates. The Urban Coastal Greenway Policy (CRMC, 2006) refines the state setback and buffer policy in the Metro Bay area in order to meet the needs and conditions of the urban core of the State. Some of the standards and good practices that are incorporated into the policy will also aid in mitigating impacts, especially where natural habitats are maintained, enhanced, or restored immediately along the shoreline. The CRMP outlines procedures for post-hurricane and storm permitting procedures (CRMC, 2007a). The CRMC can impose a temporary moratorium on coastal reconstruction for a maximum of 30 days from the disaster declaration date. There are, however, some provisions under Section 180 that allow for immediate actions with an emergency assent if certain conditions exist.

On January 15, 2008 CRMC adopted a sea level rise policy, to implement the 2007 legislation related to freeboard in collaboration with the State Building Code Commissioner. The policy states:

> "The Council recognizes that sea level rise is ongoing and its foremost concern is the accelerated rate of rise and the associated risks to Rhode Island coastal areas today and in the future. Accordingly, for planning and management purposes, it is the Council's policy to accommodate a base rate of expected 3 to 5 foot rise in sea level by 2100 in the siting,

design, and implementation of public and private coastal activities and to insure proactive stewardship of coastal ecosystems under these changing conditions. It should be noted that the 3-5 ft. rate of sea level rise assumption embedded in this policy is relatively narrow and low. The Council recognizes that the lower the sea level rise estimate used, the greater the risk that policies and efforts to adapt to sea level rise and climate change will prove to be inadequate. Therefore, the policies of the Council may take into account different risk tolerances for differing types of public and private coastal activities. In addition, this long term sea level change base rate will be revisited by the Council periodically to address new scientific evidence." (CRMC, 2007b)

The Rhode Island Emergency Operations Plan (EOP) (RIEMA, 2004) was prepared by RIEMA in 2004, and is currently being updated. This provides a framework for coordinated response to extreme events, such as natural disasters. The EOP establishes the role and responsibilities for state and municipal agencies and officials, as well as private sector and non-profit collaborators. The Plan is organized within the Federal framework that includes 17 Emergency Support Functions, such as communications, public works and engineering, and transportation. Each of the support functions includes roles and responsibilities as well as actions that fall into the categories of mitigation, preparedness, response and recovery for events. Currently, CRMC does not have an official role within the EOP to provide support for coastal disasters. Discussions in 2007 between RIEMA and CRMC focused on identifying an appropriate role and coordinating mechanism among the two agencies. To date, this has not been finalized.

Later in 2005, RIEMA completed the Rhode Island State Hazard Mitigation Plan (RIEMA, 2006), which outlines the hazards, risks, and the opportunities for increased mitigation actions throughout the state. This Plan complements the local hazard mitigation plans developed by each community. The Rhode Island State Hazard Mitigation Plan has been updated as of March 2008.

5.3. FEMA Map Amendments

Though some filling still occurs on waterfront properties within the floodplain, it is very difficult to obtain permits under the CRMP for filling in coastal waters and wetlands. Generally such activities must serve a compelling public purpose. In cases where property owners may elect to raise their base flood elevation on A-zone sites, they may apply to local building officials for fill permits and meet state building code. They may also apply to FEMA to request revisions in the designated flood zone category resulting in changes to building standards or reduced flood insurance premiums. Owners must provide new hydrological data to support their claims that their property is outside the base flood elevation or that the existing structure is located above the base flood elevation. This is referred to as a request for a Letter of Map Amendment (LOMA). Based on FEMA's records, Cranston has averaged the most LOMA approvals of the Metro Bay communities. Most of these approvals, however, are properties located out of the SAMP boundary and in the inland riverine A-zones. Property owners can also request that FEMA change the flood zone for proposed developments. This is referred to as a Conditional Letter of Map Amendment (CLOMA) for development without fill, and Conditional Letter of Map Revision with Fill (CLOMR-F). See Table 12 below for definitions.

Table 12. Flood Zone Map Amendment Definitions

LOMA Letter of Map Amendment	A letter from FEMA stating that an existing structure or parcel of land that has not been elevated by fill (natural grade) would not be inundated by the base flood.
CLOMA Conditional Letter of Map Amendment	A letter from FEMA stating that a proposed structure that is not to be elevated by fill (natural grade) would not be inundated by the base flood if built as proposed.
LOMR-F Conditional Letter of Map Revision	A letter from FEMA stating that an existing structure or parcel of land that has been elevated by fill would not be inundated by the base flood.
CLOMR-F Conditional Letter of Map Revision with Fill	A letter from FEMA stating that a parcel of land or proposed structure that will be elevated by fill would not be inundated by the base flood if fill is placed on the parcel as proposed or the structure is built as proposed.

Source: FEMA, 2008

6. KEY ISSUES

Table 13: Key Management Issues

Issue 1:	Increased risk to coastal development due to fill, infill development, sea level rise, runoff, and shoreline change.
Issue 2:	Increased flooding impacts from additional infrastructure and risks to populations in the floodplain.
Issue 3:	Emergency management, coastal management, and land use strategies are not integrated, thereby reducing community resilience.
Issue 4:	Limited financial and technical capacity reduces the effectiveness of mitigation strategies.
Issue 5:	Inconsistent policies and procedures reduce the effectiveness of hazard mitigation actions.
Issue 6:	Insufficient data for decision-makers and the public to be proactive about climate change and its impacts.
Issue 7:	Impact of existing and potential shoreline debris during a storm event is of critical concern.

Issue 1. Increased risk to coastal development due to fill, infill development, sea level rise, runoff, and shoreline change

Significant filling of shoreline areas since the hurricane of 1938 has decreased the volume of the flood storage area, and expanded the aerial extent of the floodplain. The combination of fill activity, infill development, historic and accelerated sea level rise, increased runoff from impervious watershed surfaces, and shoreline change has resulted in an expanded floodplain that reduces the coast's ability to absorb floodwaters and enlarges the area likely to be flooded. The result is that storm surges likely will rise higher than in the past and migrate inland to areas currently not designated as special flood hazard areas, and unfortunately, there are no updated models to quantify the height and extent of possible storm surges and flooding.

Given this scenario, flood elevations could be higher than previously estimated in the flood insurance studies. It is possible that some existing A-zone structures may have increased flood elevations and will need to be re-categorized as V-zone structures in the event of a new FEMA flood insurance study. (J. Boothroyd, personal communication, November 22, 2005). As a result, currently uninsured property owners would have to pay higher flood insurance premiums if they chose to purchase flood insurance through the NFIP. Any new construction or substantial remodeling will need to be built to V-zone standards. Existing commercial buildings will have to increase the height of their flood-proofing to remain above the base flood elevation. Another implication is A-zone "creep," where flooding will expand landward into areas that are currently not in the special flood hazard area. Current flood maps do not identify a “Coastal A-zone,” where structures may be subject to waves less than three feet (the cutoff for a V-zone). As sea level rises, it is anticipated that the flood zones will expand inland and exacerbate the potential impacts described above.

Issue 2. Increased flooding impacts from additional infrastructure and risks to populations in the floodplain.

Improvements in building standards and design have significantly reduced the vulnerabilities and financial impacts of flooding on new (or significantly improved) developments. However, due to the cumulative increase in waterfront development in floodplains, flood insurance claims and premiums have significantly increased (Heinz, 2002). It is likely that flood insurance costs, premiums, and infrastructure damage will increase as Metro Bay cities redevelop their waterfronts. There is also greater potential for human casualties when critical facilities, residences, and businesses are built in the floodplain.

While desirable waterfront property can provide excellent urban renewal opportunities, communities need to compare the benefits of developing in a floodplain with the costs of mitigating hazards, responding to disasters, and redeveloping devastated areas and infrastructure. Current infrastructure, such as wastewater treatment plants and storm water infrastructure will be increasingly compromised as storm surge elevations increase with sea level rise. It is also likely that such facilities will be impacted from increased peak flows resulting from more frequent extreme rainfall events.

The potential for increased risk and economic costs from hurricane and nor’easter events must also be considered for the water-dependant activities. For example, the number of slips and moorings in the Metro Bay area is anticipated to increase along with shorefront development. Forecasters can usually predict with accuracy approximately 12-24 hours in advance if a hurricane will impact Rhode Island. This generally does not give most boat owners enough time to remove their boats from the water and marinas are easily overloaded with requests for boats to be hauled out during a relatively short period of time.

When Hurricane Bob struck in 1991, several boats were allowed behind the Fox Point hurricane barrier. Unfortunately, some pilings failed when the hurricane barrier pump operations began to remove accumulating river water from behind the barrier. The result was destabilization of the nearby marina pilings and some damage to boats (Uva, personal communication, February 9, 2006). Rather than relocate boats behind the hurricane barrier, boaters should exercise other options if they cannot remove their vessels from the water such as doubling-up dock and mooring lines to better secure their boats at their facilities. Another option is to find a safer refuge (in the lee) somewhere else in the Bay (e.g., Greenwich Cove). Currently the Metro Bay communities do not have procedures to address these issues.

Issue 3. Emergency management, coastal management, and land use strategies are not integrated, thereby reducing community resilience.

Floodplain management is a highly decentralized governance system involving local, state, and federal governments, the business sector, and nongovernmental organizations. This shared responsibility structure works well when there is clear communication and coordination between all partners. All too often, a lack of funding, variances in regulatory standards, limited knowledge, slow feedback and response mechanisms, and poor integration of roles and responsibilities limit the effectiveness of the system.

At the municipal government level, coordination is often fragmented, due to the immense workload and specified responsibilities of each office. In terms of plans, there would be great benefit to have linkages among hazard mitigation plans, Local Comprehensive Plans, Master Plans, and annual capital improvement plans. Since they share authority for implementing floodplain ordinances and standards, there should be strong linkages and good communication channels between planning and building departments, though it appears that most building officials have not been involved in the zoning or master planning of waterfront redevelopment areas. Similarly, an explicit linkage to the public works department and the authority that approves capital improvements within annual budgets, would significantly improve the implementation of mitigation strategies. Emergency Management Specialists are typically not linked into the development process or the redevelopment process after an event.

At the state level, coordination for mitigation, response, and recovery is similarly fragmented. For example, while DEM is responsible for debris management within the Emergency Operations Plan, the CRMC is not designated. Their participation, however, would be useful, especially for identifying mitigation or recovery actions. Together these two agencies and the municipalities could develop and practice responses to certain scenarios, and incorporate different potential failures to infrastructure and coordination mechanisms. This would be important in a proactive planning phase, as well as the implementation phase during and after a disaster event. The State Hazard Mitigation Committee could be a venue for state agency coordination to address opportunities for enhanced disaster resilience, beyond just response.

While the state Emergency Operations Plan incorporates recovery, it does not acknowledge the role of CRMC in permitting or issuing a moratorium on rebuilding structures along the coastal shoreline. This coordination is essential, given the critical decisions that are typically made after a disaster, which could have long-term negative impacts. While policies may exist in different agencies regarding recovery, the state does not have a coordinated recovery or redevelopment plan that looks to the future of building back better.

Issue 4. Limited financial and technical capacity reduces the effectiveness of mitigation strategies.

Federal and state funding of mitigation actions is extremely limited. Strong linkages between the municipal planning department, through the local NFIP coordinator, the municipal emergency management official, and RIEMA's mitigation and floodplain management staff are also valuable. Such connections will assist in linking hazard mitigation plans to funding opportunities. Additional on-site assessments of coastal mitigation projects by FEMA, in coordination with RIEMA, as well as ongoing training in the grant development process (e.g., cost-benefit analysis) could potentially increase federal funding to municipalities. Though these activities are occurring now, they could be expanded to improve the capacity of coastal cities to submit winning proposals.

Effective outreach programs are limited at both the municipal and state level. The Community Rating System is not widely used in Rhode Island, and none of the Metro Bay communities currently participate. While this program could be an effective approach to increasing resilience and decreasing flood insurance rates for residents and businesses, the amount of staff time needed to develop a local program, apply for the rating, and maintain it, is significant. Participation in the National Flood Insurance Program is also low. Many vulnerable properties will require additional disaster support when they are damaged from a storm event.

Building technical capacity of staff is an ongoing process. Government officials have requested training in floodplain mitigation, planning, response, and redevelopment. Building officials need to stay current with floodplain standards, best practices, and basic coastal engineering knowledge. Most building offices lack expertise in coastal processes and engineering and are therefore reliant on the developers' consultants and engineers for the validity of structural integrity. CRMC sets the setback and buffer distances for development and reviews proposals within its jurisdiction, but does not review height and building standards that fall under the jurisdiction of the local building inspector and state building code. The R.I. State Building Commission supports ongoing training associated with natural hazards to help address staff turnover and the need to stay up to date with changing regulatory standards.

The tools are limited for local government officials to apply findings from build-out analyses to make planning decisions about future development and variances in the floodplain. Currently, most permitting decisions and variances are made on the basis of individual parcels rather than on the cumulative impact of buildings within the floodplain.

Issue 5. Inconsistent policies and procedures reduce the effectiveness of hazard mitigation actions.

Different vertical datums are being used by different agencies in the planning and permitting process, which results in confusion and error. This is compounded by projects that have both land and water datums on the same plan. Coastal projects and topographic features are often measured with different tools and vertical datums that result in different elevation numbers. Applying their data to a site plan can result in conversion errors that lead to unforeseen risks. A freeboard requirement is one way to address uncertainty and provide a margin of safety.

The issuance of Conditional Map Amendments through FEMA may undermine community efforts at mitigating floods, particularly with amendments where fill is placed in the flood zone (CLOMA-F and LOMA-F). There is insufficient review and education about this process. Neither municipalities nor the State educate property owners about map amendment processes, nor do they discourage them from pursuing them. Property owners are allowed to request changes to floodplain zone categories with a FEMA–approved map amendment, which can be costly on a site-by-site basis and may not adequately address cumulative impacts from these site-based decisions. The Johnson & Wales dormitory project in Fields Point was granted an amendment for fill by FEMA, thereby allowing the university to elevate the structure out of (or above) the floodplain. The studies reviewed by FEMA included an analysis of potential impacts on adjacent properties; in this case, the consultant indicated that there were no such impacts (Greenwood, personal communication, April 25, 2006). While one property may benefit from an amendment, it is not known what the cumulative impact would be if each property in the coastal floodplain applied for this exclusion and built in a similar manner.

Riverine systems and coastal areas are modeled differently and have difference flooding dynamics, so regulations for filling in the floodplain or floodway differ. The regulations and the hydrodynamics are different for riverine areas, where floodwaters can be displaced and compensatory storage of water is required for proposed fill. However, this distinction is often misunderstood by officials and project proponents.

Issue 6. Insufficient data for decision-makers and the public to be proactive about climate change and its impacts.

Maps with detailed topographic information are widely lacking along the coast. LIDAR (*Light Detection and Ranging*) is a remote sensing technology that is used for mapping land and nearshore bathymetry. The lack of detailed topographic and bathymetric data is a major limiting factor to improving the prediction of riverine and coastal flooding. Some limited LIDAR data has been obtained for several Rhode Island communities, but it's not presently available to help model the potential storm surge for Upper Narragansett Bay municipalities.

The Flood Insurance Rate Maps for Providence County have recently been updated and are scheduled to be final in March 2009. While the new maps incorporate some updated topographic data, the flood study was not revised for coastal areas. In addition, the map modifications do not incorporate changes in sea level rise or cumulative build-out analyses for the floodplain. Therefore, the new maps underestimate potential flood elevations and risk susceptibility.

Regional research and models do not adequately reflect the dynamics between the riverine and coastal systems which are present in the Metro Bay. The existing riverine flood, coastal storm surge, and hurricane models were developed for different needs and users. An integrated riverine and coastal storm surge model that incorporates sea level rise and cumulative impacts of fill and infill development is needed to accurately project the horizontal and vertical expansion of the floodplain. The National Weather Service is working on an integrated model for riverine flooding and storm surge.

Developing accurate models is one step towards an effective understanding of regional hydrodynamics. The model results then need to be conveyed in a format that decision-makers and the public can easily understand. Communicating both the potential risks and uncertainties associated with those risks is important for developing policy and mitigation strategies. Some products that would be useful for conveying risks are three dimensional depictions of storm surge which include flood water depths, the aerial extent of flooding, and projections of future flood depths and extent resulting from sea level rise.

Issue 7. Impact of existing and potential shoreline debris during a storm event is of critical concern.

Marine and shoreline debris can be hazardous to coastal infrastructure during high wind and storm surge events. Large debris, such as old docks, and pilings can become lodged in sensitive estuarine habitats and along urban shorelines, and may remain there for years. Increased development in the floodplain has the potential to create additional debris. RIEMA estimates that Providence County has the potential for 1.01 million tons of debris (RIEMA, 2005). In the 1938 and 1954 hurricanes, a tremendous amount of debris flowed into the Upper Bay region and acted as battering rams, greatly increasing the level of destruction. Reducing development or increasing building standards will lessen the potential for infrastructure to turn into harmful debris during storms.

RIEMA, DEM, and the RI Resource Recovery Corporation are currently revisiting their draft post-disaster debris management plan (Baker, personal communication, January 15, 2008). Currently CRMC requires as part of permit conditions that applicants remove all debris associated with in-water facilities if they are destroyed in a natural disaster (See CRMP Section 300.4). Coordination between RIEMA, DEM, and CRMC on this issue is crucial in planning to reduce impact and damage.

7. RECOMMENDED POLICY CHANGES, ACTIONS, AND RESEARCH NEEDS

Enhanced resilience to coastal natural hazards in the Metro Bay region will require a variety of initiatives related to policy, management, research, and outreach. The stakeholders will vary as well, from state agencies such as CRMC and the State Building Commission to municipal offices and boards concerned with planning, zoning, building permits, emergency management, and harbor management. Actions to address the priority issues of the SAMP are described below.

Table 14. Summary Recommendations

Analysis of the key issues above leads to a set of recommendations related to coastal hazards and climate change. Upon evaluation, it was determined that the majority of issues that the Metro Bay municalities are experiencing require action at the state level. Many of these recommendations would therefore apply statewide, and are as such noted. Recommendations are meant for implementation by CRMC and other state agencies, the Metro Bay Municipalities as well as other Rhode Island coastal communities in the case of statewide adoption.

<u>Proposed Changes to Policy and Regulation</u>

7.1.1. Develop standards and regulations on sea level rise and climate change adaptation (statewide)
7.1.2. Adopt freeboard standards that will increase the required first floor elevation above the base flood elevation for new or substantially improved structures in high hazard areas (statewide)
7.1.3. Implement the Coastal A-zone policy and coordinated implementation approach, where structures within A-zones subject to wave activity of 1.5 to 3 feet are designed to V-zone standards (statewide)
7.1.4. Develop a review procedure for proposals that include filling in Coastal A-zone and V-zones (Metro Bay), tracking CLOMA-F and LOMA-F to assure that fill is not used as structural support in existing and potential V zones.
7.1.5. Incorporate provisions into design and permitting of water-based projects to address preparedness, response and recovery of hazards related to hurricanes and sea level rise (statewide)

<u>Recommended Actions</u>

7.2.1. Develop and implement a model floodplain ordinance (statewide)
7.2.2. Evaluate the effectiveness of the hurricane barrier and building standards used behind the barrier based on current and future projected conditions (Metro Bay)
7.2.3. Inventory hazardous material, including household hazardous material and potential debris within the Metro Bay SAMP. Establish a marine debris removal plan for post-hazard cleanup (Metro Bay). Establish an outreach program to educate home owners about household hazardous waste.
7.2.4.... Prioritize property acquisition strategies that focus on UCG Areas of Particular Concern and flood mitigation (Metro Bay)
7.2.5..... Develop an ongoing outreach program for coastal developers, engineers, small businesses, banks, and home owners on the best ways to safeguard lives and property against coastal hazards (statewide)
7.2.6. Coordinate state and local aspects of floodplain management across the Metro Bay region (Metro Bay)
7.2.7. Develop and implement training programs (statewide)

7.1 Proposed Changes to Policy and Regulation

It is recommended that Rhode Island State agencies and the Metro Bay cities adopt more stringent building standards, flood ordinances, permitting processes, and best practices in coastal flood zones to reduce vulnerabilities to existing and future infrastructure, development and populations. In most cases, these recommendations could apply statewide, and would benefit the resilience of all coastal communities (See Table 14 above).

7.1.1. Develop standards and regulations on sea level rise and climate change adaptation - CRMC, State Building Code Commission, RI Sea Grant, Researchers, non-profit organizations, and Municipalities

While state policy on sea level rise and climate change has been recently adopted by CRMC, the standards needed to implement the policy are currently under development. This includes the development of freeboard requirements based on the structural categorization by the American Society of Civil Engineers (Standard 24-05) to elevate structures to minimize impacts from storm-induced flooding and sea level rise. It is anticipated that the freeboard requirements will be stipulated based on the type of project (e.g., residential, commercial, public infrastructure, etc.) and will be established by CRMC in collaboration with the State Building Code Commission. Once these standards and regulations are adopted into the State Building Code, the municipalities and state agencies will need to incorporate them into their planning and permitting procedures, as appropriate.

The CRMC policy will also require maintaining state-of-the-art knowledge of the changes, impacts, and adaptation strategies. The CRMC will need to work with key stakeholder groups to determine what type of real time monitoring will be required of the natural as well as the physical environment (i.e., key public infrastructure), so that policy can be responsive and adaptive to the accelerated changes that will occur in the future. This will aid in the CRMC responding to its policy which indicates that "this long term sea level change base rate will be revisited by the Council periodically to address new scientific evidence."

7.1.2. Adopt freeboard standards that will increase the required first floor elevation above the base flood elevation for new or substantially improved structures in high hazard areas - CRMC, State Building Code Commission, RI Statewide Planning, RIEMA, and Municipalities

The base flood elevation depicted on the flood maps is a *minimum* requirement of the NFIP; it is an estimate based on generalized models and it does not incorporate sea level rise. The new CRMC policy adopted in January 2008 incorporates a sea level rise rate of three to five feet by 2100. This policy provides guidance for the State Building Code to incorporate freeboard standards to minimize impacts to structures, as permissible under state law. The Metro Bay municipalities will be required to adopt new floodplain ordinances in the coming year, with the approval of the new FIRM maps that have been developed by FEMA through the Map Modernization Program. Many communities nationwide, including Pawtucket, require new or substantially improved structures built in special flood hazard areas to be elevated above the minimum federal requirement shown on the effective FIRM. This "freeboard" provides additional protection to structures and also allows property owners to qualify for substantial discounts on their flood insurance premiums. For instance, in North Carolina, it is estimated that a residential house located in a V-zone that is elevated two feet above base flood elevation may qualify for a 54 to 70 percent premium discount on building coverage and a 45 to 65 percent premium discount on contents coverage. (North Carolina Floodplain Mapping Program, 2005b). Additionally, the Massachusetts StormSmart Coast program has calculated that there is a 60% annual saving in insurance flood insurance premium for a home that costs $250,000 to build and constructed with 3-feet of freeboard when located in a special flood hazard area. (See http://www.mass.gov/czm/stormsmart/regulations/freeboard.htm) See Issues 1 and 2 above for more information related to this recommendation.

7.1.3. Implement the Coastal A-zone policy and coordinated implementation approach, where structures within A-zones subject to wave activity of 1.5 to 3-feet are designed to V-zone standards - CRMC, State Building Code Commission, RI Statewide Planning, RIEMA, and Municipalities

Coastal A zones are special flood hazard zones subject to waves of between 1.5 and 3-feet. In these zones, FEMA Coastal Construction Manual recommends that stricter V-zone building codes be required. This provision, which is now incorporated into the Rhode Island State Building Code, will help protect structures in the event of coastal storm surge. In the future, as the sea level rises, the V-zone will expand inland, into the areas currently designated as A-zones. Observations of damage after events such as Hurricane Fran and, more recently, Hurricanes Katrina and Ike, have supported recommendations to increase building standards in coastal areas. "Some coastal areas mapped as A-zones may also be subject to damaging waves and erosion (referred to as "Coastal A-zones"). Buildings in these areas that are constructed to minimum NFIP A-zone requirements may sustain major damage or be destroyed during the base flood. It is strongly recommended that buildings in A-zones subject to breaking waves and erosion be designed and constructed with V-zone type foundations" (FEMA, 2006c).

7.1.4. Develop a policy and review procedure for proposals that include filling in Coastal A and V-zones - CRMC, DEM, FEMA, RIEMA, and Municipalities

Regulations and policies related to filling in the Coastal A and V-zones should be considered to insure that cumulative impacts do not occur to the floodplain and adjacent properties. The National Flood Insurance Program restricts the use of fill to support structures when located within a V-zone, however, fill is often placed in Coastal A or V-zones without the benefit of review by state and local authorities or the state floodplain coordinator. In efforts to address cumulative impacts and to avoid unintended impacts on coastal property owners, the CRMC, municipalities, DEM and the state flood plain coordinator should establish a policy to jointly review any fill request within a Coastal A or V-zone.

7.1.5. Incorporate provisions into design and permitting of water-based projects to address preparedness, response and recovery of hazards related to hurricanes and sea level rise – CRMC and Municipalities.

Permitting of marina development or redevelopment should include a review of the hurricane preparation and response procedures established by the marina for the facility and the boats. The current procedure for reviewing infrastructure and its "fitness of purpose," should consider incorporating a provision for sea level rise to insure that the structure will be able to withstand the increased hydraulic forces for its design life.

7.2 Recommended Actions

7.2.1. Develop and implement a model floodplain ordinance - RIEMA, State Building Code Commission, RI Floodplain Mitigation Association, and Municipalities.

Several states have model ordinances that integrate all of the NFIP standards and provide both minimum standards and recommendations for increasing effectiveness beyond these minimum standards to meet state needs. Rhode Island's floodplain standards are contained in the R.I. Building Code, which incorporates the International Building Code. The new floodplain maps being adopted in Providence County will provide an opportunity to adopt revised ordinances, which comply with NFIP standards, as Bristol County has done recently. This could be used as a foundation for a model ordinance, which then can be adapted to meet the specific needs of the Metro Bay region or the State as a whole. Florida's model ordinance gives both counties and individual cities opportunities to move towards an integrated approach to comprehensive plans and coastal zone management. The ordinance establishes a flood development review system with construction criteria and standards in areas sensitive to flooding (Wade, 1996). Another example is Maine's flood model ordinance, which provides guidance for individual communities (Maine State Planning Office, 2007).

7.2.2. Evaluate the effectiveness of the hurricane barrier and current building standards upriver from the barrier, based on current and projected future conditions (e.g., sea level, potential hurricane risks, and increased development) - USACE, CRMC, State Building Code Commission, and City of Providence

Given the disaster of Hurricane Katrina on the levees of New Orleans, it would be prudent to review the design and integrity of the Fox Point Hurricane Barrier. Given accelerated sea level rise projections and the potential for increased rainfall, an analysis should be made to determine if improvements should be made to the hurricane barrier. Given the recommended policy changes proposed in this SAMP document regarding building standards, clarification should be made as to the application of these to properties behind the hurricane barrier.

7.2.3. Establish a marine debris removal plan for post-hazard cleanup - RIEMA, DEM, CRMC, and Marine Trades Association.

This should include an inventory of potential marine debris sources and identification of disposal sites with options for separating and recycling mass amounts of debris. The plan should include a shared agreement between marinas, the port industry, and cities to identify areas to temporarily stockpile debris after a storm in parks or other open coastal areas for removal.

7.2.4. Prioritize property acquisition strategies that focus on UCG Areas of Particular Concern and flood mitigation - DEM, CRMC, RIEMA, and Municipalities.

State bond funds, Coastal and Estuarine Land Conservation (CELP) funds and public-private partnerships should be explored to purchase critical parcels along the Narragansett Bay shorefront and riverine areas. Property acquisition has been called, “not only the most effective protection measure available, [but] also a way to convert a problem area into a community asset and obtain environmental benefits” (ASFPM, 2003). Rhode Island communities have used property acquisition to reduce future impacts to private and public properties and infrastructure, most notably along the south shore following the hurricanes of 1938 and 1955. This strategy of land acquisition can also be used in urban areas of Metro Bay to mitigate riverine flooding and impacts from storm surge.

As an example, in Portland, Oregon, the Johnson Creek Willing Seller Land Acquisition Program has developed a consortium of agencies to help move people and property out of flood zones and minimize repetitive losses. Acquired land has been used to increase flood storage capacity specifically in a riverine area, restore wetlands, create passive recreational activities and improve habitats (ASFPM, 2002). Since 1997, over 50 households have been moved out of flood-prone neighborhoods, and 61 properties, totaling more than 100 acres, have been purchased (Johnson Creek Watershed Council, 2003). This program has leveraged funds from HUD Community Development Block Grants, the Portland Capital Improvement Program, regional bonds and the FEMA Hazard Mitigation Grant Program. Rhode Island needs to develop expertise in this area to assist communities and organizations.

7.2.5. Develop an ongoing outreach program for coastal developers, engineers, small businesses, banks, and home owners on the best ways to safeguard lives and property against coastal hazards - RI Floodplain Mitigation Association, RI Sea Grant, RIEMA, State Building Code Commission, and CRMC

Outreach is an important cross-cutting element for all of these issues and recommendations. Professionals, such as planners and building officials, are required to maintain continuing education credits, and have requested training on coastal hazards and mitigation initiatives. Recommendations include:

- Educating developers, local officials, and property owners about the processes and costs associated with requesting flood zone map changes.
- Educating business owners on how to prepare their businesses for natural disasters by using toolkits such as the IBHS Open for Business program.
- Providing outreach on map amendments that result from the Map Modernization Program.

Rhode Island may be able to adapt some materials from other states, such as North Carolina, whom has developed a series of fact sheets that describe technical and programmatic issues that are otherwise difficult to understand (North Carolina Floodplain Mapping Program, 2005a). Fact sheets include “Saving Money in the Wake of Changing Flood Maps: A Quick Reference for Flood Insurance Policy Holders” and “Flood Insurance Facts for Coastal Homeowners.” They have prepared fact sheets to educate residents about the updates and modernization of the FIRM flood insurance maps. These can be adapted for the Metro Bay, as appropriate. The Letter of

Map Change (LOMC) fact sheet (North Carolina Floodplain Mapping Program, 2002) highlights the process for obtaining map changes from FEMA. In addition to the outreach benefits, this education program provided all county communities with CRS credit, reducing flood insurance policy rates.

7.2.6. Coordinate state and local aspects of floodplain management across the Metro Bay region – RIEMA and municipalities

Given the potential for impacts from riverine flooding and from storm surge, the Metro Bay communities would greatly benefit from collaborative efforts to enhance floodplain management. These cover outreach, mitigation, response and recovery and include the following:

- Coordinate efforts to develop a Community Rating System (CRS) ranking for each Metro Bay community. CRS programs provide citizen discounts for NFIP insurance to qualifying communities, as an incentive to having the community consolidate and improve their flood mitigation efforts. Coordination on this may take the role of hiring one staff person to develop the program and assist in information exchange. The CRS effort should incorporate a review of CRMC and other state programs, which may provide additional rating points related to community hazard mitigation.
- Collaborate on efforts to develop materials for outreach to citizens, developers, and local officials.
- Facilitate a workshop or discussion targeting post-disaster recovery and redevelopment.
- Coordinate disaster response for evacuation, debris cleanup, drop-off sites, and the ferry system to deliver emergency supplies or people across the rivers.
- Develop a central website for coastal floodplain management, similar to the Massachusetts StormSmart Coasts program

7.2.7. Develop and implement training programs - RIEMA, State Building Code Commission, CRMC, RI Flood Mitigation Association, and RI Sea Grant

There are several actions that require ongoing capacity building, to insure that initiatives are implemented effectively. This helps insure that both existing and new staff are kept up to date on regulations, policy initiatives and tools for implementation.

- Provide joint training courses and/or outreach materials on coastal dynamics, debris removal, and evacuation planning for citizens and boaters.
- Offer regular training courses for local building officials, developers, and consultants on floodplain standards, good building practices, building code updates, and post-disaster response.

7.3 Research needed

The following list of research was the result of a workshop related to sea level rise (R.I. Sea Grant, 2007b) and various Metro Bay forums over the past two years:

- Obtain aerial images through LIDAR and multi-beam, so that these can be used for mapping and modeling inundation, as well as future scenarios of sea level rise. Work and coordinate with other organizations that need this information in order to lower costs.
- Develop maps of existing Coastal A-zones.
- Develop maps of future flood zones with anticipated sea level rise to demonstrate inland creep or compression of the flood hazard area.
- State and federal agencies should explore development and use of a higher resolution model such as ADCIRC rather than the SLOSH model for evaluating coastal storm surge and flood inundation risks.
- Monitor tide gauges to update sea level rise rates, maintain erosion mapping and monitor habitat restoration areas for effectiveness with changing climate and sea level.
- Follow progress on sea level rise adaptations for other coastal communities, both regionally and internationally.
- Develop economic evaluations that include the cost of retrofitting infrastructure for sea level rise.
- Evaluate sea level rise impacts on natural resources.
- Update the 2001 risk exposure maps to incorporate development since 2001
- Develop a risk exposure model based on municipal master plans. The model should be flexible to allow for continual updates to incorporate new permitted projects.
- Identify and map areas along the Seekonk River where there is a greater risk for catastrophic bluff failure that would require greater setback distances.
- Conduct a build-out analysis for the entire coastal floodplain within the SAMP to determine the impacts on flood storage capacity, the financial implications of disasters, and inform future development and response needs.

8. REFERENCES

113 Calhoun Street Foundation, 2002. 113 Calhoun St: A Center for Sustainable Living. (http://www.113calhoun.org/).

Advanced Hydrologic Prediction Service, 2005. Blackstone Valley at Woonsocket. (http://newweb.erh.noaa.gov/ahps2/hydrograph.php?wfo=box&gage=woor1).

Association of State Floodplain Managers (ASFPM), 2002. Mitigation Success Stories. (http://www.floods.org/).

Association of State Floodplain Managers (ASFPM), (2003). No Adverse Impact: A Toolkit for Common Sense Floodplain Management. ASFPM, Madison, WI. Edited by L. Larson, M. Klitzke, and D. Brown.

Baker, J. RIEMA, personal communication, January 15, 2008

Barbarisi, D. "Hurricane Barrier needs $20,000 worth of repairs." The Providence Journal 12 December 2007.

Billington, R., (2005). "Operation October Rain Blackstone River Flood October 2005." PowerPoint presentation. Blackstone Valley Tourism Council, RI. December 2005.

Boothroyd, J.C., R.I. State Geologist, personal communication, November 22, 2005.

Boothroyd, J.C., R.I. State Geologist, personal communication, February 8, 2006

Boothroyd, J.C., (2008). "Sea Level Rise in Rhode Island." PowerPoint presentation. U.S. Senate Environment and Public Works Committee Field Briefing, Narragansett, Rhode Island. August 21, 2008.

Boothroyd, J.C. and Hehre, (2006). Shoreline Change Study, submitted to CRMC.

Boothroyd, J.C., and S. J. McCandless, (2003). Quarternary Geologic Map of the East Greenwich and parts of the Crompton, and Bristol Quadrangles, Rhode Island, RI: Open File Map 2003-01, Rhode Island Geological Survey STATEMAP Program, Glacial Morphosequence Map (scale: 1:24,000).

Case, R., Cranston Building Official, personal communication, August 2, 2005.

Church, J. A. and N. J. White, (2006). "A 20th Century Acceleration in Global Sea-Level Rise." *Geophysical Research Letters* (33).

City of East Providence, Planning Department, (2004). Strategy for Reducing Risks for Natural Hazards in East Providence, Rhode Island: A Multi-Hazard Mitigation Strategy.

Cranston, (2004). City of Cranston Ordinances online. (http://municipalcodes.lexisnexis.com/codes/cranston/).

Cranston, (2005). City of Cranston Hazard Mitigation Plan. Prepared by the Cranston Hazard Mitigation Committee.

Coastal Resources Management Council (CRMC), (1983). Providence Harbor: A Special Area Management Plan.

Coastal Resources Management Council (CRMC), (1999). Special area management plan for the Salt Ponds of Rhode Island: Chapter 4: Geologic processes.

Coastal Resources Management Council (CRMC), (2005). Greenwich Bay: Special Area Management Plan.

Coastal Resources Management Council (CRMC), (2006). Urban Coastal Greenways Policy.

Coastal Resources Management Council (CRMC), (2007a). Coastal Resources Management Program.

Coastal Resources Management Council (CRMC), (2007b). Section 145. Climate Change and Sea Level Rise. Adopted 1/15/2008.

Department of Environmental Management (DEM), (2000). State of Rhode Island 2000 Annual Report to the Governor on the Activities of the Dam Safety Program.

Department of Environmental Management (DEM), (2005). Urban Environmental Design Manual (Appendix). Dodson Associates.

Douglas, B. C., (1991). "Global Sea Level Rise." *Journal of Geophysical Research*. Vol. 96, no. C4, 6981-6992.

East Providence, (2002). Strategy for Reducing Risk from Natural Hazards in East Providence, Rhode Island: A Multi-Hazard Mitigation Strategy.

East Providence Department of Planning, (2003). East Providence Waterfront Special Development District Plan: Preliminary Plan. (http://seagrant.gso.uri.edu/metrosamp/pdf/2005_PDFs/2003_Waterfront_SDD_Prelim.pdf).

East Providence, (2005). East Providence City Ordinances online. (http://70.168.205.112/eprov_ri/lpext.dll?f=templates&fn=site_main-j.htm&2.0).

Federal Emergency Management Agency (FEMA), (1991). Projected Impact of Relative Sea Level Rise on the National Flood Insurance Program. (http://yosemite.epa.gov/oar/globalwarming.nsf/uniqueKeyLookup/SHSU5BUKNX/$file/flood_insurance.pdf?OpenElement).

Federal Emergency Management Agency (FEMA), (2000). Coastal Construction Manual: Principles and Practices of Planning, Siting, Designing, Constructing, and Maintaining Residential Buildings in Coastal Areas. FEMA 55.

Federal Emergency Management Agency (FEMA), (2002). Hurricane Preparedness Guidelines for Marinas. (http://chps.sam.usace.army.mil/USHESdata/FEMA/Marinas/Marinasframe.htm)

Federal Emergency Management Agency (FEMA), (2006). Answers to Questions about the NFIP. (http://www.fema.gov/business/nfip/qanda.shtm).

Federal Emergency Management Agency (FEMA), (2006c). Recommended Residential Construction for the Gulf Coast: Building on Strong and Safe Foundations. FEMA 550/July 2006. (http://www.fema.gov/library/viewRecord.do?id=1853)

Federal Emergency Management Agency (FEMA), (2008). Letter of Map Amendment online Database. (http://www.fema.gov/plan/prevent/fhm/fmc_loma.shtm)

Federal Emergency Management Agency (FEMA), (2006a). How are the Hurricane Categories Determined? (http://www.fema.gov/hazard/hurricane/hu_about.shtm#1).

Federal Emergency Management Agency (FEMA), (2006b). President Declares Major Disaster for New Hampshire. (http://www.fema.gov/news/newsrelease.fema?id=26567).

Federal Emergency Management Agency (FEMA), (2007a). Rhode Island Severe Storms and Inland Coastal Flooding. (http://www.fema.gov/news/event.fema?id=8127).

Federal Emergency Management Agency (FEMA), (2007b). Flood Insurance Study: Providence County, Rhode Island (All Jurisdictions) Preliminary May 31, 2007. Flood Insurance Study Number 44007CV000A.

Freedman, J., RI CRMC, personal communication, January 9, 2008.

Frumhoff, P.C., J.J. McCarthy, J.M. Melillo, S.C. Moser, and D.J. Wuebbles. 2007. Confronting Climate Change in the U.S. Northeast: Science, Impacts, and Solutions. Synthesis Report of the Northeast Climate Impacts Assessment (NECIA). Cambridge, MA: Union of Concerned Scientists.

Fugate, G., RI CRMC, personal communication, November 2, 2005.

Gilroy California, (2007). Real Estate Guide: Mandatory Disclosures. (http://www.south-county.org/REGuides/Disclosures.html).

Ginis, I., (2006). "Predicting a Hurricane's Path of Destruction in Rhode Island." PowerPoint Presentation. Rhode Island Emergency Management Agency, RI. May 2, 2006.

Goulet, D., RI CRMC, personal communication, September 7, 2005

Greenwood, J., Woodard, and Curran, personal communication, April 25, 2006.

Heinz, H. J., (2002). Human Links to Coastal Disasters. The H. John Heinz Center for Science, Economics and the Environment.

Hellested, L., RI DEM, personal communication, September 21, 2005.

Institute for Business and Home Safety (IBHS), (2005). The Institute for Business and Home Safety's Disaster Safety. (http://www.disastersafety.org/).

Intergovernmental Panel on Climate Change (IPCC), (2001). Climate Change 2001: The Scientific Basis. The Third Assessment Report of Working Group I of the Intergovernmental Panel on Climate Change.

Intergovernmental Panel on Climate Change (IPCC), (2007). Climate Change 2007: The Physical Science Basis. The Fourth Assessment Report of Working Group I of the Intergovernmental Panel on Climate Change.

International Code Council (ICC), (2006). International Building Code. CENGAGE Delmar Learning.

Johnson Creek Watershed Council, (2003). Johnson Creek Watershed Action Plan: An Adaptive Approach. (http://www.jcwc.org/actionPlan/WAP10.30.03.pdf).

Madsen, T. and E. Figdor, (2007). "When It Rains, It Pours: Global Warming and the Rising Frequency of Extreme Precipitation in the United States," Environment America.

Maine State Planning Office, (2007). Floodplain Management Ordinances. (http://www.maine.gov/spo/flood/ord/).

Massachusetts Emergency Management Agency (MEMA), (2007). New England Hurricanes of Note. (http://www.mass.gov/?pageID=eopsmodulechunk&L=3&L0=Home&L1=Public+Safety+Agencies&L2=Massachusetts+Emergency+Management+Agency&sid=Eeops&b=terminalcontent&f=mema_new_england_hurricanes_of_note&csid=Eeops).

Milligan, S. February 15, 2005. "Study predicts city flood threat due to warming." The Boston Globe 15 February 2005.

National Oceanic and Atmospheric Administration (NOAA), (2003). Bench Mark Data Sheets: Providence, RI, Station ID: 0454000. (http://tidesandcurrents.noaa.gov/data_menu.shtml?stn=8454000%20Providence,%20RI&type=Bench%20Mark%20Data%20Sheets).

National Oceanic and Atmospheric Administration (NOAA), (2007). NOAA Tides and Currents: Center for Operational Oceanographic Products and Services. (http://tidesandcurrents.noaa.gov/).

National Oceanic and Atmospheric Administration (NOAA), (2008). Historic Tide Data, Providence, RI, Station ID: 8454000. (http://tidesandcurrents.noaa.gov/data_menu.shtml?stn=8454000%20Providence,%20RI&type=Historic%20Tide%20Data).

Nixon, S.W., S. Granger, and B. Buckley, (2003). "The Warming of Narragansett Bay". *41ºN* Volume 2, Issue 1. Rhode Island Sea Grant and University of Rhode Island Coastal Institute. (http://seagrant.gso.uri.edu/41N/Vol2No1/index.html).

NOAA Coastal Services Center, (2005). Storm Surge Tools and Information: A User Needs Assessment.

NOAA Coastal Services Center, (2007). Alternatives for Coastal Development: One Site, Three Scenarios. (http://www.csc.noaa.gov/alternatives/).

North Carolina Floodplain Mapping Program, (2002). LOMC Revalidation Policy. (http://www.ncfloodmaps.com/pubdocs/revalidation.pdf).

North Carolina Floodplain Mapping Program, (2005a). Flood Insurance Facts for Coastal Homeowners. (http://www.ncfloodmaps.com/pubdocs/coastal_flood_insurance_facts.pdf).

North Carolina Floodplain Mapping Program, (2005b). Saving Money in the Wake of Changing Floodmaps: A Quick Reference for Flood Insurance Policy Holders. (http://www.ncfloodmaps.com/pubdocs/grandfathering_letter.pdf).

Overpeck, J. T., B. L. Otto-Bliesner, G. H. Miller, D. R. Muhs, R. B. Alley, and J. T. Kiehl., (2006). "Paleoclimatic Evidence for Future Ice-Sheet Instability and Rapid Sea-Level Rise." *Science* (311).

Pawtucket, (2005). City of Pawtucket Ordinances online. (http://70.168.205.112/pawtucket_ri/lpext.dll?f=templates&fn=site_main-j.htm&2.0).

Pfeffer, W.T., J.T. Harper, and S. O'Neel. 2008. Kinematic Constraints on Glacier Contributions to 21st-Century Sea-Level Rise. *Science* 321 (1340-1343).

Providence, (2000). Strategy for Reducing Risks from Natural Hazards in Providence, Rhode Island. Prepared by S. Shamoon, L. Watson, P. Pogue, V. Lee, J. Almeida, and R. Duhaime.

Providence Plan, (2006). Analysis of Hazards within the Metro Bay GIS database. (http://maps.provplan.org/sampmapper/).

Rahmstorf, S, (2007). "A Semi-Empirical Approach to Projecting Sea-Level Rise." *Science* 315: 368-370.

R.I. Economic Development Corporation (RIEDC) (2007). Major Development Projects Completed, Underway or Planned in RI. (http://www.riedc.com/files/MajorDevelopmentProjects.pdf).

R.I. Emergency Management Agency (RIEMA). (2004). State Emergency Operations Plan. Prepared by RIEMA.

R.I. Emergency Management Agency (RIEMA), (2005). Rhode Island State Hazard Mitigation Plan. Prepared by P. Pogue, RIEMA.

R.I. Emergency Management Agency (RIEMA), (2006). Hurricane Evacuation Maps. (http://www.riema.ri.gov/hazards/hurricane_evac.php).

R.I. Emergency Management Agency (RIEMA), (2007). Floodplain Management in Rhode Island Quick Guide. RCQuinn Consulting Inc. & R.I. Flood Mitigation Association.

Rhode Island Government Online, (2006). "Rhode Island NFIP Conference." (http://www.ri.gov/press/view.php?id=1990).

R.I. Sea Grant, (2007a). The Science of Sea-Level Rise: Overview and Policy Implications for the State of Rhode Island. (May 11, 2007)

R.I. Sea Grant, (2007b). Results and Recommendations *from the* Science Review Forum: Informing CRMC Policy on Sea Level Rise. (June 8, 2007)

R.I. Statewide Planning, (2006) Land Use 2025. (http://www.planning.ri.gov/landuse/policies.htm).

Salvatore, J. M., (2007). "Discussion of Coastal Insurance Issues." PowerPoint Presentation. Creating Vibrant Waterfronts in Rhode Island: 6th Annual Ronald C. Baird Sea Grant Science Symposium, Narragansett, RI. October 19, 2007.

Small Business Administration, (2004). Small Business Profile: Rhode Island. (http://www.sba.gov/advo/stats/profiles/04ri.pdf).

Spaulding, M.L., (2005). "Storm Surge in Rhode Island." PowerPoint Presentation. Metro Bay Partnership Meeting, Providence, RI. November 22, 2005.

Spaulding, M.L., (2007). "Storm Surge and Sea Level Rise in Rhode Island." PowerPoint Presentation. Creating Vibrant Waterfronts in Rhode Island: 6th Annual Ronald C. Baird Sea Grant Science Symposium, Narragansett, Rhode Island. October 19, 2007.

Titus, J.G., and C. Richman, (2001). "Maps of lands vulnerable to sea level rise: modeled elevations along the US Atlantic and Gulf coasts." *Climate Research*, 18(3), 205-228.

Union of Concerned Scientists (2006). The Changing Northeast Climate: Our Choices, Our Legacy. Union of Concerned Scientists. (http://www.ucsusa.org/assets/documents/global_warming/The-Changing-Northeast-Climate.pdf).

University of Rhode Island Ocean Engineering (URI OCE), (2007). Natural Hazards and Flood Plain Management in Upper Narragansett Bay, Metro Special Area Management Plan (SAMP). University of Rhode Island Ocean Engineering: OCE 495 Senior Design Project. Prepared by N. Banks, D. Bonanno, M. Grennan, T. Manson, Z. Marchetti, K. Mason, K. Rizzo, A. Rowe, and J. Schwartz.

U.S. Department of Transportation (USDOT), (2006). Acting U.S. Transportation Secretary Maria Cino Announces $685 Million In Emergency Funds To Repair Damaged Roads In 31 States. (http://www.fhwa.dot.gov/pressroom/fhwa0611.htm).

U.S. Army Corps of Engineers (USACE), (1988). Tidal Flood Profiles New England Coastline. New England Division U.S. Army Corps of Engineers. (http://naelibrary.nae.usace.army.mil/dp191/ned88067.pdf).

U.S. Army Corps of Engineers (USACE), (1995a). Rhode Island Hurricane Evacuation Study Technical Data Report. United States Army Corps of Engineers.

U.S. Army Corps of Engineers (USACE), (1995b). Hurricane Surge Inundation Maps for New England: Rhode Island by Town. United States Army Corps of Engineers. (http://www.nae.usace.army.mil/projects/ma/hurricanemaps/rimaps.htm).

Uva, T., Narragansett Bay Commission, personal communication, February 9, 2006.

Vallee, D, (2006). "The Realities of Rhode Island Hurricanes." PowerPoint Presentation. Rhode Island Emergency Management Agency, RI. May 2, 2006.

Vallee, D. and M. Dion, (1996). Southern New England Tropical Storms and Hurricanes: A ninety-seven year summary 1900-1996 including several early American hurricanes. Taunton, MA, National Weather Service Forecast Office.

Vanderschmidt, F., (2005). PowerPoint Presentation. Metro Bay Special Area Management Plan (SAMP) Floodplain Hazards: Understanding the Current Knowledge and Gaps meeting. RI. October 11, 2005.

Wade, J and T. Trexler, (1996). Hurricane Mitigation and Post Disaster Redevelopment: Principles and Practices. Center for Governmental Responsibility, University of Florida College of Law.

Watson, L., V. Lee, P. Pogue, J. Almeida, H. Araujo, P. Mowrey, F. Rendine, R. Leitao, and J. Condon, (1998). Strategy for Reducing Risks from Natural Hazards in Pawtucket, Rhode Island: A Multi-Hazard Mitigation Strategy. Rhode Island Sea Grant. Narragansett, RI.

Wisconsin Emergency Management, (2008). Mitigation Leads to Preservation and Economic Recovery for one Community: Darlington, Wisconsin. (http://emergencymanagement.wi.gov/docview.asp?docid=111).

9. APPENDIX 1

Major Development Projects Completed, Underway or Planned within the Metro Bay Region SAMP Boundary (RIEDC, 2007)					
City	**Project Name/Company**	**Type**	**Type of Activity**	**Status**	**Development Cost $$**
East Providence	Phillipsdale Landing	Commercial - Residential	Rehabilitation/ New Construction	Design	75,000,000
East Providence	Former Chevron Property	Commercial - Residential	New Construction	Design	150,000,000
East Providence	Tockwotten Home	Residential continuing care facility	New Construction	Designed/permitted	41,000,000
East Providence	Aspen Aerogels	Commercial	Rehabilitation/ New Construction	Completed	30,000,000
East Providence	Easte Pointe/Geonova	Commercial - Residential	New Construction	Design	$200,000,000
East Providence	Ross Commons	Residential	New Construction	Completed	10,000,000
Pawtucket	210 Main Street & 53 East Avenue	Commercial	Rehabilitation/ New Construction	Announced	
Pawtucket	Hampton Inn & Suites	Commercial	New Construction	Planned	15,000,000
Pawtucket	Riverfront Lofts/Lebanon Mills	Residential	Rehabilitation	Completed	23,700,000
Providence	GTECH Corp.	Commercial	New Construction	Completed	80,000,000
Providence	Westin Hotel Expansion	Commercial	New Construction	Under Construction	80,000,000
Providence	The Dynamo House at Providence Point	Commercial – Residential	Rehabilitation/ New Construction	Under Construction	150,000,000
Providence	WaterPlace Condominiums	Residential	New Construction	Under Construction	100,000,000
Providence	Westminster Lofts	Commercial - Residential	Rehabilitation/ New Construction	Rehabilitation Complete/Lofts and Garage Planned	100,000,000
Providence	American Locomotive Works	Commercial - Residential	Rehabilitation/ New Construction	Under Construction	300,000,000
Total					**$1.35 Billion**

Hazard Mitigation Plans: Priority Mitigation Activities Proposed	
City (year) of Adoption	
Cranston (2005)	Pocasset Riving flooding improvement; Stillhouse Cove erosion control; Meshanticut Brook flooding improvement; Pump station flood proofing; Sewage infiltration and inflow analysis; WCWD service loop; Flood proof Peters School; Increase ARC shelter capacity. (City of Cranston Hazard Mitigation Plan, 2005)
East Providence (2005)	Public education and outreach programs; Adequate number and location of emergency shelters; Assessment of vulnerability to cultural and historical resources; Assessment of vulnerability to public buildings; Inventory of elderly, disabled, and child day care facilities; Need for portable generator and 6-inch pump; Installation of second cross-bay water pipeline; Inspection, maintenance, and repair of culverts; Public/private dams; Inventory of bridges with utilities; Inventory of commercial and industrial buildings located in floodplain. (City of East Providence, 2004)
Pawtucket (1998)	Encourage neighborhood preservation/revitalization for flood proofing techniques and retrofitting for wind damage; Develop guidelines for development along the Blackstone River keeping the floodway as entirely open space and elevating houses above the 100-year flood level; Separate sanitary and storm sewers if feasible and incorporate best management techniques when undertaking new development or redevelopment projects; Develop property tax incentives, such as credits or deductions for flood proofing measures or flood aversive measures; Provide information to contractors and homeowners on risks of building in hazard-prone areas and inform builders and homeowners of benefits of building and renovating structures to current standards; Incorporate a “hazard disclosure” requirement in deed transfers, leases, or other contracts for sale or exchange of lots within flood hazard areas. (Watson, et al., 1998)
Providence (1999)	Fox Point Hurricane Barrier Routine maintenance; Fox Point Hurricane Barrier overhauling of pumps; Application for Community Rating System (CRS); Require property owners in A- and V-zones requesting permits to comply with new flood plain standards; Perform field study of Fields Point, Port of Providence, and adjacent areas; Enforce flood standard compliance within Port Area; Inspect, repair, replace, and retrofit deteriorated bridge components; Initiate study to determine the current storage situation of vital documents; Initiate tree trimming and debris management program; Centralize FEMA EOC and purchase emergency generator. (Providence, 2000)
Rhode Island Hazard Mitigation Plan (2005)	Enhance the Rhode Island Emergency Management Agency’s capacity to promote and implement projects, programs, policies and legislative action to minimize losses due to natural hazards; Build and support local capacity and commitment to continuously become less vulnerable to natural hazards; Improve coordination and communication with other relevant organizations, agencies and stakeholders; Increase public understanding, support, and demand for hazard mitigation. (RIEMA, 2005)